2024 Edition Revisions to the SUDAS Design Manual

To updated your printed manual, print this packet. Then 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 or a change in the page number. **PLEASE READ CAREFULLY - PAY ATTENTION TO THE SECTION NUMBER!** Included shading to help distinguish between chapters. Questions can be directed to Beth Richards - brich@iastate.edu. The current edition of the manual, with the latest revisions incorporated, can be found at www.iowasudas.org.

Chapter	***Section***	***pg #***	***Summary of Revision(s)***
Manual introductory info			Updated the Contributors and Acknowledgments page and the general table of contents. *Note - if you want to replace the small business card for the spine of your manual, you can print a copy from our website.*
1	1D-2	9-10; 19-22	Revised the "items to be specified" list based on corrections and SUDAS Specifications revisions.
	1D-3	5-6; 13-16; 25-28	Updated the "incidental or included items" list based on corrections and SUDAS Specifications revisions.
	1D-4	5-6; 9-10	Updated the "bid item" list based on corrections and SUDAS Specifications revisions.
2	Table of Contents	i-ii	Updated table of contents based on changes made to Chapter 2.
	2A-4, C	2	Updated to new NRCS region-specific storm distributions.
	2B-4, B	1-6	Modified discussions on minimum time of concentration.
	2B-4, C	11-13	Updated to new NRCS region-specific storm distributions.
	2B-5, C & D	3-5	Updated to new NRCS region-specific storm distributions. (Change resulted in additional page).
5	Table of Contents	i-ii; v	Updated table of contents based on changes made to Chapter 5.
	5C-1	ALL	Updated based on research project results.
	5C-2	ALL	Updated based on research project results. (Change resulted in additional pages).
	5D-1, Table 5D-1.01	4	Changed "less than or equal to 45 mph" to "any."
	5G-3, Figure 5G-3.15	17-19	Revised the spec figures that were issued last year.
	5M-1	ALL	Updated based on research project results. (Change resulted in additional pages).
7	Table of Contents	i-vi	Updated table of contents based on changes made to Chapter 7.
	7B-1, B & C	4-10	Updated the regulatory elements to match the new NPDES General Permit No. 2 requirements.
	7E-1	ALL	Revised based on Erosion and Sediment Control Committee input.
	7E-3	ALL	Revised based on Erosion and Sediment Control Committee input.
	7E-7	ALL	Revised based on Erosion and Sediment Control Committee input. (REMOVE page 5).
	7E-8	ALL	Revised based on Erosion and Sediment Control Committee input.

7 (con't)	7E-12	ALL	Revised based on Erosion and Sediment Control Committee input. (REMOVE pages 15-19).
	7E-13	ALL	Revised based on Erosion and Sediment Control Committee input (intentionally removed figure from page 4).
	7E-14	ALL	Revised based on Erosion and Sediment Control Committee input.
	7E-15	ALL	Revised based on Erosion and Sediment Control Committee input. Revised section title.
	7E-17	ALL	Revised based on Erosion and Sediment Control Committee input.
	7E-21	ALL	Revised based on Erosion and Sediment Control Committee input. Revised section title. (REMOVE page 3).
	7E-30 (NEW)	ALL	Developed NEW section based on Erosion and Sediment Control Committee input.
	7E-31 (NEW)	ALL	Developed NEW section based on Erosion and Sediment Control Committee input.
11	11A-1, B	2	Corrected Iowa Administrative Code reference.
12	ENTIRE CHAPTER	ALL	Updated ENTIRE CHAPTER based on research project results. (Added new Section 12A-5 for pedestrian safety measures at crossings).
13	Table of Contents	i	Updated table of contents based on changes made to Chapter 13.
	13A-3	ALL	Updated based on research project results.
	13A-4	ALL	Updated based on research project results. (Change resulted in additional pages).

Contributors and Acknowledgments

In 2023, SUDAS staff held many meetings to accomplish the various revisions reflected in the 2024 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.

SUDAS Corporation Board of Directors, 2023

Board Member	Government/Agency	Board Member	Government/Agency
Jenifer Bates	Iowa DOT	Aaron Lincoln	City of Sergeant Bluffs
Phillip Burgmeier	City of Ottumwa	Donna Matulac	Iowa DOT
Nick Buse	Calhoun/Sac Counties	Brent Morlok	City of Bettendorf
*David Carney	City of Sioux City	Mark Mueller	City of Ankeny
David Carroll	Warren County	Sarah Okerlund	Iowa DOT
Pamela Cooksey	City of Des Moines	Greg Parker	Johnson County
Matt Cox	City of Council Bluffs	Mark Rahm	City of Mason City
Ken DeKeyser	Hall & Hall Engineers	John Rasmussen	Pottawattamie County
Matt Ferrier	Bolton & Menk, Inc.	Brian Schadt	City of Davenport
John Gade	Fox Engineering	Bob Schiesl	City of Dubuque
Paul Geilenfeldt	Marshall County	Larry Stevens	HR Green, Inc.
Daniel Harness	Iowa DOT	Casey Stickfort	Clayton County
Eric Johnsen	Iowa DOT	*Michelle Sweeney	AECOM
*John Joiner	City of Ames	Michael Thiel	Iowa DOT
Ron Knoche	City of Iowa City	Ryne Thornburg	Van Buren County
Jamie Knutson	City of Waterloo	Lee Tippe	City of Cedar Rapids
Randy Krauel	City of Carroll	Bob Tobin	Shoemaker & Haaland
Jeff Krist	City of Council Bluffs	Dave Vermillion	City of Council Bluffs
*Scott Larson	City of Coralville	Tom Vlach	City of Des Moines

Advisory Member	Government/Agency	Advisory Member	Government/Agency
Steve Klocke	Snyder & Associates	Tara Naber	Iowa DNR
Darwin Larson	APAI	Ron Otto	AGC of Iowa
Greg Mulder	ICPA		

Staff	Position
Paul Wiegand	Program Director (until 7/14/2023)
David Carney	Program Director (starting 8/21/2023)
Beth Richards	Program Coordinator

* Denotes an officer

Table of Contents

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 preformed 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, I, 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, I, 5, b	Specify when surface tining is required. *Note - longitudinal tining is listed as the default.*
7010, 3.02, J, 1, a	Specify when the use of a linseed oil solution is required.
7010, 3.02, K, 1, a	Specify the type and locations for construction of joints.
7010, 3.02, K, 2, i	Specify when to use wet sawing for dust control.
7010, 3.02, K, 3, a	Specify the location of longitudinal and transverse construction joints.
7010, 3.02, K, 4, a	Specify the location of expansion joints.
7010, 3.07, C, 2, a	Specify when the use of an inertial profiler for pavement smoothness is required.
Figure 7010.101	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, 4, a	Specify the high spots in the existing asphalt surface to be milled.

Section 7020 - Asphalt Pavement

7020, 3.05, B, 1	Specify when the use of an inertial profiler for pavement smoothness is required.
7020, Table 7020.05	Specify if the field laboratory air voids target value is other than 4%.

Section 7021 - 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, I	Specify whenever the Contractor will be responsible for concrete compression or asphalt 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 pavers are to be used, specify the material requirements.
7030, 2.04, B	Specify the use of a pre-mixed high performance cold mix in lieu of an asphalt setting bed.
7030, 2.06	Specify the use of colored cement for brick/paver joint filler.
7030, 3.01, A-C	Specify removal limits of sidewalks, shared use paths, driveways, bricks, and curbs.
7030. 3.01, E	Specify the locations to grind or saw existing curbs to install sidewalks, shared use paths, and driveways.
7030, 3.04	Specify the line and running slope to construct sidewalks and shared use paths. Specify the cross slope.
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, 3.05	Specify the cross slope.
7030, 3.06, A, 2	Specify the cross-section and patterns to use for brick sidewalks with a concrete base.
7030, 3.11, A	Specify when testing will be the Contractor's responsibility.
Figure 7030.101	Specify the radius for commercial and industrial driveways. Specify when a 'B' joint is to be provided at the back of curb. Specify the driveway width. Specify when a 5 foot sidewalk is to be constructed through the driveway.
Figure 7030.102	Specify the radius for commercial and industrial driveways. Specify the driveway width. Specify when a 5 foot sidewalk is to be constructed through the driveway.
Figure 7030.104	Specify parking grading slope and property slope if different than 4:1.
Figure 7030.201	If a special grade is required for parking slopes, specify the grade. Specify the width of the sidewalk.
Figure 7030.202	Specify one of the curb details for Class A sidewalk.
Figure 7030.203	Specify the brick sidewalk pattern. Specify the jointing of the concrete base.

9040, 3.07, B	Specify when to remove the filter sock.
9040, 3.08, A, 2	Specify if placement of seed and fertilizer is to be accomplished before installation of temporary rolled erosion control products.
9040, 3.08, A, 3	Specify if placement of seed and fertilizer is to be accomplished on the anchor trench.
9040, 3.08, B, 1	Specify if placement of seed and fertilizer is to be accomplished before installation of temporary rolled erosion control products.
9040, 3.09, B	Specify when to remove the wattle.
9040, 3.10, A, 2	Specify when to provide an RECP under the check dam.
9040, 3.10, D	Specify when to remove check dams.
9040, 3.12, C	Specify the excavated depth behind the level spreader.
9040, 3.12, E	Specify the minimum depth of depression before accumulated sediment is removed.
9040, 3.15, B, 1	Specify the number, diameter, and configuration of holes in the riser section of sediment basin outlet structures.
9040, 3.17	Specify the size and elevations of sediment traps.
9040, 3.18, A, 1	Specify when the silt fence material is not 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.

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 not 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, 1, c	Specify PVC coating for chain link fence.
9060, 1.08, A, 2, c	Specify PVC coating for chain link fence.
9060, 1.08, B, 3	Specify the use of barbed wire for gates.

9060, 2.01, D, 2	Specify the PVC coating color.
9060, 2.02, A, 2	Specify the nominal diameter of fence height for post use, if other than shown in the table.
9060, 2.05, A	Specify the type of arm configuration for barbed wire supporting arms.
9060, 2.07, A	Specify the type, height, and width of gates.
9060, 3.01, A	Specify fence location and height.
9060, 3.01, B, 2, a	Specify post holes dimensions.
9060, 3.01, B, 2, e	Specify the required brace-post assembly.
9060, 3.01, G	Specify when to use barbed wire.
9060, 3.01, G, 1	Specify the installation of barbed wire, if other than 3 parallel wires on each barbed wire supporting arm on the outside of the area being secured.
9060, 3.01, H	Specify the installation requirements for gates.
9060, 3.01, I, 1	Specify the installation of electrical grounds.
9060, 3.02	Specify when all fences, including posts and footings, are not 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 not 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 not desired.
10,010, 3.08, E	Specify when the removal of all retaining walls is not desired.
10,010, 3.11	Specify what materials are required to be recycled from the demolition site.

Section 11,010 - Construction Survey

11,010, 1.02	Specify any additional items to be included in construction survey work.
11,010, 3.02, D	Specify if property limits are to be marked.

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.

4020, 1.08, A, 2, c	Storm Sewer, Trenchless Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; pipe connections; testing; and inspection.
4020, 1.08, B, 1, c	Storm Sewer with Casing Pipe, Trenched Furnishing and installing both carrier pipe and casing pipe; trench excavation; dewatering; furnishing, placing, and compacting bedding and backfill material; furnishing and installing annular space fill material; casing spacers; pipe connections; testing; and inspection.
4020, 1.08, B, 2, c	Storm Sewer with Casing Pipe, Trenchless Furnishing and installing both carrier pipe and casing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; casing spacers; furnishing and installing annular space fill material; pipe connections; testing; and inspection.
4020, 1.08, C, 3	Linear Trench Drain Furnishing and installing the linear trench drain including all appurtenances; furnishing and placement of PCC transition; furnishing, excavation, and backfill of discharge pipe; connection to manhole or intake, if required; installation of apron, if required.
4020, 1.08, D, 3	Removal of Storm Sewer Removal, disposal, and capping (if specified) of pipe; and furnishing, placing, and compacting backfill material.
4020, 1.08, F, 3	Storm Sewer Abandonment, Plug Trench excavation (if necessary), cutting pipe (if required), furnishing and placing plug materials, and placing and compacting backfill material.
4020, 1.08, G, 3	Storm Sewer Abandonment, Fill and Plug Trench excavation (if necessary), cutting pipe (if required), furnishing and placing pipe fill material, furnishing and placing plug materials, and placing and compacting backfill material.

Section 4030 - Pipe Culverts

4030, 1.08, A, 1, c	Pipe Culvert, Trenched Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; connectors; testing; and inspection.
4030, 1.08, A, 2, c	Pipe Culvert, Trenchless Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation, dewatering, and placing and compacting backfill material; pipe connections; testing; and inspection.
4030, 1.08, B, 3	Pipe Apron Trench excavation; dewatering; furnishing and installing the apron; furnishing, placing, and compacting bedding and backfill material; connectors; and other appurtenances.

4030, 1.08, C, 3 — Footing for Concrete Pipe Apron
Excavation; dewatering; reinforcing steel; concrete; furnishing, placing and compacting bedding and backfill material.

4030, 1.08, D, 3 — Pipe Apron Guard
Furnishing and installing the apron guard and repairing any damage to the apron from the installation process.

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, C, 1, c — Subdrain Cleanout
Trench excavation; furnishing cleanout and lid; and furnishing, placing, and compacting bedding and backfill material.

4040, 1.08, C, 2, c — Footing Drain Cleanout
Trench excavation; furnishing cleanout and lid; and furnishing, placing, and compacting bedding and backfill material.

4040, 1.08, D, 1, c — Subdrain Drain Outlets and Connections
Pipe, non-shrink grout, coupling bands, and rodent guards for pipes 6 inches or smaller.

4040, 1.08, D, 2, c — Footing Drain Outlets and Connections
Pipe, non-shrink grout, coupling bands, and rodent guards for pipes 6 inches or smaller.

4040, 1.08, E, 3 — Storm Sewer Service Stub
Trench excavation, furnishing bedding material, placing bedding and backfill material, tap, fittings, and plugs.

Section 4050 - Pipe Rehabilitation

4050, 1.08, A, 1, c — Pre-Rehabilitation Cleaning and Inspection
Pre-cleaning CCTV inspection, light sewer cleaning, debris removal and transport, post cleaning CCTV inspection for Engineer review, and identification and logging of active service taps. If specified in the contract documents, unit price also includes disposal and associated costs for all debris removed from sewer.

4050, 1.08, A, 2, c — Additional Sewer Cleaning
Heavy sewer cleaning; root cutting; deposit cutting; and removing, transporting, disposing, paying associated costs for all debris removed from sewer, and post cleaning CCTV inspection for Engineer review.

6020, 1.08, D, 3 Manhole Lining with Centrifugally Cast Cementitious Mortar Liner with Epoxy Seal
Handling of sewer flows during lining operations as required to properly complete the installation, and replacement of the existing casting with a new casting.

Section 6030 - Cleaning, Inspection, and Testing of Structures

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

Section 7010 - Portland Cement Concrete Pavement

7010, 1.08, A, 3 Pavement, PCC
Final trimming of subgrade or subbase, integral curb, bars and reinforcement, joints and sealing, surface curing and pavement protection, safety fencing, concrete for rigid headers, boxouts for fixtures, and pavement smoothness testing.

7010, 1.08, E, 3 Curb and Gutter
Final subgrade/subbase preparation, bars and reinforcement, joints and sealing, surface curing and pavement protection, and boxouts for fixtures.

7010, 1.08, F, 3 Beam Curb
Final subgrade/subbase preparation, bars and reinforcement, joints and sealing, surface curing and pavement protection, and boxouts for fixtures.

7010, 1.08, G, 3 Concrete Median
Final subgrade/subbase preparation, bars and reinforcement, joints and sealing, surface curing and pavement protection, and boxouts for fixtures.

7010, 1.08, H, 3 PCC Railroad Crossing Approach
Excavation for modified subbase and subdrain, furnishing and installing subdrain, furnishing and installing subdrain outlet or connection to storm sewer, furnishing and installing porous backfill material, furnishing and placing modified subbase material, furnishing and installing reinforcing steel and tie bars, furnishing and placing concrete, furnishing, placing, and compacting asphalt.

7010, 1.08, I, 3 PCC Pavement Samples and Testing
Certified plant inspection, pavement thickness cores, 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.
7011, 1.08, A, 3, c	Surface Preparation for Bonded PCC Overlay Sandblasting, shot blasting, scarification, and surface cleaning.
7011, 1.08, A, 4, c	Surface Preparation for Unbonded PCC Overlay Scarification and surface cleaning.
7011, 1.08, A, 5, c	Asphalt Separation Layer for Unbonded PCC Overlay Asphalt mix, including asphalt binder.
7011, 1.08, A, 6, c	Geotextile Fabric Separation Layer for Unbonded PCC Overlay Cleaning surface and furnishing, placing, and securing the geotextile fabric separation layer.
7011, 1.08, A, 7, c	Liquid Curing Compound Separation Layer on PCC Surface Patches for Unbonded PCC Overlay Cleaning PCC surface patches and furnishing and placing the liquid curing compound.

Section 7020 - Asphalt Pavement

7020, 1.08, A, 3	Pavement, Asphalt (by ton) Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
7020, 1.08, B, 3	Pavement, Asphalt (by square yard) Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
7020, 1.08, C, 3	Asphalt Base Widening (by ton) Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
7020, 1.08, D, 3	Asphalt Base Widening (by square yard) Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
7020, 1.08, E, 3	Asphalt Railroad Crossing Approach Excavation for modified subbase and subdrain, furnishing and installing subdrain, furnishing and installing subdrain outlet, furnishing and installing porous backfill material, furnishing and placing modified subbase material, furnishing and applying tack coat, furnishing, placing, and compacting asphalt.

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

Section 7021 - Asphalt Overlays

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

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

Section 7030 - Sidewalks, Shared Use Paths, and Driveways

7030, 1.08, A, 1, c — Removal of Sidewalk
Sawing, hauling, and disposal of materials removed.

7030, 1.08, A, 2, c — Removal of Shared Use Path
Sawing, hauling, and disposal of materials removed.

7030, 1.08, A, 3, c — Removal of Driveway
Sawing, hauling, and disposal of materials removed.

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

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

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

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

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

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

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

7030, 1.08, H, 2, c Driveway, Granular (by square yards)
Excavation and preparation of subgrade.

7030, 1.08, H, 3, c Driveway, Granular (by tons)
Excavation and preparation of subgrade.

Section 7040 - Pavement Rehabilitation

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

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

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

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

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

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

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

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

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

7040, 1.08, I, 3 Curb and Gutter Removal
Sawing, breaking, removing, and disposing of existing curb and gutter.

9040, 1.08, J, 3	<u>Rip Rap</u> Engineering fabric.
9040, 1.08, K, 3	<u>Temporary Pipe Slope Drain</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</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</u> Anchoring posts.
9040, 1.08, N, 2, c	<u>Silt Fence or Silt Fence Ditch Check, Removal of Sediment</u> Anchoring posts.
9040, 1.08, N, 3, c	<u>Silt Fence or Silt Fence Ditch Check, Removal of Device</u> Restoration of the area to finished grade and off-site disposal of fence, posts, and accumulated sediment.
9040, 1.08, O, 1, c	<u>Stabilized Construction Entrance (by Square Yard)</u> Subgrade stabilization fabric.
9040, 1.08, O, 2, c	<u>Stabilized Construction Entrance (by Ton)</u> Subgrade stabilization fabric.
9040, 1.08, P, 1, c	<u>Dust Control, Water</u> Furnishing, transporting, and distributing water to the haul road.
9040, 1.08, P, 2, c	<u>Dust Control Product</u> Furnishing and incorporating the dust control product.
9040, 1.08, Q, 1, c	<u>Erosion Control Mulching, Conventional</u> Furnishing and incorporating mulch in the area designated in the contract documents.

9040, 1.08, Q, 2, c — Erosion Control Mulching, Hydromulching
Furnishing mulch and tackifier (if applicable), providing equipment specific to hydromulching, and applying the mulch to the specified area.

9040, 1.08, R, 3 — Turf Reinforcement Mats
Excavation, staples, anchoring devices, and material for anchoring slots.

9040, 1.08, S, 3 — Surface Roughening
Providing equipment to complete directional tracking or grooving/furrowing and completing surface roughening of slopes specified in the contract documents.

9040, 1.08, T, 1, c — Inlet Protection Device
Removal of the device upon completion of the project.

9040, 1.08, T, 2, c — Inlet Protection Device, Maintenance
Removal and off-site disposal of accumulated sediment.

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

9040, 1.08, V, 3 — End of Season Temporary Erosion Control
Furnishing, placing, and maintaining the end of season temporary erosion control throughout the winter season.

Section 9050 - Gabions and Revet Mattresses

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

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

Section 9060 - Chain Link Fence

9060, 1.08, A, 1, c — Chain Link Fence, Residential
Posts, fabric, rails, fitting, ties, PVC coating (if specified in the contract documents), excavation of post holes, and concrete encasement of posts.

9060, 1.08, A, 2, c — Chain Link Fence, Commercial
Posts, fabric, rails, braces, truss rods, ties, tension wire, tension bands, tension bars, grounds, fittings, PVC coating (if specified in the contract documents), excavation of post holes, and concrete encasement of posts.

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

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

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

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

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

Section 9070 - Landscape Retaining Walls

9070, 1.08, A, 3 — Modular Block Retaining Wall
Excavation, foundation preparation, furnishing and placing wall units, geogrid (if necessary), leveling pad, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, granular backfill material, suitable backfill material, and shoring as necessary.

9070, 1.08, B, 3 — Limestone Retaining Wall
Excavation, foundation preparation, furnishing and placing leveling pad, limestone, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, suitable backfill material, and shoring as necessary.

9070, 1.08, C, 3 — Landscape Timbers
Excavation, foundation preparation, furnishing and placing leveling pad, landscape timbers, spikes, reinforcing bar, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, suitable backfill material, and shoring as necessary.

Section 9071 - Segmental Block Retaining Walls

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

9071, 1.08, C, 3 — Granular Backfill Material
Furnishing, transporting, placing, and compacting material.

Section 9072 - Combined Concrete Sidewalk and Retaining Walls

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

Section 9080 - Concrete Steps, Handrails, and Safety Rail

9080, 1.08, A, 3 — Concrete Steps
Reinforcement, expansion joint material, and preparation of subgrade.

9080, 1.08, B, 3 — Handrail
Posts, mounting hardware or concrete grout, and finishing (painted, galvanized, or powder coated).

9080, 1.08, C, 3 — Safety Rail
Posts, concrete for ground mounting, pickets, mounting hardware, epoxy grout, and finishing (painted, galvanized, or powder coated).

Section 10,010 - Demolition

10,010, 1.08, A, 3 — Demolition Work
Removal of trees, brush, vegetation, buildings, building materials, contents of buildings, appliances, trash, rubbish, basement walls, foundations, sidewalks, steps, and driveways from the site; disconnection of utilities; furnishing and compaction of backfill material; furnishing and placing topsoil; finish grading of disturbed areas; placing and removing safety fencing; removal of fuel and septic tanks and cisterns; seeding; and payment of any permit or disposal fees.

10,010, 1.08, B, 3 — Plug or Abandon Well
Obtaining all permits; plug or abandon private wells according to local, state, and federal regulations.

Section 11,010 - Construction Survey

11,010, 1.08, A, 3 — Construction Survey
The costs of resetting project control points, re-staking, and any additional staking requested beyond the requirements of this section.

11,010, 1.08, B, 3 — Monument Preservation and Replacement
Property research and documentation, locating monuments prior to construction, replacement of disturbed monuments, and preparation and filing of the monument preservation certificate.

Section 11,020 - Mobilization

11,020, 1.07, B — When the proposal form does not include a bid item for mobilization, all costs incurred by the contractor for mobilization are incidental to other work and no separate payment will be made.

11,020, 1.08, A, 3 — Mobilization
The movement of personnel, equipment, and supplies to the project site; the establishment of offices, buildings, and other facilities necessary for the project; and bonding, permits, and other expenses incurred prior to construction.

Item No.	Item Description	Unit
Section 7011 - Portland Cement Concrete Overlays		
7011-A-1	PCC Overlay, Furnish Only	CY
7011-A-2	PCC Overlay, Place Only	SY
7011-A-3	Surface Preparation for Bonded PCC Overlay	SY
7011-A-4	Surface Preparation for Unbonded PCC Overlay	SY
7011-A-5	Asphalt Separation Layer for Unbonded PCC Overlay	SY
7011-A-6	Geotextile Fabric Separation Layer for Unbonded PCC Overlay	SY
7011-A-7	Liquid Curing Compound Separation Layer on PCC Surface Patches for Unbonded PCC Overlay	SY
Section 7020 - Asphalt Pavement		
7020-A	Pavement, Asphalt, ____ (Mix Design Level), ____ (Layer), ____ (Aggregate Size), ____ (Binder Grade),	TON
7020-B	Pavement, Asphalt, ____ (Mix Design Level), ____ (Thickness), ____ (Layer), ____ (Aggregate Size), ____ (Binder Grade)	SY
7020-C	Asphalt Base Widening, ____ (Mix Design Level), ____ (Layer), ____ (Aggregate Size), ____ (Binder Grade)	TON
7020-D	Asphalt Base Widening, ____ (Mix Design Level), ____ (Thickness), ____ (Layer), ____ (Aggregate Size), ____ (Binder Grade),	SY
7020-E	Asphalt Railroad Crossing Approach	SY
7020-I	Asphalt Pavement Samples and Testing	LS
Section 7021 - Asphalt Overlays		
7021-A	Asphalt Overlay, ____ (Layer), ____ (Aggregate Size), ____ (Binder Grade), ____ (Mix Design Level)	TON
7021-B	Asphalt Overlay, ____ (Thickness), ____ (Layer), ____ (Aggregate Size), ____ (Binder Grade), ____ (Mix Design Level)	SY
Section 7030 - Sidewalks, Shared Use Paths, and Driveways		
7030-A-1	Removal of Sidewalk	SY
7030-A-2	Removal of Shared Use Path	SY
7030-A-3	Removal of Driveway	SY
7030-B	Removal of Curb	LF
7030-C	Shared Use Path, ____ (Type), ____ (Thickness)	SY
7030-D	Special Subgrade Preparation for Shared Use Path	SY
7030-E	Sidewalk, PCC, ____ (Thickness)	SY
7030-F	Brick/Paver Sidewalk with Pavement Base	SY
7030-G	Detectable Warnings	SF
7030-H-1	Driveway, Paved, ____ (Type), ____ (Thickness)	SY
7030-H-2	Driveway, Granular, ____ (Thickness)	SY
7030-H-3	Driveway, Granular, ____ (Thickness)	TON
7030-I-1	Sidewalk Assurance Testing	LS
7030-I-2	Shared Use Path Assurance Testing	LS
7030-I-3	Driveway Assurance Testing	LS
Section 7040 - Pavement Rehabilitation		
7040-A	Full Depth Patches, ____ (Type), ____ (Thickness)	SY
7040-B	Subbase Over-excavation	TON
7040-C	Partial Depth Patches, ____ (Type)	SF

Item No.	Item Description	Unit
7040-D	Crack and Joint Cleaning and Filling, Hot Pour	LF
7040-E-1	Crack Cleaning and Filling, Emulsion	LF
7040-E-2	Asphalt for Crack Filling	TON
7040-F	Diamond Grinding	SY
7040-G	Milling	SY
7040-H	Pavement Removal	SY
7040-I	Curb and Gutter Removal	LF
7040-J	Dowel Bar Retrofit, ____ (Size)	EA
7040-K	Core Hole Cutting and Replacement	EA
Section 7050 - Asphalt Stabilization		
7050-A	Asphalt Stabilization	SY
Section 7060 - Bituminous Seal Coat		
7060-A	Bituminous Seal Coat	SY
7060-B-1	Cover Aggregate	TON
7060-B-2	Binder Bitumen	GAL
Section 7070 - Emulsified Asphalt Slurry Seal		
7070-A	Emulsified Asphalt Slurry Seal	SY
7070-B-1	Aggregate	TON
7070-B-2	Asphalt Emulsion	GAL
Section 7080 - Permeable Interlocking Pavers		
7080-B	Engineering Fabric	SY
7080-C	Underdrain, ____ (Type), ____ (Size)	LF
7080-D	Storage Aggregate	TON
7080-E	Filter Aggregate	TON
7080-F	Permeable Interlocking Pavers, ____ (Type)	SY
7080-G	PCC Edge Restraint, ____ (Type), ____ (Size)	LF
Section 7090 - Cold-in-Place Pavement Recycling		
7090-A	Cold-in-Place Recycling	SY
7090-B	Bituminous Recycling Agents	GAL
7090-C	Chemical Recycling Additives	TON
Section 7091 - Full Depth Reclamation		
7091-A	Full Depth Reclamation	SY
7091-B	Mechanical Stabilization Agents	TON
7091-C	Bituminous Stabilization Agents	GAL
7091-D	Chemical Stabilization Agents	TON
7091-E	Microcracking	SY
7091-F	Interlayer for Cement Stabilized Base, ____ (Type), ____ (Thickness)	SY
Section 7092 - Crack and Seat Existing PCC Pavement		
7092-A	Crack and Seat of PCC Pavement	SY
7092-B	Remove and Replace Curb and Gutter, ____ (Type), ____ (Size)	LF
7092-C	Full Depth Saw Cut	LF
7092-G	Intake Adjustment, Major	EA

Item No.	Item Description	Unit
9040-R	Turf Reinforcement Mats, ____ (Type)	SQ
9040-S	Surface Roughening	SF
9040-T-1	Inlet Protection Device, ____ (Type)	EA
9040-T-2	Inlet Protection Device, Maintenance	EA
9040-U	Flow Transition Mat	SF
9040-V	End of Season Temporary Erosion Control	AC
Section 9050 - Gabions and Revet Mattresses		
9050-A	Gabions, ____ (Type)	CY
9050-B	Revet Mattresses, ____ (Type)	CY
Section 9060 - Chain Link Fence		
9060-A-1	Chain Link Fence, Residential, ____ (Type), ____ (Size)	LF
9060-A-2	Chain Link Fence, Commercial, ____ (Type), ____ (Size)	LF
9060-B	Gates, ____ (Type), ____ (Size)	EA
9060-C	Barbed Wire, ____ (Type of Supporting Arm)	LF
9060-D	Removal and Reinstallation of Existing Fence, ____ (Type), ____ (Size)	LF
9060-E	Removal of Fence	LF
9060-F	Temporary Fence, ____ (Type), ____ (Size)	LF
Section 9070 - Landscape Retaining Walls		
9070-A	Modular Block Retaining Wall	SF
9070-B	Limestone Retaining Wall	SF
9070-C	Landscape Timbers	SF
Section 9071 - Segmental Block Retaining Walls		
9071-A	Segmental Block Retaining Wall	SF
9071-C	Granular Backfill Material	TON
Section 9072 - Combined Concrete Sidewalk and Retaining Wall		
9072-A	Combined Concrete Sidewalk and Retaining Wall	CY
Section 9080 - Concrete Steps, Handrails, and Safety Rail		
9080-A	Concrete Steps, ____ (Type)	SF
9080-B	Handrail, ____ (Type)	LF
9080-C	Safety Rail	LF
Section 10,010 - Demolition		
10,010-A	Demolition Work	LS
10,010-B	Plug or Abandon Well	EA
Section 11,010 - Construction Survey		
11,010-A	Construction Survey	LS
11,010-B	Monument Preservation and Replacement	LS
Section 11,020 - Mobilization		
11,020-A	Mobilization	LS
Section 11,030 - Temporary Services During Construction		
11,030-A	Maintenance of Postal Service	LS
11,030-B	Maintenance of Solid Waste Collection	LS

Item No.	Item Description	Unit
Section 11,040 - Temporary Sidewalk Access		
11,040-A	Temporary Pedestrian Residential Access	SY
11,040-B	Temporary Granular Sidewalk	SY
11,040-C	Temporary Longitudinal Channelizing Device	LF
Section 11,050 - Concrete Washout		
11,050-A	Concrete Washout	LS

B. Supplemental Bid Items

When a new bid item needs to be created, the following format is suggested:

1. If the bid item falls within a SUDAS Specifications Section, but is not identified in SUDAS, use the four digit section number, followed by 999, then a letter. For example, if you want to add a new bid item for sanitary sewers, use 4010-999-A.

2. If the bid item generally falls within a SUDAS Specifications Division (broader category), but is not identified as a particular SUDAS Specifications Section, use the division number, followed by 999, then a letter. For example, if you add pipe bursting and want the bid items organized with the other pipe items, use 4999-A. Or if a supplemental specifications section has been created, the first four digits should match the numbers used in the supplemental. In that instance, it is suggested to use the division number as the first digit, followed by a 9, and then the next numbers as you see fit.

3. If the bid item does not fall within a SUDAS Specifications Division or Section, use 0000, followed by 999, then a letter. For example, 0000-999-A.

4. When making modifications to a standard SUDAS bid item, be sure to address such modifications in the estimate reference notes.

Table of Contents

Chapter 2 - Stormwater

2A General Information

2B Urban Hydrology and Runoff

2C Pavement Drainage and Intake Capacity

Project Drainage Report

A. Purpose

The purpose of the project drainage report is to identify and propose specific solutions to stormwater runoff and water quality problems resulting from existing and proposed development. The report must include adequate topographic information (pre- and post-development) to verify all conclusions regarding offsite drainage. Unless known, the capacity of downstream drainage structures must be thoroughly analyzed to determine their ability to convey the developed discharge.

The drainage report and plan will be reviewed and approved by the Jurisdictional Engineer prior to preparation of final construction drawings. Approval of these preliminary submittals constitutes only a conceptual approval and should not be construed as approval of specific design details. The Project Engineer may be required by law to submit the drainage report and plan to the Iowa DNR and/or USACE. An application for a permit to construct will follow the Iowa DNR and NPDES applicable permit requirements and USACE rules and regulations, and the application will be the responsibility of the Project Engineer.

B. Instructions for Preparing Report

1. Include a cover sheet with project name and location, name of firm or agency preparing the report, Professional Engineer's signed and sealed certification, and table of contents. Number each page of the report.

2. Perform all analyses according to the intent of professionally recognized methods. Support any modifications to these methods with well documented and industry accepted research.

3. It is the designer's responsibility to provide all data requested. If the method of analysis (for example, a computer program) does not provide the required information, then the designer will select alternative or supplemental methods to ensure the drainage report is complete and accurate.

4. Acceptance of a drainage report implies the Jurisdiction concurs with the project's overall stormwater management concept. This does not constitute full acceptance of the improvement plans, alignments, and grades, since constructability issues may arise in plan review.

5. Use all headings listed in the contents (Section 2A-4, C). A complete report will include all the information requested in this format. If a heading listed does not apply, include the heading and briefly explain why it does not apply. Include additional information and headings as required to develop the report.

6. This manual does not preclude the utilization of methods other than those referenced, nor does it relieve the designer of responsibility for analysis of issues not specifically mentioned.

C. Contents

The following information contains summaries for hydrology and detention (see Tables 2A-4.01, 2A-4.02, and 2A-4.03), as well as design considerations for the preparation of project drainage reports. They are provided as a minimum guide and are not to be construed as the specific information to be supplied on every project drainage report, and other information may be required. Existing and proposed conditions for each development will require analysis unique to that area.

1. Site Characteristics:

a. **Pre-development Conditions:** Describe pre-developed land use, topography, drainage patterns (including overland conveyance of the 100 year storm event), storm sewer, ditches, and natural and man-made features. Describe ground coverage, soil type, and physical properties, such as hydrologic soil group and infiltration. If a geotechnical study of the site is available, provide boring logs and locations in the appendix of the report. If a soil survey was used, cite it in the references.

   For the pre-development analysis where the area is rural and undeveloped, a land use description reflecting current use is typical; however, the jurisdiction may apply more stringent requirements due to downstream drainage conditions. In addition, some jurisdictions require use of pre-settlement (meadow) conditions for all development. The jurisdiction should be contacted to determine what pre-development conditions are required.

b. **Post-development Conditions:** Describe post-developed land use and proposed grading, change in percent of impervious area, and change in drainage patterns. If an existing drainage way is filled, the runoff otherwise stored by the drainage way will be mitigated with stormwater detention, in addition to the post-development runoff.

c. **Contributing Off-site Drainage:** Describe contributing off-site drainage patterns, land use, and stormwater conveyance. Identify undeveloped contributing areas with development potential and list assumptions about future development runoff contributed to the site.

d. **Floodways, Floodplains, and Wetlands:** Identify areas of the site located within the floodway or floodplain boundaries as delineated on Flood Insurance Rate Maps, or as determined by other engineering analysis. Identify wetland areas on the site, as delineated by the National Wetlands Inventory, or as determined by a specific wetland study.

e. **Pre-development Runoff Analysis:**
   1) **Watershed Area:** Describe overall watershed area and relationship between other watersheds or sub-areas. Include a pre-development watershed map in the report appendix.
   2) **Time of Concentration:** Describe method used to calculate the time of concentration. Describe runoff paths and travel times through sub-areas. Show and label the runoff paths on the pre-development watershed map.
   3) **Precipitation Model:** Describe the precipitation model and rainfall duration used for the design storm. Typical models may include one or more of the following:
      a) NRCS MSE3 or MSE4 Rainfall Distribution.
      b) Huff Rainfall Distribution. Select the appropriate distribution based on rainfall duration.
      c) Frequency-Based Hypothetical Storm.
      d) Rainfall Intensity Duration Frequency (IDF) Curve.
      e) User-defined model based on collected precipitation data, subject to the Jurisdictional Engineer's approval. Total rainfall amounts for given frequency and duration should

Runoff and Peak Flow

A. Introduction

Determining the volume and peak rate of runoff from a site is critical in designing and signing stormwater infrastructure including storm sewer, ditches, culverts, and detention basins. The common methods used to evaluate stormwater runoff include the Rational method for determination of peak flow and SCS methods for determination of both peak flow and runoff volume.

B. Rational Method

The Rational equation is commonly used for design in developed urban areas. The Rational equation is given as:

$$Q_T = Ci_TA$$ **Equation 2B-4.01**

where:

Q_T = estimate of the peak rate of runoff (cfs) for some recurrence interval, T
C = runoff coefficient; fraction of runoff, expressed as a dimensionless decimal fraction, that appears as surface runoff from the contributing drainage area.
i_T = average rainfall intensity (in/hr) for some recurrence interval, T, during that period of time equal to the T_c.
A = the contributing drainage area (acres) to the point of design that produces the maximum peak rate of runoff.
T_c = Time of concentration, minutes.

1. Rational Method Characteristics:

a. When using the Rational formula, an assumption is made that the maximum rate of flow is produced by a constant rainfall, which is maintained for a time equal to the time of concentration, which is the time required for the surface runoff from the most remote part of the drainage basin to reach the point being considered. There are other assumptions used in the Rational method, and thus the designer or engineer should consider how exceptions or other unusual circumstances might affect those results.
   1) The rainfall is uniform in space over the drainage area being considered.
   2) The rainfall intensity remains constant during the time period equal to the time of concentration.
   3) The runoff frequency curve is parallel to the rainfall frequency curve. This implies that the same value of the runoff coefficient is used for all recurrence intervals. In practice, the runoff coefficient is adjusted with a frequency coefficient (Cf) for the 25 year through 100 year recurrence intervals.
   4) The drainage area is the total area tributary to the point of design.

b. The following are additional factors that might not normally be considered, yet could prove important:
   1) The storm duration gives the length of time over which the average rainfall intensity (i_T) persists. Neither the storm duration, nor i_T, says anything about how the intensity varies during the storm, nor do they consider how much rain fell before the period in question.
   2) A 20% increase or decrease in the value of C has a similar effect as changing a 5 year recurrence interval to a 15 year or a 2 year interval, respectively.
   3) The chance of all design assumptions being satisfied simultaneously is less than the chance that the rainfall rate used in the design will actually occur. This, in effect, creates a built-in factor of safety.
   4) In an irregularly-shaped drainage area, a part of the area that has a short time of concentration (T_c) may cause a greater runoff rate (Q) at the intake or other design point) than the runoff rate calculated for the entire area. This is because parts of the area with long concentration times are far less susceptible to high-intensity rainfall. Thus, they skew the calculation.
   5) A portion of a drainage area that has a value of C much higher than the rest of the area may produce a greater amount of runoff at a design point than that calculated for the entire area. This effect is similar to that described above. In the design of storm sewers for small subbasin areas such as a cul-de-sac in a subdivision, the designer should be aware that an extremely short time of concentration will result in a high estimate of the rainfall intensity and the peak rate of runoff. The time of concentration estimates should be checked to make sure they are reasonable.
   6) When utilizing the Rational Method for street intake design (spacing, street spread calculations, and storm sewer pipe sizing) a minimum T_c of 15 minutes may be used. Using T_c values lower than 15 minutes may result in an overly conservative design with unnecessarily short intake spacing and over-sized storm sewer pipes. T_c values less than 15 minutes for street intake spacing may still be appropriate based on engineering judgement and the size and shape of the drainage area. When not using the Rational Method for street intake spacing, the appropriately calculated T_c should be used.
   7) In some cases, runoff from a portion of the drainage area that is highly-impervious may result in a greater peak discharge than would occur if the entire area was considered. In these cases, adjustments can be made to the drainage area by disregarding those areas where flow time is too slow to add to the peak discharge. Sometimes it is necessary to estimate several different times of concentration to determine the design flow that is critical for a particular application.
   8) When designing a drainage system, the overland flow path is not necessarily the same before and after development and grading operations have been completed. Selecting overland flow paths in excess of 100 feet in urban areas and 300 feet in rural areas should be done only after careful consideration.

2. Rational Method Limitations: The use of the rational formula is subject to several limitations and procedural issues in its use.

a. The most important limitation is that the only output from the method is a peak discharge (the method provides only an estimate of a single point on the runoff hydrograph).

b. The average rainfall intensities used in the formula have no time sequence relation to the actual rainfall pattern during the storm.

c. The computation of T_c should include the overland flow time, plus the time of flow in open and/or closed channels to the point of design.

d. The runoff coefficient, C, is usually estimated from a table of values (see Table 2B-4.01). The user must use good judgment when evaluating the land use in the drainage area under consideration. Note in Table 2B-4.01, that the value of C will vary with the return frequency.

e. Many users assume the entire drainage area is the value to be entered in the Rational method equation. In some cases, the runoff from the only interconnected impervious area yields the larger peak flow rate.

f. Studies and experience have shown that the Rational method tends to underestimate runoff rates for large drainage areas. This is due, in part, to the fact that a difference can exist between intense point rainfall (rainfall over a small area) and mean catchment area rainfall (average rainfall). For these reasons, use of the Rational method should be limited to drainage areas 40 acres or less.

3. Use of the Rational Method:

a. Runoff Coefficient: The runoff coefficient (C) represents the integrated effects of infiltration, evaporation, retention, flow routing, and interception; all of which affect the time distribution and peak rate of runoff. The runoff coefficient is the variable of the Rational method that requires the most judgment and understanding on the part of the designer. While engineering judgment will always be required in the selection of runoff coefficients, a typical coefficient represents the integrated effects of many drainage basin parameters. The Engineer should realize the C values shown in Table 2B-4.01 are typical values, and may have to be adjusted if the site deviates from typical conditions such as an increase or decrease in percent impervious.

The values are presented for different surface characteristics, as well as for different aggregate land uses. The coefficient for various surface areas can be used to develop a composite value for a different land use. The runoff values for business, residential, industrial, schools, and railroad yard areas are an average of all surfaces typically found in the particular land use.

The hydrologic soil groups used in Table 2B-4.01 are discussed in detail later in this section.

Table 2B-4.01: Runoff Coefficients for the Rational Method

Cover Type and Hydrologic Condition		**Runoff Coefficients for Hydrologic Soil Group**											
		A			***B***			***C***			***D***		
	Recurrence Interval	***5***	***10***	***100***	***5***	***10***	***100***	***5***	***10***	***100***	***5***	***10***	***100***
Open Space (lawns, parks, golf courses, cemeteries, etc.)													
Poor condition (grass cover < 50%)		.25	.30	.50	.45	.55	.65	.65	.70	.80	.70	.75	.85
Fair condition (grass cover 50% to 75%)		.10	.10	.15	.25	.30	.50	.45	.55	.65	.60	.65	.75
Good condition (grass cover >75%)		.05	.05	.10	.15	.20	.35	.35	.40	.55	.50	.55	.65
Impervious Areas													
Parking lots, roofs, driveways, etc. (excluding ROW)		.95	.95	.98	.95	.95	.98	.95	.95	.98	.95	.95	.98
Streets and roads:													
Paved; curbs & storm sewers (excluding ROW)		.95	.95	.98	.95	.95	.98	.95	.95	.98	.95	.95	.98
Paved; open ditches (including ROW)		---	---	---	.70	.75	.85	.80	.85	.90	.80	.85	.90
Gravel (including ROW)		---	---	---	.60	.65	.75	.70	.75	.85	.75	.80	.85
Dirt (including ROW)		---	---	---	.55	.60	.70	.65	.70	.80	.70	.75	.85
Urban Districts (excluding ROW)													
Commercial and business (85% impervious)		---	---	---	---	---	---	.85	.85	.90	.90	.90	.95
Industrial (72% impervious)		---	---	---	---	---	---	.80	.80	.85	.80	.85	.90
Residential Districts by Average Lot Size (excluding ROW)[1]													
1/8 acre (36% impervious)		---	---	---	---	---	---	.55	.60	.70	.65	.70	.75
1/4 acre (36% impervious)		---	---	---	---	---	---	.55	.60	.70	.65	.70	.75
1/3 acre (33% impervious)		---	---	---	---	---	---	.55	.60	.70	.65	.70	.75
1/2 acre (20% impervious)		---	---	---	---	---	---	.45	.50	.65	.60	.65	.70
1 acre (11% impervious)		---	---	---	---	---	---	.40	.45	.60	.55	.60	.65
2 acres (11% impervious)		---	---	---	---	---	---	.40	.45	.60	.55	.60	.65
Newly Graded Areas (pervious areas only, no vegetation)													
Agricultural and Undeveloped													
Meadow - protected from grazing (pre-settlement)........		.10	.10	.25	.10	.15	.30	.30	.35	.55	.45	.50	.65
Straight Row Crops													
Straight Row (SR)	*Poor Condition*	.33	.39	.55	.52	.58	.71	.70	.74	.84	.78	.81	.89
	Good Condition	.24	.30	.46	.45	.51	.66	.62	.67	.78	.73	.76	.86
SR + Crop Residue (CR)..............	*Poor Condition*	.31	.37	.54	.50	.56	.70	.67	.72	.82	.75	.79	.87
	Good Condition	.19	.25	.41	.38	.45	.61	.55	.60	.73	.62	.67	.78
Contoured (C)	*Poor Condition*	.29	.35	.52	.47	.53	.70	.60	.65	.77	.70	.74	.84
	Good Condition	.21	.26	.43	.38	.45	.61	.55	.60	.73	.65	.69	.80
C+CR	*Poor Condition*	.27	.33	.50	.45	.51	.66	.57	.63	.75	.67	.72	.82
	Good Condition	.19	.25	.41	.36	.43	.59	.52	.58	.71	.62	.67	.78
Contoured & Terraced (C&T)......	*Poor Condition*	.22	.28	.45	.36	.43	.59	.50	.56	.70	.55	.60	.73
	Good Condition	.16	.22	.38	.31	.37	.54	.45	.51	.66	.52	.58	.71
C&T + CR....................................	*Poor Condition*	.13	.19	.35	.31	.37	.54	.45	.51	.66	.52	.58	.71
	Good Condition	.10	.16	.32	.27	.33	.50	.43	.49	.65	.50	.56	.70

[1] The average percent impervious area shown was used to develop composite coefficients.

Note: Rational coefficients were derived from SCS CN method

b. Composite Runoff Analysis: Care should be taken not to average runoff coefficients for large segments that have multiple land uses of a wide variety (i.e., business to agriculture). However, within similar land uses, it is often desirable to develop a composite runoff coefficient based on the percentage of different types of surface in the drainage area. The composite procedure can be applied to an entire drainage area, or to typical sample blocks as a guide to selection of reasonable values of the coefficient for an entire area.

c. **Rainfall Intensity:** The intensity (i_T) is the average rainfall rate in inches per hour for the period of maximum rainfall of a given frequency, with duration equal to the time of concentration. The method(s) for determining time of concentration are presented in Section 2B-3.

After the T_c has been determined, the rainfall intensity should be obtained. For the Rational method, the design rainfall intensity is that which occurs for the design year storm whose duration equals the time of concentration. Tables 2B-2.02 through 2B-2.10 in Section 2B-2 provide the Iowa rainfall data from Bulletin 71 to allow determination of rainfall intensity based on duration equaling the time of concentration.

d. **Area:** The area (A) of the basin in acres. A map showing the limits of the drainage basin used in design should be provided with design data and will be superimposed on the grading plan showing subbasins. As mentioned earlier, the configuration of the contributing area with respect to pervious and impervious sub-areas and the flow path should be considered when deciding whether to use all or a portion of the total area.

C. SCS Methods

Several methods of determining total runoff and peak runoff have been developed by the SCS (now known as the NRCS). The two methods described below include the SCS Runoff Curve Number method for determining the total runoff depth and the SCS Peak flow method, which utilizes the runoff depth and site conditions to determine the peak rate of runoff from a drainage area.

These methods are described in full detail in the NRCS Technical Release 55: Urban Hydrology for Small Watersheds. This document is also the basis for the publicly available computer program WIN-TR55. This section also includes information from the NRCS National Engineering Handbook, Part 630.

1. **SCS Curve Number:** The SCS methods classify the land use and soil type by a single parameter called the Curve Number (CN). The CN can be used to represent the drainage properties for any sized homogeneous watershed with a known percentage of imperviousness.

The major factors that determine CN are the hydrologic soil group, cover type, treatment, hydrologic condition, and antecedent runoff condition. Tables 2B-4.03 through 2B-4.05 include typical CN values for urban and agricultural areas respectively.

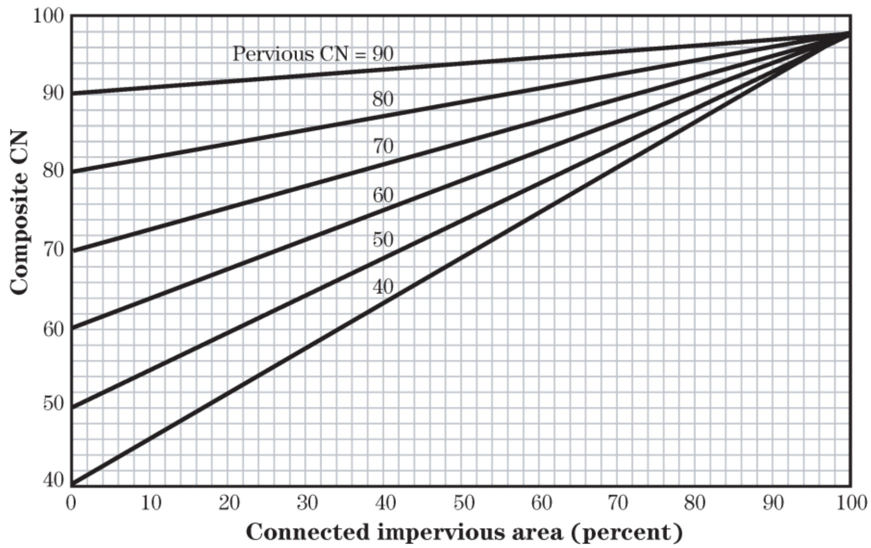
Several factors, such as the percentage of impervious area and the means of conveying runoff from the impervious areas to the drainage system, should be considered in computing the CN for urban areas. For example, do the impervious areas connect directly to the drainage system, or do they outlet onto lawns or other pervious areas where infiltration can occur?

The urban CN values (Table 2B-4.03) were developed for typical land use relationships based upon specific assumed percentages of impervious area. These CN values were developed on the assumptions that (a) the pervious urban areas are equivalent to pasture in good hydrologic condition, (b) impervious areas have a CN of 98 and are directly connected to the drainage system, and (c) the CN values for urban and residential districts assume an average percent impervious as shown in Table 2B-4.03.

a. Connected Impervious Areas: An impervious area is considered connected if runoff from it flows directly into the drainage system. It is also considered connected if runoff from it occurs as concentrated shallow flow that runs over a pervious area and then into the drainage system.

If all of the impervious area is directly connected to the drainage system, but the impervious area percentages in Table 2B-4.02, or the pervious land use assumptions are not applicable, use Figure 2B-4.01 or Equation 2B-4.02 to compute a composite CN.

Figure 2B-4.01: Composite CN with Connected Impervious Area



Source: NRCS National Engineering Handbook, Part 630, Chapter 9

$$CN_c = CN_p + \left(\frac{P_{imp}}{100}\right)\left(98 - CN_p\right)$$ **Equation 2B-4.02**

where:

CN_c = composite runoff curve number
CN_p = pervious runoff curve number
P_{imp} = percent imperviousness

b. Unconnected Impervious Areas: If runoff from impervious areas occurs over a pervious area as sheet flow prior to entering the drainage system, the impervious area is unconnected. To determine the CN when all or part of the impervious area is not directly connected to the drainage system use Figure 2B-4.02 or Equation 2B-4.03 if the total impervious area is less than 30% of the total area. If the total impervious area is equal to or greater than 30% of the total area, utilize Figure 2B-4.02 or Equation 2B-4.02 because the absorptive capacity of the remaining pervious area will not significantly affect runoff.

Table 2B-4.05: Runoff Curve Numbers for Other Agricultural Lands[1]

Cover Description		CN's for Hydrologic Soil Group			
Cover Type	***Hydrologic Condition[3]***	***A***	***B***	***C***	***D***
Pasture, grassland, or range - continuous forage for grazing[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow - continuous grass, protected from grazing and generally mowed for hay	---	30	58	71	78
Brush - brush-weed-grass mixture with brush the major element[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods - grass combination (orchard or tree farm)[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads - buildings, lanes, driveways, and surrounding lots	---	59	74	82	86

[1] Average runoff condition and I_a=0.2S.
[2] *Poor*: <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.
[3] *Poor*: <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
[4] Actual curve number is less than 30; use CN = 30 for runoff computations
[5] CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
[6] *Poor*: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed, but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing and litter and brush adequately cover the soil

2. **SCS Depth of Runoff:** Depth of runoff may be calculated through the SCS Curve Number Method. This method separates total rainfall into direct runoff, retention, and initial abstraction to yield the following equation for rainfall runoff.

$$Q = \frac{(P-I_a)^2}{(P-I_a)+S}$$ **Equation 2B-4.04**

where:

Q = Depth of direct runoff, in
P = Depth of 24 hour precipitation, in. for design year storm (e.g. 10 year, 24 hour)
S = Potential maximum retention after runoff begins, in
I_a = Initial abstraction, in

The initial abstraction (I_a) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration during the early part of the storm. Interception and surface depression storage may be estimated from cover and surface conditions, but infiltration during the early part of the storm is highly variable and dependent on such factors as rainfall intensity, soil crusting, and soil moisture. Establishing a relationship for I_a

is not easy. Therefore, I_a is assumed to be a function of the maximum potential retention, S. An empirical relationship between I_a and S is expressed as:

$$I_a = 0.2S$$ **Equation 2B-4.05**

Removing I_a and substituting Equation 2B-4.05 into Equation 2B-4.04 gives:

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)}$$ **Equation 2B-4.06**

The potential maximum (S) is related to the soil cover and conditions of the watershed through the CN as follows:

$$S = \frac{1000}{CN} - 10$$ **Equation 2B-4.07**

After determining the CN and calculating the value for S, the total amount of rainfall, P, for the 24 hour storm with the selected return interval must be determined. Values for total rainfall depth by storm duration and return interval are listed in Section 2B-2. These values are inserted into Equation 2B-4.06 to calculate the total depth of runoff from the watershed.

3. **SCS Peak Runoff:** TR-55 presents a Graphical Peak Discharge Method for manually calculating peak runoff using the SCS Depth of Runoff values calculated above with the NRCS Standard Type II Rainfall distribution. SUDAS has adopted the NRCS Updated Rainfall Distributions (MSE3 and MSE4) based on the Atlas 14 rainfall (see Section 2B-5); however, graphical representations of these distributions are not provided within the TR-55 documentation or other NRCS National Engineering Handbook documentation. For these reasons, manual calculation using the SCS Peak Runoff method is not allowed.

   The designer should utilize Win-TR-55 or other software that can incorporate the MSE distributions for calculating peak runoff.

4. **SCS Limitations:** The SCS methods presented herein are subject to the following limitations.

   a. These methods provide a determination of total runoff or peak flow only. If a hydrograph is needed or watershed subdivision is required the Tabular Hydrograph method (Section 2B-5) should be utilized.

   b. The watershed must be hydrologically homogenous, that is, describable by one of the CN. Land use, soils, and cover are distributed uniformly throughout the watershed.

   c. The watershed may have only one main stream or, if more than one, the branches must have nearly equal time of concentrations.

   d. The method cannot perform valley or reservoir routing.
   e. The F_p factor can be applied only for ponds or swamps that are not in the t_c flow path.

   f. I_a/P values should be between 0.1 and 0.5.

   g. This method should only be used if the composite CN is greater than 40.

   h. The SCS methods are typically applicable for drainage areas between 0 and 2,000 acres.

D. References

NRCS. *NOAA Atlas 14 Rainfall for Midwest and Southeast States.* Merkel and Moody. 2015

U.S. Department of Transportation. *Urban Drainage Design Manual*. Hydraulic Engineering Circular, No. 22. Third Ed. 2009.

USDA Natural Resource Conservation Service. *National Engineering Handbook* - *Part 630. Chapter 9: Hydrologic Soil Cover Complexes*. 2004.

C. Tabular Hydrograph Method

The TR-55 Tabular Hydrograph Method is used for computing discharges from rural and urban areas, using the time of concentration (T_c) and travel time (T_t) from a subarea as inputs. The SCS TR-55 methodology can determine peak flows from areas of up to 2,000 acres, provide a hydrograph for times of concentration between 0.1 to 2 hours, and estimate the required storage for a specified outflow.

This method can develop composite flood hydrographs at any point in a watershed by dividing the watershed into homogeneous subareas. In this manner, the method can estimate runoff from non-homogeneous watersheds; a common occurrence in developed urban areas. The method is especially applicable for estimating the effects of land use change in a portion of a watershed.

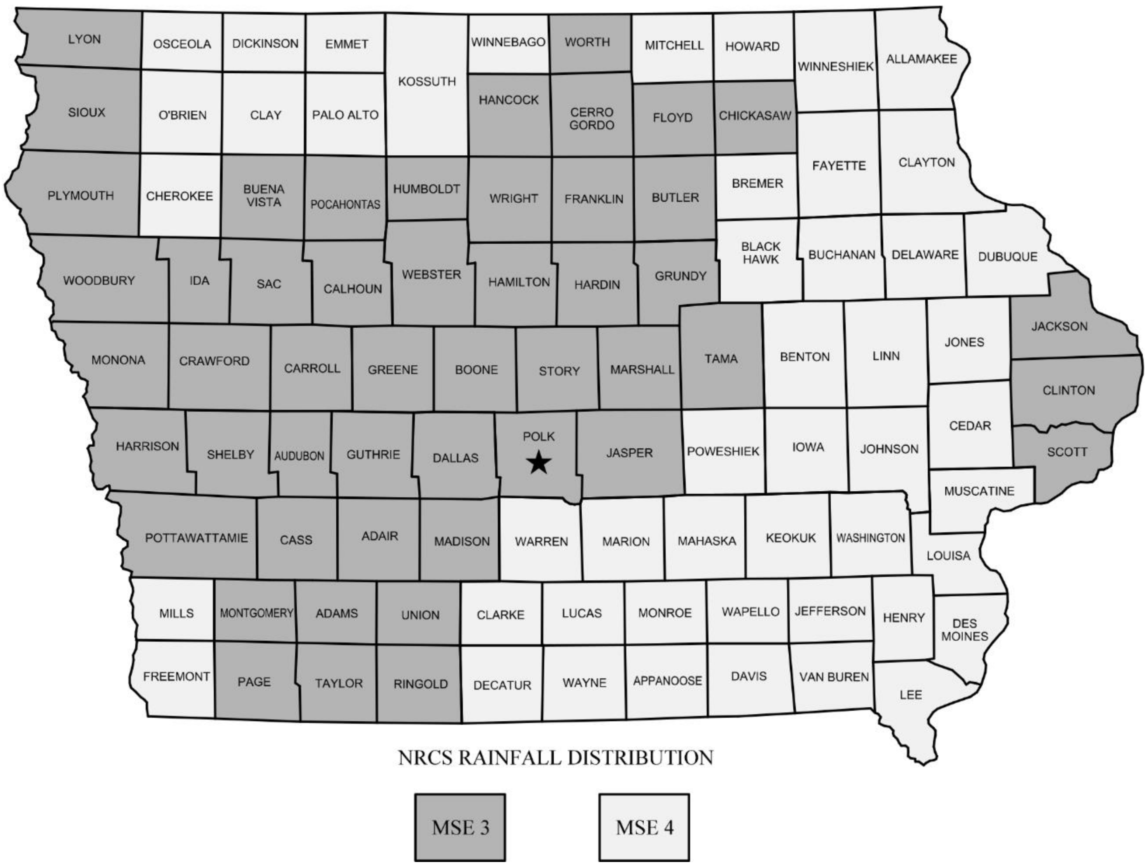
1. **Method Description:** The Tabular Hydrograph method is based on a series of unit discharge hydrographs developed by the SCS. The tabular data was developed by computing hydrographs for one-square mile of drainage area for selected T_c's and routing them through stream reaches with a range of T_t's. The resulting values, expressed in cubic feet per second per square mile of watershed per inch of runoff, are summarized in ten tables provided in the SCS TR-55 manual.

   Chapter 5 of TR-55 provides a detailed description for manual calculation with the tabular hydrograph method, in addition to the tables necessary to complete the calculation. The input data required to develop a flood hydrograph by the SCS TR-55 method includes:
   - 24 hour rainfall, in
   - Appropriate rainfall distribution, (MSE Types 1-6) (Iowa is Type 3 and 4)
   - Curve Number (Refer to Section 2B-4)
   - Time of Concentration, T_c, hr.
   - Travel Time, T_t, hr.
   - Drainage Area, sq. mi.

   Using the Weather Bureau's TP-40 (1961) data, SCS developed four 24 hour synthetic storm distributions (Type I, IA, II, and III) associated with broad climatic regions across the United States. The Type II rainfall distribution applied to a vast majority of the continental United States (including Iowa), even though typical storm events can vary widely between regions. With the release of NOAA's Atlas 14 database (2013), more than 50 years of new rainfall data became available. NRCS's analysis of this data led to the development of new synthetic rainfall distributions, including distributions specifically intended for Midwest and Southeast (MSE) regions. These MSE distributions reflect regional variation, consider recent changes in weather patterns, and prevent the over/under estimation of peak discharges. The new MSE distributions also better account for shorter rainfall durations within the 24 hour rainfall distribution (e.g. 24 hour, 2 hour, 10 minute, 5 minute, etc.) (Merkel and Moody, 2015).

   Six MSE distributions were developed for regions in the Midwest and Southeast. Most of Iowa falls within two of the MSE distributions: MSE3 and MSE4. Several outlier areas of the state fall into the MSE2 and MSE5 regions; however, the areas are small enough that the Iowa NRCS has assigned all counties in the state to either the MSE3 or MSE4 distribution. The following figure identifies which distribution is applied within each county.

Figure 2B-5.03: NRCS MSE Rainfall Distributions



The 24 hour rainfall amount, rainfall distribution, and the runoff curve number are used in Equations 2B-4.06 and 2B-4.07 to determine the runoff depth in each subarea. The product of the runoff depth times drainage is multiplied times each tabular hydrograph value to determine the final hydrograph ordinate for a particular subarea. Subarea hydrographs are then added to determine the final hydrograph at a particular point in the watershed.

Calculating runoff hydrographs manually utilizing the tabular method is time consuming, tedious, and rarely done. This calculation is typically completed utilizing user-created spreadsheets, WinTR-55, or other software that utilizes the TR-55 methodology. The NRCS has incorporated the MSE storm distributions into WinTR-55.

2. **Limitation:** The tabular method is used to determine peak flows and hydrographs within a watershed. However, the accuracy of the Tabular Method decreases as the complexity of the watershed increases. The Tabular Method should not be used if any of the following conditions exist:
   - The drainage area of the watershed is greater than 2,000 acres.
   - T_t is greater than 3 hours (largest T_t in tabular hydrograph data)
   - T_c is greater than 2 hours (largest T_c in tabular hydrograph data)
   - Drainage areas of individual subareas differ by a factor of 5 or more

   If any of the above situations exist, NRCS TR-20, or another applicable methodology should be utilized.

D. References

NRCS. *NOAA Atlas 14 Rainfall for Midwest and Southeast States.* Merkel and Moody. 2015

U.S. Department of Agriculture. *Urban Hydrology for Small Watersheds.* Technical Release No. 55. 1975.

U.S. Department of Transportation. *Urban Drainage Design Manual*. Hydraulic Engineering Circular, No. 22. Third Ed. 2009.

Table of Contents

Chapter 5 - Roadway Design

5A General Information

5B Street Classifications

5C Geometric Design Criteria

5D Asphalt Pavement Mixture Selection

5E PCC Pavement Mixture Selection

5F Pavement Thickness Design

5G PCC Pavement Joints

5M Complete Streets

5N Traffic Impact Studies

5O Railroad Crossings

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.

Values are described as “preferred” or “acceptable” allowing for design flexibility based on the roadway context. When a value is described as “preferred,” designers should strive to provide a design that meets or exceeds the criteria. For designs where this is not practical, values between the “preferred” and “acceptable” tables may be utilized, with approval of the Engineer.

The following is additional guidance from the 2018 AASHTO Green Book:

- From Section 1.6.2: “The designer’s goal should be a balanced design that serves multiple transportation modes, as appropriate. This does not necessarily mean that facilities for every mode are provided on every road and street. In fact, the appropriate balance among transportation modes may vary widely between specific roads and streets. But the guiding design principle is that the balance among transportation modes selected for each road and street should be a conscious decision arrived at after thorough consideration of the needs of each mode, local and regional transportation agency master plans, and community needs. Key factors in considering the appropriate facilities to be provided on a roadway or at an intersection are the functional classification and context of the road or street, the expected demand flows for each transportation mode (both current and anticipated), and area-wide or corridor plans established by the community.”
- From Section 1.8: “Design flexibility does not mean that designers can use arbitrary discretion in the design of projects. Flexibility should be exercised in order to better meet specific project goals or to work within defined constraints. Documentation should be provided to explain why the proposed design is an appropriate solution for the project, how it serves the need for each transportation mode, how it is expected to perform in the future, and how it fits within available funding.”

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.

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.

B. Design Controls and Criteria

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

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 one basis for the cross-sectional design criteria shown in Tables 5C-1.01 and 5C-1.02.

   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. **Context Sensitive Design:** The 2018 AASHTO Green Book recognizes five land use context classifications for geometric design: rural; rural town; suburban, urban, and urban core. The five context classifications are generally defined by development density (existence of structures and structure types), land use types (e.g., residential, commercial, or industrial), and building setbacks (distance of structures to adjacent roadways). Understanding the context classification is important to conduct a more thorough assessment of multimodal needs and to identify priorities among transportation modes within a corridor. While a street may have one functional classification, it may pass through multiple context classifications, and the transitions between those classifications is often gradual. Possible changes in context classification resulting from future development must also be considered in design.

   Designers should assume pedestrians and bicyclists will be present in urban, suburban, and rural town context classifications; residential or commercial land use types; and along roadways with transit. For these locations, designers should refer to Section 5M-1. For all other locations, designers should use the values presented in Section 5C-1. Some local jurisdictions have complete streets policies requiring street projects to consider bicycle and pedestrian accommodations independent of context.

   a. **Land Use Context Classifications:** Context classifications can be generally summarized as follows.
      - The rural context applies to roads in rural areas with few houses or structures.
      - The rural town context applies to roads in rural towns, which generally have diverse land uses, on-street parking, sidewalks in some locations, and small building setbacks.
      - The suburban context applies to roads and streets with low to medium development density, typically in the outlying portions of urban areas. Building setbacks are varied with mostly off-street parking. Drivers have higher speed expectations than the urban context. Pedestrian, bicyclist, and transit are more prevalent than the rural context but may not be as high as found in urban areas, or in rural towns.
      - The urban context has high-density development, mixed land uses, and on-street parking. Driver speed expectations are generally lower and pedestrian and bicyclist flows higher than in suburban areas. Transit routes are prevalent in this context and should be considered in design.

- The urban core context includes areas of the highest density in major cities, with high-rise structures and may have a combination of on-street parking and other curbside uses and large off-street parking structures. Pedestrian and bicyclist flows are generally highest in these areas and a high density of transit is also prevalent. In Iowa, very few cities have "urban cores," so SUDAS does not include criteria for that context.

b. **Land Use Types:** Within each land use context classification, areas can be further described by the specific land use types. Land use types influence travel patterns and travel demand of all modes and should be considered when selecting design values. Land use can be categorized into three groups: residential, commercial, and industrial.
   - 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. These facilities typically have lower overall traffic volumes, low truck volumes, and are utilized primarily by drivers who are familiar with the roadway.
   - Commercial areas include entertainment, cultural, recreational, and institutional uses and can range from low to high density developments. These often consist of restaurants, local shops, convenience or grocery stores, museums, theatres, hospitals, schools and universities, government agencies, and offices.
   - Industrial and large commercial areas are highly developed regions generally defined by commercial and industrial zoning districts where factories, office parks, strip malls, and large shopping centers are located. These areas typically experience higher motor vehicle traffic volumes, increased truck volumes, and may have less driver familiarity.

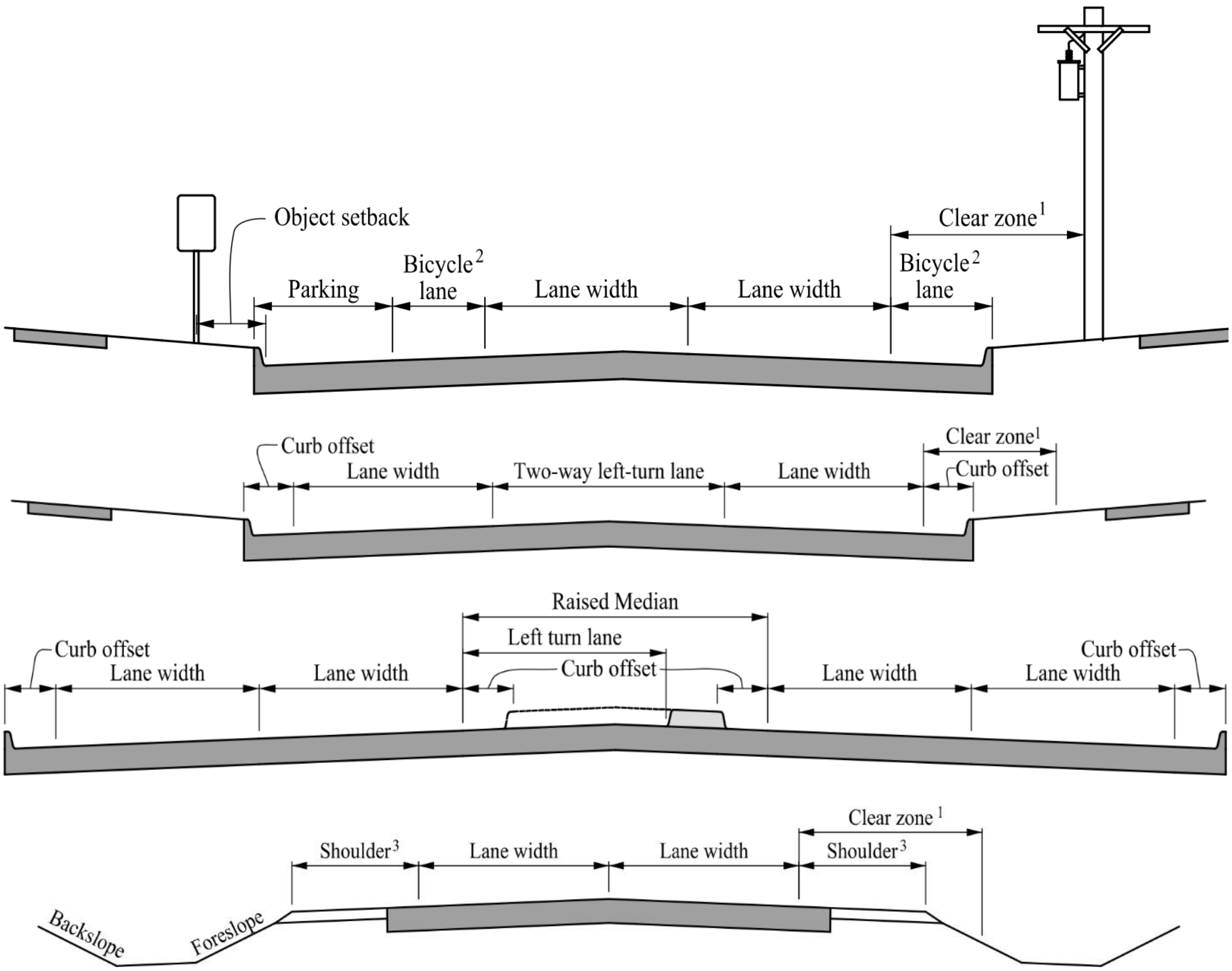
3. **Design Speed:** Design speed is the selected speed used to determine various geometric features of the roadway, including horizontal and vertical alignment. The design speed should be selected considering functional classification, context classifications, and surrounding land uses to attain the desired degree of safety, mobility, and efficiency. It has been past practice to select a design speed that is at least 5 mph greater than the anticipated posted speed limit of the roadway. However, in urban, suburban, and rural town areas, the design of the street should limit the maximum speed that drivers can operate comfortably in order to balance the needs of all users. For roadways with posted speed limits of 35 mph or less, the design speed should match the posted speed. For roadways with posted speeds of 40 to 45 mph, selecting a design speed equal to the posted speed limit may also be appropriate and should be evaluated on a project by project basis, subject to approval of the Engineer. Once a design speed is selected, all pertinent roadway features should be related to that speed to obtain a balanced design. Additional discussion of design speed can be found in Section 5M-1.

   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).

C. Roadway Design Tables

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

Figure 5C-1.01: Roadway Design Elements



[1] Clear zone is measured from the edge of the traveled way.
[2] See Chapter 12 for bicycle lane requirements.
[3] Shoulder is measured from the lane line.

Table 5C-1.01: Preferred Roadway Elements

Elements Related to Functional Classification

Design Element	Local		Collector		Arterial	
	R	***C/I***	***R***	***C/I***	***R***	***C/I***
General						
Design level of service[1]	D	D	C/D	C/D	C/D	C/D
Lane width (single lane) (ft)[2]	10.5	12	12	12	12	12
Two-way left-turn lanes (TWLTL) (ft)	N/A	N/A	14	14	14	14
Width of new bridges (ft)[3]	See Footnote 3					
Width of bridges to remain in place (ft)[4]	----------	----------	----------	----------	----------	----------
Vertical clearance (ft)[5]	14.5	14.5	14.5	14.5	16.5	16.5
Object setback (ft)[6]	3	3	3	3	3	3
Clear zone (ft)	Refer to Table 5C-1.03, Table 5C-1.04, and 5C-1, C, 1					
Urban						
Curb offset (ft)[7]	2	2	2	3	3	3
Parking lane width (ft)	8	8	8	10	N/A	N/A
Roadway width with parking on one side[8]	26/27/31[9]	34	34	37	N/A	N/A
Roadway width without parking[10]	26	31	31	31	31	31
Raised median with left-turn lane (ft)[11]	N/A	N/A	19.5	20.5	20.5	20.5
Cul-de-sac radius (ft)	45/48[12]	45/48[12]	N/A	N/A	N/A	N/A
Rural Sections in Urban Areas						
Shoulder width (ft)						
ADT: under 400	4	4	6	6	10	10
ADT: 400 to 1,500	6	6	6	6	10	10
ADT: 1,500 to 2000	8	8	8	8	10	10
ADT: above 2,000	8	8	8	8	10	10
Foreslope (H:V)	4:1	4:1	4:1	4:1	6:1	6:1
Backslope (H:V)	4:1	4:1	4:1	4:1	4:1	4:1

R = Residential, C/I = Commercial/Industrial

Elements Related to Design Speed

Design Element	Design Speed, mph[13]							
	25	***30***	***35***	***40***	***45***	***50***	***55***	***60***
Stopping sight distance (ft)	155	200	250	305	360	425	495	570
Passing sight distance (ft)	900	1090	1,280	1,470	1,625	1,835	1,985	2,135
Min. horizontal curve radius (ft)[14]	198	333	510	762	1,039	926	1,190	1,500
Min. vertical curve length (ft)	50	75	105	120	135	150	165	180
Min. rate of vertical curvature, Crest (K)[15]	18	30	47	71	98	136	185	245
Min. rate of vertical curvature, Sag (K)	26	37	49	64	79	96	115	136
Minimum gradient (percent)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Maximum gradient (percent)	5	5	5	5	5	5	5	5

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

Table 5C-1.01 Footnotes:

[1] Number of traffic lanes, turn lanes, intersection configuration, etc. should be designed to provide the overall specified LOS at the design year ADT. Two LOS values are shown for collectors and arterials. The first indicates the minimum overall LOS for the roadway as a whole; the second is the minimum LOS for individual movements at intersections.

[2] Width shown is for through lanes and turn lanes.

[3] Bridge width is measured as the clear width between curbs or railings. Minimum bridge width is based upon the width of the traveled way (lane widths) plus 4 feet clearance on each side; but no less than the curb-face to curb-face width of the approaching roadway. Minimum bridge widths do not include medians, turn lanes, parking, or sidewalks. At least one sidewalk should be extended across the bridge.

[4] See Table 5C-1.02, for acceptable values for width of bridges to remain in place.

[5] Vertical clearance includes a 0.5 foot allowance for future resurfacing.

[6] Object setback does not apply to mailboxes constructed and installed according to US Postal Service regulations, including breakaway supports.

[7] Values shown are measured from the edge of the traveled way to the back of curb. Curb offset is not required for turn lanes. On roadways with an anticipated posted speed of 45 mph or greater, mountable curbs are required. For pavements with gutterline jointing, the curb offset should be equal to or greater than the distance between the back of curb and longitudinal gutterline joint.

[8] Parking is allowed along one side of local or collector streets unless restricted by the Jurisdiction. Some jurisdictions allow parking on both sides of the street. When this occurs, each jurisdiction will set their own standards to allow for proper clearances, including passage of large emergency vehicles. Parking is normally not allowed along arterial roadways.

[9] For local, low volume residential streets, two free flowing lanes are not required and a 26 foot or 31 foot (back to back) roadway may be used where parking is allowed on one side or both sides respectively. For higher volume residential streets, which require two continuously free flowing traffic lanes, a 31 foot or 37 foot roadway should be used for one sided or two sided parking respectively. The minimum street width with parking on one side stipulated in the 2018 International Fire Code is 27 foot back to back. Some jurisdictions allow narrower street widths in low density residential areas due to the size of their firefighting apparatus.

[10] Some minimum roadway widths have been increased to match standard roadway widths. Unless approved by the Jurisdiction, all two lane roadways must comply with standard widths of 26, 31, 34, or 37 feet.

[11] Median width is measured between the edges of the traveled way of the inside lanes and includes the curb offset on each side of the median. Values include a left turn lane with a 6 foot raised median as required to accommodate a pedestrian access route (refer to Chapter 12) through the median (crosswalk cut through). At locations where a crosswalk does not cut through the median, the widths shown can be reduced by 2 feet to provide a 4 foot raised median.

[12] The minimum cul-de-sac radius stipulated by the 2018 International Fire Code is 48 feet. Some jurisdictions allow lesser radii due to the size of their firefighting apparatus.

[13] 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.

[14] Values for low design speed (<50 mph) assume no removal of crown (i.e. negative 2% superelevation on outside of curve). Radii for design speeds of 50 mph or greater are based upon a superelevation rate of 4%. For radii corresponding to other superelevation rates, refer to the AASHTO's Green Book.

[15] Assumes stopping sight distance with 6 inch object.

Table 5C-1.02: Acceptable Roadway Elements

Elements Related to Functional Classification

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

R = Residential, C/I = Commercial/Industrial

Elements Related to Design Speed

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

R = Residential, C/I = Commercial/Industrial

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

Table 5C-1.02 Footnotes:

[1] Number of traffic lanes, turn lanes, intersection configuration, etc. should be designed to provide the specified LOS at the design year ADT.

[2] Width shown is for through lanes and turn lanes.

[3] Bridge width is measured as the clear width between curbs or railings. Minimum bridge width is based upon the width of the traveled way (lane widths) plus 3 feet clearance on each side; but no less than the curb-face to curb-face width of the approaching roadway. Minimum bridge widths do not include medians, turn lanes, parking, or sidewalks. At least one sidewalk should be extended across the bridge.

[4] The values shown are the clear width across the bridge between curbs or railings. Values are based upon the width of the traveled way (lane width) and include a 1 foot and 2 foot offset on each side for collectors and arterials respectively. Values do not include medians, turn lanes, parking, or sidewalks. In no case should the minimum clear width across the bridge be less than the width of the traveled way of the approach road.

[5] Vertical clearance includes a 0.5 foot allowance for future resurfacing. Vertical clearance of 14.5 feet on arterials is allowed only if an alternate route with 16 feet of clearance is available.

[6] Object setback does not apply to mailboxes constructed and installed according to US Postal Service regulations, including breakaway supports.

[7] Values shown are measured from the edge of the traveled way to the back of curb. Curb offset is not required for turn lanes. On roadways with an anticipated posted speed of 45 mph or greater, mountable curbs are required. For pavements with gutterline jointing, the curb offset should be equal to or greater than the distance between the back of curb and longitudinal gutterline joint.

[8] At locations where a 1.5 foot curb offset is used, an alternative intake boxout, with the intake set back a minimum of 6 inches from the curb line, must be used to prevent intake grates from encroaching into the traveled way.

[9] Some jurisdictions allow parking on both sides of the street. When this occurs, each jurisdiction will set their own standards to allow for proper clearances, including passage of large emergency vehicles.

[10] For low volume residential streets, two free flowing lanes are not required and a 26 foot roadway may be used where parking is allowed on one side only. For higher volume residential streets, which require two continuously free flowing traffic lanes, a 31foot roadway should be used.

[11] Some minimum roadway widths have been increased to match standard roadway widths. Unless approved by Jurisdiction, all two lane roadways must comply with standard widths of 26, 31, 34, or 37 feet.

[12] Median width is measured between the edges of the traveled way of the inside lanes and includes the curb offset on each side of the median. Values include a left turn lane with a 6 foot raised median as required to accommodate a pedestrian access route (refer to Chapter 12) through the median (crosswalk cut through). At locations where a crosswalk does not cut through the median, the widths shown can be reduced by 2 feet to provide a 4 foot raised median.

[13] The use of 3:1 foreslopes is allowed, as shown, but may require a wider clear zone as slopes steeper than 4:1 are not considered recoverable by errant vehicles.

[14] It is preferred to select a design speed that is at least 5 mph greater than the anticipated posted speed limit of the roadway. Selecting a design speed equal to the posted speed limit may also be acceptable and should be evaluated on a project by project basis, subject to approval of the Engineer

[15] Values for low design speed (<50 mph) assume no removal of crown (i.e. negative 2% superelevation on outside of curve). According to the AASHTO Green Book (Table 3-1 and 3-13b) for low volume roadways with 10 or less units beyond the curve and projected traffic volumes of less than 100 vehicles per day beyond the curve, the horizontal curve radius may be a minimum of 107 feet if at least 115 feet of stopping sight distance is provided or the radius may be a minimum of 50 feet if at least 80 feet of stopping sight distance is available. Radii for design speeds of 50 mph or greater are based upon a superelevation rate of 6%. For radii corresponding to other superelevation rates, refer to the AASHTO's Green Book.

[16] Assumes stopping sight distance with 2 foot high object.

[17] Use only if roadway has continuous overhead lighting.

[18] A typical minimum grade is 0.5%, but a grade of 0.4% may be used in isolated areas where the pavement is accurately crowned and supported on firm subgrade.

[19] Maximum gradient may be steepened by 2% for short distances and for one way downgrades.

Table 5C-1.03: Preferred Clear Zone Distances

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					
Curbed Roadways 40 or less	All	For low-speed urban roadways, refer to 5C-1, C, 1.					
Uncurbed Roadways 40 or less	Under 750	10	10	*	10	10	10
	750 to 1,500	12	14	*	14	14	14
	1,500 to 6,000	14	16	*	16	16	16
	Over 6,000	16	18	*	18	18	18
All Roadways 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
All Roadways 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
All Roadways 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*, 2011

Table 5C-1.04: Acceptable Clear Zone Distances

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					
Curbed Roadways 40 or less	All	For low-speed urban roadways, refer to 5C-1, C, 1.					
Uncurbed Roadways 40 or less	Under 750	7	7	*	7	7	7
	750 to 1,500	10	12	*	12	12	12
	1,500 to 6,000	12	14	*	14	14	14
	Over 6,000	14	16	*	16	16	16
All Roadways 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
All Roadways 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
All Roadways 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*, 2011

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

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

Table 5C-1.05: Motor Vehicle Design Level of Service

Targets[1]	Local	Collector	Arterial
Preferred	D	C/D	C/D
Acceptable	D	D/E	D/E

1 Number of traffic lanes, turn lanes, intersection configuration, etc. should be designed to provide the overall specified LOS at the design year ADT. Two LOS values are shown for collectors and arterials. The first indicates the minimum overall LOS for the roadway as a whole; the second is the minimum LOS for individual movements at intersections.

D. References

American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* (referred to as “Green Book”). Washington, DC. 2018.

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

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

National Cooperative Highway Research Program Report 330 *Effective Utilization of Street Width on Urban Arterials*. Transportation Research Board. Washington, D.C. 1990.

Potts, I., Harwood, D., and Richard, K. *Relationship of Lane Width to Safety for Urban and Suburban Arterials.* Transportation Research Record. 2007.

Geometric Design Elements

A. Design Flexibility and Performance-Based Approach

The 2018 AASHTO Green Book introduced a new design process that takes a performance-based approach to design. Performance-based design is problem-driven, and helps designers prioritize certain goals in order to make decisions and tradeoffs to best meet the needs of all transportation modes. In nearly all road construction projects, there are constraints requiring tradeoffs that do not allow the use of all the preferred design criteria presented in Section 5C-1. Designers should consult the design criteria set forth in this section, but it may be impractical to use them all because of existing constraints in the corridor and the need to fit the roadway into the community context and meet the needs of all transportation modes. For example, if analysis of the crash history of the existing road identifies one or more crash patterns that are potentially correctable by a specific design improvement, the designer may place greater priority on incorporating design improvements to reduce those crashes, at the expense of maintaining or improving the traffic operational level of service (see below).

Section 5M-1 provides more background on applying flexibility in street design to meet project goals.

B. Level of Service

Level of service (LOS) measures motor vehicle delay for a roadway facility and is one measure to assess roadway performance. It should be considered along with other factors to reflect the goals of the project. LOS is based upon motor vehicle traffic conditions and is related to speed, travel time, freedom to maneuver, traffic interruptions, and comfort and convenience. The LOS scale 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 a 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. Designers should select a design year and target LOS based on the context of the project location, the goals of the project, and modes present. The current Highway Capacity Manual, the current AASHTO Green Book, and other references should be used for traffic projections and to determine the number of lanes and intersection configurations for the target LOS. Designers should refer to Table 5C-1.01 and 5C-1.02 for target design LOS and Section 5M-1, C, 3 for guidance on appropriately sizing roadways in urban, suburban, and rural town contexts.

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

As a planning tool, refer to the generalized service volume tables in FHWA's *Simplified Highway Capacity Calculation Method for the Highway Performance Monitoring System*.

The 2010 Highway Capacity Manual, issued in 2013, indicates there is no reduction in lane capacity until the lane width is less than 10 feet. For lanes less than 10 feet wide, the adjustment factor is 0.96.

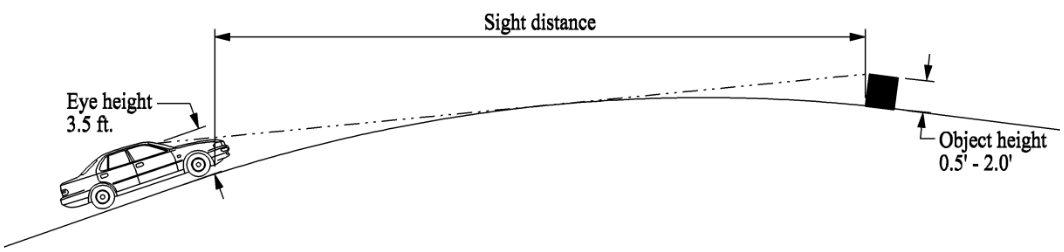
C. Sight Distance

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.

1. **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.

   Figure 5C-2.01: Vertical Sight Distance Determination

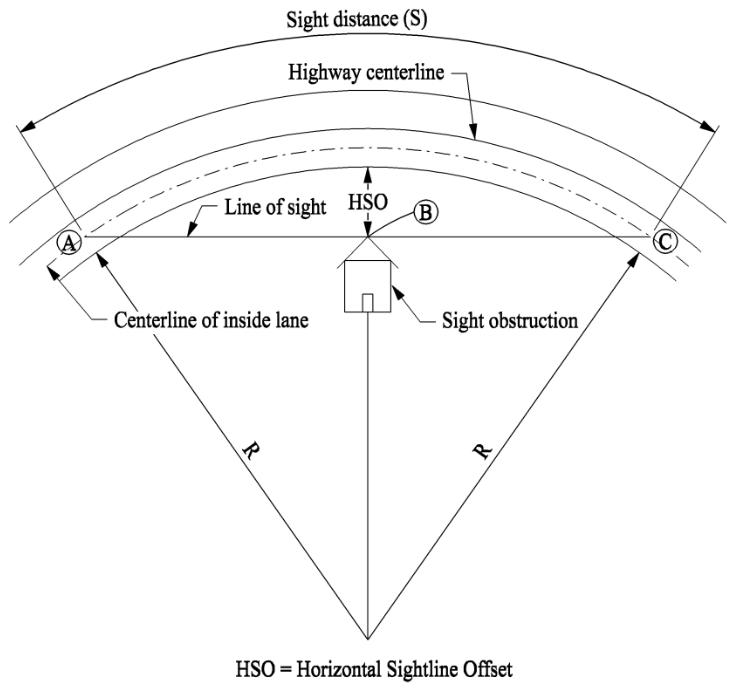
   Stopping sight distance is calculated based upon an assumed height of the driver's eye and an assumed height of an object in the roadway. For all sight distance criteria, the height of the driver's eye is assumed to be 3.5 feet above the surface of the road, as recommended by AASHTO. Section 5C-1, Tables 5C-1.01 and 5C-1.02 assume two different values for the height of the object in the roadway. The "Acceptable" values in Table 5C-1.02 use a 2 foot object height according to the current edition of the AASHTO Green Book. The "Preferred" values in Table 5C-1.01 assume an object height of only 6 inches. This lower object height was the design value used in previous versions of the AASHTO Green Book. The results of assuming a smaller object height for the preferred values in Table 5C-1.01 are higher required K values and longer vertical curves.

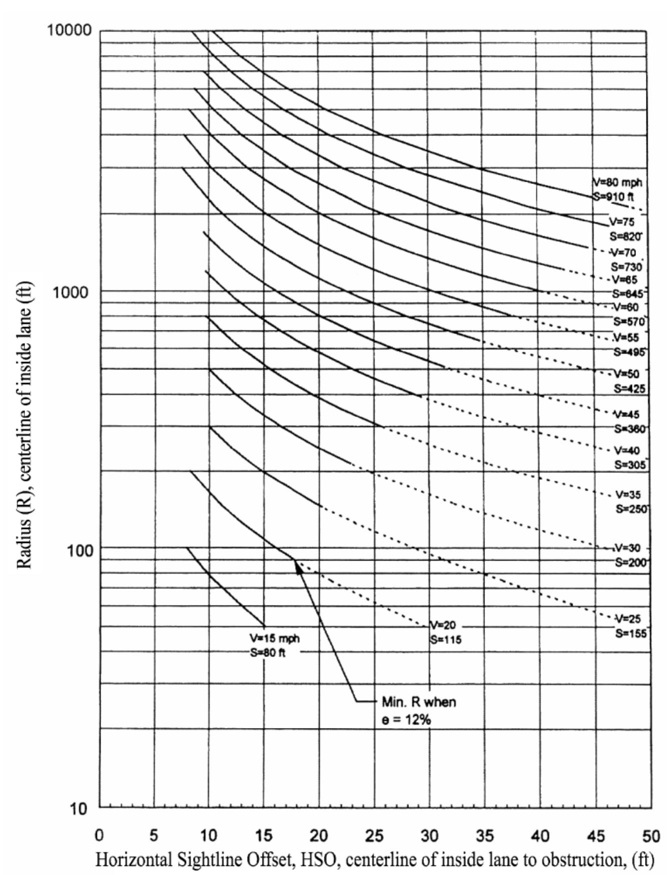
2. **Sight Distance on Horizontal Curves:** The horizontal alignment must provide at least the minimum stopping distance for the design speed at all points. This includes visibility around curves and roadside encroachments.

   Where there are sight obstructions such as walls, cut slopes, buildings, fences, bridge structures, or other longitudinal barriers on the inside of curves, an adjustment in the minimum radius of the curve may be necessary. In no case should sight distance be less than the stopping sight distance specified in Section 5C-1, Tables 5C-1.01 and 5C-1.02. The sight distance design procedure should assume a 6 foot fence (as measured from finished grade) exists along all property lines except in the sight distance triangles required at all intersections.

   Available sight distance around a horizontal curve can be determined graphically using the method shown in Figures 5C-2.02 and 5C-2.03 below. From the center of the inside lane (Point A), a line is projected through the point on the obstruction that is nearest to the curve (Point B). The line is then extended until it intersects the centerline of the inside lane (Point C).

Figure 5C-2.02 and Figure 5C-2.03: Sight Distances for Horizontal Curves





Source: Adapted from AASHTO Green Book, 2004 Edition, Exhibits 3-53 and 3-54

3. **Passing Sight Distance:** Passing sight distance is the minimum sight distance that must be available to enable the driver of one vehicle to pass another safely and comfortably without interfering with oncoming traffic traveling at the design speed. Two lane roads should provide adequate passing zones at regular intervals. Minimum passing sight distances are shown in Section 5C-1, Tables 5C-1.01 and 5C-1.02.

   Passing sight distance is measured between an eye height of 3.5 feet and an object height of 3.5 feet. On straight sections of roadway, passing sight distance is determined primarily by the vertical curvature of the roadway. On horizontal curves, obstructions adjacent to the roadway on the inside of the curve can limit sight distance. This is most common in a cut section where the adjacent terrain projects above the surface of the roadway. Passing sight distance should be verified using the methods described in the current edition of the AASHTO Green Book.

4. **Intersection Sight Distance:** In addition to the stopping sight distance provided continuously in the direction of travel on all roadways, adequate sight distance at intersections must be provided to allow drivers to perceive the presence of potentially conflicting vehicles. Sight distance is also required at intersections to allow drivers of stopped vehicles to decide when to enter or cross the intersecting roadway. If the available sight distance for an entering or crossing vehicle is at least equal to the appropriate stopping sight distance for the major road, then drivers have sufficient sight distance to anticipate and avoid collisions. However, in some cases, this may require a major road vehicle to slow or stop to accommodate the maneuver by a minor road vehicle. To enhance traffic operations, intersection sight distances that exceed stopping sight distances are desirable along the major road.

   Each intersection has the potential for several different types of vehicular conflicts. The possibility of these conflicts actually occurring can be greatly reduced by providing proper sight distance and appropriate traffic controls. Each quadrant of an intersection should contain a triangular area free of obstructions that might block an approaching driver's view of potentially conflicting vehicles. This clear area is known as the sight triangle.

   a. **Sight Triangles:** Proper sight distance at intersections is determined through the establishment and enforcement of sight triangles. The required dimensions of the legs of the triangle depend on the design speed of the roadways and the type of traffic control provided at the intersection. Two types of clear sight triangles are considered in intersection design: approach sight triangles and departure sight triangles.
      1) **Approach Sight Triangles:** Approach sight triangles allow the drivers at uncontrolled or yield controlled intersections to see a potentially conflicting vehicle in sufficient time to slow or stop before colliding within the intersection. Although desirable at all intersections, approach sight triangles are not needed for intersections approaches controlled by stop signs or traffic signals.
      2) **Departure Sight Triangles:** A second type of clear sight triangle provides sight distance sufficient for a stopped driver on a minor-road approach to depart from the intersection and enter or cross the major road. Departure sight triangles should be provided in each quadrant of each intersection approach controlled by a stop sign.

      At signalized intersections, the first vehicle stopped on one approach should be visible to the driver of the first vehicle stopped on each of the other approaches. Left turning vehicles should have sufficient sight distance to select gaps in oncoming traffic.

      The recommended dimensions of the sight triangles vary with the type of traffic control used at an intersection because different types of controls impose different legal constraints on drivers and, therefore, result in different driver behavior. The AASHTO Green Book contains the required procedures, equations, and tables for determining the required sight distance under various intersection and traffic control configurations.

b. Identification of Sight Obstructions within Sight Triangles: Within a sight triangle, any object at a height above the elevation of the adjacent roadways that would obstruct the driver's view should be removed or lowered if practical. Such objects may include buildings, parked vehicles, highway structures, roadside hardware, hedges, trees, bushes, unmowed grass, tall crops, walls, fences, and the terrain itself. Particular attention should be given to the evaluation of clear sight triangles at intersection ramp/crossroad intersections where features such as bridge railings, piers, and abutments are potential sight obstructions.

The determination of whether an object constitutes a sight obstruction should consider both the horizontal and vertical alignment of both intersecting roadways, as well as the height and position of the object. In making this determination, it should be assumed that the driver's eye is 3.5 feet above the roadway surface and that the approaching vehicle to be seen is 3.5 feet above the surface of the intersecting road.

D. Horizontal Alignment

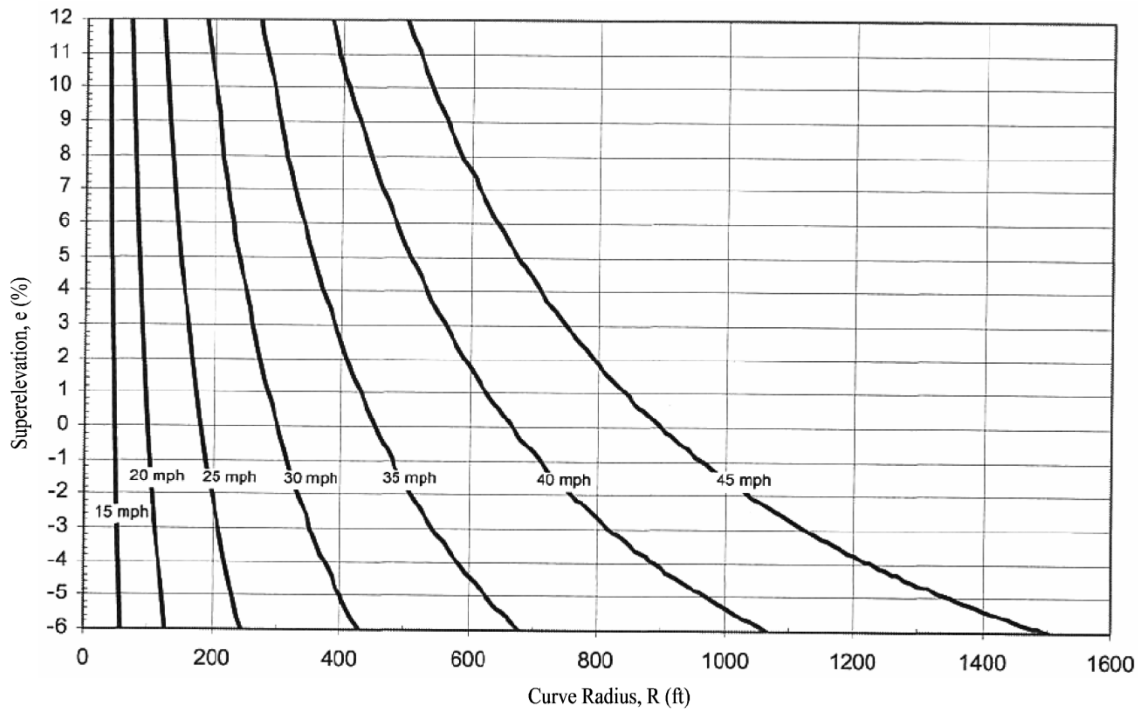
1. **Roadway Curvature and Superelevation:** On urban streets where operating speed is relatively low and variable, the use of superelevation for horizontal curves can be minimized. Although superelevation is advantageous for traffic operation, in urban areas the combination of wide pavements, the need to meet the grade of adjacent properties, the desire to maintain low speed operation, the need to maintain pavement profiles for drainage, and the frequency of cross streets and driveways and other urban features often combine to make the use of superelevation impractical or undesirable. Generally, the absence of superelevation on low speed urban streets is not detrimental to the motorist and superelevation is not typically provided on urban streets with a design speed of 45 mph or less.

   The preferred radii shown in Section 5C-1, Table 5C-1.01 assume that a normal crown is maintained around a horizontal curve. With a standard 2% pavement cross-slope, this effectively results in a negative 2% superelevation for the outside lane. For roadways with a cross-slope other than 2%, including four lane and wider sections that utilize a steeper cross-slope for the outside lanes, the required curve radius should be determined from the guidance provided in the current AASHTO Green Book or from Figure 5C-2.04 below.

   While superelevation on low speed urban roadways is not desirable, it may be necessary in situations where site conditions require a horizontal curve that cannot sustain traffic with the negative superelevation that results from maintaining the normal crown. For these situations, superelevation equal to the normal cross-slope may be provided for the outside lane. Section 5C-1, Table 5C-1.02 assumes the adverse crown in the outside lane of a curve is removed. For a roadway with a normal 2% cross-slope, this results in a superelevation of 2% across the width of the pavement. For roadways with cross-slopes other than 2%, the required radius and the resulting superelevation should be determined from the guidance provided in current AASHTO Green Book or from Figure 5C-2.04 below. The maximum superelevation for low speed urban roadways should not exceed the normal cross-slope or a maximum of 3%.

   For roadways with design speeds of 50 mph or greater, superelevation of the roadway is acceptable and expected by motorists. The radii provided in Section 5C-1, Tables 5C-1.01 and 5C-1.02 are based upon superelevation rates of 4% and 6% respectively. The maximum superelevation rate in urban areas should not exceed 6%.

Figure 5C-2.04: Superelevation, Radius, and Design Speed for Low Speed (<50mph) Urban Street Design



Source: AASHTO Green Book, 2004 Edition, Exhibit 3-17

2. **Intersection Alignment:** The centerline of a street approaching another street from the opposite side should not be offset. If the offset cannot be avoided, the offset should be 150 feet or greater for local streets. The centerline of a local street approaching an arterial or collector street from opposite side should not be offset unless such offset is 300 feet or greater.

3. **Adding, Dropping, or Redirecting Lanes:**

   a. **Dropping or Redirecting Through Lanes:** When dropping a lane, the minimum taper ratio to be used should be determined by the following formula, or from Table 5C-2.01:

      L = WS for velocities of 45 mph or more

      $L = \frac{WS^2}{60}$ for velocities of 40 mph or less.

      L = Minimum length of taper.
      S = Numerical value of posted speed limit or 85th percentile speed, whichever is higher.
      W = Width of pavement to be dropped or redirection offset.

   Preferably, taper ratios should be evenly divisible by five. Calculations that result in odd ratios should be rounded to an even increment of five. The table below utilizes the formulas to determine the appropriate taper ratio for dropping a 12 foot wide lane. The ratio remains constant for a given design speed while the length varies with the pavement width.

The procedure for determining minimum taper ratios for redirecting through lanes is the same as for lane drops, except for design speeds over 45 mph the use of reverse curves rather than tapers is recommended.

Table 5C-2.01: Length and Taper Ratio for Dropping 12 Foot Lane

Design Speed (mph)	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
Taper Ratio	10:1	15:1	20:1	25:1	45:1	50:1	55:1	60:1
Length (feet)	120	180	240	300	540	600	660	720

b. Adding Through or Turn Lanes: For design speeds of 45 mph or greater, a 15:1 lane taper should be used when adding a left or right turn lane. For design speeds less than 45 mph, a 10:1 taper may be used.

For design speeds less than 45 mph, shorter tapers that are squared off or taper at 1:1 may provide better "targets" for approaching drivers and give more positive identification to an added through lane or turn lane. For turn lanes, the total length of taper and deceleration length should be the same as if a standard taper was used. This results in a longer length of full width pavement for the turn lane. This design provides increased storage that may reduce the likelihood turning vehicles will back up into the through lane during peak traffic periods. The use of short taper sections must be approved by the Engineer.

Figure 5C-2.05: Adding or Dropping Lanes

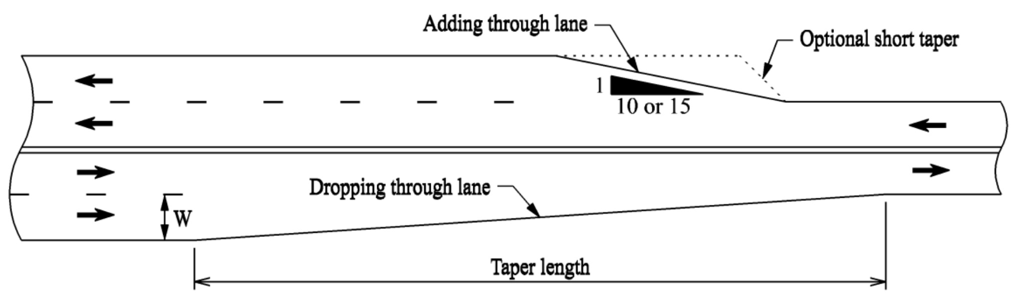
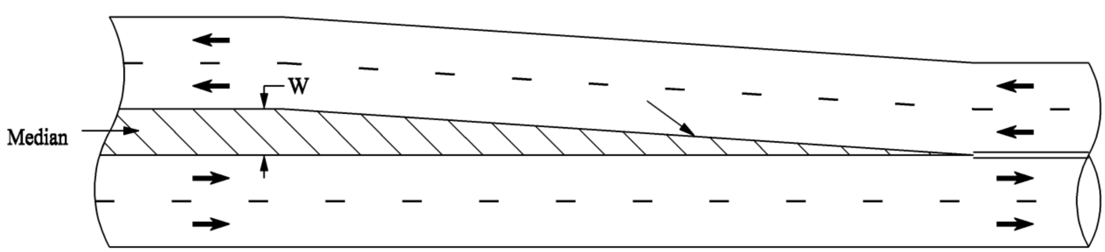


Figure 5C-2.06: Redirecting Through Lanes



E. Vertical Alignment

1. **Minimum Grades:** Flat and level grades on uncurbed pavements are preferred when the pavement is adequately crowned to drain the surface laterally. However, with curbed pavements, longitudinal grades must be provided to facilitate surface drainage. 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. The minimum allowance grade for bubbles and cul-de-sacs is 1%. Particular attention should be given to the design of stormwater inlets and their spacing to keep the spread of water on the traveled way within tolerable limits. Roadside channels and median swales frequently require grades steeper than the roadway profile for adequate drainage.

2. **Maximum Grades:** Grades for urban streets should be as level as practical, consistent with the surrounding terrain. The maximum design grades specified in Section 5C-1, Table 5C-1.02 should be used infrequently; in most cases grades should be less than the maximum design grade.

   Where sidewalks are located adjacent to a roadway, a maximum roadway grade of 5% is desirable. ADA requirements allow sidewalks adjacent to a roadway to match the running grade of the roadway, regardless of the resulting grade. However, sidewalk accessibility is greatly enhanced, especially over long distances, when grades are limited to 5% or less. It is recognized that meeting limitations will not be possible or practical in many situations; however, an attempt should be made to limit roadway grades to this level, especially in areas with high levels of anticipated pedestrian usage.

3. **Maximum Grade Changes:** Except at intersections, the use of grade breaks, in lieu of vertical curves, is not encouraged. However, if a grade break is necessary and the algebraic difference in grade does not exceed 1%, the grade break will be considered by the Engineer.

4. **Vertical Curves:** Vertical curves should be simple in application and should result in a design that is safe, comfortable in operation, pleasing in appearance, and adequate for drainage.

   The major control for safe operation on crest vertical curves is the provision of ample sight distances for the design speed. Minimum stopping sight distance should be provided in all cases. Wherever economically and physically feasible, more liberal stopping sight distances should be used. Furthermore additional sight distance should be provided at decision points.

   a. **Crest Vertical Curves:** Minimum lengths of crest vertical curves as determined by sight distance requirements are generally satisfactory from the standpoint of safety, comfort, and appearance. Figure 5C-2.06 shows the required length of crest vertical curve to provide stopping sight distance based upon design speed and change in grade.

   b. **Sag Vertical Curves:** Headlight sight distance is generally used as the criteria for determining the length of sag vertical curves. When a vehicle approaches a sag vertical curve at night, the portion of highway lighted ahead is dependent on the position of the headlights and the direction of the light beam. A headlight height of 2 feet and a 1 degree upward divergence of the light beam from the longitudinal axis of the vehicle is commonly assumed. For safety purposes, the sag vertical curve should be long enough that the light beam distance is the same as the stopping sight distance. Figure 5C-2.07 specifies the required sag curve length to meet the sight distance assumptions made above.

For both sag and crest vertical curves with a low algebraic difference in grade, sight distance restrictions may not control the design of the curve. In these cases, rider comfort and curve appearance are the primary considerations for vertical curve design. Generally, vertical curves with a minimum length (in feet) equal to three times the design speed (in mph) are acceptable.

If a roadway has continuous lighting, the length of sag vertical curve (L) may be based on passenger comfort instead of headlight sight distance. Use the following equation for the curve length:

$$L = \frac{AV^2}{46.5}$$

where A = algebraic difference in grades, %
V = design speed, mph

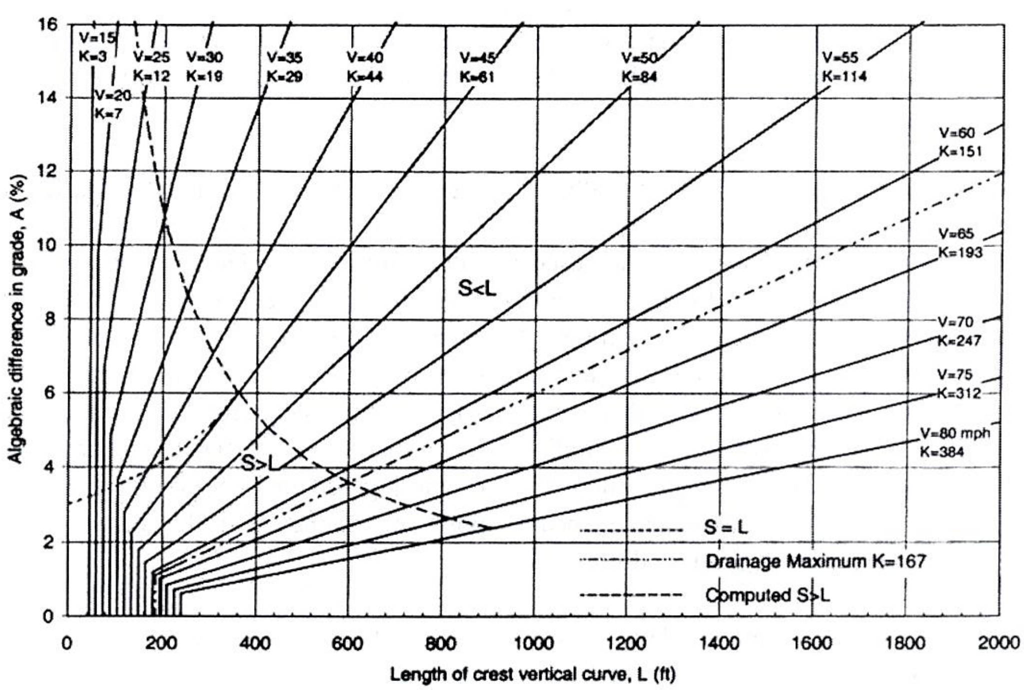
(Equation 3-51 AASHTO Green Book, 2011)

Drainage considerations also affect the design of vertical curves where curbs are utilized. Both crest and sag vertical curves that have a grade change from positive to negative (or vice versa) contain a level area at some point along the curve. Generally, as long as a grade of 0.30% is provided within 50 feet of the level area, no drainage problems develop. This criterion corresponds to a K value of 167 and is indicated by a dashed line in Figures 5C-2.06 and 5C-2.07 below. K values greater than 167 may be utilized, but additional consideration should be given to drainage in these situations.

$$K = \frac{L(ft)}{(g_2 - g_1)}$$

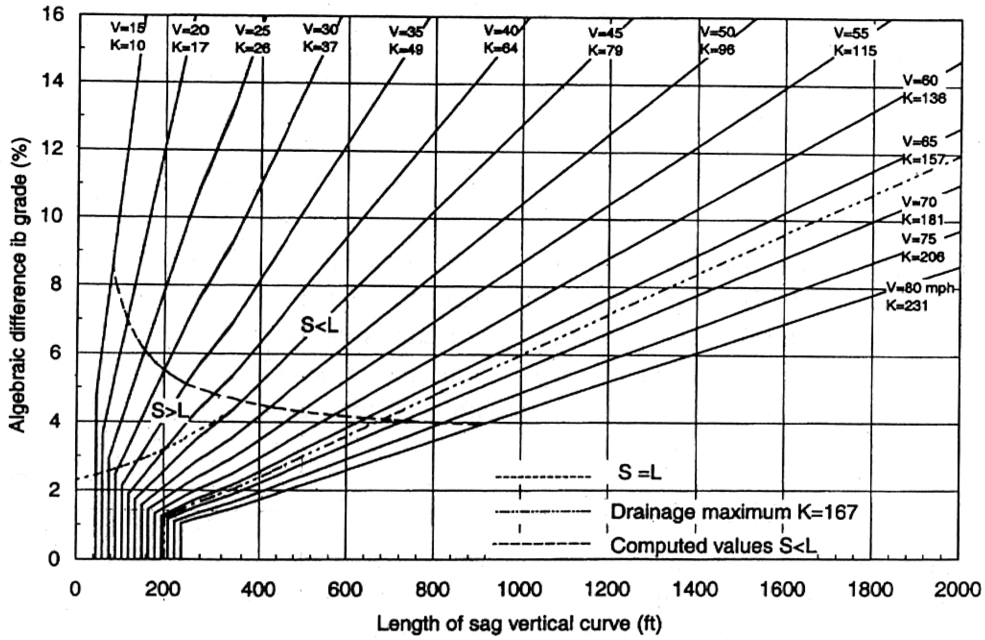
where g_1 and g_2 are in percent

Figure 5C-2.07: Design Controls for Crest Vertical Curves
for Stopping Sight Distance and Open Road Conditions



Source: AASHTO Green Book, Exhibit 3-71, 2004

Figure 5C-2.08: Design Controls for Sag Vertical Curves, Open Road Conditions



Source: AASHTO Green Book, Exhibit 3-78, 2004

5. **Intersection Grades:** The grade of the "through" street should take precedence at intersections. At intersections of roadways with the same classifications, the more important roadway should have this precedence. Side streets are to be warped to match through streets with as short a transition as possible, which provides a smooth ride. Consideration must be given to minimize sheet flow of stormwater across the intersection due to loss of crown on the side street.

   Carrying the crown of the side street into the through street is not allowed. In most cases the pavement cross-slope at the warped intersection should not exceed the grade of the through street.

   The maximum desirable grades of the through street at the intersection and the side street cross-slope should be 2% and should not exceed 3%. The maximum desirable approach grade of the side street should not exceed 4% for a distance of 100 feet from the curb of the through street.

   Establishing intersection spot grades by matching “curb corners” of intersecting streets is not recommended since it may result in an undesirable travel path from the through street to the side street because of the resulting bump on the side street centerline. At sidewalk curb ramps in intersections, the street grades may need to be warped at the curb line to ensure the resulting cross-slope at the bottom of the ramp does not exceed 2%. A detail of the jointing layout with staking elevations should be shown on the plans.

   ADA regulations set specific limits for crosswalk cross-slopes that directly impact street and intersection grades. ADA regulations limit the cross-slope to 2% (measured perpendicular to the direction of pedestrian travel) for crosswalks that cross a roadway with stop control (stop sign) at the intersection. For roadways without stop control (through movement or traffic signal) the cross-slope of the crosswalk is limited to 5%. Effectively, this requirement limits street grades to a maximum of 2% or 5% depending on intersection controls.

   For steep roadways without stop control, construction of a flattened “table” may be necessary to reduce the street grade to 5% or less at the location of the crosswalk. Crosswalk tables at these locations must utilize vertical curves, appropriate for the design speed, to avoid a sudden change in grade at the intersection that could cause vehicles to bottom out or lose control.

For steep roadways with stop control, construction of a flattened “table” may utilize grade breaks or shortened vertical curves to reduce the street grade to 2% or less at the location of the crosswalk. A check should be made to verify that vehicles will not bottom out when traveling over the crosswalk table.

F. Pavement Crowns

The following typical pavement crowns are straight line cross-slope and are desirable sections.

1. **Urban Roadways (Curb and Gutter):** For streets with three or fewer travel lanes, the pavement crown should be 2%.

   For streets with four or more travel lanes, the pavement crown for all inside lanes, including left turn lanes, should be 2%. In order to reduce stormwater spread, the pavement crown for the outside lanes should be 3%.

   For all streets, auxiliary right turn lanes will have varying pavement crowns depending on the desired drainage pathway.

2. **Rural Roadways:** For pavement crowns, a 2% cross-slope is normal with 4% shoulder slope. Where sidewalks are not present and shoulders are designated as the pedestrian access route, they must not exceed 2% cross slope per ADA requirements. Iowa DOT Standard Road Plans should be checked for Federal Aid, Farm to Market, and Secondary Roads.

G. Lane Width

The lane width of a roadway influences driver speed. Narrow lanes force drivers to operate their vehicles closer to each other laterally than they would normally desire, resulting in lower operating speeds.

Section 5C-1, Tables 5C-1.01 and 5C-1.02 indicate minimum lane widths based on the roadway classification and adjacent land use. Refer to Section 5M-1 for additional discussion of lane width for multimodal streets.

Auxiliary lane and turn lane widths at intersections should be equal to the adjacent through lanes. The width for turn lanes is measured to the face of curb. Because motorists are slowing in anticipation of making a turning movement, drivers are comfortable operating their vehicle closer to an adjacent obstacle (curb); therefore, turn lanes do not require a curb offset.

H. Two-way Left-turn Lanes (TWLTL)

Two-way left-turn lanes work well where design speeds are relatively low (25 to 50 mph) and there are no heavy concentrations of left turning traffic. The width of TWLTLs should be limited to a maximum of 14 feet to discourage left-turning motorists from pulling out into the TWLTL and stopping perpendicular to the direction of traffic, while they wait for oncoming traffic to clear. Section 5C-1, Tables 5C-1.01 and 5C-1.02 indicate preferred and acceptable widths for TWLTLs.

I. Raised Median Width

A median is defined as the portion of a roadway separating opposing directions of the traveled way. The median width is expressed as the dimension between the edges of the traveled way and includes the left turn lanes, if any are present (refer to Section 5C-1, Figure 5C-1.01). The principal functions of a median are to separate opposing traffic, allow space for speed changes and storage of left turning and U-turning vehicles, minimize headlight glare, and provide width for future lanes. For maximum efficiency, a median should be highly visible both night and day and contrast with the traveled way lanes.

At unsignalized intersections on rural divided highways, the median should generally be as wide as practical. However, in urban areas, narrower medians appear to operate better at unsignalized intersections. If right-of-way is restricted, a wide median may not be justified if provided at the expense of a narrowed border area. A reasonable border width is needed to adequately serve as a buffer between private development along the road and the traveled way. Narrowing the border area may create operational issues similar to those that the median is designed to avoid. In addition, wide medians at signalized intersections result in increased time for pedestrians, bicyclists, and vehicles to cross the median. This can lead to an increase in exposure time for pedestrians resulting in reduced safety and inefficient signal operation. Therefore, in urban areas, it is recommended that median width be only as wide as necessary to accommodate left turn lanes. Wider medians should only be used where needed to accommodate turning and crossing maneuvers by larger vehicles.

Medians and boulevards are not normally used on collector streets. However, when allowed, the median or boulevard should conform to the same design standards as set forth for arterial streets.

Median widths are also affected by sidewalk and crosswalk locations. Where a crosswalk cut through is present or proposed, the minimum width for a crossing island to provide an accessible refuge is 6 feet, measured from outside edge of the detectable warning surfaces, and the minimum width between detectable warning surfaces is 24 inches. The detectable warnings must be separated by a minimum 2 foot strip without detectable warnings. Where the median has no curb, the detectable warnings must be placed along the edge of the roadway. At locations where a raised median is stopped short of the crosswalk, the 6 foot raised median and associated detectable warnings are not required, and a standard 4 foot raised median section may be used. See Section 12A-5 for more guidance on designing safe pedestrian and bicycle crossings at medians.

J. Bridges

The bridge widths listed in Section 5C-1, Tables 5C-1.01 and 5C-1.02 represent the clear roadway width (width between barrier rail faces). The widths shown do not account for barrier rail widths, sidewalk, recreational trails, etc. In addition, designers should consider a sidewalk on one side in rural areas and should include sidewalks on both sides in rural town, suburban, and urban areas, even when sidewalks may not exist today. Sidewalks are difficult to retrofit on existing bridges and not including them now may preclude future sidewalk connections. For bridges with a shared use path, see Section 12B-2, 1.

For existing bridges, a structural analysis should be conducted. The existing bridge should be able to accommodate legal loads. Bridge guardrail should be upgraded if necessary.

K. Clear Zone

The AASHTO Roadside Design Guide (RDG) defines the clear zone as "the total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope, and/or a clear runout area. The desired width is dependent upon the traffic volumes and speeds and on the roadside geometry."

The intent of the clear zone is to provide an errant vehicle that leaves the roadway with an unobstructed recovery area. This area, including medians on divided roadways, should be kept free of all unyielding objects, including utility and light poles, culverts, bridge piers, sign supports, and any other fixed objects that might severely damage an out of control vehicle. Any obstruction that cannot be placed outside of the clear zone should be shielded by traffic barriers or guardrails.

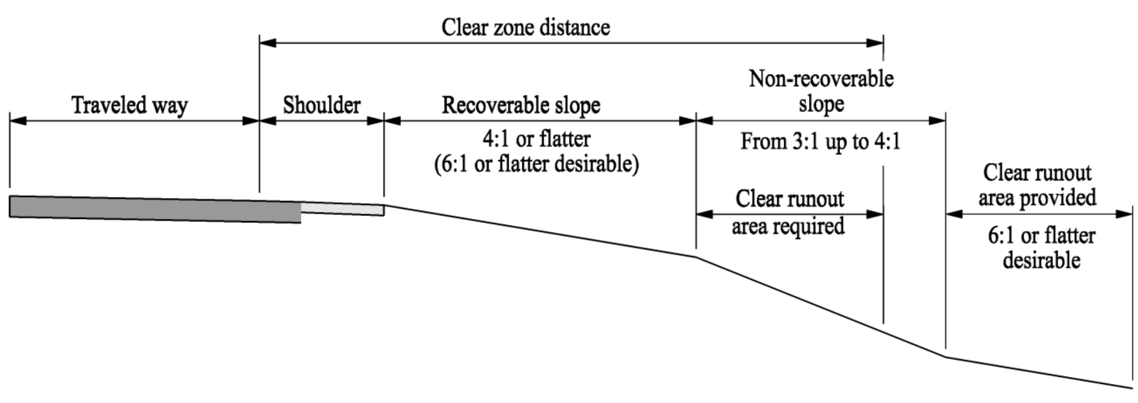
According to the AASHTO RDG, the width of this area varies based upon traffic volumes, design speed, and embankment slope.

Embankment slopes can be classified as recoverable, non-recoverable, or critical. Embankment slopes of 4:1 and flatter are considered recoverable. Drivers who encroach on recoverable slopes can generally stop their vehicles or slow them enough to return to the roadway safely.

A non-recoverable slope is defined as one that is passable, but from which most motorists will be unable to stop or to return to the roadway easily. Vehicles on such slopes are likely to reach the bottom before stopping. Embankments between 3:1 and 4:1 generally fall into this category. Since many vehicles will reach the toe of these slopes, the clear zone distance cannot logically end on a non-recoverable slope, and a clear runout area at the base of the slope is required. Fixed objects should not be present on a non-recoverable slope.

A critical slope is one on which a vehicle is likely to overturn. Slopes steeper than 3:1 generally fall into this category. If a slope steeper than 3:1 begins closer to the traveled way than the suggested clear zone, a barrier might be warranted if the slope cannot be flattened.

Figure 5C-2.09: Clear Zone Components



Source: Adapted from *Roadside Design Guide*, 2006

For horizontal curves, an adjustment factor may be applied to the clear zone width taken from Section 5C-1, Tables 5C-1.03 or 5C-1.04. This adjustment is only required at selected locations. Widening the clear zone should be considered along the outside of curves when crash history suggests the need for additional clear zone width, or whenever the radius of the curve is less than 2,860 feet, the design speed is 55 mph or greater, and the curve occurs on a normally tangent alignment (one where the curve is preceded by a tangent more than a mile in length).

The clear zone along an urban section may contain minor obstructions (traffic signs, mailboxes, etc.). In addition, along lower (<40 mph design speed) urban roadways, larger objects designed to "break-away" when struck by a vehicle may also be located within the clear zone (light poles, cast-iron fire hydrants, etc.). All objects, however, should be kept free from the object setback zone as described in the next section.

L. Object Setback

Like clear zone, object setback is intended to provide an area adjacent to the roadway that is clear of obstructions. However, the purpose of the object setback is to provide an operational clearance to increase driver comfort and avoid a negative impact on traffic flow. It also improves aesthetics, provides an area for snow storage and, in areas with curbside parking, provides a clear area to open car doors.

As shown in Section 5C-1, Tables 5C-1.01 and 5C-1.02, minor obstructions and larger "breakaway" objects may be located in the clear zone on lower speed roadways (<40 mph design speed), but must be kept free from the object setback. Mailboxes constructed and installed according to US Postal Service regulations, including breakaway supports, may be located within the object setback area.

Additional object setback (typically 3 feet), as measured from the back of curb, may be required around radii at intersections and driveways in order to provide sufficient clearance to keep the overhang of a truck from striking an object.

M. Border Area

Border area is the area between the roadway and the right-of-way line and is sometimes referred to as the "parking" in urban areas. The grade for the border area is normally 1/2 inch per foot. The border area between the roadway and the right of way line should be wide enough to serve several purposes including provision of a buffer space between pedestrians and vehicular traffic, sidewalk space, and an area for both underground and above ground utilities such as storm sewer, traffic signals, parking meters, and fire hydrants. The border area also provides snow storage and aesthetic features such as grass or other landscaping features. The border width ranges from 14 to 16 feet, including the sidewalk width. Traffic signals, utility poles, fire hydrants, and other utilities should be placed as far back of the curb as practical for safety reasons. Breakaway features should be built when feasible and as an aid to safety considerations.

Table 5C-2.02: Preferred Border Area

Street Classification	Border Area Width (feet)
Major/minor arterial	16
Collector	14.5
Local streets	14

N. Curbs

1. **Curb Offset:** The curb offset is measured from the back of curb to the edge of the lane. The curb offset increases driver comfort and roadway safety. The presence of the curb, and potential vehicle damage and loss of control resulting from striking the curb, causes drivers to move away from the curb, reducing the effective width of the through lane. Due to this driver reaction, and to accommodate the flow of drainage and intake structures, an offset between the curb and the edge of the traveled way is provided.

   The curb offset widths specified in Section 5C-1, Tables 5C-1.01 and 5C-1.02 do not necessarily indicate the width of the curb and gutter or the location of a longitudinal joint; however, the width of the curb and gutter can affect the required width of the curb offset. The presence of a longitudinal joint near the curb (gutterline jointing) can be a limiting factor for usable lane width as some drivers are uncomfortable driving on or near the joint line. This is especially true for HMA roadways with PCC curb and gutter. For pavements with a longitudinal joint line near the gutter, the curb offset should be equal to or greater than the width of the curb and gutter section. In addition, grates and special shaping for curb intakes and depressions for open-throat intakes should be located within the curb offset width and should not encroach into the lane.

2. **Curb and Gutter:** Typically, a curb should be 6 inches high, 6 inches wide. Where curb and gutter is used, the standard gutter width is 2 feet, 6 inches. When a gutter is used, it should not be included in the travel lane width. If the design speed is 40 mph or below, an 8 inch curb may be used for certain arterial and collector streets. For design speeds greater than 40 mph, a 1 foot wide, 6 inch high sloped curb with up to a 2 foot offset may be used. Where a gutter is used, its width is considered part of the curb offset width.

O. Parking Lane

Where curbed sections are used, the curb offset width may be included as part of the parking lane.

1. Parking lanes are not allowed on arterial streets.

2. Although on-street parking may impede traffic flow, parallel parking may be allowed by the Jurisdiction on urban collectors where sufficient street width is available to provide parking lanes.

3. Parking lane width determinations should include consideration for the potential use of the lane as a through or turn lane for moving traffic either during peak hours or continuously. If this potential exists, additional parking width should be provided.

P. Cul-de-sacs

A local street open at one end only should have a cul-de-sac constructed at the closed-end. The 2018 International Fire Code stipulates a minimum cul-de-sac radius of 48 feet however some jurisdictions allow lesser radii due to the size of their fire apparatus. The minimum radius for cul-de-sacs is 45 feet, which may be increased in commercial areas or if significant truck traffic is anticipated. The border area around the cul-de-sac should be the same as the approach street. The transition radius with the approach street will be 50 feet for residential streets and 75 feet for commercial and industrial streets.

The length of a cul-de-sac determines how many people are impacted by maintenance operations, traffic accidents, and other incidences that may stop traffic flow. Many Iowa cities limit the length of a cul-de-sac to 500 to 600 feet. Studies indicate the longer the cul-de-sac, the higher the vehicular speeds along it. The 2018 edition of the International Fire Code recommends the length of the cul-de-sac be less than 750 feet unless additional steps such as intermediate turnarounds are implemented. ITE, the Urban Land Institute, and ASCE indicate cul-de-sacs should be less than 1,000 feet long or the length that generates less than 200 trips per day according to the adjacent land use. For single family dwellings that generate 8 to 10 trips per day, the 200 trips per day would be produced by about 20 parcels.

Consider building cut through sidewalks or shared use paths at the closed end of the cul-de-sac to improve pedestrian and bicyclist connections to surrounding neighborhood or land uses. The cut through sidewalk or shared use paths is likely to reduce vehicular trips by encouraging walking and bicycling.

Q. Shoulder Width

Shoulders accommodate stopped vehicles, emergency use, and provide lateral support of the subbase and pavement. In some cases, the shoulder can accommodate pedestrians when no sidewalks are present and bicyclists. Where no curb and gutter is constructed a soil, granular, or paved shoulder will be provided. When pedestrians and/or bicyclists are expected to use the shoulder, the shoulder should be paved. Refer to Section 12B-3 for guidance on paved shoulder widths. The AASHTO *Guide for the Planning, Design and Operation of Pedestrian Facilities* presents appropriate methods for accommodating pedestrians on paved shoulders. Where shoulders are designated as the pedestrian access route, shoulder must also meet accessibility requirements.

Desirably, a vehicle stopped on the shoulder should clear the pavement edge by 2 feet. This preference has led to the adoption of 10 feet as the desirable shoulder width that should be provided along high volume facilities. In difficult terrain and on low volume highways, usable shoulders of this width may not be practical.

Where roadside barriers, walls, or other vertical elements are used, the graded shoulder should be wide enough that these vertical elements can be offset a minimum of 2 feet from the outer edge of the usable shoulder. It may be necessary to provide a graded shoulder wider than used elsewhere on the curved section of a roadway or to provide lateral support for guardrail posts and/or clear space for lateral dynamic deflection required by the particular barrier in use. On low volume roads, roadside barriers may be placed at the outer edge of the shoulder; however, a minimum of 4 feet should be provided from the traveled way to the barrier.

R. Intersection Radii and Right Turning Vehicle Speeds

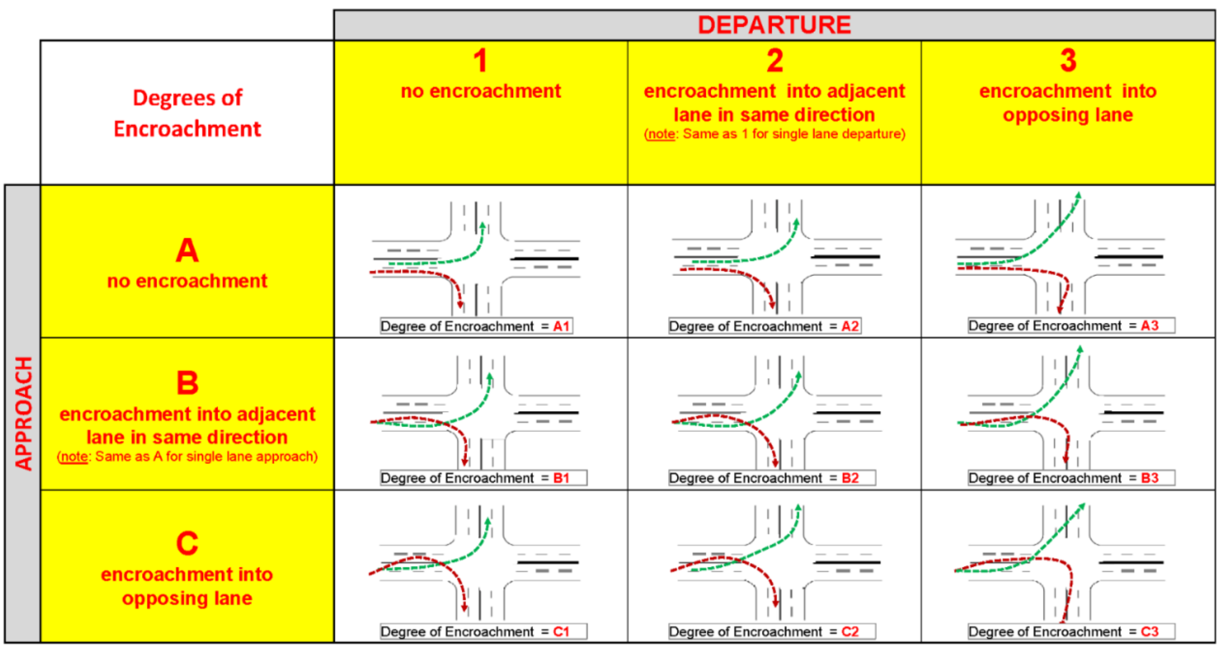
Vehicle turning movements affect operations and safety at an intersection and driveways – especially the safety of pedestrians and bicyclists. It is important to consider the size of vehicles that will reasonably be expected to move through the intersection, the frequency of these movements, and any local jurisdictional policies for lane encroachment. For roadways where the most common vehicle is a passenger car, delivery vehicle, or single unit truck, designing intersections to easily accommodate larger vehicles with large turning radii can negatively affect crossing distances, exposure to conflicts, the speed of turning vehicles, the severity of crashes, and amount of right-of-way needed for the intersection. Similarly, using a smaller design vehicle at intersections that are regularly used by larger vehicles should also be avoided because frequent operational challenges may occur, may lead to encroachment beyond the edge of pavement or curb line, and can lead to damage to infrastructure such as curb ramps, signs, or poles. The following sections describe the process for selecting the appropriate design vehicle and intersection turning radii.

1. **Selecting Intersection Design and Control Vehicles:** Typical design and control vehicles, described below, are shown in Table 5C-2.03 for different roadway classifications. Refer to the current AASTHO Green Book for turning templates.

   a. **Intersection Design Vehicle (IDV):** The design vehicle is the least maneuverable vehicle that routinely uses the street. Designers use a design vehicle to determine corner radii at intersections and should use this vehicle when completing analysis with turning analysis software. If an intersection includes a bus route where buses make turns, an appropriately-sized bus may be used as the design vehicle. In many jurisdictions, a standard box truck (SU-30) or a school bus is the default design vehicle. The current AASHTO Green Book provides turning templates for a variety of design vehicles. The Iowa DOT has an Iowa truck vehicle that can be used to check the proposed radii for truck routes.

   b. **Intersection Control Vehicle (ICV):** The control vehicle is an infrequent but necessary user of the street. The control vehicle for intersection design is often a moving truck or a fire truck; there may be local jurisdictional policies to decide which control vehicle to use. The control vehicle can be assumed to use other traversable parts of an intersection, including across centerlines, also known as encroachment. Encroachment is the ability for a vehicle to use space outside of its designated travel lane, but within the roadway, to navigate a turning movement. Encroachment does not include tracking over curbs or onto the sidewalk area. Encroachment into opposing traffic lanes is discouraged on all roadways. Consult the local jurisdiction's current fire official to ensure the design meets emergency response needs.

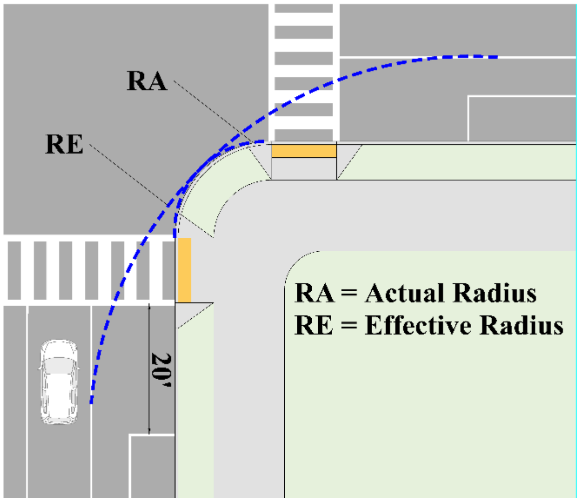
Figure 5C-2.10: Degrees of Encroachment



Source: Adapted from WisDOT Facility Design Manual

3. **Actual and Effective Curb Radius:** Two distinct radii need to be considered when designing street corners. The first is the actual radius of the street corner itself, and the second is the effective turning radius of the selected design vehicle or control vehicle, see Figure 5C-2.11. The effective turning radius is the radius needed for a turning vehicle to clear any adjacent parking lanes and/or to align itself with its new travel lane. Using an effective turning radius allows a smaller curb radius than would be required for the motorist to turn from curb lane to curb lane. It is critical that encroachment does not include tracking over the curbs or into the sidewalk area.

Figure 5C-2.11: Actual Corner Radius vs. Effective Turning Radius



Source: Adapted from NACTO Urban Street Design Guide

4. **Turning Vehicle Design Speed:** At both signalized and unsignalized intersections (including roundabouts), steps should be taken to ensure that turning speeds are kept low and that sight distance is not compromised for pedestrians, bicyclists, or motorists. While performing swept path analyses, the maximum recommended turning speed of the design and control vehicle is 10 mph. See Section 5M-1 for turning speeds when pedestrians and bicyclists are present.

5. **Selecting Intersection or Driveway Corner Radii:** Designers should strive to provide the appropriate corner radius for the given IDV and ICV, target turning speeds, acceptable lane encroachment, number of receiving lanes, and effective pavement width. In addition to discouraging higher turning speeds, smaller corner radii are preferred in order to better align curb ramps with pedestrian paths of travel and shorten crossing distances.

S. Pavement Thickness

Refer to Section 5F-1 for pavement thickness determination and design.

T. References

American Association of State Highway and Transportation Officials (AASHTO). *A Policy on Geometric Design of Highways and Streets* (referred to as “Green Book”). Washington, DC. 2018.

American Association of State Highway and Transportation Officials (AASHTO). *Guide for the Planning, Design, and Operation of Pedestrian Facilities*. Washington, DC. 2004.

American Association of State Highway and Transportation Officials (AASHTO). *Roadside Design Guide*. 3rd ed. Washington, DC. 2006.

Des Moines Area Metropolitan Planning Organization (MPO). *Des Moines Area Daily Directional Capacities at Level of Service D*. Des Moines. 2000.

Federal Highway Administration (FHWA). Achieving Multimodal Networks: *Applying Design Flexibility and Reducing Conflicts.* Washington, DC. 2016.

National Association of City Transportation Officials, (NATCO). *Urban Street Design Guide.* New York, New York. 2013.

Wisconsin Department of Transportation (WisDOT). *Facilities Development Manual* (FDM). Madison, WI. 2022.

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 (NMAS) 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 Asphalt 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 Iowa, PG 58-28S binders will provide full 98% reliability.

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

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		Criteria			
Design Traffic (1×10^6 ESALs)	**Mix Designation**	**Design Traffic (1×10^6 ESALs)**		**Design Speed (MPH)**	**PG Binder**
≤ 0.3 M	LT	≤ 0.3 M	and	ANY	58-28S
0.3 M to 1 M	ST	0.3 M to 1 M	and	> 45	58-28S
0.3 M to 1 M	ST	0.3 M to 1 M	and	15 to 45	58-28S[1]
1 to 10 M	HT	1 to 10 M	and	15 to 45	58-28H
Overlays	LT/ST/HT	≤ 10M	and	15 to 45	64-22S[2] or 58-28S or H

L = Low S = Standard H = High

[1] Use of PG 58-28H should be considered if heavy truck or bus traffic is present.
[2] If methods are used to retard reflective cracking, PG 58-28S or H is recommended.

b. Asphalt Mixture Size: Each mixture size (NMAS) 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 $ESAL_{20}$ 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.

Figure 5G-3.14: Cul-de-sac Joint Locations - Quarter-point Jointing Examples
(SUDAS Specifications Figure 7010.905, sheet 1)

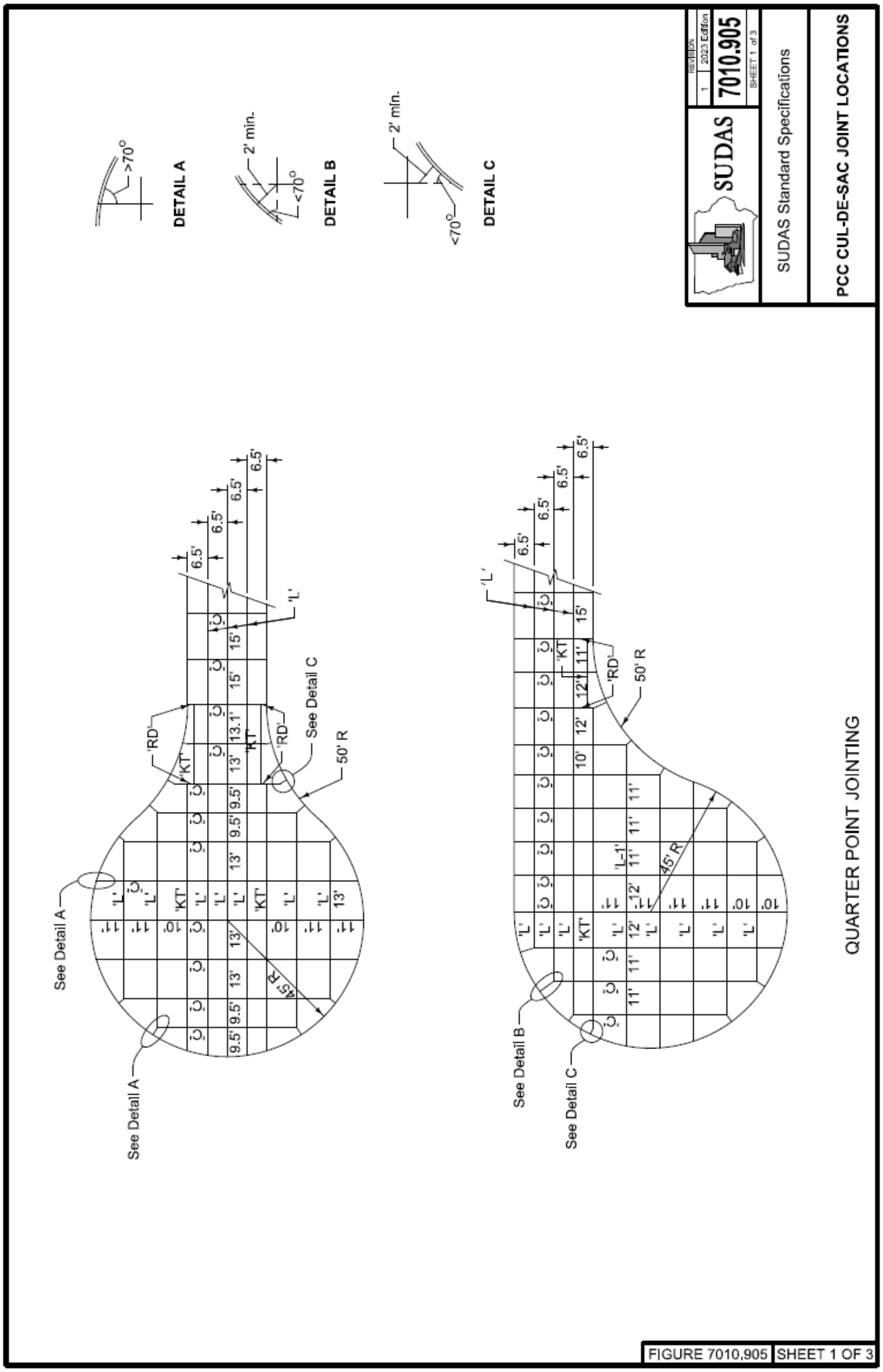


Figure 5G-3.15: Cul-de-sac Joint Locations - Third-point Jointing Examples
(SUDAS Specifications Figure 7010.905, sheet 2)

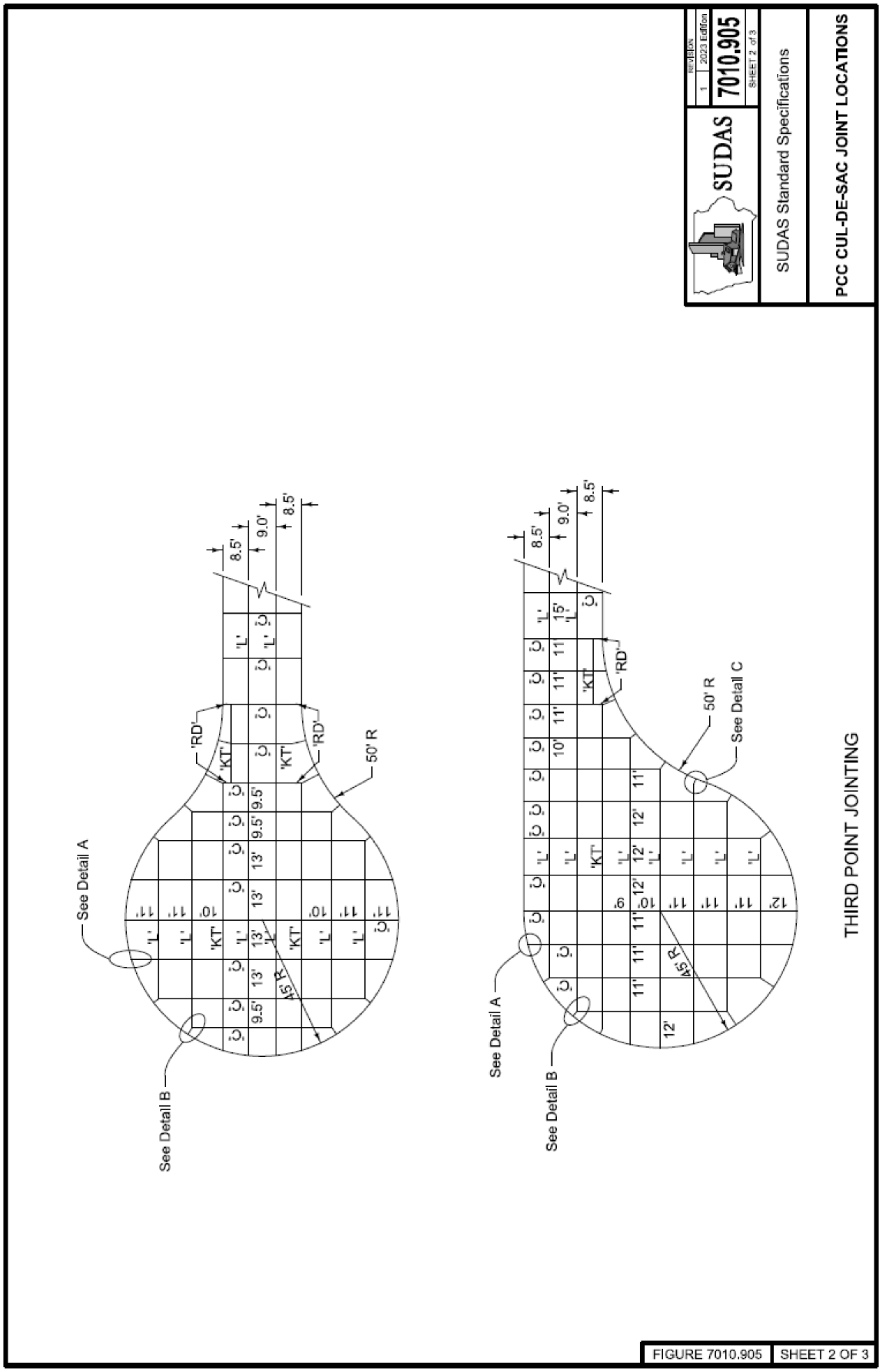
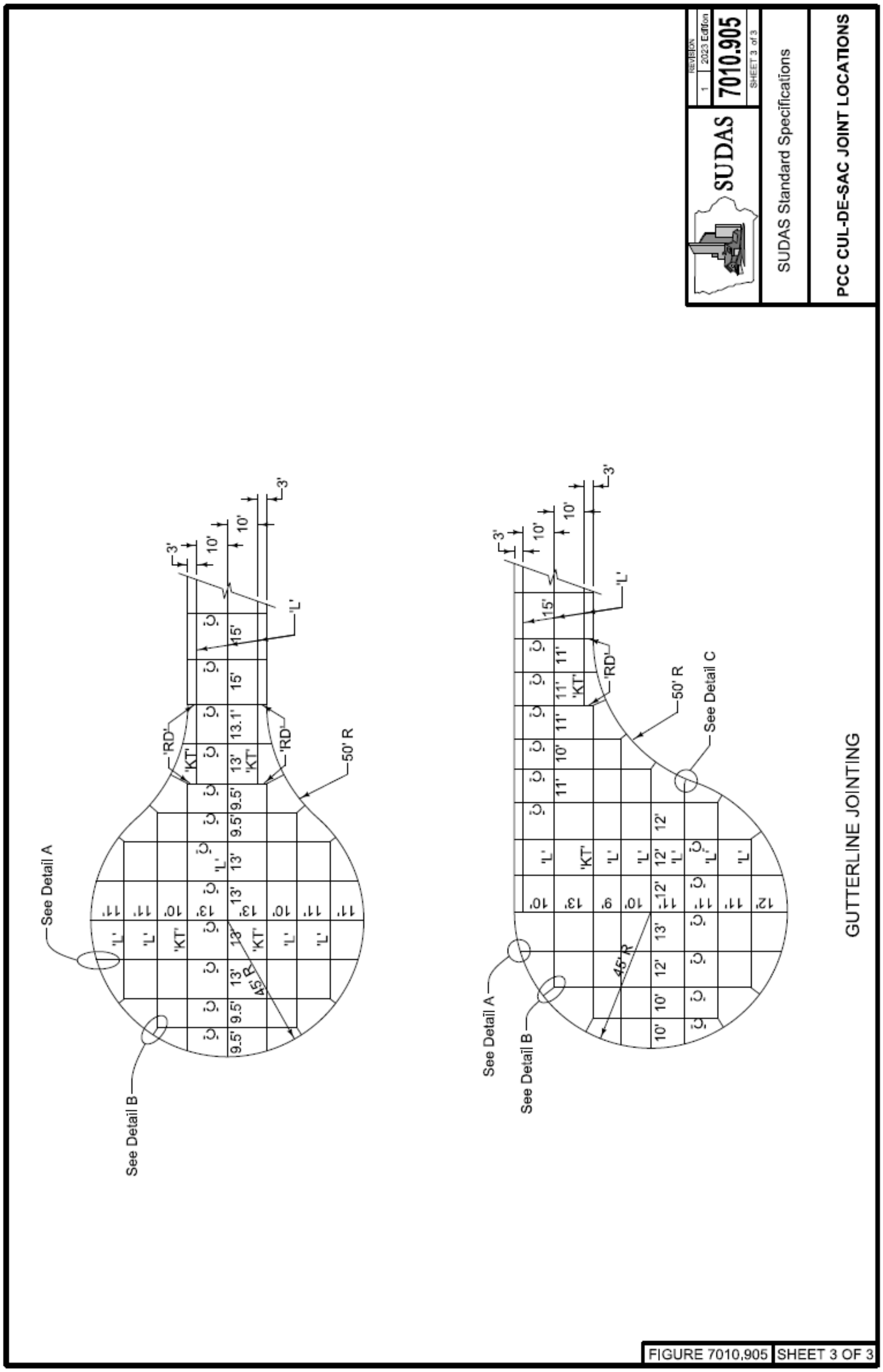


Figure 5G-3.16: Cul-de-sac Joint Locations - Gutterline Jointing Examples
(SUDAS Specifications Figure 7010.905, sheet 3)



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. Several 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. Safety and accommodation of all users should guide decisions when evaluating different designs and tradeoffs between factors that may be in conflict with each other, such as:

- Number and types of users - cars, trucks, transit buses, pedestrians, bicyclists, and other modes
- 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 TMAs/MPOs to adopt a complete streets policy for all federally funded projects.

B. Design Guidance

There are numerous 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. In addition to safety, complete streets planning and design works to address issues of health, livability, economic development, sustainability, and aesthetics. In the past, functional classification, traffic volumes, and level of service have been used as the critical factors for street design. However, a complete streets approach emphasizes safety for vulnerable users and identifies core goals for street design through stakeholder input. Public input may determine that sidewalk amenities, bicycle facilities, or transit accommodation are more important than the vehicular level of service. It is important to develop a spectrum of alternatives that consider the needs of various users and reach a design decision that addresses those needs.

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. For general guidance:

- AASHTO's A Policy on Geometric Design of Highways and Streets (the "Green Book")
- MUTCD
- The Highway Capacity Manual (HCM)
- ITE Traffic Engineering Manual
- FHWA *Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts*

For designing streets in urban areas:

- ITE *Designing Walkable Urban Thoroughfares: A Context-Sensitive Approach*
- NACTO *Urban Streets Design Guide*
- NCHRP 880 *Design Guide for Low-Speed Multimodal Roadways*
- FHWA *Road Diet Information Guide*

For bikeway design guidance:

- AASHTO *Guide for the Development of Bicycle Facilities* (the "Bicycle Guide")
- NACTO *Urban Bikeway Design Guide*
- FHWA *Incorporating On-Road Bicycle Networks into Resurfacing Projects*

For pedestrian-specific design guidance:

- FHWA STEP *Guide for Improving Safety at Uncontrolled Crossing Locations* ("STEP Crossings Guide")
- US Access Board PROWAG

Other design guidance:

- NFPA Fire Code
- Local design ordinances

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 also be different. 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 established standards or fall within the range of acceptable guidelines provided by the above manuals.

C. Design Elements

Many elements must be considered during the complete streets 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. In commercial/retail areas, there is an expectation that pedestrians, transit, and bicyclists will be present in larger numbers. 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.

   Five basic land use context classifications and three basic land use types are discussed in Section 5C-1, but many communities will have a broader range of both categories. 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.

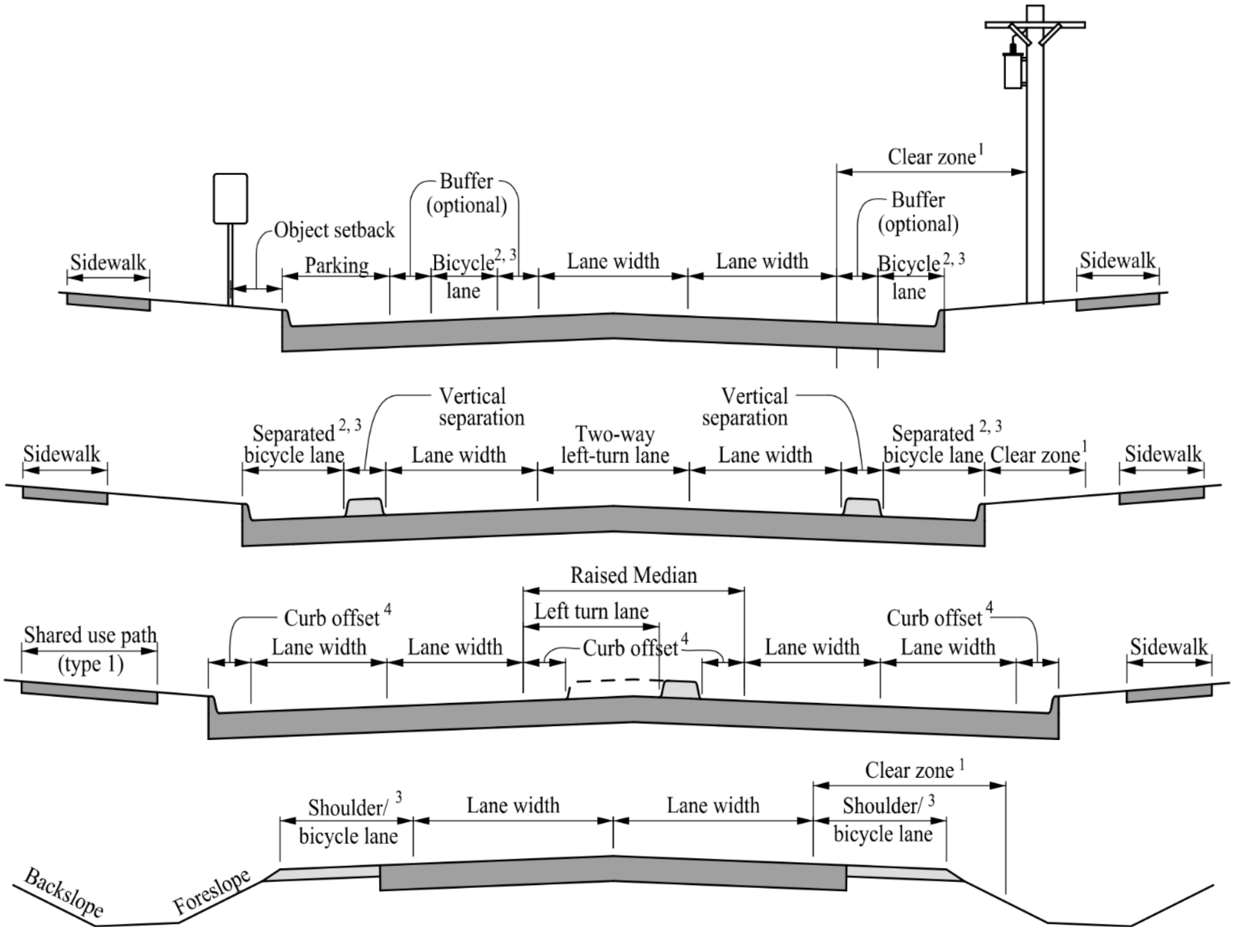
   Designers should also be cognizant of roadways that are transit routes, bikeways such as bicycle boulevards, truck routes, etc. as identified through state or local transportation plans as this influences the purpose and use of a roadway as well.

3. **Roadway Sizing:** Many communities have streets with excess lane capacity and oversized lane widths for motor vehicles. Multilane roads can take longer for pedestrians to cross, increase pedestrian exposure, and can facilitate faster speeds by motor vehicle traffic. During resurfacing and re-construction, designers should consider lane reductions and road reconfigurations (often called “road diets”) to decrease the number and widths of lanes. This can reduce vehicle speeds, reduce pedestrian crossing distances, and provide space for bicycle facilities. A typical “four-to-three lane” roadway reconfiguration converts an existing four-lane, undivided roadway into a roadway with one through lane in each direction and a center, two-way left-turn lane (TWLTL). This conversion can often provide space for bicycle lanes, as shown in Section 12B-3, G, or other users, including pedestrian refuge islands, on-street parking, or widened sidewalks and wider landscaped buffers (often called “the parking” in Iowa).

   Suitable candidates for a “four-to-three lane" roadway reconfiguration have an average daily traffic (ADT) equal to or less than about 20,000 vehicles per day. In some instances, roadway reconfigurations have been successfully applied on roads with ADTs as high as 25,000. FHWA’s Road Diet Information Guide further discusses the safety and operational benefits of road diets.

   For new roadway construction in urban, suburban, and rural town contexts, adequate sidewalk, sidewalk buffers, and bicycle facilities should be provided. Right of way may be reserved to accommodate longer term (10 years or greater) projected volumes, but roadways should not be overbuilt as wider than necessary roadways can encourage higher motor vehicle speeds and decrease overall safety. Overbuilt roadways also increase maintenance and life-cycle costs.

Figure 5M-1.01: Roadway Design Elements

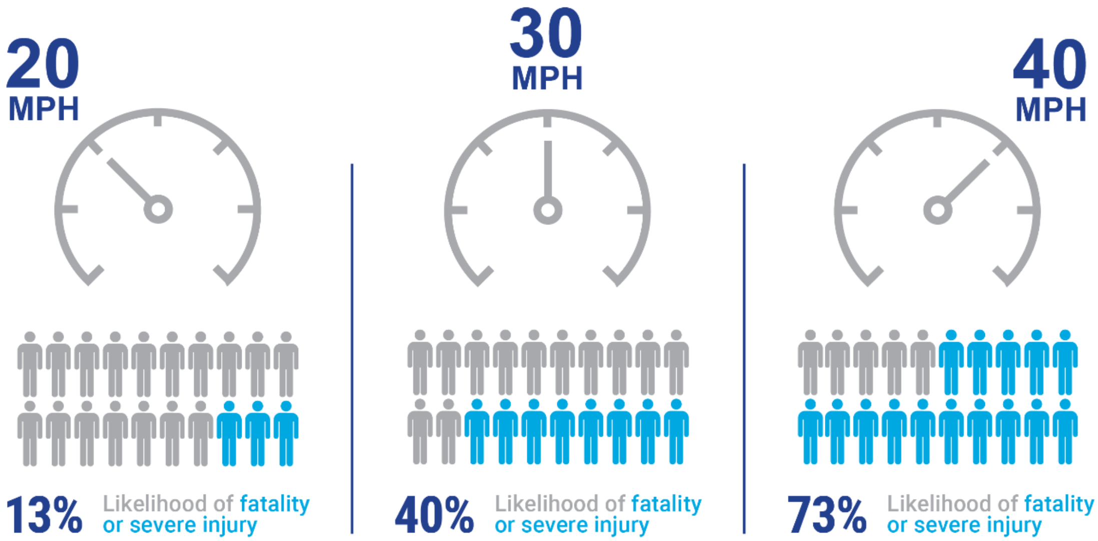


[1] Clear zone is measured from the edge of the traveled way.
[2] See Chapter 12 for bicycle lane requirements.
[3] Bicycles may be placed between the curb and parking on corridors with higher traffic volume and speed, see Sections 12B-1 and 12B-3 for separated bicycle lane design with on-street parking buffers
[4] For low-speed street conditions in urban and rural town areas, curbs may be placed at the edge of the traveled way.

4. **Speed:** Operating speeds influence the design of the roadway including stopping sight distance, passing sight distance, intersection sight distance, and horizontal and vertical curve elements. The design speed should therefore be equal to the posted speed to encourage operating speeds at or below the posted speed. Design values from the AASHTO Green Book 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.

   In the past, it was considered best 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. People walking and bicycling are particularly vulnerable in the event of a crash, and vehicle speeds where conflicts occur are a primary factor in the likelihood of serious injuries and fatalities, see Figure 5M-1.01. In general, the speed chosen for design should reflect the network needs and the adjacent land use. On existing roadways with operating speeds that exceed the posted speed, roadway redesign and traffic calming measures should be considered to reduce speeds and improve safety and comfort for all users. Traffic calming or roadway redesign should also be considered on roadways where lowering the posted speed is desirable to reinforce to drivers that slow speeds are expected.

Figure 5M-1.02: Vehicle Speeds and Risks to Pedestrians



Source: Tefft, B.C.

In general, streets in urban areas should be designed and control devices regulated to allow speeds of 20 to 45 mph. Speeds in the lower portion of this range are applicable to local and collector streets through residential areas, and to arterial streets through more crowded business districts, while the speeds in the higher portion of the range apply to arterial streets in outlying suburban areas.

Iowa Statute 321.285 establishes the following statutory speed limits, although city councils may adopt by ordinance higher or lower speed limits upon the basis of engineering or traffic studies (§321.290):

- 20 mph in a business district
- 25 mph in any residence or school district
- 45 mph in any suburban district

The AASHTO Green Book provides further guidance on appropriate design speeds for specific roadway types.

5. **Intersection Design and Control Vehicle:** The selection of the design and control vehicle is an important element in complete streets design. Lane width and curb radii are directly influenced by the design vehicle. Section 5C-2, R provides guidance on selecting design vehicles, control vehicles, and typical curb radii for different roadways.

   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.

To achieve the smallest appropriate corner radius, designers should follow these strategies:

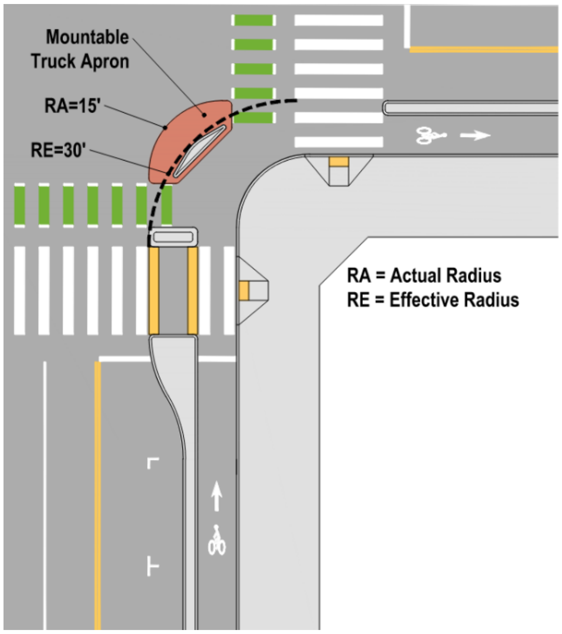
- Using vehicle turning software or turning templates, designers should minimize the actual corner radius while accommodating the effective turning radius of vehicles.
- Where pedestrians or bicyclists are expected and the effective turning radius exceeds 15 feet., consider the following:
  - Push back the stop line of the receiving street beyond the minimum 4 feet from crosswalks where appropriate. Ensure any encroachment does not conflict with overlapping phases at signalized intersections. In general, stop lines should not be pushed back more than 30 feet from crosswalks as motorist compliance may be diminished; however, the maximum distance from the stop line to traffic signals cannot exceed the sight distance and clear zone requirements established in MUTCD Chapter 4D.
  - Provide a truck apron to increase the effective radius for larger vehicles, including SU-30, while providing a smaller effective radius for the majority of vehicles (e.g., passenger car), see Section 5C-2, S for additional information and design guidance.
  - Provide a raised crossing, see Section 12A-5, D, 2.
  - At skewed intersections and where truck aprons would exceed 15 feet, consider a right-angle channelized island as described in the Iowa DOT Design Manual Section 6A-11. A raised crosswalk should be considered at channelized right turn lanes where motorists do not face stop or traffic signal control to encourage motorist yielding. They may also be beneficial at yield, stop, and signal control intersections where it is desirable to reduce encroachments into the crosswalk. When used at a channelized island, the crosswalk should be located to allow one vehicle to wait between the crosswalk and the cross street. Refer to Section 12A-5 for the design of pedestrian crossing islands with a refuge area.

As described in Section 12A-5, curb extensions are an FHWA approved countermeasure for improving pedestrian safety. It is acceptable to have a curb bulb with a larger curb radius that shortens crossing distances while accommodating large vehicles. For uncurbed roadways, care should be taken at corners to ensure proper design treatments are included to identify safer turning distances for large vehicles. Such treatments may include pavement coloring, different materials, and other features that provide a visual indication of the apex of the turn.

Flexible delineator posts or engineered rubber curbs may be used as an interim treatment to reduce larger corner radii. When used, they are often placed at least 1 foot offset from the turning radius of design vehicles at all intersections and driveways to decrease maintenance.

6. **Truck Aprons:** Truck aprons are most common within the center island of a roundabout, but can also be considered at intersection corners to accommodate the turning characteristics of larger vehicles while slowing the turning speeds of the design and smaller vehicles. The truck apron must be designed to be mountable by ICV to accommodate their larger effective turning radius while the IDV and smaller vehicles follow the smaller actual radius along the outside edge of the truck apron.

Figure 5M-1.03: Typical Truck Apron Layout at a Protected Intersection



The outside edge of a truck apron (i.e., closest to the travel lane) is constructed using a mountable curb and should be designed so passenger vehicles follow this mountable curbline at the desired speed. Larger vehicles, including SU-30, can traverse the truck apron if desired, but the intersection control vehicle should be used to determine the effective radius.

The truck apron is part of the motorist travel way. Do not extend truck aprons through bicycle lanes or crosswalks unless they are designed to accommodate these users. Bicycle stop bars and pedestrian accommodations (e.g., curb ramps, crosswalks) must be placed to prevent these users from waiting in the travel way. Colored concrete and/or pavement markings should be used within the truck apron area to provide a visual contrast from the adjacent roadway and sidewalk, communicating this is not an area to drive over. Where truck apron widths exceed 15 feet., the intended use of the apron may not be clear and designers may consider a channelizing island to limit the street crossing distance for pedestrians and bicyclists (see Section 5C-2, R, 5 and Iowa DOT Design Manual Section 6A-11).

In retrofit conditions, a truck apron extending all the way to the existing curb line may not be possible without significant stormwater system modifications. In these situations, truck pillows, which are the mountable portion of a curb extension which is designed to discourage smaller vehicles from tracking over it while allowing larger vehicles to do so while maintaining drainage along the existing curb line may be more practical and feasible.

An edge line should be provided along the outside edge of wider truck aprons and designers should consider reflective raised pavement markers, where appropriate, to ensure the path of travel is visible. Gore markings may be installed on the truck apron itself, but this is often unnecessary if colored pavement is used.

Where buses frequently make turns (such as transit or school bus routes), truck aprons should be designed to allow the bus to complete the turn without traversing the truck apron. A tiered truck apron with a curb reveal from 0 to 1 inch can be constructed for use by buses while the second tier can be designed with a 3 inch curb reveal for use by larger trucks.

Figure 5M-1.04: Truck Apron with Concrete and Pavement Markings (left) and Truck Pillow (right)

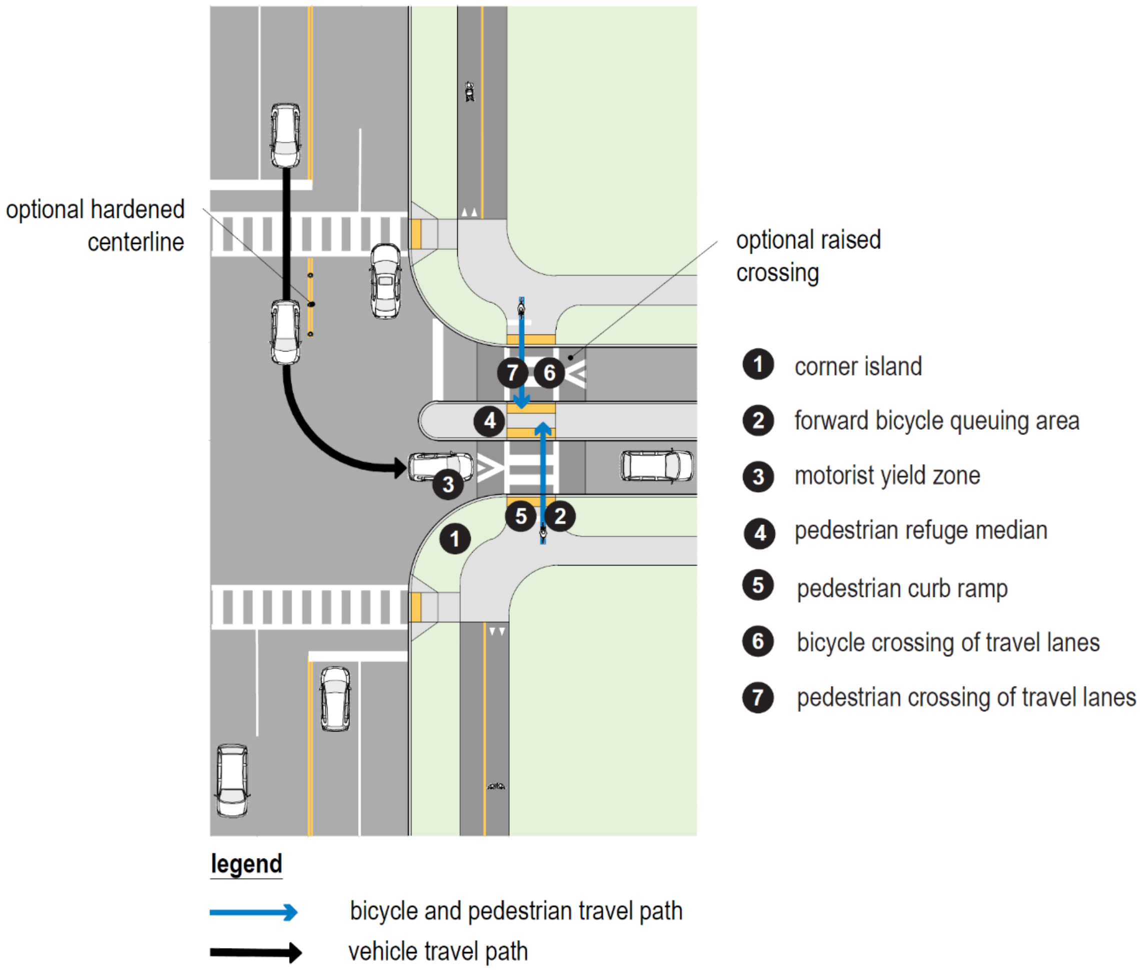
Source: City of Los Angeles, 2020

7. **Intersection Treatments for Minimizing Left Turning Vehicle Speeds:** Median islands, hardened centerlines, and raised crossings can be appropriate on both the departure roadway and the receiving roadway to control the left turning motorist's path of travel and reduce turning speeds, which can improve the safety for all roadway users. Section 12A-5 discusses how a raised median island can be used to provide pedestrian refuge space to cross a major street. In that situation, a minimum of 6 feet is required to accommodate a pedestrian or bicyclist waiting to cross the second portion of the crossing. When less than 6 feet in width is available, designers can still provide a center median of less than 6 feet or a hardened centerline, to channelize and slow the speeds of left turning motorists as they prepare to cross the path of pedestrians and bicyclists.

   A hardened centerline is comprised of a painted centerline supplemented by a dashed center or lane line extended along the turning path, flexible delineators, mountable curb, rubber curb, concrete curb, in-street pedestrian crossing signs (R1-6), or a combination of these treatments. The dimensions of a hardened centerline will depend on the intersection geometry and vehicle turning radius. Hardened centerlines should be considered where higher speed left turns occur concurrent with pedestrian and/or bicyclist movements, as they have been found to reduce the speed of left turning motorists by reducing the effective turning radius.

   For raised crossing design considerations, see Section 12A-5, D, 2.

Figure 5M-1.05: Example of Hardened Centerline Applications with Flexible Delineators on the Departure Roadway and a Pedestrian Crossing Island on the Receiving Roadway



8. **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 and reduce overall speeds. The lane widths selected 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, transit vehicles, 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 store the snow and it may require loading and removing on a more frequent basis.

   Collector and arterial streets in the urban and rural town context may have lane widths between 10 to 12 feet wide. Lane widths of 10 feet may be used where truck and bus volumes are relatively low and speeds are less than 35 mph. Collector street speeds should not exceed 35 mph. At least one 11 foot lane in each direction may be appropriate for streets where there is a heavy volume of truck traffic or buses. It is preferable that bus- or transit-only lanes be 11 feet wide.

Lane widths for local streets in urban and rural town areas should be 10 feet, except in industrial areas, which should be 11 to 12 feet due to the larger volume of trucks expected with that land use. Local streets can have lane widths of 9 feet in residential areas where the available right-of-way imposes limitations. For low volume local residential streets, two free flowing lanes are generally not required. This creates a yield situation when two vehicles meet; see Section 5C-1, Tables 5C-1.01 and 5C-1.02.

It was previously thought lanes less than 12 feet could reduce traffic flows and capacity. New research has shown lane widths of 10 feet do not reduce capacity and the Highway Capacity Manual has eliminated capacity adjustments for lane widths between 10 and 13 feet. In addition, NCHRP 330 *Effective Utilization of Street Width on Urban Arterials* found the use of 10 feet lanes has resulted in lower or unchanged crash rates.

9. **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. Smaller curb radii slow turning traffic and create shorter crossing distances, but make it difficult for larger vehicles to safely navigate the intersection. Sections 5C-2, R and 5M-1, C, 5 provide guidance on selecting design vehicles, control vehicles, and typical curb radii for different roadways.

10. **Curb Extensions or Bump-outs:** Curb extensions or bump-outs are an expansion of the curb line into the adjacent street. They are traditionally found at intersections where on-street parking exists, but could also 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. Refer to Section 12A-5 for more design guidance on curb extensions.

11. **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. Shared lanes are not recommended for roadways with speeds over 35 mph or traffic volumes over 5,000 ADT. In addition, shared lanes on roadways with speeds greater than 25 mph or volumes over 3,000 ADT are unlikely to accommodate the “interested but concerned bicyclist” (see Section 12B-1).

    c. **Bicycle Lanes:** Dedicated bicycle lanes are used to separate higher speed vehicles from bicyclists to improve safety. These should be considered where there are frequent interactions between vehicles and bicyclists when conflicts in shared lanes become problematic, typically when vehicular volumes exceed 3,000 vehicles per day and operating speeds are 25 mph or greater. 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 and selection guidance 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.

12. **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 feet 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 should be prohibited so as to not impede sight lines of pedestrians entering crosswalks; see Section 12A-5, D, 1 for parking restrictions near 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.

13. **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 more comfortable to the user than if the sidewalk is located at the back of curb. Sidewalks set back from the curb also provide space for the storage of snow plowed from the street and space for signs and other street furniture. It may be helpful to divide sidewalks in mixed-use (i.e., commercial and residential) urban areas into several “zones”: the building frontage zone, next to the building, to allow for doors that open directly onto the sidewalk and other building appurtenances; the pedestrian walkway zone, which should be 5 feet or greater (preferred), 4 feet minimum per ADA; and the furnishing zone, where street furniture, landscaping seating areas, bus stops, bicycle racks, and café dining areas can further enhance the urban environment, support local business activities, and encourage pedestrian activity.

14. **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, and thereby reduce common crash types such as rear-end crashes and sideswipes. Turn lanes also allow continuous movement and potentially

faster speeds in the through lanes, increased crossings distances for pedestrians, and increased conflict areas for bicyclists where merging and weaving areas intersect with bicycle lanes therefore designers should evaluate both the operations and safety of all modes when considering turn lanes. Where turn lanes are present, designers should work to minimize or eliminate conflicts through geometric design and traffic control.

Dedicated left and right turn lane widths and TWLTL lanes should match the width of the lanes on the street when complete street designs are chosen. Local streets should not provide separate turn lanes.

15. **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 needed for pedestrian refuge is 6 feet; see Section 12A-5 for additional design guidance for pedestrian refuge islands. At shared use path crossings, the preferred minimum crossing island width is 10 feet, which accommodates bicyclists with trailers and wheelchair users more comfortably. The minimum width of a median for access control and adjacent to left turn lanes is 4 feet. However, greater widths provide more opportunities for more extensive landscaping. Low height plantings may be considered for all median widths provided that the plantings can be maintained. For landscaped medians that include trees, shrubs, or gateway features, designers should adhere to urban lateral offset clear zone requirements, 4 feet (acceptable) 6 feet (preferred).

16. **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. Safe street crossings should be provided near bus stops, typically within 100 feet. For guidance on providing safe street crossings on a variety of road types, refer to Section 12A-5.

    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.

17. **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, see Section 13A-4, E. Traffic signal timing can be designed to control vehicle operating speed along the street and to provide differing levels of protection for crossing pedestrians and bicyclists, see Sections 13A-4, F and 12B-3, L for signal timing strategies to minimize conflicts among pedestrians, bicyclists, and motorists.

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 13A-4, F for more information on accessible pedestrian signals.

18. **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**			
Posted Speed (mph)	< 25		< 35		35		< 35		35 to 45	
Land use[1]	*R/C*	*I*	*R/C*	*I*	*R/C*	*I*	*R/C*	*I*	*R/C*	*I*
Travel lane width (ft)	10[2]	11	10	11	10[3]	11	10[3]	11	11	12[4]
Turn lane width (ft)	--	--	10	11	10	11	10	11	11	12[4]
Two-way left-turn lanes width (ft)	--	--	10	11	10	11	10	11	11	12[4]
Curb Offset (ft)[5]	0	0	0	0	0 to 2	0 to 2	0	0	0 to 2	0 to 2
Parallel parking width (no buffer) (ft)[6]	8	8	8	9	8	9	8	9	9	9
Sidewalk Width (ft)	See Section 12A-1									
Bicycle lane width (ft)	See Section 12B-3									

[1] R = Residential, C = Commercial, I = Industrial

[2] 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.

[3] When transit is present on a curbed four lane roadway, an 11 foot outside lane may be considered to better accommodate trucks and buses if present.

[4] Where additional width is necessary to accommodate the preferred bikeway, designers may consider using a lane width of 11 feet.

[5] Travel lane widths shown provide sufficient width for both the physical and operating space of a typical vehicle for each classification. A curb offset is not required for roadways with a posted speed of 35 mph or less or where on street parking is present. Where the gutter is a different material than the travel lane, it should not be included in the travel lane width. For posted speeds higher than 35 mph, curbs may be offset up to 2 feet from the edge of the travel lane. The gutter width should be considered a part of the curb offset width.

[6] For arterial or high speed collectors, the parallel parking stall width may be reduced if a minimum 3 foot buffer strip is included.

D. Traffic Calming

Traffic calming is related, but different from complete streets. Through retrofitted 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. Traffic calming devices are intended to reduce motor vehicle volumes, speeds, or both and by doing so can create conditions appropriate for bicycle boulevards (Section 12B-3, H). However, traffic calming mitigation needs to be carefully considered to not divert vehicles to adjacent streets and just move the problem. A larger study area than just the street being considered may be needed when evaluating traffic calming measures.

Some traffic calming measures are proven safety measures that reduce crash risk for pedestrians and other road users. They are discussed in more detail in other sections. These include the following.

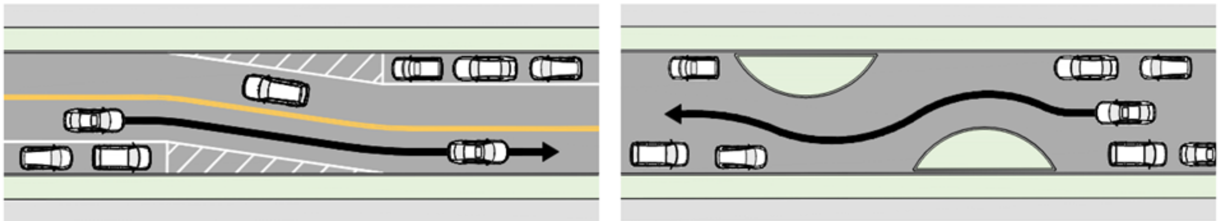
- Road diet (see Sections 5M-1, C, 3 and 12B-3, G)
- Curb extension (Section 12A-5)
- Raised crosswalk and raised intersection (Section 12A-5)
- Pedestrian refuge island (Section 12A-5)

In addition to those safety measures, designers can consider the following traffic calming elements to slow speeds or reduce traffic volumes:

1. **Horizontal Deflection:** These devices force a motorist to slow the vehicle in order to comfortably navigate the traffic calming measure. Horizontal deflection is most appropriate on local and collector streets. It is most effective when parking is robust throughout the day.

   a. **Lateral Shifts and Chicanes:** Lateral shifts cause travel lanes to shift in one direction, often by shifting on-street parking from one side of a street to the other side of the street. Chicanes are a series of curb extensions, pinch points, parking bays, or landscaping features that alternate from one side of the road to the other to establish a serpentine path of travel for motorists along a street. Chicanes can be implemented on local, collector, and minor arterial streets. The following design guidance should be considered for both treatments.
      - Lateral shifts and chicanes can be used on two-way streets with one lane in each direction, and one-way streets with no more than two lanes.
      - Traffic calming effects are greatest when deflection shifts vehicles back and forth by at least one full lane width.
      - The shifting taper of horizontal deflections should be based on the posted speed. Provide advisory speed plaques (W13-1P) where appropriate to supplement horizontal alignment signs (see MUTCD Section 2C.07). Otherwise, the design of chicanes generally follows curb extensions design (see Section 12A-5, D, 5).
      - Avoid using these horizontal deflection treatments along streets with bus, freight, or emergency response activity unless traffic volumes are very low and large vehicles can use the full roadway width.

Figure 5M-1.03: Examples of Lateral Shift (left) and Chicane (right)



b. **Traffic Circles:** Neighborhood traffic circles are primarily used at four-leg, two-lane local streets and are installed to reduce crash severity and slow traffic speeds. Splitter islands are not required on approaches (unlike a modern roundabout), and the central island is typically raised with a mountable apron to prevent a straight-through movement of the typical design vehicle. The occasional movement of a control vehicle should not be precluded from operating within the intersection with encroachment, if necessary, which may include going the "wrong way" to the left of the traffic circle to make a left turn. Landscaping may be planted in the center median if it does not need to be traversable.

2. **Vertical Deflection:** These devices include speed humps and raised crosswalks and are effective means for controlling the speeds of motor vehicles. Vertical deflection as a traffic calming measure is only appropriate on local and collector streets where posted speeds are less than 35 mph and where roadway grades do not exceed 8%. In general, all vertical traffic calming devices within roadways should be built with a bicycle friendly vertical deflection profile. The preferred profile is sinusoidal, which is easier for bicyclists to traverse than a circular or flat profile. Sinusoidal profiles are also easier for maintenance vehicles to traverse for street sweeping or snow plowing activities, and they have less of an effect on emergency vehicle access.

   Where speed humps are used to control speeds along a roadway, they are most effective when they are placed periodically along the route (every 200 to 400 feet) to reinforce speed control. These devices should be designed to maintain existing drainage patterns to avoid requiring additional inlets and storm sewer. Tapering the speed hump near the edge of pavement or curb line will minimize retrofit installation costs and allow stormwater to flow into existing gutters.

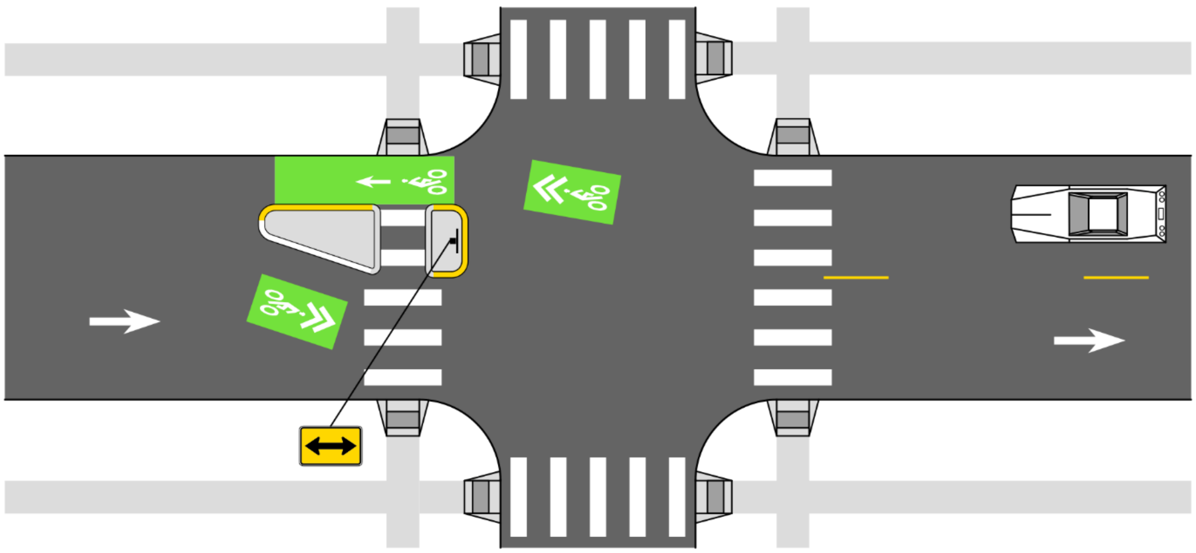
3. **Traffic Diversion:** Traffic diversion strategies are used to reroute traffic from one roadway onto other adjacent streets by installing design treatments that restrict motorized traffic from passing through. These are often used on bicycle boulevards (see Section 12B-3, H) to reduce motorist volumes to desired thresholds, and can be used on other roadways where volumes are above desired thresholds for bicycle or pedestrian accommodation.

   a. **Regulatory signage:** Signs can be used to prohibit vehicles from entering a roadway using movement prohibition signs (R3-1, R3-2, R3-3, R3-5, etc., or DO NOT ENTER signs (R5-1). These prohibitions can be for all hours or for peak hours only. Signs should be supplemented with an EXCEPT BICYCLES plaque when bicyclists are allowed to perform the movements that are prohibited for motorists. Signs may be supplemented by pavement marking arrows to emphasize the restriction, but pavement markings should not be used when restrictions vary by time of day. Signs and pavement markings alone may not be effective at discouraging motor vehicle access.

   b. **Diverters:** A diverter is an island built at an intersection to alter the movement of through and/or turning vehicle traffic. Diverters are commonly designed to maintain through travel for people walking and bicycling while altering routes for motor vehicles. The NACTO *Urban Bikeway Design Guide* provides examples of different types of diverters to reduce traffic volumes on bicycle boulevards. For all diverters, designers should consider the following.

- Diverter islands are designed to maintain bicycle and pedestrian access by providing cut-throughs. Standard cut-through width for bicyclists is 6 feet.
- Diverter islands can include a combination of public art or other vertical elements, so long as they keep sight lines clear. Other vertical elements such as signing, flexible delineator posts, etc. may be appropriate to make the features more visible to motorists and assist snowplow operators when clearing roadways.
- A diverter's effectiveness at limiting speeds is generally limited to the intersection where it is installed. The street may require additional traffic calming treatments in addition to the intersection treatments to achieve the desired operating characteristics.
- Diverters must be designed with transit and emergency vehicle navigation in mind. In some cases, emergency vehicles must be able to travel over or through the diverter if gaps are spaced to accommodate them or if breakaway gates are used.

Figure 5M-1.04: Diverter



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

American Association of State Highway and Transportation Officials (AASHTO). *A Guide for Achieving Flexibility in Highway Design.* Washington, DC. 2004.

American Association of State Highway and Transportation Officials (AASHTO). *A Policy on Geometric Design of Highways and Streets* (referred to as "Green Book"). Washington, DC. 2004.
American Association of State Highway and Transportation Officials (AASHTO). *Guide for the Development of Bicycle Facilities*. Fourth Edition. Washington, DC. 2012.

City of Fort Lauderdale. *Complete Streets Manual*. Available here. Accessed March 2023.

City of Los Angeles Department of Transportation. *Supplemental Street Design Guide*. Available here. Accessed March 2023.

Department of Health and Human Services and Los Angeles County Department of Public Health. *Model Design Manual for Living Streets*. Available here. Accessed March 2023.

Federal Highway Administration (FHWA). Accommodating Bicycle and Pedestrian Travel: A Recommended Approach. Available here. Accessed March 2023.

Federal Highway Administration (FHWA). Achieving Multimodal Networks: *Applying Design Flexibility and Reducing Conflicts.* Washington, DC. 2016.

Federal Highway Administration (FHWA). Public Roads Magazine. Vol. 74 No. 1 - Street Design: Part 1 - Complete Streets. 2010. Available here. Accessed March 2023.

Federal Highway Administration (FHWA). Road Diet Informational Guide. Washington, DC. 2014. Available here. Accessed March 2023.

Harwood, D.W. et al. *NCHRP Project 783: Evaluation of the 13 Controlling Criteria for Geometric Design*. The American Association of State Highway and Transportation Officials. Washington, DC. 2014. Available here. Accessed March 2023.

National Association of City Transportation Officials (NACTO). *Urban Street Design Guide*. 2013.

National Association of City Transportation Officials (NACTO). *Urban Bikeway Design Guide*, 2nd edition. 2014.

Ray, B.L. et al. *NCHRP Report 785: Performance-Based Analysis of Geometric Design of Highways and Streets*. The American Association of State Highway and Transportation Officials. Washington, DC. 2014. Available here. Accessed March 2023.

Sando, T., Moses, R. Integrating Transit into Traditional Neighborhood Design Policies - The Influence of Lane Width on Bus Safety. Florida Department of Transportation. 2009.

Tefft, B. C. Impact speed and a pedestrian's risk of severe injury or death. Accident Analysis & Prevention. 50. 2013.

United States Department of Transportation. Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations. 2010. Available here. Accessed March 2023.

Table of Contents

Chapter 7 - Erosion and Sediment Control

7A General Information

7B Regulatory Requirements

7C The Erosion and Sedimentation Process

7D Design Criteria

7E Design Information for Erosion and Sediment Control Measures

7E Design Information for Erosion and Sediment Control Measures (Continued)

7E Design Information for Erosion and Sediment Control Measures (Continued)

7E Design Information for Erosion and Sediment Control Measures (Continued)

7E Design Information for Erosion and Sediment Control Measures (Continued)

7F Appendix

7G References

2. **Permitting Process:** For most construction projects, coverage under the NPDES program will be obtained from the Iowa DNR through General Permit No. 2. The steps required to obtain coverage under this permit are as follows:

   a. **Prepare a Stormwater Pollution Prevention Plan:** A Stormwater Pollution Prevention Plan (SWPPP) describes the site and identifies potential sources of pollution. The SWPPP also provides a description of the practices that will be implemented to mitigate erosion and sediment loss from the site. The SWPPP must be prepared prior to submittal of the Notice of Intent. Detailed information on the required SWPPP content is provided later in this section.

   b. **Publish a Public Notice:** Arrange for publication of a public notice of stormwater discharge that states the applicant's intention to file a Notice of Intent for coverage under the General Permit No. 2. This notice must be published for at least one day in the one newspaper with the largest circulation in the area of the discharge. A link to Iowa DNR for a copy of a typical public notice is contained in the Appendix.

   c. **Notice of Intent:** Complete and sign a "Notice of Intent for NPDES Coverage Under General Permit" form. Note that there are specific restrictions on which individuals are authorized to sign the Notice of Intent (NOI). The Notice of Intent must be signed by an authorized individual (see Part VI.G of the NPDES permit for a list of individuals authorized to sign the permit). Also note that that the form contains an area to fill in information for a contact person. This is the person to whom all future correspondence will be sent. This person does not need to be the owner or other authorized signatory, but should be a person who will be involved with the project for the duration of the permitting period. A link to Iowa DNR for a Notice of Intent is contained in the Appendix.

      Acceptable proof of publication consists of an affidavit from the publisher or a newspaper clipping of the NOI that includes the date of publication and newspaper name.

      Construction may not be initiated until the Iowa DNR issues a construction authorization.

   d. **Notice of Discontinuation:** The final step in the NPDES General Permit No. 2 process is to file a Notice of Discontinuation (NOD) with the Iowa DNR. The NOD ends the coverage of the site under the permit, relieving the permittees from the responsibilities of the permit and the possibility of enforcement actions against the permittees for violating the requirements of the permit.

      An NOD should be filed with the Iowa DNR within 30 days after the site reaches final stabilization. Final stabilization means that all soil-disturbing activities are completed, and that a permanent vegetative cover with a density of 70% or greater has been established over the entire site. It should be noted that the 70% requirement does not refer to the percent of the site that has been vegetated (i.e. 7 out of 10 acres). In order to file a Notice of Discontinuation, 100% of the disturbed areas of the site must be vegetated. The density of the vegetation across the site must be at least 70% and sufficient to preclude erosion from the entire site. The NRCS Line-Transect method can be used to determine vegetation density if actual measurements are required.

      Like the Notice of Intent, the Notice of Discontinuation must be signed by an authorized individual and must contain a specific certification statement. A link to Iowa DNR for a Notice of Discontinuation is provided in the Appendix.

e. **Local Requirements:** As part of the NPDES regulations, some communities are required to review SWPPPs for land-disturbing activities that occur within their communities. Other communities may have elected to pass erosion and sediment control ordinances that must be adhered to. The designer should check with the local jurisdiction to determine if local requirements exist.

3. **Compliance with NPDES General Permit No. 2:** Once a Notice of Intent has been filed, activities at the site must comply with the requirements of NPDES General Permit No. 2. These requirements include:

   a. Implement pollution prevention practices as detailed on the SWPPP.

   b. Maintain the SWPPP and keep it current by noting significant changes.

   c. Inspecting the site and pollution prevention measures at the required intervals.

   d. Contractors and subcontractors, identified in the SWPPP, are required to sign on as co-permittees.

   e. Note changes of ownership or transfer of the permit responsibilities.

   f. If there is a construction trailer, shed, or other covered structure located on the property, retain a copy of the SWPPP required by this permit at the construction site from the date of project initiation to the date of final stabilization. If there is no construction trailer, shed, or other covered structure located on the property, retain a copy of the plan from the date of project initiation to the date of final stabilization at a readily available alternative site approved by Iowa DNR and provide it for inspection upon request.

   g. Retain copies of the SWPPP and all reports required by this permit, and all records used to complete the Notice of Intent covered by this permit, for a period of at least 3 years from the date that the site is finally stabilized and a Notice of Discontinuation has been submitted to Iowa DNR.

C. Stormwater Pollution Prevention Plans (SWPPP)

1. **Purpose:** The NPDES General Permit No. 2 requires that a Stormwater Pollution Prevention Plan (SWPPP) be developed. The practices described in the SWPPP designed to reduce contamination of stormwater that can be attributed to activities on a construction site. Construction creates the potential for contamination of stormwater from many different sources. Grading removes protective vegetation, rock, pavement, and other ground cover, exposing the soil to the elements. This unprotected soil can erode and be carried off by stormwater runoff to lakes and streams. In addition, construction often involves the use of toxic or hazardous materials such as petroleum products, pesticides and herbicides, and building materials such as asphalt, sealants, and concrete, which may pollute stormwater running off of the site.

   The SWPPP must clearly identify all potential sources of stormwater pollution and describe the methods to be used to reduce or remove contaminants from stormwater runoff.

   The SWPPP is not intended to be a static document; rather it must be updated as necessary to account for changing site conditions that have a significant impact on the potential for stormwater contamination. The SWPPP must also be revised if the current plan proves to be ineffective at significantly minimizing pollutants.

2. **Preparation of a SWPPP:** The individual preparing the SWPPP should have a thorough understanding of the project and the probable sequence of construction operations.

   The process of preparing a SWPPP should begin by reviewing the existing site, and identifying the work required to complete the desired improvements. Next, the project should be broken down into major components or phases (e.g. clearing, grading, utility work, paving, home building, etc.). The specific phasing may vary for each project, depending on the scope of the work. On large projects with multiple areas that will be completed in stages, each stage of construction should be broken down separately.

   Next, a system of erosion and sediment controls should be designed for each phase of construction. The system of controls should take into account the anticipated condition of the site during each stage. For example, at the end of the grading phase, it is likely that the entire site will be stripped and highly vulnerable to erosion; temporary seeding and/or other stabilization practices may be the major control employed at this stage. At the end of the utility phase, the site may now have storm sewer and other drainage structures installed. This creates a direct route for sediment-laden runoff to easily leave the site. Implementing sediment retention may be an important control at this stage.

   An individual erosion or sediment control practice should not be utilized as the sole method of protection. Each phase of construction should incorporate multiple erosion and sediment control practices. Utilizing a variety of both erosion control and sediment control practices is an effective and efficient method of preventing stormwater pollution.

   Once the phasing has been determined, and the methods of protection have been selected, a SWPPP can be developed. The following section summarizes the elements of a SWPPP that are required by General Permit No. 2.

3. **Required Content of the SWPPP:** Part IV of the Iowa DNR NPDES General Permit No. 2 contains a description of the specific items that must be included within the SWPPP. A summary of those items is provided below.

   a. **Site Description:** The first step in preparing a SWPPP is to provide a detailed description of the site. This description must include the following items:
      1) The nature of the construction activity (e.g. roadway construction, utility construction, single family residential construction, etc.) and major soil-disturbing activities (i.e. clearing, grading, utility work, paving, home building, etc.).
      2) An estimate of the total area of the project site and the area that is expected to be disturbed by construction.
      3) An estimate of the runoff coefficient for the site after construction (See Chapter 2 - Stormwater for determination of runoff coefficients).
      4) A summary of available information describing the existing soil and soil properties (e.g. type, depth, infiltration, erodibility, etc.).
      5) Information describing the quality of the stormwater runoff currently discharged from the site (required only if data exists, it is not necessary to collect and analyze runoff).
      6) The name of the receiving waters and ultimate receiving waters of runoff from the site. If the site drains into a municipal storm sewer system, identify the system, and indicate the receiving waters to which the system discharges.
      7) A site map that includes limits of soil-disturbing activities, existing drainage patterns, drainage areas for each discharge location (including off-site drainage), proposed grading, surface waters and wetlands, and locations where stormwater is discharged to surface water.
      8) Approximate slopes after major grading activities.

9) The location of structural and nonstructural controls.
10) The location of areas where stabilization practices are expected to occur.

b. Controls: The plan needs to show what erosion and sediment controls and stormwater management practices will be used to reduce or eliminate contamination of stormwater by pollutants.

1) Sequence: List the anticipated sequence of major construction activities and clearly describe the order for implementation of the control measures. It is not necessary to list anticipated dates for completion of the various stages of construction and implementation of practices; rather the SWPPP should indicate the stage of construction at which individual control measures are to be installed.

2) Stabilizing Practices:

- Describe the temporary and permanent stabilizing practices (protection of existing vegetation, surface roughening, seeding, mulching, compost blankets, Rolled Erosion Control Products (RECPs), sod, vegetative buffer strips, etc.). Temporary or continued stabilization must be implemented and maintained when necessary to prevent erosion of seeded areas prior to the establishment of vegetative cover of sufficient density and height to preclude erosion.
- Note that areas not subject to construction activity for 14 calendar days or more must have stabilizing measures initiated immediately after construction activity has ceased.

3) Structural Practices:

- Describe any structural practices that will be used to divert flows away from disturbed areas, store runoff, limit erosion, or remove suspended particles from runoff (silt fence, filter socks, diversion structures, sediment traps, check dams, slope drains, level spreaders, inlet protection, rip rap, sediment basins, etc.).
- For sites with more than 10 acres disturbed at one time, which drain to a common location, a sediment basin providing 3,600 cubic feet of storage per acre drained is required where attainable. When sediment basins of the size required are not attainable, other methods of sediment control that provide an equivalent level of protection are required.
- For disturbed drainage areas smaller than 10 acres, a sediment basin or sediment control along the sideslope and downslope boundaries of the construction area is required. The sediment basin should provide 3,600 cubic feet of storage per acre drained.
- Unless infeasible, the following measures should be implemented at all sites: utilize outlet structures that withdraw water from the surface when discharging from basins, provide and maintain natural buffers around surface waters, and direct stormwater to vegetated areas to both increase sediment removal and maximize stormwater infiltration.
- According to General Permit No. 2 Part IV.D.2.a.(2).iii, the permittee(s) shall minimize soil compaction and, unless infeasible, preserve topsoil. "Infeasible" shall mean not technologically possible, or not economically practicable and achievable in light of the best industry practices. "Unless infeasible, preserve topsoil" shall mean that, unless infeasible, topsoil from any areas of the site where the surface of the ground for the permitted construction activities is disturbed, shall remain within the area covered by the applicable General Permit No. 2 authorization. Minimizing soil compaction is not required where the intended function of a specific area of the site dictates that it be compacted. Preserving topsoil is not required where the intended function of a specific area of the site dictates that the topsoil be disturbed or removed. The permittee(s) shall control stormwater volume and velocity to minimize soil erosion in order to minimize pollutant discharges and shall control stormwater discharges, including both peak flowrates and total stormwater volume, to minimize channel and streambank erosion and scour in the immediate vicinity of discharge

points. An affidavit signed by the permittee(s) may be submitted to demonstrate compliance.

- For construction activity that is part of a larger common plan of development, such as a housing or commercial development project, in which a new owner agrees in writing to be solely responsible for compliance with the provisions of this permit for the property that has been transferred or in which the new owner has obtained authorization under this permit for a lot or lots (as specified in subrule 567-64.6(6) of the Iowa Administrative Code), the topsoil preservation requirements described above must be met no later than at the time the lot or lots have reached final stabilization as described in this permit.
- In residential and commercial developments, a plat is considered a project. For other large areas that have been authorized for multiple construction sites, including those to be started at a future date such as those located at industrial facilities, military installations, and universities, a new construction project not yet surveyed and platted out is considered a project. This stipulation is intended to be interpreted as requiring the topsoil preservation requirements on development plats and construction activities on other extended areas that may have several construction projects allowed under the same authorization to be implemented on those projects not yet surveyed and platted out prior to October 1, 2012, even if other plats and construction activities in the same development or other extended area were authorized prior to October 1, 2012.

4) Stormwater Management:

- Describe the features that will be installed during construction to control pollutants in stormwater after construction operations are completed.
- Pollutant removal features may include detention/retention ponds, vegetated swales, and infiltration practices.
- Post-construction erosion control features may include channel protection/lining and velocity dissipation at outlets.

5) Other Controls:

- Note in the SWPPP that any waste materials from the site must be properly disposed of.
- Describe practices for preventing hazardous materials that are stored on the site from contaminating stormwater.
- Describe a method to limit the off-site tracking of sediment by vehicles.
- Define construction boundaries to limit the disturbance to the smallest area possible.
- Identify areas to be preserved or left as open space.

6) State and Local Requirements:

- List additional state or local regulations that apply to the project. Note that some local jurisdictions may have an erosion and sediment control ordinance. The requirements of this ordinance must be listed in the SWPPP.
- List any applicable procedures or requirements specified on plans approved by state or local officials.
- Section 161A.64 of the Code of Iowa requires that prior to performing any “land-disturbing” activity (not including agricultural activities) in a city or county that does not have an erosion control ordinance and a 28E agreement with the Soil and Water District, a signed affidavit must be filed with the local Soil and Water Conservation District stating that the project will not exceed the soil loss limits stated. It should be noted that this requirement is not a condition of the NPDES General Permit No. 2.
- An indication of whether this facility has existing quantitative data describing the concentration of pollutants in storm water discharges. Any existing data should be retained as part of the SWPPP.

c. **Maintenance:** The SWPPP must describe the maintenance procedures required to keep the controls functioning in an effective manner. Adequate laboratory controls and appropriate quality assurance procedures will be provided to maintain compliance with the permit. For each type of erosion or sediment control practice utilized, a description of the proper methods for maintenance must be provided. In addition, maintenance should include removal of sediment from streets, ditches, or other off-site areas.

d. **Inspections:** The SWPPP must describe the inspection requirements of General Permit No. 2. Inspections are required every 7 calendar days. Check local agency regulations for permit inspection and reporting requirements. The inspections must include the following:

1) Inspect disturbed areas and areas used for storage of materials for evidence of pollutants leaving the site and/or entering the drainage system.
2) Inspect erosion and sediment control measures identified in the SWPPP to ensure they are functioning correctly.
3) Inspect discharge locations to ascertain if the current control measures are effective in preventing significant impacts to the receiving waters.
4) Inspect locations where vehicles enter/exit the construction site for signs of sediment tracking.
5) Prepare an inspection report that lists the date, the name of the inspector, and the inspector's qualifications. The report must summarize the inspection and note any maintenance of the controls or changes to the SWPPP that are required.
6) Implement required maintenance or changes to the SWPPP identified during the inspection as soon as practicable after the inspection, but no more than seven calendar days following the inspection. If the permittee determines that making these changes at the construction site or to the plan less than 72 hours after the inspection is impracticable, the permittee shall document in the plan why it is impracticable and indicate an estimated date by which the changes will be made.

The Project Engineer should note that SUDAS Specifications Section 9040 provides for two bid items related to the SWPPP. The first relates to the Contractor preparing the SWPPP. The second bid item involves management of the SWPPP, which includes the actions necessary to comply with the General Permit No. 2, conduct regular inspections, documentation, updates to the SWPPP, and filing of the Notice of Discontinuation.

e. **Non-stormwater Discharges:** Various non-stormwater related flows are allowed to be discharged into the stormwater system, provided that they are not contaminated by detergents or spills/leaks of toxic/hazardous materials. Allowable non-stormwater discharges include flows from fire hydrant and potable waterline flushing, vehicle washing, external building washdown that does not use detergents, pavement washwater where spills or leaks of toxic or hazardous materials have not occurred, air conditioning condensate, springs, uncontaminated groundwater, and footing drains. When there is a possibility for these types of discharges on the site, they must be identified in the SWPPP and include a description of the measures that will be implemented to prevent these flows from becoming contaminated by hazardous materials or sediment.

f. **Contractors:** The SWPPP must clearly identify all of the contractors or subcontractors that will implement each measure in the plan. Each contractor or subcontractor identified is required to sign a certification statement making them a co-permittee with the owner and other contractors. The certification must read as follows:

"I certify under penalty of law that I understand the terms and conditions of the general National Pollutant Discharge Elimination System (NPDES) permit that authorizes the stormwater discharges associated with industrial activity from the construction site as part of this certification. Further, by my signature, I understand that I am becoming a co-permittee,

along with the owner(s) and other contractors and subcontractors signing such certifications, to the Iowa Department of Natural Resources NPDES General Permit No. 2 for "Storm Water Discharge Associated with Industrial Activity for Construction Activities" at the identified site. As a co-permittee, I understand that I, and my company, am legally required under the Clean Water Act and the Code of Iowa, to ensure compliance with the terms and conditions of the stormwater pollution prevention plan developed under this NPDES permit and the terms of this NPDES permit."

Under most circumstances, the identity of the contractor and any subcontractors implementing the pollution prevention measures will not be known at the time of SWPPP preparation. The SWPPP should provide a blank certification form and a location to identify who will be responsible for implementing each pollution prevention measure. The contractor responsible for maintaining the SWPPP can then complete this information, as it becomes available.

D. Who is Responsible

1. **Property Owner:** Coverage under the NPDES General Permit No. 2 is granted to the property owner. The property owner has the ultimate responsibility for ensuring that the conditions of the permit are met. Enforcement actions associated with non-compliance with the permit are normally directed against the property owner.

2. **Designer:** The project designer typically prepares the initial SWPPP, although the contractor may be required to develop the SWPPP and obtain the NPDES permit if so directed in the contract documents. The designer may continue to review and approve changes to the SWPPP (on behalf of the owner).

3. **Jurisdiction:** On public improvement projects, the Jurisdiction serves as the owner of the site (see requirements for owners above).

   According to Iowa DNR regulations, certain MS4 jurisdictions are required to conduct inspections on public construction projects that require coverage under an NPDES permit. Under most circumstances, these inspections must be conducted utilizing the MS4's own staff. The contractor is not allowed to perform these inspections. The purpose of these inspections is to ensure that contractors are correctly implementing the BMPs identified in the SWPPP and to ensure that the jurisdiction maintains an active role in preventing stormwater contamination from its public improvements projects.

   The inspections by the jurisdiction must be conducted every 7 days. These jurisdictional inspections may also be used to satisfy the inspection requirements of the NPDES General Permit No. 2.

   The preparer of the SWPPP should check with the local jurisdiction for additional review and permitting requirements.

4. **Contractor/Builder:** Contractors and builders that are involved in implementing any of the measures identified for controlling pollution of stormwater runoff must sign on as a co-permittee with the owner. As a co-permittee, the contractor is required to comply with all of the requirements of the NPDES permit.

   In addition, most owners will contractually assign all responsibility for compliance with the NPDES permit to the contractor. Under this situation, any fines levied against the owner will normally be passed along to the contractor.

E. Transfer of Ownership and Responsibilities

On many construction projects, such as private residential subdivisions or commercial developments, it is common for a developer to sell off individual lots before work on the entire subdivision is complete. Coverage under General Permit No. 2 cannot be discontinued for individual portions of a project; the permit requires that the entire project reach final stabilization before a Notice of Discontinuation can be filed, and coverage for the entire site terminated. This creates a situation where the developer and any co-permittees are responsible for compliance with the permit for land they no longer own or have control over.

A provision within the Iowa Administrative Code [567 IAC 64.6(6)(b)] addresses this situation. This provision allows the developer and new property owner to become co-permittees under the NPDES permit. This provision requires that the new owner be notified, in writing, of the existence and location of the permit and the SWPPP and of their responsibility to comply with the permit.

This provision within the Code also allows the new owner to accept sole responsibility for compliance with the permit for the transferred property. This transfer of responsibility requires written acknowledgement by the new owner that they accept responsibility for complying with the permit for the property in question.

A copy of all property transactions, notifications of coverage, and transfer of responsibility agreements must be included with the SWPPP.

Design Information for Erosion and Sediment Control Measures

A. General

The following sections provide design information for a variety of erosion and sediment control measures. Each section describes the measure, how to properly design and implement it, and the benefits that it provides. Each measure's benefits are shown on the first page and a rating (high, medium, or low) is given for each; a summary of the individual measures and their benefits is shown in Table 7E-1.01. The benefits have been divided into five categories that directly affect erosion or sediment transportation. The following are descriptions of each of the benefits shown in Table 7E-1.01.

B. Flow Control

Flow control refers to the ability of a practice to reduce flow velocity (either sheet or concentrated flow). Reducing flow velocity helps reduce erosion and transportation of sediment. Controlling velocity is important on long or steep slopes. High-velocity flows can quickly cause severe erosion.

C. Erosion Control

Erosion control is the measure's ability to stabilize the surface and prevent soil particles from becoming displaced. Erosion control should be utilized on all disturbed surfaces. Preventing erosion from taking place is the simplest and most cost-effective method of keeping sediment from leaving a site.

D. Sediment Control

Sediment control is the ability of a practice to remove suspended soil particles from runoff after erosion has taken place. Sediment control measures are the last line of protection against releasing sediment laden runoff into water bodies or waterways. Where sediment control devices are used along a water body (stream, lake, pond, wetland, etc.), it is recommended that two or more redundant practices be installed to provide an additional level of protection if one practice fails.

E. Runoff Reduction

Runoff reduction is the ability to reduce the volume of runoff from a site. Reducing the volume from an area also reduces the potential for both erosion and sediment transportation. These methods utilize absorption or increase the potential for infiltration of stormwater into the soil.

F. Flow Diversion

Flow diversion consists of routing upland runoff around disturbed areas. By reducing the amount of runoff over a disturbed area, the potential for erosion and sediment transportation is also reduced.

G. Selecting Control Measures

The following table may be used to select a system of both erosion control and sediment control measures. No single measure should be relied upon as the sole method of erosion control and sediment control.

Table 7E-1.01: Summary of Erosion and Sediment Control Measures and Benefits

Section	**Control Measure**	**Benefits**				
		Flow Control (Velocity)	**Erosion Control (Stabilization)**	**Sediment Control (Removal)**	**Runoff Reduction (Volume)**	**Flow Diversion**
Vegetative and Soil Stabilization Erosion Control Measures						
7E-2	Compost Blanket	M	M	L	M	
7E-5	Temporary Rolled Erosion Control Products	L	H			
7E-16	Dust Control		M			
7E-17	Erosion Control Mulching	L	M	L	L	
7E-18	Turf Reinforcement Mats	L	H			
7E-19	Surface Roughening	L	L		L	
7E-22	Temporary Erosion Control Seeding	M	H	M	L	
7E-23	Grass Channel	L	H	L	L	
7E-24	Permanent Seeding	M	H	M	M	
7E-25	Sodding	M	H	M	M	
7E-26	Vegetative Filter Strip	L	L	M	L	
Structural Erosion Control Measures						
7E-7	Check Dams	H		L		
7E-8	Temporary Earth Diversion Structures					H
7E-9	Level Spreaders	H				M
7E-10	Rip Rap	H	H			
7E-11	Temporary Pipe Slope Drains					H
7E-21	Flow Transition Mats	L	H			
7E-27	Rock Chutes and Flumes	M	H			
Sediment Control Measures						
7E-3	Filter Berms	L		L		L
7E-4	Filter Socks	L		L		L
7E-6	Wattles	L		L		
7E-12	Sediment Basin	H		H	L	
7E-13	Sediment Traps	H		H	L	
7E-14	Silt Fences	L		M		M
7E-15	Stabilized Construction Entrance			L		
7E-20	Inlet Protection			L		
7E-28	Flocculants			H		
7E-29	Flotation Silt Curtain			M		

Filter Berms

Source: Minnesota Stormwater Manual

BENEFITS

	L	M	H
Flow Control	■		
Erosion Control	■		
Sediment Control	■	■	
Runoff Reduction			
Flow Diversion	■		

Description: A filter berm is a windrow-shaped structure constructed of ‘filter material’; typically constructed from slash mulch generated during site clearing and grubbing, organic products used to slow flow velocity, capture and degrade chemical pollutants, and trap sediment.

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

Advantages:

- Maintains a separation between clean off-site water and sediment-laden water allowing sediment basins and traps to function more efficiently.
- Easily constructed and maintained with equipment found on most construction sites.
- 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.

Limitations:

- Not suitable for areas of concentrated water flow or below culvert outlet aprons.
- Equipment operators may drive over berms, damaging the practice.

Longevity: Six months

SUDAS Specifications: Refer to Section 9040, 2.03 and 3.06

A. Description/Uses

A filter berm typically consists of a windrow slash mulch that diverts flow or slows and filters water to capture sediment. Its natural permeability allows water to seep through it while capturing sediment behind its mass, slowing water velocity and absorbing water pollutants such as nutrients.

B. Design Considerations

Filter berms are typically constructed from slash mulch generated from on-site clearing and grubbing operations or may be imported from off-site.

1. General Guidelines:

a. Typical filter berms should be trapezoidal with a bottom width of 5 to 7 feet and a minimum height of 2 feet. For small drainage areas and individual residential lots, more compact filter berms with a bottom width of 3 to 5 feet and a minimum height of 18 inches may be used.

b. When possible, filter berms should be placed away from the toe of a slope on the flattest area possible to allow concentrated flow to dissipate into sheet flow and to provide greater storage area for sediment.

c. Filter berms should typically not be used in areas of concentrated flows such as ditches, swales, or around pipe outlets; however, filter berms may be appropriate as ditch checks for very small drainage areas.

2. Slope Control:

a. When installed on slopes, filter berms should be installed along the contour of the slope, perpendicular to sheet flow, with the ends turned up to prevent flows from bypassing the berm.

b. The upland drainage area slope should not exceed 10%. On steep slopes (> 6%) and/or long slopes (> 50 to 75 feet), multiple berms should be placed at regular intervals down the slope.

c. A common location to place filter berms for sediment control is at the toe of a slope. When used for this application, the berm 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.

C. Application

When utilized for slope control, filter berms should be spaced according to Table 7E-3.01.

Table 7E-3.01: Maximum Filter Berm Spacing*

Slope	Maximum Spacing (feet)
0% to 2%	100
2% to 5%	40
5% to 10%	20

*For typical filter berms with a 2 foot height

D. Maintenance

Surface erosion should be repaired and the surface stabilized. Accumulated sediment should be removed when it reaches approximately one-half of the berm height. If concentrated flows are bypassing or breaching the berm, it must be expanded, enlarged, or augmented with additional erosion and sediment control practices. Additional filter material should be added as required to maintain the dimensions of the berm. Any damage should be repaired immediately.

Check Dams

BENEFITS

	L	M	H
Flow Control	■	■	■
Erosion Control			
Sediment Control	■		
Runoff Reduction			
Flow Diversion			

Description: Check dams, sometimes called ditch checks, consist of a vertical barrier constructed across swales, ditches, and waterways. These structures are commonly constructed of erosion stone, although silt fence, fiber logs, erosion control blanket (ECB) pillows, and sandbags are also used.

Typical Uses: Check dams are used to control the velocity of concentrated runoff in ditches and swales and to prevent gully erosion until the channel can be stabilized. The structures may also provide some sediment removal benefits; however, this is not their primary function.

Advantages:
- Highly effective at reducing flow velocities in channels.
- Simple to construct.
- Low maintenance.

Limitations:
- Steep slopes require short spacing between check dams.
- Sediment removal practices are still required.
- Removal difficulties if not permanent

Longevity: Rock check dams - may be considered permanent. Silt fence, fiber logs, and manufactured devices - 6 months to 2 years. ECB pillow - effective for 3 to 6 months and then degrades.

SUDAS Specifications: Refer to Section 9040, 2.07 and 3.10.

A. Description/Uses

A check dam is a small, temporary obstruction in a ditch or waterway used to prevent erosion by reducing the velocity of flow. A check dam placed in the ditch or channel interrupts the flow of water, thereby reducing the velocity. Although some sedimentation may result behind the dam, check dams are not intended to function as sediment control devices.

Erosion stone or rip rap is typically used for check dams intended to remain as a permanent control feature while temporary check dams can include products such as silt fence, straw wattles, fiber logs, erosion control blanket (ECB) pillows, and sandbags.

Manufactured triangular ditch checks are also available. These products are produced in a variety of different configurations but are typically constructed from synthetic materials, allowing them to be removed and reused at the completion of the project.

B. Design Considerations

Regardless of the type of check dam installed, the concept for controlling the flow is the same. The check dam interferes with the flow in the channel, dissipating the energy of the flowing water, thereby reducing velocity and channel erosion.

Check dams should be designed to pass the two-year storm without overtopping the roadway or side slopes of the channel. A weir equation can be used to determine the depth of flow over the structure if necessary.

1. **Rock Check Dams:** Where long-term or permanent velocity control is desired, a rock check dam should be considered. Rock check dams should keyed into the bottom and sides of the channel a minimum of 6 inches and placed on a blanket of engineering fabric. Typical rock check dams are a minimum of 2 feet high with 1.5:1 side slopes. An overflow in the center of the check dam should be 6 inches lower than the sides to prevent flows from eroding the sides of the channel. These dimensions are approximate and may be modified based on individual needs and for larger flows. However, heights much greater than 2 feet increase the potential for scour on the downstream side of the dam. For larger check dams, additional channel protection may be required on the downstream side.

   The aggregate used should be large enough to prevent the flows from pushing individual stones downstream. A 6 inch erosion stone is normally sufficient for smaller rock checks. For larger check dams, or if failures occur, larger Class D material may be used.

   Refer to SUDAS Specifications Figure 9040.107.

2. **Silt Fence:** Silt fence is often used incorrectly as a check dam under moderate or high flows. Silt fence may be used as a check dam where the flow rate is low (less than 1 cfs). When installed, silt fence checks should be constructed across the channel with the ends secured up the banks to prevent flows from bypassing around the sides. See Section 7E-14 for additional information on this application.

   The pressure of ponded water and sediment against the upstream face of the silt fence can pull the buried portion out of the ground resulting in undermining. Adding mulch, straw bales, or wattles along the upstream face can relieve some of the sediment pressure against the fence and is recommended to help prevent failures. If failures still occur with these additional practices, the silt fence should be replaced with a different practice.

3. **Manufactured Devices:** Triangular-shaped manufactured check dam products should be designed and installed according to their manufacturer's recommendations. These products require secure anchoring to the ground to keep them in place and may require the installation of a rolled erosion control product (RECP) below them. When installed, manufactured checks should be constructed across the channel with the ends located higher up on the banks to prevent flows from bypassing around the sides.

4. **Erosion Control Blanket Pillow Checks:** ECB pillow checks are formed by folding a 12 to16 inch length of erosion blanket over on itself and securing it with long staples or wooden stakes. The shallow humps created by the folded ECB interrupt and slow flows. These "pillows" should be spaced at 50-foot intervals for flat slopes with a tighter 15 to 20-foot spacing for steeper slopes.

5. **Fiber Logs:** Fiber logs include straw wattles, wood excelsior logs, and compost filter tubes which can be used to create mini-check dams. These products are available in several different diameters. When installed, fiber log checks should be constructed across the channel in a half-moon shape with the center pointed downstream and the ends secured up the banks to prevent flows from bypassing around the sides.

   Installing fiber log checks on top of an RECP greatly enhances their performance and is highly recommended. The effectiveness of fiber logs as check dams by themselves is more limited than other products, but they can be an effective alternative for very low flow situations or for use on frozen ground when other practices cannot be effectively installed.

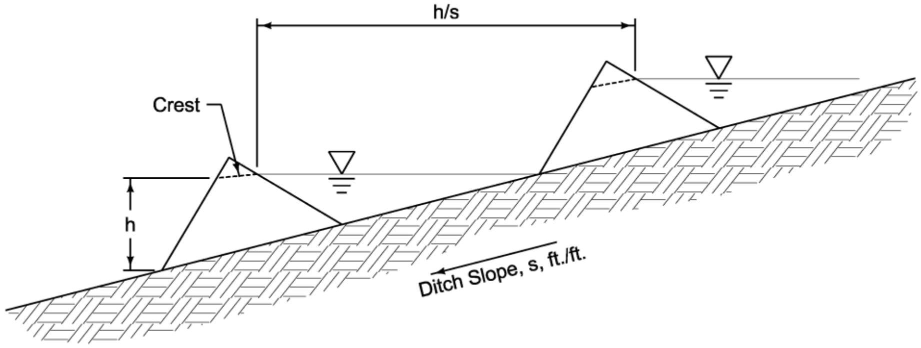
6. **Rock/Sandbags:** Rock/sandbags are relatively low-cost and easy to install, move, and reuse. The bags may be constructed from a variety of porous fabrics, and are filled with clean, poorly-graded gravel. Rock/sandbags are a good short-term solution where concentrated flows are causing erosion.

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. 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 to allow for proper maintenance. If check dams are not spaced as noted above, or 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 provided in between the check dams to provide additional stabilization for the channel surface.

Figure 7E-7.01: Typical Check Dam Spacing
(From SUDAS Specifications Figure 9040.106)



MANUFACTURED CHECK DAM

Table 7E-7.01: Spacing and Longevity of Various Check Dams

Check Dam Type	Spacing for Various Ditch Slopes				Slope Applications	Longevity*
	Up to 2%	3-5%	6-9%	10-15%		
Rock (2')	100	67-40	33-22	20-13	Up to 15%	> 2 years
Silt Fence (24")	75	50-35	25-17	15-10	Up to 15%	Up to 1 year
Triangular sediment dike (10")	42	28-17	14-19	8-6	Up to 15%	1-2 years
Fiber Logs - wood (9")	38	25-15	12-8	7-5	Up to 15%	1-2 years
Fiber Logs - wood (12")	50	33-20	17-11	10-7	Up to 15%	1-2 years
Fiber Logs - straw (9")	38	25-15	12-8	7-5	Up to 15%	Up to 6 months
Fiber Logs - straw (12")	50	33-20	17-11	10-7	Up to 15%	Up to 6 months
Fiber Logs - compost (8")	33	22-13	11-7	7-4	Up to 15%	Up to 1 year
Fiber Logs - compost (12")	50	33-20	17-11	10-7	Up to 15%	Up to 1 year
Fiber Logs - compost (18")	75	50-30	25-17	15-10	Up to 15%	Up to 1 year
ECB Pillow Check	50	15-20	N/A	N/A	N/A	Up to 6 months
Rock Bags	Varies depending on size					Up to 1 year

*Longevity is highly dependent on weather; maintenance may be required at more frequent intervals.

D. Maintenance

Check dams should be inspected for damage every seven calendar days or after any significant 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, any temporary check dams should be removed, including any stone that has been washed downstream, and any bare spots stabilized.

E. Time of Year

Check dams function on a year-round basis.

F. Regional Location

Check dams should be designed to account for the individual characteristics of each site.

Temporary Earth Diversion Berms

Source: Clackamas County, 2000

BENEFITS

	L	M	H
Flow Control			
Erosion Control			
Sediment Control			
Runoff Reduction			
Flow Diversion	■	■	■

Description: A diversion berm is a constructed practice intended to divert off-site flow away from disturbed areas (or areas to be disturbed) to prevent erosion or to direct sediment-laden runoff to sediment control practices such as sediment traps or basins for treatment. Typically constructed from compacted earth.

Typical Uses: Diversion berms are used to intercept surface flows and divert runoff away from disturbed areas and environmentally sensitive areas such as wetlands and waterways. Diversion berms can be constructed along slopes to reduce the slope length, intercepting and carrying runoff to a stable outlet point or sediment control structure.

Advantages:

- Reduces the volume of flow across disturbed areas, thereby reducing the potential for erosion.
- Breaks up the concentration of water on long slopes.
- Maintaining a separation between clean water and sediment-laden water allows sediment basins and traps to function more efficiently.
- Easily constructed with equipment found on most construction sites.

Limitations:

- High flow velocities can erode the diversion structure.
- Diversion structures must be stabilized immediately after installation, necessitating careful planning to ensure vegetation will establish.
- Equipment operators may drive over berms, damaging the practice.

Longevity: One year or longer if properly stabilized

SUDAS Specifications: Refer to Section 9040, 3.11.

A. Description/Uses

Diversion Berms are used to temporarily divert water around an area that is under construction or is being stabilized. Specific applications include perimeter control, diversion away from disturbed slopes, and diversion of sediment-laden water to treatment facilities.

As a perimeter control, temporary berms may be constructed above large, disturbed areas to divert upstream run-on around the site. This serves several purposes. First, the amount of runoff flowing over the disturbed area is reduced, reducing the erosion potential. Secondly, clean water can be separated from sediment-laden water and can be passed through or around the site. Sediment-laden water can be directed to a sediment trap or basin for treatment. Separating the upstream runoff from the sediment-laden water allows the designer to reduce the required size of the sediment removal structure, and allows the structure to work more efficiently.

On long slopes, diversion berms can be constructed at regular intervals to trap and divert sheet flow before it concentrates and causes rill and gully erosion.

B. Design Considerations

Diversion structures should be designed to carry peak flows from the 2 year, 24 hour storm.

The depth of the diversion should be based upon the design capacity, plus an additional 4 inches of freeboard. The minimum depth provided should be 18 inches. This may be provided solely by a berm or developed with a combination of berm and swale. The shape of the diversion may be parabolic, trapezoidal, or V-shaped, with side slopes of 2:1 or flatter.

The minimum slope of the diversion structure should be sufficient to carry the design flow. The maximum slope of the diversion is limited by the permissible velocities of flows within the structure, as shown in Table 7E-8.01. Since any existing vegetation will likely be destroyed during construction of the diversion structure, the bare surface situation should be considered for most applications or the practice should be stabilized immediately with seed and mulch, sod, RECP, or other means.

1. **Materials:** Soil diversion berms can typically be constructed during mass-grading operations by shaping and compacting on-site soils into a trapezoidal ridge. Soils used for diversion berms should be free of roots, large rocks, and vegetation, and not have a sand content of more than 70 percent. On-site topsoil could be stockpiled as a diversion berm until it is required elsewhere on the site.

2. **General Guidelines:**

    a. Diversion berms should be trapezoidal with a bottom width of five to seven feet, a minimum height of 2 feet, and side slopes of 2:1.

    b. When possible, diversion berms should be placed away from the toe of a slope on the flattest area possible to allow concentrated flow to dissipate into sheet flow and to provide a greater storage area for sediment.

    c. Diversion berms should not be used in areas of concentrated flows such as ditches, swales, or around pipe outlets.

3. Slope Control:

a. When installed on slopes, diversion berms should be installed along the contour of the slope, perpendicular to sheet flow, with the ends turned up to prevent flows from bypassing the berm.

b. Where diversion berms are installed to re-route flow to other areas, and water is intended to flow along the toe of the berm, erosion protection may be required, especially if surface vegetation is in poor condition or has been removed.

Table 7E-8.01: Maximum Longitudinal Slope for Diversion Berm

Soil Type	**Permissible Slope**			
	SurfaceVegetation			
	Bare	***Poor***	***Fair***	***Good***
Sand, silt, sandy loam, and silty, loam	0.3%	0.75%	1.5%	4%
Sandy clay, loam, and sandy clay, loam	0.5%	1.5%	4%	7.5%
Clay	0.75%	3.0%	6%	10%

Source: Adapted from Smoot, 1999

C. Application

Diversion berms should be used around the perimeter of sites to prevent run-on of off-site flows over disturbed ground. In addition, diversion berms may be used on-site to direct sediment-laden water to sediment removal practices.

D. Maintenance

Surface erosion should be repaired and the surface stabilized. If concentrated flows are bypassing or breaching the berm, it should be enlarged or augmented with additional erosion and sediment control practices.

E. Time of Year

When diversion structures are constructed during times when vegetation cannot be established to stabilize the surface, alternative stabilization methods such as sodding or matting may be required.

F. Regional Location

As mentioned above, the allowable velocity within the diversion structure is based on the soil characteristics of the site. Silty and sandy soils are more prone to erosion than clay soils. However, with the proper design and stabilization methods, diversion structures may be used in all appropriate locations.

Temporary Sediment Basin

Source: City of Waukee

BENEFITS

	L	M	H
Flow Control	■	■	■
Erosion Control			
Sediment Control	■	■	■
Runoff Reduction	■		
Flow Diversion			

Description: Sediment basins, like sediment traps, are temporary structures that are used to detain sediment-laden runoff long enough to allow a majority of sediment to settle out. Sediment basins are larger than sediment traps, serving drainage areas between 5 and 100 acres.

Sediment basins use a release structure to control the discharge, and normally have an emergency spillway to release the flow from larger storms. If properly planned, the basins may also serve as permanent stormwater management facilities, such as detention basins or permanent sediment removal structures.

Typical Uses: Used below disturbed areas where the contributing drainage area is greater than 5 acres. Basins require significant space and the appropriate topography for construction.

Advantages:

- Can greatly improve the quality of runoff being released from a site by removing suspended sediment on a large-scale basis.
- May be designed as a permanent structure to provide future detention, or for long-term water quality enhancement.

Limitations:

- Large in both area and volume.
- Use is somewhat dependent on the topography of the land.
- Must be carefully designed to account for large storm events.
- Not to be located within live streams.
- May require protective fencing.

Longevity: 18 months; may be converted to a permanent feature

SUDAS Specifications: Refer to Section 9040, 2.11 and 3.15.

A. Description/Uses

Sediment basins, like sediment traps, are temporary structures used to detain runoff so sediment will settle before it is released. Sediment basins are much larger than sediment traps, serving drainage areas up to 100 acres. If properly planned and designed, sediment basins can be converted to permanent stormwater management facilities upon completion of construction.

B. Design Considerations

Adequate storage volume is critical to the performance of the basin. Sediment basins that are undersized will perform at much lower removal efficiency rates. Sediment basin volumes and dimensions should be sized according to the criteria in Section 7D-1.

Proper erosion controls need to be implemented within the sediment basin itself to limit erosion of the side slopes which can contribute to the need for increased clean out frequency. The primary method of erosion control within a sediment basin should be to provide vegetative cover over the side slopes. Depending on how water enters the basin and the side slopes of the basin, additional flow controls such as filter socks may also be necessary. It is not necessary to stabilize the collected sediment at the bottom of the basin while it is actively in service as it is recognized that this material will need to be removed.

A sediment basin consists of several components for releasing flows: a principal spillway, a dewatering device, and an emergency spillway. The principal spillway is a structure designed to pass a given design storm. It also contains a de-watering device that slowly releases the water contained in the temporary dry storage. An emergency spillway may also be provided to safely pass storms larger than the design storm.

1. **Principal Spillway:** The principal spillway consists of a vertical riser pipe connected at the base to a horizontal outlet pipe. The outlet pipe carries water through the embankment and discharges beyond the downstream toe of the embankment.

   The first step in designing a principal spillway is to set the overflow elevation of the riser pipe. The top of the riser should be set at an elevation corresponding to a storage volume of 3,600 cubic feet per acre of disturbed ground. When an emergency spillway is provided, this elevation should be a minimum of 1 foot below the crest of the emergency spillway. If no emergency spillway is used, the top of the riser should be set at least 3 feet below the top of the embankment.

   The next step is to determine the size of the riser and outlet pipes required. These pipes are sized to carry the peak inflow, Q_p, for the design storm. If an emergency spillway will be included, the principal spillway should be designed to handle the peak inflow for a 2 year, 24 hour storm, without exceeding the elevation of the emergency spillway. If an emergency spillway is not included, the principal spillway must be designed to pass the 25 year storm, with at least 2 feet of clearance between the high-water elevation and the top of the embankment. Peak inflow flow rates should be determined according to the methods described in Chapter 2. The peak rate should account for the lack of vegetation and high runoff potential that is likely to occur during construction.

   The riser size can be determined using the following equations. The flow through the riser should be checked for both weir and orifice flow. The equation, which yields the lowest flow for a given head, is the controlling situation.

Weir Flow Orifice Flow

$$Q = 10.5 \times d \times h^{\frac{3}{2}} \qquad Q = 0.6 \times A \times \sqrt{2gh}$$

Equations 7E-12.01 and 7E-12.02

Where:

Q	=	Inlet capacity of the riser, cfs
d	=	Riser diameter, ft
h	=	Allowable head above the top of riser, ft
A	=	Open area of the orifice, ft^2
g	=	Acceleration of gravity, (32.2 ft/s^2)

The allowable head is measured from the top of the riser to the crest of the emergency spillway or the crest of the embankment if no emergency spillway is provided. Refer to SUDAS Specifications Figures 9040.113 and 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 the maximum elevation of the water (design high water). The size of the outlet barrel can be determined using Chapter 2 for culvert design.

3. **Anti-vortex Device:** An anti-vortex device should be installed on top of the riser section to improve the flow characteristics of water into the principal spillway, and prevent floating debris from blocking the spillway.

   There are numerous ways to protect 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.

   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.

   Refer to SUDAS Specifications Figure 9040.116.

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. 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 draw down the runoff in the basin from the crest of the riser to the wet pool elevation over at least 6 hours.

   One common method of dewatering a sediment basin is to perforate the riser section to achieve the desired draw-down of the dry storage volume. Riser pipes with customized perforations to meet individual project requirements can be easily fabricated from a section of corrugated metal pipe. The contractor or supplier can drill holes of the size, quantity, and configuration specified on the plans. The lower row of perforations should be located at the permanent pool elevation (top of the wet storage volume). The upper row should be located a minimum of 3 inches from the top of the pipe (principal spillway elevation).

Dewatering device design begins by determining the average flow rate for a 6 hour drawdown time. Once the average discharge is known, the number and size of perforations required can be determined. To calculate the area of the perforations, a single rectangular orifice that extends from the wet pool elevation to the proposed elevation of the top row of holes (a minimum of 3 inches below the principal spillway) is assumed.

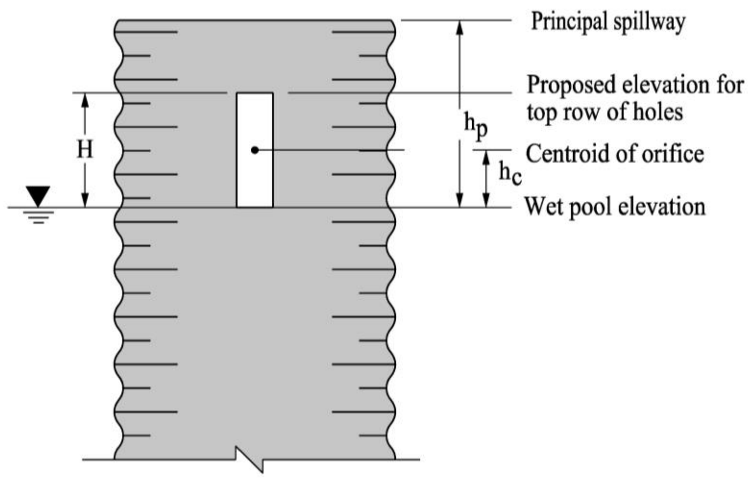
Next, the average head acting on the rectangular orifice as the basin is dewatered is determined. This average head is approximated by the following equation:

$$h_a = \frac{(h_P - h_c)}{2}$$ **Equation 7E-12.03**

Where:

h_a = Average head during dewatering
h_p = Maximum head (between the wet pool and principal spillway)
h_c = Distance between the wet pool elevation and the centroid of the orifice, ft

Figure 7E-12.01: Theoretical Discharge Orifice for Design of Perforated Risers



Once the average head is known, the area of the rectangular orifice is sized according to Equation 7E-12.04 to provide the average flow rate for the 6 hour drawdown. Providing evenly spaced perforations that have a combined open area equal to that of the calculated rectangular orifice, will provide the desired discharge rate for a 6 hour drawdown.

$$A = \frac{Q_a}{0.6 \times (2g \times h_a)^{1/2}}$$ **Equation 7E-12.04**

Where:

A = Total area of the orifices, sf
h_a = Average head acting on the orifice (Equation 7E-12.03)
Q_a = Average flow rate required for 6-hour drawdown, cfs
Q = S/21,600 sec. (6 hour drawdown only)
S = Dry storage volume required, cf

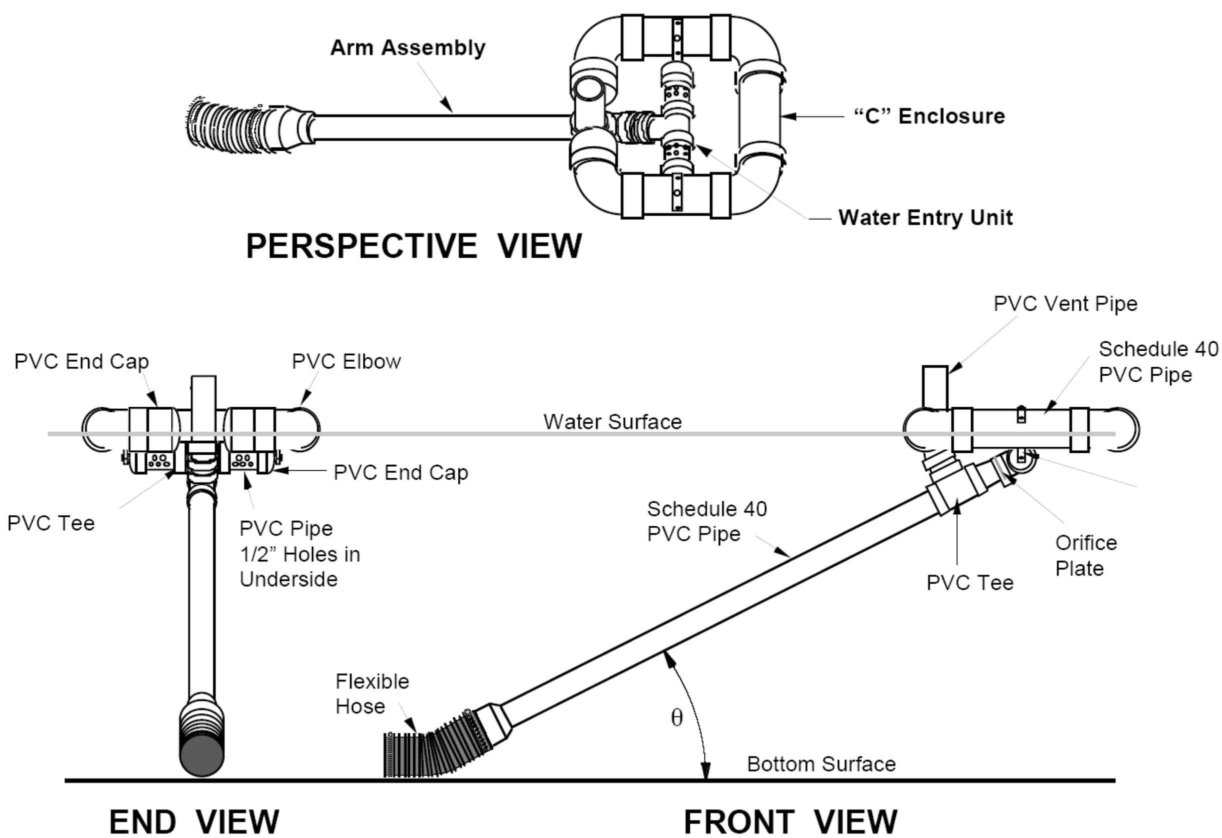
The number and diameter of the holes are variable. The diameter selected should be a minimum of 1 inch to minimize clogging, and should be a multiple of 1/4 of an inch. The perforation configuration should consist of a minimum of three horizontal rows and two vertical columns of evenly spaced perforations. Selecting a combination of hole diameter and number of holes is a trial and error process. Once the configuration is determined, the required information should be specified on the plans.

An alternative to the traditional riser is to provide a skimmer device that floats on the surface of the water in the basin. The skimmer is made of a straight section of PVC pipe equipped with a float and attached with a flexible coupling to an outlet at the base of the riser. Because the skimmer floats, it rises and falls with the level of the water in the basin and drains only the cleanest top layer of runoff. Sediment removal rates from basins equipped with skimmers are significantly more effective than with a perforated riser or orifice.

Depending on the elevation of the outlet, the skimmer device may need to be supported to prevent the device from drawing the basin down below the wet storage elevation. This can be accomplished utilizing a pile of riprap or a simply constructed stand placed on the bottom of the basin and secured against movement and flotation.

Skimming devices are normally proprietary. Discharge information should be obtained from the manufacturer.

Figure 7E-12.02: Example Skimmer for Drawdown of Wet Storage



Source: Penn State University

5. **Emergency Spillway:** An emergency spillway acts as an overflow device for a sediment basin by safely passing the large, less frequent storms through the basin without damage to the embankment. It also acts in case of an emergency such as excessive sedimentation or damage to the riser that prevents flow through the principal spillway. The emergency spillway should consist of an open channel constructed adjacent to the embankment over undisturbed material, not fill. This channel should be stabilized with matting, seeding, or sodding.

   Where conditions will not allow the construction of an emergency spillway on undisturbed material, the spillway may be constructed on top of the embankment and protected with non-erodible material such as erosion stone.

   An evaluation of the site and downstream conditions must be made to determine the feasibility of, and justification for, the incorporation of an emergency spillway. In some cases, the site topography does not allow a spillway to be constructed in undisturbed material, and the temporary nature of the facility may not warrant the cost of disturbing more acreage to construct and armor an emergency spillway. The principal spillway should then be sized to convey a 25 year storm event, providing 2 feet of freeboard between the design high water elevation and the top of the embankment. If the facility is designed to be permanent, the added expense of constructing and armoring an emergency spillway may be justified.

   When an emergency spillway is required, it should be designed to safely pass the 25 year design storm with a minimum of one-foot clearance between the high water elevation and the top of the basin embankment. Since the principal spillway is only designed to carry the 2 year event, the emergency spillway must carry the remainder of the 25 year event.

   $$Q_e = Q_{25} - Q_p$$ **Equation 7E-12.05**

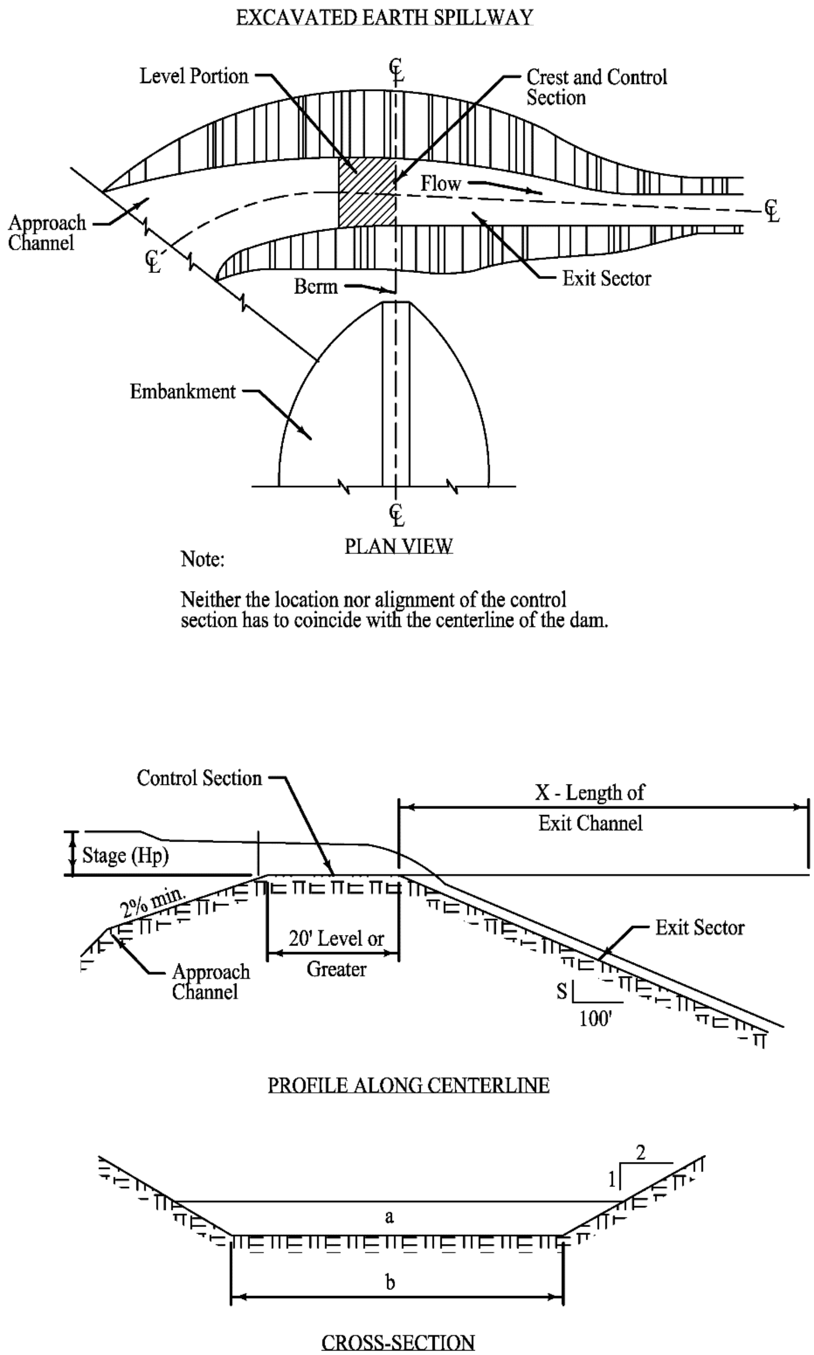
   Where:

   Q_e = Required emergency spillway capacity, cfs
   Q_{25} = 25-year, 24 hour peak flow, cfs
   Q_p = Principal spillway capacity at high water elevation, cfs

   Based upon the flow requirements, Table 7E-12.01 can be used to determine the minimum width of the emergency spillway (b), the minimum slope of the exit channel (S), and the minimum length of the existing channel (X).

   A control section at least 20 feet in length should be provided to determine the hydraulic characteristics of the spillway, according to Table 7E-12.01. The control section should be a level portion of the spillway channel at the highest elevation in the channel. If the length and slope of the exit channel indicated in Table 7E-12.01 cannot be provided, alternative methods of evaluating the spillway must be conducted.

Figure 7E-12.03: Typical Sediment Basin Emergency Spillway



Source: Roberts, 1995

Table 7E-12.02: Design Data for Earthen Emergency Spillways

Stage (H_p) in feet	Spillway Variables	Bottom Width (b) in feet																
		8	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**
0.5	Q	6	7	8	10	11	13	14	15	17	18	20	21	22	24	25	27	28
	V	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	S	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
	X	32	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
0.6	Q	8	10	12	14	16	18	20	22	24	26	28	30	32	34	35	37	39
	V	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	S	3.7	3.7	3.7	3.7	3.6	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	X	36	36	36	36	36	36	37	37	37	37	37	37	37	37	37	37	37
0.7	Q	11	13	16	18	2	23	25	28	30	33	35	38	41	43	44	46	48
	V	3.2	3.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
	S	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
	X	39	40	40	40	41	41	41	41	41	41	41	41	41	41	41	41	4
0.8	Q	13	16	19	22	26	29	32	35	38	42	45	46	48	51	54	57	60
	V	3.5	3.5	3.5	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	S	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
	X	44	44	44	44	45	45	45	45	45	45	45	45	45	45	45	45	45
0.9	Q	17	20	24	28	32	35	39	43	47	51	53	57	60	61	68	71	75
	V	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
	S	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	X	47	47	48	48	48	48	48	48	48	48	49	49	49	49	49	49	49
1.0	Q	20	24	29	33	38	42	47	51	56	61	63	68	72	77	81	86	90
	V	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	S	3.1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	X	51	51	51	51	52	52	52	52	52	52	52	52	52	52	52	52	52
1.1	Q	23	28	34	39	44	49	54	60	65	70	74	79	84	89	95	100	105
	V	4.2	4.2	4.2	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	S	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	X	55	55	55	55	55	55	55	56	56	56	56	56	56	56	56	56	56
1.2	Q	28	33	40	45	51	58	64	69	76	80	86	92	98	104	110	116	122
	V	4.4	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
	S	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	X	58	58	59	59	59	59	59	59	60	60	60	60	60	60	60	60	60
1.3	Q	32	38	46	53	58	65	73	80	86	91	99	106	112	119	125	133	140
	V	4.5	4.6	4.6	4.6	4.6	4.6	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
	S	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	X	62	62	62	63	63	63	63	63	63	63	63	64	64	64	64	64	64
1.4	Q	37	44	51	59	66	74	82	90	96	103	111	119	127	134	142	150	158
	V	4.5	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
	S	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
	X	65	66	66	66	66	67	67	67	67	67	67	68	68	68	68	68	69
1.5	Q	41	50	58	66	75	85	92	101	108	116	125	133	142	150	160	169	178
	V	4.8	4.9	4.9	5	5	5	5	5	5	5	5	5	5	5	5.1	5.1	5.1
	S	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.5	2.5	2.5
	X	69	69	70	70	71	71	71	71	71	71	71	72	72	72	72	72	72
1.6	Q	46	56	65	75	84	94	104	112	122	132	142	149	158	168	178	187	197
	V	5	5.1	5.1	5.1	5.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
	S	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	X	72	74	74	75	75	76	76	76	76	76	76	76	76	76	76	76	76
1.7	Q	52	62	72	83	94	105	115	126	135	145	156	167	175	187	196	206	217
	V	5.2	5.2	5.2	5.3	5.3	5.3	5.3	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
	S	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	X	76	78	79	80	80	80	80	80	80	80	80	80	80	80	80	80	80
1.8	Q	58	69	81	93	104	116	127	138	150	160	171	182	194	204	214	226	233
	V	5.3	5.4	5.4	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.6	5.6	5.6	5.6	5.6	5.6
	S	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	X	80	82	83	84	84	84	84	84	84	84	84	84	84	84	84	84	84
1.9	Q	64	76	88	102	114	127	140	152	164	175	188	201	213	225	235	246	260
	V	5.5	5.5	5.5	5.6	5.6	5.6	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
	S	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	X	84	85	86	87	88	88	88	88	88	88	88	88	88	88	88	88	88
2.0	Q	71	83	97	111	125	138	153	164	178	193	204	218	232	245	256	269	283
	V	5.6	5.7	5.7	5.7	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.9	5.9	5.9	5.9	5.9	5.9
	S	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	X	88	90	91	91	91	91	91	92	92	92	92	92	92	92	92	92	92

Data to the right of the heavy vertical lines should be used with caution, as the resulting sections will be either poorly proportioned, or have velocities in excess of 6 feet per second

Q=Spillway Capacity, cfs
V=Velocity, fps
S=Minimum downstream embankment slope, %
X=Minimum length of the exit channel, ft

Source: Roberts, 1995

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.

6. **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 typically required for temporary 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.

   For structures that are to become permanent wet ponds, the use of a chimney drain or filter diaphragm is recommended in place of an anti-seep collar. 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. Refer to the NRCS National Engineering Handbook, Part 628, Chapter 45 for design guidance and material selection for chimney drains and filter diaphragms.

   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 by the following:

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

   Where:

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

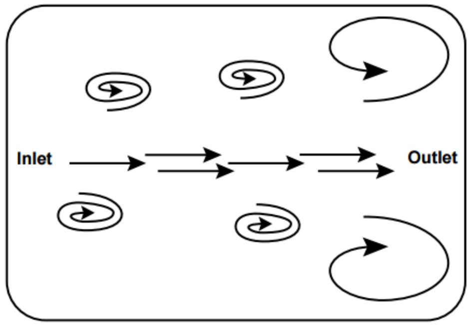
   An increase in the seepage length along the barrel of 10% should be provided. Determine the length required to achieve this by multiplying L_s by 10% ($0.10L_S$). This increase in length represents the total collar projection. This can be provided for by one or multiple collars.

   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.

7. **Enhanced Sediment Capture:** As discussed above, sediment removal is achieved by providing time for sediment to settle out before the flow reaches the outlet. The design approach assumes flow through the basin is uniform; however, currents within the basin can develop which allow for short-circuiting of the flow path from the basin inlet directly to the outlet.

Figure 7E-12.04: Flow in Sediment Basin/Trap Short-Circuiting During Peak Runoff

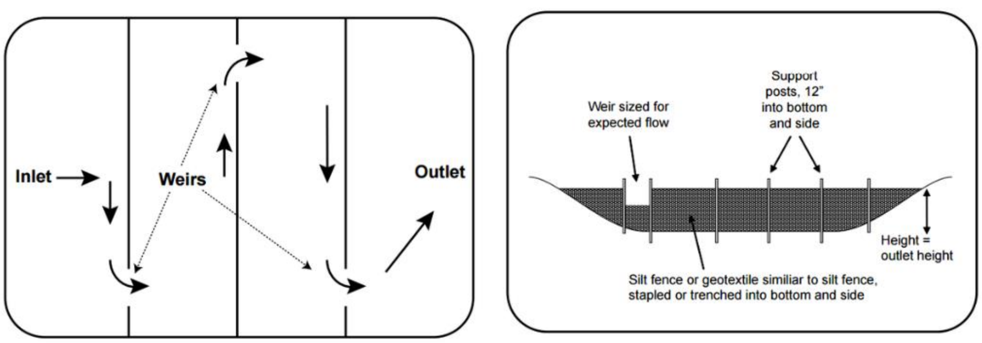


Source: NC State Extension

a. Solid Baffles: A simple way to mitigate short-circuiting and lengthen the flow path within the sediment basin is by installing solid baffles. Silt fence, being inexpensive and readily available on most construction sites, can be constructed in a series of rows perpendicular to the flow. A notch or weir at alternating ends of each row, force flow along a back and forth pattern, increasing the flow length. Solid baffles should be designed according to the following guidelines:

- The weir should be sized to accommodate the anticipated flows for the 2 year storm. For a 1 foot deep weir, the width of the weir in feet should equal the flow rate in cfs divided by three.
- The weirs should be placed on opposite sides of each other, but not too close to the basin's perimeter to keep the flow from eroding the basin's sides.
- The first bay should be easily accessible for maintenance as most of the sediment will accumulate in this area.

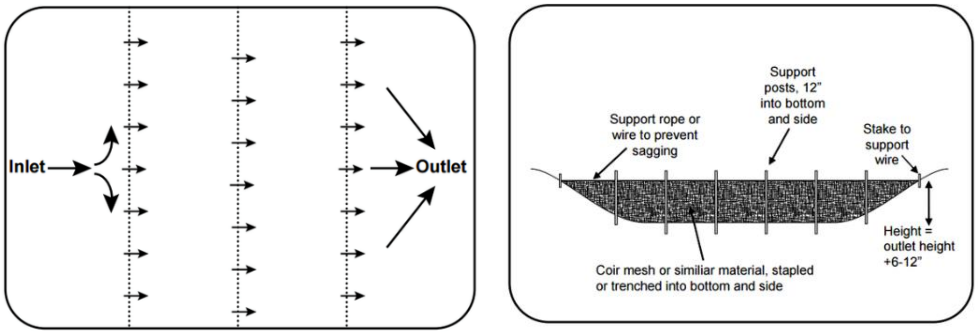
Figure 7E-12.05: Solid Baffles to Lengthen Flow Path



Source: NC State Extension

b. Porous Baffles: Another effective method to improve a basin's capture efficiency is to spread the flow uniformly across the width of the basin. One way to accomplish this is with a porous baffle. Porous baffles are installed perpendicular to the flow like solid baffles but without the weir. The porous nature of the baffle breaks up concentrated flows to prevent short circuiting while developing uniform flow through the baffle. This maximizes the cross-sectional flow area through the basin, minimizing flow velocity. This combination increases sediment deposition and makes porous baffles even more effective than solid baffles.

Figure 7E-12.06: Porous Baffles Develop Uniform Flow



Source: NC State Extension

Porous baffles can be constructed from TRM or RECP blankets constructed of coir or wood excelsior. These blankets should be attached to steel posts and firmly anchored. The top of the blankets can be secured to a rope or wire stretched across the installation if they begin to sag.

8. **Safety Fence:** Depending on the depth, location, and local ordinances, a safety fence and appropriate signing may be required around the sediment basin.

9. **Additional Considerations:** Sediment basins that are more than 10 feet high, or which have storage capacities above 10 acre-feet may require review and approval from the Iowa DNR per IAC 567-71.3. A vast majority of temporary sediment basins will not fall under these regulations. Basins that are intended to become permanent features are more likely to require this review.

C. Application

1. **Standalone Basins:** On some construction sites, sediment basins are installed as a temporary facility, separate from any permanent, post-construction, stormwater management facilities. In these situations, the sediment basin is installed and maintained during active grading operations and removed upon completion and permanent stabilization of the site.

2. **Combination Stormwater Management / Sediment Basins:** Many residential or commercial subdivisions experience re-disturbance of the ground while individual lot grading and building construction take place. This intermittent disturbance can last several years until full build-out of the site is achieved. In these situations, it may be prudent to incorporate a temporary sediment basin within a permanent, post-construction, stormwater management facility.

   This approach can be successfully implemented with careful planning and coordination with the developer, future owner(s), and jurisdiction concerning maintenance after initial grading and removal upon full buildout. The following should be considered:

   a. **Outlet:** A perforated riser or skimmer device can be temporarily connected to the stormwater management outlet structure or the stormwater management outlet structure can be temporarily plugged and a separate outlet provided for the sediment control drawdown outlet.

   b. **Wet Storage:** Regardless of the type of sediment control outlet provided, care must be taken to maintain the required "wet storage" volume in the bottom of the dry basin. A skimmer may need to be supported and the bottom of the dry basin may need to be over-excavated to provide this volume.

c. **Overflow:** Ensure that the emergency/auxiliary overflow is not impeded. The sediment control outlet will likely restrict discharge rates more than the normal stormwater management outlet control structure. This will result in increased ponding and a greater likelihood of engaging the emergency/auxiliary overflow during moderate to large storm events.

d. **Removal:** Upon completion of the development, the sediment control structure, accumulated sediment, and any temporary pipe plug must be removed. The stormwater management facility must be restored to its intended purpose, and the site stabilized.

It must be clear which party will be responsible for this work as it will likely fall upon someone other than the original contractor or developer. Generally, this will be the party responsible for the permanent ownership and maintenance of the stormwater management facility. These responsibilities must be clearly stated within any development agreements or purchase agreements.

D. Maintenance

Maintenance and cleanout frequencies for sediment basins depend greatly on the amount of precipitation and sediment load arriving at the basin. During inspections, the embankment should be reviewed for signs of seepage, settlement, or slumping. These problems should be repaired immediately. Sediment should be removed from the basin when it accumulates to one-half of the wet storage volume.

During sediment cleanout, trash should be removed from the basin, and the dewatering device and riser pipe should be checked and cleared of any accumulated debris.

E. Design Example

Assume a construction site has 12 acres of disturbed ground which drains to a common location. In addition, 8 acres of off-site area drains through the construction site. Due to site restrictions, the 8 acres of off-site drainage cannot be routed around the site. Design a temporary sediment basin, with an emergency spillway, to handle and treat the runoff from the 20 acre site.

Solution:

1. **Basin Volume:** The Iowa DNR NPDES General Permit No. 2 requires a minimum storage volume of 3,600 cubic feet of storage per acre drained.

   Therefore: 20 acres x 3,600 cf = 72,000 cf.

   According to Section 7D-1, D, 3, this volume should be split equally between wet and dry storage (36,000 cf each).

   For the remaining calculations, assume that a basin has been sized and laid out to provide the following elevations:

   Elevation A (Bottom of Basin) = 100
   Elevation B (Wet Storage) = 103.0
   Elevation C (Dry Storage) 105.0
   Elevation D (Invert of emergency spillway) = 106.5
   Elevation E (Top of embankment) = 108.5

2. **Size the Principal Spillway (Riser):** From TR-55, using the methods described in Chapter 2, assume the peak inflow from the 2 year, 24 hour storm is 41 cfs.

   To determine the required diameter of the principal spillway, the available head elevation above the spillway must be determined. From the elevation information provided above, the principal spillway is at elevation 105.0, and the invert of the emergency spillway is at elevation 106.5. Based on this, the allowable head is 1.5 feet (106.5-105.0).

   The diameter of the principal spillway (riser) is found by trial and error process, with the weir and orifice equations:

   Try a 24 inch diameter riser: (d=2 ft, A=3.14 ft^2)

   Weir Flow

   $$Q = 10.5 \times d \times h^{\frac{3}{2}}$$

   $$Q = 10.5 \times 2 \times 1.5^{\frac{3}{2}} = 39 \text{ cfs}$$

   Orifice Flow

   $$Q = 0.6 \times A \times \sqrt{2gh}$$

   $$Q = 0.6 \times 3.14 \times \sqrt{2 \times 32.2 \times 1.5} = 19 \text{ cfs}$$

   The lower flow rate (orifice) controls at 19 cfs. The design flow rate was 41 cfs; therefore, the proposed 24 inch riser is too small. Try a larger diameter.

   Try a 36 inch diameter riser. (d=3’, A=7.1 ft^2)

   Weir Flow

   $$Q = 10.5 \times 3 \times 1.5^{\frac{3}{2}} = 58 \text{ cfs}$$

   Orifice Flow

   $$Q = 0.6 \times 7.1 \times \sqrt{2 \times 32.2 \times 1.5} = 42 \text{ cfs}$$

   The lower flow rate (orifice) controls at 42 cfs. This is greater than the design flow. Select a 36 inch diameter riser pipe for the principal spillway.

3. **Size the Dewatering Orifice:** To dewater 36,000 cubic feet, the average discharge, Q_a, is found as follows:

   $$Q_a = \frac{36{,}000}{6 \times 60 \times 60} = 1.7 \text{ cfs.}$$

   Next, determine the average head acting on the perforations during dewatering. Assume a rectangular orifice extends from the lowest set of perforations at the wet storage elevation (103.0), up to the upper row of perforations, 3 inches below the principal spillway (105.0-0.25 = 104.75). Based upon this, the maximum head, h_p, is 2 feet (105-103) and the distance to the centroid of the orifice is 0.875 feet [(104.75-103)/2].

   From Equation 7E-12.03, the average head acting on the openings is:

   $$h_a = \frac{(h_P - h_c)}{2} = \frac{(2 - 0.875)}{2} = 0.56 \text{ feet}$$

   Once the average head and average discharge are known, the total orifice area can be calculated from Equation 7E-12.04:

$$A = \frac{Q_a}{0.6 \times (2g \times h_a)^{1/2}} = \frac{1.7}{0.6 \times (2 \times 32.2 \times 0.56)^{1/2}} = 0.47 \text{ sf}$$

Several perforation configurations could provide this area. One feasible selection would be to provide 18, 2 1/4 inch holes in three rows (6 holes per row).

4. **Size the Emergency Spillway:** Since this basin will have an emergency spillway, the principal spillway (riser) was only designed only to carry the 2 year storm. Larger storms, which exceed the capacity of the principal spillway, will be carried by the emergency spillway. The emergency spillway will be designed to carry the 25 year storm event.

   From TR-55, using the methods described in Chapter 2, assume the inflow from the 25 year storm is 99 cfs.

   During high flow events, both the principal spillway and the emergency spillway will be bypassing flow from the basin. From step 2, the capacity of the principal spillway is 42 cfs. Therefore, from Equation 7E-12.05, the required capacity of the emergency spillway is as follows:

$$Q_e = Q_{25} - Q_p = 99 - 42 = 57 \text{ cfs}$$

   The capacity of the emergency spillway must be at least 57 cfs. From the assumptions above, the difference in elevation between the invert of the emergency spillway, and the top of the embankment is 2 feet. Since a minimum of 1 foot must be provided between the design high-water elevation and the top of the embankment, 1 foot of head is available for discharge across the spillway.

   From Table 7E-12.01, find the discharge (Q) that equals or exceeds the design value of 57 cfs. From the table, for 1-foot of head, move horizontally to the discharge value of 61 cfs. Moving vertically in the table, the corresponding width for a discharge of 61 cfs is 26 feet.

5. **Design Example Summary:**

   Basin Volume: 72,000 cubic feet (split equally between wet and dry storage)

   Principal Spillway Diameter: 36 inches

   Dewatering Device: 18, 2 1/4 inch holes in 3 rows (6 holes per row)

   Emergency Spillway Width: 26 feet

Sediment Traps

Source: North Carolina State University Extension

BENEFITS

	L	M	H
Flow Control	■	■	■
Erosion Control	□	□	□
Sediment Control	■	■	■
Runoff Reduction	■	□	□
Flow Diversion	□	□	□

Description: A sediment trap is a temporary structure used to detain sediment-laden runoff from small drainage areas (less than 5 acres) long enough to allow sediment to settle out. These devices are constructed by excavating a temporary pond to a pre-determined shape and volume. A stone weir or spillway most commonly controls flow from the structure.

Typical Uses: Used to remove suspended soil particles before releasing runoff from a construction site. Normally located at the lowest point of a construction site.

Advantages:
- One of the most useful and cost-effective measures for treating sediment-laden runoff.
- Helps control overall stormwater runoff for small storms, thus protecting streams and rivers.
- Relatively easy and cost-effective to construct.

Limitations:
- May be large and require a substantial amount of site area.
- Sediment traps may need to be eliminated before final stabilization on high-density sites because the occupied area is planned for development. This may make it difficult to keep the sediment trap functioning during the entire construction phase.
- Sediment traps are fairly ineffective at removing fine silts or clay particles.
- Not designed to treat runoff during intense rainfall events, which can re-suspend sediment within the trap.

Longevity: 18 months

SUDAS Specifications: Refer to Section 9040, 2.12 and 3.17.

A. Description/Uses

Sediment traps are temporary sediment control structures or ponds, having a simple outlet structure stabilized with engineering fabric and rip rap. They are typically installed in a drainage way or other point of discharge downstream from a disturbed area.

Sediment traps are one of the most reliable measures for treating sediment-laden runoff from small construction sites and may be considered the primary method of sediment removal for many sites.

Sediment traps are highly effective at treating runoff from disturbed sites up to 5 acres. For larger sites, multiple traps are recommended. For disturbed areas greater than 10 acres, a sediment basin may be required (see Section 7E-12).

B. Design Considerations

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

2. **Location:** Sediment traps should be constructed at a low point, or at the point where concentrated flows leave the site. The location should be reviewed to ensure that the trap can be easily accessed for cleanout and maintenance and that failure of the sediment trap will not cause a loss of life or property. Sediment traps are often constructed in ditches or swales by excavating a small area to create a depression.

3. **Phasing:** Construction phasing must be considered when locating sediment traps. As construction progresses, the sediment trap may need to be removed to complete the proposed improvements. Select a location that will allow the sediment trap to remain in service as long as possible. If construction phasing does not allow a sediment trap to remain in service until final stabilization, the trap may need to be relocated.

4. **Embankment:** The outlet for a sediment trap normally consists of a stone embankment which the runoff flows through. The embankment slows the rate and velocity of the runoff, creating a temporary pond, which allows sediment to settle out. Equations for calculating the flow through a porous medium, which would allow for exact sizing of the outlet, are available. However, these equations require that the porosity of the stone be known. In addition, an adjustment would need to be made to account for clogging of the voids over time. These criteria are difficult to determine, therefore, it is recommended that the width of the embankment be based upon the drainage area as indicated in the following table:

Table 7E-13.01: Sediment Trap Sizing Guidelines

Drainage Area (ac)	Total Volume (ft^3)	Wet Volume (ft^3)	Dry Volume (ft^3)	Min. Depth (ft)	Depth of Perm. Pool (ft)	Min. Bottom Length (ft)	Min. Bottom Width (ft)	Weir Length (ft)
1	3,600	1,800	1,800	2.5	1.5	46	23	4
2	7,200	3,600	3,600	2.5	1.5	64	32	6
3	10,800	5,400	5,400	3.5	2.0	68	34	8
4	14,400	7,200	7,200	3.5	2.0	80	40	10
5	18,000	9,000	9,000	3.5	2.0	92	46	12

Assumes rectangular trap with 2:1 side slopes; minimum depth is from trap bottom to weir crest and includes both wet and dry storage. Basin dimensions may be adjusted as long as volume requirements are met.

Source: Roberts, 1995 (FHWA) and Adapted from Minnesota Stormwater Manual

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.

5. **Enhanced Sediment Capture:** Enhanced sediment capture can be accomplished by incorporating solid or porous baffles into the trap. Refer to the enhanced sediment capture discussion in Section 7E-12, B, 7. The same concepts of short-circuiting and enhanced capture for sediment basins can be applied to sediment traps.

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.

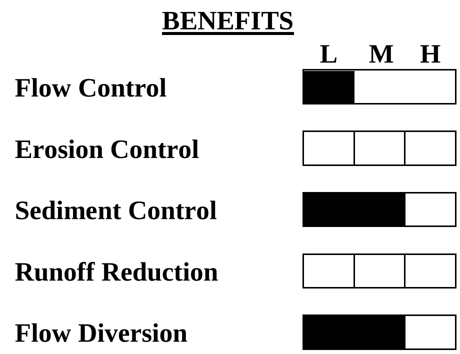
Sediment trap volumes and dimensions should be sized according to the criteria in Section 7D-1. 3,600 cf of storage should be provided for every acre of disturbed ground. This storage volume should be divided equally between wet storage and dry storage.

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.

Refer to SUDAS Specifications Figure 9040.118.

Silt Fences



Description: Silt fence is a temporary sediment barrier of geotextile fabric that is anchored into the ground and supported by posts on the downstream side of the fabric. Silt fences temporarily impound runoff and retain sediment onsite. They are most effective when designed to provide comprehensive water and sediment control throughout a construction site and if used in conjunction with erosion control practices.

Typical Uses: Used to control sheet flow runoff from disturbed land. May also be used to create a sediment trap for the removal of suspended particles from low volume concentrated flows.

Advantages:
- Widely used BMP due to ease of installation and availability of materials.
- Relatively low cost.

Limitations:
- Ineffective against high flows.
- Must be removed after final stabilization.
- Could involve frequent maintenance related to removing accumulated silt behind the silt fence.
- Wet ground may prohibit installation.

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

SUDAS Specifications: Refer to Section 9040, 2.13 and 3.18

A. Description/Uses

Silt fence is a temporary barrier used to remove sediment from runoff. The fence works by intercepting sheet flow from slopes, causing the runoff to pond behind the fence, thereby promoting deposition of sediment on the uphill side of the fence.

Silt fence consists of a geotextile fabric that is trenched or sliced into the ground. The bottom of the fence is anchored into the ground by compacting the disturbed soil along both sides of the trench or slice. The top of the fence is attached to steel posts for support, creating a barrier to the flow of contaminated stormwater runoff.

Silt fence is one of the most commonly used sediment control practices. As such, it is often used improperly, or installed incorrectly. It should be placed at regular intervals on slopes to impound water. Silt fence can also be used in ditches and swales to create a small sediment containment system or ditch check. However, use as a ditch check should be limited to minor ditches and swales due to the potential for blow-out or undermining of the silt fence by high flows.

A common misconception among many designers is that the silt fence actually “filters” suspended particles from runoff. The effectiveness of silt fence is primarily derived from its ability to pond water behind the fence. This ponding action allows suspended particles to settle out on the uphill side of the fence. Particles are not removed by filtering the runoff through the fabric.

B. Design Considerations

1. Overland Flow:

a. **General Guidelines:** Silt fence for sediment and slope control should be installed along the contour of the slope (i.e. the entire length should be at the same elevation). At each end of the silt fence, a 20 foot segment should be turned uphill (“J” hook) to prevent ponded water from flowing around the ends of the silt fence. Individual sections of silt fence 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 damage to the fence.

b. **Sediment Control:** When used for sediment control, silt fence should be located to maximize the storage volume created behind the fence. Larger storage volumes increase the sediment removal efficiency of the silt fence and decrease the required replacement/clean-out intervals.

   A common location to place silt fence for sediment control is at the toe of a slope. When used for this application, the silt fence 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.

c. **Slope Control:** Silt fence can be installed on a slope to reduce the effective length and limit the velocity of runoff flowing down the slope. Silt fence also helps prevent concentrated flows from developing, which can cause rill and gully erosion. As a secondary benefit, silt fence installed on slopes can remove suspended sediment from runoff that results from any erosion that has occurred. For slopes that receive runoff from above, a silt fence 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. Refer to SUDAS Specifications Figure 9040.119.

d. **Perimeter Control:** Silt fence is commonly used as a perimeter control along streets or adjacent to water bodies to prevent polluted water from leaving the site. When a diversion or perimeter control silt fence is installed in the direction of a slope, a 20 foot length of fence should be turned in, across the slope, at regular intervals (100 feet) to create a "J"-hook. These "J"-hooks act as check dams, controlling the velocity of the diverted runoff as it travels along the fence. Refer to SUDAS Specifications Figure 9040.119.

2. **Concentrated Flow:** For concentrated flows in swales or ditches, the silt fence is installed at right angles to the flow of water with the end posts turned uphill to prevent water from flowing around the edges. The 2 year discharge in the ditch should be checked to ensure that it does not exceed 1 cfs. For ditch or swale applications greater than 1 cfs, alternative methods of sediment removal and velocity control within the ditch, such as rock or manufactured ditch checks and sediment traps, are required.

3. **Diversion:** Silt fence can also be utilized as a synthetic diversion structure to redirect clean water around a site and intercept sediment-laden runoff and transport it to a sediment removal practice.

C. Application

For sediment control applications, the maximum contributing area should not exceed 1/4 acre per 100 feet of fence. If the contributing area exceeds this value, additional silt fence should be installed to break up the runoff into multiple storage areas.

When used as a velocity control measure for sheet flow on long slopes of disturbed ground, silt fence should be placed at the spacing interval stated in the table below:

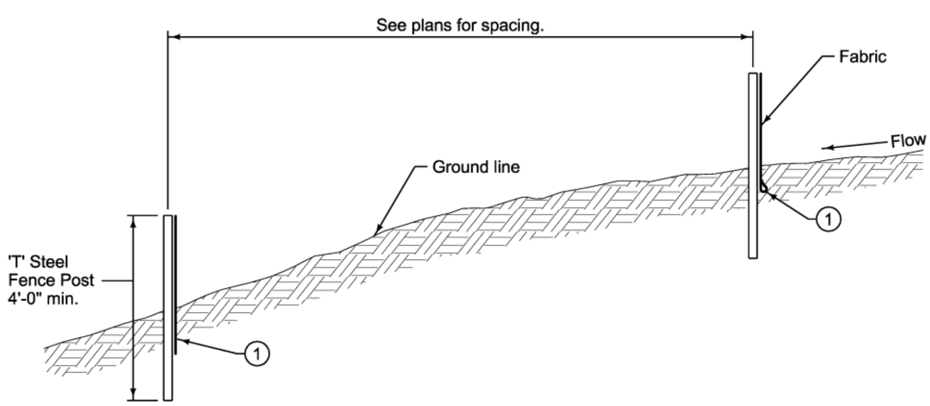
Table 7E-14.01: Silt Fence Spacing on Slopes

Slope	Placement Interval (feet)
≤ 10:1 (10%)	100
5:1 (20%)	60
4:1 (25%)	50
3:1 (33%)	40

When silt fence is used under concentrated flow, as a ditch check to intercept soil and debris from water flowing through ditches or swales, the following spacing guidelines should be used:

Figure 7E-14.01: Typical Ditch Check Spacing

Ditch Grade (%)	Spacing (feet)
1 to 2	150
2 to 4	75
4 to 6	40
> 6	25



D. Maintenance

When accumulated sediment reaches approximately one-half of the fence height, a new silt fence should be installed, leaving the existing fence in place, and locating the new silt fence a sufficient distance away from it to provide an area for sediment accumulation. When site conditions require that the silt fence be cleaned out, rather than replaced, extreme care must be taken to ensure that the silt fence is not damaged. Removed sediment should be spread out and stabilized. Any areas of damaged silt fence should be replaced immediately.

Upon project completion, fence fabric, posts, and accumulated sediment should be removed. Any areas disturbed by the removal of the silt fence or sediment should be stabilized.

E. Time of Year

Silt fences are effective on a year-round basis. Installation may not be possible when there is frost in the ground due to the requirement to trench or slice the fence below the ground surface. In those circumstances, alternative products such as straw wattles, compost socks, or wood excelsior logs may be viable alternatives.

Stabilized Construction Exit

BENEFITS

	L	M	H
Flow Control			
Erosion Control			
Sediment Control	■		
Runoff Reduction			
Flow Diversion			

Description: A stabilized construction exit is a temporary practice located where traffic leaves a construction site and enters a public road or other paved areas. The purpose is to prevent soil from construction equipment from being deposited on roadways where it can be picked up and carried away by stormwater runoff. Stabilized exits often consist of a layer of large aggregate that helps remove soil from construction equipment. Alternative methods include shaker racks which help shake sediment loose from vehicles, or wheel wash with integrated containment system, which uses high-pressure water to wash sediment from vehicles before exiting the site.

Typical Uses: Used where construction vehicles leave a construction site and enter onto a public street. The purpose of the stabilized construction exit is to prevent mud from being tracked out onto the roadway, where it can cause plugging of storm sewers, water quality issues, and fugitive dust problems.

Advantages:

- Low cost (based on stone availability) and easily installed.
- Helps prevent tracking of mud onto public streets, reducing fugitive dust, water quality issues, and clogged storm sewers.
- Provides stable exit/entrance for construction traffic.

Limitations:

- Rock must be replaced once the voids become plugged with mud.
- May not remove all soil from vehicles, especially on muddy sites.
- Rock and sediment must be disposed of upon completion.

Longevity: Varies, based upon site conditions and volume of traffic

SUDAS Specifications: Refer to Section 9040, 2.14 and 3.19.

A. Description/Uses

A stabilized construction exit consists of a pad of large aggregate, often underlain with engineering fabric. Rock exits should be located at any point where traffic will be leaving a construction site and entering a public roadway.

Additional methods, including shaker racks, track-out control mats, and wheel wash/wash rack systems can also be employed to remove additional soil or caked sediment.

B. Design Considerations

The exit from a construction site is a significant source of offsite sediment deposition. Exits and parking areas are continuously disturbed, leaving no opportunity for vegetation stabilization. During wet weather, these areas often become muddy, and construction vehicles track this mud off of the site and deposit it onto the public roadway where it clogs storm sewers and creates fugitive dust problems.

A stabilized construction exit can reduce the amount of sediment that is tracked into the street by construction traffic. A rock entrance/exit stabilizes the access to the site and helps remove mud from vehicle tires before they leave the site. A stabilized construction exit should be constructed on every construction site before the mobilization of construction equipment.

1. **Location:** A stabilized construction exit should be located at every point where construction traffic leaves a construction site. Vehicles leaving the site should travel over the entire length of the rock exit. When possible, the exit should be located on level ground, at a location with appropriate sight distance. Construction vehicles should be prohibited from leaving the site at locations other than the stabilized construction exit. Fencing should be constructed if necessary. If additional access to the site is required, additional rock exits should be constructed

2. **Site Preparation:** The area of the exit should be excavated to the proposed thickness of the stone, stripping any topsoil, vegetation, and soft soils as necessary to provide a stable subgrade. When soft soil conditions exist, or when earthmoving or other heavy equipment will use the exit, a subgrade stabilization fabric should be placed over the entire length and width of the exit before placing the rock.

3. **Drainage:** Slopes should not exceed 15% and should be carefully graded to drain transversely to prevent runoff from the exit from flowing into the street. All surface water flowing off of the construction exit should be directed to a sediment removal device (sediment basin or trap, silt fence, filter sock, etc.).

4. **Shaker Rack:** A shaker rack (also called a track out pad, rumble rack, etc.) located in advance of the rock exit can be used to remove loose material before vehicles track across the rock. This approach removes more material than the rock alone and can help keep the rock exit clean longer, reducing the frequency of replacement.

5. **Wheel Washing or "Wash-rack":** A properly constructed rock exit should not be relied upon to remove all the mud from construction traffic. In some cases, the action of tires moving over a shaker rack or gravel pad may not adequately clean tires. If conditions on the site are such that the majority of the mud is not removed by these practices, the tires of the vehicles should be washed before entering the public road. Manual washing of the tires should be provided, or automated wash racks should be installed.

   When wheel washing is provided, the location of the wash station must be carefully considered. The wash station needs to be located near an available water source (fire hydrant, service line, etc.) unless water is being provided from a portable source. It may be necessary to elevate the wash station or locate it near a natural high point to allow sediment-laden wash water to drain to an appropriate sediment removal device. Additional drainage features such as culverts or swales may need to be installed to direct the sediment-laden water to an appropriate location. These conveyance features should employ appropriate erosion control features to prevent erosion from the flowing wash water. All wheel wash water must be directed to a sediment removal device (sediment basin or trap, silt fence, filter tube, etc.).

C. Application

1. **Exit Length:** Minimum of 50 feet with an exception for single family residential lots which should be 30 feet. For sites that will be utilizing the exit to haul a large volume of earth, the length of the exit should be increased.

2. **Exit Width:** Minimum of 20 feet wide. Busy exits will need the capability of handling a lane of traffic each way, typically 30 feet wide. Flare the exit where it meets the existing road to provide a turning radius.

3. **Geotextile:** If soft soil conditions exist, or when earthmoving or other heavy equipment will utilize the exit, a layer of subgrade stabilization fabric should be placed over the prepared subgrade before placement of the rock to minimize migration of stone into the underlying soil by heavy vehicle loads. The barrier created by the fabric also aids in the removal of the stone upon completion of the project, or as required for maintenance.

4. **Stone:** The rock for the exit should consist of a nominal 2 to 3 inch clean crushed stone or recycled concrete. A 6 to 12-inch thick layer of stone, depending on anticipated traffic, should be placed over the entire length and width of the construction exit. Rock with smaller aggregate does not adequately remove mud and clay from vehicles, and may be picked up by vehicle tires and carried out into the street.

5. **Shaker Rack:** A variety of manufactured systems are available or can be configured by the contractor. The shaker rack system should be wide enough to handle the widest vehicles anticipated. The rack should have at least 4 inches of soil storage space below the top of the rack or be installed over a pad of coarse aggregate.

D. Maintenance

Construction exits should be inspected daily to ensure that mud and dirt are not being tracked onto roadways. All sediment deposited on roadways should be removed at the end of each workday. It may not be washed into the stormwater system or waterways. If tracking into the roadway continues to occur, the construction exit may need to be expanded, or additional practices implemented, to eliminate tracking.

Stabilized construction exits may require additional stone to be placed if the existing material becomes buried or if the subgrade is soft or becomes saturated.

Upon completion of the project the rock exit, engineering fabric, and any accumulated sediment should be removed and disposed.

Erosion Control Mulching

BENEFITS

	L	M	H
Flow Control	■		
Erosion Control	■	■	
Sediment Control	■		
Runoff Reduction	■		
Flow Diversion			

Description: Mulching is the application of organic material over soil that is bare or immediately over soil that has been seeded. Mulch prevents erosion by preventing the detachment of soil particles, slows runoff velocity, and retains moisture to improve germination and establishment of vegetative cover.

Typical Uses: This practice may be applied on exposed soils as a temporary control where soil grading or landscaping has taken place or in conjunction with temporary or permanent seeding. When time constraints prevent the establishment of vegetation (seeding), mulch such as wood chips, straw, or compost can be used independently as a temporary soil stabilization practice that protects the soil surface until vegetation establishment can be completed.

Advantages:
- Provides immediate surface protection.
- Suppresses weed growth.
- Conserves soil moisture.
- Acts as a thermal layer for seed.
- If used in conjunction with seed, allows seed growth through the mulch.
- Useful for dust control.

Limitations:
- If applied too thick, it may inhibit seed germination.
- Can blow or wash away if not anchored properly.

Longevity: Varies by material (three months to one year)

SUDAS Specifications: Refer to Section 9040, 2.16 and 3.21.

A. Description/Uses

Used alone or applied over seed, mulch provides immediate erosion protection. Mulching without seeding may be considered for very short-term protection. Mulch protects the disturbed soil surface by absorbing the impact of raindrops, thereby preventing the detachment of the soil particles. It also retains and absorbs water, slowing runoff. These properties allow for greater infiltration of water into the soil; help to retain seeds, fertilizer, and lime in place; and improve soil moisture and temperature conditions for seed germination. Mulch is essential in establishing good stands of grasses and legumes. To prevent movement by wind or water, the mulch must be anchored to the soil.

B. Design Considerations

The plans and specifications should address the type of mulch used, application rate, timing of the application, method of anchoring, and schedule for installation, inspection, and maintenance.

1. **Site Preparation:** The soil surface shall be prepared before the application of mulch to achieve the desired purpose and to ensure optimum contact between soil and mulch.

2. **Material Considerations:**

   a. **General:**
      1) Mulching should not be performed during periods of excessively high winds that would preclude the proper placement of mulch.
      2) Concentrated flows should be diverted around areas where mulch is applied.
      3) If ground is seeded, mulching should be completed during or immediately after seeding.
      4) Depending on the seeding period, a heavier application of mulch may be needed to prevent seedlings from being damaged by frost.
      5) In areas where lawn-type turf will be established, the use of tackifiers is the preferred anchoring method. Crimping tends to leave an uneven surface and netting can become displaced and entangled in mowing equipment.
      6) The product longevity should match the length of time the soil will remain bare or until vegetation occurs.

   b. **Straw:**
      1) Straw mulch should be applied in conjunction with temporary or permanent seeding, except when applied for short-term (less than 3 months) stabilization prior to the allowable seeding date.
      2) To prevent straw mulch from being windblown, it is anchored to the soil surface using tackifiers, nets, or a mulch crimping machine.
      3) Mechanical anchoring or crimping is recommended only for slopes flatter than 2:1. Mulch on slopes steeper than 2:1 should be anchored to the soil with netting, or other alternatives, such as a rolled erosion control product, considered.
      4) The use of straw mulch behind the curb line or at the edge of the roadway may be undesirable due to the potential for displacement by vehicle air turbulence. Anchor straw mulch with netting or consider the use of hydromulch, an erosion mat, or sod as an alternative.
      5) Only use straw free from all noxious weeds, seed bearing stalks, or roots.
      6) Expected longevity is less than 3 months.

c. Wood Chips/Grindings:

1) Do not use wood chips/grindings over newly seeded areas.
2) Chips may be produced from vegetation removed from the site.
3) Chips are effective on slopes up to 3:1.
4) Wood chips decompose over an extended period. This process may take nitrogen from the soil. To prevent nitrogen deficiency in the soil, the wood mulch should be treated with a nitrogen rich fertilizer.
5) Do not use in areas where fine turf will be established.
6) Expected longevity is less than 12 months.

d. Hydromulch: Hydromulching is normally conducted in conjunction with hydroseeding, but can also be applied as a stand-alone practice. Several different types of hydromulch are available, and each has different material properties and typical uses:

1) Wood Cellulose Fiber Hydromulch:
   a) Produced from wood pulp and recycled paper
   b) Most commonly used hydromulch
   c) Use is limited to slopes 6:1 or flatter.
   d) Typically requires 24 hours to dry before rainfall occurs to be effective against erosion.
   e) Expected longevity is 3 to 12 months.

2) Bonded Fiber Matrix (BFM) Hydromulch:
   a) Produced from strands of elongated wood fibers and a binding agent
   b) May be used on slopes up to and including 2:1.
   c) Typically requires 24 hours to dry before rainfall occurs to be effective against erosion.
   d) Expected longevity is 3 to 12 months.
   e) Provides significantly superior erosion protection than straw mulch or wood cellulose hydromulch.

3) Mechanically Bonded Fiber Matrix (MBFM) Hydromulch:
   a) Produced from strands of elongated wood fibers and crimped synthetic fibers to create an interlocking mechanism between the fibers. Material is combined with additional binding agents.
   b) May be used on slopes up to and including 2:1.
   c) Provides immediate protection against erosion. No cure time is required to develop surface protection.
   d) Expected longevity is 12 months or greater.
   e) Provides significantly superior erosion protection than straw mulch or wood cellulose hydromulch.

e. Compost:

1) Compost may be used as mulch, either with or without seeding for erosion protection. See Section 7E-2.
2) Expected longevity is less than 12 months.

C. Application

1. **Mulching without Seeding:** Wood mulch and compost applied without seed, should be applied to a uniform depth of 1 to 3 inches depending on the slope. Straw mulch should be applied at a rate of 2 tons per acre to achieve the specified coverage rate. Wood cellulose fiber hydromulch should be applied at a rate of 2,600 pounds per acre. BFM and MBFM hydromulch should be applied at a rate of 3,600 pounds per acre.

The application of straw mulch over frozen ground or snow cover in the late fall or early winter, while not ideal, is one of the few practices available for this type of situation. Mulch placed over snow or frozen ground provides some level of erosion protection and surface stabilization as the snow melts or frost leaves the ground and before the application of other stabilizing practices in the spring.

2. **Mulching for Seeding:** Straw mulch over newly seeded areas should be applied at a rate of 1 1/2 tons per acre. This application provides some protection to the surface while allowing some sunlight to penetrate and air to circulate thereby promoting seed germination. When compost is used as mulch over newly seeded areas, a minimum thickness of 1 inch should be spread evenly over flat surfaces. For compost used as mulch on slopes, see compost blankets in Section 7E-2. Hydromulch products applied with seeding (hydroseeding) are applied at the same rate as without seeding (see paragraph above).

The NPDES General Permit No. 2 requires that stabilization measures be initiated immediately when earth disturbing activities have permanently ceased or if temporarily ceased and will not resume again for 14 or more days. Mulching is one way to meet this requirement.

D. Maintenance

Inspect mulched areas for signs of thin or bare spots. Add mulch as required to maintain the thickness of the cover. Areas that show signs of erosion should be repaired and may require additional protection with an erosion control blanket or another method.

E. Time of Year

Mulch applications for establishing vegetation should be done when weather and soil conditions are favorable. Mulch can be applied over bare frozen ground that has not been seeded to help prevent erosion until vegetation can be established.

Rip Rap Alternatives

Source: Flexamat

BENEFITS

	L	M	H
Flow Control	■		
Erosion Control	■	■	■
Sediment Control			
Runoff Reduction			
Flow Diversion			

Description: As described within this section, rip rap alternatives encompass a variety of products that can be used in situations and locations where rip rap has traditionally been used or in locations where rip rap alone may not be sufficient.

Typical Uses: Used to dissipate energy at culvert outlets, provide wave protection at shorelines, stabilize streambanks, and prevent scour at the transition from highly concentrated flow outlets to channel flow.

Advantages:
- Some products can be vegetated, providing a “softer” appearance than traditional rip rap.
- Some installations can be mowed with conventional equipment.
- Some products may provide a greater level of protection than rip rap.
- Some products can be driven over, allowing access for maintenance vehicles

Limitations:
- Continuous flow channels may not support vegetation.

Longevity: Permanent

SUDAS Specifications: Refer to Section 9040, 2.19 and 3.25 for HDPE transition mats.

A. Description/Uses

This section describes a variety of manufactured products intended to be used in place of riprap for stabilization or scour protection.

1. **Transition Mat:** Flexible, UV-stabilized HDPE panels with multiple voids to allow vegetation to grow through and provide energy dissipation and scour protection. The panels are typically installed at pipe outlets. The mat protects the area at pipe outlets from scour until the water spreading out in the channel diminishes the turbulent forces. The channel downstream of the outlet, where the flow becomes uniform, must still be evaluated to ensure that the channel lining can withstand the anticipated shear stress. Transition mats can typically be vegetated or installed over sod which will grow up through the mat, obscuring the visibility of the mat and enhancing the erosion protection of the system.

2. **Grid-Tied Concrete Block Mat:** Manufactured from individual concrete blocks tied together with high-strength geogrid. Each block is tapered on all four sides, forming a pyramid shape. This product has a wide range of uses, including outlet protection, channel lining, shoreline protection, scour protection, streambank stabilization, slope protection, spillways and overflows, low water crossings, and boat ramps. Grid-tied concrete block mats provide enough space between the blocks to allow vegetation to grow up through the block, obscuring the visibility of the mat and enhancing the erosion protection of the system.

3. **Articulated Concrete Mat:** Consists of individual concrete blocks connected with cables to develop a mattress of interconnected concrete blocks. Articulated concrete mats provide a high level of resistance to scour and shear stress and can be used for outlet protection, channel lining, shoreline protection, scour protection, slope protection, spillways and overflows, low water crossings, and boat ramps. The blocks can be provided with either an open-cell or closed-cell configuration allowing the system to be backfilled with soil and vegetated if desired.

B. Design Considerations

Manufacturers of rip rap alternative products typically provide guidelines, design information, product specifications, and installation instructions for their products. It is recommended that designers contact the product representative to assist with the design and specification of these products.

A common cause of failure for some rip rap alternatives is the failure to properly anchor the product to the ground. Ensure the installation utilizes the type and quantity of anchors recommended by the manufacturer.

C. Application

Rip rap alternative products are intended to be used where traditional rip rap will not provide the desired appearance or performance.

D. Maintenance

While rip rap alternative products are intended for permanent installations, maintenance and replacement may be required. They should be inspected regularly to determine if there are performing adequately and for damage after large storms or overtopping events.

Stockpile Management

Source: Illinois Urban Manual

BENEFITS

	L	M	H
Flow Control			
Erosion Control	■	■	■
Sediment Control	■	■	
Runoff Reduction			
Flow Diversion			

Description: Stockpiles are highly susceptible to soil erosion and are a leading contributor to sediment runoff on many construction sites. Stockpile management is employed to control erosion and contain sediment at the source.

Typical Uses: Typical erosion and sediment control best management practices can be employed around construction site stockpiles.

Advantages:
- Ability to employ effective erosion and sediment control practices within a targeted area.
- Address one of the leading causes of sediment runoff at the source.

Limitations:
- Actively graded stockpiles do not provide opportunities for stabilization.
- Small stockpiles may only be present on the site for a short time, making stabilization impractical.

Longevity: Varies depending on the practice

SUDAS Specifications: N/A

A. Description/Uses

Stockpile management practices should be employed whenever topsoil, on-site soils, or imported soils are stored on a construction site. Stockpile management uses regular erosion and sediment control best management practices that are employed to protect the stockpile and contain sediment runoff from the stockpile.

B. Design Considerations

1. **Erosion and Sediment Control:** In determining which best management practices to employ, consideration needs to be given to the 0 and 14-day rule in the NPDES General Permit Number 2. NPDES requires that stabilization measures be initiated immediately when earth disturbing activities have permanently ceased or if temporarily ceased and will not resume for 14 or more days. Typical stabilization practices include temporary or permanent seeding, straw or hydro-mulching, or rolled erosion control products.

   Since stabilization of actively graded stockpiles is not practical, sediment control measures should be carefully planned and employed around and downslope of the stockpile. Typical sediment control practices may include filter socks, wattles, silt fences, diversion berms, sediment basins and traps, and vegetative filter strips. Sediment control practices should be held away from the toe of the stockpile a minimum of 20 feet to provide an area for water ponding, sediment accumulation, and access for equipment to clean out accumulated sediment.

2. **Alternative Protection:** For small material stockpiles or very short-term stockpiles, typical erosion and sediment control best management practices may not be practical. For these situations, alternative protection measures may be appropriate.

   Manufactured tarp systems designed for stockpile protection can be utilized to cover the surface of small or short-term stockpiles to protect them from erosion. In place of a manufactured system, plastic sheeting or tarps, weighted down to prevent displacement, may also be implemented.

Figure 7E-30.01: Small Material Stockpile with Protective Tarp Cover

C. Application

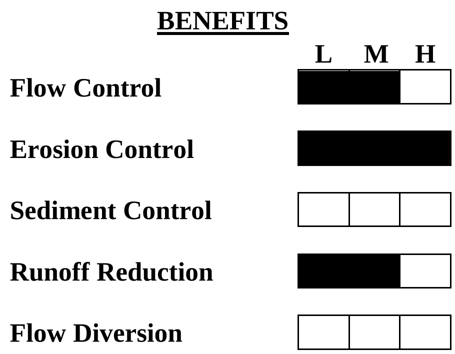
Erosion and sediment control practices utilized for stockpile management should be designed according to the guidelines provided for those same practices described elsewhere in this manual. Stockpiles, like any other disturbed area, need to be stabilized immediately whenever grading operations have permanently ceased or temporarily ceased and will not resume for a period exceeding 14 days.

D. Maintenance

The maintenance requirements of erosion and sediment control practices implemented on or around stockpiles is the same as for those same practices described elsewhere in this manual.

Greenspace and Buffer Areas

Minnesota Stormwater Manual



Description: Protecting undisturbed areas and preserving existing vegetation is one of the simplest and most effective methods of erosion protection and runoff reduction.

Typical Uses: Preservation of existing vegetation, protection of sensitive areas, buffer areas around bodies of water.

Advantages:
- Undisturbed areas generate less runoff and sediment.
- Reduced soil compaction due to equipment.
- Buffer areas filter sediment and nutrients from runoff before entering streams and lakes.

Limitations:
- May limit staging areas, potentially complicating construction phasing.
- Requires planning during design to prevent the need for grading and improvements within the targeted area.

Longevity: Permanent

SUDAS Specifications: N/A

A. Description/Uses

Preserving greenspace and protecting sensitive vegetated areas from disturbance reduces the potential for erosion and sediment runoff from the construction site as well as post construction soil compaction. This provides exceptional benefits both during and after project construction.

Buffer areas around sensitive waters protect water quality and aquatic habitat by providing shade that moderates sunlight and water temperature, infiltrating and slowing runoff, trapping sediment and other pollutants, providing habitat for fish and wildlife, stabilizing shorelines, and preventing erosion.

B. Design Considerations

1. **Greenspace Preservation:** The designer should take a comprehensive look at the overall construction site, proposed phasing, type of work, and staging areas necessary to identify potential areas of the site that should remain undisturbed.

   The designer should limit the construction area to as small a footprint as possible while recognizing that the contractor still requires adequate staging areas for equipment and materials. Severely limiting the allowable work area can increase project costs.

2. **Buffer Zones:** General Permit No. 2 requires that natural buffers be maintained around water bodies unless it is infeasible to do so. While General Permit No. 2 does not provide any specific requirements for buffer widths, a minimum 50 foot wide vegetative buffer is recommended. In sensitive areas or where a wide area of disturbance is proposed adjacent to the water body, wider buffers should be provided.

   The preservation of a buffer zone is not considered a standalone best management practice for construction stormwater, but a protective area around a water body to remain undisturbed during or after construction activities. Appropriate erosion and sediment controls are still required within the area of work.

   Improvement or repair of buffer zones that are actively eroding and contributing sediment or other pollutants to the adjacent surface water is both allowed and encouraged. Such enhancements, which must be addressed in the SWPPP, and approved by the permitting authority, can include targeted grading, seeding and mulching, application of rolled erosion control products, and other measures intended solely to address the actively eroding areas. Depending on the location and drainage area of this work, an Iowa DNR Floodplain Development Permit may be required.

   Where the scope of work makes it infeasible to maintain the recommended buffer area, redundant sediment control BMPs should be provided. For example, if silt fence is provided as a perimeter control, a straw RECP could also be installed to provide pollutant removal similar to the natural buffer zone.

C. Application

Areas to be preserved should be clearly identified on the construction plans. To ensure greenspace and buffer areas are protected, the contract documents may require the contractor to erect construction fence or silt fence around the perimeter of the work area prior to initiating grading operations.

General Information

A. General

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

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

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

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

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

B. Iowa Code

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

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

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

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

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

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

   "**199-35.15(476) - Exterior Flood Lighting**

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

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

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

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

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

Table of Contents

Chapter 12 - Pedestrian and Bicycle Facilities

12A Pedestrian Facilities

12B Bicycle Facilities

General Sidewalk Requirements

A. Introduction

Sidewalks are an integral component of the transportation system. They provide a designated area, separated from the roadway, for pedestrians to use for both travel and recreation. Along roadways where pedestrians are present or anticipated, consideration should be given to constructing sidewalks on both sides of the road to minimize conflicts between vehicles and pedestrians.

Where sidewalks are provided, they must be constructed so they are accessible to all potential users, including those with disabilities. Design standards for pedestrian access routes are provided in Section 12A-2.

B. Sidewalk and Walkway Widths

A 5 foot sidewalk is the minimum sidewalk width required for Iowa DOT projects and local projects with state or federal funding. Local jurisdictions may have minimum sidewalk width standards of 4 feet. Consideration should be given to providing minimum 5 foot sidewalks (or wider). A 5 foot sidewalk better accommodates two people walking abreast, and allows for encroachment on the sidewalk by snow, shrubbery, and grass. If sidewalks are less than 60 inches wide, a passing area at least 60 inches on all sides must be constructed a maximum of every 200 feet to comply with ADA requirements.

Clear sidewalk widths greater than the minimum are desirable in many locations. Along arterials not in downtown areas, sidewalk widths of 6 to 8 feet are desirable where a planting strip is provided between the sidewalk and curb, and sidewalk widths of 8 to 10 feet are desirable where the sidewalk is flush against the curb. In downtown areas, the desirable sidewalk width is 10 feet or sufficiently wide to provide the desired level of service to accommodate particular volumes, see the Highway Capacity Manual. Contact the local jurisdiction for minimum width requirements.

C. Sidewalk Classes

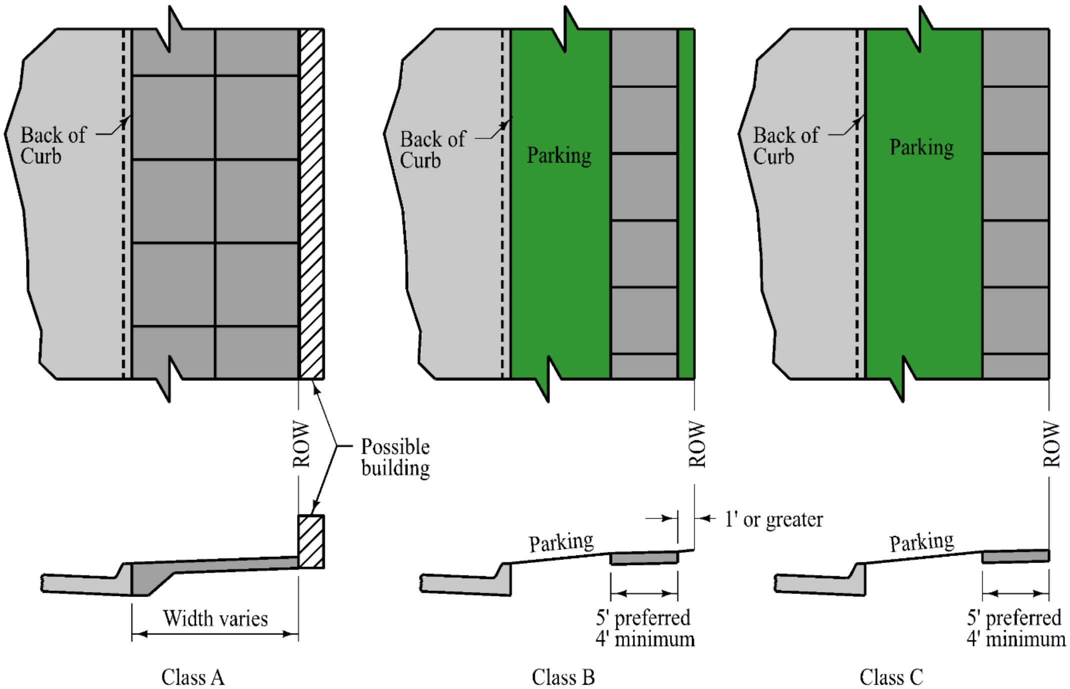
SUDAS identifies three classes of sidewalks, which are described below. Class B and C sidewalks provide a grass strip between the back of curb and the sidewalk, often referred to as the "parking."

1. **Class A:** Class A sidewalks begin at the back of curb and generally extend to the right-of-way line. These types of sidewalks are typical in downtown areas. Consideration must be given to street sign location, street lighting, utilities, mailboxes, snow storage, and other potential obstacles.

2. **Class B:** Class B sidewalks are constructed with the back edge of the sidewalk 1 foot or more off of the right-of-way line.

3. **Class C:** Class C sidewalks have the back edge of the sidewalk on the right-of-way line.

Figure 12A-1.01: Classes of Sidewalk



D. Accessible Sidewalk Design

It has been common practice to place the responsibility for sidewalk ramp layout on the contractor or construction inspector. This has resulted in the sidewalk, curb ramps, driveway crossings, etc. being designed in the field, often with mixed accessibility results. As public right-of-way accessibility comes under greater scrutiny, it is increasingly important that newly constructed or altered sidewalks meet accessibility requirements. Therefore, sidewalks, curb ramps, and street crossings shall be included as part of the design process and the details of those designs shall be included in the contract documents as appropriate. Projects reviewed or let by the Iowa DOT will require use of S sheets according to the Iowa DOT Design Manual Section 1F-18.

E. Construction Requirements

1. **Sidewalk Thickness:** Sidewalks should be constructed of PCC with a minimum thickness of 4 inches. Where sidewalks cross driveways, the minimum thickness is 6 inches, or the thickness of the driveway, whichever is greater.

2. **Obstructions:** All obstructions are to be removed or relocated except for those that are impractical to move. In new development areas, these items should never occur, but in older, established areas, they will have to be addressed. In the case where the sidewalk is shifted to avoid an obstacle, use of a minimum 2:1 taper to and from the obstruction with a straight section adjacent to the obstruction should be considered. Flatter tapers may be used if space is available and user volume is high.

3. **Construction Tolerances:** Dimensions are subject to conventional industry tolerances except where dimensions are stated as a range, minimum, or maximum. Conventional industry tolerances include tolerances for field conditions and tolerances that may be a necessary consequence of a particular manufacturing process. Conventional industry tolerances do not apply to design work; see PROWAG R103.1. Designing features to the target values, rather than the allowable maximum or minimum, allows for appropriate construction tolerances and field adjustment during construction while maintaining compliance with PROWAG.

Accessible Sidewalk Requirements

A. Introduction

SUDAS and Iowa DOT jointly developed this section based on the July 26, 2011 "Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way." This section was developed in accordance with Federal regulations (23 CFR 652 and 28 CFR 35) and is the standard for use by all governmental entities in the State of Iowa. A local jurisdiction may elect to produce their own standards; however, these will require review and approval by FHWA and/or the United States Department of Justice.

Where sidewalks are provided, they must be constructed so they are accessible to all potential users, including those with disabilities. This section establishes the criteria necessary to make an element physically accessible to people with disabilities. This section also identifies what features need to be accessible and then provides the specific measurements, dimensions, and other technical information needed to make the feature accessible. The requirements of this section were developed based on the following documents:

1. **ADAAG:** The "Americans with Disabilities Act Accessibilities Guidelines" (ADAAG) was written by the US Access Board and adopted by the Department of Justice (DOJ) in 2010. This document includes a broad range of accessibility guidelines including businesses, restaurants, public facilities, public transportation, and sidewalks. These standards were originally adopted in 1991 and have been expanded and revised several times.

2. **PROWAG:** The July 26, 2011 "Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way" was written by the US Access Board and is also known as the Public Right-of-Way Accessibility Guidelines or PROWAG. PROWAG provides more specific information than the ADAAG for transportation facilities within the right-of-way including pedestrian access routes, signals, and parking facilities. The PROWAG requirements are currently in the development and adoption process and have not been officially adopted by the Department of Justice; however, the Federal Highway Administration has issued guidance that the draft version of the PROWAG is "currently recommended best practices, and can be considered the state of the practice that could be followed for areas not fully addressed" in the existing ADAAG requirements.

   Due to the widespread acceptance of the PROWAG, and its pending adoption in the future, the standards of this chapter are based upon the PROWAG requirements. The designer is encouraged to reference the complete PROWAG document for additional information (www.access-board.gov). References to the PROWAG in this section are shown in parentheses, e.g. (R302.7). Buildings and other structures not covered by PROWAG must comply with the applicable requirements of the ADAAG. For parks, recreational areas, and shared use paths, refer to other sections within this chapter.

B. Transition Plan

The ADA law passed in 1990 required public entities with more than 50 total employees to develop a formal transition plan identifying the steps necessary to meet ADA accessibility requirements for all pedestrian access routes within their jurisdiction by upgrading all noncompliant features. Recognizing that it would be difficult to upgrade all facilities immediately, the law provided the opportunity to develop a transition plan for the implementation of these improvements. Covered entities had until 1992 to complete a transition plan. In addition, any local public agency that is a recipient of US DOT funds must have a transition plan. For those agencies that have not completed a transition plan, it is critical that this process be completed. Although the transition plan may cover a broader scope, this section will only cover requirements within the public right-of-way.

Key elements of a transition plan include the following:
- Identifying physical obstacles in the public agency's facilities that limit the accessibility of its programs or activities to individuals with disabilities.
- A detailed description of the methods that will be used to make the facilities accessible.
- A schedule for taking the steps necessary to upgrade pedestrian access in each year following the transition plan.
- Identification of the individual responsible for implementation of the plan.

The document: *ADA Transition Plans: A Guide to Best Management Practices* (NCHRP Project No. 20-7 (232)) provides guidance for the development and update of transition plans. The document also assists communities in prioritizing required improvements for accessibility.

Public entities not required to have a formal transition plan are still required to address noncompliant pedestrian access routes.

C. Definitions

Accessible: Facilities that comply with the requirements of this section.

Alteration: An alteration is a change that affects or could affect the usability of all or part of a building or facility. Alterations of streets, roadways, or highways include activities such as reconstruction, rehabilitation, resurfacing, widening, and projects of similar scale and effect.

Alternate Pedestrian Access Route: A route provided when a pedestrian circulation path is temporarily closed by construction, alterations, maintenance operations, or other conditions.

Curb Line: A line at the face of the curb that marks the transition between the curb and the gutter, street, or highway.

Cross Slope: The grade that is perpendicular to the direction of pedestrian travel.

Crosswalk: See pedestrian street crossing.

Curb Ramp: A ramp that cuts through or is built up to the curb. Curb ramps can be perpendicular, parallel, or a combination of parallel and perpendicular curb ramps.

Detectable Warning: Detectable warnings consist of small, truncated domes built in or applied to a walking surface that are detectable by cane or underfoot. On pedestrian access routes, detectable warning surfaces indicate the boundary between a pedestrian route and a vehicular route for pedestrians who are blind or have low vision.

New Construction: Construction of a roadway where an existing roadway does not currently exist.

Pedestrian Access Route: A continuous and unobstructed path of travel provided for pedestrians with disabilities within, or coinciding with, a pedestrian circulation path.

Pedestrian Circulation Path: A prepared exterior or interior surface provided for pedestrian travel in the public right-of-way.

Pedestrian Street Crossing: A marked or unmarked route providing an accessible path to travel from one side of the street to the other. Pedestrian street crossings are a component of the pedestrian access route and/or the pedestrian circulation path.

Running Slope: The grade that is parallel to the direction of pedestrian travel.

PROWAG: The Public Right-of-way Accessibility Guidelines establish the criteria for providing a feature within the public right-of-way that is physically accessible to those with physical disabilities.

Scope of the Project: Work that can reasonably be completed within the limits of the project. This is not defined by the written project scope; however, it focuses on whether the alteration project presents an opportunity to design the altered element, space, or facility in an accessible manner.

Structurally Impracticable: Something that has little likelihood of being accomplished because of those rare circumstances when the unique characteristics of terrain prevent the incorporation of full and strict compliance with this section. Applies to new construction only.

Technically Infeasible: With respect to an alteration of an existing facility, something that has little likelihood of being accomplished because existing structural conditions would require removing or altering a load-bearing member that is an essential part of the structural frame; or because other existing physical or site constraints prohibit modification or addition of elements, spaces, or features that are in full and strict compliance with the requirements of this section. (2010 ADAAG 106.5)

Turning Space: An area at the top or bottom of a curb ramp, providing a space for pedestrians to stop, rest, or change direction.

D. Applicability

1. **New Construction:** Newly constructed facilities within the scope of the project shall be made accessible to persons with disabilities, except when a public agency can demonstrate it is structurally impracticable to provide full compliance with the requirements of this section. Structural impracticability is limited to only those rare situations when the unique characteristics of terrain make it physically impossible to construct facilities that are fully compliant. If full compliance with this section is structurally impracticable, compliance is required to the extent that it is not structurally impracticable. [2010 ADAAG 28 CFR 35.151(a)]

2. **Alterations:** Whenever alterations are made to the pedestrian circulation path, the pedestrian access route shall be made accessible to the maximum extent feasible within the scope of the project. If full compliance with this section is technically infeasible, compliance is required to the extent that it is not technically infeasible. [2010 ADAAG 28 CFR 35.151(b)]. Alterations shall not gap pedestrian circulation paths in order to avoid ADA compliance.

Resurfacing is an alteration that triggers the requirement for curb ramps if it involves work on a street or roadway spanning from one intersection to another. Examples include, but are not limited to, the following treatments or their equivalents:

- New layer of surface material (asphalt or concrete, including mill and fill)
- Reconstruction
- Concrete pavement rehabilitation and reconstruction
- Open-graded surface course
- Microsurfacing and thin lift overlays
- Cape seals (slurry seal or microsurfacing over a new chip seal)
- In-place asphalt recycling

[DOJ/U.S. DOT Glossary of Terms and DOJ/U.S. DOT Technical Assistance; June 28, 2013]

Where elements are altered or added to existing facilities, but the pedestrian circulation path is not altered, the pedestrian circulation path is not required to be modified (R202.1). However, features that are added shall be made accessible to maximum extent feasible. The following are examples of added features:

- Installation of a traffic sign does not require sidewalk improvements; however, the sign cannot violate the protruding objects requirements.
- Installation of a traffic or pedestrian signal does not require sidewalk improvements; however, the signal must be accessible.
- Installation of a bench adjacent to the pedestrian access route would not require sidewalk improvements, but the bench cannot be placed in a manner that would reduce the sidewalk width below the minimum requirement.

3. **Maintenance:** Accessibility improvements are not required for work that is considered maintenance. Examples of work that would be considered maintenance include, but are not limited to, the following items.

- Painting pavement markings, excluding parking stall delineations
- Crack filling and sealing
- Surface sealing
- Chip seals
- Slurry seals
- Fog seals
- Scrub sealing
- Joint crack seals
- Joint repairs
- Dowel bar retrofit
- Spot high-friction treatments
- Diamond grinding
- Minor street patching (less than 50% of the pedestrian street crossing area)
- Curb and gutter repair or patching outside the pedestrian street crossing
- Minor sidewalk repair that does not include the turning space and curb ramps
- Filling potholes

If a project involves work not included in the list above, or is a combination of several maintenance items occurring at or near the same time, the agency administering the project is responsible for determining if the project should be considered maintenance or an alteration. If either of these two situations is determined to be maintenance, the agency administering the project must document the reasons for this determination. If the project is defined as maintenance, federal funding and Farm-to-Market funds cannot be used.

When a maintenance project modifies a crosswalk, installation of curb ramps at the crosswalks is recommended, if none already exists. The other accessibility improvements of this section are also recommended, but not required with such projects.

4. **Technical Infeasibility:** Examples of existing physical or site constraints that may make it technically infeasible to make an altered facility fully compliant include, but are not limited to, the following:
   - Right-of-way availability. Right-of-way acquisition in order to achieve full compliance is not mandatory, however, it should be considered. Improvements may be limited to the maximum extent practicable within the existing right-of-way.
   - Underground structures that cannot be moved without significantly expanding the project scope.
   - Adjacent developed facilities, including buildings that would have to be removed or relocated to achieve accessibility.
   - Drainage cannot be maintained if the feature is made accessible.
   - Notable natural or historic features that would have to be altered in a way that lessens their aesthetic or historic value.
   - Underlying terrain that would require a significant expansion of the project scope to achieve accessibility.
   - Street grades within the crosswalk exceed the pedestrian access route maximum cross slopes, provided an engineering analysis has concluded that it cannot be done without significantly expanding the project scope (for example, changing from resurfacing an intersection to reconstructing that intersection).

5. **Safety Issues:** When accessibility requirements would cause safety issues, compliance is required to the maximum extent practicable.

6. **Documenting Exceptions:** If the project cannot fully meet accessibility requirements because the accessibility improvements are structurally impracticable, technically infeasible, or create safety issues, a document should be developed to describe how the existing physical or site constraints or safety issues limit the extent to which the facilities can be made compliant. This document should identify the specific locations that cannot be made fully compliant and provide specific reasons why full compliance cannot be achieved. It is recommended that this document be retained in the project file. For local agency projects administered through Iowa DOT, an "Accessibility Exceptions Certification" (Form 517118) with supporting documentation shall be signed by a registered professional engineer or landscape architect licensed in the State of Iowa and submitted to the Iowa DOT administering bureau. The certification shall be as prescribed by Iowa DOT Local Systems I.M. 1.080. For Iowa DOT projects, contact the Design Bureau, Methods Section.

   Note: Documenting exceptions does not remove an agency's responsibility to consider making accessibility improvements the next time the facility is altered, because physical or site constraints and safety issues may change over time. The determination of exceptions and corresponding documentation needs to be made each time a facility is altered, based on the existing conditions and the scope of the proposed project.

7. **Reduction in Access:** Regardless of whether the additions or alterations involve the modification of the existing pedestrian circulation path, the resulting work cannot have the result of reducing the existing level of accessibility below the minimum requirements. For example, the installation of a bench cannot have the effect of reducing the width of the pedestrian access route to 3 feet (4 feet is the minimum). Likewise, the construction of an overlay cannot result in a street cross slope of more than 5%, nor have a lip at the curb ramp that exceeds 1/2 inch. Pedestrian facilities may be removed if they are being re-routed for safety reasons, or terminated because they do not connect to a destination or another pedestrian circulation path.

8. **Addition of Pedestrian Facilities:** If a sidewalk exists on both sides of the street, curb ramps shall be installed on both sides when the street is altered. PROWAG does not require construction of pedestrian facilities where none currently exists, although the jurisdiction's transition plan may require them.

9. **Utility Construction:** If the pedestrian circulation path is disturbed during utility construction, the requirements of this section and Section 12A-4 shall apply.

E. Standards for Accessibility

The following section summarizes the design standards for the elements of an accessible pedestrian access route. The minimum and maximum values stated are taken from the PROWAG. Target values are also provided. Designing features to the target values, rather than the allowable maximum or minimum, allows for appropriate construction tolerances and field adjustment during construction while maintaining compliance with the PROWAG standards.

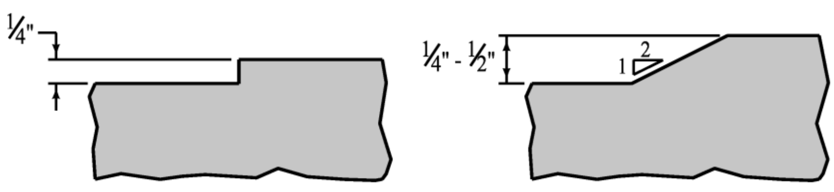
1. **General Requirements:** These requirements apply to all parts of the pedestrian access route.

   a. **Surfacing:** PROWAG requires all surfaces to be firm, stable, and slip resistant (R302.7). All permanent pedestrian access routes, with the exception of some Type 2 shared use paths (see Section 12B-2), shall be paved. When crossing granular surfaced facilities, consider paving wider than the pedestrian access route; see the shared use path section.

   b. **Vertical Alignment:** Vertical alignment (smoothness) shall be generally planar within the pedestrian access routes (R302.7.1). Although no definition for generally planar is provided, the Advisory statement for R302.7.1 indicates surfaces must be smooth and chosen for easy rollability and minimizing vibration for users of wheelchairs, scooters, and walkers. Surfaces that are heavily textured, rough, or chamfered and paving systems consisting of individual units that cannot be laid in plane should be reserved for borders and decorative accents located outside of and only occasionally crossing the pedestrian access route. Research has shown that bricks/pavers with no or narrow chamfers and narrow joint spacing between pavers can minimize vibration for all users. Bricks/pavers with sand bedding on natural soil should not be used in pedestrian access routes due to maintenance problems.

   c. **Changes in Level:** Changes in level, including bumps, utility castings, expansion joints, etc. shall be a maximum of 1/4 inch without a bevel or up to 1/2 inch with a 2:1 bevel. Where a bevel is provided, the entire vertical surface of the discontinuity shall be beveled (R302.7.2).

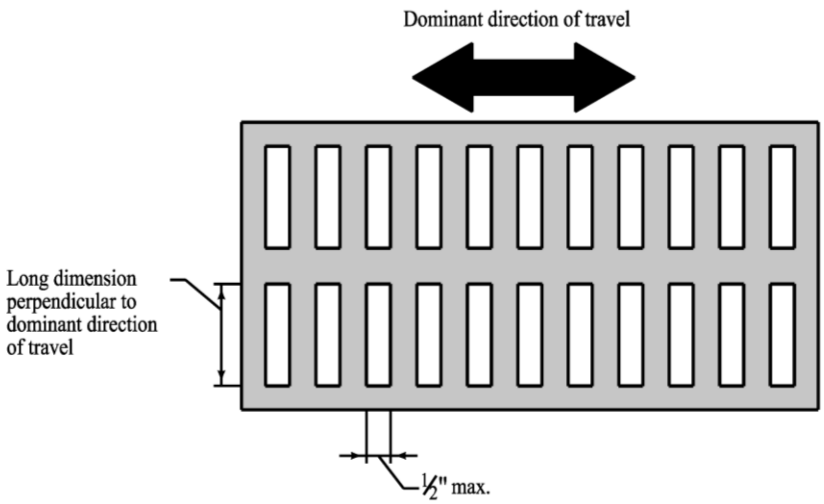
Figure 12A-2.01: Vertical Surface Discontinuities



d. **Horizontal Openings:** Horizontal openings shall not allow passage of a sphere more than 1/2 inch in diameter. Elongated openings in grates shall be placed so the long dimension is perpendicular to the dominant direction of travel. The use of grates within the pedestrian access route is discouraged; however, where necessary, the grate should be located outside of curb ramp runs, turning spaces, and gutter areas if possible. (R302.7.3)

It should be noted that none of the standard SUDAS/Iowa DOT intake grates meet the requirements for use within a pedestrian access route; therefore, a special design is required.

Figure 12A-2.02: Horizontal Openings



2. **Standard Sidewalk:**

a. **Cross Slope:** The maximum cross slope is 2.0% with a target value of 1.5% (R302.6).

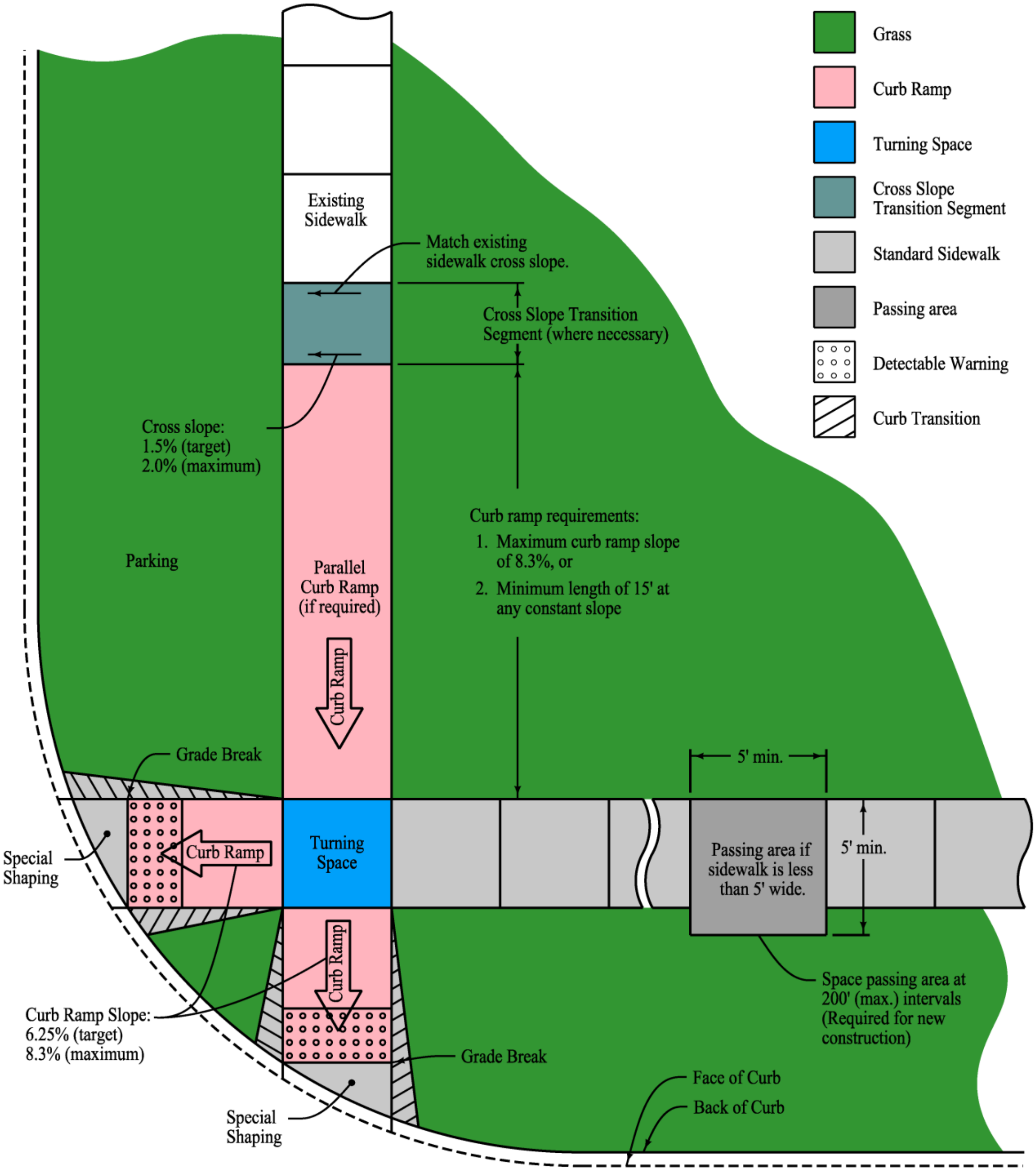
b. **Running Slope:** Sidewalks with a running slope of 5% or less are acceptable. However, where the sidewalk is contained within the street right-of-way, the grade of the sidewalk shall not exceed the general grade of the adjacent street (R302.5). For design, consider the general grade of the adjacent street to be within approximately 2% of the profile grade of the street.

c. **Width:** The minimum width of the pedestrian access route is 4 feet. Five foot sidewalks are encouraged and may be required by the Jurisdiction. Iowa DOT will design 5 foot sidewalks unless otherwise requested. (R302.3)

d. **Passing Spaces:** Where the clear width of the pedestrian access route is less than 5 feet, passing spaces are required at maximum intervals of 200 feet. The passing space shall be 5 foot minimum by 5 foot minimum. Passing spaces may overlap with the pedestrian access route. (R302.4). Driveways may be used as passing spaces, as long as the 2.0% maximum cross slope is not exceeded.

Note: Sidewalks solely serving private residences are not required to follow requirements a, b, c, and d above.

Figure 12A-2.03: Standard Sidewalk and Curb Ramp Elements

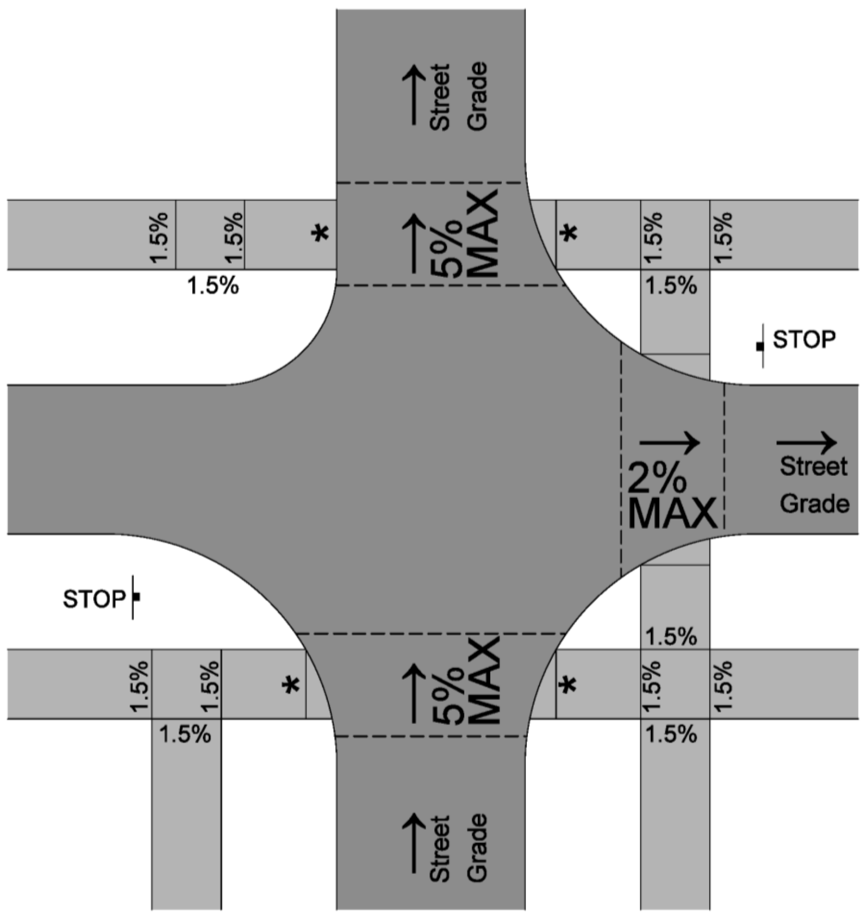


3. **Pedestrian Street Crossings:**

   a. **Cross Slope:** The longitudinal grade of a street becomes the cross slope for a pedestrian street crossing. PROWAG has maximum limits for the cross slope of pedestrian street crossings, which vary depending on the location of the crossing and the type of vehicular traffic control at the crossing. These requirements, in effect, limit the longitudinal grade of a street, or require a “tabled crosswalk” at the intersection. (R302.6)

      1) **Intersection Legs with Stop or Yield Control:** For pedestrian street crossings across an intersection leg with full stop or yield control (stop sign or yield sign), the maximum cross slope is 2.0% (maximum 2.0% street grade through the crossing).
      2) **Intersection Legs without Stop or Yield Control:** For pedestrian street crossings across an intersection leg where vehicles may proceed without slowing or stopping (uncontrolled or signalized), the maximum cross slope of the pedestrian street crossing is 5.0% (maximum 5.0% street grade through the crossing).
      3) **Midblock Pedestrian Street Crossings:** At midblock crossings, the cross slope of the pedestrian street crossing is allowed to equal the street grade.

Figure 12A-2.04: Example Street Intersection

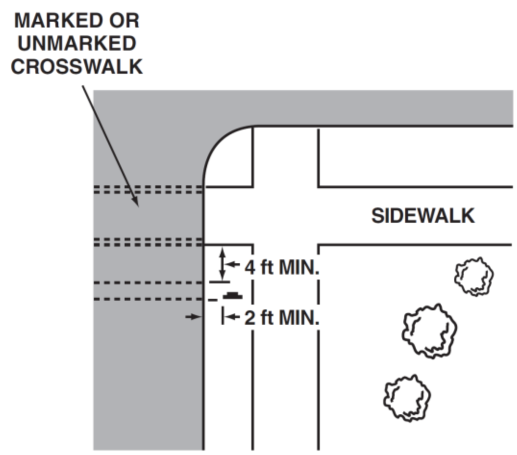


* Match pedestrian street crossing cross slope or flatter

   b. **Running Slope:** The running slope of the pedestrian street crossing is limited to a maximum of 5.0% (maximum street cross slope or superelevation of 5.0%) (R302.5.1).

c. **Location:** Driver anticipation and awareness of pedestrians increases as one moves closer to the intersection. Therefore, curb ramps and pedestrian street crossings should be located as close to the edge of the adjacent traveled lane as practical. Where a stop sign or yield sign is provided, MUTCD requires the pedestrian street crossing, whether marked or unmarked, be located a minimum of 4 feet from the sign, between the sign and the intersection. It is recommended stop and yield signs be located no greater than 30 feet from the edge of the intersecting roadway; however, MUTCD allows up to 50 feet. Consult MUTCD for placement of curb ramps and pedestrian street crossings at signalized intersections.

Figure 12A-2.05: Pedestrian Street Crossing Location



Source: MUTCD, FHWA

d. **Medians and Pedestrian Refuge Islands:** Medians and pedestrian refuge islands in pedestrian street crossings shall be cut through level with the street or complying with the curb ramp requirements. The clear width of pedestrian access routes within medians and pedestrian refuge islands shall be 5.0 feet minimum (R302.3.1). If a raised median is not wider than 6 feet, it is recommended the nose not be placed in the pedestrian street crossing.

4. **Curb Ramps:**

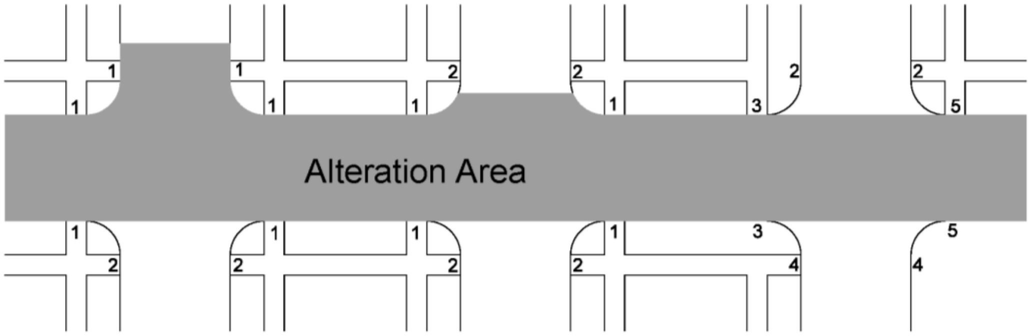
a. **General:** There are two types of curb ramps: perpendicular and parallel. Perpendicular curb ramps are generally perpendicular to the traffic they are crossing with the turning space at the top. Parallel curb ramps have the turning space at the bottom. Parallel curb ramps may be used where the sidewalk begins at or near the back of curb and there is little or no room between the sidewalk and curb for a perpendicular curb ramp.

A separate curb ramp is required at each pedestrian street crossing for new construction. Parallel ramps with a large turning space, as shown in Figure 12A-2.08, are allowed. For alterations, follow the new construction requirements if possible; however, a single diagonal curb ramp is allowed but not recommended where existing constraints prevent two curb ramps from being installed.

For transitions into and out of driveways, curb ramp requirements may be used.

For curb ramps within and near an alteration area, see Figure 12A-2.06. It is critical to provide a new ramp opposite an existing ramp if the existing ramp is maintained so a positive exit point from the street is provided.

Figure 12A-2.06: Curb Ramps for Alterations



1. Required.
2. Strongly recommended.
3. Required due to barriers in the path of travel between the sidewalk on one side of the street to the sidewalk on the other side of the street.
4. Recommended, but not required because it is outside the alteration area. Consider based on pedestrian usage, safety, and land development.
5. Install both sides or remove the existing one, based on pedestrian usage, safety, and land development.

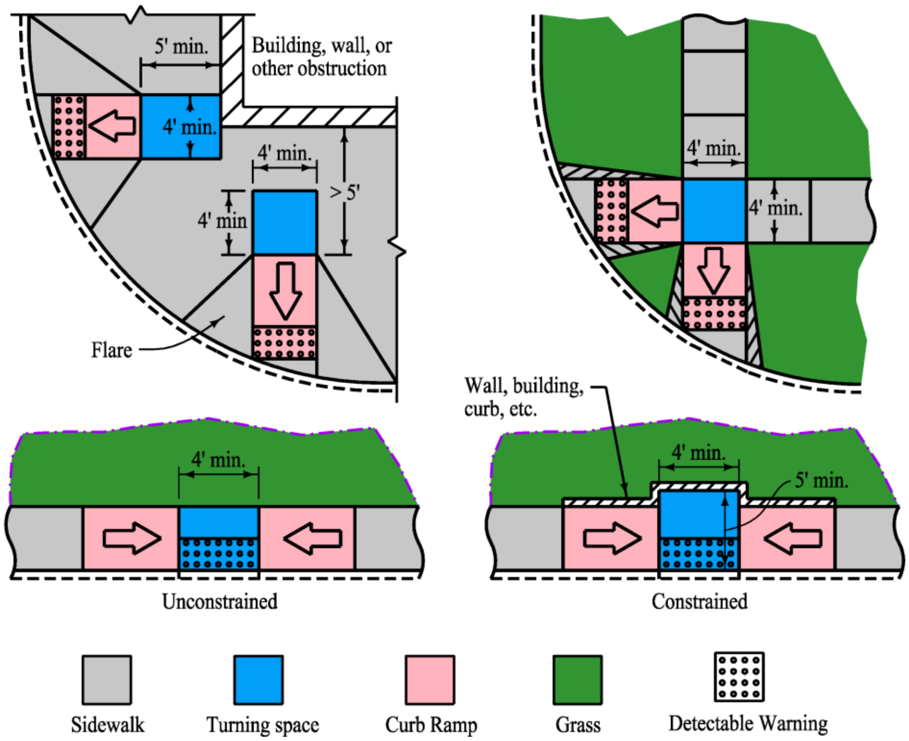
b. Technical Requirements:

1) **Cross Slope:** The maximum cross slope is 2.0% with a target value of 1.5%; however, for intersection legs that do not have full stop or yield control (i.e. uncontrolled or signalized) and at mid-block crossings, the curb ramp cross slope is allowed to match the cross slope in the pedestrian street crossing section. See “pedestrian street crossings” for additional details. (R304.5.3)
2) **Running Slope:** Provide curb ramps with a target running slope of 6.25% and a maximum slope of 8.3%; however, curb ramps are not required to be longer than 15 feet, regardless of the resulting slope. (R304.2.2 and R304.3.2)
3) **Width:** The minimum width of a curb ramp is 4 feet, excluding curbs and flares. If the sidewalk facility is wider than 4 feet, the target value for the curb ramp is equal to the width of the sidewalk. (R304.5.1)
4) **Grade Breaks:** Grade breaks at the top and bottom of curb ramps must be perpendicular to the direction of the curb ramp run. Grade breaks are not allowed on the surface of curb ramp runs and turning spaces. (R304.5.2)
5) **Flared Sides:** For perpendicular curb ramps on Class A sidewalks, or configurations where the pedestrian circulation path crosses the curb ramp, PROWAG requires the flares along the sides of the curb ramp to be constructed at 10% or flatter. (R304.2.3) This allows pedestrians to approach the curb ramp from the side and prevents a tripping hazard. It is recommended to design these flares at a slope between 8% and 10%, which will clearly define the curb ramp from the sidewalk.
6) **Clear Space:** At the bottom of perpendicular curb ramps, a minimum 4 foot by 4 foot area must be provided within the width of the pedestrian street crossing, but wholly outside of the parallel vehicle travel lanes. (R304.5.5)
7) **Turning Space:** Turning spaces allow users to stop, rest, and change direction on the top or bottom of a curb ramp (R304.2.1 and R304.3.1).
   a) **Placement:** A turning space is required at the top of perpendicular curb ramps and at the bottom of parallel curb ramps.
   b) **Slope:** The maximum cross slope and running slope is 2.0% with a target value of 1.5% (R304.2.2 and R304.3.2). When turning spaces are at the back of curb, cross slopes may be increased to match allowable values in the pedestrian street crossing section (R304.5.3).

c) **Size:** The turning space shall be a minimum of 4 feet by 4 feet. Where the turning space is constrained on one or more sides, provide 5 feet in the direction of the pedestrian street crossing.

8) **Special Shaping Area:** Transition area between the back of curb and the grade break. The longest side cannot exceed 5 feet.

Figure 12A-2.07: Curb Ramp Turning Spaces



c. **Curb Ramp Design Considerations:**

1) **Combination Curb Ramps:** For many intersection configurations, a perpendicular curb ramp will not provide enough length to establish the top turning space at the sidewalk elevation; in these situations, a parallel curb ramp is often required to transition from the turning space up to the sidewalk elevation. The use of a perpendicular curb ramp from the curb to the turning space in conjunction with a parallel curb ramp between the turning space and the sidewalk elevation is referred to as a combination curb ramp. When transitioning from a turning space to sidewalk elevation on a steep street, it is not necessary to chase the grade. As noted in the technical requirements above, a parallel curb ramp is not required to exceed 15 feet in length, regardless of the resulting curb ramp slope. In practice, the parallel curb ramp should be extended to the next joint beyond 15 feet.
2) **Cross Slope Transition Segment:** When connecting to existing construction that is out of cross slope compliance, the cross slope transition should be completed beyond the parallel curb ramp or turning space; this recommendation eliminates the need to list this curb ramp in the transition plan. It is recommended this cross slope transition take place at 1% or less per foot. Typically, this can be accomplished in a single panel.
3) **Parking Slope:** In situations where the length of the perpendicular curb ramp is insufficient to bring the turning space up to sidewalk elevation, consider lowering the sidewalk and flattening the parking slope.

5. **Blended Transitions:** A blended transition is allowed but not recommended. Design and constructability is difficult to meet compliance requirements. In lieu of a blended transition, a curb ramp or standard sidewalk should be used.

6. **Detectable Warnings:**

   a. **General:** Detectable warning surfaces are detected underfoot or with a cane by blind and low vision individuals. The warnings indicate the location of the back of curb. Detectable warnings also provide a visual queue to pedestrians with low vision and aid in locating the curb ramp across the street. For these reasons, the detectable warning shall contrast visually (light on dark or dark on light) from the surrounding paved surfaces (R305.1.3).

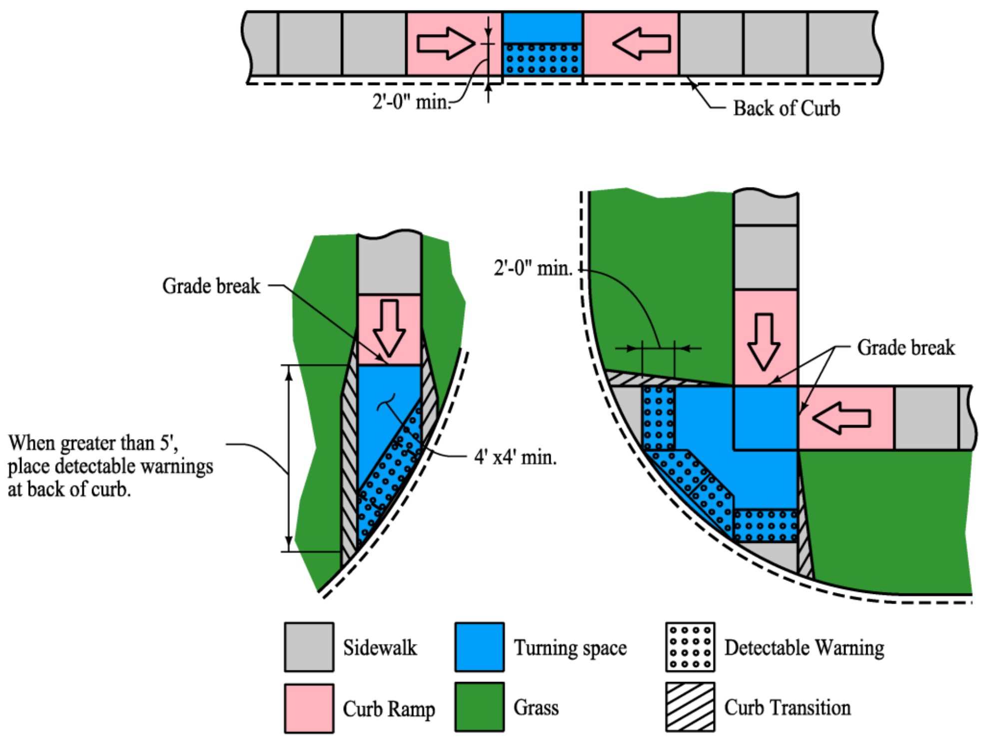
   b. **Location:** Detectable warnings shall be installed at all pedestrian street crossings and at-grade rail crossings (R208.1). Detectable warning surfaces should not be provided at crossings of residential driveways since the pedestrian right-of-way continues across the driveway. Where commercial driveways are provided with yield control, stop control, or traffic signals at the pedestrian access route, detectable warnings should be installed at the junction between the pedestrian access route and the driveway (Advisory R208.1).

   c. **Size:** Detectable warning surfaces shall extend a minimum of 2 feet in the direction of pedestrian travel and extend the full width of the curb ramp or pedestrian access route (R305.1.4).

   d. **Dome Orientation:** On curb ramps, the rows of truncated domes should be aligned perpendicular to the grade break so pedestrians in wheelchairs can track their wheels between the domes. On surfaces less than 5% slope, dome orientation is less critical.

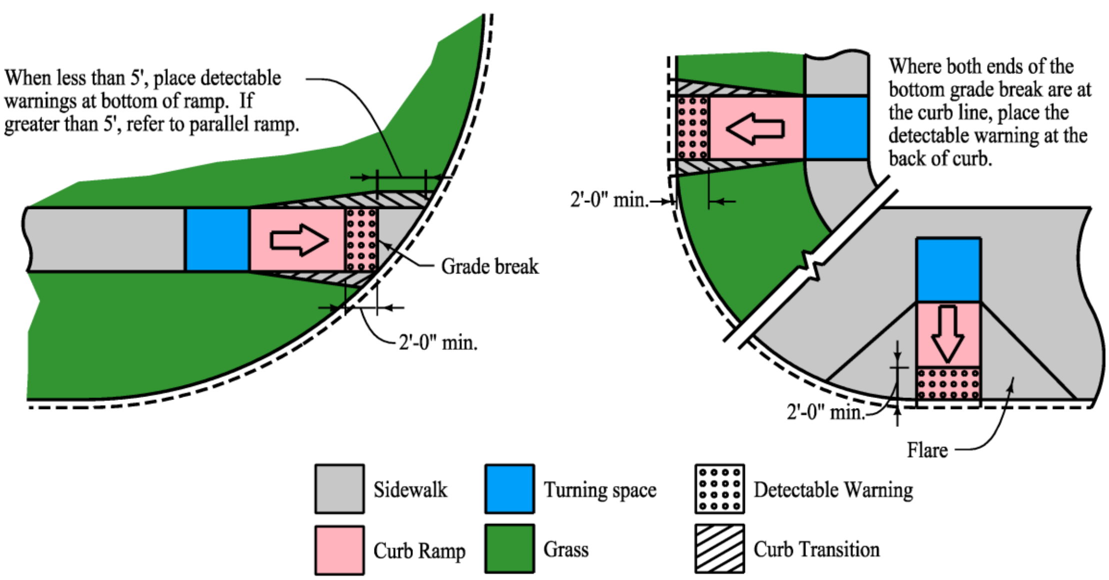
   e. **Parallel Curb Ramps:** On parallel curb ramps, detectable warning shall be placed on the turning space at the back of curb (R305.2.2).

Figure 12A-2.08: Detectable Warnings on Parallel Curb Ramps



f. **Perpendicular Curb Ramps:** Placement of detectable warning varies based upon location of grade break as shown in Figure 12A-2.09.

Figure 12A-2.09: Detectable Warnings on Perpendicular Curb Ramps



g. **Refuge Islands:** Where refuge islands are 6 feet wide or greater from back of curb to back of curb, detectable warning shall be placed at the edges of the pedestrian island and separated by a minimum 2 foot strip without detectable warnings. Where the refuge island is less than 6 feet wide, a 2 foot strip without detectable warnings cannot be installed. In these situations, detectable warnings shall not be installed at the island and the pedestrian signal must be timed for full crossing. (R208.1 and R208.2)

h. **Rural Cross-section:** Detectable warnings should be placed similar to urban layouts, except at the edge of shoulder instead of the back of curb.

F. Bus Stop

1. **Bus Stop Pads:** New and altered bus stop pads shall meet the following criteria.
   - Provide a firm, stable, and slip resistant surface (R308.1.3.1).
   - Provide a minimum clear length of 8 feet (measured from the curb or roadway edge) and minimum clear width of 5 feet (measured parallel to the roadway) (R308.1.1.1).
   - Connect the pad to streets, sidewalks, or pedestrian circulation paths with at least one accessible route (R308.1.3.2).
   - The slope of the pad parallel to the roadway will be the same as the roadway to the maximum extent practicable (R308.1.1.2).
   - Provide a desirable cross slope of 1.5% up to a maximum cross slope of 2.0% perpendicular to the roadway (R308.1.1.2).

2. **Bus Shelters:** Where new or replaced bus shelters are provided, install or position them to allow a wheelchair user to enter from the public way. An accessible route shall be provided from the shelter to the boarding area. (R308.2)

3. **Safe Street Crossings:** Most bus users need to cross streets when traveling to or from transit stops. Safe street crossings should be provided near bus stops, typically within 100 feet (FHWA Pedestrian Safety Guide for Transit Agencies). Where bus stops are near to a signalized intersection, designers should evaluate the signal to ensure appropriate pedestrian intervals, cycle lengths, and equipment are present.

G. Accessible Pedestrian Signals

An accessible pedestrian signal is an integrated device that communicates information about the WALK and DON’T WALK intervals at signalized intersections in a non-visual format (i.e. audible tones and vibrotactile surfaces) to pedestrians who have visual disabilities. Consistency throughout the pedestrian system is very important. Contact the Engineer regarding the standards and equipment types that should be incorporated into the design of the accessible pedestrian system. Where new or altered pedestrian signals and pushbuttons are provided they shall comply with MUTCD 4E.08 through 4E.13. Operable parts shall comply with R403. (R209.1)

1. **New Pedestrian Signals:** Each new traffic signal project location should be evaluated to determine the need for accessible pedestrian signals. An engineering study should be completed that determines the needs for pedestrians with visual disabilities to safely cross the street (MUTCD 4E.09). The study should consider the following factors:
   - Potential demand for accessible pedestrian signals.
   - Requests for accessible pedestrian signals by individuals with visual disabilities.
   - Traffic volumes when pedestrians are present, including low volumes or high right turn on red volumes.

- The complexity of the signal phasing, such as split phasing, protected turn phases, leading pedestrian intervals, and exclusive pedestrian phases.
- The complexity of the intersection geometry.

If a pedestrian accessible signal is warranted, audible tones and vibrotactile surfaces should be included. Pedestrian pushbuttons should have locator tones for the visually impaired individual to be able to access the signal.

2. **Existing Pedestrian Signals:** Excluding routine maintenance or repairs due to accidental damage, when the existing pedestrian signal controller and software are altered, or the pedestrian signal head is replaced, the pedestrian signals shall include accessible pedestrian signals and pushbuttons. (R209.2)

If pedestrian signals are non-compliant, upgrades are recommended but not required when alterations are being made to the pedestrian circulation path.

H. On-Street Parking

- When on-street parking is marked or metered, provide accessible parking spaces according to Table 12A-2.01 (R214 and R309.1).

Table 12A-2.01 On-Street Accessible Parking Spaces

Total Number of Marked or Metered Parking Spaces on the Block Perimeter	Minimum Required Number of Accessible Parking Spaces
1 to 25	1
26 to 50	2
51 to 75	3
76 to 100	4
101 to 150	5
151 to 200	6
201 and over	4% of total

- Identify accessible parking spaces by displaying signs with the International Symbol of Accessibility (R411).
- Comply with R403 Operable Parts for parking meters and pay stations that serve accessible parking spaces.
- Locate accessible parking spaces where the street has the least crown and grade (R309.1).
- Accessible parking spaces located at the end of the block can be served by the curb ramps or blended transitions at the pedestrian street crossing (R309.4).
- Keep sidewalks adjacent to parallel accessible parking spaces free of signs, street furniture, and other obstructions. Locate curb ramps or blended transitions so the van side-lift or ramp can be deployed to the sidewalk (R309.2).
- At parallel accessible parking spaces, locate parking meters at the head or foot of the parking space (R309.5.1). Ensure information is visible from a point located 3.3 feet maximum above the center of the clear space in front of the parking meter or parking pay station (R309.5.2).
- For areas where the sidewalk width or available right of way exceeds 14 feet, provide an access aisle 5 feet wide at street level the full length of the parallel parking space and connect it to a pedestrian access route (R309.2.1). When an access aisle is not provided due to the sidewalk or right-of-way not exceeding 14 feet, locate the accessible parallel parking space at the end of the block face (R309.2.2).

- Provide an 8 foot wide access aisle the full length of the parking space for perpendicular or angled accessible parking spaces. Two accessible parking spaces are allowed to share a common access aisle (R309.3).
- For perpendicular or angled spaces, connect the access aisle to the pedestrian access route with a curb ramp. Do not locate curb ramps within the access aisle (R309.4).

Protruding Objects

A. Introduction

This section provides guidance to comply with section R402 of the Public Right-of-Way Accessibility Guidelines (PROWAG). The pedestrian area is any prepared area available for pedestrians (equivalent to the pedestrian circulation path as defined in PROWAG). A protruding object is any obstacle that reduces the clearance width and/or the clearance height within a pedestrian area. The pedestrian area is not limited to the sidewalk or the pedestrian access route intended by the designer. The pedestrian area includes any areas that may be perceived as a pedestrian walking space, including adjacent parking lots and paved frontage.

Common protruding objects include:

- Signs and Sign poles
- Landscaping and branches
- Utility boxes or poles and their stabilizing wires
- Mailboxes (public and private)
- Trash cans
- Transit shelters
- Bike racks
- Planters
- Fire hydrants
- Parking meters
- Benches
- Public Art

B. Protruding Object Locations

1. **Outside the Pedestrian Area:** A protruding object can result in narrow passing spaces, reduced access, and injury. Therefore, protruding objects should be placed completely outside of the pedestrian area whenever possible.

2. **Within the Pedestrian Area:** Ideally, the full width of the pedestrian area should be free of protruding objects and the pedestrian access route would be clearly separated from other paved surfaces. However, if some obstacles must be located within the pedestrian area, they should all be placed either right or left of center to provide a consistent pedestrian access route. Figure 12A-3.01 shows an acceptable pedestrian area with obstacles aligned, providing a consistent pedestrian access route. Figure 12A-3.02 shows an undesirable pedestrian area with a poorly defined pedestrian access route. The pedestrian access route within the pedestrian area must meet guidelines defined in this chapter. Special sidewalk treatments (such as brick pavers or stamped concrete) are recommended to provide a different surface texture to differentiate between the object corridor and the pedestrian access route.

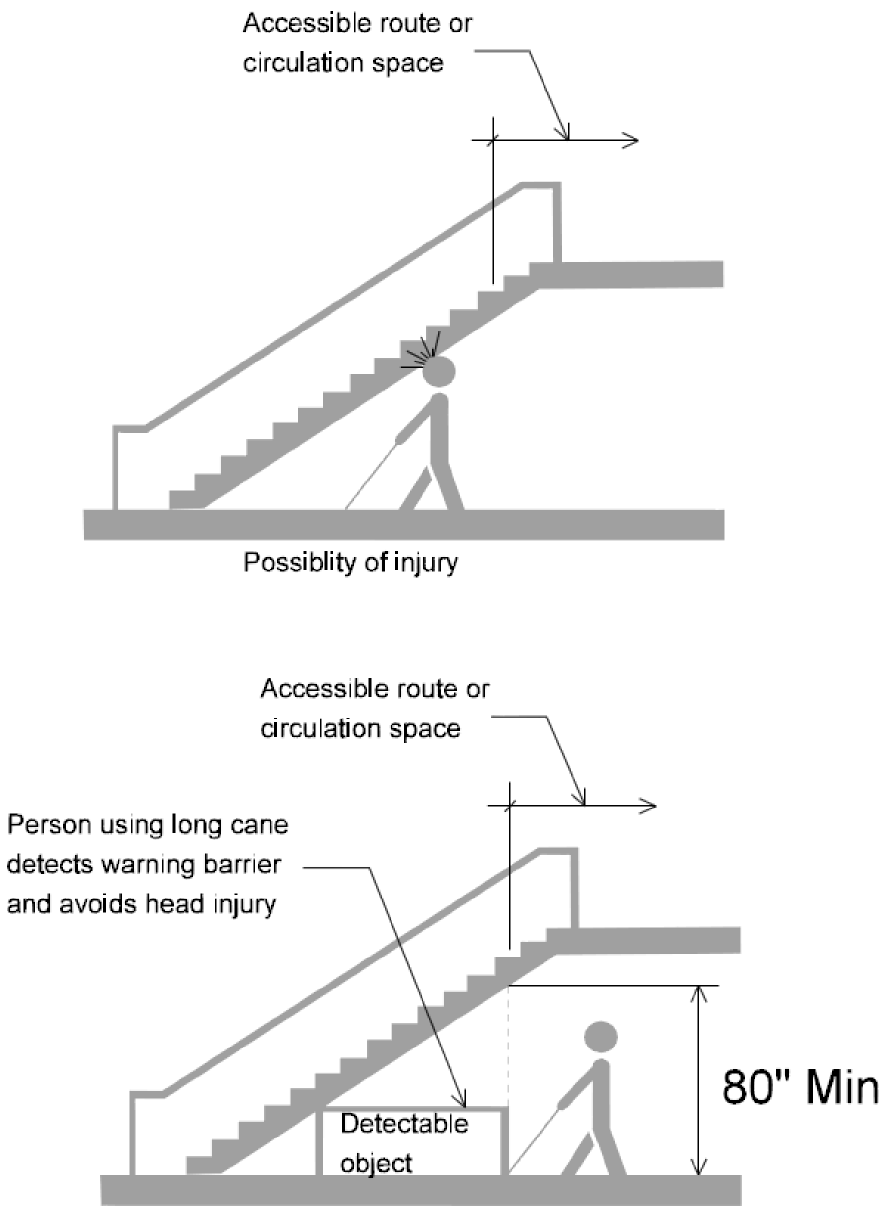
Figure 12A-3.01: Acceptable Pedestrian Area

Figure 12A-3.02: Undesirable Pedestrian Area

C. Clearance

1. **Vertical Clearance:** Vertical clearance is minimum unobstructed vertical passage space required along the entire width of the pedestrian corridor. A minimum vertical clearance of 80 inches must be provided or the object must be shielded with a barrier. The leading edge of the barrier shall be a maximum of 27 inches above the finished surface. See Figure 12A-3.03.

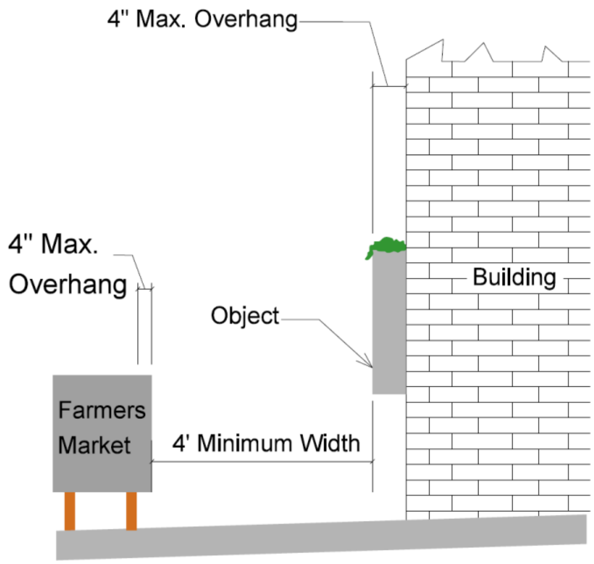
Figure 12A-3.03: Shielding for Vertical Clearance Obstacles



2. **Horizontal Clearance:** Objects mounted at or below 27 inches may extend from a fixed structure into the pedestrian area, provided the remaining sidewalk width complies with Section 12A-2. Objects that extend below 27 inches are easily detectable by most pedestrians.

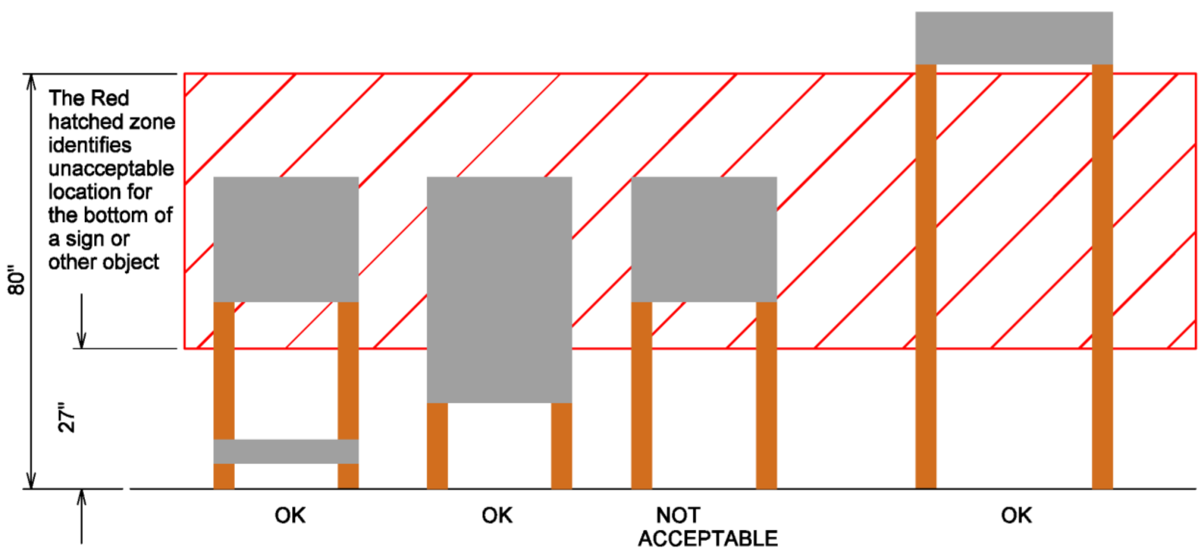
Objects that extend into the pedestrian area at a height above 27 inches are not easily detected with a cane and pedestrians may walk into them. This type of object cannot extend into the pedestrian corridor more than 4 inches from its base. The base shall be at least 2.5 inches in height. See Figure 12A-3.04.

Figure 12A-3.04: Horizontal Clearance



3. **Objects Mounted Between Posts:** Where an object is mounted between posts or pylons and the clear distance between the posts or pylons is greater than 12 inches, the lowest edge of the object shall be between 0 and 27 inches or 80 inches or more above the ground (see Figure 12A-3.05). For objects mounted on posts closer than 12 inches, follow the requirements for horizontal clearance defined above.

Figure 12A-3.05: Height Restriction for Signs Mounted Between Posts



Pedestrian Facilities During Construction

A. Introduction

When projects impact pedestrians, it is important for the engineer to develop a temporary traffic control plan for pedestrians, including those with disabilities. For Iowa DOT projects, see Iowa DOT Design Manual Section 9A-5 for temporary traffic control plans. The applicable guidelines for the temporary traffic control plan are the Public Right-of-Way Accessibility Guidelines (PROWAG) and Manual on Uniform Traffic Control Devices (MUTCD).

According to PROWAG, when a pedestrian circulation path is temporarily closed for construction or maintenance activities, an alternate pedestrian access route complying with Sections 6D.01, 6D.02, and 6G.05 of the MUTCD shall be provided (R205). However, MUTCD (Section 6D.01) also requires knowledgeable persons to conduct appropriate evaluations or use engineering judgment in determining temporary traffic controls for pedestrian circulation paths. This section includes guidance on conducting the evaluation when an alternate pedestrian access route may not be practical.

B. Evaluating Pedestrian Needs

The initial design activity should be to determine the level of the accessibility of the current pedestrian circulation path within the area of the project and the adjacent areas. The impact to the pedestrian circulation path, including transit stops, from the construction or maintenance activity needs to be determined. Develop pedestrian accommodations to provide the best accessibility practical through all stages of work. Consider obtaining local input through a public meeting or contact with residents or public officials to see where additional accessibility needs should be addressed (e.g. senior centers, medical facilities, schools, public facilities, etc.).

Whenever possible, the work should be done in such a manner that does not create a need to detour pedestrians from existing routes. Pedestrians rarely observe detours and the cost of providing accessibility and detectability might outweigh the cost of maintaining a continuous route through the construction zone (MUTCD 6D-01). All methods should be given consideration, including providing alternate means of traversing the construction zone. If pedestrians are to be directed through the construction zone, safety as well as accessibility must be addressed. If a pedestrian detour is developed, it should replicate the accessibility of the existing route. If possible, stage construction to keep one side of the street open to pedestrian travel.

C. Facility Options

To address the impacts to the pedestrian circulation path, including transit stops, consider the following:

- Develop a temporary traffic control plan to guide the pedestrians through the construction zone.
- Close the pedestrian circulation path through the construction zone.
- Close the pedestrian circulation path through the construction zone; develop a detour route consistent with the accessibility features present in the pedestrian circulation path being closed.
- Provide alternate means for pedestrians to traverse the construction zone, such as free accessible shuttles or other forms of assistance.

D. Barricades, Channelizing Devices, and Signs

Pedestrian barricades and channelizing devices shall comply with sections 6F.63, 6F.68, and 6F.71 of the MUTCD. Do not allow post-mounted signs to encroach on sidewalks, shared use paths, or bicycle lanes. Do not place portable signs or barricades on sidewalks unless those facilities are officially closed.

1. **Barricades:** Barricades are used for pedestrian circulation path closures. See Iowa DOT Specifications Section 2528.

2. **Channelizing Devices:** The designer should consider the safety of pedestrians and vehicles when choosing channelizing devices.

    a. **Type A:** Type A devices are redirective barriers designed for highway applications. These devices are suitable when pedestrians are routed into the travel way and allow for the most protection for pedestrians from vehicular intrusion.

    b. **Type B:** Type B devices are crashworthy but do not redirect vehicles. These devices are designed to minimize risks associated with flying debris.

    c. **Type C:** Type C devices include any device that meets ADA requirements for channelizing pedestrians and may not be crashworthy. These devices are for locations where vehicular intrusions are unlikely (e.g. closed roads, when there is a separation between pedestrians and vehicular traffic, or where vehicular traffic is at low speeds).

3. **Signs:** See Iowa DOT Standard Road Plan TC-601 and TC-602.

E. Temporary Pedestrian Facilities

Temporary pedestrian facilities should comply with the other sections within this chapter to the extent practical. It is strongly recommended that detour routes be on paved surfaces.

Temporary pedestrian facility surfaces must be firm, stable, and slip resistant. Granular surfacing for short term, temporary pedestrian facilities is acceptable. The granular surfacing material should be well graded, such as Class A road stone (Iowa DOT Specifications Section 4109, Gradation No. 8) or special backfill (Iowa DOT Specifications Section 4109, Gradation No. 30). Maintenance of the temporary pedestrian facility surface to meet the firm, stable, slip resistant, and minimum width is required at all times. The temporary pedestrian facility surface must be removed and a permanent pedestrian facility must be replaced prior to the end of the construction season.

F. Utility Construction

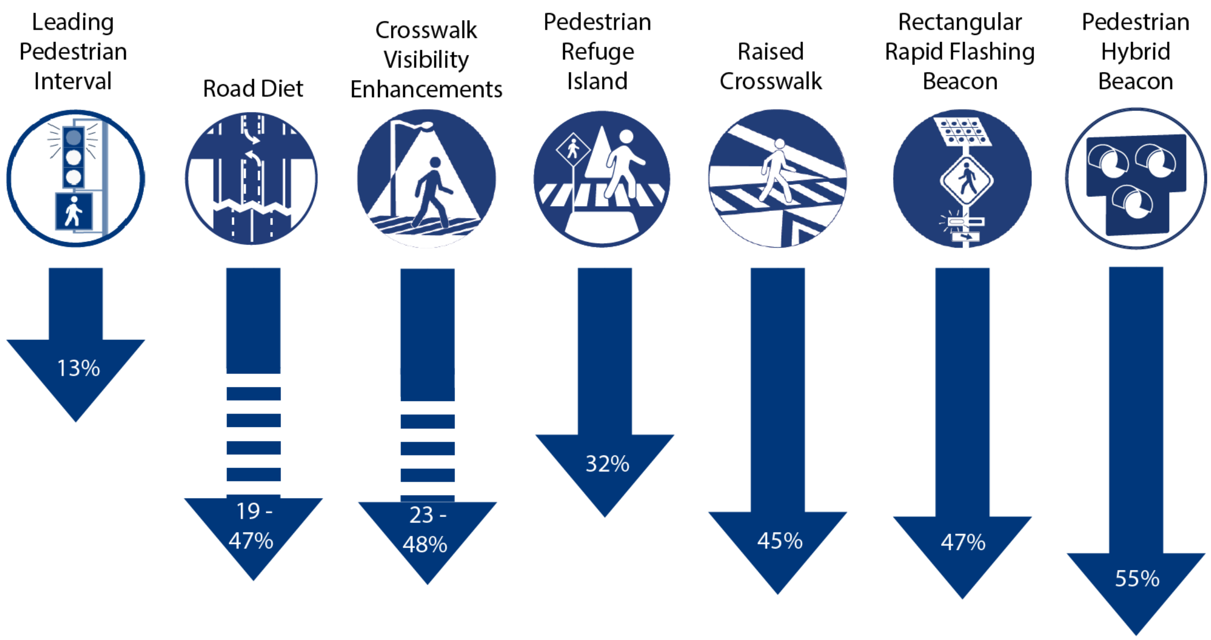
If the pedestrian circulation path is disturbed during utility construction, the requirements of this section and Section 12A-2 shall apply.

Pedestrian Safety Measures at Crossings

A. Safe Transportation for Every Pedestrian (STEP)

FHWA's Safe Transportation for Every Pedestrian (STEP) program produces technical assistance and design guidance on proven countermeasures for improving pedestrian safety. The purpose of this section is to provide guidance on how to select and implement these measures. The pedestrian safety measures and their crash mitigation reduction factor (CRF) are shown on Figure 12A-5.01.

Figure 12A-5.01: Crash Reduction Factors for Pedestrian Safety Measures



Source: Based on FHWA STEP Countermeasure Tech Sheets

B. Selecting Crossing Locations for Pedestrian Safety Measures

The provision of pedestrian safety crossing measures should be assessed along any road where pedestrians are allowed. In rural town, suburban, and urban land uses, pedestrians are expected and a well-connected pedestrian network is necessary for safe travel. However, agencies should prioritize implementing pedestrian safety measures in areas more likely to result in serious or fatal crashes. Ideally, an agency would engage in a systemic safety evaluation to identify roadway safety problems and select safety improvements. A systemic safety evaluation analyzes crash data in conjunction with other roadway data to understand the combination of conditions possibly creating high crashes, and allows planners and engineers to identify high risk crossing locations, even if no crash has occurred. When using crash data, it is important to review at least 5 years of data to analyze anomalies that might occur in a single year.

In the absence of a systemic safety analysis, enhanced pedestrian crossing safety measures should be considered at crosswalks with intersecting traffic volumes of 9,000 vehicles/day, where vehicle speeds exceed 30 mph, or the number of travel lanes to be crossed exceeds 2 lanes. In these instances, designers should consider enhanced crossings treatments at currently uncontrolled intersections or midblock where signalized crossings exceed 600 feet.

Crossings should be located where there is a desire to cross due to existing or future land use. Examples include:

- Schools, public parks, libraries, post offices, or community centers.
- Commercial centers, government centers, and a hospital or school/university campus spanning across a street.
- Transit stops.
- Shared use path crossings.
- Existing pedestrian demand demonstrates a need (as determined by counts, or a parking lot and an office building on opposite sides of the roadway).

When evaluating a corridor to determine appropriate pedestrian safety measures at crossings, it is important to consider land uses, destinations directly on the corridor, and the areas immediately adjacent to the corridor. For example, a commercial street may have parks and schools located within several blocks of the street. Considering pedestrian circulation to those destinations within neighborhoods will help identify key crossings serving the larger area as well as land uses along the street.

To promote and achieve high compliance, mid-block crossings should be located where intersection spacing is greater than 600 feet and there is a natural desire line for the pedestrian's path of travel. Mid-block crosswalks should not be installed within the functional area of intersections. They should be located a minimum of:

- 200 feet from signalized intersections.
- 120 feet to 200 feet or more from unsignalized intersections.

Engaging the public is an important aspect of crossing location and pedestrian safety measure selection process. It can build public trust in the process, improve the overall quality of the work, ensure the project aligns with local needs and priorities, and encourage community ownership of the final result. People who walk and bike in the community have the best knowledge of current conditions at different times of day, special events, and even weather. Designers can also consider hosting walk and bike audits with local stakeholders to better understand safety issues through both local knowledge and professional expertise. The demographic characteristics of participants in public engagement should reflect the demographics of the community being served to ensure the full needs of the community are being met.

C. Design for Safe Pedestrian Crossings

A safe and intuitive pedestrian crossing incorporates the proper layout of design elements such as curb ramps, traffic control devices, intersection corner radii, and sight distance to accommodate all users. The following discusses the intersection elements and recommendations to provide effective crossing for pedestrians.

1. **Characteristics of Safe, Accessible, and Convenient Crossings:** Whether marked or unmarked, crosswalks exist at all legs of all intersections represented by the extension of curb lines or edge of the traversable roadway through the intersection including T-intersections, except where pedestrians are prohibited. Motorists are required to yield to pedestrians crossing the roadway within any marked or unmarked crosswalk. The following are characteristics of safe, accessible, and convenient pedestrian crossings:

a. **Proper Visibility Between Approaching Motorists and Crossing Pedestrians:** It is critical for pedestrians to have adequate visibility of motorists approaching within travel lanes and for motorists in the travel lanes to easily see pedestrians waiting at intersections and mid-block crossings. Elements such as parked vehicles, buildings, hedges, and walls can impede the visibility between motorists and pedestrians. When possible, these elements should be restricted or relocated to provide proper visibility. Curb extensions or bump outs can increase visibility at intersections and mid-block crossing locations particularly for shorter pedestrians, such as people using wheelchairs and children.

   Visibility is also impacted by large corner radii, which by design place curb ramps and sidewalks farther back from the intersection.

b. **Appropriate Frequency of Crossing Opportunities:** Pedestrians will generally not travel out of direction and will cross at the most convenient location. In general, the frequency of crossing opportunities should be approximately the same spacing as the street grid in the surrounding area. In locations where the street grid results in block lengths over 600 feet in length, and adjacent land uses generate pedestrian traffic, mid-block crossings may be desirable to improve walkability.

c. **Minimal Exposure to Conflicts with Motorists:** Short street crossings improve pedestrian safety and comfort by reducing exposure time and reducing the potential of vehicle-pedestrian conflicts. Depending on signal timing phasing, short street crossings may also reduce vehicle delay. Short pedestrian crossing distances may be achieved through smaller curb radii, building curb ramps aligning directly with crosswalks, curb extensions, pedestrian refuge islands, realignment of crosswalks at offset intersections, reducing lane widths, and reducing the number of vehicle lanes through road diets. At signalized intersections, pedestrian exposure to motor vehicle traffic may also be reduced or eliminated using signal phasing strategies including right turn on red restrictions, leading pedestrian intervals, protected pedestrian phasing, and exclusive pedestrian phases.

d. **Minimal Delay to Pedestrians Waiting to Cross at Both Signalized and Unsignalized Crossings:** When pedestrians experience delays, they are more likely to cross the street against a signal or without a sufficient gap in traffic. At signalized intersections, pedestrian delay can be minimized by maintaining short signal cycles. At uncontrolled crossings, designers should evaluate the crossing conditions to understand if pedestrians will have a sufficient frequency and length of gaps in traffic.

e. **Low Speeds and Improved Visibility for Turning Vehicles:** At both signalized and unsignalized intersections, steps should be taken to ensure that turning speeds are kept low and that adequate sight distance is provided for roadway users and pedestrians. This is critical given that the chance of severe injuries for the pedestrian is higher as vehicle speeds increase. Low turning speeds and improved visibility can be achieved through smaller curb radii, turning restrictions, pedestrian refuge islands, and raised crosswalks.

f. **High Motorist Yielding Rates at Uncontrolled Crossings:** At intersections without a stop sign or traffic signal, where street conditions are not conducive to motorists yielding, and where pedestrians or bicyclists are likely to be present, additional design treatments may be necessary in order to encourage motorists to yield to pedestrians waiting to cross. To encourage motorist yielding at uncontrolled crossings, consider traffic calming treatments such as raised crosswalks or curb extensions to slow motor vehicle speeds, and signs and markings that remind motorists of their obligation to yield to pedestrians such as Rapid rectangular flashing beacons and advance yield markings. At certain speed and volume thresholds, motorists cannot be expected to yield and a traffic control device such as a pedestrian hybrid beacon may be necessary.

2. **Selecting Pedestrian Safety Measures at Uncontrolled Crossings:** Uncontrolled pedestrian crossings, including those crossings shared with bicyclists such as shared use paths, should be designed with appropriate treatments and countermeasures to improve motorist yielding. Table 12A-5.01 summarizes countermeasures which have been found to be effective at improving pedestrian safety based on research related to the number of motorist lanes, volumes, and operating speeds.

Table 12A-5.01: Application of Pedestrian Safety Measures at Uncontrolled Crossings by Roadway Speed, Volume, and Configuration

Roadway Configuration	Posted Speed Limit and AADT								
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 lanes (1 lane in each direction)	❶ 2 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6 7 9	① 5 6 7 9	① 5 6 ❾
3 lanes with raised median (1 lane in each direction)	❶ 2 3 4 5	❶ ❸ 5 7 9	① ❸ 5 ❼ ❾	① 3 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① ❸ 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❾
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 ❾	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 ❾	① ❸ 4 5 6 7 9	① ❸ 5 6 ❾	① ❸ 5 6 ❾
4+ lanes with raised median (2 or more lanes in each direction)	❶ ❸ 5 7 8 9	❶ ❸ 5 7 8 9	① ❸ 5 8 ❾	① ❸ 5 7 8 9	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 8 ❾
4+ lanes w/o raised median (2 or more lanes in each direction)	❶ ❸ 5 6 7 8 9	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 8 ❾

Given the set of conditions in a cell,

- \# Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1 High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2 Raised crosswalk
3 Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4 In-Street Pedestrian Crossing sign
5 Curb extension
6 Pedestrian refuge island
7 Rectangular Rapid-Flashing Beacon (RRFB)**
8 Road Diet
9 Pedestrian Hybrid Beacon (PHB)**

Source: FHWA STEP *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations*

Table 12A-5.01 should not be used to evaluate crossings and select measures without first establishing at which intersections or mid-block locations pedestrians desire to cross. Section 12A-5, C provides guidelines for determining existing and potential pedestrian crossing locations. Designers should recognize that the consideration of pedestrian accommodations and safety measures is not based on a pedestrian volume threshold, but instead recognizes that if there is a desire for pedestrians to cross then these features should be considered.

The FHWA STEP *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* provides additional guidance on when each of the pedestrian safety measures are appropriate, including the safety issues, the surrounding land context, and planning level costs.

A marked crosswalk is useful to show pedestrians and drivers preferred crossing locations. However, for multilane roadway crossings where vehicle AADTs are in excess of 10,000, a marked crosswalk alone is typically not sufficient. Under such conditions, more substantial crossing improvements are also needed to prevent an increase in pedestrian crash potential. Examples of more substantial treatments include the refuge island, PHB, and RRFB. Refer to the symbols used in Table 12A-5.01 for when a marked crosswalk should be paired with one or more of the other countermeasures described. To further increase visibility of pedestrian crossings, agencies often integrate multiple countermeasures. For example, the pedestrian hybrid beacon is often installed in conjunction with advance stop markings and signs. Also, road diets present opportunities for adding pedestrian refuge islands and curb extensions at key crossing locations. Agencies should consider roadway geometry and the MUTCD when integrating multiple countermeasures.

3. **Additional Considerations at Mid-block Crossings:** Mid-block pedestrian crossings may be appropriate in a variety of contexts based on pedestrian desire lines, transit stop locations, land use context, and intersection spacing. Motorists are more likely to expect pedestrians at intersection locations and often are driving at higher speeds in mid-block locations. Because of this, the use and design of mid-block crossings should be deliberate to address pedestrian safety and improve motorist compliance. Given the differences between intersection and mid-block crossings, there are several key considerations designers must keep in mind:
   - The crosswalk must be marked to establish a crossing.
   - The crossing location should be convenient for pedestrians. Pedestrians have a strong desire to stay on their path of travel and do not want to go unnecessarily out of their way to utilize a crossing, so crossing locations should be placed at or near the pedestrian's desired path of travel.
   - Motorists should be alerted of the crossing as they approach it.
   - Pedestrians must be able to assess opportunities to cross.
   - All users must be aware of their responsibilities and obligations at the crossing and designers should ensure to provide opportunities to meet those responsibilities and obligations.

D. Design of Pedestrian Safety Measures

A safe and intuitive pedestrian crossing incorporates proper layout of design elements. A summary of most of the pedestrian safety measures in Table 12A-5.01 is provided below.

1. **Crosswalk Visibility Enhancement Markings:**

   a. **Crosswalk Markings:** Crosswalk markings are a basic tool for directing pedestrians across the street and alerting motorists and bicyclists of crossing pedestrians. Engineering judgement should be used to determine when to mark a crosswalk. In general, marked crosswalks and other safety treatments should be prioritized at locations where pedestrians are vulnerable to conflicts with vehicles due to:
      - High pedestrian and vehicle volumes, typical in town centers, at major bus stops, or near schools including universities.
      - Vulnerable populations such as children, senior citizens, people with disabilities, or hospital are frequently present.
      - Difficult roadway conditions for pedestrians to cross, such as wide crossing distances, high traffic speeds, complex intersection geometry.

There are two types of standard crosswalks:

- Standard (Transverse) Crosswalk Markings: A standard crosswalk consists of two transverse (parallel) lines, each a minimum of 6 inches in width.
- High-Visibility (Longitudinal) Crosswalk Markings: A high visibility crosswalk consists of longitudinal lines striped parallel to the direction of travel. The longitudinal lines may be used alone or in addition to the transverse lines, thus creating a ladder-style crossing.

In general, longitudinal markings are more visible than the two transverse lines to drivers. The FHWA *STEP Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* strongly recommends providing high-visibility crosswalks at all established midblock pedestrian crossings. NCHRP Report 926 *Guidance to Improve Pedestrian and Bicyclist Safety at Intersections* notes that transverse crosswalk markings are only appropriate at stop-controlled or signalized intersections and should not be used for uncontrolled locations without supplemental treatments. In addition, local jurisdictions may have established policies that require high-visibility crosswalks near schools, other pedestrian generators, or at all intersections meeting certain thresholds.

Refer to the Iowa DOT Traffic and Safety Manual (TAS), Sections 3B-1 and 3B-2; and MUTCD, Section 3B.18 for line widths and spacing criteria for both standard and high-visibility crosswalks. At any marked crosswalk, curb ramps and other sloped areas should be wholly contained within the crosswalk markings. The crosswalk lines should extend the full length of the crossing. Longitudinal markings require more pavement marking material than transverse markings, and as a result have higher installation costs. Staggered spacing on longitudinal markings to avoid vehicle wheel paths can, however, reduce maintenance costs.

b. **Parking Restriction on Crosswalk Approach:** Iowa state law prohibits stopping, standing, or parking within 10 feet of the approach to any flashing beacon, stop sign, or traffic-control signal. (Iowa Code §321.358). Ten feet will usually be insufficient to permit proper visibility between approaching motorists and crossing pedestrians. Agencies should consider implementing parking restrictions on the crosswalk approach at all established pedestrian crossings (both approaches) so there is adequate sight distance for motorists on the approaches to the crossings and ample sight distance for pedestrians attempting to cross. The minimum setback is 20 feet where speeds are 25 mph or less, and 30 feet between 26 mph and 35 mph. If this cannot be achieved, curbs should be "bulbed out" to allow the pedestrian to see past the parked vehicle along the street.

c. **Adequate Nighttime Lighting:** It is best to place streetlights along both sides of arterial streets and provide a consistent level of lightning along a roadway. This includes lighting pedestrian crosswalks and approaches to the crosswalk. A single luminaire placed directly over the crosswalk does not adequately illuminate the pedestrian for the approaching motorist. To achieve the illumination necessary for motorists to detect a pedestrian in the crosswalk, the lights should be placed 10 to 15 feet in advance of the crosswalk on both sides of the street and on both approaches to better light the front of the pedestrian and avoid silhouette lighting (where possible).

d. **Crossing Warning Signs:** Consider supplementing high-visibility crosswalks with pedestrian crossing warning signs (sign W11-2 in the MUTCD) on each approach to the crosswalk. MUTCD Section 2C.50 - Non Vehicular Warning Signs and Section 3B.18 - Crosswalk Markings provide additional information.

2. **Raised Crosswalk:** Raised crosswalks or raised intersections are ramped speed tables spanning the entire width of the roadway or intersection. Raised crosswalks are often placed at midblock crossing locations and only the width of a crosswalk. The crosswalk is demarcated with paint and/or special paving materials, and curb ramps are eliminated because the pedestrians cross the road the same level as the sidewalk. Raised crossings make the pedestrian more prominent in the driver's field of vision. Additionally, approach ramps may reduce vehicle speeds and improve motorist yielding.

   The crosswalk table is typically at least 10 feet wide and designed to allow the front and rear wheels of a passenger vehicle to be on top of the table at the same time. Detectable warnings (truncated domes) and curb ramps (if the raised crossing is not at sidewalk height) are installed at the street edge for pedestrians with impaired vision or mobility disabilities. In addition to their use on local and collector streets, raised crosswalks can be installed in campus settings, shopping centers, and pick-up/drop-off zones (e.g., airports, schools, transit centers).

   Designers should consider the following for raised crosswalks or intersections:
   - May not be appropriate for bus transit routes or primary emergency vehicle routes. These vehicles may experience issues with vertical deflection associated with raised crossings.
   - Particular attention should be paid to impacts on drainage.
   - May be inappropriate for crossings on curves or steep roadway grades.
   - Additional markers and training for snow plow drivers may be needed.

   See MUTCD Section 3B.25 - Speed Hump Markings for additional information about markings that can be used alongside raised crosswalks.

3. **Advance Yield Here to Pedestrians sign and Yield Line:** Advance Yield Here To Pedestrians signs (sign R1-5 in the MUTCD) are placed between 30 and 50 feet in advance of the marked crosswalk along with the "shark's teeth" yield line. Advance Yield markings and signs can greatly reduce the likelihood of a multiple-threat crash, which occurs when a motorist stopped in one lane blocks the view of a second motorist. The treatment should be strongly considered for any established pedestrian crossing on roads with four or more lanes and/or roads with speed limits of 35 mph or greater. Refer to the TAS Sections 3B-1 and 3B-2; and MUTCD Section 2B.11 - Yield Here To Pedestrians Signs and Section 3B.16 - Stop and Yield Lines contain additional information.

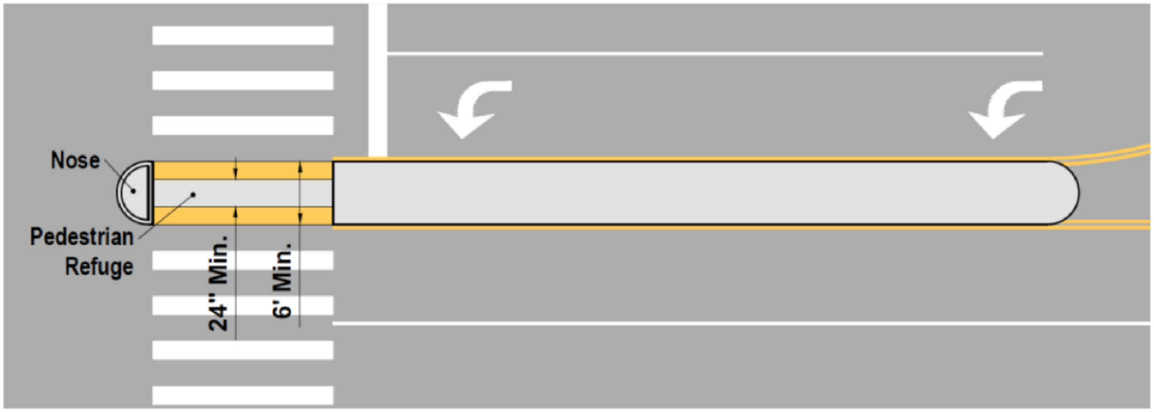
4. **In-Street Pedestrian Crossing Sign:** In-street signs are placed in the middle of the road at a crossing and are often used in conjunction with refuge islands. These signs may be appropriate on 2 lane or 3 lane roads with speed limits of 30 mph or less. On higher-speed, higher-volume, and/ or multilane roads, this treatment may not be as visually prominent; therefore, it may be less effective (drivers may not notice the signs in time to stop in advance of the crosswalk). For such roadways, more robust treatments will be needed. When making the choice to use these signs, the agency should consider making a plan and securing a funding source for the maintenance and prompt replacement of damaged signs. The MUTCD permits in-street pedestrian signs for installation on centerlines and along lane lines. MUTCD Section 2B.12 - In-Street and Overhead Pedestrian Crossing Signs contains additional information about these signs.

5. **Curb Extension:** On streets with on-street parking, curb extensions can be used at both uncontrolled crossings and signalized or stop-controlled intersections to extend the sidewalk or curb line into the parking lane. Curb extensions reduce crossing distance for pedestrians and bicyclists, improve sight distance for all road users, and prevent parked cars from encroaching into the crosswalk area. At intersections, curb extensions can better control the effective turning radius and can be used in conjunction with truck aprons. Designers should consider the following for intersection and mid-block locations:
   - Curb extensions are typically used where there is an on-street parking lane and the curb extension width is typically the width of, or 1 foot less than, the width of the parking lane. Curb extensions should not extend into paths of travel for bicyclists.
   - Mid-block curb extensions can be co-located with fire hydrants to maintain access to hydrants and to reduce impacts to on-street parking.
   - Curb extensions can create additional space for curb ramps, low-height landscaping, and street furniture where sidewalks are otherwise too narrow. Care should be taken to ensure that street furniture and landscaping do not block motorists' views of pedestrians.
   - Curb extension designs should facilitate adequate drainage, either by providing inlets upstream of the curb extension, providing grading that maintains drainage flows along the curb line, or by providing a drainage bypass channel beneath the sidewalk. The designer should consider factors such as maintenance in the selection of drainage facilities, as some options may be more prone to clogging and require more routine maintenance to function properly, and the ability of bicyclists or pedestrians to safely traverse the structures or grading.
   - Designers should consider providing reflective vertical elements to alert drivers and snowplow operators to the presence of curb extensions.
   - The length of curb extension should extend at least 20 feet long on both sides of the crosswalk, but can be longer depending on the use desired within the extension (e.g., stormwater management, bus loading, restricting parking) or where additional parking restrictions are desired (e.g., where "Advance Yield Here To Pedestrians Sign" and Yield Lines are provided more than 20 feet from the crosswalk).
   - Painted curb extensions may be used as an interim measure and should be paired with edge objects such as flexible delineators to create a sense of enclosure and buffer from motor vehicle traffic.
   - Approaches to curb extensions can be created as a straight taper or using reverse curves, though reverse curves are easier for snowplow operators to guide along without catching the plow edge.

6. **Pedestrian Refuge Island:** Pedestrian refuge islands are appropriate at both uncontrolled locations (i.e., where no traffic signals or stop signs exist) and signalized crossings. At uncontrolled crossings, pedestrian refuge islands allow pedestrians to focus on one direction of traffic at a time as they cross and provide space to wait for an adequate gap in oncoming traffic or for motorists to yield before finishing the second phase of a crossing. At signalized intersections where a wide intersection cannot be designed or timed to accommodate a pedestrian crossing of the intersection at one time, a pedestrian refuge island must be provided. A median refuge should be considered where crossing distances are greater than 50 feet to better accommodate slower-moving pedestrians.

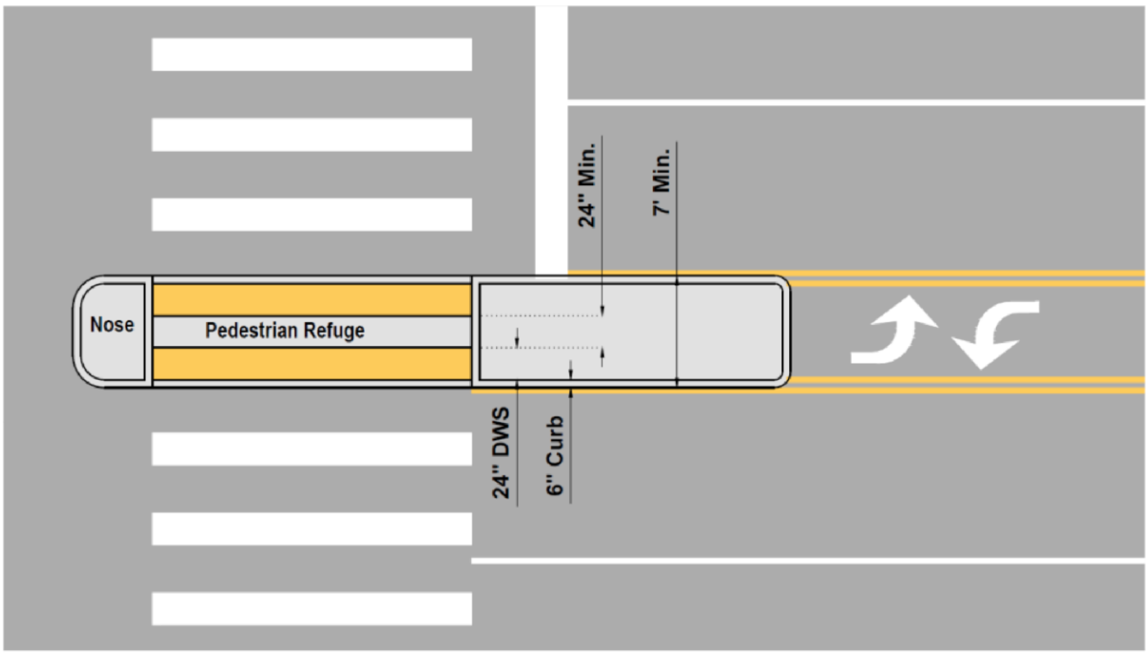
   Designers should consider the following for intersection and mid-block locations:
   - The minimum width for a crossing island to provide an accessible refuge is 6 feet, measured from outside edge of the detectable warning surfaces, and the minimum width between detectable warning surfaces is 24 inches (Figure 12A-5.02) Where medians are constructed using curbing and the detectable warnings are placed at the back of curb, the minimum width of the island is 7 feet, measured from curb face to curb face (Figure 12A-5.03).

Figure 12A-5.02: Pedestrian Refuge Island - Detectable Warning Surface Placed in Line with Island Face of Curb



Source: Based on PROWAG figure R 305.2.4

Figure 12A-5.03: Pedestrian Refuge Island - Detectable Warning Surface Placed at Back of Curb



Source: Based on PROWAG figure R 305.2.4

- The preferred width of the crossing is 10 feet, which accommodates bicyclists with trailers and wheelchair users more comfortably. At a minimum, cut-through openings should match the width of the corresponding crosswalk and on roadways with speeds of 50 mph or greater, the minimum crossing opening width is 8 feet. A "nose" that extends past the crosswalk toward the intersection is recommended to separate people waiting on the crossing island from motorists, and to slow turning motorists. Traffic control equipment, vegetation, and other aesthetic treatments may be incorporated, but must not obscure pedestrian visibility.
- When a refuge is placed at a signalized crossing, use pedestrian recall to prevent "trapping" a pedestrian in the refuge island.
- Triangular channelization islands adjacent to right turning lanes can also act as refuge islands.
- Median refuges can be coupled with other traffic calming features, such as partial diverters and curb extensions at mid-block and intersection locations.

7. **Rectangular Rapid-Flashing Beacon (RRFB):** An RRFB is a pedestrian-actuated flashing light used in combination with a pedestrian, school, or trail crossing warning sign to improve safety at uncontrolled, marked crosswalks. The device includes two rectangular-shaped yellow indications, each with an LED-array-based light source, that flash with high frequency when activated. The RRFB design differs from the standard flashing beacon by utilizing:
   - A different shape.
   - A much faster rapid-pulsing flash rate.
   - A brighter light intensity, directed at eye level of approaching drivers.

   The RRFB is a treatment option at many types of established pedestrian crossings. RRFBs are particularly effective at multilane crossings with speed limits less than 40 mph. Consider the Pedestrian Hybrid Beacon (PHB) instead for roadways with higher speeds. On four to six lane streets, RRFBs produce higher driver yielding rates when mounted in the median (or overhead) as well as on the right edge of the roadway in combination with advanced stop or yield lines.

   RRFBs are placed on both sides of a crosswalk below the pedestrian crossing sign and above the arrow indication pointing at the crossing. It is preferable to erect crosswalk signage on the far-side of crosswalks less than 20 feet in width. This placement helps ensure that sightlines between pedestrians and motorists are not obstructed. The flashing pattern can be activated with pushbuttons or automated (e.g., video or infrared) pedestrian detection, and should be unlit when not activated.

   The Federal Highway Administration has issued interim approval for the use of the RRFB (IA-21). The Iowa Department of Transportation has applied for, and received, interim approval for all highway agencies in the state to use RRFBs under IA-21. IA-21 provides additional information about the conditions of use, including dimensions, placement, and flashing requirements. IA-21 does not provide guidance or criteria based on number of lanes, speed, or traffic volumes.

8. **Road Diet:** A road diet reconfigures the roadway. A frequently-implemented Road Diet involves converting a 4 lane, undivided roadway into a 3 lane roadway with a center turn lane. This is a candidate treatment for any undivided road with wide travel lanes or multiple lanes that can be narrowed or repurposed to improve pedestrian crossing safety.

9. **Pedestrian Hybrid Beacon (PHB):** A PHB head consists of two red lenses above a single yellow lens, and is used in conjunction with pedestrian signal heads installed at each end of a marked crosswalk. Figure 12A-5.04 shows a photo of a PHB. The PHB has also been referred to as the High-Intensity Activated crosswalk beacon (HAWK), but the MUTCD refers to this device as the PHB.

Figure 12A-5.04: Pedestrian Hybrid Beacon

Source: Toole Design

Unlike a traffic signal, the PHB rests in dark until a pedestrian activates it via pushbutton or other form of detection. When activated, the beacon displays a sequence of flashing and solid lights that control vehicular traffic while the pedestrian signal heads indicate the pedestrian walk interval and a pedestrian clearance interval.

The PHB should meet the installation guidelines - based on speed, pedestrian volume, vehicular volume, and crossing length - as provided in MUTCD Section 4F.01 (see Figure 4F-1 for speeds of 35 mph or less; Figure 4F-2 for speeds greater than 35 mph). Research indicates that PHBs are most effective on roads with three or more lanes that have AADTs above 9,000. PHBs should be strongly considered for all midblock crossings where the roadway speed limits are equal to or greater than 40 mph. Refer to Table 1 for other conditions where PHBs should be strongly considered. It should be noted that the PHB and RRFB are not both installed at the same crossing location.

Designers have the flexibility to estimate future demand in the absence of a PHB (or signal) if existing conditions limit vulnerable user crossing opportunities. In some cases, people may not be crossing a street in sufficient numbers to satisfy PHB guidelines (or signal warrants) because there are not adequate gaps in traffic or they do not feel comfortable doing so, thus they avoid the crossing altogether. For these locations, it may be more appropriate to use an estimated crossing demand for analysis that assumes better crossing protection. Experience shows once a street can be crossed more safely, people will generally cross in greater numbers compared to prior conditions. Designers may also include bicyclists in the volume estimating. Depending on the crossing location, they may operate as a motor vehicle or a pedestrian.

PHBs have also been installed successfully at intersections under certain conditions. Since the current MUTCD guidance is to locate PHBs at least 100 feet away from an intersection, engineering judgment/engineering study must be carefully applied if considering an installation at an intersection.

E. Pedestrian Safety at Interchanges

Any work on the design of interchanges, including facilitating pedestrian travel, must be coordinated with Iowa DOT. This subsection is provided for informational purposes because interchanges are often a barrier and safety hazard for people walking. The challenges posed by pedestrians crossing interchanges include the following.

1. **Multiple Crossings:** Interchanges often require pedestrians to cross several ramps and intersections in stages. This can result in complex movements, and pedestrian signal delays.

2. **Free-flow Movements:** Where ramps are free-flowing, it can be difficult and unsafe for pedestrians to find safe gaps to cross in a motor vehicle traffic stream that is high volume, high speed, or both.

3. **Long Crossings and Skewed Crossings:** On and off-ramps often require pedestrians to cross a channelized traffic lane at a skewed crossing angle, which results in longer crossings. In urban areas, off ramps may have several lanes of traffic to store motor vehicles exiting the freeway and turning at signalized intersections. The more lanes of traffic, the longer the crossing distance for pedestrians.

Two design guides provide detailed guidance on how to accommodate people walking through interchanges safely and accessibly:

- ITE's *Design Guidelines to Accommodate Pedestrians and Bicyclists at Interchanges* identifies specific dimensions, safety features, signage, pavement markings, design geometries, and other treatments.
- NCHRP's *Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges* provides specific guidance for other alternative interchange designs such as diverging diamond interchange, restricted crossing U-turn, median U-turn, and displaced left-turn.

F. References

American Association of State Highway and Transportation Officials (AASHTO). *Guide for the Planning, Design, and Operation of Pedestrian Facilities* ("AASHTO Ped Guide"). Washington, DC. 2004.

Federal Highway Administration (FHWA). *Field Guide for Selecting Countermeasures at Uncontrolled Pedestrian Crossing Locations*. Washington, DC. 2018.

Federal Highway Administration (FHWA). *STEP Guide for Improving Pedestrian Safety at Uncontrolled Crossings*. Washington, DC. 2018.

Federal Highway Administration (FHWA). STEP – Resources. Countermeasure Tech Sheets. https://highways.dot.gov/safety/pedestrian-bicyclist/step/resources. Accessed November 2023.

Institute of Transportation Engineers (ITE). *Design Guidelines to Accommodate Pedestrians and Bicyclists at Interchanges*. Washington, DC. 2016.

Institute of Transportation Engineers (ITE). *Designing Walkable Urban Thoroughfares: A Context-Sensitive Approach*. Washington, DC. 2010.

National Academies of Sciences, Engineering, and Medicine. *Design Guide for Low-Speed Multimodal Roadways* (NCHRP Research Report 880). Washington, DC. 2018.

National Academies of Sciences, Engineering, and Medicine. *Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges* (NCHRP Research Report 948). Washington, DC. 2021

National Academies of Sciences, Engineering, and Medicine. *Guidance to Improve Pedestrian and Bicyclist Safety at Intersections* (NCHRP Research Report 926). Washington, DC. 2020.

National Academies of Sciences, Engineering, and Medicine. *Systemic Pedestrian Safety Analysis* (NCHRP Research Report 893). Washington, DC. 2018.

US Access Board. *(Proposed) Public Rights-of-Way Accessibility Guidelines* (PROWAG). Washington, DC. 2011.

Selecting Bicycle Facilities

A. Introduction

The major categories for bicycle and pedestrian facilities include sidewalks, shared use paths, on-street, and trails. Sidewalks are an integral component of the transportation system, usually used only by pedestrians. For information on designing sidewalks, see Sections 12A-1 and 12A-2. Shared use paths are also an integral component of the transportation system and use the sidewalk standards, but must also be designed for bicycle usage. Shared use paths are generally separate from the street, but in limited instances it may be necessary to utilize an on-street facility.

Iowa DOT's Bicycle and Pedestrian Long Range Plan recommends the core of a local or regional bicycle network be a system of low-stress bikeways. Interconnected multi-use trails often serve as the foundation for this system, but it is also necessary to identify potential low-stress connections along streets. This section provides guidance on how to select the appropriate bicycle facility type based on posted speed limit, traffic volume, and other context.

The word "trail" has conflicting definitions in ADA, AASHTO, program funding, and common usage. Projects developed around the state and those let through the Iowa DOT are generally shared use paths as defined by the Access Board, not trails. Facilities with a transportation purpose cannot use the trail guidelines published by the Access Board, even though they are commonly referred to as trails. The trail information from the Access Board only applies in parks and other limited locations; therefore, they are not covered in this manual.

B. Definitions

The following definitions are from the "AASHTO Guide for the Development of Bicycle Facilities" (or AASHTO *Bicycle Guide*) and Iowa DOT's Bicycle and Pedestrian Long Range Plan. The definition for advisory bicycle lanes is from the FHWA Bikeway Selection Guide.

Advisory Bicycle Lanes: A portion of the roadway that has been demarcated with dashed lines to indicate preferred space for bicyclists and motorists on narrow streets that would otherwise be shared lanes. Unlike bicycle lanes, motor vehicle use is not prohibited in the advisory bicycle lane and is expected on occasion.

Bicycle Boulevard: A street, usually a low volume, low speed local street, that has been modified to prioritize bicycle travel. It usually includes treatments such as shared lane markings, wayfinding signs, and traffic calming features.

Bicycle Facilities: A general term denoting improvements and provisions to accommodate or encourage bicycling, including parking and storage facilities, and shared roadways not specifically defined for bicycle use.

Bicycle Lane and Buffered Bicycle Lanes: A portion of roadway that has been designated for preferential or exclusive use by bicyclists by pavement markings and, if used, signs. It is intended for one-way travel, usually in the same direction as the adjacent traffic lane, unless designed as a contra-flow lane. A buffered bicycle lane features a striped buffer (typically 18 inches to 3 feet in width) for further separation between motor vehicles and bicyclists.

Separated Bicycle Lanes: A bicycle lane physically separated by a vertical element - such as a concrete or engineered rubber curb, planter, flex post, or a parking lane - from the adjacent motor vehicle lanes. Buffered bicycle lanes without a vertical element are not considered separated bicycle lanes. Some communities refer to separated bicycle lanes as cycle tracks or protected bicycle lanes.

Bicycle Route: A roadway or bikeway designated by the jurisdiction having authority, either with a unique route designation or with BIKE ROUTE signs, along which bicycle guide signs may provide directional and distance information. Signs that provide directional, distance, and destination information for bicyclists do not necessarily establish a bicycle route.

Bikeway: A generic term for any road, street, path, or way that in some matter is specifically designated for bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes.

Electric Bicycle (e-bike): Iowa Code Section 321.1 defines 'low-speed electric bicycle' as a device having a saddle or seat for the use of a rider, up to 4 wheels, equipped with fully operable pedals, and an electric motor of less than 750 watts that meets the requirements of one of the following classes:

- 'Class 1 low-speed electric bicycle' - a low-speed electric bicycle equipped with a motor that may be used to provide assistance only when the rider is pedaling and ceases to provide assistance when the bicycle reaches a speed of 20 mph or more.
- 'Class 2 low-speed electric bicycle' - a low-speed electric bicycle equipped with a motor that may be used exclusively to propel the bicycle and is not capable of providing assistance when the bicycle reaches a speed of 20 mph or more.
- 'Class 3 low-speed electric bicycle' - a low-speed electric bicycle equipped with a motor that may be used to provide assistance only when the rider is pedaling and ceases to provide assistance when the bicycle reaches a speed of 28 mph or more.

Independent Right-of-Way: A general term denoting right-of-way outside the boundary of a conventional highway.

Roundabout: A type of circular intersection that provides yield control to all entering vehicles and features channelized approaches and geometry to encourage reduced travel speeds through the circular roadway.

Rumble Strips: A textured or grooved pavement treatment designed to create noise and vibration to alert motorists of a need to change their path or speed. Longitudinal rumble strips are sometimes used on or along shoulders or center lines of highways to alert motorists who stray from the appropriate traveled way. Transverse rumble strips are placed on the roadway surface in the travel lane, perpendicular to the direction of travel.

Shared Lane: A lane of a traveled way that is open to both bicycle and motor vehicle travel, usually a low volume local street.

Shared Lane Marking: A pavement marking or symbol that indicates an appropriate bicycle positioning in a shared lane.

Shared Use Path: (From U.S. Department of Transportation, Federal Highway Administration) The term "shared use path" means a multi-use trail or other path, physically separated from motorized vehicular traffic by an open space or barrier, either within a highway right-of-way or within an independent right-of-way, and usable for transportation purposes. Shared use paths may be used by pedestrians, bicyclists, skaters, equestrians, and other authorized users.

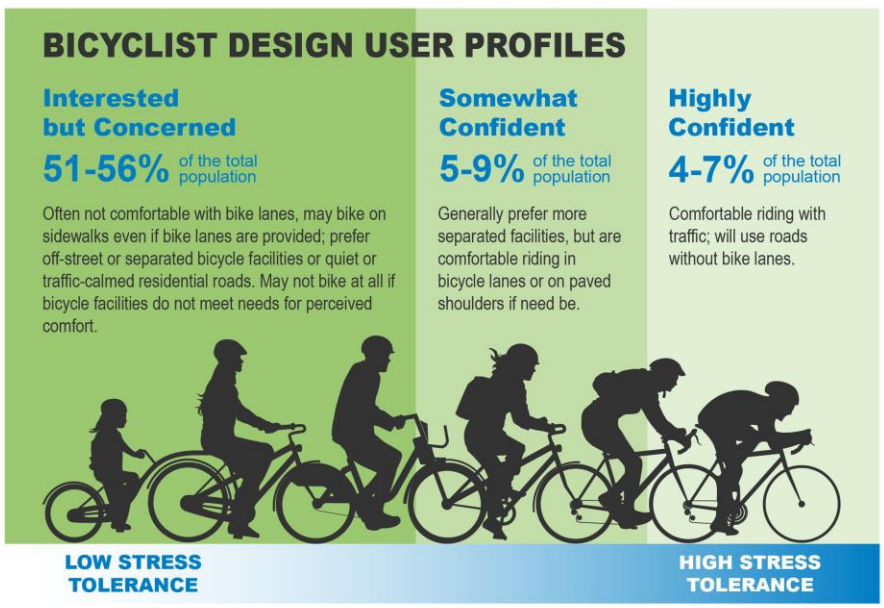
Traveled Way: The portion of the roadway intended for the movement of vehicles, exclusive of shoulders and any bicycle lane immediately inside of the shoulder.

C. Bicycle Design User Profiles

Of adults who have stated an interest in bicycling, research has identified three types of potential and existing bicyclist profiles (see Figure 12B-1.01). These bicyclist profiles consider a person's comfort level operating a bicycle with motorized traffic, bicycling skill and experience, age, and trip purpose. These user profiles of common types of adult bicycle users and trips can be used to inform bikeway design.

The "interested but concerned" bicyclist profile should typically be used to identify the bikeway design in urban, suburban, and rural town contexts because this group represents the largest of the bicyclist profiles, consisting of 51 to 56% of the general population. Bicycling as a form of transportation by this group is underrepresented in many communities due to a lack of connected low stress bicycle networks. To maximize the potential for bicycling as a viable transportation option, it is important to design facilities to meet the needs of the "interested but concerned" bicyclist user, which will also naturally accommodate the "somewhat confident and highly confident" users.

Figure 12B-1.01: Bicycle Design User Profiles



Source: FHWA *Bikeway Selection Guide*

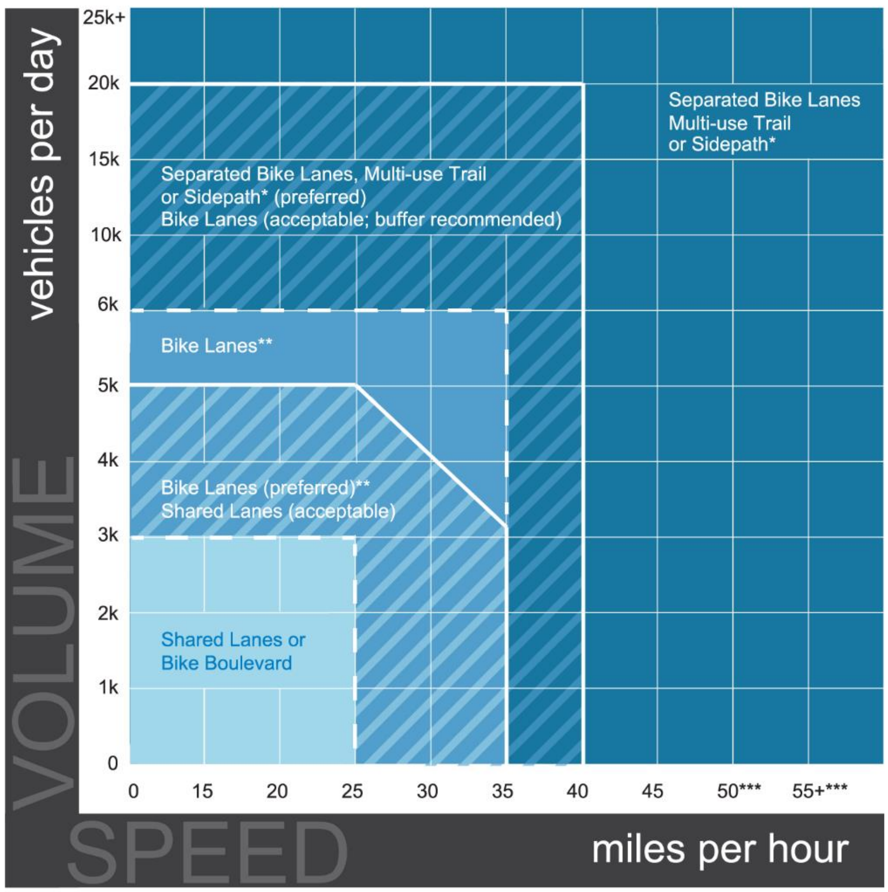
D. Bicycle Network Design Process

Chapter 4 of Iowa DOT's Bicycle and Pedestrian Long Range Plan provides guidance on planning bicycle networks and facility selection. The bicycle facility selection process is linked to the larger transportation planning process. It should be informed by a plan for a future bicycle network developed with input from agency staff and members of the public. Ideally, the facility selection process is also controlled by local bikeway selection or complete streets policies ensuring decisions are consistently and objectively applied across a jurisdiction.

Bicycle networks should be continuous, connect seamlessly across jurisdictional boundaries, and provide access to destinations. Bicycle transportation depends on access to local destinations, many of which are located along higher traffic arterial streets. Adequate, context sensitive bicycle facilities should therefore be provided along these streets. If a continuous bicycle facility is not feasible on a higher-traffic street, alternative routes along parallel lower traffic streets may be provided in the interim until the preferred facility can be implemented.

1. **Bikeway Facility Selection:** Motor vehicle traffic volume and speed are critical contextual considerations for bicyclist and pedestrian safety and comfort. Proximity to motor vehicle traffic is a significant source of stress, safety risks, and discomfort for bicyclists, and corresponds with sharp rises in crash severity and fatality risks for vulnerable users when motor vehicle speeds exceed 25 miles per hour. Furthermore, as motorized traffic volumes increase, it becomes increasingly difficult for motorists and bicyclists to share roadway space. Figure 12B-1.02 is provided to help determine appropriate types of bicycle (and in some cases, pedestrian) accommodations for any given context. The matrix includes preferred and acceptable values for each facility type. Designers should use forecast traffic volumes if available. Additionally, designers should default to selecting the preferred facility when possible.

Figure 12B-1.02 Urban and Suburban Bicycle Facility Selection Matrix



*To determine whether to provide a multi-use trail/sidepath or separated bike lane, consider pedestrian and bicycle volumes or, in the absence of volume, consider land use.
**Advisory bike lanes may be an option where traffic volume < 4,000 ADT
***Speeds 50 mph or greater in urban areas are typically found in urban/rural transition areas.

Source: Iowa DOT Bicycle and Pedestrian Long Range Plan

2. **Bikeway Feasibility Assessment:** Once the preferred bikeway type is identified, designers will need to assess its feasibility in the given project location against potential project constraints limiting the ability to implement the preferred bikeway. This assessment may involve determining whether additional separation between motorists and bicyclists is warranted, identifying portions of the roadway to reallocate to achieve desired widths, selecting the "next best" bikeway type, or selecting an alternative route for the bikeway. Designers have an ethical obligation to provide for the health, safety, and welfare of the public, which may require a careful evaluation of mobility and safety for each user. One user's convenience or mobility should not be prioritized over another user's safety. When evaluating safety trade-offs, options reducing serious injuries and fatalities should be prioritized over options reducing property damage or minor injuries.

   a. **Conditions for Increasing Separation:** There are a variety of conditions indicating the need for greater separation between motorists and bicyclists, which could increase the width of the bikeway or materials used in the buffer. The conditions where greater separation may be appropriate to accommodate the selected design user include the following:
      - Unusual peak hour motor vehicle volumes (more than 15% of AADT);
      - High percentage of heavy vehicles (trucks, buses, and heavy vehicles are more than 5% of traffic);
      - Motor vehicle operating speeds exceed posted speed;
      - Frequent parking turnover or heavy curbside activity;
      - High volumes of bicyclists (500 bicyclists per hour);
      - Presence of vulnerable populations (i.e. school children);
      - Network connectivity gaps;
      - Proximity to transit; and
      - Frequent driveways.

   b. **Options for Reallocating Roadway Space:** When constructing new roads, bikeways should be built to the recommended preferred dimensions rather than constrained dimensions. For retrofit projects, it may be necessary to evaluate options to reallocate existing space or use minimum or constrained dimensions. The following are strategies for reallocating roadway space to accommodate a bikeway:
      - Narrowing travel lanes, including medians/turn lanes;
      - Removing travel or turn lanes;
      - Removing parking on one side of street; and
      - Converting angled parking to parallel parking.

   c. **Selecting the "Next Best" Bikeway Type or Parallel Routes:** Impacts on ridership, comfort/stress, safety, and overall network connectivity should be considered when evaluating alternative bikeway designs or potential parallel routes to ensure the project will still meet the purpose identified at the outset. The following trade-offs should be considered and documented in the design process:
      - Reduced or suppressed ridership where the bikeway does not meet the needs of the target design user;
      - Additional length of trip when bicyclists must use a parallel route (this length should not exceed 30% more than original route and should not add excessive delay);
      - Critical gaps in the network when projects fail to provide bicycle accommodations;
      - Reduced safety where bicyclists must operate with relatively high motor vehicle speed and/or high-volume traffic in shared lanes;
      - Reduced safety where bicyclists must operate in narrow space (e.g. narrow bicycle lanes adjacent to parking lanes or narrow shared use paths with high volumes of pedestrians or bicyclists);

- Reduced safety where bicyclists improperly use facilities (e.g., ride the wrong way on shared lanes, sidewalk riding, etc.); and
- Increased sidewalk bicycling where bicyclists are avoiding low comfort/high stress roadway conditions.

If selecting a parallel route as the preferred route for the "interested but concerned" bicyclist occurs, the provision of a bikeway along the desired route should still be considered to accommodate the "highly confident" bicyclist and to provide connections for bicyclists to and from properties along the desired route. An example would be the provision of a bicycle lane or shoulder on a higher volume roadway, which can benefit the "highly confident" bicyclists while a convenient, direct parallel route on an adjacent low volume street serves the "interested but concerned" bicyclists.

Chapter 4 of Iowa DOT's Bicycle and Pedestrian Long Range Plan provides additional guidance on facility selection, with context characteristics for each of the common facility types shown in Figure 12B-1.02, and additional guidance on facility selection and other considerations.

Shared Use Path Design

A. Accessible Shared Use Path Design

1. **General:** Applicable portions from the following draft documents were used to develop this section.

    a. **AASHTO Bicycle Guide:** The fourth edition (2012) of the AASHTO "Guide for the Development of Bicycle Facilities" (or AASHTO *Bicycle Guide*). References made to the AASHTO *Bicycle Guide* within this section are shown in parentheses, e.g. (AASHTO *Bicycle Guide* 5.2.1).

    b. **AGODA:** The June 20, 2007 Proposed Architectural Barriers Act "Accessibility Guidelines for Outdoor Developed Areas" (AGODA). This document is primarily used for shared use paths designed as bicycle facilities.

    c. **PROWAG:** The Public Right-of-Way Accessibility Guidelines (PROWAG) are primarily used for shared use paths designed as sidewalks.

2. **Documenting Exceptions:** If the project cannot fully meet the minimum requirements included within this section, a document should be developed to describe why the minimum requirements cannot be met. It is recommended that this document be retained in the project file. For local agency projects administered through Iowa DOT, a certification with supporting documentation shall be submitted to the Iowa DOT administering bureau. The certification shall be as prescribed by the Iowa DOT and signed by a registered professional engineer or landscape architect licensed in the State of Iowa. For Iowa DOT projects, contact the Design Bureau, Methods Section.

B. Shared Use Path Categories

1. **Type 1:** A shared use path adjacent or in close proximity to the roadway and functions similar to a sidewalk and separated bicycle lane. Due to the proximity to the roadway, intersection crossings of type 1 shared use path should closely follow the best practices of separated bicycle lanes. In rural cross-sections, these paths would be at the top of the foreslope.

2. **Type 2:** A shared use path similar to Type 3, except they serve as a transportation route to facilities that fulfill a basic life need, provide access to a program or service, or provide a safe route for non-drivers.

3. **Type 3:** A shared use path in independent right-of-way or not in close proximity to the roadway. Although Type 3 paths may fulfill a transportation function, these paths primarily serve a recreation and fitness benefit.

One shared use path project may have different combinations of Type 1, Type 2, and/or Type 3 segments, based on location and function. If Federal or State funding is being used on a project, the funding application should identify where Type 1, Type 2, or Type 3 segments will be used.

C. Shared Use Path Design Elements

The following considerations should be used as a guide when designing shared use paths.

1. **Width:** A bicyclist requires a minimum of 4 feet and a preferred 5 feet of essential operating space based upon their profile. The typical path width is 10 to 12 feet to accommodate two-way traffic. The minimum width needed for a bicyclist to pass another path user while maintaining sufficient space for another user approaching from the opposite direction is 11 feet. Consider wider paths (12 to 15 feet) when at minimum one of the following is anticipated:
   - User volume exceeding 300 users within the peak hour.
   - Curves where more operating space should be provided.
   - Large maintenance vehicles.

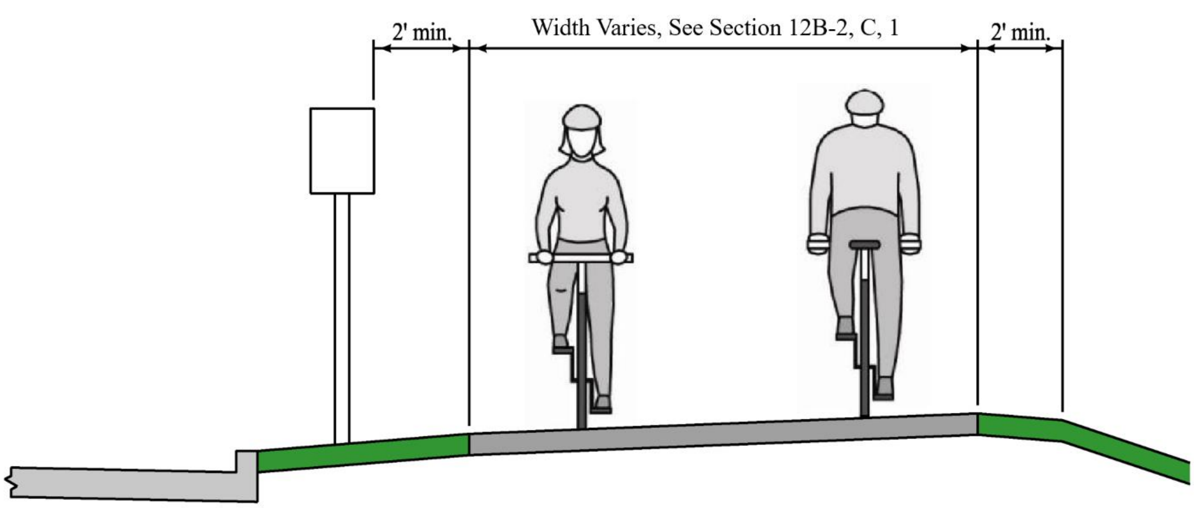
   Path width can be reduced to 8 feet where the following conditions prevail:
     - Bicycle traffic is expected to be low.
     - Pedestrian use is generally not expected.
     - Horizontal and vertical alignments provide well-designed passing and resting opportunities.
     - The path will not be regularly subjected to maintenance vehicle loading conditions.
     - A physical constraint exists for a short duration such as a utility structure, fence, etc.
     - Protection of environmental features.

   Path widths between 8 and 5 feet should be avoided; paths less than 5 feet do not meet ADA requirements. If the path width is less than 8 feet, a design exception must be developed.

   For Iowa DOT projects involving paths on structures, contact the Bridges and Structures Bureau to determine the structural impacts of shared use path widths.

   If segregation of pedestrians and bicycle traffic is desirable, a minimum 15 foot width should be provided. This includes 10 feet for two-way bicycle traffic and 5 feet for two-way pedestrian traffic. (AASHTO *Bicycle Guide* 5.2.1).

Figure 12B-2.01: Typical Cross-Section of Two-Way Shared Use Path on Independent Right-of-Way



Source: Adapted from AASHTO *Bicycle Guide* Exhibit 5.1

2. **Minimum Surface Thickness:** For Iowa DOT projects, contact the Pavement Design Section in the Design Bureau for a pavement determination. For local agency projects administered through Iowa DOT, Iowa DOT will accept the thickness design as determined by the engineer.

   For local projects, the pavement depth for both PCC and HMA pavements should have a minimum of 4 inches and a recommended thickness of 5 inches. If pavement thickness is proposed to be less than 4 inches, a pavement determination should be completed and documented.

3. **Cross Slope:** Shared use paths must have the capabilities to serve people with disabilities.

   a. **Type 1 and Type 2:** Cross slopes shall not exceed the requirements in Section 12A-2.

   b. **Type 3:** A 1.5% cross slope is recommended, but cross slopes should be a minimum of 1% and shall not exceed 5%. Cross slopes greater than 2% should be sloped to the inside of the horizontal curve regardless of drainage conditions. On unpaved paths, cross slopes may increase up to 5% due to the need of draining water off the path. On rare bicycle only facilities, the path does not need to meet accessibility guidelines and the cross slope can be between 5% and 8%. Cross slope transition should be comfortable for the user; therefore, a minimum transition length of 5 feet for each 1% change in cross slope should be used.

4. **Separation of Roadway and Path:** A separation of 6 feet or greater between the curb or edge of roadway and the path is desirable to increase pedestrian and bicyclist comfort. Where the distance between the edge of roadway and the edge of the path is less than 5 feet, a vertical element of separation should be provided between the edge of roadway and type 1 or type 2 shared use path for the safety and comfort of path users. This is particularly important at night. For streets with curbs to provide the vertical element, a minimum 2 foot buffer should be provided between the path and the adjacent roadway. On high-speed roadways or uncurbed roadways where the separation from the edge of the traveled way to the near edge of the path 5 feet or less, a crashworthy barrier or railing is needed due to high speeds and clear zone requirements.

   At uncontrolled approaches of intersections and at signalized intersections where turning vehicles and bicycle through movements are expected, designers should offset the bicycle crossing between 6 and 16.5 feet from the adjacent motor vehicle lane. This treatment creates a yielding space for motorists and has been shown to reduce crashes at uncontrolled and permissive conflict locations.

5. **Lateral and Vertical Clearance:** The provision of adequate clearance to a wide variety of potential obstructions that may be found along a prospective route is important for creating a safe and comfortable shared use path facility. Guidelines for lateral and vertical clearance are particularly important in view of the wide range of riding proficiency that is found among riders. See Section 12B-3, B for clearance values for obstructions adjacent to bikeways (including shared use paths).

   a. **Lateral Clearances to Fixed and Movable Obstructions:** When minimum clearance in Section 12B-3 cannot be achieved, refer to Section 12A-3 for protruding object requirements; refer to the *AASHTO Bicycle Guide* for mitigation measures, such as pavement markings, delineation, and signing.

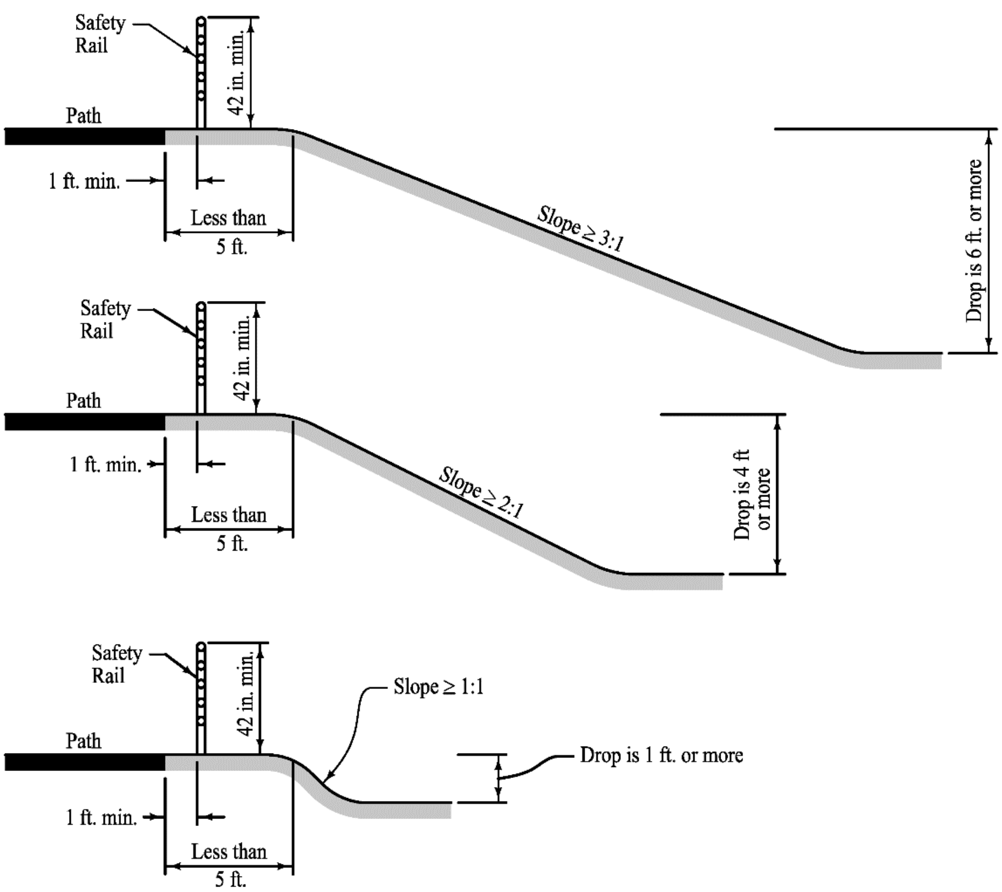
b. Vertical Clearances to Overhead Obstructions: The minimum vertical clearance is 10 feet. In some situations, such as tunnels and bridge underpasses, the vertical clearance should be greater than 10 feet in order to accommodate maintenance and emergency vehicles. In constrained areas, AASHTO allows the vertical clearance to obstructions to be a minimum of 8 feet. (AASHTO *Bicycle Guide* 5.2.1).

Refer to Section 12A-3 for legal requirements in low clearance situations.

6. **Shoulder Width and Slope:** The minimum graded shoulder width is 2 feet. The maximum shoulder area cross slope is 6:1.

7. **Safety Rail:** Safety rail should be a minimum of 42 inches in height. Provide safety rails at the outside of a structure. On steep fill embankment as described below, provide a safety rail or widen the shoulder area to 5 feet. (AASHTO *Bicycle Guide* 5.2.1)
   - Slopes 3:1 or steeper with a drop of 6 feet or greater.
   - Slopes 3:1 or steeper adjacent to a parallel body of water or other substantial obstacle.
   - Slopes 2:1 or steeper with a drop of 4 feet or greater.
   - Slopes 1:1 or steeper with a drop of 1 foot or greater.

Figure 12B-2.02: Safety Rail between Path and Adjacent Slope



See Iowa DOT Design Manual Section 12B-10 for guidance on safety rails.

Source: Adapted from *AASHTO Bicycle Guide* Exhibit 5.3

8. Design Speed and Alignments:

a. Type 1: Grades shall meet the requirements of Section 12A-2.

b. Type 2: Grades shall be less than or equal to 5% and all other Type 3 requirements should be met.

c. Type 3: For most shared use paths with higher volumes of users in relatively flat areas, a design speed of 15 mph is generally sufficient due to the mixed-use operation with pedestrians on the facility. Table 12B-2.01 describes cases in which the design speed should be adjusted based on context. (AASHTO *Bicycle Guide* 5.2.4)

Table 12B-2.01: Shared Use Path Design Speed by Context

Design Speed	Shared Use Path Context	Description
12 mph	Unpaved path surfaces	On unpaved path surfaces, bicyclists tend to travel slower to compensate for reduced braking ability, so a lower design speed (12 mph) may be used.
15 mph	Paved, high volumes with diverse users	For most shared use paths with higher volumes of users in relatively flat areas, a design speed of 15 mph is generally appropriate due to the mixed-use operation with pedestrians on the facility.
18 to 30 mph	Paved, low volume of users, especially pedestrians	For shared use paths with lower volumes of users, where pedestrian volumes are low (less than 30%), where the primary purpose of the shared use path is to provide a higher speed bicycling opportunity between destinations, or on wider paths where bicycles are provided separate spaces from pedestrians, a design speed of 18 to 30 mph may be appropriate.
18 to 30 mph	Paved, rolling terrain	On shared use paths with rolling terrain and sustained steeper grades (greater than 5%), the appropriate design speed should be selected based on the anticipated travel speeds of bicyclists going downhill; however, design speed should generally not exceed 30 mph.

Source: ODOT *Multimodal Design Guide*

The minimum radius of curvature negotiable by a bicycle can be calculated using the lean angle of the bicyclist or the superelevation and coefficient of friction of the shared use path. A bicyclist must lean two wheeled bicycles while cornering to prevent falling outward due to forces associated with turning movements. A lean angle of 20 degrees is considered the typical maximum lean angle for users to continue pedaling through a turn. Lean angles greater than this typically require bicyclists to stop pedaling to avoid pedal strikes on the pavement. The minimum radii of curvature for a paved path are shown in Table 12B-2.02 based on the typical lean angle of the bicyclists.

Table 12B-2.02: Minimum Radii for Horizontal Curves at Lean Angle

Design Speed (mph)	Minimum Radius (feet)
12	27
14	36
16	47
18	60
20	74
25	115
30	166

Source: *AASHTO Bicycle Guide* Exhibit 5.6

The minimum radii of curvature for a paved path based on superelevation should be calculated per the equations shown in the *AASHTO Bicycle Guide*. (AASHTO *Bicycle Guide* 5.2.2, 5.2.5, 5.2.6, and 5.2.8).

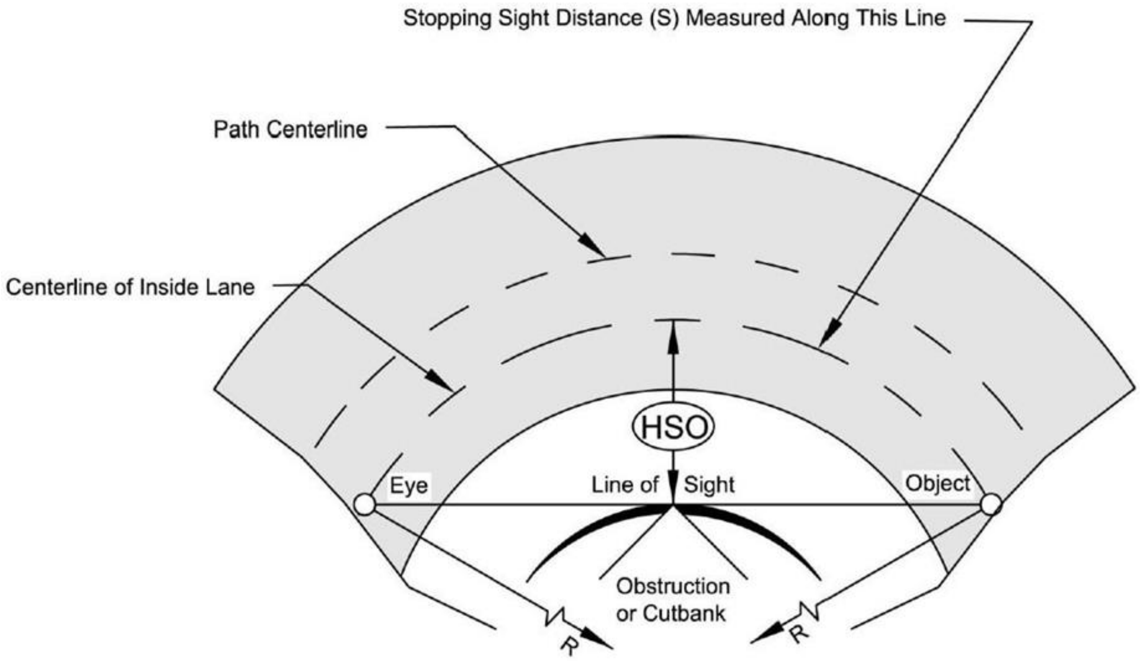
Table 12B-2.03 and Figure 12B-2.03 should be used to determine the minimum clearance necessary to avoid line-of-sight obstructions for horizontal curves. The lateral clearance (horizontal sight line offset or HSO) can be obtained from Table 12B-2.03, given the stopping sight distance from Equation 12B-2.01 and the proposed horizontal radius of curvature. Lateral clearances on horizontal curves should be calculated based on the sum of the stopping sight distances for both users traveling in opposite directions around the curve because bicyclists have a tendency to ride near the middle of narrow paths.

Table 12B-2.03: Minimum Lateral Clearance (Horizontal Sightline Offset or HSO) for Horizontal Curve

R	S= Stopping Sight Distance (ft)														
(ft)	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300
25	2.0	7.6	15.9												
50	1.0	3.9	8.7	15.2	23.0	31.9	41.5								
75	0.7	2.7	5.9	10.4	16.1	22.8	30.4	38.8	47.8	57.4	67.2				
95	0.5	2.1	4.7	8.3	12.9	18.3	24.7	31.8	39.5	48.0	56.9	66.3	75.9	85.8	
125	0.4	1.6	3.6	6.3	9.9	14.1	19.1	24.7	31.0	37.9	45.4	53.3	61.7	70.6	79.7
155	0.3	1.3	2.9	5.1	8.0	11.5	15.5	20.2	25.4	31.2	37.4	44.2	51.4	59.1	67.1
175	0.3	1.1	2.6	4.6	7.1	10.2	13.8	18.0	22.6	27.8	33.5	39.6	46.1	53.1	60.5
200	0.3	1.0	2.2	4.0	6.2	8.9	12.1	15.8	19.9	24.5	29.5	34.9	40.8	47.0	53.7
225	0.2	0.9	2.0	3.5	5.5	8.0	10.8	14.1	17.8	21.9	26.4	31.3	36.5	42.2	48.2
250	0.2	0.8	1.8	3.2	5.0	7.2	9.7	12.7	16.0	19.7	23.8	28.3	33.1	38.2	43.7
275	0.2	0.7	1.6	2.9	4.5	6.5	8.9	11.6	14.6	18.0	21.7	25.8	30.2	34.9	39.9
300	0.2	0.7	1.5	2.7	4.2	6.0	8.1	10.6	13.4	16.5	19.9	23.7	27.7	32.1	36.7
350	0.1	0.6	1.3	2.3	3.6	5.1	7.0	9.1	11.5	14.2	17.1	20.4	23.9	27.6	31.7
390	0.1	0.5	1.2	2.1	3.2	4.6	6.3	8.2	10.3	12.8	15.4	18.3	21.5	24.9	28.5
500	0.1	0.4	0.9	1.6	2.5	3.6	4.9	6.4	8.1	10.0	12.1	14.3	16.8	19.5	22.3
565		0.4	0.8	1.4	2.2	3.2	4.3	5.7	7.2	8.8	10.7	12.7	14.9	17.3	19.8
600		0.3	0.8	1.3	2.1	3.0	4.1	5.3	6.7	8.3	10.1	12.0	14.0	16.3	18.7
700		0.3	0.6	1.1	1.8	2.6	3.5	4.6	5.8	7.1	8.6	10.3	12.0	14.0	16.0
800		0.3	0.6	1.0	1.6	2.2	3.1	4.0	5.1	6.2	7.6	9.0	10.5	12.2	14.0
900		0.2	0.5	0.9	1.4	2.0	2.7	3.6	4.5	5.6	6.7	8.0	9.4	10.9	12.5
1000		0.2	0.5	0.8	1.3	1.8	2.4	3.2	4.0	5.0	6.0	7.2	8.4	9.8	11.2

Source: *AASHTO Bicycle Guide* Exhibit 5.10

Figure 12B-2.03: Components for Determining Horizontal Sight Distance



Source: *AASHTO Bicycle Guide* Exhibit 5.9

For vertical alignment, use the preferred maximum segment length shown in Table 12B-2.04 whenever possible. Using the acceptable and allowed criteria should only be done when the engineer considers the ability of the users. For example, long rural segments would generally serve more physically capable users who have selected the path and could navigate the steeper grades over longer lengths.

Table 12B-2.04: Vertical Alignment

Grade Range	Maximum Segment Length (feet)		
	Preferred	***Acceptable*[1]**	***Allowed*[2]**
< 5%	Any length	Any Length	Any Length
≥ 5% and < 8.33%	--	50	200
≥ 8.33% and < 10%	--	30	30
≥ 10% and < 12.50%	--	--	10

[1] Derived from AGODA Section 1016 (Outdoor Recreation Access Routes)

[2] Derived from AGODA Section 1017 (Trails)

The minimum length of vertical curve needed to provide minimum stopping sight distance at various speeds on crest vertical curves is presented in Table 12B-2.05. The eye height of the typical adult bicyclist is assumed to be 4.5 feet. For stopping sight distance calculations, the object height is assumed to be 0 inches. (AASHTO *Bicycle Guide* 5.2.7). Equation 12B-2.01 can also be used to determine the minimum length of crest vertical curve necessary to provide adequate sight distance.

$$S > L \qquad L = 2S - \frac{200(\sqrt{h_1}+\sqrt{h_2})^2}{A}$$

Equation 12B-2.01

$$S > L \qquad L = 2S - \frac{200(\sqrt{h_1}+\sqrt{h_2})^2}{A}$$

$$L > S \qquad L = \frac{AS^2}{100(\sqrt{2h_1}+\sqrt{2h_2})^2}$$

where:

L= Minimum length of vertical curve (ft)
A = Algebraic grade difference (percent)
S = Stopping sight distance (ft)
h_1 = Eye height (4.5 feet for a typical bicyclist)
h_2 = Object height (0 ft)

Table 12B-2.05: Minimum Length of Crest Vertical Curve Based on Stopping Sight Distance

A	S=Stopping Sight Distance (ft)														
(%)	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300
2												30	70	110	150
3								20	60	100	140	180	220	260	300
4						15	55	95	135	175	215	256	300	348	400
5					20	60	100	140	180	222	269	320	376	436	500
6				10	50	90	130	170	210	267	323	384	451	523	600
7				31	71	111	151	191	231	311	376	448	526	610	700
8			8	48	88	128	168	208	248	356	430	512	601	697	800
9			20	60	100	140	180	220	260	400	484	576	676	784	900
10			30	70	110	150	190	230	270	444	538	640	751	871	1000
11			38	78	118	158	198	238	278	489	592	704	826	958	1100
12		5	45	85	125	165	205	245	285	533	645	768	901	1045	1200
13		11	51	91	131	171	211	251	291	578	699	832	976	1132	1300
14		16	56	96	136	176	216	256	296	622	753	896	1052	1220	1400
15		20	60	100	140	180	220	260	300	667	807	960	1127	1307	1500
16		24	64	104	144	184	224	264	304	711	860	1024	1202	1394	1600
17		27	67	107	147	187	227	267	307	756	914	1088	1277	1481	1700
18		30	70	110	150	190	230	270	310	800	968	1152	1352	1568	1800
19		33	73	113	153	193	233	273	313	844	1022	1216	1427	1655	1900
20		35	75	115	155	195	235	275	315	889	1076	1280	1502	1742	2000
21		37	77	117	157	197	237	277	317	933	1129	1344	1577	1829	2100
22		39	79	119	159	199	239	279	319	978	1183	1408	1652	1916	2200
23		41	81	121	161	201	241	281	321	1022	1237	1472	1728	2004	2300
24	3	43	83	123	163	203	243	283	323	1067	1291	1536	1803	2091	2400
25	4	44	84	124	164	204	244	284	324	1111	1344	1600	1878	2178	2500

The line between the shaded and un-shaded portions of the table shows when the stopping sight distance is equal to the length of the crest vertical curve.

Source: *AASHTO Bicycle Guide* Exhibit 5.8

9. **Stopping Sight Distance:** Shared use paths must be designed with adequate stopping sight distance along the entire path to provide users with the opportunity to see and react to unexpected conditions. The distance needed to bring a path user to a fully controlled stop is a function of the user's perception and braking reaction time, the initial speed, the coefficient of friction between the wheels and the pavement, the braking ability of the user's equipment, and the grade. Minimum stopping sight distances can be determined using Equation 12B-2.02. Stopping sight distance must be provided along the entire length of the pathway and should be checked at all horizontal and vertical curves. (AASHTO *Bicycle Guide* 5.2.8).

$$S = \frac{V^2}{30(f \pm G)} + 3.67V$$

Equation 12B-2.02

where:

S = Stopping sight distance (ft)
V = Velocity (mph)
f = Coefficient of friction (use 0.16 for a typical bicycle)
G = Grade (ft/ft) (rise/run)

10. **Accessibility Requirements:** For construction of curb ramps and placement of detectable warnings, see Section 12A-2 to ensure ADA compliance.

D. Intersection Sight Distance

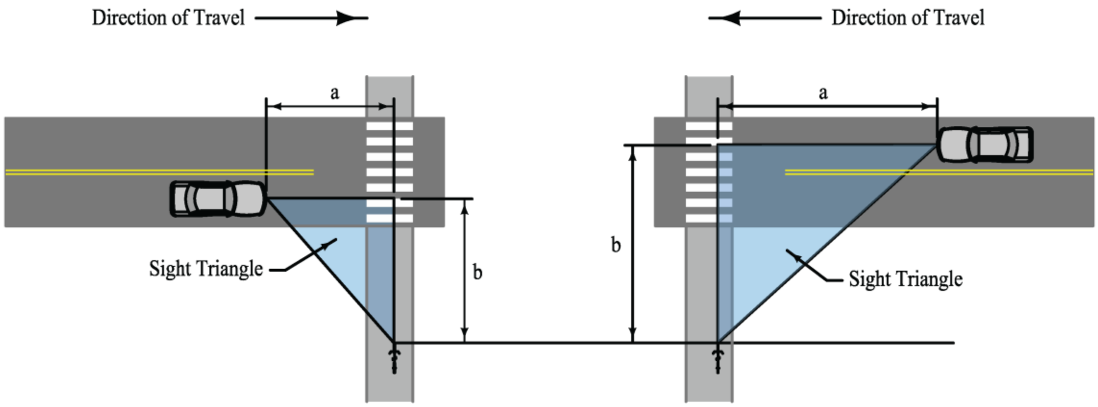
1. **General:** Intersection sight distance is a fundamental component in the selection of appropriate control at a midblock path-roadway intersection. The least restrictive control that is effective should be used. The line of sight is considered to be 2.3 feet above the path surface.

   Roadway approach sight distance and departure sight triangles should be calculated using motor vehicles, which will control the design criteria. (AASHTO *Bicycle Guide* 5.3).

2. **Approach Sight Distance:** Pathway approach sight distance should be determined by the fastest path user, typically the adult bicyclist. If yield control is to be used for either the roadway approach or the path approach, available sight distance adequate for a traveler on the yield controlled approach to slow, stop, and avoid a traveler on the other approach is required. The roadway leg (a) of the sight triangle is based on the ability of a bicyclist to reach and cross the roadway if they do not see a conflict (see Figure 12B-2.04). Similarly, the path leg (b) of the sight triangle is based on the ability of a motorist to reach and cross the junction if they do not see a conflict (see Figure 12B-2.04). If sufficient sight distance is unable to be provided by the yield sight triangle described above, more restrictive control should be implemented.

   For Type 1 shared use paths crossing a roadway near an intersection, refer to Section 12B-3, F, 3 for additional geometric design treatments.

Figure 12B-2.04: Yield Sight Triangles



Source: Adapted from *AASHTO Bicycle Guide* Exhibit 5.15

$$a = 1.47V_{Road}\left(\frac{S}{1.47V_{Path}} + \frac{w + L_a}{1.47V_{Path}}\right)$$

Equation 12B-2.03
Length of Roadway Leg of Sight Triangle

$$b = V_{Path}\left(\frac{1.47V_e - 1.47V_b}{a_i} + \frac{w + L_a}{0.88V_{Road}}\right)$$

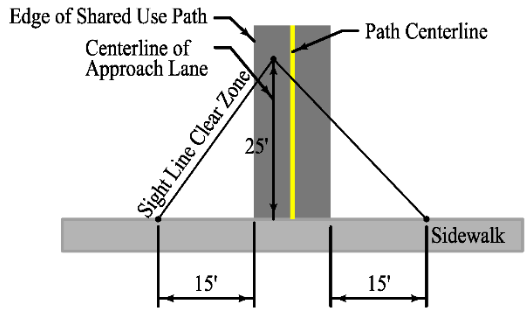
Equation 12B-2.04
Length of Path Leg of Sight Triangle

where:

a = Length of leg of sight triangle along the roadway approach (ft)
b = Length of leg of sight triangle along the path approach (ft)
w = Width of the intersection to be crossed (ft)
L_a = Design vehicle length
For Equation 12B-2.03: Typical bicycle length = 6 ft
For Equation 12B-2.04: Design vehicle length (ft)
V_{Path} = Design speed of the path (mph)
V_{Road} = Design speed of the road (mph)
S = Stopping sight distance for the path user traveling at design speed
V_e = Speed at which the motorist would enter the intersection after decelerating (mph) (assumed 0.60 x road design speed)
V_b = Speed at which braking by the motorist begins (mph) (same as road design speed)
a_i = motorist deceleration rate (ft/s^2) on intersection approach when braking to a stop is not initiated (assume -5.0 ft/s^2)

3. **Path-Sidewalk Intersection:** At an intersection of a shared use path and a sidewalk, a clear sight triangle extending at minimum 15 feet along the sidewalk must be provided. Refer to Figure 12B-2.05. If two shared use paths intersect, the same process for the roadway-path intersection should be used.

Figure 12B-2.05: Minimum Path-Sidewalk Sight Triangle



Source: Adapted from *AASHTO Bicycle Guide* Exhibit 5.16

E. Surface

It is important to construct and maintain a smooth riding surface on shared use paths. Shared use path pavements should be machine placed. Surface texture is needed but care must be exercised not to cause operational problems with too little or too much texture. Broom finish or burlap drag concrete surfaces are preferred over trowel finishes. Joints shall be sawed, not hand tooled.

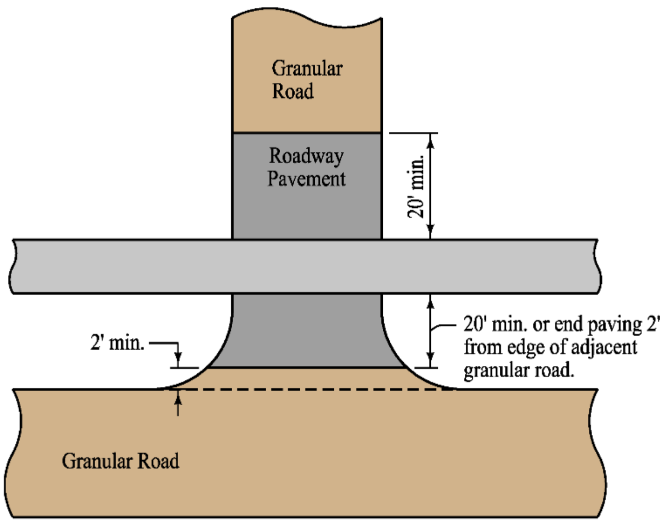
1. **Type 1 and Type 2:** Type 1 and Type 2 shared use paths shall be paved.

2. **Type 3:** Hard, all-weather pavement surfaces are preferred to unpaved surfaces due to the higher service quality and lower maintenance. Type 3 shared use paths should be paved; however, a granular surface may be allowed. If a granular surface is used, it must be maintained to be firm, stable, and slip resistant.

F. Crossings at Unpaved Surfaces

When crossing an unpaved roadway, alley, or driveway, a minimum of 20 feet in addition to the path width should be paved on each side of the path to reduce the amount of gravel tracked onto the path. If edge of parallel unpaved roadway is less than 20 feet from the closest edge of the path, only pave to within 2 foot of edge of the parallel unpaved roadway. The thickness of the path and adjacent roadway paving should be designed to accommodate vehicular traffic and meet the requirements of the agency responsible for the roadway.

Figure 12B-2.06: Crossing at Unpaved Surface



G. At-grade Railroad Crossing

Whenever it is necessary to cross railroad tracks with a bicycle, special care must be taken. The crossing should be at least as wide as the approaches of the shared use path. Whenever possible, the crossing should be straight and between 90 and 60 degrees to the rails. The greater the crossing angle deviates from being perpendicular, the greater the chance that a bicyclist's front wheel may be trapped in the flangeway causing a loss of control. (AASHTO *Bicycle Guide* 4.12).

H. Drainage

Drainage structures underneath paths should typically be designed to the same design year storm as the roadway drainage structures. When a Type 3 shared use path is built on a berm, consider the drainage needs of that path. For shared use paths constructed on slopes, drainage design should take into account control of the runoff from the slope. For higher flows it may be necessary to develop parallel ditches and culverts under the path. Drainage designs should also provide for low flows and seepage from the slope. Due to the potential for accidents from buildup of algae from low flows and side hill seepage, the need for subdrains or other treatments on the high side of the path should be evaluated.

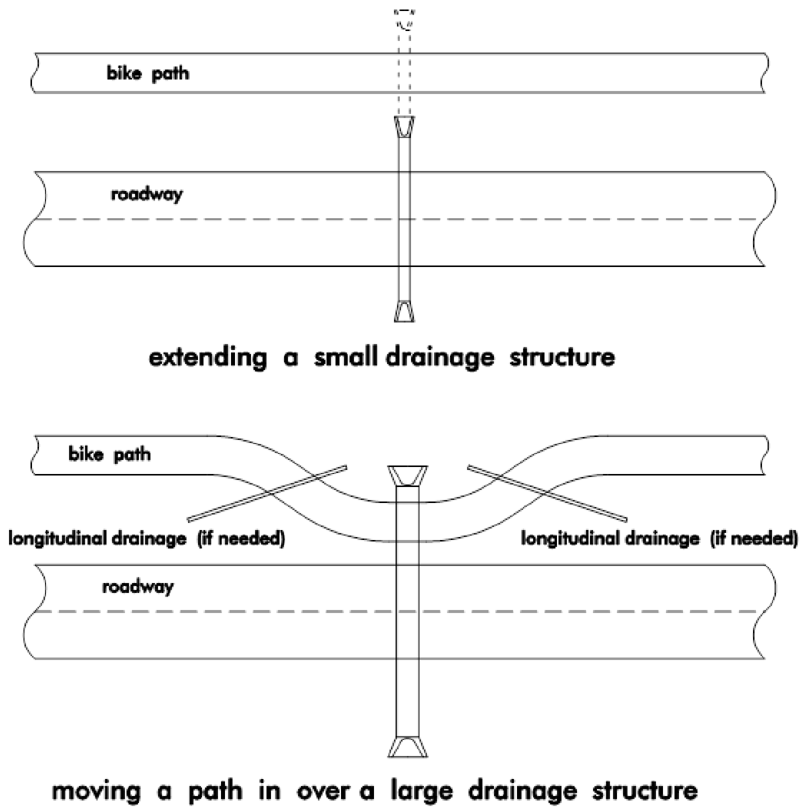
1. **Urban Areas:** The minimum recommended pavement cross slope of 1% usually provides enough slope for proper drainage. Sloping in one direction, usually toward the street, instead of crowning is preferred and usually simplifies the drainage and surface construction. However, care must be exercised not to trap water on the high side of the shared use path, particularly in curved areas. (AASHTO *Bicycle Guide* 5.2.11).

2. **Rural Areas:** The best way to accomplish drainage underneath a shared use path is by extending smaller structures under the path or moving the path closer to the roadway to cross larger structures, see Figure 12B-2.07.

   For paths placed on the backslope, smaller drainage structures (normally pipes less than 60 inches and box culverts less than 5 feet by 4 feet) should be extended through the path. For larger culverts, the path should be moved in to cross the structure and then moved back out to the backslope. If this is done, longitudinal drainage will have to be provided where the path crosses the ditch. Depending upon how close the path comes to culvert openings, safety railing may be needed on the culverts.

For paths on the foreslope, culverts should be extended as necessary.

Figure 12B-2.07: Accommodating Drainage Structures



I. Structure Design

The preferred bridge width for shared use path is equal to the width of the path plus 4 feet, which provides 2 feet of clearance on each side, according to the AASHTO *Bicycle Guide*. It is acceptable to provide bridge widths equal to the width of the path plus 2 feet, which provides 1 foot of clearance on each side. In constrained situations, the bridge width may equal the path width so long as the landings are adequately tapered from the clear zone to the bridge. For a 10 foot wide path, the resulting specified bridge widths are:

- 14 feet (preferred)
- 12 feet (acceptable)
- 10 feet (in constrained conditions)

For Iowa DOT administered projects, the designer should contact the Design Bureau and the Traffic and Safety Bureau for further assistance if considering a narrowed path across a bridge.

J. Pavement Markings

Ladder or zebra pavement markings per MUTCD are recommended at crosswalks. Other pavement markings are not required, except as mitigation strategies. (AASHTO *Bicycle Guide* 5.4).

K. Signing

All signs should be retroreflective and conform to the color, legend, and shape requirements described in the MUTCD. In addition, guide signing, such as to indicate directions, destinations, distances, route numbers, and names of crossing streets should be used. In general, uniform application of traffic control devices, as described in the MUTCD, should be used and will tend to encourage proper bicyclist behavior. (AASHTO *Bicycle Guide* 5.4).

L. Lighting

Fixed-source lighting reduces conflicts along shared use paths and at intersections. In addition, lighting allows the bicyclist to see the shared use path direction, surface conditions, and obstacles. Lighting for paths is important and may be considered where heavy nighttime riding is expected (e.g., paths serving college students or commuters) and at roadway intersections. Lighting should be considered through underpasses or tunnels and when nighttime security could be a problem. Where special security problems exist, higher illumination levels may be considered. Light standards (poles) should meet the recommended horizontal and vertical clearances. (AASHTO *Bicycle Guide* 5.2.12).

On-Street Bicycle Facilities

A. General

Except where prohibited, bicycles may operate on all roadways. This section describes the different types of bicycle facilities located on the roadway, along with their design criteria.

Bicyclists have similar access and mobility needs as other transportation users. However, bicyclists must use their own strength and energy to propel the bicycle or use e-bike. Even then, a bicyclist is generally slower than other vehicles operating on the roadway. Additionally, bicyclists are more vulnerable to injury during a crash and are of any age group. With these factors in mind, it is imperative to design bicycle facilities with great care.

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

B. Elements of Design

Since bicyclists 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 bicyclists. Additional considerations and exceptions are described below.

1. **Bicyclist Design Speed:** Where bicyclists are operating on roadways (bicycle lanes, shared lanes, bicycle boulevards, and paved shoulders), designing streets meeting basic geometric design guidelines for motor vehicles will result in a facility generally accommodating bicyclists in terms of grades, stopping sight distance, horizontal and vertical alignment, and cross slopes.

   Where separated bicycle lanes are present and geometric elements such as shifting tapers are introduced specifically for bicyclists, a design speed for the typical bikeway user is appropriate. Using the typical adult bicyclist to establish design speeds ensures the geometric design accommodates slower users, including children, seniors and less confident adult bicyclists, pedestrians, and others. The typical adult bicyclist travels at speeds of less than 15 mph on flat level terrain, with average speeds closer to 10 mph. Consideration should also be given to higher speed e-bikes, which are allowed to reach speeds of 28 mph.

   Speeds slower than the design speed should be considered for some elements of design, such as using 8 mph for signal timing to account for slower bicyclists (e.g., children and seniors) who need more time to cross intersections.

2. **Stopping Sight Distance:** Bicycle stopping sight distance is the distance needed to bring a bicycle to a fully controlled stop. It is a function of the user's perception and brake reaction time, the initial speed, the coefficient of friction between the wheels and the pavement, the braking ability of the user's equipment, and the grade. See AASHTO *Bicycle Guide* 5.2.8 for calculating stopping sight distance.

3. **Intersection Sight Distance:** Roadway approach sight distance and departure sight triangles should be calculated according to procedures in AASHTO's *A Policy on Geometric Design of Highways and Streets* because motor vehicles will control the design criteria.

   Where a stop controlled roadway intersects an uncontrolled roadway, bicyclists must judge the speed of, and gaps in, approaching motor vehicle traffic from their location at the edge of the roadway (see Figure 12B-3.01). Providing the minimum stopping sight distance for the motorist on the uncontrolled roadway approach will allow the motorist sufficient time to exercise due care to slow or stop for the crossing bicyclist who may still be in the intersection. Table 12B-3.01 provides the length of the departure sight triangle along the roadway to allow the bicyclist enough time to judge a gap in traffic and complete a full crossing of the roadway without a motorist needing to slow or stop. The table assumes a bicyclist with a:

   - design acceleration of 2.5 square feet,
   - maximum speed of 8 mph to account for a slow bicyclist, and
   - bicycle length of 6 feet.

Figure 12B-3.01: Bicyclist Crossing from a Minor Road

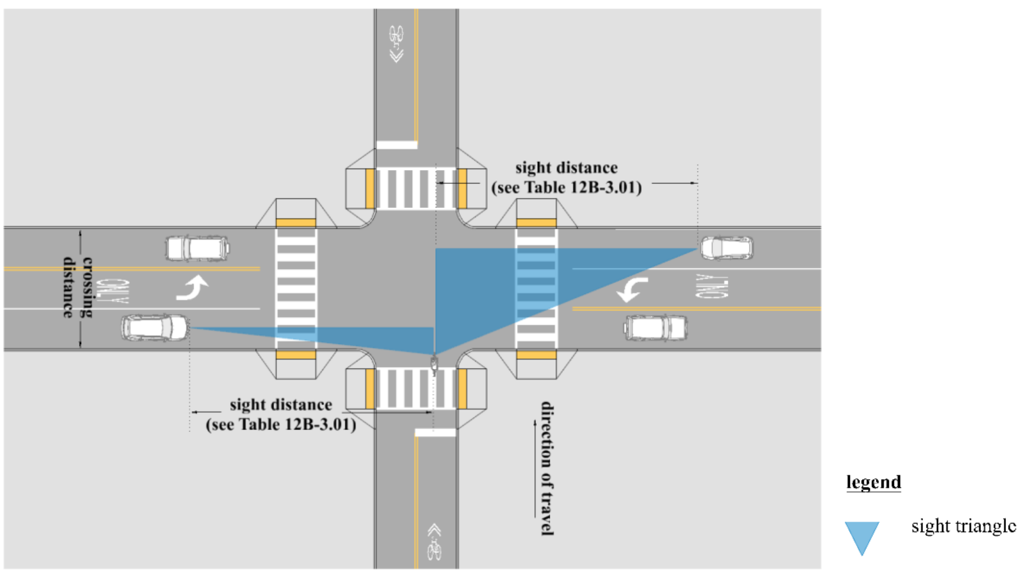


Table 12B-3.01: Bicyclist Sight Distance Crossing from a Minor Road

Bicyclist Sight Distance (ft) Crossing from a Minor Road						
Crossing Distance (ft)	**Speed of Roadway to be Crossed (mph)**					
	20	**25**	**30**	**35**	**40**	**45**
10	149	187	224	261	299	336
15	165	206	247	288	329	370
20	178	223	267	312	356	401
25	191	238	286	333	381	429
30	202	252	303	353	404	454
35	216	270	324	378	431	485
40	228	285	342	399	456	514
45	241	301	361	421	481	542
50	253	317	380	443	506	570
55	266	332	399	465	531	598
60	278	348	417	487	556	626

Based on Standing Bicycle Crossing Time and Motor Vehicle Stopping Sight Distance

4. **Bicyclist Operating Space and Shy Space**: As stated in Section 12B-2, C, a bicyclist requires a minimum of 4 feet operating space. To maintain comfort and safety of bicyclists, it is preferable to provide shy spaces (lateral clearances for vertical elements or obstructions adjacent to bikeways) outside the operating space of the bicyclist. However, for bikeways within the roadway, it may not be practicable to provide shy space to parked and moving motor vehicles. Where minimum shy spaces are not provided, the usable width intended for bicycle travel, and the level of comfort for the facility, is likely to be reduced. Table 12B-3.02 provides guidance for determining an appropriate clearance distance to common vertical elements.

Table 12B-3.02: Bicyclist Shy Space

Vertical Element	Shy Space (in)	
	Preferred	**Acceptable**
Bicycle Traffic	12	6
Intermittent (tree, flex post, pole, etc.)	12	0
Continuous (fence, railing, planter etc.)	24	12
Vertical Curb*	12	6
Mountable / Sloping Curb	0	0

* Vertical curb without gutter 3 inches or greater. Where a gutter is provided, the shy space is equal to the width of the gutter.

Source: Adapted from *Minnesota Bicycle Facility Design Manual*

In addition to fixed objects, bicyclists have the potential to collide into other bicyclists or pedestrians (on shared use paths) where a bikeway width limits their ability to operate side-by-side, to pass other bicyclists, or to pass pedestrians. Bikeways should be constructed to serve the expected volume of users to minimize this crash risk. Table 12B-3.02 describes the preferred shy space for "bicycle traffic," which accommodates passing or side-by-side bicycling. Where it is desired to accommodate side-by-side bicycling or frequent passing, shy space should be provided between the operating spaces of each bicyclist. Where it is not desired to encourage bicyclists to ride side-by-side, shy space should still be provided between the physical spaces of each bicyclist to accommodate the occasional passing of bicyclists.

5. **Bicycle Tapers:** Tapers may occur where designers wish to slow bicyclists in advance of an intersection or where a bicycle lane must be shifted to introduce a turn lane. Tapers should generally occur gradually, with a minimum length as calculated using Equation 12B-3.01. If the bikeway is delineated by paint only, and if the off tracking of a bicycle pulling a trailer would not put the trailer into a motor vehicle lane, a maximum taper ratio of 2:1 (longitudinal: lateral) may be considered, see Figure 12B-3.02.

$$L = \frac{WS^2}{60}$$

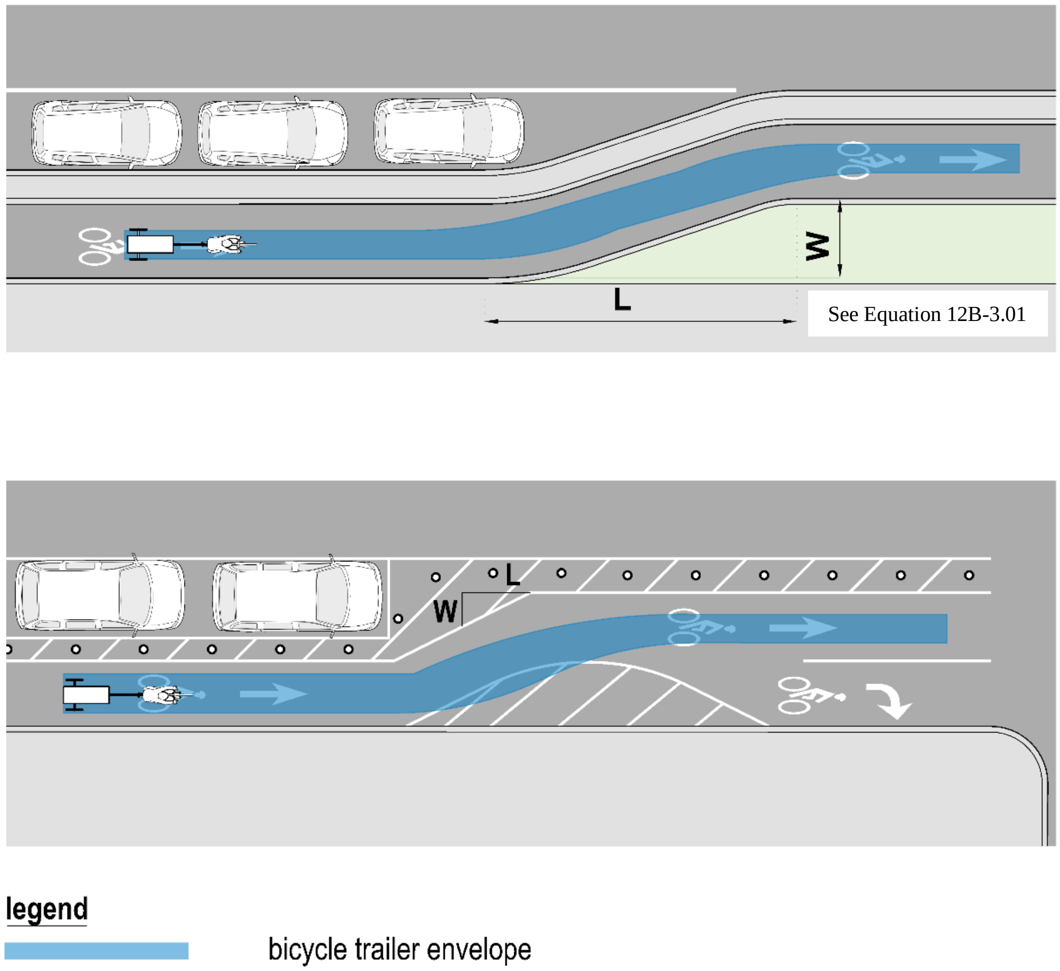
Equation 12B-3.01

where:

L = Lane shift, ft (minimum 20 feet)
W = Width of offset, ft
S = Target bicyclist operating speeds, mph

Source: MUTCD for speeds less than 45 mph

Figure 12B-3.02: Shifting Taper Equation



Source: Adapted from MUTCD Figure 3B-14

6. **Pavement Conditions:** Surface conditions affect bicyclists 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 *Bicycle Guide* 4.2).

C. Shared Lanes

Shared lanes already exist on local neighborhoods and city streets. Shared lanes may be identified with signage and markings or be left unmarked. They are not recommended for roadways with speeds over 35 mph or traffic volumes over 5,000 AADT. In addition, shared lanes on roadways with speeds greater than 25 mph or volumes over 3,000 AADT are unlikely to accommodate the “interested but concerned” bicyclist but could accommodate the “highly confident” bicyclists (see Section 12B-1).

The designs and dimensions for shared lanes differ by location, but attention to design features can make the lanes more comfortable for all bicyclists. This includes good pavement quality, adequate sight distance, lower motor vehicle speeds, appropriate signal timing and detection systems, bicycle-compatible drainage grates, bridge expansion joints, railroad crossings, etc. (AASHTO *Bicycle Guide* 4.3).

Where bicyclists are operating in shared lanes, travel lane widths should generally be the minimum widths appropriate for the context of the roadway. In the past, it was common practice to provide wider outside lanes (14 feet or greater) under the assumptions motorists in such a lane could pass a person riding a bicycle without encroaching into the adjacent lane and this practice would improve operating conditions and safety for both bicyclists and motorists. However, research finds this configuration does not adequately provide safe passing distance and motorists generally do not recognize this additional space is intended for bicyclists. Wider travel lanes are also associated with increases in motor vehicle speeds, which reduce comfort and safety for bicyclists. Wide lanes are therefore not recommended as a strategy to accommodate bicycling. Where wide lanes exist, roadways should at a minimum be restriped to reduce wide lanes to minimum lane widths. Additional space may be reallocated to other purpose such as bicycle lanes, wider sidewalks, etc.

The use of constrained width bicycle lanes (see Section 12B-3, C, 3) is preferable to a wide outside lane. However, the use of minimum constrained width bicycle lanes should be limited to constrained roadways where preferred minimum bicycle lane widths cannot be achieved after all other travel lanes have been narrowed to minimum widths appropriate for the context of the roadway.

1. **Shared Lane Markings:** 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 *Bicycle Guide* 4.4.

2. **Shared Lane Signs:** Along with pavement markings, signage is very useful to reinforce to motorists the legal right of bicyclists about shared operating along a roadway.

   The recommended sign for use in shared lane conditions is the “BICYCLES MAY USE FULL LANE” sign (R4-11). This sign is used on roadways without bicycle lanes or usable shoulders where travel lanes are too narrow for bicyclists and motorists to operate side by side within a lane (typically less than 14.5 feet). Use of the “SHARE THE ROAD” sign (W16-1P) is not recommended due to the ambiguous message it sends. Refer to both the MUTCD and *AASHTO Bicycle Guide* 4.3.2.

Figure 12B-3.03: Shared Roadways

R4-11

D. Paved Shoulders

“Highly confident” or “somewhat confident” bicyclists are most likely to travel long distances on rural roadways between towns and cities and are often assumed as the default design user profiles. Paved shoulders can improve these bicyclists’ safety and comfort along higher speed and higher volume roadways. This will not only benefit the cyclists and motorists by giving the bicyclists 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.

Paved shoulders should meet the standards set forth in Iowa DOT’s Bicycle and Pedestrian Long Range Plan and shown in Table 12B-3.04, which vary depending on Average Daily Traffic of the roadway. Also, they should include shy space for guardrails or vertical obstructions, as set forth in Table 12B-3.02. Additionally, the width may be increased in areas of heavy truck traffic.

Table 12B-3.04: Paved Shoulder Standards

Design Year Average Daily Traffic (ADT) Thresholds	Preferred Paved Shoulder Width (ft)	Acceptable Paved Shoulder Width (ft
ADT > 5,000 (Bicycle Routes*)	10	6
ADT > 5,000	6	5**
2,000-5,000 ADT (Bicycle Routes*)	6**	5**
2,000-5,000 ADT	5**	4**
1,000-2,000 ADT (Bicycle Routes*)	5**	4**
1,500-2,000 ADT	3**	2**

*On roadways where a higher level of bicycle traffic is expected (e.g. bicycle routes identified by municipalities or other agencies.
**Paved width exclusive of rumble strips

Source: Iowa DOT Bicycle and Pedestrian Long Range Plan

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 is beneficial in uphill roadway sections to provide slow-moving bicyclists additional maneuvering space and sections with vertical or horizontal curves that limit sight distance over crests and on the inside of horizontal curves.

Paved shoulders can be designated as bicycle lanes by installing bicycle lane symbol markings and must follow the criteria in Section 12B-3, E. Along rural roads with higher speeds (45 mph or greater) it is preferable to provide a shared use path separated from the road if the road segment:

- is a well used and important bicycle route,
- is located in an area that attracts larger volumes of bicycling due to scenic views, and
- serves as a key bicycle connection between major destinations.

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 bicyclists. 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. A bicyclist requires a minimum of 4 feet and a preferred 5 feet of essential operating space based upon their profile. When rumble strips are used, a minimum clear path 4 feet from the rumble strip to the outside edge of paved shoulder or 5 feet to the adjacent curb or other obstacle should be provided, with wider clear paths preferred. Gaps of 12 to 15 feet and a recommended distance of 40 to 60 feet for the rumble strips should also be provided in order to allow room for bicyclists to leave or enter the shoulder without crossing the rumble strip. A 15 foot gap allows approximately half a second for a bicyclist to cross the rumble strip at an operating speed of 20 mph or less. Designers should consider increasing the gap length to a range of 15 to 20 feet or shifting the rumble strip to the right side of the shoulder in locations where bicyclists are traveling at speeds over 20 mph and likely need to traverse the rumble strip into the travel lane. Rumble strips should have the following design and meet NCHRP Report 641:

- Width: 7 inches
- Depth: 0.375 inches
- Spacing: 11 to 12 inches (may be reduced to 6 inches)
- Length: 6 to 12 inches

E. Bicycle Lanes

Bicycle lanes are a portion of the roadway that is designated for bicycle traffic. The following sections discuss several types of bicycle lanes including buffered bicycle lanes, separated bicycle lanes, and contraflow bicycle lanes. For guidance on how to select one of these bicycle facilities, refer to Section 12B-1. 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 *Bicycle Guide* 4.6). Designers need to be aware that pavement joints, especially near curb and gutter sections, could impact the usability of the bicycle lane.

1. **Bicycle Lane Widths:** The widths prescribed in Table 12B-3.05 accommodate a bicyclist operating space, occasional passing, and shy distances to vertical elements as presented in Table 12B-3.02. The bicycle lane should be a hard and smooth rideable surface, clear of defects, joints, and other potential obstructions. The gutter should not be included in the measurement of the bicycle lane width because it is not a rideable surface and the gutter presents a potential crash hazard. The only exception is locations where the gutter is incorporated into the full width of the bicycle lane. In those instances, the gutter should be designed to provide a smooth rideable surface with no longitudinal joints or seams parallel to the bicyclist's line of travel.

Table 12B-3.05: One-Way Bicycle Lane Width Criteria

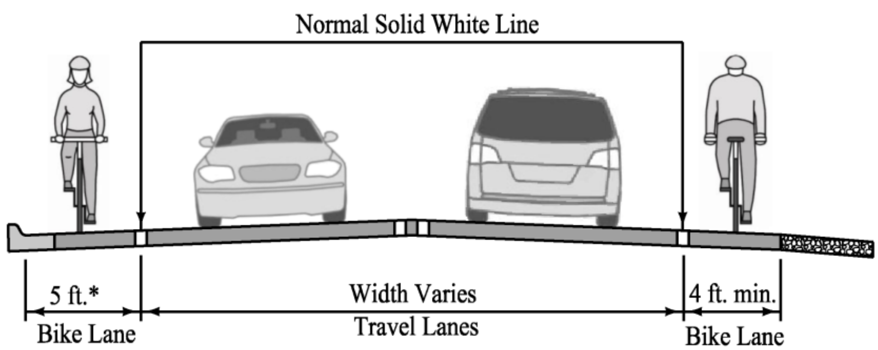
Bicycle Lane Description	Preferred Width (ft)	Minimum Width (ft)
Adjacent to curb[1] or edge of pavement	5 to 7	4
Between travel lanes or buffers	5 to 7	4
Adjacent to parking[2]	6 to 7	5
Intermediate or sidewalk level raised bicycle lane	5.5 to 7.5	5
To allow side-by-side bicycling or passing	8 to 10	7

[1] Exclusive of the gutter unless the gutter is integrated into the full width of the bicycle lane.
[2] Raised bicycle lanes adjacent to parking should have a minimum width of 7 feet.

Source: Adapted from *Minnesota Bicyle Facility Design Manual*

Where a bicycle lane is adjacent to a curb with no gutter, the bicycle lane width should be measured from the face of curb to the center of bicycle lane line. For streets with on-street parking, the bicycle lane width should be measured from the center of the parking lane or buffer line to the center of the bicycle lane line.

Figure 12B-3.04: 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 *Bicycle Guide* Exhibit 4.13

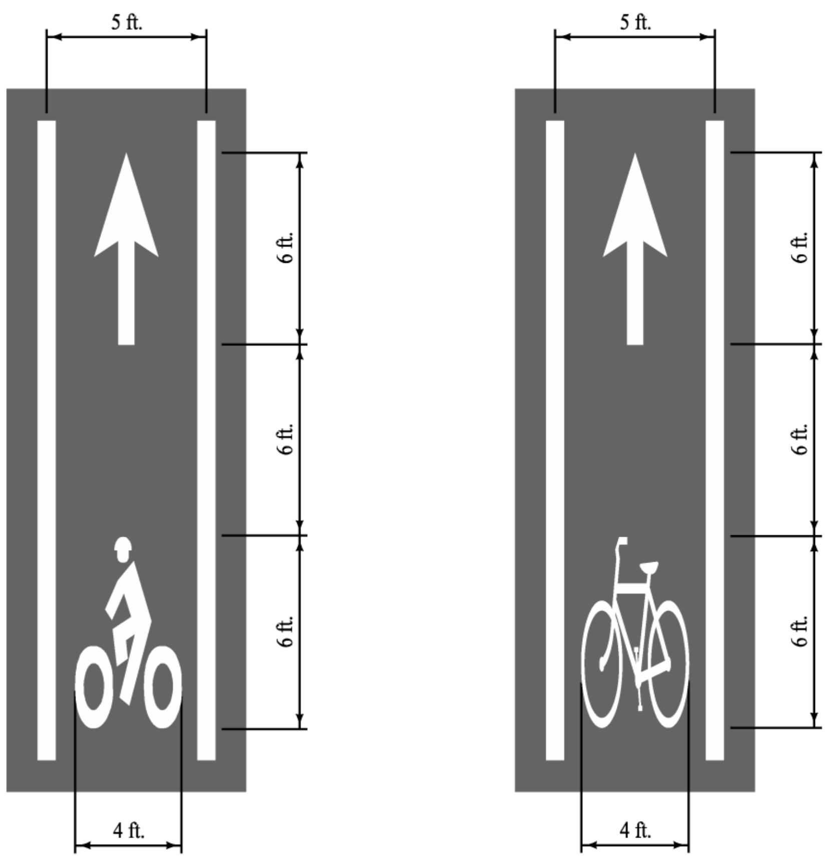
The width of a bicycle lane and buffer (if provided) have a significant impact on a bicyclist comfort and their operating position within a bicycle lane. As the adjacent motorized traffic volume and speed increases, bicyclists will try to move away from vehicles operating in the adjacent travel lane, positioning themselves closer to parked vehicles or the edge of roadway, which can increase their crash risk. Bicycle lanes should therefore be built to preferred widths to address the comfort and safety of bicyclists operating within the lane adjacent to the motorized traffic. While bicycle lanes wider than 7 feet may be provided, they should be complemented by a buffer to minimize their appearance as a travel or parking lane for motorists (see Section 12B-3, E, 7).

Example conditions where wider bicycle lanes or buffered bicycle lanes may be preferable include:

- Locations with high parking turnover.
- Locations where it is desirable to allow bicyclists to travel side-by-side or pass each other.
- On roadways with posted speeds over 30 mph or 6,000 vehicles/day.
- On roadways with more than 5% heavy vehicles/trucks.
- Locations where bicycle lanes are located between two moving travel lanes such as between a through lane and turning lane.

2. **Markings for Bicycle Lanes:** Bicycle lanes are designated for preferential use by bicyclists with a white lane line and one of the two standard bicycle lane symbols, which should be supplemented with a directional arrow marking indicating the correct direction of travel in the bicycle lane. The lane line may be a normal width (4 to 6 inches wide) or it may be a wide width (8 to 12 inches wide) to add emphasis, see Figure 12B-3.5. Bicycle lane signs may be used to supplement the pavement markings. All bicycle lane markings should be retroreflective. Refer to both the MUTCD and *AASHTO Bicycle Guide* 4.7 for bicycle lane markings and Section 12B-3, F for bicycle lane markings at intersections.

Figure 12B-3.05: Conventional Bicycle Lane Symbol Markings



Source: Adapted from *AASHTO Bicycle Guide* Exhibit 4.17

3. **Bicycle Lanes on One Side of a Two-way Street:** It is recommended that bicycle lanes are provided on both sides of two-way streets. Bicycle lanes on only one side may encourage wrong-way use. The following scenarios note when it may be acceptable to provide a bicycle lane on one side and how to select which side:
   - On streets where downhill grades are long enough to result in bicycle speeds similar to typical motor vehicle speeds, then a bicycle lane may be provided only in the uphill direction, with shared lane markings in the downhill direction. This design can be especially advantageous on streets where fast downhill bicycle speeds have the potential to increase the likelihood of crashes with fixed objects, particularly in locations with on-street parking.
   - Where a roadway narrows on one side of a roadway for a short segment with an otherwise continuous bicycle lane.
   - Where an adjacent parallel roadway of similar width provides a bicycle lane in the opposing direction.

   When a bicycle lane is only provided in one direction, shared lane markings should be added in the opposing direction if the roadway speed is 35 mph or below.

4. **Bicycle Lanes on 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 right turn lanes, or if left sided bicycle lanes will reduce conflicts with bus traffic, on-street parking, and/or heavy right-turn movements, etc. Left side bicycle lanes may increase crash risks for bicyclists because it is generally an unexpected location for bicyclists. To mitigate this risk, left side bicycle lanes should be restricted to streets with posted speeds below 30 mph and implemented on a consistent basis in a community. Consideration should be given to increasing the conspicuity of the bicycle lane through the use of wider bicycle lane lines, additional bicycle lane markings, green colored pavement, and additional regulatory or warning signs notifying motorists of the left side placement.

   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.

5. **Counterflow Bicycle Lanes:** Bicycle lanes should typically be provided on both streets of a one-way couplet. If a one-way roadway pair in the opposite direction does not exist or would significantly increase bicyclist travel time due to out of direction travel, there may be an increase in wrong way riding. If sufficient width exists, a counterflow bicycle lane can also be added to provide for two-way bicycle travel on a one-way street. A bicycle lane should be provided for bicyclists traveling in the same direction as motor vehicle traffic. If there is insufficient room to provide a bicycle lane in the dominant flow direction of the street, shared lane markings should be considered to emphasize that bicyclists must share the travel lane on this side of the street.

   To mitigate potential safety challenges associated with counterflow bicycle travel, the following should be considered:
   - The bicycle lane should be marked according to normal rules of the road so bicyclists using the lane are traveling on the right-hand side of the roadway, with opposing traffic on their left.
   - Bicycle lane symbols and directional arrows should be used on both the approach and departure of each intersection, to remind bicyclists to use the bicycle lane in the appropriate direction, and to remind motorists to expect two-way bicycle traffic.
   - Because counterflow bicycle travel can be unexpected by motorists when entering, exiting or crossing the roadway, additional treatments including signs and green colored conflict markings (see Section 12B-3, F) should be considered at intersections, alleys, grade crossings, and driveways.

- At intersecting streets, alleys, and major driveways, “DO NOT ENTER” signs and turn restriction signs should include a supplemental “EXCEPT BICYCLES” plaque to establish that the street is two-way for bicyclists.
- At traffic signals, signal heads should be provided for counterflow bicyclists, as well as suitable bicycle detection measures. A supplemental plaque that says “BICYCLE SIGNAL” may be needed beneath the signal to clarify its purpose. See Section 12B-3, L, 1 for information on signal options for controlling bicyclists.
- A solid double yellow center line should be used to separate the counterflow bicycle lane from opposite direction traffic. Medians or traffic separators should be considered to provide more separation between motorists and bicyclists traveling in opposing direction, particularly at intersections. This treatment is required when posted speeds exceed 35 mph.

6. **Bicycle Lanes Adjacent to On-street Parking:** Where on-street parking facilities are present, bicycle lanes should be located between the general purpose travel lane and the parking lane, unless designated as a separated bicycle lane. Delineating the bicycle lane with two stripes, one along the street side and one along the parking side, is preferable to a single stripe between the bicycle lane and travel lane.

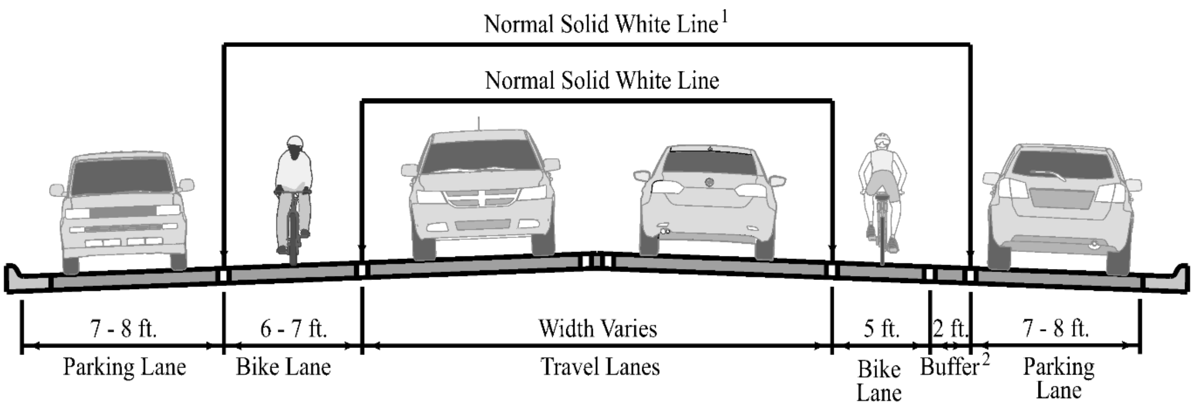
   When parallel parking lanes are narrow or there is a high parking turnover, it is preferable to provide a separated bicycle lane to reduce conflicts with the vehicles. When a separated bicycle lane is not feasible or an interim solution is needed, a buffered bicycle lane should be provided, see Section 12B-3, E, 7. It is preferable that the combined width of the parking lane and buffer be at least 10.5 feet wide to allow the opening of motor vehicle doors.

   If a striped buffer is not desired, the bicycle lane width may be increased to provide bicyclists with more operating space to ride out of the area of opening vehicle doors; however, as bicycle lane widths increase, they may appear more like travel lanes and may result in instances of double parking. Designers may consider the use of green pavement to discourage motorists using the bikeway. If a buffered bicycle lane is not feasible, designers should consider the following options in the order stated:
   - Evaluate the reduction of travel lane widths and parking lane widths to accommodate the design widths for buffered bicycle lanes. For parallel on-street parking, the recommended width of a marked parking lane is 8 feet to encourage vehicles to stay within the parking lane. A parking lane of 9 feet may be preferable in areas where trucks are routinely present.
   - Evaluate if parking can be consolidated to one side of the street or removed to provide the additional space necessary to accommodate the design widths for buffered bicycle lanes.
   - On constrained streets where it is not feasible to eliminate parking, or to narrow or remove a travel lane, in order to achieve the minimum dimensions, research indicates there is a slightly reduced risk of dooring in bicycle lanes as compared to shared lanes. The bicycle lane may be narrowed to a minimum width of 4 feet to provide a buffer within the door zone area. The door zone buffer may vary from 2 feet to 4 feet. The buffer markings will encourage bicyclists to ride farther from parked vehicles and encourage motorists to park closer to the curb.
   - The minimum combined bicycle lane and parking lane width is 12 feet. All other travel lanes should be narrowed to the allowable constrained width before the minimum combined bicycle and parking lane width is considered. Diagonal pavement markings may be used within the bicycle lane to identify the potential door zone area by extending parking tees or diagonal pavement markings into the bicycle lane up to 3.5 feet from the parking lane line.
   - When insufficient widths are available, providing a shared lane in lieu of a bicycle lane is unlikely to accommodate the “interested but concerned” bicyclist, but could accommodate the “highly confident” bicyclist. An alternative route should be considered if the target design user is the “interested but concerned” user.

For the scenarios listed above, green colored pavement may be used within the bicycle lane to improve the visibility of the bicycle lane adjacent to parking or loading areas.

Bicycle lanes should not be placed adjacent to head-in angled parking, since drivers backing out of parking spaces have poor visibility of bicyclists in the bicycle lane. The use of back-in angled parking can help mitigate the conflicts normally associated with bicycle lanes adjacent to head-in angled parking (AASHTO *Bicycle Guide* 4.6.5).

Figure 12B-3.06: Bicycle Lane Cross-sections Adjacent to On-street Parking



[1] The normal (4 to 6 inch) solid white line is preferred to make the presence of a bicycle lane more evident. Parking stall markings may also be used.

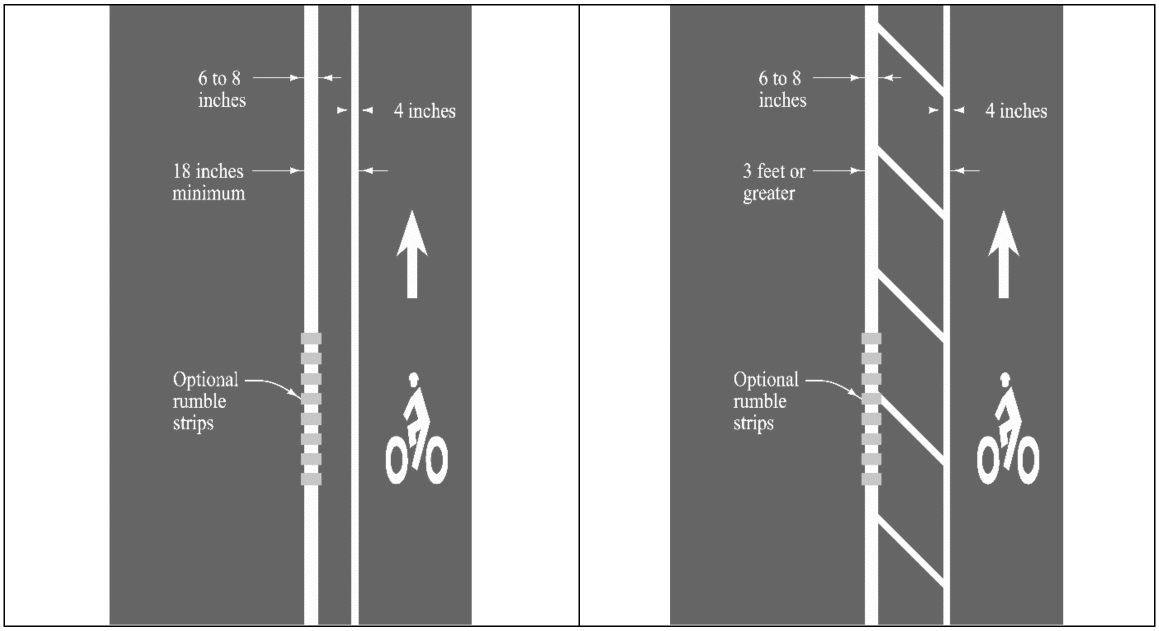
[2] Buffers are preferred where parking turnover is high.

Source: Adapted from *AASHTO Bicycle Guide* Exhibit 4.13

7. **Buffered Bicycle Lanes:** Where space is available, bicycle lanes can be improved through the provision of a painted buffer between the bicycle lane and the 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 or to reduce the risk of dooring where bicycle lanes are adjacent to on-street parallel parking.

   The lane widths are the same as those set forth in Table 12B-3.05. 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. Typical spacing of the chevron markings is 20 feet. The maximum spacing should not exceed the equivalent of the speed limit. 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. Rumble strips can present a hazard to bicyclists and should not be used in areas where bicyclists are likely to merge in the adjacent general purpose lane to complete turns.

Figure 12B-3.05: Buffered Bicycle Lane Markings

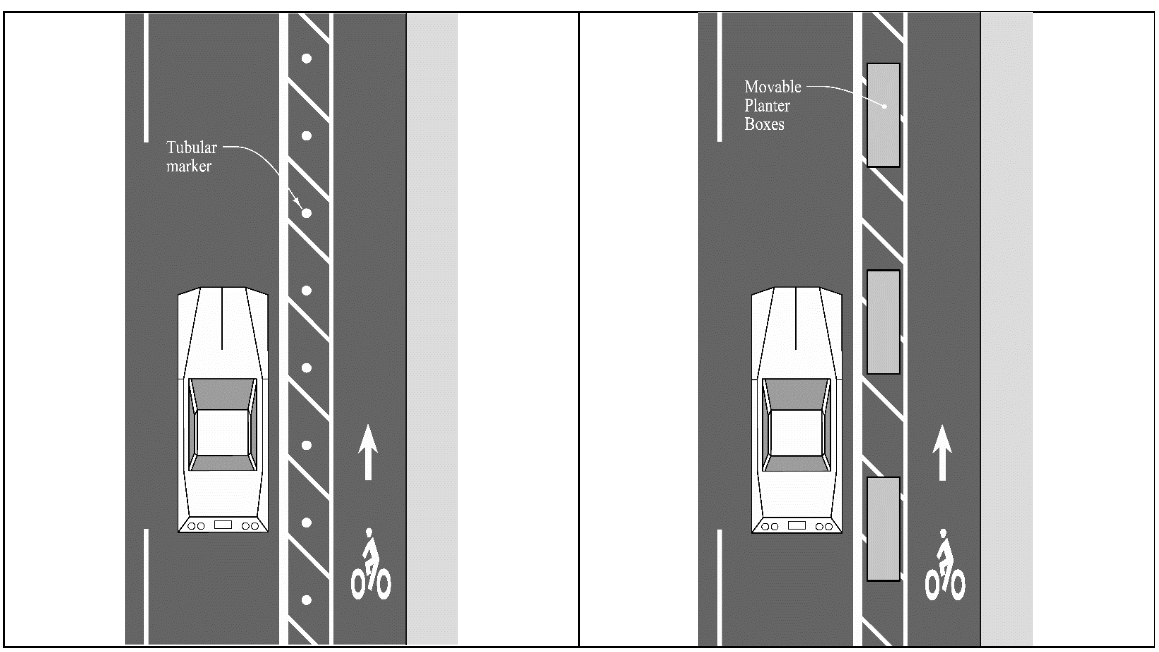


Note: Buffered bicycle lane markings should be measured from the middle of the lane line.

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

8. **Separated Bicycle Lanes:** In order to feel comfortable riding on high speed and high-traffic streets, most bicyclists prefer separation from motor vehicle traffic, see Section 12B-1. Separated bicycle lanes provide an exclusive space that is physically separated from motor vehicle or parking lanes by a vertical element. Examples of vertical separation include delineators, bollards, curbs, medians, planters, concrete barriers, and on-street parking, see Figure 12B-3.08. Where on-street parking is present, designers may need to evaluate parking restrictions to ensure adequate sight distance, see Section12B-3, E, 9.

Figure 12B-3.08: Separated Bicycle Lane



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

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 may be located at street elevation, sidewalk elevation, or an intermediate elevation in between the sidewalk and street. When built at sidewalk level, care must be taken to ensure they are distinct from the sidewalk to discourage pedestrian encroachment and to provide a detectable edge for persons with vision disabilities.

Separated bicycle lanes may be installed in one-way and two-way configurations, each of which present opportunities and challenges that must be considered during the design process. Two-way separated bicycle lanes might be appropriate where key destinations exist along one side of the road, where driveways and intersections are sparse along one side of road but frequent along the other side, or for other context-based reasons. If used, signings and markings at intersections, driveways, and other conflict points should be employed as appropriate to ensure people walking and driving are aware of the two-way operations. At signalized intersections, additional equipment and phasing adjustments may be necessary, see Section 12B-3, L.

Separated bicycle lane width should be selected based on the desired elevation of the bicycle lane, adjacent curb type(s), anticipated volume of users, likelihood of passing maneuvers, and one-way vs. two-way operation. Bicyclists typically do not have the option to pass each other by moving out of a separated bicycle lane as they would in a standard bicycle lane because of the vertical elements between the bikeway and the motor vehicle travel lane. It is therefore preferable for the width of the separated bicycle lane to accommodate passing and potentially allow side-by-side bicycling. The preferred, minimum, and constrained bicycle lane widths for one-way and two-way separated bicycle lane(s) are provided in Table 12B-3.6. When designing separated bicycle lane widths, consideration should also be given to the following factors:

- Shy distances to different curb types and vertical elements (see Table 12B-3.02).
- 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.
- Tactile warning devices when level with adjacent sidewalk.

Table 12B-3.06: Separated Bicycle Lane Widths

Bikeway Operation and Context	Separated Bicycle Lane Widths (ft)[1]		
	Preferred Width	Acceptable Width	Constrained Condition[2]
One-way, Adjacent to One Vertical Curb	8	6	4
One-way, Between Sloped Curbs or at Sidewalk Level	7.5	5.5	3.5
Two-way, Adjacent to One Vertical Curb	11.5	9.5	8
Two-way, Between Sloped Curbs or at Sidewalk Level	11	9	7.5

[1] The widths shown are for separated bicycle lanes where the peak bicycle activity is less than 150 bicycles per hour. Where volumes exceed this, additional width should be provided.

[2] In constrained conditions, the minimum widths for separated bicycle lanes will not accommodate passing maneuvers between bicyclists. As such, constrained minimum widths are not recommended for long distances. However, they may be appropriate adjacent to accessible parking spaces, loading zones, or transit stops if sufficient width is not available to accommodate the preferred widths.

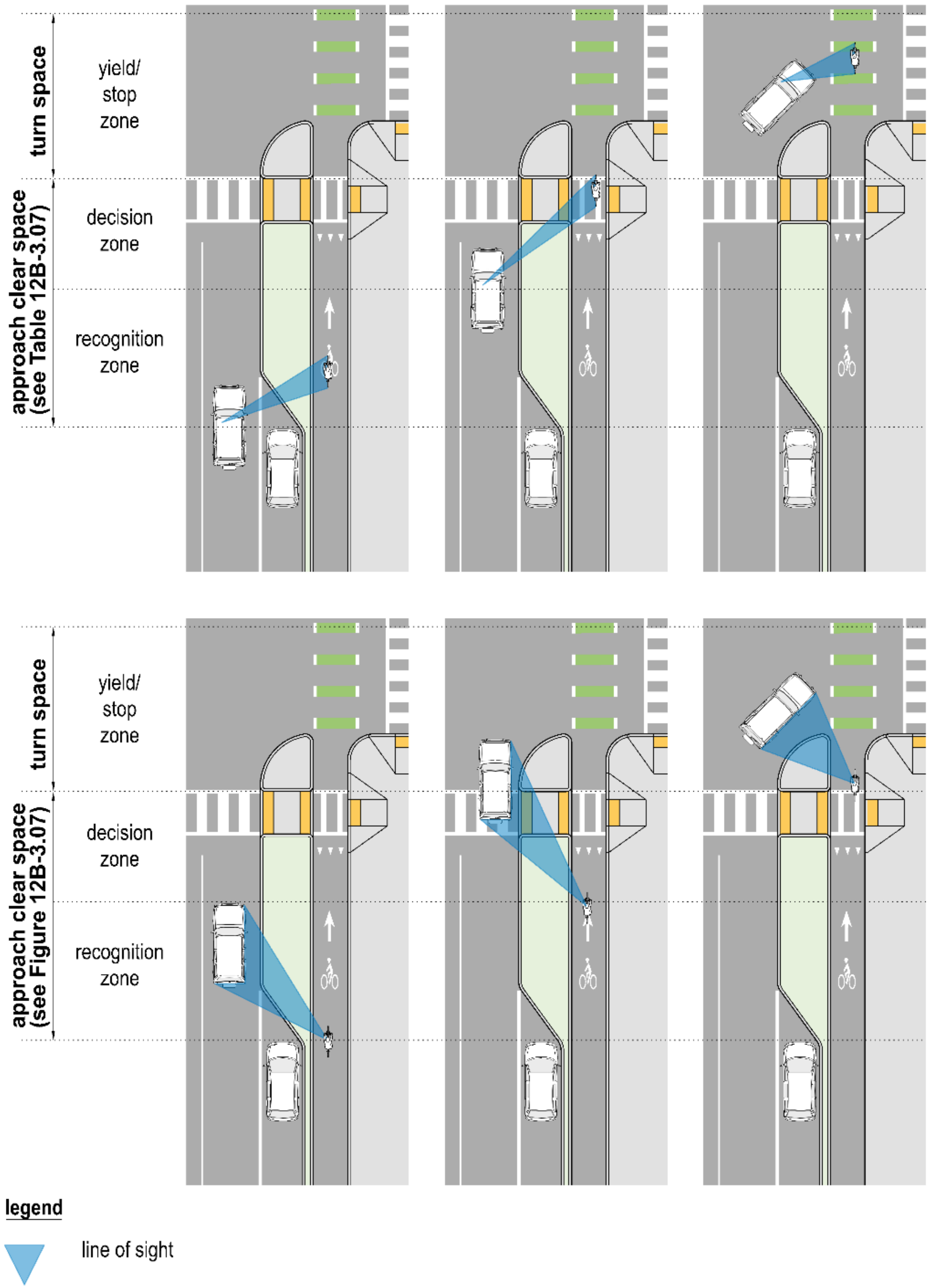
Source: Adapted from *Minnesota Bicyle Facility Design Manual*

Interaction between transit stops and separated bicycle lanes can be difficult. When possible, the bicycle lane should be routed behind the bus platform. Where on-street parking is present, a floating bus stop may be provided, see NACTO's *Transit Street Design* Guide. If bus traffic is infrequent (less than four buses per hour), bus stops can utilize the bicycle lane space. When buses are present, bicyclists may merge left and pass the stopped bus.

9. **Separated Bicycle Lane Parking Buffer Design for Intersection Sight Distance:** When a separated bicycle lane is located adjacent to a parking lane, it may be necessary to restrict parking and other vertical obstructions in the vicinity of a crossing to ensure adequate sight distance are provided for both bicyclists and motorists. To determine parking restrictions near the crossing, it is necessary to know the approach speed of the bicyclist and the turning speed of the motorist. The overall objective of the design is to provide adequate sight distances for each user to detect a conflicting movement of another user and to react appropriately. The approach to the conflict point consists of these three zones:
   - **Recognition Zone:** The approaching bicyclist and motorist have an opportunity to see the other and evaluate their respective approach speeds.
   - **Decision Zone:** The bicyclist or motorist identifies who is likely to arrive at the intersection first and adjusts their speed to yield or stop if necessary.
   - **Yield/Stop Zone:** A space for the motorist or bicyclist to yield or stop, if necessary.

   At intersections with permissive turning movements where bicyclists and motorists are traveling in the same direction, there are two yielding scenarios that occur depending upon who arrives at the crossing first. The two scenarios are described below and illustrated in Figure 12B-3.09.
   - **Right Turning Motorist Yields to Through Bicyclist:** This scenario occurs when a through moving bicyclist arrives at the crossing prior to a turning motorist, who must stop or yield to the through bicyclist. Parking must be set back sufficiently for the motorist to see the approaching bicyclist
   - **Through Bicyclists Yields to Turning Motorist:** This scenario occurs when a turning motorist arrives at the crossing prior to a through moving bicyclist. Again, parking must be set back sufficiently to enable bicyclists and motorists to see and react to each other.

Figure 12B-3.09: Yielding Scenarios Illustrating Intersection Sight Distance Case A



Source: Adapted from *MassDOT Separated Bike Lane Planning & Design Guide*

The following provides sight distance considerations for situations where motorists turn right, left, or cross separated bicycle lanes. The recommended approach clear space assumes the bicyclist is approaching the intersection at a constant speed of 15 mph. Clear space recommendations are provided for various turning speeds of motorists that may vary based on the geometric design of the corner and the travel path of the motorist. The recommended clear space allows 1 second of reaction time for both parties as they approach the intersection. If bicyclists' speeds are slower (such as on an uphill approach) or motorists' turning speeds are slower than 10 mph, the clear space can be reduced. Where either party may be traveling faster, such as on downhill grades, the clear space may benefit from an extension.

a. Bicycle Case A - Right-Turning Motorist Across Separated Bicycle Lane: In this case, the motorist will be decelerating for the right turn approaching the intersection. Table 12B-3.07 identifies the minimum approach clear space, measured from the point of curvature of the motorist's effective turning radius, which represents the location where the motorist will have decelerated to the turning speed; this location may or may not be the curb line point of curvature. For locations with two-way separated bicycle lanes, additional approach clear space is not typically required because the recognition zone between the counterflow bicyclist movement and the right-turning motorists should exceed the recommended sight distances. Approach clear space may be increased to account for steeper slopes or higher speeds for bicyclists.

Table 12B-3.07: Intersection Approach Clear Space by Vehicular Turning Design Speed

Effective Vehicle Turning Radius	Target Vehicular Turning Speed	Approach Clear Space
<18 ft	<10 mph[1]	20 ft
18 ft	10 mph	40 ft
25 ft	15 mph	50 ft
30 ft	20 mph	60 ft
≥50 ft	25 mph	70 ft

[1] Most low volume driveways and alleys

Source: Adapted from MassDOT *Separated Bicycle Lane Planning & Design Guide*

b. Bicycle Case B - Left-Turning Motorist Across Separated Bicycle Lane: This case applies when a motorist is making a permissive left turn at a traffic signal or from an uncontrolled approach (e.g., a left turn from an arterial onto a local street or driveway). On one-way streets with a left-side separated bicycle lane, this case has the same operational dynamics and approach clear space requirements as Bicycle Case A since the left-turning motorist will be turning adjacent to the separated bicycle lane. On two-way streets with a left-side separated bicycle lane, there are two sight lines that should be maintained. A left-turning motorist approaching a turn needs a line of sight to bicyclists approaching from the same direction. Table 12B-3.07 identifies the minimum approach clear space based on the effective turning radius for the left-turning motorist. The provision of Bicycle Case A for motorists making a right-turn across a two-way bikeway will already provide the necessary line of sight between a left-turning motorist and a bicyclist approaching from the opposite direction.

On streets with two-way traffic flow, the operational dynamic of a motorist looking for gaps in traffic creates unique challenges that cannot be resolved through improving sight distance. This is a challenging maneuver because the motorist is primarily looking for gaps in oncoming motor vehicle traffic and is less likely to scan for bicyclists approaching from behind. Unlike for Bicycle Case A or Bicycle Case B on one-way streets where the motorist is decelerating towards the crossing, the motorist in this case will be accelerating towards the crossing once they perceive a gap in traffic. This creates a higher potential for conflicts on roads with the following:

- High traffic volumes and multiple lanes.
- Higher operating speeds.
- High left turn volumes.

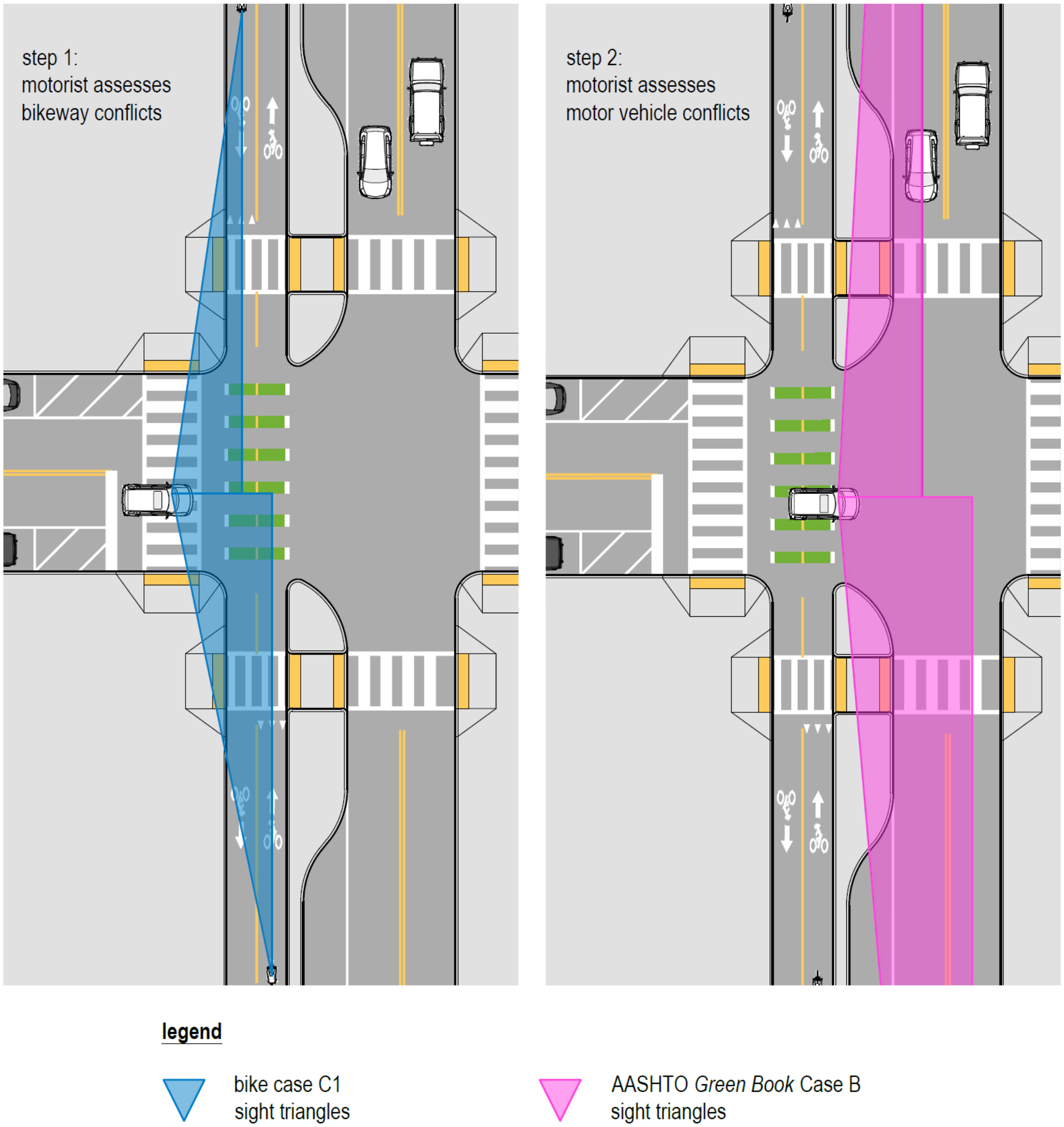
Where it is not feasible to eliminate high speed and high volume conflicts through signalization, turn prohibitions, or other traffic control, it may be necessary to reevaluate whether a two-way separated bicycle lane is appropriate at the location, or provide an adequate motorist yield zone that allows the motorist to complete the turn while still yielding to crossing pedestrians or bicyclists, see Section 12B-3, F, 5.

c. **Bicycle Case C - Motorist Crossing of a Separated Bicycle Lane or Shared Use Path:** This case applies when a motorist crosses a separated bicycle lane and is similar to the cases in the AASHTO *Bicycle Guide* where a motorist crosses a bicycle lane or a mid-block path. The bicycle lane case is expanded upon below, including near-side and far-side intersection scenarios.

1) **Bicycle Case C1 - Near-Side Crossing:** This case applies when a motorist crosses a near-side separated bicycle lane before continuing straight or turning at an intersection. The two potential design scenarios are as follows:

   - **Two-Stage Crossing:** In this scenario, the motorist will first assess the bicycle conflicts, then move forward and assess motor vehicle conflicts (i.e., designers should perform two calculations from two different locations) as shown in Figure 12B-3.10. Similar to when a motorist moves forward after assessing pedestrian conflicts, when the motorist moves forward, they might block the bikeway to look for gaps in traffic. The equation in Table 12B-3.08 should be used to calculate the departure sight triangle between a passenger vehicle and the bikeway using a time gap (t_g) of 5.5 seconds for the motorist to clear the bikeway. This time gap uses an assumption that the vertex (decision point) of the departure sight triangle is 10 feet from the edge of bikeway and the bikeway width is no wider than 14 feet. The appropriate sight distance from AASHTO Green Book Case B should then be used to calculate departure sight triangle between the motorist and the intersecting motorist travel lanes.

Figure 12B-3.10: Bicycle Case C1 - Two-Stage Crossing Scenario



Use the following equation to determine the Bicycle Case C intersection sight distance.

$$ISD_{bike} = 1.47V_{bike}t_g$$ **Equation 12B-3.01**

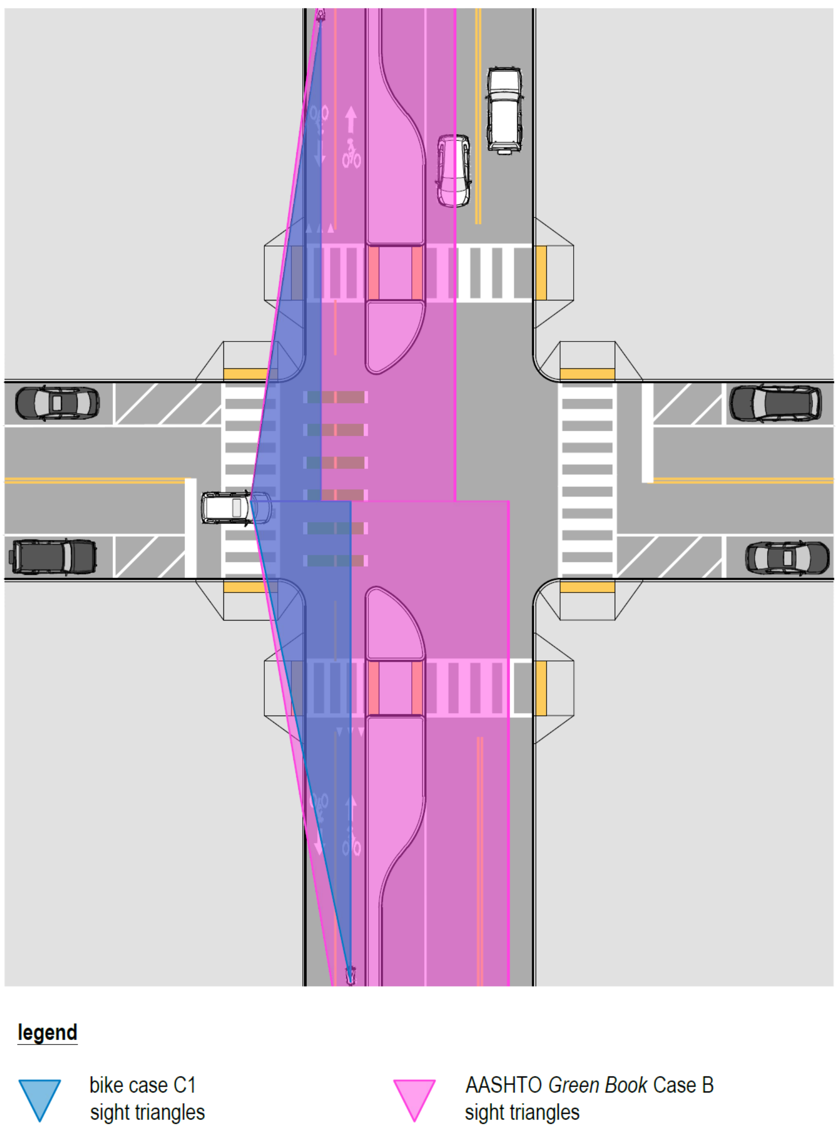
where:

ISD_{bike} = Intersection sight distance (length of the leg of sight triangle along the bikeway) (ft)
V_{bike} = Design speed of bikeway (mph)
t_g = Time gap for passenger vehicle to cross bikeway(s)

Source: AASHTO Green Book

- **Single Crossing:** In this scenario, the motorist assesses both the bikeway conflicts and motor vehicle conflicts from one stopped location, then performs the turning movement when there is a sufficient gap in both the bikeway and motor vehicle traffic (Figure 12B-3.11). This scenario may be appropriate in locations where the motorist would otherwise block the bicycle facility for extended periods of time or where bicycle volumes or motorist volumes are anticipated to be high. The equation in Table 12B-3.08 should be used to calculate the departure sight triangle between a passenger vehicle and the bikeway using a time gap (t_g) of 4 seconds for the motorist to clear the bikeway. This time gap uses an assumption that the vertex (decision point) of the departure sight triangle is 10 feet from the edge of bikeway and the bikeway width is no wider than 14 feet. The vertex of the departure triangle between the motorist and the intersecting motorist travel lanes will remain the same, but designers will need to adjust the typical time gap for the appropriate sight distance from AASHTO Green Book Case B to account for the longer distance the motorist will traverse. As shown in Figure 12B-3.11, the provision of the motorist intersection sight distance will often accommodate the sight distance along the bikeway.

Figure 12B-3.11: Case C1 - Single-Stage Crossing Scenario

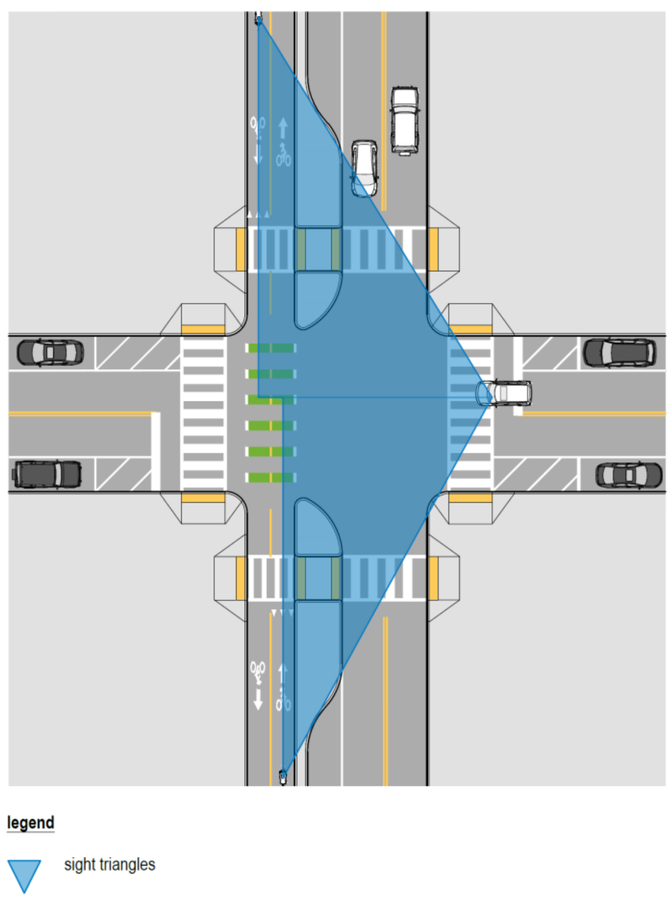


2) **Bicycle Case C2 - Far Side Crossing:** This case applies when a motorist crosses a far side separated bicycle lane, see Figure 12B-3.12. Where both the motorist and bikeway approaches are stop-controlled, providing a line of sight between the stopped motorist and the stopped bikeway user is appropriate.

   Where the motorist approach is stop-controlled and the bikeway crossing is uncontrolled, the intersection sight distance described in AASHTO Green Book Case B3 should be used to calculate departure sight triangle between the motorist and the intersecting bikeway. The bikeway design speed should be used in the intersection sight distance triangle calculation. The bikeway width and street buffer width should be converted to equivalent lane widths to adjust the time gap (t_g) for the crossing of the roadway and the bikeway. In constrained situations, at a minimum, the stopping sight distance for bicyclists should be provided to allow a bicyclist to slow or stop if a vehicle encroaches into the bikeway.

   As with Bicycle Case B, this case creates a challenging dynamic that is often difficult to resolve by increasing the size of the sight triangle. In urban areas, it may be difficult to increase the sight triangle enough to provide the intersection sight distance to judge gaps that allow a motorist to cross all the travel lanes as well as the separated bicycle lane on the opposite side of the road. As such, designers should consider the frequency of through movements at these types of intersections and provide either traffic control devices or adequate sight distance (i.e. minimum stopping sight distance) for bicyclists to see and react to a crossing vehicle and stop if necessary. It may be appropriate to restrict these through motorist movements where traffic control devices or sight distances are inadequate.

Figure 12B-3.12: Bicycle Case C2 - Single-Stage Crossing Scenario



10. **Curbside Management, Accessible Parking, and Loading Zones:** At locations where vehicles frequently stop or stand in the bicycle lane, in addition to the signing strategies noted above, it may be beneficial to implement curbside management strategies to result in increased parking and loading space availability during peak periods and to address various curbside uses. Where on-street parking is present, loading zones may be delineated within the parking lane, and the bicycle lane may be preserved alongside them. See the ITE *Curbside Management Practitioners Guide* for more information.

    Accessible parking and loading spaces require additional space adjacent to parking stalls for vans with ramps to allow passenger boarding and alighting, and to ensure an accessible route is provided to and from the sidewalk. This can present a unique challenge when separated bicycle lanes are present between the on-street parking and sidewalk. In constrained locations where accessible parking is provided, the protected bicycle lane may be narrowed to a minimum constrained width adjacent to the parking. It is preferable to use a raised crossing such that the separated bicycle lane is an intermediate or sidewalk level thus reducing the risk of pedal strikes. In addition, this may slow bicyclists down and reinforce that pedestrians will be crossing at this location. At locations without on-street parking but where an accessible parking or loading area is desired, a lateral deflection (bend-out) of the separated bicycle lane will often be required to accommodate the accessible space. Bicycle lane deflection should occur gradually but should not exceed the shifting taper guidelines to maintain bicyclist safety and comfort

F. Intersection Design

Due to the vulnerability of bicyclists as well as the low visibility the bicyclists 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. As a bicycle lane approaches an intersection, designers should provide a continuous and direct route through the intersection, driveway, or alley that is legible to all users of the roadway. Designers should minimize or eliminate conflict areas between bicyclists and motor vehicles, where possible. To minimize the potential for conflicts, designers should adhere to the following design principles:

- Designers should communicate where motorists are expected to yield to bicyclists (e.g., markings and signage).
- Bicycles should not operate between turning lanes and moving lanes with traffic operating over 30 mph on either side of them for distances longer than 200 feet.
- Bicycle crossings of weaving or merging movements by motor vehicles operating over 20 mph should be avoided or minimized to a length of 200 feet or less.
- It is preferable for motorists merging and crossing movements across bicycle lanes be confined to a location where motor vehicles are likely to be traveling at speeds less than 20 mph.
- It is preferable for bicycle crossings of intersections to be marked.

A conventional or buffered bicycle lane can be transitioned to a protected bicycle lane and follow the design of a protected intersection to increase the comfort of the bikeway at the intersection. Designers should consider this design as operating speeds reach 35 mph or higher. When a protected intersection is not feasible for operating speeds of 35 mph or greater or motor vehicle turning volumes exceed 150 turning vehicles per hour, a bicycle ramp should be considered to give bicyclists a choice to exit the roadway to a shared use path or sidewalk prior to the intersection, see Section 12B-3, Q for bicycle ramp design parameters.

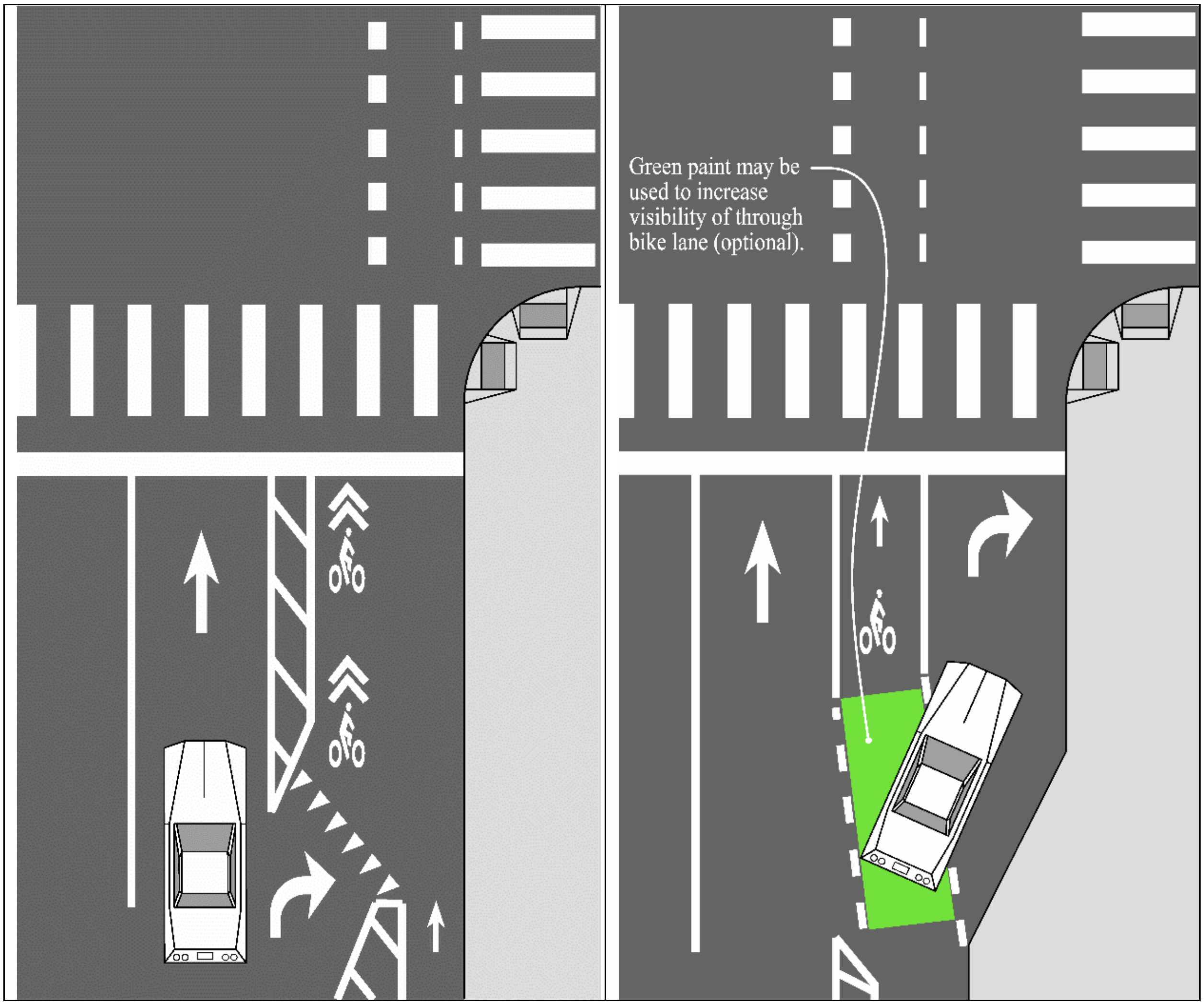
Where conflicts occur, intersection treatments like bicycle boxes, protected intersections, and bicycle signals can improve the safety, visibility, and/or comfort of bicyclists. Where conflict areas are present, pavement markings and signage should be used as speeds and volumes increase to improve legibility and safety. Bicycle crossing or lane extension lines, two stage turn boxes, 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 Bicycle Lanes (IA-14)." Because drivers and bicyclists in Iowa may not be 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.

1. **Shared Through/Right Motor Vehicle Lane:** When bicycle lanes are present on two-lane roadways, bicycle lane lines may be solid or dotted on the approach to and within intersections where motor vehicles are allowed to enter a bicycle lane to prepare for a turning, crossing, or merging maneuver. A solid line may be appropriate where turning volumes are low. At intersection approaches with limited space where a right-turn lane is not required but there are relatively high right-turn volumes (more than 150 vehicles during the peak hour) or an existing crash history, designers should consider converting the conventional bicycle lane to a separated bicycle lane by adding a 2 foot minimum buffer with flexible delineator posts beginning at least 50 feet in advance of the intersection to provide added comfort for bicyclists, slow the speed of turning motorist, and reduce the conflict area. Signal phase separation of bicyclists and motorists should be considered, but if concurrent movements are allowed, a bicycle box or forward bicyclist queuing area should be considered.

2. **Right Turn Only Lanes:** Where right turn lanes are introduced and conventional or buffered bicycle lanes are present, the through bicycle lane should be shifted to the left of the right turn lane and markings and signage should clearly indicate conflict areas. Merging areas should be minimized and should not exceed 200 feet to limit the conflict area. Depending on how a turn lane is introduced (e.g., in the parking lane, intersection widening, etc.), designers should refer to Section 12B-3, A, for the design of the lateral shift of the bicycle lane to a position to the left of the right turn lane; see Figure 12B-3.13. See Section 12B-3, F, 4 for conflict marking recommendations. Dual right turn only lanes should be avoided on streets with bicycles. If dual right turn lanes are necessary to accommodate heavy right-turn volumes, a designer should transition the bicycle lane to a separated bicycle lane or shared use path in advance of the intersection. The high right turn volumes will require the provision of a separate bicycle crossing phase; see Section 12B-3, L.

3. **Bicycle Ramps and Mixing Zones:** On roadways with operating speeds over 35 mph, or at locations where right turn lanes exceed 200 feet in length, designers should consider providing a bicycle ramp to allow bicyclists to exit the roadway to an off-street bikeway or sidewalk prior to the merge area; see Section 12B-3, Q for the design of bicycle ramps. On lower speed roadways where there is insufficient width to maintain a bicycle lane through the intersection, a mixing zone may be appropriate. A mixing zone is an area at an intersection where the bicycle lane becomes a shared lane with the turning vehicles; see Figure 12B-3.13. For separated bicycle lanes, the vertical element should be discontinued prior to the location motorists are expected to merge into the shared bicycle and right turn only lane. Merging area and turn lane length should both be minimized (each to a maximum of 200 feet) to limit the conflict area. Sharrow markings are used to guide the bicyclists from the bicycle lane through the intersection.

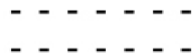
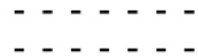
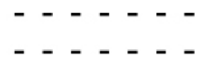
Figure 12B-3.13: Mixing Zones and Through Bicycle Lane



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

4. **Intersection Pavement Markings:** Intersection pavement markings are used to highlight conflict areas and aid bicyclist navigation. Figure 12B-3.14 summarizes the preferred pavement markings based on the intersection and bikeway type.

Figure 12B-3.14: Bicycle Crossings and Intersection Marking Selection Guidelines

Intersection Type	Condition	Separated Bicycle Lane	Conventional/ Buffered Bike Lane	Bicycle Boluevard
Signalized	Turn Conflict			No Markings
	No Turn Conflict			No Markings
	Bikeway Corridor Turns Left			
Unsignalized	High Turning Volume			No Markings*
	All other conditions			No Markings
	Bikeway Corridor Turns Left			No Markings

*Additional treatment may be needed

Source: Adapted from Ohio DOT *Multimodal Design Guide*

a. **Bicycle crossing Markings / Lane Extension Lines:** Where a bikeway crosses an intersection separate from a crosswalk, bikeway lane markings may be extended through the intersection to delineate the bicycle crossing and raise awareness of the presence of bicyclists. Bicycle lane crossings are desirable to:
   - Delineate a preferred path for people bicycling through the intersection, especially crossings of wide or complex intersections;
   - Improve the legibility of the bicycle crossing to roadway users; and
   - Encourage motorist yielding behavior, where motorists must merge or turn across the path of a bicyclist.

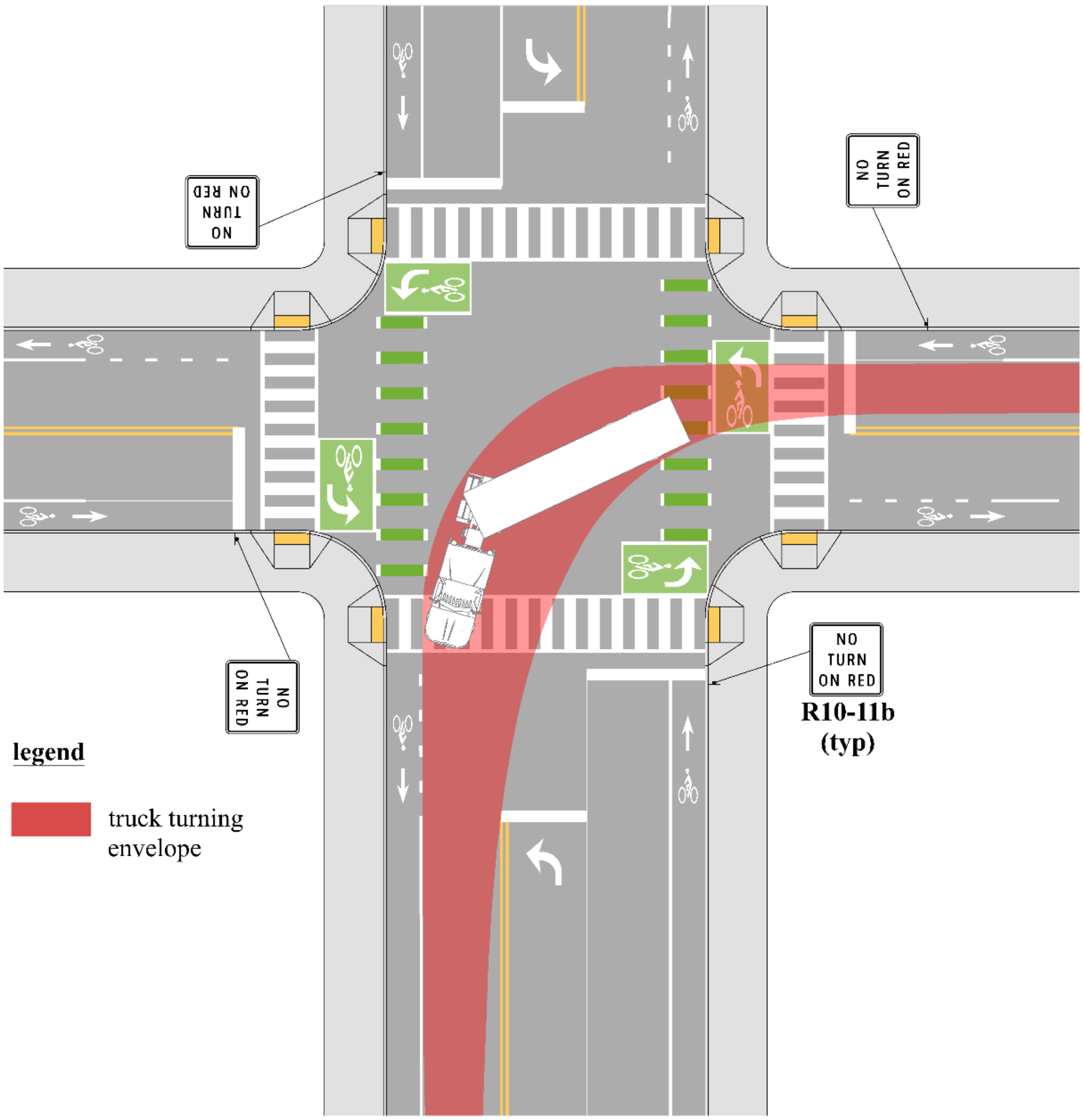
   Bicycle crossings may also be supplemented with green colored pavement. If used, the green colored pavement should align with the dotted extension line pattern of the dotted edge lines.

b. **Two-Stage Turn Boxes:** Weaving across travel lanes and merging with motor vehicle traffic to reach the left side (or right side when the bicycle lane is located on the left-hand side of a one-way street) of the street is challenging for most bicyclists. Where there are high volumes of left-turning bicyclists, or where a designated or preferred bicycle route requires a left turn, a provision for left-turning bicyclists should be provided. This can generally be accomplished by providing a two-stage turn box, which has interim approval in the MUTCD (IA-20).

   With the two-stage bicycle turn box, bicyclists traverse the intersection within the bicycle lane, stop within the turn box, reorient themselves to the cross street, and wait for the green signal for the cross street to proceed, eliminating the need to merge across travel lanes, see Figure 12B-3.15. It may be used for left or right turns (e.g., where a bicycle lane is placed on the left side of a one-way street). It may be used at any signalized intersection but is preferable on high volume and multilane roads.

A two-stage bicycle turn box must be located outside of the path of through and turning traffic; should be located adjacent to, preferable to the right of, the direct path of bicyclist travel; and should be located downstream of the crosswalk and downstream of the stop line. It must include a bicycle symbol and a turn arrow to clearly indicate proper direction and positioning.

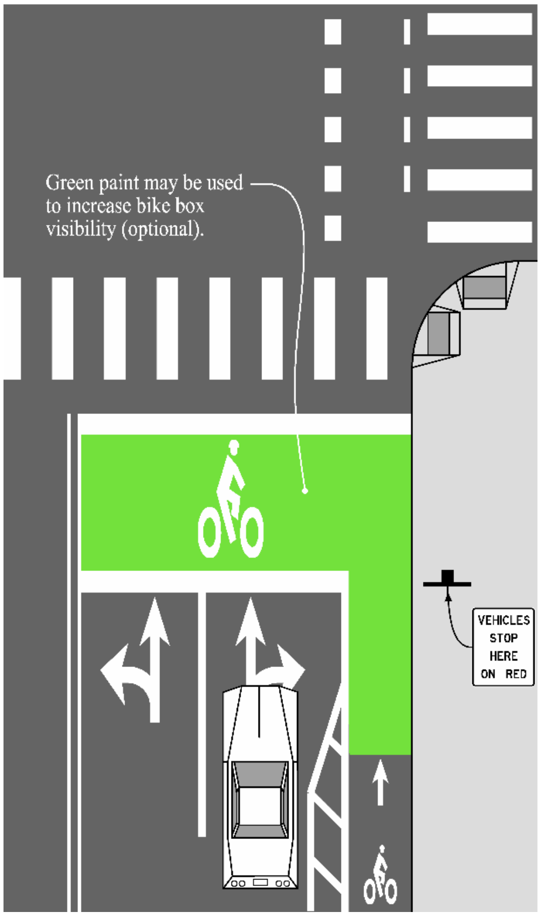
Figure 12B-3.15: Two-Stage Bicycle Turn Box Placement



c. Bicycle Box: Bicycle boxes, which have interim approval in the MUTCD (IA-18), are placed between the vehicle stop line and the pedestrian crosswalk; see Figure 12B-3.16. Bicycle boxes increase the visibility of bicyclists to motorists, provide an advance queuing area to store larger numbers of bicyclists, and reduce bicyclist encroachment into crosswalks during the red signal phase. Bicycle boxes are limited to signalized intersections. Bicycle box are typically formed by two transverse lines, typically 10 to 16 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.

In limited situations, bicycle boxes may be used to facilitate left turns for bicyclists when there is unusually heavy left turn volume of bicyclist, such as near the entrance to a popular shared use path. Research shows the use of bicycle boxes to make left turns is limited in practice; the preferred treatment is the two-stage bicycle turn box.

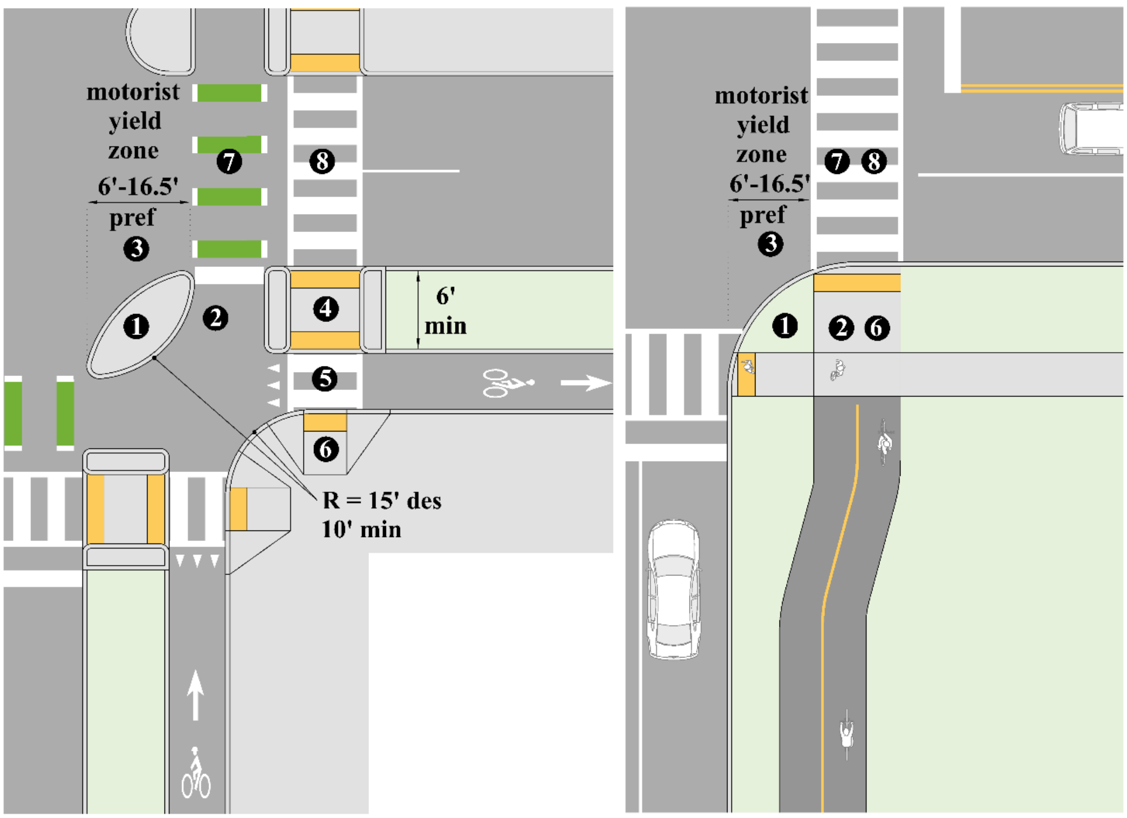
Figure 12B-3.16: Bicycle Box



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

5. **Protected Intersections:** A major goal in providing separated bicycle lanes is to minimize conflicts between bicyclists, pedestrians, and motorists at intersections. For this reason, it is preferable to maintain separation between the separated bicycle lane and the adjacent motor vehicle travel lanes at intersections. Protected intersections provide a design that maintains separation between modes and can work for intersections of separated bicycle lanes and Type 1 shared use paths. The following discussion focuses on design guidance for the geometric elements of a protected intersection for separated bicycle lanes and shared use paths (See Figure 12B-3.17).

Figure 12B-3.17: Protected Intersection Design for Separated Bicycle Lanes and Shared Use Paths



1. corner island
2. forward bicycle queuing area
3. motorist yield zone
4. pedestrian refuge island
5. pedestrian crossing of the separated bike lane
6. pedestrian curb ramp
7. bicycle crossing of travel lanes
8. pedestrian crossing of travel lanes

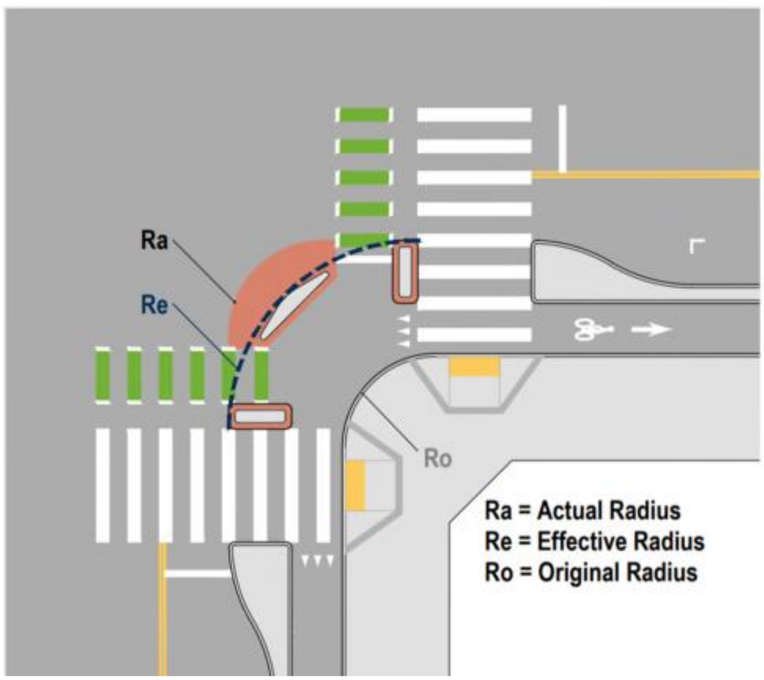
Source: Adapted from MassDOT *Separated Bike Lane Planning & Design Guide*

a. **Corner Island:** The corner island (labeled as 1 in Figure 12B-3.17) allows the bicycle lane or shared use path to be physically separated up to the intersection crossing point where potential conflicts with turning motorists can be controlled more easily. It also creates space for a forward bicycle queuing area, creates additional space for vehicles to wait while yielding to bicyclists and pedestrians who are crossing the road, reduces motorist turning speeds; and can reduce through bicyclist speeds by adding deflection to the bicycle lane or shared use path.

Corner islands may be constructed of concrete and curbing, or may be constructed with low cost materials, such as paint and flexible delineator posts or engineered rubber curbs and/or rubber speed cushion. If a corner island is constructed of mountable materials, such as rubber speed cushions, designers should understand the forward queuing area for bicyclists and pedestrian crossing islands may no longer be protected from turning motorists and should therefore be removed. Where flex posts or other vertical elements are used, they should be placed at least 1 foot offset from the turning radius of design vehicles at all intersections and driveways.

b. **Truck Apron:** A truck apron is a design strategy used to accommodate the turning needs of large vehicles while slowing the turning speeds of smaller vehicles by reducing the actual radius. A truck apron is designed to be mountable by larger vehicles to accommodate their larger effective turning radius needs. The mountable surface encourages the design vehicle, typically a passenger (P) or delivery vehicle (SU-30), to turn without using the apron and reduces their effective turning radius and speed.

Figure 12B-3.18: Actual vs Effective Radius



Source: City of Des Moines' Bike Guide

Truck aprons can be installed with corner reconstruction or in a retrofit condition. They can be constructed with a gap between the mountable curb and the curb face to facilitate surface drainage, if necessary.

For constructability and visibility, truck aprons have a minimum size requirement to be effective. Where the distance between the effective radius and the actual radius is less than 5 feet, truck aprons are not feasible. A smaller distance will become difficult to visually differentiate from the surrounding surfaces and may be more difficult to construct.

Truck aprons that are too large may similarly not be effective at communicating the use of the space, which may be confusing to motorists and people trying to navigate the intersection. Where the distance between the effective radius and the actual radius is greater than 15 feet, truck aprons are not recommended. This situation can be found in intersections where full reconstruction of the intersection should be considered.

Designers should consider the following guidance when implementing a truck apron:

- The pavement color and texture within the truck apron should be distinct from the adjacent roadway and sidewalk.
- Reflective raised pavement markers should be used at the actual radius to ensure the path of travel is visible at night. Retroreflective lane edge line striping should also be provided.
- Channelizing pavement markings may be installed on the mountable truck apron to discourage use of the space by smaller vehicles.
- A truck apron should have a mountable section between 2 and 3 inches high when the control vehicle represents less than 5% of the total turns at an intersection.
- When the control vehicle represents more than 5% of the total turns at an intersection, or where both cross streets are served by frequent transit, a truck apron with a 1 to 2 inch height mountable section may be used.

c. **Forward Bicycle Queuing Area:** The forward bicycle queuing area is a waiting area for stopped bicyclists (labeled as 2 in Figure 12B-3.17). The area is fully within view of motorists who are waiting at the stop bar (if present), which improves bicyclist visibility. Ideally, the bicycle queuing area should be at least 6 feet long to accommodate a typical bicycle length.

d. **Motorist Yield Zone:** The motorist yield zone is a bicycle and pedestrian crossings set back from the intersection to create space for turning motorists to yield to bicycles and pedestrians (labeled as 3 in Figure 12B-3.17). The offset improves motorist view of approaching bicycles by reducing the need for motorists to scan behind them and potentially creates space for a motorist to yield to bicyclists and pedestrians without blocking traffic.

e. **Pedestrian Refuge Median:** The pedestrian refuge median is a space where pedestrians may wait between the street and the separated bicycle lane (labeled as 4 in Figure 12B-3.17). It should be a minimum width of 6 feet and should include detectable warning surfaces. A pedestrian refuge median allows pedestrians to negotiate potential bicycle and motor vehicle conflicts separately, improves visibility of pedestrians to motorists approaching the intersection, shortens the pedestrian crossing distance, and reduces the likelihood of pedestrians blocking the bicycle lane.

f. **Pedestrian Crossing of the Separated Bicycle Lane:** Where pedestrians are expected to cross separated bicycle lanes, crosswalks (labeled as 5 in Figure 12B-3.17) indicate a preferred crossing location and communicate a clear message to bicyclists that pedestrians have the right-of-way. Yield lines and YIELD HERE FOR PEDESTRIANS signs in the bicycle lane in advance of the crosswalk may be used to emphasize pedestrian priority.

g. **Pedestrian Curb Ramp:** Curb ramps and detectable warning surfaces (labeled as 6 in Figure 12B-3.17) should meet pedestrian accessibility guidelines. It is preferable to use the curb ramp style that will shorten crossing distances and provide directional cues to pedestrians.

h. **Bicycle Crossing of Travel Lanes:** For separated bicycle lanes, bicyclists cross the motorist travel lane between the motorist yield zone and pedestrian crossing. For shared use paths, bicyclists cross with pedestrians in the pedestrian crossing (labeled as 7 in Figure 12B-3.17). Bicycle crossings for separated bicycle lanes are often striped using bicycle crossing markings and should be striped using crosswalks for shared use paths.

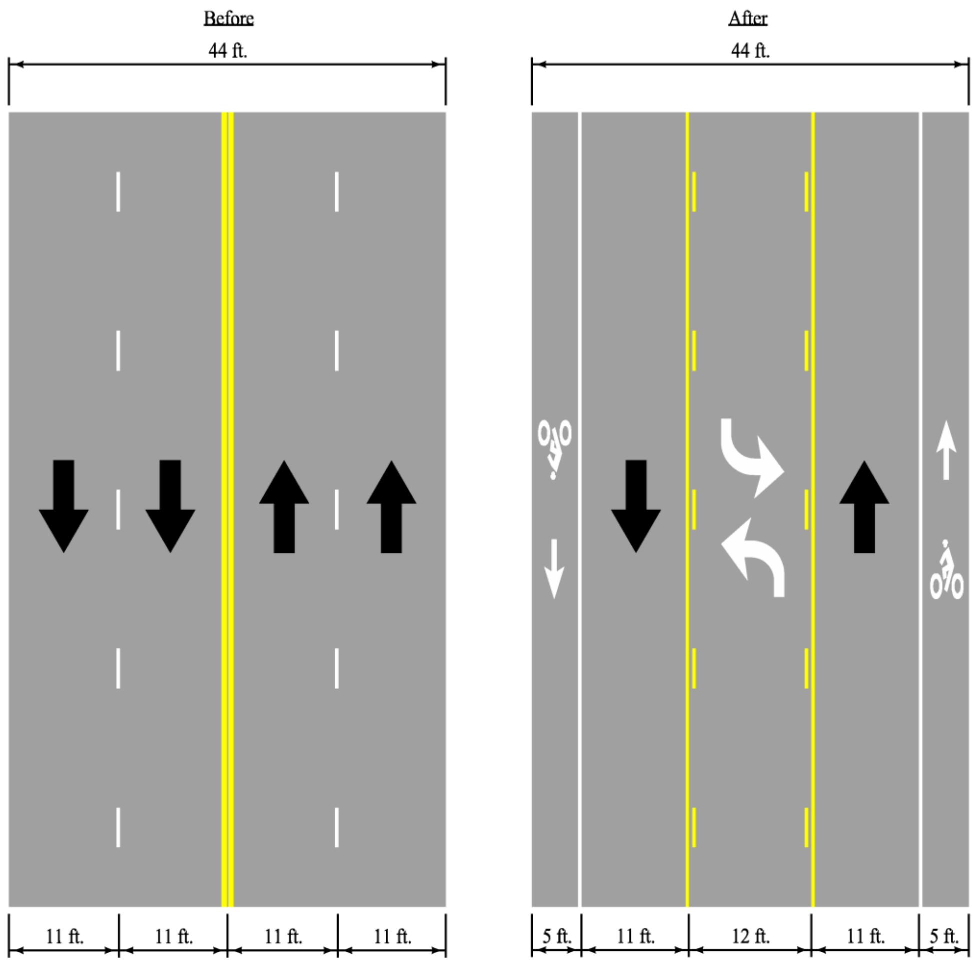
i. **Pedestrian Crossing of Travel Lanes:** Pedestrians cross the motorist travel lane behind the motorists yield zone and behind bicycle crossings when present (labeled as 8 in Figure 12B-3.17).

6. **Traffic Signals and Bicycle Signals:** Special signal timings and bicycle signal heads may be used at intersections to separate bicycle through movements from vehicle movements for increased safety. More detailed guidance on traffic signals for bicycle facilities is found in Section 12B-3, L.

G. 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 *Bicycle Guide* 4.9).

Figure 12B-3.19: Example of Road Diet



* Dimensions are illustrative

Source: Adapted from AASHTO *Bicycle Guide* Exhibit 4.23

H. 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 bicyclists 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. Section 12B-1 provides additional guidance on when bicycle boulevards are an appropriate bicycle facility.

Due to the low traffic volumes and speeds, local streets naturally create a bicycle-friendly environment for bicyclists to share the roadway with 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. The following three principles should guide bicycle boulevard planning and design:

1. **Manage Motorized Traffic Volumes and Speeds:** To minimize conflicts and the frequency of motorists passing bicyclists, bicycle boulevards should meet the guidelines of Table 12B-3.09 for daily and hourly motor vehicle volumes and operating speeds:

Table 12B-3.09: Bicycle Boulevard Motorized Traffic Volume and Speed Performance Criteria

	Peak Hourly Traffic Volume (vehicles/hour)[1]	**Average Daily Traffic Volume (ADT)**	**Operating Speed**
Preferred	150	1,000	15
Acceptable	300	2,000	20
Maximum	450	3,000	25

[1] Assumed to be 15% of ADT

Source: Based on NACTO Urban Bikeway Design Guide

The design of the street should result in the preferred motorist volumes and operating speeds being achieved at all times of the day. Where daily or peak hourly traffic volumes or traffic speeds exceed the maximum guidelines, traffic calming or traffic diversion strategies should be considered. Traffic diverters are treatments that allow bicycle through traffic but reduce or deny vehicle traffic.

2. **Prioritize Right-of-way at Local Street Crossings:** Along bicycle boulevards, most of the intersections a bicyclist will cross will be local streets crossing other local streets. For bicycle boulevards to serve as efficient routes for longer distance travel, they should minimize the need for bicyclists to stop at crossings of local streets. Consider the following elements:
   - Two-way stop-controlled intersection that give the bicycle boulevard priority
   - Neighborhood traffic circles or mini roundabouts

3. **Provide Safe and Convenient Crossings at Major Streets:** Major street crossings along bicycle boulevards can be significant barriers. Treatments such as median refuge islands, beacons, and signals should be installed to accommodate bicyclists crossing.

I. Bicycle Guide Signs

Guide signs are an important element to all bicycle facilities because they help bicyclists 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 Bicycle Guide* 4.11.

J. 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 bicyclists. 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 Bicycle Guide* 4.12.1.

K. Obstruction Markings for Bicycle Lanes

The design of bicycle facilities should avoid obstruction and barriers as much as possible. However, in rare circumstance when an obstruction or barrier cannot be avoided, signs, reflectors, and markings should be used to alert they bicyclists. (AASHTO *Bicycle Guide* 4.12.2).

L. Traffic Signals for Bicycles

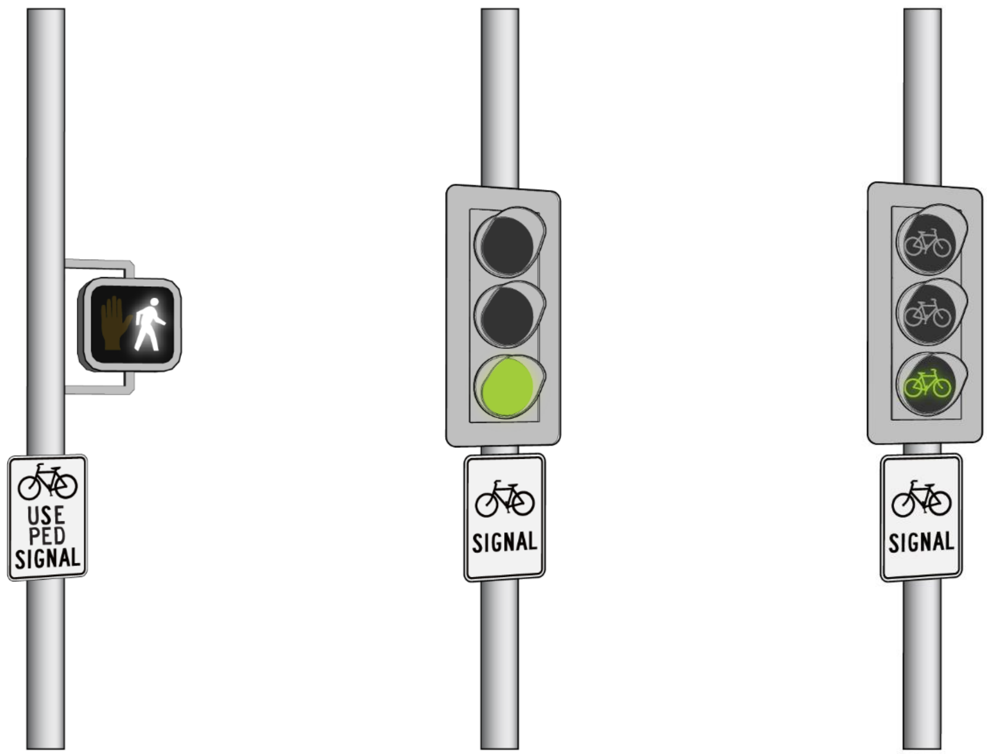
Traffic signals have traditionally been designed based off the operating characteristics of motor vehicles. At intersections where shared lanes, bicycle boulevards, or bicycle lanes are present, traffic signal designers should include the characteristics of bicyclists to their traffic signals. The signal parameters that should be evaluated are minimum green interval, total phase length, and extension time. This information can be found below in 12B-3, L, 2, in AASHTO *Bicycle Guide* 4.12.3 and 4.12.4, as well as the latest edition of the "Highway Capacity Manual."

In addition, designers should ensure signals are actuated, the existing signal detection can reliably detect the presence of bicyclists in a shared lane, and detection is provided for bicycle lanes. Additional markings and signage should be considered as needed for bicyclists to position themselves within the detection zone in shared lanes; see MUTCD 9C.05.

1. **Traffic Signal Indication Options for Bicycles**. A bicyclist traveling in a shared lane is controlled by the vehicular signal head. Where it is necessary or desirable to control a bicycle operating in a separated bicycle lane independently from a motor vehicle, a bicyclist may be controlled by a pedestrian signal head, a traffic signal head designated for bicycle use, or a bicycle signal face. Each of these three options are shown in Figure 12B-3.20 and briefly discussed below. Along a corridor, it is recommended that traffic signal indications for bicyclists are consistent and as uniform as possible.
    - **Pedestrian Signal Heads:** Some agencies direct bicyclists to follow pedestrian signal indications when bicyclists are operating in a separated bicycle lane in the roadway and bicyclists cannot see vehicle signal faces, or when bicyclists have a separate signal phase from motor vehicle movements. To do this, the BIKES USE PED SIGNAL sign (MUTCD R9-5) should be mounted adjacent to the pedestrian signal heads.

- **Standard Traffic Signal, Designated for Bicycle Use:** A standard traffic signal face may be designated exclusively for bicyclists by mounting a BICYCLE SIGNAL sign (MUTCD R10-10b) adjacent to the traffic signal. This may be beneficial where bicyclists cannot see existing vehicle signal faces, where they have a separate signal phase, or where it is desired to maximize the time a bicyclist may legally enter an intersection.
- **Bicycle Signal Heads (Interim Approval):** 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. Bicycle signal faces currently have interim approval for situations where there are no conflicting motor vehicle movements with the signalized bicycle movement.

Figure 12B-3.20: Examples of Signal Indication Options for Bicyclists



Pedestrian Signal Head	**Standard Traffic Signal Face Designated for Bicycle Use**	**Bicycle Signal Face (Interim Approval)**

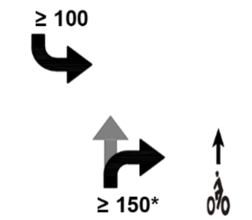
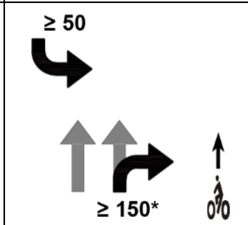
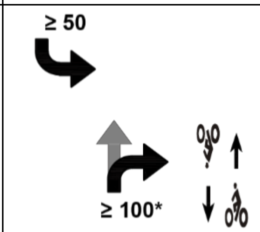
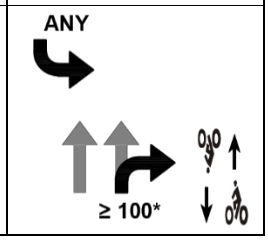
Source: Adapted from MassDOT *Separated Bike Lane Planning & Design Guide*

2. **Traffic Signal Phasing and Timing for Bicyclists:**

   a. **Signal Phasing:** Several signal phasing schemes can be used to reduce conflicts or reinforce bicyclists’ and motorists’ responsibility to yield:
      - A flashing yellow right turning arrow and flashing bicycle signal to reinforce yielding where the bicycle phase is concurrent with permissive motor vehicle turns.
      - A leading bicycle signal phase, which provides 3 to 5 seconds of green time before the corresponding vehicle green indication.
      - A concurrent protected bicycle phase, which runs concurrently with parallel through-vehicle phases, but conflicting vehicle turns across the bikeway are restricted.
      - An exclusive bicycle phase, in which all vehicle movements are restricted.

The decision to provide a protected phase or a leading bicycle interval for a separated lane or shared use path (see Section 12B-2) should be based on a need to eliminate or manage conflicts and improve safety at an intersection. The potential for conflict at a given intersection is evaluated using the volume of turning motor vehicles crossing the bikeway. Table 12B-3.10 provides peak hourly volume thresholds for turning motor vehicle traffic crossing a bikeway to determine when a protected phase or leading bicycle interval should be considered.

Table 12B-3.10: Hourly Turning Traffic Thresholds for Time-Separated Bicycle Movements

Facility Operation	Left Turn Crossing One Oncoming Lane	Left Turn Crossing Two Oncoming Lanes
One-Way Separated Bike Lane		
Two-Way Separated Bike Lane or Shared Use Path		

* Threshold also applies to left turns on one-way streets

Source: Adapted from MassDOT *Separated Bike Lane Planning and Design Guide*

b. Signal Timing: Practitioners should consider the operating characteristics for bicyclists when calculating minimum green, yellow change, and red clearance interval design, which in most cases are determined by signal timing requirements for higher speed motor vehicles. A design speed of 8 mph and acceleration of 2.5 ft/s^2, which is the speed and acceleration of a slow moving adult bicyclist, is recommended.

- **Bicycle Minimum Green:** In many cases, the existing vehicle minimum green will not be adequate for a bicyclist. Vehicle minimum green types, ranging between 4 and 15 seconds, are based primarily on driver expectancy and queue clearances. With a 4 second minimum green (not uncommon for a minor street approach), a typical adult bicyclist only has time to react and begin accelerating, traveling less than 10 feet. A minimum green time based on a bicyclist traveling halfway across the intersection will typically result in a phase length long enough for a bicyclist to fully clear the intersection before the conflicting approach receives the green indication. However, at some wider crossings, the minimum green time may need to be longer.

Table 12B-3.11: Bicycle Minimum Green Time

D (ft)	Minimum Green (s)	D (ft)	Minimum Green (s)
25	6.5	110	13.7
30	6.9	115	14.1
35	7.3	120	14.6
40	7.8	125	15
45	8.2	130	15.4
50	8.6	135	15.8
55	9.0	140	16.3
60	9.5	145	16.7
65	9.9	150	17.1
70	10.3	155	17.5
75	10.7	160	18.0
80	11.2	165	18.4
85	11.6	170	18.8
90	12.0	175	19.2
95	12.4	180	19.7
100	12.9	185	20.1
105	13.3	190	20.5

Source: Adapted from MnDOT *Bicycle Facility Design Manual*

Equation 12B-3.02

$$G_{min} = t + \frac{1.47v}{2a} + \frac{d + L}{1.47v}$$

where:

G_{min} = bicycle minimum green time, s
v = attained bicycle crossing speed, assumed 8 mph
t = perception reaction time, assumed 1.5 s
a = the bicycle acceleration, assumed 2.5 ft/s^2
d = distance from stop bar to middle of the intersection, ft
L = typical length of a bicycle, assumed 6 ft

- **Total Phase Length**: Depending upon intersection width, change, and clearance intervals, the total phase time may not be sufficient for a bicyclist to clear the far side of the intersection before the conflicting approach receives the green indication. After the minimum green time is calculated based on the following equation, it should be evaluated to verify that the total phase time is greater than the total time for a bicyclist starting from a stop to cross the intersection. The minimum green time should be increased until the total phase time is equal to or greater than the total time for a bicyclist to cross the intersection.

Equation 12B-3.03

$$G_{min} + Y + R_{clear} \geq t + \frac{1.47v}{2a} + \frac{W + L}{1.47v}$$

where:

G_{min} = bicycle minimum green time, s
Y = yellow change interval, s
R_{clear} = all red interval, s
W = intersection width, ft
L = typical length of a bicycle, assumed 6 ft
v = attained bicycle crossing speed, assumed 8 mph
t = perception reaction time, assumed 1.5 s
a = bicycle acceleration, assumed 2.5 ft/s^2

M. Bridges and Viaducts for Bicycles

Two considerations should be considered 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 including paved shoulders, shared lanes, or a 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 bicyclists will be deterred. (AASHTO *Bicycle Guide* 4.12.5).

N. Traffic Calming and Management of Bicycles

There are many things a designer can do to reduce the traffic speed of bicyclists 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 *Bicycle Guide* 4.12.6 and 4.12.7).

O. Intake Grates and Manhole Castings for Bicycle Travel

Intake grate openings should run perpendicular to the direction of travel to prevent bicycle wheels from dropping into the gaps and causing crashes. SUDAS Specifications Figure 6010.603, Type R and Type S, are intake grates 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 completely eliminate the grate. The presence of the depressed throat of the intake should be considered.

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 to avoid “birdbaths” or low spots that are not drainable in the pavement. (AASHTO *Bicycle Guide* 4.12.8).

P. Bicycles at Interchanges

Any work on the design of interchanges, including facilitating bicycle travel, must be coordinated with Iowa DOT. This subsection is provided for informational purposes because freeways and limited access facilities pose major barriers to people bicycling. The challenges posed by bicyclists crossing interchanges include:

- **Multiple Crossings:** Interchanges often require bicyclists to cross several ramps and intersections in stages. This can result in complex movements and delays.
- **Free-flow Movements:** Where ramps are free-flowing, it can be difficult and unsafe for bicyclists to find safe gaps to cross in a motor vehicle traffic stream that is high volume, high speed, or both.
- **Long Crossings and Skewed Crossings:** On and off-ramps often require bicyclists to cross a channelized traffic lane of motor vehicles traveling at high speeds at skewed angles. In urban areas, off ramps may have several lanes of traffic to store motor vehicles exiting the freeway and turning at signalized intersections. The more lanes of traffic, the longer the crossing distance for bicycles.

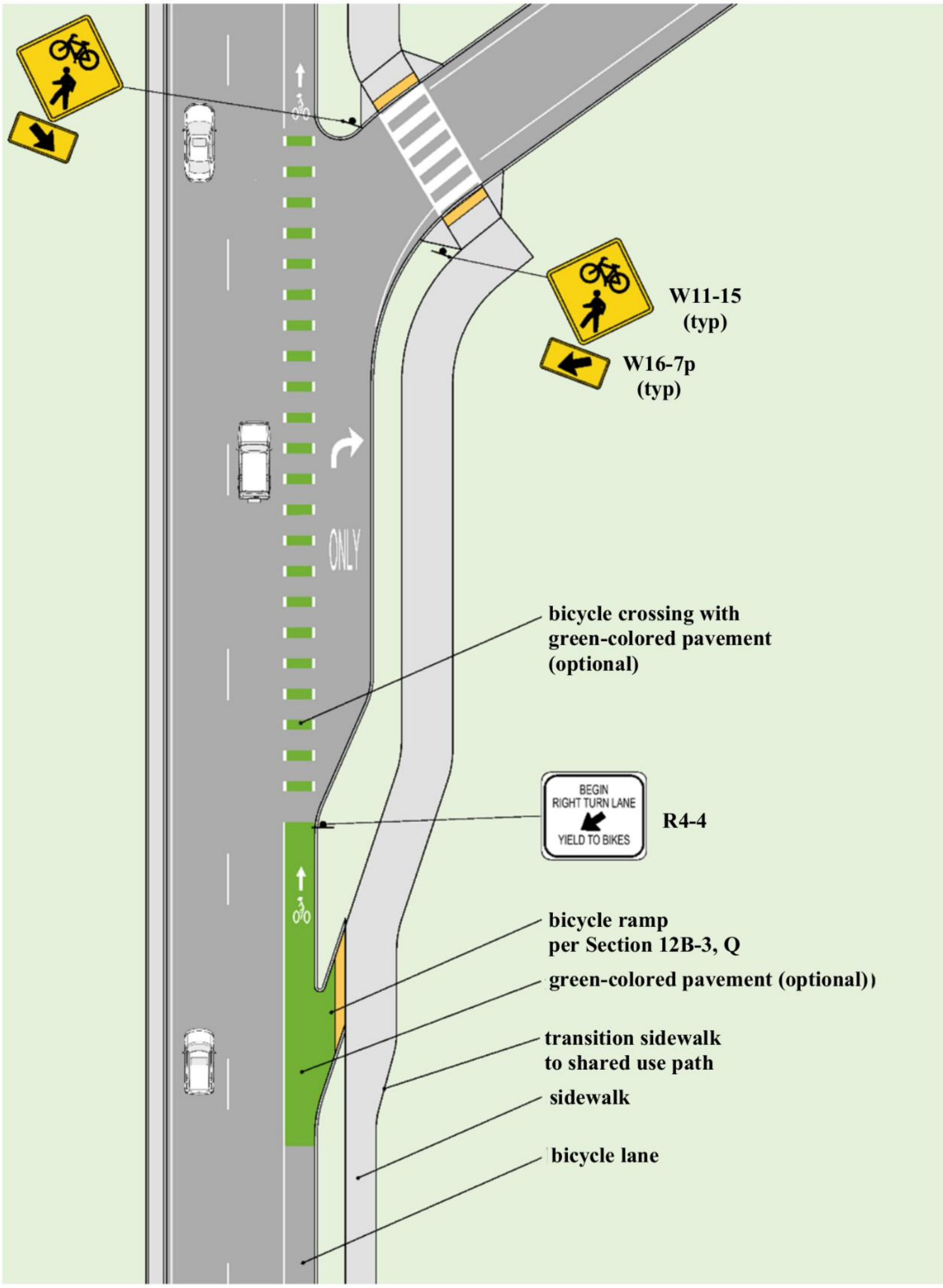
To be in compliance with Iowa DOT's Complete Streets policy, the paved shoulder widths and/or bicycle lane widths specified in Sections 12B-3, D and 12B-3, E must be continued through interchanges unless a design exception is granted.

When designing bicycle facilities at interchanges, it is important to consider safety, comfort, and convenience for the bicyclists. This is best achieved by designing ramps to intersect roadways at an angle of 60 to 90 degrees, and/or using single lane roundabouts for traffic control at the intersection between the local route and the ramps. Although freeways and limited-access facilities pose major barriers to bicyclists, continue paved shoulders at least 4 feet wide of bicycle lanes through interchanges unless a design exception is granted. These designs promote low speeds, minimize conflict areas, and increase visibility.

In many cases, it is not feasible to design interchanges with those preferred elements. In these cases, the higher speeds and volumes at these locations may justify the selection of a separated bicycle lane or shared use path following the bikeway selection guidance in Section 12B-1. For a shared use path to provide the desired level of comfort and safety, crossings of traffic streams will require special consideration.

1. **Entrance Ramps**: Many of the safety challenges associated with entrance ramps are due to right and left-turn movements across a bikeway to access the ramp. For ramp crossing locations where vehicle speeds are likely to be 30 mph or less at the crossing, and ramp volumes result in regular gaps in traffic, it may be acceptable to provide on-street bicycle lanes. The potential conflict zone with turning motorists should be marked with dotted lines and green colored pavement at the crossing, see Figure 12B-3.20. However, at locations with higher speeds and ramp volumes of right turning motor vehicles, the designer should consider a bicycle lane, separated bicycle lane, or a shared use path following the bikeway selection guidance in Section 12B-1.

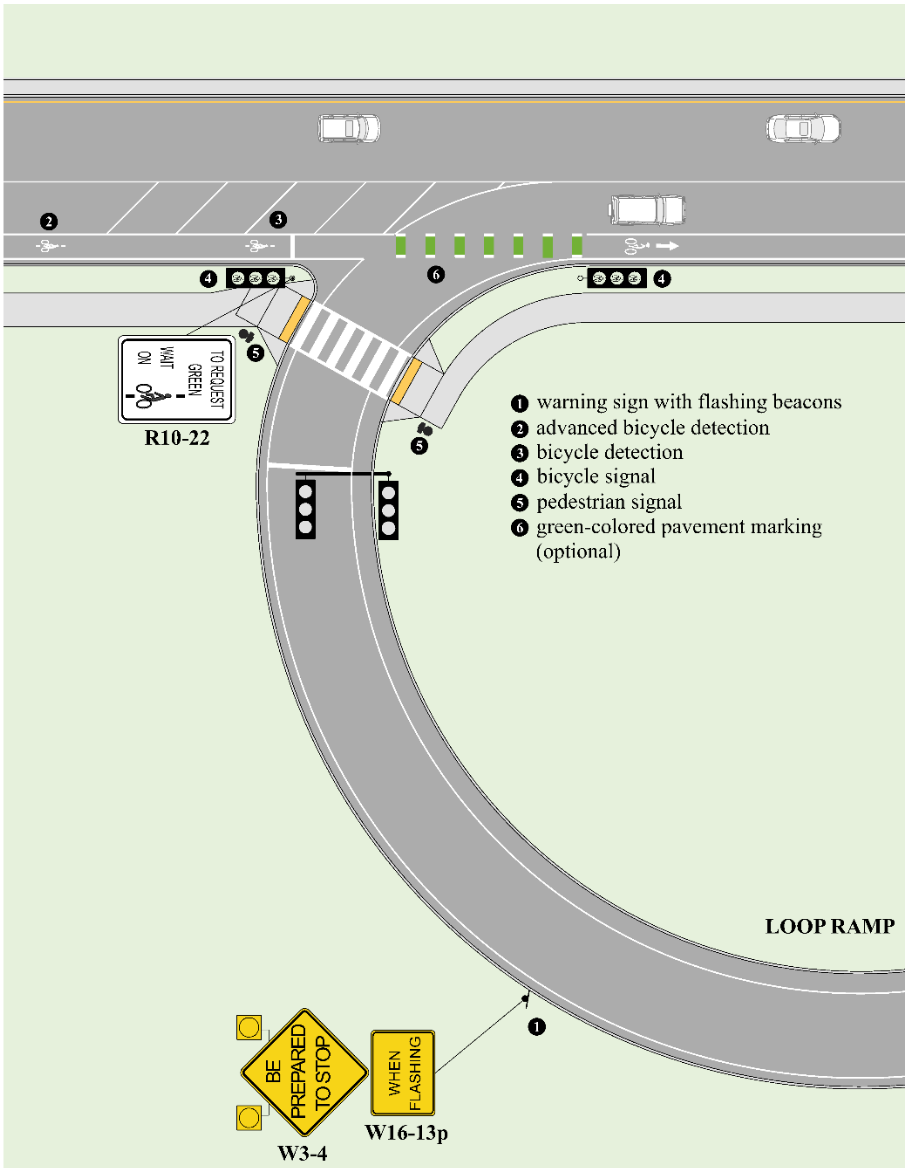
Figure 12B-3.21: Entrance Ramp with Right-Turn Lane, Bicycle Lane, and Shared Use Path



Source: Adapted from MnDOT *Bicycle Facility Design Manual*

2. **Exit Ramps:** Exit ramps can be difficult and unsafe for bicyclists to traverse due to the angle of the ramp and the often significant speed differential between bicyclists and motorists. Stop signs or signals are encouraged for motorists turning from the off ramp to the local route rather than allowing a free-flowing movement because this will increase the safety of the bicyclists. For ramp crossings where vehicle speeds are likely to be 30 mph or less at the crossing and ramp volumes result in regular gaps in traffic, it may be acceptable to provide on-street bicycle lanes. The potential conflict zone with turning motorists should be marked with dotted lines and green colored pavement at the crossing. Designs that permit high-speed free-flow movements from the exit ramp to an arterial roadway are not advised if regular bicycle and pedestrian activity is expected at the crossing locations. If prevailing vehicle speeds and volumes limit yielding behavior or adequate gaps in traffic, or where sight distance does not meet recommended criteria, it may be necessary to consider an active warning device or a traffic signal, as shown in Figure 12B-3.21.

Figure 12B-3.22: Exit Ramp with Bicycle Lane Crossing and Advance Warning or Traffic Signal



Source: Adapted from MnDOT *Bicycle Facility Design Manual*

At complex interchanges that have high volumes of bicyclists or pedestrians, 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 *Bicycle Guide* 4.12.9).

Two design guides provide detailed guidance on how to safely and accessibly provide safe facilities for people biking through interchanges:

1. ITE *Design Guidelines to Accommodate Pedestrians and Bicyclists at Interchanges*, 2016, identifies specific dimensions, safety features, signage, pavement markings, design geometries, and other treatments.

2. NCHRP Research Report 948: *Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges*, 2021, provides specific guidance for other alternative interchange designs such as Diverging Diamond Interchange, Restricted Crossing U-Turn, Median U-Turn, and Displaced Left-Turn.

Q. Bicycles at Roundabouts

In designing roundabouts for bicycle usage, single lane roundabouts are safer and easier to navigate for bicyclists. Multi-lane roundabouts include too many conflict points due to bicyclists weaving/changing lanes and motorist cutting off bicyclists 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 bicyclists to merge into traffic. While some bicyclists may be comfortable traversing a roundabout in a shared lane environment, many bicyclists will not feel comfortable navigating roundabouts with vehicular traffic, especially multi-lane roundabouts, high-speed design roundabouts, and/or complex roundabouts. For comfort and safety reasons, roundabouts may be designed to facilitate bicycle travel on a shared use path.

Although the MUTCD directs on-street bicycle lanes to be terminated in advance of roundabouts, bicyclists should be given the option to merge with traffic and ride through the roundabout as a vehicle, or exit onto the adjacent sidewalk via a ramp. In many jurisdictions, bicyclists riding on sidewalks may be prohibited. However, the sidewalk can be widened and converted to a shared use path so it is lawful for bicyclists to traverse the roundabout separated from traffic. Bicycle ramps transition from the roadway to sidewalks prior to a roundabout and 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 to prevent pedestrians from mistaking the ramp as a crosswalk.
- Bicycle ramps should be placed at a 35 to 45 degree angle to the roadway.
- Bicycle ramps are intended for the exclusive use of bicyclists and therefore the slopes need not comply with pedestrian accessibility guidelines. Ramp grades can be steeper than pedestrian curb ramps; however, grades of 5 to 8% can help to address issues of comfort when transitioning from one elevation to another.

- Where a bicycle ramp connects directly into a sidewalk or shared use path, use a detectable warning surface at the top of the bicycle ramp and supplement with a directional indicator to guide pedestrians away from the bicycle ramp.
- The cross slope of a bicycle ramp should not be more than 2% to reduce the chance of bicyclists slipping on the bicycle ramp, especially during winter months.

If the ramp is placed within the sidewalk, it should be designed to meet accessibility requirements and include detectable warning surfaces at the bottom of the ramp instead of the top.

Bicycle ramps at the exits of roundabouts should be built with the similar geometry and placement as ramps 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 *Bicycle Guide* 4.12.11 and the FHWA Roundabout Guide.

R. References

American Association of State Highway and Transportation Officials (AASHTO). *A Policy on Geometric Design of Highways and Streets* (referred to as “Green Book”). Washington, DC. 2004.

American Association of State Highway and Transportation Officials (AASHTO). *Guide for the Development of Bicycle Facilities*. Fourth Edition. Washington, DC. 2012.

Federal Highway Administration (FHWA). *Separated Bike Lane Planning and Design Guide*. U.S. Department of Transportation, Washington, DC. 2015.

Institute of Transportation Engineers (ITE). *Recommended Design Guidelines to Accommodate Pedestrians and Bicycles at Interchanges.* Washington, DC. 2016.

National Association of City Transportation Officials, (NACTO). *Urban Bikeway Design Guide.* Second Edition. New York, New York. 2014.

National Association of City Transportation Officials, (NACTO). *Don’t Give Up at the Intersection.* New York, New York. 2019.

National Cooperative Highway (NCHRP) Research Report 641: *Guidance for the Design and Application of Shoulder and Centerline Rumble Strips.* Transportation Research Board, Washington, DC. 2016.

National Cooperative Highway (NCHRP) Research Report 766: *Recommended Bicycle Lane Widths for Various Roadway Characteristics*. Transportation Research Board, Washington, DC. 2014.

National Cooperative Highway (NCHRP) Research Report 926: *Guidance to Improve Pedestrian and Bicycle Safety at Intersections.* Transportation Research Board, Washington, DC. 2020.

National Cooperative Highway (NCHRP) Research Report 948: *Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges*. Transportation Research Board, Washington, DC. 2021.

Ohio Department of Transportation (Ohio DOT). *Multimodal Design Guide.* Columbus, Ohio. 2022.

Table of Contents

Chapter 13 - Traffic Control

13A Traffic Signals

13B Work Zone Traffic Control

Traffic Signal Features

A. Traffic Control Signal Features

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

B. Pedestrian Control Features

The MUTCD Chapter 4E Pedestrian Control Features establishes pedestrian control uniformity and serves as a critical resource for each traffic signal design. Pedestrian signal heads provide special types of traffic signal indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK), an UPRAISED HAND (symbolizing DONT WALK), and a countdown display.

Accessible pedestrian signals (APS) communicate information about pedestrian signal timing in nonvisual formats and are integrated with pedestrian pushbuttons. For jurisdictions complying with PROWAG, APS installation is required on any new traffic signal with a pedestrian signal or where there will be significant changes to an existing signal (R209.1). All intersections where pedestrians are expected, regardless of whether the pedestrian phase is automatic or requires actuation, shall be accessible for people with disabilities. This often means accessible pushbuttons are installed in locations with automatic pedestrian phases. APS should be installed at locations where signals are retimed to include a leading pedestrian interval (LPI) or exclusive pedestrian phase (EPP). Without APS units, pedestrians with low or no vision may not be able to maximize the advantage of these signal timing strategies, as they otherwise use the noise of concurrent vehicles to determine when to begin walking. Signal design guidance for pedestrian control and safety is provided in Section 13A-4, F.

C. Agency Specific Information

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

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

- The MUTCD requires a maximum distance of 180 feet from the stop line to the 12 inch signal faces unless a near side supplemental signal face is used. A previous version required a maximum distance of 150 feet and some agencies continue to follow the old requirement.
- Some agencies center mast arm mounted signal heads over the lane line and others center them over the center of the lane.
- Certain agencies elect to install supplemental signal heads on the vertical shaft of the mast arm pole and others elect not to.
- Doghouse style five section heads are used for protected/permissive left turns by some agencies but not others.
- Protected / permissive left turn operation can vary. Some agencies configure left turn lane detection to call the protected phase only when two to three vehicles are queued, while other agencies always call the protected phase.
- Detector types, sizes, and layouts vary between agencies.
- The size and number of conduits, handholes, and wiring varies greatly among agencies.
- Some agencies share conduit between signal cable, street light power, and/or interconnect while others keep these cables in separate conduits.
- Some agencies choose to install emergency vehicle preemption.
- Some agencies choose to install traffic monitoring (PTZ) cameras.
- Signal wiring details vary among agencies.
- Some agencies use the “astro” type brackets to mount all signal heads and others do not use this on side of pole mounted heads. Bracketing and banding of all hardware (typically to the poles) varies greatly among agencies.
- Traffic signal cabinets, cabinet risers, and controller types and preferences vary greatly among agencies.
- Mounting heights for signal heads, street light luminaires, detection cameras, monitoring cameras, etc. vary greatly among agencies.
- Pedestrian signals may or may not include assessible pedestrian signals (APS), with or without voice messages.
- Pedestrian signals may or may not have leading pedestrian intervals (LPI).
- Agencies use a variety of signal interconnect and communication systems including fiber optic cable, wireless systems, and GPS timeclocks.
- Pedestrian walking speed for crossing interval timing may vary.

D. Signal Design Criteria

Signal designers should coordinate with the agency regarding specific traffic signal elements to be included in a project. This is particularly important for a first project with a new agency. A list or memoranda regarding signal design criteria for review by and discussion with the agency early in the project development may be of significant benefit to both the engineer and agency. The following is a list of possible signal design criteria items to consider:

1. **General:** General nature of the signal project - new installation, replacement, minor modifications, or major modifications.

2. **Signal Phasing:**
   a. Phase numbering (Phase 2 southbound or major through movement)
   b. Left turn phasing for each approach (protected-only, protected-permissive, permissive-only, split-phase)
   c. Leading pedestrian interval
   d. Use of overlaps
   e. Bicycle green time, if applicable

3. **Signal Heads:**
    a. Based on proposed left turn phasing
    b. Overhead locations relative to lane lines
    c. Side-of-pole locations
    d. Head configurations, displays, color
    e. Pedestrian signal head type (1-section or 2-section)
    f. Head mounting hardware and bracket types
    g. Backplates, visors

4. **Poles:**
    a. Pole types (mast arm, combination mast-arm/ lighting, pedestal)
    b. Pole locations considering clear zone, sidewalk, utilities and right-of-way constraints
    c. Pole base types (T-base or anchor base)
    d. Luminaire mounting height for combination poles
    e. Special pole finishes (paint, powdercoat)
    f. Special pole handhole needs

5. **Detection:**
    a. Type of vehicle detection (video, pavement loops, microwave, other)
    b. Advance detection based on approach speeds
    c. Detection to accommodate Automated Traffic Signal Performance Measures
    d. Emergency Vehicle Preemption (EVP) detectors
    e. Pedestrian pushbuttons (APS or non-APS)
    f. Pushbutton locations per ADA and MUTCD guidance
    g. Special detection needs (bicycles)

6. **Controller/ Cabinet:**
    a. Controller type or model (NEMA, ATC, 2070)
    b. Cabinet type or model (TS1, TS2, ATC, 2070)
    c. Cabinet location
    d. Pad or pole-mounted cabinet
    e. Battery back-up (UPS)
    f. Cabinet riser height
    g. Meter location
    h. Misc. cabinet equipment
    i. Voltage output
    j. Number of inputs/outputs

7. **Conduit and Wiring:**
    a. Conduit sizes and types
    b. Separate conduits for lighting, power and/or fiber optic cable
    c. Signal cable configurations (number of conductors)
    d. Lighting cable sizes
    e. Ground wire, tracer wire and pull tape
    f. Fiber optic cable configuration, routing, termination and splicing
    g. Misc. cables (video, EVP, Cat 5/6, etc.)

8. **Handholes:** Handhole types and locations, including whether to provide one near the controller, and for the ground rod near the foundation.

9. **Interconnect:**
   a. Need for coordinated signal operation
   b. Type of interconnect
   c. Modifications needed at adjacent signalized intersections

10. **Power Service:**
    a. Coordination with utility company for exact location of power service and identification on plans
    b. Power source location and type (overhead or pad-mounted transformer)
    c. Meter requirements
    d. Metered or un-metered lighting

11. **Signs:**
    a. Street name signs
    b. Lane use signs
    c. Traffic signal signs
    d. Pedestrian pushbutton signs

12. **Construction Staging:**
    a. Potential need for temporary signals and/or detection
    b. Lane closures
    c. Special requirements

13. **Miscellaneous:**
    a. Potential need for advanced warning flasher
    b. Construction schedule and anticipated pole and equipment lead times
    c. Supplemental specifications and/or plan notes as needed
    d. Signal turn-on procedure, possible portable dynamic message signs
    e. Luminaires for combination poles

E. Additional Information

In addition to typical vehicle and pedestrian signals, the MUTCD also provides guidance on the following types of traffic signals:

Chapter 4F Pedestrian Hybrid Beacons
Chapter 4G Traffic Control Signals and Hybrid Beacons for Emergency-Vehicle Access
Chapter 4H Traffic Control Signals for One-Lane, Two-Way Facilities
Chapter 4I Traffic Control Signals for Freeway Entrance Ramps
Chapter 4J Traffic Control for Movable Bridges
Chapter 4K Highway Traffic Signals at Toll Plazas
Chapter 4L Flashing Beacons
Chapter 4M Lane-Use Control Signals
Chapter 4N In-Roadway Lights

Traffic Signal Design Considerations

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

A. Geometrics

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

References are made to *Signalized Intersections: Informational Guide*, Second Edition, FHWA-SA-13-027, July 2013, which provides a single, comprehensive document with methods for evaluating the safety and operations of signalized intersections and tools to remedy deficiencies. The treatments in this guide range from low-cost measures such as improvements to signal timing and signage, to high-cost measures such as intersection reconstruction or grade separation. While some treatments apply only to higher volume intersections, much of this guide is applicable to signalized intersections of all volume levels.

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

   Geometric design profoundly influences roadway safety; it shapes road user expectations and defines how to proceed through an intersection where many conflicts exist. In addition to safety, geometric design influences the operational performance for all road users. Minimizing impediments, reducing the need for lane changes and merge maneuvers, and minimizing the required distance to traverse an intersection all improve intersection safety and operational efficiency.

   All possible road users' (Chapter 2 of the guide) needs must be considered to achieve optimal safety and operational levels at an intersection. When road user groups' design objectives conflict, the practitioner must carefully examine the needs of each user, identify the tradeoffs associated with each element of geometric design, and make decisions with all road user groups in mind. However, one user's convenience or mobility should not be prioritized over another user's safety. For instance, practitioners may design corner radii to accommodate large vehicles. However, these larger radii could be detrimental to pedestrian safety due to the increase in walking distances and the increase in speed of turning vehicles. Stop bars may be adjusted or truck aprons added to allow for larger vehicle turning movements while keeping speeds lower, which prioritizes the safety of all users. In areas of high pedestrian activity and/or where vulnerable users are likely to be present, e.g. near schools, hospitals, church, etc., or when a local jurisdiction's adopted transportation plan calls for prioritizing pedestrian safety, designers should incorporate geometric design features to improve safety for pedestrians, see Section 12A-5.

The geometric design chapter (Chapter 4 of the guide) addresses the following design topics to be considered when designing traffic signal controlled intersections:

- 4.1 Number of Intersection Legs
- 4.2 Channelization
- 4.3 Horizontal and Vertical Alignment
- 4.4 Corner Radius
- 4.5 Sight Distance
- 4.6 Pedestrian Treatments
- 4.7 Bicycle Facilities
- 4.8 Transit Facilities

2. Additional Sight-Distance Considerations:

a. Sight distance is a safety requirement that impacts intersection geometrics as fundamental as horizontal and vertical alignments. It is a design requirement that is discussed in detail as it relates to the visibility of traffic signal indications in the MUTCD. In addition to the sight distance requirements of the MUTCD, the AASHTO "Policy on Geometric Design of Highways and Streets 2018" states that at signalized intersections, the first vehicle stopped on one approach should be visible to the driver of the first vehicle stopped on each of the other approaches. It also states that left turning drivers need sufficient site distance to decide when to turn left across the lane(s) used by opposing traffic. This requires consideration of offset left turn lanes for permissive left turns to provide adequate left turn sight distance. If right turns are allowed on a red signal indication, the appropriate sight distance to the left of the right turning vehicle should be provided. See Chapter 9 - Intersections in the AASHTO "Policy on Geometric Design of Highways and Streets 2018" for additional sight distance information.

b. One sight distance issue that deserves additional consideration is the sight triangle and the sight obstructions found within it. Certain obstructions are obvious like structures near the street. Other obstructions are not always obvious or are installed after the traffic signal is designed and constructed. These obstructions seem to blend into the background. They are obstructions like entrance monuments, parked vehicles, special street name signs, business signs, and landscape vegetation that may not be a problem initially but become a problem as the plants reach maturity. Finally, be aware of the signal cabinet size and location including the height of the footing or cabinet riser so it does not become a sight obstruction.

c. Sight distance requirements are less restrictive at signalized intersections as drivers are required by law to obey the signal indications; however, there are instances when drivers do not obey traffic signals. A traffic signal should be designed to exceed minimum sight distance requirements when possible. Drivers are taught to drive defensively and providing additional sight distance will only aid drivers in collision avoidance.

3. Turn Lanes:

a. Traffic volumes, turning movement counts, and crash history are used to complete intersection capacity and safety analyses. The results of the analyses determine the need for and length of turn lanes. The turn lane information is used to properly design the geometrics of signalized intersection approaches.

b. Turn lane capacity issues often create safety problems. Left or right turning vehicle queues blocking through traffic create increased potential for rear-end crashes. Sideswipe potential also increases as traffic attempts to maneuver out of defacto turn lanes or around left turn queues blocking through lanes. High volumes of turning vehicles combined with high volumes of opposing vehicles significantly reduce the number and size of available gaps needed to complete turning maneuvers increasing the potential for right angle collisions. As a result, properly designed turn lanes improve safety as well as capacity.

c. The need for turn lanes, turn lane storage lengths, and other geometric or traffic control improvements should be determined based on traffic operations analyses of existing and projected design year peak hour traffic. Traffic engineers typically use traffic analysis and/or simulation software for these analyses.

B. Operational Characteristics

The behavior of the traffic at an intersection is another highly important element of signal design. The MnDOT Traffic Engineering Manual Section 9-7.03 notes the various elements that should be considered.

C. System (Arterial) Considerations

In many cases, an individual traffic control signal must be considered as part of a system, either as one of a series of signals along a linear route, or as one signal in a grid network. MnDOT Section 9-7.04 notes the elements to be considered. In addition, note the following:

Traffic actuated controllers are most often used. The actuated controller tends to reduce the number of stops and does not cut off platoons of vehicles. In the suburban environment, the arterial streets tend to be very wide, and traffic volumes are often significant.

Signals are typically timed to prioritize the “major” street movements, which under certain conditions may increase delay for pedestrians and bicyclists waiting to cross the major street. Streets in lower density, suburban settings often do not have comparable pedestrian volumes as more dense, urban networks. However, these corridors may have transit operation or land uses across the major street to encourage pedestrian crossings (e.g. a park across from a residential neighborhood), which may make road crossing decisions challenging without appropriate crossing opportunities.

In some instances, where pedestrians routinely experience long delays at signals, they may elect to cross away from the crosswalk at locations where conflicts are not controlled by a signal. Therefore, strategies to reduce overall cycle length and provision of safe crossing based on the surrounding land use is important for pedestrian safety. Designers should also evaluate the frequency and location of crossing opportunities along a linear route and provide safe crossings where needed based on the roadway context; see Section 12A-5.

A split is the relative percentage of green, yellow, and red clearance time allocated to each of the various phases at a single intersection. An offset is a system reference time, usually expressed in seconds but sometimes in percent of cycle length.

D. Signal Design Elements

The following publications provide a wide range of guidance in the design of traffic signals and the needs of pedestrian and bicyclists at signalized intersections:

- Manual of Traffic Signal Design, Second Edition, ITE
- Traffic Control Devices Handbook, Second Edition, ITE
- Signalized Intersections: Informational Guide, Second Edition, FHWA
- Signal Timing Manual, NCHRP Report 812
- Achieving Multimodal Networks, FHWA
- Urban Street Design Guide, NACTO
- Walkable Urban Thoroughfares, ITE
- Don't Give Up at the Intersection, NACTO

Traffic signal designs should be based on project and intersection-specific design criteria (Section 13A-3, D). Key elements to consider and include in the design, as appropriate, include the following:

1. Signal Layout:

a. Pole locations considering clear zone requirements, existing and proposed utilities, signal head locations, mast arm lengths, lighting needs, elevation differences, pedestrian pushbutton locations, and right-of-way constraints.

b. Cabinet location considering proposed power service, signal interconnect, sight distance, and cabinet accessibility.

c. Motor vehicle and pedestrian signal head locations and configurations considering visibility and proposed phasing. Where bicycle lanes are present, signals must be visible to bicyclists or provide a separate indication, see Section 12B-3, L for guidance.

d. Handhole locations and conduit layout to minimize lengths of conduit runs. Consider providing a larger (Type III or IV) handhole near the signal cabinet and routing all signal conduits to the cabinet through this handhole.

e. Signing needs.

f. Stop line and advance detection.

g. Miscellaneous equipment (EVP, traffic monitoring camera, etc.)

2. Conduit and Wiring:

a. Conduit sizes considering conduit fill percentage.

b. Wiring quantities and configurations based on equipment needs.

c. Fiber optic cable configuration, terminations, and splicing.

3. Phasing and Timing:

a. Type of left turn phasing (protected-only, protected-permissive, permissive-only) for each approach.

b. Possible right turn overlap for right turn lanes or turn restrictions to reduce conflicts with pedestrians and bicyclists.

c. Phasing sequence diagram.

d. Recommended initial timings.

4. Miscellaneous Items:

a. Traffic signal notes and supplemental specifications, as needed.

b. Estimated traffic signal quantities.

c. Specific equipment or materials requirements.

d. Reference or include applicable SUDAS Specifications Section 8010 figures and/or special details needed.

E. Traffic Signal Operations

The following publications provide guidance regarding traffic signal timings and operations:

- Signal Timing Manual, NCHRP Report 812
- Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections, NCHRP Report 731
- Section 4E.06 Pedestrian Intervals and Signal Phases, MUTCD
- Interim Approval for Optional Use of a Bicycle Signal Face, FHWA IA-16
- Section 12B-3, L

1. Left Turn Phasing Considerations: Traditionally, protected-only left turn phasing has been used for dual left turn lanes, due to safety concerns with permissive operation. However, protected-only left turn phasing can be inefficient, particularly during off-peak times. If protected-permissive or permissive-only left turn phasing is being considered, a traffic engineering study should be performed, including evaluation of the following:

- Operating speeds
- Possible sight distance obstructions (vehicles in opposing left turn lane(s), horizontal/vertical roadway geometry)
- Left turn and opposing through traffic volumes (vehicle mix - trucks)
- Left turn crossing distance
- Crash history
- Vehicle delays and queuing
- Potential pedestrian crossing conflicts
- Controller, cabinet and equipment flexibility and limitations

If protected-permissive or permissive-only operation is determined to be acceptable, flashing yellow arrow signal heads are required for separate signal faces per the MUTCD. Consideration should be given to providing this type of operation only during off-peak times.

2. **Automated and Adapted Traffic Signal Control:** To help jurisdictions better manage the variations in traffic volumes and operating speeds along signalized corridors, the use of automated traffic signal performance measures (ATSPMs) and/or adaptive traffic signal control (ATSC) could be considered.

   The use of ATSPMs give agencies a better idea of how signal timing plans are performing throughout the day / week / month / year and provide the information needed to make adjustments to fine tune timing plans and coordination plans. New traffic signal controllers, or third party equipment added to existing traffic signal controllers, collect the real-time data needed to produce the performance reports. More information can be found on the FHWA ATSPM Website.

   The data produced through the ATSPMs can be used to determine the potential need for an ATSC system, which utilizes much of the same data collected for ATSPMs and adjusts traffic signal plans or coordination plans automatically. ATSC systems can be useful for corridors in which traffic is more variable or unpredictable than what could be addressed with specific time-of-day timing and coordination plans. More information can be found on the FHWA ATSC Website.

3. **Signal Cycle Length:** The signal cycle length at an intersection can have a significant impact on pedestrian and bicyclist travel. Signal cycle lengths of 60 to 100 seconds are common in urban areas, as they allow frequent street crossings and encourage efficient use of a street network. In suburban areas where vehicle traffic is consolidated on a relatively small number of arterial and collector streets, signal cycle lengths are typically longer - between 100 and 120 seconds, sometimes even longer during peak periods. At intersections with a longer signal cycle length, all users approaching from a minor street can experience significant delays. This can result in reduced signal compliance for both pedestrians and bicyclists where gaps are present. Consideration should be given to providing shorter signal cycle lengths during peak and off-peak times, or operating in "free" or fully actuated mode during off-peak periods so the signal switches to the side street phase more quickly to minimize delays to side street users including bicyclists. However, signal cycle length reductions must not come at the cost of adequate pedestrian crossing intervals.

4. **Pedestrian and Bicyclist Signal Timing and Phasing for Reducing Delay and Managing Conflicts:** Frequent crossings accommodating walking and biking speeds for all ages and abilities are key to creating a safe, accessible, and connected pedestrian and bicycling network. Sections 13A-4, F and 12B-3, L provide guidance on pedestrian and bicycle signal timing and detection, respectively. As motor vehicle speeds and volumes increase, separate signal phasing may be appropriate to improve safety for all users. Guidance for signal phase separation is also described in Sections 13A-4, F and 12B-3, L.

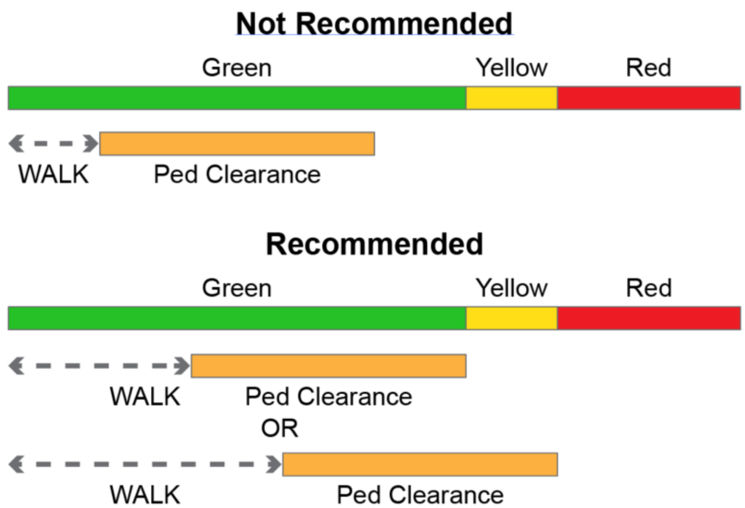
F. Pedestrian Signal Timing and Design

1. **Signal Timing:**

   a. **Signal Cycle Length:** In some instances, where pedestrians routinely experience long delays at signals, they may elect to cross away from the crosswalk at locations where conflicts are not controlled by a signal. Therefore, strategies to reduce overall cycle length can be particularly important for pedestrian safety. Where pedestrians are expected regularly, cycle lengths greater than 90 seconds should often be discouraged. In addition to reducing cycle lengths, designers may also consider using half-cycle lengths, particularly during off-peak hours. Adaptive signal control, where employed, should have limited variation in cycle length. Operations for adaptive signal control should be confined to suburban settings and event venues where traffic patterns can be highly variable.

b. **Pedestrian Signal Phase Timing:** Details for programming the walk and clearance interval are provided in MUTCD Section 4E.06. Signal timing should strive to maximize the WALK + FLASHING DON'T WALK phase so total pedestrian time is equal to the total concurrent vehicle green and yellow timing; see Figure 13A-4.01. To address conflicts, designers should instead use one or a combination of treatments listed in Section 13A-4, F, 2.

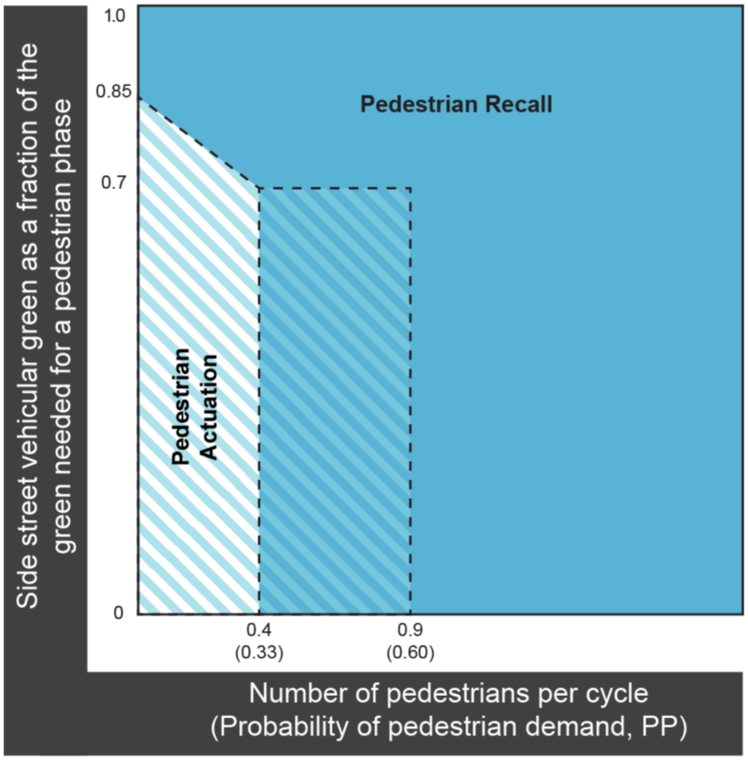
Figure 13A-4.01: Maximizing the WALK Interval.



c. **Recall and Actuation:** Pedestrians should not always be required to push a button to call the pedestrian phase at locations with high pedestrian volumes. This is particularly important in downtown corridors or business districts where there tends to be significant pedestrian volume and relatively short cycle lengths. In such environments, fixed time operation with time-of-day phase plans often functions more efficiently compared to actuated or semi-actuated signal timing. Fixed time operation allows for signal controllers to call pedestrian phases each cycle. In a fixed time grid, pedestrian WALK + FLASHING DON'T WALK intervals are often the maximizing factor for phase length, as the time necessary to accommodate pedestrian movements exceeds the time needed for motor vehicles. Designers may consider providing an automatic pedestrian phase according to Figure 13A-4.02. This could be accomplished based on different signal timing plans at certain times of day or day of the week.

If it is determined the pedestrian phase should switch from actuated to recall based on the time of day, designers can minimize confusion by ensuring the pushbutton includes a confirmation light. When the signal operations have switched to pedestrian recall, the detection indicator can be programmed to illuminate by default.

Figure 13A-4.02: Recall versus Actuated Pedestrian Phase for Coordinate-Actuated Arterials



Source: Cesme, Furth, Cashman, and Lee, 2021

2. **Signal Phasing for Managing or Reducing Conflicts:** There are a variety of alternative signal phasing options for reducing or eliminating conflicts between motorist and pedestrians. Designers should consider both the operational and safety impacts of signal phasing changes at an intersection. Designers should also be aware a phasing scenario may necessitate a separate motor vehicle turn lane and an additional signal phase, which may increase delay for some users, including pedestrians. Fully separated crossings may require longer cycle lengths, which may result in reduced user compliance with signal indications and increased potential for conflict. The four major phasing scenarios, criteria, and considerations are described below. There may not be one solution but a combination of treatments for specific periods or scenarios to address pedestrian safety.

   a. **Leading Intervals:** Leading pedestrian intervals (LPIs) or leading through intervals (LTIs) may be used to give pedestrians a head start (typically a minimum of 3 seconds) when crossing the street. LPIs are a proven safety countermeasure to reduce vehicle-pedestrian crashes at intersections. Implementation allows waiting pedestrians to enter the crosswalk where they become more visible to conflicting motorists. Both LPIs and LTIs accomplish the same goal through different strategies.

      - **Leading Pedestrian Intervals:** With traditional signal phasing, parallel pedestrian WALK and motor-vehicle circular green indications start at the same time, immediately after the conclusion of the red clearance interval. With LPIs, the walk phase begins as usual and parallel motor vehicle circular green indications start after a brief period. Designers should include APS units where LPIs are provided; without APS units, pedestrians with low or no vision may not be able to maximize the advantage of LPIs, as they otherwise use the noise of concurrent vehicles to determine when to begin walking.

- **Delayed Turn or Leading Through Intervals:** A delayed left (or right) turn or LTI provides a green signal to through movements while delaying permissive left (or right) turns for a specific period. This delay time may vary based on site specific conditions, but (similar to an LPI) is usually between 3 and 6 seconds. This option minimizes intersection capacity impacts while providing a partially protected pedestrian phase, allowing those on foot a head start in order to establish themselves in the intersection before turning movements are allowed after the protected left (or right) turn phase.

The following equation is used for calculating the LPI interval (rounded to the nearest second).

$$LPI(sec.) = \frac{W_1 + W_2}{S_w}$$

Equation 13A-4.01

where:

LPI = Leading pedestrian interval, sec
W1 = Width of first lane of moving vehicles, ft
W2 = Width of shoulder, bicycle lane, and/or parking lane, ft
S_w = Walking speed,typically 3.5 ft/sec

Source: Lin, 2017

An approach meeting any one of the following criteria may be a good candidate for the installation of an LPI:

- Reported crash history finds one or more crashes per year have occurred over the last 3 years between vehicles turning on green and pedestrians crossing the street on the associated crosswalk with the pedestrian WALK signal;
- A visibility issue exists between the driver's view of pedestrians on the crosswalk due to obstructions or poor sight distance at an intersection approach that can be improved through an LPI. LPIs by themselves don’t resolve sight distance limitations, as they don’t protect pedestrians who arrive at the end of the WALK phase. Physical measures to remove corner sight obstructions should be given primary consideration;
- Intersection observations reveal conflicts between crossing pedestrians and turning vehicles in which there is a risk of collision should their movements and speeds remain unchanged;
- One of the two movement volumes (turning vehicle volume (A), or pedestrian volume (B), identified in Equation 13A-4.01) meet at least one the thresholds identified in the table for a given warrant.

Table 13A-4.01: LPI Volume Warrant Thresholds

Warrant	Turning Vehicles Volume (A)	Pedestrian Volume (B)
Vehicle Peak Hour	≥ 130 per hour	≥ 25 per hour
Pedestrian Peak Hour	≥ 100 per hour	≥ 50 per hour
4 Hour Vehicular and Pedestrian Volume	≥ 105 per hour	≥ 30 per hour
8 Hour Vehicular and Pedestrian Volume	≥ 100 per hour	≥ 25 per hour
School Crossing	≥ 50 per hour	

Source: Modified Lin, 2017

When a protected left turn phase is provided, it should occur as a lag to prevent left turning vehicles from continuing to cross during the LPI. Designers must avoid the “yellow trap” (see NCHRP Report 812 Section 4.3.1.3) when providing a lagging turn phase.

b. Protected Pedestrian Phase and Turn Restrictions: Protected pedestrian phases or protected-only signal phasing for turn movements can significantly reduce conflicts between pedestrians and motorists. This process eliminates specific motor vehicle phases (e.g. left turns) that cross concurrent pedestrian phases. For example, if the permissive left turns (either green ball or flashing yellow arrow), the cross pedestrian WALK/FLASHING DON’T WALK phase is eliminated and there is no longer a turning conflict for the crossing during that phase. In these cases, pedestrian phases may occur before (lead) or after (lag) conflicting vehicular movements.

Turn restrictions or protected pedestrian phases may be considered when one or more of the following criteria are met:

- There are high conflicting turning vehicles volumes. High turning volumes are defined as equal to or exceeding:
  - 200 total right and left turning vehicles per hour;
  - 50 left turning vehicles per hour when crossing one lane of through traffic; or
  - 100 right turning vehicles per hour.
- There is a high volume of total approaching traffic (greater than 2,000 vehicles per hour for all approaches);
- There are high pedestrian volumes (pedestrians are 30% of vehicle volumes or 300 pedestrians per hour);
- Crash patterns at the study location or nearby locations with similar geometry support the use of separating motor vehicle and pedestrian phasing. Typically, this encompasses three or more left turn or right turn collisions where pedestrians had the right-of-way over a 3 year period;
- The available sight distance is less than the minimum stopping sight distance criteria;
- The intersection geometry is unusual (streets intersect at acute/obtuse angles or streets have significant curvature approaching the intersection), which may result in unexpected conflicts and/or visibility issues;
- The intersection is in close proximity to senior housing, elementary schools, recreational areas, playgrounds, and/or health facilities.

Protected pedestrian phases or protected-only turn phases may be implemented on a permanent basis, during specific hours, or "on-demand" when a pedestrian is present and activates the pushbutton. When used for a specific time of day (school arrival and departure, e.g.), blank out NO TURN ON RED signs or red arrows should be used for conflicting motorist movements when the protected pedestrian phase is in operation. If only one movement or street meets the criteria above, consider a treatment to address those specific issues before implementing an intersection-wide approach (i.e., provide protected-only turns for the major roadway and allow for permissive turns on the minor roadway, if turning volumes are low on the minor roadway).

c. **Concurrent Pedestrian Phase with Permissive Vehicle Turns:** At most signals, the WALK indication for pedestrians is displayed concurrent with the green indication for parallel through vehicular movements. Concurrent timing often allows vehicles to turn left or right across the crosswalk during the WALK and FLASHING DON'T WALK phases with change interval countdown indication (pedestrian clearance interval), provided the motorists yield to pedestrians. To mitigate conflicts and improve motorist yielding, designers may consider the following treatments:
   - Regulatory signs, such as the R10-15a series "TURNING VEHICLES YIELD TO [PEDESTRIANS]"
   - Flashing yellow arrows (see below)
   - Geometric treatments to reduce vehicle speeds and increase sight distances such as raised pedestrian crossings and curb extensions (see Sections 12A-5 and 5M-1)

   Flashing yellow arrows (FYAs) may be used for left or right turning motor vehicles to emphasis drivers may proceed after yielding to oncoming traffic and/or pedestrians in a crosswalk. FYAs allow flexibility in providing permissive turns while warning drivers of potential conflicts. Refer to the Interim Approval (IA-10) and MUTCD for additional guidance.

d. **Exclusive Pedestrian Phases:** An exclusive pedestrian phase (EPP), sometimes referred to as a "Barnes Dance", stops vehicular traffic in all directions, allowing pedestrians to cross the intersection in all directions, including diagonally. This treatment can produce a safer operation over conventional phasing, but delays for both pedestrians and motorists can be higher than conventional signal timing. A protected pedestrian phase, specific turn restrictions, or LPIs are more appropriate solutions. An EPP may be preferred over a protected pedestrian crossing for the following scenarios.
   - A combination of the criteria listed in Section 13A-4, F, 1, a, is met and 15% of pedestrians desire to cross diagonally
   - During special events occupying a substantial portion of the public right-of-way (street fairs, parades, etc.)
   - The start and end of school days for major school crossings
   - Intersections where certain motor vehicle turning movements are either not allowed or not in conflict with designated pedestrian crossings

   Signs may be attached to signal poles or pedestrian pushbuttons to inform people the intersection has an EPP and they may cross diagonally; to inform where an EPP must be actuated by a person waiting to cross; or to deter crossing against the pedestrian signal concurrently with vehicle traffic. Signals including EPP should time pedestrian phases to accommodate the longest possible crossing.

   If a diagonal crossing is employed, designers may need to consider how a person with a visual disability would know they could cross diagonally. Such determinations need to be carefully considered along with pushbutton placement and pedestrian ramp design for accessibility. Pavement markings should be designed according to MUTCD Figure 3B-20.

3. **Geometrics:**

a. Geometrics have a significant impact on pedestrian operations and safety at signalized intersections as alluded to in the previous section. Intersection skew, number of lanes, lane width, medians, islands, and curb returns all impact the distance pedestrians must travel to cross an intersection. As the distance to traverse an intersection approach increases, so does the signal timing that must be allocated to the pedestrian clearance interval. Long pedestrian clearance intervals can have a negative impact on traffic capacity and operations including increased delays to pedestrians, therefore designers minimize overall crossing distance to improve safety and reduce delay for all. Pedestrian actuation will disrupt traffic signal coordination and it may take several cycles to bring a corridor back into coordination; but it can improve safety and have minimal impact to operations during motor vehicle off-peak hours. A traffic engineer must balance the priorities and safety of vehicles and pedestrians at signalized intersections.

b. Right turns present challenges for pedestrians. A driver of a vehicle turning right on red will be looking left for a gap in traffic. A pedestrian approaching from the right may have a walk indication. If the driver sees a gap but does not look back to the right, the pedestrian may not be seen by the driver resulting in a collision. As a result, a traffic engineer must decide whether to allow right turns on red. Right turn on red restrictions may be used to reduce this conflict, though such signs may not be effective if sight distance is not limited by geometry or other roadway features (landscaping, business signs, etc.) without significant enforcement efforts. A NO TURN ON RED (R10-11) sign may be used to always prohibit this movement, or a dynamic NO TURN ON RED sign may be installed to limit turns at specific times or conditions. Where left turns on red are legal on one-way streets, such restrictions may be appropriate for similar reasons.

c. Pedestrian volume and safety are important considerations when designing right turn lanes. Right turn lanes can present additional challenges for pedestrians, especially if the returns are large and channelize traffic with an island and are therefore discouraged where pedestrians are expected. Designers should work to reduce the curb radius and may use elements such as truck aprons to keep speeds low. Where intersections are skewed, channelizing islands can mitigate larger corner radii. Channelizing islands should be designed to slow speeds and maintain visibility between pedestrians and motorists through geometric design; see Exhibit 5-7 of NCHRP Report 834. For retrofits, a raised crossing may be considered to reduce speeds of right turning vehicles and encourage yielding.

d. An additional geometric consideration as it relates to pedestrians is the pedestrian refuge. Right turn islands and medians often double as pedestrian refuges. If islands and medians are intended to be used as pedestrian refuges, they must be large enough to hold pedestrians and be ADA compliant. A traffic engineer must consider the likelihood that pedestrians will stop and get stranded in an island or median. On large approaches, it may be intended that pedestrians only cross a portion of the approach and stop in a median or island. As a result, a traffic engineer must decide whether to install supplemental pushbuttons in the right turn island or median. If islands and medians are not intended to function as pedestrian refuges, they must be located so they do not obstruct the path of pedestrians. See Section 12A-5 for refuge island design guidance.

4. **Visibility:** Visibility is important to the safe operation of the pedestrian indications. Pedestrian indications as well as the pushbuttons should be easily located by pedestrians. Consider where vehicles, especially large trucks, may stop so they do not obstruct the view of the pedestrian indications. This will require careful location of median noses, stop bars, crosswalks, and the pedestrian heads. Finally, make sure there are no obstructions in the returns that may prevent drivers and pedestrians from seeing one another such as the signal cabinet or vegetation.

5. **Countdown Pedestrian Heads:** Pedestrian signals with countdown displays show the number of seconds remaining in the clearance interval and their use has been shown to reduce both pedestrian and vehicular crashes at signals. MUTCD requires countdown pedestrian heads where the pedestrian change interval (the flashing upraised hand signal) is more than 7 seconds; see MUTCD Section 4E.07. Traffic engineers should consider using countdown pedestrian heads for crosswalks where the pedestrian change interval is 7 seconds or less because they are easier to understand for all users.

6. **Americans with Disabilities Act:** The Americans with Disabilities Act (ADA) addresses several design requirements relating to pedestrians. ADA addresses design requirements for items such as sidewalk ramps, truncated domes, and pedestrian pushbuttons. These topics are addressed in detail in Chapter 12 and other design guides such as the MUTCD and the AASHTO Policy on Geometric Design of Highways and Streets.

   a. **Accessible Pedestrian Signals (APS):** Evaluate each traffic signal project location to determine the need for accessible pedestrian signals, especially if the project location presents difficulties for individuals with visual disabilities. The MUTCD contains standards for APS and pedestrian pushbuttons but does not require them. PROWAG requires APS and pedestrian pushbuttons when new signals are installed. For existing pedestrian signals, PROWAG requires APS and pedestrian pushbuttons when the signal controller and software are altered, or the signal head is replaced. An engineering study should be completed that determines the needs for pedestrians with visual disabilities to safely cross the street. The study should consider the following factors:
      - Potential demand for accessible pedestrian signals
      - Requests for accessible pedestrian signals by individuals with visual disabilities
      - Traffic volumes when pedestrians are present, including low volumes or high right turn on red volumes
      - The complexity of the signal phasing, such as split phasing, protected turn phases, leading pedestrian intervals, and exclusive pedestrian phases
      - The complexity of the intersection geometry

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

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

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

1) **Pushbutton Stations:** An APS pushbutton station is a weather-tight housing with a 2 inch diameter pushbutton, a speaker, and a pedestrian sign. Braille signing, raised print or a tactile map of the crosswalk may also be provided. The pushbutton has a vibrotactile arrow pointing in the direction of the crossing.
2) **Location of Pedestrian Pushbuttons:** Pushbuttons (APS and non-APS) should be located adjacent to the sidewalk, between 1.5 and 6 feet from the edge of curb, shoulder, or pavement and no more than 5 feet from the outside crosswalk line (extended). Where physical constraints make the 6 feet maximum impractical, pushbuttons should be located no more than 10 feet from the edge of curb, shoulder, or pavement. Where two pushbuttons are provided on the same corner of the intersection, they should be separated by at least 10 feet. If the 10 feet separation is not feasible, audible speech walk messages are required for APS. Supplemental pushbutton poles or posts will typically be needed to meet the above criteria. The MUTCD requires a pedestrian pushbutton mounting height of approximately 3.5 feet above the sidewalk; keep in mind that the 3.5 feet is above the grade where the pedestrian would be when accessing the button. The pushbutton should be located so pedestrians using the audible or vibrotactile indication can align themselves and prepare for the crossing while waiting close to the pushbutton station and the crossing departure point.

   It is common to see a narrow grass strip between the sidewalk and pole used to mount the pushbuttons or to only see sidewalk on one side of a pole containing multiple pushbuttons. It is difficult to impossible for a person in a wheelchair to reach the pushbutton in cases like these since it often requires the person to struggle with one wheel in the grass and one on the sidewalk. As a result, sidewalks must be paved up to the pole used to mount the pushbuttons and be at a reasonable slope. There should also be sidewalk on each side of a pole that has a pushbutton.
3) **Locator Tone:** APS pushbuttons have a locator tone to allow visually impaired individuals to access the signal. The locator tone should be audible 6 to 12 feet from the pushbutton. The locator tone is active during the pedestrian clearance and “DON’T WALK” intervals.
4) **Walk Indications:**
   - In addition to visual indications, APS include audible and vibrotactile walk indications. When at least 10 feet separation is provided between pedestrian pushbutton stations, the audible walk indication is a percussive tone. If 10 feet separation is not provided, speech messages are required. The speech message should name the street to be crossed and indicate that the walk sign is on. For example: “Main. Walk sign is on to cross Main.” Designations such as “Street” or “Avenue” should not be used unless necessary to avoid ambiguity at a particular location. If the traffic signal rests in WALK, the tone/message should be limited to 7 seconds and be recalled by a button press during the WALK interval, provided that the crossing time remaining is greater than the pedestrian change interval.
   - The vibrotactile walk indication is provided by a high visual contrast tactile arrow on the pushbutton that vibrates during the walk interval. The vibrotactile indication is particularly useful to individuals who have both visual and hearing impairments. The pedestrian must be able to place a hand on the device while being aligned and waiting to begin the crossing. The arrow should be aligned parallel to the direction of travel on the associated crosswalk.

c. APS System Options:

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

G. Motorists, Bicyclists, and Pedestrian Expectations

Other traffic signal design considerations involve driver and pedestrian expectancy. A traffic engineer must look beyond the traffic signal being designed and consider the characteristics of the corridor and the attributes of the existing traffic signals along the corridor. For example, left turn phasing should be applied consistently and not switch between protected only and protected/ permissive without legitimate reasons. Pedestrian signal heads and audible pedestrian signals should be provided at signalized intersections in urban and suburban contexts that have sidewalks and curb ramps on the approaches in order to establish consistent expectations and safety for pedestrians. In places lacking sidewalks, other criteria may also be used to determine when pedestrian signal devices should be provided. These other criteria can be considered as part of engineering studies and could include pedestrian activity; expected or anticipated land use; transit stops; or the presence of schools, parks, or employment. If pedestrian signal heads are used, they should be used consistently and not sporadically where one intersection uses the heads and the next intersection relies on vehicular signal heads to guide pedestrians. Similarly, where separated bicycle lanes are present, the type of signal used for bicyclists should be consistent throughout; see Section 12B-3, L. Traffic signal head style, placement, and orientation for both general purpose lanes and separated bicycle lanes should be consistent along a corridor as well as sign type, size, and location. Intersections should not randomly switch between doghouse and vertical five section heads, center of lane and lane line placement, or vertical and horizontal signal head orientation. Consistently applied design criteria improve motorist, bicyclist, and pedestrian expectations, which typically promote improved safety and operations. However, circumstances exist that may, at times, require changes to design criteria to increase vehicle and pedestrian safety and operations.

H. Future Development and Improvements

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

I. References

Cesme, B., P.G. Furth, R. Cashman, and K. Lee. *Development of Pedestrian Recall versus Actuation Guidelines for Pedestrian Crossings at Signalized Intersections*. 2021.

Lin, Pei-Sung, et al. "Development of Statewide Guidelines for Implementing Leading Pedestrian Intervals in Florida." Florida Department of Transportation. 2017.

Signalized Intersections: Informational Guide, Second Edition, FHWA-SA-13-027, July 2013