Chapter 5—Designing Trail Crossings and Structures

Some of the most complex elements on trails are crossings and structures. Trails intercept roads, highways, railroad rights-of-way, wetlands, and waterways. Trails can pass over, under, or across such obstacles. Constructing even the simplest at-grade road or stream crossing means evaluating safety issues, trail user needs, design parameters, environmental concerns, and cost. Solutions range from simple to complex, and they require input from engineers and scientists representing many disciplines, as well as trail designers, legal experts, and local riders. This guidebook provides only a basic overview for trail crossings and structures. Consult governing authorities and qualified professionals for requirements, laws, standards, and guidelines.

At-Grade Road Crossings

Horse trails often cross roads or highways *at grade*—on the same elevation as the road. Ideally, the amount of motorized traffic in such areas is low, or the intersection has a traffic light with a push-button signal actuator that the rider can easily reach. Push-button signal actuators allow users to control the traffic light. When horse trails intersect with roads, safety is the most important factor. Road crossings must conform to legal requirements, and they require the expertise of transportation engineers. When designing trail crossings, it is wise to consult a designer familiar with the special requirements of riders and stock.

Crossing Locations

Where trails cross roads, the trail should be perpendicular to the road. The crossing generally should be on a straight segment of road. Locations where motorists might expect an intersection are good sites for trail crossings. Consistency in the placement and design of intersections allows all users to identify them more readily. Federal, State, or local regulations usually affect trails that intersect roads.

Trail Talk

Dogleg Approaches

The Haney Horsemen in British Columbia, Canada, sometimes advocate the use of T- or L-shaped trail jogs just before intersections with roads (Archibald, personal communication). The jog allows riders to slow down before they reach the road. When nearby vegetation is cleared appropriately, the added turns allow trail users and drivers to see each other in advance. Trails that approach an intersection by an S-shaped or zigzag path also allow trail users to see vehicles in several directions as they approach the road. Circuitous routes have another benefit—they can force stock to observe traffic, instead of blindly following the animal in front. When using dogleg approaches, provide adequate sight distance for both road and trail users, and make sure the immediate approach and crossing are perpendicular to the road.

Appropriate tread surfaces at road crossings are critical to rider safety. Most asphalt and concrete road surfaces don't provide enough texture or traction for a horse or mule. These surfaces can be as slippery to stock as compacted snow and ice are to pedestrians. For more information, see *Chapter 6—Choosing Horse-Friendly Surface Materials*.

The use of warning signs, decreased speed limits, road markings, narrowed travel lanes, and other traffic control devices can enhance the safety of riders and other users at road crossings. On public roads, signs and other traffic control devices must conform to the *Manual on Uniform Traffic Control Devices* (MUTCD).

Resource Roundup

Intersection and Road Crossing Guides

Shared-use trails may intersect with roads or have segments that need to meet Federal, State, or local requirements. Many agencies adopt the standard references listed below as part of their own requirements. The references listed are updated frequently—consult the latest edition.

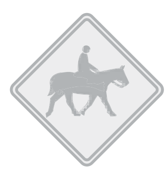
- ✫ *A Policy on Geometric Design of Highways and Streets* (AASHTO 2001a) can be ordered from the AASHTO online bookstore at *https://bookstore.transportation.org/item_details.aspx?ID=110.*
- ✫ *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)* (AASHTO 2001b) can be ordered from the AASHTO online bookstore at *https://bookstore.transportation.org/item_details.aspx?ID=157.*
- ✫ *Roadside Design Guide* (AASHTO 2002) can be ordered from the AASHTO online bookstore at *https://bookstore.transportation.org/item_details.aspx?ID=148*
- ✫ *Manual on Uniform Traffic Control Devices* (FHWA 2004a) is available at *http://mutcd.fhwa.dot.gov.*
- ✫ *MUTCD Standard Highway Signs* (FHWA 2004b), a companion document to the MUTCD, is available at *http://mutcd.fhwa.dot.gov/ser-shs_millennium.htm.*

Crossing Sight Triangles and Visibility

Riders need to see the road before they approach an intersection or a crossing that has rapidly moving traffic. To each side of the trail, vehicles need to see the approaching stock. These sight distances, sometimes called the *sight triangle*, allow sufficient time for everyone to stop safely once they have seen each other.

The required sight distances vary with the speed of the traffic involved and the eye height of the travelers. Refer to the appropriate AASHTO geometric design guidelines when calculating sight triangles for bicyclists and motorists on roads that intersect horse trails. Refer to the *Trail Sight Distance* discussion in *Chapter 4—Designing Trail Elements* for more information regarding riders' needs.

Many riders recreate after sundown and during evening hours, particularly in warmer climates. While lighting at rural or wildland crossings generally is not feasible, in areas with high levels of development, crossing lights may be advisable.



Trail Talk

Trails Crossing Roads

Where shared-use trails approach road crossings, Baughman and Serres (2006) recommend adding "…a tight turn, ridges and dips in the tread, and/or narrowing the clearing width to slow down trail users. On the final approach the trail must be at a right angle (90 degrees) to the road, nearly level, and have a sight distance adequate for trail users to see the oncoming road in time to stop." They also recommend expanding the clearing width or thinning forest trees to provide good visibility from the trail to the road.

Waiting Areas at Crossings

Riders generally ride in pairs or groups. When a trail group comes to a road crossing, riders may have difficulty keeping stock off the road. Solutions include trimming vegetation to provide a clear view farther from the road or providing a waiting area that allows stock to stand back from traffic until it is safe to cross. Consider expanding the width of the trail surface before it meets the road, forming a rectangular or fan-shaped waiting area.

Trail Talk

Waiting to Go

In the United Kingdom, rider waiting areas—also called *refuges*—are required where equestrian routes cross roads at grade (figure 5–1). *The Geometric Design of Pedestrian, Cycle and Equestrian Routes* (The Highways Agency 2005b) specifies a grassy area measuring 16.4 by 32.8 feet (5 meters by 10 meters). Two L-shaped fences or barriers are set opposite each other to create a dogleg in the bridle path, slowing trail traffic before it reaches the waiting area. Fence segments guide riders and their stock and make the refuge more noticeable to other users. When reviewing this design, keep in mind that traffic in the United Kingdom travels on the left-hand side of the road. U-turns are usually prohibited near rider refuge areas. When refuges are necessary in medians between multiple lanes of traffic, the designated size is 16.4 feet wide by 9.8 feet long (5 by 3 meters). Structures associated with equestrian routes, such as bridle gates or horse stiles, must be placed at least 13.1 feet (4 meters) from the road.

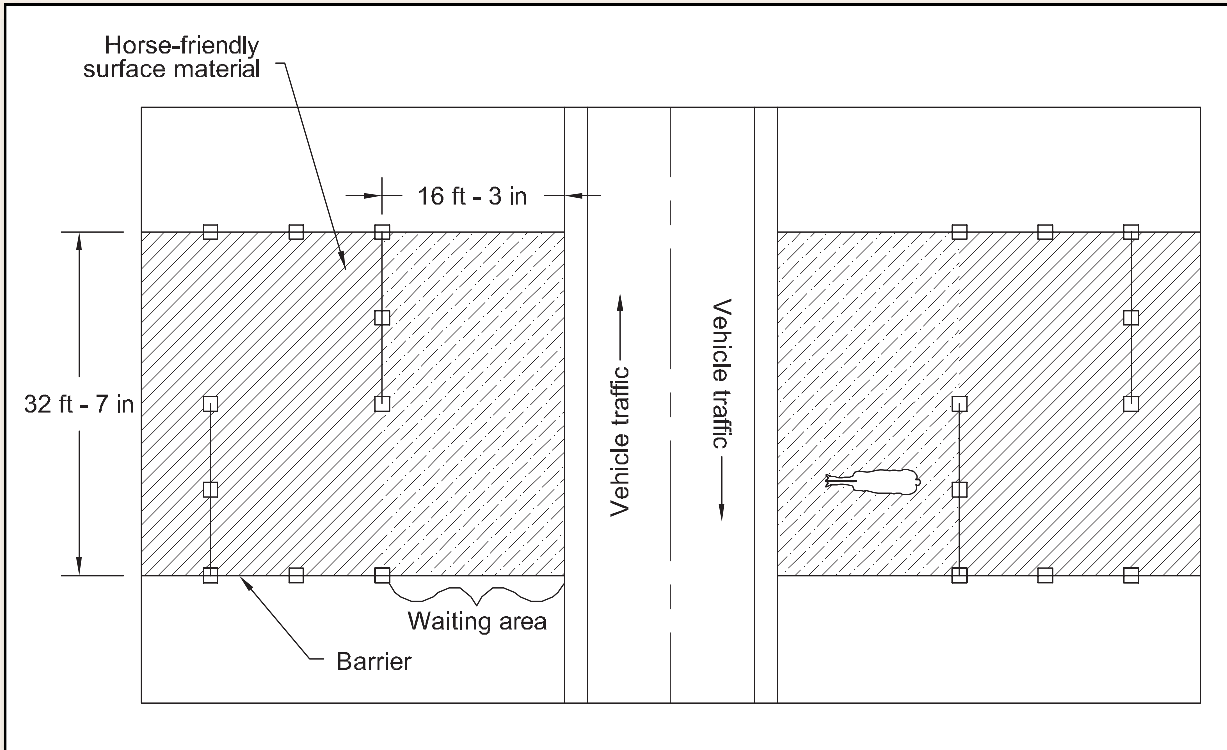


Figure 5–1—A bridleway crossing with waiting area in the United Kingdom. —*Courtesy of The Highways Agency. The original figure was edited for clarity.*

Road Signs and Traffic Signals

Road signs are critical for the safety of riders and other trail users where trails cross roads. Consider standard equestrian crossing signs for all at-grade road crossings used by horses and mules. *Chapter 12—Providing Signs and Public Information* has more information regarding road signs.

Most push-button signal actuators are installed too low for riders to reach without dismounting. To solve the problem, install a second push button for riders. Most seated riders can operate a push button that is between 5 and 6 feet (1.5 and 1.8 meters) above the ground (figure 5–2). Set the post far enough back from the road to keep stock out of the traffic lane.

Trail Talk

Push-Button Signal Actuators

Equestrian Crossings (The Highways Agency 2003) discusses crossings with and without traffic signals in the United Kingdom. The Highways Agency places push-button signal actuators in a position that encourages riders to first check the nearest approaching traffic. They also recommend placing push buttons at least 6.6 feet (2 meters) from the road edge so the animal's head does not encroach on traffic. The leaflet is available at *http://www.dft.gov.uk/pgr/roads/tpm/tal/signsandsignals/equestriancrossings*.

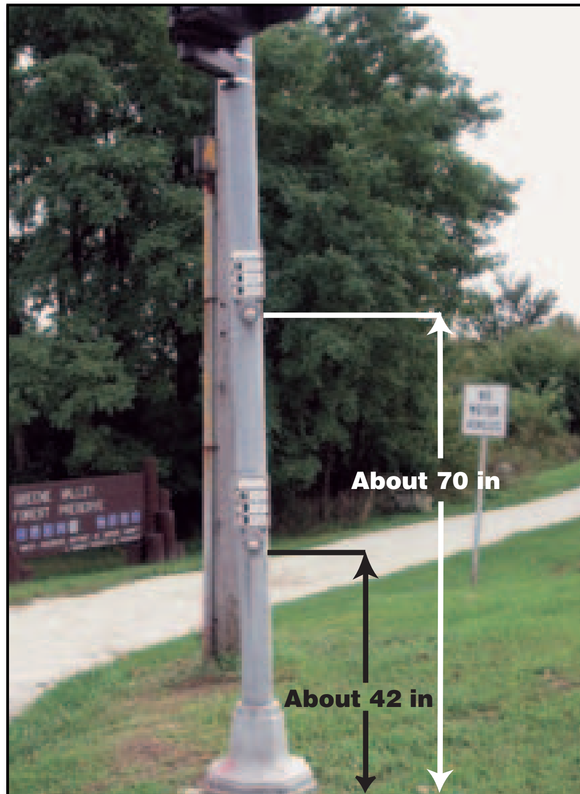


Figure 5–2—Two push-button signal actuators serve pedestrians and riders. The push button for equestrians is about 70 inches above the trail's surface. —*Courtesy of Forest Preserve District of DuPage County, IL.*

Road Intersections

Trail intersections with roads require site-specific engineering studies and must comply with the MUTCD standards, AASHTO guidelines, and other applicable requirements for signs, push-button signal actuators, and related elements. Figures 5–3 and 5–4 illustrate two concepts for shared-use trails that intersect with roads. Figure 5–3 illustrates a concept for an at-grade road crossing with traffic signals, curbs, and sidewalks. Figure 5–4 illustrates a concept for an at-grade trail crossing without signals. According to the MUTCD (2003), nonvehicular signs with symbols may be used to alert road users in advance of locations where unexpected entries may occur.

Resource Roundup

Early Warning

Usually, when there is no electricity, traffic warning lights can't be used. This presents problems when recreation trails cross roads or when crossing sight distance is poor. One solution is the Cross Alert System, a motion-activated, solar-powered, warning light. Activity on the trail triggers a radio-controlled amber warning beacon, alerting motorized traffic that trail users are at or near the intersection. The self-contained system handles rough conditions and senses many users, including pedestrians, bicyclists, and equestrians. A wide detection zone can be set up to monitor dual parallel treads, and early warning signs can be placed as far away as 500 feet (152.4 meters). Options include an integrated counter. More information is available at *http://measur.*

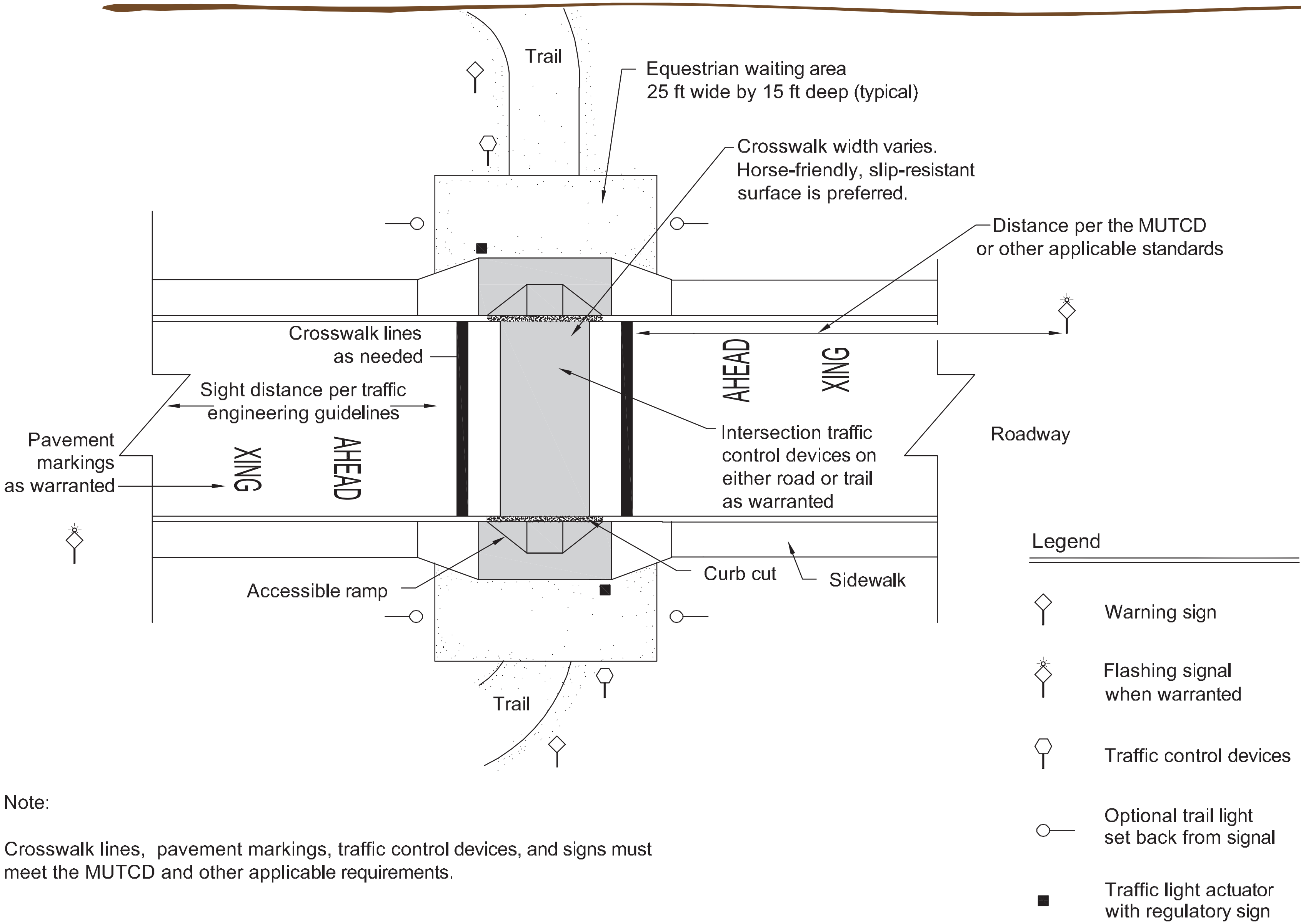


Figure 5–3—An at-grade trail crossing (with signals) for equestrians. —*Adapted from the Manual on Uniform Traffic Control Devices (FHWA 2003).*

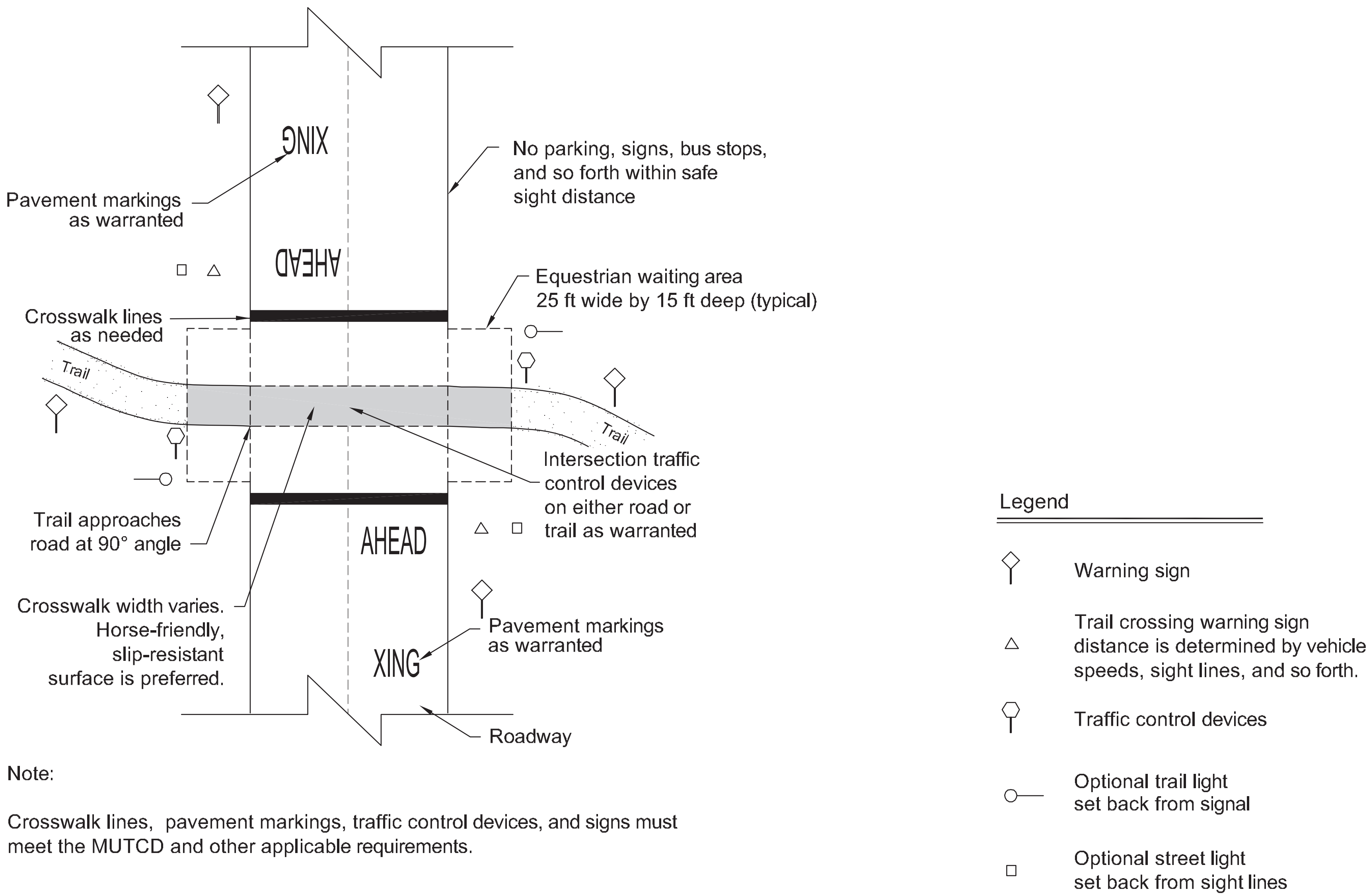


Figure 5–4—An at-grade trail crossing (without signals) for equestrians. —*Adapted from the Manual on Uniform Traffic Control Devices (FHWA 2003).*

In highly developed areas, horse trails sometimes cross driveways leading into private property, or intersect with road entrances into commercial areas. Two scenarios are common when an unpaved trail crosses a driveway—the unpaved tread continues across the drive, or the unpaved drive continues across the tread. If a paved surface is required, roughen it to improve traction, or choose material that is horse-friendly. Consult *Chapter 6—Choosing Horse-Friendly Surface Materials* for information regarding options. Figure 5–5 is an example of an unpaved trail that crosses a private driveway.

Figure 5–5—Unpaved trails that continue across driveways are more comfortable for riders than trails that are interrupted with pavement. The Murphy Bridle Path in North Central Phoenix, AZ, was established in 1895 and preserved as an unpaved trail in the heart of a modern community. Unpaved trail sections across driveways may not be suitable in all regions of the country.

Trail Talk

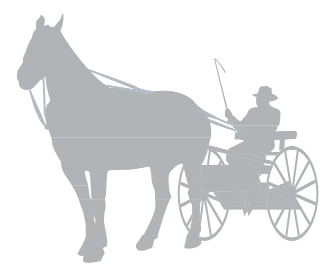
Crossing the Street

Town of Queen Creek Parks, Trails and Open Space Master Plan (HDR and others 2005) lists the following design considerations for shared-use, enhanced at-grade crossings in Queen Creek, AZ.

- ☆ Crosswalks and curb ramps at right angles to moving traffic, ladder crosswalk markings, curb extensions with landscaping, detectable warnings, and accessible pedestrian signals. Where the trail crosses, surface the crosswalk with washed concrete or incise grooves in the concrete perpendicular to the direction of trail travel.
- ☆ Adequate sight distances that consider time, visibility, amenities, warning signs, and lighting.
- ☆ Gathering spaces [*waiting areas*], large enough for riders, at each crossing corner.
- ☆ Push-button signal actuators where trails cross. Locate one button at 6 feet (1.8 meters) above the tread for riders and another push button at pedestrian height. Allow maneuvering space around actuator posts.
- ☆ A crossing island or median (raised or flush) safe zone with curb ramps or cut-throughs the same width or greater than the trail or path.
- ☆ Traffic calming techniques.
- ☆ Fences or barriers to separate the trail from paths, adjoining property, and similar situations.
- ☆ Optional lighting scaled for pedestrians and riders.

The elements are variable at corners and crosswalks, depending on how trails converge at the site. Complex intersections require engineering to meet safety and legal requirements. Consult the MUTCD and AASHTO publications for more information.

Continuing an unpaved tread across a driveway in snow country frequently is impractical because winter plowing can disturb the surface materials. Consult governing authorities for requirements regarding construction, signs, traffic patterns, and applicable accessibility requirements.



Railway Corridors and Crossings

Routing horse trails along active railroad corridors generally is ill-advised. Most riders don't want to ride on a trail adjacent to active rail tracks. Train speeds, sounds, vibrations, and size are threatening to stock that are not familiar with them. Controlled crossings with crossing bells, sirens, horns, lights, or traffic gates can frighten stock and cause them to become uncontrollable. However, in limited circumstances horse trails or crossings in railroad corridors may be unavoidable (figure 5–6).

Figure 5–6—The sights and sounds of a moving train frequently frighten animals. Trails in rail corridors are subject to many safety and legal requirements. —*Courtesy of Anne M. O'Dell.*

For safety reasons, most railroad companies are reluctant to allow other uses within their rights-of-way. Railroad rights-of-way are private property—walking or riding there without explicit authorization from the railroad company is trespassing.

Arrangements to use railroad corridors or crossings require extensive negotiation between trail developers, governing jurisdictions, and property owners. Safety arrangements have to be negotiated in areas where proposed equestrian trails will be close to railroads.

Locating horse trails or crossings in active railroad corridors is a lengthy and costly process. Permits, easements, or rights-of-way are an absolute necessity. In addition, stringent safety and liability issues must be addressed. When at-grade railroad crossings intersect highways, they also are subject to the governing highway authority. Frequently, the highway authority pays to install crossing signs and signals on highways, and the railroad maintains them.

Lingo Lasso

Rails, Tracks, Railways, and Railroads

Operation Lifesaver (Hall, personal communication) explains easily confused railroad terms:

- ☆ *Rails*—The steel strips
- ☆ *Tracks*—The pair of rails with ties holding them together
- ☆ *Railways and railroads*—Generally, the companies that own the tracks
- ☆ *Highway-rail grade crossings*—The intersections where roads and railroad tracks meet

Trails parallel to *active* railroad tracks are called *rails-with-trails* (RWTs). Don't mistake RWTs for *rails-to-trails*, which follow former—or *inactive*—rail lines. Safety is the most important factor when designing RWTs that include riders. According to *Rails-with-Trails: Lessons Learned* (Alta Planning and Design 2002): "Trail width is an overriding design issue when considering equestrian use on RWTs. RWTs designed to accommodate equestrian use should provide separate treads for multiple users. Narrow rights-of-way that afford width for only a single paved trail, or that provide inadequate shy distance for a horse frightened by near or oncoming trains are not appropriate candidates for accommodation of equestrian use. Trestles and bridges require additional considerations. Many horses are frightened by bridges and other elevated environments, particularly lattice or perforated bridges and trestles that allow the animal a view of the ground substantially below the bridge deck. Most horses are not accustomed to this environment and will respond unpredictably with potentially negative consequences."

Because there are no national planning standards or guidelines for trail setback distances parallel to active railroads, guidance must be pieced together from relevant standards for shared-use trails, pedestrian facilities, railroad facilities, and/or railroad crossings or railroad rights-of-way. Consider these factors (Alta

Planning and Design 2002) during trail feasibility studies:

- ☆ Type, speed, and frequency of trains in the trail corridor
- ☆ Maintenance needs
- ☆ Applicable State standards
- ☆ Separation techniques
- ☆ Historical problems
- ☆ Track curvature
- ☆ Topography
- ☆ Engineering judgment

Because every case is different, determine the setback distance and other considerations on a case-by-case basis after engineering analysis and consideration of liability concerns.

Resource Roundup

Rail and Trail Information

Visit these online resources for more information regarding railway crossings:

- ☆ Federal Railroad Administration at *http://www.fra.dot.gov.*
- ☆ Operation Lifesaver at *http://www.oli.org.*

Generally, horses and mules can maneuver over railroad tracks that intersect trails when the crossing is wide enough and has solid, level footing—at the approach, between the rails, and on the opposite side of the railroad track. Trails, roads, or sidewalks should approach a railroad crossing perpendicular to the direction of train travel. Build the tread surface level with the top rail flange, filling in the gap (figure 5–7) as specified by railroad regulations. Materials commonly used to fill the gap include concrete, asphalt, hardened rubber, wood planks, gravel, or other durable materials. Rubber or concrete lasts longer than wood or asphalt and requires less maintenance. When trails cross abandoned tracks, consider removing the rails and ties.

Figure 5–7—Building a horse trail in an active railroad corridor requires extensive negotiation to address safety and liability concerns for trail users and railroad personnel. If trails must cross tracks, the tread should be level and the gaps filled according to railroad requirements. Trails also must approach tracks at a 90-degree angle.

Railcars overhang the tracks by 3 feet (0.9 meter) on each side, and trains need a dynamic operating space for loose loads or straps and thrown debris. To reduce the hazards associated with stock waiting for a train to pass through a crossing, a waiting area may be appropriate. Locate waiting areas back and away from rails as required at each site to meet the needs of trail users and railroad personnel.

Resource Roundup

Train and Trail Laws

Rails-with-Trails: Lessons Learned (Alta Planning and Design 2002) has valuable information regarding setbacks, separation distance, and other considerations dealing with trails and rail corridors, including sample legal agreements and a useful matrix of State laws regarding railroads and trails.

- ☆ The entire document is available at *http://www.fhwa.dot.gov/environment/rectrails/rwt.*
- ☆ *Appendix B: State-by-State Matrix of Applicable Laws and Statutes* is available at *http://www.fhwa.dot.gov/environment/rectrails/rwt/appendixb.htm.*

Water and Wet Area Crossings

Recreation trails generally cross water at grade or above. Constructing a crossing over or through water generally requires authorization from the governing authority and may require special construction techniques or environmental considerations. Horse trails may incorporate bridges or culverts to maximize habitat protection and reduce trail maintenance. Sometimes fording a stream is the best option.

Shallow Stream Fords

Locate fords in an area where the stream is straight and shallow, avoiding areas that are deeper than 2 feet (0.6 meter) during most of the use season. Avoid locations where the stream turns, because water undercuts the outside bank. Routing the trail to a good natural ford is better than building a new ford. When constructing a ford across a shallow stream, stabilize banks to prevent sedimentation, if necessary. Figure 5–8 shows a ford that crosses a fish ladder. Where suitable, angle trail approaches upstream to protect the bank from erosion caused by rising water. To block rising water from running down the main trail, construct approaches so they climb a short distance above the usual high water line (figure 5–9). Options for stabilizing banks include the use of geotextiles in combination with riprap. Figure 5–10 shows installation of soil-filled geocell layers to stabilize a bridge approach. Articulating

Figure 5–8—This fish ladder includes a ford for trail users while still allowing trout to move up the creek. The steps have big landings—about 8 to 10 feet long—and stock tolerate them. The rocks alongside the ford keep stock on the desired path.

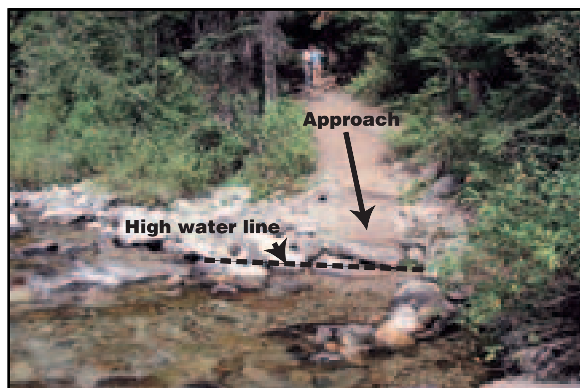


Figure 5–9—This ford has a rock step up to a landing. The trail approach rises to keep the stream from flowing down the tread. Rocks on the side of the ford guide stock to the step. *Caution*: large, wet rocks can be hazardous for all trail users.

and interlocking concrete pavers are other options for stabilizing streambeds. Pavers with voids for soil or plant material are less likely to be a slip hazard. Figure 5–11 shows interlocking hard pavers used to stabilize a bridge approach.

Figure 5–10—Workers have compacted soil into layers of geocell to provide stability at a bridge approach. The top layer will bring the tread level even with the deck level.

Provide solid footing, such as medium-sized gravel or a stabilized surface. Place it at a consistent depth from one bank to the other (figure 5–12). Choose the surface materials carefully—hardened surfaces reduce sedimentation and stream erosion, but can be slippery when wet.

Curbs that run across treads and smooth, hardened tread edges at water crossings are trip hazards and are not appropriate for horse trails. Natural rocks and

Figure 5–11—The approach to this trail bridge is reinforced with interlocking pavers to withstand wear from off-highway vehicle use. The pavers may not offer enough traction for horses and mules. A similar approach using horse-friendly pavers could be used on equestrian bridges.

crushed gravel can help sustain the edges of stream crossings when stabilization is necessary (figure 5–13). Do not include fines that will wash away. To prevent steep dropoffs, gradually transition from the tread to stream bottom. The underwater portion of the tread may need to be wider than the rest of the trail to accommodate stock that step to the side. On Forest Service horse trails, fords have a trail base that is at least 3 feet (0.9 meter) wide. Consult an engineer or hydrologist for additional techniques to stabilize fords and areas nearby. Figure 5–14 shows a concept for an urban channel crossing at grade. Geosynthetics stabilize the banks.

Fords get the most use when flows are low to moderate and are not intended for use during high runoff. Where fords traverse water with a strong current, the downstream side should be free of dangerous objects. Place pedestrian bridges or stepping stones on the upstream side of the equestrian bridge to prevent fallen stock from being swept into other trail users or pinned against structures.

Resource Roundup

Treading Water

These Forest Service references provide trail construction information regarding fords and wetlands:

- ☆ *Trail Construction and Maintenance Notebook: 2007 Edition* (Hesselbarth, Vachowski, and Davies 2007) is available at *http://www.fs.fed.us/t-d/pubs/htmlpubs/htm07232806*. This Web site requires a username and password. (Username: t-d, Password: t-d)
- ☆ *Wetland Trail Design and Construction* (Steinholz and Vachowski 2007) available at *http://www.fs.fed.us/t-d/pubs/htmlpubs/htm07232804*. This Web site requires a username and password. (Username: t-d, Password: t-d)

Figure 5–12—A stable tread surface is essential for shallow stream crossings. Stepping stones for pedestrians should be placed on the upstream side of the tread.

Figure 5–13—Rocks and gravel can be used to reduce erosion along waterways, but medium and large rocks can be slippery when wet. These riders chose the side of the tread with the best horse footing—small rocks and gravel.

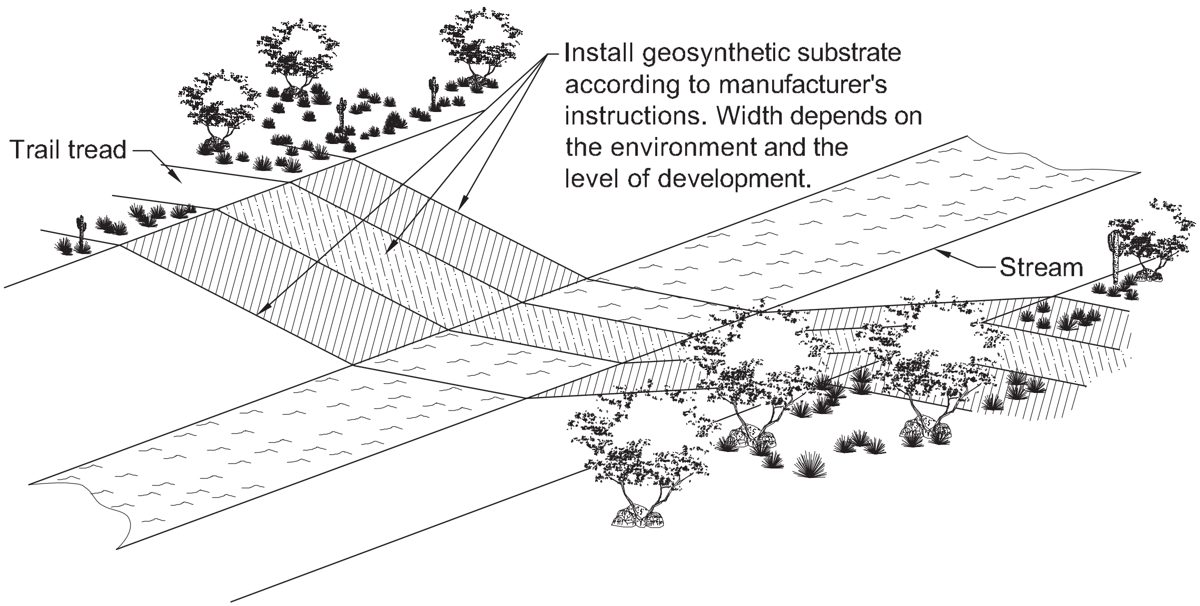


Figure 5–14—A channel crossing using geosynthetics to stabilize the banks. This example is suitable for areas with high levels of development.

Wet Area Trail Structures

In areas where at-grade stream crossings are not suitable, consider elevating the tread. Causeways, turnpikes, boardwalks, and puncheon bridges are construction methods that minimize damage to wet areas. These techniques often are used in combination with rock, fill, and geosynthetics, where permitted. Determine the type of support and drainage systems that will safely withstand the weight of stock on elevated trail treads.

Turnpikes

Turnpikes incorporate fill material taken from parallel side ditches and from offsite to build the trail base higher than the surrounding water table on wet or boggy ground (figure 5–15). Turnpikes are practical in areas with a trail grade up to 10 percent and in flat areas with 0- to 20-percent sideslopes. Use turnpike construction to provide a stable trail base in areas with a high water table and fair- to well-drained soils.

To build a turnpike, ditch both sides of the trail to lower the water table. Next, install geotextile, or other geosynthetic materials, and retainer logs or rocks. Place the geotextile under any retainers. Lay the geotextile over the ground with no excavation, and then add high-quality fill.

The two most important considerations when constructing a turnpike are lowering the water level below the trail base and carrying the water under and away from the trail at frequent intervals. Turnpikes require some degree of drainage. A turnpike is easier and cheaper to build than puncheon and may last longer. Use puncheon when the ground is so wet that drainage is impossible and grading is precluded.

Figure 5–15—A turnpike elevates the trail in boggy or wet areas. Ditches provide drainage. This turnpike has log stringers filled with coarse, well-drained rock.

Turnpikes Without Ditches

A more environmentally friendly relative of the turnpike is one without side ditches. Sometimes turnpikes without ditches are called causeways. In the Sierra Nevada, causeways filled with crushed rock create elevated, hardened treads across seasonally wet alpine meadows. A single causeway often replaces multiple, unwanted parallel treads. These causeways create less environmental impact than turnpikes, because they lack ditches and don't lower the water table. The risk is that turnpikes without ditches could sink into highly saturated soils, a problem mitigated by geotextiles. The encapsulation technique sometimes works well on causeways.

Horse Sense

Encapsulation: The Sand Sausage

Encapsulation, an alternative method of building tread in a turnpike, provides separation between good fill and clay and keeps a layer of soil drier than the muck beneath. To *encapsulate*—or create a sand sausage—excavate 10 to 12 inches (254 to 305 millimeters) of muck from the middle of the turnpike. Lay a roll of geotextile the length of the turnpike, wide enough to fold back over the top with a 12-inch (305-millimeter) overlap. Place 6 inches (152 millimeters) of crushed stone, gravel, or broken stone on top of the single layer of geotextile, then fold the geotextile back over the top and continue to fill the turnpike with tread material.

Puncheon

Puncheon is a wood walkway used to cross bogs or deep muskeg, to bridge boulder fields, or to cross small streams (figure 5–16). Puncheon can be constructed where uneven terrain or inadequate tread material makes turnpike construction impractical. It is easier to support puncheon on muddy surfaces than to construct a turnpike.

Puncheon resembles a short log-stringer trail bridge that has a deck made of native logs or sawn, treated timber. The deck of surface puncheon is placed on stringers to elevate the trail across wet, difficult-to-drain areas. The Student Conservation Association (Birkby 2006) constructs puncheon for horse trails using log stringers that are at least 10 inches (254 millimeters) in diameter and decking that is at least 4 inches (102 millimeters) thick. The puncheon is 48 inches (1,219 millimeters) wide.

Subsurface puncheon is placed flush with the wetland surface. Creating subsurface puncheon involves constructing mudsills, stringers, and decking under the surface. This design depends on continual water saturation for preservation. To improve traction, cover the surface between the curb logs with a layer of gravel, wood chips, or soil.

In areas with deep mud, sometimes trail users find it difficult to see and follow the trail on subsurface

Figure 5–16—Puncheon walkways can be level with the surface or lie below it. Log stringers support this deck.

puncheon. Once an animal steps off the tread, it can severely damage the area when attempting to regain solid footing. If the animal becomes trapped in muck, it may be very difficult or impossible to get it out alive.

Boardwalks

Boardwalks have multiple pilings, and are essentially a series of connected bridges. Horse trails rarely have boardwalks.

Retaining Curbs

Install longitudinal edging—*retaining curbs*—to delineate the edges on elevated treads or puncheon (see figures 5–15 and 5–16). Treat elevated treads, such as boardwalks, as if they were a bridge and use the guidelines for equestrian bridge designs.

5

Above-Grade Crossings

The design of *above-grade crossings*—bridges and overpasses—is complex and beyond the scope of this guide. Designing an appropriate above-grade crossing that meets the special needs of riders requires qualified and knowledgeable engineers, as well as other key resource specialists, who may include hydrologists, soil scientists, bridge and geotechnical engineers, and landscape architects. Design must comply with regulations established by the authorizing agency and Federal and State laws. Bridges require regular certified inspection according to governing regulations. Bridges on Forest Service lands, for example, must undergo inspection every 5 years.

Bridge and Overpass Design

Bridges and overpasses on horse trails require careful design to accommodate animal behavior. Horses and mules may hesitate if a bridge or overpass is narrow, sways, swings, vibrates, or is constructed of unfamiliar materials. Stock also are uncomfortable if the structure creates or amplifies noise. Even well-trained stock may balk at ramp approaches to bridges, especially where there are no approach rails. If a structure or tread appears dangerous, horses and mules usually refuse to go any farther. Incorporate skid-resistant surfaces and avoid designing steps on equestrian overpasses and bridges.

In general, there are six types of trail bridges:

- ☆ Cable bridges
- ☆ Deck girder/truss bridges
- ☆ Side girder/truss bridges—pony-truss bridges
- ☆ Arch bridges—deck or suspended bridges
- ☆ Miscellaneous single-unit bridges
- ☆ Covered bridges

Each bridge type and construction material has different span limitations that must be matched to site conditions. Longer crossings may have a very limited selection of suitable bridge types or materials. Prefabricated bridges, shipped in sections for reassembly on the site, may be appropriate for some situations. For example, the remote bridge shown in figure 5–17 consists of sections that were packed in and bolted into place. Engineering analysis is required for these products, along with strict adherence to the manufacturer's installation and maintenance instructions.

Figure 5–17—This packable bridge comes in 6-foot sections that are bolted together at the site. Nearby cliffs encourage stock to stay on the tread, so approach rails are unnecessary.

A simple bridge (figure 5–18) is adequate for many stream crossings. Horse and pedestrian trails frequently cross suspension bridges (figure 5–19). Long or swaying suspension bridges (figure 5–20) can be daunting to stock and riders that are not accustomed to crossing them.

Figure 5–18—The weathered steel and wood of this sturdy stock bridge fit the setting.

Figure 5–19—This wood suspension bridge is designed for packstock use in a wildland setting. The design would be appropriate for other users in other settings.

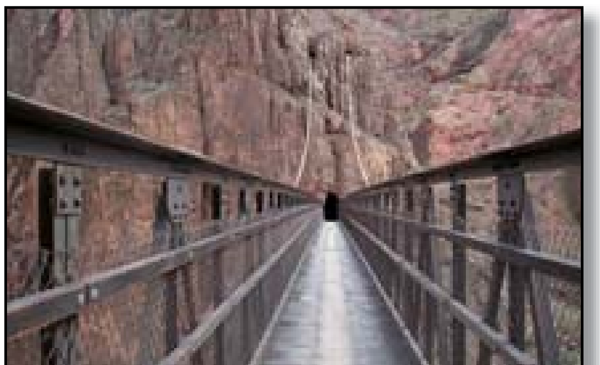


Figure 5–20—Inexperienced stock—and some people—may hesitate before crossing this suspension bridge over the Colorado River.

Resource Roundup

Crossing the Bridge

For more information regarding bridges and overpasses:

- ☆ *A Guide to Fiber-Reinforced Polymer Trail Bridges* (Groenier and others 2006) is available at *http://www.fs.fed.us/t-d/pubs/htmlpubs/htm06232824*. This Web site requires a username and password. (Username: t-d, Password: t-d)
- ☆ *Guide Specifications for Design of Pedestrian Bridges, 1st Edition* (AASHTO 1997) is available from the bookstore at *https://bookstore.transportation.org/item_details.aspx?ID=37.*
- ☆ *Guide for the Development of Bicycle Facilities* (AASHTO 1999) is available at *http://www.communitymobility.org/pdf/aashto.pdf.*
- ☆ *Standard Specifications for Highway Bridges* (AASHTO 1996) is available from the bookstore at *https://bookstore.transportation.org/item_details.aspx?ID=51.*
- ☆ Transportation Structures Handbook FSH 7709.56b (U.S. Department of Agriculture Forest Service 2005c) is available at *http://www.fs.fed.us/cgi-bin/Directives/get_dirs/fsh?7709.56b.*
- ☆ *Trail Bridge Catalog* (Eriksson 2000) is available at *http://www.fs.fed.us/t-d/bridges.* This Web site requires a username and password. (Username: t-d, Password: t-d)

Bridge Site Selection

Bridges with the horizontal alignment perpendicular to the stream are the shortest and usually the least costly to build. Avoid sharp and blind curves on the immediate approaches to bridges, because curves adversely affect sight distance. The vertical alignment—or *grade*—of bridges also affects sight distance, drainage, and footing. Adjusting the trail alignment to address these issues usually costs less than modifying the bridge.

Bridge Grade

Bridges with a slight grade or camber shed water better than flat bridges. However, grades that are too steep can cause footing problems. Bridge grades on trails should not be greater than any part of the trail itself and when possible, should not exceed 5 percent. Camber on arch bridges also should not exceed 5 percent. Figure 5–21 shows a trail bridge with camber.

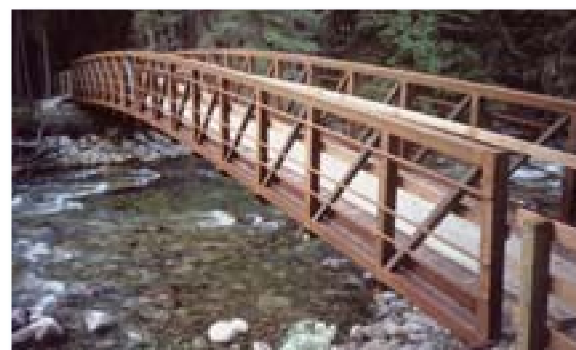


Figure 5–21—For safety, the camber on equestrian bridges should not exceed 5 percent.

5

Bridge Width

The minimum suggested bridge width on horse trails in areas with low levels of development is 5 feet (1.5 meters). In areas with high levels of development, 12 feet (3.6 meters) is preferred. Bridges in areas with moderate levels of development often range between 5 and 8 feet (1.5 and 2.4 meters) wide. Bridges that are wider than 6 feet (1.8 meters) and narrower than 10 feet (3 meters) are only suitable for riding single file, but riders may be tempted to pass or ride two abreast, a potential source of conflict. For facilities subject to the AASHTO guidelines, match the clear bridge width to the width of the shared-use trails that lead up to them. Then add an additional 2 feet (0.6 meter) on each side (AASHTO 1999). This extra width gives all trail users the minimum horizontal shy distance from the railing or barrier. It also provides maneuvering space when trail users encounter others who have stopped.

Trail Talk

Bridging Streams and Ditches

The British Horse Society (2005b) prefers bridges that are 6.6 feet (2 meters) wide for streams and ditches in the United Kingdom. The organization recommends a bridge width of 13.1 feet (4 meters) when the river measures at least 26.2 feet (8 meters) across. They also advise consulting with highway engineers for site-specific requirements.

Bridge Load Limits

Bridges, causeways, and boardwalks on horse trails must meet engineering specifications to support the weight of a large group of stock. Structures designed primarily for pedestrians and bicycles are not strong enough for horses and mules, because the decking cannot withstand the force of horseshoes or the point load per hoof. In addition, bridges must be engineered to withstand the vibration caused by single or multiple animals. Stock, including their riders or loads, usually weigh from 1,000 to 1,700 pounds (454 to 771 kilograms).

Trail Talk

Mule Maneuvers

Suspension Bridges for Mountain Warfare (U.S. War Department 1944) provided specifications for suspension bridges with spans of up to 400 feet (122 meters). These bridges were used to carry light loads over long gaps. The War Department required standard military suspension footbridges to carry three packmules, each with a handler, spaced one-third of the span length apart. Light equipment bridges were designed to carry seven mules and handlers, spaced at intervals of one-seventh the span length. Intervals are crucial for figuring a structure's load capacity and fundamental frequency.

Design bridge beams and stringers for the anticipated maximum loading or load combinations, including live loads, snow, wind, snow groomers, earthquakes, and light vehicles. Covered bridges in snow country have additional load considerations.

Resource Roundup

Live Loads

Live loads for hikers, ATVs, motorcycles, bicycles, snowmobiles, and stock or packstrings are grouped together as pedestrian live loads. When designing bridges, consult the live load, deflection, and small load criteria outlined in the *Guide Specifications for Design of Pedestrian Bridges, 1st Edition* (AASHTO 1997), or other applicable sources. The guide is available from the bookstore at *https://bookstore.transportation.org/item_details.aspx?ID=37.*

Bridge and Overpass Structural Materials

Select materials for bridges and overpasses based on durability as well as for strength, esthetics, cost, and appropriate level of development. Common bridge materials include timber, steel, concrete, and fiberglass. Many companies have engineered plans for standard bridge lengths of wood, steel, and fiberglass. Table 5–1 shows suggested structural materials suitable for different levels of trail development. Esthetics and the setting—wildland, rural, urban—also affect choices.

Table 5–1—Suggested structural materials for bridges on horse trails.

Material	Low development	Moderate development	High development
Sawn timber or engineered wood	X	X	X
Concrete		X	X
Steel	X	X	X
Fiberglass	X	X	

Bridge and Overpass Surface Materials

Select surface treatments for bridges and wetland structures carefully. Most stock will hesitate to step from the tread to the bridge unless the transition between tread and bridge is as smooth and uninterrupted as possible. The surface of the tread and bridge should be flush and have similar colors. A step up or down to the bridge draws the trail animal's attention to the change in material.

Common bridge decking materials include wood, concrete, steel grates, fiberglass, and composites made from plastic and wood. Wood decking can be planks or glue-laminated panels. Because wood surfaces may be slippery when wet, they work best in areas that don't get a lot of rain. Concrete bridges surfaced with appropriate natural soils, sand, crushed rock, or a rough surface generally are horse friendly. Avoid steel grates because stock may be frightened when they look through the grate or hear a horseshoe striking it. Fiberglass decks must have a wearing surface that can withstand the impact of horseshoes. The surface of plastic laminates can be slick, requiring that they be manufactured with a roughened surface. Avoid decks that sound hollow when stock travel across them.

Bridge wearing surface refers to a temporary layer of decking that is easily replaced when worn. Often less expensive, untreated wood is used for this purpose. The wearing surface frequently is the same width as the trail on each end and tapers to a narrower width toward the center (figure 5–22). This gradual reduction in width serves to funnel trail traffic to the center of the bridge tread. This pattern is less costly than providing a wearing surface that extends the full bridge width for the entire span length.

In areas with low levels of development, the Forest Service often constructs decking from wood planks that are 3 inches (76 millimeters) thick if no wearing surface is included. When used along with wearing surfaces, the decking consists of transverse wood planks 2 inches thick by at least 8 inches (51 by 203 millimeters) wide, placed on the bridge stringers. The wearing surface consists of longitudinal planks 2 inches thick by 12 inches (51 by 305 millimeters) wide. Horse loads normally are concentrated loads. Horse loads determine the thickness of bridge decking and wearing surfaces. Pedestrian live loads are uniform loads over the entire deck. Pedestrian live loads determine the size of bridge stringers.

Select tread surface materials that don't become slick from use, particularly if the bridge has any slope. Timber cleats, rubber matting, or other wearing surfaces can be installed to improve traction.

Figure 5–22—Wearing surfaces are a relatively easy and economical way to prolong the life of bridge decking. The tapered pattern guides stock to the wearing surface in the center of the bridge.

Bridge and Overpass Sides and Railings

Trail bridges require railings, except in certain circumstances. Trail bridges that don't have railings must have longitudinal edging, commonly called *curbing* or *curbs*. Before constructing bridge curbs instead of railings, agencies may require documentation that substantiates the decision. For example, if an analysis shows that the potential hazards along the trail are the same or greater than the hazards of a bridge without a railing, curbs may be used in place of railings. The Forest Service requires an engineering analysis to determine whether the hazards along the trail are the same or greater than those on a bridge without a railing. In general, trail users in rural and urban settings are more likely to be small children or less experienced adults who will need a railing. In wildland settings, trail users normally are more experienced and railings may be unnecessary.

The first consideration in selecting railings must be safety. According to the *Trail Bridge Catalog* (Eriksson 2000), guidelines for rail systems fall under the following:

- ✰ Building Code—Railings on trail bridges in urban settings must meet building code requirements, such as the International Building Code (IBC). These railings are designed for pedestrians, not riders, and must have vertical balusters that are not easy to climb. The code requires a handrail at least 42 inches (1.067 meters) high that does not allow a 4-inch (101.6-millimeter) sphere to pass through.
- ✰ AASHTO Code—Horizontal railings on trail bridges frequently used by children must meet AASHTO Standard Specifications for Highway Bridges. A 6-inch (152.4-millimeter) sphere must not pass through the railing in the bottom 27 inches (685.8 millimeters), and an 8-inch (203.2-millimeter) sphere must not pass through the area higher than 27 inches (685.8 millimeters). The code also requires a handrail at least 54 inches (1,372 millimeters) high for equestrian traffic.
- ✰ Remote Areas—Railings on remote trail bridges must be at least 54 inches (1,372 millimeters) high for equestrian traffic. The handrail system also must have one or more intermediate rails so that the vertical distance between rails does not exceed 15 inches (381 millimeters). The Forest Service requires handrail systems on bridges to have at least two horizontal rails above the tread level.

Table 5–2 gives selected design criteria for Forest Service bridges on horse trails. Live load pressures for hikers, ATVs, motorcycles, bicycles, snowmobiles, stock, or packstrings are grouped together under pedestrian live loads.

Other considerations may justify railings or barriers. For example, horses and mules may become frightened if they can see high-speed vehicles or other distractions passing beneath or near the bridge. Provide a solid barrier or panel topped with an open-view railing (see figures 3–18 and 5–23). Use a similar design on the bridge approach to ease the transition from the trail onto the bridge deck. Such panels on approaches guide a reluctant trail animal onto the bridge. Construct the panels on one or both sides to extend a distance appropriate to site conditions. Angle the extensions outward from the bridge structure to form approach rails (figure 5–24).

Table 5–2—Selected Forest Service trail bridge criteria for pack and saddle trails.

Trail use	Clear width*	Live load**	Railing height***
Tread width	5 feet without railing 6 feet with railing****	Pedestrian load or snow load	54 inches

* Widths shown are recommended minimum clear widths between railings or curbs. Use design parameters developed for each particular trail, which may recommend narrower bridge width. If groomers are to be used on the trail, check the specific snow groomer machines for necessary width.
** See [FSH 7709.56b] section 7.62 for a description and minimum requirements of pedestrian live load.
*** Railing height is the minimum if railing is required. Provide analysis to determine whether railings may be eliminated.
**** For trail bridges that require access for light administrative vehicles, a minimum width of 8 feet [2.4 meters] is required. The design live load shall be AASHTO H-5 (10,000 pounds [4,535 kilograms]) vehicle loading.

—Excerpted from Transportation Structures Handbook FSH 7709.56b (U.S. Department of Agriculture Forest Service 2005c).

Figure 5–23—A solid barrier topped with an open view railing is often more acceptable to horses and mules than an open view fence alone. This open view railing is on the Marjorie Harris Carr Cross Florida Greenway Land Bridge. Figures 5–27 and 5–28 show additional views of the land bridge.

Figure 5–24—Approach rails guide stock onto a bridge. Large rocks or other natural objects sometimes are used to block alternate routes.

Railings should be free of protrusions that can catch on legs, feet, stirrups, or tack. Install all connecting hardware with the smooth side toward the trail user.

Horse Sense

Rubbing the Right Way

Some shared-use bridges incorporate an optional *rub rail*—a smooth, flat panel that is attached to the inside of the railing (figure 5–25). Rub rails keep bridge users or their gear from catching bridge members. Make sure the rails have no edges or gaps that can snag reins, ropes, people, or stock.

Figure 5–25—Wood rub rails are frequently used on bridges to keep saddles, backpacks, bicycle handlebars, and other equipment from snagging on posts.

Bridge Clearance

Safety is compromised when riders are forced into areas with narrow or low clearance. Construct bridges with a minimum overhead clearance of 10 feet (3 meters) in the equestrian trail corridor. The preferred overhead clearance is 12 feet (3.6 meters). Pedestrian and bicycle bridges over freeways frequently have vertical curved fences or roofs to prevent anything being thrown from the bridge. Tread location and inadequate trail clearance (horizontal or overhead) should not force riders to the center of the corridor or make it difficult for riders to pass stopped users safely. Loud traffic noises on these bridges may make them questionable for equestrian use.

Trail Talk

Low Down

The British Horse Society (2005b) advises building new road underpasses that have a vertical clearance of 12 feet (3.6 meters). If that is not possible, the minimum clearance is 11 feet (3.4 meters). The preferred width is 16.5 feet (5 meters) and the minimum width is 10 feet (3 meters).

Figure 5–26 illustrates a shared-use bridge for nonmotorized travel over a freeway. It has a separate, 12-foot- (3.6-meter-) wide equestrian tread in the center of the bridge where the vertical clearance is greatest. Pedestrians, bicyclists and other nonmotorized users use the separate treads on either side of the horse tread.

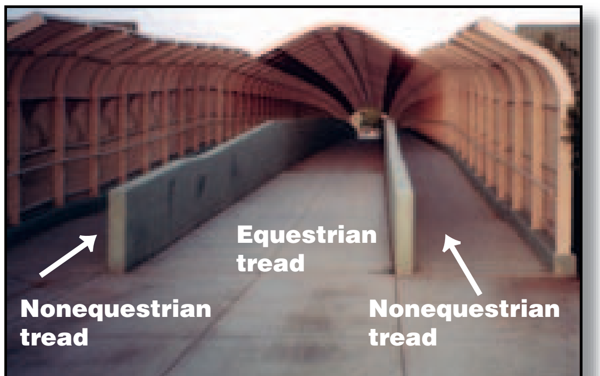


Figure 5–26—Separation barriers on this shared-use bridge are short enough for horses and mules to see over, so stock are more comfortable. The roof over the equestrian tread (center) has a high overhead clearance to accommodate equestrians.

Horse Sense

To Dismount or Not?

Asking riders to dismount for trails or structures with low or narrow clearance is not recommended. Dismounting can lead to dangerous situations because riders have less control of a nervous or aggressive trail animal from the ground than when they're in the saddle. Dismounted riders risk being run over by a spooked animal. Occasionally, low clearance, narrow passages, or trail obstacles are unavoidable. In all cases, safety is the determining factor when deciding whether to require riders to dismount. Some riders are not able to dismount or remount on a trail without stepping up on something. If passages don't have adequate vertical or horizontal clearance for mounted riders, or if other considerations warrant leading an animal, warn riders with signs and provide mounting blocks at both ends of the obstacle. Consult *Chapter 7—Planning Recreation Sites* for more information regarding mounting blocks and ramps.

Bridge Sight Distance

Sight distance can be restricted by a bridge's arc or because approaches are placed at a poor angle. A long sight distance on bridges allows riders to see problems in advance, preferably the entire length of the bridge, plus approaches. When sight distance or visibility on bridges is limited, work with bridge and traffic engineers to determine proper remedial action. In urban and rural areas, this may include installing signs and signals.

Trails on Bridges and Overpasses With Traffic

Many stock are unfamiliar with bridges that also have vehicle traffic. The speed of the traffic on the bridge, noise level, and vibrations can make some stock nervous. Occasionally, managers designate a bridge for equestrians only. For bridges where motorized use is very low, if budgets and bridge conditions permit, separate riders from vehicles and other trail users. Where feasible, bridge design can incorporate barriers between two or more treads to separate riders and slow motorized traffic. The barrier would be subject to careful analysis and regulatory approval.

It is best if bridges over high-speed roads separate stock and traffic. Some shared bridges route traffic on one level and trail users on a different—usually lower—level. The traffic is not visible to the animal, and the sound of traffic is contained in the separate corridor.

Specialty Bridges

Several specialty land bridges over major roads in the United States have grass and shrubs planted in a soil-covered deck. Many user groups appreciate this design, which is costly. Figures 5–27 and 5–28 show the Marjorie Harris Carr Cross Florida Greenway Land Bridge over Interstate 75 just south of Ocala, FL.

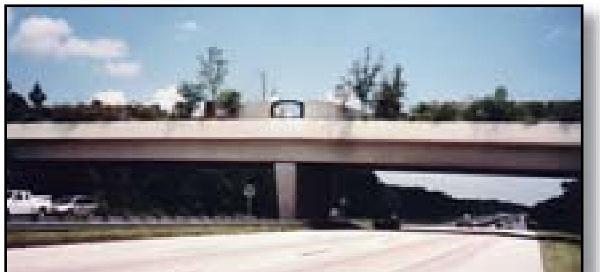


Figure 5–27—The Marjorie Harris Carr Cross Florida Greenway Land Bridge across Interstate Highway 75 south of Ocala allows riders, hikers, and bicyclists to cross six lanes of traffic. The bridge is 52.5 feet wide and 200 feet long.

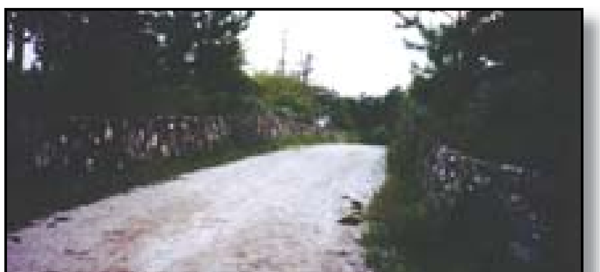


Figure 5–28—Native vegetation in irrigated planters on the land bridge buffer users from the sight of traffic below. Natural surfaces enhance the trail experience.

Below-Grade Crossings—Culverts and Underpasses

In some cases, underpasses—or *below-grade* crossings—are more suitable than at-grade crossings or bridges. Large-diameter structures—culverts and underpasses—generally serve riders well. Prefabricated underpasses are available in aluminum, steel, and concrete. They can be round, elliptical, arched, or box-shaped. Examples of underpasses are shown in figures 5–29 and 5–30. Trails with below-grade crossings must meet design regulations or guidance such as AASHTO specifications, and they require the expertise of engineers. The advantage to recreationists and wildlife can sometimes justify the higher cost of below-grade crossings rather than at-grade crossings. When designing below-grade crossings, carefully consider the safety of approaches, drainage structures, the tread surface, clearance, sight distance, and lighting. Figure 5–31 shows separate, adjacent underpasses for motorized traffic and trail users.

Figure 5–29—Underpasses can have different configurations, such as this one with approach wings. —*Courtesy of Bridgetek*.

Figure 5–30—Make horizontal trail clearance in underpasses the same width as the trail or wider. —*Courtesy of Bridgetek*.

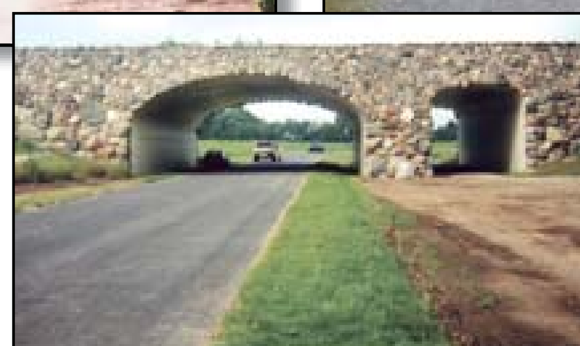


Figure 5–31—For safety, provide separate underpass routes for motorized users and trail users. —*Courtesy of Bridgetek*.

Below-Grade Approaches

It is often difficult to provide the necessary overhead clearance required by riders when approaches slope down into below-grade passages. Design new structures so approaches are level with the trail tread. If drainage or site conditions require a slight slope, make it constant from one end of the passage to the other. Retrofitted below-grade trail approaches sometimes slope downward at both ends, reducing clearance and making drainage difficult. Avoid this situation wherever possible. When sloped approaches to retrofitted culverts or underpasses are unavoidable, design them with no more than a 5-percent grade. Avoid hard, smooth tread treatments for approaches.

Below-Grade Tread Surfaces

Relatively level, natural tread surfaces leading into underpasses generally require no additional treatment. The exception is a tread surface that is frequently wet or muddy. Sloping trails that are frequently wet may benefit from geosynthetic materials. If culverts don't drain adequately, they are unsuitable for horse trails. Design the approach and surfaces of the underpass to prevent water, snow, sand, soil, or other materials from collecting where they will hamper traction or interfere with clearance. Use horse-friendly surface materials. Make sure that the below-grade crossings are large enough for the equipment needed to maintain them. See *Chapter 6—Choosing Horse-Friendly Surface Materials* for more information.

Below-Grade Clearance

If a trail animal startles while in an underpass or below-grade culvert, the animal, rider, and other trail users may be injured. This is especially true in narrow underpasses or those with low, curved ceilings. For safety, design culverts and underpasses on horse trails so the vertical clearance is no lower than 10 feet (3 meters) across the entire width of the tread. The preferred height is 12 feet (3.6 meters). Horizontal clearance often extends 2 to 3 feet (0.6 to 0.9 meter) beyond the tread edge on both sides of the trail. Horizontal and vertical clearance in passages should be no less than the clearing limits on the rest of the trail.

When figuring horizontal and vertical clearance in underpasses, allow space for maneuvering and passing. Box-shaped structures should meet the standard height guidelines and be no less than 8 feet (2.4 meters) wide. A preferred width of 12 feet (3.6 meters) allows space for trail users to pass. The culvert in figure 5–32 appears wide enough for riders, but the vertical clearance is suspect. Culverts that curve near the top must provide 10 to 12 feet (3 to 3.6 meters) of overhead clearance without forcing riders to the center of the trail. Riders can suffer severe injuries if they hit their heads. The horizontal clearance at head height should be at least as wide as the trail itself and no narrower than 5 feet (1.5 meters) wide. This may be difficult to achieve with tapered culverts (figure 5–33).

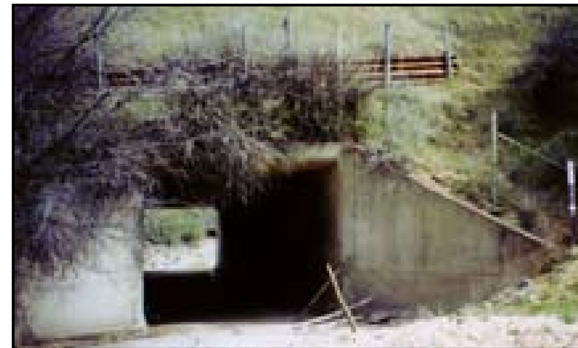


Figure 5–32—When selecting equestrian underpasses, such as this common box culvert, carefully consider overhead and horizontal clearance.

Figure 5–33—Riders need more lateral clearance near the top of underpasses than other users. Provide 12 feet of overhead clearance that is the entire width of the trail. Avoid sloping roofs that force riders to the center of the tread.

Enclosed-Area Lighting

Adequate lighting and sight distance are important inside, outside, and at approaches to enclosed trail corridors. The eyes of stock don't adjust quickly to lighting changes, and many animals stop or hesitate when they can't see well.

In highly developed areas, artificial lights may be helpful, especially if the corridor approach is sloped. If possible, install fixtures flush with the approach walls. In trail corridors, locate fixtures at least 10 feet (3 meters) above the trail surface where they will not encroach on clearance. Keep the scale appropriate to trail users, and vary the light intensity for trail conditions or location. Consult a professional lighting designer or engineer for a site-specific plan.

Some divided highways provide a *light well*—or opening—in the median to allow sunlight into the passage below and enhance visibility during the day.

Trail Talk

Light on the Subject

Night travel often occurs on shared-use trails, which may suggest the need for lights. The *Guide for the Development of Bicycle Facilities* (AASHTO 1999) suggests maintaining average horizontal illumination levels of between 5 and 22 lux for trails, highway intersections, and in underpasses or tunnels. Higher levels may be advisable if security is an issue.

Culverts That Carry Water

With careful design, some culverts that carry water can include a separate trail tread (figure 5–34). Successful designs prevent trail tread material from being eroded at either end of the culvert.

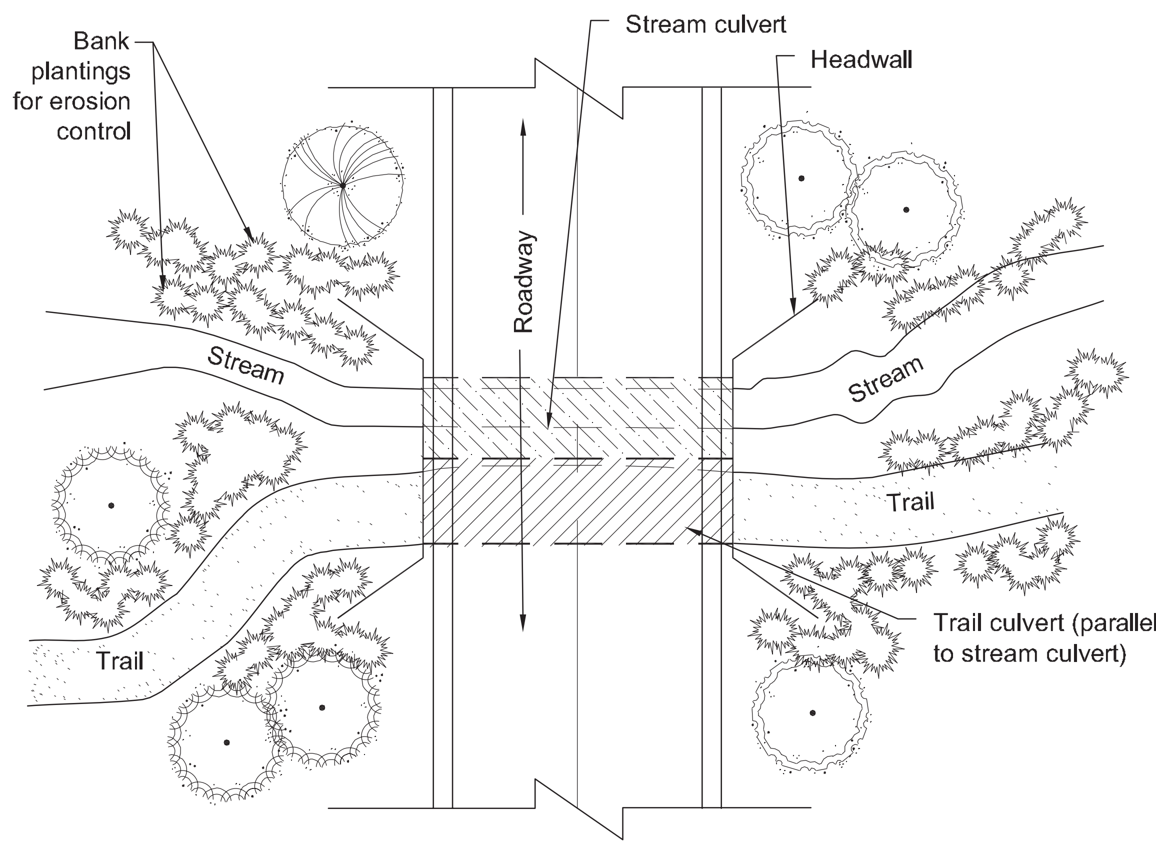


Figure 5–34—A culvert shared by a stream and the trail. When flooding occurs, both courses channel floodwater.

Figure 5–35 illustrates a culvert that carries water and also includes a trail. Inside the culvert, a channel along the outer edge of the trail carries water out of the culvert. Abutments direct the water to a catchment pond below the trail tread.

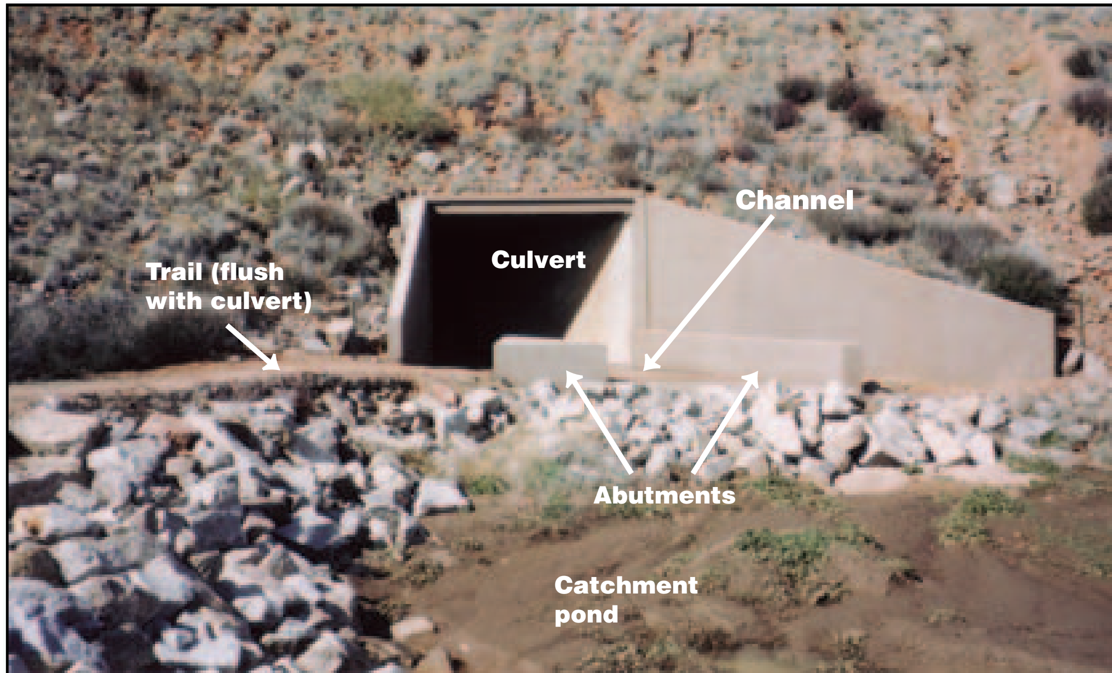


Figure 5–35—A trail and a water channel share this specially designed culvert. The channel keeps water off the trail and abutments direct the runoff into a catchment pond.