

Annual Revisions to the SUDAS Design Manual

2018 Edition

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!** Added shading to help distinguish between chapters. Questions can be directed to Beth Richards, SUDAS Program Coordinator, at 515-294-2869 or brich@iastate.edu.

Please replace the following: the small business card on the spine with the card titled "2018 Edition," and the Contributors and Acknowledgments page. You might also find it helpful to keep this sheet just behind the general table of contents.

Chapter	Section	pg #	Summary of Revision(s)
1	Table of Contents	ii	Updated to reflect changes made in Chapter 1.
	1D-1, I through K	15-60	Revised "Items to be Specified" list based on SUDAS Specifications revisions. Updated "Incidental or Included Items" list. Updated "Bid Items" list.
2	2A-1, D	5-7	Corrected table and figure numbers; updated Iowa Administrative Code reference.
	2D-2	3	Updated Table 2D-2.01.
4	4C-1, D	3	Clarified when to use slide type valve boxes and when to use screw type boxes.
	Table of Contents	i-v	Updated to reflect changes made in Chapter 5.
	5B-1	1	Corrected mistake in page header.
	5C-1	1	Corrected mistake in page header.
	5C-1, Table 5C-1.02	7	Revised footnote #15.
	5C-2	1	Corrected mistake in page header.
5	5D-1	ALL	Updated information on binder selection for northern tiers of counties, intermediate and base layers, and for overlays
	5E-1, C, 2	5-6	Removed the restriction for use of fly ash and slag only with ready mix concrete.
	5E-1, I, 2, c and J	13-15	Added information on joint durability (C-SUD) mixes to match recent research and clarified information on admixtures.
	5G-2, B	1	Minor correction.
	5G-2, C, 3	5-6	Revised language to match a specifications change.
	5G-6 through 5O-1	ALL	REMOVE remaining sections of Chapter 5 and replace with enclosed pages. Added new sections for jointing of PCC roundabouts, automated machine guidance, and overlays. Renumbered various sections to better organize the chapter with the new additions.
	7E-4, A and B	1-4	Updated requirements to reflect current construction practices.
	7E-7	3-4	Updated specifications figure number references.
	7E-9	3-4	Updated specifications figure number reference.
	7E-10	5-6	Updated specifications figure number references.
7	7E-11	3-4	Updated specifications figure number reference.
	7E-12	3-8; 15-16	Updated specifications figure number references.
	7E-13	3-4	Updated specifications figure number reference.
	7G-1	ALL	Updated references.

9	Table of Contents	i	Updated to reflect changes made in Chapter 9.
	9B-5, C	3-8	Added depth of bury information for polypropylene pipe.
	9C-1, B	1	Corrected table numbering and reference in paragraph.
	9D-1, B	1	Updated reference.
12	Table of Contents	ii	Updated to reflect changes made in Chapter 12.
	12B-3	ALL	Corrected bike guide reference; added more detailed design information on buffered and separated bicycle lanes; corrected bike vs. bicycle terminology; added references.
13	Table of Contents	i	Updated to reflect changes made in Chapter 13.
	13A-1, B	1	Updated references.
	13B-1	ALL	Corrected mistake in page header; added interim change to Warrant 7.
14	14D-1	1	Updated reference.

Contributors and Acknowledgments

In 2017, SUDAS staff held many meetings to accomplish the various revisions reflected in the 2018 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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Figure 4040.233 Specify when to use a CMP outlet.

Section 4050 - Pipe Rehabilitation

4050, 1.07, C Specify who will provide water for installation of cured-in-place pipe if not the owner.

4050, 2.01, A, 3 Specify the maximum outside diameter and SDR of polyethylene or polyolefin pipe for sliplining.

4050, 2.06, B, 1 Specify the nominal internal diameter and length of existing pipe.

4050, 2.06, B, 5 Specify the minimum SDR wall thickness for DRP-HDPE.

4050, 2.07, B, 1 Specify the nominal internal diameter and length of existing pipe.

4050, 2.07, B, 5 Specify the minimum SDR wall thickness for FFP-PVC pipe lining.

4050, 2.09, B Specify materials to be used for pipe replacement (spot repairs).

4050, 3.08 Specify the installation process for DRP-HDPE or FFP-PVC, if other than manufacturer's recommendations.

4050, 3.08, C, 1 Specify the material used to replace pipe of the same nominal size as the existing pipe.

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 not 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.

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

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.
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.
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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.

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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.

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

6010, 2.11, B, 2	Specify whenever sanitary sewer manhole lining is required.
6010, 2.13, A	Specify if steps are to be provided for structures other than circular, precast manholes. Specify if steps are NOT to be provided in circular, precast manholes.
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.
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.

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

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.

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.

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. *Note - longitudinal tining is listed as the default.*

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.

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

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.

7030, 2.03, B If concrete brick pavers are to be used, specify the material requirements.

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 sand base.

7030, 3.06, B, 1, b 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.

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

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.
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.

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

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.

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 not 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.

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

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.

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.
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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 8010 - Traffic Signals

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.

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

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.
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.

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

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.

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.

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

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.
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 <u>not</u> 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.

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

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 <u>not</u> 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 <u>not</u> 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 <u>not</u> to be installed along the contour.
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.

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

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.
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.

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

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.

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.

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

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.

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.

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

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.

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.

Section 11,050 - Concrete Washout

11,050, 3.02, A Specify locations of temporary granular sidewalks.

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> a. Site preparation for, and the construction of, embankment, fills, shoulder backfill, and backfill behind curbs. b. Overhaul. c. Finishing the soil surface, including roadways, shoulders, behind curbs, side ditches, slopes, and borrow pits. d. Repair or replacement of any fences that have been unnecessarily damaged or removed. e. Compaction testing, as specified in the contract documents.
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.
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 bedding material, placing bedding and backfill material, wyes and other fittings, pipe joints, pipe connections, testing, and inspection.
- 4010, 1.08, A, 2, c Sanitary Sewer Gravity Main, Trenchless
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation, dewatering, and placing backfill material; pipe connections; testing; and inspection.

J. Incidental or Included Items (Continued)

- | | |
|---------------------|---|
| 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 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 bedding material, placing bedding and backfill material, 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, and placing 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 bedding material, placing 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, and placing 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 bedding material, placing 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 bedding and backfill material, connection back to existing service, compaction, testing, and inspection. |
| 4010, 1.08, G, 3 | <u>Sewage Air Release Valve and Pit</u>
Excavation, furnishing bedding material, placing bedding and backfill material, compaction, and testing. |
| 4010, 1.08, H, 3 | <u>Removal of Sanitary Sewer</u>
Removal, disposal, and capping (if specified) of pipe. |

J. Incidental or Included Items (Continued)

- 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, 1 Plugging sanitary sewers is incidental to other work and will not be paid for separately.

Section 4020 - Storm Sewers

- 4020, 1.08, A, 1, c Storm Sewer, Trenched
Trench excavation, dewatering, furnishing bedding material, placing bedding and backfill material, joint wrapping, wyes and other fittings, pipe joints, pipe connections, testing, and inspection. The length of elbows and tees of the pipes installed will be included in the length of pipe measured.
- 4020, 1.08, A, 2, c Storm Sewer, Trenchless
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation, dewatering, and placing 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 bedding material, placing 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, and placing backfill material; casing spacers; furnishing and installing annular space fill material; pipe connections; testing; and inspection.
- 4020, 1.08, C, 3 Removal of Storm Sewer
Removal, disposal, and capping (if specified) of pipe.
- 4020, 1.08, E, 1 Plugging storm sewers is incidental to other work and will not be paid for separately.

Section 4030 - Pipe Culverts

- 4030, 1.08, A, 1, c Pipe Culvert, Trenched
Trench excavation, dewatering, furnishing bedding material, placing bedding and backfill material, connectors, testing, and inspection. The length of elbows and tees of the pipes installed will be included in the length of pipe measured.
- 4030, 1.08, A, 2, c Pipe Culvert, Trenchless
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation, dewatering, and placing backfill materials; pipe connections; testing; and inspection.

J. Incidental or Included Items (Continued)

4030, 1.08, B, 3 Pipe Apron
Trench excavation, furnishing bedding material, placing bedding and backfill material, connectors, and other appurtenances.

4030, 1.08, C, 3 Footings for Concrete Pipe Aprons
Excavation, reinforcing steel, and concrete.

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.

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, 3 Pipe Lining
Removal of internal obstructions, pipe cleaning, inspection, and all costs associated with the public information and notification program.

4050, 1.08, B, 3 Building Sanitary Sewer Service Reconnection
Removal of internal obstructions, pipe cleaning, and all costs associated with the public information and notification program.

4050, 1.08, C, 1, c Spot Repairs (by Pipe Replacement)
Uncovering and removing existing pipe, placing backfill material for replacement pipe, and restoring the surface.

4050, 1.08, C, 2, c Spot Repairs (by Linear Foot)
Furnishing and installing replacement pipe and connections.

4060 - Cleaning, Inspection, and Testing of Sewers

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.

J. Incidental or Included Items (Continued)**Section 5010 - Pipe and Fittings**

5010, 1.08, A, 1, c	<u>Water Main, Trenched</u> Trench excavation, dewatering, furnishing bedding material, placing bedding and backfill material, tracer system, testing, disinfection, and polyethylene wrap for ductile iron pipe and for fittings.
5010, 1.08, A, 2, c	<u>Water Main, Trenchless</u> Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation, dewatering, and placing 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 bedding material, placing 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, and placing 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 bedding material, installation of tracer wire system for non-metallic service pipe, and placing bedding and backfill material.
5010, 1.08, E, 1, c	<u>Water Service Stub (by length), Water Service Pipe</u> Trench excavation, dewatering, furnishing bedding material, installation of tracer wire system for non-metallic service pipe, and placing bedding and backfill material.

Section 5020 - Valves, Fire Hydrants, and Appurtenances

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 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 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 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 bedding material, placing bedding and backfill material, compaction, 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 bedding material, placing bedding and backfill material, compaction, base, structural concrete, reinforcing steel, precast units (if used), concrete fillets, pipe connections, castings, and adjustment rings. |
| 6010, 1.08, C, 3 | <u>Drop Connection</u>
The connection to the manhole and all pipe, fittings, concrete encasement, and 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. |
| 6020, 1.08, C, 3 | <u>In-situ Manhole Replacement, Cast-in-place Concrete with Plastic Liner</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, sealing at the frame and cover, sealing pipe penetrations as recommended by the manufacturer, and testing the manhole upon completion. |

J. Incidental or Included Items (Continued)

- 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, 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.
- 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.

J. Incidental or Included Items (Continued)

7011, 1.08, A, 3, c	<u>Surface Preparation for Bonded PCC Overlay</u> Sandblasting, shot blasting, scarification, and surface cleaning.
7011, 1.08, A, 4, c	<u>Surface Preparation for Unbonded PCC Overlay</u> Scarification and surface cleaning.
7011, 1.08, A, 5, c	<u>HMA Separation Layer for Unbonded PCC Overlay</u> HMA mix, including asphalt binder.
7011, 1.08, A, 6, c	<u>Geotextile Fabric Separation Layer for Unbonded PCC Overlay</u> Cleaning surface and furnishing, placing, and securing the geotextile fabric separation layer.

Section 7020 - Hot Mix Asphalt Pavement

7020, 1.08, A, 3	<u>Pavement, HMA (by ton)</u> Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
7020, 1.08, B, 3	<u>Pavement, HMA (by square yard)</u> Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
7020, 1.08, C, 3	<u>HMA Base Widening (by ton)</u> Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
7020, 1.08, D, 3	<u>HMA Base Widening (by square yard)</u> Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
7020, 1.08, H, 3	<u>HMA Pavement Samples and Testing</u> 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	<u>HMA Overlay (by ton)</u> Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
7021, 1.08, B, 3	<u>HMA Overlay (by square yard)</u> 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	<u>Removal of Sidewalk, Shared Use Path, or Driveway</u> Sawing, hauling, and disposal of materials removed.
7030, 1.08, B, 3	<u>Removal of Curb</u> Hauling and disposal of materials removed.

J. Incidental or Included Items (Continued)

7030, 1.08, C, 3	<u>Shared Use Paths</u> Subgrade preparation, jointing, sampling, smoothness testing and correction, and testing.
7030, 1.08, D, 3	<u>Special Subgrade Preparation for Shared Use Paths</u> Water required to bring subgrade moisture content to within the required limits.
7030, 1.08, E, 3	<u>Sidewalk, PCC</u> 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, 1, c	<u>Brick Sidewalk with Sand Base</u> Subgrade preparation, brick edge restraints, furnishing and placing compacted sand base, and sand/cement joint filler.
7030, 1.08, F, 2, c	<u>Brick Sidewalk with Concrete Base</u> Subgrade preparation, concrete base, HMA setting bed, neoprene asphalt adhesive for asphalt setting bed, and sand/cement joint filler.
7030, 1.08, G, 3	<u>Detectable Warning</u> Steel bar supports and manufactured detectable warning panels.
7030, 1.08, H, 1, c	<u>Driveway, Paved</u> Excavation, subgrade preparation, jointing, sampling, and testing.
7030, 1.08, H, 2, c	<u>Driveway, Granular</u> Excavation and preparation of subgrade.

Section 7040 - Pavement Rehabilitation

7040, 1.08, A, 3	<u>Full Depth Patches</u> 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	<u>Subbase Over-excavation</u> 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	<u>Partial Depth Patches</u> 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.

J. Incidental or Included Items (Continued)

7040, 1.08, D, 3	<u>Crack and Joint Cleaning and Filling, Hot Pour</u> Furnishing crack and joint filler material and routing, sawing, cleaning, and filling joints or cracks.
7040, 1.08, E, 1, c	<u>Crack Cleaning and Filling, Emulsion</u> Furnishing emulsified crack filler material, cleaning cracks, placing soil sterilant, and filling cracks.
7040, 1.08, E, 2, c	<u>Hot Mix Asphalt for Crack Filling</u> Cleaning, applying tack coat, and furnishing and placing HMA for crack filling.
7040, 1.08, F, 3	<u>Diamond Grinding</u> 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	<u>Milling</u> Milling pavement; furnishing water; and salvaging, stockpiling, and removing cuttings and debris.
7040, 1.08, H, 3	<u>Pavement Removal</u> Sawing, breaking, removing, and disposing of existing pavement and reinforcing steel.
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

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

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.
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J. Incidental or Included Items (Continued)

7060, 1.08, B, 1, c Bituminous Seal Coat (by units), Cover Aggregate
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 Bituminous Seal Coat (by units), Binder Bitumen
Furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts; and final clean up.

Section 7070 - Emulsified Asphalt Slurry Seal

7070, 1.08, A, 3 Emulsified Asphalt Slurry Seal (by area)
Surface preparation and furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts.

7070, 1.08, B, 1, c Emulsified Asphalt Slurry Seal (by units), Aggregate
Surface preparation and furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts.

7070, 1.08, B, 2, c Emulsified Asphalt Slurry Seal (by units), Asphalt Emulsion
Surface preparation and furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts.

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, placement of bedding course, installing permeable interlocking pavers, 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 8020 - Pavement Markings

8020, 1.08, B, 3 Painted Pavement Markings, Solvent/Waterborne
Reflectorizing spheres, layout, surface preparation, and application of marking paint.

J. Incidental or Included Items (Continued)

8020, 1.08, C, 3	<u>Painted Pavement Markings, Durable</u> Layout, surface preparation, and application of marking paint.
8020, 1.08, D, 3	<u>Painted Pavement Markings, High-Build</u> Layout, surface preparation, and application of marking paint.
8020, 1.08, E, 3	<u>Permanent Tape Markings</u> Layout, surface preparation, and application of marking tape.
8020, 1.08, F, 3	<u>Wet, Retroreflective Removable Tape Markings</u> Layout, surface preparation, application, and removal.
8020, 1.08, G, 3	<u>Painted Symbols and Legends</u> Layout, surface preparation, and application of each symbol and legend.
8020, 1.08, H, 3	<u>Precut Symbols and Legends</u> Layout, surface preparation, and application of each symbol and legend.
8020, 1.08, I, 3	<u>Temporary Delineators</u> Installation and removal of delineators.
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.
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J. Incidental or Included Items (Continued)**Section 9010 - Seeding**

9010, 1.08, A, 1, c

Conventional Seeding, Seeding

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

Hydraulic 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, 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.

J. Incidental or Included Items (Continued)

- 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.
- 9040, 1.08, A, 1, c SWPPP Preparation
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 SWPPP Management
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 Filter Socks, Installation
Anchoring stakes.
- 9040, 1.08, D, 2, c Filter Socks, Removal
Restoration of the area to finished grade and off-site disposal of filter socks and accumulated sediment.
- 9040, 1.08, E, 3 Temporary RECP
Excavation, staples, anchoring devices, and material for anchoring slots.
- 9040, 1.08, F, 1, c Wattles, Installation
Anchoring stakes.
- 9040, 1.08, F, 2, c Wattles, Removal
Restoration of the area to finished grade and off-site disposal of wattle and accumulated sediment.
- 9040, 1.08, G, 1, c Check Dams, Rock
Engineering fabric.

J. Incidental or Included Items (Continued)

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.
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.

J. Incidental or Included Items (Continued)

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.
9040, 1.08, U, 3	<u>Flow Transition Mat</u> Anchoring devices.

Section 9050 - Gabions and Revet Mattresses

9050, 1.08, A, 3	<u>Gabions</u> 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	<u>Revet Mattresses</u> 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	<u>Chain Link Fence</u> 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	<u>Gates</u> 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	<u>Barbed Wire</u> Furnishing and installing all necessary strands of barbed wire, anchors, and barbed wire supporting arms.

J. Incidental or Included Items (Continued)

- 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.

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.

J. Incidental or Included Items (Continued)**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).
- 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.

J. Incidental or Included Items (Continued)

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.

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-2	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	Removal of Storm Sewer, ____ (Type), ____ (Size)	LF
4020-108-E-2	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-0	Pipe Lining, ____ (Type), ____ (Size)	LF
4050-108-B-0	Building Sanitary Sewer Service Reconnection	EA
4050-108-C-1	Spot Repairs by Pipe Replacement	EA
4050-108-C-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

K. Bid Items (Continued)

Item Number	Bid Item	Unit
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-0	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
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

K. Bid Items (Continued)

Item Number	Bid Item	Unit
	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-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-H-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
	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-1	Brick Sidewalk with Sand Base	SY
7030-108-F-2	Brick Sidewalk with Concrete Base	SY
7030-108-G-0	Detectable Warning	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

K. Bid Items (Continued)

Item Number	Bid Item	Unit
	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
	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
	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 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

K. Bid Items (Continued)

Item Number	Bid Item	Unit
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
	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

K. Bid Items (Continued)

Item Number	Bid Item	Unit
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
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

K. Bid Items (Continued)

Item Number	Bid Item	Unit
	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
	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

D. Unified Sizing Criteria

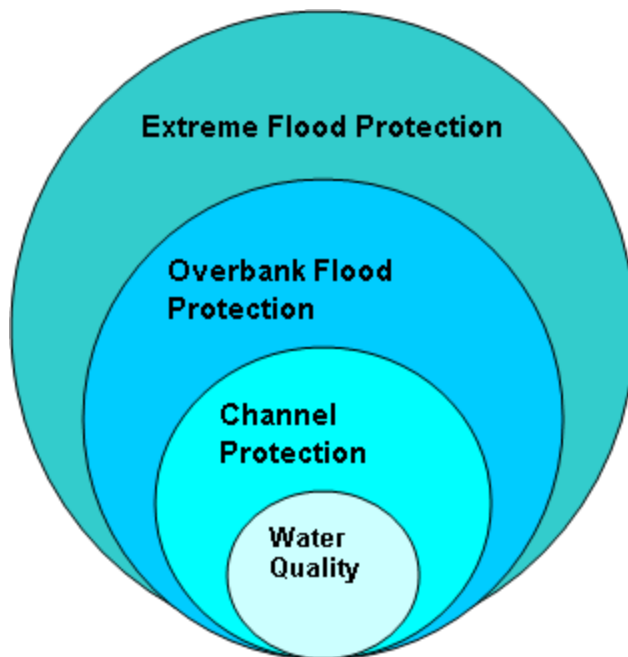
- 1. General Information:** This section provides a brief description of the unified sizing criteria utilized as part of overall stormwater management. The unified sizing criteria are intended to be used collectively, to address overall stormwater impacts, including both stormwater quality and quantity, of site development. When used as a set, the unified criteria control the entire range of hydrologic events, from the smallest runoff producing rainfalls (≥ 0.1 inches) to the 100 year storm.

While this manual does not address stormwater quality requirements (refer to the Iowa Stormwater Management Manual for stormwater quality design), the overall unified sizing criteria is summarized in Table 2A-1.01 and Figure 2A-1.01 below to give the designer an understanding of how each criterion fit together in the overall stormwater management approach.

Table 2A-1.01: Summary of the Recommended Unified Stormwater Sizing Criteria for Management of Stormwater Quality and Quantity

Sizing Criteria	Recommended Method
Water Quality Volume, WQv	Treat the runoff from 90% of the storms that occur in an average year. For Iowa, this equates to providing water quality treatment for the runoff resulting from a rainfall depth of 1.25 inches or less. Goal is to reduce average annual post-development total suspended solids loadings by 80%.
Recharge Volume, Rev	Fraction of WQv, depending on pre development soil hydrologic group.
Channel Protection Storage Volume, Cpv	Provide 24 hours of extended detention of the runoff from the 1 year 24 hour duration storm event to reduce bank-full flows and protect downstream channels from erosive velocities and unstable conditions.
Overbank Flood Protection, Qp	Provide peak discharge control of the 5 year storm event such that the post-development peak rate does not exceed the downstream conveyance capacity and/or cause overbank flooding in local urban watersheds. Some jurisdictions may require peak discharge control for the 2 year storm event.
Extreme Flood Protection, Qf (Major Storm)	Evaluate the effects of the 100 year storm on the stormwater management system, adjacent property, and downstream facilities and property. Manage the impacts of the extreme storm event through detention controls and/or floodplain management.

Figure 2A-1.01 illustrates the relative volume requirements of each of the unified stormwater sizing criteria, as well as demonstrates that the criteria are “nested” within one another, i.e., the extreme flood protection volume requirement also contains the overbank flood protection volume, the channel protection volume, and the water quality treatment volume.

Figure 2A-1.01: Relationship of the Unified Stormwater Sizing Criteria

Source: Adapted from Georgia Stormwater Manual, Vol. 2, 2001

As previously mentioned, this manual does not address the stormwater quality aspects of the unified sizing criteria. Additional information for the stormwater quality criteria, including overbank and extreme flood protection, is provided below.

- 2. Overbank Flood Protection Volume Requirements (Q_p):** The primary purpose of the overbank flood protection volume sizing criteria is to prevent an increase in the frequency and magnitude of out-of-bank flooding generated by development (e.g., flow events that exceed the bank-full capacity of the channel and therefore must spill over into the floodplain). Overbank flood protection for the 10 year storm is only required if local approval authorities have no control of floodplain development, no control over infrastructure and conveyance system capacity design, or determine that downstream flooding will occur as a result of the proposed development.

For most regions of the state, the overbank flood control criteria equates to preventing the post-development 5 year (or 10 year), 24 hour storm peak discharge rate (Q_{p5}) from exceeding the pre-development peak discharge rate. In some local jurisdiction drainage systems, piped conveyance constraints may dictate the use of a 2 year pre-development peak discharge for post-development flows. In many jurisdictions, the storm sewer intake and piping capacity is sized for conveyance of the 5 year frequency runoff. For control of local flooding for areas connected to these conveyance systems, the upstream release rate must be restricted to meet the existing conveyance capacity to prevent local flooding of streets and properties. For drainage areas connected directly to open channel conveyances (swales and natural stream channels), the 10 year frequency runoff discharge is used.

- 3. Extreme Flood Volume (Q_f):** The intent of the extreme flood criteria is to prevent flood damage from large storm events and maintain the boundaries of the pre-development 100 year Federal Emergency Management Agency (FEMA) and/or locally designated floodplain.

This is typically done in two ways:

- a. **100 Year Control:** Requires storage to attenuate the post development 100 year, 24 hour peak discharge (Q_f) to pre-development 100 year rates. The Q_f is the most stringent and expensive level of flood control, and is generally not needed if the downstream development is located out of the 100 year floodplain. In many cases, the conveyance system leading to a stormwater structure is designed based on the discharge rate for the 10 year storm (Q_{p10}). In these situations, the conveyance systems may be the limiting hydrologic control.
- b. **Reserve Ultimate 100 Year Floodplain:** 100 year storm control may be required by an appropriate review authority in the following cases.
 - Buildings or developments are located within the ultimate 100 year floodplain
 - The reviewing authority does not completely control the 100 year floodplain

Hydraulic/hydrologic investigations may be required to demonstrate that downstream roads, bridges, and public utilities are adequately protected from the Q_f storm. These investigations typically extend to the first downstream tributary of equal or greater drainage area or to any downstream dam, highway, or natural point of restricted stream flow. Specific requirements for floodplain management and construction of infrastructure and/or excavation within the floodway can be found in Iowa Administrative Code 567, Chapters 70-75.

E. Floodplain Management

Although not a direct element of the municipal stormwater conveyance design, floodplain management should be considered along with the overall stormwater management plan to manage the floodplain as it relates to the various stormwater conveyance means, pipes, culverts, streams, and open channels.

Floodplain management, when integrated with the overall stormwater management program, provides a regulatory means to improve the surface water system throughout the municipality.

F. References

Georgia Stormwater Manual. Vol. 2. 2001.

Table 2D-2.01: Manning Coefficients for Common Storm Sewer Materials

Type of Pipe	Manning's n
Concrete pipe	0.013
PVC pipe (smooth wall)	0.010
HDPE or Polypropylene (corrugated exterior, smooth interior - dual or triple wall)	0.012
HDPE or Polypropylene (corrugated exterior and interior - single wall)	0.020
CMP (2-2/3" x 1/2" corrugations)	0.024
CMP (3" x 1" corrugations)	0.027
CMP (5"x1" corrugations)	0.025
Structural Plate	0.032

Note: for additional manning coefficients, see the pipe manufacturer's information.

D. Conservation of Energy

- Bernoulli Equation:** The law of conservation of energy, as expressed by the Bernoulli Equation, is the basic principle most often used in hydraulics. This equation may be applied to any conduit with a constant discharge. Friction flow formulas such as the Manning's Equation have been developed to express the rate of energy dissipation as it applies to the Bernoulli Equation. The theorem states that the energy head at any cross-section must equal that in any other downstream section plus the intervening losses.

Bernoulli's equation, where the total energy at Section 1 is equal to the energy at Section 2 plus the intervening head loss, is summarized in two versions below:

For open (non-pressure) conduit flow:

$$\frac{V_1^2}{2g} + Y_1 + Z_1 = \frac{V_2^2}{2g} + Y_2 + Z_2 + h_f \quad \text{Equation 2D-2.02}$$

For pressure conduit flow

$$\frac{V_1^2}{2g} + \frac{P_1}{\gamma} + Z_1 = \frac{V_2^2}{2g} + \frac{P_2}{\gamma} + Z_2 + h_f \quad \text{Equation 2D-2.03}$$

where:

EGL = Energy grade line

HGL = Hydraulic grade line

Y = Water depth, ft

$V^2/2g$ = Energy head, ft

V = Average velocity, fps

S_f = Slope of EGL

S_w = Slope of HGL

g = acceleration of gravity (32.2 fps)

P/γ = Pressure head, ft

P = Pressure at given location (lb/ft²)

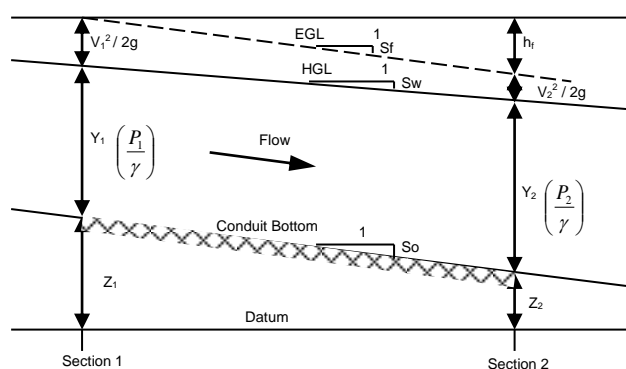
γ = Specific weight of water (62.2 lb/ft³)

Z = Elevation relative to some datum

S_0 = Slope of bottom, ft/ft

h_f = Head loss, ft

Figure 2D-2.01: Terms Used in the Energy Equation



Source: FHWA, HEC-22

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-1.04 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-1.04 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.

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Street Classifications

A. General

The classifying of streets and highways is necessary for communication among engineers, administrators, and the general public. Streets can be classified based upon major geometric features (e.g. freeways, streets, and highways), route numbering (e.g. U.S., State, and County), or Administrative classification (e.g. National Highway System or Non-National Highway System). However, functional classification, the grouping of streets and highways by the character of service they provide, was developed specifically for transportation planning purposes and is the predominant method of classifying streets for design purposes. For urban areas, the functional classification hierarchy consists of major arterials, minor arterials, collectors, and local streets.

The information contained in this section is based on AASHTO criteria. The Project Engineer should use the various AASHTO publications and particularly the current edition of AASHTO's "Green Book" to verify the application of values provided herein when complex design conditions or unusual situations occur.

B. Arterial Streets

1. **Major (Principal) Arterial:** The major arterial (referred to as a principal arterial by AASHTO) serves the major center of activities of urbanized areas, the highest traffic volume corridors, the longest trip, and carries a high proportion of a total urban travel on a minimum of mileage. The system should be integrated both internally and between major rural connections.

The major arterial system carries most of the trips entering and leaving the area as well as most of the through movements bypassing the central city. In addition, significant intra-area travel such as between central business districts and outlying residential areas, between major inner-city communities, and between major suburban centers, is served by major arterials. Frequently, the major arterial carries important intra-urban as well as inter-city bus routes. Finally, in urbanized areas, this system provides continuity for all rural arterials that intercept the urban boundary.

Access to private property from the major arterial is specifically limited in order to provide maximum capacity and through movement mobility. Although, no firm spacing rule applies in all or even in most circumstances, the spacing between major arterials may vary from less than 1 mile in highly developed central areas to 5 miles or more in developed urban fringes.

2. **Minor Arterial:** The minor arterial inter-connects with and augments the major arterial system. It accommodates trips of moderate length at a somewhat lower level of travel mobility than major arterials. This system places more emphasis on land access but still has specific limits on access points. A minor arterial may carry local bus routes and provide intra-community continuity but ideally does not penetrate identifiable neighborhoods. This system includes urban connections to rural collector roads where such connections have not been classified as urban major arterials.

The spacing of minor arterials may vary from 1/8 to 1/2 mile in highly developed areas to 2 to 3 miles in suburban fringes but is not normally more than 1 mile in fully developed areas.

C. Collector Streets

The collector street system provides both land access and traffic circulation within residential neighborhoods and commercial and industrial areas. It differs from the arterial system in that facilities on the collector system may penetrate residential neighborhoods, distributing trips from the arterials through the area to their ultimate destinations. Conversely, the collector street also collects traffic from local streets in residential neighborhoods and channels it into the arterial system. In the central business district, and in other areas of similar development and traffic density, the collector system may include the entire street grid.

1. **Major Collector:** This type of street provides for movement of traffic between arterial routes and minor collectors and may collect traffic, at moderately lower speeds, from local streets and residential and commercial areas. A major collector has control of access to abutting properties with a majority of access at local street connections. Normally, a slightly higher emphasis is placed on through movements than direct land access.
2. **Minor Collector:** This type of street provides movement of traffic between major collector routes and residential and commercial local streets as well as providing access to abutting property at moderate low speeds. Consideration for through movements and direct land access is normally equal.

D. Local Streets

Local streets allow direct access to abutting land and connections to the higher order street systems. They offer the lowest level of mobility and deliberately discourage major through traffic movements.

E. Private Streets

Certain Jurisdictions allow private streets in specific situations. Private streets are similar to the local streets but generally are located on dead-end roads less than 250 feet in length, short loop streets less than 600 feet in length, or frontage roads parallel to public streets. Design criteria for local private streets are not included in this manual. The Jurisdiction should be contacted to determine if they are allowed.

Geometric Design Tables

A. General

The following sections present two sets of design criteria tables - Preferred Roadway Elements (Table 5C-1.01) and Acceptable Roadway Elements (Table 5C-1.02). In general, the “Preferred” table summarizes design values taken from the AASHTO’s “Green Book” that may be considered “preferred” while the “Acceptable” table represents AASHTO minimums or practical minimums not covered in AASHTO.

Designers should strive to provide a design that meets or exceeds the criteria established in the “Preferred” table. For designs where this is not practical, values between the “Preferred” and “Acceptable” tables may be utilized, with approval of the Engineer.

The Federal Highway Administration has modified some of the controlling geometric design criteria for projects on the National Highway System (NHS). These changes were based on an analysis of the 13 controlling criteria reported in NCHRP Report 783 and are incorporated in 23 CFR 625. The changes include reducing the number of criteria to 10 by eliminating bridge width, vertical alignment, and horizontal clearance since those elements were covered under another criteria or they were found not to have significant operational or safety impacts. For lower speed facilities with a design speed of less than 50 mph, the controlling criteria only includes design speed and structural capacity.

However, since all projects on the NHS, regardless of funding source, must meet the design guidelines in the [Iowa DOT Design Manual](#), which includes the FHWA criteria, SUDAS has not modified the geometric design criteria contained herein that is used for locally funded and non-NHS Federal-Aid projects.

B. Design Controls and Criteria

The selection of various values for roadway design elements is dependent upon three general design criteria: functional classification, design speed, and adjacent land use.

- 1. Functional Classification:** The first step in establishing design criteria for a roadway is to define the function that the roadway will serve (refer to [Section 5B-1](#) for street classifications). The functional classification of the roadway is the basis for the cross-sectional design criteria shown in Tables 5C-1.01 and 5C-1.02. It also serves as the basis for the ultimate selection of design speed and geometric criteria.

Under a functional classification system, design criteria and level of service vary according to the intended function of the roadway system. Arterials are expected to provide a high level of mobility for longer trip length; therefore, they should provide a higher design speed and level of service. Since access to abutting property is not their main function, some degree of access control is desirable to enhance mobility. Collectors serve the dual function of accommodating shorter trips and providing access to abutting property. Thus, an intermediate design speed and level of service is important. Local streets serve relatively short trip lengths and function primarily for property access; therefore, there is little need for mobility or high operating speeds. This function is reflected by use of lower design speeds and an intermediate level of service.

- 2. Design Speed:** Design speed is the selected speed used to determine various geometric features of the roadway, including horizontal and vertical alignment. The design speed selected should be as high as practical to attain the desired degree of safety, mobility, and efficiency. 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. Once the design speed is selected, all pertinent roadway features should be related to it to obtain a balanced design.

In some situations, it may be impractical to conform with the desired design speed for all elements of the roadway (e.g. horizontal radius or clear zone). In these situations, warning signs or additional safety treatments may be required (e.g. warning signs or guard rail).

- 3. Adjacent Land Use:** In addition to functional classification and design speed, the surrounding land use can impact the design elements of the roadway corridor as well. Land use can be categorized into three groups: residential, commercial, and industrial.
- a. Residential areas are regions defined by residential or multi-family zoning districts where single-family houses, apartment buildings, condominium complexes and townhome developments are located. Because these facilities typically have lower overall traffic volumes, low truck volumes, and are utilized primarily by drivers who are familiar with the roadway, some design values can be set at a lower level than for commercial or industrial areas.
 - b. Commercial and industrial areas are highly developed regions generally defined by commercial and industrial zoning districts where factories, office buildings, strip malls, and shopping centers are or will be located. The areas typically require higher level design values due to increased traffic volumes, increased truck volumes, and decreased driver familiarity.

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 Table 5C-1.05.					
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 Table 5C-1.05.					
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.

Geometric Design Elements

A. Level of Service

Level of service (LOS) is a measure of the operating conditions of a roadway facility. LOS is based upon traffic performance related to speed, travel time, freedom to maneuver, traffic interruptions, and comfort and convenience. The LOS ranges from A (least congested) to F (most congested). Refer to the Highway Capacity Manual for a more thorough discussion of the LOS concept.

Based upon the traffic capacity analysis, the number of lanes, turn lanes, and intersection controls should be selected to provide a design with the desired LOS for the design year traffic. Design year traffic is based upon a 20 year traffic projection. The current Highway Capacity Manual and the current AASHTO “Green Book” should be used for traffic projections and to determine the number of lanes and intersection configuration at the desired LOS.

The LOS for the roadway overall is based upon Average Daily Traffic (ADT), while the LOS at signalized intersections is based upon the peak hourly volume (PHV).

As a planning tool, the following tables are provided to indicate approximate capacities for two lane and four lane streets and highways and intersection capacity for four way stop and signalized intersections. These tables do not consider site specific details and should not be utilized for final design purposes.

Table 5C-2.01: Maximum ADT vs. LOS and Type of Terrain for Two Lane Highways

Terrain	LOS		
	<i>B</i>	<i>C</i>	<i>D</i>
Level	3,200 - 4,800	5,300 - 7,900	9,000 - 13,500
Rolling	1,800 - 2,800	3,500 - 5,200	5,300 - 8,000
Hilly	900 - 1,300	1,600 - 2,400	2,500 - 3,700

Table 5C-2.02: Reduced Capacity of Narrow Lanes with Restricted Lateral Clearance

Usable Shoulder Width or Clearance to Obstruction (feet)	Two Lane Roadway (percent of capacity of 12 foot lane)		
	<i>12 foot lanes</i>	<i>11 foot lanes</i>	<i>10 foot lanes</i>
6	100	93	84
4	92	85	77
2	81	75	68
0	70	65	58

Table 5C-2.03: Planning Capacity at LOS C¹, D, and E²
Two Way Arterial Streets (Non-intersection)

Number of Lanes	Turn Lanes	Capacity, VPD at LOS D			
		<i>Minimal Side Friction</i>	<i>Light (Residential) Side Friction</i>	<i>Moderate (Mixed Zoning) Side Friction</i>	<i>Heavy Side Friction</i>
Two Lanes Undivided	Without turn lanes	12,100	11,600	11,200	10,400
	With turn lanes	16,000	15,300	14,000	13,900
Four Lanes Undivided	Without turn lanes	24,300	23,400	23,400	21,900
	With left turn lanes or 5 lane with center TWLTL	32,100	30,900	30,900	29,100
Four Lanes Divided	Without turn lanes	27,100	26,200	26,100	23,300
	With left turn lanes	35,400	34,200	34,100	32,500
	With left and right turn lanes	37,500	36,200	34,400	34,400

LOS - Level of Service

TWLTL - Two-Way Left-Turn Lane

VPD - Vehicles per Day

¹ Capacity at LOS C may be determined by multiplying LOS D values above by 0.8.

² Capacity at LOS E may be determined by multiplying LOS D values above by 1.2.

Source: Adapted from "2000 Des Moines Area Daily Directional Capacities At Level of Service D" - Des Moines Area MPO

Table 5C-2.04: Approximate LOS C Service Volumes (VPH) for
Four Way Stop-controlled Intersections (Sum of all Four Legs)

Demand Split	Two Lanes on Each Street	Street 1: Two Lanes Street 2: Four Lanes	Four Lanes on Each Street
50/50	1,200	1,800	2,200
55/45	1,140	1,720	2,070
60/40	1,080	1,660	1,970
65/35	1,010	1,630	1,880
70/30	960	1,610	1,820

B. Sight Distance

The following information is taken from the 2004 AASHTO "Green Book." The Project Engineer should check the current edition of the AASHTO "Green Book" when specific information is needed to verify values provided.

- Stopping Sight Distances:** The minimum stopping sight distance is the distance required by the driver of a vehicle traveling at the design speed to bring the vehicle to a stop after an object on the road becomes visible. This distance directly affects the length and rate of curvature for vertical curves.

The method for measuring stopping sight distance on vertical curves assumes a height for the driver's eye and a height for an object in the road. For a crest vertical curve, the sight distance is the distance at which an object in the road appears to the driver over the crest of the curve.

Asphalt Pavement Mixture Selection

A. Scope

This section is intended for the engineers and technicians who specify asphalt paving material criteria for urban projects, generally ranging from low to medium volume, up to 10M ESALs. Vehicle volumes exceeding 10M ESAL₂₀, or projects outside of these design standards, may require more detailed design and/or expert consultation. The section provides a step-by-step process for determining the appropriate mixture criteria and gives the designer additional background information on specific mixture criteria. The section is intended to assist in selecting the mixture criteria that best satisfy the project demands and limitations. Statewide use of this section will improve the standard application of current accepted gyratory mix design technology. In accordance with AASHTO and [Iowa DOT Materials I.M. 510](#), mixture selection involves the use of a 20 year design life whereas pavement thickness design is based on a 50 year design life.

B. Definitions

Equivalent Single Axle Load (ESAL): A standard unit of pavement damage created by a single pass of a vehicle axle.

Car axle = 0.0002 ESAL 18kip truck axle = 1.0 ESAL 24kip truck axle = 3.0 ESAL

ESAL₂₀: Estimated cumulative ESALs over a 20 year period.

N: The number of gyratory compaction revolutions at which HMA mixture properties are measured. N_{des} represents 20 years of traffic loading.

Gyratory Mix Design: A laboratory process for achieving desired pavement performance by determining the optimum proportions of aggregates and asphalt binder for hot mix asphalt using a SHRP Superpave gyratory compactor.

Lift Designation (Surface, Intermediate, Base): The terms for the lifts in the hot mix asphalt pavement structure. The surface lift is the top lift, about 1 1/2 inches thick. The intermediate lift(s) is one or more lifts placed under the surface lift, generally 2 to 4 inches thick. The base lift(s) is all mixture placed below the intermediate lift, generally limited to full depth construction.

Modified Asphalt Binders: For design traffic levels greater than 1,000,000 ESALs (High, Very High, and Extremely High), the binders may need to be modified and thus may be more costly.

Nominal Maximum Aggregate Size (NMAS): The mixture size designation used for the combined aggregate gradation. Defined as one sieve size larger than the first sieve to retain more than 10%.

Performance Graded (PG): National asphalt binder grading system, developed by AASHTO, based on high and low pavement operating temperatures (°C). A PG binder is identified using a nomenclature of PG XXYY, followed by an ESAL designation (L, S, H, V, E). The XX is the high pavement temperature in degrees Celsius in which the binder should resist rutting. The YY, in negative Celsius, is the low pavement temperature in which the binder should resist cracking. For example a PG 58-28S should resist rutting to 58 °C and cracking of the pavement to a temperature of -28 °C under standard (0.3 M to 1 M ESALs) traffic loading.

C. Design Checklist

Designers should follow the steps below to ensure that the material criteria selected will best meet the needs of the project and the constraints of the owner agency.

- 1. Determine the Level of Traffic Forecasted for the Next 20 Years:** Both current and future traffic levels are needed to determine the appropriate asphalt mixture for the project. Even if the project is not expected to remain in place for 20 years, the material selection levels are based on 20 year values. Common values are average daily traffic (ADT) for the current year, ADT for the 20 year forecast, and percent trucks. In addition to these annualized daily values, the designer should consider potential seasonal high truck volumes, and give particular attention to point sources and future development areas that may generate heavy truck volumes, like quarries, industrial parks, and bus lanes. Seasonal truck volumes may reflect a rate of pavement loading well in excess of the annualized values.
- 2. Understand the Pavement Section Design or Rehabilitation Strategy:** In order to make the proper mixture selection, the designer must have knowledge of the proposed pavement construction or rehabilitation and intended pavement performance. The thickness of the pavement will also affect the material and mixture selection. Particular parameters include required structural thickness, existing pavement cross section and condition (dominant distress patterns), traffic patterns and speed, and past maintenance.
- 3. Determine the Regional Climate Conditions:** Iowa's 1 day low pavement temperature ranges approximately 5°C from north to south. Adjusted for 98% reliability, the values range from -29 °C to -24 °C. The 7 day high pavement temperature across the state only varies by 3 °C. These values are computed from daily high air temperatures. Adjusted for 98% reliability, the pavement temperature values range from 56 °C to 59 °C. Climate details for a specific location can be obtained from the LTPPB software package available on the FHWA website (<https://infopave.fhwa.dot.gov/>). See Figures 5D-1.01 and 5D-1.02.
- 4. Compute the Anticipated 20 Year Pavement Loading:** The design pavement loading is the starting point for selecting the material and mixture selection criteria. The design pavement loading is measured in ESALs, not ADT. To determine the design ESALs on the project, use the traffic conditions from Step 1 and compute the ESAL₂₀. Use the examples outlined in Examples 5D-1.01 and 5D-1.02, for two lane, two way traffic; use Example 5D-1.03 for urban multi-lane situations. Design ESAL levels for asphalt criteria selection are divided into relatively large brackets. While a firm understanding of the traffic and pavement loading is important, good approximations of truck traffic are normally sufficient to determine the design requirements.
- 5. Identify Any Special Conditions that Impact the Pavement:** The standard selection process is based on high speed traffic with a broad distribution of vehicle types. There are numerous special conditions that may, through engineering judgement, require changes in the standard pavement materials/mixture selection. These special conditions are outlined below.
 - a. Heavy Trucks:** If the pavement's history has regularly been impacted by heavy trucks, the designer may consider increasing either the binder grade through the designation of a higher design traffic loading, the mix designation (ESAL level), or both. Typical examples of this condition are routes adjacent to quarries, grain elevators, or regional commercial freight distribution centers.

- b. Slow/Stop/Turning:** Urban roadways normally require slower running speeds and often include signed or signaled intersections. The pavement loading condition significantly increases at slower speeds (less than 45 MPH) and stopped vehicles at intersections. The designer may consider increasing the binder grade through the designation of a higher design traffic loading and/or the percent of crushed aggregate to account for this condition. Economics will determine if the higher grade of binder can be applied to the whole project, or just the impacted length of pavement (i.e. intersection and approaches).
 - c. Durability:** Many low-volume asphalt pavements are more susceptible to failure due to long term aging than to rutting or fatigue. For pavements with good maintenance histories the designer may want to ensure that the mixture selection will provide adequate durability and, if economically necessary, sacrifice some reliability against rutting or fatigue. This can be accomplished through the selection of a lower compaction level and/or the selection of a softer grade of binder.
 - d. Urban vs. Rural:** Separate from the issue of traffic speed, rural projects that pass through urban locations should consider mix sizes (NMAAS) that will appeal to the pedestrian traffic. In general, smaller mix sizes will have a better surface appearance than larger mix sizes. The designer can specify smaller mix sizes than those provided in the material selection guide table, but should also consider the availability of the aggregates when making that decision. Similarly, the designer may choose to use a larger mix size on rural sections for the purpose of reducing the asphalt binder content in the mixture.
 - e. New Construction vs. Rehabilitation:** The design guide takes into account the major pavement performance factors including rutting, fatigue, and low temperature cracking. When an overlay is placed directly on a slab to be rehabilitated, the existing pavement distress influences the overlay performance and thus the design. If the underlying pavement is PCC or asphalt with thermocracking, the reflective cracking in the overlay will dominate over low temperature cracking so the design parameters related to low temperature cracking for the overlay become less of a factor in the design. If a stress relief layer is included in the overlay design, low temperature cracking should be considered.
 - f. Seasonal Traffic:** Seasonal traffic occurs over a relatively short period of time and may create pavement damage in excess of the normal traffic. For example, grain harvest, Iowa State Fair, festivals, etc. may generate higher volumes (in terms of ESALs) of traffic for a short period of time. This does not only take into account traffic volumes, but also pavement loads.
 - g. Mixture Workability:** Smaller mixture sizes are easier to use for hand work.
- 6. Select the HMA Mixture Criteria for Each Pavement Layer:** Using the information developed in steps 1 through 5, select the PG binder grade, mixture size, mix design level, and aggregate properties.
- a. PG Asphalt Binder Grade:** Engineers should evaluate the initial costs, traffic loadings, historical experience, and potential maintenance costs when selecting the appropriate binder for a project. The designer should select a binder that nominally satisfies 98% temperature reliability for both the 7 day high pavement temperature and the 1 day low pavement temperature (see 5D-1, C, 3). The 98% reliability level described by LTPP Bind designates the areas that are covered to the most extreme high and low temperatures in Iowa. When evaluating the binder to select, the engineer should balance initial costs for the binder and the likelihood of maintenance requirements caused by rutting/shoving for high pavement temperatures and low temperature cracking during the 1-day cold temperatures. In the central

and southern counties of Iowa, PG 58-28S binders will provide full 98% reliability. For the northern three tiers of counties about 87% of the weather stations report temperatures that provide a 97% or 98% reliability using a PG 58-28S binder. The majority of the weather stations in that northern area reporting a reliability less than 98% for the PG 58-28S binder are located east of I-35 in far northeast Iowa. The Iowa DOT has chosen to use PG 58-34S binders on their Primary and Interstate projects in order to ensure a 98% reliability related to low temperature cracking in that northern portion of the state.



For local residential and collector roadway projects in some sections of the northern tier of counties, designers should consider use of PG 58-28S binders in lieu of the PG 58-34S binder due to increased binder cost. If the project area does not meet the 98% reliability with PG 58-28S binders, the increased cost of the PG 58-34S binder should be evaluated against the possibility of an increase in maintenance costs as a result of the potential incremental thermal cracking. The designer should also include the size of the project and the availability of the alternate binder (PG 58-34S) in the binder selection analysis. The use of a binder with lower reliability against low temperature cracking could result in lower initial binder cost that could offset the potential additional maintenance costs over the life of the pavement. Also in that northern area, designers should closely evaluate the use of PG 58-28H and PG 58-34H binders for projects involving higher volume arterial roadways.

Engineers may designate an “H” binder, such as PG58-28H or PG 58-34H, to accommodate higher truck traffic and/or slower stop and go traffic. For the very highest volume roadways, a PG-58-28V or a PG 58-34V should be considered.

For all base and intermediate layers that are 3 to 4 inches below the surface, PG 58-28S is the recommended binder. The surface binders will insulate the lower layers from the severe one day low temperature event. For projects in the central and southern parts of the state that involve overlays, it may be appropriate to use PG 64-22S. If no method is used to retard the reflective cracking, such as an interlayer, rubblization, or crack and seat, the resistance to low temperature cracking is not critical. If there are methods employed to retard the reflective cracking, a PG 58-28S or PG 58-28H should be used.

The designer should first evaluate use of a conventional binder that best satisfies the project conditions. The conventional binder in Iowa is a PG 58-28S. Agencies in the central and southern part of the state who have had historical success using PG 64-22S may continue use of that binder grade.

Table 5D-1.01: Asphalt Binder for Local Agencies

Asphalt Mixture		PG Binder			
Design Traffic (1 x 10 ⁶ ESALs)	Mix Designation	Design Traffic (1 x 10 ⁶ ESALs)	Design Speed (MPH)		
≤ 0.3 M	LT	≤ 0.3 M	and ≤ 45	58-28S	58-28S
0.3 M to 1 M	ST	0.3 M to 1 M	and > 45	58-28S	58-28S or 58-34S ¹
0.3 M to 1 M	ST	0.3 M to 1 M	and 15 to 45	58-28S ²	58-28S ² or 58-34S ^{1,3}
1 to 10 M	HT	1 to 10 M	and 15 to 45	58-28H	58-34H
Overlays	LT/ST/HT	≤ 10M	and 15 to 45	64-22S ⁴ or 58-28S or H	58-28S or H

L = Low S = Standard H = High

¹ Use of PG 58-34 binder should consider the low temperature reliability in the project area, the availability and cost of different binders, and the ability of the contracting agency to provide on-going maintenance activities.

² Use of PG 58-28H should be considered if heavy truck or bus traffic is present.

³ For high traffic roadways use 58-34H binders.

⁴ If methods are used to retard reflective cracking, PG 58-28S or H is recommended.

- b. HMA Mixture Size:** Each mixture size (NMA) is a function of the available aggregates, project conditions, and lift thickness. Minimum lift thickness is a function of density and mixture constructability. The following table shows the minimum lift thickness for the following mix sizes:

Mix Size	Minimum Lift Thickness
3/8"	1"
1/2"	1 1/2"
3/4"	2 1/4"
1"	3"

- c. Mix Design Level:** Based on the projected ESAL₂₀ value, seasonal traffic loading and current pavement distress, the designer must select a mix design level. The boundaries of the design levels are not absolute, so the designer should take into consideration the assumptions used to compute the ESAL value.
- d. Aggregate Properties:** The mixture design criteria (Table 5D-1.03) is derived from [Iowa DOT Materials I.M. 510](#). Table 5D-1.03 specifies a 15% increase in percent crushed aggregate for surface and intermediate mixes 1 M ESALs and less to account for slow, stop, and turning conditions. This will be a local decision based on past performance and available aggregates. The actual percent crushed needed to achieve the mix design gyratory compaction volumetrics will vary with the quality of the aggregates used. Both the specified percent crushed and the gyratory compaction volumetrics must be satisfied by the asphalt mixture.

- 7. Check for Availability of Materials to Meet the Mix Design Criteria:** Review the mix design criteria selected in step 6 and determine if the binder and aggregates required to meet the mix design criteria are readily available or accessible at a reasonable cost. Contact local producers

and/or district materials engineers, if the designer plans to use non-standard criteria. Imported aggregates and modified binders generally cause higher costs. The designer should be ready to justify the mix selection decision.

- 8. Place Mix Criteria in the Project Plans and Proposal:** The following information should be placed in the plans and proposal:
- a. Traffic and ESAL₂₀ Projections:** The traffic and ESAL₂₀ projections should be listed on the title sheet of the plans. The ESAL₂₀ value should coincide with the selected mix design level. If seasonal ESALs are used for design, the title sheet should note that the ESAL₂₀ value is based on seasonal loading. The following is an example title sheet.

Traffic	
Current ADT	_____
Future ADT	_____
Present Trucks	_____
ESAL ₂₀	_____

- b. HMA Mixture:** Each asphalt mixture bid item is defined by the ESAL level, lift designation, and aggregate size. The mixture properties for each mixture level are specified in the specifications and Table 5D-1.03. If the designer specifies a different percent crushed aggregate, this should be identified in the bid item note on the plans. The designer should avoid placing the mix size in additional sections of the plans to minimize errors associated with duplication. The exception to this guide would be a bid item note or tabulation intended to identify locations of different mix sizes for the same lift.
- c. Asphalt Binder Grade PG XX -YY:** The asphalt binder grade should be specified in the bid item. The designer should avoid placing the binder grade in additional sections of the plans to minimize errors associated with duplication. The exception to this guide would be a bid item note or tabulation intended to identify binder use when multiple binders are specified. The following is an example bid item.

Lift Designation	Mix Size	Binder Grade	Mix Design Level
↓	↓	↓	↓
HMA Standard Traffic (ST) Surface, 3/8", PG 58-28S			

D. Material Properties

- 1. Typical PG Grades and Their Application:** Two grades (PG 58-28S and PG 58-34S) are common conventional binders used in Iowa. A PG 58-28S asphalt binder will cover the climate range for a majority of projects in Iowa with 98% reliability. The northern tier counties may desire a PG 58-34S for better low temperature protection. Southern counties may consider a PG 58-28H binder for better high temperature properties.

Some applications utilize specific binder grades. Use PG 58-34E meeting AASHTO T-321 with a minimum of 100,000 cycles to failure for asphalt interlayer applications. Use PG 58-34E meeting AASHTO T-324 with a minimum 90% elastic recovery for high performance thin lift applications.

When recycled asphalt materials (RAM) are used and they exceed 20% replacement of the total binder, the binder grades may need to be modified. See [Iowa DOT Materials I.M. 510](#).

If warm mix asphalt (WMA) technologies are utilized, the binder grade selection is based on plant mixing temperatures and the level of field compaction. See [Iowa DOT Materials I.M. 510](#) for information on the appropriate binder grade.

2. **Aggregate Source Properties:** Aggregate source properties are defined in [Iowa DOT Specifications Section 4127](#). The mixture criteria listed in Table 5D-1.03 defines the aggregate type for each mixture level specified for the project. Each individual source of aggregate is expected to meet these criteria. The designer may specify a different aggregate type in the bid item note.
3. **Aggregate Consensus Properties:** Aggregate consensus properties are listed in Table 5D-1.03 for each mixture level. These properties include percent crushed aggregate, fine aggregate angularity, clay content (sand equivalent), and flat and elongated particles. These aggregate properties are measured on the combined aggregate, not individual aggregates.

If the designer specifies a value different from Table 5D-1.03, the value selected should be based on the local practice and desired pavement performance. The asphalt mixture must satisfy both the percent crushed aggregate and laboratory compaction volumetric criteria. The percent crushed aggregate specified is interdependent on the compaction level and the quality of the aggregate.

E. Use of Mixture Selection Guide and Design Criteria Tables

Two tables in Subsection H are provided to assist designers with the selection of asphalt materials for projects. The Asphalt Mixture Selection Guide (Table 5D-1.02) provides the project designer with a set of standard material selections that will satisfy most projects. The Asphalt Mixture Design Criteria (Table 5D-1.03) is derived from [Iowa DOT Materials I.M. 510](#) and provides the mix designer with the detailed mix criteria for each mixture level. The mixture selection guide and mixture design criteria represent the current understanding of accepted asphalt properties for application on urban routes.

The Asphalt Mixture Selection Guide (Table 5D-1.02) represents commonly used mixture parameters, but does not preclude the project designer from deviating from the "recommended" values. The designer should understand the impact of any modification. The first two columns define the standard mixture levels based on traffic loading. The middle columns establish lift thickness and mix size relationships. It should be noted that Table 5D-1.02 does not address required pavement thickness to meet structural needs ([Section 5F-1](#)). The Bid Item Designation column ties the mixture levels to the bid items. The final column gives a general statewide guide for the estimated binder content. Local binder content experience may be more appropriate for project estimated quantities. This table does not address the need for special friction aggregate. In general terms, urban routes do not require special friction aggregate.

As mentioned earlier, the Asphalt Mixture Design Criteria (Table 5D-1.03) is derived from [Iowa DOT Materials I.M. 510](#). However, the table differs from I.M. 510. For the surface and intermediate layers of the LT mixes, the amount of crushed aggregate was increased by 15% and for the ST mixes, all layers have an additional 15% crushed aggregate. A different aggregate type and the percent crushed aggregate may be specified by the designer for the project. These values established in the table are prescribed for each mixture and care should be exercised if altered by the project designer. The designer should only change these values when familiar with the material properties and mixture performance for the local area. The bid item plan note must include these values, if it differs from the value in Table 5D-1.03.

F. Example Plans

1. **Title Page:** The traffic and ESAL₂₀ projections should be listed on the title sheet of the plans. The ESAL₂₀ value should coincide with the selected mix design level. If seasonal ESALs are used for design, the title sheet should note that the ESAL₂₀ value is based on seasonal loading.
2. **Typical Section:** Lift thickness should be shown on the typical section. The lift thickness should match or exceed the recommended lift thickness for the mixture size selected, provided compactive requirements are also achieved. The lift should be designated as surface, intermediate, or base. Mixture size or design ESAL₂₀ level should not be added to the typical section (it is specified in the bid item).
3. **Bid Items:** Unless otherwise specified, each bid item covers the mixture and binder grade selected. The corresponding bid item note must specify the minimum percent crushed aggregate, if it differs from the value in Table 5D-1.03.

G. Examples for Determination of Traffic ESALs

Similar to pavement thickness design, the asphalt mixture is designed for the frequency and size of the load applied to the pavement. While it is important to have a good understanding of the traffic, it is possible to select the asphalt paving materials based on reasonable approximations. If the designer has actual traffic data, including a distribution of truck types and loads, the current annual ESAL value can be computed from the AASHTO pavement design tables. For most projects however, the designer will determine estimated values based on a general familiarity with the route. The following examples can be used to approximate the design ESAL₂₀ for a project.

Example 5D-1.01: Two Lane, Two Way Traffic, Low Volume Street

Step	Task	Values
1	Given: Current AADT Percent Trucks Percent Annual Growth Rate Design Period	1,000 5% 2% 20 years
2	Base Year Design ESALs [from Section 5F-1, Table 5F-1.08]	8,000 ESALs
3	Growth Factor [from Section 5F-1, Table 5F-1.11]	24.3
4	Compute ESAL ₂₀ [8,000 ESALs x 24.3]	194,400 ESALs
5	Select HMA mixture design level [from Table 5D-1.02, <i>HMA Mixture Selection Guide</i>]	≤ 0.3 M

Example 5D-1.02: Two Lane, Two Way Traffic, High Volume Street

Step	Task	Values
1	Given: Current AADT Percent Trucks Percent Annual Growth Rate Design Period	10,000 3% 3% 20 years
2	Base Year Design ESALs [from Section 5F-1, Table 5F-1.08]	50,000 ESALs
3	Growth Factor [from Section 5F-1, Table 5F-1.11]	26.9
4	Compute $ESAL_{20}$ [50,000 ESALs \times 26.9]	1,345,000 ESALs
5	Select HMA mixture design level [from Table 5D-1.02, HMA Mixture Selection Guide]	1 to 10 M

Example 5D-1.03: Four Lane Street

Step	Task	Values
1	Given: Current AADT Percent Trucks Percent Annual Growth Rate Design Period	15,000 5% 2% 20 years
2	Base Year Design ESALs [from Section 5F-1, Table 5F-1.10]	75,000 ESALs
3	Growth Factor [from Section 5F-1, Table 5F-1.11]	24.3
4	Compute $ESAL_{20}$ [75,000 ESALs \times 24.3]	1,822,500 ESALs
5	Select HMA mixture design level [from Table 5D-1.02, HMA Mixture Selection Guide]	1 to 10 M

H. Tables and Figures

Table 5D-1.02: Mixture Selection Guide

Design ESAL ₂₀ (Millions)	Layer Designation	Lift Thickness ³			Mix Size ¹	Bid Item Designation	Binder Content ²
		<i>min</i>	<i>rec</i>	<i>max</i>			
≤ 0.3	Surface	1.5	1.5	2.5	1/2"	Low Traffic (LT)	6.00
	Intermediate	1.5	1.5	3			
	Base	1.5	3	4.5			
0.3 to 1.0	Surface	1.5	1.5	2.5	1/2"	Standard Traffic (ST)	6.00
	Intermediate	1.5	1.5	3			
	Base	1.5	3	4.5			
1.0 to 10.0	Surface	1.5	2	2.5	1/2"	High Traffic (HT)	6.00
	Intermediate	2	2.5	3	3/4"		5.50
	Base	3	4	4.5	1"		5.25

¹ The Common mix size is shown. When other mix sizes are used, the minimum lift thickness also changes (see Section 5D-1, C, 6, b).

² These values are for estimating quantities only. The actual asphalt binder content is established in the approved job mix formula.

³ Some lift thickness values in this guide may conflict with traffic control or allowable compaction criteria.

Table 5D-1.03: Mixture Design Criteria
(derived from [Iowa DOT Materials I.M. 510](#))

Mix	Layer Designation	Gyratory Density		Film Thickness	Aggregate ²			
		N _{des}	Design % G _{mm} (target)		Quality Type	Crush (min)	FAA (min)	Sand Equivalent (min)
LT	0.3 M S	50	96.0	8.0 - 15.0	A ¹	60 ¹	---	40
	0.3 M I		96.0		A ¹	45		
	0.3 M B		97.0		A ¹	45		
ST	1M S	50	96.0	8.0 - 15.0	A	75 ¹	40	40
	1M I		96.0		A ¹	60 ¹		
	1M B		97.0		A ¹	60 ¹		
HT	10M S	75	96.0	8.0 - 15.0	A	75	43	45
	10M I		96.0		A	75		
	10M B		96.5		A ¹	60		

For mix design levels exceeding 10M ESALs, see [Iowa DOT Materials I.M. 510](#).

¹ Requirements differing from [Iowa DOT Materials I.M. 510](#); for base mixes, aggregate quality improved from B to A and percent crushed aggregate increased by 15%.

² Flat & Elongated 10% maximum at a 5:1 ratio

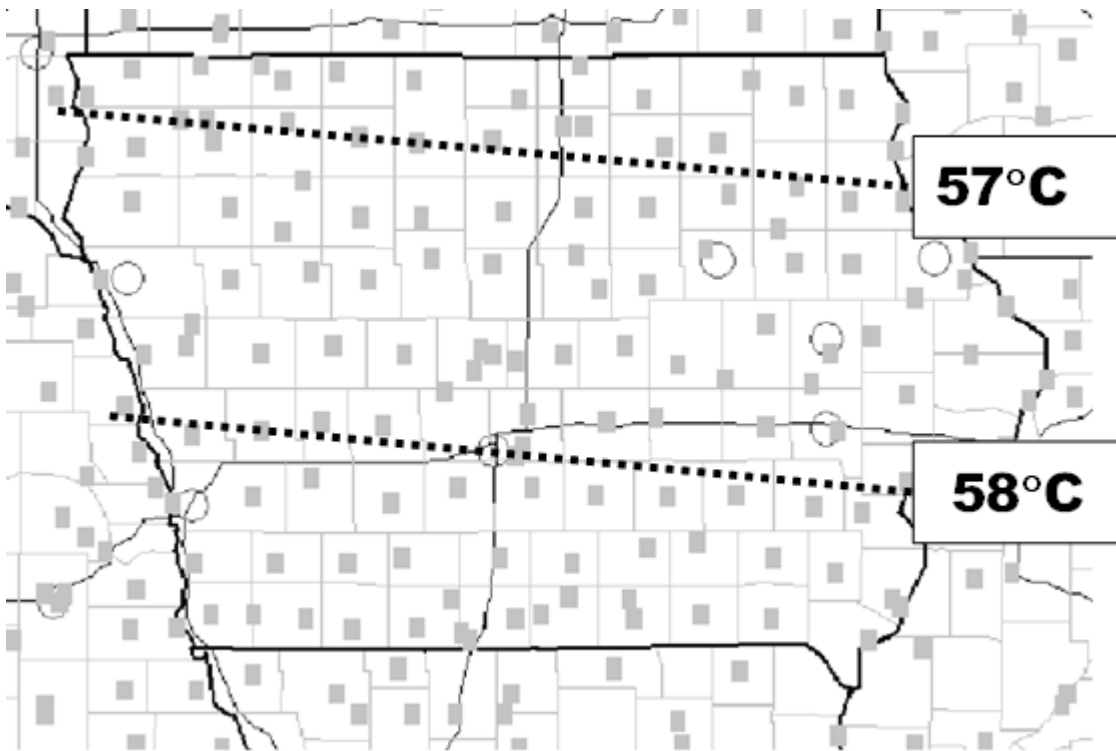
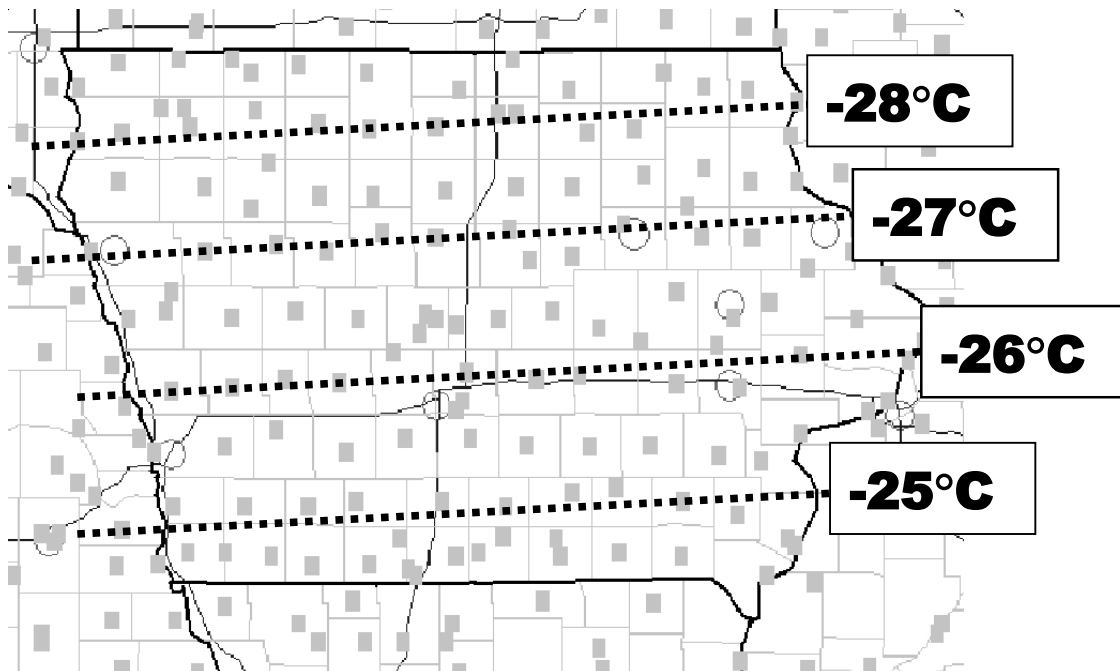
Figure 5D-1.01: High (7 Day) Pavement Temperature at 98% Reliability**Figure 5D-1.02: Low (1 Day) Pavement Temperature at 98% Reliability**

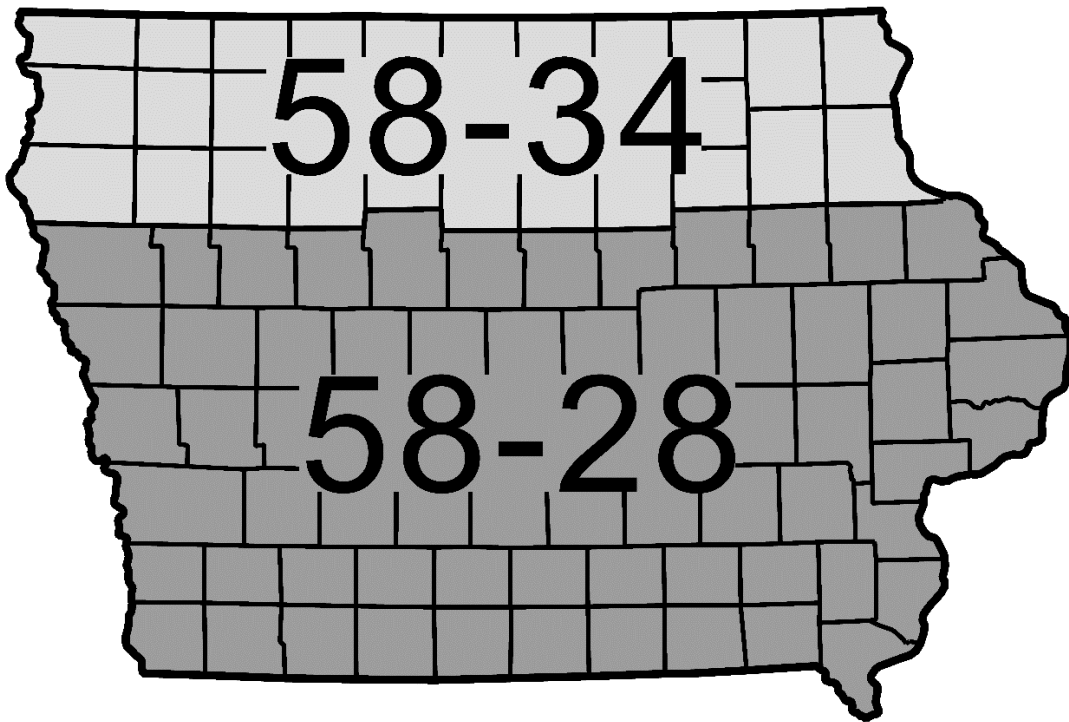
Figure 5D-1.03: Standard Binder Grades for 98% Temperature Reliability

Table 5E-1.03: Effects of SCMs on Hardened Concrete Properties

	Fly ash		GGBF slag	Silica fume	Natural pozzolans		
	Class F	Class C			Calcined shale	Calcined clay	Metakaolin
Early strength	↓	↔	↓	↑↑	↓	↓	↑↑
Long-term strength	↑	↑	↑	↑↑	↑	↑	↑↑
Permeability	↓	↓	↓	↓↓	↓	↓	↓↓
Chloride ingress	↓	↓	↓	↓↓	↓	↓	↓↓
ASR	↓↓	↓↑	↓↓	↓	↓	↓	↓
Sulfate resistance	↑↑	↑↑	↑↑	↑	↑	↑	↑
Freezing and thawing	↔	↔	↔	↔	↔	↔	↔
Abrasion resistance	↔	↔	↔	↔	↔	↔	↔
Drying shrinkage	↔	↔	↔	↔	↔	↔	↔

Sources: Thomas and Wilson (2002b); Kosmatka, Kerkoff, and Panarese (2003)

Key: ↓ reduced
 ↓↓ significantly reduced
 ↑ increased
 ↑↑ significantly increased
 ↔ no significant change
 † effect varies

Source: Taylor et al, 2006

- Limitations on the Use of SCMs:** Table 5E-1.04, which is adapted from ACI 218, provides recommended maximum amounts of SCMs for concrete exposed to deicing chemicals, such as Iowa concrete pavements. The Iowa DOT and SUDAS Specifications limit the usage of SCMs below the ACI maximum amounts. By those specifications, the maximum allowable fly ash substitution rate is 20%, and the GGBF slag substitution rate is limited to no more than 35% by weight (mass). The total mineral admixture substitution rate cannot exceed 40%. When Type IP or IS cement is used in the concrete mixture, only fly ash substitution is allowed.

Table 5E-1.04: Cementitious Materials Requirements for Concrete Exposed to Deicing Chemicals

Cementitious Materials*	Maximum Percent by Total Cementitious Materials by Mass**	
	ACI Values	Iowa Values
Fly ash and natural pozzolans	25	20
GGBF slag	50	35
Silica fume	10	0
Total of fly ash, GGBF slag, silica fume, and natural pozzolans	50***	40
Total of natural pozzolans and silica fume	35***	20

* Includes portion of supplementary cementitious materials in blended cements.

** Total cementitious materials include the summation of portland cements, blended cements, fly ash, slag, silica fume, and other pozzolans.

*** Silica fume should not constitute more than 10% of total cementitious materials and fly ash or other pozzolans must not constitute more than 25% of cementitious materials.

Source: Taylor et al, 2006

D. Aggregates

Aggregates account for 60% to 75% of concrete by volume and are seldom susceptible to moisture and chemical changes, making them an important ingredient in concrete mixtures. Aggregates influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy. They must be durable and free of any absorbed materials, clay, and materials that effect the interaction with the cement.

1. Types of Aggregates:

- a. **Carbonate Rock:** Mainly limestone and dolomite with low porosity and low absorption rate.
- b. **Granite:** Igneous rocks composed mainly of silica and silicates with the highest modulus of elasticity of any rock type available.
- c. **Gravel and Sand:** Typically mixtures of many minerals and rocks. Gravel and sand from shale, siltstone, or unsound material rich rocks tend to be unsound and not recommended. Sand and gravel from higher elevations and that have been smoothed by water are best.
- d. **Manufactured Aggregates:** Produced by crushing rocks into smaller pieces. Least likely to be contaminated, but mixtures with manufactured aggregates tend to be harder to work with and require more water.
- e. **Recycled Aggregates:** Made from crushing concrete pavement and mixed with new aggregates. Typically has a higher absorption rate.

The following aggregate properties are important to consider when mixing concrete: gradation, durability, particle shape, surface texture, absorption, coefficient of thermal expansion, and resistance to freezing and thawing

2. **Gradation:** Gradation is a measure of the size distribution of aggregate particles, determined by passing aggregate through sieves of different sizes (ASTM C 136 / AASHTO T 27). Grading is most commonly shown as the percentage of material passing sieves with designated hole sizes. Aggregates are classified as coarse or fine by ASTM C 33/AASHTO M 6/M 80 as follows:

- a. **Coarse Aggregate:** Coarse aggregate consists of gravel, crushed gravel, crushed stone, or crushed concrete that is retained on the No. 4 sieve. The maximum size of a coarse aggregate is generally 3/8 inch to 1 1/2 inch.
 - 1) Coarse aggregate requirements allow a wide range in selection.
 - 2) If the proportion of fine aggregate to total aggregate produces concrete of good workability, the grading for a given maximum size coarse aggregate can be varied moderately without appreciably affecting a mixture's cement and water requirements.
 - 3) Coarse aggregate size is limited by local availability, the maximum fraction of the minimum concrete thickness or reinforcing spacing, and the ability of the equipment to handle the concrete.
- b. **Fine Aggregate:** Fine aggregate consists of natural sand, manufactured sand, or combinations of the two that pass the No. 4 sieve. Very fine particles (passing the No. 100 sieve) are limited by specifications because they have extremely high surface-to-volume ratios that require more paste.
 - 1) A relatively wide range in fine aggregate gradation is allowed.
 - 2) If the water to cementitious materials (w/cm) ratio is kept constant and the ratio of fine to coarse aggregate is chosen correctly, a wide range in grading can be used without a measurable effect on strength.
 - 3) Generally, increasing amounts of fine material will increase the water demand of concrete.

- c. **SUDAS Concrete Mix Proportioning Specifications:** The concrete mixes currently used in Iowa were developed in the 1950s. Classes A, B, and C were specified for concrete paving. As originally developed, Classes A and B, with minimum design compressive strengths of 3,500 psi and 3,000 psi respectively, were utilized for rural county paving. Class C concrete, with a higher compressive strength of a minimum of 4,000 psi and a w/cm ratio of less than 0.45, was the standard for primary roads. With its history of proven performance, Class C concrete is now the standard for all concrete road paving in Iowa. In areas where early opening strength is desired, such as intersections and driveways, an M mix can be substituted for C mix. M mix has a higher cement content, which accelerates the heat of hydration and set time of the concrete.

Unless the designer otherwise specifies, the contractor can choose any of the Iowa DOT Class C mixes and the materials that are allowed within the specifications. Generally, economy, workability, and availability of materials are key factors in the decision making process of the contractor and the concrete supplier.

Iowa DOT Materials I.M. 529 establishes the mix proportions for the various concrete mixes used by the Iowa DOT and SUDAS. Each mixture has specific requirements for the coarse and fine aggregates as well as the type of cement, including SCMs. The mix proportions include unit volumes for all materials.

If the concrete mix for a project is specifically needed to address joint durability, consideration should be given to the C-SUD mixes that are included in Table 4 of I.M. 529. Two main differences highlight these mixes. The first is the water-cement ratio. Using a lower water-cement ratio will create lower paste permeability and higher strength. The basic w/c ratio is 0.40 with the maximum set at 0.45. In addition to the w/c ratio, use of pozzolanic materials (SCMs) for substitution of cement will improve freeze-thaw durability in the presence of deicers. Consideration should be given to provide cement replacement rates of 20-25% Class F fly ash or 30-35% Class C fly ash or a combination of 20% slag and 20% Class C fly ash.

1) **Mix Designation:**

Example: C-4WR-S35

- The first letter indicates the class of concrete
- The first number indicates the percentages of fine aggregate and coarse aggregate
 - 2 is composed of 40% fine and 60% coarse
 - 3 is composed of 45/55
 - 4 is composed of 50/50
 - 5 is composed of 55/45
 - 6 is composed of 60/40
 - 7 is composed of 65/35
 - 8 is composed of 70/30
 - 57 is composed of 50/50
- The WR indicates water reducer is used in the mixture
- SCMs are then indicated with their percentage of cementitious material substitution. C and F fly ashes are indicated with a C and F, respectively. GGBF slag is indicated with an S. The percentage of substitution is indicated after the SCM letter.
- The example designates a Class C concrete mix, a combined aggregate composed of 50% fine aggregate and 50% coarse aggregate, water reducer admixture, and 35% GGBF slag cementitious material substitution.

- 2) **Mix Proportions:** Iowa DOT Materials I.M. 529 provides material proportioning for the various Iowa DOT concrete mixes and includes basic absolute volumes of cement, water, air, and fine and coarse aggregate per unit volume of concrete (cy/cy). Target and maximum w/cm ratios are provided for each of the mix classes. Also included is guidance for calculation of fly ash and GGBF slag cementitious material substitution of cement.
 - 3) **Admixtures:** Sources of Iowa DOT approved admixtures are provided in Iowa DOT Materials I.M. 403, along with their maximum dosages. Generally, the maximum dosages are as recommended by the manufacturers. Do not exceed the maximum dosages according to the manufacturer's recommendations.
3. **Modification of the Standard Concrete Mix Specifications:** While care should be exercised, achieving the required properties in the concrete may require making adjustments to the materials selected, to materials proportions, or even to other factors such as temperature, as follows.
- a. **Workability:** Water content, proportion of aggregate and cement, aggregate properties, cement characteristics, admixtures, and time and temperature can be adjusted to achieve the desired workability. The slump test (ASTM C 143 / AASHTO T 119) is most often used to measure the workability of fresh concrete.
 - b. **Stiffening and Setting:** The rates of stiffening and setting of a concrete mixture are important because they affect its ability to be placed, finished, and sawed. Stiffening and setting can be affected by the following in the concrete mixture: cementitious materials, chemical admixtures, aggregate moisture, temperature, and water-cementitious materials (w/cm) ratios.
 - c. **Bleeding:** Techniques can be used to prevent and minimize bleeding. These techniques (Kosmatka 1994) include reducing the water content, w/cm, and slump; increasing the amount of cement or supplementary cementitious materials in the mix; increasing the fineness of the cementitious materials; using properly graded aggregate; and using certain chemical admixtures such as air-entraining agents may reduce bleeding.
 - d. **Air-void System:** The air-void system is important to concrete durability in environments subject to freezing and thawing. It includes total air content, spacing factors, and specific surface. The air-void system can be controlled with cement, supplementary cementitious materials, aggregates, and workability. The air-void system in the field will be affected by changes in the grading of the aggregate, water, admixture dosage, delays, and temperature.
 - e. **Density:** Conventional concrete used in pavements has a density in the range of 137 to 150 lb/yd³. Density varies depending on the amount and density of the aggregates, the amount of entrained air, the amount of water, and the cement content. Density is affected by the following factors: density of the material in the mixture, mostly from coarse aggregates; moisture content of the mixture; and relative proportions of the materials, mainly water.
 - f. **Strength:** Strength and rate of strength gain are influenced by water-cementitious materials ratio, cement chemistry, SCMs, chemical admixtures, aggregates, and temperature. Changes in the environmental conditions and variation in materials, consolidation, and curing affect the strength at a specified age and affect strength development with age. Increased temperatures will increase early strength but may decrease long-term strength gain.
 - g. **Volume Stability:** Concrete experiences volume changes as a result of temperature and moisture variations. To minimize the risk of cracking, it is important to minimize the tendency to change in volume by considering paste content, aggregates, and curing.

- h. Permeability and Frost Resistance:** Permeability is a direct measure of the potential durability of a concrete mixture. Lower permeability is achieved by the following factors.
- Increasing the cementitious materials content
 - Reducing the water-cementitious materials ratio
 - Using supplementary cementitious material at dosages appropriate to the expected likelihood of freezing water
 - Using good curing practices
 - Using materials resistant to the expected form of chemical attack
 - Using aggregates that have proven to resist D-cracking. Reducing maximum coarse aggregate size will reduce the risk of damage if aggregates prone to damage are unavoidable.
 - Ensuring that a satisfactory air-void system is provided

J. References

Kosmatka, S.H., B. Kerkhoff, W.C. Panarese. *Design and Control of Concrete Mixtures*. EB001.14. Skokie, IL: Portland Cement Association. 2002.

Taylor, P.C., S.H. Kosmatka, G.F. Voigt, et al. *Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual*. FHWA HIF-07-004. National Concrete Pavement Technology Center/Center for Transportation Research and Education, Iowa State University. 2006.

Weiss, J., Ley, M.T., Sutter, L., Harrington, D., Gross, J., Tritsch, S. *Guide to the Prevention and Restoration of Early Joint Deterioration in Concrete Pavements*. National Concrete Pavement Technology Center/Institute for Transportation, Iowa State University. 2016.

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 20 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 13 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	20'

¹ No dowels within 24" of the back of curb

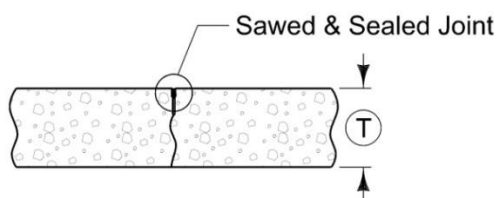
Source: [SUDAS Specifications Figure 7010.901](#)

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 $T/3$. 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.

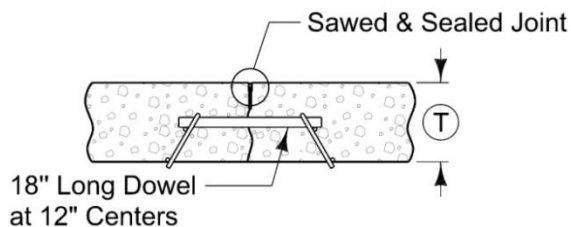
Figure 5G-2.01: 'C' Plain Contraction Joint



- 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 20 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.

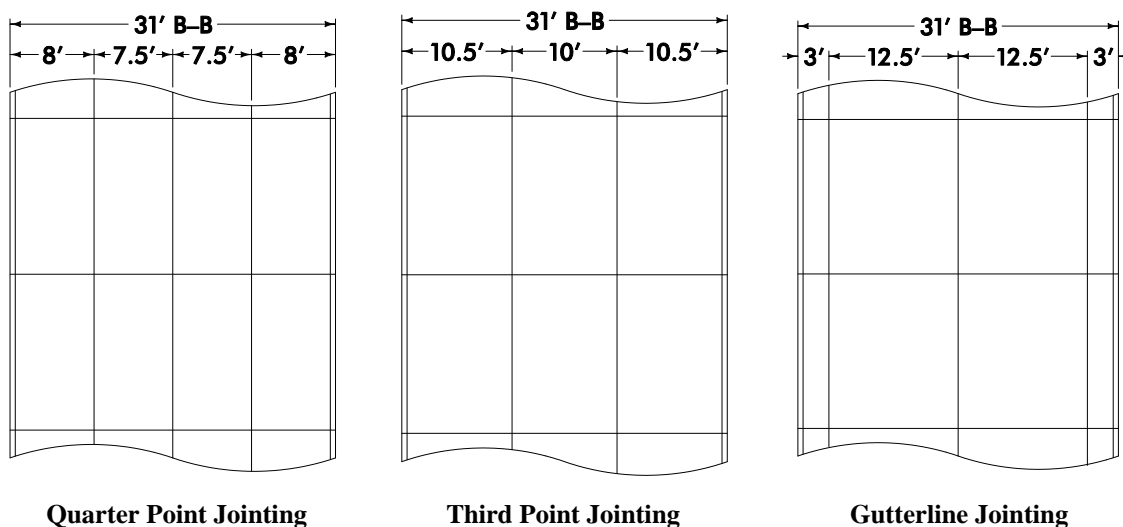
Figure 5G-2.02: 'CD' Doweled Contraction Joint



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.

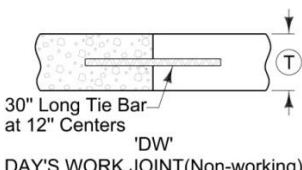
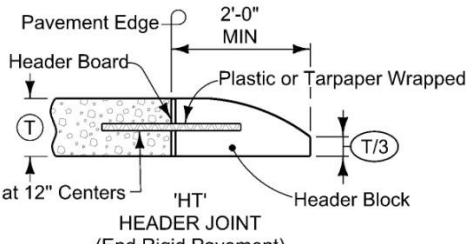
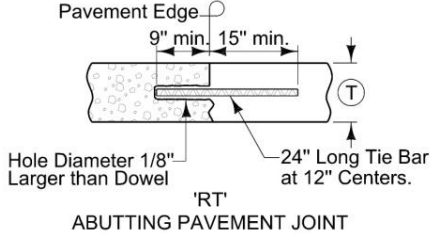
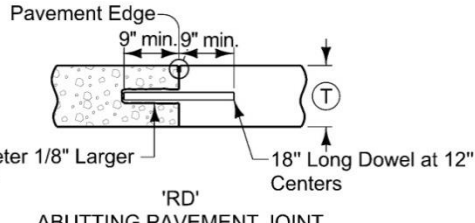
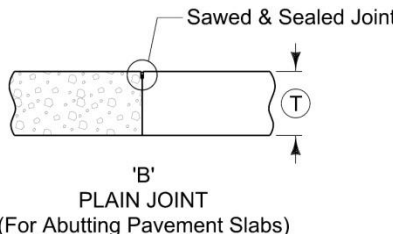
pavement may be widened in the future, and the delineation of the lanes is desired. Care must be exercised with this option to prevent random cracking at the quarter point. Typically, gutterline jointing is used on streets with pavement thickness greater than or equal to 9 inches.

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' 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 Block</p> <p>HEADER JOINT (End Rigid Pavement)</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

Jointing Concrete Roundabouts

A. General Information

Roundabouts are an increasingly popular intersection type due to their traffic flow and safety characteristics. When using concrete for the roundabout, it is critical to develop a workable jointing plan to make sure the joint layout will be constructed properly. The jointing plan is the key by which the joints will be correctly located. Because concrete jointing is sometimes used for lane delineation, it is important to recognize the impact of the jointing plan on drivers who are unfamiliar with the operation of roundabouts.

The jointing plan should avoid the following:

- Slabs less than 2 feet wide
- Slabs greater than 15 feet wide
- Angles less than 60 degrees
- Creation of interior corners
- Creation of odd shapes

B. Types of Jointing Patterns

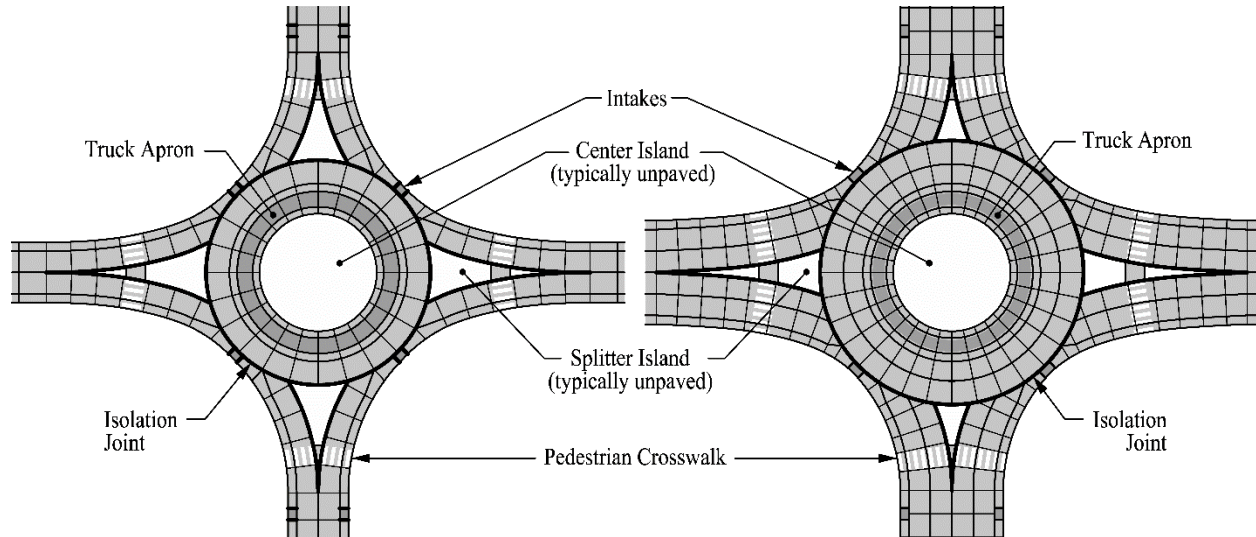
There are three general types of overall jointing plans, including isolation, pave-through, and pinwheel. Very early in the design process, the type of jointing plan needs to be selected because of the impact the jointing plan has on the overall design. It is important to note that, in general, the joints in the circular portion should radiate from the center and the joints in the legs should be perpendicular to the circle. The apron paving must be isolated from the vehicle lane paving. If the inner circle is paved, provide an isolation joint between it and the truck apron. Jointing on the inner circle should also radiate from the center point but care is needed to prevent the creation of small slabs. The construction staging required for the project will influence selection of the jointing type. The designer should understand that once the contract is let, the successful contractor may request modification in the jointing plan to better fit the contractor's equipment and processes. The designer should closely evaluate any requests for change in the jointing plan in order to ensure that the original objectives are maintained. The same types of joints are used for roundabouts as for any other concrete pavements and the same rules for construction apply.

The type of jointing pattern to be used is dependent on the project staging and if a specific directional movement(s) is to be emphasized. The jointing plans for double lane, single lane, and mini-roundabouts follow the same philosophy. Since the total inscribed circle for mini-roundabouts is paved, the jointing pattern will most often follow the isolated circle type, but pave through can also be used. Pinwheel jointing is generally not used for single lane and mini-roundabouts. Splitter islands for some mini-roundabouts may be formed by painted lines so the jointing pattern is not impacted.

Because all approach legs of a roundabout are under yield control, the targeted street grade in the pedestrian crossing area should be 1.5%, with a maximum of 2%, unless a determination is made that it is technically infeasible. See Section 12A-2.

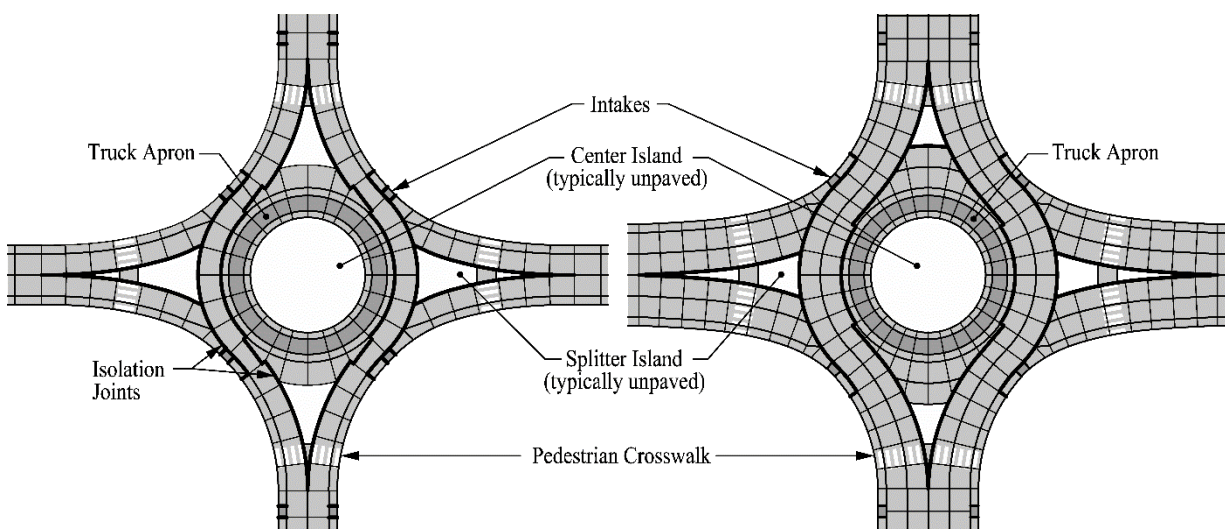
1. **Isolated Circle Jointing:** This jointing type is particularly useful on large roundabouts. All joints within the circle radiate out through the center point of the circle. Longitudinal and transverse joints within the legs of the roundabout connect to the nearest joint in the circle. See Figure 5G-6.01.

Figure 5G-6.01: Isolated Circle Jointing



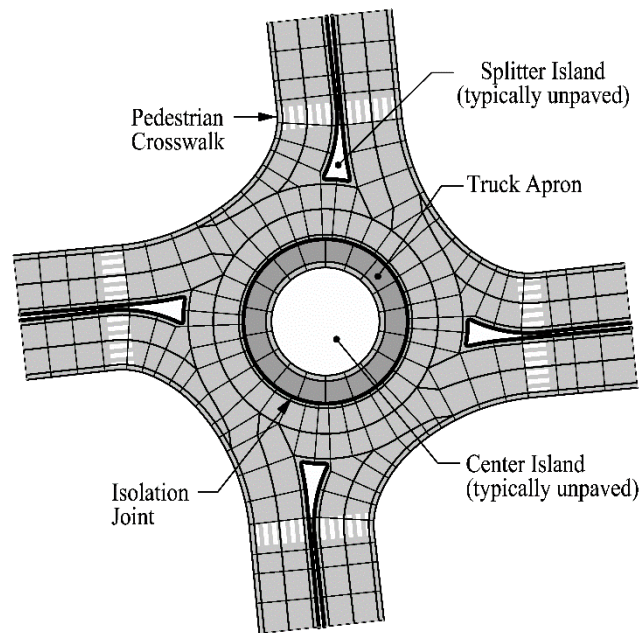
2. **Pave Through:** This jointing pattern is useful when faster construction under traffic conditions is needed. It is also used when directional assistance from the jointing plan will enhance vehicle operations. The first step is to pick the legs that are to be paved through. Generally, these would be the highest volume movements. Being able to use a slipform paver to speed construction requires the designer to make sure curvature, cross slopes, and longitudinal slopes are set so the paver may be used. Joints on the legs of the roundabout should be set perpendicular to the longitudinal direction of the leg and set to radiate from the center of the circle as the paving passes through the circle. The other two legs should provide for transverse joints perpendicular to the curbs or edge of the slab and the longitudinal joint should connect to the nearest joint on the pave through legs. See Figure 5G-6.02.

Figure 5G-6.02: Pave Through Jointing



3. **Pinwheel:** This jointing type is sometimes called spiral jointing. It is a combination of the isolation and pave through types. Emphasis is provided for each exiting leg of the roundabout. The jointing for the exit legs is set as for the major pave through legs. The jointing for entering legs is set similarly to the lesser legs of the pave through option. Joints within the circle are set to radiate from the center and the others are perpendicular. See Figure 5G-6.03.

Figure 5G-6.03: Pinwheel Jointing



C. Jointing Layout Steps

1. Draw all pavement edge and back of curb lines in a plan view. Draw locations of all manholes, intakes, and water valves so the joints can intersect with them.
2. Draw all lane lines as applicable on the legs and in the circular portion. If isolating the circle from the legs, do not extend the lane lines into the circle. If using the pave through method, determine which roadway will be paved through. Take precaution not to exceed maximum longitudinal width.
3. In the circle, add transverse joints radiating out from the center of the circle. Make sure that the largest dimension of a pie-shaped slab is smaller than the maximum recommended and the smallest dimension is not less than 2 feet. Extend these joints through the curb or edge of pavement.
4. Add transverse joints on the legs at all locations where a width change occurs such as at the nose of median islands, the beginnings and ends of curves, tapers, tangents, and curb returns. Extend these joints through the curb or edge of pavement.
5. Add transverse joints beyond and between those added in Step 4. Space joints out evenly to make sure that the maximum joint spacing is not exceeded.
6. Make adjustments for in-pavement objects and to eliminate odd shapes and small triangular slabs.

Automated Machine Guidance

A. Concept

Automated machine guidance (AMG) for grading is a process in which grading equipment, such as a motor grader or dozer, utilizes onboard computers and positioning systems to provide horizontal and vertical guidance to the equipment. Automated machine guidance for grading reduces the need for grade stakes and improves the safety of construction personnel.

In addition to automated machine guidance for grading, paving and milling equipment has the ability to utilize “stringless” control to guide the machine both vertically and horizontally. Stringless milling and paving operations eliminate the time of setting and removing the string line along a project. In addition, stringless technology results in fewer traffic disruptions as traffic does not need to be routed around the string line. These benefits result in increased safety for construction personnel and the traveling public.

B. Deliverables and Computer Inputs

Contractors should use the same 3D engineered model for all aspects of construction. This ensures consistency between the grading, trimming, and paving surfaces. For example, if the contractor were to use a grading file that has been manipulated, the unmodified paving surface may not match the ground elevations after grading. Using the same 3D model for all AMG activities reduces the risk of surface elevations that do not match.

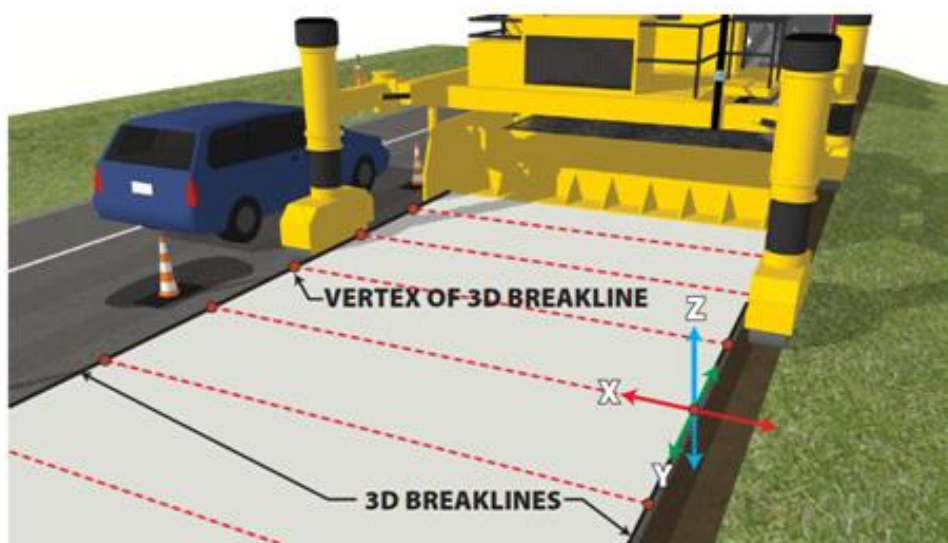
As with all AMG-equipped machinery, the contractor will need to upload the 3D engineered model into the AMG system. AMG systems are only capable of accepting specific file types. Rather than providing 3D file types to contractors in specific formats that are compatible with individual pieces of equipment, it is recommended the designer provide files in generic formats as shown in the table below. LandXML and DXF file formats are generic formats that are compatible with a wide range of CAD and survey software programs.

Information Contained Within File	Recommended File Format
Alignment	Land XML
Surfaces	Land XML
3D Line Strings	DXF

Providing files in a generic format saves time for the designer since they do not need to provide the data in multiple formats. The generic file types will need to be converted by the contractor into a compatible file type prior to uploading it to their system. A fully designed 3D engineered model for AMG grading contains the existing grading surface, proposed grading surface, and proposed features. It is able to guide grading machines and excavators when they are referenced to control points set up on or near the project site.

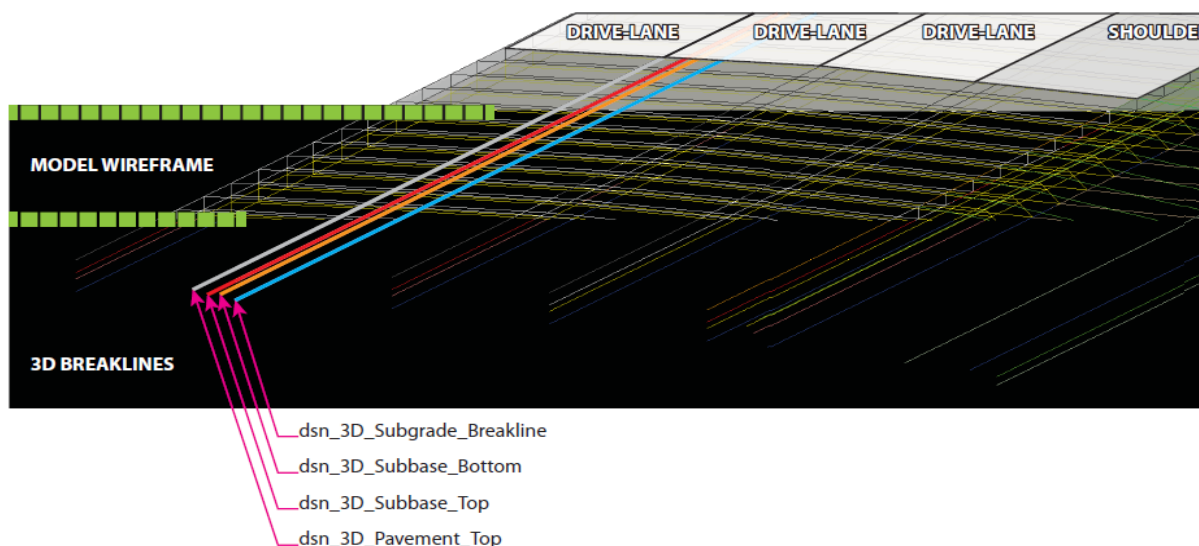
Stringless paving uses different inputs compared to AMG grading and milling. Design data for stringless paving must be derived from the 3D engineered model, including the pavement plan, profile, and geometrics. The data that will control the paving machine is referred to as 3D break lines. 3D break lines are lines in a file that reflect a distinct change in the surface type or slope. 3D break lines contain X, Y, and Z coordinate information that can be referenced by AMG equipment. Figure 5H-1.01 shows how a stringless paving machine uses 3D break lines for horizontal and vertical control.

Figure 5H-1.01: Pavement Edge Lines and Break Lines



It is recommended that the engineer perform data conversion to transform the CAD coordinate data contained within the 3D engineered model into 3D line strings and curve equations representing the pavement edges and interior break lines. A typical CAD file contains a significant amount of information that is not actually necessary for paver guidance. Therefore, part of the transformation process is to extract the 3D break lines that represent the pavement edge lines, significantly reducing the amount of information the onboard stringless computer must interpret. Figure 5H-1.02 shows a cross-section of 3D break lines in a CAD file for horizontal and vertical control.

Figure 5H-1.02: 3D Break Lines Contained within the 3D Engineered Model



The files that are available for AMG also need to be designed at the correct interval. The interval refers to the lateral distance between X, Y, and Z coordinates that make up a 3D surface. The interval can also be used interchangeably with the term “template drop”. For final design, a maximum interval of 5 feet should be used to minimize the opportunity for irregularities between template drops. The shorter interval improves the accuracy of the model and reduces the potential for errors within the project limits. The preliminary design stage may use 25 foot intervals since the project would not be constructed from the model and accuracy requirements are not as stringent.

C. What to Include/Not Include in 3D Engineered Models

Through several years of successful 3D implementation, the Iowa DOT determined that it is not necessary for engineers to spend a great deal of time merging side-road models and other features into a single “master” model. Contractors will take whatever information they can get and have the ability to merge information on their own to match specific staging operations. Additionally, designers should not expend effort trimming 3D models into more manageable sizes. Most software programs that contractors utilize have the capability to trim files into their desired area.

The 3D engineered model should contain the appropriate beginning and ending of transitions for key geometric features. Beginnings and endings of vertical and horizontal curves should be included in the model. Intersection radii and intersection grading should also be modeled to clearly communicate the drainage patterns and design intent of the project. All unique grading areas such as berms, detention ponds, and ditches should be included in the model for AMG construction.

The 3D engineered model that is provided to the contractor should not contain gaps or void spaces within the model boundaries. Traditional design methods have gapped difficult areas such as bridge berms and intersection radii. This required contractors to spend time and money to fill in the gapped areas and created difficulties for construction personnel in interpreting design intent. Misinterpretation by construction personnel can lead to errors and costly rework. Agencies need to strike a balance between the level of model completeness and how much effort is required by the designer. For example, it is often too labor-intensive to model ADA compliant pedestrian ramps when contractors will likely not be using the 3D model to construct them. In this type of situation, the engineer needs to decide whether or not to model intricate details.

D. Component Naming

Although CAD standards are helpful for consistency purposes, agencies should not let the lack of CAD standards prevent the use of 3D design and construction. Designers must clearly communicate what each layer and line type represents within the model to prevent confusion during AMG and stringless paving. Clear and intuitive naming of each line and layer within the model is recommended.

E. Bid Letting

All 3D files that will be used by the contractor for construction purposes should be provided prior to the letting. This approach levels the playing field for all potential bidders and avoids an unfair advantage for contractors who knew the files would be available after the bid letting. All deliverables that are provided to contractors should be well documented for each project.

The paper plan set and specifications should be considered the “signed and sealed” data. The electronic 3D files are provided for information only and are not signed by a professional engineer. The contractor is responsible for ensuring the project is constructed according to the “signed and sealed” plan set. A disclaimer statement should also be included in the paper plan set that indicates the paper copy on file with the agency is the official copy and the contractors are responsible for

constructing the project to those plans.

The use of AMG should be considered incidental to construction and be at the option of the contractor. If approved by the Engineer, the use of stringless paving should be considered incidental to construction. No separate payment should be made for the use of AMG and stringless paving as the reduction in survey needs and improved operational efficiency offset the added costs.

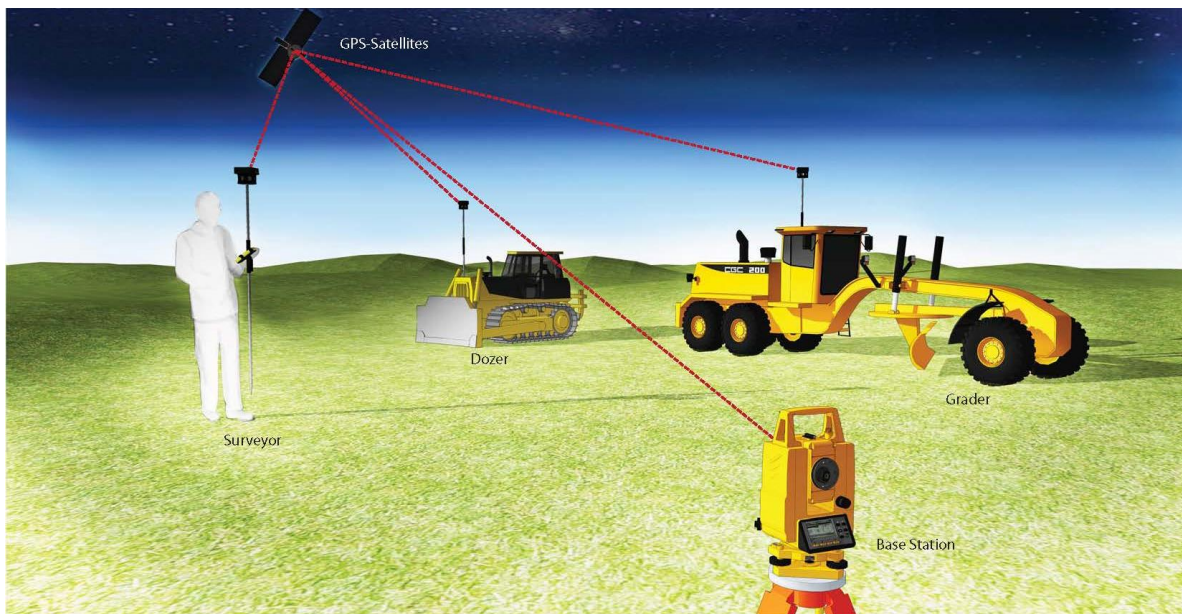
F. Construction Staking Requirements

Traditional construction staking requirements can be reduced for machine guidance in an effort to increase cost savings. Reducing the requirements for construction staking also improves safety for surveyors traversing the construction site while in close proximity to large equipment. Construction staking, although limited, is still required at reduced intervals to ensure the 3D engineered model and construction equipment is giving the correct layout and elevations. This provides another layer of quality control for a more accurate finished product.

G. Survey Control for AMG Grading

A survey base station or control network needs to be set up near the site prior to any machine control use. Machine control grading activities including dozers, excavators, and motor graders typically use GPS for AMG. The AMG system needs to be able to reference a known X, Y, Z coordinate location through a GPS base station, such as a portable GPS unit on site. The GPS base station transmits corrections to the GPS receiver on the associated AMG equipment.

Figure 5H-1.03: AMG Utilizes Satellite Positioning and Onboard Computers to Guide Equipment



For proper use of AMG technology, accurate survey control is a necessity. The survey control should contain at least one “monument” survey point that is set by a licensed surveyor and remains undisturbed throughout construction. Some states that have successfully implemented AMG technology rely on a monumented survey point that has specific X, Y, Z coordinate data that are used by the surveyor, contractor, and inspection personnel. The benefit of all parties using the same control point is an added layer of quality assurance that construction is meeting the designed elevations.

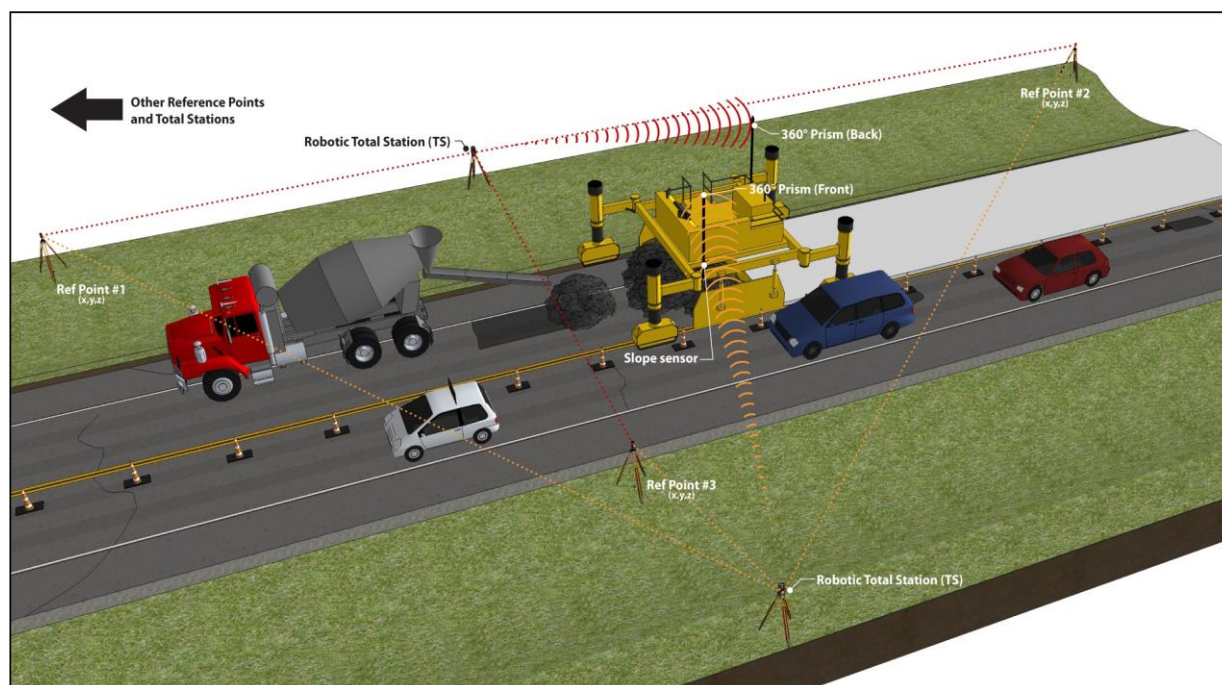
H. Survey Control for Stringless Operations

Survey and machine control for stringless operations is different than the GPS base stations used for grading operations. Stringless paving and milling machines typically use total stations or laser augmented GPS for machine control purposes because paving and milling operations require tighter tolerances than what is necessary for grading purposes. As with machine control grading, stringless guidance systems need to know their location in space (X, Y, Z coordinate). For total stations, survey control points are set by a surveyor. Typically, control points are set along the project corridor at approximately 250 foot intervals. Control points for stringless paving should be established from accurate field surveying and tied to known benchmarks. These control points should be positioned so they are out of the way of any operations and will not be disturbed by the public, but will allow instruments for machine control to see at least three control points at all times. Figure 5H-1.04 shows how stringless paving machines use robotic total stations for horizontal and vertical control.

When stringless paving is utilized, location and elevation of the finished slab should be verified against grade check hubs for the first 100 feet of each days run and at critical locations, such as intakes and through intersections where grades may be flat. The Engineer may waive these requirements if experience has shown compliance with the design elevations.

After each modification to the paving machine, verify the paving equipment is calibrated per the manufacturer's recommendations.

Figure 5H-1.04: Typical Layout of Control Points on Stringless Paving Applications



I. Quality Assurance

Conventional 2D methods of construction required inspectors to rely upon grade stakes, pavement hubs, and 2D paper plan sheets to ensure that grading and paving operations were constructed according to the intended design. However, with the proposed grading surface within the 3D engineered model, inspectors should traverse the site and take random spot checks with GPS rovers to make sure the site is being graded properly. Similarly, the inspector should spot-check elevations behind the paving machine to ensure the paving equipment is set up and working properly. Inspectors should be working from the same up-to-date files the contractor is using to eliminate the possibility of irregularities or discrepancies between different 3D files.

It is recommended that agencies require the contractor to provide GPS equipment for use by inspection personnel during grading construction. One benefit of this is the cost of the equipment does not need to be budgeted by the contracting agency. Another benefit is that any potential discrepancy caused by different equipment manufacturers is eliminated. If the contractor provides the rover, all parties are working from the same files and equipment.

J. References

Reeder, G. and G. Nelson. 2015. *Implementation Manual - 3D Engineered Models for Highway Construction: The Iowa Experience*. National Concrete Pavement Technology Center, Ames, IA.

General Information for Pavement Preservation Program

A. Concept

As effective financial resources for management of infrastructure systems continue to decline, it is necessary to explore different techniques to meet the needs of the public. This is particularly the case for pavements. One such technique is to develop a program of pavement preservation. Pavement preservation techniques have been in use for many years, but most transportation agencies have not developed a complete long-term pavement preservation program that is a part of an overall asset management program. The implementation of a pavement preservation program focuses on maximizing the condition and life of a network of pavements while minimizing the network's life-cycle cost.

The concept of a long-term pavement preservation program is a different approach than has been done in the past; the biggest difference is preservation focuses on being proactive as opposed to reactive. The concept of adopting a proactive preservation approach enables agencies to reduce the frequency of costly, time-consuming rehabilitation and reconstruction projects. It is important to understand, that pavement preservation activities do not include any structural upgrades to the pavement. All treatments are non-structural in nature.

The process to establish a long-term pavement preservation program involves data gathering for each particular pavement section concerning its construction and previous maintenance history, examining the current condition of the pavement, and then determining the appropriate treatment technique to preserve and extend the pavement life.

Customer satisfaction is the greatest benefit of a successful pavement preservation program. From project selection to treatment selection to construction, a good pavement preservation program will benefit users. Safer roads, faster repairs, and a pavement network in better condition that needs fewer repairs are the logical outcomes of a preventative maintenance program.

Transitioning from the traditional rehabilitation and reconstruction activities to a greater emphasis on pavement preservation can be difficult and will require an active educational program. Government officials and the public must be convinced that it is best to provide for continuation of proactive activities to maintain a roadway in good condition as opposed to delaying preservation until major work is required. NCHRP Repot 742 *Communicating the Value of Preservation: A Playbook* is a good source of educational program examples.

B. Definitions

Minor Rehabilitation: Non-structural enhancements made to existing pavements to eliminate age related top-down surface deterioration.

Pavement Preservation: A program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extends pavement life, improves safety, and meets motorist expectations (FHWA, 2005). A pavement preservation

program is achieved through the application of routine maintenance, preventative maintenance, and minor non-structural rehabilitation.

Preventative Maintenance: A planned strategy of cost effective treatments to an existing roadway system that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system without significantly increasing the structural capacity. (AASHTO, 1997) Preventive maintenance treatments are applied to pavements in good condition and that have significant remaining service life. Preventative maintenance activities are often undertaken by contract, although in-house staff can accomplish them as well.

Routine Maintenance: Day-to-day activities that are scheduled by maintenance personnel to maintain and preserve the condition of the roadways at a satisfactory level of service. Routine maintenance activities are traditionally completed by in-house forces and not contracted out.

C. Benefits

Preventive maintenance activities are the backbone of a pavement preservation program. Simply constructing a roadway and allowing it to deteriorate over its design life is not acceptable. Some of the benefits of a strong preventative maintenance program, besides higher customer satisfaction, include:

- Better informed decisions
- Improved pavement condition
- Cost savings
- Improved strategies and techniques
- Improved safety
- Extended pavement life

An essential part of the pavement preservation process is utilizing all forms of information about a pavement section as the appropriate treatment type is selected. Once the history of a pavement section and the current condition are known, the type of treatment can be selected and the timing of the treatment can be established.

Through the implementation of a pavement preservation program, pavement conditions stabilize because pavements in good condition are maintained in good condition longer. Although it is difficult to prove, especially in the early stages of a pavement preservation program when there are a number of pavements that require major rehabilitation or reconstruction, many agencies have shown that the cost to maintain their roadway system is reduced because of less expensive treatments and extended service lives.

As pavement preservation decisions are being made, agencies are examining different materials and processes that will improve performance of the treatments. The use of high quality materials and quality control are increasingly important.

To users, safety is one of the fundamental expectations they have as they travel. Most pavement preservation treatments will improve the surface characteristics of smoothness and friction. Other surface defects are also addressed. In addition, pavement preservation treatments are less disruptive to traffic movements and extend the time when reconstruction with its extensive impact to traffic flow is needed.

Pavement Preservation Process

A. Pavement Deterioration

The concept behind pavement preservation is to treat pavements while they are still in good condition and without serious structural damage. Successive, systematic treatments will extend the service life and delay the more expensive major reconstruction project. In order to apply the appropriate preventative maintenance treatment at the optimum time, the history and the current condition of a pavement section must be evaluated. Preventative maintenance techniques address the pavement surface condition and do not impact the structural capacity of the pavement. If the structural carrying capacity is affecting the condition of the roadway, it is probably not a candidate for preventative maintenance and it is best to program as a reconstruction project. The causes of any pavement deterioration for various types of pavements must be accurately determined. Typical causes of deterioration for each pavement type include the following:

1. **Flexible Pavements:** Flexible pavements, hot mix asphalt, or other bituminous pavements are affected by traffic, environmental/aging, material problems, and moisture intrusion. These elements impact the pavement in different ways:
 - a. **Traffic:** Traffic can lead to load related distresses, such as rutting or fatigue cracking in the wheel paths. Fatigue can lead to development of potholes. Also polishing of the surface leads to friction loss.
 - b. **Environmental/Aging:** The environment and aging can lead to oxidation of the asphalt, block cracking, and raveling. Environmental elements can also cause the development of thermal cracks, which are seen as regularly spaced transverse cracks.
 - c. **Material Problems:** Material problems include bleeding, shoving, stripping, and surface deformation.
 - d. **Moisture Infiltration:** Moisture infiltration can cause further breakdown of existing cracks and thus increased roughness.
2. **Rigid Pavements:** For rigid PCC pavements, the general causes of deterioration include traffic loading, environmental factors, material problems, construction problems, joint deterioration, and moisture infiltration.
 - a. **Traffic:** Traffic can lead to load related distress, such as mid-slab cracking, pumping, faulting, and corner breaks. Polishing and the subsequent loss of friction is also traffic related.
 - b. **Environmental and Materials:** D-cracking and alkali-silica reactivity (ASR) are material problems. Freeze-thaw action and poor entrained air can affect joint stability.
 - c. **Construction Problems:** Construction quality can cause cracking and surface defects in the form of map cracking and spalls.

- d. **Joint Deterioration:** Incompressible materials in the joint from poor joint seal maintenance can cause joint spalls.
- e. **Moisture Infiltration:** Moisture can lead to further breakdown of cracks and spalls and increased roughness. It can also contribute to pumping, transverse joint faulting, and corner breaks.

B. Evaluating Pavement Conditions

Numerous pieces of information need to be examined in order to determine if the pavement section is a candidate for preventative maintenance and the selection of the type of treatment that best meets that pavement section's needs. The extent of the evaluation process will vary depending on the roadway classification and the type of project. In each case, once the information is compiled, engineering judgment must be applied to determine the correct treatment to use to address the distresses exhibited by each section of pavement.

1. **Background Data:** Obtain data from project files, such as original design parameters, construction information regarding materials, subgrade/subbase information, current traffic data, and maintenance activities undertaken on that roadway section. This information can sometimes be difficult to locate if a good record system has not been established, but as much information as possible should be compiled. Discussions with agency engineering and maintenance staff members can potentially fill in gaps in records.
2. **Existing Condition:** Undertake a visual site inspection to obtain information about the condition of the pavement. Ascertain information on what types of distress are exhibited by the pavement section. Note any restrictions such as right-of-way limitations, presences of bridges, drainage problems, and obstructions.

The specific severity and extent of each type of pavement distress should be examined closely. Additional field testing such as falling weight deflectometer (FWD), pavement cores, friction testing, splash and spray, and materials testing may be necessary. The extent of the additional testing may be dependent on the roadway classification. Much of this information should be contained in a pavement management system (PMS). The PMS can be in many forms including a sophisticated computer program, a relatively simple spreadsheet, or notes accumulated by maintenance personnel.

The Iowa DOT has a program of data collection on all roads in the state and is one source of pavement condition information. The program is administered by the CTRE program at The Institute for Transportation at Iowa State University. Information can be accessed at <http://www.ctre.iastate.edu/ipmp/services/>. It is necessary to undertake additional effort to convert the raw data to useable information.

3. **Future Projections:** It is also important to evaluate any future changes that may be expected for each roadway section. Changes in adjacent land use or improvements to area roadways could impact the traffic volume and the vehicle mix of a roadway section. Long-range transportation planning documents should provide this information. This information is critical to understanding the service life expectancy of the existing pavement and then the subsequent preventative maintenance treatments to match that service life.

Preventative Maintenance Treatment Type Selection

A. Introduction

Once all of the background, existing pavement condition, and future changes have been determined for a pavement section, the appropriate preventative maintenance treatment or treatments can be selected. Professional engineering judgment is critical in order to analyze the available data and select the most effective treatment. The selection of the most appropriate treatment must also take into consideration the availability of qualified contractors and the availability of quality materials to accomplish the work. In some instances, a combination of treatments may be needed to maintain the pavement in good condition.

In addition to the technical analysis, it is important to complete a financial review that will compare the various treatment types, their expected service life, and the associated costs. Comparisons can be made by calculating a simplified annualized cost through dividing the estimated cost of the treatment by the expected service life of each treatment type.

B. Flexible Pavement Treatment Types

Several traditional preventative maintenance treatments are available for flexible pavements. These include:

- Crack filling
- Crack sealing
- Full/partial depth patches
- Fog seals
- Slurry seals
- Microsurfacing
- Bituminous seal coats
- Milling
- Thin overlays

The above treatments will be described in greater detail. Additional treatments are available, but generally involve use of proprietary materials or processes or are not included in this manual. If appropriate, designers should include some of these other treatments in their analyses. These treatments are only effective if there are no structural problems with the pavement or the supporting subbase/subgrade.

1. **Crack Filling:** Crack filling is a good treatment method for reducing intrusion of moisture through the pavement slab. It will assist in reducing further crack deterioration, associated roughness, and rutting. Crack filling will traditionally involve minimal preparation and use of lower quality bituminous materials. Treatment should occur during cool, dry weather, which will provide for wider crack widths. Proper cleaning and a dry condition are the key to achieving good performance and maximizing service life. Cracks should be cleaned to a depth of 3 inches. Crack filling material is generally an asphalt emulsion since actually sealing of the crack is not

expected. Crack filling is appropriate for non-working cracks between 1/4 inch and 1 inch wide. The potential exists for increased roughness and loss of surface friction if the joint is overfilled. See [SUDAS Specifications Section 7040, 3.07](#). Service life is from 2 to 4 years.

2. **Crack Sealing:** Crack sealing is effective at reducing moisture intrusion in the pavement as well as minimizing the amount of incompressible materials in the cracks. It differs from crack filling in that it is used on working cracks and involves crack routing, substantial crack preparation, and higher quality sealant material. Crack sealing is appropriate for cracks between 1/4 inch and 3/4 inch wide. Use on longitudinal or transverse cracks with little or no secondary cracking or raveling at the crack face. Proper crack preparation and cleaning are essential to optimal performance. Saw or rout cracks to a minimum 3/8 inch width and a depth of 1/2 inch. The width and depth may be adjusted depending on the sealant to be used. Clean cracks of existing joint filler material, vegetation, dirt, or other foreign material. See [SUDAS Specifications Section 7040, 3.06](#). Service life is from 2 to 8 years.
3. **Full/Partial Depth Patches:** Patches restore a pavement's structural integrity and improve its ride. Partial depth patches address distress in the upper one-third of the pavement slab. Slab removal may be accomplished by sawing and jackhammer or by milling. Minimum partial patch depth is 2 inches and maximum depth is 1/2 of the slab thickness. Prior to placement of patch material, clean partial depth patch area and ensure it is dry. Cover entire patch area with tack coat. Lifts should not exceed 3 inches in thickness with the top lift 2 inches or less. Ensure the final compacted surface is level with or not more than 1/8 inch above the surrounding pavement. Full depth patches will address various types of more structural distress, such as broken down thermal cracks. Apply tack coat to all vertical edges. Maximum lift thickness is 3 inches with the top lift being 2 inches or less. Compact intermediate lifts with a roller or vibratory compactor, depending on patch size. Compact final lift with steel-wheeled finish roller. Ensure final compacted surface is level with or not more than 1/8 inch above the surrounding pavement. See [SUDAS Specifications Section 7040, 3.02](#) and [3.03](#). Patches are often completed in advance of a surface treatment. Service life is from 3 to 15 years.
4. **Fog Seals:** Fog seals are applications of diluted emulsion without a cover aggregate and are used to seal the pavement, inhibit raveling, and slightly enrich hardened or oxidized asphalt. Application rates vary from 0.05 to 0.10 gallons per square yard. If necessary, vegetation control should be completed in advance of the treatment. Ensure pavement is clean and dry prior to application. See [Section 5I-4](#) for additional information. Fog seals can have a negative effect on friction and stripping in susceptible asphalts. Service life is from 1 to 3 years.
5. **Slurry Seals:** Slurry seals are effective at sealing low-severity cracks, waterproofing the pavement, and restoring friction. Slurry seals also address raveling, oxidation, and hardening of asphalt. They are a mixture of crushed, well-graded aggregate, a mineral filler, and asphalt emulsion that is spread across the full width of the pavement or it can be used as a strip treatment for low areas and cracks. Thickness is generally less than 1/2 inch. The slurry is basically placed one aggregate layer thick. Allow a minimum of 7 days cure time before applying permanent pavement markings. See [Section 5I-4](#) and [SUDAS Specifications Section 7070](#). Service life is 3 to 6 years.
6. **Microsurfacing:** Microsurfacing corrects or inhibits raveling and oxidation of the pavement, improves surface friction, reduces moisture infiltration, addresses low to medium severity bleeding, and can be used to fill surface irregularities and ruts up to 1 1/4 inch deep. Microsurfacing materials are similar to slurry seals except that microsurfacing uses latex modified asphalts versus an emulsified asphalt. Application of the microsurfacing is by specialized equipment using an augured screed. Microsurfacing typically breaks within a few

minutes of placement and can carry traffic after about an hour. See [Section 5I-4](#). Service life is 4 to 7 years.

7. **Bituminous Seals Coats:** Seal coats, also sometimes known as chip seals, are effective at improving surface friction, inhibiting raveling, correcting minor roughness and bleeding, and sealing the pavement surface. Bituminous seal coats are also used to address longitudinal, transverse, and block cracking, as well as sealing medium severity fatigue cracks. Seal coats can be applied in multiple layers to address more serious problems. Asphalt emulsion is applied directly to the pavement surface and is followed by the application of aggregate chips that are immediately rolled to embed them into the emulsion. Application rates depend upon the aggregate gradation and maximum size. Loose chips may be a problem on higher speed roadways. Fog seals may be used in conjunction with seal coats to provide a greater degree of binding for the aggregates. See [Section 5I-4](#) and [SUDAS Specifications Section 7060](#). Single layer service life is 4 to 6 years.
8. **Milling:** Milling is used to reduce pavement irregularities and to produce a uniform surface. Milling should be considered if rutting is at a level of 1/4 inch or more. Milling is used in conjunction with other surface treatments, such as slurry seals and microsurfacing in addition to thin asphalt overlays, and is not suggested to be used as a final stand-alone treatment. It can be used to restore proper grades and pavement cross-slopes. For best results, the milling depth should match the lift thickness of the exiting pavement. See [Section 5I-4](#) and [SUDAS Specifications Section 7040, 3.05](#).
9. **Thin Overlays:** Thin overlays are placed in a single lift less than 1 1/2 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. Thin overlays dissipate heat rapidly and rely on timely compaction to be successful. Dense-graded, open-graded, and stone-matrix mixes may be used. See [SUDAS Specifications Section 7020](#). Service life is 7 to 10 years.

C. Rigid Pavement Treatment Types

Several preventative maintenance treatment types are available to address pavement distresses in PCC pavements. These include:

- Crack sealing
- Joint resealing
- Partial depth patches
- Full depth patches
- Dowel bar retrofit
- Diamond grinding
- Pavement undersealing/stabilization
- Pavement slab jacking
- Concrete overlays

These are the traditional preventative maintenance treatment types. Other less frequently used treatments are available to address specific distress needs.

1. **Crack Sealing:** Crack sealing is accomplished to reduce moisture intrusion and retard the rate of deterioration of the cracks. It is accomplished by thorough preparation and placement of high quality materials. It is used on random transverse and longitudinal cracks of low to medium severity where the crack width is less than 1/2 inch. Proper preparation of the crack and placement of the sealing material are critical for attainment of the expected 4 to 8 year service

life. The sealant material is critical to the success of the operation. Thermoplastic (rubberized asphalt) and thermosetting (silicone) sealants are the usual materials. The crack should be routed to 3/8 inch wide and 1/2 inch deep. The crack should be thoroughly cleaned and dried prior to application of the sealant. Refacing the sides of the crack with sandblasting is recommended. See [SUDAS Specifications Section 7040, 3.06](#).

2. **Joint Resealing:** Joint resealing is important to minimize moisture in the joint and the subgrade/subbase, in addition to minimizing the intrusion of incompressible materials into the joint. Proper resealing of joints will reduce faulting, pumping, and spalling. Removal of the old sealant material and cleaning of the joint prior to resealing are critical. Removal of the old joint material can be accomplished by using a rectangular joint plow, diamond saw, or high-pressure water blast. Following refacing of the joint with a diamond bladed saw, the joint should be cleaned with high pressure air or water. Immediately prior to sealant application, the joint should be blown again with high pressure air to remove any sand, dust, or other incompressible that may remain in the joint. The joint must be dry and clean as joint sealant material is applied. See [SUDAS Specifications Section 7040, 3.06](#). Service life is 4 to 8 years.
3. **Partial Depth Patches:** Partial depth patches are used to address spalling and surface scaling, as well as other problems in the top one-third of the pavement slab. Repair materials are selected based on available curing time, ambient temperature, size and depth of the repair, and cost. The materials are generally classified as cementitious, polymers, or bituminous. Rapid cure and high strength proprietary products are also available. It is critical to identify the limits of the weakened concrete so the patch can connect to sound concrete. The actual extent of the deterioration is often greater than what is visible at the surface. The removal area should extend a minimum of 3 inches beyond the deteriorated area in all directions. The patch area can be prepared by chipping with a lightweight jackhammer, milling with a carbon tipped milling machine, and sawing the edges of the patch and removal with a lightweight jackhammer. The patch area should be square or rectangular in shape and in line with existing joint patterns. The repair area must be swept, sandblasted, and air blasted to ensure a clean, dry patch area. Sandblasting is very effective at removing any dirt, oil, thin layers of unsound concrete, and laitance. Bonding agents are generally required for the patch materials. Sand-cements grouts consisting of one part sand and one part Type III cement with sufficient water to create a thick, creamy consistency have proven successful. Epoxy bonding agents can also be used with PCC and proprietary patching materials. Compressible joint materials must be used against the adjoining slab or to extend an existing joint through the patch area. The compressible material should extend 1 inch below and 3 inches beyond the repair boundaries. It may be possible to saw the joint through the patch, but timing is very critical. Since partial depth patches have large surface areas compared to their volume, it is very important to apply a curing compound as soon as the water has evaporated from the surface. The curing compound should be applied at 1.5 to 2 times the normal rate. The final step is resealing of the joint. See [SUDAS Specifications Section 7040, 3.03](#). Service life of a well done partial depth patch is 5 to 15 years.
4. **Full Depth Patches:** Typical PCC pavement distresses that can be addressed by full depth repairs include transverse cracking, corner breaks, deteriorated joints, and blowups. Full depth repairs are an effective means for restoring the rideability and structural integrity of deteriorated PCC pavements. Long lasting full depth repairs are dependent upon selecting appropriate locations, effective load transfer design, and correct construction procedures, including finishing, texturing, and curing the patch. If the pavement exhibits a materials related deficiency, such as D-cracking, the service life of the patch will be short. Sizing the patch is critical to its success. Distressed areas should be identified and marked. Extent of the patch area may have to be adjusted if a period of time passes between initial identification and actual work activity. It may be necessary to do coring and deflection studies to identify the extent of deterioration below the slab surface. Full depth patches should be a minimum of 6 feet long and a full lane wide. All

joints through or adjacent to full depth patches must be re-established. Connect patches to make one large patch if the patches are 8 to 10 feet from each other in a single lane. The load transfer technique used in the patch should match the load transfer technique in the existing slab. Full depth repairs could be used in conjunction with diamond grinding to correct any roughness problems. [See SUDAS Specifications Section 7040, 3.02](#). Service life is expected to be from 10 to 15 years.

- 5. Dowel Bar Retrofit:** Dowel bar retrofit (DBR) is a method of load transfer restoration. It is used on non-doweled plain jointed concrete pavements. A successful dowel bar retrofit project will enhance pavement performance by reducing pumping, faulting, and corner breaks. Pavements with structurally adequate slab thickness, but exhibiting significant loss of load transfer due to poor aggregate interlock or base/subbase/subgrade erosion, are good candidates for DBR. It will also retard deterioration of transverse joints and cracks. Typical design includes three or four dowels inserted into the pavement at joints in each wheel path. The size of the dowel bar varies from 1 inch to 1 1/2 inches in diameter according to the slab thickness. See SUDAS Figure 7010.101. The slots are generally 3 feet long, centered on the joint or crack. The slot must be long enough to allow the dowel to lie flat in the slot without hitting the curve of the saw cut. The width of the slot should be 2.5 inches and the depth sufficient to position the center of the dowel at the mid-depth of the slab. The slot must be parallel to the centerline of the pavement slab so the dowels do not lock up pavement movements. The dowel assembly will have end caps to facilitate movement and a compressible insert to form the joint across the slot. The slot filler materials are the critical element to a successful installation. Desirable properties include little or no shrinkage, similar coefficient of thermal expansion as the existing concrete, good bond strength, and the ability to gain strength rapidly. Concrete with Type III cement, sand, and 3/8 inch maximum sized aggregate can be used or there are proprietary products available. Dowel bar retrofit projects often include following up with diamond grinding. All transverse joints should be re-established by sawing over the joint and through the fill board. The joint should then be prepared and sealed. Dowel bar retrofit projects will allow the original service life of the pavement to be restored.
- 6. Diamond Grinding:** Diamond grinding is the removal of a thin layer of pavement surface using closely spaced diamond saw blades. It is used to improve ride quality by eliminating joint and crack faulting. In addition, surface friction, transverse cross slope, and tire/pavement noise are improved. It does not address structural problems or material related distress. Structural problems, such as pumping, corner breaks, and working transverse cracks, must be addressed before grinding. If joint/crack faulting exceeds 1/4 inch, the project may not be a candidate for diamond grinding. The blade spacing and width of groove are dependent on the hardness of the aggregate. As the aggregates get softer, the width of the land area and groove get larger. The depth of cut should be set so that 95% of the area is ground. The surface distresses will redevelop if the root cause of the distress is not corrected prior to diamond grinding. Thus, it may be necessary to complete full and partial depth patches, load transfer restoration, and slab stabilization prior to grinding. See [SUDAS Specifications Section 7040, 3.04](#). Service life varies from 5 to 15 years, depending on the hardness of the aggregates and the level of structural distress correction completed prior to grinding.
- 7. Pavement Undersealing/Stabilization:** Slab stabilization is pressure insertion of a flowable material to restore support beneath PCC slabs. It fills existing voids but does not lift the slab. Pavement stabilization restores pavement support, reduces pavement deflections, and reduces progression of pumping, faulting, and corner breaks. Slab stabilization must be completed prior to significant pavement damage. The main issue with slab stabilization is identifying where the voids are located and the extent of the voids. Distress surveys and deflection testing are necessary. Deflections may be measured using a FWD or by using a loaded truck with gauges placed at the corners of the slab. Other methods, such as ground penetrating radar or

thermography, are also available. Pozzolan-cement grout and polyurethane are the most common materials used for slab stabilization. Other proprietary products are available. It is important to only apply the material at locations where voids exist. If it is placed in areas without voids, the material can induce pressure points and actually increase the pavement deterioration. Once the area of the void is determined, the grout insertion holes can be drilled. Holes should be placed as far as possible from cracks and joints. Holes should be placed close enough to achieve flow from one insertion hole to another. Service life is from 5 to 10 years, depending on the level of truck traffic.

8. **Pavement Slab Jacking:** Slab jacking consists of the pressure insertion of a grout or polyurethane material beneath the PCC slab as a means of raising the slab to a smoother profile. Slab jacking is normally used to correct localized settlement areas, such as over culverts or at bridge approaches. It should not be used to correct faulted joints. Grout insertion holes should be a minimum of 12 inches from a transverse joint or the edge of the slab. Holes should be spaced 6 feet or less center-to-center. It is critical to monitor the amount of lift performed at each location. The slab should not be lifted more than 1/4 inch at a time so that excessive stresses are prevented and slab cracking minimized. Uniform positioning of the grout holes is also important. Work should start from the lowest point of the section being raised and proceed out to the edges of the settled area in a repeating pattern. Materials for slab jacking are typically stiffer than those used for slab stabilization. Cement grout and polyurethanes are typically used.
9. **Overlay:** Concrete overlays exist for all types of pavements, including concrete, asphalt, and composite. Thickness for preservation projects are generally between 3 to 4 inches. Similar to other concrete pavements, overlays require uniform support and effective management of movement. The overlay type can be bonded or unbonded. Bonded overlays are used to eliminate surface distresses when the existing pavement is in good structural conditions. Bonded overlays utilize the existing pavement as an integral part of the new monolithic system and thus thorough surface preparation is critical. Unbonded overlays are essentially a new pavement over a stabilized base (the old pavement). A bond breaker, such as a thin asphalt layer or a layer of non-woven geotextile, is needed between the existing pavement and the overlay. Typically, overlays are constructed using standard concrete mixes and standard construction techniques. Fibers may be added to the concrete mix for additional strength. Joints in bonded concrete overlays must match those in the existing pavement. Service life of concrete overlays is 15 to 20 years. Visit the National Concrete Pavement Technology Center's website (www.cptechcenter.org) for more publications on concrete overlays.

D. References

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Thin Maintenance Surfaces

A. General

Seal coats, slurry seals, microsurfacing, and fog seals are termed thin maintenance surfaces or TMS. These thin maintenance surfaces can be a cost effective approach to maintaining flexible pavements. Studies have shown that agencies can maintain a city street or county road network in better condition at lower costs through the use of TMS. Project selection, treatment selection, and timing are critical to the use of TMS.

Since TMS do not involve increasing the structural carrying capacity of a street, it is vitally important to apply the appropriate treatment prior to the start of pavement deterioration. Pavement condition, traffic volumes, materials availability, roadway classification, and local preference must be evaluated before determining the type of TMS to use. General uses for TMS are noted in the following table:

Criteria	Seal Coat	Slurry Seal	Microsurfacing
Traffic Volume:			
Low (< 2,000 vpd)	Recommended	Recommended	Recommended
Medium (2,000 to 5,000 vpd)	Marginal	Marginal	Recommended
High (> 5,000 vpd)	Not Recommended	Not Recommended	Recommended
Bleeding	Recommended	Recommended	Recommended
Rutting	Not Recommended	Recommended	Recommended
Raveling	Recommended	Recommended	Recommended
Cracking			
Slight	Recommended	Recommended	Recommended
Moderate	Recommended	Not Recommended	Not Recommended
Low Friction	May improve	May Improve	May Improve
Snowplow Damage	Most susceptible	Moderately susceptible	Least susceptible

Source: Jähren, 2003

Design of these TMS treatments must take into account the type of pavement distress that is being addressed with the proposed project. It may be necessary to complete crack filling, patching, or other maintenance activities prior to implementing the TMS.

B. Seal Coat

A seal coat is a single layer of asphalt binder that is covered by embedded aggregate with its primary purpose to seal fine cracks in the underlying pavement and retard water intrusion into the pavement and subgrade/subbase. The aggregate protects the asphalt binder layer and provides macrotexture for improved skid resistance. Seal coating is also a cost effective way to address bleeding and raveling. Most often, the asphalt binder is an emulsion. Cutback asphalts may be used as well. Emulsified asphalt is a mixture of liquid asphalt and water. A cutback is a mixture of liquid asphalt and a distillate, such as kerosene or fuel oil. The aggregates are typically less than 1/2 inch in size.

One of the most critical factors in the design is to determine the quantities of asphalt binder and aggregate. The goal should be to have the single layer of stone 70% into the asphalt binder layer with

little or no stones to clean up. In order to attain that goal, the designer must take into account the traffic volume; the absorption of the binder into the cover aggregate; the texture of the existing pavement; and size, shape, and gradation of the aggregate. Seal coat projects have an expected life span of 4 to 6 years.

Seal coating is recommended for low and medium volume roadways with low speeds due to the increased chance for insurance claims for vehicle damage from the loose rock as traffic volumes and speed increases. In addition, the impact to the public is compounded on high volume roadways due to the time the facility is out of service, generally 24 hours. As traffic volumes increase, it becomes more critical to include very high quality, durable aggregates in the mix design.

Selection of the asphalt binder is important to the success of the project. Although cutback asphalts can be used, their use has rapidly declined over the years due to the costly and harmful solvents used. Typically, asphalt emulsions are used. They are made up of asphalt cement, water, and an emulsifying agent (surfactant). The asphalt cement is typically in the same range as is used for hot mix production and makes up about 2/3 of the volume of the binder. Water provides the medium to keep the asphalt in suspension. The surfactant (usually soap) causes the asphalt particles to form tiny droplets that remain in suspension in the water, and it determines the electrical charge of the emulsion. It is important that the emulsion and the aggregate have opposite electrical charges in order to maximize the bond between the emulsion and the aggregate. Since most aggregates have a negative charge, emulsions such as CRS-2P with a positive (cationic) charge are used.

Cover aggregate should be clean and dust free to maximize adherence. A uniform gradation of hard, durable aggregate will increase the resistance to impact from traffic and snowplows. Aggregate application needs to follow binder application very closely. The cover aggregate should be applied so it is only one layer thick. Excess aggregate increases the chance for dislodging properly embedded aggregate during the cleanup operation, as well as increasing the potential for vehicle damage. The aggregate may be gravel, crushed stone, or a mixture. Cubical shaped aggregate is preferable to flat aggregate. Flat and elongated aggregates can be susceptible to bleeding due to traffic causing the flat chips to lie on their flattest side. If flat aggregate is used and the binder is applied too thick, the pavement will bleed; if it is too thin, the pavement will ravel. Angular aggregate is preferable to round aggregate because angular aggregate chips tend to lock together.

One of the problems with seal coats is the generation of dust from the aggregate. One way to address the dust problem is to pre-coat the aggregate. Pre-coating involves applying either a film of paving grade asphalt or a specially formulated pre-coating bitumen to the aggregate. The use of pre-coated aggregate improves aggregate bonding properties, as well as reducing dust. It also shortens the required curing time and vehicle damage from loose aggregate. Fog seals may also be used to address dust problems and to cover the “gravel road” appearance of seal coat. Fog seals are generally a 50-50 mix of emulsion and water. It is important to recognize that skid resistance may be compromised with the use of fog seals.

Many design tools are available. One of the most often used is the Minnesota Seal Coat Handbook. It can be found at: <http://www.lrrb.org/media/reports/200634.pdf>. Another source is the Thin Maintenance Surfaces Manual developed by the Institute for Transportation at Iowa State University. It can be found at: http://www.intrans.iastate.edu/publications/documents/handbooks-manuals/thin-maintenance-surfaces/thin_maint_surf.pdf.

C. Slurry Seal

Slurry seal is a mixture of emulsified asphalt oil, aggregates, water, and additives. It is pre-mixed and placed as a slurry onto the pavement. Slurry seals are commonly recommended for use on low and medium volume roadways. They are used to treat low to medium levels of raveling, oxidation, and rutting. Applications of slurry seals will improve skid resistance. Slurry seals are often described as the most economical, versatile TMS for low to medium volume roadways.

Aggregates commonly used for slurry seal applications consist of a combination of crushed stone and additives, such as Portland cement, lime, and aluminum sulfate. The additives are used to modify curing time. Aluminum sulfate retards curing time and Portland cement and lime shortens curing time. The aggregate gradations are described as fine and coarse. Coarse gradations have greater stability and are preferred for rut filling and scratch (bottom) courses. The additives make up less than 2% of the mixture and the aggregates are about 75% to 80%. Higher quality aggregates such as granite and quartzite will provide for a more durable application of slurry seal. Smaller aggregate gradations are used for maximum crack sealing, while coarse gradations are used when the project goal is to improve skid resistance.

The asphalt binder is an asphalt emulsion. The usual grades are CSS-1h or SS-1h, which are cationic and anionic slow setting emulsions, respectively. The emulsion is formulated with relatively stiff base asphalt (the suffix h = hard) for use in warm climates. The emulsion will make up about 7% to 14% of the mixture. Water is the remaining element of the mixture.

Temperature and humidity are critical to the cure time of the slurry seal. Temperatures must be 50°F and rising before application can begin. Slurry seals should not be placed at night. Slurry seals can be used to address slight rutting distress as well as to fill open joints by a strip treatment.

Mix design is generally completed by a laboratory certified by the International Slurry Seal Association (ISSA). Compatibility of the emulsion, aggregates, water mineral filler additives, and any other elements needs to be checked using materials that will be incorporated into the project.

D. Microsurfacing

Microsurfacing is a mixture of polymer-modified asphalt emulsion, graded aggregates, mineral filler, water, and other additives. It is mixed in a pug mill and evenly spread over the pavement. It is used to address oxidation, raveling, rutting, and skid resistance problems. Microsurfacing can be applied to higher speed, higher volume roadways than slurry seals and it can be used on both asphalt and concrete roadways. It can be placed at a thickness that is two or three times the size of the largest aggregate; however, trying to lay it too thick may result in rippling, displacement, and segregation. Multiple lifts are used if thicker application rates are needed.

Microsurfacing differs from slurry sealing in four main areas. They are:

- Microsurfacing can be placed in layers thicker than a single aggregate size.
- Microsurfacing always contains polymer modifiers.
- It cures through a chemical reaction versus evaporation.
- Higher quality aggregates are used.

Microsurfacing can also be accomplished at night to potentially minimize traffic impacts. If specifically designed for rapid opening, a microsurfacing project may be returned to traffic in as little as 1 hour.

Design of the microsurfacing mix is generally included in the contract to be completed by the

contractor and/or the emulsion supplier. It is critical that all elements of the mix be compatible with each other in order to develop a mix that will address the project conditions. Publication A143 from the ISSA is used as a guide for development of the mix design.

Generally, a single emulsion that works for the climatic conditions and traffic volumes is selected. Cationic emulsions, such as CSS-1h, are typically used, but CQS-1h can be used if it is important to minimize traffic delays due to construction activities. Polymers are added to the emulsions to reduce thermal susceptibility, improve thermal crack resistance, and improve aggregate retention.

Aggregates must be high quality with fractured faces to form higher bonds with the emulsions. Freshly crushed aggregates, as opposed to weathered aggregates, have a higher electrical charge and improve the bond as well. Washing the aggregate to remove clay, silt, and dust is important to ensure proper cohesion.

Mineral fillers are used to aid in the mixing process and spreading of the mixture. Typical mineral fillers are Portland cement, hydrated lime, fly ash, kiln dust, limestone dust, and baghouse fines.

Additives may also be included in the mix. Aluminum sulfate, aluminum chloride, and borax are typically used. These additives allow the contractor to control breaking and curing times.

Properly designed and applied microsurfacing projects have a service life of up to 7 years.

E. Fog Seal

A fog seal is an application of diluted asphalt emulsion without a cover aggregate. It is used to seal and enrich the asphalt surface, seal minor cracks, and provide shoulder delineation. Fog seals are used on low and high volume roads. Its primary use on high volume roads has been to prevent raveling of open-graded friction courses in addition to delineating between the mainline and shoulder.

A fog seal is designed to coat, protect, and/or rejuvenate the existing asphalt binder. Fog seal use on mainline pavements should generally be restricted to only those locations having an open surface texture. This includes chip seals, heavily aged dense graded pavements, and open graded pavements. The fog seal emulsion must fill the voids in the surface of the pavement. A slow setting emulsion such as CSS-1 or SS-1, diluted to one part asphalt emulsion to four parts water is used. Emulsions that are not correctly diluted may not properly penetrate the surface voids and a slippery surface may be the result.

Before placing the fog seal, the pavement must be dry and clean and all pavement repairs accomplished. The diluted asphalt emulsion should be applied at 0.12 gallons per square yard. Success of application is impacted by temperature so summertime application is required. Generally, no application past August 31 is allowed. Pavement and air temperatures must be greater than 60°F to apply the fog seal.

The service life of a fog seal is fairly short, ranging from 1 to 2 years.

Overlays

A. General

Overlays can extend the life of an existing pavement if good selection, design, and construction practices are followed. They can be constructed rapidly and while the roadway is open to traffic if warranted.

In order to achieve successful performance, it is important to choose the correct type of overlay based on the conditions of the existing roadway. This process of evaluation is critical to the success of the pavement and long-term performance. Design practices include thickness design, selection of specific materials, and construction details. Good construction practices include pre-overlay repairs to prepare the existing pavement if required.

B. Concrete Overlays

There are two options for concrete overlays - bonded and unbonded. Bonded overlays are designed as part of the pavement thickness where unbonded overlays are essentially new pavement on a stable base (existing pavement). For complete and detailed guidance on the design and construction of concrete overlays, refer to the [Guide to Concrete Overlays](#), Third Edition (Harrington and Fick 2014). This guide includes the latest information on the evaluation of the existing pavement, guidance on the overlay selection and managing concrete overlay design and construction. Table 5J-1.01 summarizes the characteristics and applications of the different types of concrete overlay.

1. **Bonded Overlays:** The purpose of a bonded concrete overlay is to add structural capacity and eliminate surface distresses on pavements that are in good to fair structural condition. The new concrete overlay is bonded to the existing pavement and acts as one monolithic unit that increases the structural capacity and provides a means of addressing surface deficiencies or overall ride quality issues. Typically, bonded concrete overlays are relatively thin - typically 2 to 6 inches thick.

Bonded concrete overlays are not good solutions when any of the following situations exist:

- Existing concrete pavement has widespread material related deficiencies issues such as ASR or D-cracking, subgrade support is inadequate or non-uniform, or drainage is poor.
- Existing asphalt or composite pavement exhibits significant structural deterioration, inadequate base or subgrade support or poor drainage condition.

When the situations discussed above exist, unbonded concrete overlays may be considered.

2. **Unbonded Overlays:** The purpose of the unbonded concrete overlay is to restore the structural capacity of an existing pavement that is moderately to significantly deteriorated. On unbonded concrete overlays, bonding is not needed to reach the desired performance. Unbonded concrete overlays are considered a minor or major rehabilitation strategy depending on the condition of the existing pavement. When the unbonded concrete overlay is placed on an existing concrete pavement, a separation layer is required to prevent bonding and un-necessary stress between the two layers. The separation layer can be provided by either a thin asphalt layer or a nonwoven geotextile fabric. Typically, unbonded concrete overlays are 4 to 11 inches thick.

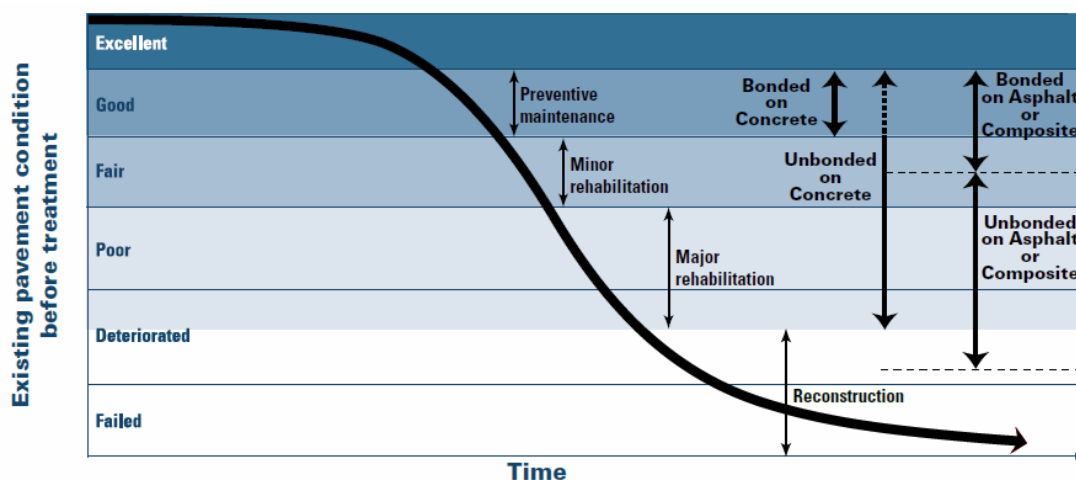
Table 5J-1.01: Concrete Overlay Characteristics and Applications

	Bonded Concrete Overlay	Unbonded Concrete Overlay
Purpose	Improve structural capacity & eliminate surface distresses	Restore structural capacity & eliminates surface distresses
Preservation Strategy	Preventative Maintenance	Minor or Major Rehabilitation
Typical Overlay Thickness	2" to 5" (on concrete) 2" to 6" (on asphalt)	4" to 11"
Condition of Existing Pavement	Good to fair structural condition or repaired to that condition	Moderately or significantly deteriorated, must be firm and stable
Special Design/ Construction Considerations	<ul style="list-style-type: none"> For bonded concrete overlays of concrete, the coefficient of thermal expansion of the aggregate in the concrete overlay must be similar those of the existing pavement Existing joints must be in fair to good condition, or repaired Critical to establish a good bond with existing pavement Shotblasting or sandblasting may be needed to prepare concrete surfaces For overlays over existing concrete, joints must match existing spacing and transverse joints sawed through the new overlay plus 0.5", longitudinal joints shall be at least T/2, new overlay joints must match existing concrete pavement joints The width of the new overlay joint must be equal to or wider than the joint in the existing concrete pavement Curing should be applied at 2 times the usual application rate. Apply PAMS per manufacturer's recommendation. Surface distress on existing asphalt pavements may be removed by milling 2" or more of surface distortions (min. 3" asphalt shall remain) For overlays over asphalt-surfaced pavements, smaller square panel sizes from 3' to 8' is recommended For bonded overlays on asphalt, water should be sprinkled on the surface when surface temperature is greater than 120 degrees Fahrenheit during overlay placement 	<ul style="list-style-type: none"> Full-depth repairs may be needed to restore structural integrity of poor deteriorated areas Surface distress on existing asphalt pavements may be removed by milling 2" or more of surface distortions Concrete patches in the existing asphalt pavement should be separated with a bond breaker For unbonded concrete overlays on asphalt, the underlying asphalt surface temperature should be maintained below 120 °F; this can be done by sprinkling the asphalt with water prior to the overlay, no standing water shall remain Shorter panel sizes may be needed to help address curling and warping stresses Unbonded concrete overlays on concrete require a separation layer of thin asphalt (typically 1") or a non-woven geotextile fabric to provide drainage, separation and minimize reflective cracking If there are material related distress in the existing concrete or existing composite section, repairs may be needed For unbonded concrete overlays 6" and thinner, curing should be applied at 2 times the usual application rate. Apply PAMS per manufacturer's recommendation.
Available Design Procedures	ACPA (2014a, 2014b), StreetPave12; AASHTO (1993, 2008, 2015), WinPAS 12; Vandenbossche (2014) BCOA	ACPA (2014b), StreetPave12; AASHTO (1993, 2008, 2015), WinPAS12

Source: Adapted from Harrington and Fick 2014

3. **Evaluation:** The evaluation and characterization of the existing pavement is a critical step in determining the suitability of a concrete overlay for the prevailing design conditions. Figure 5J-1.01 shows a typical pavement condition curve with various preservation strategies and the applicability of bonded and unbonded concrete overlays. Table 5J-1.02 summarizes the steps involved in evaluating an existing pavement.

Figure 5J-1.01: Timing of Application of Bonded and Unbonded Concrete Overlays



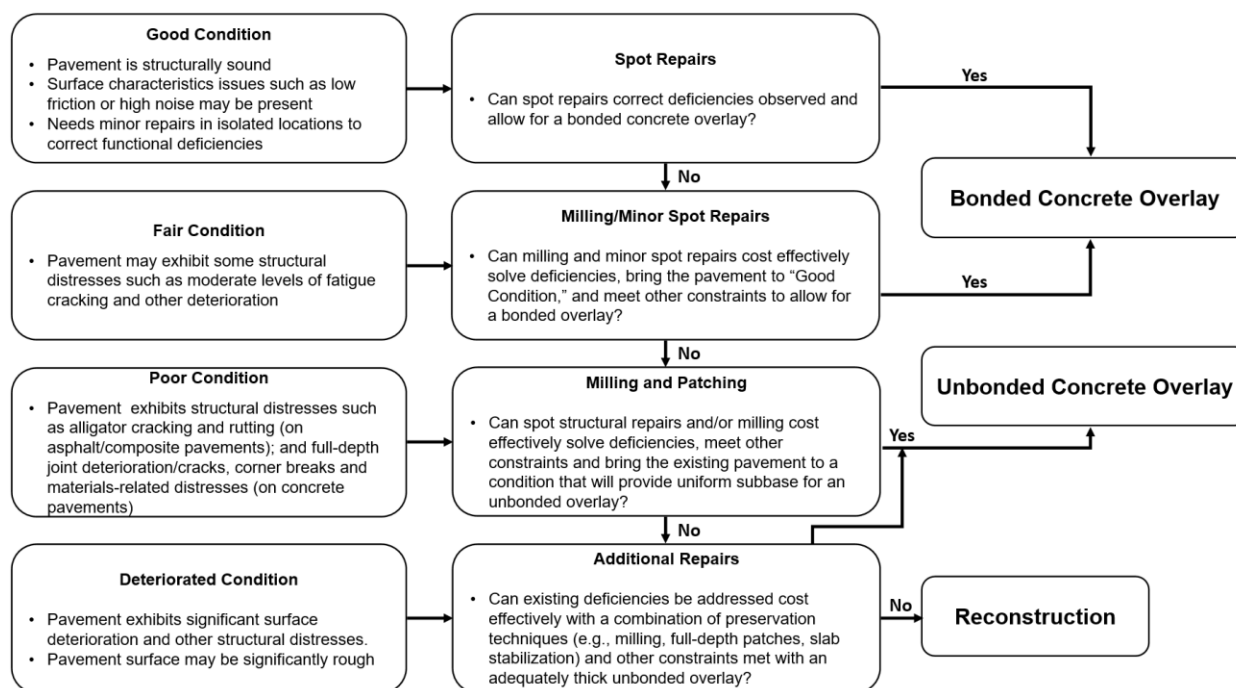
Source: Harrington and Fick 2014

Table 5J-1.02: Pavement Evaluation Process

Process	Details
Step 1: Review pavement history and performance goals.	<ul style="list-style-type: none"> • Pavement design, layer types and thicknesses, length, width, age, drainage system. • Existing traffic and performance level (classification) • Design life and remaining life. • Design traffic and performance requirements. • Existing elevation and grade restrictions. • Other historical information.
Step 2: Perform visual examination of pavement.	<ul style="list-style-type: none"> • Note visible surface and structural distresses and determine overall condition of pavement (good, fair, poor, deteriorated). PCI may be determined and compared to condition curve.
Step 3: Conduct a thorough examination of pavement structure through core analysis.	<ul style="list-style-type: none"> • Identify type, extent, and severity of pavement distress. • Verify pavement layer types and thicknesses.
Step 4: Optional Analysis <ul style="list-style-type: none"> • Material-related tests (4a) • Subsurface test (4b) • Surface texture tests (4c) 	<ul style="list-style-type: none"> • Material-related tests: <ul style="list-style-type: none"> ○ Petrographic analysis to identify material-related distress issues and determine quality of air-void system in existing concrete. ○ Determine if asphalt stripping issues exists. ○ Determine aggregate coefficient of thermal expansion for existing concrete. • Tests of existing pavement: <ul style="list-style-type: none"> ○ Falling weight deflectometer testing to determine: <ul style="list-style-type: none"> ▪ Subgrade/subbase support (k-value) or stiffness. ▪ Subgrade/subbase variability. ▪ Load transfer efficiency of concrete pavements. ▪ Presence of voids. ▪ Concrete flexural strength. ○ Subgrade tests to determine: <ul style="list-style-type: none"> ▪ Frost heave characteristics. ▪ Shrink-swell characteristics. ▪ Soil strength (dynamic cone penetration or standard penetration test). ○ Surface texture tests: conduct if before/after comparisons of pavement surface friction are needed.

Source: Adapted from Harrington and Fick 2014

After the evaluation, it is necessary to select the type of concrete overlay. Figure 5J-1.02 illustrates the basic steps involved. The process begins by entering the flowchart on the left, based on the condition of the existing pavement, and then following through the chart.

Figure 5J-1.02: Selecting Appropriate Concrete Overlay Solution

Source: FHWA Tech Brief

4. Construction Materials: Conventional concrete materials are utilized in concrete overlay construction including cement, supplementary cementitious materials (SCMs), aggregate, water and chemical admixtures. Other conventional materials including steel tie bars, dowel bars, curing compound, and joint sealant are used. The key considerations related to concrete overlay materials and mixtures are summarized in the *Concrete Overlays*.

a. Fibers: Although the use of structural fibers are not normally necessary for most concrete overlays, their use may be warranted in certain situations including those where the overlay thickness is limited, heavier weight traffic loads are expected and increased joint spacing is desirable. Structural fibers improve residual strength of the overlay. Structural fibers can perform the following functions in a concrete mix:

- 1) Help increase concrete toughness
- 2) Help control differential slab movement caused by curling and warping, heavy loads, temperatures, etc. (allowing for longer joint spacing)
- 3) Increase concrete's resistance to plastic shrinkage cracking (enhancing aesthetics and concrete performance)
- 4) Hold cracks tightly together (enhancing aesthetics and concrete performance)

Table 5J-1.03 provides a summary of the different types of fibers, including general descriptions and typical application rates. Additional details on the characteristics and application of fibers in concrete overlays is provided in Appendix C of the *Guide to Concrete Overlays*.

Table 5J-1.03: Summary of Fiber Types

Fiber Type	Size (D = dia.) (L = length)	Years Used in U.S.	Typical Fiber Volume (lb/yd ³)	Comments
Micro Synthetic Fibers	D < 0.012 in. L 0.50 to 2.25 in.	35	1.0 to 3.0	To reduce plastic shrinkage cracking and settlement cracking; limited effect on concrete overlay overall performance; more workability issues when using higher rates
Macro Synthetic Fibers	D > 0.012 in. L 1.50 to 2.25 in.	15	3.0 to 7.5	Increases post-crack flexural performance, fatigue-impact endurance; thinner concrete thickness; longer joint spacing; tighter joints, cracks; better handling properties, dispersion characteristics than steel fibers; not subject to corrosion
Macro Steel Fibers (carbon)	L 0.75 to 2.50 in.	40	33 to 100	Increases strain strength, impact resistance, postcrack flexural performance, fatigue endurance, crack width control per ACI 544.4R
Blended		15	Varies	Blend a small dosage of micro synthetic fibers and larger dosage of either macro synthetic fibers or macro steel fibers

Source: Harrington and Fick 2014

b. Separation Layer Materials: Separation layers for unbonded concrete overlays on concrete may serve three purposes.

- Provide isolation from movement of the underlying pavement. The separation layer is a shear plane that relieves stress, mitigates reflective cracking, and may prevent bonding with the existing pavement
- Provide drainage separation either by use of an impervious material or channel water along the cross slope to the pavement edge
- Provide a cushion or bedding layer to reduce bearing stress and to prevent keying from the underlying pavement

The separation layer may be either a hot mix asphalt or a non-woven geotextile fabric.

1) Asphalt Separation Layer: Conventional HMA mixtures have been used for several years to provide separation for unbonded concrete overlays. Typically, a 1 inch thick layer is used to provide separation from irregularities in the existing pavement, although thicker layers may be used when the irregularities are large enough to impact placement operations.

Poorly drained unbonded concrete overlays under heavy traffic may result in scouring or stripping of the asphalt interlayer. In an effort to reduce scour pore pressure and decreased stability, some agencies increase the porosity of asphalt mixtures. The sand content is reduced and the volume of 0.38 inch chip aggregate is increased. This modified (porous) mixture has a lower unit weight and lower asphalt content, and is comparable in cost to typical surface course mixtures.

2) Nonwoven Geotextile Separation Layer: Nonwoven geotextile interlayers are an alternative to an asphalt interlayer in providing separation, drainage and cushion for an unbonded concrete overlay. The structural condition of the existing concrete pavement must be carefully assessed before geotextile layers are used in lieu of an asphalt interlayer. Leykauf and Birmann (2006) also note that geotextile interlayers are especially recommended for concrete overlays on old concrete pavements.

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 58-34E) 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.

A uniformly applied tack coat is essential to the success of thin lift overlays. Raveling and slipping of the surface course at the interface with the existing pavement are problems when tack coats are insufficient or applied in streaks.

With the thin lift thickness, it is difficult to isolate the density of the overlay from the density of the underlying pavement. Thus, in most cases, a rolling pattern is established. To date, experience has shown that three passes with a vibratory steel-wheeled roller provides appropriate density.

As noted, the performance of thin lift overlays will depend on traffic, climate, underlying pavement quality, surface preparation, materials, and construction quality. In colder climates such as in Iowa, special attention needs to be paid to thermal cracking and damage created by snowplows.

Because of the thin lift thickness, the mix will cool quicker than normal; therefore, it is important the ambient air temperatures be at least 60°F and rising before initiating pavement placement. Ensure the entire mat has cooled to a point below 150°F before opening to traffic.

- c. **Interlayers:** HMA interlayers can be placed prior to the HMA overlay to minimize reflective cracking from the underlying pavement. An asphalt interlayer is a specially designed lift of HMA placed over a pavement and under an asphalt overlay. The asphalt interlayer is usually about 1 inch thick and uses a highly polymerized asphalt binder (PG 58-34E), fine aggregates, and a higher than normal asphalt cement content to develop a flexible layer. The interlayer will have the elasticity to resist and partially absorb the tension, shear, and bending exerted on the pavement. The asphalt interlayer assists in retarding reflective cracking of the HMA overlay caused by movement of the underlying pavement. The asphalt interlayer also helps keep additional moisture from penetrating through any cracks that are reflected and thus delaying any further deterioration of the pavement structure.

The condition of the underlying pavement is critical. If an underlying pavement has deteriorated or become unstable, it may be necessary to do removal and patching or placement of a leveling course with standard HMA prior to placement of the interlayer. Due to the higher cost, the asphalt interlayer should not be used as a leveling course.

- 2. **Crack and Seat with HMA Overlay:** Cracking and seating with HMA overlay is considered a major rehabilitation. Crack and seat will typically reduce the occurrence and severity of reflection cracks in the asphalt surface overlay. The existing concrete is broken with a guillotine or segmental type breaker to produce hairline cracks at approximately 3 to 4 foot spacing. The cracked slabs are then seated by use of a weighted roller to reestablish support between the underlying subbase or subgrade and the existing pavement. The roller is usually a rubber tired piece of equipment with a minimum gross load of 30 tons.



Crack and Seat - Photo courtesy of Antigo Construction

In urban areas, a full depth saw cut along the curbline is required prior to conducting crack and seat operations. In addition, a guillotine style breaker should be used with caution where structures are near the roadway. Impacts from the large single breaker can vibrate structures and cause concerns for property owners. A segmental breaker results in lower magnitude vibrations and is recommended for crack and seat projects in urban areas.

- 3. Rubblizing with HMA Overlay:** Rubblizing of an existing concrete pavement and placement of an HMA overlay is an optional major rehabilitation method. This process includes breaking up the concrete pavement into small pieces and rolling it into place to produce a sound base, which prevents reflective cracking in the asphalt surface. Rubblizing a concrete pavement successfully is predicated on having a stable subgrade so the concrete material does not intermix with the subgrade. In urban areas, care must be taken not to damage utilities with minimal cover. The final surface is HMA overlay.



Rubblizing - Photo courtesy of Antigo Construction

It may be necessary to work with the rubblizing contractor to establish a 100 to 200 foot test section as a means of determining the effectiveness of the rubblization. The goal is to break the existing PCC pavement into pieces with a nominal maximum size of 4 inches. In certain circumstances, the designer may allow larger pieces but they should not exceed 12 inches in size and should only be allowed for a limited area. It may be appropriate to require the contractor to excavate a test pit (4 feet by 4 feet) to assure that the PCC has been fractured throughout its entire thickness and that the bond between any steel and the concrete has been broken.

The displacement of the rubblized pieces into the subgrade should be minimized. A steel drum vibratory roller having a minimum gross weight of 10 tons is required to compact the rubblized pavement.

In areas of soft subgrade, it may be necessary to remove the pavement and patch with 2 inch limestone chokestone. Geogrid may be used under the patch rock to add additional support.

A 2 inch to 3 inch rock interlayer of 3/4 inch roadstone may be placed on the rubblized concrete and rolled prior to placing the HMA overlay if surface variations remain after rolling. The use of the interlayer provides a more stable work platform and enhances the overlay's ability to stop reflective cracking.

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Permeable Interlocking Pavers

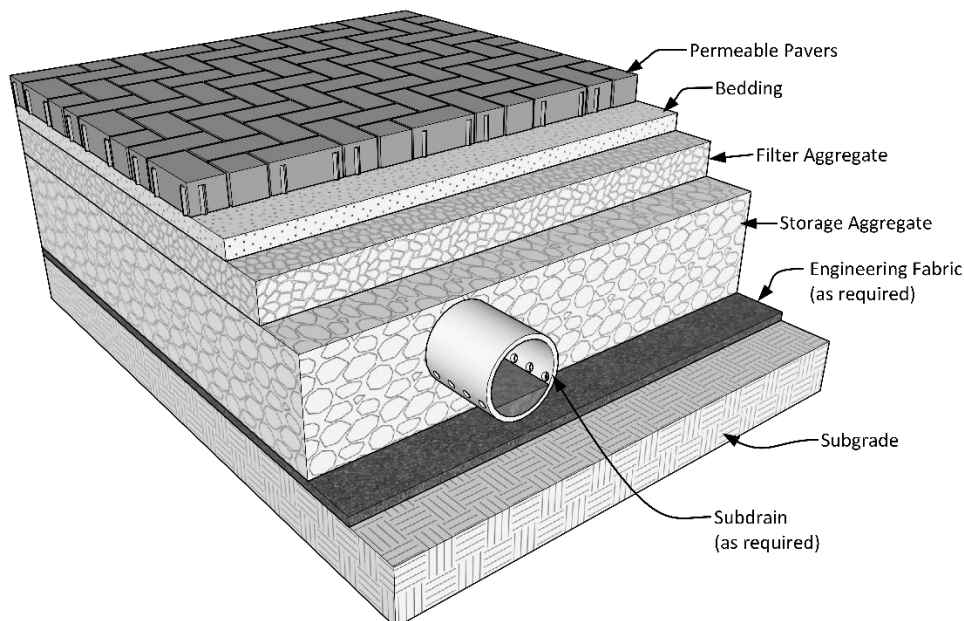
A. General

Permeable pavements are designed to infiltrate runoff, whereas runoff sheds off the surface of conventional pavements. In permeable pavements, runoff passes through the surface and is stored in the aggregate base. In pervious soils, the runoff infiltrates the soil; in less permeable soils, a subdrain system is placed to slowly discharge the runoff. Runoff volume reduction is achieved as the water is infiltrated into the underlying soils. The peak runoff rate is reduced due to the stormwater being stored in the aggregate subbase and slowly released to the downstream piping systems. Traditionally, at a minimum, the depth of the aggregate subbase is designed to meet the storage needs for the Water Quality Volume (WQv), which is 1.25 inches of rainfall in Iowa.

Permeable pavements can dramatically reduce the surface runoff from most rainfall events by disconnecting and distributing runoff through filtration and detention. The use of permeable pavements can result in stormwater runoff conditions that approximate the predevelopment site conditions for the immediate area covered by the pavers.

The design of permeable interlocking pavements (PIP) involves both structural and hydrological analyses. Figure 5K-1.01 illustrates a typical cross-section of a PIP. These two design elements are typically not interconnected and in reality are often in conflict. This is particularly the case with the subgrade treatment and volume of aggregate subbase. Structural design requires a compacted subgrade and the hydrologic design desires an uncompacted subgrade to allow as much infiltration as possible. In most instances, the hydrologic requirements for filter and storage aggregate exceed the structural needs for the unbound aggregate subbase.

Figure 5K-1.01: Permeable Interlocking Paver Cross-section



PIP are used for low speed/low volume streets, alleys, parking lots, and driveways. The design and operating speed of the facility should be below 35 mph. Permeable paver projects should only be developed in areas dominated by impermeable surfaces or surfaces that are fully vegetated so that sediment runoff is minimized and life of the pavement is maximized. PIP are capable of handling truck traffic.

The following elements should be reviewed prior to undertaking a detailed design process:

- Underlying geology and soils
- NRCS hydrologic soils groups
- History of fill, disturbance, or compaction of underlying soils
- Current drainage patterns and volume of runoff
- Local and downstream drainage facilities
- Distances to potable water supply wells
- Elevation of the static water table
- Traffic volumes, including percent trucks

Because water is stored in the subbase rock, it may be necessary to protect structures that are adjacent to the permeable paver project by sealing the foundation walls. The PIP must be a minimum of 100 feet from a municipal water supply well.

There are two types of permeable interlocking pavers. One type is concrete pavers that are 3 1/8 inches thick; the other type is clay brick pavers that are at least 2 5/8 inches thick. The concrete pavers must comply with ASTM C 936. There are two ASTM standards for brick pavers, depending on the traffic loading. ASTM C 902 is for pedestrian and light vehicular traffic locations. ASTM C 1272 is for heavier vehicular traffic and will be the type listed in the SUDAS Specifications. The clay pavers should be 2 3/4 inches thick, Type F brick for PX applications according to ASTM C 1272.

B. Structural Design

The design procedure for permeable interlocking pavers is the same as for flexible pavements. Research has shown that the load distribution and failure modes of PIP are similar to other flexible pavements. Because the designs are the same as for flexible pavements, the AASHTO *Guide for Design of Pavement Structures* (AASHTO, 1993) can be used. The paver used in design for concrete pavers is a 3 1/8 inch thick paver with a minimum 1 inch bedding layer. The structural coefficient is 0.44 per inch. This provides a structural number of 1.82. The clay brick paver is 2 3/4 inches thick, which has a corresponding structural number of 1.21. The remaining structural support comes from the aggregate layers and the soil subgrade.

The American Society of Civil Engineers has developed a design standard called *Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways* (ASCE/T&DI/ICPI 58-10). The structural design for clay brick pavers is the same as for concrete pavers. The engineer will need to determine or select the following:

- Design traffic loading (ESALS)
- Design life (40 years minimum)
- Design reliability (usually 75% to 80%)
- Overall standard deviation (0.45)
- Required structural number to meet traffic loading
- Initial serviceability (flexible pavements = 4.2)
- Terminal serviceability (local streets = 2.0)
- Subgrade resilient modulus based on saturated soil characteristics, including seasonal variability
- Drainage conditions

Once these elements are determined, the design thickness of the unbound aggregate subbase can be determined. The ASCE design standard has tables showing thickness of the layers that were developed using the AASHTO 1993 Guide. Thickness is selected based on the ESALS, the soil category, and the drainage.

Three types of interlock are critical to achieve: vertical, rotational, and horizontal. Vertical interlock is achieved by the shear transfer of loads to surrounding pavers through the material in the joints. Rotational interlock is maintained by the pavers being of sufficient thickness and aspect ratio (3:1 minimum), being placed close together, and restrained by a curb from lateral forces of vehicle tires. Rotational interlock can be further enhanced if there is a slight crown to the pavement cross-section. Horizontal interlock is primarily achieved through the use of laying patterns that disperse forces from braking, turning, and accelerating vehicles. Herringbone patterns, either 45° or 90°, are the most effective patterns for maintaining interlock. A string or soldier course should be used at the interface between the pavers and the edge restraint.

A PCC edge restraint is typically used for street and alley projects. The edge restraint may be a standard curb and gutter section, a vertical curb section, or a narrow concrete slab, and should be placed on the subbase aggregates.

After placement, the pavers are compacted with a high frequency plate compactor, which forces the joint material into the joints and begins compaction of the paver into the bedding layer. The pavement is transformed from a loose collection of pavers into an interlocked system capable of spreading vertical loads horizontally through the shear forces in the joints.

One of the direct conflicts with the hydrologic design of PIP is the compaction of the subgrade soils. The structural design calls for subgrades compacted to 95% Modified Proctor Density according to AASHTO T 180. The effective compaction depth should be 12 inches minimum. This compaction requirement will prevent efficient infiltration of water through the subgrade and thus will likely necessitate a piping design to handle the stormwater that accumulates in the storage aggregate (unbound subbase).

The engineer should provide a geotextile between the subgrade and the storage aggregate (subbase) as a means of preventing mixing of the materials. The geotextile should comply with [Iowa DOT Section 4196](#) for subsurface drainage.

C. Hydrologic Design

The design process follows traditional storm sewer procedures for pavements. The initial step in the hydrologic design is the determination of the design storm event. Some agencies may establish the storm return period and the rainfall intensity. Information on intensity-duration-frequency for various return periods can be found in Chapter 2. In addition, the contributing area must be determined. The runoff volume should be determined according to the methods described in Chapter 2 using a design rainfall depth of 1.25 inches as a minimum, unless the jurisdiction has a different policy.

The next step involves establishing the drainage area. The storm event is then applied to the drainage area and the volume of runoff is determined.

The permeability of the subgrade soil is a critical design element. If the subgrade soil permeability is less than 1/2 inch per hour, a subdrain piping network will be needed. Soil compaction to support vehicular traffic will decrease permeability. Good design practice for vehicular traffic loads is to provide a minimum CBR of 5. Thus as the soil permeability is determined it should be assessed at the density required to realize a CBR of 5 under soaked conditions.

To maximize the effectiveness of the PIP, the pavement grade should be as flat as possible, although steeper grades can be used. The general guideline is that the longitudinal grade should be greater than 1% and less than 12%. Three design alternatives exist for the PIP. They are:

- Full infiltration: All of the stormwater runoff from the design storm is infiltrated into the subgrade soils. See Figure 5K-1.02.A.
- Partial exfiltration: Some of the design storm runoff is infiltrated and the remainder is collected in the subdrain system and slowly discharged into the downstream systems. This is accomplished by setting the subdrain pipe above the top of the subgrade. See Figure 5K-1.02.B.
- Full Exfiltration: Soil permeability is limited and thus all of the runoff volume is carried away through the subdrain piping. See Figure 5K-1.02.C.

Designers must also evaluate and provide for larger storm events. One way to provide for the larger storms but still provide for infiltration of the water quality storms is to raise the elevation of the intakes above the pavers so the small storms are infiltrated and the large storms are handled by the intakes and pipe network.

Once the volume of runoff and the soil permeability are known, the thickness of the storage aggregate layer (Iowa DOT Gradation No. 13/ASTM Gradation No. 2) can be determined. The void space (volume of voids/volume of aggregate) for Iowa DOT Gradation No. 13 is 40%. A 40% void space provides 0.4 cubic feet of stormwater storage for each cubic foot of aggregate. Thus, the volume of the storage aggregate will need to be 2.5 times the volume of water to be stored.

Due to the need to compact the subgrade soil to handle vehicles, it is very likely that subdrains will be needed to discharge at least a portion of the runoff. The elevation and sizing of the subdrains should be set to provide for full discharge of the design storm within 72 hours either through infiltration into the subgrade soil or through subdrain pipe discharge.

In order to prevent absorption of the bedding stone into the storage aggregate layer, a layer of filter aggregate (Iowa DOT Gradation No. 3/ ASTM Gradation No. 57) is needed. This layer is typically 4 inches thick. The bedding aggregate (Iowa DOT Gradation No. 29/ASTM Gradation No. 8) is then placed 2 inches thick, compacted, and leveled. Fine graded sand should not be used as the bedding and for filling of voids due to the increased clogging potential.

The pavers are placed, additional bedding stone is added to fill the voids in between the pavers, the area is swept, and finally the pavers are compacted. Sweeping prior to compaction is important to prevent stones on the surface from marring or cracking the pavers. That process may need to be repeated to entirely fill the voids. The final step is to sweep and remove any excess void filler stone.

Figure 5K-1.02: Permeable Interlocking Paver Design Alternatives

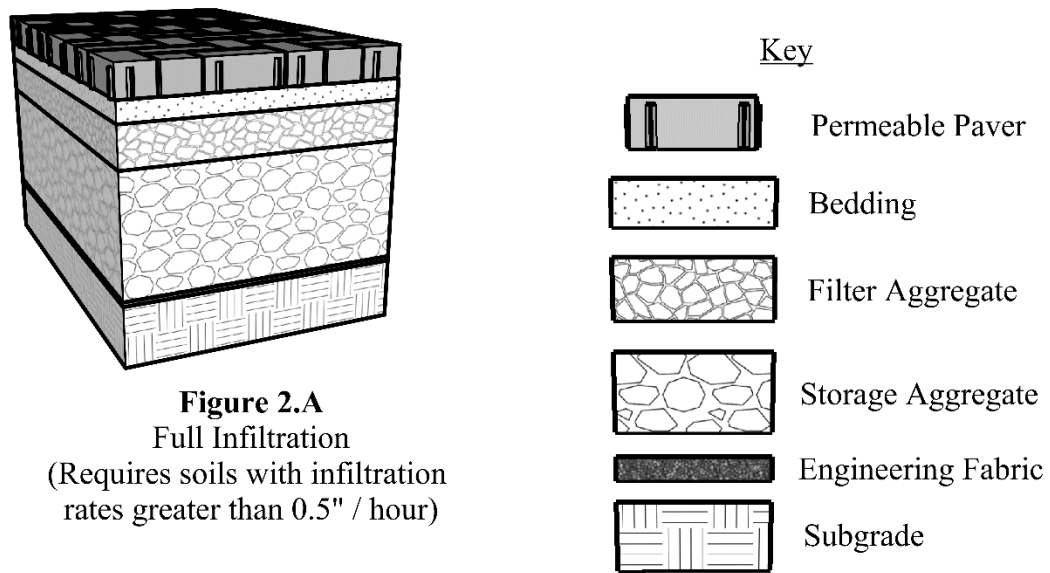


Figure 2.A
Full Infiltration
(Requires soils with infiltration
rates greater than 0.5" / hour)

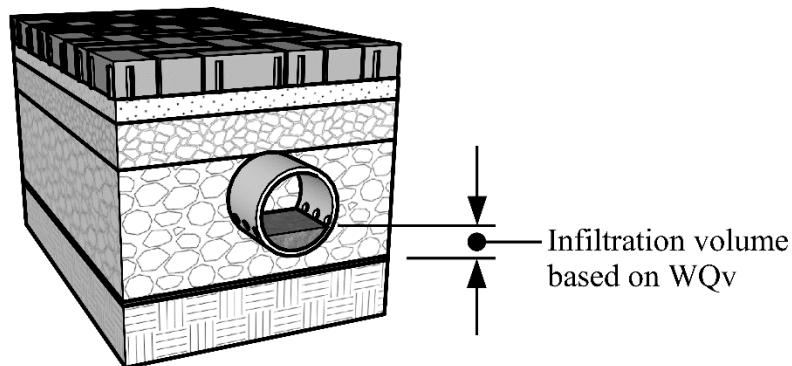


Figure 2.B
Partial Infiltration

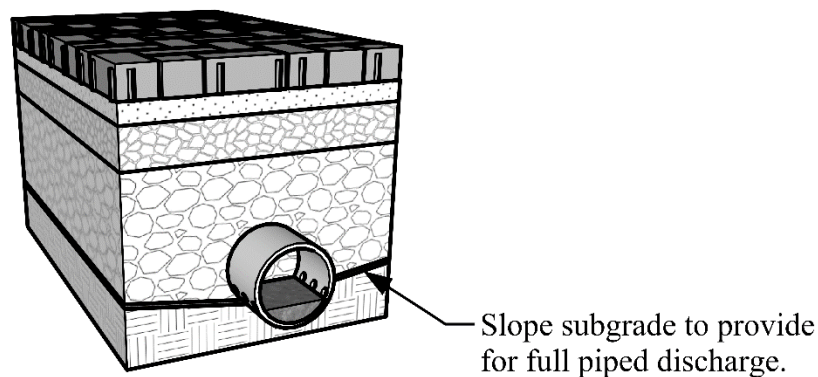


Figure 2.C
Full Exfiltration

D. Construction Elements

Monitoring and controlling the construction activities of a permeable interlocking paver project are critical to the long-term performance of the permeable pavement. Preventing and diverting sediment from entering the aggregates and pavement during construction must be of the highest priority. Aggregate stockpiles must be isolated to prevent contamination by sediment. Erosion and sediment control devices must be placed and maintained throughout the project until vegetation is fully established. All unnecessary vehicle and pedestrian traffic should be restricted once the aggregate placement has initiated. It may be necessary to wash vehicle and equipment tires to prevent tracking dirt and mud onto the aggregate layers.

A test section (approximately 5 feet by 5 feet) should be constructed to provide a basis for construction monitoring. The test section should be placed on the prepared subgrade to illustrate the processes used to place the pavers and illustrate the paver pattern and the edge details.

Restrict all equipment and workers from the paver placement area once the bedding stone has been placed, leveled, and compacted. Pavers may be placed by hand or mechanically. Placement should proceed from one end or side and continue work from the completed placement areas. An important consideration with mechanically placed pavers for large projects is to ensure the wear on the paver molds does not change the size of the pavers and thus impact the ability to correctly place the pavers.

E. Maintenance

As with any pavement, particularly permeable pavements, specific maintenance activities are necessary to achieve the design life of the pavement. PIP can become clogged with sediment that affects its infiltration rate. The rate of sedimentation can depend on the number and type of vehicles using the pavement, as well as the control of erosive soils adjacent to the pavement. The most important element of maintenance is keeping the sediment out of the pavement by vacuum sweeping. Regular vacuum street sweeping will maintain a high infiltration rate and keep out vegetation. Calibration of the vacuum force may be necessary to remove the sediment but minimize removal of the filler material from the joints. Over time, it may be necessary to add additional joint filler material to prevent intrusion by sediment.

Winter maintenance involves plowing snow and applications of de-icing chemicals. Although not required, snowplows can be equipped with rubber edged blades to minimize chipping of the pavers. Use of de-icing chemicals is often not necessary because the PIP remains warmer throughout the winter. Sand should not be used as an abrasive for traction. The sand will clog the filler material in the pavement joints.

General Access Management

A. General Information

The efficiency and safety of a street or highway depends largely upon the amount and character of interruptions to the movement of traffic. The primary cause of these interruptions is vehicular movements to and from businesses, residences, and other developments along the street or highway. Regulation and overall control of access is necessary to provide efficient and safe highway operation and to utilize the full potential of the highway investment.

The Jurisdictions reserve the right to make exceptions to the criteria where the exercise of sound and reasonable engineering judgment indicates that the literal enforcement of the criteria would cause an undue hardship to any interested party.

B. Access Permit Procedure

An access permit may be required for any public or private access constructed to a public street. The Jurisdictional Engineer will stipulate the information required and the permit form to use. Access to streets or highways under the jurisdiction of the Iowa DOT will be governed by requirements of the Iowa DOT with Jurisdictional review (See [Section 5N-1](#)).

In addition to specific details, the following general criteria will be used by the Jurisdiction when reviewing an access request:

1. Safety to the traveling public
2. Preservation of the traffic-carrying capacity of the highway
3. The impact upon the economy of the area
4. Protection of the rights of the traveling public and of property owners, including the rights of abutting property owners

C. Definitions

Access management definitions can be found in the following resources:

1. Iowa Department of Transportation - "Iowa Primary Road Access Management Policy."
2. Transportation Research Board - "Access Management Manual."

D. Entrance Type

1. **Major:** An entrance developed to carry sporadic or continuous heavy concentrations of traffic. Generally, a major entrance carries in excess of 150 vehicles per hour. An entrance of this type would normally consist of multiple approach lanes and may incorporate a median. Possible examples include racetracks, large industrial plants, shopping centers, subdivisions, or amusement parks.
2. **Commercial/Industrial:** An entrance developed to serve moderate traffic volumes. Generally, a commercial/industrial entrance carries at least 20 vehicles per hour but less than 150 vehicles per hour. An entrance of this type would normally consist of one inbound and one outbound traffic lane. Possible examples include service stations, small businesses, drive-in banks, or light industrial plants.
3. **Residential:** An entrance developed to serve light traffic volumes. Generally, a residential entrance carries less than 20 vehicles per hour. An entrance of this type would not normally accommodate simultaneous inbound and outbound vehicles. Possible examples include single-family residence, farm, or field entrances.

E. Access Management Principles

A variety of access management, location, and design practices and policies can be used to improve the safety and operations of the roadway within a state's, city's, or county's jurisdiction.

Following are the 10 Principles of Access Management identified by the TRB:

1. **Provide a Specialized Roadway System:** Different types of roadways serve different functions. It is important to design and manage roadways according to the primary functions that they are expected to serve.
2. **Limit Direct Access to Major Roadways:** Roadways that serve higher volumes of regional through traffic need more access control to preserve their traffic function. Frequent and direct property access is more compatible with the function of local and collector roadways.
3. **Promote Intersection Hierarchy:** An efficient transportation network provides appropriate transitions from one classification of roadway to another.
4. **Locate Signals to Favor through Movements:** Long uniform spacing of intersections and signals on major roadways enhances the ability to coordinate signals and ensure continuous movement of traffic at the desired speed.
5. **Preserve the Functional Area of Intersections and Interchanges:** The functional area of an intersection or interchange is the area that is critical to its safe and efficient operation. This is the area where motorists are responding to the intersection or interchange, decelerating, and maneuvering into the appropriate lane to stop or complete a turn.
6. **Limit the Number of Conflict Points:** Drivers make more mistakes and are more likely to have collisions when they are presented with the complex driving situations created by numerous conflict points.
7. **Separate Conflict Areas:** Drivers need sufficient time to address one potential set of conflicts before facing another. The necessary spacing between conflict areas increases as travel speed increases, to provide drivers adequate perception and reaction time.

8. **Remove Turning Vehicles from Through-traffic Lanes:** Turning lanes allow drivers to decelerate gradually out of the through lane and wait in a protected area for an opportunity to complete a turn. This reduces the severity and duration of conflict between turning vehicles and through traffic, and improves the safety and efficiency of roadway intersections.
9. **Use Nontraversable Medians to Manage Left Turn Movements:** Medians channel turning movements on major roadways to controlled locations. Nontraversable medians and other techniques that minimize left turns or reduce driver workload can be especially effective in improving roadway safety.
10. **Provide a Supporting Street and Circulation System:** Provide a supporting network of local and collector streets to accommodate development, as well as unified property access and circulation systems.

F. References

American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets*. 2004.

Institute of Transportation Engineers. *Transportation and Land Development*. 2002.

Iowa Department of Transportation. *Iowa Primary Road Access Management Policy*. 2012.

Transportation Research Board. *Access Management Manual*. 2003.

Transportation Research Board. *NCHRP Report 420: Impacts of Access Management Techniques*. 1999.

Transportation Research Board. *NCHRP Report 457: Evaluating Intersection Improvements: An Engineering Study Guide*. 2001.

Transportation Research Board. *NCHRP Report 659: Guide for the Geometric Design of Driveways*. 2010.

Transportation System Considerations

This section addresses transportation system considerations in access management, including TRB Principles of Access Management 1 through 4 and 10:

A. Provide a Specialized Roadway System (Principle 1)

The primary function of major arterial roadways is to safely and efficiently accommodate through traffic. The primary function of local streets is to provide access to adjacent properties. Minor arterials and collectors provide a blend of the mobility and access functions. Design and management of transportation facilities, including access management, must consider the classification and intended function of roadways.

B. Limit Direct Access to Major Roadways (Principle 2)

Providing direct property access to major roadways can significantly affect corridor operations and safety, and is not consistent with the function of the major roadway. Higher levels of access control become more necessary as major road through traffic volumes and speeds increase.

C. Promote Intersection Hierarchy (Principle 3)

Provide appropriate transitions from one roadway classification to the next.

- Freeways intersect arterials with interchanges.
- Arterials intersect collectors.
- Collectors intersect local streets.
- Local streets provide connections to private accesses.

D. Locate Signals to Favor through Movements (Principle 4)

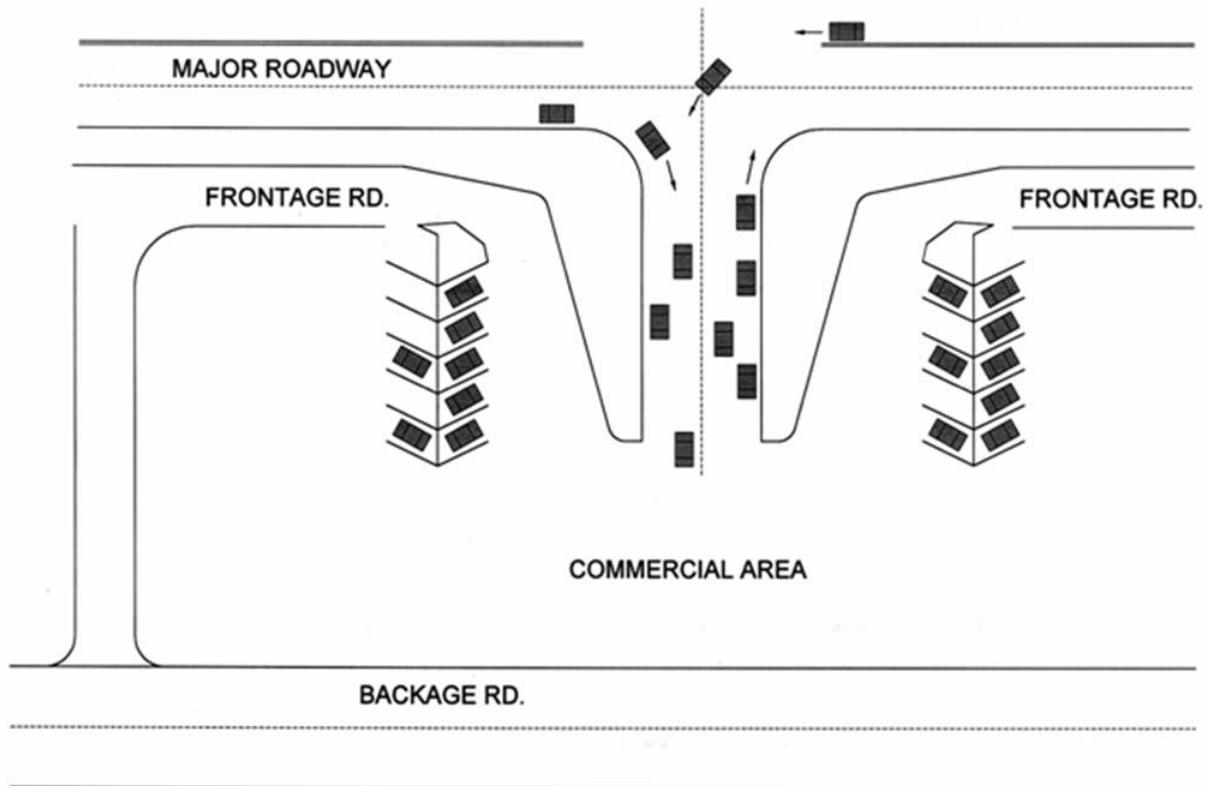
All major arterials, minor arterials, and major collectors within urbanized areas, the urban fringe or areas that may ultimately be subject to urban growth should have long, uniform traffic signal spacing.

- Provides the flexibility to use timing plans that can provide efficient traffic progression over a wide range of speeds and cycle lengths.
- Use a minimum of 1/2 mile spacings on major suburban/urban arterials.
- Use a minimum of 1/4 mile spacings on minor arterials and major collectors where traffic progression is less important than on major arterials.
- Locate cross-roads and full median openings only at locations that conform to the selected spacing interval so that the intersection may be signalized when conditions warrant.
- Where signal location does not conform to recommended spacing, reduce the cross-street green and increase the major street green so as to maintain progression on the major street.

E. Provide a Supporting Street and Circulation System (Principle 10)

- Provide local and collector streets to accommodate access to development.
- Provide access connections between adjacent parcels.
- Require adequate internal circulation for development.
- Provide alternate access from minor roads.
- Provide frontage and backage roads (see Figure 5L-2.01).

Figure 5L-2.01: Frontage and Backage Roads with Adequate Vehicle Queue Storage



Access Location, Spacing, Turn Lanes, and Medians

This section addresses access location, spacing, turn lane and median needs, including TRB Principles of Access Management 5-9:

A. Preserve the Functional Area of Intersections and Interchanges (Principle 5)

AASHTO states, “Ideally, driveways should not be located within the functional area of an intersection or in the influence area of an adjacent driveway. The functional area extends both upstream and downstream from the physical intersection area and includes the longitudinal limits of auxiliary lanes.”

- 1. Upstream Functional Distance:** The upstream functional distance of the intersection can be further defined as the approach distance to an intersection that is required for the driver to change speeds in order to complete a movement, such as entering an auxiliary lane or slowing down for a turn or signal. The upstream functional distance includes the sum of:

d_1 , distance traveled during driver’s perception - reaction time

d_2 , deceleration distance while the driver maneuvers to a stop

d_3 , queue storage length required (50 foot minimum)

Table 5L-3.01: Distance Traveled During Driver’s Perception-reaction, (d_1)

Speed (mph)	Rural (feet)	Urban/ Suburban (feet)
20	75	45
30	110	65
40	145	90
50	185	110
60	220	135
70	255	155

Source: TRB Access Management Manual

Table 5L-3.02: Desirable Maneuver Distances, (d_2)

Speed (mph)	Distance (feet)
20	70
30	160
40	275
50	425
60	605
70	820

Source: TRB Access Management Manual

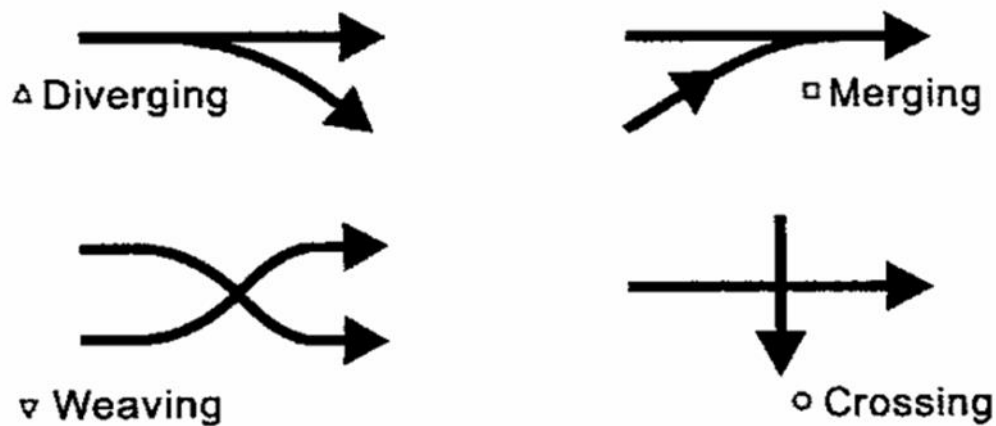
For example, at an urban intersection approach with a 30 mph speed and minimal queuing, the upstream functional distance would be 275 feet (65 feet + 160 feet + 50 feet).

2. **Downstream Functional Distance:** The downstream functional distance from an intersection should be based on upstream functional distance for the proposed adjacent access point. Minimum separation should be no less than the AASHTO stopping sight distance.

B. Limit the Number of Conflict Points (Principle 6)

Traffic conflicts occur where the paths of traffic movements cross. Eliminating or reducing conflict points will simplify the driving task, contributing to improved traffic operations and fewer collisions.

Figure 5L-3.01: Types of Vehicular Conflicts

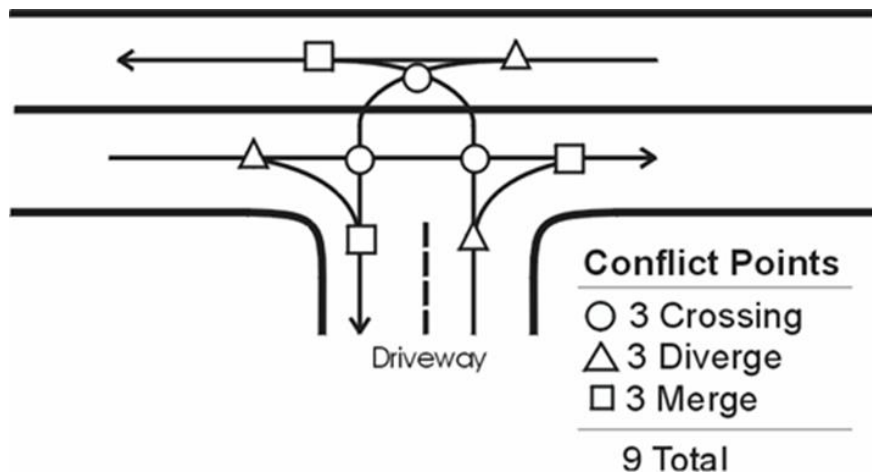
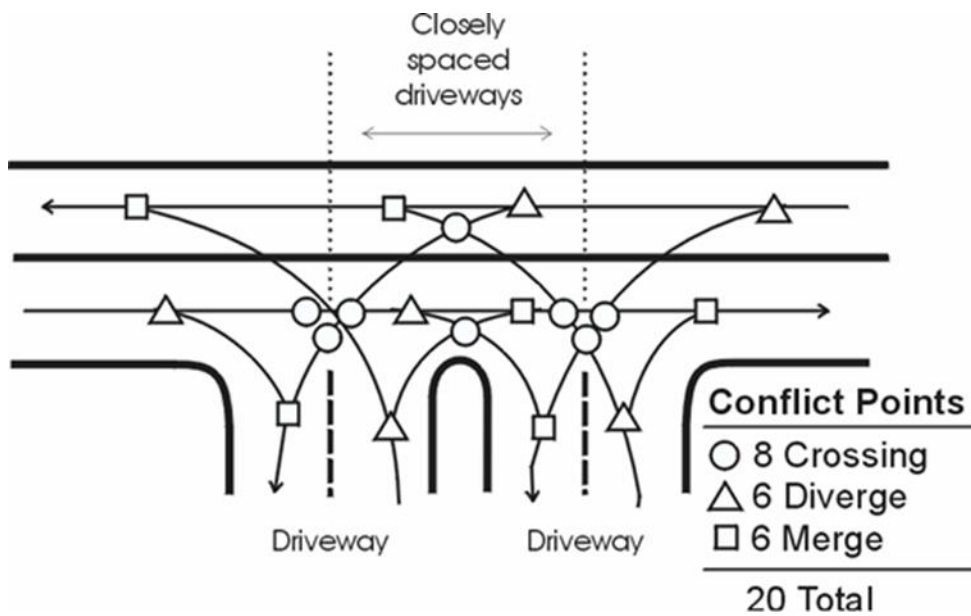


C. Separate Conflict Areas (Principle 7)

Separating conflict areas allows drivers to address one potential set of conflicts at a time. The higher the speed, the longer the distance a vehicle will travel during a given perception-reaction time. Also, drivers need more time to react to complex conflict areas. Hence minimum separation distances are a function of both the speed of traffic on a given section of roadway and the complexity of the decision with which the driver may be presented. The complexity of the problem, in turn, increases with both the number and type of conflicts and the volume of traffic.

Various methods that can be utilized to separate conflict areas include the following:

- Minimum access spacing
- Minimum corner clearance
- Minimum property line clearance
- Limit the number of accesses per property
- Designate the access for each property

Figure 5L-3.02: Two Lane Undivided Roadway (Single Entrance)**Figure 5L-3.03:** Two Lane Undivided Roadway (Closely Spaced Entrances)

1. **Driveway Density:** The number of driveways per block or per mile significantly affects the safety of the corridor. Crash rates increase very quickly as the number of access points increases on arterial and collector roadways.

Table 5L-3.03: Crash Rates (crashes per million vehicle miles traveled) vs. Access Point Density

Access Points per Mile	Approximate Accesses per 500 feet	Representative Crash Rate for an Undivided Roadway	Increase in Crashes Associated with More Access Density
Under 20	Under 2	3.8	----
20 to 40	2 to 4	7.3	+92%
40 to 60	4 to 6	9.4	+147%
Over 60	Over 6	10.6	+179%

Source: National Cooperative Highway Research Program Report 420.

2. **Access Spacing for Major Arterials:** Provide separation between access connections so that drivers can assess potential conflict locations one-at-a-time. Applicable spacing criteria may include:
 - Functional area ([Section 5L-2](#))
 - AASHTO stopping sight distance
 - Preventing right turn overlap (see below)
 - Other criteria as established by the Jurisdiction

Right turn overlap occurs when a through vehicle must monitor two egress right turning vehicles at once while still performing other driving tasks. By separating access points a proper distance, the overlap does not occur, and the through driver has only one egress right turning vehicle to monitor. Recommended minimum access spacings to avoid right turn overlap shown in Table 5L-3.04 are comparable to AASHTO stopping sight distances.

Table 5L-3.04: Minimum Access Spacing to Prevent Right Turn Overlap

Speed (mph)	Recommended Minimum (feet) ¹
25	120
30	185
35	245
40	300
45	350

¹ Intersection clearance should be the same as driveway spacings or at least as long as stopping sight distance.

Source: Transportation Research Board Record 644, 1977.

3. **Access Spacing for Minor Arterials, Collectors, and Local Streets in Urban/Suburban Areas:** For minor arterials and major collectors, direct access from individual properties should be avoided wherever possible. Property access should be provided from minor collectors, local streets, frontage roads and backage roads. Major arterial access spacing criteria should be used for minor arterials and major collectors when possible.

Table 5L-3.05: Minimum Distance between Driveways or from Intersecting Streets

	Minor Arterial			Collector			Local		
	Res. Area	C/I Area	Ag Area	Res. Area ³	C/I Area	Ag Area	Res. Area ³	C/I Area	Ag Area
A. Minimum intersection clearance¹	145'	170'	300'	100'	100'	300'	75'	75'	150'
B. Minimum driveway spacing²	100'	200'	300'	75'	100'	300'	--- ⁴	--- ⁴	150'

Res = Residential, C/I = Commercial/Industrial

¹ Values are measured from the back of the curb, intersecting road to the adjacent driveway near edge.

² Values are measured between driveway edges.

³ One access drive allowed per lot. Depending on lot size, an additional drive may be allowed upon approval of the Jurisdiction.

⁴ See Jurisdictional Engineer for local requirements.

- 4. Access Spacing for State Primary Roads:** In rural areas, travel speeds are usually 55 mile per hour and above. This means that driveway spacing in rural areas must be longer to provide for a safe driving environment. On state highways, spacing is also longer because the routes are primarily designed to carry through traffic rather than to serve as property access routes. The more important a route is for through traffic and commerce, the longer the spacing between driveways. The following table shows the State of Iowa's standards for its highway system.

Table 5L-3.06: Iowa DOT Access Control - Minimum Spacings

State Highway Priority	Minimum Spacing Between Driveways	Number of Driveways Per Mile
Priority I (Full Access Control)	Interchanges at roads	N/A
Priority II (Four Lane Divided)	2,640' (minimum) ¹ 5,280' (preferred) ¹	2 2
Priority III	1,000' rural (minimum) ¹ 1,320' rural (preferred) ¹	4 4
Priority IV(a) Priority IV(b)	600' rural (≥ 45 mph) 300' urban (≤ 40 mph)	8 16
Priority V (Access Right Acquired Between 1956 to 1966)	1 access per 1,000' of frontage not exceeding 2,000'	2 to 5
Priority VI	Safety and need	Varies

¹ Access allowed only at interchanges and selected at-grade locations

- 5. Access Spacing for County Roads:** On county roads, the spacing standard should also depend on the nature of the road, e.g. how important the road is for through traffic. Even on the lowest functional levels, some sort of driveway spacing standard is important for traffic safety.

Table 5L-3.07: County Road Minimum Access Spacings

County Road Route Type	Minimum Spacing Between Driveways	Number of Driveways Per Mile
Minor arterials	600'	9
Collectors	300'	18
Local traffic service	150'	36

6. Additional Access Spacing Considerations:

- At a minimum, the upstream corner clearance should be longer than the longest expected queue at the adjacent intersection.
- High speed, high volume roadways need longer corner clearances whereas the corner clearance on a local street can be much shorter.
- Residential streets - driveways on corner lots should be located on the lesser street and near the property line most distant from the intersection.
- Typically, all elements of an access drive, including the radii should be within a property frontage.
- At a minimum, all driveway geometrics should be along the frontage of the property served by the driveway.
- On major roadways, the corner clearance should be at least as long as the stopping sight distance so that vehicles turning corners can make safe stops when encountering entering traffic.
- Encourage owners of adjacent properties to construct joint-use driveways in lieu of separate driveways.
- Encourage a property owner to replace two or more driveways with a single driveway (or fewer driveways).
- For adjacent properties, locate joint access on the property line. Reciprocal easements must be executed.

D. Remove Turning Traffic from Through-traffic Lanes (Principle 8)

All driveway and intersection geometrics require that turns be made at very slow speeds and hence result in high speed differentials. Providing auxiliary lanes (left-turn and right-turn bays) is the most effective means of limiting the speed differential. This is especially important on high volume and high speed roadways.

The several methods by which turning vehicles can be removed from through traffic lanes are:

- Install isolated left-turn bay
- Install a nontraversable median with left-turn bays
- Install right-turn deceleration bay
- Install right-turn lane
- Install a continuous two-way left-turn lane (TWLTL)

1. **Turn Lane Warrants for Urban/Suburban Areas (Unsignalized):** Providing left and/or right turn lanes can significantly improve the operation and safety of an intersection. They allow turning vehicles to exit the through traffic lane with reduced speed differential and provide queue storage without interference with through traffic. Rear-end and side-swipe collisions are greatly reduced. Capacity is increased and delay decreased.

General information regarding improvements for intersections, including guidelines for including left and right turn lanes, can be found in NCHRP Report 457. More specific information and warrants for installation of left turn lanes is presented in NCHRP Report 745.

In general, the decision to provide turn lanes should be based on safety rather than just capacity. Where practical, left turn lanes should be provided at median openings on divided roads, regardless of projected traffic volumes.

2. **Rural Turn Lane Warrants and Right Turn Deceleration Length (Unsignalized):** See Iowa Department of Transportation's Design Manual, Chapter 6 - Geometric Design.
3. **Three Lanes with TWLTL:** Three lane roadway designs can be effectively used in situations where there are low to moderate levels of through traffic, yet there are concerns about conflict points and crashes caused by left-turning traffic. The upper limit for using a three lane design is about 17,000 vehicles per day of traffic. Three lane designs are ideal where right-of-way width is limited due to existing land development or other constraints. Three lane roads can either be designed that way originally or can be created by widening an existing two lane route or by modifying an existing four lane undivided route.
4. **Five lanes with TWLTL:** When the average daily traffic (ADT) on a street exceeds about 17,000 vehicles per day, four lane roadways with raised medians or five lane roadways with TWLTL are more appropriate designs. The limit for five lane roadway (with TWLTL) is approximately 24,000 ADT. TWLTL should generally not be used in situations where there are more than four total through lanes.

E. Use Nontraversable Medians to Manage Left Turn Movements (Principle 9)

The majority of access-related crashes involve left turns. Providing nontraversable medians limits and defines locations of left turns, thereby improving safety. Full access median openings that allow left turns from all directions are best provided at signalized intersections and unsignalized junctions of arterial and collector streets. Providing median closures or partial access medians at other intersections and access points reduces the number and types of conflicts.

1. Median Closures: Median openings should be considered for closure where:

- A safety or operational problem is evident and an appropriate retrofit cannot be made.
- Median width is less than 11 feet, thereby not allowing for construction of left turn lanes.
- The left-turn bay of a nearby signalized intersection needs to be extended.
- A pattern of left-turn crashes is evident.
- Heavy pedestrian use is predicted or crashes involving pedestrians have occurred at the intersection.

Implementation of a median closure involves providing a section of median of the same design as existing on either side of the opening. The following should be considered during design:

- Tree lines, building lines, and lighting may lead drivers into believing the median can be crossed.
- Visual cues should be provided to clearly inform drivers that the opening has been closed.
- The need for visual cues is especially critical during nighttime hours where a four way intersection previously existed or there are access drives directly opposite each other.
- Minimum 4 feet median width face-to-face of curbs is recommended.
- Select and locate landscaping materials to delineate the median while considering potential sight distance obstructions.

Figure 5L-3.04: Two Lane Roadway Conflict Points at Typical Three Way Intersection or Driveway

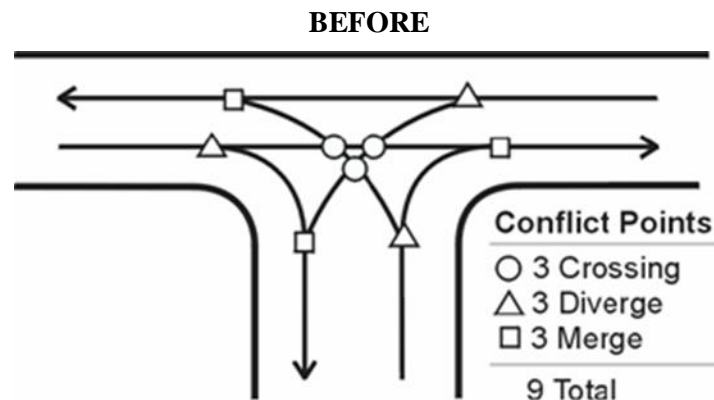
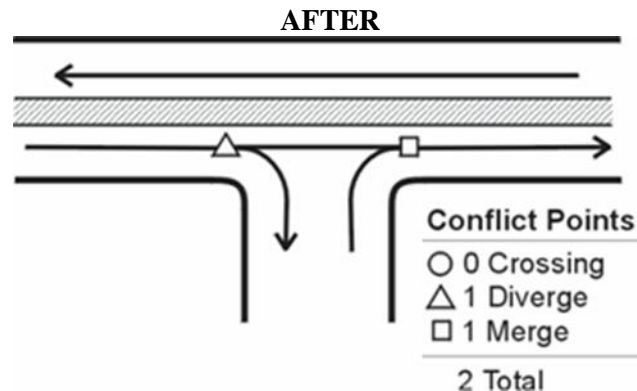
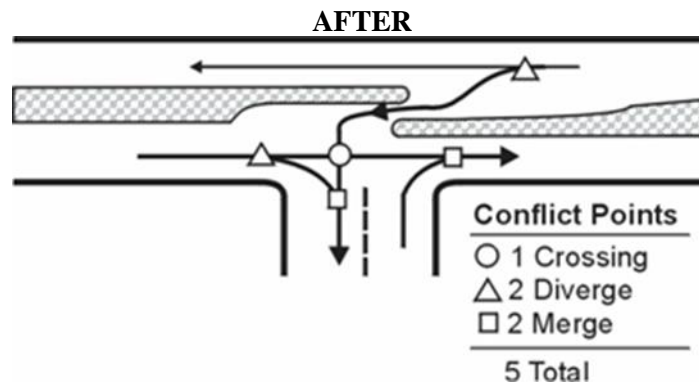


Figure 5L-3.05: Two Lane Roadway with Raised Median Closure (right-in/right-out only access)**Figure 5L-3.06:** Two Lane Roadway with Raised Median (left turn ingress allowed into driveway)

2. Raised Medians vs. Two Way Left Turn Lanes:

- Because they are the most restrictive access management treatment, constructing raised center medians along arterials is often very controversial among business and property owners. Two way left turn lanes (TWLTL) are usually much less controversial. Business persons and property owners feel that installation of raised medians will have a large, negative impact on their customers, sales, and property values. Therefore, TWLTL are often suggested as compromise solutions.
- Arterial roadways with raised medians are statistically safer and operate better than any other configuration. Research indicates that raised median roadways are significantly safer than undivided roadways in urban areas. When traffic volume on an arterial roadway is projected to exceed about 24,000 average annual daily traffic (AADT) during the next 20 years, including a raised median is prudent.
- In general, TWLTL projects function well when traffic levels are moderate, when the percentage of vehicles turning as opposed to traveling through is high, and when the density of commercial driveways is low. TWLTL will function very well on most arterials where AADT is in the range of 10,000 to 24,000 AADT (five lane TWLTL).
- TWLTL projects can also work very well in places where the number of driveways per block or mile is high, but the land use is such that not many turning movements are generated per hour. An example would be an arterial street passing through a predominately residential area.

- TWLTL are much less effective in situations where commercial driveway densities are high and these driveways are spaced close together. In such a situation, the number of conflict points is high, and this will be reflected in crash experience. Research from many states indicates that raised median roadways are always safer than TWLTL roadways. If TWLTL are considered, driveway density and driveway spacing must be managed very aggressively.

Table 5L-3.08: Crash Rates (crashes per million vehicle miles traveled) vs. Median Type

Access Points Per Mile	Undivided (Painted Centerline) Crash Rate	TWLTL Crash Rate	Raised Median Crash Rate	Rate Reduction Raised Median Versus TWLTL
Less than 20	3.8	3.4	2.9	-0.5 (15%)
20 to 40	7.3	5.9	5.1	-0.8 (14%)
40 to 60	9.4	7.4	6.5	-0.9 (12%)
Over 60	10.6	9.2	8.2	-1.0 (11%)

Source: National Cooperative Highway Research Program Report 420

F. References

Transportation Research Board - National Cooperative Highway Research Program (NCHRP). *NCHRP Report 420: Impacts of Access Management Techniques*. National Academy Press. Washington, DC. 1999.

Transportation Research Board - National Cooperative Highway Research Program (NCHRP). *NCHRP Report 644: Guidelines for Conducting a Disparity and Availability Study for Federal DBE Program*. National Academy Press. Washington, DC. 1977.

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

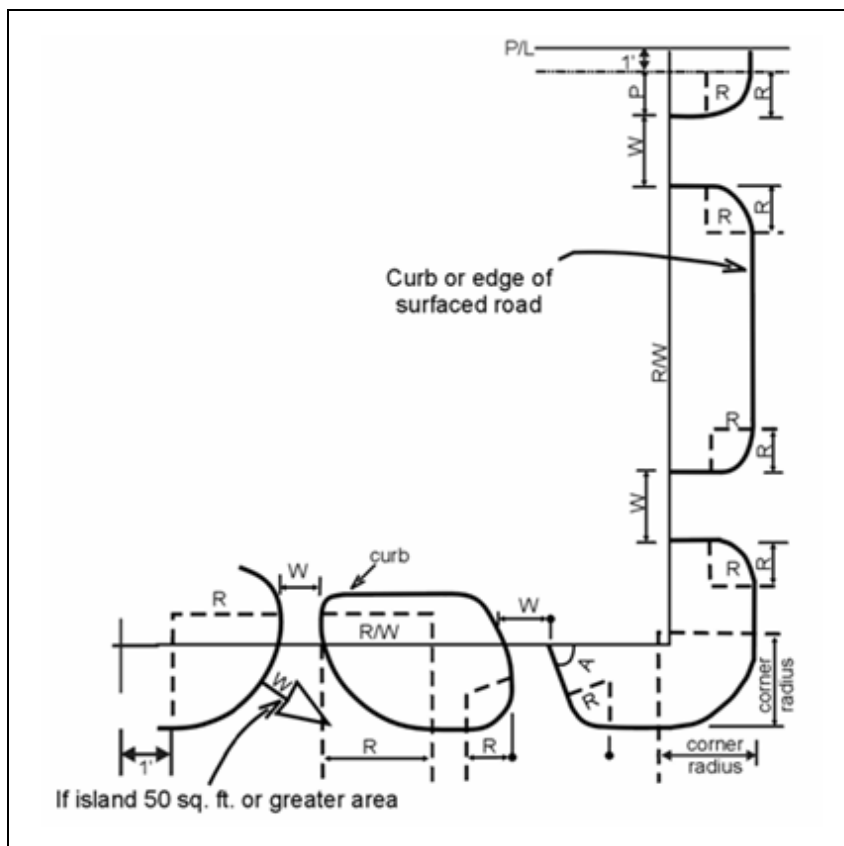


Table 5L-4.01: Driveway Dimensions¹
(all dimensions are in feet)

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 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 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.

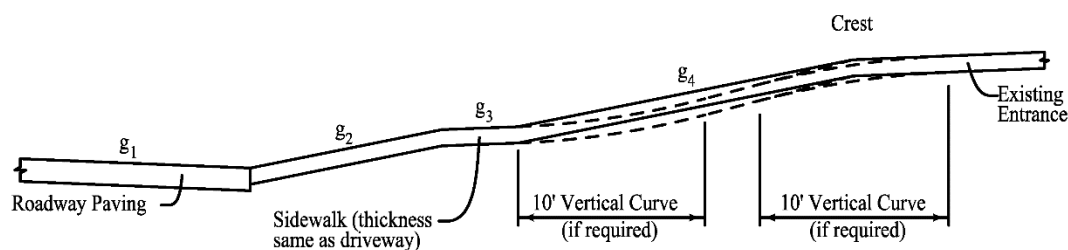
Table 5L-4.05: Speed Differential and Crashes

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 Figures 5L-4.02A and 5L-4.02B.

Figure 5L-4.02A: 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

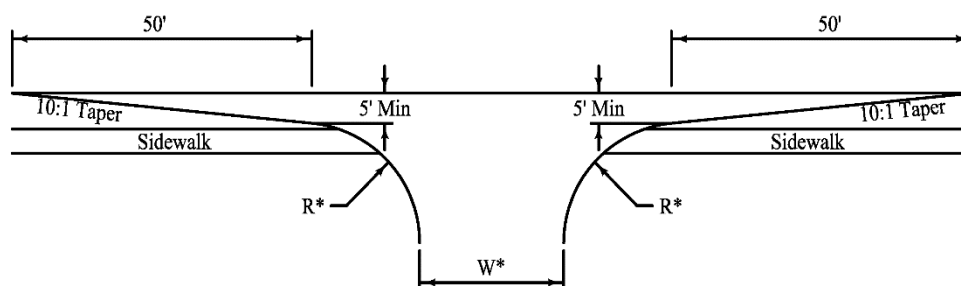
3. Non-curb and Gutter Roadways:

- 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.

Complete Streets

A. Background

Design professionals face an increasingly complex set of competing demands in development and delivery of street projects involving public rights-of-way. Designing a safe facility, completing construction, and installing various traffic control measures are only a part of a much larger picture. Street projects today also need to meet the objectives of regulatory, policy, and community requirements aimed at integrating the roadway into the existing natural and built environments. Among the many factors influencing the planning, design, and operation of today's streets are concerns about minimizing transportation costs; improving public health, creating and maintaining vibrant neighborhoods; accommodating the needs of the young, the physically challenged, as well as an aging population; and adopting greener and more sustainable lifestyles.

In the past, street design was focused on the need to move motor vehicles. The number and width of lanes was determined based on future projected traffic volumes or a set of standards based on the functional classification of the street. The functional classification and the adjacent land use also determined the general operating speed that was to be used for the design. Integration of facilities for pedestrians and bicyclists was not always a high priority. Some observers claim if you do not design for all modes of travel, then you preclude them.

Citizens within some cities are asking agencies to change the way they look at streets and the street function within each community. These agencies are looking to make their streets more "complete." Complete streets are designed and operated to enable safe access to all motorists, pedestrians, bicyclists, and transit users, regardless of age and ability. According to the National Complete Streets Coalition, there are in excess of 600 agencies that have adopted some form of a complete streets policy. Nineteen Iowa agencies, both small communities and larger cities, have adopted complete streets policies. Many other Iowa communities are looking into the concepts of complete streets. Complete streets also complement the principles of context sensitive design by ensuring that streets are sensitive to the needs of all users for the land use within the area. Proponents of complete streets note that by rethinking the design to include all users, the "balance of power" is altered by indicating that streets have many purposes and are not exclusively for motor vehicle traffic. The objectives of the complete streets philosophy are met by slowing vehicles down and providing better facilities for transit, pedestrians, and bicyclists. It is important to understand that safe and convenient walking and bicycling facilities may look different depending on the context. Appropriate facilities in a rural area will be different from facilities in a dense urban area.

There is no one size fits all design for complete streets. While the ultimate design goal for a complete street is a street that is safe and convenient for all users, every design should take into account a number of factors, some of which may be in conflict with each other. The factors include such elements as:

- Number and types of users - vehicles, trucks, transit buses, pedestrians, bicyclists
- Available right-of-way
- Existing improvements
- Land use
- Available budget
- Parking needs
- Community desires

In larger communities where the traffic volumes are heavy and land use density is greater, all of the above elements may be factors to consider. However, in smaller communities with lower traffic volumes and less dense developments, only a few may be important. The application of complete streets principles is most effective when neighborhoods are compact, complete, and connected to encourage walking and biking comfortable distances to everyday destinations such as work, schools, and retail shops. Past land use practices of large tracts for single use development are less effective in encouraging short walking or biking trips.

Complete streets are designed to respect the context of their location. For example, downtown locations may involve greater emphasis on pedestrians, bicyclists, and transit users than single family neighborhoods. Additionally context includes social and demographic factors that influences who is likely to use the street. For example, low income families and those without their own vehicle have the need for an interconnected pedestrian, bicycle, and transit network serving important destinations in the community.

The U.S. DOT adopted a policy statement regarding bicycle and pedestrian accommodations in March of 2010. It states:

"The U.S. DOT policy is to incorporate safe and convenient walking and bicycling facilities into transportation projects. Every transportation agency has the responsibility to improve conditions and opportunities for walking and bicycling and to integrate walking and biking into their transportation systems. Because of the numerous individual and community benefits that walking and bicycling provide – including health, safety, environmental, transportation, and quality of life – transportation agencies are encouraged to go beyond minimum standards to provide safe and convenient facilities for these modes."

In addition to the U.S. DOT policy, members from the U.S. House of Representatives and the U.S. Senate have introduced a bill entitled "Safe Streets Act of 2014" that calls for all state DOTs and TMA/MPOs to adopt a complete streets policy for all federally funded projects.

B. Design Guidance

There are a myriad of ways to address the development of complete streets in terms of a planning function, but there are not specific complete streets design elements identified for engineers to use to develop construction or reconstruction projects. The concept of complete streets goes beyond safety, tying in issues of health, livability, economic development, sustainability, and aesthetics.

Applying flexibility in street design to address the complete streets philosophy requires an understanding of each street's functional basis. It also requires understanding how adding, altering, or eliminating any design element will impact different users. For instance, large radii may make it easier for trucks to navigate the street, but they create wider streets for pedestrians to cross. Designers of complete streets should understand the relationship between each criterion and its impact on the safety and mobility of all users.

Various manuals are available to provide design guidance including:

- AASHTO's A Policy on Geometric Design of Highways and Streets (the Green Book)
- The Manual on Uniform Traffic Control Devices (MUTCD)
- The Highway Capacity Manual (HCM)
- AASHTO Guide for the Development of Bicycle Facilities
- ITE Traffic Engineering Manual
- NFPA Fire Code
- Local design ordinances
- The Access Board's PROWAG

Some elements within these manuals are specific standards and some are guidelines with ranges of acceptable values. The MUTCD has been adopted as law; therefore the standards within it need to be met. In addition, there may be different standards for facilities that are under the Iowa DOT's jurisdiction than those for local control. If federal or state funding is being used to assist in a project's financing, the standards may be different yet. Local jurisdictions utilize the above manuals for design as a means of protection from lawsuits. Thus from a liability standpoint, it is very important that the design guidance meet the standards or fall within the range of acceptable guidelines provided by the above manuals.

As always, functional classification, traffic volumes, and level of service are factors to consider in any street design, and may be the highest priority for certain facilities. Through stakeholder input, it is important to identify the core issues, develop a spectrum of alternatives, and reach a design decision considering the needs of all of the users. The project development process may determine vehicular level of service is not the critical element and improved service for the other travel modes for pedestrians, bicyclists, and transit users is equal or more important.

C. Design Elements

If a complete streets design is contemplated, many elements must be determined during the design process. Traditionally designers have focused on those related to motor vehicles. With a complete streets design, other elements are also addressed. Each of those elements will be discussed and design guidance presented.

1. **Land Use:** The type of adjacent land use provides insight into several factors. For instance, in industrial areas, the expectation is that truck volumes will be higher. Also in commercial/retail areas, there is an expectation that pedestrians, transit, and bicyclists will have a greater impact. In residential land use areas, the street and right-of-way should accommodate pedestrians of all ages and abilities, and shared use of the street by motorists and bicyclists should be expected.

Land use will influence speed, curb radii, lane width, on-street parking, transit stops, sidewalks, and bicycle facilities.

2. **Functional Classification:** Most jurisdictions classify their streets as a means of identifying how they serve traffic. Streets are generally classified as arterial, collector, or local facilities. Complete streets projects must take into consideration each street classification because it helps determine how the street and network needs to be treated to handle traffic volumes and other conflicts that may arise if design changes are made.

Street classifications and the functions of each type are explained in detail in [Section 5B-1](#). It is important to note that all jurisdictions, regardless of size have at least one street in each category. That means that in a larger community an arterial street may carry 20,000 vehicles per day, but in a smaller city the volume on their arterial street might be 2,000 vehicles per day. Similar differences exist in the collector classifications. Generally arterial streets are designated because their primary purpose is to move traffic. Collectors serve the traffic mobility function, but also provide access to adjacent property. Local streets are primarily there to serve adjacent property and should not have through traffic. Designs appropriate for low density residential areas are not likely to fit in the downtown commercial areas due to the likelihood of more pedestrians, bicyclists, trucks, and buses.

3. **Speed:** Because of the differences from community to community in functional classifications, a better criteria to use for design is speed. There are two types of speed to consider in design. The first is operating speed and the other is design speed. Operating speed is typically the posted speed limit and the design speed is often set at 5 miles per hour greater as a factor of safety. It is

also permissible to set the design speed and the posted speed the same. The design speed determines various geometric requirements for safe operations at that speed. These include stopping sight distance, passing sight distance, intersection sight distance, and horizontal and vertical curve elements. These standards are from the AASHTO Green Book and are outlined in [Tables 5C-1.01](#) and [5C-1.02](#) and for liability reasons should be met at all times, especially for new streets. If it is not possible for any design element to meet the geometric standards on existing streets, warning signs and other safety treatments must be used.

It has been past practice to set the design speed at the highest level that will meet the safety and mobility needs of motor vehicles using the street. One of the principles of complete streets provides for slowing vehicles down to improve safety for all users, especially pedestrians and bicyclists. In general, the maximum speed chosen for design should reflect the network needs and the adjacent land use. The speed limit should not be artificially set low to accomplish complete streets objectives if the roadway environment does not create the driver expectation that they should slow down.

The maximum speed for arterial streets should be 45 miles per hour (mph), but only in rural sections or situations where access control is established and free flowing traffic is the normal situation. A maximum of 35 mph is more typical for most arterial streets in urban developed areas.

Collector streets serve both a mobility and property access function and thus the maximum speed is generally 30 mph. In some cases, 35 mph could be used but only when property access is very limited.

Local streets should be designed at 25 mph since their primary function is for property access.

4. **Design Vehicle:** The selection of the design vehicle is an important element in complete streets design. Lane width and curb radii are directly influenced by the design vehicle. It is not always practical to select the largest vehicle that may occasionally use a street as the design vehicle. In contrast, selection of a smaller vehicle if a street is regularly used by larger vehicles can invite serious operational and safety problems for all types of users.

When selecting a design vehicle, the designer should consider the largest vehicle that will frequently use the street and must be accommodated without encroaching into opposing traffic lanes during turns. It is generally acceptable to have encroachment during turns into multiple same-direction lanes on the receiving street but not opposing lanes. The choice of a design vehicle is particularly important in intersection design where pedestrians, bicyclists, and vehicles routinely share the same space.

All street designs must meet the minimum standards for fire departments and other emergency vehicle access and must consider the needs of garbage trucks and street cleaning equipment.

5. **Lane Width:** The AASHTO Green Book provides for lane widths from 9 to 12 feet wide. Narrower lanes force drivers to operate their vehicles closer to each other than they would normally desire. The drivers then slow down and potentially stagger themselves so they are not as close. The actual lane widths for any given street are subject to professional engineering judgment as well as applicable design standards and design criteria. The width of traffic lanes sends a specific message about the type of vehicles expected on the street, as well as indicating how fast drivers should travel. With painted lane lines being 4 to 6 inches wide, the actual “feel” to the driver will be about 1 foot narrower than the design lane width. Wider lanes are generally expected on arterial and collector streets due to truck traffic and higher operating speeds. Snow plowing and removal practices must also be considered as lane width decisions are being made,

especially for the curb lane. Narrower curb lane widths may necessitate different handling of snow because no space is available to plow the snow and it may require loading and removing on a more frequent basis.

It is preferred that arterial streets with 3 to 5% trucks or buses or operating speeds of 35 mph or greater have lanes that are 12 feet wide. That is especially important on the outside lane of multi-lane facilities. It is acceptable to have 11 foot wide lanes on arterial streets when speeds are 30 mph or less, but the entire street context, such as the presence of on-street parking, bicycle lanes, buffer areas, turn lanes, and volume of trucks and buses, needs to be considered before lane widths are chosen.

Collector streets can have 11 foot wide lanes if the number of trucks and buses is low. Collector street speeds should not exceed 35 mph.

Local commercial and industrial streets should be no narrower than 11 feet due to the larger volume of trucks expected with that land use. Local streets can have lane widths down to 10 foot wide in residential areas. For low volume local residential streets, two free flowing lanes are generally not required. This creates a yield situation when two vehicles meet.

The designer should recognize that there is an impact to the capacity of a street as the lanes are narrowed. According to the Highway Capacity Manual, capacity is lowered by 3% if lane widths are narrowed from 12 feet to 11 feet and 7% if lanes are narrowed to 10 feet.

6. **Curb Radii:** The curb radius of intersection corners impacts turning vehicles and pedestrian crossing distances. Larger radii allow larger vehicles, such as trucks and buses, to make turns without encroaching on opposing travel lanes or the sidewalk, but increase the crossing distance for pedestrians and allows smaller vehicles to turn at faster speeds. Shorter curb radii slow turning traffic and create shorter crossing distances, but make it difficult for larger vehicles to safely navigate the intersection. The curb radii that is chosen by the designer should reflect the number of pedestrians, the number of right turns by larger vehicles, length of the pedestrian crossing, and the width of intersecting streets.

The curb radii must meet the AASHTO Green Book turning templates for the design vehicle selected. The curb radii may be modified if parking lanes and or bicycle lanes are present. It is acceptable to have encroachment into same-direction lanes on the receiving street. It is not acceptable to design a curb radius that calls for turning vehicles to encroach upon the opposing traffic lanes. The minimum curb radii in all cases should be 15 feet.

7. **Curb Extensions or Bump-outs:** Curb extensions or bump-outs are expansion of the curb line into the adjacent street. They are traditionally found at intersections where on-street parking exists, but may be located mid-block. Bump-outs narrow the street both physically and visually, slow turning vehicles, shorten pedestrian crossing distances, make pedestrians more visible to drivers, and provide space for street furniture. Use of curb extensions does not preclude the necessity to meet the turning radii needs of the selected design vehicle.
8. **Bicycle Facilities:** Bicycle facilities provide opportunities for a range of users and are a fundamental element of complete streets design. In Iowa, bicycles are legally considered a vehicle and thus have legal rights to use any street facility unless specifically prohibited. They also have legal responsibilities to obey all traffic regulations as a vehicle. Bicycle facilities generally are one of the following three types:
 - a. **Shared Use Paths:** Separate travel ways for non-motorized uses. Bicycles, pedestrians, skaters, and others use these paths for commuting and recreation. Generally used by less experienced bicyclists.

- b. Shared Lanes:** These are lanes shared by vehicles and bicycles without sufficient width or demand for separate bicycle lanes. They may be marked or unmarked. Low speed, low volume residential streets generally will not have pavement markings. For higher speed or higher volume facilities, sharrow pavement markings and signage are used to remind drivers of the presence of bicyclists in the travel lane. Placing the sharrow markings between vehicle wheel tracks increases the life of the marking. These types of shared lanes are used more for commuting than recreation.
- c. Bicycle Lanes:** Dedicated bicycle lanes are used to separate higher speed vehicles from bicyclists to improve safety. Conflicts in shared lanes generally become problematic when vehicular volumes exceed 3,000 vehicles per day and operating speeds are 30 mph or greater. Use of bicycle lanes will influence the capacity of the roadway unless widening is possible. The mobility and potential safety benefits of the bicycle lanes need to be evaluated against the capacity impacts. There are generally three types of bicycle lanes:
 - 1) Conventional:** Located between the travel lanes and the curb, road edge, or parking lane and generally flow in the same direction as motor vehicles. They are the most common bicycle facility in the United States.
 - 2) Buffered:** Conventional bicycle lanes coupled with a designated buffer space separating the bicycle lane from adjacent motor vehicle lanes and/or a parking lane.
 - 3) Separated:** An exclusive facility for bicyclists that is physically separated from motor vehicle or parking lanes by a vertical element. Separated bicycle lanes are also called cycle tracks or protected bicycle lanes.

Design information for each bicycle facility type is detailed in [Sections 12B-1 through 12B-3](#). Bicycle parking facilities at destination points will assist in encouraging bicycle usage.

Snow and ice control activities impact vehicular lanes and bicycle lanes differently. Generally, plows will leave some snow on the pavement. Vehicles are able to travel through this material but bicyclists may have more difficulty. In addition, the material may refreeze and make bicycle use more treacherous.

- 9. On-Street Parking:** On-street parking can be an important element for complete street design by calming traffic, providing a buffer for pedestrians if the sidewalk is at the back of curb, in addition to benefiting adjacent retail or residential properties. The width of parallel parking stalls can vary from 7 to 10 feet. Streets with higher traffic volumes and higher speeds should have wider parking spaces or a combination of parking space and buffer zone. Narrower parking spaces can be used if a 3 foot buffer zone is painted between the parking stall and a bicycle or traffic lane. The buffer zone will minimize exposure of doors opening into bicyclists, as well as facilitate faster access into and out of the parking space. Placement of parking stalls near intersections or mid-block crossings is critical so as to not impede sight lines of pedestrians entering crosswalks. Snow plowing could impact the availability of on-street parking intermittently. Requirements for ADA accessible on-street parking numbers and stall design must be adhered to. Information on those requirements can be found in [Section 12A-2](#).
- 10. Sidewalks:** Sidewalks are the one element of a complete street that is likely to provide a facility for all ages and abilities. Often sidewalks are the only way for young and older people alike to move throughout the community. Sidewalk connectivity is critical to encourage users. Sidewalks should be provided on both sides of all streets unless specific alternatives exist or safety is of concern. All sidewalks are required to meet ADA guidelines or be a part of a transition plan to be upgraded. [Sections 12A-1](#) and [12A-2](#) identify the specific ADA requirements for sidewalks.

Sidewalks that are set back from the curb are safer than if the sidewalk is located at the back of curb. Street furniture and landscaping can add character and improve safety for sidewalks that are located at the back of curb. Providing seating areas within the sidewalk area can further enhance the urban environment and encourage pedestrian activity.

- 11. Turn Lanes:** Turn lanes located at intersections provide opportunities for vehicles to exit the through lanes and improve capacity of the street. Two Way Left Turn Lanes (TWLTL) provide the opportunity to access midblock driveways without causing backups in the through lanes. Turn lanes also allow faster speeds in the through lanes so a trade-off with safety exists especially at intersections.

Width of turn lanes should reflect the character of the traffic. Dedicated left and right turn lane widths should match the width of the lanes on the street. Local streets should not provide separate turn lanes. TWLTL should be a minimum of 12 feet wide because of the presence of through traffic on each side.

- 12. Medians:** Medians provide for access management, pedestrian refuge, and additional space for landscaping, lighting, and utilities. Use of medians and the functions provided are dependent upon the width of available right-of-way and the other types of facilities that are included. The minimum width for pedestrian refuge is 6 feet. The minimum width of a median for access control and adjacent to left turn lanes is 4 feet. The minimum width for landscaped medians is 10 feet. Greater widths provide more opportunities for more extensive landscaping.

- 13. Transit:** Bus service within the state is limited to the larger metropolitan areas. Currently there are a number of fixed route systems in the state. Smaller communities do not have fixed route service due to lack of demand. Children, elderly, and low-income people are the primary users of a fixed route transit system. In addition to system reliability, use of transit systems as a viable commuting option is directly dependent on the frequency of service and the destinations within the fixed route. To have a successful transit system, stops must be within walking or biking distance of residential areas to attract riders and it must have major retail, employment, and civic centers along its route system.

Transit stops should be located on the far side of intersections to help reduce delays, minimize conflicts between buses and right turning vehicles, and encourage pedestrians to cross behind the bus where they are more visible to traffic. Far side stops also allow buses to take advantage of gaps in vehicular traffic.

Bus turn out lanes are also best located on the far side of intersections. These turn outs free up the through lanes adjacent to the bus stop. Transit bulb outs are more pedestrian friendly than turnouts because they provide better visibility of the transit riders, as well as potentially providing space for bus shelters without creating congestion along the sidewalk. With buses stopping in the through lane, bulb-outs also provide traffic calming for the curb lane.

- 14. Traffic Signals:** Traffic signals are not usually considered an element of complete streets, but they have many components with direct implications for complete streets. The timing, phasing, and coordination of traffic signals impacts all modes. Well-planned signal cycles reduce delay and unnecessary stops at intersections, thus improving traffic flow without street widening. Traffic signal timing can be designed to control vehicle operating speed along the street and to provide differing levels of protection for crossing pedestrians.

The flashing don't walk pedestrian phase should be set using a 3.5 feet per second walking speed and the full pedestrian crossing time (walk/flashing don't walk) set using 3.0 feet per second. Some agencies representing the elderly are indicating that the overall walking speed should be 2.7

feet per second to cover a larger portion of the elderly population. ADA accessible pedestrian signal elements, such as audible signal indications, should be included in all new pedestrian signal installations and any installations being upgraded. See [Section 13D-1, F](#) for more information on accessible pedestrian signals.

15. Summary: The table below summarizes some of the critical design elements that should be examined if a complete streets project is implemented. Other geometric elements can be found in [Table 5C-1.02](#). Some of the lane width values shown in the table below differ from the acceptable values from [Section 5C-1](#) because the expectation is that the complete street environment includes the potential for on-street parking and/or bicycle lanes. Adjustments in the values may be necessary to accommodate large volumes of trucks or buses. Contact the Jurisdictional Engineer if design exceptions are being considered.

Table 5M-1.01: Preferred Design Elements for Complete Streets

Classification	Local				Collector						Arterial					
	25		30		25		30		35 and Up		25		30		35 and Up	
Posted Speed (mph)	Res.	C/I	Res.	C/I	Res.	C/I	Res.	C/I	Res.	C/I	Res.	C/I	Res.	C/I	Res.	C/I
<i>Land use</i> ¹																
Travel lane width (ft) ²	10 ³	11	10	11	11	11	11	11	11	12	11	11	11	12	12	12
Turn lane width (ft)	--	--	--	--	11	11	11	11	11	12	11	11	11	12	12	12
Two-way left-turn lanes width (ft)	--	--	--	--	12	12	12	12	12	12	12	12	12	12	12	12
Curb Offset (ft) ⁴	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2	2	2	2	2	2
Parallel parking width (no buffer) (ft) ⁵	8	8	8	8	8	9	8	9	9	9	10	10	10	10	10	10
Curb radii (ft) ⁶	15	15	15	15	15	25	15	25	25	30	15	25	15	25	25	30
Bicycle lane width (ft) ⁷	--	--	--	--	5	5	5	5	5	5	5	5	5	5	5	5

¹ Res. = Residential, C/I = Commercial/Industrial

² Minimum sharrow lane width is 13 feet.

³ For low volume residential streets, two free flowing lanes are not required. They can operate as yield streets if parking is allowed on both sides and vehicles are parked across from each other.

⁴ Curb offset, less the width of the curb, may be used in the parallel parking lane width.

⁵ For arterial or high speed collectors, the parallel parking stall width may be reduced if a minimum 3 feet wide buffer strip is included.

⁶ Curb radii may be adjusted based on design vehicle, presence of bicycle lanes or parking lanes, and the number of receiving lanes. Encroachment of turning vehicles into opposing lanes is not allowed.

⁷ If paving is integral without a longitudinal gutter joint, the curb offset, less the width of the curb, may be used as part of a bicycle lane.

D. Traffic Calming

Traffic calming is different from but related to complete streets philosophies. Through design measures, traffic calming aims to slow traffic down to a desired speed. By slowing vehicular traffic, biking and pedestrian activities are made safer.

It is absolutely critical that traffic calming measures recognize the need to maintain access for emergency vehicles. Unless the situation is unusual, realizing slower speeds involves a series of traffic calming measures. However, too many measures along a street is likely to divert vehicles to adjacent streets and just move the problem or frustrate drivers to the point of complaining to the level necessary for removal of the traffic calming measures. Because of the anticipation that traffic will be just displaced to adjacent streets, it is very important to study a larger area than a single street when evaluating traffic calming measures.

Many design elements will accomplish traffic calming. These include the following.

- Reduction in lane widths:
 - Short medians
 - Bulb outs
 - Lane striping
- Lateral shifts
 - Chicanes
- Raised/abled intersections
- Raised/abled cross walks
- Speed humps or speed cushions
- Traffic circles
- Radar speed signs

Choosing the design elements to use for a particular area will depend on the neighborhood context and the specific concern to be addressed. Prior to evaluating alternative measures, stakeholders must be educated so they can have meaningful involvement. The evaluation needs to involve all stakeholders in the definition of the problem. If possible, all stakeholders, including drivers, pedestrians, bicyclists, and area property owners, would achieve some level of agreement on the traffic calming plan prior to implementation.

E. References

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United States Department of Transportation. Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations. 2010. Available at: http://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/policy_accom.cfm. Accessed: April 2015.

Traffic Impact Studies

A. General

A traffic impact study may be required for commercial, industrial, or residential developments in obtaining site plan, rezoning, or access permit approval. The Jurisdictional Engineer must be contacted to determine if a traffic impact study is required. If a study is required, the study scope (study limits, analysis years, scenarios, etc.) should be determined through discussion with the Jurisdictional Engineer.

B. Study Process

Traffic impact studies typically include the following elements. Specific tasks, level of analysis, and documentation requirements will depend on the specific needs of the study and Jurisdictional requirements.

1. **Data Collection:** Gather and review needed information regarding existing and proposed conditions, possibly including:
 - Current and historic daily and hourly traffic volume counts.
 - Recent intersection turning movement counts.
 - Projected volumes from previous studies, travel demand models, or area transportation plans.
 - Current land uses, densities, and occupancy near the site.
 - Preliminary site plan for proposed development with land uses, building areas, phasing and completion dates, and proposed access locations identified.
 - Other approved projects and anticipated development near the site.
 - Land use and zoning plans near the site.
 - Current street system information (functional classifications, lane configurations, speed limits, access locations, traffic control, parking)
 - Traffic signal locations, phasing, timing, and coordination.
 - Planned or proposed transportation improvement projects in the area.
 - Crash history (3 to 5 years), if safety concerns have been identified.
2. **Background Traffic:** Determine estimated background traffic for analysis years and scenarios. For simple studies with a short-term analysis year, this may simply be current traffic count data. For more complex studies or longer-range analysis years, background traffic may also include trip generation from proposed area development or land uses, annual traffic growth rates, and/or area travel demand model traffic forecasts.
3. **Site Traffic:** If available, local data should be used in determining estimated daily and peak hour trip generation for the site. If local data is not available, the latest edition of *ITE Trip Generation* or other national data should be used as a basis for estimating trip generation for the site. Sound judgment must be used in reviewing, adjusting, and applying published trip generation data. Depending on specific site characteristics, generated trips may need to be adjusted for mixed-use developments (internal or multi-purpose trips) or unique pedestrian, bicycle, or transit usage. After site-generated trips are prepared, they are distributed and assigned to the study area roadway system, considering the following:

- Type of proposed development and area from which trips will be attracted
- Size of proposed development
- Surrounding land uses and population density
- Proposed site access locations and configurations
- Proposed or anticipated traffic control at access points
- Conditions of surrounding street system
- Competing developments, where applicable

Site traffic is normally distributed in terms of a percentage of inbound or outbound traffic at each study access point, intersection, or ramp junction for each analysis period. These distributions are then used to calculate assigned peak hour traffic turning movement volumes. Assigned traffic is combined with background traffic to determine total traffic for each analysis scenario to be analyzed. Depending on the type of development, the total traffic is often adjusted for pass-by trips. Pass-by trips (or diverted trips) are those trips already on the adjacent street network (background traffic) that will enter and exit the site.

- 4. Analysis:** Total peak hour traffic for each study access point, intersection, and ramp junction is analyzed for each analysis scenario according to current *Highway Capacity Manual* (HCM) procedures. Analyses will determine projected vehicle delays, volume/capacity ratios, levels of service, and vehicle queuing. Analysis software such as Highway Capacity Software (HCS) or *Synchro* is typically used. For complicated roadway systems or conditions, additional simulation analysis may also be necessary. In addition to capacity analysis results, several other factors should be considered in evaluating traffic operations for the study, including the following:
 - Crash history, crash rates, predominate crash types, and safety concerns
 - Traffic control needs, including MUTCD traffic signal warrant analysis
 - Anticipated impacts and vehicle queuing and access point/intersection spacing
 - On-site parking, circulation, and potential impacts on adjacent street system
 - Pedestrian, bicycle, and transit needs
 - Service and delivery vehicle access
- 5. Improvement Needs:** Based on analysis results, identify access and/or street network improvement needs necessary to provide acceptable operations. Perform capacity analyses with proposed improvements to evaluate expected operations. Typical improvement needs may include:
 - Adding or lengthening intersection turn lanes
 - Widening, reconstructing, or reconfiguring streets to provide needed lanes and geometry
 - Constructing new street connections for access or through traffic
 - Interchange modifications
 - Changes to traffic control or intersection type (such as all-way STOP, signalization, right-in/right-out only access, or roundabout)
 - Changes to traffic signal phasing, timing, and coordination
 - Access management (combining, eliminating, adding, or improving spacing of access points)
 - Revising site circulation or on-site queue storage
 - Signing or pavement marking modifications
- 6. Report:** Prepare and submit to Jurisdictional Engineer a draft traffic impact study report summarizing data collected, analyses performed, and recommendations. Include appropriate tables and graphics. Finalize the report based on comments or concurrence received from the Jurisdictional Engineer.

C. Iowa DOT Access Permits

If a new or modified access is proposed from a highway under the jurisdiction of the Iowa DOT, the applicable District office should be contacted early in the project development to determine access requirements, limitations, and documentation needed. Guidance is provided in the Iowa DOT *Iowa Primary Road Access Management Policy*. Analyses and documentation required will depend on the proposed type and size of development, current access provided, and priority type of the highway. For proposed Type “A” entrances, detailed geometric plans, opening year and full-build year traffic data, and proposed site data are required. Capacity analysis and MUTCD traffic signal warrant analysis may also be required.

D. References

Institute of Transportation Engineers. *Manual of Transportation Engineering Studies*. 2010.

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Institute of Transportation Engineers. *Trip Generation: An ITE Informational Report*. 2008.

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Transportation Research Board. *Highway Capacity Manual 2010*. 2011.

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Railroad Crossings

A. Railroad Crossing Improvements

Improvements to railroad crossings can take several forms. These include closing of an existing crossing, improvements to the existing crossing, and separating the roadway from the railroad tracks. Potential improvements to existing crossings include installation of adequate signage, signals, and signals with gate arms.

The local jurisdiction must use judgment in the selection process for crossing improvements. Several factors weigh into the selection process including the amount and speed of traffic on the roadway and railroad, available sight distance, and safety benefits. Traffic control systems for railroad-highway grade crossings must comply with the Manual on Uniform Traffic Control Devices (MUTCD).

The Jurisdiction should contact the offices of Rail Transportation and Local Systems at the Iowa DOT for any agreements and requirements that must be followed.

B. Railroad Crossing Construction

When railroad crossings are required on streets subject to heavy loads, an approved high quality grade crossing material should be installed. Some railroads may require an asphalt separation between the header and the crossing to allow for easier railroad maintenance of the crossing. Some railroads may require that the crossing material be installed by their own forces, with the costs borne by or shared with the local jurisdiction. Example railroad crossing approaches are included in Figures 1 and 2. In all cases, the railroad should be contacted for their specific crossing requirements.

C. Working with a Railroad

Working with a railroad company requires coordination at numerous steps along the planning, design, and construction process. A list of potential coordination steps follows; however, these requirements differ for each company and should be verified early in the planning process.

Phase	Possible Coordination Required
Planning	Right of entry permit for survey Coordination regarding potential modifications/improvements
Design	Right of Entry Permit for Survey Utility Accommodation Permit Maintenance Consent Agreement Coordination regarding crossing material and safety elements
Construction	Railroad Protective Liability Insurance Right of Entry for Construction Railroad Flaggers

D. Railroad Related Agencies in Iowa

Two governmental agencies are involved in regulating railroad activities within the State of Iowa. Additional information about these organizations is available at their respective websites:

Iowa DOT, Rail Transportation

<http://www.iowadot.gov/iowarail/index.htm>

800 Lincoln Way
Ames, Iowa 50010
515-239-1140

Federal Railroad Administration
Region 6 Office

<http://www.fra.dot.gov/>

901 Locust Street – Suite 464
Kansas City, MO 64106
816-328-3840

E. Railroad Companies in Iowa

Currently there are nineteen railroads operating within the State of Iowa. These include three Class I railroad companies, Amtrak, and several regional and local railroads. The Iowa DOT maintains a website with links to the websites of the freight railroads operating within the State (<https://iowadot.gov/iowarail/highway-railroad-crossings/profiles>).

Figure 5O-1.01: PCC Railroad Crossing Approach
(SUDAS Specifications Figure 7010.903)

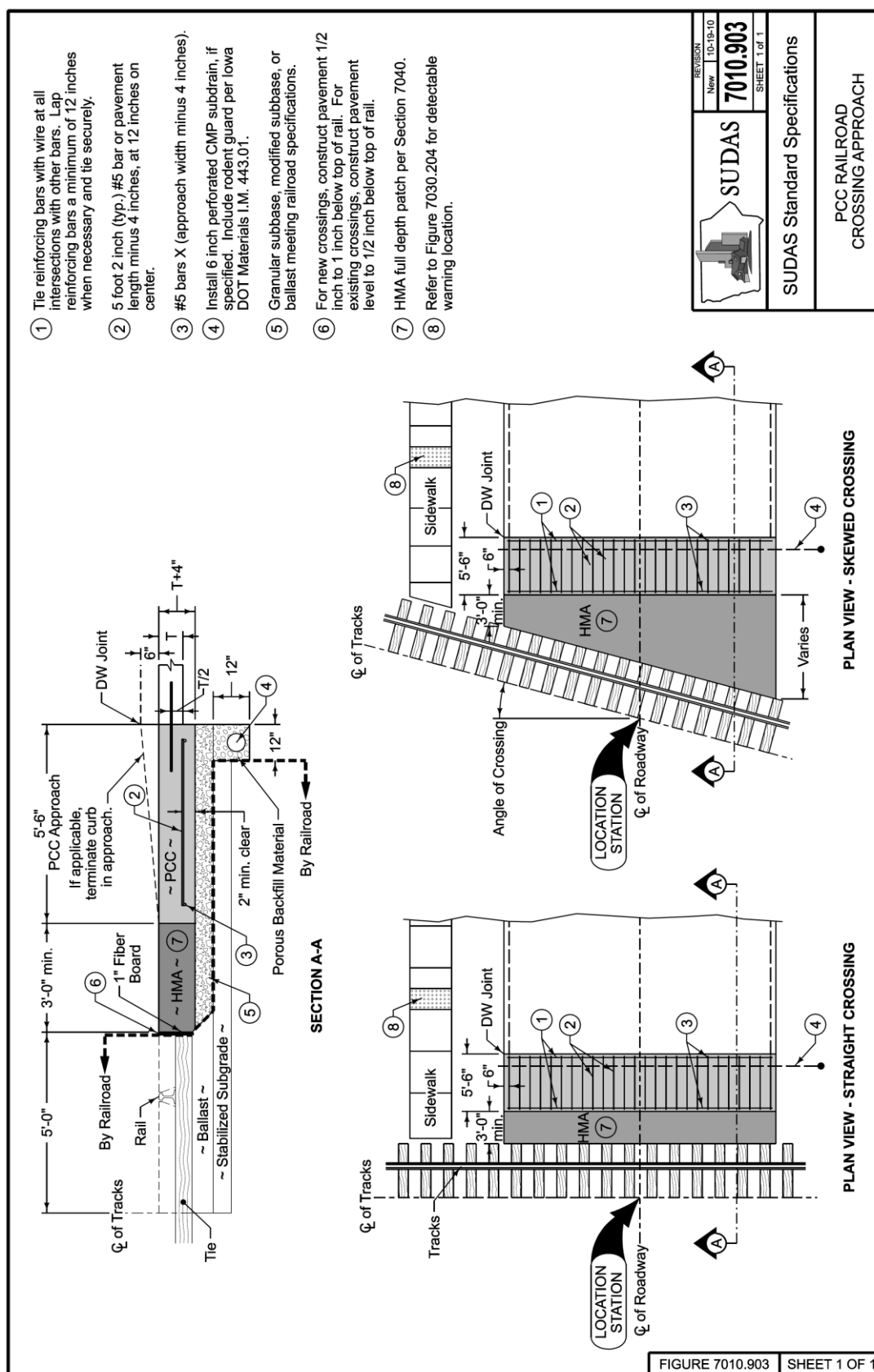
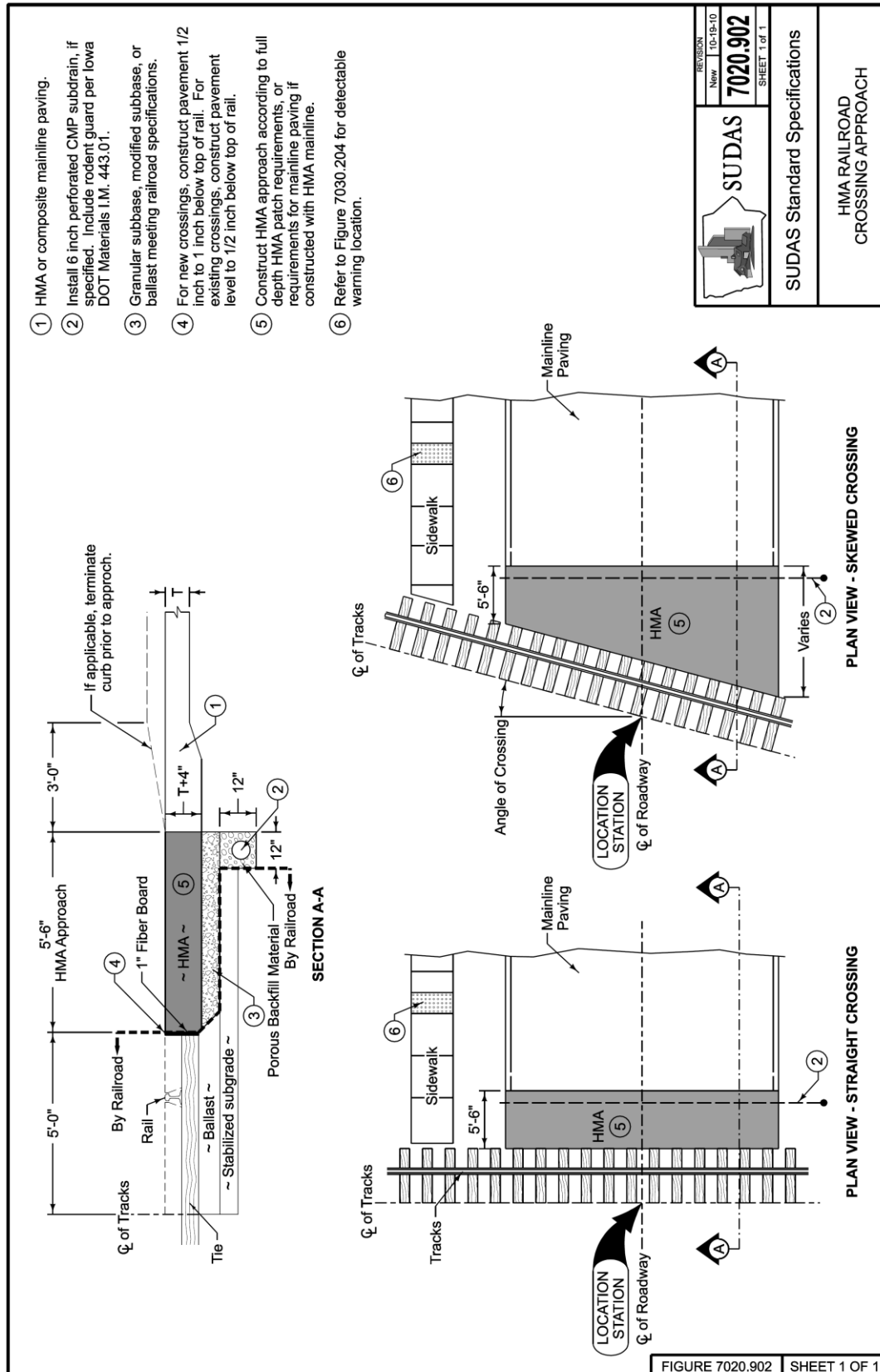


Figure 50-1.02: HMA Railroad Crossing Approach
[\(SUDAS Specifications Figure 7020.902\)](#)



Filter Socks



Source: Soil-Tek

BENEFITS

	L	M	H
Flow Control	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Erosion Control	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sediment Control	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Runoff Reduction	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Flow Diversion	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Description: A filter sock is a tubular mesh sock filled with a specified ‘filter material’ that normally is a blend of composted materials or similar organic products, used to slow flow velocity, capture and degrade chemical pollutants, and trap sediment. They are most effective when designed to provide comprehensive water and sediment control throughout a construction site and if used in conjunction with other erosion control practices.

Typical Uses: Perimeter control, inlet protection, slope length reduction, flow diversion for small drainage areas, environmentally sensitive areas such as wetlands and waterways, at the edge of gravel parking lots, and general areas under construction.

Advantages:

- Less likely to obstruct wildlife movement and migration than other practices.
- Does not always need to be removed, thereby eliminating removal and disposal costs.
- Can be installed year-round in difficult soil conditions such as frozen or wet ground, on hard compacted soils, near pavements, and in wooded areas, as long as stakes can be driven.
- Relatively low cost.

Limitations:

- Not suitable for areas of concentrated water flow, low points of concentrated runoff or below culvert outlet aprons.
- Availability of suitable sock filtering materials and equipment may be limited.
- Equipment operators may drive over socks, damaging the product.
- Often used improperly as the sole method of sediment control.
- Uneven ground may cause leakage under socks.

Longevity: Until sediment accumulates to one-half the height of the sock

SUDAS Specifications: Refer to [Section 9040, 2.04](#) and [3.07](#)

A. Description/Uses

A filter sock typically consists of a three-dimensional matrix of certified, composted organic material and/or other organic matter to create a filter medium. These various sized particles enclosed in a tubular mesh material slows and filters water to capture sediment and degrade pollutants. Its natural permeability allows water to seep through it while capturing sediment in its pore space and behind its mass, slowing water velocity, and absorbing water pollutants, such as hydrocarbons, nutrients, and bacteria.

The filter socks are typically constructed by filling a mesh tube with organic filter material, although other materials, such as crushed rock or gravel may be used. The sock may be filled by blowing the material into the tube with a pneumatic blower or similar device such as an auger system. Hand filling is not an acceptable means to fill the tube as the material is not compacted in the sock.

B. Design Considerations

1. **Materials:** Several types of materials can be utilized for filter material in the sock. The key to achieving the proper balance between sediment removal and flow-through rate is using a material with the proper particle size. Filter material with a high percentage of fine particles will clog and create a barrier to flow. This will cause water to pond and the pressure could cause the installation to fail. Alternatively, filter materials with particles that are too large will allow flows to pass through the barrier with little or no resistance, eliminating the velocity reduction and sediment trapping benefits of the barrier. Refer to [SUDAS Specifications Section 9040](#) for proper filter material size.

Filter material normally consists of wood chips or mulch that is screened to remove some of the fines and produce the desired gradation. Crushed stone or gravel is an ideal material to use when the sock will be used on a paved street for inlet protection, or other areas where the sock cannot be staked to hold it in place. The additional weight of the stone helps prevent the sock from moving. Socks can be filled with a fine compost material for applications where the sock is to be vegetated and remain as a permanent feature. This material should only be used in areas where ponding water is acceptable since it has a low flow-through rate, and will quickly plug with sediment.

The mesh sock used to contain the compost is designed to photo-degrade over time (approximately 18 months).

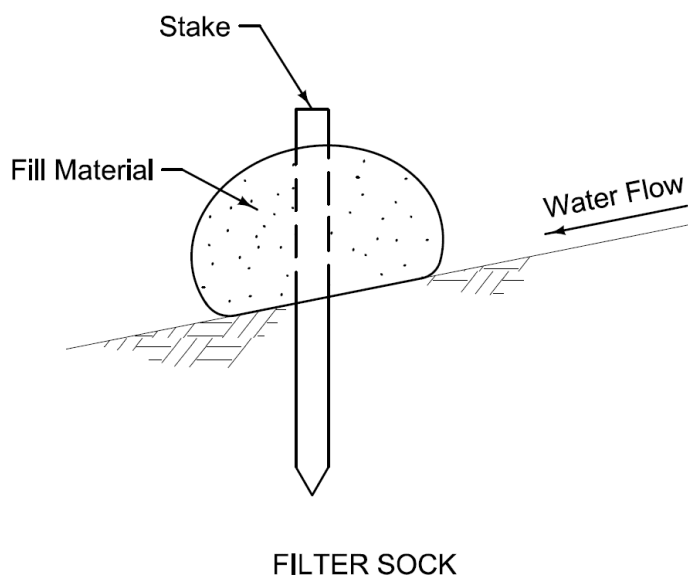
2. **General Guidelines:** When installed on slopes, filter socks should be installed along the contour of the slope, perpendicular to flow, and staked at 10 foot intervals. The beginning and end of the installation should point slightly up the slope, creating a “J” shape at each end to contain runoff and prevent it from flowing around the ends of the sock. Individual section of filter sock should be limited to 200 foot lengths. This limits the impact if a failure occurs, and prevents large volumes of water from accumulating and flowing to one end of the installation, which may cause undermining or damage to the sock.

3. **Slope Control:** Filter socks can be installed at regular intervals on long slopes to reduce the effective slope length, and limit the velocity of runoff flowing down the slope. The design layout of filter socks will help prevent concentrated flows from developing, which can cause rill and gully erosion. As a secondary benefit, filter socks installed on slopes can remove suspended sediment from runoff that results from any erosion that has occurred. Allowable slope length for filter socks is dependent upon the size of the sock and the grade of the slope as shown in Table 7E-4.01. For slopes that receive runoff from above, a sock should be placed at the top of the slope to control the velocity of the flow running onto the slope, and to spread the runoff out into sheet flow. On steep or excessively long slopes a number of socks may be placed at regular intervals down the slope.
4. **Sediment Control:** Filter socks remove sediment both by filtering, and by ponding water behind them. When used for sediment control, filter socks should be located to maximize the storage volume created behind the sock.

A common location to place filter socks for sediment control is at the toe of a slope. When used for this application, the sock should be located as far away from the toe of the slope as practical to ensure that a large storage volume is available for runoff and sediment.

5. **Inlet Protection:** Filter socks may also be used to provide inlet protection. The drainage area to a filter sock around an intake should not exceed 1/4 acre for every 100 feet of sock unless used in conjunction with other erosion and sediment control practices. Filter socks used for inlet protection should be staked at regular intervals, not exceeding 6 to 8 feet, to prevent movement of the sock. For protection of curb inlets in pavement, the length of sock recommended above is not practical. Using short sections of filter socks, such as those for curb intakes in pavement, should be done with caution. Because the length of filter sock is short, it is only able to filter a small volume of runoff. This increases the chances that significant ponding will occur, possibly dislodging the sock, or that the flows will simply bypass or overtop the sock, eliminating any treatment potential. For additional information on inlet protection, refer to [Section 7E-20](#).

Figure 7E-4.01: Typical Filter Sock Installation
(From [SUDAS Specifications Figure 9040.102](#))



C. Application

Filter socks, placed on slopes, should be spaced according to Table 7E-4.01.

Table 7E-4.01: Maximum Filter Sock Spacing

Slope	Sock Diameter			
	8"	12"	18"	24"
2%	85'	100'	100'	100'
5%	50'	75'	100'	100'
10%	40'	50'	85'	100'
5:1	35'	40'	55'	60'
4:1	30'	40'	50'	50'
3:1	30'	35'	40'	40'

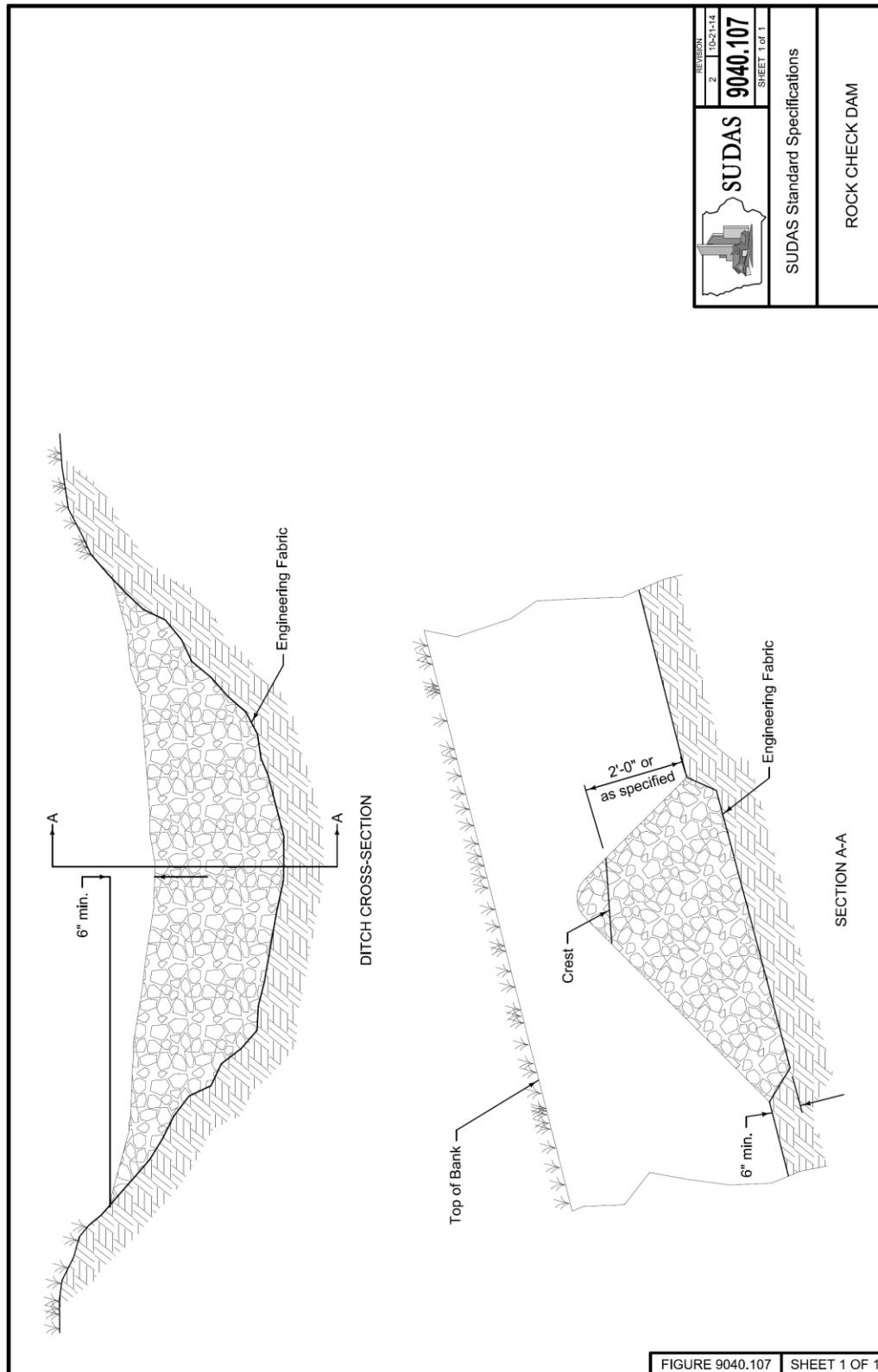
As mentioned previously, the material properties of the filter are a significant factor in the performance of the sock. The wood chip product typically used as a filter material may not be readily available in all areas. This may limit the utilization of filter socks as an economical sediment control option in some areas.

D. Maintenance

Accumulated sediment should be removed, or a new sock installed, when it reaches approximately one-half of the sock diameter. If sheet flows are bypassing or breaching the sock during design storm events, it must be repaired immediately and better secured, expanded, enlarged, or augmented with additional erosion and sediment control practices.

The aggregate used should be large enough to prevent the flows from pushing individual stones downstream. A 6 inch erosion stone is normally sufficient.

Figure 7E-7.01: Typical Rock Check Dam
([SUDAS Specifications Figure 9040.107](#))



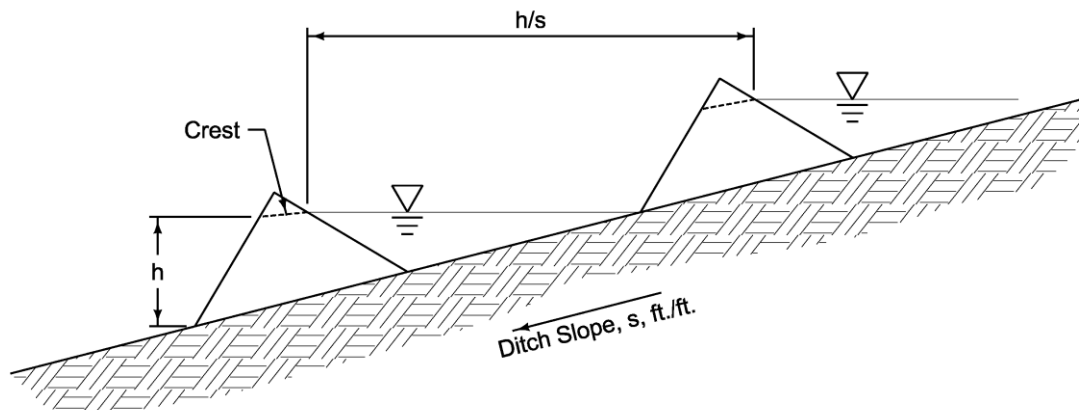
2. **Manufactured Devices:** Triangular-shaped manufactured products should be designed and installed according to their manufacturer's recommendations. These products require anchoring to the ground to keep them in place and may require the installation of a blanket of engineering fabric below them.
3. **Gravel Bag Berms:** Gravel bag berms should be placed and spaced in the same manner as rock check dams. The berms should be placed on a layer of engineering fabric, and be limited to a height of 24 inches. The crest of the check dam should be 6 inches lower than the sides to prevent flows from going around the dam, and eroding the sides of the channel.
4. **Silt Fence:** Silt fence may be used as a ditch check device for very low flow applications. See [Section 7E-14](#) for additional information on this application.

C. Application

Achieving the proper spacing is the most important aspect of check dam design. The spacing between structures is dependent on the height of the check dam, and the grade of the waterway. In order to protect the channel between the check dams, the devices should be spaced such that the elevation of the toe of the upstream check dam is equal to the elevation of the crest of the downstream check dam. This allows the water between the check dams to pond, resulting in a greatly reduced flow velocity.

As a rule, check dams should not be spaced closer than 20 feet in order to allow for proper maintenance. If slopes and check dam height call for a spacing closer than 20 feet, a Rolled Erosion Control Product or Turf Reinforcement Mat should be considered as an alternative.

Figure 7E-7.02: Typical Check Dam Spacing
(From [SUDAS Specifications Figure 9040.106](#))



MANUFACTURED CHECK DAM
(Synthetic Permeable and Triangular Foam Check Dam)

D. Maintenance

Check dams should be inspected for damage every seven days and after any 1/2 inch or greater rainfall until final stabilization is achieved. Sediment should be removed when it reaches one-half of the original dam height. Upon final stabilization of the site, the check dams should be removed, including any stone that has been washed downstream, and any bare spots stabilized.

E. Time of Year

Level spreaders will function on a year-round basis.

F. Regional Location

For soils that are highly sensitive to erosion, even when fully vegetated, the length of the spreader may need to be increased beyond that shown in the table.

Figure 7E-9.01: Typical Level Spreader Configuration
 (SUDAS Specifications Figure 9040.109)

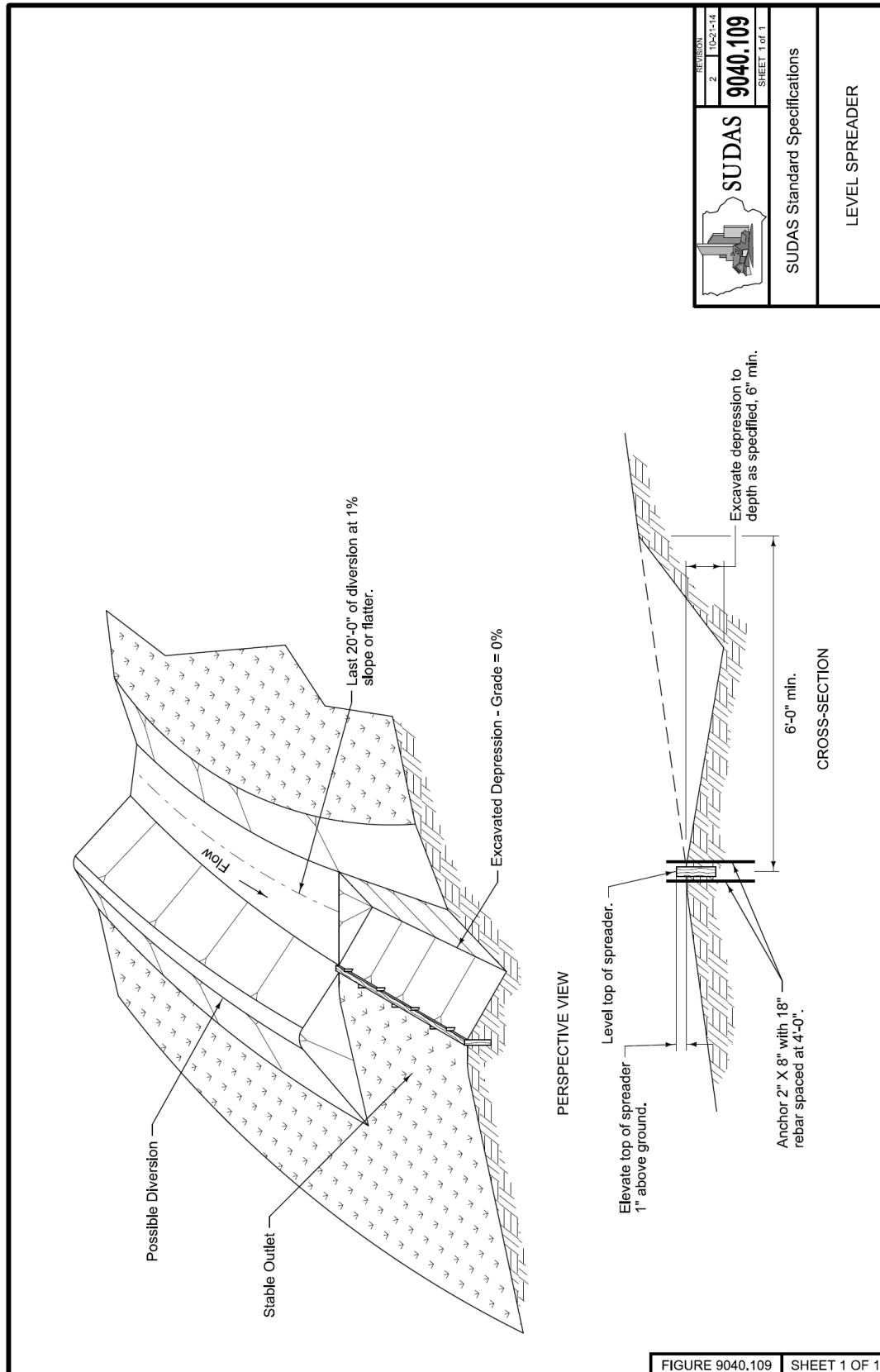


FIGURE 9040.109 SHEET 1 OF 1

Figure 7E-10.01: Rip Rap Apron for Pipe Outlet into Channel
 (SUDAS Specifications Figure 9040.111)

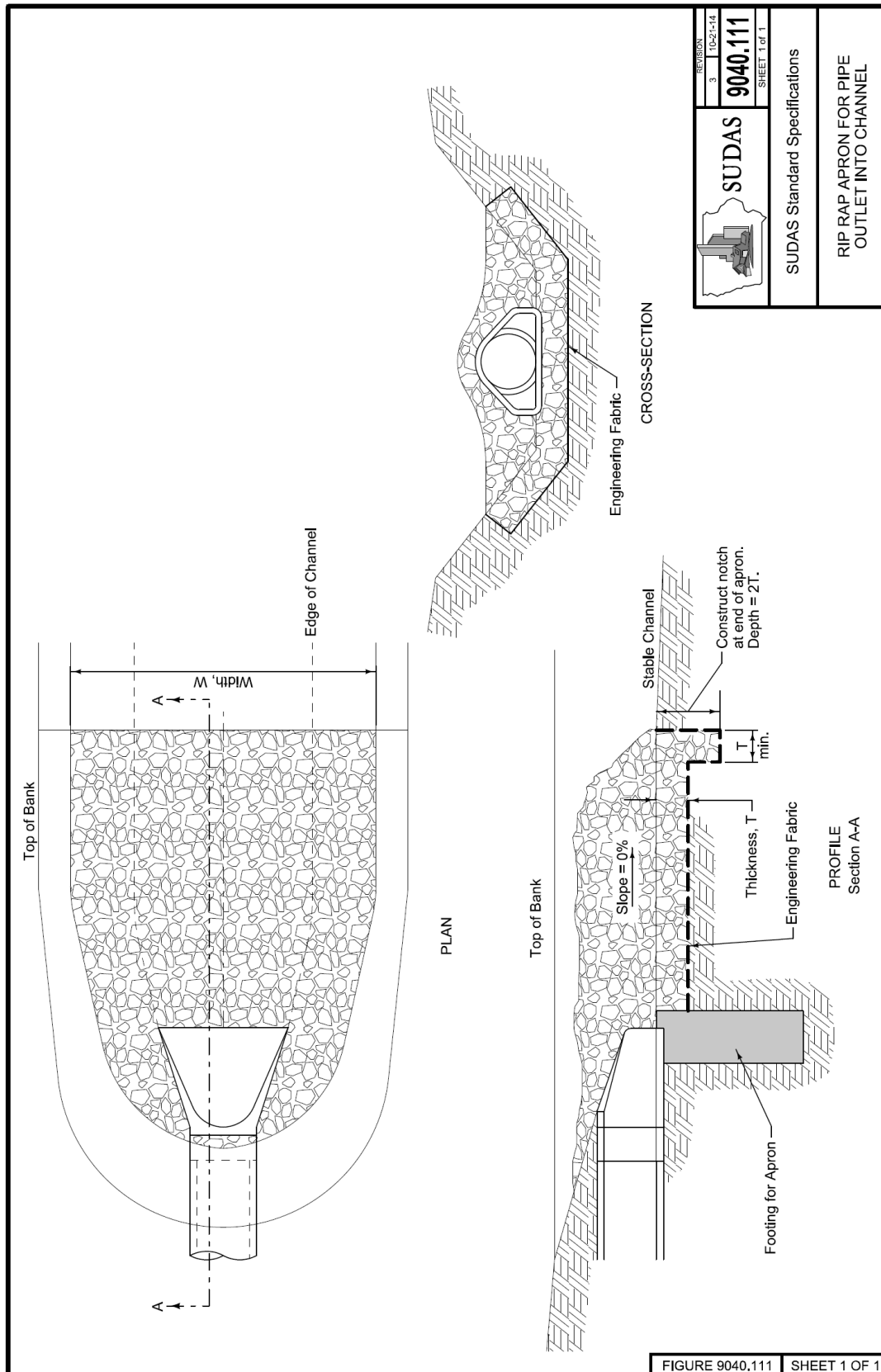


Figure 7E-10.02: Rip Rap Apron for Pipe Outlet onto Flat Ground
([SUDAS Specifications Figure 9040.110](#))

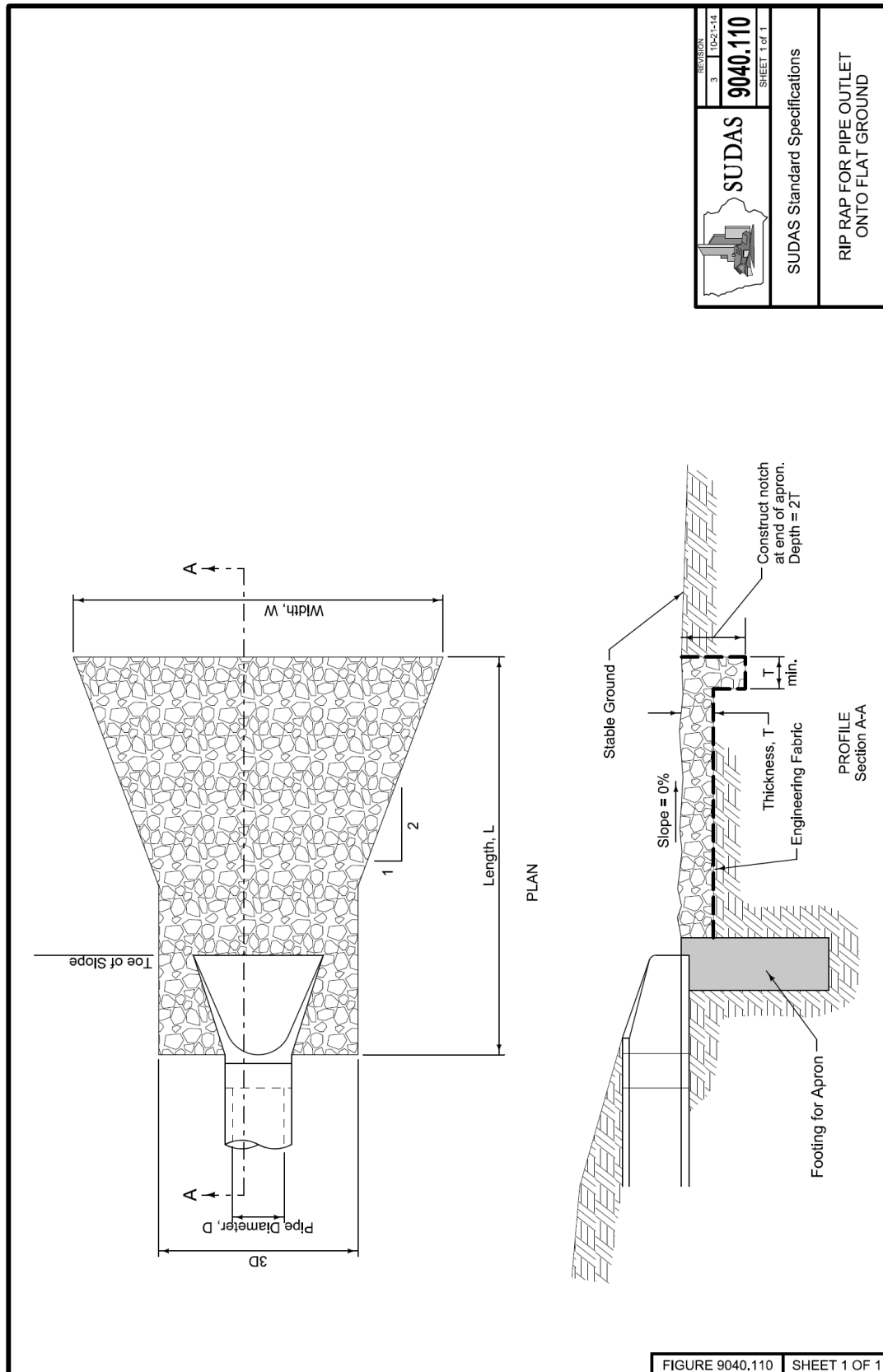
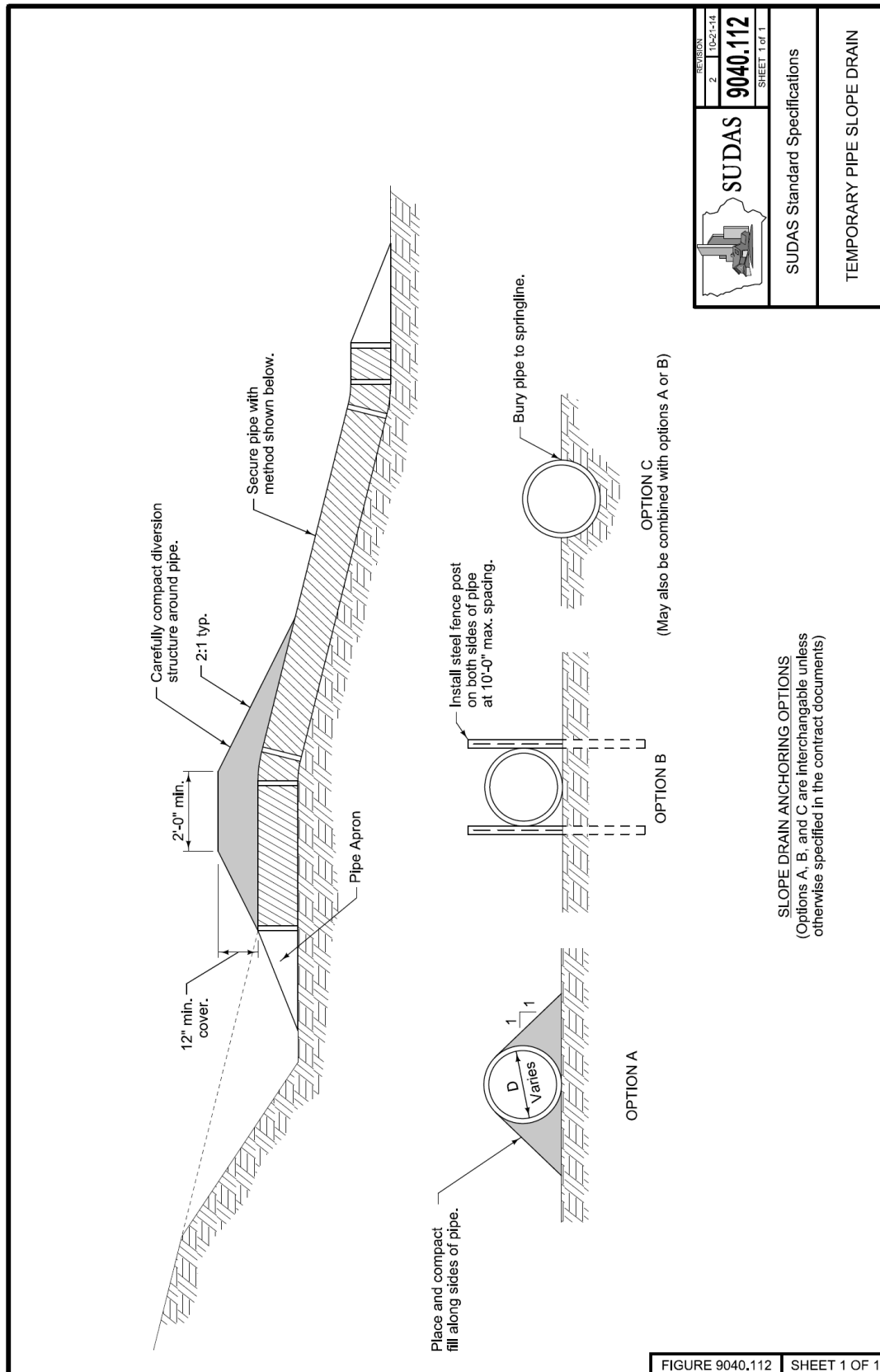


Figure 7E-11.01: Temporary Pipe Slope Drain
 (SUDAS Specifications Figure 9040.112)



C. Application

Slope drains should be considered whenever a diversion structure is constructed on a disturbed slope steeper than 3%. When properly incorporated, diversion structures with slope drains provide a method to separate runoff from disturbed and stabilized areas, reducing the size requirements for sediment basins or traps.

D. Maintenance

The slope drain should be inspected for signs of leaking joints, pipe movement, erosion at the inlet and outlet, and seepage through the berm at the inlet.

E. Design Example

Assume the runoff from 7.5 acres of bare ground is intercepted by a diversion structure and carried to the location of a proposed slope drain. Determine the required diameter of the slope drain.

Using the techniques described in Chapter 2 - Stormwater, the following information is determined:

Time of Concentration, $T_c = 15$ minutes

Rainfall Intensity, $I = 3.48$ (Region 7)

Runoff Coefficient for bare ground, $C = 0.5$.

Using this information, the peak runoff is found to be 13.1 cfs by the Rational Method.

The minimum pipe diameter is found with the orifice equation (assume head to top of pipe).

$$Q = (0.6)(A)\sqrt{2gh}$$

Where:

- Q = Runoff volume, cfs
- A = Area of pipe opening
- g = Acceleration of gravity, 32.2 ft/s^2
- h = Head pressure ($h=D/2$ for head to top of pipe)

$$13.1 = (0.6) \left(\frac{\pi \times D^2}{4} \right) \sqrt{2 \times 32.2 \times \frac{D}{2}}, \text{ Solving for } D \text{ yields a diameter of } 1.9' \text{ or } 23 \text{ inches.}$$

Conclusion: Based upon the analysis, a 24 inch diameter pipe would be selected.

The allowable head is measured from the top of the riser to the crest of the emergency spillway or to the crest of the embankment if no emergency spillway is provided.

Figure 7E-12.01: Sediment Basin Without Emergency Spillway
([SUDAS Specifications Figure 9040.113](#))

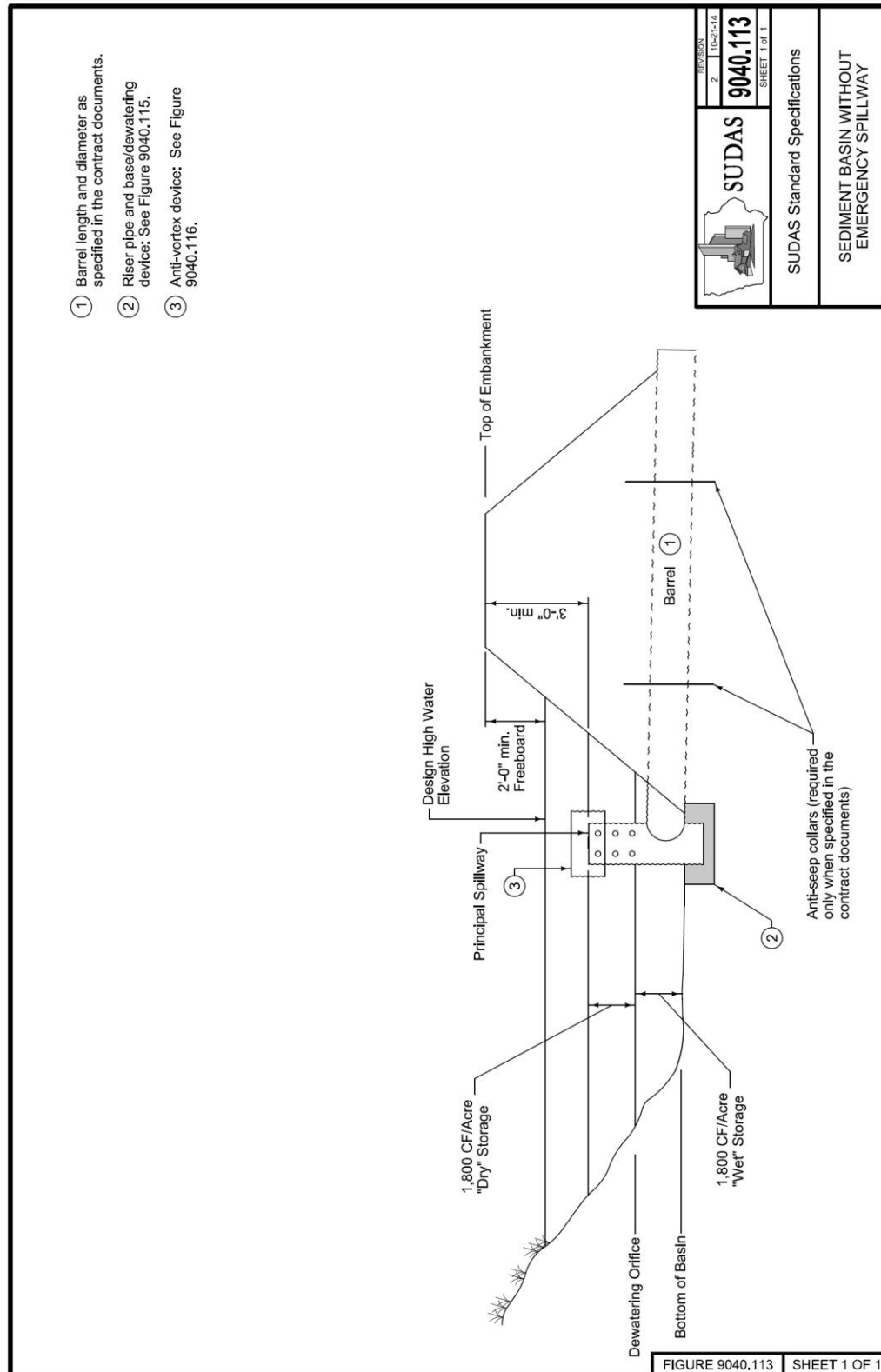
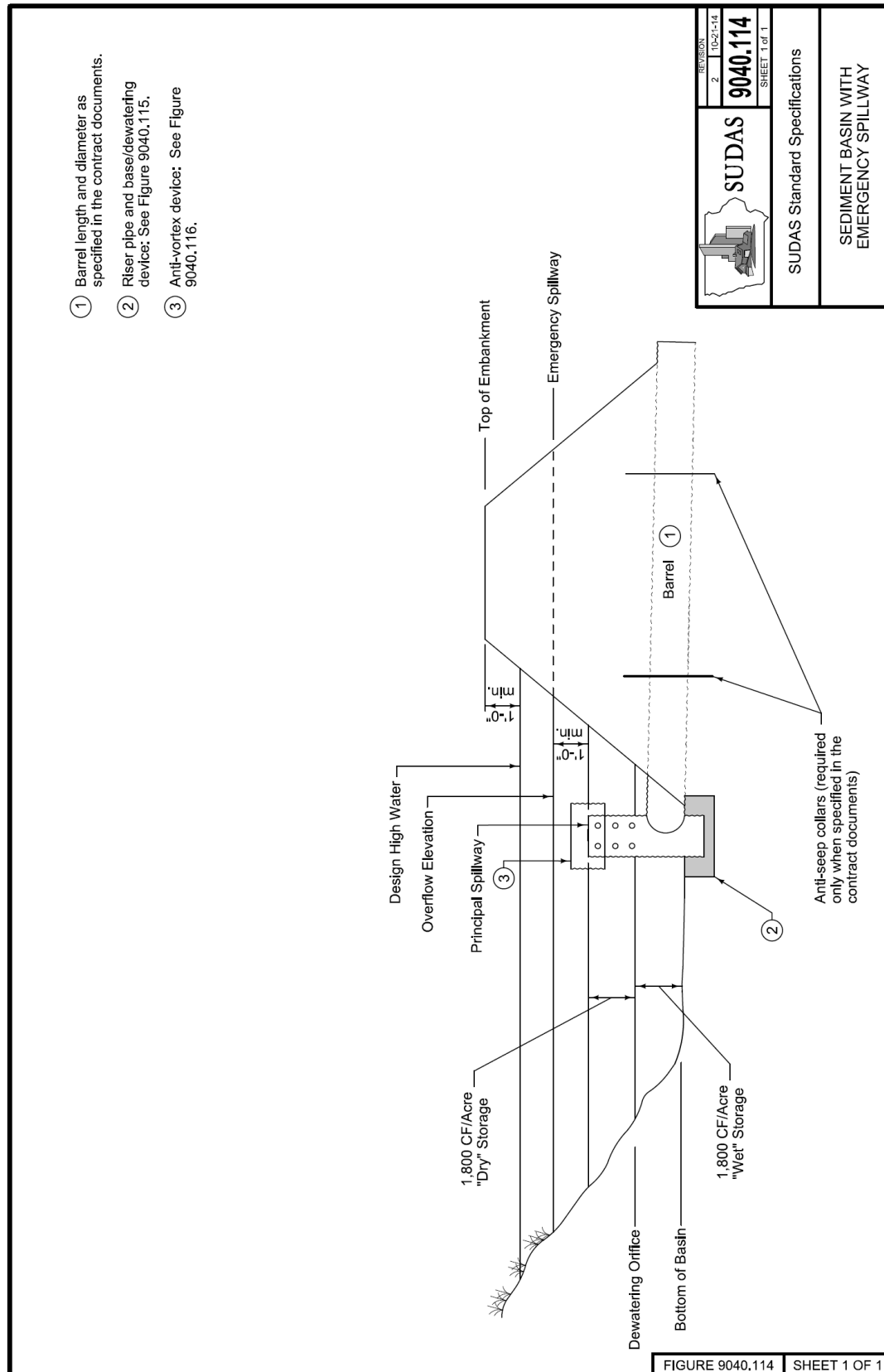


Figure 7E-12.02: Sediment Basin With Emergency Spillway
[\(SUDAS Specifications Figure 9040.114\)](#)



2. **Outlet Barrel:** The size of the outlet barrel is a function of its length and the total head acting on the barrel. This head is the difference in elevation of the centerline of the outlet of the barrel and maximum elevation of the water (design high water). The size of the outlet barrel can be determined using [Chapter 2 - Stormwater](#) for culvert design.
3. **Anti-vortex Device:** An anti-vortex device should be installed on top of the riser section to improve flow characteristics of water into the principal spillway, and prevent floating debris from blocking the spillway.

There are numerous ways to provide protection for concrete pipe including various hoods, grates, and rebar configurations that are part of the project-specific design, and will frequently be part of a permanent structure.

The design information provided in the following detail and table are for corrugated metal riser pipes.

Figure 7E-12.03: Example Anti-vortex Device
(SUDAS Specifications Figure 9040.116, sheet 1)

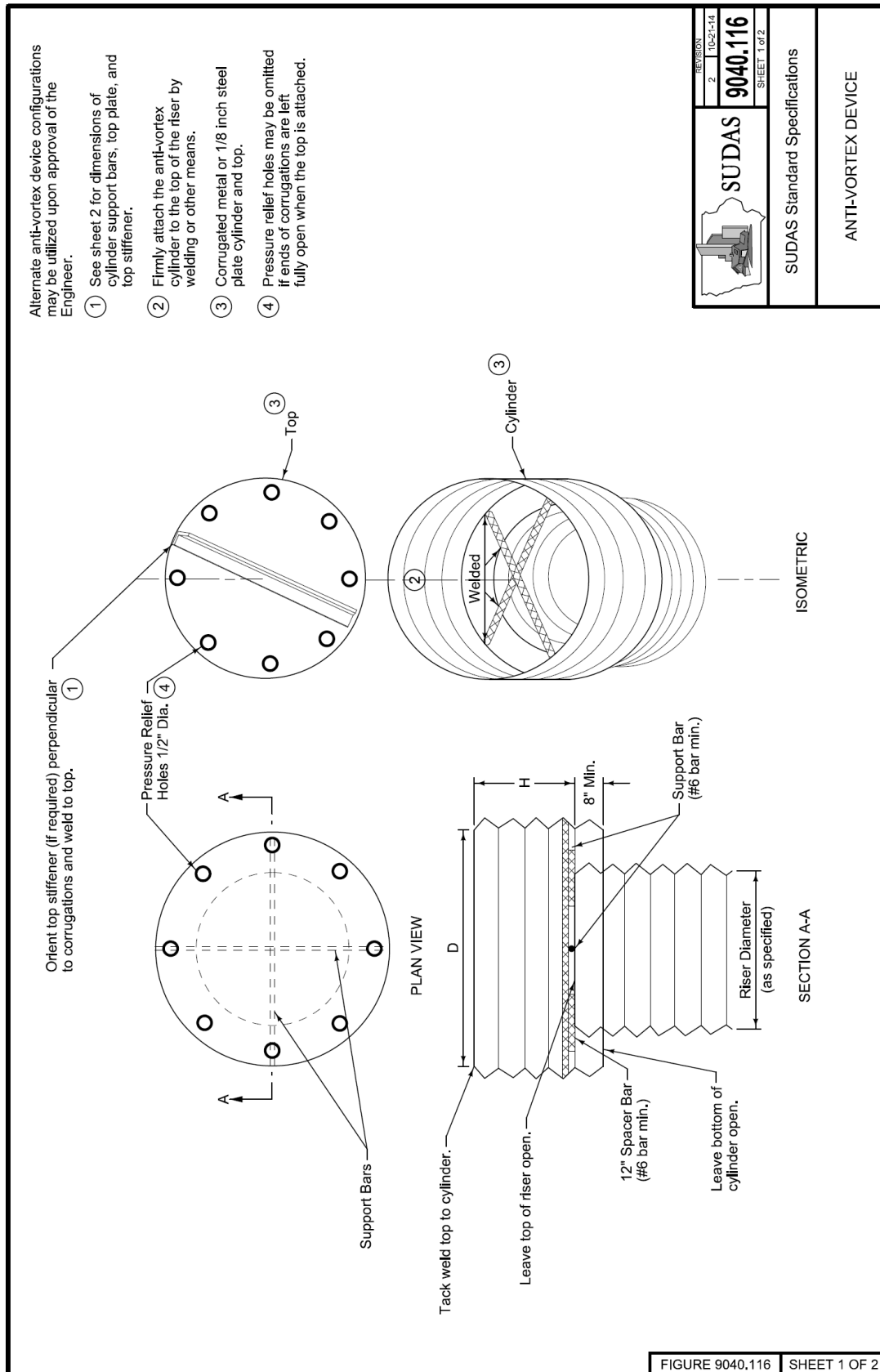


Table 7E-12.01: Design Information for Anti-vortex and Trash Rack Device
([SUDAS Specifications Figure 9040.116, sheet 2](#))

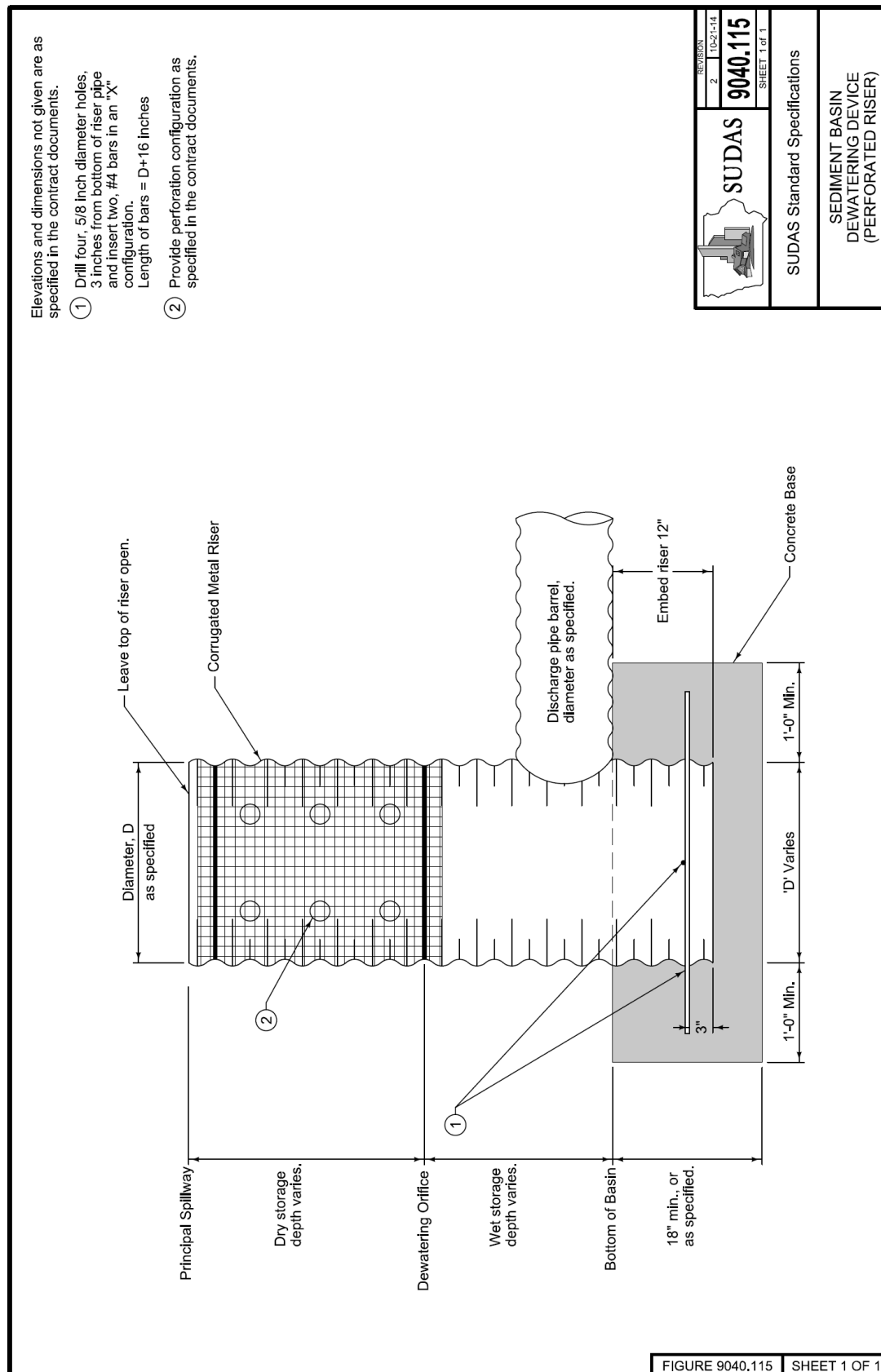
RISER	CYLINDER				MINIMUM TOP	
Diameter (in.)	Diameter (in.)	Thickness (gage)	Height (H) (in.)	Minimum Size Support Bar	Thickness	Stiffener
12	18	16	6	#6 rebar or 1 1/2" X 3/16" angle	16 ga F & C	---
15	21	16	7	#6 rebar or 1 1/2" X 3/16" angle	16 ga F & C	---
18	27	16	8	#6 rebar or 1 1/2" X 3/16" angle	16 ga F & C	---
21	30	16	11	#6 rebar or 1 1/2" X 3/16" angle	16 ga (C), 14 ga (F)	---
24	36	16	13	#6 rebar or 1 1/2" X 3/16" angle	16 ga (C), 14 ga (F)	---
27	42	16	15	#6 rebar or 1 1/2" X 3/16" angle	16 ga (C), 14 ga (F)	---
36	54	16	17	#8 rebar	14 ga (C), 12 ga (F)	---
42	60	16	19	#8 rebar	14 ga (C), 12 ga (F)	---
48	72	16	21	1 1/4" pipe or 1 1/4" X 1 1/4" X 1/4" angle	14 ga (C), 10 ga (F)	---
54	78	16	25	1 1/4" pipe or 1 1/4" X 1 1/4" X 1/4" angle	14 ga (C), 10 ga (F)	---
60	90	14	29	1 1/2" pipe or 1 1/2" X 1 1/2" X 1/4" angle	12 ga (C), 8 ga (F)	---
66	96	14	33	2" pipe or 2" X 2" X 1/4" angle	12 ga (C), 8 ga (F)	2" X 2" X 1/4" angle
72	102	14	36	2" pipe or 2" X 2" X 1/4" angle	12 ga (C), 8 ga (F)	2 1/2" X 2 1/2" X 1/4" angle
78	114	14	39	2 1/2" pipe or 2" X 2" X 1/4" angle	12 ga (C), 8 ga (F)	2 1/2" X 2 1/2" X 1/4" angle
84	120	12	42	2 1/2" pipe or 2" X 2" X 1/4" angle	12 ga (C), 8 ga (F)	2 1/2" X 2 1/2" X 5/16" angle
Notes:						
1. The criterion for sizing the cylinder is that the area between the inside of the cylinder and the outside of the riser is equal to or greater than the area inside the riser. Therefore, the above table is invalid for use with concrete pipe risers.						
2. C - Corrugated F - Flat.						

The riser pipe needs to be firmly attached to a base that has sufficient weight to prevent flotation of the riser. The weight of the base should be designed to be at least 1.25 times greater than the buoyant forces acting on the riser at the design high water elevation.

A base typically consists of a poured concrete footing with embedded anchors to attach to the riser pipe to anchor it in place.

4. **Dewatering Device:** The purpose of the dewatering device is to release the impounded runoff in the dry storage volume of the basin over an extended period of time. This slow dewatering process detains the heavily sediment-laden runoff in the basin for an extended time, allowing sediment to settle out. The dewatering device should be designed to drawdown the runoff in the basin from the crest of the riser to the wet pool elevation over a period of at least 6 hours.

Figure 7E-12.04: Theoretical Discharge Orifice for Design of Perforated Risers
([SUDAS Specifications Figure 9040.115](#))



In addition to checking the capacity of the spillway, the discharge velocity should also be considered. The allowable velocity for vegetated channels or channels lined with a turf reinforcement mat should be carefully analyzed. See [Section 7E-23](#) and [7E-18](#) for information on permissible velocities. For non-erodible linings such as concrete or rip rap, design velocities may be increased.

5. **Anti-seep Collars:** Anti-seep collars help prevent water from flowing along the interface between the outlet barrel and the embankment. This movement of water can, over time, destabilize the embankment, causing it to wash out or burst.

Anti-seep collars are not normally required for sediment basins. However, when the height of the embankment exceeds 10 feet, or the embankment material has a low silt-clay content, anti-seep collars should be used. Anti-seep collars should be used on all structures that may be converted to permanent features.

The first step in designing anti-seep collars is to determine the length of the barrel within the saturated zone. The length of the saturated zone is determined with the following:

$$L_s = Y(Z + 4) \left(1 + \frac{S}{0.25 - S} \right) \quad \text{Equation 7E-12.06}$$

Where:

- L_s = Length of the barrel within saturated zone, ft
- Y = Depth of water at principal spillway crest, ft
- Z = Slope of upstream face of embankment, Z ft H: 1 ft V.
- S = Slope of the barrel in ft per ft

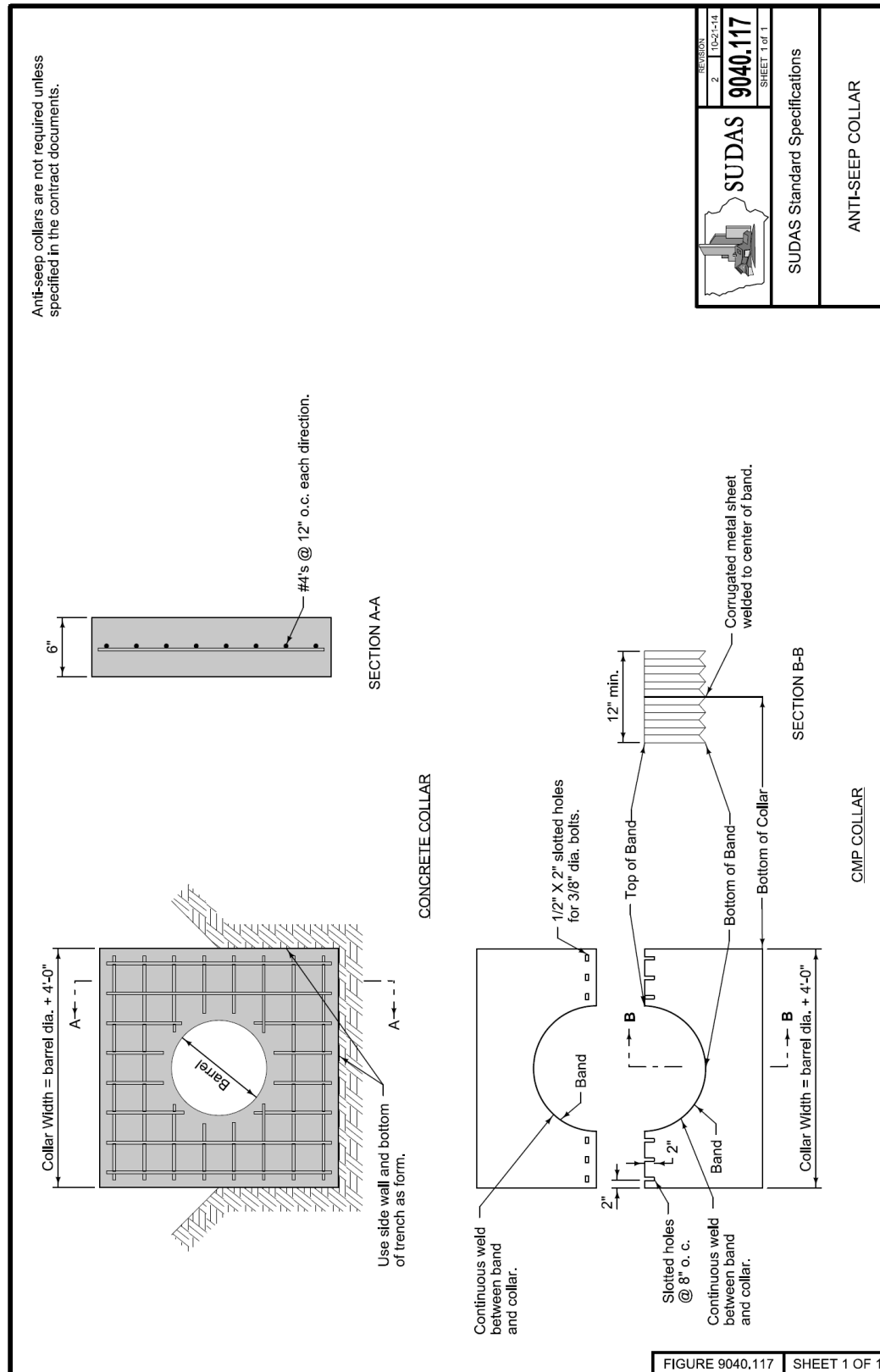
An increase in the seepage length along the barrel of 10% should be provided. Determine the length required to achieve this by multiplying L_s by 10% ($0.10L_s$). This increase in length represents the total collar projection. This can be provided for by one or multiple collars.

Choose a collar size that is at least 4 feet larger than the barrel diameter (2 feet in all directions). Calculate the collar projection by subtracting the pipe diameter from the collar size. Then determine the number of collars required by dividing the seepage length increase ($0.10L_s$) by the collar projection. To reduce the number of collars required, the collar size can be increased. Alternatively, providing more collars can decrease the collar size.

Collars should be placed at a maximum spacing of 14 times the minimum projection above the pipe, and a minimum spacing of 5 times the minimum projection. All collars should be located within the saturated zone. If spacing will not allow this, at least one collar should be located within the saturated zone.

Alternative methods of controlling seepage, such as a filter diaphragm may also be acceptable. A filter diaphragm consists of a layer of porous material running perpendicular to the outlet barrel which intercepts and controls water movement and fines migration within the embankment.

Figure 7E-12.08: Anti-seep Collar
 (SUDAS Specifications Figure 9040.117)



Source: Adapted from Virginia DCR, 1999

The stone embankment should be located at the low point of the basin. The bottom of the stone embankment should equal the elevation of the top of the wet storage portion of the trap. The stone embankment serves two purposes. The porous nature of the crushed stone allows water to seep through the embankment, providing a means to dewater the dry storage volume of the trap after each rainfall event. The top of the embankment serves as an overflow spillway to control the outlet of flows during large storm events.

Construction of the stone embankment should begin by placing a layer of engineering fabric down to protect the underlying soils and help prevent them from being washed away. Next, erosion stone, or a similarly-sized material, is placed over the filter fabric to create an embankment of the height and width required.

C. Application

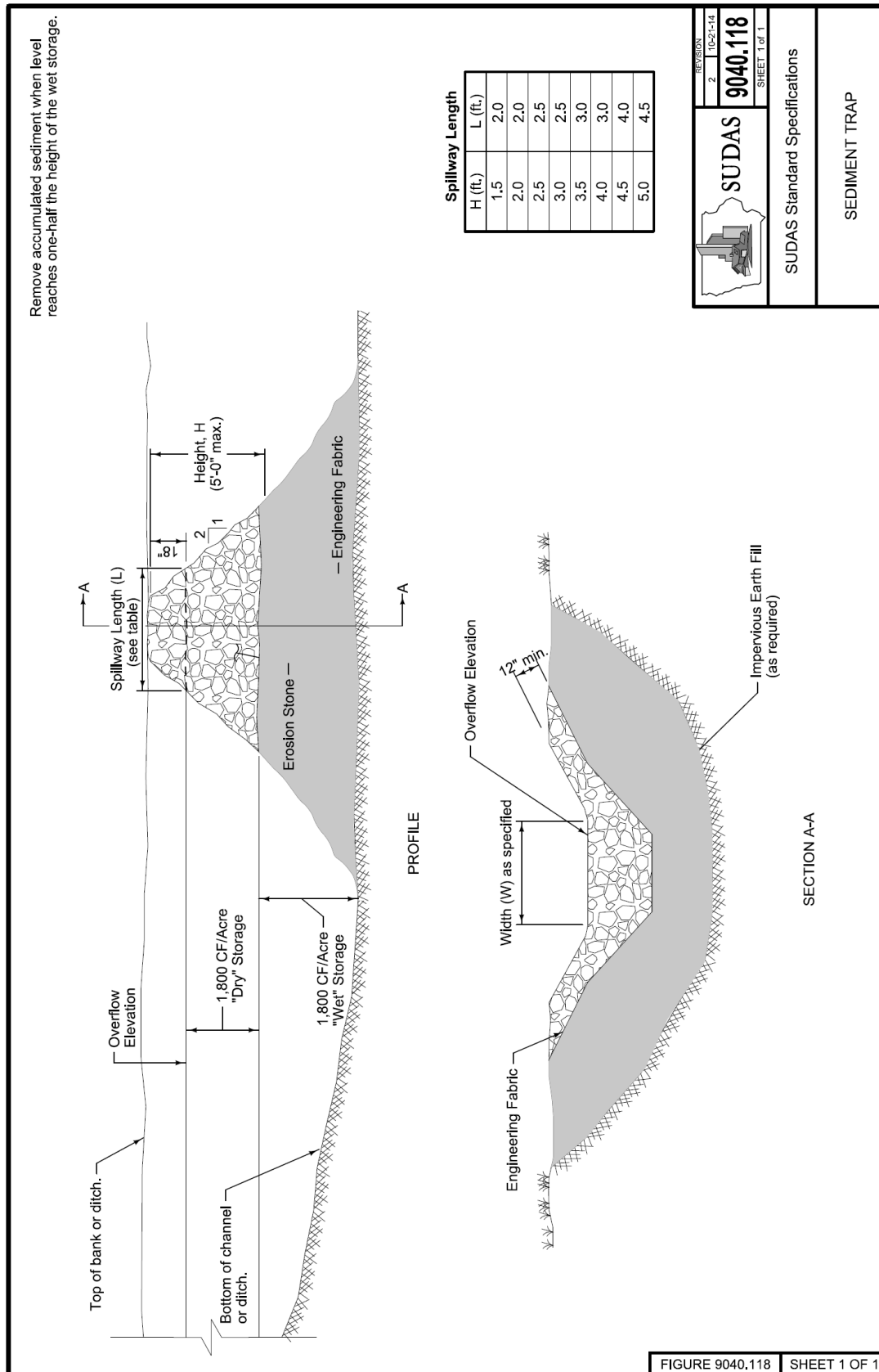
Sediment traps, in conjunction with other erosion control features, should be considered whenever more than 2 acres are disturbed. If more than 5 acres are disturbed, a sediment basin should be considered. If less than 2 acres are disturbed, sediment laden runoff may be controlled by other means such as silt fence or filtering products.

Sediment trap volumes and dimensions should be sized according to the criteria in [Section 7D-1](#). 3,600 cf of storage should be provided for every acre of disturbed ground. This storage volume should be divided equally between wet storage and dry storage.

D. Maintenance

Sediment traps must be cleaned out as sediment accumulates within the trap. It is recommended to clean out the trap when it has lost one-half of the wet storage volume. Upon completion of the project, the trap area should be backfilled and stabilized. Alternatively, the trap may be converted to a permanent sediment basin or detention basin.

Figure 7E-13.01: Typical Sediment Trap with a Stone Outlet
 (SUDAS Specifications Figure 9040.118)



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Table 9B-5.03: Allowable Depth of Bury for Class V (3750D) RCP

Pipe Diameter (inches)	Bedding Class (feet)				
	<i>R-1</i>	<i>R-2</i>	<i>R-3 & R-4</i>		
			<i>A_s=0.0%</i>	<i>A_s=0.4%</i>	<i>A_s=1.0%</i>
12	1 to 18	1 to 23	1 to 35	1 to 40	1 to 40
15	1 to 19	1 to 24	1 to 40	1 to 40	1 to 40
18	1 to 19	1 to 30	1 to 40	1 to 40	1 to 40
21	1 to 25	1 to 40	1 to 40	1 to 40	1 to 40
24	1 to 34	1 to 40	1 to 40	1 to 40	1 to 40
27	1 to 40	1 to 40	1 to 40	1 to 40	1 to 40
30	1 to 40	1 to 40	1 to 40	1 to 40	1 to 40
33	1 to 40	1 to 40	1 to 40	1 to 40	1 to 40
36	1 to 40	1 to 40	1 to 40	1 to 40	1 to 40
42	1 to 37	1 to 40	1 to 40	1 to 40	1 to 40
48	1 to 35	1 to 40	1 to 40	1 to 40	1 to 40
54	1 to 33	1 to 40	1 to 40	1 to 40	1 to 40
60	1 to 32	1 to 40	1 to 40	1 to 40	1 to 40
66	1 to 31	1 to 40	1 to 40	1 to 40	1 to 40
72	1 to 31	1 to 40	1 to 40	1 to 40	1 to 40

Table 9B-5.04: Allowable Depth of Bury for Reinforced Concrete Arch Pipe

Pipe Size (inches)	Equivalent Diameter (inches)	Pipe Class A-III (feet)	Pipe Class A-IV (feet)
18 by 11	15	2 to 11	2 to 16
22 by 13	18	2 to 11	1 to 20
26 by 15	21	2 to 14	1 to 27
29 by 18	24	2 to 15	1 to 31
36 by 22	30	1 to 15	1 to 29
44 by 27	36	1 to 15	1 to 28
51 by 31	42	1 to 15	1 to 27
58 by 36	48	1 to 15	1 to 26
65 by 40	54	1 to 15	1 to 26
73 by 45	60	1 to 15	1 to 25
88 by 54	72	1 to 15	1 to 25

Table 9B-5.05: Allowable Depth of Bury for Extra Strength VCP

Pipe Diameter (inches)	Bedding Class (feet)				
	R-1	R-2	R-3 & R-4		
			$A_s=0.0\%$	$A_s=0.4\%$	$A_s=1.0\%$
6	1 to 25	1 to 30	1 to 30	1 to 30	1 to 30
8	1 to 20	1 to 26	1 to 30	1 to 30	1 to 30
10	1 to 18	1 to 23	1 to 30	1 to 30	1 to 30
12	1 to 16	1 to 20	1 to 30	1 to 30	1 to 30
15	1 to 15	1 to 19	1 to 28	1 to 30	1 to 30
18	1 to 14	1 to 18	1 to 30	1 to 30	1 to 30
21	1 to 15	1 to 22	1 to 30	1 to 30	1 to 30
24	1 to 18	1 to 28	1 to 30	1 to 30	1 to 30
27	1 to 20	1 to 30	1 to 30	1 to 30	1 to 30
30	1 to 19	1 to 29	1 to 30	1 to 30	1 to 30
33	1 to 20	1 to 30	1 to 30	1 to 30	1 to 30
36	1 to 20	1 to 30	1 to 30	1 to 30	1 to 30
39	1 to 19	1 to 29	1 to 30	1 to 30	1 to 30
42	1 to 18	1 to 26	1 to 30	1 to 30	1 to 30

C. Flexible Pipe Assumptions

The depth of bury calculations for PVC pipe were done in accordance with the Uni-Bell PVC Pipe Association's *Handbook of PVC Pipe: Design and Construction*. The depth of bury calculations for HDPE pipe were done according to the Plastic Pipe Institute's: *The Complete Corrugated Polyethylene Pipe Design Manual and Installation Guide*. The AASHTO design method was used for the determination of live load for both materials. The results of the depth of bury calculations for PVC and HDPE pipe indicated in Tables 9B-5.06, 9B-5.07, and 9B-5.08 were developed with the following assumptions:

1. PVC Assumptions:

- Unit weight of backfill is 120 lb/ft³
- Prism load for backfill
- Deflection lag factor (D_L) of 0.1
- Modulus of soil reaction (E') of 0 psi, 1000, lb/in², and 1000 lb/in² for pipe classes F-1, F-2, and F-3 respectively.
- An HS-20 live load applied in an unpaved condition. If the pipe will not be subjected to live load, the minimum depth of bury does not apply.
- Maximum allowable pipe deflection of 5%. A value of 3% is used for design based upon the published deflection accuracy of $\pm 2\%$ for dumped crushed rock bedding.
- Maximum allowable depth of bury was cut off at 40 feet. Calculated values may exceed this depth, but were not shown. For depths greater than 40 feet, an independent analysis should be done using values for actual site conditions.

2. HDPE Assumptions:

- Unit weight of backfill is 120 lb/ft³
- Prism load for backfill
- Water table 2 feet below ground surface
- Deflection lag factor (D_L) of 0.1
- Crushed rock bedding with a 1,000 lb/in² modulus of soil reaction (E')

- An HS-20 live load applied in an unpaved condition. If the pipe will not be subjected to live load, the minimum depth of bury does not apply; however sufficient cover should be provided to protect the pipe from damage by ultraviolet radiation or maintenance equipment.
- Maximum allowable pipe deflection of 5%
- Pipe also checked for wall thrust, critical buckling pressure, bending stress, and bending strain.

Table 9B-5.06: Allowable Depth of Bury for Gravity Flow PVC Pipe - Bedding Class F-2 or F-3

Pipe Diameter (inches)	ASTM (feet)					
	<i>D 3034 Solid Wall</i>		<i>F 679 Solid Wall</i>	<i>F 949 Corrugated Exterior</i>	<i>F 1803 Closed Profile</i>	<i>D 2680 Composite</i>
	<i>SDR 26</i>	<i>SDR 35</i>	<i>SDR 35</i>			
8	2 to 28	2 to 24	---	2 to 24	---	2 to 32
10	2 to 28	2 to 24	---	2 to 24	---	2 to 32
12	2 to 28	2 to 24	---	2 to 24	---	2 to 32
15	2 to 28	2 to 24	---	2 to 24	---	2 to 32
18	---	---	2 to 24	2 to 24	---	---
21	---	---	2 to 24	2 to 24	2 to 24	---
24	---	---	2 to 24	2 to 24	2 to 24	---
27	---	---	2 to 24	---	2 to 24	---
30	---	---	2 to 24	2 to 24	2 to 24	---
33	---	---	2 to 24	---	---	---
36	---	---	2 to 24	2 to 24	2 to 24	---
42	---	---	2 to 24	---	2 to 24	---
48	---	---	2 to 24	---	2 to 24	---
54	---	---	---	---	2 to 24	---
60	---	---	---	---	2 to 24	---

Table 9B-5.07: Allowable Depth of Bury for AWWA C900/C905 PVC Pressure Pipe

Pipe Diameter (inches)	Bedding Class (feet)		
	<i>P-1</i>	<i>P-2</i>	<i>P-3</i>
4	2 to 19	2 to 40	2 to 40
6	2 to 19	2 to 40	2 to 40
8	2 to 19	2 to 40	2 to 40
10	2 to 19	2 to 40	2 to 40
12	2 to 19	2 to 40	2 to 40
14	2 to 19	2 to 40	2 to 40
16	2 to 19	2 to 40	2 to 40
18	2 to 19	2 to 40	2 to 40
20	2 to 19	2 to 40	2 to 40
24	2 to 19	2 to 40	2 to 40

Table 9B-5.08: Allowable Depth of Bury for HDPE Pipe - Bedding Class F-2 or F-3

Pipe Diameter (inches)	AASHTO M 294 (feet)
6	2 to 8
8	2 to 8
10	1 to 9
12	2 to 8
15	1 to 9
18	1 to 9
24	1 to 9
30	1 to 9
36	1 to 9
42	1 to 8
48	1 to 8
54	1 to 8
60	1 to 8

- 3. Polypropylene Assumptions:** The depth of bury calculations for polypropylene pipe were completed in accordance with the AASHTO LRFD Bridge Design Specifications, Sixth Edition. Most of the design criteria are as noted below and the remaining load factors and modifiers are as specified in AASHTO.
- General Design Criteria
 - Design Interval: 50 years
 - Live load applied per NCHRP 647 (checked against AASHTO LRFD)
 - Deflection limit: $\Delta_A = 5\%$
 - Site Assumptions:
 - Clay soils
 - Groundwater assumed 2 feet below ground surface
 - Unit weight of wet soil: $g_s = 120$ pcf
 - Void ratio of soil: $e = 1.9$ (soft, slightly organic clay)
 - Installation Properties
 - Soil compaction: 90% (note: 95% is required by the specs, but a lower value was used for design to recognize the fact that trench compaction is difficult to achieve and sometimes lacking).
 - Pipe Embedment Material: Crushed stone envelope
 - Pipe Embedment Material Compaction: Dumped condition
 - Bedding coefficient = $K_B = 0.100$
 - Deflection lag factor: $D_L = 1.5$
 - AASHTO Load Factors & Modifiers
 - Factor for uncertainty in groundwater: $K_{wa} = 1.0$
 - Installation Factor: $K_{gE} = 1.5$
 - Coefficient for Variation of Thrust: $K_2 = 1.0$ (at springline)
 - Load Factor for vertical earth pressure: $g_{EV} = 1.3$

Table 9B-5.09: Allowable Depth of Bury for Polypropylene Pipe

Pipe Diameter (inches)	ASTM F 2736 (feet)	ASTM F 2764 (feet)
12	24	---
15	25	---
18	22	---
24	20	---
30	22	22
36	---	21
42 ¹	---	22
48 ¹	---	23
54 ¹	---	21
60 ¹	---	21

¹ Storm Sewer only.

Minimum depth of cover for all diameters 12 to 54 inches is 1 foot. Minimum cover for 60 inch pipe is 2 feet.

D. Ductile Iron Pipe Assumptions

The depth of bury calculations for ductile iron were done according to the DIPRA publication “Design of Ductile Iron Pipe.” The results of the depth of bury calculations for ductile iron pipe indicated in Table 9B-5.09 were developed with the following assumptions:

- Unit weight of backfill is 120 lb/ft³
- Prism load for backfill
- An HS-20 live load applied for all conditions
- Live load impact factor of 1.5
- Bedding classes P-1, P-2, and P-3 follow DIPRA laying conditions Type 2, Type 4, and Type 5, respectively.
- Maximum allowable pipe deflection of 3%
- 48,000 psi ring bending stress limit.
- Maximum allowable depth of bury was cut off at 40 feet. Calculated values may exceed this depth, but were not shown. For depths greater than 40 feet, an independent analysis should be done using values for actual site conditions.

Table 9B-5.10: Allowable Depth of Bury for Ductile Iron Pipe (Thickness Class 52)

Pipe Diameter (inches)	Bedding Class (feet)		
	<i>P-1</i>	<i>P-2</i>	<i>P-3</i>
4	2.5 to 40	2.5 to 40	2.5 to 40
6	2.5 to 40	2.5 to 40	2.5 to 40
8	2.5 to 40	2.5 to 40	2.5 to 40
10	2.5 to 36	2.5 to 40	2.5 to 40
12	2.5 to 31	2.5 to 40	2.5 to 40
14	2.5 to 26	2.5 to 40	2.5 to 40
16	2.5 to 23	2.5 to 37	2.5 to 40
18	2.5 to 20	2.5 to 34	2.5 to 40
20	2.5 to 18	2.5 to 32	2.5 to 40
24	2.5 to 16	2.5 to 29	2.5 to 38
30	2.5 to 13	2.5 to 23	2.5 to 31
36	2.5 to 13	2.5 to 22	2.5 to 30
42	2.5 to 13	2.5 to 21	2.5 to 29
48	2.5 to 13	2.5 to 19	2.5 to 27
54	2.5 to 13	2.5 to 19	2.5 to 27

Casing Pipe

A. General

Utilities must often be encased in a steel pipe when crossing under roadways or railroads. Steel casing pipe complying with the requirements of ASTM A252 (Standard Specification for Welded and Seamless Steel Pipe Piles) is generally used.

Depending on the timing of the installation, the casing pipe can be either installed in an open cut trench or by one of the trenchless techniques described in [Chapter 14](#).

Regardless of the installation method, the casing pipe thickness and casing pipe diameter should be specified on the plans.

B. Casing Thickness

The casing pipe must have sufficient thickness to withstand both earth loads and any live loads imposed from traffic above. Table 9C-1.01 provides minimum recommended casing pipe thicknesses for both roadway and railroad installations. The roadway values are based upon common industry standards. The railroad values are based upon American Railway Engineering and Maintenance-of-Way Association (AREMA) design standards. Individual railroad standards may vary.

Table 9C-1.01: Minimum Casing Pipe Thickness

Nominal Diameter (inches)*	Roadway (inches)	Railroad (inches)
6 through 14	0.250	0.25
16	0.250	0.281
18	0.250	0.312
20	0.250	0.344
24	0.281	0.375
30	0.312	0.469
36	0.344	0.531
42	0.344	0.625
48	0.344	0.687
54		0.719
60		0.843
66		0.937
72		1.000

*Additional casing diameters are available.

Notes: Minimum thicknesses assume a minimum of 4.5 feet of cover over top of pipe.

C. Casing Diameter

The casing pipe should be sized to provide a minimum of 4 inches of clearance between the inside of the casing pipe and the largest outside diameter of the carrier pipe (including pipe bells) to allow for deflection of the casing pipe and installation of casing spacers.

Utility Cut Restoration

A. General

Utility cuts are made in existing pavement sections to install a myriad of utilities and to repair those that experience maintenance needs. Once a utility cut is made in the pavement, the restoration materials and process will have a significant impact on the life of the pavement patch. When a utility cut is made, the native material surrounding the perimeter of the trench is subjected to loss of lateral support. This leads to loss of material under the pavement and bulging of the soil on the trench sidewalls into the excavation. Subsequent refilling of the excavation does not necessarily restore the original strength of the soils in this weakened zone. The weakened zone around a utility cut excavation is called the “zone of influence.” Poor performance of pavements over and around utility trenches on local and state systems often causes unnecessary maintenance problems due to improper backfill placement (i.e., under compacted, too wet, too dry). It has been reported that the life of a utility cut replacement patch is only 2 to 3 years. The costs of repairing poorly performing utility cut restorations can potentially be avoided with a better understanding of proper material selection and construction practices. In addition to the resources spent by the public agency to maintain the pavement patch area, there is a significant impact to the traveling public due to rough streets and the traffic interruptions that occur frequently when maintenance activities are occurring.

The improper use and placement of backfill materials and failure to provide for the loss of lateral support of the trench walls are the primary causes of pavement patch failure.

While planning of utility modifications can be accommodated as part of a larger project, frequently these excavations occur at odd-hours and with no advance notice to repair a facility (i.e., water main break). It is therefore important to plan ahead to help ensure that desirable methods are used to restore utility trenches, even when weather, timing, or other factors may be less than ideal.

B. Background

The Iowa Highway Research Board (IHRB) commissioned two projects focusing on how best to reconstruct utility trenches. The goal of the projects has been to mitigate the negative effects utility trenches have on the surrounding roadway pavement. The two studies are described below.

- IHRB Project TR-503 (2005) Utility Cut Repair Techniques - Investigation of Improved Cut Repair Techniques to Reduce Settlement in Repaired Areas
- IHRB Project TR-566 (2010) Utility Cut Repair Techniques - Investigation of Improved Utility Cut Repair Techniques to Reduce Settlement in Repaired Areas, Phase II

The above reports can be accessed at the following websites:

- www.intrans.iastate.edu
- <https://iowadot.gov/research/research/reports-library>

The research identified the following problems with current trench restoration methods:

- Large equipment bearing on the trench edges (causing damage to the trench sidewalls and the remaining pavement)

- 2 to 4 foot lifts of backfill material
- Sporadic compaction of the backfill lifts
- Utilizing native, saturated material in the excavation in an attempt to clean the excavation site
- General lack of density and moisture quality control

The research identified three modes of failure for the utility trenches.

- Settlement of utility cut restoration, caused by poor compaction and wet/frozen conditions
- A “bump” forming over the restoration, resulting from uplift or settlement of surrounding soil
- Weakening of the surrounding soils

Many of the studied patches showed signs of failure within 2 years.

C. Factors Affecting Patch Performance

1. **Compaction:** Proper compaction of the non-manufactured backfill material is a critical element of good trench construction. Use of granular backfill has previously been thought of as a means to achieve an acceptable level of trench compaction with a minimal level of effort; however, that is not the case. Even with granular materials, the material should be placed in lifts not exceeding 12 inches in thickness. Each lift of granular material should receive an appropriate level of compactive effort to achieve a minimum relative density of 65%. If cohesive soils are used in the top 2 feet to match existing subgrade materials, the soil should be placed in 8 inch lifts and compacted to 95% of Standard Proctor Density for that soil.

Backfill materials are often compacted using large compaction equipment, which is placed close to the edges of the cut, resulting in damage to pavement surfaces around the perimeter of the excavation. Note Figure 9D-1.01. It is important to keep equipment away from the edges of the trench.

Figure 9D-1.01: Cracking Pavement Surrounding the Utility Cut Area Because of Construction Equipment Getting Too Close to the Edge of the Open Cut



Source: IHRB Project TR-566

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On-Street Bicycle Facilities

A. General

Cyclists have similar access and mobility needs as other transportation users. However, cyclists must use their own strength and energy to propel the bicycle, thus a bicyclist is generally slower than other vehicles that are operating on the roadway. Additionally, cyclists are more vulnerable to injury during a crash and are of any age group. With these factors in mind, it is imperative that designing bicycle facilities is done with great care.

The fourth edition (2012) of the AASHTO “Guide for the Development of Bicycle Facilities” (or *AASHTO Bike Guide*) was used as a reference for developing this section. References made to the *AASHTO Bike Guide* within this section are shown in parentheses, e.g. (AASHTO 4.2).

B. Elements of Design

Since cyclists usually have a higher eye height and are slower than the adjacent traffic, the roadway design elements for motor vehicles usually meet or exceed the minimum design elements required for cyclists.

Surface conditions affect cyclists more significantly than motor vehicles. Therefore, when establishing bicycle lanes and routes, it is important that the roadway surface is in good condition and is free of potholes, bumps, cracks, loose gravel, etc. If the roadway is not in good bicycle riding condition, it should be repaired either with resurfacing or reconstruction. Chip-sealed surfaces prove to create difficult riding conditions. (AASHTO 4.2).

C. Facilities

Except where prohibited, bicycles may be operated on all roadways. The following are the different types of bicycle facilities that are located on the roadway along with their design criteria.

1. **Shared Lanes:** Shared lanes already exist on local neighborhoods and city streets. However, these lanes can include design features that will make the lanes more bicycle friendly. This includes good pavement quality, adequate sight distance, lower speeds, bicycle-compatible drainage grates, bridge expansion joints, railroad crossings, etc. (AASHTO 4.3).
 - a. **Major Roads (Wide Curb/Outside Lanes):** Lane widths should be 13 to 15 feet wide with 14 foot lanes as preferred. Lane widths of 14 feet and greater allow motorists to pass cyclists without encroaching into adjacent lanes; however, it is important to note that 15 foot lanes should be used only on appropriate sections with steep grades or sections where drainage grates, raised delineators, or on-street parking effectively reduces the usable width. The gutter should not be included in the measurement as usable width. Lanes 15 feet or wider could encourage faster vehicular movements or even two vehicles operating side by side in one lane. (AASHTO 4.3.1).

- b. Marked Shared Lanes:** In areas that need to provide enhanced guidance for cyclists, shared lanes may be marked with pavement marking symbols. This marking should be provided in locations where there are insufficient widths to provide bicycle lanes or shared use paths. This pavement marking not only lets the cyclists know where to be located within the lane but also the direction of travel.

Shared lane markings are not appropriate for paved shoulders or bicycle lanes, and should not be used on roadways that have a speed limit above 35 mph. Markings should be placed immediately after an intersection and spaced not greater than 250 foot intervals. Refer to both the MUTCD and AASHTO 4.4.

- c. Signs for Shared Roadways:** Along with pavement markings, signage is a very useful tool to communicate and inform both motorists and cyclists about shared roadways. It is important to note, that signs shall be used only when needed in order to prevent confusion, reduce clutter, and improve visibility. Refer to both the MUTCD and AASHTO 4.3.2.

Figure 12B-3.01: Share the Road Sign Assembly



Source: AASHTO Bike Guide Exhibit 4.1

- 2. Paved Shoulders:** For higher speed and higher traffic roadways, adding or improving a paved shoulder can greatly improve cyclist accommodations on roadways. This will not only benefit the cyclists and motorists by giving the cyclists a place to ride that is located outside of the travel lane, but it also can extend the service life of roads by reducing edge deterioration.

It is important to note that paved shoulders should not be confused with bicycle lanes, as bicycle lanes are travel lanes and paved shoulders are not. Paved shoulders should have a minimum width of 4 feet wide with a preferred width of 5 feet. Also, they should be at least 5 feet in locations of guardrails, curbs, or other roadside barriers. Additionally, the width may be increased in areas where the speeds exceed 50 mph, areas of heavy truck traffic, or locations with static obstruction exist at the right side of the roadway.

It is preferred to have paved shoulders on both sides of a two-way roadway; however, in constrained locations and where pavement widths are limited, it may be preferable to provide a wider shoulder on one side of the roadway and a narrower shoulder on the other. This may be beneficial in uphill roadway sections to provide slow-moving cyclists additional maneuvering

space and sections with vertical or horizontal curves that limit sight distance over crests and on the inside of horizontal curves.

In locations where unpaved driveways or roadways meet a paved shoulder, it is recommended to pave at least 10 feet of the driveway and 20 feet or to the right-of-way line, whichever is less, of the unpaved public road. This will help minimize loose gravel from spilling onto the travel way and affecting the cyclists. Additionally, raised pavement markers should not be used, unless they are beveled or have tapered edges.

Rumble strips may be used on paved shoulders that include the bicycle traffic; however, the minimum clear path should be 4 feet from the rumble strip to the outside edge of paved shoulder or 5 feet to the adjacent curb or other obstacle. Gaps at a minimum of 12 feet and a recommended distance of 40 to 60 feet for the rumble strips should also be provided in order to allow room for cyclists to leave or enter the shoulder without crossing the rumble strip. (AASHTO 4.5). Rumble strips should have the following design:

- Width: 5 inches
- Depth: 0.375 inches
- Spacing: 11 to 12 inches (may be reduced to 6 inches)

3. **Bicycle Lanes:** Bicycle lanes are a portion of the roadway that is designated for bicycle traffic. They are one-way facilities that typically carry bicycle traffic in the same direction as the adjacent motor vehicle traffic. They are appropriate and preferred on corridors located in both urban and suburban areas; however, they may be used on rural roadways. They are typically used when vehicle traffic exceeds 3,000 vehicles per day and vehicle speeds are greater than 30 mph. Frequent use of visible pavement markings is essential to identify the lane for use by bicycles only. Color may be added for increased visibility. The use of colored markings should be consistent throughout the corridor and community. Public information and education programs may be necessary when a specific type of bicycle lane is introduced into a community. Programs should include a focus for drivers, as well as for bicyclists. Paved shoulders can be designated as bicycle lanes by installing bicycle lane symbol markings, yet marked shoulders will still need to meet the criteria listed herein.

Bicycle lanes should have a smooth surface with utility and grate covers flush with the surface of the lane. Additionally, bicycle lanes should be free of ponding water, washouts, debris accumulation, and other potential hazards. (AASHTO 4.6). Designers need to be aware that pavement joints, especially near curb and gutter sections, could impact the usability of the bicycle lane.

There are three types of bicycle lanes:

- Conventional
- Buffered
- Separated

- a. **Conventional:** Located between the travel lanes and the curb, road edge, or parking lane and generally flow in the same direction as motor vehicles. They are the most common bicycle facility in the United States.

- 1) **Two-way Streets:** It is recommended that bicycle lanes are provided on both sides of two-way streets as bicycle lanes on only one side may encourage wrong-way use. The exceptions are in cases of long downhill grades where bicyclists' speeds are similar to typical motor vehicle speeds. In this case, shared lane markings may be used in the downhill direction and a bicycle lane in the uphill direction.

- 2) **One-way Streets:** On one-way streets, the bicycle lane should be on the right-hand side of the roadway. A bicycle lane may be placed on the left side of the roadway if there are a significant number of left turn lanes, or if left-sided bicycle lanes will reduce conflicts with bus traffic, on-street parking, and/or heavy right-turn movements, etc.

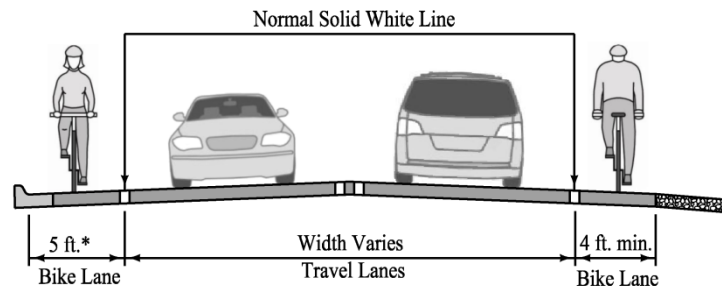
Bicycle lanes should also be provided on both streets of a one-way couplet as to provide a more complete network and discourage wrong-way riding. If width constraints are in effect, shared lane markings should be considered.

In some designated one-way streets, it may be preferred to provide bicyclists a contra-flow bicycle lane using markings and separated by a double yellow centerline. This design should be used where there are few intersecting driveways, alleys, and streets on the side of the street with the contra-flow lane. (AASHTO 4.6.3).

- 3) **Lane Widths:** The preferred operating width for bicycle lanes is 5 feet; however, 4 feet is the minimum in locations where there is an absence of on-street parking and a curb and gutter. In some instances, wider lanes may be more desirable. These instances are:
- In locations with narrow parking lanes and high turnover. A wider bicycle lane of 6 to 7 feet will allow cyclists to ride out of the area of opening vehicle doors.
 - In areas with high bicycle use. A bicycle lane width of 6 to 8 feet will allow cyclist to pass each other or ride side-by-side.
 - In high-speed and high-volume roadways and/or high heavy vehicle traffic. A wider lane will provide an additional separation between cyclists and motorist, thus increasing safety and comfort of the cyclists.

With wider bicycle lanes, appropriate signage and markings shall be used to delineate the bicycle lanes from the vehicle lanes.

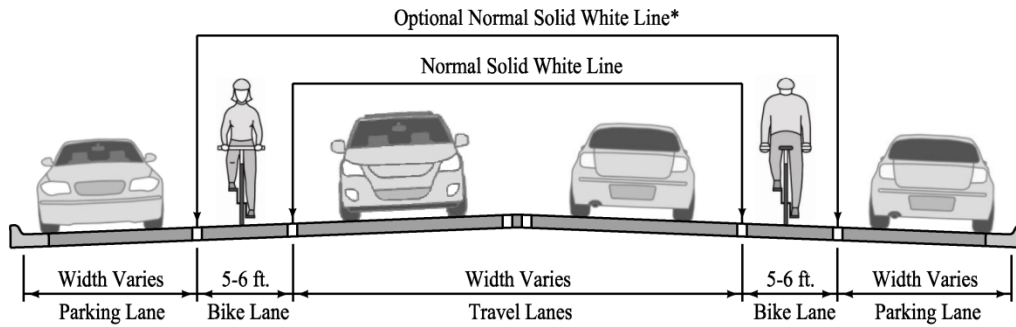
Figure 12B-3.02: Conventional Bicycle Lane Cross-sections - Parking Prohibited



* On extremely constrained, low-speed roadways with curbs but no gutter, where the preferred bicycle lane width cannot be achieved despite narrowing all other travel lanes to their minimum widths, a 4 foot wide bicycle lane can be used.

Source: Adapted from AASHTO *Bike Guide* Exhibit 4.13

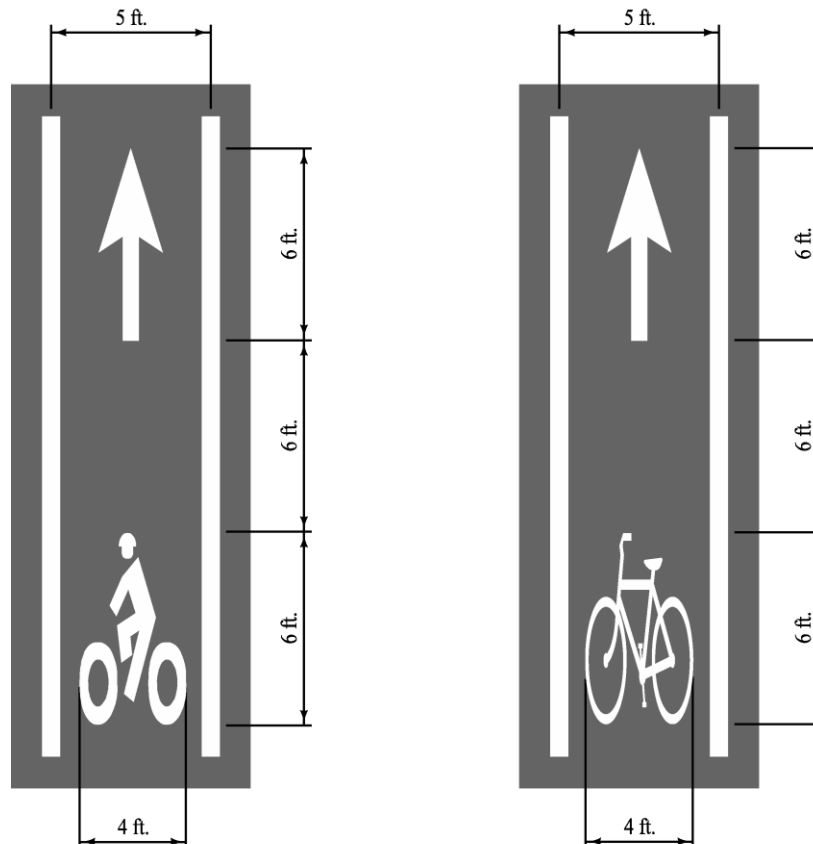
- 4) **Bicycle Lanes and On-street Parking:** With on-street parking facilities, bicycle lanes shall be located between the vehicle travel lane and the parking spot. For parallel on-street parking, the recommended width of a marked parking lane is 8 feet with a minimum of 7 feet. When the parking lane is not marked, the recommended width of the shared bicycle and parking lane is 13 feet with a 12 foot minimum. Any on-street diagonal parking that is adjacent to bicycle lanes shall be back-in parking as to prevent accidents due to poor visibility of bicyclists. (AASHTO 4.6.5).

Figure 12B-3.03: Conventional Bicycle Lane Cross-sections - On-street Parking

* The optional normal (4 to 6 inch) solid white line may be helpful even when no stalls are marked (because parking is light), to make the presence of a bicycle lane more evident. Parking stall markings may also be used.

Source: Adapted from *AASHTO Bike Guide* Exhibit 4.13

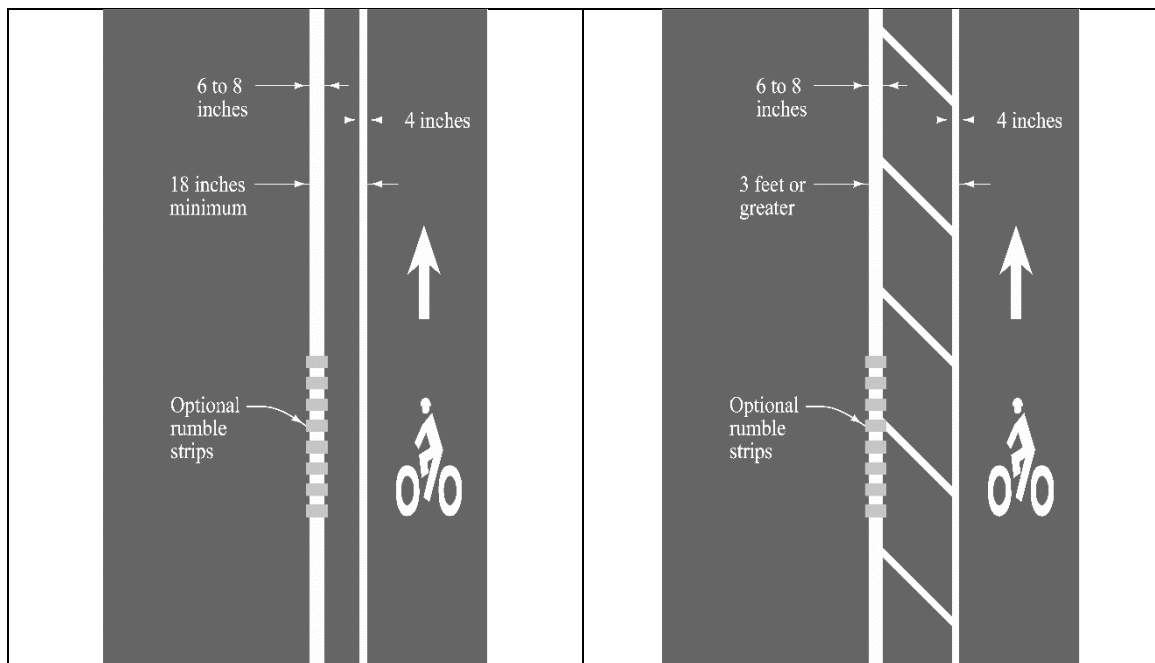
- 5) Signs and Markings:** Bicycle lanes are designated for preferential use by bicyclists with a normal white line (4 to 6 inches wide) and one of the two standard bicycle lane symbols, which may be supplemented with a directional arrow marking. Pavement signs and non-raised pavement markings should be used instead of curbs, posts, raised pavement markings, or barriers. Raised devices are hazardous to cyclists and make it more difficult for cyclists to maintain riding in the bicycle lane. Refer to both the MUTCD and AASHTO 4.7.

Figure 12B-3.04: Conventional Bicycle Lane Symbol Markings

Source: Adapted from *AASHTO Bike Guide* Exhibit 4.17

- b. Buffered:** Conventional bicycle lanes coupled with a designated buffer space separating the bicycle lane from adjacent motor vehicle lanes and/or a parking lane. They are generally used when traffic volumes include high percentages of trucks or buses and higher travel speeds. The lane widths are the same as for conventional bicycle lanes. The buffered bicycle lane provides a greater space for cycling without making the bicycle lane appear so wide that it might be mistaken for a travel or parking lane. The buffer should be a minimum of 18 inches wide and marked with two solid white lines with diagonal hatching or chevron markings if the width is 3 feet or greater. Colored markings may be used at the beginning of each block to discourage motorists from entering the buffered lane. The combined width of the buffer(s) and bicycle lane should be considered the “bicycle lane width.” For buffered lanes between travel lanes and on-street parking, the bicycle lane should be a minimum of 7 feet wide (inclusive of buffer width) to encourage bicyclists to ride outside the door zone. Rumble strips may be added to the painted buffer area as an additional indicator for vehicles to remain clear of the bicycle lane. Placement of rumble strips should comply with Iowa DOT requirements.

Figure 12B-3.05: Buffered Bicycle Lane Markings



Source: Adapted from *Urban Bikeway Design Guide*, NACTO

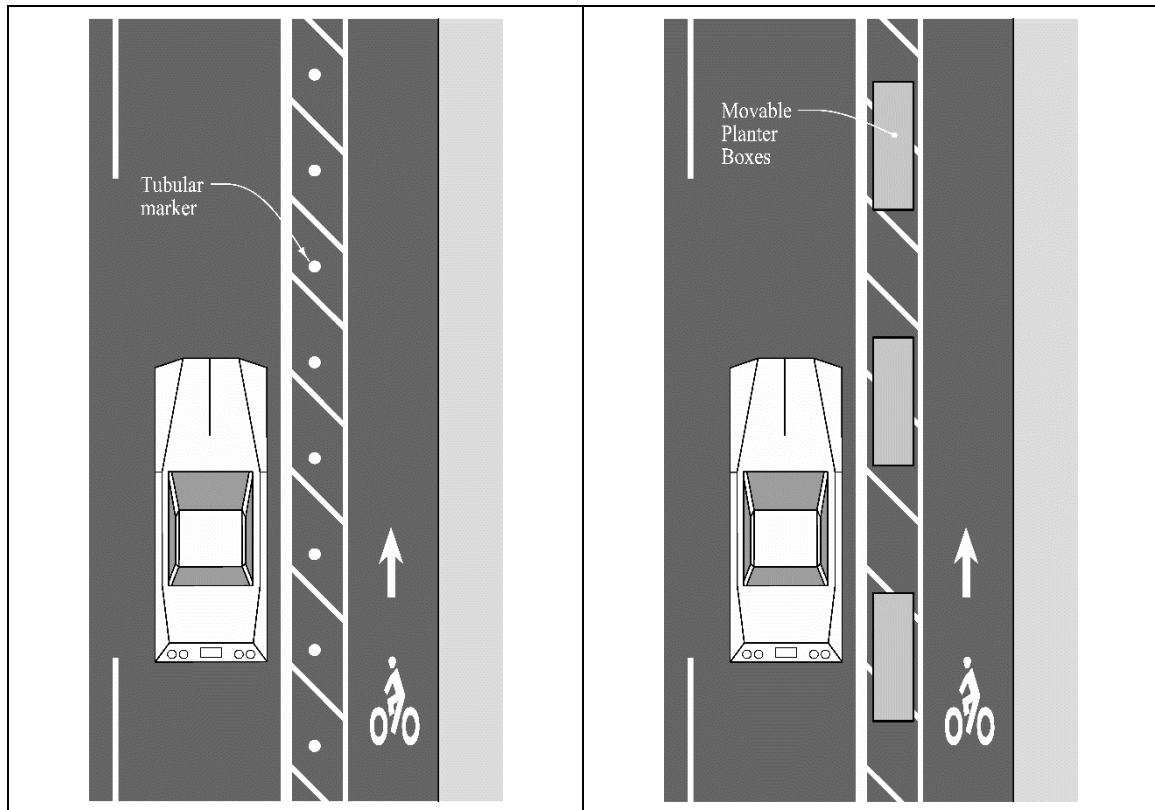
- c. Separated:** An exclusive facility for bicyclists that is physically separated from motor vehicle or parking lanes by a vertical element. Separated bicycle lanes are also sometimes called cycle tracks or protected bicycle lanes. Examples of vertical separation include delineators, bollards, curbs, medians, planters, concrete barriers, and on-street parking. Separated bicycle lanes can provide a safer, more comfortable experience for less-skilled bicycle riders and encourage more use of bicycles for travel if interconnected with other community bicycle facilities. Separated bicycle lanes typically include a painted buffer space that is used to locate the vertical element. Separated bicycle lanes are often implemented through the removal of a parking lane or by moving the parking lane between the separated bicycle lane and the travel lanes.

If the separated bicycle lane is parking protected, parking should be prohibited a minimum of 30 to 50 feet from the crosswalk of an intersection. Make sure to provide ADA access across the separated bicycle lane from parking spaces.

Separated bicycle lanes can operate as one-way or two-way facilities. Minimum width is 5 feet (exclusive of width for physical separation) for a one-way facility. Widths of 7 feet or greater are required for passing or side-by-side riding. Consideration should be given to the equipment that will be needed to perform sweeping and snow removal maintenance. Unobstructed widths of less than 8 feet will likely require specialized maintenance equipment. If a solid median is used as the means of vertical separation, drainage may also be impacted. Separation devices such as delineators or planters may be removed during the winter months to facilitate snow plowing and removal activities.

Interaction between transit stops and separated bicycle lanes can be difficult. When possible, the bicycle lane should be routed behind the bus platform. If bus traffic is infrequent (less than four buses per hour), bus stops can utilize the bicycle lane space. When buses are present, cyclists should merge left and pass the stopped bus.

Figure 12B-3.06: Separated Bicycle Lane

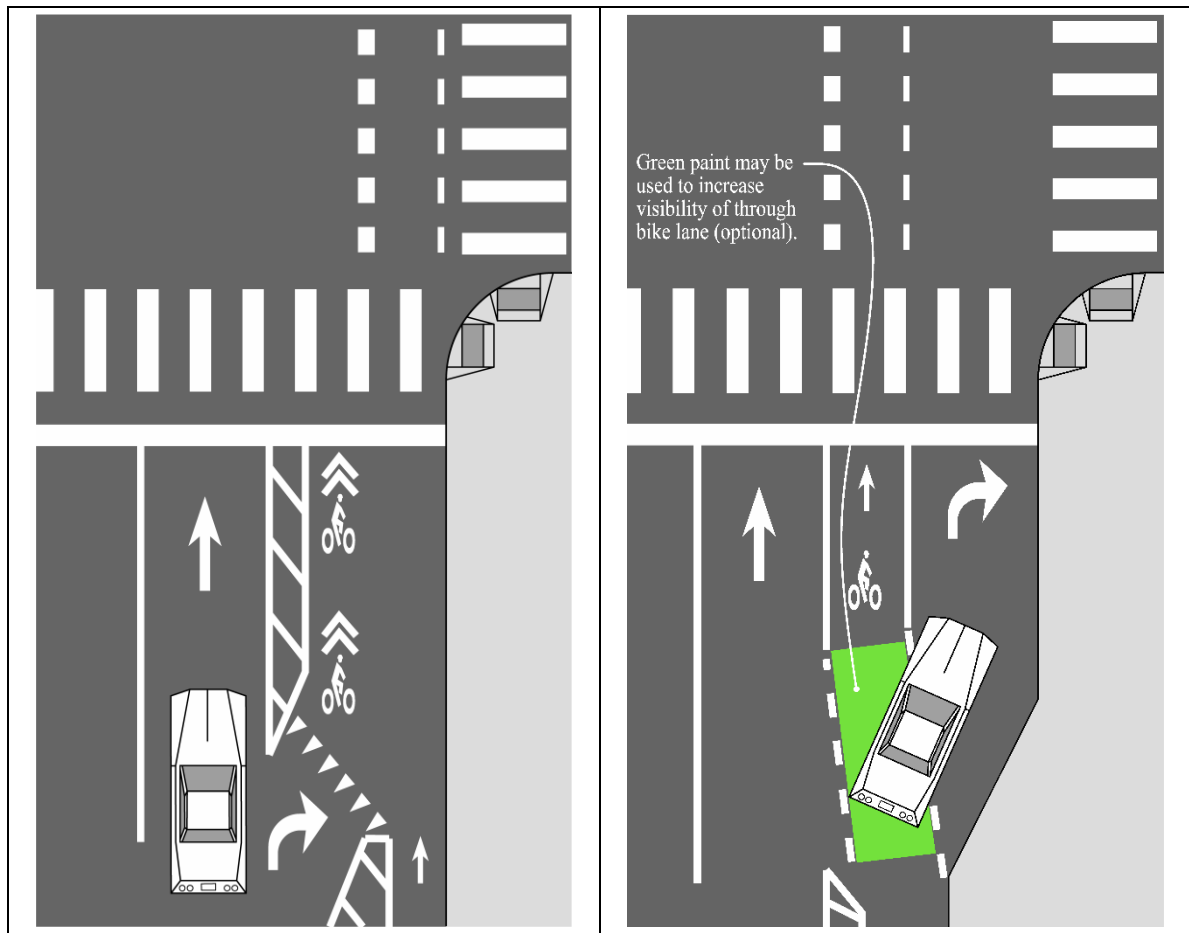


Source: Adapted from *Urban Bikeway Design Guide*, NACTO

- d. Intersection Design:** Most conflicts between motor vehicles and bicyclist occur at intersections and driveways. Due to the vulnerability of cyclists as well as the low visibility the cyclists have in relationship to the motorists, good intersection bicycle lane design and intersection pavement marking design is crucial to the success of an intersection that incorporates bicycle lanes. Refer to both the MUTCD and AASHTO 4.8 for additional information pertaining to intersection pavement marking and bicycle lane design.

Intersection design is critical since it is not possible to maintain physical separation between bicycles and vehicles where cross-street traffic and turning movements must cross the bicycle lane. One technique for intersections that do not have sufficient volumes for traffic signals is to use a mixing zone. The vertical element is discontinued about 100 feet from the intersection and the bicycle lane becomes a shared lane with the turning vehicles. Sharrow markings are used to guide the bicyclists to the left side of the right turning vehicles. The combined lane should be a minimum of 9 feet and a maximum of 13 feet wide. Another technique involves a lateral shift of the bicycle lane to a position to the left of the right turn lane (through bicycle lane). The transition involves a 30 feet long merge area without the vertical elements for vehicles to cross the bicycle lane and eliminate the conflict with right turning vehicles. The lateral shift also positions bicyclists to take advantage of a bicycle box that provides a space for bicycles to queue in front of vehicles during red signal indications.

Figure 12B-3.07: Mixing Zones and Through Bicycle Lane



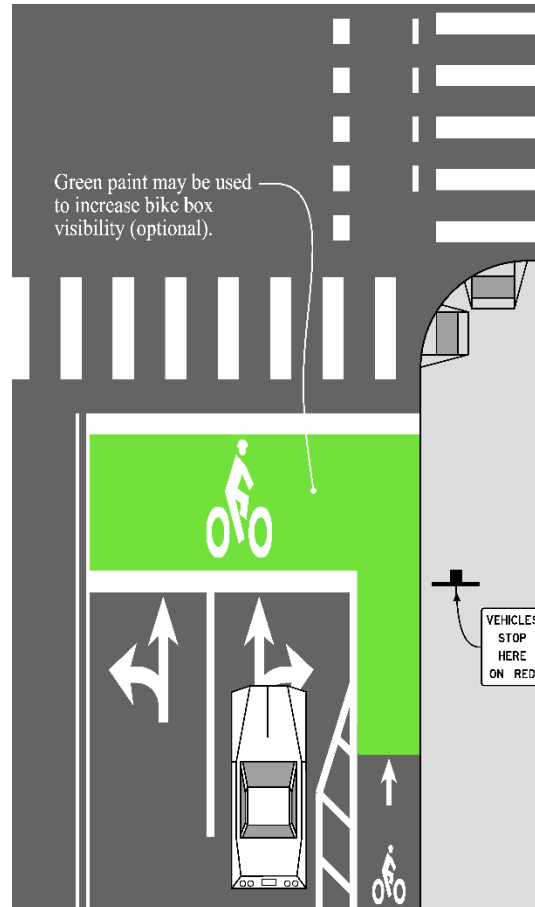
Source: Adapted from *Urban Bikeway Design Guide*, NACTO

The mixing zones and bicycle boxes may include an optional green pavement paint. If used, the green pavement paint must meet the MUTCD “Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes (IA-14).”

Bicycle boxes, which have experimental status by the MUTCD, are placed between the vehicle stop line and the pedestrian crosswalk. Bicycle boxes increase the visibility of bicyclists and provide them with the ability to start up and enter the intersection in front of motor vehicles when the signal turns green. Bicycle boxes are used at signalized

intersections with high volumes of bicycle left turns. The bicycle box should be a minimum of 10 feet deep and the combined width of the bicycle lane, the buffer space, and all of the adjacent same direction traffic lanes at the intersection. Bicycle boxes provide the opportunity for bicyclists to position for a left turn.

Figure 12B-3.08: Bicycle Box



Source: Adapted from *Urban Bikeway Design Guide*, NACTO

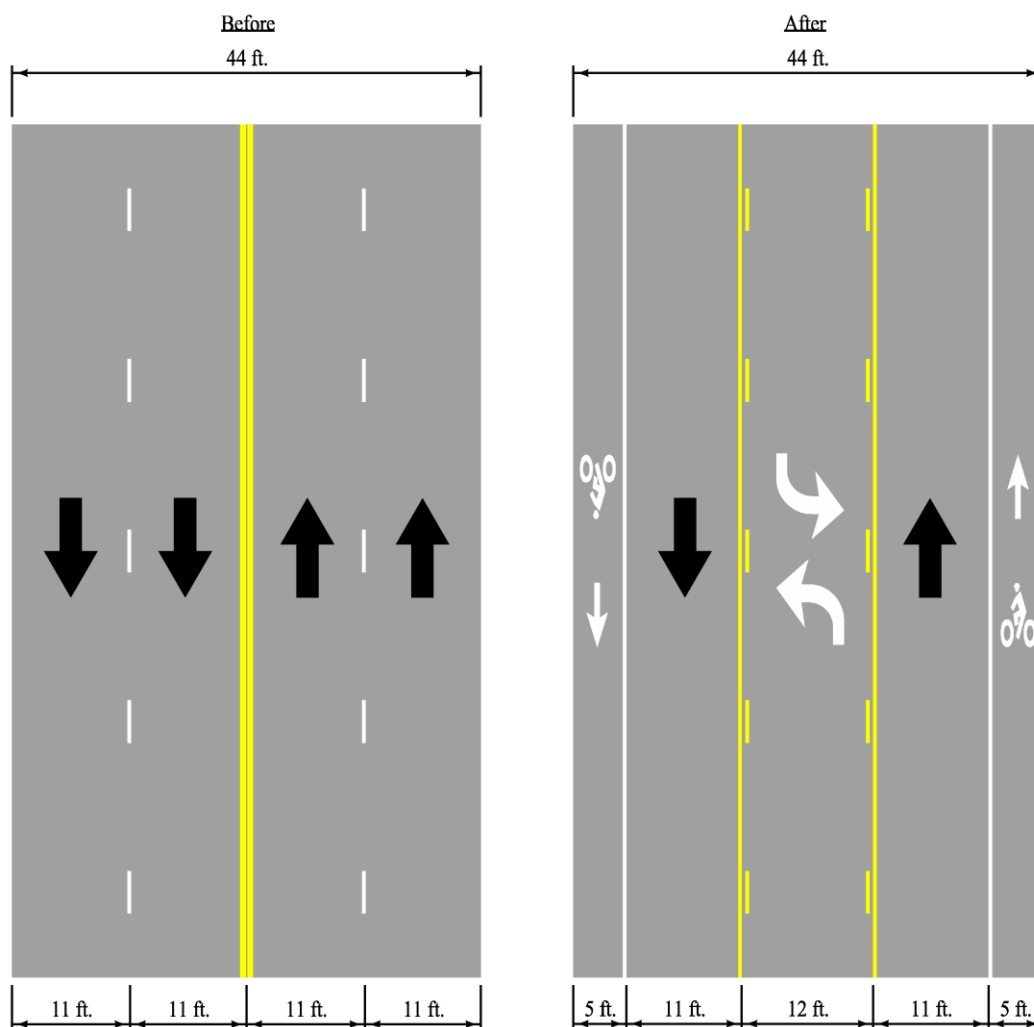
Bicycle signals may be used to separate bicycle through movements from vehicle movements for increased safety. They should only be used in combination with a conventional traffic signal. Bicycle signal heads use the traditional green, yellow, and red indications but have bicycle stenciled lenses. A supplemental “Bicycle Signal” plaque should be added below the bicycle signal head. A leading bicycle signal phase, which uses a bicycle signal lens to provide three to five seconds of green time before the corresponding vehicle green indication, can be used to increase the visibility and safety for bicyclists. Bicycle signal detection is critical to appropriate operation of a bicycle signal. There are four major types of bicycle detection including induction loop, video, push-button, and microwave.

Because drivers and bicyclists in Iowa are not familiar with the use of bicycle boxes and bicycle signals, it is critical to provide extensive educational information prior to implementing either of these strategies at urban intersections.

4. **Retrofitting Bicycle Facilities on Existing Roadways:** Existing streets and highways may be retrofitted to improve bicycle accommodations by either reconfiguring the travel lanes to accommodate bicycle lanes or by widening the roadway to accommodate bicycle lanes or paved

shoulders. These retrofits are best accomplished as either a reconstruction project or a repaving project as these projects will eliminate traces of old pavement markings. (AASHTO 4.9).

Figure 12B-3.09: Example of Road Diet



* Dimensions are illustrative

Source: Adapted from *AASHTO Bike Guide* Exhibit 4.23

- 5. Bicycle Boulevards:** A bicycle boulevard is described as a local street or a series of contiguous street segments that have been modified to function as a through street for cyclists while discouraging through vehicle traffic. To be effective, bicycle boulevards should be long enough to provide continuity over a distance of between 2 and 5 miles.

Due to the low traffic volumes and speeds, local streets naturally create a bicycle-friendly environment in which the cyclists share the roadway with the vehicles. However, many local streets are not continuous enough for long bicycle routes. Therefore, in order to create a bicycle boulevard, some short sections of paths or segments may need to be constructed between local streets in order to create the continuous route.

Some design elements that are involved in the design of bicycle boulevards are:

- Traffic diverters at key intersections that allow bicycle through traffic but reduce or deny vehicle traffic
- Two-way stop-controlled intersection that give the bicycle boulevard priority
- Neighborhood traffic circles or mini-roundabouts
- Traffic-calming features
- Wayfinding signs to guide bicyclists
- Shared lane markings where appropriate
- Bicycle-sensitive traffic signals at busy intersections
- Median refuges large enough for bicycles
- Curb extensions on crossed thoroughfare with on-street parking

It is important to note that before the design of a bicycle boulevards, an investigation of the proposed boulevards should be performed since many of the design elements listed may already be in use. (AASHTO 4.10).

D. Bicycle Guide Signs

Guide signs are an important element to all bicycle facilities as they help cyclists navigate to their destination. There are many guidelines and standards that go along with the type and placement of guide signs. See both the MUTCD and AASHTO 4.11.

E. Railroad Crossings for Bicycles

Where roadways or shared use paths cross railroad tracks on a diagonal, the designer should take care in the design of the crossing as to prevent steering difficulties for the cyclists. This includes:

- Increasing the skew angle between the tracks and the bicycle path to 60 degrees or greater so bicyclists can avoid catching their wheels in the flange of the tracks. This can be accomplished with reverse curves or with a widened shoulder.
- Creating a smooth crossing surface that will last over time and not be slippery when wet.
- Minimizing flange openings as much as possible. Under special rail conditions, rubber fillers products may be used. Contact the railroad company for approval prior to the design and installation of the fillers.

See both the MUTCD and AASHTO 4.12.1.

F. Obstruction Markings for Bicycle Lanes

The design of bicycle facilities should avoid obstruction and barriers as much as possible. However, in rare circumstance in which an obstruction or barrier cannot be avoided, signs, reflectors, and markings should be utilized to alert they cyclists. (AASHTO 4.12.2).

G. Traffic Signals for Bicycles

Traffic signals have traditionally been designed based off the operating characteristics of motor vehicles. However, at intersections with medium to high bicycle usage that incorporates shared lanes or bicycle lanes, traffic signal designers should include the characteristics of bicyclists to their traffic signals. The signal parameters that could be modified to accommodate bicyclists when appropriate are minimum green interval, all-red interval, and extension time. This information can be found in AASHTO 4.12.3 and 4.12.4 as well as the latest edition of the “Highway Capacity Manual.”

H. Bridges and Viaducts for Bicycles

Two considerations should be taken into account before the design of bicycle accommodations with bridges - the length of the bridge and the design of the approach roadway. If the bridge approach does not include bicycle accommodations, the bridge can still facilitate use by bicyclists by including a wide shoulder or bicycle lanes and include paved shoulder, shared lanes, or shared use path as part of the bridge project. Additionally, if the bridge is continuous and spans over a 1/2 mile in length with speed of excess of 45 mph, a concrete barrier separated shared use path on both sides of the bridge should be considered. By allowing paths on both sides of the bridge, wrong-way travel of the cyclists will be deterred. (AASHTO 4.12.5).

I. Traffic Calming and Management of Bicycles

There are many things that a designer can do to reduce the traffic speed of cyclists and to manage bicycles effectively. These things include narrowing streets to create a sense of enclosure; adding vertical deflections such as speed humps, speed tables, speed cushions, and raised sidewalks; adding curb extension or chokers; adding chicanes; installing traffic circles; and incorporating multi-way stops. (AASHTO 4.12.6 and 4.12.7).

J. Intake Grates and Manhole Castings for Bicycle Travel

It is important to have intake grate openings run perpendicular to the direction of travel as this will prevent bicycle wheels from dropping into the gaps and causing crashes. [SUDAS Specifications Figure 6010.603](#), Type R and Type S, are intake grates that are appropriate for use on bicycle routes. Where it is not immediately feasible to replace existing grates, metal straps can be welded across slots perpendicular to the direction of travel at a maximum longitudinal spacing of 4 inches. Additionally, open-throat intakes can be used instead of grate intakes in order to eliminate the grate all together. The presence of the depressed throat of the intake should be taken into account.

Surface grates and manhole castings should be flush with the roadway surface. In the case of overlays, the grates and castings should be raised to within 1/4 inch of the new surface. If this is not possible or practical, the pavement must taper into drainage inlets so it does not have an abrupt edge at the inlet. Take care in the design of the taper of the pavement around inlets and castings so to avoid “birdbaths” or low spots that are not drainable in the pavement. (AASHTO 4.12.8).

K. Bicycles at Interchanges

When designing bicycle facilities at interchanges, it is important to consider both safety and convenience for the cyclists. This is best achieved by designing right-angle intersection or single lane roundabouts at the intersection between the local route and the ramps. These designs promote low speeds, minimize conflict areas, and increase visibility. Additionally, stop signs or signals are encouraged for motorists turning from the off ramp to the local route rather than allowing a free-flowing movement as this will increase the safety of the cyclists.

At complex interchanges that include high-speeds and free-flowing motor vehicle movements, a well signed and clearly directed grade-separated crossings may be necessary. These grade-separated facilities should still include good visibility, be convenient, and consist of adequate lighting. (AASHTO 4.12.9).

L. Bicycles at Roundabouts

In designing roundabouts for bicycle usage, single lane roundabouts are safer and easier to navigate for cyclists. Multi-lane roundabouts include too many conflict points due to bicycle weaving/changing lanes and motorist cutting off cyclists when exiting the roundabout.

In instances of bicycle lanes approaching a roundabout, the bicycle lane should be terminated at least 100 feet from the edge of the entry curve of the roundabout and prior to the crosswalk. Also, prior to the roundabout and after the termination of the bicycle lane, a tapering of the bicycle lane to the travel lane should be provided. This is done to achieve the appropriate entry width for the roundabout and the taper should be 7:1 for a 20 mph design speed or 40 feet for a 5 to 6 foot bicycle lane. Additionally, the bicycle lane line should be dotted 50 to 200 feet in advance of the taper to encourage cyclists to merge into traffic.

In rare circumstances, bicyclists should be given the option to merge with traffic prior to the roundabout or exit onto the adjacent sidewalk via a ramp. These instances include multi-lane roundabouts, high design speed roundabouts, and/or complex roundabouts. However, in some jurisdictions, cyclists riding on sidewalks may be prohibited. In designing bicycle ramps prior to a roundabout, the following criteria should be followed:

- Place bicycle ramps at the end of the full width bicycle lane and just before the taper of the bicycle lane.
- Where no bicycle lane is present on the approach to the roundabout, a bicycle ramp should be placed at least 50 feet prior to the crosswalk at the roundabout.
- Bicycle ramps should be placed at a 35 to 45 degree angle to the roadway.
- If the ramp is placed outside of the sidewalk, it can have up to a 20% slope; if the ramp is placed within the sidewalk, it should be designed in a manner to prevent a tripping hazard.
- If the ramp is placed outside the sidewalk, a detectable warning device should be placed at the top of the ramp; if the ramp is placed within the sidewalk, the detectable warning device should be placed at the bottom of the ramp.
- Bicycle ramps should be placed relatively far from the marked crosswalk as to prevent pedestrians from mistaking the ramp as a crosswalk.

Bicycle ramps at the exits of roundabouts should be built with the similar geometry and placement as the ramps that are designed at roundabout entries. Bicycle ramps at the exits of roundabouts should be placed at least 50 feet beyond the crosswalk of the roundabout. Refer to AASHTO 4.12.10 and the FHWA Roundabout Guide.

M. References

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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](#)
- [Missouri DOT Traffic Control Devices](#)
- [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 - modified by [FHWA Interim Approval IA-19](#) (2/24/2017)

[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

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ASTM F 1871. *Standard Specification for Folder/Formed Poly (Vinyl Chloride) Pipe Type A for Existing Sewer and Conduit Rehabilitation*. ASTM International.

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