UNH T² Center Technical Note

Proper Culvert Installation

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A culvert is a closed conduit used to allow the passage of water, usually from one side of a road to the other (*see Figure 1*). Use culverts as an effective way of improving drainage and decreasing erosion. While design is imperitive, this article will discuss proper culvert installation techniques.

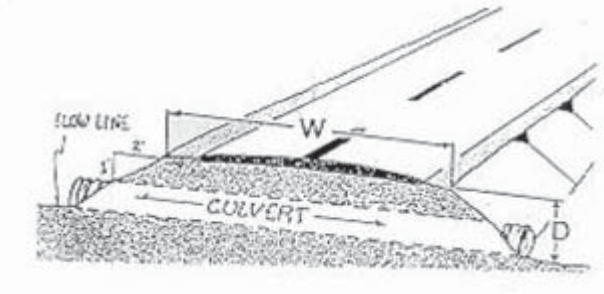

Figure 1 – Road cross-section showing culvert slope (Skorseth, Place Culverts Correctly the First Time)

There are two categories of culverts: stream-crossing and run-off management. A stream crossing culvert allows water to pass under a roadway that crosses a stream. A runoff management culvert (or cross-drain) is strategically placed to route roadway runoff under and away from the roadway. Roadway runoff is water that runs off the road and into the environment after a rainfall. Runoff can cause erosion, pooling of water, and pollution from toxins that are moved to other areas by the runoff.

Installation

Install culverts when stream flow and rain expectancy are low. Divert existing stream flows during installation. Ensure the project is complete before the next major rainfall. Major rainfalls affect the flow path and velocity of water. If a major rainfall occurs during the construction phase of the project, hazards and delays can arise.

The goal of installing a culvert is to maintain the natural flow rate of a stream. A civil engineer (or other qualified person) should determine the size and slope of the culvert to ensure natural flow. Engineering, as well as soil analysis, is necessary on large pipe or deep fill installations and may be needed on smaller projects as well.

Soil analyses are used to find necessary information about the soil, such as strength and permeability. These can be conducted in a lab on a field sample or directly in the field. Either way, soil information is needed to design a sufficient foundation for the culvert to be placed on.

Foundation

A strong and stable soil is needed as a foundation for a successful culvert installation. Weak soils provide inadequate support for culverts. They can cause major damage to the culvert and the roadway, especially during winter due to freeze-thaw cycles.

Use a dense, compacted foundation that will not allow water to penetrate through it. Replace existing material with proper foundation material if needed. Also, do not place culverts directly on bedrock. If it is not possible to excavate through rock or to place

desirable foundation material, then a concrete cradle must be cast to anchor the culvert to the bedrock and ensure a stable slope.

Excavation

Dig a trench that is about twice as wide as the diameter of the culvert. Slope the trench sides to not exceed 1½: 1 (1.5" horizontal to 1" vertical) (*see Figure 2*). This decreases the chance of a cave-in during installation. Shape and compact the bottom of the trench in an arc for the pipe to be lain.

Slope

The slope of a culvert should be between ½" and 1" per foot. This ensures that the flow rate through the pipe is not too fast, nor too slow. If water runs through the pipe at a higher velocity than what is normal, erosion will occur at the outlet. If water runs through the pipe at a lower velocity than what is normal, pooling will occur behind the inlet of the culvert. This increases the chance of a blockage, which disturbs the surrounding natural environment.

The slope of a culvert is determined by the engineer who designed the culvert. Check the elevations of the culvert inlet and outlet to ensure the slope is correct before backfilling.

Compaction

Ensure backfill material is free of topsoil, sod, vegetative debris, and rock bigger than 2.5". Topsoil, sod, and vegetative matter decompose and become more compact over time, which creates air voids and large rocks create inconsistent compaction throughout the fill (*See Figure 3*).

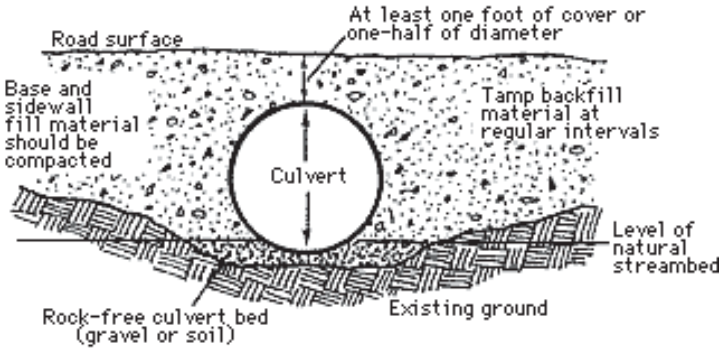

Figure 3: Cross-section of proper culvert foundation backfill and compaction.

Ensure consistent density throughout the fill by compacting in layers of 6" or less. Ensure every layer is the same thickness. Voids are created in the backfill by under-compacting, which causes the material to settle. Settling can cause the flow through the culvert to change, which creates drainage problems and interferes with the surrounding natural processes.

Dips, potholes, and cracks may form in the roadway above if the soil is poorly compacted. Voids also contribute to erosion around the outside circumference of the culvert. Additionally, the fill material may be washed away if large air voids exist or if there are too many of them.

Over-compaction must be avoided as well. If there is too much compaction, the soil may act as a

Figure 2: Culvert trench side slope (OSHA)

wedge and lift the culvert out of place. It may also cause the culvert to bend or dent. Hand tamping is the best method for compaction for the first half of the culvert on smaller scale projects. Other compaction equipment that will get the job done faster may be more desirable once the fill reaches half way up the culvert. Using proper compaction techniques makes it possible to achieve the tight seal around the pipe that is needed to avoid erosion. Once the trench is filled and compacted, road work may begin.

End protection

The potential for pipe end damage during severe floods is due to the velocity of water flowing through the pipe. If water can't flow fast enough through a culvert to keep up with rainfall, the water level builds up above the inlet height. This is called a "head." When there is a head above the inlet of a pipe with high water flow velocity, a vortex is formed above the inlet and very high pressure is exerted on the pipe. This pressure can be great enough to collapse the pipe, or even lift it out of place completely.

The inlet of culverts must be protected and anchored with extensions at the entrance of the pipe called head walls (or headers) to prevent this from happening. Head walls are flush with the end of the culvert and extend out perpendicularly from the pipe (*see Figure 4*). Head walls can also be used to help direct water to the inlet of the culvert by using "wing walls." Wing walls extend off the head wall at a given

Figure 4: Typical Headwall

Figure 5: Header with Wing Walls

angle (*see Figure 5*). Headers may be made of poured concrete, bagged concrete, concrete blocks, bricks, logs, cut wood, or even shaped loose rock riprap.

The outlet of the pipe may need modification to protect it from erosion in some cases as well. Outlet structures should be installed at the outlet where scour and erosion are likely to occur from high exit velocity due to steep culvert installation, near proximity to ditch banks, drops at the end of the culvert, or other situations of high velocity at the outlet. These structures are used to reduce and control energy from ditch or culvert discharge, and release the discharge downstream under controlled, stable conditions.

One common type of outlet structure is called a plunge basin. Plunge basins are designed to be filled with water during run-off events. This pooled water dissipates the energy of the flowing water discharged by the culvert. There are two types of plunge basins: depressed type (*see figure 6*) and weir-formed (*see figure 7*).

Depressed type plunge basins are constructed by making a depression below the outlet channel elevation which allows for the water to pool. Weir-formed plunge basins are made by keeping the basin bottom at the original channel elevation and constructing a weir across the outlet channel. The plunge basin is wider than the outlet channel by design and tapers to fit the existing channel at the basin exit point. End protection structures require the design services of a professional engineer.

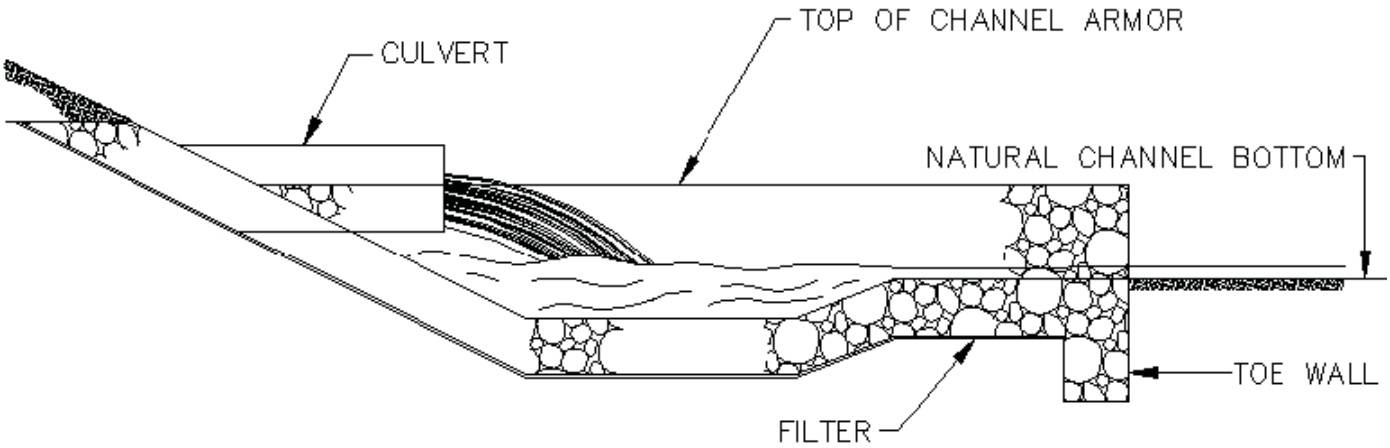

Figure 6: Depressed Type Plunge Basin

Ensure your culvert is installed correctly every time! Rushed installation, inadequate fill material, under-designed pipes, poor compaction, and weak foundations are all short cuts that can save time and money during installation, but will have far greater repair costs in the future. Although it may cost more up front to use proper installation techniques, it will always cost less than fixing a problem that arises in the future due to poor installation.

The problems that do arise are usually quite extensive. Usually the culvert, surrounding area and the roadway above are all negatively impacted. Both a collapsed culvert and under-compacted fill will cause the roadway to dip dramatically and rapidly deteriorate causing safety issues and large repair costs. The cost of repairing these problems is much higher in comparison to the cost of proper culvert design and installation.

For information on concrete culvert design, refer to the American Concrete Pipe Association (ACPA) (http://www.concrete-pipe.org/) and the American Concrete Institute code (ACI 346-09 & ACI 301-05). For more information on culvert installation, refer to the ACPA Concrete Pipe and Box Culvert Installation Manual and ACI 346-09.

References:

- *Arnault, James D. "Culvert Inspection Manual." Report No. FHWA-IP-86-2. July 1986.*
- *Illinois LTAP. "Inspect and Maintain Culverts." Illinois Interchange Fall 1996.*
- *Nevada Technology Transfer Center. "Culvert Maintenance and Repair." Nevada Milepost Spring 2002: 7.*
- *NH Department of Transportation. "Highway Design Manual." Vol. 1. July 2007. ch 6: Drainage.*
- *OSHA. "Sloping and Benching: Safety and Health Regulations for Construction: Excavations." 1926 Subpart P App B. n.d.*
- *Skorseth, Ken. "Place Culverts Correctly the First Time." Special Bulletin #43. South Dakota Local Transportation Assistance Program, July 2002.*
- *Skorseth, Ken. "Preventing Culvert Failure." The Connection Summer 2008: 4, 5.*
- *UNH Technology Transfer Center. "Drainage, Drainage, Drainage." 1996.*

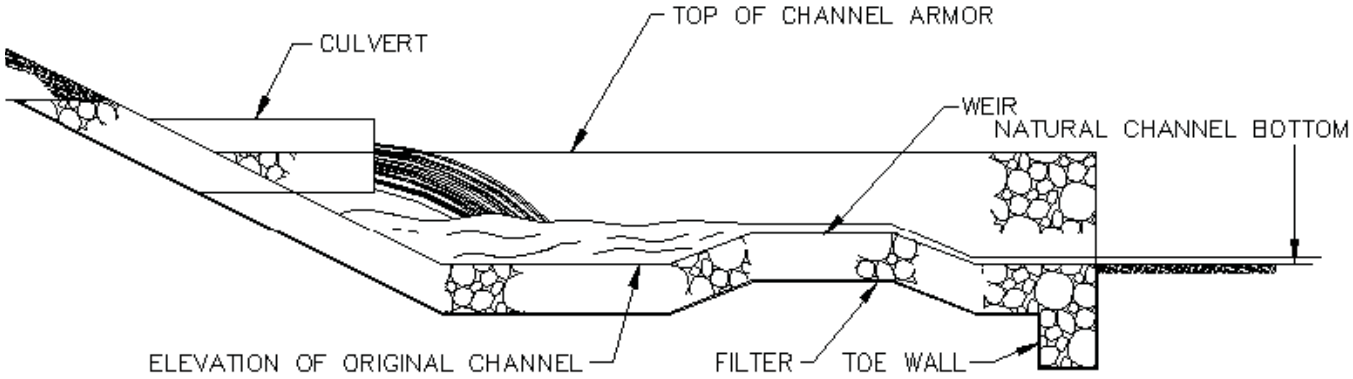

Figure 7: Weir-formed Plunge Basin