Culverts — Proper Use and Installation

Culverts are used to transfer water from one side of the highway to the other, to equalize ponds and marshes on both sides of a road, and to permit cattle, wildlife or vehicles to pass beneath the road.

Installing culverts is generally quite simple, and most replacements are relatively uncomplicated. Unfortunately, culvert installation on a local road is sometimes seen as a quick, one-day project. One day may be enough to actually put the pipe in place, but only if you have already completed a design review, secured the permits and the correct equipment, and have the materials on the site.

It is essential to start planning well before the installation date. Environmental permits may be required, and you can't tell which projects will need them just by looking at the site. You may need or want an engineering review to ensure good operation and avoid unintended impacts up or down stream. Also, you must allow time for utilities to review any services they may have in the right-of-way. Knowledge, planning and timing are the real keys to a successful job.

This bulletin discusses the conditions to review in selecting and sizing culverts, critical design considerations for installation, methods of installation, environmental concerns and required permits, and important maintenance factors.

Planning and permit considerations

Culvert projects on Wisconsin local roads may affect water quality, navigation, wetlands, flooding, agricultural drainage, erosion, fish, other aquatic organisms, bird nesting, endangered species habitat, and natural scenic beauty. Some of these potential impacts may not be obvious. For example, some areas that are dry most of the year may actually be wetlands or navigable intermittent streams protected under state law. Appropriate stormwater soil erosion control is important on any project; for those which disturb more than an acre of soil you are required to submit an approved erosion control plan in advance and obtain a construction site erosion permit. Some counties require permits for even smaller areas. Shoreland and floodplain zoning regulations may also come into play.

You are responsible for preparing the required plans and getting the appropriate permits before starting any culvert installation. However, most counties and the Wisconsin DNR have tried to make it relatively easy to find out what permits you need and to streamline the process of getting them. Standard erosion control plans, technical standards, and acceptable products are now widely available. Begin with your county highway department or land conservation office and contact the DNR District Transportation Liaison responsible for your area.

Start early. It could take anywhere from one day to a couple months to get the permits you need. Replacing culverts for a permanent stream will involve more concerns, such as culvert size and placement, fish passage, and flow control during installation, than a simple dry cross-drain. If a site inspection is needed, the DNR person may need some snow-free time to do it. Late fall, in November or December, is a good time to contact DNR about projects planned for the next construction season.

Selecting culvert type

Although culverts are made from a variety of materials, the most common are concrete, reinforced concrete, and corrugated metal pipe (CMP). Metal culverts may be galvanized steel or aluminum and can be coated with asphalt, aluminum or polymer for corrosion resistance. Plastic pipe is available for smaller diameter culverts on lower volume roads (4500 ADT or less).

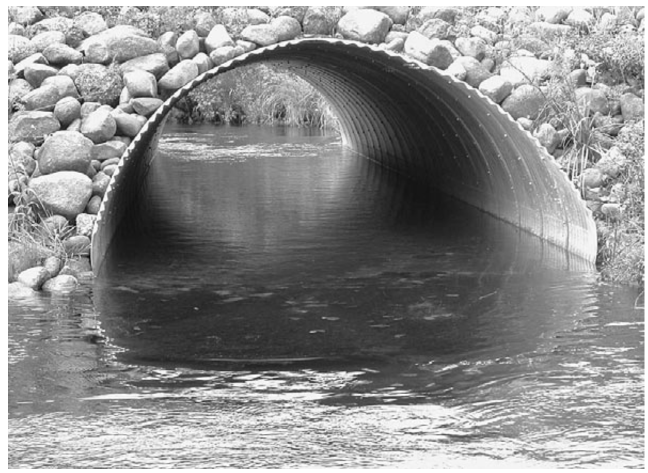
Selecting a culvert type involves reviewing several factors. Material and installation cost, special site characteristics, ease of installation, and the needs of fish and other aquatic organisms are the most significant. Local preference and environmental considerations often dictate which type is chosen.

Concrete and corrugated metal pipe prices are highly competitive. Where the situation allows its use, plastic pipe costs may be lower. Concrete pipe can have a price advantage due to lower shipping costs if you are within 50 to 75 miles of its manufacturing site. Concrete culvert is more labor intensive to install than corrugated metal pipe because its pipe sections are shorter. It also requires heavier equipment to manage its weight. To get the best price, design an installation for both types of culvert and solicit bids for both alternatives.

Other issues which affect pipe selection are corrosion and fish passage. Corrosion is a concern in areas with low pH (dark-stained water), or where drainage originates in bogs, swamps or barnyards. For these sites choose concrete, aluminum, plastic, or coated steel unless galvanized culvert has previously given acceptable service of at least 20 years. In most fish passage situations, corrugated metal culverts are preferred over smooth bottom culverts in shallow water conditions. The corrugated surface slows down water velocity, making it more fish friendly.

Pipe culverts also come in a variety of shapes such as circular, elliptical, and pipe arch. While circular is the most common, it may be necessary to use other shapes, or multiple smaller pipes, when roadway height is a constraint. Selection of culvert shape is based on water depth, roadway embankment height, hydraulic performance, and fish and wildlife concerns. One larger culvert is generally preferable. It is less likely to plug from ice, debris or beaver activity and better accommodates fish passage on streams. Where vertical clearance is shallow, you can use multiple pipes. Where the culvert is carrying a stream, a single large pipe or one of the multiple pipes should be buried 6″-12″ into the streambed and aligned with the stream channel as much as possible. This lets fish and other aquatic organisms pass through during periods of low flow.

Open-bottom culverts are preferred where fish and wildlife migration is a major concern. These preserve the natural creek substrate and do not disturb the streambed. Bottomless structures are 30% to 50% more expensive than a round or oval pipe. Common shapes include semicircular arch, elliptical arch, and concrete box culverts. These types of structures must be supported on footings, and creation of a bypass or similar arrangement during installation is required. On certain high-value streams, bridges are the preferred option.



This beveled or mitered culvert is set sufficiently low to minimize upstream channel impacts, will allow fish to pass because of good depth and low velocity, has adequate size to pass flood flows, and good erosion control (2:1 side slopes, riprap, vegetation).

Special site characteristics

Use care in selecting a type of culvert pipe for a particular installation. Review both high and low water flow, soil conditions, and potential for stream fragmentation. Matching culvert width to bank full stream width will minimize channel erosion impacts. Because concrete pipe is relatively smooth compared to corrugated metal pipe, it has good hydraulic characteristics, permitting more water to flow through a given size than can pass through corrugated metal pipe of the same size. Concrete pipe also better resists corrosion from acids in marshy soils, although in extreme conditions it too can be affected. Plastic pipe with a smooth interior also has higher flow rates and resists corrosion. It is a good idea to test the soil pH at your site if you suspect there have been problems with corrosion.

Corrosion due to road salt can be a problem, particularly as pipe ages. The protective coating of steel pipe erodes permitting salt to damage the base metal, and the concrete pipe spalls or develops cracks allowing salt to attack the reinforcing steel. However, in nearly all cases, the culvert pipe will outlast the road under which it is installed.

Timing culvert installation

A culvert installation plan should consider several timing issues: periods of high water flow, erosion control, stream impacts, and nesting season for migratory birds. Avoid high water seasons to minimize installation problems. To control erosion on disturbed soils at the installation site it is generally best to complete work before mid-September. This allows time for seed to germinate and stabilize the soils. Erosion matting can be used for later projects but adds expense.

Whenever a culvert will be installed on a stream or wetland, you must consult with the DNR Transportation Liaison and obtain a permit. The permit will give a time period for installation that minimizes impact on the fish and other aquatic organisms in that specific stream.

Swallows and other protected migratory birds sometimes nest in larger culverts, generally between May 15 and August 20. Inspect your culvert before May 15 for signs of bird nesting. If they are present, plan your project for before or after nesting season, or remove unoccupied nests and install barrier netting before May 15. Otherwise contact the U.S. Fish and Wildlife Service for a permit.

Design

Properly *designed, installed,* and *maintained* culvert pipe will provide satisfactory performance for many years. However, inattention to any one of these conditions can result in failure.

The need to replace a culvert may result from a variety of factors:

- Inadequate pipe capacity
- Structural failure due to excessive soil loading
- Washout due to water overtopping the road
- End scouring from poor end treatment
- Improper jointing resulting in water piping along the outside of the pipe
- Erosion due to excessive water transport of sand and gravel
- Corrosion from acid or salt laden soils and water
- Improper end walls resulting in embankment failures
- Poor installation and/or bedding condition resulting in settling, joint separation, or structural failure of the pipe.

Selecting culvert diameter

Culvert size selection on local roads is often done by rule of thumb or experience. This usually results in replacing the old culvert with a new one of the same size. The old culvert size may be adequate, but before you assume so, thoroughly examine its history during periods of high flow such as snow melt or occasional very heavy rainfalls, as well as during low flow for protection of fish and other aquatic organisms. Look at culvert or bridge sizes both upstream and downstream. Also consider whether there have been any recent land use changes or development, or some are likely in the near future, that may influence runoff or flooding.

Review any records to determine if there was flooding upstream of this culvert, or if water flowed over the road. Consider whether these conditions may be attributed to insufficient capacity of the current culvert. Some telltale evidence of past high flows are: grass and brush deposits on fences, high water marks on headwalls and utility poles, and soil erosion and deposits in areas away from the normal flow line or stream. Conversations with neighbors and "old timers" are also helpful.

Next, review downstream conditions. Look for signs of erosion or flooding that indicate problems with the existing culvert. If the immediate downstream culvert has served adequately, then the replacement culvert at your site probably does not have to be sized any larger.

Before you decide to install a new culvert that is a larger diameter than the old one, beware that the greater flow may cause problems downstream. Faster release of runoff upstream can cause flooding at downstream culverts if they are too small. This situation is often encountered when residential, commercial, institutional, or industrial development makes it necessary to replace existing culverts.

Erosion, a sign of inadequate capacity, has undercut the end of this culvert pipe.

If it is not clearly apparent from your review of the history what size culvert pipe to install, you should seek design assistance. Typical sources of assistance include engineering consultants, and county highway, land conservation or zoning staff.

Size and shape determine a culvert's capacity to handle water. To calculate the required capacity, determine both average flows and projected high flows. Consider local factors such as historical rainfall records, area and slope of the watershed draining to the culvert, and type of surface (grass, forest, paved) in the watershed.

The capacity of a culvert is directly related to the area of its opening. Circular openings are usually most efficient. Small increases in diameter can significantly increase culvert capacity. For example, a 30″ culvert can handle 50% more water than a 24″ culvert. A culvert that will be partially buried in a streambed will have less capacity because the effective diameter is smaller. The minimum recommended culvert diameter under public roadways is 24″ except where limited by conditions such as available cover or trenching limitations (discussed below). Culverts with diameters smaller than 24″ may have maintenance and cleaning problems.

On permanent streams, select a culvert diameter that matches the average width of the stream. Measure stream widths at the top of the banks to represent its size during normal high water or bank-full conditions. Special care is needed when installing larger culverts on streams with low seasonal flow. A 6″ minimum water depth during low-flow dry periods is recommended.

Sometimes multiple culverts may be necessary. If so, be aware that debris is more likely to accumulate between culverts which can cause flooding and erosion. Often one culvert is set lower to maintain a minimum water depth during low flow periods.

The spacing between multiple culverts should be wide enough to allow good compaction. A rule of thumb for round culverts has the spacing at one-half the diameter, but 12″ minimum and 36″ maximum. Spacing for a pipe arch should be one-third the span and 12″ minimum and 36″ maximum.

Length, grade and alignment

Your design needs to specify the length of the culvert, the grade, and the alignment to the watercourse and the road. These elements are related since a culvert which is perpendicular to the road is shorter than a diagonal one.

Length Determining the culvert length may not be as simple as it sounds. Don't try to use a standard approach such as "if the road is 24 feet wide, we'll put in a 30 foot pipe!" Every road is different. To begin this process, you have to determine the height of the road shoulder above the stream bed or ditch bottom. Then you need to determine what the foreslope of the roadway will be after the pipe installation is finished. A slope that is 3:1 or flatter is desirable for vehicle safety. Certainly, a 2:1 foreslope is the steepest practical slope. On roads where traffic is heavier or faster moving side slopes should be flatter for safety when an errant vehicle runs off the road.

Once you have calculated the length of pipe needed to reach the toe (bottom) of the foreslope from the edge of shoulder on each side of the road, then add the width of the traveled roadway and shoulders to determine the overall length of the pipe (See Figure 1). As simple as this calculation sounds, it is too often neglected in the planning phase of pipe installation.

Another reason to extend the culvert well beyond the shoulder is simply for safety. If the end of a pipe does not extend out far enough from the road shoulder, the force of fast-flowing water will often cause the soil to erode away from the area near the end of the pipe. Erosion can cut into the shoulder and even into the traveled part of the roadway. This creates a dangerous condition and a serious liability if someone drives into the washed-out area and has an accident. At the very least, it creates a condition that requires frequent inspection and repair after each heavy rain.

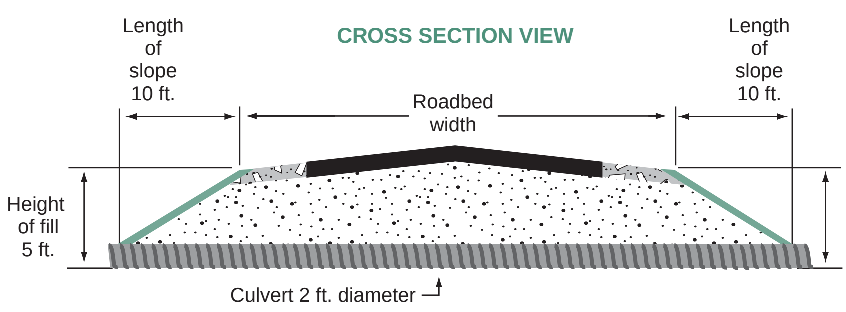


Figure 1: Take side slopes into account when calculating culvert length.

The length of culvert equals the length of slope on the left and right, plus the roadbed width.

If the slope is 10 feet on each side and the roadbed width is 24 feet, the culvert length should be 44 feet:

10′ + 24′ + 10′ = 44′

Grade The design of the culvert must specify the grade of the pipe. The objective is to match the culvert grade to the flow line of the abutting ditches or stream. Setting the culvert at the wrong grade, or with one end too high or too low, can cause flooding, scouring and erosion.

Inspect the site carefully ahead of time, and use basic surveying techniques to determine what the elevation should be, then make sure the pipe is placed accordingly. Don't use the "eyeball" method of determining elevation! On many jobs, a hand level will be sufficient to take the measurements you need.

Begin by recording the existing elevation at the inlet and outlet of the pipe currently in place, or record the elevation of the ditch or stream bed on new installations. While a replacement pipe is generally placed at the same elevation as the original, there may be reasons to raise or lower the new pipe, such as fixing an erosion problem or improving conditions for fish passage. Generally you will match the existing grade on a dry run or intermittent stream. If the culvert is long, you may need a steeper grade to keep water moving through it.

On "normal" permanent flow streams, record the streambed elevations for at least 100′ upstream and downstream from the culvert. Locate the deepest part of the streambed, then place the culvert 6″-12″ below that depth and match the slope to that of the stream. This will allow a stream channel to form within the pipe with an acceptable water velocity for fish passage. Your DNR Transportation Liaison will advise you of any other concerns specific to the particular stream.

A "normal" streambed has a slope of 0.5% (a vertical drop of 6″ in 100′ of distance) or less, fine substrate materials (such as clay-sand), and a meandering pathway. Water in a stream with a minimal slope would appear calm with no surface ripples. Streams that do not meet these criteria will likely need an engineering analysis to determine correct culvert placement.

Alignment A common culvert problem is that water scours away stream banks and fill from around the pipe ends. One cause is turbulence created by water changing direction to enter a pipe, and changing direction again when leaving a pipe to return to its normal course.

Good culvert design will skew the pipe through the roadbed in order to align it more nearly to the upstream and downstream watercourse (Figure 2). This will increase the cost by requiring a longer culvert pipe, but will help ensure against future undercutting and end scouring. It will also avoid creating barriers to passage by fish and other aquatic organisms.

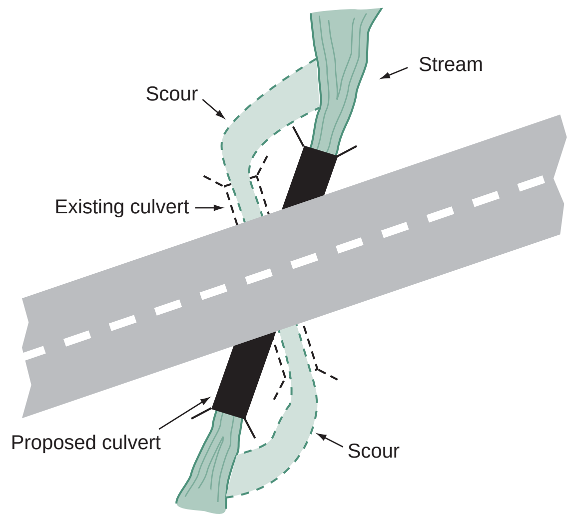


Figure 2: Placing the culvert in line with the streambed helps reduce water turbulence at inlet and outlet.

End treatment

How you treat the inlet and outlet of a culvert pipe is important. It must be designed to prevent improper flows which can result in flooding, excessive erosion, and scouring at the ends. It is common on small culverts to run the culvert out of the roadway. This is called a projecting pipe. While this is low cost, it is not as efficient in handling water, and the end can be a safety hazard.

An alternative is to have the supplier cut the culvert end to fit the slope of the ditch side. This is called a mitered end and results in better hydraulics. Mitered ends can handle up to 10% more water and are much less likely to be plugged by ice, debris, or beaver.

LEFT ***Projecting pipe ends are a hazard.***

CENTER ***Mitered ends handle more water.***

RIGHT ***Flared ends improve flow.***

Flared ends at the inlet to a culvert improve flow by guiding the water into the culvert, minimizing turbulence. Flared ends at the outlet of a culvert distribute the flow over a wider opening, reducing the discharge velocity which helps prevent scouring. This end treatment can be constructed in concrete or purchased from suppliers (apron end walls) for both concrete and corrugated metal pipe culverts. Make sure the water depth is adequate for fish passage.

End treatment of multiple culverts requires special attention. High flow conditions will tend to erode soil between culverts in multiple installations. Be sure to protect the ends with riprap or concrete end treatments.

One treatment for streambeds and banks is to use geotextiles overlain with riprap. The geotextile is placed on the ground and extended away from the culvert pipe at least 10′. This eliminates scouring in the immediate area of the pipe end. The riprap reduces the velocity.

When the culvert installation is completed, be sure to install marker posts. These locate the culvert for maintenance crews and warn motorists that it is there.

Installation

A critical consideration in designing a culvert installation is whether the culvert is rigid or a flexible pipe. Concrete pipe is considered a rigid pipe; corrugated metal pipe (CMP) and plastic (HDPE) pipe are considered flexible. Understanding the characteristics of these two types of culverts and how they resist loads is important because they require different backfilling and bedding treatments.

It is also important to determine if the soil at the site will make an adequate foundation for the new pipe. Sometimes this is hard to determine before excavating. Have a good source of granular material readily available in case you have to undercut and remove poor soil.

Another key item in planning is to excavate a large enough area so that you can work along side of the new pipe and do proper compaction, whether by hand or with equipment. Installing culverts in dry conditions is less expensive, and it is easier to achieve good soil compaction. For dry run and intermittent flow streams, it is desirable to schedule culvert replacements for dry conditions. Permanent streams will require diversion or pumping. Maintain adequate downstream flow with at least 25% but preferably the entire flow volume.

Manufacturers have developed simplified tables and charts to help users select proper culvert strength. Figure 3 is a typical table for selecting corrugated steel pipe.

Installation is of prime importance when completing road construction, rehabilitation, or replacement. If culverts are installed early in construction and heavy equipment is allowed to cross over them, place a 3′ cushion over the top of the culvert to minimize live impact loading.

Installing flexible pipe

Flexible pipe depends on its flexibility to accommodate the loads placed on top of it — both the live load (vehicles) and the dead load (soils and pavement). As loads are applied to the top, the pipe flexes, transferring the load to the soil beside it. However, you must limit the degree of flexibility to 5% to 7% to keep the pipe from excessive deformation and the joints from failing. The compacted soil under and on either side of the pipe is essential for supporting and reinforcing it, helping it to carry the load. Properly compacting the soil, especially under the haunches of the culvert (its lower curves), is the key to resisting excessive flexing.

Trench height and steel thickness for round corrugated steel pipe
(2 2/3" x 1/2" corrugation, H20 or E80 live load)

Diameter	Gage for max. height of trench above pipe (feet) Minimum H20 cover = 12″					
	15′	16-20′	21-25′	26-30′	31-35′	36-40′
15″						
18″						
24″			18 gage = 0.052″			
30″						
36″						
42″						
48″					16 gage = 0.064″	
54″						
60″			14 gage = 0.079″			
66″						
72″			12 gage = 0.109″			
78″						
84″						
90″					8 gage = 0.168″	
96″		10 gage = 0.138″				

Backfill around pipe must be compacted to a specified AASHTO T-99 density of 90%.

Source: sewer manual for corrugated steel pipe, National Corrugated Steel Pipe Association.

Figure 3. Culvert manufacturers and trade associations provide standard charts to assist in selecting the proper size culvert pipe. Major factors are corrugation size, backfill depth, pipe diameter, and metal thickness.

The next step is to set the pipe and align it properly. If more than one section of steel pipe is used, make sure the connecting band is installed tightly and over the center of the joint. Never start backfilling until the pipe is in the correct position and its entire length is resting firmly on the foundation.

Never place corrugated metal pipe on piling or on a concrete bed. It should be installed on a compacted bed of good soil 4″-6″ deep to provide uniform and adequate support. Concrete pipe can be installed on piling.

Installing rigid pipe

In rigid pipe, the bedding is of extreme importance. Unlike the flexible pipe, the rigid pipe cannot flex and shed some of the load imposed on it from above. It is especially important to shape the soil or other material under the pipe to support its underside. It is also important to compact soil thoroughly under its haunches. As Figure 4 demonstrates, the pipe can withstand larger loads when the bedding has been improved.

Laying the concrete culvert in a bedding of concrete (Class A bedding) provides the strongest support. Up to 33′ of fill averaging 130 pounds per cubic foot may be loaded over such an emplacement. The least strong bedding is a Class D in which the culvert is simply placed on the flat trench bottom with no special bedding preparation. Class D bedding permits less than 7′ of the same weight fill.

If concrete pipe is used, make sure the joints are tight. It is becoming a standard practice to wrap each joint with a filtration fabric that will not allow fine soils to migrate into the pipe.

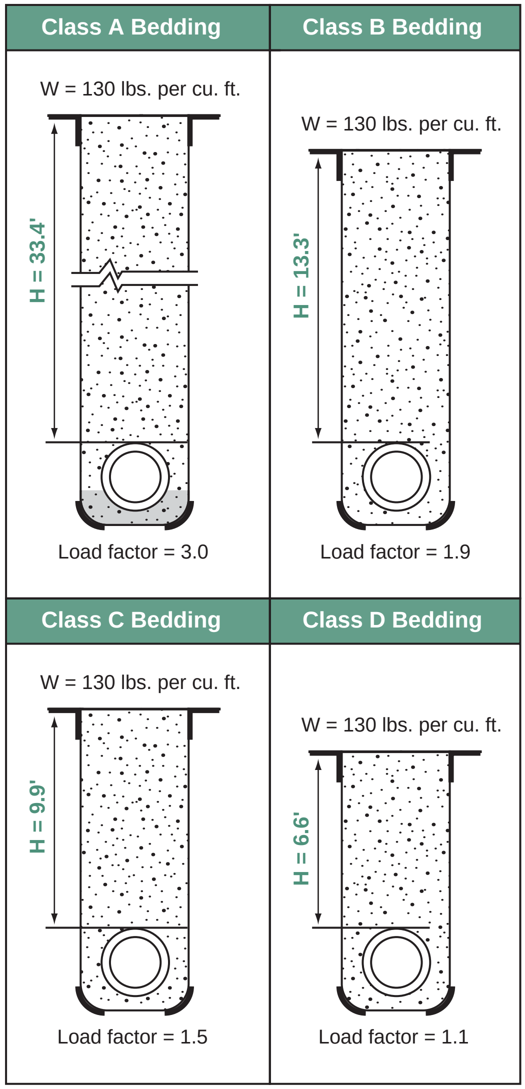


Figure 4. Bedding is extremely important for rigid pipe. The Class A bedding, a concrete bed, permits culvert pipe to withstand three times the load of Class D bedding, unprepared native soil in the trench bottom.

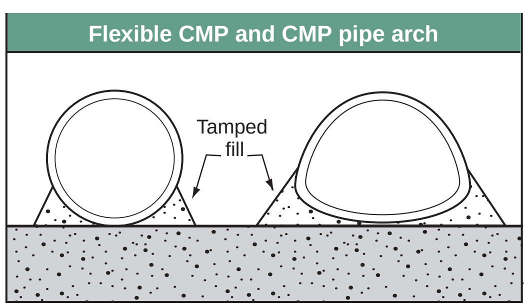


Figure 5. Installing tamped fill beneath the haunches of any shape or type of pipe helps it withstand the soil and traffic loads.

On large diameter installations, it is also wise to order pipe that can be tied together so that the sections do not separate.

Unlike flexible pipe, rigid pipe does not shed any of the load imposed on it by the prism of soil directly above it. With proper compaction methods and controlled trenching conditions, however, the prism directly above the pipe can be literally held up by adjacent soils, thus relieving some of this dead load.

Compaction

The capacity of any culvert to carry loads depends on proper backfilling, especially in the area under the haunches (lower third). The soil surrounding the culvert provides critical support to it. For maximum strength, and to prevent wash outs and settling, the backfill must be properly placed and carefully compacted. Dry trench conditions make the process more efficient.

The National Corrugated Steel Pipe Association's culvert installation manual tells us: "Too much emphasis cannot be placed on the necessity of adequate compaction of backfill. Faulty compaction has led to more trouble with pipe installations, flexible and rigid, than all other factors combined!" There is no way to say it better.

There are two important things to consider in backfilling: use no more than 6″ lifts at a time and compact it evenly and well, particularly under the haunch of the pipe. Backfill material should be free of rocks larger than 3″ in diameter. The material must be dumped carefully and evenly along both sides of the pipe. Avoid dumping large quantities at once against or on top of the pipe. The material should also have enough moisture to compact well, but not too much so as to become unstable. This can be difficult to achieve, but produces excellent results. Watch the weather closely during installation, particularly the chance of heavy rain.

Hand tamping is adequate and is often the best method to compact and seal the backfill against the lower half of the pipe. If you use mechanical compaction, work parallel to the pipe, not against it. If large equipment is used for compaction, don't over-compact so that the pipe begins to lift or is pushed laterally out of alignment. This is particularly important for flexible pipe arches. Continue filling in even lifts until the installation is finished. It is best to have at least 24″ of fill over a pipe, even on low-volume rural roads.

The most common problem with backfilling operations is that the filling crew works too fast and the tamping crew never has a chance to adequately compact the first material before more is placed in the trench. To prevent this, instruct filling crews to wait until a layer is fully compacted before adding another layer. For more information on compaction and backfilling see *Compaction Improves Pavement Performance,* Wisconsin Transportation Bulletin No. 11.

Adequate compaction is essential to culvert installation. Hand tamping is often best.

Alternative installation methods — Jacking, boring and tunneling

Jacking, boring and tunneling are other methods of culvert installation which are not commonly used. These untrenched construction methods are specialties, and most road agencies will hire private contractors. Many communities are turning to these methods as alternatives to street cuts, to avoid disrupting traffic and to eliminate settling of pavement patches. Supervising traffic engineers should keep track of local contractors' and utilities' abilities to do untrenched construction since it demands special skills.

Jacking is one of the most popular untrenched methods for installing pipes in rock-free, compressible soils. A casing or corrosion-resistant carrier must be used. A pilot shoe is installed on the pipe. Force is then applied to the other end of the pipe using steady thrust, hammering or vibrating. Care must be exercised as the casing may wander far from the desired line and grade, depending on the resistance of the soils.

Boring is a popular alternative, especially for street cuts. Line and grade are easy to control. Large pipes can be jacked through oversize bores which are carved progressively ahead of the pipe. The spoil is mucked back through the pipe. The auger shouldn't be more than one inch larger than the outside diameter of the following pipe. Good practice dictates using grout backfill.

Tunneling is also now being used as an alternative. This method uses a drill bit followed by the pipe culvert, eliminating the need for a casing.

Erosion control

Projects that disturb more than one acre of soil are required to have a soil erosion control plan and secure a Construction Site Erosion Permit, under state administrative code NR 216. Some counties may also require erosion control plans and permits, and may regulate even smaller disturbance sites.

Soil stabilization is important from the project's beginning, whether required or not, to avoid maintenance problems and protect streams. Complete your installation quickly, and especially avoid leaving soils exposed over the winter. Melting snow and heavy spring rains can easily erode unprotected soil. Installing appropriate erosion and sediment controls on disturbed soils before site work is finished can reduce long-term costs. Preventing erosion, by vegetating the site with seed and mulch, is often easier than trying to control moving soil.

Control erosion during and after construction.

Erosion mat and rock are two effective ways to control erosion.

Erosion control practices for municipal transportation projects not administered by WisDOT are specified in Trans 207.09. Projects should be constructed in compliance with the *Standard Specifications for Road and Bridge Construction* (DOT 2003) and Wisconsin DNR *Storm Water Construction Technical Standards.* These standards specify the minimum requirements needed to plan, design, install, and maintain a wide array of conservation and erosion control practices. When buying erosion control products, use tested and approved items from the WisDOT Product Acceptability Lists (PAL).

Environmental considerations and permits

Culvert projects on Wisconsin local roads may have significant environmental effects, some of which may not be obvious. That is why state law requires municipalities to notify Wisconsin DNR before they do any construction near lakes, wetlands, and navigable streams. A stream is considered navigable if "it has a discernible bed and banks and is capable of floating a recreational craft of the shallowest draft on an annual recurring basis." The District DNR Transportation Liaison (DNR TL) will help you determine whether a project site involves a navigable stream or wetland, and will advise you about other permits that may be needed. Your county zoning administrator can tell you whether the area is part of a mapped floodplain.

Contact the DNR TL well before the planned start of any culvert project. Late fall (November–December) is an optimum time to notify them about next year's culvert and road projects. Early contact can save time and expense and avoid potentially costly mistakes.

Trans 207 approval process

Trans 207 is a Wisconsin administrative rule that applies to all bridges, arches, and culverts constructed in or over navigable streams by counties, towns, cities and villages, where the construction is under the control of the municipality. The Departments of Transportation and Natural Resources jointly developed the rule in 1981. The basic effect of Trans 207 is to replace formal permit procedures with a less formal cooperative approach between the Department of Natural Resources and municipalities.

Under Trans 207, the county, town, village or city construction authority notifies DNR TL of the intended construction or reconstruction. This can be done by either submitting a conceptual plan for the proposed project, or by obtaining a "waiver" through early coordination with the DNR liaison, indicating the planned activities will have no adverse effect. In some situations early coordination will not resolve all difficulties and detailed conceptual plans will still be required. Also, some projects may impact wetlands, lakes or private property and may require permits under other sections of state law, such as Chapter 30, or may require review and approval by the U.S. Army Corps of Engineers. The DNR TL should be able to advise you about other required permits.

"Minor replacements" of culverts

There is a simplified process for projects that are considered "minor replacements" under Trans 207. This is a simple replacement of an existing structure that meets ALL of the following conditions:

- An equivalent or larger-sized, manufactured structure at the same location.
- The existing structure has a cross-sectional area no greater than 50 square feet.
- The existing road grade line will not be raised in the area adjacent to the culvert so that overflow sections remain to permit flood waters to pass over the road.
- Water conveyance of the new structure will be at least as effective as the existing structure.
- The structure will be manufactured elsewhere; that is, concrete structures will not be poured on site.

For a minor replacement, submit a map with the site location, a description of the existing and proposed structures, and proposed changes in flow elevations. For all other projects, Trans 207.05(2) requires a more detailed conceptual plan. The following section lists the required elements. DNR can waive the requirement for a conceptual plan if early coordination clearly indicates that the activity will have no adverse effect.

New or larger culvert project requirements

If the proposed structure is new, or will reduce existing navigational clearance, public notice is required.

New structures must conform with existing floodplain zoning ordinances.

If a river is used by boaters, a minimum of 5′ of navigational clearance may be required.

Construction erosion and sedimentation must be adequately controlled. If the project disturbs more than one acre of land, then a Notice of Intent to obtain stormwater permit coverage will be needed. The DNR Transportation Liaison will help coordinate with appropriate DNR stormwater staff. Erosion control guidance is provided in the WisDOT's *Standard Specifications for Road and Bridge Construction* and the Wisconsin DNR *Storm Water Construction Technical Standards.* Plans for erosion control should be submitted to DNR before construction.

Additional activities such as stream relocations, wetland fills not directly associated with placing the structure, dredging beyond that necessary to place new structure elements, and disturbance not associated with a public roadway may require permits and are not automatically covered under the exemptions of Trans 207.

If the existing structure contains asbestos material, contact the DNR Air Management Specialist.

Other environmental responsibilities

Wetlands Some stream bottoms qualify as wetland, if they have aquatic vegetation. Wetland impacts must be avoided or minimized.

Fish and aquatic organisms The culvert should be set so that the stream is not fragmented and fish and other aquatic organisms can migrate upstream and downstream during low-flow conditions. This requires that the inside bottom of the culvert be at least 6″ (10%-20% of culvert diameter) below the final stream bed. In addition, the structure should be rocked on both the upstream and downstream margins, as well as the downstream face in the water. The desired end-result is that during high-flow conditions, the currents don't cause a large pool to develop downstream of the edge of the structure, which creates an impassable barrier to aquatic organisms during low flows in the fall.

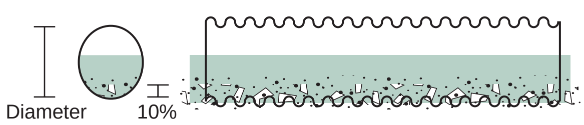


Figure 6. Set culvert at least 6″, or 10%-20% of its diameter (whichever is greater), below the final stream bed so fish and other aquatic organisms can move up and down stream in low flow conditions.

Spawning periods To avoid spawning periods, do in-stream work between June 15 and September 15 on warm water streams, and between April 15 and September 15 on coldwater/trout streams.However, to be safe, consult the DNR TL about your particular stream.

Birds Swallows or other migratory birds often nest on the existing structure. Destruction of swallows and other migratory birds, or their nests, is unlawful under the U.S. Migratory Bird Treaty Act, unless a permit is obtained from the U.S. Fish & Wildlife Service (USFWS). Therefore, the project should either use measures to prevent nesting (such as removing unoccupied nests during the non-nesting season and installing barrier netting before May 15), or should occur only between August 20 and May 15 (non-nesting season). If neither of these options is possible, then the USFWS must be contacted to apply for a depredation permit.

Floodplain zoning If the structure is in a mapped floodplain, the plans must comply with the provisions of the local community's floodplain zoning ordinance. "Appropriate legal arrangements" must be completed with affected landowners if the new culvert will cause the backwater to increase 0.01 foot or more. Contact the county zoning administrator for information on mapped floodplain locations.

Endangered resources/critical habitat These are handled on a case-by-case basis.

Dewatering If dewatering is required, the dirty water removed should be pumped into a stilling basin. Water must be clean before it is allowed to enter the stream.

Waste piles/soil borrow areas Must provide erosion control on these areas.

Maintenance

Any drainage system is doomed to failure if it is not properly maintained. These failures can range from scoured stream banks or stream bottoms to such large failures as road washouts and damaged property adjacent to the stream. Large culverts should be inspected every two years. Maintenance should include periodic inspection to see that:

- The inside of the pipe is free from obstructions.
- Both the inlet and the outlet ends are free of debris and beaver dams.
- Embankment soils are free of erosion.
- The endwalls or riprap are in place, and undercutting has not washed away soil from below and around the culvert, creating a perched or elevated culvert end.

Cracks and settling in asphalt indicate a failing culvert.

Silt filling this culvert drastically cuts flow capacity.

- There is no misalignment or joint failure of the pipe.
- Culvert materials are not corroded or deteriorated.
- There are no pavement cracks or settling on the surface above the culvert.

Misalignment and joint failure can show up as soft spots in relatively shallow fills and as piping, or water movement outside the pipe, on the outside of the pipe's discharge end.

Remove large brush, weed growth, and any other materials from the upstream end of the culvert. This is to prevent their reducing flow by getting in and becoming lodged in or blocking the pipe. Repair ends and correct erosion problems.

Be prepared to contact DNR for appropriate permits should the cleanout project expand beyond the bounds of the culvert opening. Any stream dredging associated with cleaning a culvert may require permits from DNR under Chapter 30, *Wisconsin Statutes.* Contact your local DNR Transportation Liaison for a determination.

Summary

Culvert installations are generally quite simple and straightforward. However, this fact tends to mislead. Even responsible designers may make quick installations without regard to the original design considerations that went into sizing and designing the pipe, or to recent changes that make the old design obsolete. These human failures can result in serious flooding problems, property damage, and road failures. Thus, it is important that all responsible parties understand the important considerations in designing, installing and maintaining a culvert pipe drainage system. Begin planning early — November-December for the following construction seasons — to ensure that you can coordinate with DNR and any utilities which have facilities along the road.

References

Compaction Improves Pavement Performance, Wisconsin Transportation Bulletin No. 11, T.I.C.

Concrete Pipe Design Manual, American Concrete Pipe Association, 222 W. Las Colinas Blvd., Suite 641, Irving, TX 75039-5423. Phone (972) 506-7216 Available online at: www.concrete-pipe.org/designmanual.htm.

Facilities Development Manual, Chapter 10, Wisconsin Department of Transportation, Madison, WI.

Fish Friendly Culverts: Proper design, installation, and maintenance can protect both roadways and fish, UW-Extension. Contact John Haack, St. Croix Basin Natural Resources Educator, 715/635-7406, john.haack@ces.uwex.edu.

Handbook of PVC Pipe Design and Construction, 2001, Uni-Bell PVC Pipe Association, 2655 Villa Creek Drive, Suite 155, Dallas, Texas 75234. www.uni-bell.org/pubs

Hydraulic Design of Highway Culverts, HDS No. 5, Federal Highway Administration. www.FHWA.DOT.gov/bridge/hyd.htm

Installation Manual for Corrugated Steel Drainage Structures, American Iron and Steel Institute, 13140 Coit Rd., Suite 320, LB 120, Dallas, TX 75240-6737. www.ncspa.org/publications.htm

Place Culverts Correctly the First Time, Special Bulletin #43, South Dakota Local Transportation Assistance Program, South Dakota State University, Box 2220, Harding Hall, Brookings, SD 57007-0199. Phone: 605/688-4185, 800/422-0129.

Product Acceptability Lists (PAL), WisDOT. The PAL lists tested and approved erosion control products by name and manufacturer. Updated 3 times a year. Available at www.dot.wisconsin.gov/business/engrserv/pal.htm

Roadway and Roadside Drainage, No. 98-5, Cornell Local Roads Program, 416 Riley-Robb Hall, Ithaca, NY 14853-5701, TEL: 607/255-8033, www.clrp.cornell.edu/

Standard Specifications for Road and Bridge Construction, Wisconsin DOT 2003.

Storm Water Construction Technical Standards, Wisconsin DNR, 2004. Standards for storm water erosion control methods that specify the minimum requirements needed to plan, design, install, and maintain a wide array of conservation practices. Available online at www.dnr.state.wi.us/org/water/wm/nps/stormwater/techstds.htm#Post

Sources of assistance

Consider contacting the following for local assistance with placing culverts in streams:

County Highway Department
County Land Conservation Department
County Zoning Department

Wisconsin DNR Transportation Liaison. First point of contact for projects affecting wetlands and navigable streams as well as advice on other required environmental permits and contacts. Call your District DNR office for the Liaison responsible for your area. A map and current listing is available online at: www.dnr.state.wi.us/org/es/science/DOT_liaison_list.pdf

Transportation Information Center Publications

Pavement Surface Evaluation and Rating (PASER)

- **Asphalt PASER Manual,** 2002, 28 pp.
- **Brick and Block PASER Manual,** 2001, 8 pp.
- **Concrete PASER Manual,** 2002, 28 pp.
- **Gravel PASER Manual,** 2002, 20 pp.
- **Sealcoat PASER Manual,** 2000, 16 pp.
- **Unimproved Roads PASER Manual,** 2001, 12 pp.

Drainage Manual

Local Road Assessment and Improvement, 2000, 16 pp.

SAFER Manual

Safety Evaluation for Roadways, 1996, 40 pp.

Flagger's Handbook (pocket-sized guide), 1998, 22 pp.

Work Zone Safety

Guidelines for Construction, Maintenance, and Utility Operations, (pocket-sized guide), 2003, 58 pp.

Wisconsin Transportation Bulletins

#1 Understanding and Using Asphalt
#2 How Vehicle Loads Affect Pavement Performance
#3 LCC—Life Cycle Cost Analysis
#4 Road Drainage
#5 Gravel Roads
#6 Using Salt and Sand for Winter Road Maintenance
#7 Signing for Local Roads
#8 Using Weight Limits to Protect Local Roads
#9 Pavement Markings
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#14 Mailbox Safety
#15 Culverts—Proper Use and Installation
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