3

GENERAL DESIGN CONSIDERATIONS

This chapter introduces various configurations and dimensions of separated bike lanes. It explains design treatments and other considerations that impact the safety and functionality of separated bike lanes. Refer to **Chapter 4** for design considerations at intersections and **Chapter 5** for design considerations adjacent to curbside activities such as loading, parking and bus stops.

3.1 SEPARATED BIKE LANE ZONES

The cross section of a separated bike lane is composed of three separate zones (see EXHIBIT 3A and EXHIBIT 3B):

- **Bike lane** – the bike lane is the space in which the bicyclist operates. It is located between the street buffer and the sidewalk buffer.
- **Street buffer** – the street buffer separates the bike lane from motor vehicle traffic.
- **Sidewalk buffer** – the sidewalk buffer separates the bike lane from the sidewalk.

While each zone has unique considerations, design choices in one often affects the others and may result in trade-offs that alter the utility and attractiveness of the separated bike lane cross section (see Section 3.6 for evaluating trade-offs by zone). The following general design principles should be followed with respect to the design of the zones to appeal to those who are interested in bicycling but concerned about their safety on the roadway:

- Changes in the bike lane elevation and horizontal alignment should be smooth and minimized (see Section 3.2).
- The bike lane should be wide enough to accommodate existing and anticipated bicycle volumes (see Section 3.3.2).
- The bike lane should allow passing of slower bicyclists and side by side travel, where feasible (see Section 3.3.2).
- The bike lane edges should be free from pedal and handlebar hazards (see Section 3.3.3).
- The street buffer should provide adequate horizontal and vertical separation from motor vehicles, including curbside activities like parking, loading and transit (see Section 3.4).
- The sidewalk buffer should discourage pedestrians from walking in the separated bike lane and discourage bicyclists from operating on the sidewalk (see Section 3.5).
- The sidewalk should accommodate pedestrian demand (see Section 3.5).

Additional considerations that should be evaluated for their effect on the separated bike lane cross section include drainage and stormwater management, lighting, utilities, curbside activities, landscaping and maintenance.

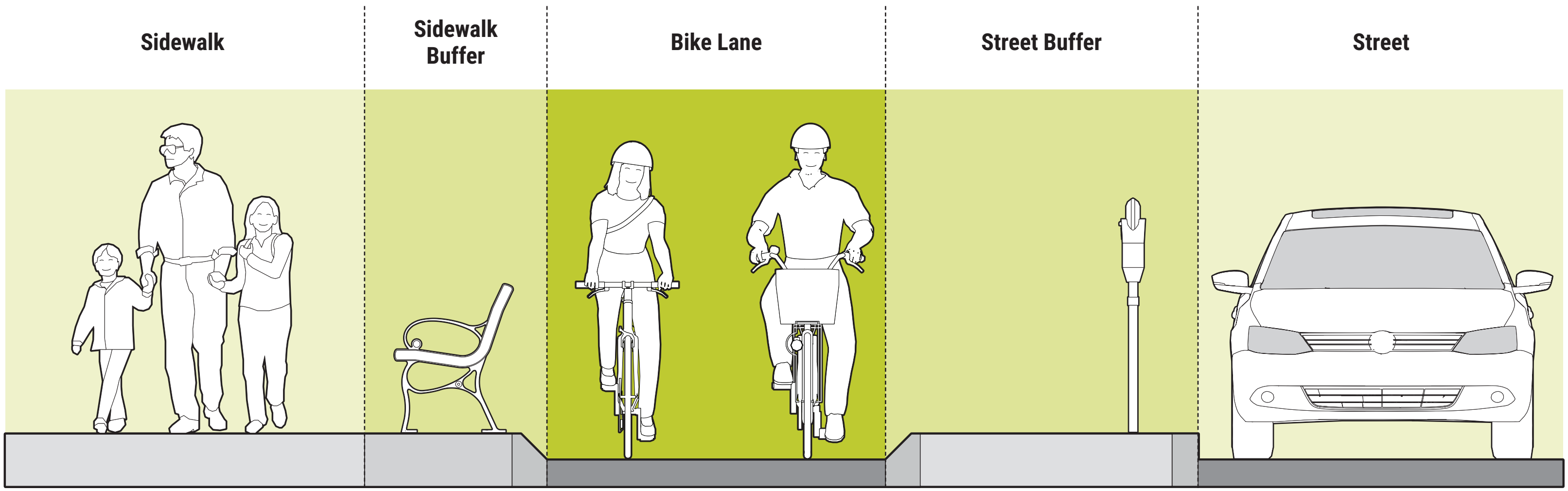


EXHIBIT 3A: Separated Bike Lane Zones

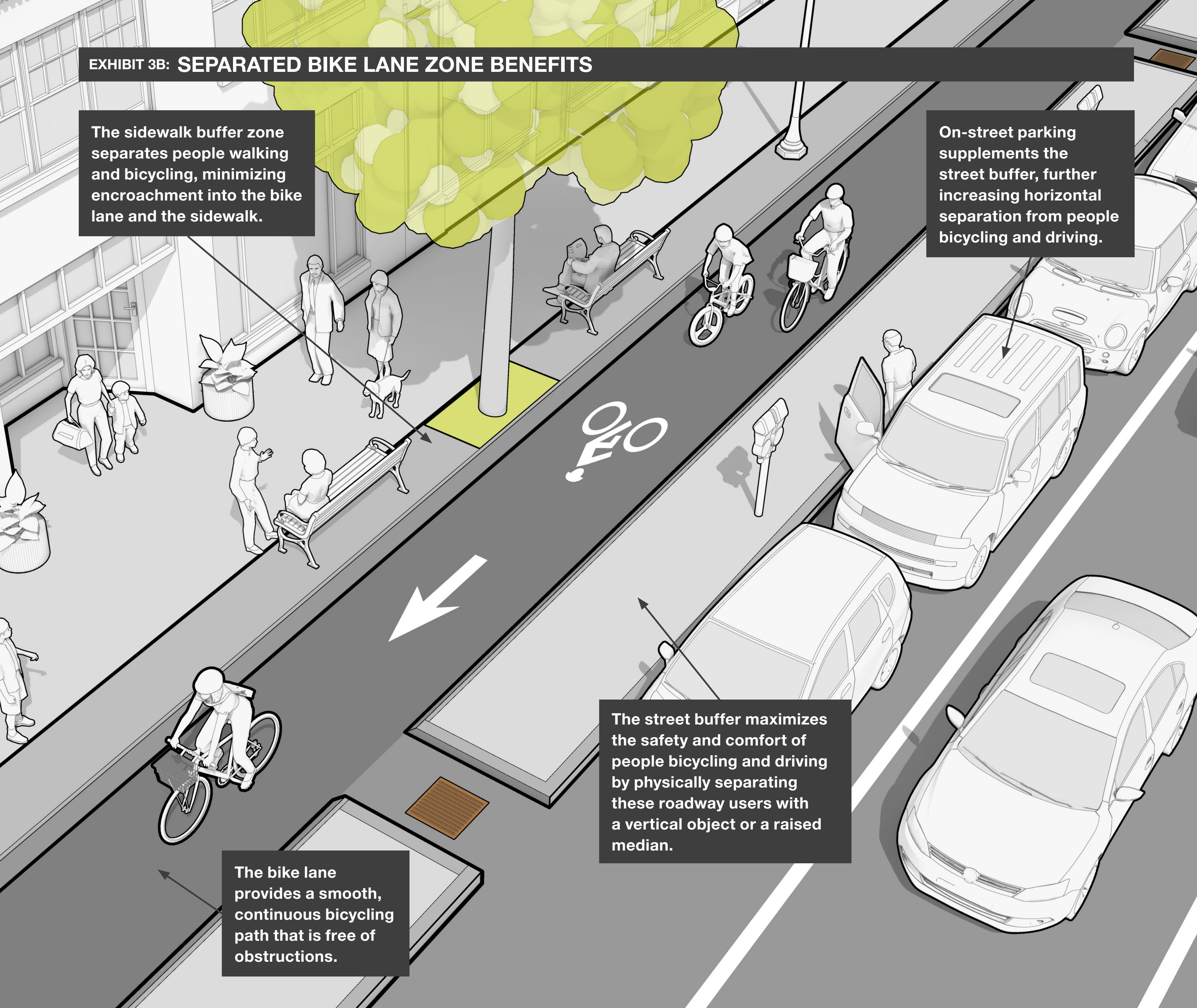


EXHIBIT 3B: SEPARATED BIKE LANE ZONE BENEFITS
The sidewalk buffer zone separates people walking and bicycling, minimizing encroachment into the bike lane and the sidewalk.
On-street parking supplements the street buffer, further increasing horizontal separation from people bicycling and driving.
The street buffer maximizes the safety and comfort of people bicycling and driving by physically separating these roadway users with a vertical object or a raised median.
The bike lane provides a smooth, continuous bicycling path that is free of obstructions.

3.2 BIKE LANE ELEVATION

Separated bike lanes may be flush with the sidewalk or street, or located at an intermediate elevation in between (see EXHIBIT 3C). Providing vertical separation between people walking and bicycling is the primary consideration for separated bike lane elevation. A separated bike lane flush with the sidewalk may encourage pedestrian and bicyclist encroachment unless discouraged with a continuous sidewalk buffer. Where used, a **2 in. minimum** change in elevation between the sidewalk and separated bike lane should be used to provide a detectable edge for the visually impaired.

The bike lane elevation may vary within a single corridor via bicycle transition ramps, rising or sinking as needed at pedestrian crossings, bus stops and intersections. It is important that a network and corridor-wide perspective is maintained during the design process, as frequent elevation changes may result in an uncomfortable bicycling environment.

Often the decision about elevation is based on physical constraints and feasibility, especially in retrofit situations where the separated bike lane is incorporated into the existing cross section. However, for new construction or substantial reconstruction, there are a number of factors to consider when deciding whether the bike lane should be at street level, sidewalk level or a level in between.

Reasons to place the bike lane at a lower elevation than the adjacent sidewalk:

- **Minimizes pedestrian encroachment in the bike lane and vice versa.**
- **May simplify design of accessible on-street parking and loading zones (see Chapter 5).**
- **May enable the use of existing drainage infrastructure (see Section 3.8).**

Reasons to place the bike lane at the same elevation as the adjacent sidewalk:

- **Allows separation from motor vehicles in locations where the street buffer width is constrained.**
- **Maximizes the usable bike lane width (see Section 3.3.3).**
- **Makes it easier to create raised bicycle crossings at driveways, alleys or streets (see Section 4.2.2).**
- **May provide level landing areas for parking, loading or bus stops along the street buffer (see Chapter 5).**
- **May reduce maintenance needs by prohibiting debris build up from roadway run-off (see Section 7.3.2).**
- **May simplify plowing operations (see Section 7.3.4).**

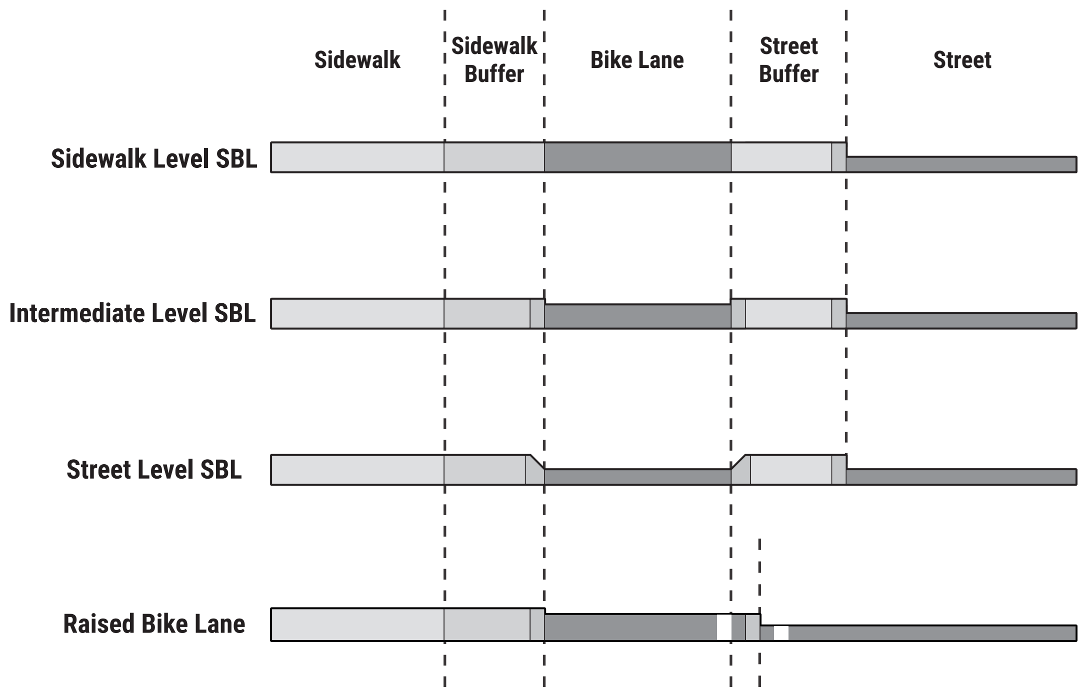


EXHIBIT 3C: Bike Lane Elevation

3.2.1 SIDEWALK LEVEL SEPARATED BIKE LANE

Sidewalk level separated bike lanes are typically separated from the roadway by a standard vertical curb (see **EXHIBIT 3D**). The design of sidewalk level bikes lanes should provide a sidewalk buffer that discourages pedestrian encroachment into the bike lane and bicyclist encroachment onto the sidewalk. This can be achieved by providing a wide buffer, a sidewalk buffer with frequent vertical elements, or a significant visual contrast between the sidewalk and bike lane. In constrained corridors, the sidewalk level separated bike lanes may help facilitate passing maneuvers in areas of low bicycle or pedestrian volumes if a portion of either the sidewalk or street buffer space is usable by bicyclists.

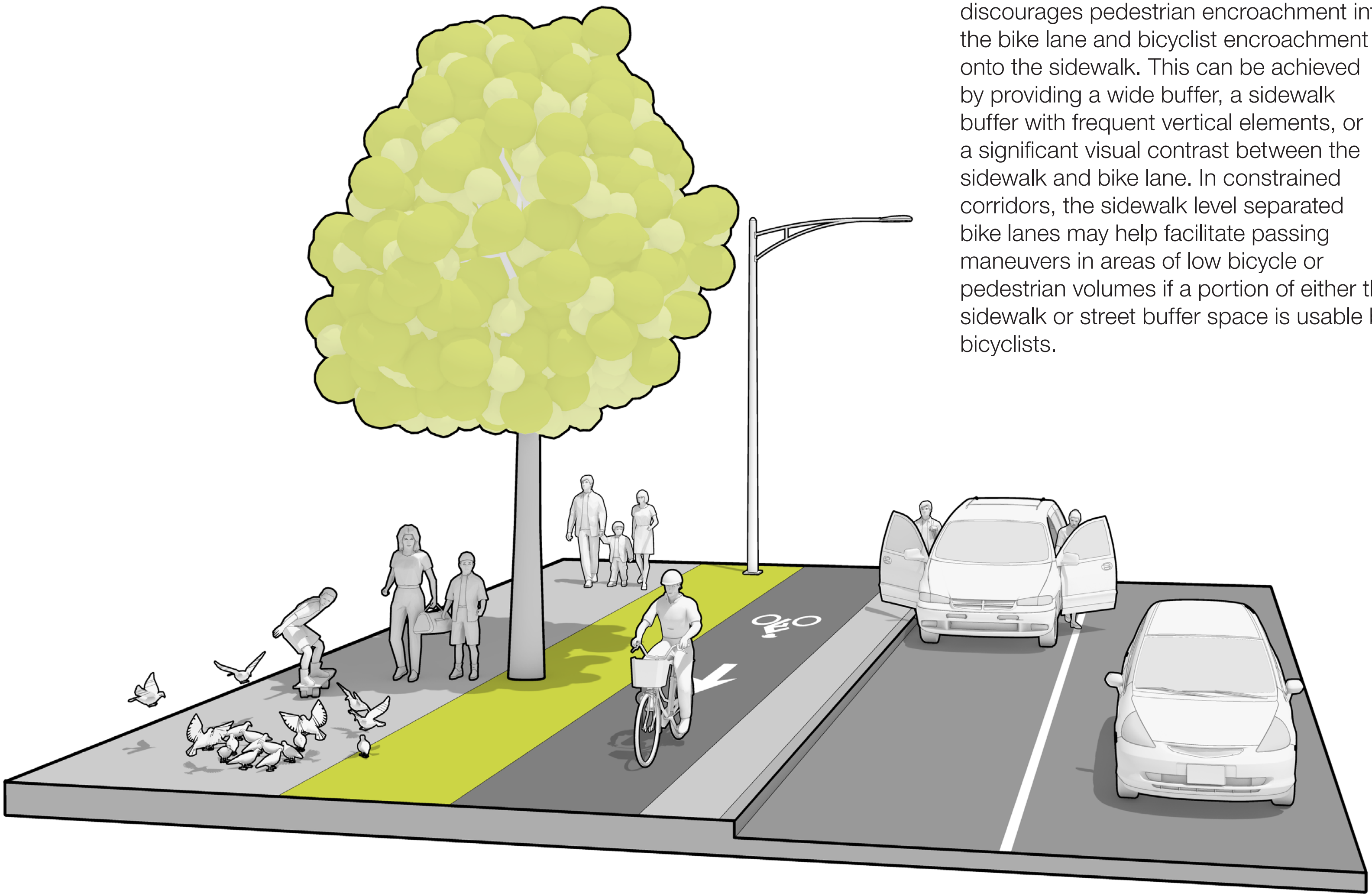


EXHIBIT 3D: Sidewalk Level Separated Bike Lane

3.2.2 STREET LEVEL SEPARATED BIKE LANE

Street level separated bike lanes are common in retrofit situations where a separated bike lane is incorporated into the existing cross section of the street (see **EXHIBIT 3E**). They are also used for new construction where there is a desire to provide a strong delineation between the sidewalk and the bike lane in order to reduce pedestrian encroachment in the bike lane. Street level separated bike lanes are usually compatible with accessible on-street parking and loading zones. Street level separated bike lanes may also minimize the need to relocate or reconfigure existing drainage infrastructure.

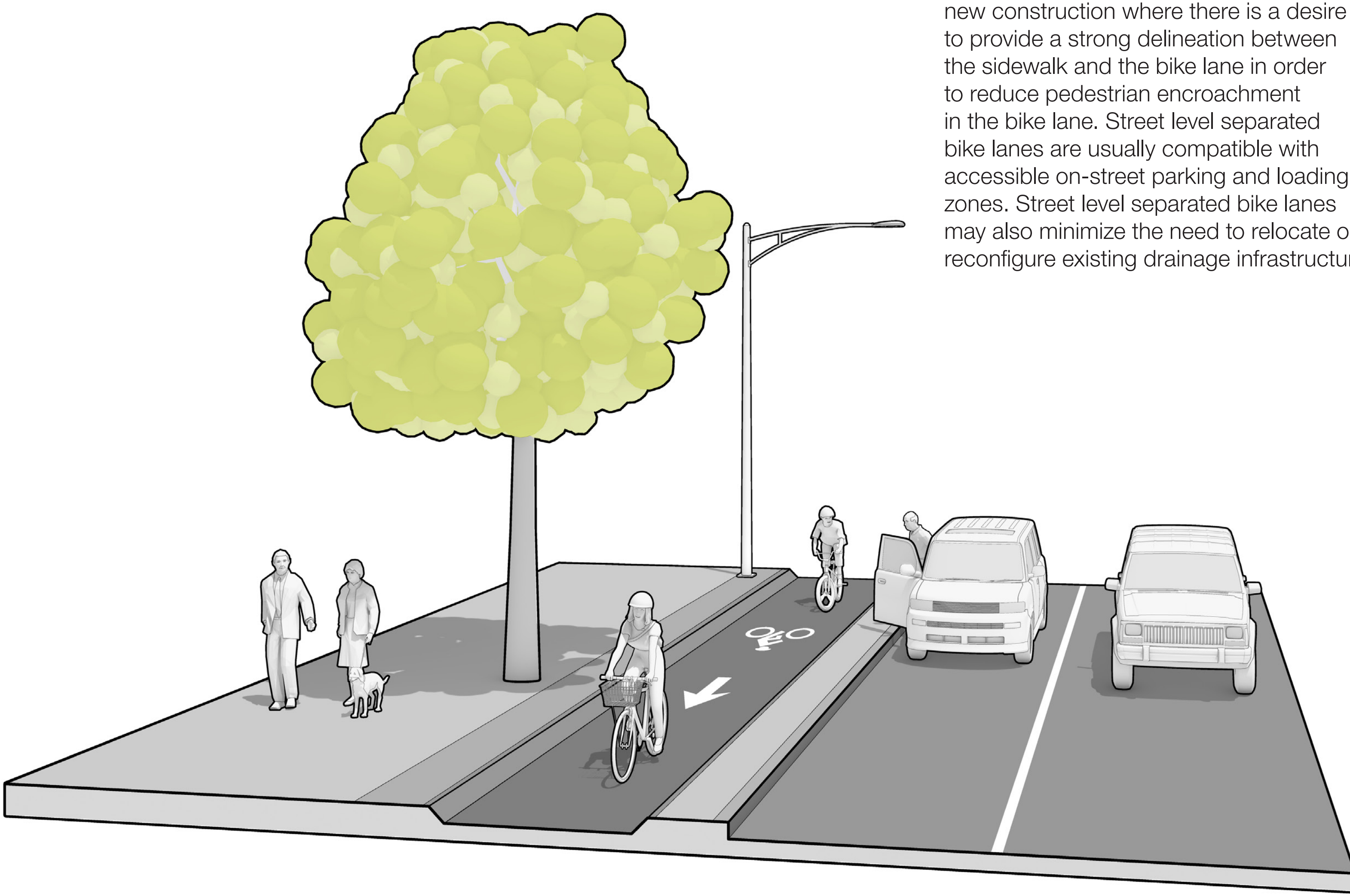


EXHIBIT 3E: Street Level Separated Bike Lane

3.2.3 INTERMEDIATE LEVEL SEPARATED BIKE LANE

Intermediate level separated bike lanes provide greater design flexibility for curb reveal and drainage (see **EXHIBIT 3F**). They provide many of the safety and comfort benefits of sidewalk and street level separated bike lanes, and require smaller transitions when changing elevation to and from street or sidewalk level bicycle crossings at intersections.

A curb reveal of **2-3 in.** below sidewalk level is recommended to provide vertical separation to the adjacent sidewalk or sidewalk buffer, and to provide a detectable edge for visually impaired pedestrians. Where the curb reveal is greater than **3 in.**, a beveled or mountable curb is recommended to minimize pedal strikes (see **Section 3.3.4**). Stormwater may drain either toward the street buffer, or to existing catch basins along the sidewalk buffer.

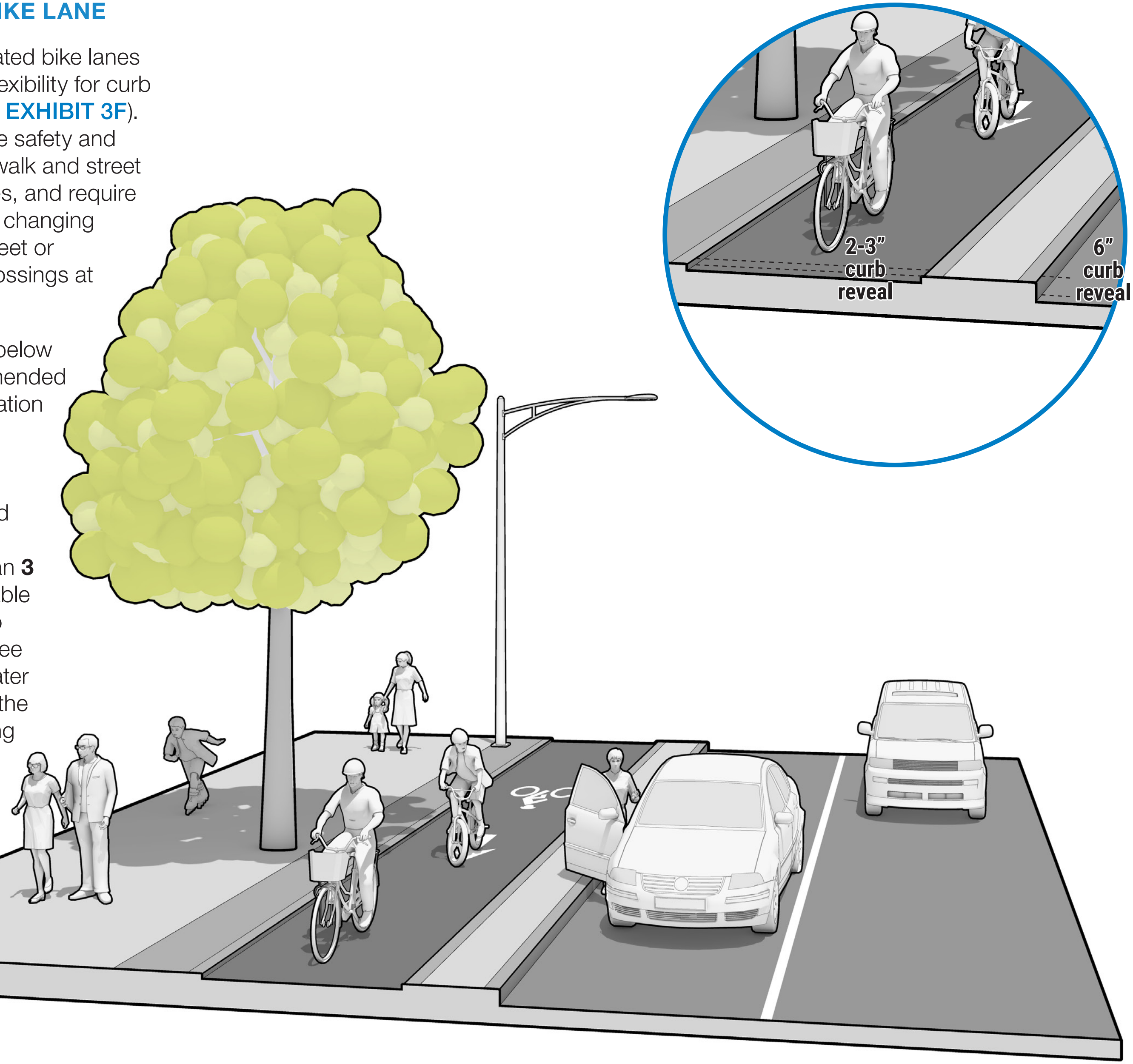


EXHIBIT 3F: Intermediate Level Separated Bike Lane

3.2.4 RAISED BIKE LANE

Like intermediate level separated bike lanes, raised bike lanes may be built at any level between the sidewalk and the street (see **EXHIBIT 3G**). They are directly adjacent to motor vehicle travel lanes at locations where provision of a street buffer is not feasible. Their street-facing curbs are flush with the bike lane surface and may be mountable to motorists and bicyclists. Mountable curbs are preferred if encroachment is desired, otherwise vertical curbs should be used to prohibit encroachment (see **Section 3.3.4**). Stormwater may drain either toward the street buffer, or to existing catch basins along the sidewalk buffer.

Raised bike lanes are only appropriate in constrained locations where the combined bike lane and street buffer width is **less than 7 ft.** and sidewalks are narrow or the sidewalk buffer is eliminated (see **Section 3.6**). Because of their narrow street buffer, raised bike lanes are not recommended for two-way operation or adjacent to on-street parking. Their narrow street buffer also presents snow storage challenges.

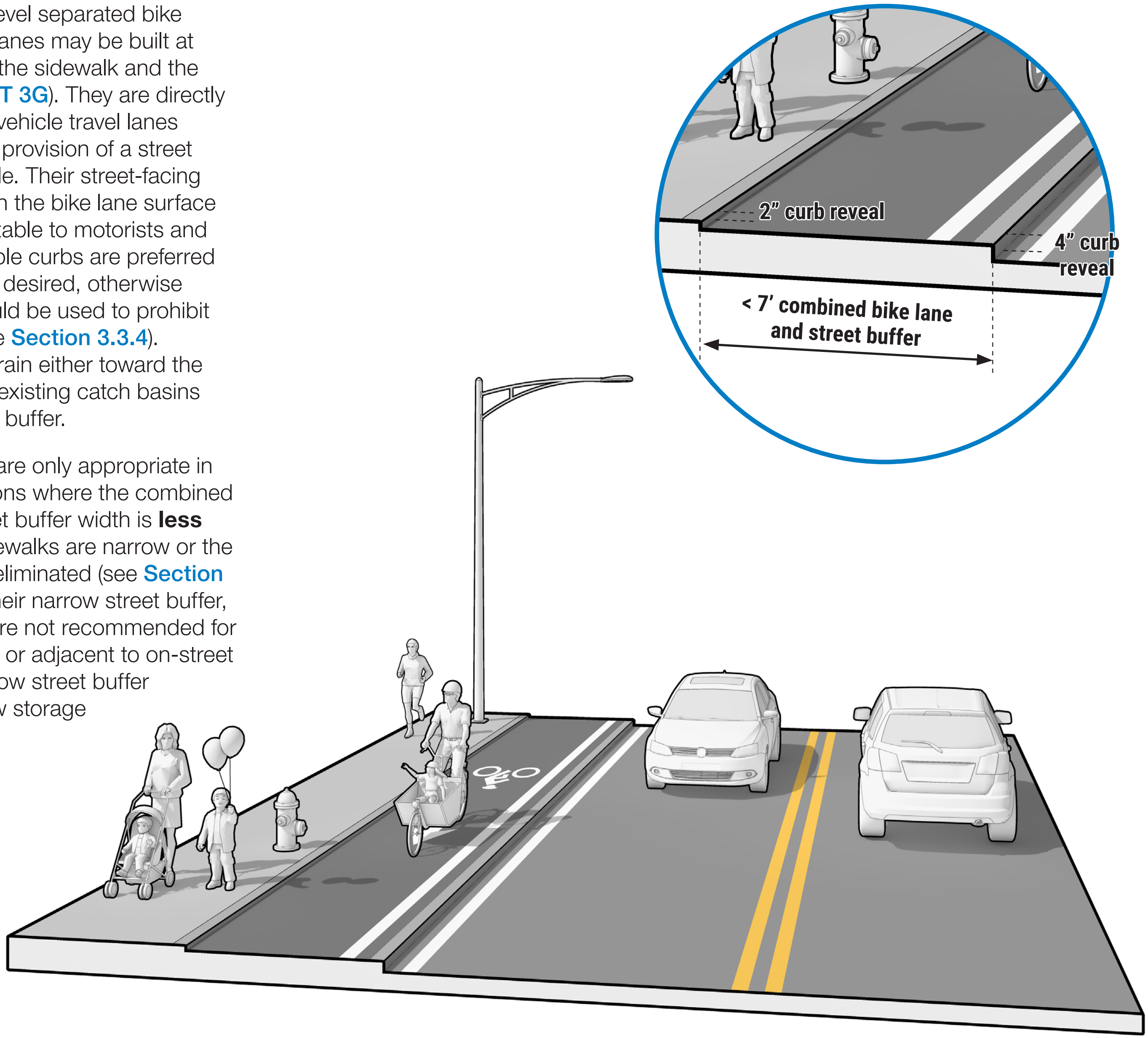


EXHIBIT 3G: Raised Bike Lane

3.3 BIKE LANE ZONE

3.3.1 BIKE LANE SURFACE

Bicyclists are sensitive to pavement defects. Asphalt is generally recommended for the surface of the bike lane zone because it provides a smooth, stable and slip resistant riding surface. If concrete is chosen, joints should be saw-cut to maintain a smooth riding surface. Subsurface preparation is critical to avoid future surface irregularities. The use of unit pavers should generally be avoided, as they require extensive subsurface preparation and are more susceptible to becoming dislodged over time, creating hazards for people bicycling and long-term maintenance challenges.

In some cases, a permeable surface is desired. More information on permeable surfaces is found in **Section 3.8.2**.

The bike lane should provide a smooth, continuous bicycling path and must be free from obstructions. Refer to **Section 3.8.1** for preferred drainage grate type and placement, and **Section 3.11** for recommended placement of utility covers.

In general, people operating two-wheel bicycles are not affected by the cross slope of a street. However, to maintain comfort for people bicycling with more than two wheels (e.g., cargo bike or tricycle) or with a trailer, bike lane cross slopes should not exceed **2 percent**. Gentler cross slopes are recommended where these bicycles are more common. Steeper cross slopes of up to **8 percent** are acceptable for limited distances in retrofit conditions.


Cambridge, MA

3.3.2 BIKE LANE WIDTH

The decision regarding the width of the bike lane zone is impacted by the elevation of the bike lane and the volume of users. Separated bike lanes generally attract a wider spectrum of bicyclists, some of whom operate at slower speeds, such as children or seniors. Because of the elements used to separate the bike lane from the adjacent motor vehicle lane, bicyclists usually do not have the option to pass each other by moving out of the separated bike lane. The bike lane zone should therefore be sufficiently wide to enable passing maneuvers between bicyclists. On constrained corridors with steep grades for example, it may be more desirable to provide wider bike lanes on the uphill portion of the roadway than the downhill portion to enable a faster moving bicyclist to pass a slower moving bicyclist.

The bike lane zone should also be wide enough to accommodate the volume of users. For one-way separated bike lanes with low volumes of bicyclists (**less than 150 per peak hour**), the recommended width of the bike lane zone is **6.5 ft**. (see **EXHIBIT 3H**). This is the width needed to enable passing movements between bicyclists. In constrained conditions where the recommended width cannot be achieved, the bike lane zone can be a minimum of **5 ft.** wide. Where additional space is available, **6.5 ft.** wide passing zones should be provided.

In locations with higher volumes of bicyclists, a wider bike lane zone should be provided, as shown in **EXHIBIT 3H**. When considering the volume of users, the designer should be aware that peak hour volumes for bicycling may not correspond to the parallel roadway motorized traffic volumes. For example, peak bicycle activity may occur during the mid-day on a weekend if the separated bike lane connects to a popular regional trail. There may also be significant land use driven (e.g., university or school) or seasonal (e.g., summer vs. winter) variability in bicycling activity that should be considered when evaluating volume counts or projections. Lastly, when estimating future volumes of bicyclists, the designer should be aware that separated bike lanes have been documented to significantly increase bicycling once constructed over baseline conditions with shared lanes or on-road bicycle lanes.

There is more flexibility with respect to the width of the bike lane zone when it is not separated from adjacent zones with vertical curbs. When the bike lane zone is located at the same elevation as the adjacent buffer zones, the bicyclist can operate more closely to the edges of the bike lane during passing movements.


Chicago, IL

Beveled or short curbs (2-3 in.) are recommended for separated bike lanes <6.5 ft. wide (see Section 3.3.3).

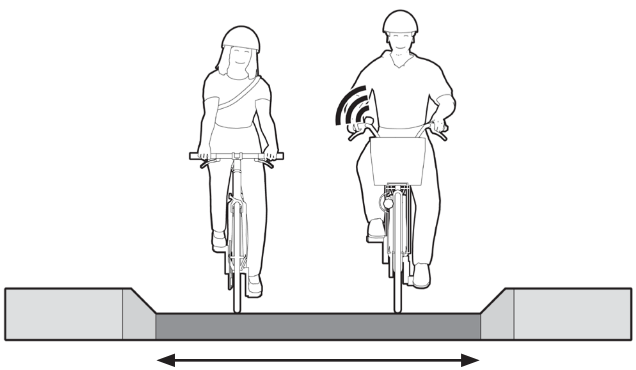
Separated bike lanes <5 ft. wide and between two curbs must be raised to sidewalk level.

A bike lane width narrower than 5 ft. requires a design exception.

Narrower widths are not recommended in locations where there are higher volumes of pedestrians or bicyclists during peak hours. In extremely constrained conditions where the recommended or minimum width cannot be achieved, it may be acceptable to reduce the bike lane width to **4 ft.** for short distances such as around bus stops or accessible parking spaces (see Chapter 5). Separated bike lanes narrower than **5 ft.** and between two curbs must be raised to sidewalk level.

Two-way bike lanes are wider than one-way bike lanes to reduce the risk of collisions between opposing directions of travel. For two-way bike lanes with low volumes of bicyclists (**less than 150 per peak hour**), the recommended width of the bike lane zone between two curbs is **10 ft.**

In constrained conditions where the recommended width cannot be achieved, the bike lane zone should be a minimum of **8 ft.** wide. In locations with higher volumes of bicyclists, wider two-way bike lanes should be provided to accommodate passing in the same and opposing directions of travel simultaneously, as shown in EXHIBIT 3I.

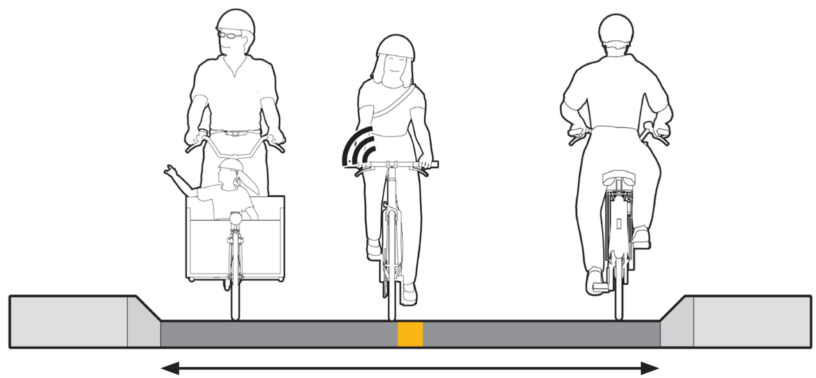


at least 6.5 ft. recommended to enable passing movements

Same Direction Bicyclists/ Peak Hour	Bike Lane Width (ft.)	
	Rec.	Min.*
<150	6.5	5.0
150-750	8.0	6.5
>750	10.0	8.0

* A design exception is required for designs below the minimum width.

EXHIBIT 3H: Bike Lane Widths for One-way Operation



at least 10 ft. recommended to enable passing movements

Bidirectional Bicyclists/ Peak Hour	Bike Lane Width (ft.)	
	Rec.	Min.*
<150	10.0	8.0
150-400	11.0	10.0
>400	14.0	11.0

* A design exception is required for designs below the minimum width.

EXHIBIT 3I: Bike Lane Widths for Two-way Operation

3.3.3 SHY DISTANCE

Proximity to objects or vertical curbs along the bike lane edge can affect the operation of a separated bike lane. Bicyclists shy away from vertical obstructions to avoid handlebar or pedal strikes. The rideable surface of the bike lane is reduced when vertical objects are adjacent to the bike lane zone.

For this reason, the type of curbs adjacent to the bike lane zone is an important factor. Section 3.3.4 on the following page discusses various types of curbs and their appropriate use.

Any object that is less than **36 in.** in height from the bike lane surface does not require an offset and can be directly adjacent to the separated bike lane.

Any object that is greater than or equal to **36 in.** in height from the bike lane surface should be offset from the bike lane zone. Where a curb separates the bike lane zone from the adjacent buffer zones, there should be a minimum **6 in.** offset between the face of curb and the edge of a vertical object such as a sign post or parking meter. Where there is no curb, a minimum **12 in.** offset is needed between the edge of the bike lane zone and a vertical object.

A **100 in.** vertical clearance should be maintained over the bike lane surface.

Utrecht, Netherlands

3.3.4 CURBS

The selection of appropriate curb angle and height is an important design consideration for separated bike lane zone buffers.

CURB ANGLE

The curb angle—vertical, beveled or mountable—influences the crash risk to bicyclists and ease of encroachment:

- **Vertical curbs are designed to prohibit encroachment by motor vehicles and bicycles. They present a crash risk to people bicycling if their wheels or pedals strike the curb. They may be granite or concrete.**
- **Beveled curbs are angled to reduce pedal strike hazards for bicyclists and to ease access to the sidewalk for dismounted bicyclists. They may be granite or concrete.**
- **Mountable curbs are designed to be encroached by motor vehicles and bicycles. Their forgiving angle allows safe traversal for bicyclists and eliminates pedal strike hazards, but consumes more cross-section width that may otherwise be allocated to the bike lane or a buffer. Mountable curbs help bicyclists safely exit the bike lane without impeding other bicyclists. They may be concrete or asphalt, or constructed as a berm.**

CURB HEIGHT

Curbs may be constructed at heights between **2-6 in.** from the roadway surface. Short curbs (**2-3 in.** from the roadway) of any angle eliminate pedal strike risk, increasing the usable bike lane width by permitting bicyclists to safely ride closer to the edge of the bike lane. Note that even short vertical curbs may be unforgiving if struck by a bicycle wheel. Tall vertical or beveled curbs (**6 in.** from the roadway) discourage encroachment by motor vehicles. Mountable curbs at any height encourage encroachment.

SELECTING CURBS BY PROJECT TYPE

In retrofit situations, separated bike lanes are typically incorporated into the existing cross section of a street with standard vertical curbs. However, designers should consider curb angle and height in tandem for new construction or substantial reconstruction, as these characteristics are directly related to the safety and comfort of the separated bike lane.

- **Short curbs (2-3 in.) are recommended adjacent to the bike lane zone to increase usable width of the bike lane and reduce pedal strike crash risks. Beveled or mountable curbs are recommended adjacent to shops and other destinations to ease access to the adjacent sidewalk. Where a taller curb along the bike lane is unavoidable (e.g., to accommodate drainage patterns), a beveled curb is recommended to somewhat mitigate pedal strike hazards.**
- **Standard 6 in. vertical curbs are recommended adjacent to motor vehicle travel lanes and on-street parking to discourage encroachment into the separated bike lane.**

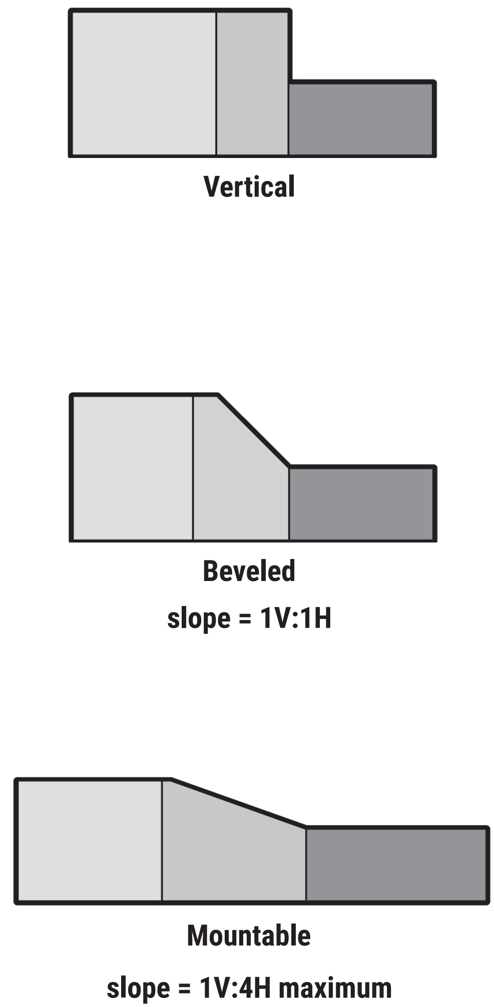


EXHIBIT 3J: Curb Profiles

3.4 STREET BUFFER ZONE

The street buffer zone is one of the most important elements of separated bike lane design. The goal of the street buffer is to maximize the safety and comfort of people bicycling and driving by physically separating these roadway users with a vertical object or a raised median. The width of the street buffer also influences intersection operations and bicyclists safety, particularly at locations where motorists may turn across the bike lane (see Chapter 4). Many factors influence design decisions for the street buffer, including number of travel lanes, motor vehicle speeds and volumes, bike lane elevation, right-of-way constraints, drainage patterns and maintenance activities. Aesthetics, durability, cost, and long-term maintenance needs should be considered as well.

The street buffer can consist of parked cars, vertical objects, raised medians, landscaped medians, and a variety of other elements. Elements that must be accessed from the street (e.g., mailboxes) should be located in the street buffer. The minimum width of the street buffer is directly related to the type of buffer.

3.4.1 STREET BUFFER WIDTH

Central to the design of the street buffer is its width. Appropriate street buffer widths vary greatly depending on the degree of separation desired, right-of-way constraints, and the types of structures or uses that must be accommodated within the buffer. In general, the recommended width of a street buffer is **6 ft.**, regardless of the type of street buffer. Street buffers may be narrowed to a minimum of **2 ft.** in constrained conditions, or a minimum of **1 ft.** alongside a raised bike lane.


San Francisco, CA


Vancouver, Canada

A wider street buffer may be desirable to improve bicyclists' comfort on multi-lane, higher speed roadways. Clear zone requirements for higher speed roadways may also impose additional requirements for street buffer width that should be considered (see **Section 5.6.1 of the PD&DG** for clear zone guidance).

In addition to providing increased physical separation mid-block, street buffers also affect bicyclists' safety at intersections, including driveways and alley crossings. Street buffer widths that result in a recessed crossing between **6 ft.** and **16.5 ft.** from the motor vehicle travel lane have been shown to significantly reduce crashes at uncontrolled separated bike lane crossings[1] (see **EXHIBIT 3K**). This offset improves visibility between bicyclists and motorists who are turning across their path, and creates space for motorists to yield (this is discussed in more detail in **Chapter 4**).

It is important that a corridor-wide perspective be maintained during the evaluation and design process, as excessive lateral changes between midblock sections and intersections may result in an uncomfortable bicycling environment. The designer will need to carefully consider intersection operations as the horizontal alignment is determined.

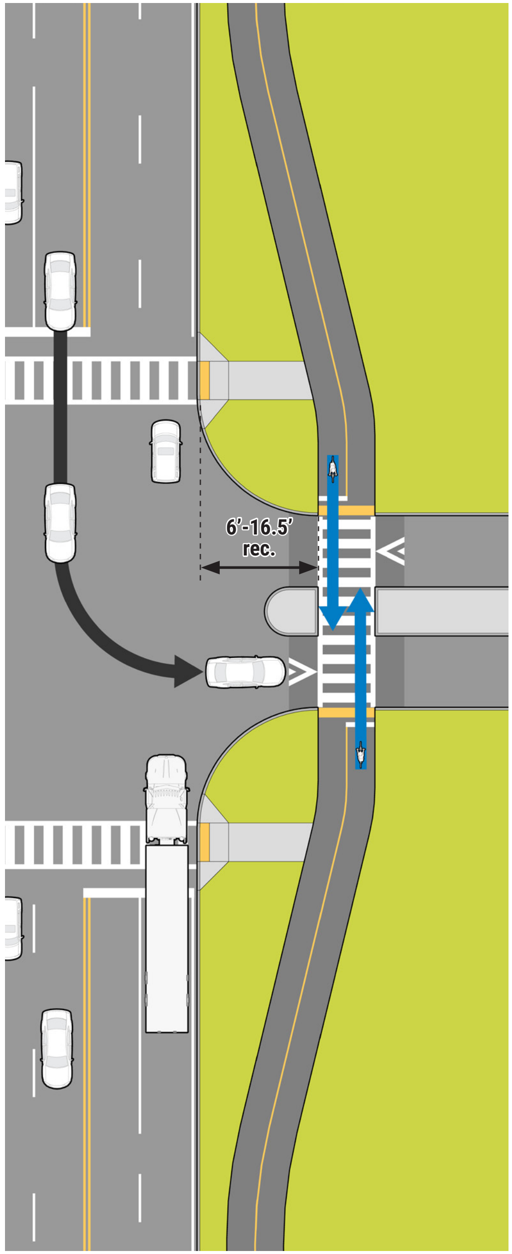


EXHIBIT 3K: Recessed Crossing at Shared Use Path Intersection

3.4.2 VERTICAL OBJECTS

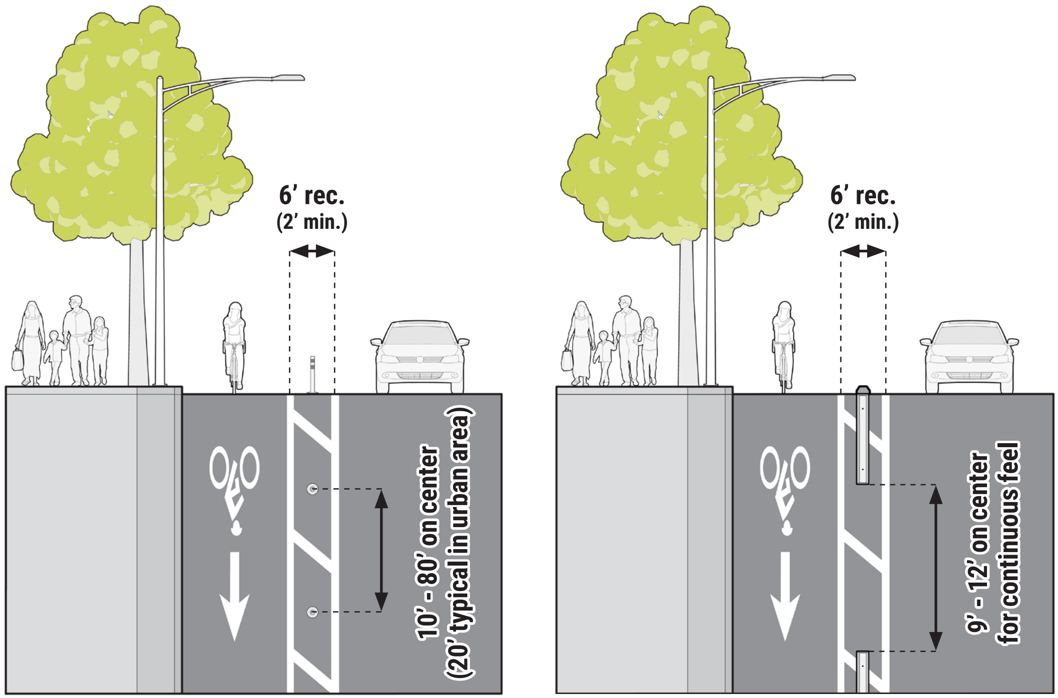
For street level separated bike lanes without a raised median, vertical objects are needed in the street buffer to provide separation. Examples of vertical objects include flexible delineator posts, parking stops, planter boxes, concrete barriers or rigid bollards (see **EXHIBIT 3L**). They must be supplemented with a painted median to mark the buffer (see **Section 3.7**). The horizontal placement of vertical objects within the buffer should consider the need for shy distance to the bike lane and to the travel lane. Preference should be given to locating the vertical object to maximize the width of the bicycle lane.

It may be necessary to utilize more frequently spaced vertical objects where motor vehicle encroachment in the bike lane is observed or anticipated. Where on-street parking is located adjacent to the street buffer, it may not be necessary to provide vertical objects to improve separation, except in locations where parking is absent, such as near intersections. Exceptions include locations where on-street parking is prohibited for portions of the day, commercial areas where on-street parking turnover is high, or locations where parking demand is low.

Capital costs for vertical objects are typically lower than raised medians, making them ideal for retrofit projects. However, vertical objects may require routine maintenance and replacement, increasing long-term costs. Some vertical objects may be temporarily removed to accommodate standard sweeping and snow clearance (see **Section 7.3**). Most vertical objects are non-continuous, which facilitates positive drainage along the established roadway crown to existing catch basins.

Ensuring the vertical separation is visible to approaching bicyclists and motorists should be considered. Vertical objects in the street buffer are considered delineators and must be retroreflective, per the MUTCD.

EXHIBIT 3L: VERTICAL OBJECTS IN THE STREET BUFFER ZONE



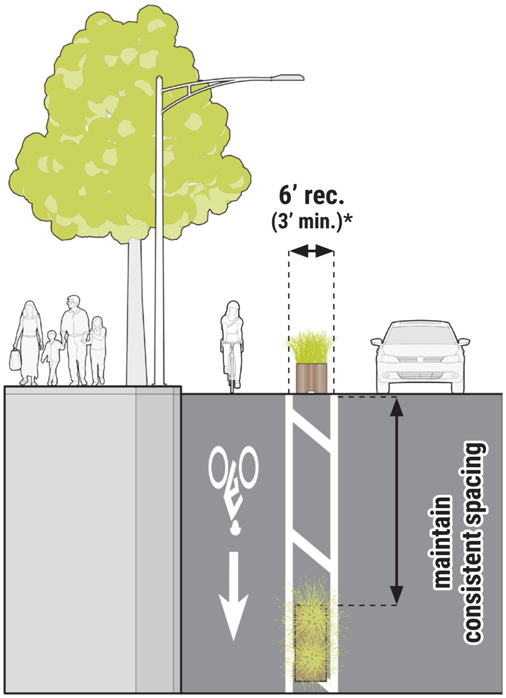
Flexible Delineator Posts

- Removable
- Lowest initial capital costs
- May require closer spacing where parking encroachment is likely
- Small footprint compatible with variety of buffer designs
- Low durability
- May need routine replacement, increasing long-term maintenance costs.

Parking Stops

- Maintain consistent spacing between parking stops
- Removable
- Highly durable
- May need supplemental vertical objects or on-street parking to increase visibility

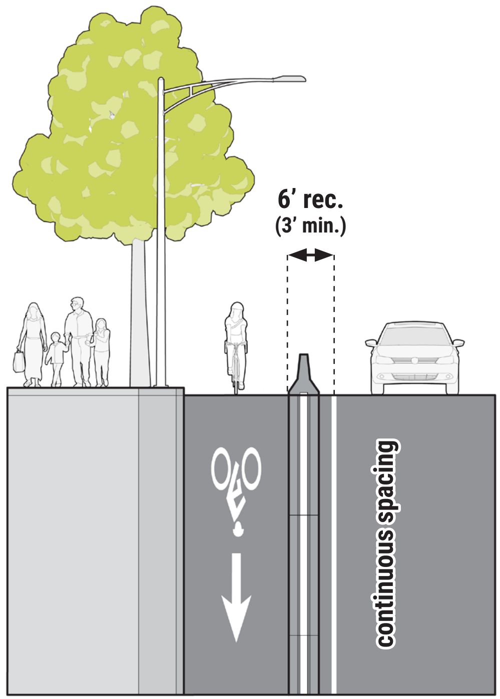
EXHIBIT 3L: VERTICAL OBJECTS IN THE STREET BUFFER ZONE (CONTINUED)



Planter Boxes

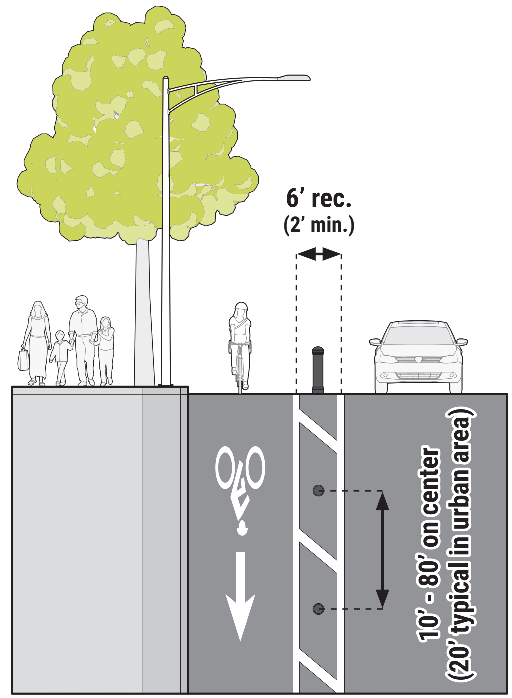
* Buffer may need to be wider when adjacent to on-street parking to accommodate an open motor vehicle door.

- Removable
- May be closely spaced for near-continuous vertical separation
- Can be used to enhance community aesthetics
- May serve as a gateway treatment
- May be incompatible with clear zone requirements for roadways with higher motor vehicle speeds
- Plants require routine care, increasing long-term maintenance costs



Concrete Barriers

- Provides continuous vertical separation
- Highly durable
- Recommended for locations where physical protection from motor vehicles is needed, for example on bridges with high speed traffic
- May need crash cushion at barrier ends
- Incompatible with on-street parking



Rigid Bollards

- Typically permanent
- Higher capital cost
- May require closer spacing where parking encroachment is likely
- May be incompatible with clear zone requirements for roadways with higher motor vehicle speeds
- Refer to MUTCD 3H.01 for color and retroreflectivity specifications
- Removable rigid bollards may require substantial maintenance

3.4.3 RAISED MEDIANS

A raised median provides curb separation from motor vehicles (see **EXHIBIT 3M**). Raised medians offer a high degree of design flexibility: they are compatible with street, intermediate and sidewalk level separated bike lanes as well as a variety of street furniture and landscaping treatments. They are typically continuous but may include curb cuts for drainage gaps. Capital costs for raised medians are often higher than vertical objects, but their high durability requires less long-term maintenance.

A **2-3 in.** curb is recommended along the bike lane zone to reduce pedal strike hazards and encourage full use of the bike lane width; where a taller curb is required along the bike lane, a beveled curb is recommended to mitigate pedal strike hazards (see **Section 3.3.4**). A standard **6 in.** vertical curb facing the street is recommended to discourage motor vehicle encroachment in the bike lane.

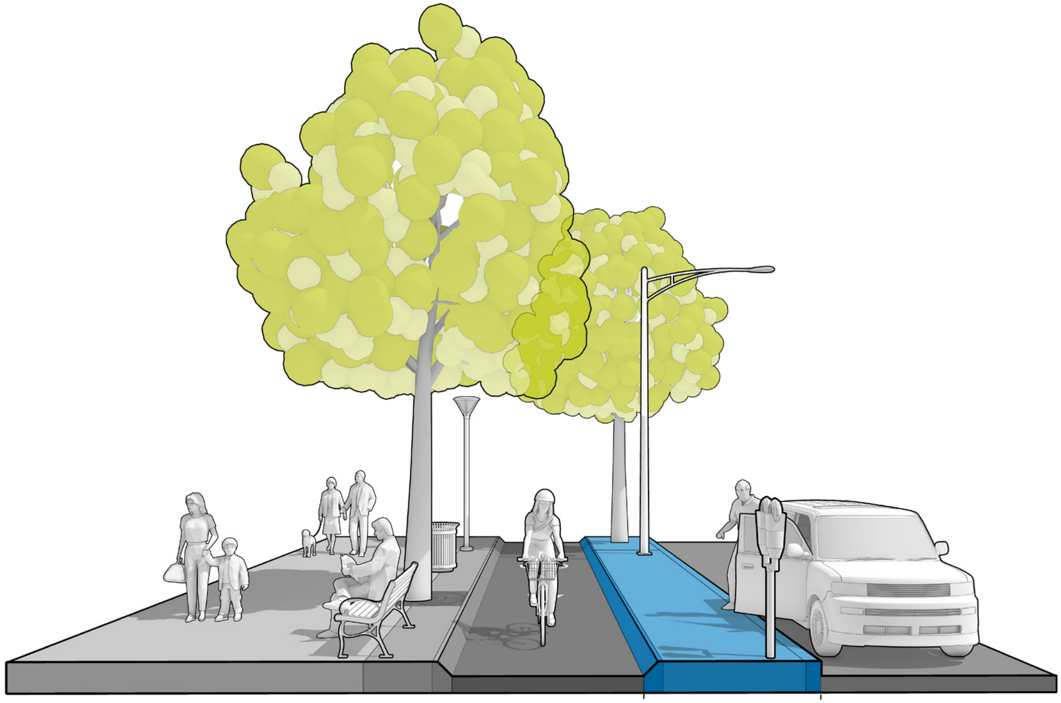


EXHIBIT 3M: Raised Median Width

6' rec. (2' min.*)

* Minimum 1 ft. street buffer when adjacent to a raised bike lane only.

3.5 SIDEWALK BUFFER ZONE

The sidewalk buffer zone separates the bike lane from the sidewalk. It communicates that the sidewalk and the bike lane are distinct spaces. By separating people walking and bicycling, encroachment into these spaces is minimized and the safety and comfort is enhanced for both users. Design strategies for the sidewalk buffer include object separation (e.g., street furniture or landscaping), curb separation or visual separation (i.e., variation of surface materials). The design team may use a combination of these strategies, for example supplementing street furniture with brick or unit pavers.

Physical separation with street furniture, landscaping or other objects is recommended for the sidewalk buffer provided that an accessible path of travel and sufficient sidewalk width is maintained for unobstructed pedestrian flow.

In constrained locations where physical separation is desirable because of moderate to high pedestrian demand, for example town centers and urban areas, curb separation is preferable to ensure pedestrians do not walk in the bike lane, and bicyclists do not ride on the sidewalk. However it is also possible to achieve the desired separation when the sidewalk and bike lane are at the same elevation and are directly adjacent to each other by providing a high degree of visual contrast between the two. This can be accomplished through the utilization of different materials for each zone, stained surfaces, or applied surface colorization materials.

- Sidewalks must provide a **4 ft.** minimum continuous and unobstructed clear width, excluding the width of the curb.
- A sidewalk width narrower than **5 ft.** excluding the width of the curb requires a design exception. Wider sidewalks ranging from **6 ft. to 20+ ft.** are recommended for town centers and urban areas (see Section 5.3.1 of the PD&DG).
- Shy distances to objects and curbs may impact the usable width of the bike lane (see Section 3.3.3) and the sidewalk (see Section 5.3.1 of the PD&DG).
- Maintain adequate offsets between objects (e.g., trees, streetlights, hydrants, etc.) and locations (e.g., driveways, loading zones, transit stops and intersections).
- Refer to local streetscape and historic district guidelines for recommended sidewalk buffer materials.
- Sidewalk buffer may utilize permeable pavers to assist with on-site stormwater management (see Section 3.8.2).

Cambridge, MA

3.6 DETERMINING ZONE WIDTHS IN CONSTRAINED CORRIDORS

When designing separated bike lanes in constrained corridors, designers may need to minimize some portions of the cross section, including separated bike lane zones, to achieve a context-sensitive design that safely and comfortably accommodates all users.

3.6.1 CONSIDERATIONS FOR MINIMIZING ZONE WIDTHS

Designers should initially consider reducing the number of travel lanes, narrowing existing lanes or adjusting on-street parking. ❶ Space captured from these uses can be allocated to separated bike lane zones. If needed, designers should then consider minimizing the width of the separated bike lane and associated buffer and sidewalk zones.

The sidewalk ❷ should accommodate pedestrian demand (see **Section 3.5** for minimum and recommended sidewalk widths). All sidewalks must meet accessibility requirements of the Americans with Disabilities Act (ADA) and the Massachusetts Architectural Access Board (AAB). When narrowing the sidewalk buffer, ❸ appropriate separation between the sidewalk and the bike lane should be provided, preferably through vertical separation (see **Section 3.5**). Where pedestrian demand is low, consider a shared use path in lieu of a separated bike lane (see **Section 2.4.2**).

The street buffer ❹ is critical to the safety of separated bike lanes, therefore narrowing or eliminating it should be avoided wherever possible. Providing a larger buffer at intersections can be achieved by tapering the bike lane toward the sidewalk as it approaches the intersection. In this case, sidewalk buffer width is transferred to the street buffer as the bike lane shifts toward the sidewalk. For example, a cross section with a **4 ft.** sidewalk buffer and a **2 ft.** street buffer at mid-block can transition to a cross section with no sidewalk buffer and **6 ft.** street buffer at the intersection (see **Section 4.3.2**). If appropriate, designers may consider a raised bike lane to further reduce the street buffer width (see **Section 3.2.4**).

If necessary, designers may also use the minimum bike lane width ❺ for the appropriate bicycle volume threshold (see **Section 3.3.2**).

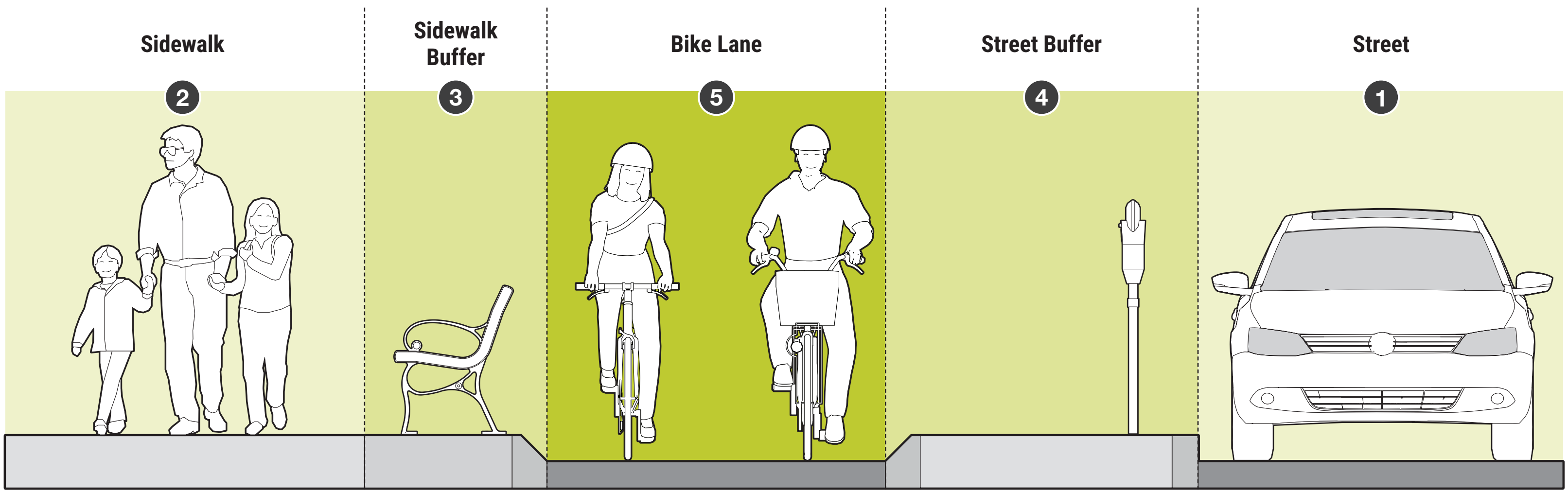


EXHIBIT 3N: Considerations for Minimizing Zone Widths

3.7 PAVEMENT MARKINGS AND SIGNS

Standard bike lane symbols and arrows may be provided in separated bike lanes (see EXHIBIT 3O). In some cases, the size of the symbols and arrows may be reduced to fit within the lane. Two-way separated bike lanes should have yellow centerlines: dotted to indicate where passing is permitted and solid to indicate where passing is undesirable. Green markings or surface colors should be reserved for conflict points including driveways and intersections, which are further detailed in Chapter 4. It may be desirable to demarcate the edges of vertical curbs or other objects with solid white edge lines on either side of the bike lane to improve night time visibility. Street level painted medians must be marked with diagonal cross hatching or, if **3 ft. or wider**, chevrons.

See Section 5.4 of the AASHTO Bike Guide, Chapter 5 of the FHWA Separated Bike Lane Planning and Design Guide and Chapter 9 of the MUTCD for additional guidance on the use of pavement markings for midblock locations.

Standard bike lane signage is not required to identify the separated bike lane; however, the R9-7 sign may be considered for locations with sidewalk level separated bike lanes to further communicate the appropriate use of each space. Wayfinding signage should be provided in accordance with MUTCD and local standards.

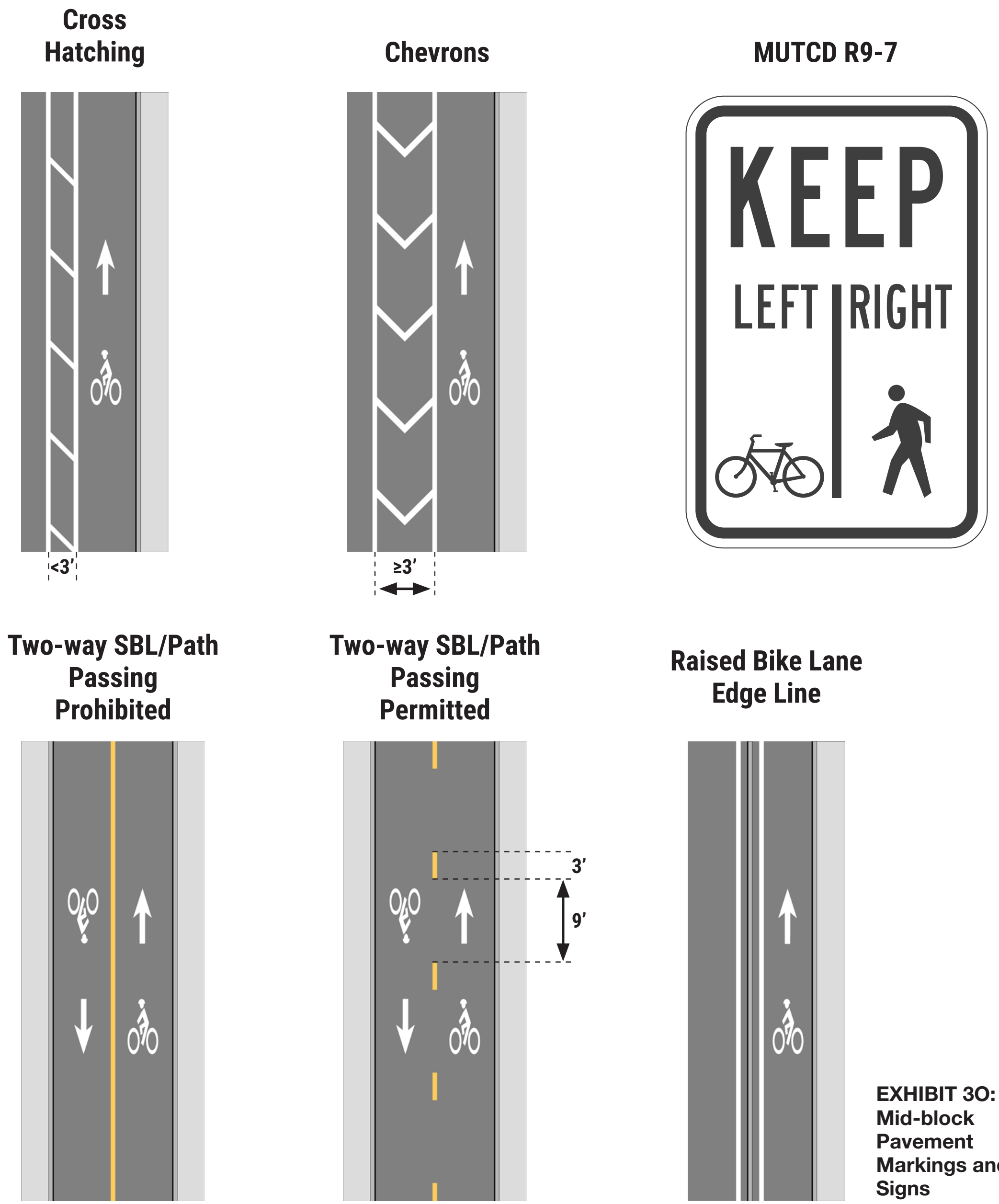


EXHIBIT 3O: Mid-block Pavement Markings and Signs

3.8 DRAINAGE AND STORMWATER MANAGEMENT

Providing proper drainage as part of separated bike lane projects enhances the safety and comfort of all users by reducing water ponding and the accumulation of debris. Proper drainage also protects the longevity of the roadway infrastructure and ensures that drainage features are adequate to accommodate MassDOT requirements to manage stormwater and minimize erosion.

Runoff from bike lanes must also be properly managed to minimize the environmental impacts associated with urban runoff and to meet current regulatory requirements, including applicable Massachusetts Stormwater Management Standards to the maximum extent practicable (see MassDOT's drainage design guidelines in **Chapter 8 of the PD&DG**, and in **MassDOT's Stormwater Handbook for Highways and Bridges**).

3.8.1 DRAINAGE PATTERNS

Many factors influence the decision to manage the flow of stormwater from paved bike lanes. In urban areas, stormwater may need to be directed toward the sidewalk buffer, street buffer or both, depending on the elevation of the separated bike lane (see **Section 3.2**), the presence of a raised median in the street buffer (see **Section 3.4.3**), the locations of existing catch basins and utilities, and the project budget. Illustrative separated bike lane drainage patterns for urban areas are shown in **EXHIBIT 3P**. In suburban and rural areas, the preferred practice would be to direct runoff onto adjacent vegetated areas, where soils and slopes allow for runoff to naturally infiltrate (a practice known as 'pavement disconnection'). Alternatively, other 'green infrastructure' practices can be considered (see **Section 3.8.2**).

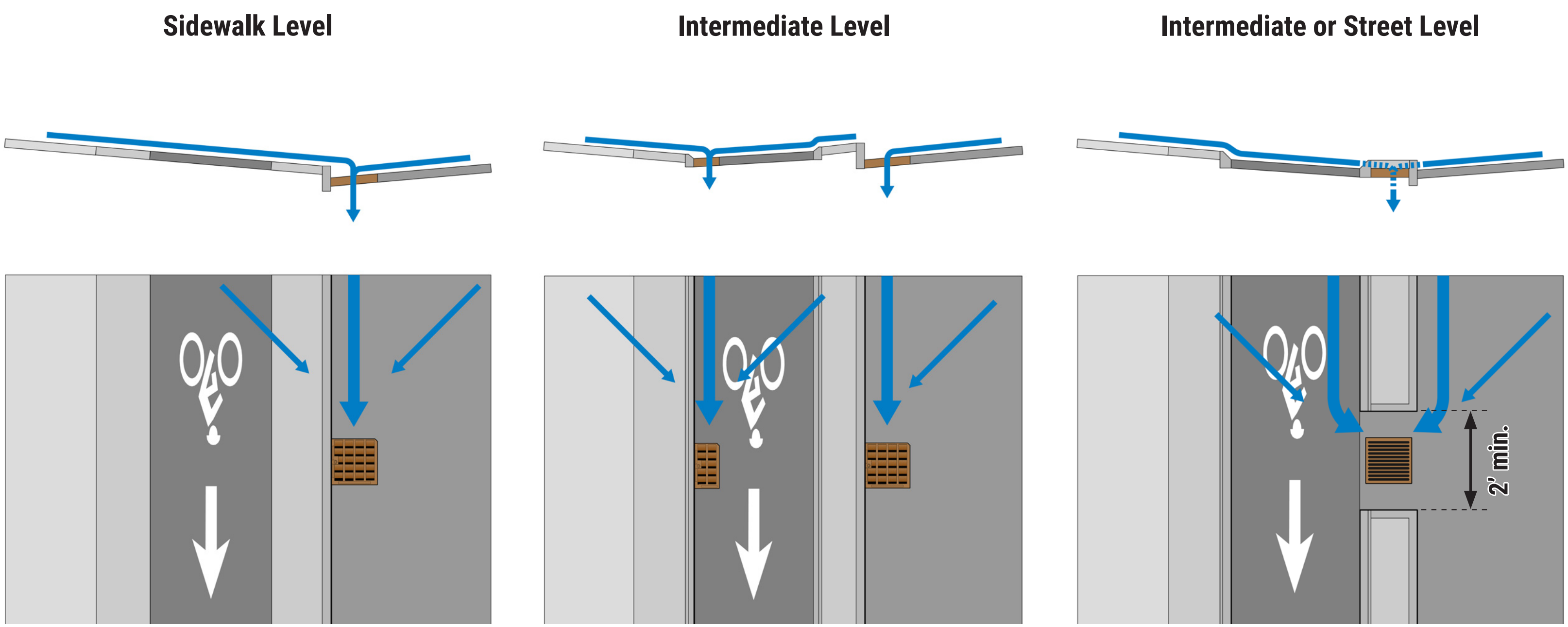


EXHIBIT 3P: Examples of Separated Bike Lane Drainage Options

Where such green infrastructure designs are impracticable, it is recommended to connect into closed drainage systems where they exist. For sidewalk and intermediate level separated bike lanes, new catch basins and/or trunk conveyance systems in the street or sidewalk buffers may be required to connect to existing trunk lines. For street level separated bike lanes, gaps between vertical objects or openings in raised medians may be used to channelize stormwater across the street buffer towards existing catch basins along the sidewalk buffer. These median cuts may be open channels or covered with steel plates. Steel plates should be considered in areas where parallel parking is proposed and should meet **AASHTO HS20** loading conditions to accommodate traversing people.

Drainage design for separated bike lanes should follow general design principles outlined in the PD&DG and the MassDOT Stormwater Handbook.

Where the roadway will drain across the bike lane, the design team should consider supplementary catch basins in the street buffer or more frequent raised median curb cuts to control the speed and spread of flow of water along the roadway and within the separated bike lane. Spread of flow within the roadway should follow the guidance provided in **Chapter 8 of the PD&DG**; however, spread of flow (and velocity) within the bike lane should consider the volume of bicyclists, the depth of flow within the bike lane, and the potential for the accumulation of debris or ice associated with larger stormwater spreads. Low points should be specifically considered for curbed street-level facilities to address safety and drainage issues associated with the spread of flow within the bike lane.

Drainage grates should be located outside of the bike lane whenever feasible to maintain a comfortable riding surface. However, grate location will largely be determined by the location of existing catch basins. When their placement in the bike lane cannot be avoided, drainage grates must be bicycle-friendly (e.g., hook lock cascade grates as noted in **Engineering Design Directive E-09-002**). Designers should consider narrower grates in the bike lane, as illustrated in **EXHIBIT 3P**, or eliminating bike lane grates in favor of trench grates in buffer areas or curb inlets.

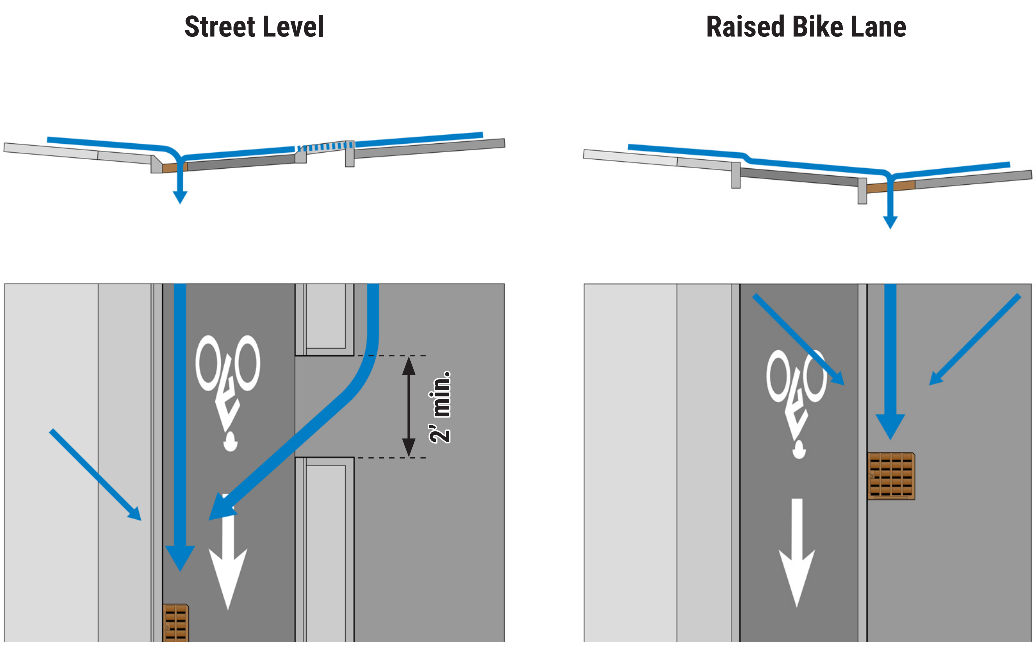


EXHIBIT 3P: Examples of Separated Bike Lane Drainage Options (Continued)

3.8.2 GREEN STORMWATER INFRASTRUCTURE

Green stormwater infrastructure increases infiltration of water back into the ground, which improves water quality and reduces flooding. The addition of separated bike lanes to a roadway presents an opportunity to introduce stormwater management strategies, including continuous treatments (e.g., permeable hardscape surfaces, linear bioretention areas, and linear water quality swales) and those that may only be implemented at spot locations (e.g., bioretention areas, bioretention curb extension area, and tree boxes) (see **EXHIBIT 3Q**). Their inclusion into the design of separated bike lanes is both a functional use of buffer areas and a sustainable way to enhance corridor aesthetics.

The design team should consider project objectives, regulatory requirements, maintenance requirements, cost-effectiveness of treatments, and the location of existing utilities, buildings and other physical features when screening and selecting stormwater treatments. The opportunities to include green stormwater infrastructure will largely be determined by the available street buffer or sidewalk buffer width; as such, the widths of these buffers should be a significant consideration during the design of the separated bike lane and the stormwater management planning.

In addition to buffer areas, the use of permeable asphalt or concrete may be considered for the bike lane zone. By facilitating gradual absorption of water into the ground, permeable pavement can increase bike lane traction and reduce icing by providing an outlet for standing water, provided that the surface is vacuumed periodically to remove dirt and debris.

It is preferred to maintain natural drainage patterns through the use of vegetated swales and medians in rural and lower-density suburban areas that lack curbing or drainage systems (see **Section 3.9.2**).

The addition of separated bike lanes into a roadway presents an opportunity to introduce 'green infrastructure' stormwater management strategies.

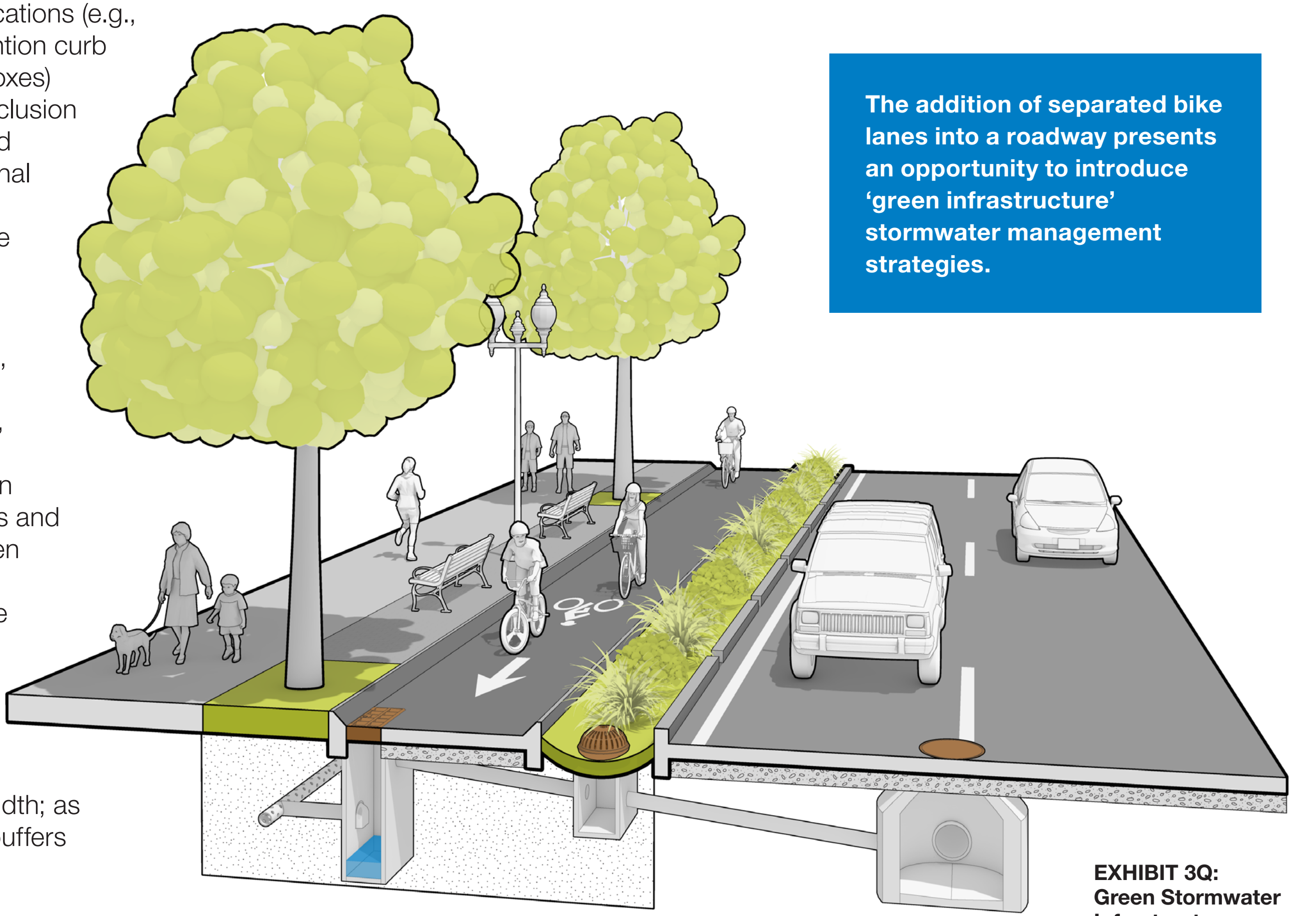


EXHIBIT 3Q: Green Stormwater Infrastructure Options

3.9 LANDSCAPING

Well-designed landscaping—trees, shrubs and grasses—alongside separated bike lanes creates a more pleasant bicycling environment, improves community aesthetics and provides a traffic calming benefit by visually narrowing the roadway. Buffer designs should incorporate native species whenever possible. Landscaping, including defining maintenance roles, should be coordinated during preliminary design stages. Refer to Chapter 13 of the PD&DG for comprehensive landscape design guidance.

3.9.1 LANDSCAPING ON ROADWAYS THROUGH DEVELOPED AREAS

Street trees are the primary considerations for landscape design along separated bike lanes in urban and well-developed suburban environments. With respect to the separated bike lane cross section, trees may be located in the street or sidewalk buffers. The street buffer is the recommended tree planting location to preserve usable sidewalk width and enhance separation, but the sidewalk buffer may be considered to provide shade for the sidewalk or where the street buffer is too narrow (see EXHIBIT 3R).

- When selecting tree species, ensure compatibility with the bicyclist operating height (**100 in.** from bike lane surface to tree branches). Avoid shallow rooted species and species that produce an abundance of fruits, nuts and leaf litter. Properly designed tree trenches, tree pits or raised tree beds can support root growth to preserve pavement quality of the adjacent separated bike lane.
- Where on-street parking is present, intermittent curb extensions with street trees between parking spaces can preserve sidewalk space and visually narrow the roadway for traffic calming.
- Integrate tree plantings with stormwater management techniques, including permeable surface treatments (see Section 3.8.2).

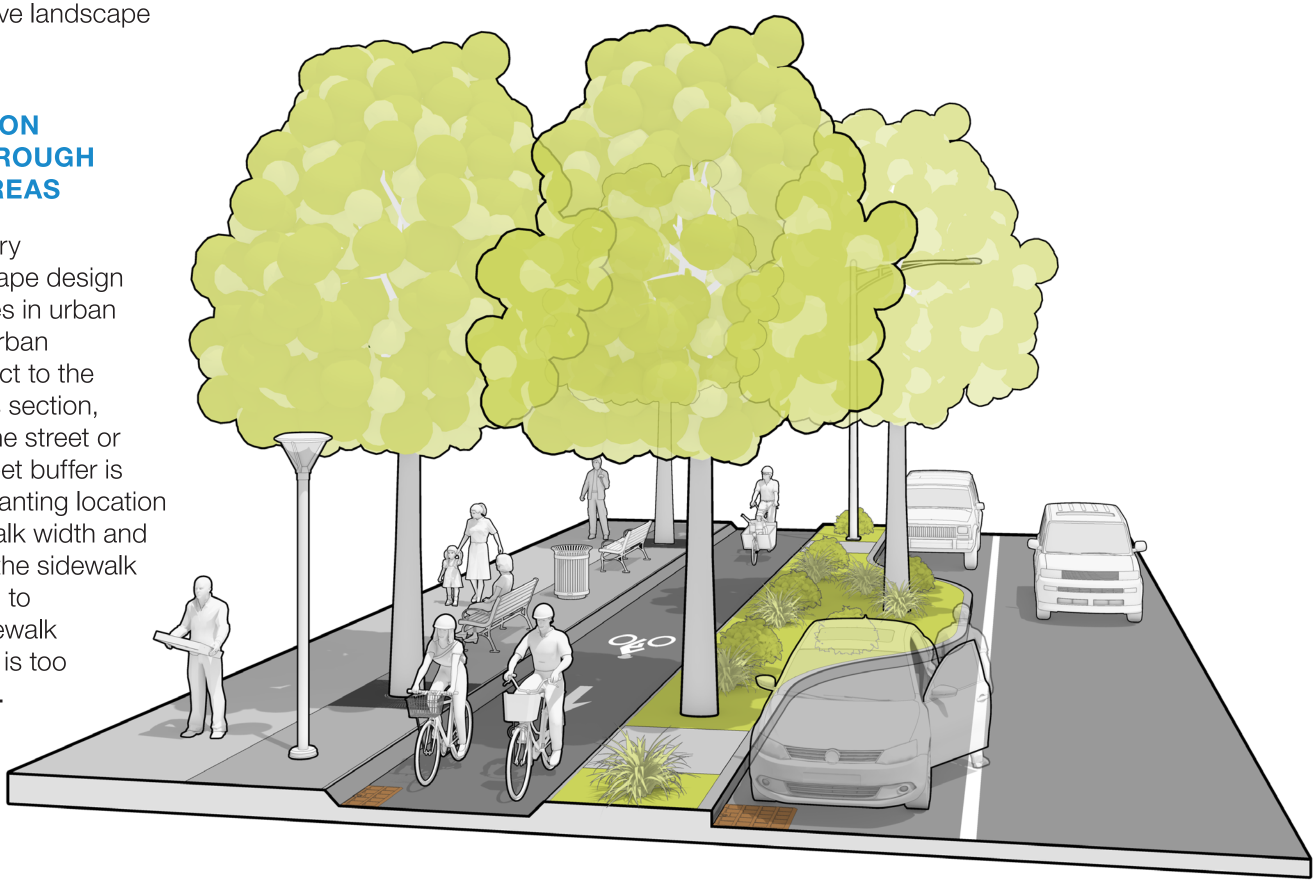


EXHIBIT 3R: Landscaping on Roadways through Developed Areas

3.9.2 LANDSCAPING ON ROADWAYS THROUGH SUBURBAN AND RURAL AREAS

The design of separated bike lanes and shared use paths in rural and low-density suburban communities should follow natural roadside design considerations. Natural roadside corridors are bound by the limits of the right-of-way and are relatively undisturbed beyond basic roadway infrastructure, open drainage systems and minimal utilities (see **EXHIBIT 3S**). Motor vehicle speeds in these corridors are typically higher than urban environments, so the design team may need to consider clear zone requirements with regard to the design of the street buffer (see **Section 5.6.1 of the PD&DG**) and should be mindful of sight lines at curves and intersections.

- **Fit the separated bike lane or sidepath to the natural terrain, but maintain grades that are comfortable for bicycling.**
- **Avoid and minimize impacts to wetland resources or other natural environments.**
- **Maintain all natural drainage patterns and minimize erosion through the use of vegetated drainage channels in the street buffer.**
- **Maintain access for periodic mowing and other maintenance activities.**
- **Where available right-of-way is sufficient, consider directing runoff from the separated bike lane or shared use path onto adjacent vegetated surfaces where topography and soils are suitable for managing runoff using 'pavement disconnection' practices.**

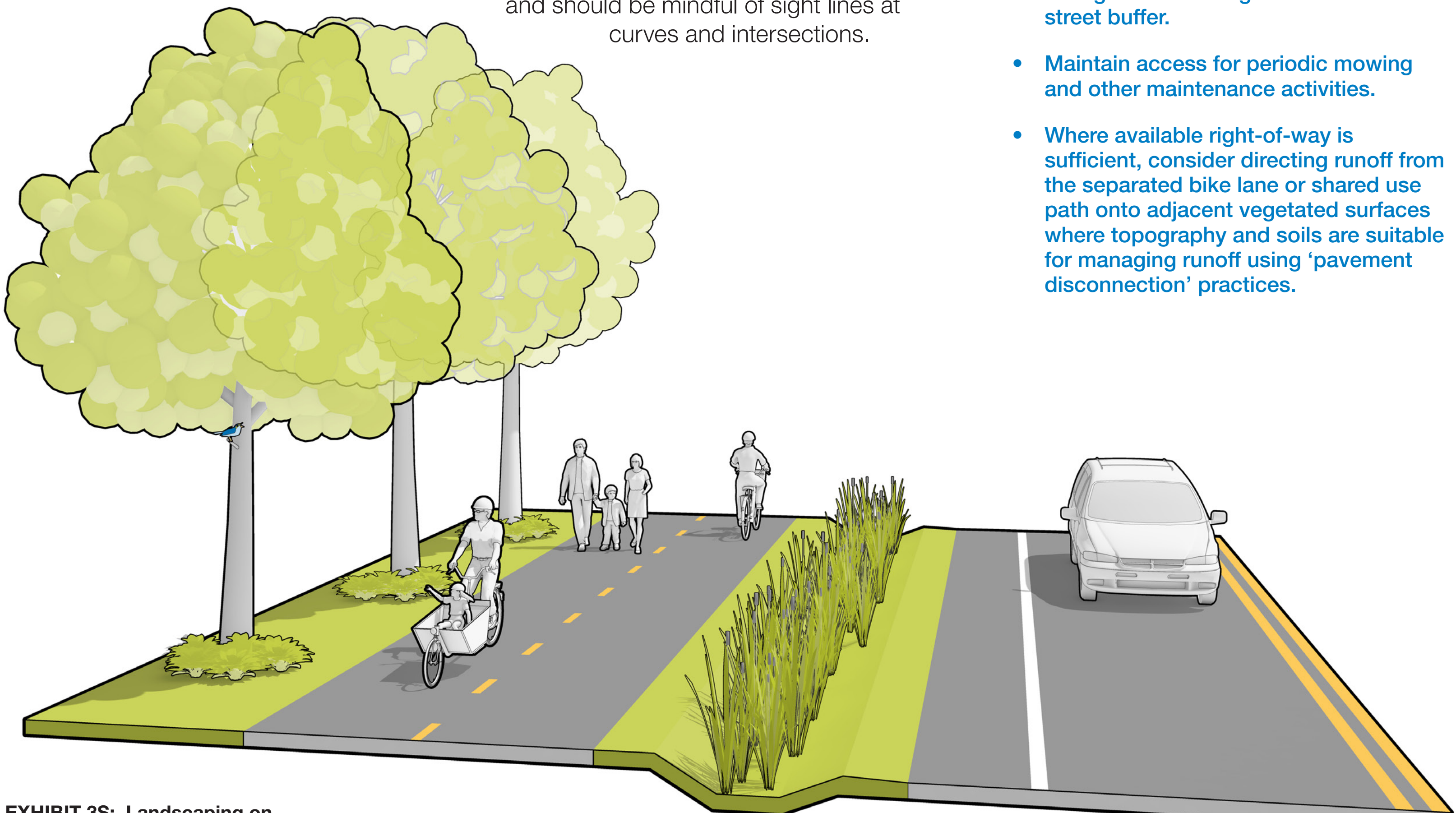


EXHIBIT 3S: Landscaping on Roadways through Suburban and Rural Areas

3.10 LIGHTING

The type, spacing and location of streetlights are important considerations for the safety and comfort of separated bike lanes. Sufficient and even illumination of the roadway, separated bike lane and sidewalk should be the primary considerations when deciding where to locate streetlights.

Streetlights may be located in the street buffer, sidewalk buffer or both, depending on the available width of the buffer areas. Pedestrian-scale acorn fixtures (between **11 ft.** and **16 ft.** in height) are recommended for their ability to enhance the attractiveness of the street. They may be used in combination with pendant or contemporary fixtures (up to **25 ft.** in height) to further illuminate intersections and areas of conflict. In constrained corridors taller fixtures may be sufficient on their own.

Motor vehicle headlights may pose a blinding hazard for contra-flow bicyclists where ambient light is low. Designers should consider increased lighting along two-way or contra-flow separated bike lanes to reduce this risk.

Streetlight design for separated bike lanes should follow local streetscape and historic district guidelines as well as guidance from FHWA and the Illumination Engineering Society.

Cambridge, MA

Boston, MA

Cambridge, MA

3.11 UTILITY PLACEMENT

The placement of utilities and utility covers should also be considered during the design of separated bike lanes. Because bicyclists are sensitive to surface irregularities and shy away from nearby vertical objects, awkward placement of utilities may reduce the comfort and attractiveness of separated bike lanes.

Implementing separated bike lanes may present an opportunity to perform utility work in a corridor. Designers should coordinate with utility companies in advance of construction in order to minimize disruption.

Addressing utility location may not be practical in retrofit situations where minimal reconstruction is anticipated. However, new construction or substantial reconstruction presents opportunities to proactively address utility placement.

- **The usable width of the bike lane is reduced if utility poles are located too closely to the separated bike lane. Designers should locate utility poles and all other vertical objects at least 6 in. from the face of the curb adjacent to the bike lane zone, and at least 18 in. from the face of the curb adjacent to the motor vehicle lane.**

- **It is preferable to locate fire hydrants in the sidewalk buffer to avoid proximity to on-street parking. Hydrants should be located at least 6 in. from the face of the curb adjacent to the bike lane zone. Designers should coordinate with the local fire department to determine final placement.**

- **Utility covers should be located outside of the bike lane zone and in the street buffer or sidewalk buffer, where feasible, to maintain a level bicycling surface and minimize detours during utility work. Where unavoidable, utility covers in the bike lane should be smooth and flush with the bike lane surface, and placed in a manner that minimizes the need for avoidance maneuvering by bicyclists.**

3.12 OTHER POLICIES AND GUIDELINES

3.12.1 DESIGN EXCEPTIONS

A Design Exception Report (DER) is required when any of FHWA's applicable controlling criteria are not met (http://safety.fhwa.dot.gov). Additionally, there are requirements for pedestrian and bicycle accommodations under the **Healthy Transportation Compact** and **Engineering Directive E-14-006**.

3.12.2 REQUEST FOR EXPERIMENTATION

While the decision to provide separated bike lanes in federally funded projects does not require a Request for Experimentation (RFE) from FHWA, some traffic control devices and treatments, such as non-standard pavement markings, may require an approved RFE from FHWA. FHWA must approve the RFE prior to the **100 percent** design submittal. The designer should consult the FHWA website section on bicycle facilities and the MUTCD to determine the current approval status of potential treatments.

3.12.3 ACCESSIBILITY

Separated bike lanes, like all MassDOT designs and projects, shall maintain equal access for disabled individuals, as required by the **Americans with Disabilities Act of 1990**. Design guidance in this document is consistent with all applicable accessibility standards and guidelines, including **521 CMR** (Rules and Regulations of the Massachusetts Architectural Access Board) and proposed **PROWAG** guidelines to the extent possible, given the fact that separated bike lanes are a relatively new facility type and are not specifically addressed in existing standards and guidelines.

3.12.4 SHOULDER REQUIREMENTS

MassDOT requires an analysis of applicable design criteria for outside shoulder width for all projects. In urban areas with constrained right-of-way, separated bike lanes with or without on-street parking fulfill some shoulder functions including bicycle use, drainage, lateral support of pavement, and, in street and sidewalk buffer areas, snow storage. Therefore, an additional shoulder is not required provided that a design exception is obtained. However, in suburban and rural areas with fewer right-of-way constraints and higher motor vehicle speeds, a paved shoulder may be necessary in addition to a separated bike lane. For shoulder function and width criteria, refer to **Section 5.3.3.1 of the PD&DG**.

3.13 ENDNOTES

1 J.P. Schepers, P.A. Kroeze,W. Sweers, J.C. Wüst. (2011) Road factors and bicycle–motor vehicle crashes at unsignalized priority intersections. Accident Analysis and Prevention. Volume 43.

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