Unpaved Roads Stormwater Management Toolkit

June 2025

Franklin Regional Council of Governments

BRPC Berkshire Regional Planning Commission

Catalyst for Regional Progress PVPC

Unpaved Roads Stormwater Management Toolkit

June 2025

Prepared by:

Franklin Regional Council of Governments

Kimberly Noake MacPhee, P.G., CFM, Land Use & Natural Resources Program Manager
Andrea Donlon, Senior Land Use & Natural Resources Planner
Tamsin Flanders, Senior Land Use & Natural Resources Planner
Ryan Clary, Senior GIS Specialist
Megan Rhodes, AICP, Livability Program Manager
Laurie Scarbrough, Senior Transportation Planning Engineer

Berkshire Regional Planning Commission

Melissa Provencher, Environment & Energy Program Manager
Alison Dixon, Senior Planner, Environment & Energy Program
Mark Maloy, GIS, Data & IT Manager
Britney Danials, Planner, Environment & Energy Program

Pioneer Valley Planning Commission

Angela Panaccione, Senior Environmental Planner II, Land Use & Environment
Matt Liebel, Senior Planner I, Land Use & Environment

Engineering design and technical assistance

This project has been funded by an MVP Action Grant from the MA Executive Office of Energy and Environmental Affairs with the Town of Lanesborough as the lead applicant

Photo and line drawing credits: All images by FRCOG and PVPC staff except when cited and except several in the BMP Fact Sheets that are from the road manuals listed on page 10.

Thank you to the Towns of Ashfield, Becket, Blandford, Cheshire, Clarksburg, Colrain, Egremont, Goshen, Lanesboro, Leyden, New Marlborough, Peru, Shelburne, Shutesbury and Washington Highway Departments who provided us with expertise and real-world insights as we developed this Toolkit.

We appreciate the input and information we received by members of the "Dirt Road Coalition," a group convened several times during the fall of 2025 to spring of 2025. The Coalition was composed of Massachusetts state agency staff, local highway departments, nonprofit organizations, and staff from Vermont.

Thank you to the Vermont Agency of Transportation for granting permission to adapt content from the *VTrans State Highway System Roadside Terrestrial Invasive Plants* guidance. The referenced best practices for roadside invasive plants have been modified to reflect Massachusetts communities' conditions, resources, and operational context.

Updated and expanded upon from the September 2024 version

Produced by FRCOG

Franklin Regional Council of Governments

Engineering design and technical assistance

GZA GeoEnvironmental, Inc.

The September 2024 Toolkit project was financed with Federal Funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MassDEP) under a §319 competitive grant (Project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or of the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

Table of Contents

Glossary

The definitions below are provided for use with this toolkit and may not be applicable in different regulatory or scientific contexts.

Bank slope: The slope of the land adjacent to the road.

Best management practice (BMP): A structural, natural, or maintenance technique for managing stormwater and other stressors on and around unpaved roads to maintain the quality of the road to prevent or reduce nonpoint source pollutants from entering surface waters.

Coldwater streams: Waters that are favorable for supporting a year-round population of aquatic life that require cold water, like trout. These can be designated as coldwater fisheries by the Massachusetts Department of Environmental Protection (MassDEP) in 314 CMR 4 (MA Surface Water Quality Standards) or determined by the MA Division of Fisheries and Wildlife (MassWildlife). The MA Surface Water Quality Standards define cold water bodies as having a mean daily maximum temperature over a 7-day period that does not exceed 68°F or 20°C. MassWildlife conducts fish surveys on waterbodies throughout Massachusetts; where they find streams with coldwater fish, the waterbody is determined to have coldwater habitat and are deemed a coldwater fisheries resource. Coldwater fish include, but are not limited to, brook trout, rainbow trout, brown trout, and fallfish.

Concentrated flow: Water that is flowing within a confined channel, either manmade (in a constructed ditch) or due to its own erosive forces (gullying, rilling). Opposite of dispersed flow.

Contributing drainage area: The area of land contributing runoff to a single location. Also referred to as a catchment.

Crown: A road profile that allows water to shed efficiently off the road. Roads can have a centerline crown or cross-slope crown (in-sloping or out-sloping).

Culvert: A closed conduit that allows water to flow from one area to another, typically under a road or driveway. Culverts can be used for stormwater drainage or for stream crossings under a road. Stream crossing culverts in Massachusetts must be designed to meet Massachusetts Stream Crossing Standards.

Discharge: When a concentrated flow of water is released to a new location. This usually refers to water in a ditch being directed to a roadside area or into a stream.

Dispersed flow: Water, usually stormwater runoff, flowing in a thin layer over the ground surface (also called distributed or sheet flow) or in multiple directions. Opposite of concentrated flow.

Drainage: Stormwater and other surface runoff flow rather than natural stream flow. Also referred to as surface runoff.

Driveway culvert: A drainage conduit under a driveway. Often provides continuity of flow along a roadside drainage ditch on each side of a driveway.

Entrenched road: The driving surface of the road is lower than the surrounding land and there is nowhere for runoff to drain.

False ditch: A ditch forming on its own within the road, created by runoff eroding the driving surface. This can also be called a secondary ditch if there is a constructed ditch along the road, but the grade transition between road shoulder and ditch does not allow for water to drain into the constructed ditch.

Grader berm: A row of road material on the side of a road, created by a road grader or snowplow. Grader berms are also called “shoulder berms” and “windrows.”

Grade break: An intentional rise in road elevation on a downhill slope, which causes water to flow to both sides of the road, where it can be collected in ditches or dispersed at a stable outlet.

Gully: Severe erosion that is more than 12 inches deep.

Inlet basin: A dug-out basin at the inlet of a culvert.

Pothole: A depression or hole in the driving surface of a road.

Rill: Moderate erosion between 1 and 12 inches deep.

Road drainage infrastructure: Any structural modification designed to collect and control runoff from and around the road, such as a ditch or a culvert.

Road grade: The slope of a road as measured at the center line. The slope is a measurement of the rate of rise (vertical distance), over the run (horizontal distance). To calculate % slope, use (rise/run) x 100.

Road shoulder: The strip of land immediately adjacent to the traveled portion of the road; typically, a natural, non-landscaped area.

Road material: Materials covering the driving surface of the road, typically a mixture of crushed stone (e.g., gravel) and fine materials (e.g., sand).

Runoff: The unconfined flow of stormwater over the ground surface. Typically, stormwater runoff from rain or snowmelt. Also referred to as surface runoff.

Rut: A linear wheel depression in the road.

Sedimentation: Deposition of material from unpaved roads into wetlands and waterbodies.

Stable vegetated area: Area where vegetation has established a root base that holds the soil in place.

Subbase: The layer of road below the surface layer.

Subgrade: The prepared earth surface upon which base layers and other structural layers of the road are laid (i.e., below the subbase).

Treatment train: A sequence of stormwater BMPs strategically arranged so that runoff flows through the drainage system in a way that maximizes the ability to prevent erosion and control sedimentation.

Turnout: Extension of a ditch that directs water off the road to filtering areas, sometimes called a “bleeder,” “diversion,” “tail ditch,” and other names.

Unpaved road: A road, also known as a dirt road or gravel road, without a paved surface like asphalt or concrete. A “dirt” road is typically a road that is made of native material, whereas an unpaved road is constructed with base material and surficial material to create a drivable surface that is not paved.

Washboard: Periodic ripples running across the surface of road. Also called corrugation.

Water velocity: The speed of water flow measured in feet per second.

Waterbody: This is a term used to cover a variety of surface water types, including rivers, streams, lakes, ponds, and oceans.

Wetland: Under the Massachusetts Wetlands Protection Act Regulations (310 CMR 10.55), a wetland must consist of wetlands vegetation, hydric soils and have evidence of hydrology. It is important to note that wetlands are not always wet—in fact the most common type of wetland in Western Massachusetts is the forested wetland such as a red maple swamp. Often dominated by mature trees with over 40% canopy cover they are only seasonally saturated and are often “mucky” opposed to having noticeable standing water.

Introduction

Though Massachusetts is the third most densely populated state in the United States, the rural parts of Massachusetts have many miles of unpaved roads, particularly the four counties of western Massachusetts (Franklin, Berkshire, Hampshire, and Hampden Counties). Many of these dirt or gravel roads—called unpaved roads in this toolkit—are vulnerable to extreme weather events and are located near sensitive environmental resources such as wetlands or coldwater streams. If not properly constructed or maintained, unpaved roads will degrade over time, especially from erosion. The loss of road material and creation of driving hazards are costly for the small towns in the region as they must continually repair and rebuild their unpaved roads.

The primary objective of this *Unpaved Roads Stormwater Management Toolkit* is to be a resource to Highway Departments and Departments of Public Works (DPW) staff, Town Administrators, Town and regional planners, Conservation Commissioners, and other practitioners to help "keep the road on the road." Minimizing loss of road material and maximizing drivability can improve public safety.

This toolkit was developed for unpaved roads in western Massachusetts, but is designed to be used and adapted, as needed, to local conditions in other communities across Massachusetts or the country.

Changing Weather and Road Conditions

Warmer winters, heavy rains, and droughts are happening more frequently than ever before and often wreak havoc on local roads, especially unpaved roads. Late snowstorms that occur when the road has started to thaw are very difficult to plow and may cause the removal of road surface. Mud season now happens several times a year due to multiple freeze/thaw cycles and can make roads impassable. Heavy rain falling on steep, unpaved roads can cause serious erosion and washouts. Longer, drier periods in spring, summer, and fall can result in excessive dust, increasing the rate of road material loss (as much as 3 inches per year).

This toolkit examines the variety of issues that may be caused by extreme weather but emphasizes stormwater management because it is the key to the majority of long-term unpaved road problems. The toolkit provides a suite of best management practices (BMPs) to manage, slow, and control stormwater, and guidance for essential road maintenance practices and maintenance BMPs. Using this toolkit, Town governments will be able to save time and money, and protect critical environmental resources.

Why Does Erosion Matter to our Waterways?

The unpaved roads in rural areas in western Massachusetts often cross or run along sensitive environmental resources such as rivers, streams, wetlands, and ponds. Our rural areas have some of the healthiest waters in the Commonwealth of Massachusetts, and residents value living in or near a relatively pristine environment.

The sediment in the stormwater runoff from this unpaved road in Franklin County has turned this stream to a murky brown.

Unpaved roads are vulnerable to erosion from uncontrolled stormwater, snowmelt, and plowing when the road is soft. When heavy precipitation or plowing causes road material to dislodge and move off the road, this can impact water quality or fish habitat. Though the sand and gravel that make up unpaved road material is natural (mixed asphalt shavings and millings are not), unnatural sedimentation and siltation in gravel-bottom streams reduces food sources for aquatic insect larvae, smothers fish spawning locations, and fills spaces between cobbles that otherwise serves as cover and protection for newly hatched young fish. For this reason, sediment is considered a water quality pollutant.

Young fish like this rainbow trout alevin need spaces in between gravel for protection. Sedimentation from nearby roads can fill in the spaces between particles and reduce or degrade fish habitat. Photo credit: Ryan Hagerty, USGS Eastern Ecological Science Center.

The *2024 Final Massachusetts Statewide Total Maximum Daily Load (TMDL) for Pathogen-Impaired Waterbodies* shows significant levels of bacteria impairments across western

Massachusetts, requiring reduction targets in several watersheds.[1] High bacteria levels are a water quality pollutant, and a threat to human health and safety at high concentrations. High *E.coli* levels can result in beach closures, often hurting local recreation economies and impacting the quality of life for area residents. It is thought that runoff from unpaved roads may contribute bacterial pathogens to waterbodies, especially *E. coli*, because bacteria can attach to fine particles, including dust, and be washed into nearby waterways during storms.

Why Does Erosion Matter to our Municipalities?

Erosion of an unpaved road costs towns money to repair and can impact driving safety or make roads impassable. Annual cycles of erosion and temporary repairs are expensive and not sustainable because the problems are bigger than one site or stretch of road. Many problems can be avoided by proper road construction and maintenance practices.

The information provided by the toolkit can help towns save on road maintenance costs and protect sensitive natural areas by reducing erosion, or in other words, "keep the road on the road." As many regions experience more frequent and intense storms due to climate change and wetter snowstorms in spring, effective stormwater and snow management will make roadways and rivers and streams more resilient to the worsening effects of climate change.

Changing River and Stream Channels

Rivers and streams naturally change course over time and need space in which to expand laterally. Unfortunately, many of our roads have been built so close to streams that the stream can't move without undercutting the streambank and causing the shoulder or road surface to collapse.

If this is happening in your town, this is a complex situation that will likely require the services of an engineering and fluvial geomorphology consultant (fluvial geomorphology is the study of how rivers interact with the landscape around them).

A road shoulder collapsed into a river.

[1] https://www.epa.gov/system/files/documents/2025-04/final-ma-statewide-tmdl-pathogen-impaired-waters.pdf

Key Principles of Unpaved Road Stormwater Management

Unpaved roads require more regular maintenance than paved roads but perform well if properly constructed and maintained. Good maintenance practices and appropriately selected and sized stormwater infrastructure save money by decreasing road problems and preventing untimely repairs and can be protective of water quality and sensitive resource areas.

- Get water off the driving surface quickly and avoid having water run lengthwise down the road
- Slow the flow of runoff passing through road drainage infrastructure whenever possible to reduce erosion and trap sediment
- Divert as much runoff as possible from road drainage structure outlets away from surface waters to vegetated areas where it can be absorbed into the ground
- Keep road drainage infrastructure and surrounding areas stable with vegetation or stone

How to Use this Toolkit

There are numerous road manuals for unpaved roads from across the country. These road manuals often identify best management practices (BMPs) for constructing, repairing, and maintaining unpaved roads. These documents are typically geared towards improving the quality of the road, and some are focused on or keep water quality impacts in mind. Excellent resources for unpaved road issues are listed under *Recommended Road Manuals* (page 10).

One of the most important unpaved road manuals available has been *The Massachusetts Unpaved Roads BMP Manual: A Guidebook on How to Improve Water Quality While Addressing Common Problems*, published in 2001. This *Unpaved Roads Stormwater Management Toolkit* provides an update to many parts of the 2001 Manual, such as guidance on culvert sizing based on predicted storm sizes and new concepts for structural, management, and maintenance BMPs inspired by innovations in western Massachusetts and around the region over the past several years. While the *Unpaved Roads Stormwater Management Toolkit* does not formally replace the 2001 Manual, it provides a substantial amount of new information necessary for effective management of unpaved roads today.

The *Unpaved Roads Stormwater Management Toolkit* is not a comprehensive road manual. It does not, for example, provide detailed information on unpaved road construction and maintenance. Instead, it identifies common rural unpaved road maintenance issues, particularly those related to stormwater, and provides a series of tools for assessment and problem solving. The tools can be used independently, but they ideally build on each other to promote practices that are protective of water quality and reduce costs for towns.

Tool 1: Essential Road Maintenance Practices is a guide to unpaved road design, management, and maintenance best practices. Often, many future problems can be avoided by regular use of these best practices.

Tool 2: GIS Screening for Vulnerable Unpaved Roads is a method for identifying municipal roads most vulnerable to erosion and saturation. The method is summarized in the toolkit. Town-wide maps are available from the western Massachusetts RPAs upon request.

Tool 3: Unpaved Road Criticality Checklist and Field Assessment provide forms that help assess problem roads and identify fixes.

Tool 4: Best Management Practices (BMP) Selection describes road types and typical problems by road type. There are also several tables to help the user to identify appropriate BMPs to use.

Tool 5: Stormwater BMP Fact Sheets and Design Typicals provides more information about BMPs, with 15 design typicals to provide information about installation of these BMPs.

Tool 6: Round Stormwater Drainage Culvert Right-Sizing Guide provides guidance on determining the best size stormwater drainage culvert, depending on the contributing drainage area**.**

Tool 7: Treatment Trains provides examples of multiple stormwater BMPs installed at a site to provide maximum benefit.

Tool 8: Managing Invasive Plants Along Roadsides provides guidance for reducing the spread of invasive plants.

This toolkit's fact sheets and design typicals (**Tool 5**) are aimed at giving municipalities the tools to develop and install their own BMPs; complicated sites may require the services of an engineering consultant and additional funding.

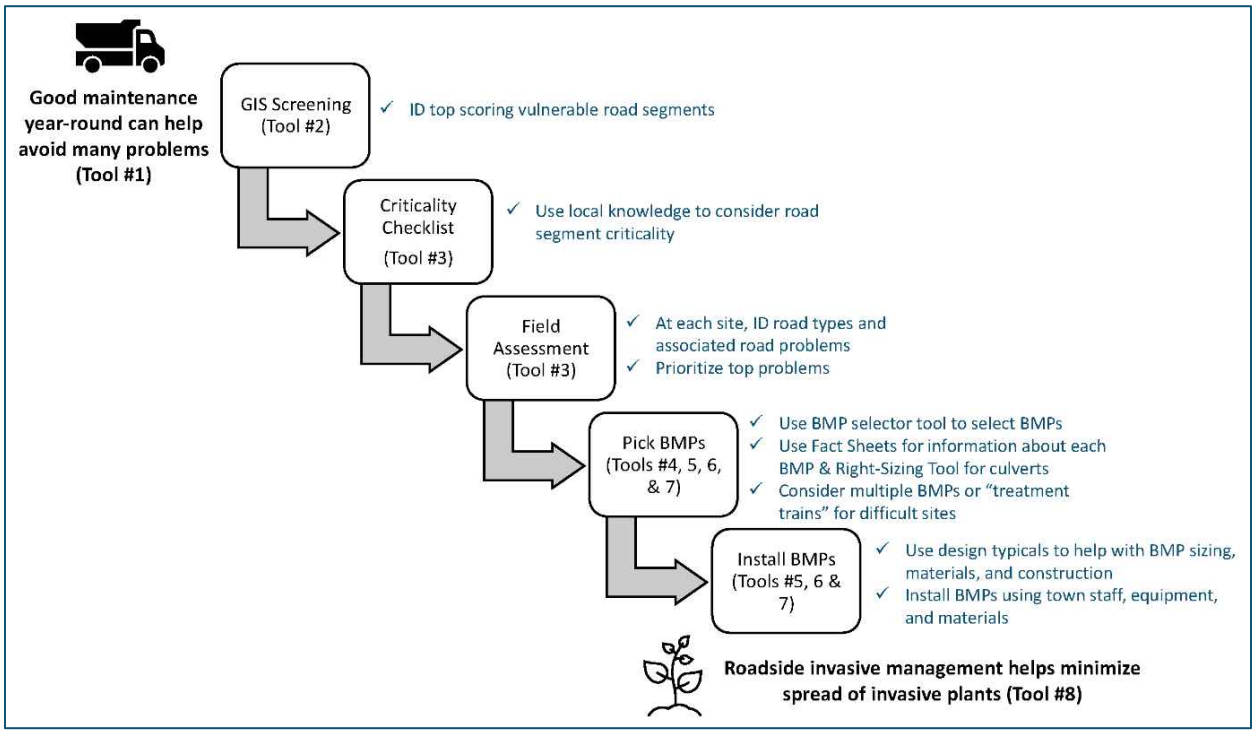


Figure 1-1. Flow chart demonstrating how to use this Toolkit.

Recommended Road Manuals

Unpaved Road Management Digital Info Center:
A clearinghouse for dozens of the recommended and additional unpaved road resources.
https://airtable.com/appFtKR1jKIqUWIb4/shrIU08qzrenHA1ZX
https://bit.ly/UnpavedRoadManagement

- **Alabama**: Recommended Practices Manual: A Guideline for Maintenance and Service of Unpaved Roads (Choctawatchee, Pea, and Yellow Rivers Watershed Management Authority, 2000)
- Franklin County Rural Road Guide (Franklin Regional Council of Governments, 2021)
- **Maine**: Gravel Road Maintenance Manual: A Guide for Landowners on Camp and Other Gravel Roads (Maine Department of Environmental Protection, 2016)
- **Massachusetts**: The Massachusetts Unpaved Roads BMP Manual: A Guidebook on How to Improve Water Quality While Addressing Common Problems (Berkshire Regional Planning Commission, 2001)
- **New Hampshire**: A Ditch in Time: An owner's manual for those who live and travel on dirt and gravel roads (Russ Lanoie, Conway NH, 2014)
- **New York**: Rural Roads Active Management Program (Champlain Watershed Improvement Coalition of New York, 2014)
- **Pennsylvania**: Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads (U.S. Forest Service and Penn State University Center for Dirt and Gravel Road Studies, 2012)
- **U.S.**: Gravel Roads Construction & Maintenance Guide (U.S. DOT, Federal Highway Administration, 2015)
- **Virginia**: Dirt and Gravel Road Best Management Practice Guide (Culpeper VA Soil and Water Conservation District, 2019)
- **Vermont**: Vermont Better Roads Manual (Vermont Agency of Transportation, 2024)

Tool 1: Essential Road Maintenance Practices

Introduction

Many rural Massachusetts communities struggle to maintain their roads due to the challenges of increasing costs, staff shortages, and severe weather events. Though it can be challenging to properly build and maintain unpaved roads, doing so can reduce repair costs, protect public safety, and extend the lifetime of the road.

Before installing any stormwater BMPs, communities should have basic unpaved road maintenance practices in place.

A trial-and-adjust approach is helpful for Highway staff looking to improve their unpaved roads. It is important to try new methods and products over one or two seasons, record what works and what does not, and adjust as needed. This tool provides an overview of key unpaved road maintenance practices.

Additional road maintenance resources can be found in the list of Recommended Road Manuals (Toolkit page 10) or via the Baystate Roads program.[2]

Checklist of Essential Design, Management, and Maintenance practices:

- ☑ Proper road structure
- ☑ Grading
- ☑ Removal of grader berms (or addition in certain cases)
- ☑ Compaction of road after grading
- ☑ Constructed ditches
- ☑ Ditches disconnected from waterbodies
- ☑ Sufficient turnouts
- ☑ Sufficient stormwater drainage culverts
- ☑ Right-sized drainage culverts
- ☑ Follow MA Stream-Crossing Standards
- ☑ Inspection and maintenance
- ☑ Proper snow and ice management
- ☑ Proper dust control
- ☑ Excess road material management

[2] https://www.umasstransportationcenter.org/umtc/Baystate_Roads.asp

Overview of Maintenance Equipment

This section lists key equipment that significantly improves road quality and the productivity of road maintenance work for unpaved roads. It may be unrealistic for every town to own all the equipment listed below due to cost, but knowing which tools yield the best results helps prioritize investments. Used equipment, rentals, or sharing between towns may be feasible alternatives to purchasing.

Recommended Equipment

- **Grader**: For towns with over 10 miles of unpaved roads, a grader is crucial. Articulated frames on graders improve maneuvering and grading accuracy. New technologies such as all-wheel drive, more horsepower, tire styles, cutting edge options, scarifier and ripper options, and slope control for the blade boost fuel efficiency and reduce operator learning curves. The cost of new graders, the lack of a rental market, and the issue with manufacturers not producing parts for the full potential lifetime of the machine can be a challenge. Leasing programs may be available to help ease the large upfront cost of a new grader.
- **Scarifier:** A scarifier is mounted on a grader and uses sharp, replaceable teeth to break up compacted unpaved road surfaces and dig below potholes. A scarifier is a more effective tool than a standard grader blade or rake. Using a scarifier will significantly save wear and tear on grader blades.
- **Roller:** A vibratory roller incorporates vibration while applying pressure to the roll, achieving significantly better compaction. A vibratory roller generally requires fewer passes to achieve the desired compaction level compared to a static roller.
- **Articulating bucket:** An articulating bucket is an excavator attachment that has the ability to tilt at different angles, allowing for more precise control and grading. Articulating buckets can shape and clean out ditches, turnouts, and culvert inlets/outlets without damaging their structure.
- **Skeleton bucket**: A skeleton bucket (also called a screening, riddle, or shaker bucket) is an excavator attachment that is similar to a regular bucket but has square holes and is designed to separate different-sized materials like soil, rocks, and debris. It can be used to clean sediment from stone-lined ditches or screen gravel.
- **Dust control sprayer and storage:** Dust control sprayer options vary widely. Thinking through truck types, tank size, nozzle type (changeable nozzles), pressure gauge, and electric on/off switches before purchase or set-up is important. A material storage tank is also needed for dust management. The number of gallons being applied each year will determine tank size and number, the loading pump, and minimum delivery amounts. Dust control materials and application methods are discussed in the *Dust Control* section.
- **Hydroseeder**: A hydroseeder is designed to spray a mixture of seed, water, fertilizer, and mulch over a bare-soil surface. Hydroseeding ensures an even distribution of seed and

mulch, speeds up the germination process, and reduces erosion in ditches and banks after construction, ditch cleaning, or after large storm events. A hydroseeder could be shared between towns.

Working with your Conservation Commission

In Massachusetts, municipal boards called Conservation Commissions are charged with protecting wetlands, waterways, and natural resources under the Wetlands Protection Act (WPA) and local wetland bylaws. Highway Departments are responsible for maintaining safe, passable roads year-round, sometimes needing to work in or near environmentally sensitive areas. These roles are not in opposition, but they can sometimes have conflicting priorities. Highway crews have to make time-sensitive road repairs, but projects near wetlands or streams may require permitting, which takes time and documentation. Conservation Commissioners (and Conservation Agents) may not be aware of operational needs such as proper drainage techniques, while Highway crews may not understand the Commission's legally mandated jurisdiction.

With the increasing frequency of extreme storms, flooding, and freeze-thaw cycles, road maintenance and environmental protection are more interconnected than ever. This is an opportunity to work as a team. With communication, shared knowledge, and common goals, Highway staff and Conservation Commissions can become powerful allies.

Opportunities to Work with Conservation Commissions

- Develop emergency permitting procedures to avoid delays (e.g., pre-agree on standing conditions for various Emergency Certifications).
- Create a standing policy that the Highway Department will notify the Conservation Commission at the beginning of each maintenance season of its planned work and, if needed, the two groups can schedule a meeting and/or site visit to discuss potentially environmentally sensitive projects.
- Explore funding opportunities together (e.g., MVP, culvert replacement grants) to protect infrastructure and the environment.
- Develop a Bundled Notice of Intent (NOI) for roadway maintenance that satisfies WPA rules and regulations (only applicable to Western Massachusetts communities).

Road Structure

Many existing unpaved roads were originally old cart paths or logging trails that were never intended for vehicle traffic. This has resulted in roads without proper structure or drainage to accommodate increased traffic. Often these roads become entrenched—a condition in which

the driving surface of the road is lower than the surrounding land and stormwater runoff cannot drain off the road.

Structure of a Well-built Road

- A subbase of processed gravel (ideally 18 – 36 inches deep).
- A surface layer blend of aggregates and fines (4 – 6 inches thick).
- The surface of the road and shoulder are elevated above natural grade (not entrenched).
- Shoulders at least 1 foot wide.
- Proper crown (4% or ½" per foot).

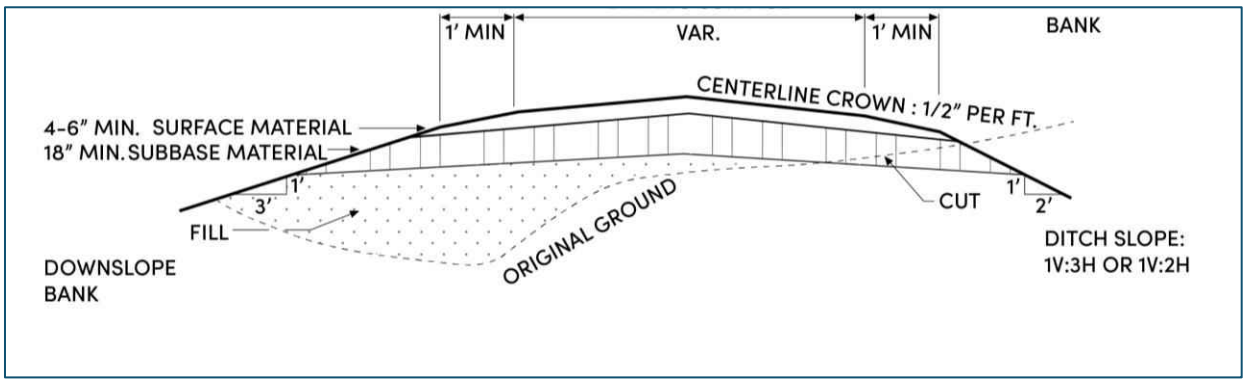


Figure1-2. Proper structure of an unpaved road. Figure not to scale.

Subbase

The road subbase provides a stable foundation for the road. A proper subbase is made of crushed stone and gravel at least 18 inches deep, though 36 inches (3 feet) deep is ideal. Although drainage on the surface of the road is very important, drainage in the subbase is critical. Subbase drainage can be achieved with proper roadside drainage BMPs. See the VEGETATED DITCH, STONE-LINED DITCH, UNDERDRAIN, and FRENCH MATTRESS BMP FACT SHEETS for more information on these drainage forms.

Mud Season

Primary contributors to severity of mud season include:

- Poor road structure and material mix
- Lack of ditches
- Water not draining property off travel lanes
- High traffic volume
- Heavy vehicles
- Depth of frost

If mud season problems persist, the road or parts of it may be a good location to add geogrid under the subbase (see GEOGRID BMP FACT SHEET).

Road Surface

The surface layer of an unpaved road should be about 4 – 6 inches thick. Typically, about ½ inch to 3 inches of fine materials are lost off the

typical unpaved road each year depending on traffic volumes and moisture levels. If a road experiences stormwater erosion, much more material can be lost. Steep roads are particularly vulnerable to stormwater erosion**. A rule of thumb for budgeting is to add 3 inches of surface material to every unpaved road in town every three years to account for routine material loss**. See "Road Surface Materials" below for information about proper material specs.

Road Materials

Selecting effective road materials is a top priority for constructing and maintaining a road that is stable and drains well. The surface layer of an unpaved road needs to be a blend of course aggregates (angular gravel/stone) and fines (sand, silt, and clay particles) to support traffic. Sand-sized fines fill the voids around stones, giving the road stability. Silt- or clay-like material binds the other fine materials and forms a crust that effectively sheds water.

Though more expensive, crushed stone has seven times the holding strength of round stones. Avoid using gravel bank run, round stone products, and aggregate at too small of a grade as road surface material.

It is recommended that the Town (or the bidder, if purchasing through a group procurement) pay for a sieve analysis on gravel samples once yearly to find out the exact composition of what is being purchased; this should be done in the middle to end of the season to ensure that the grade is consistent with the specifications. As gravel suppliers fulfill different orders throughout the season, the composition and availability of gravel types may change.

Every town has varying conditions that may require a unique blend of gravel types and sizes.

Recommended Gravel Specifications

- For subbase gravel:
  MassDOT's M2.01.7: Dense Graded Crushed Stone for Sub-base[3]
- For surface gravel:
  Generally, recommended size for coarse aggregates is ¾-inch minus, but should not exceed 1 ½ inch minus.[4] Table 1-1 shows possible gradation requirements for gravel surface materials.

[3] MassDOT. *Commonwealth of Massachusetts Department of Transportation Standard Specifications for Highways and Bridges*, 2025 Edition: https://www.mass.gov/doc/2025-standard-specifications-for-highways-and-bridges-division-iii-materials-specifications/download.

[4] "¾ minus" refers to a type of gravel where the largest size of aggregate is ¾-inch but can include a mix of smaller pieces and fines.

Table 1-1: Example of gradation requirements for gravel surface materials

Requirement Sieve	Gravel Surfacing Percent (%) Passing
¾”	100
No. 4	50-78
No. 8	37-36
No. 40	13-35
No. 200	4-15*

*The amount of No. 200 could be decreased due to New England’s wetter climate.
Source: South Dakota Standard Specifications for Roads and Bridges, Gravel Surfacing

Use of Asphalt Millings for Surface Material

A somewhat common practice is to incorporate asphalt millings into the surface materials. It is believed that the flexible and binding nature of the asphalt will create a more solid crust for an unpaved road and recycled millings are often more affordable than processed gravel. While this may be true in the short-term, the long-term savings do not necessarily hold up. Asphalt millings often lead to more frequent and difficult to fix potholes; extreme hot weather will result in rutting as the millings soften; and maintenance of the road is difficult on equipment as the millings can form a hard layer for scarifiers and graders.

Do not use directly next to streams. The chemicals from the asphalt millings can leach into streams running next to unpaved roads.

The Federal Highway Administration’s *Gravel Roads Construction & Maintenance Guide* states that if using, mix the millings at a ratio 30- 60% with new surface gravel.

Crown

A road must be shaped to have a high point so runoff can drain off the surface of the road, either into ditches or as dispersed (evenly distributed) flow off the road shoulder. A center-line crown is an "A"-shape in the road with the high point in the center of the road. A road with a cross-slope crown has the highest point on one side of the road. The recommended slope for all crowns is ½-inch per foot, or 4%. Refer to the CENTERLINE CROWN and CROSS-SLOPE CROWN BMP FACT SHEETS.

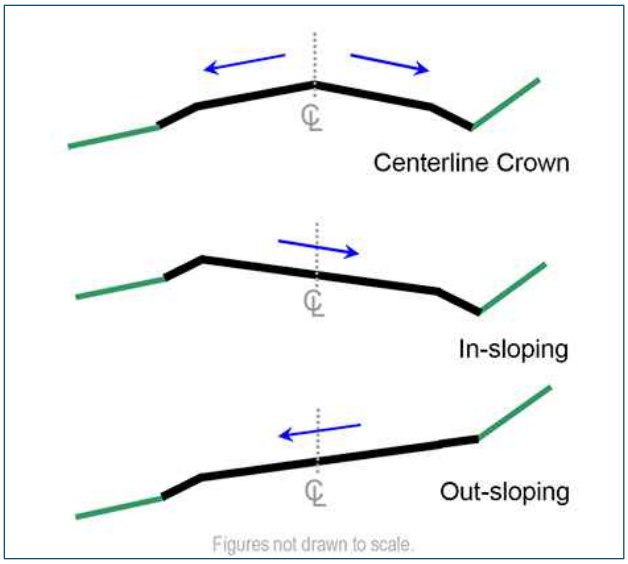


Figure 1-3. Road crowns.

Common Crowning Mistakes

- Having too much crown will cause gravel to wash sideways and potentially cause erosion. Too much crown does not feel safe for motorists, and drivers will be more inclined to drive in the center of the road because the road will appear narrower than it is.
- A parabolic crown develops when the ideal "A" profile of a gravel road becomes rounded, leading to drainage issues such as water retention, potholes, and rutting. Parabolic crowns are often caused by a "hollow" moldboard whose center has been worn away. To fix this, it is recommended to harden or thicken the center section of the moldboard, use carbide tipped bits or a "stinger blade," or flip or replace the grader blade.

Grading

Grading is the process of re-establishing the proper crown of an unpaved road and smoothing the driving surface. Regular grading also helps redistribute road material that has been washed or pushed to the edge of a road.

Tips for Grading

- Where the average crown is maintained at 4%, the shoulder grade should increase to 6 – 8% to ensure quick runoff and to create a visual break between travel lane and shoulder.
- Year-round roads should be graded at a minimum once a year in spring to reshape the road after a season of snow plowing. Spot grading in summer or fall is recommended where needed. A limited need for grading in the summer or fall can mean that the Highway Department has adopted good maintenance practices.
- A high shoulder can form over years of grading, making the road level lower over time. High shoulders also prevent water from leaving the road surface, causing the road to become entrenched. To fix a high shoulder, the road can be built back up or material can be excavated to reshape the shoulder. If this is not possible, consider structural stormwater BMPs recommended for entrenched roads in this toolkit.

Potholes

Potholes are caused by excessive moisture, poor drainage, inadequate crown, and poorly graded road materials. Filling in potholes with crushed aggregates is only a temporary fix and potholes will likely form again in the same place.

Properly fixing potholes requires that the scarifier cut through the road surface to *below* the bottom of the pothole when grading. If the compacted bottom of the pothole stays intact, potholes will quickly reform.

The quality of properly graded roads largely depends on the grader operator and the equipment that they use. A great resource for Highway staff to learn about grading technique and other road maintenance practices is the Baystate Roads program.

Compaction of Road after Grading

Grading loosens and re-sorts road materials. After grading, the road surface must be compacted into place before it rains to help lock the fine particles in with the coarser ones. If the road is not compacted after grading, fines can be easily eroded off the road, losing a key binding element of the road and making the road surface less stable. Compacting the road shoulder as well as the driving surface provides better drainage, helps the road support heavier vehicle loads, and provides a safe area for vehicles to pull over.

An 8-10-ton vibratory steel drum roller is the best equipment for compaction. A rubber tire vibratory roller installed on the rear of a grader can also provide very adequate compaction (such as the “walk and roll” system). If neither are available, a static drum fitted to the back of a grader or a loaded pickup truck can be driven over the entire road surface several times. Passenger vehicles driving in the travel lanes do *not* provide adequate compaction.

Road compaction works best when there is some moisture in the road material, whether from natural rainfall earlier in the week or added by spraying water or dust control material.

Grader Berm Removal

Grading can create a berm, or windrow, at the center of the crown or on the shoulders where material is lost off the edge of the blade. Plowing snow on unfrozen roads can also create berms. During the summer, grader berms can be difficult to recognize because vegetation can obscure them.

A berm will keep water on the road surface by acting as a dam. This creates a secondary "false ditch" that erodes the road surface. The longer a grader berm is left, the higher the risk that the road will erode and become entrenched.

Grader berms should be bladed or "pulled" back into the roadway. It is helpful to mow before grading so that grader berms can be more easily pulled into the road and less organic matter is incorporated.

Road with grader berm.

Bermed Road Edges

In some instances, bermed road edges can be beneficial to prevent sediment from reaching a waterbody. Berms may be appropriate in the following cases:

- On each side of water crossings, such as bridges and culverts, where runoff would otherwise flow directly into waterbody.
- Shoulders with steep downslopes where runoff is finding an exit point and causing bank erosion. With a strategic section of bermed road shoulder, runoff can be directed to a stabilized ditch, turnout, or infiltration area.

Generally, berms should be the exception, not the rule.

Grading for Road and Driveway Intersections

Tips for Grading Intersections

- When grading two intersecting unpaved roads or a road and driveway, the crown should only be maintained on one of them.
- If the intersection is a four-way controlled intersection, the primary road maintains the crown and the secondary road with the stop or yield signs are shaped to flat to meet the primary road 100 feet prior to the intersection.
- If the intersection is a four-way uncontrolled intersection, the crown is eliminated from all directions over the 100-foot stretch approaching the intersection, and the intersection itself is flat with no noticeable dip or bump in any direction.
- Be careful not to make the intersection a low point so that water collects in the intersection area.

Ditches

The best roads are built above the elevation of the surrounding land and shed water evenly off the shoulder into stable vegetated areas where vegetation holds the soil in place and normal amounts of surface runoff will not erode the ground. However, ideal conditions do not always exist. Where this evenly dispersed flow is not possible, installing ditches with frequent turnouts and stormwater drainage culverts is the best option. Properly designed and constructed ditches direct flow away from roads and away from sensitive water resources. Ditches also help drain the road base, which helps road drivability during mud season.

Ditch Design

The best ditch shape for proper drainage is trapezoidal or parabolic (rounded). Rectangular ditches are fast and easy to construct, but the sides are highly prone to erosion. V-shaped ditches can be easily constructed and do keep erosion to a minimum, but do not hold as much water. Though more difficult to construct, trapezoidal and parabolic ditches channel water effectively, hold greater water volume, and require less maintenance. Parabolic ditches are the least prone to erosion of the four options.

Ditches should be a minimum of 1 foot deep, though 3-foot ditches are recommended to contain the runoff from intense storms.

Table 1-2 shows how much roadside space is needed to construct a ditch following recommended dimensions for a 1 foot-, 2 foot- and 3 foot- ditch depth.

Table 1-2: Ditch depth and sizing

Depth (feet)	Side Slope	Total width (feet) with 1-foot-wide base
1	2H:1V	5
1	3H:1V	7
2	2H:1V	9
2	3H:1V	13
3	2H:1V	13
3	3H:1H	19

In cases where there is not enough space to construct the ideal ditch dimensions, the ditch shape can be asymmetrical. For example, the backslope (the furthest side from the road) of the ditch can be steeper. Often, there is simply not enough right-of-way for the ideal ditch and in that case, **any ditch is better than none to protect the roadway.**

Strategies for Making Room for Ditches

With the increased volume of stormwater runoff from unpaved roads that western Massachusetts communities are experiencing, many Highway Departments are becoming more willing to make room for ditch installation by cutting back trees or removing ledge. In some cases, narrowing the travel way within the road is also an option depending on traffic volumes and line-of-sight.

Proactively working with the Conservation Commission and Tree Warden/Committee can facilitate efforts to create room for drainage.

Town Right-of-Way

Highway staff can legally do work within the Town road right-of-way (ROW). When road ROWs were established by a town, they were typically measured at 3 rods, or 49.5 feet. This was not standardized, however, and ROWs can vary from town to town and road to road.

Often, the Town is in possession of a plan of the road layout. When that is missing, Highway staff can use assessor's maps as a guide. Property pins, stone walls, and boundary markers in the field can help ground-truth what the maps show.

Land use and activities within the ROW, along with landowner temperament, may dictate what Highway staff actually try to do. Communicating with landowners to get their buy-in before a project is highly recommended and generally results in a better outcome.

Ditch Lining & Erosion Control

Whether and how to line the ditch depends on the time of year, the road grade, and the amount of water the ditch is anticipated to handle. Table 1-3 recommends ditch types by road grade.

Table 1-3: Recommended ditch type by road grade

Grade	Ditch type
0 – 5%	Vegetated
5 – 8%	Vegetated with stone check dam
Greater than 8%	Stone-lined
As needed up to 10%	Stone-lined with stone check dam

For more information, refer to the VEGETATED DITCH or STONE-LINED DITCH BMP FACT SHEETS.

Ditch Disconnection

Because stormwater runoff carries sediment and other pollutants, it is important to prevent ditches from discharging directly into a stream.

Methods for Disconnecting a Ditch from a Waterbody (see also Figure 1-3)

- **Option A**: Adding turnout outlet protection to a curving turnout as outlet protection directs water discharges away from the stream.
- **Option B**: Adding a stormwater drainage cross culvert at the end of the ditch to direct the runoff to a more suitable area across the road.
- **Option C**: Ending the ditch 20 or more feet before the waterbody and allowing runoff to flow in a distributed manner through turnout outlet protection such as a riprap apron and a vegetated buffer zone before reaching the waterbody (see VEGETATED BUFFER ZONE BMP FACT SHEET).

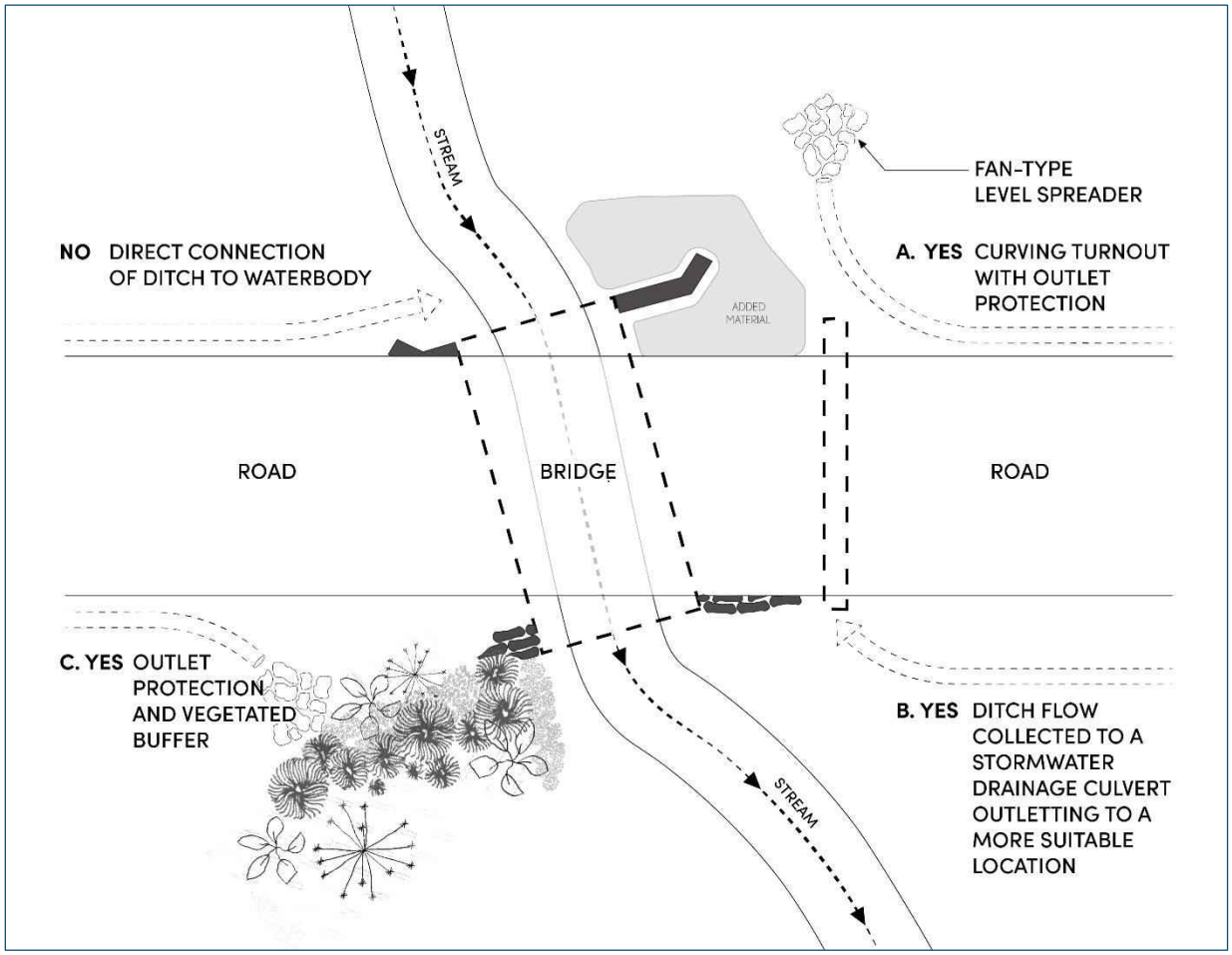


Figure 1-4. Methods for disconnecting a ditch from a waterbody.

Turnouts

Turnouts (also referred to as bleeders, diversion ditches, tail ditches, and other names) direct stormwater from a ditch into a stable vegetated area that can slow and spread runoff and allow sediment to settle out.

The appropriate spacing of turnouts is site specific and depends on contributing drainage area, topography of this drainage area, road slope, and soil infiltration rate.

Generally, turnouts should be placed at intervals frequent enough to prevent large volumes of water moving fast enough to cause erosion of the road surface/shoulder or cause unstable slopes near the road. Table 1-4 provides minimum spacing guidelines as a starting point. Site-specific conditions should also be considered.

Contributing Drainage Area

Knowing the contributing drainage area for a stretch of road or for a culvert can be extremely useful for appropriately spacing turnouts and culverts and is necessary for right-sizing round stormwater drainage culverts.

If you are in western Massachusetts, contact your Regional Planning Agency (RPA) for assistance in calculating drainage area.

Table 1-4. Minimum recommended spacing for turnouts

Road grade (percent)	Distance between turnouts (ft)
2 – 5	135 – 250
5 – 10	80 – 135
11 – 15	60 – 80
16 – 20	45 – 60

Turnouts may need outlet protection to control erosion at the outflow. See TURNOUT and TURNOUT OUTLET PROTECTION BMP FACT SHEETS.

Stormwater Drainage Culverts

When the terrain does not allow for turnouts, water from ditches can be routed from one side of the road to the other by installing a stormwater drainage culvert under the road. Drainage culverts are also used to continue the flow of ditches when driveways intersect with a road. Drainage culverts should never discharge into a waterbody and instead should outlet into stable vegetated areas that can slow and spread runoff and allow sediment to settle out.

Stormwater Drainage Culvert Spacing

Like turnouts, appropriate spacing of culverts is site specific and depends on contributing drainage area, topography of this drainage area, road slope, and soil infiltration rate. Generally, drainage culverts should be placed at intervals frequent enough to prevent large volumes of water moving fast enough to cause erosion of the road surface/shoulder or cause unstable slopes near the road. Table 1-5 provides minimum spacing guidelines as a starting point. Site-specific conditions should also be considered.

Table 1-5. Spacing recommendations for stormwater drainage culverts

Road grade (percent)	Distance between culverts (ft)
2 – 5	135 – 250
5 – 10	80 – 135
11 – 15	60 – 80
16 – 20	45 – 60

Drainage culverts may need outlet protection to control erosion at the outflow. See ROUND STORMWATER DRAINAGE CULVERT and OUTLET PROTECTION: RIPRAP APRON, OUTLET PROTECTION: PLUNGE POOL, and OUTLET PROTECTION: LEVEL SPREADER BMP FACT SHEETS.

Stormwater Drainage Culvert Right-Sizing

Sizing culverts correctly to accommodate current and anticipated future flows due to more frequent and intense storm events helps avoid washouts and clogging. FRCOG has developed a drainage culvert right-sizing methodology (see **Tool 6**) and rule-of-thumb chart (Table 1-6) to determine the appropriate size when replacing a round drainage culvert.

Table 1-6. Rule-of-thumb sizing chart for right-sized drainage culverts

Contributing Drainage Area (acres)	Culvert diameter needed (inches)
0 – 1.5	12*
1.5 – 4	18
4 – 8	24
8 – 15	32
15 – 20	36
Greater than 20	Greater than 36 is likely a stream that will need to follow MA Stream Crossing Standards[5]

**Some road manuals, such as the 2024 Vermont Better Roads Manual, recommend a minimum of 18 inches for any stormwater culvert, and a minimum of 15 inches for any driveway culvert.*

[5] See the MA Stream Crossing Standards at https://www.nae.usace.army.mil/Portals/74/docs/regulatory/StreamRiverContinuity/MA_RiverStreamCrossingStandards.pdf and the MA Division of Ecological Restoration's MA Stream Crossings Handbook at https://www.mass.gov/files/documents/2018/08/23/Stream%20Crossings%20booklet%20Web.pdf

When replacing a drainage culvert, installing proper inlet and outlet protection with headwalls and potentially aprons will help extend the life of a culvert. See the STONE HEADWALL BMP FACT SHEET.

Stormwater Drainage Structure Inspection and Maintenance

Tips for Inspection of Culverts, Ditches, and Turnouts

- Inspect as often as possible, but prioritize in fall and spring when plants are dormant and after major storms.
- Inspect prior to fall seeding deadlines (45 days before the last frost date).
- Inspect for structural failures such as clogging, collapsing, and washouts.
- Inspect for standing water, sediment, leaves, and debris.
- It is helpful to mark drainage infrastructure with a stake or keep an inventory so they do not get missed during inspections.
- Installing a depth marker in a basin designed to collect sediment can assist in assessing when it is time to clean the basin.
- If a culvert, ditch, or turnout is failing, it is important to understand the cause so the repair can be addressed appropriately.

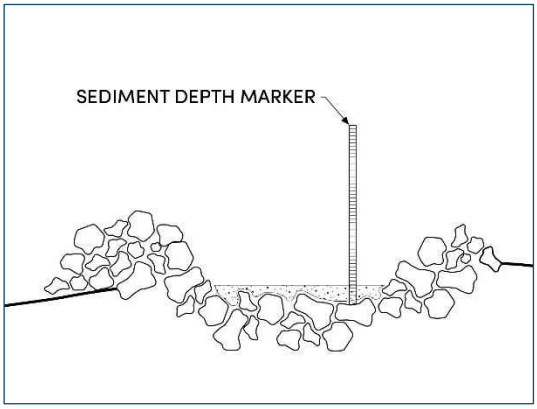


Figure 1-5. Sediment depth marker in a plunge pool or settling basin.

See **Tool 5: Stormwater BMP Fact Sheets** for inspection details of specific BMPs.

Tips for Maintenance of Culverts, Ditches, and Turnouts

- Remove anything obstructing the flow of water.
- Clear sediment, leaves, and debris by hand, with a leaf blower, or with machinery.
- Clean ditches and settling basins when the sediment is one-half the depth.
- Replace or reposition riprap or stone as needed.
- Reseed as needed to prevent erosion.
  - Use MassDOT recommended seed mix.[6]
  - Reseed with a hydroseeder, if available, to ensure fastest regrowth.
  - If seeding in the fall, seed grass at least 45 days before the first frost date.
- Replace culverts with the same size pipes if they already meet the sizing requirements.

[6] MassDOT Upland Seed Mix Guidance: https://www.mass.gov/doc/massdot-upland-native-seed-mix-guidance/download.

- Increase culvert size if properly constructed culvert repeatedly washes out, as development along the road increases, or as sizing guidelines change.

See **Appendix A** for sample Road Maintenance Checklists. Highway Departments can use these to track time and costs to maintain their unpaved roads and have records of costs and maintenance issues available in case the information is needed for regulatory compliance, annual budget requests or grant applications.

Road Stream Crossings

Stream Crossing Standards

When an unpaved road crosses a stream, a new or replacement structure must comply with the Massachusetts Stream Crossing Standards.[7] Thousands of existing culverts are undersized throughout Massachusetts, creating flood hazards and barriers to fish and wildlife passage.

The Massachusetts Stream Crossing Standards are guidelines for selecting types of crossing structures and their design. The Massachusetts Association of Conservation Commissions (MACC) also provides a webpage with multiple links that provide information about the wetlands regulation and stream crossing standards.[8]

[7] See the MA Stream Crossing Standards at https://www.nae.usace.army.mil/Portals/74/docs/regulatory/StreamRiverContinuity/MA_RiverStreamCrossingStandards.pdf and the MA Division of Ecological Restoration's MA Stream Crossings Handbook at https://www.mass.gov/files/documents/2018/08/23/Stream%20Crossings%20booklet%20Web.pdf

[8] MACC Wetland Regulations Resource Page: https://www.maccweb.org/page/Wetlands_Regulation

Tools for Designing and Installing Stream-Crossing Culverts

Municipal Guide to Following Massachusetts Stream Crossing Standards

The Franklin Regional Council of Governments (FRCOG) has developed a Municipal Guide to Following Massachusetts Stream-Crossing Standards to help municipalities navigate the process of replacing culverts that must follow stream-crossing standards, to be released in late 2025. https://frcog.org/program-services/transportation-planning/

Flow Photo Explorer

The Flow Photo Explorer is an integrated database, machine learning, and data visualization platform for monitoring streamflow and other hydrologic conditions using timelapse images. The goal of this project is to collect hydrologic data in streams, lakes, and other waterbodies where it has traditionally been hard to get. Anyone can create an account to add and annotate photos. https://www.usgs.gov/apps/ecosheds/fpe/

Maximum Extent Practicable Tool

The Massachusetts Department of Environmental Protection (MassDEP), the U.S. Geological Survey (USGS), and the University of Massachusetts are developing a "Maximum Extent Practicable" tool to help municipalities and state agencies evaluate the costs and benefits of different stream-crossing designs. Statewide buildout of the site is anticipated to continue into 2028 and the state is currently drafting technical guidance with standards for meeting "Maximum Extent Practicable" stream crossing standards.

Beaver Management

Beavers can create serious road management issues when their dams flood or wash out a road. Repeatedly clearing blocked culverts can be expensive and time consuming. If a blockage is removed from a culvert, beavers are capable of quickly re-blocking it.

It is possible to manage beaver issues by protecting road crossing culverts with simple technologies called flow devices, or water-level control devices, that can be built by Highway staff. When properly designed, flow devices have success rates over 95% and require little maintenance, making them cost-effective over the long term, environmentally friendly, and a humane alternative to beaver removal. The following are general categories of flow devices. Each of the flow devices can be used together with others. Refer to the recommended resources provided to learn more about these devices and how to design them using online

resources or by attending Baystate Roads trainings.[9] Hiring a professional to design the control device may increase the success rate.

Diversion Dam (pre-dam)

- Used where a roadbed is high enough that upstream water levels are not a concern.
- Installed upstream of the culvert inlet to direct the beaver's attention away from the culvert and stimulate the beaver to build a dam against the new structure.
- Requires strong mesh fencing supported by metal fence posts.
- Because this design takes into account the expectation that beavers will continue damming, no maintenance is needed.

Diversion dam. Photo credit: Beaver Institute

Culvert Protective Fence

- An exclusion fence with a long perimeter and trapezoidal shape emanating from the culvert.
- Requires strong mesh fencing with openings large enough to minimize debris build up, but small enough to prevent beavers from entering, supported with strong metal fence posts.
- Maintenance typically consists of removing debris along the fence three to four times a year.

Culvert protective fence. Photo credit: Beaver Solutions.

[9] Recommended online resources for learning more about beaver diversion technologies:
Mass.gov: https://www.mass.gov/info-details/prevent-conflicts-with-beavers
Beaver Solutions (MA based) : https://www.beaversolutions.com/ (MA based)
Beaver Institute: https://www.beaverinstitute.org/get-beaver-help/blocked-road-culverts-and-drains/

Fence and Pipe System

- Used where a roadbed is high enough that upstream water levels are not a concern.
- A fence is constructed around the inlet so that beavers can dam against it, but a flexible pipe that runs from a domed intake fence through the culvert protective fence continues moving water through the culvert.
- The flexible pipe outlet is placed at the outlet side to the desired level of water for the inlet side. Even though beavers can dam against the fence, the height of the pond is controlled by the pipe system.

Fence and pipe system. Photo credit: Beaver Solutions.

- Maintenance typically consists of inspecting debris along the culvert fence and removing debris as needed, at least annually.

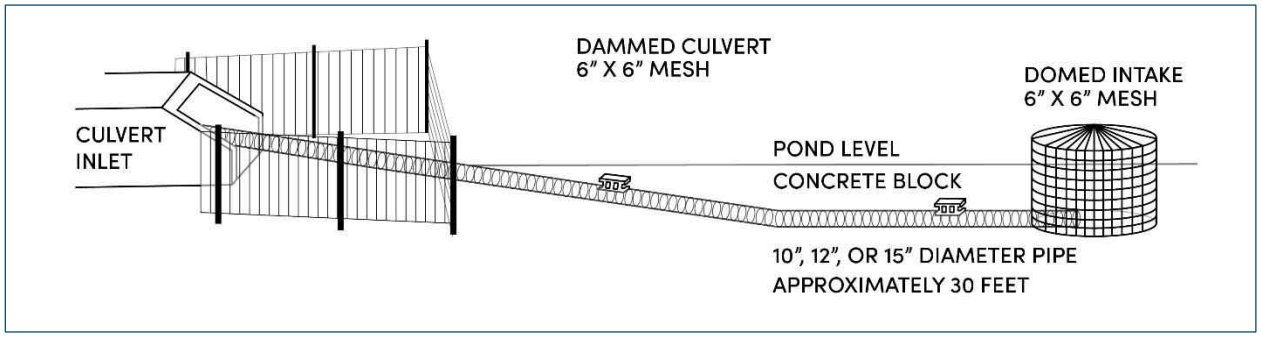


Figure 1-6. Fence and flexible pond-leveler pipe.

Excess Road Material Management

Highway Departments often have excess material from work sites or ditch, turnout, and culvert clearing that need disposal or a place to be stored for future use. Improper disposal or storage of excess material can increase the amount of sediment that enters streams and wetlands.

Tips for Disposal and Storage of Excess Road Material

- Material should never be temporarily or permanently stored or disposed of near wetlands, within 200 feet of streams, in ditches or other drainage swales, on steep slopes, or in other locations that may potentially cause water pollution.
- Vegetated buffers surrounding a disposal area will help trap sediment.
- Material that is being saved for future road construction or maintenance should be kept in a designated storage or borrow area, such as a salt/sand shed or sand pit, covered and well away from waterbodies.
- If invasive plants such as Japanese knotweed, bittersweet, common reed (phragmites), mugwort, garlic mustard, purple loosestrife, and others are dug up along roads, this soil should be disposed of properly to not spread the invasive plant to a new area. Please refer to **Tool 8: Managing Invasive Plants Along Roadsides** for detailed management instructions.

Bank Stabilization

Bank stabilization may be necessary during and after road work, or when a bank is experiencing erosion or slope failure. Stabilization generally involves planting live vegetation or placing structural materials such as stone, wood, or geotextile. A complementary technique is to "naturalize" the bank shape by leaving surface roughness, grade imperfections, and debris. These imperfections mimic the natural variation in the landscape and reduce erosion.

Table 1-7 is a matrix of bank stabilization BMPs.[10] Each site must be evaluated for the appropriate stabilization technique. With live vegetation, it is best practice to use native plants adapted to the site conditions whenever possible. Also keep in mind that vegetation needs adequate time and temperature to set root and survive the winter.

[10] More information on these bank stabilization strategies can be found in the resources Rural Roads Active Management Program (Champlain Watershed Improvement Coalition of New York, 2014) and Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads (U.S. Forest Service and Penn State University Center for Dirt and Gravel Road Studies, 2012).

Table 1-7. Bank stabilization BMPs

Bank Stabilization Technique	Examples	Appropriate Uses	The Role of Vegetation
Grading Techniques	• Cut and fill • Notching • Terracing • Counterweights • Bank bench • Interceptor swale	On slopes no greater than 2H:1V and where structural stabilization techniques are not needed	Once reestablished, it is considered permanent stabilization
Vegetative	• Sowing grass seed • Hydroseeding	On slopes where slight to moderate stabilization is needed to control water and wind erosion and minimize frost effects	To control weeds, bind and retain soil, filter runoff, and maintain infiltration
Bioengineering Techniques* (Trees and shrubs)	• Live fascine • Live stakes • Brush layering • Sprigs & plugs	On slopes where stabilization is needed to control rill and gully erosion and filter sediments	Same as Vegetative, also reinforces soil, minimizes downslope movement of soil, and improves appearance
Combination Techniques*	• Live crib wall • Vegetated gabion • Vegetated rock wall • Joint planting	Same as Bioengineering, also controls erosion on cut and fill slopes that are subject to scour and erosion	Same as listed for Vegetative, also reinforces soil, minimizes downslope movement of soil, and improves appearance
Structural*	• Rock wall • Gabion baskets • Riprap • Geotextiles, mats & blankets	On eroding slopes with seepage problems and/or slopes with non-cohesive soils	Not applicable

* May require an engineer

Adapted from: Rural Roads Active Management Program, Champlain Watershed Improvement Coalition of New York

Snow and Ice Management

Unpaved roads are generally more challenging to maintain in winter than paved roads. Certain practices and techniques can make winter snow and ice management work better for unpaved roads.

As winters have become warmer, communities are frequently experiencing heavy snowfall on unfrozen roads. Plowing under these conditions is difficult, as road surface material can easily be scraped up by the plow blade and left in the snow piles along the road shoulder. If plowing on unfrozen roads cannot be avoided, plows adapted to soft road conditions should be used.

Winter Preparation Strategies

- In the summer, mow back vegetation to provide more sunlight on the road to promote melting during the colder months.
- Clear dead wood from the shoulder and maintain ditches and culverts to promote good drainage in winter and spring.
- Pre-season review of problem areas such as obstacles or road sections with no shoulders can help avoid costly errors that damage the road or equipment when everything is covered with snow.
- A well-compacted road will make a difference in how easy a road is to plow.

Snow and Ice Plowing Strategies

- Ideally, it is best to wait until unpaved roads are frozen before they are plowed (plow techniques for *unfrozen* roads are provided in the next subsection).
- If snow or ice is allowed to build up on the road, not only can that be a safety hazard, but it also insulates the road and may not allow it to freeze.
- Do not plow down the middle of the road since this will compromise the crown.
- Plow more slowly on unpaved roads than paved roads. This can reduce the amount of gravel picked up and tossed into drainage ditches.
- Angle the blade the same as a paved road. Optionally, angle the plow back or in a way that does not throw the snow too much to the side, which would make material difficult to retrieve and re-grade into the road at the end of the season.
- Plow to the road edge, and if there is a large amount of snow, bench plow at the road edges (plow a foot or so above the ground) after the storm subsides to reduce snow creep into the travel lane, to keep sight lines open, and to make room for more snow coming later.
- In ice conditions, a blade with serrated teeth can cut ice and roughen the road surface for better traction.

Snow and Ice Traction Strategies

- Salt and brine should *not* be used on unpaved roads because they will melt the road surface and make it more difficult to plow without disturbing the road material.
- Abrasives or sand can be applied to provide road traction, but excessive sanding should be avoided because it can create a loose surface that does not have traction and can clog culverts.
- 3/8-inch traprock or 1/2-inch minus crushed sand/rock can be more easily worked back into the road surface at the end of the season.
- Some northern states and Scandinavian countries recommend pre-wetting abrasives (sometimes with a small amount [<5%] of brine) to maintain workability.

Plowing Adaptations for Unfrozen Roads

- C-edge or "mud plow" that is a standard plow with a plow blade or cutting edge that is folded back.
- A rubber blade, or something commercially available, such as the WinterFLEX® blade, can also work well on unpaved roads if the road is frozen.
- If neither plow types are available, use lighter equipment or equipment that has good control of plow height. Graders or trucks with underbody plows can be used during this part of the season because they weigh less and cause less damage to the road.
- Grader rakes should be avoided as they bounce on the road and can create washboarding.

Reducing Impacts of Snow and Ice Management to Nearby Streams

When the snow melts, loose and erodible piles of leftover road material can be easily washed into ditches and culverts or directly into nearby waterbodies. Where possible, plow snow to areas where melting snow will flow into a stable vegetated area and remove major road material piles left behind after the snow has melted.

Road material from a plow pile collapsing into an adjacent brook.

Dust Control

When the fines in a road surface material become excessively dried out, they easily become dust. Road dust is a nuisance to drivers and homeowners and is also a form of erosion, hastening the deterioration of the road surface. Up to three inches of fines leave the road each year. As fines leave the road, the gravel loosens, causing poor traction and washboarding.

Dust control products can have negative impacts on the environment, especially if more is applied than can be absorbed by the road. However, dust is bad for both the road and the environment and must be managed.

Materials

The two most commonly used dust control products are the water-absorbing calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$). Both products are hygroscopic materials, meaning they attract and retain moisture. They should be used in liquid rather than flake form for more uniform and cost-effective application. The two products should never be mixed. De-sugared beet juice is another hygroscopic product sometimes combined with one of the chloride products. It reduces the amount of salt needed and can be more cost-effective.

Other forms of dust control products are adhesives and binders that physically glue particles together. The most commonly used binder in the region is lignin sulfonate (LS), a liquid by-product of the paper industry that is biodegradable and considered less harmful to the environment. This product is most successful when combined with one of the chloride products. On its own, it does not protect against potholes and washboards and is generally less effective at preventing the formation of dust.

Application

- Application of dust control during the grading process (before compaction) can lead to better outcomes for both grading and dust management.
- Application of calcium and magnesium chloride works best when the road surface is somewhat moist, or it gets rained on.
- Application should follow the supplier's recommended application rate.
- Application of too much product can cause the road surface to be slick, greasy, and corrosive. If the product is running off the road, too much is being applied.
- Use of dust control products must be limited or not used at all in areas near drinking water wells, wetlands, and stream crossings.
- If the dust control application is not lasting for a full season, Highway staff can request that it be tested to confirm the percentage of the mix.
- Places to prioritize dust control application include higher-traffic roads, hills, and corners.

When to Pave

The decision to pave can be a very difficult one for a Highway Department who must consider construction and maintenance costs, safety, and costs to the road user.[11] Residents along unpaved roads often have an emotional tie to the road remaining unpaved because of the slower traffic, the better walkability, the impact on neighborhood character, aesthetics, and the feeling of it being the community's road.

Benefits of Paving

- Seals the surface from precipitation and erosion.
- Protects subbase material.
- Eliminates dust problems.
- Provides a safer surface with higher skid resistance.
- Provides a smoother surface that increases user satisfaction and reduces vehicle maintenance costs.
- Accommodates larger vehicles that do not operate well on unsurfaced roads.

Benefits of Unpaved Roads

- Lower construction and maintenance costs if they are low-volume roads.
- Slower, safer vehicle driving speeds.
- Easier to repair in the case of damage from excess vehicle weight.
- Small municipal Highway Departments are typically capable of making repairs.

Conducting a cost-benefit analysis of construction and maintenance of each road type can help a Town decide when to pave a gravel road. This decision should also factor in traffic volumes, traffic weight, safety factors and the quality of road subbase and drainage.

[11] Useful resources on when to pave include *When to Pave a Gravel Road* by the New Hampshire Technology Transfer Center, the *Economics of Upgrading an Aggregate Road* by the Minnesota Local Technical Assistance Center, and materials created by the South Dakota Local Transportation Assistance Program.

Traffic Volumes

Current and future anticipated traffic volumes influence the cost-benefit analysis of when to pave. A Minnesota study[12] found that road maintenance costs *are higher on high-volume unpaved roads* compared to low- and high-volume paved roads. Generally, major wear and tear on an unpaved road, and the costs associated with maintenance and repairs, becomes problematic when the average daily traffic (ADT) reaches 500 vehicles per day. However, the Minnesota study found that the *cost-per-mile to maintain unpaved roads appeared to increase considerably after the ADT reached 200 vehicles per day*. A South Dakota report found this threshold to be 150 vehicles per day.[13]

Traffic Counts

Regional planning agencies (RPAs) can conduct traffic counts at a municipality's request to determine vehicle volumes.

Western Massachusetts traffic counting programs:

BRPC: https://berkshireplanning.org/program/transportation-planning/

FRCOG: https://frcog.org/project/traffic-counting-program/

PVPC: https://www.pvpc.org/projects/traffic-counting-system

Traffic Weight

Traffic volumes alone are merely guides. Types of traffic, such as trucks and the weight of those trucks, should also be considered. A road should not be paved unless a sufficient load-bearing pavement can be laid if heavy loads are anticipated.

Safety

Paved roads allow for higher speeds of travel, so the road must be designed to provide safe travel for the expected volume at the design speed. Eighteen feet is considered the minimum acceptable width for a paved road, with 1-foot shoulders on each side, totaling 20 feet.

Road Subbase and Drainage

It is imperative that the road subbase is well constructed and drained before paving. Construction and drainage issues are very difficult to fix after paving, and if the foundation fails,

[12] Minnesota Department of Transportation. *Economics of Upgrading an Aggregate Road,* 2005: https://www.lrrb.org/pdf/200509.pdf

[13] South Dakota Department of Transportation and Applied Pavement. *Local Road Surfacing Criteria*, 2004: https://rosap.ntl.bts.gov/view/dot/82461

the pavement will fail. Therefore, Highway staff must consider whether it is possible to properly construct and adequately drain the subbase before paving.

Cost-Benefit Analysis of Paving

Municipalities can estimate their maintenance costs per mile for paved and unpaved roads by taking the following steps.

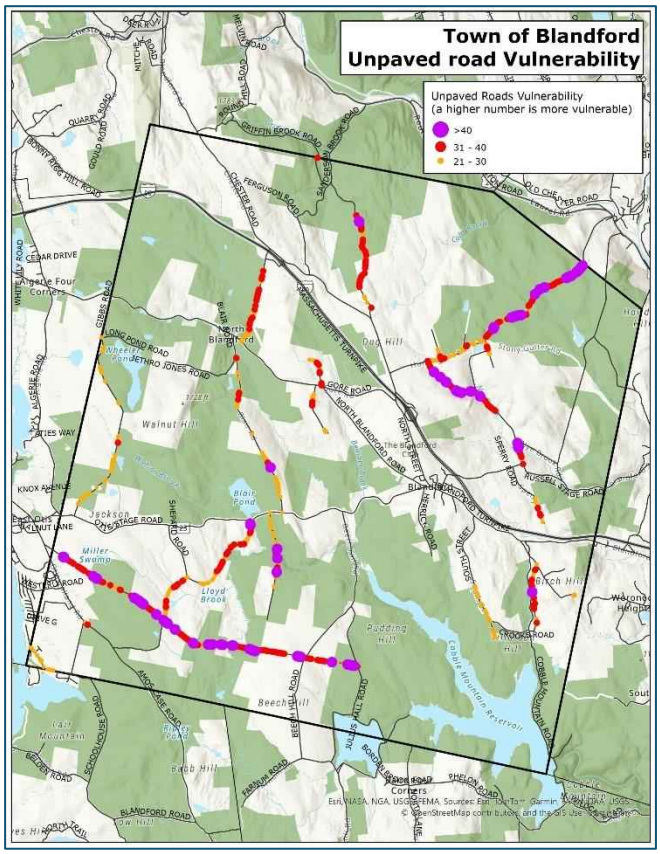
1. Calculate historical costs per mile of maintaining your unpaved roads over a chosen number of years and calculate the average cost per year. These costs should try to capture the wear and tear from current traffic volumes and damage from intense rain events.
2. Multiply this annual cost of maintaining an unpaved road over the intended lifetime of the paved road to be built.
3. Calculate historical costs per mile of maintaining your paved roads over the same number of years chosen for unpaved roads and calculate the average cost per year.
4. Multiply this annual cost of maintaining a paved road over the intended lifetime of the paved road to be built.
5. Calculate total estimated costs for the proposed paved road upgrade per mile. The proposed upgrade costs should include all preparation, such as removing trees or rock, improving drainage, straightening dangerous curves, improving slopes and elevation, constructing new guardrails, upgrading signs, and other preparations. It should also consider costs to properly build the subbase.
6. Add the totals from steps 4 (maintenance) and 5 (construction) together to understand the total cost of the new paved road over its lifetime.
7. Compare the total maintenance and construction costs for a paved road from step 6 to the total maintenance costs of an unpaved road from Steps 1 and 2.
8. Make a decision!

The cost of maintaining an unpaved road that is poorly constructed or maintained will likely increase year after year. A third scenario can be considered, in which the unpaved road is properly rebuilt or more investment is made in annual maintenance.

Tool 2: GIS Screening for Vulnerable Unpaved Roads

Introduction

The first step in making major improvements to recurrent issues with unpaved roads is identifying roads that may be particularly prone to problems, such as steep roads or locations near waterbodies. This step allows a town to flag particular road segments for follow up field observations described in **Tool 3**. FRCOG and BRPC used a geographic information system (GIS) to remotely identify unpaved roads that may be particularly vulnerable to road damage from extreme weather events. The GIS methods developed by the FRCOG for this tool are described in detail in **Appendix B** and are replicable across Massachusetts.



GIS screening for unpaved roads in Blandford, MA.

Method

The GIS screening identifies unpaved roads and gives scores based on surrounding slope, road grade, locations within a flood plain, proximity to a stream, stream crossings, and proximity to perennial streams, wetlands, and lakes. The tool was developed and revised based on field observations of unpaved roads and road material reaching waterbodies. In FRCOG's experience, steep road grade, a steep slope between the road and a waterbody, and close proximity to waterbodies can lead to the toughest problems to solve. All stream crossings are also areas where road material often reaches the stream.[14]

[14] Our observations corroborate with a Lake Champlain Basin Program study which found that suspended sediment concentrations in streams near dirt roads tended to be positively related to road gradient. See Lake Champlain Basin Program, Technical Report No. 74: Assessing the Effects of Unpaved Roads on Lake Champlain Water Quality, 2013

How to Use the GIS Screening Tool Maps for Field Assessment

The intention of the GIS screening is to identify "hot spot" areas on maps. It is recommended that Town or regional staff ground-truth the GIS screening analysis by investigating the high-risk sections of road and documenting issues using **Tool 3: Unpaved Road Criticality Checklist and Field Assessment** described in the next section.

Maps

A desktop GIS analysis has been completed for all of Berkshire, Franklin, Hamden, and Hampshire Counties in Massachusetts. **Please contact GIS staff at your Regional Planning Agency for access to this GIS mapping analysis.**

Tool 3: Unpaved Road Criticality Checklist and Field Assessment

Introduction

Tool 2: GIS Screening for Vulnerable Unpaved Roads identifies the roads most likely to be "high risk" or "some risk." As a next step, the **Unpaved Road Criticality Checklist** can be used to further prioritize roads for assessment and improvement.

The **Unpaved Road Field Assessment** can be used to document the conditions of roads and to generate ideas for best management practices (BMPs) to install or maintenance practices to improve upon.

Method

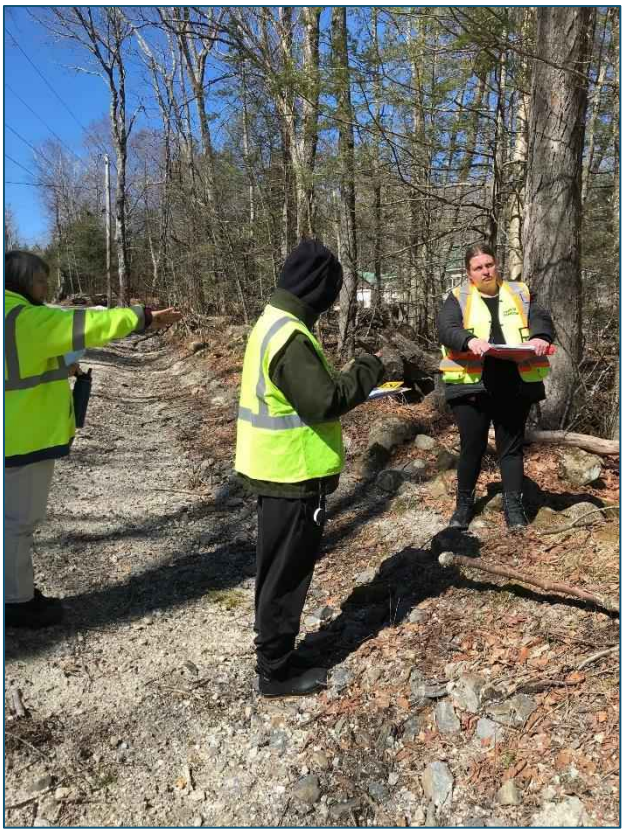
Criticality Checklist

The Criticality Checklist takes into account the relative importance of a particular road for business, municipal, and residential use. If an unpaved road repeatedly requires costly maintenance, is on a school bus route, or serves as an important alternative route, these things can be considered.[15]

Field Assessment

Two field assessment forms were developed to help the user document general road characteristics, any unpaved road issues, their causes, and their impact on any nearby waterbodies.

1. The Unpaved Road Field Assessment Form (available in this tool) is designed to assess the presence of all



After identifying high-vulnerability road segments using the GIS screening tool, use the criticality check list and field assessment form to evaluate high-scoring road segments.

[15] The Criticality Checklist was modified based on a scoring system developed for an MVP grant project for the towns of Sandisfield, Sheffield, and New Marlborough and completed by contractors BSC Group.

road characteristics that lead to unpaved road problems and identify weather-related issues on an unpaved road. This short assessment form was developed and tested during field visits on many unpaved roads in Franklin, Hampshire, Hampden, and Berkshire Counties.

2. FRCOG's Field Assessment Form for Impacts to Waterbodies (available in **Appendix C**) is for users who are interested in a more detailed form specifically geared to road impacts to waterbodies, and particularly coldwater streams. It was developed as part of a Nonpoint Source (319) grant in September 2024.

How to Use the Criticality Checklist and Field Assessment Forms

Criticality Checklist

The Criticality Checklist can be used by anyone from the Town or public who understands how municipal roads are related to community function. The checklist looks at the road's maintenance burden, its role in access and circulation, its importance for emergency access or evacuation, the population living along the road, and its impact on the local economy. The checklist is designed to be a comparison tool between top-scoring vulnerable roads to help further prioritize the Town's efforts in assessing and improving these roads. The checklist also helps provide an understanding of the level of importance of certain roads for emergency access and community function. Highway staff likely have first-hand knowledge of road areas that frequently receive complaints or are problem areas for one reason or another that they can also consider with this process.

Field Assessment

The field assessment forms are designed to be completed on foot, to allow the observer to track and document sources of erosion that are causing specific road deterioration problems and other issues. The forms are intended to be understandable to anyone from the Town or public and are designed to be applicable to unpaved roads with similar topography and development patterns as western Massachusetts. A set of directions and term sheet comes with each field form. Field assessment can be conducted without doing the GIS vulnerability screening (**Tool 2**) step first. The forms can also be used to generate ideas for fixing problems. The forms ask the user to identify if the road has any road type characteristics that are commonly associated with erosion and water quality issues. The user can then browse **Tool 4: Best Management Practices (BMP) Selection** for a more detailed description of commonly associated problems, and management solutions and BMPs that best address the specific issues linked with the seven typical road types. The Unpaved Road Field Assessment Form provides the full list of BMPs described in the toolkit for discussion and preliminary selection in the field.

Unpaved Road Criticality Checklist

Category	Question -> Mark if answer is yes in each box	Road Name	Road Name	Road Name	Road Name	Road Name	Road Name
Maintenance Burden	Road is a source of recurring repair or maintenance due to weather-related impacts						
Community Access	Road is on a bus route or there is a school located on the unpaved road						
	Road has town hall, fire department, or highway garage located on it						
	Road is critical access to grocery store, pharmacy, gas station, hardware store, etc.						
Impact on Public Health and Safety	Road is an emergency evacuation route or a crucial backup route						
	Road is residence or emergency access to a low-income population						
	Road is residence or emergency access to elderly, disabled, or medically dependent person or people						
	Road is located in a public water supply area						
Number of Residences along Road	Road serves several/many residential properties						
Impact on Local Economy	Road serves or is the address of one or more local businesses or farms						

Notes/Summaries:

Directions for Unpaved Road Field Assessment Form

Purpose of the unpaved roads field assessment form

Losing road material can impact road safety and the environment. Repairing roads add expenses for the Town.

This form is designed to:

1. Help the user see and understand how water is draining from the road and how erosion, subbase saturation, and dust are leading to road deterioration.
2. Provide a resource in the field for identifying which unpaved road BMPs might be applicable.
3. Provide documentation of road issues and priority projects, which can be used to prioritize projects for scheduling and construction and provide information for grant applications.

What should you know prior to using this assessment form?

This field assessment form is part of **Tool 3** in the *Unpaved Roads Stormwater Management Toolkit.* The assessment is designed to be conducted once you have used **Tool 2: GIS Screening for Vulnerable Unpaved Roads** to identify unpaved road segments in your town that are vulnerable to damage from extreme weather events, are challenging to maintain and/or have the potential to impact water quality through stormwater and sediment-laden runoff. Contact your Regional Planning Agency if you are located in western Massachusetts and need a copy of your GIS screening.

The next step is to use the Criticality Checklist in **Tool 3** to identify which vulnerable roads are also critical local roads from an emergency response and community perspective. Once you have a list of priority roads to investigate, use this form to conduct site visits. These directions and the accompanying term sheet should be reviewed prior to filling out the form.

The Unpaved Road Field Assessment Form is a stand-alone form and may be used on its own, without using **Tool 2** and the Criticality Checklist.

How should you use this assessment form?

Visit the top scoring sites in your town and walk along the road to see what is going on. **This assessment cannot be done solely from a vehicle—it is essential to walk along the road to see and document all the issues.**

When should you do the assessment?

The best time to go out is just after snowmelt in the spring or other times when conditions

are wet, such as during or after a rainstorm. Observing conditions in early spring or late fall when vegetation is dormant makes it easier to see road material that has left the road.

How much of an area should you look at and assess?

Start at a low point where the road crosses or comes nearest a waterbody, if applicable. Assess the section of road where water will drain to that low point. This will be your "site." **Fill out a separate field assessment sheet for each site**. For roads that run alongside a stream/waterbody, use your best judgement to identify one or several sites. **Evaluate the entire length of the road that scored high in the GIS screening** and Criticality Checklist.

What should your site drawing include?

Include the road and any waterbodies. Use arrows to show which way the runoff flows. For smaller sites, include the location of ditches, culverts, turnouts, and where problems occur. If you have ideas for where improvements are needed, it is recommended to mark the locations of those BMPs in a different color or with small labels such as (A) or (1).

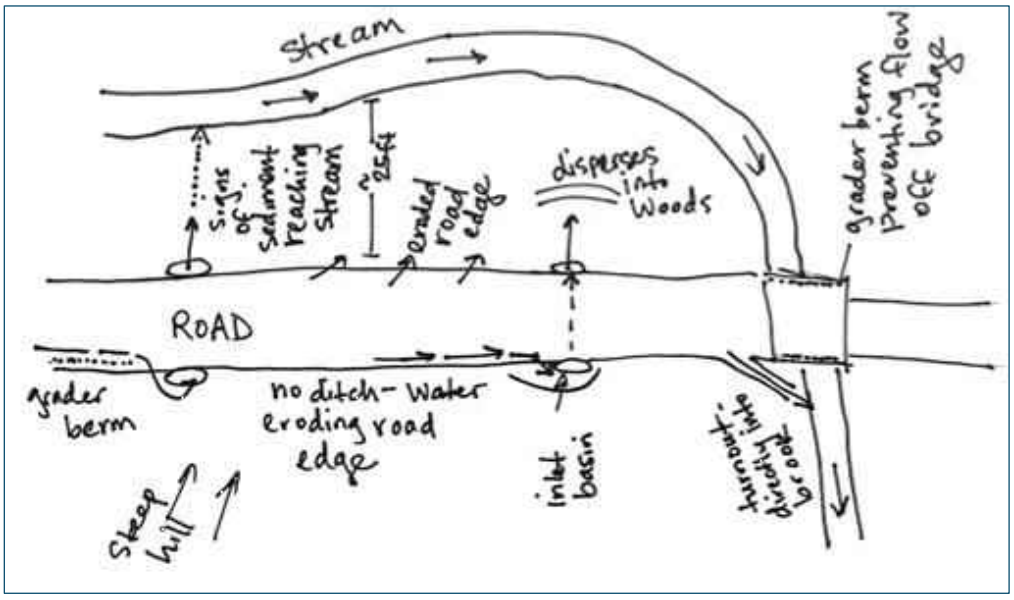


Figure 3-1. Example Site Drawing of Existing Conditions.

How do you use this form to select BMPs?

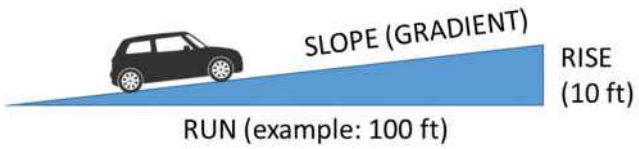
After observing the road site closely, the BMP selection tables present a list of road problems that are characteristic of each road type. BMPs that can be helpful for that road problem can be circled as a preliminary selection in the field before the user learns more about the BMPs in **Tool 4: Best Management Practices (BMP) Selection** and **Tool 5: Stormwater BMP Fact Sheets and Design Typicals**.

UNPAVED ROAD FIELD ASSESSMENT FORM TERM SHEET

Road grade: The steeper the grade of the road, the more likely stormwater runoff will cause erosion issues. Road grade, or slope, is usually calculated as a percentage.

Slope(%) = Rise/Run x 100

Example: 10/100 x 100 = 10% slope



Gentle grade: <5% slope
Moderate grade: 5-8% slope
Steep grade: >8% slope

Shoulder: The part of the road surface that is outside the travel lane but not part of the ditch (red arrows).

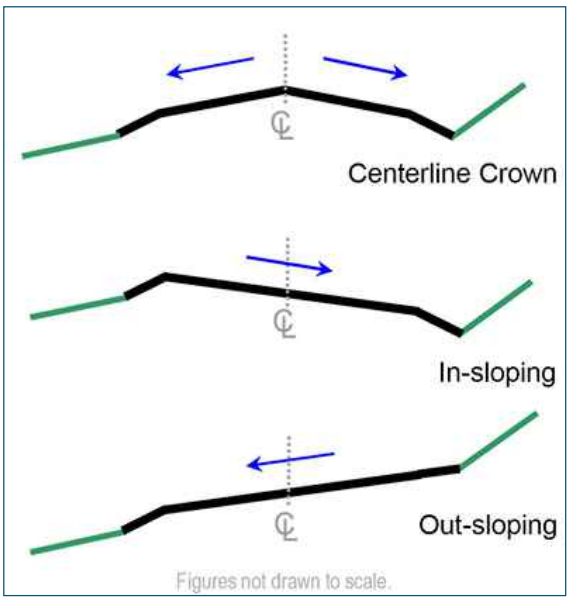
Downslope bank: Bank that is downhill of the road surface (yellow arrow).

Upslope bank: Bank that is uphill of the road surface (blue arrow).

Crown: Properly crowned roads shed water efficiently off both sides of the road. Proper crowning is 1/2 inch per foot of road width, with an A-shaped top, not a domed top.

Crown slope is calculated by measuring the difference in elevation between one point near the centerline and the another point 12" away from the centerline.

Crown slope (%) = Drop in elevation (inches) / 12 inches



Ditch: An open channel that conveys water from storm runoff to an adequate outlet without causing erosion or sedimentation.

Culvert: A closed conduit used to convey water from one area to another, usually from one side of a road to the other side.

Grader berm: A row of road material on the side of a road, created by a road grader or snow plow.

Turnout: Extension of a ditch that directs water off the road to filtering areas. They should not drain directly into a stream.

Rill: Moderate erosion between 1 and 12 inches deep.

Entrenched Road: Road surface is lower than surrounding land. There is nowhere for water to drain.

False ditch: Ditch forming on its own from run-off, leading to road material loss. If a grader berm is preventing water from getting into a ditch, this can be called a secondary ditch.

Gully: Severe erosion more than 12 inches deep.

UNPAVED ROAD FIELD ASSESSMENT FORM

[Please see Directions and Term Sheet that accompany this form]

Town: _____ Date: _____

Road Name: _____ Segment ID: _____

Name of Evaluator(s): _____ Length of Site: _____

Site Beginning: _____ Site Ending: _____

WATER FLOW and DRAINAGE

In order to answer the following questions, you will need to walk the site and closely examine how water moves on and off the road. Be sure to look at the road surface, the road shoulders, ditches, stormwater culverts, and stream crossings. Take note of areas where you see road materials off the road.

Road Grade (at maximum): _____ **Crown slope (at maximum): _____**

1. If **road material is washing off the road**, is there a clear area that the road material is coming from? *Check all that apply.*
   - ☐ Road surface
   - ☐ Shoulder
   - ☐ Ditch
   - ☐ Turnout
   - ☐ Culvert or bridge
   - ☐ Road material piled up from plowing or cleaning ditches

2. If the **road, shoulder, or ditch are eroding**, what is the cause of the erosion? *Check all that apply.*
   - ☐ Road not adequately crowned (appx. 1/2 inch per foot or 4%)
   - ☐ Poor road construction
   - ☐ Grader berms, mounded shoulders, or entrenched road (circle one) keeping water on the road
   - ☐ Water breaking through grader berm in unplanned places
   - ☐ No constructed ditch
     Is there room for a ditch? Y / N
   - ☐ Long stretch of road without culverts or turnouts
   - ☐ Excess water from an upslope bank
     - ☐ Excess water from a steep private driveway or road intersection
     - ☐ Missing or damaged driveway culvert

Document road surface issues:

- ☐ Washboarding
- ☐ Rutting (linear wheel depressions)
- ☐ Potholes
- ☐ Excessive dust
- ☐ Drivability issues during mud season
- ☐ Rilling
- ☐ Gullying

Document additional concerns:

- ☐ Beaver activity clogging drainage
- ☐ Invasive plants along roadside

3. If the area around a **bridge or culvert is eroding**, what is the cause of the erosion? *Check all that apply.*

   ☐ Bridge/culvert and/or support structure damaged or in poor condition
   ☐ Bridge/culvert undersized
   ☐ Bridge/culvert installed at improper angle or height
   ☐ Runoff directed at or concentrating around sides of culvert/bridge
   ☐ High velocity at culvert inlet

4. If the **road has a wet subbase**, where is the water coming from?

   ☐ Wetland ☐ Seeps ☐ Unknown

5. Is there a ditch large enough to handle water flow without erosion occurring? Y / N
6. Are there enough culverts to handle water flow without erosion occurring? Y / N
7. Are there enough turnouts to handle water flow without erosion occurring? Y / N

Additional notes:

Draw or take notes on the existing conditions of the road, problems, and needed improvements.

Select all **Road Types** and **Road Problems** that apply to your road segment (check box). Then *circle* **Stormwater BMPs** and **Maintenance BMPs** that you think might be appropriate for this road segment. **Tool 4: Best Management Practices (BMP) Selection** includes more detailed information about each road type and the common problems associated with the road type, along with the same tables in the Unpaved Road Field Assessment Form. Reviewing this information before or after conducting the field assessment could be helpful in selecting the right BMPs for your particular site.

Road Type	Road Problem	Stormwater BMP	Maintenance BMP
☐ **Steep Grade**	☐ Erosion of road surface	Centerline crown	Proper road structure
		Cross-slope crown	Grading
		Grade break*	Removal of grader berms
		Turnout*	Compaction of road after grading
			Sufficient turnouts
	☐ Erosion of shoulder	Stone-lined ditch*	Constructed ditches
			Excess road material management
	☐ Erosion of constructed ditch	Stone-lined ditch*	Sufficient turnouts
		Stone check dam*	Sufficient stormwater drainage culverts
		Ditch settling pool*	Ditch, turnout and culvert inspection and maintenance
		Turnout*	
		Outlet protection for turnout*	
		Round stormwater drainage culvert	
	☐ Erosion around stormwater drainage culvert	Stone headwall*	Sufficient turnouts
		Inlet protection*	Sufficient stormwater drainage culverts
		Outlet protection for culvert*	Right-sized round stormwater drainage culverts
			Ditch, turnout and culvert inspection and maintenance
	☐ Erosion around stream-crossing culvert/bridge	Stone headwall*	Follow *MA Stream-Crossing Standards*

Road Type	Road problem	Stormwater BMP	Maintenance BMP
☐ **Steep Bank Slope**	☐ Erosion of upslope bank	Log check dam	Excess road material management
		Bank bench and interceptor ditch*	
	☐ Erosion of road surface	Centerline crown	Grading
		Cross-slope crown	Removal of grader berms
	☐ Erosion of shoulder	Underdrain*	Sufficient turnouts
		Armored shoulder*	Excess road material management
		Vegetated ditch*	
	☐ Erosion of constructed ditch	Round stormwater drainage culvert	Sufficient stormwater drainage culverts
			Right-sizing round stormwater drainage culverts
			Ditch, turnout and culvert inspection and maintenance
	☐ Erosion around stormwater drainage culvert	Round stormwater drainage culvert	Sufficient turnouts
		Stone headwall*	Sufficient stormwater drainage culverts
		Inlet protection*	Right-sizing round stormwater drainage culverts
		Outlet protection for culvert*	Ditch, turnout and culvert inspection and maintenance
	☐ Erosion around stream-crossing culvert/bridge	Armored shoulder*	Follow *MA Stream-Crossing Standards*
		Turnout*	
	☐ Erosion of downslope bank	Turnout*	Excess road material management
		Outlet protection for turnout*	
		Vegetated buffer zone	
		Log check dam	
	☐ Runoff carrying sediment directly from shoulder into waterbody	Cross-slope crown	Proper snow and ice management
		Armored shoulder*	Excess road material management
		Vegetated ditch*	
		Turnout*	
		Outlet protection for turnout*	

Road Type	Road problem	Stormwater BMP	Maintenance BMP
☐ **Stream Crossing**	☐ Erosion around stream-crossing culvert/bridge	Stone headwall*	Follow *MA Stream-Crossing Standards*
			Excess road material management
	☐ Sediment on stream-crossing culvert or bridge falling directly into waterbody	Armored shoulder*	Addition of grader berm
		Turnout*	
	☐ Runoff carrying sediment directly from ditch/turnout into waterbody	Centerline crown	Ditches disconnected from waterbodies
		Cross-slope crown	Sufficient turnouts
		Vegetated ditch*	Sufficient stormwater drainage culverts
		Ditch settling pool*	Ditch, turnout, and culvert inspection and maintenance
		Turnout*	
		Outlet protection for turnout*	
		Round stormwater drainage culvert	
		Vegetated buffer zone	

Road Type	Road problem	Stormwater BMP	Maintenance BMP
☐ **Adjacent to Stream**	☐ Road stability problems due to excess moisture	Geogrid*	Proper road structure
	☐ Erosion of road surface	Centerline crown	Proper road structure
		Cross-slope crown	Grading
			Removal of grader berm
			Compaction of road after grading
	☐ Erosion of shoulder	Underdrain*	Sufficient turnouts
		Vegetated ditch*	Excess road material management
		Turnout*	
		Outlet protection for turnout*	
		Round stormwater drainage culvert	
	☐ Erosion around stormwater drainage culvert	Stone headwall*	Sufficient turnouts
		Outlet protection for culvert*	Sufficient stormwater drainage culverts
			Right-sized round stormwater drainage culverts
			Ditch, turnout, and culvert inspection and maintenance
	☐ Runoff carrying sediment directly from road shoulder into waterbody	Vegetated buffer zone	Excess road material management
		Cross-slope crown (in-slope)	Proper snow and ice management
		Log check dam	Constructed ditches
	☐ Runoff carrying sediment directly from ditch/turnout into waterbody	Turnout*	Sufficient turnouts
		Outlet protection for turnout*	Ditches disconnected from waterbodies
			Ditch, turnout, and culvert inspection and maintenance
	☐ Runoff carrying sediment from drainage culvert into waterbody (directly or indirectly)	Vegetated ditch*	Sufficient turnouts Ditch, turnout, and culvert inspection and maintenance
		Ditch settling pool*	
		Inlet protection*	
		Outlet protection for culvert*	
		Vegetated buffer zone	

Road Type	Road Problem	Stormwater BMP	Maintenance BMP
☐ **Adjacent to Wetland**	☐ Road stability problems due to excess moisture	Raise the road profile	Proper road structure
		French mattress*	
		Geogrid*	
		Underdrain*	
	☐ Erosion of road surface	Centerline crown	Proper road structure
		Cross-slope crown	Grading
		Raise the road profile	
	☐ Erosion of road shoulder	Underdrain*	Sufficient turnouts
		Vegetated ditch*	Ditch, turnout, and culvert inspection and maintenance
		Turnout*	Excess road material management
		Outlet protection for turnout*	
		Round stormwater drainage culvert	
	☐ Erosion around stormwater drainage culvert	Stone headwall*	Sufficient turnouts
		Outlet protection for culvert*	Sufficient stormwater drainage culverts
			Right-sized round stormwater drainage culverts
	☐ Runoff carrying sediment directly from road shoulder into waterbody	Turnout*	Addition of grader berms
		Outlet protection for turnout*	Constructed ditches
		Vegetated buffer zone	Ditches disconnected from waterbodies
		Log check dam	Proper snow and ice management
			Excess road material management
	☐ Runoff carrying sediment directly from ditch/turnout into waterbody	Vegetated ditch	Disconnect ditches from waterbodies
		Round stormwater drainage culvert	Ditch, turnout, and culvert inspection and maintenance
		Log check dam	

Road Type	Road Problem	Stormwater BMP	Maintenance BMP
☐ **Steep Private Driveway**	☐ Erosion of road surface (for Town Highway staff)	Centerline crown	Proper road structure
		Cross-slope crown	Grading
		Grade break*	Removal of grader berms
			Compaction of road after grading
	☐ Erosion of constructed ditch (for Town Highway staff)	Vegetated ditch*	Sufficient turnouts
		Stone-lined ditch*	Sufficient stormwater drainage culverts
		Stone check dam*	Ditch, turnout, and culvert inspection and maintenance
		Ditch settling pool*	
		Turnout*	
		Round stormwater drainage culvert	
	☐ Erosion of private driveway intersection (for driveway owner)	Centerline crown	Grading (no crown near intersection with public road)
		Cross-slope crown	Removal of grader berms
		Turnout*	Compaction of road after grading
		Stone headwall*	Sufficient turnouts
		Broad-based dip*	Sufficient stormwater drainage culverts
		Water bar	Right-sized round stormwater drainage culverts
		Driveway intersection culvert*	

Road Type	Road Problem	Stormwater BMP	Maintenance BMP
☐ **Entrenched**	☐ Road stability problems due to excess moisture	Raise the road profile	Proper road structure
		French mattress*	
		Geogrid*	
		Underdrain*	
	☐ Erosion of road surface	Centerline crown	Proper road structure
		Cross-slope crown	Right-sized round stormwater drainage culverts
		Raise the road profile	
		Vegetated ditch*	
		Stone headwall*	
		Through-the-bank pipe	

Tool 4: Best Management Practices (BMP) Selection

Introduction

This BMP selection tool is designed to help municipal Highway staff easily identify BMPs that will manage stormwater, reduce erosion and the loss of road material, and maintain drivability over a range of weather conditions.

Certain characteristics of unpaved roads are more likely to lead to drainage problems and water quality impacts and mud season problems. This tool identifies the following seven road types known to increase the risk that an unpaved road will erode or degrade in some way:

- Steep Grade
- Steep Bank Slope
- Stream Crossing
- Adjacent to Stream
- Adjacent to Wetland
- Steep Private Driveway
- Entrenched

The *BMP Selection by Road Type and Problem* section below describes each road type, the typical problems and management solutions associated with it, and provides a table of recommended BMPs suitable for addressing those problems. This guidance is designed to be transferable to other areas of Massachusetts with similar topography and development patterns.

Refer to **Tool 5: Stormwater BMP Fact Sheets and Design Typicals** for additional information about these BMPs. The design typicals provided for 15 BMPs can help Highway staff with BMP installation.

Method

The guidance and BMPs that form this tool were developed from review of the documents listed as *Recommended Road Manuals* (page 10), many hours of field observation, and conversations with Highway staff in Berkshire, Franklin, Hampshire, and Hampden Counties, Windham County in Vermont, and Massachusetts Department of Transportation (MassDOT) staff. Ten of the BMPs and their guidelines for use were developed in partnership with the environmental engineering firm GZA GeoEnvironmental, Inc. Five of the BMPs and their guidelines, as well as updates to the previous 10 BMPs, were developed in partnership with the engineering firm BSC Group.

Every road type identified in this toolkit has a set of typical road problems that can be addressed by one or more stormwater or maintenance BMPs. The *BMP Selection by Road Type and Problem* section organizes these problems concisely by their road types and aligns them with potential BMPs.

How to Use the BMP Selection Tool for Identifying and Implementing BMPs

This BMP selection tool can be used to identify solutions to unpaved road problems by using the following recommended steps:

Step 1: Review the completed road type tables in the Unpaved Road Field Assessment Form **(Tool 3)** for each priority road segment. Note the *road problems* checked off for each priority road segment and the suggested stormwater and maintenance BMPs.

Step 2: Refer to the fact sheets in **Tool 5: Stormwater BMP Fact Sheets and Design Typicals** to learn about the recommended BMPs and whether they are feasible for your road. Refer also to **Tool 1: Essential Road Maintenance Practices** for descriptions of the maintenance BMPs that make for good unpaved roads.

Step 3: Consider if several stormwater BMPs can be used in a treatment train to maximize benefits. **Tool 7: Treatment Trains** includes three examples of possible treatment trains that use several BMPs in sequence to address common unpaved road types and problems observed in western Massachusetts.

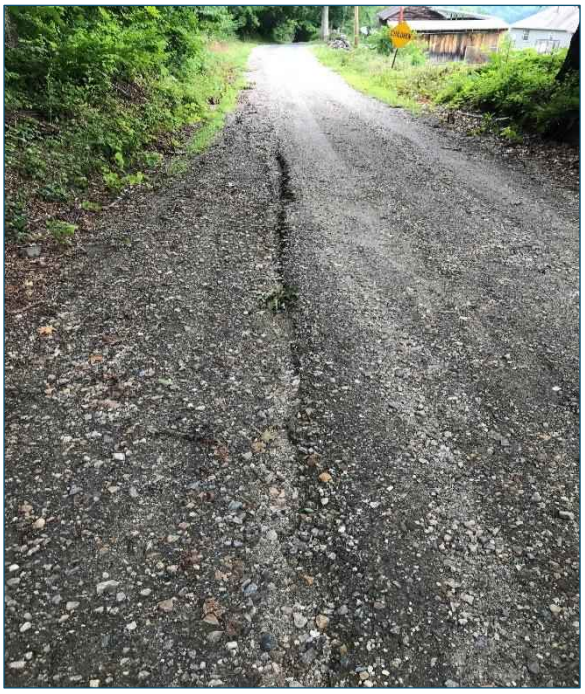
Repeat **Steps 1 through 3** for each road type that applies to the priority road segment/problem areas.

The rest of this section includes more detailed information about each road type and the common problems associated with the road type, along with the same tables that are in the Unpaved Road Field Assessment Form. The Stormwater BMP Fact Sheets and Design Typicals in **Tool 5** could also be helpful in selecting the right BMPs for your particular site.

BMP Selection by Road Type and Problem

Steep Grade

Roads with steep grades often require the most stormwater management because water velocity is faster and can result in severe erosion of the road. It has been observed that roads with 6% grade or steeper are at high risk for major erosion problems. In heavy rainstorms, runoff can quickly create erosion channels over a short distance. This process is especially pronounced on entrenched roads and roads with grader berms. Shoulders, ditches, and stormwater drainage culverts on steep roads are also more prone to erosion.



This road is on a steep slope and is forming a rill in the middle of the road. The road lacks a proper crown, has no ditch, and is also entrenched.

Management Solutions

On steep roads, it is very important to get runoff both off the road and out of a ditch into a stable vegetated area as often as possible. Steep roads should have proper crowns and no grader berms, constructed ditches, and frequent turnouts or cross culverts draining water off the road and into adjacent vegetated areas that are not connected to a waterbody. On public roads, grade breaks can be installed with turnouts on each side to help water move off the road. On private driveways or very low volume roads, broad-based dips and water bars can be used to move water off the road. Where road grade is steeper than 5%, stone check dams and stone-lined ditches help stabilize the ditches, and inlet and outlet protection will stabilize the areas around the culvert and help capture sediment. Where there is space alongside the road and a short break in the steep grade, settling pools can be

A gully has formed on this steep road because it lacks a constructed ditch or had an insufficiently sized ditch.

used to slow water and trap sediment. These BMPs are described more fully in the BMP Fact Sheets in **Tool 5**.

Inspecting and cleaning debris and sediment out of ditches, culverts, and turnouts on a regular basis, especially after rain events, is also very important on steep roads. Clogged or degraded stormwater management structures can result in more flooding and erosion. Road material and sediment that have accumulated in ditches and culverts can also be flushed into a waterbody during the next heavy storm.

Table 4-1. Recommended BMPs for typical road problems for steep grade road type

Road problem	Stormwater BMP (BMPs with * have design typical)	Maintenance BMP
Erosion of road surface	Centerline crown	Proper road structure
	Cross-slope crown	Grading
	Grade break*	Removal of grader berms
	Turnout*	Compaction of road after grading
		Sufficient turnouts
Erosion of shoulder	Stone-lined ditch*	Constructed ditches
		Excess road material management
Erosion of constructed ditch	Stone-lined ditch*	Sufficient turnouts
	Stone check dam*	Sufficient stormwater drainage culverts
	Ditch settling pool*	Ditch, turnout and culvert inspection and maintenance
	Turnout*	
	Outlet protection for turnout*	
	Round stormwater drainage culvert	
Erosion around stormwater drainage culvert	Stone headwall*	Sufficient turnouts
	Inlet protection*	Sufficient stormwater drainage culverts
	Outlet protection for culvert*	Right-sized round stormwater drainage culverts
		Ditch, turnout and culvert inspection and maintenance
Erosion around stream-crossing culvert/bridge	Stone headwall*	Follow *MA Stream-Crossing Standards*

Steep Bank Slope

Roads that have a steep bank on either side of the road have a higher chance of runoff eroding the banks on either side of the road. The steeper the slope, the higher the flow velocity, and the farther runoff may carry road material and other sediment.

Gullies can form downhill as runoff finds its way off the road.

Management Solutions

Carefully plan how water drains off the stream-side edge of a road. How the road is crowned will dictate which BMPs may be necessary. If there is a long distance from the road to the waterbody (greater than 50 feet) and the area is well vegetated, one option is to outslope the road to the waterbody/downslope side in order to encourage dispersed flow across the bank and prevent having to manage concentrated flows coming out of stormwater drainage culverts on the downslope side. It is essential to remove grader berms if this is the case. A centerline crown would split the runoff volume so that half would be managed on the bank side and half via drainage infrastructure. If the road runs very close to the waterbody and the shoulders and banks are unstable, but there is space to manage the runoff on the non-waterbody side, insloping the road and using frequent turnouts, settling pools, culverts with outlet protection, and bank stabilization may be more optimal. An insloping or outsloping road may need to be regraded before winter to prevent cars slipping across or off the road.

Road material shown off the road next to a coldwater stream.

If stabilizing the road shoulder is needed, particularly around a stream crossing where the road is at a low point, consider armoring the road shoulder. If large amounts of runoff are flowing into the ditch from the upslope bank, it may be important to stabilize the ditch with vegetation or stone.

A stormwater drainage culvert discharging to a steep bank, whether or not it free-falls to the ground, will likely need outlet protection if there is sufficient space. Where outlet protection is

not enough to stop water from eroding a bank at the outlet of a culvert, a level spreader-type of outlet protection can take the water from the outlet and disperse it over a bigger area.

Runoff may pick up velocity and create more erosion as it travels down a bank slope. Large log check dams and bank benches or interceptor ditches help slow and spread water to reduce its erosive force, and trap sediment being carried by the runoff. A bank bench, interceptor ditch, or log check dam are also options to address erosion occurring upslope from the roadside ditch.

Table 4-2. Recommended BMPs for typical road problems for steep bank slope road type

Road problem	Stormwater BMP (BMPs with * have design typical)	Maintenance BMP
Erosion of upslope bank	Log check dam	Excess road material management
	Bank bench and interceptor ditch*	
Erosion of road surface	Centerline crown	Grading
	Cross-slope crown	Removal of grader berms
Erosion of shoulder	Underdrain*	Sufficient turnouts
	Armored shoulder*	Excess road material management
	Vegetated ditch*	
Erosion of constructed ditch	Round stormwater drainage culvert	Sufficient stormwater drainage culverts
		Right-sizing round stormwater drainage culverts
		Ditch, turnout and culvert inspection and maintenance
Erosion around stormwater drainage culvert	Round stormwater drainage culvert	Sufficient turnouts
	Stone headwall*	Sufficient stormwater drainage culverts
	Inlet protection*	Right-sizing round stormwater drainage culverts
	Outlet protection for culvert*	Ditch, turnout and culvert inspection and maintenance
Erosion around stream-crossing culvert/bridge	Armored shoulder*	Follow *MA Stream-Crossing Standards*
	Turnout*	
Erosion of downslope bank	Turnout*	Excess road material management
	Outlet protection for turnout*	
	Vegetated buffer zone	
	Log check dam	

Road problem	Stormwater BMP (BMPs with * have design typical)	Maintenance BMP
Runoff carrying sediment directly from shoulder into waterbody	Cross-slope crown	Proper snow and ice management
	Armored shoulder*	Excess road material management
	Vegetated ditch*	
	Turnout*	
	Outlet protection for turnout*	

Stream Crossing

Any time a road and stream intersect, there is the risk of road material eroding off the road and entering the stream. Culverted stream crossings and bridge decks often lack bermed concrete or earthen edges on the road surface above the stream, and those areas accumulate road material and winter sand that washes off directly into the stream. Also a common problem at stream crossings are ditches that lead directly to streams without giving road material a place to settle out.

Road material loss on a bridge without berms.

False ditch discharging directly to a stream at a stream crossing.

Stream crossings on unpaved roads that have poorly designed or undersized culverts and lack proper drainage features can also contribute to erosion problems. Inadequate armoring, lack of vegetated buffers, and poor maintenance further accelerate sediment washout, degrading water quality and aquatic habitat downstream.

Management Solutions

Runoff draining from a stream crossing bridge or culvert should be managed to prevent road material and sediment fall into the stream. Vegetated and stone-lined ditches, sediment settling pools, and rock check dams, that are cleaned on a regular basis, will also help remove sediment before runoff reaches these other BMPs. This could include berming the road section

over a stream or directing runoff into an armored shoulder or a turnout that discharges into a stabilized vegetated area.

Ditches and turnouts that lead directly to waterbodies should be "disconnected" from the stream. Address the problem upstream as much as possible by frequently using grade breaks (if on a steep grade road), turnouts, and stormwater drainage culverts to move runoff out of the road drainage system well before the stream crossing. For any concentrated runoff that does come close to the stream, place a curving turnout or outlet protection at the end of the ditch. Be sure that runoff discharges into a stable vegetated area. Planting a vegetated buffer zone between the ditch outlet and the stream will further ensure that road material and other sediments are filtered out before reaching the waterbody.

Turnout directed toward stream. Turnouts should be directed away from streams to allow water to infiltrate into the ground before reaching a stream.

Table 4-3. Recommended BMPs for typical road problems for stream crossing road type

Road problem	Stormwater BMP (BMPs with * have design typical)	Maintenance BMP
Erosion around stream-crossing culvert/bridge	Stone headwall*	Follow *MA Stream-Crossing Standards*
		Excess road material management
Sediment on stream-crossing culvert or bridge falling into waterbody	Armored shoulder*	Addition of grader berm
	Turnout*	
Runoff carrying sediment directly from ditch/turnout into waterbody	Centerline crown	Ditches disconnected from waterbodies
	Cross-slope crown	Sufficient turnouts
	Vegetated ditch*	Sufficient stormwater drainage culverts
	Ditch settling pool*	Ditch, turnout, and culvert inspection and maintenance
	Turnout*	
	Outlet protection for turnout*	
	Round stormwater drainage culvert	
	Vegetated buffer zone	

Adjacent to Stream

When unpaved roads run alongside a stream in close proximity, there is an excellent chance that road material dislodged from the road will eventually enter the stream. Road shoulders are more likely to be unstable and covered in loose sand and gravel from plowing and cars. Any runoff that has been concentrated in a channel, such as a rill or false ditch is also likely to be carrying sediment.

During the winter, snow plowing can deposit piles of road material mixed in with the plowed snow, particularly if the roads are not frozen during plowing. These piles of loose material are very likely to be carried into the stream with heavy rainfall.

Many roads in western Massachusetts were built so close to a stream that there is not much room for managing stormwater, leaving many opportunities for road material to reach the stream.

As noted earlier in this document, rivers and streams naturally change course over time and need lateral spaces in which to move. Unfortunately, many of our roads were built so close to streams that the stream can't move without undercutting the streambank and causing the shoulder or road surface to collapse. If a road cannot be moved further away from the river, other solutions often require the services of an engineering and fluvial geomorphology consultant to ensure that any bank protection will stand up to expected flows, and to ensure the work does not create additional problems for landowners upstream, downstream, or across the stream. This type of effort also will require permitting from the local Conservation Commission (see **Tool 1** for more information).

Management Solutions

When deciding which measures to use to prevent road material from reaching a nearby stream, the steepness of the road shoulders and proximity to the road need to be taken into consideration (see *Steep Bank Slope* road type for additional management solutions). If grader berms or a lack of turnouts means that a lot of concentrated runoff is leaving the road at certain locations, then a centerline crown, removal of grader berms, and sufficient turnouts are the first measures to consider. Woody debris strategically positioned on the embankment can help catch sediment coming off the road and can generally stabilize the road embankment.

On the upslope side of the road, directing water off the road with turnouts as often as possible reduces the amount of runoff coming towards the stream via stormwater drainage culverts. Where the stream runs close to the road, berming the road shoulder may actually be useful to direct water down the road to where the sediment can settle out in a stable vegetated area.

If the road is shedding material into the stream via the downslope side of the road, the road could be regraded to be insloped so that water drains to the inside and is controlled by BMPs that slow flow velocity and settle out sediment. Stormwater drainage culverts that drain towards the stream should have outlet protection. Planted buffers and log check dams can be used to slow down the water and capture sediment before it reaches the stream. It is very important to clean out ditches and culverts on a regular basis during a rainy season because accumulated road material can be transported into the stream in a heavy rain event.

Avoid plowing up road material during wet snowstorms and plow away from the waterbody and drainage infrastructure whenever possible.

Without proper planning, stormwater will create a path off the road and into a stream.

Table 4-4. Recommended BMPs for typical road problems for adjacent to stream road type

Road problem	Stormwater BMP (BMPs with * have design typical)	Maintenance BMP
Road stability problems due to excess moisture	Geogrid*	Proper road structure
Erosion of road surface	Centerline crown	Proper road structure
	Cross-slope crown	Grading
		Removal of grader berm
		Compaction of road after grading
Erosion of shoulder	Underdrain*	Sufficient turnouts
	Vegetated ditch*	Excess road material management
	Turnout*	
	Outlet protection for turnout*	
	Round stormwater drainage culvert	
Erosion around stormwater drainage culvert	Stone headwall*	Sufficient turnouts
	Outlet protection for culvert*	Sufficient stormwater drainage culverts
		Right-sized round stormwater drainage culverts
		Ditch, turnout, and culvert inspection and maintenance
Runoff carrying sediment directly from shoulder into waterbody	Vegetated buffer zone	Excess road material management
	Cross-slope crown (inslope)	Proper snow and ice management
	Log check dam	Constructed ditches
Runoff carrying sediment directly from ditch/turnout into waterbody	Turnout*	Sufficient turnouts
	Outlet protection for turnout*	Ditches disconnected from waterbodies
		Ditch, turnout, and culvert inspection and maintenance
Runoff carrying sediment from drainage culvert into waterbody (directly or indirectly)	Vegetated ditch*	Sufficient turnouts
	Ditch settling pool*	Ditch, turnout, and culvert inspection and maintenance
	Inlet protection*	
	Outlet protection for culvert*	
	Vegetated buffer zone	

Adjacent to Wetland

Unpaved roads in Massachusetts often pass near or through priority habitats, coldwater streams, and wetland resource areas regulated under the Massachusetts Wetlands Protection Act. Without stabilization, these roads can contribute excess sediment and pollutants to surface waters, degrading habitat and threatening water quality.

Roads that run alongside or through wetlands tend to have high water tables and little ability to drain water. As a result, they can be muddy and develop ruts even outside of mud season. Often, when the road width is narrow, the road erodes directly into the wetland. Managing water movement on the road surface and below the surface is key to properly maintaining a road through or near a wetland. Road material plowed in winter or otherwise left near wetlands is also an important concern.

This wetland is so close to the road that it is difficult to manage stormwater and prevent road material from reaching it.

Management Solutions

Water should be moved off of the road as much as possible on its approach to the wetland using the BMPs identified in the *Stream Crossing* road type.

For many small towns with limited resources, geogrid installation offers a low-cost, low-maintenance alternative to the constant volume of gravel needed for maintenance and resurfacing. Geogrids extend road life and reduce the frequency of grading and maintenance. By investing in geogrid-reinforced roads, towns can align road work with natural resource protection. Geogrids stabilize the roadbed, reducing ruts, washouts, and sediment transport into nearby wetlands, streams, or drinking water sources. This protects aquatic habitats and reduces sediment in runoff—key to protecting water quality.

If properly installed, geogrids work best on unpaved roads that are often wet due to a saturated subbase, which is very common to roads adjacent or through wetlands. When paired with a well-crowned road and constructed ditches, they will also hold up well against repeated freeze/thaw cycles, heavy rain events, washouts, and flooding.

Road shoulders should always be vegetated, ideally with plants or shrubs that have deep roots that can help stabilize the soil.

As with roads adjacent to streams, it may be appropriate to berm the edge of the road for a short distance where the road runs close to the wetland to direct runoff to a stable vegetated area such as a turnout or a bank bench. Where road shoulders are already stable and there is sufficient space, log check dams on the road shoulder can help catch sediment coming off the road and can generally stabilize the road embankment.

Unpaved road alongside a wetland.

If the wetland is only on one side of the road, it may be possible to inslope the road toward the non-wetland side and manage the runoff with a ditch and turnouts or a stormwater drainage culvert that outlets away from the wetland.

Rebuilding the road so water can move through it more easily can be highly beneficial. If a Town is considering major road work, French mattresses and raising the road profile can allow for more efficient flow under the road.

Underdrains are also an option for draining the road base. Culverts that connect wetlands are not subject to the Massachusetts Stream Crossing Standards unless a noticeable channel is present.

Table 4-5. Recommended BMPs for typical road problems for adjacent to wetland road type

Road problem	Stormwater BMP (BMPs with * have design typical)	Maintenance BMP
Road stability problems due to excess moisture	Raise the road profile	Proper road structure
	French mattress*	
	Geogrid*	
	Underdrain*	
Erosion of road surface	Centerline crown	Proper road structure
	Cross-slope crown	Grading
	Raise the road profile	
Erosion of shoulder	Underdrain*	Sufficient turnouts
	Vegetated ditch*	Ditch, turnout, and culvert inspection and maintenance
	Turnout*	Excess road material management
	Outlet protection for turnout*	
	Round stormwater drainage culvert	
Erosion around stormwater drainage culvert	Stone headwall*	Sufficient turnouts
	Outlet protection for culvert*	Sufficient stormwater drainage culverts
		Right-sized round stormwater drainage culverts
Runoff carrying sediment directly from shoulder into waterbody	Turnout*	Addition of grader berms
	Outlet protection for turnout*	Constructed ditches
	Vegetated buffer zone	Ditches disconnected from waterbodies
	Log check dam	Proper snow and ice management
		Excess road material management
Runoff carrying sediment directly from ditch/turnout into waterbody	Vegetated ditch	Disconnect ditches from waterbodies
	Round stormwater drainage culvert	Ditch, turnout, and culvert inspection and maintenance
	Log check dam	

Steep Private Driveway

Private unpaved driveways can damage public roads when they are situated uphill from the road and are not properly designed or maintained to manage the runoff they receive. Driveways with steep grades and without stormwater BMPs have a high likelihood that runoff will erode the driveway into the public road. Conversely, drainage off unpaved roads can damage driveways when the driveway is downhill from the road.

This private driveway is impacting the road by sending runoff to the road and causing the formation of a false ditch.

Management Solutions

A municipality has limited options to address problems with private driveway drainage and material once it is built. To help prevent issues caused by private driveways before they occur, Town general bylaws, zoning bylaws, and subdivision regulations can be used to establish review and enforce driveway design to ensure that the Town Highway Department approves of the construction.[16] Many towns have a form on their Town website to fill out when applying for a new driveway. The form is then reviewed by Town staff and approved or modified before construction. Collaboration with homeowners is very important for this road type. Highway staff describe various arrangements in which both the homeowner and the Town Highway staff contribute different parts of a project to fix a problem. Working in partnership with a property owner will go a long way to achieving proper road drainage around private driveways.

Steep private driveways should have the same BMPs as well-designed and constructed *Steep Grade* roads, with the additional option of water bars or broad-based dips. Where there are roadside ditches, the private driveway should also have a driveway culvert.

A public road receiving runoff from a steep private driveway can be managed similarly to a *Steep Grade* road because the water will have gathered velocity down the driveway. A sediment settling pool or stone-lined ditch around the curve of the driveway where it meets the road will help reduce erosion of the ditch and road surface. The public road should be centerline crowned and compacted, with shoulder berms removed, so that any driveway runoff that discharges onto the road surface can drain off quickly into a ditch.

[16] PVPC created example bylaws for driveways under a previous grant. Contact PVPC staff listed in the title page of this document for more information.

Steep Private Driveway

Table 4-6. Recommended BMPs for typical road problems for steep private driveway road type

Road problem	Stormwater BMP (BMPs with * have design typical)	Maintenance BMP
Erosion of road surface (for Town Highway staff)	Centerline crown	Proper road structure
	Cross-slope crown	Grading
	Grade break*	Removal of grader berms
		Compaction of road after grading
Erosion of constructed ditch (for Town Highway staff)	Vegetated ditch*	Sufficient turnouts
	Stone-lined ditch*	Sufficient stormwater drainage culverts
	Stone check dam*	Ditch, turnout, and culvert inspection and maintenance
	Ditch settling pool*	
	Turnout*	
	Round stormwater drainage culvert	
Erosion of private driveway intersection (for driveway owner)	Centerline crown	Grading (no crown near intersection with public road)
	Cross-slope crown	Removal of grader berms
	Turnout*	Compaction of road after grading
	Stone headwall*	Sufficient turnouts
	Broad-based dip*	Sufficient stormwater drainage culverts
	Water bar	Right-sized round stormwater drainage culverts
	Driveway intersection culvert*	

Entrenched

Routine road maintenance practices such as grading and plowing, combined with the wear and tear of traffic and natural erosion, can have the cumulative effect of lowering the elevation of the road relative to its surroundings. This can lead to the road being entrenched. When a road is entrenched, water is trapped on the road. On roads with slope, runoff unable to exit the road will erode the road surface as it increases in volume and flow velocity. Once a road is entrenched, it generally continues to become more entrenched as the trapped runoff erodes down the road. Entrenched road profiles make installation of stormwater drainage culverts, turnouts, and other drainage outlets intended to shed water from the road challenging or impossible.

Management Solutions

This road is entrenched, and water is eroding off the road in the foreground left.

Deeply entrenched roads are difficult to improve because the adjacent land does not allow the water to move off the road. It is therefore important to address entrenchment early on in the process when there are still options for fixing the problem. For example, the road profile could be raised if the material needed is within the Highway Department budget. Where there is only a small hill or berm between the road and surrounding land at lower elevation, an excavator bucket can be used to breach the bank or a through-the-bank pipe can be installed to direct water off the road. When through-the-bank pipes outlet to a sloping bank, outlet protection will reduce erosion at the outlet.

In cases where the road is only entrenched on one side, the road can be regraded with a cross-slope crown to drain runoff to the ditch side. See *Steep Grade* road type for a description of how best to move runoff out of the ditch.

BMPs that manage surface and subsurface flow or saturation can also be used in entrenched roads, depending on road slope and other conditions.

Table 4-7. Recommended BMPs for typical road problems for entrenched road type

Road problem	Stormwater BMP (BMPs with * have design typical)	Maintenance BMP
Road stability problems due to excess moisture	Raise the road profile	Proper road structure
	French mattress*	
	Geogrid*	
	Underdrain*	
Erosion of road surface	Centerline crown	Proper road structure
	Cross-slope crown	Right-sized round stormwater drainage culverts
	Raise the road profile	
	Vegetated ditch*	
	Stone headwall*	
	Through-the-bank pipe	

BMP Selection Background

Road Problems and Their Causes

This table summarizes typical causes of unpaved road problems, which can inform the selection of BMPs.

Table 4-8. Road problems and their causes

Problem	Cause
Erosion of road surface (a.k.a. rilling and gullying)	Poor original road construction
	Road not properly crowned
	Grader berms or high shoulders
Road surface unstable and wet	Poor original road construction
	Road entrenched
	Site-specific hydrology and water not draining
Fine material lost to dust	Poor road mix
	Minimal/no natural shading from trees
	Improper/no dust control application
Erosion of shoulder	Concentrated runoff breaking through grader berm
	Shoulder soil unstable
Erosion of Constructed ditch	Steep ditch grade
	Ditch undersized
	Insufficient outlets
	No constructed ditches
	Road entrenched/no space for ditch
Erosion around stormwater drainage culvert (piping at inlet or scour at outlet)	Culvert undersized
	Culvert damaged
	Culvert incorrectly installed or positioned
	High velocity at culvert inlet
	Runoff free-falls from culvert outlet, causing scour
Erosion around stream-crossing culvert/bridge	Stream-crossing culvert/bridge undersized
	Stream-crossing culvert/bridge damaged
	Stream-crossing culvert/bridge incorrectly installed or positioned
	Runoff concentrating around sides of culvert/bridge
Erosion of upslope bank	Steep bank w/ natural erosion
	Exposed soil from excavation work
	Groundwater seep present
Erosion of downslope bank	Steep bank
Erosion of private driveway intersection	Poor original road or driveway construction
	Road not properly crowned (proper crowning is ½ inch per foot; crown does not flatten to meet road)
	Grader berms or high shoulders

Problem	Cause
	Uncontrolled runoff in shoulder/ditch area
	Missing or damaged driveway culvert
Runoff carrying sediment directly from road shoulder into waterbody	Plow pile with road material left near waterbody
	Road material from cleaning ditches and culverts left near waterbody
	Lack of Constructed ditch
	Lack of runoff outlets
	Uncontrolled bank runoff
Runoff carrying sediment directly from ditch/turnout into waterbody	Ditch/turnout directly connected to waterbody
Runoff carrying sediment from drainage culvert into waterbody (directly or indirectly)	Culvert directly connected to waterbody
	Culvert has no sediment trap
	Uncontrolled bank runoff
Sediment on stream-crossing culvert or bridge falling directly into waterbody	Lack of edges on bridge or road shoulder

The table on the next page organizes BMPs by the corresponding road type all in one page for reference.

BMP Selection Matrix by Road Type

	Road Type ---->	Steep Grade	Steep Bank Slope	Stream Crossing	Adjacent to Stream	Adjacent to Wetland	Steep Private Driveway	Entrenched
Stormwater BMPs								
Driving Surface of the Road	Centerline crown	X	X	X	X	X	X	X
	Cross-slope crown	X	X	X	X	X	X	X
	Raise the road profile					X		X
	Grade break	X					X	
	French mattress					X		X
	Geogrid				X	X		X
Shoulders	Underdrain		X		X	X		X
	Armored shoulder		X	X				
Ditches	Vegetated ditch		X	X	X	X	X	X
	Stone-lined ditch	X					X	
	Stone check dam	X					X	
	Ditch settling pool	X		X	X		X	
	Turnout	X	X	X	X	X	X	
	Outlet protection for turnout	X	X	X	X	X		
Culverts	Round stormwater drainage culvert	X	X	X	X	X	X	
	Stone headwall	X	X	X	X	X	X	X
	Inlet protection	X	X		X			
	Outlet protection for culvert	X	X	X	X	X		
Banks	Vegetated buffer zone		X	X	X	X		
	Log check dam		X		X	X		
	Through-the-bank pipe							X
	Bank bench and interceptor ditch		X					
Private Driveway Intersections	Broad-based dip						X	
	Water bar						X	
	Driveway intersection culvert						X	
Maintenance BMPs								
Beneficial for all road types but particularly good for those marked with an "X."	Proper road structure	X			X	X	X	X
	Grading	X	X		X	X	X	
	Removal (or addition) of grader berms	X	X	X	X	X	X	
	Compaction of road after grading	X			X		X	
	Constructed ditches	X			X	X		
	Ditches disconnected from waterbodies			X	X	X		
	Sufficient turnouts	X	X	X	X	X	X	
	Sufficient stormwater drainage culverts	X	X	X		X	X	
	Right-sized round stormwater drainage culverts	X	X		X	X	X	
	Follow *MA Stream-Crossing Standards*	X	X	X				
	Ditch, turnout, and culvert inspection and maintenance	X	X	X	X	X	X	X
	Proper snow and ice management		X		X	X		
	Excess road material management	X	X	X	X	X		

Tool 5: Stormwater BMP Fact Sheets and Design Typicals

Introduction

The Toolkit thus far has helped identify typical problems and the best management practices (BMPs) that may help fix these problems. In this tool, Stormwater BMP Fact Sheets describe each of the 27 BMPs in detail. Additionally, this tool contains Design Typicals for 15 BMPs to help Highway staff with installation of BMPs at a specific site.

To help you understand which stormwater or maintenance BMP is appropriate for your road, refer also to the results of the field assessment using **Tool 3: Unpaved Road Criticality and Field Assessment** and the information in **Tool 4: Best Management Practices (BMP) Selection**.

Functions of Stormwater BMPs

Most unpaved road stormwater best management practices (BMPs) help with stormwater-related erosion prevention or sediment control, which lengthens the life of the road surface, reduces long term maintenance costs, and helps prevent pollution of a nearby wetland or waterbody.

Table 5-1 lists and describes the functions and benefits that unpaved road stormwater BMPs provide, and whether the function is an erosion prevention or sediment control practice. These terms and definitions are to be used within the context of this toolkit and may not be applicable in different regulatory or scientific contexts.[17] Other BMPs in this toolkit focus on managing water issues below the road surface, which often cause road stability issues, and maintenance BMPs.

[17] The unpaved stormwater management BMPs in this toolkit support one or more of the goals of source control and pollution prevention, peak flow attenuation, capture and treatment of runoff, and groundwater recharge in the *Massachusetts Stormwater Handbook*: https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards. Erosion prevention falls within the source control and pollution prevention framework. Sediment control captures and treats runoff. The handbook provides guidance for managing stormwater in the state of Massachusetts. It is primarily used by developers, engineers, and environmental professionals to design stormwater management systems that comply with the state's environmental regulations.

Table 5-1. Unpaved road stormwater BMP functions

Function	Purpose	Description and Benefits
Road Surface Drainage	Erosion prevention	Promotes stormwater drainage off the driving surface of the road, reducing the susceptibility of the road surface to erosion.
Conveyance		Conveys stormwater runoff or other waters from one location to another in a way that prevents erosion.
Stabilization		Prevents soil from coming into contact with erosive forces of stormwater. Reduces erosion and prevents bank sliding or collapse.
Detention	Sediment control	Temporarily captures stormwater runoff. Reduces the flow velocity of stormwater runoff and may trap some sediment.
Velocity Control		Creates a barrier that slows the velocity of stormwater runoff. May trap some sediment.
Infiltration		Allows stormwater to permeate back into the ground. Reduces the volume of stormwater runoff and recharges groundwater supply.
Filtration		Traps and removes sediment carried by stormwater runoff.
Accessory	Both	Improves the functionality of another BMP.

How to Use the BMP Fact Sheets and Design Typicals

Fact Sheets

Each BMP fact sheet describes the benefits, planning and design considerations, and materials needed for construction. The fact sheets provide information for Highway staff to consider the applicability of the BMP, the estimated cost of the BMP in 2024 dollars, and in some cases, sufficient information to install it.[18] Fact sheets are listed under the part of the road they most commonly apply to: the driving surface of the road, shoulders, ditches, culverts, banks, and private driveway intersections.

Design Typicals

Typical designs are provided for 15 BMPs to present engineering standards and construction guidance. The design typicals provide additional information on construction sequencing, construction costs, and limitations. Ten of the design typicals include an estimation of sediment pollutant reduction if the BMP were to be installed; these designs were originally completed in

[18] Costs in 2024 were used in this document because the first version of the toolkit was published in 2024.

2024 under a nonpoint source pollution grant from MassDEP (§319 grant). Common pollutants from unpaved roads are total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP). A pollutant "load" is the total amount (in lbs.) of pollutant expected per acre of contributing drainage area per year. A memo explaining the methods for calculating the pollutant load reduction estimates can be found in **Appendix D**.

The design typicals are not drawn to fit a particular site, and so site-specific decisions will need to be made. First, it is important to think of the intended design life of the BMP as well as the criticality of the road or the infrastructure to be installed, and finally, the typical size storm the infrastructure should be able to withstand. Note that sizing guidance provided on each design typical (if included) is based primarily on water quality treatment considerations. The Massachusetts Executive Office of Energy and Environmental Affairs (EEA) has climate resilient design standards that can be consulted.[19] For example, see Table 4.11 in https://eea-nescaum-dataservices-assets-prd.s3.amazonaws.com/cms/GUIDELINES/V1.2_SECTION_4.pdf.

When considering the storm design, NOAA has a helpful calculator for conceptualizing the statistical risk of a certain storm event happening over a particular time period, such as the design life of a culvert. See https://www.weather.gov/epz/wxcalc_floodperiod. For example, if you type in 100 on the top left and 25 in the bottom left, and click on "convert," you'll see that there's a 22.2% chance of a 100-year event happening in a 25-year period. Typing a 1 in the bottom left gives you the percent chance in any single year. As a practitioner working with or for a town, you'll need to decide if this is an acceptable level of risk.

To find different precipitation frequencies, consult https://hdsc.nws.noaa.gov/pfds/ and click on Massachusetts. To find the precipitation statistics for your location, click on the location information that you prefer to use—you can use a weather station, an address, a point on a map, or a latitude/longitude location. This will generate a precipitation frequency table for this site that you can use to estimate rainfall. To take into account extreme events, it is recommended that you use the higher number in the range, rather than the larger average number.

The decision of what is an acceptable level of risk must balance the criticality of the infrastructure and anticipated design life against the potential increase in cost that may be associated with constructing a larger BMP to accommodate bigger, but possibly less frequent, storm events, as well as feasibility of construction. For example, it may be worth the investment to build a larger culvert to convey a stream beneath a heavily used roadway with a long detour if the road were to fail, even if a large flood has a lower likelihood of occurring. On the other hand, the size of a drainage ditch may be limited based on space constraints, and the

[19] See MA Climate Resilient Design Standards https://resilientma.mass.gov/rmat_home/designstandards/, then click on the design standards under Climate Resilience Design Standards Output.

higher cost to construct a larger ditch may not be worthwhile, depending on the importance of the infrastructure that the ditch is protecting.

Because stormwater BMPs are most effectively used in a sequence, this toolkit provides example treatment trains in the next section, **Tool 7: Treatment Trains.**

Fact Sheets

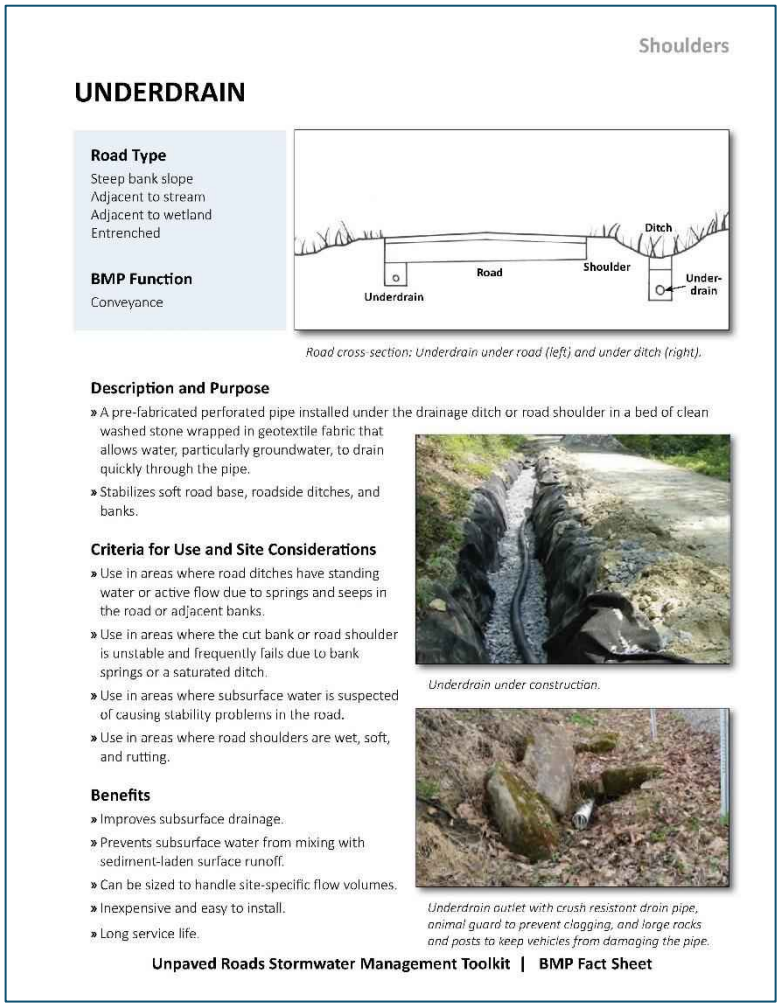
Fact sheets with an asterisk (*) have design typicals included.

Fact sheets with a plant leaf symbol ( ) might be considered Nature-Based Solutions (NBS) by grant funders, like the Commonwealth's Municipal Vulnerability Preparedness (MVP) program.[20]

Driving Surface of the Road
- Centerline Crown
- Cross-Slope Crown
- Raise the Road Profile
- Grade Break*
- French Mattress*
- Geogrid*

Shoulders
- Underdrain*
- Armored Shoulder*

Ditches
- Vegetated Ditch*
- Stone-lined Ditch*
- Stone Check Dam*
- Ditch Settling Pool*
- Turnout
- Outlet Protection for Turnout*



Shoulders

UNDERDRAIN

Road Type
Steep bank slope
Adjacent to stream
Adjacent to wetland
Entrenched

BMP Function
Conveyance

Road cross-section: Underdrain under road (left) and under ditch (right).

Description and Purpose
- A pre-fabricated perforated pipe installed under the drainage ditch or road shoulder in a bed of clean washed stone wrapped in geotextile fabric that allows water, particularly groundwater, to drain quickly through the pipe.
- Stabilizes soft road base, roadside ditches, and banks.

Criteria for Use and Site Considerations
- Use in areas where road ditches have standing water or active flow due to springs and seeps in the road or adjacent banks.
- Use in areas where the cut bank or road shoulder is unstable and frequently fails due to bank springs or a saturated ditch.
- Use in areas where subsurface water is suspected of causing stability problems in the road.
- Use in areas where road shoulders are wet, soft, and rutting.

Benefits
- Improves subsurface drainage.
- Prevents subsurface water from mixing with sediment-laden surface runoff.
- Can be sized to handle site-specific flow volumes.
- Inexpensive and easy to install.
- Long service life.

Underdrain under construction.

Underdrain outlet with crush resistant drain pipe, animal guard to prevent clogging, and large rocks and posts to keep vehicles from damaging the pipe.

Unpaved Roads Stormwater Management Toolkit | BMP Fact Sheet

Figure 5-1. Example Fact Sheet of Underdrain BMP.

[20] Nature-Based Solutions (NBS) are adaptation measures focused on the protection, restoration, and/or management of ecological systems to safeguard public health, provide clean air and water, increase natural hazard resilience, and sequester carbon. MVP Toolkit: Nature-Based Solutions is available from the MA Climate Change Clearinghouse at https://resilient.mass.gov/mvp/content.html?toolkit=nature_based.

Culverts

- Round Stormwater Drainage Culvert
- Stone Headwall*
- Inlet Protection
- Outlet Protection: Riprap apron*
- Outlet Protection: Plunge Pool*
- Outlet Protection: Level Spreader*

Banks

- Vegetated Buffer Zone
- Log Check Dam
- Through-the-Bank Pipe
- Bank Bench and Interceptor Ditch*

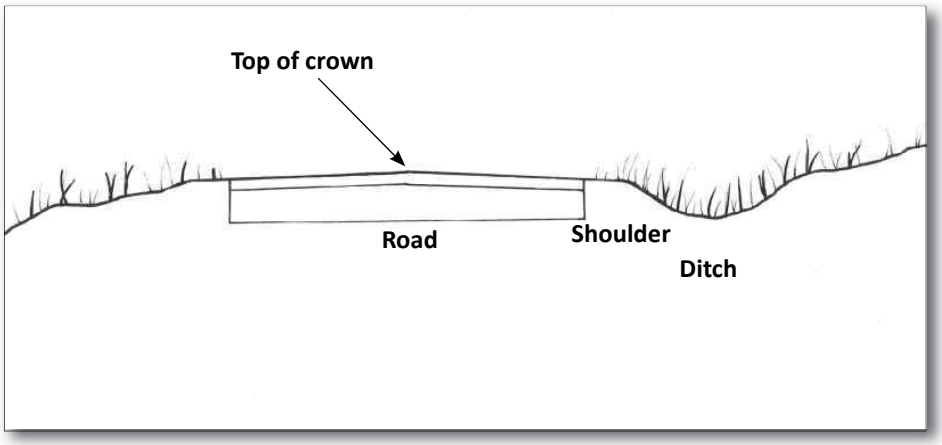
Private Driveway Intersections

- Broad-based Dip*
- Water Bar
- Driveway Intersection Culvert*

CENTERLINE CROWN

Road Type
All road types

BMP Function
Road surface drainage



Road cross-section: A centerline crown is A-shaped with two sides that are recommended to rise a half inch per foot, or 4% .

Description and Purpose

» The road is shaped to have its highest point in the center of the road between lanes of travel, shaped like the letter A (not rounded).

» Proper crowning of the road surface is essential for efficient drainage of water, either into roadside ditches or as dispersed (evenly distributed) flow off of the road shoulder.

Criteria for Use and Site Considerations

» Use on all roads when drainage can be split to drainage infrastructure on either side of the road (see Cross-Slope Crown BMP to determine when inslope or outslope would be applicable).

Road with centerline crown

Benefits

» Reduces surface material loss.

» Reduces base saturation, improving stability.

» Improves drivability and ride quality.

» Lengthens the life of the road surface and reduces long term maintenance cost.

Planning and Design

» Grade a straight line from the shoulder to the centerline to rise approximately ½ inch per foot, or 4%. A crown slope greater than 4% may shed water more efficiently, but steep lanes can cause erosion perpendicular with the road and can also encourage drivers to straddle the center of the road.

» Use a good blend of stone, sand, and fine material capable of being shaped and compacted to effectively create the desired shape in the road. Use fractured stone and fines with a binding agent.

CENTERLINE CROWN

Material and Equipment

» Grader

» Scarifier

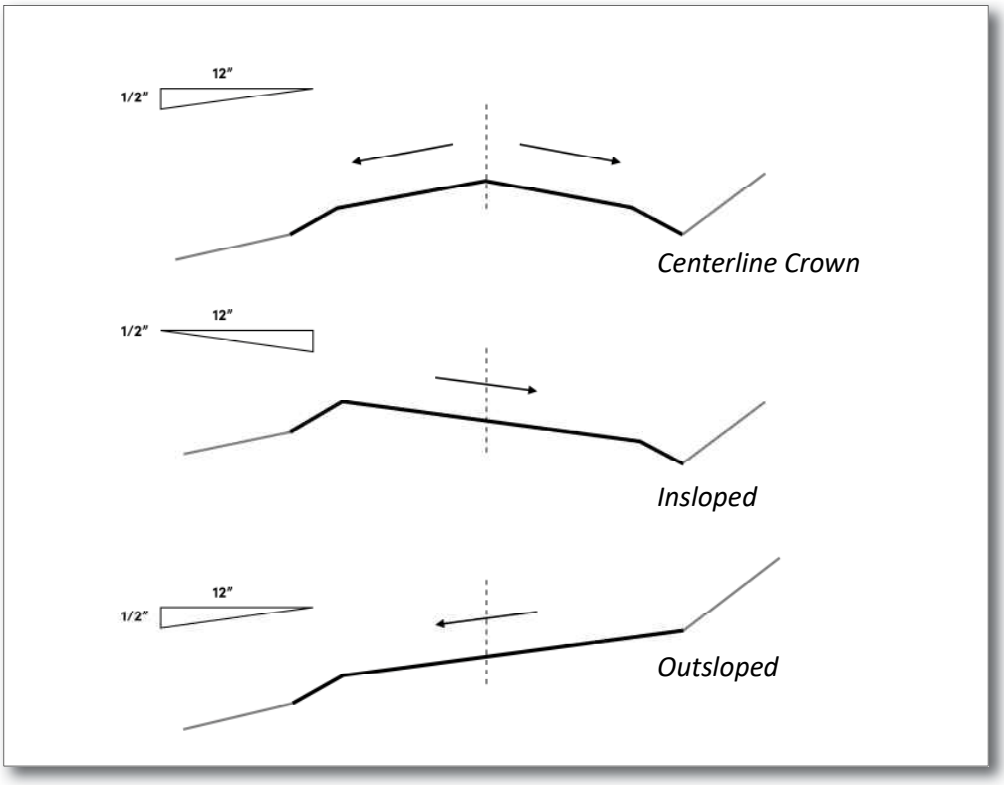
» Vibratory roller

» Slope board (slope confirmation)

Maintenance

» Regrade after winter plowing season and in summer when needed.

» Remove any berm left on the roadside from grading and plowing to allow proper road drainage.



This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

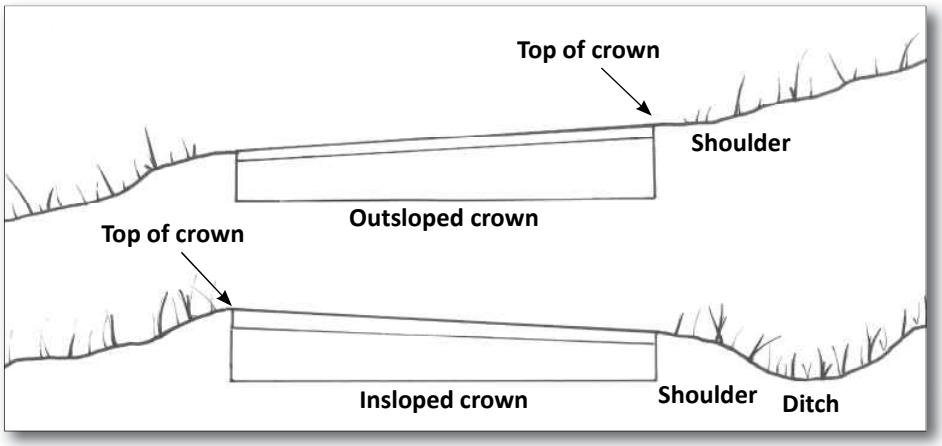
CROSS-SLOPE CROWN

Road Type

All road types

BMP Function

Road surface drainage



Road cross-section: Outsloped road may eliminate the need for ditches on low-traffic roads with minimal downslope banks. Insloped road funnels all runoff into the ditch.

Description and Purpose

» A continuous slope across the width of the road with the highest point on one side of the road.

» There are two types of cross-slope: an outsloped road tilts with the slope of the bank and an insloped road tilts into the slope of the bank.

» Proper crowning of the road surface is essential for efficient drainage of water, either into roadside ditches or as dispersed (evenly distributed) flow off of the road shoulder.

» Cross-slope is also known as superelevation or bank.

Criteria for Use and Site Considerations

» Outslope: Consider on low-traffic, low-speed roads with minimal downslope banks to reduce concentrated flow of water from stormwater drainage culvert outlets.

» Inslope: Consider when a steep downslope bank exists where the downslope shoulder is prone to erosion; this also improves the safety of vehicles traveling in the outside lane.

Benefits

» Can provide additional control over drainage flow where needed.

» Reduces surface material loss.

» Reduces base saturation, improving stability.

» Improves drivability and ride quality.

» Lengthens the life of the road surface and reduces long term maintenance cost.

Planning and Design

» For inslope or outslope, grade a straight line from one shoulder to the other that rises approximately a half inch per foot, or 4%.

CROSS-SLOPE CROWN

» Have a minimum of 100 feet of crown-shape transition between a centerline crown and cross-slope crown.

Material and Equipment

» Grader

» Scarifier

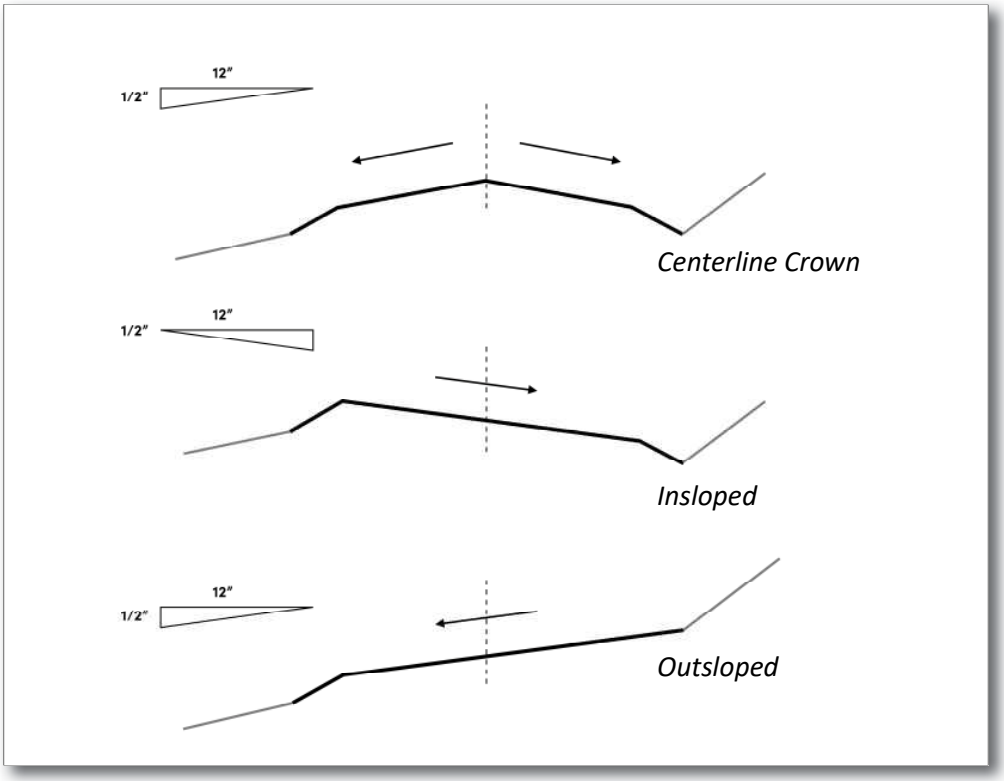
» Vibratory roller

» Slope board (slope confirmation)

Maintenance

» Insloping and outsloping sections of road are sometimes regraded when there is risk of vehicles sliding on ice, and re-established in the spring.

» Remove any grader berm left on the roadside from grading and plowing to allow proper road drainage.



This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

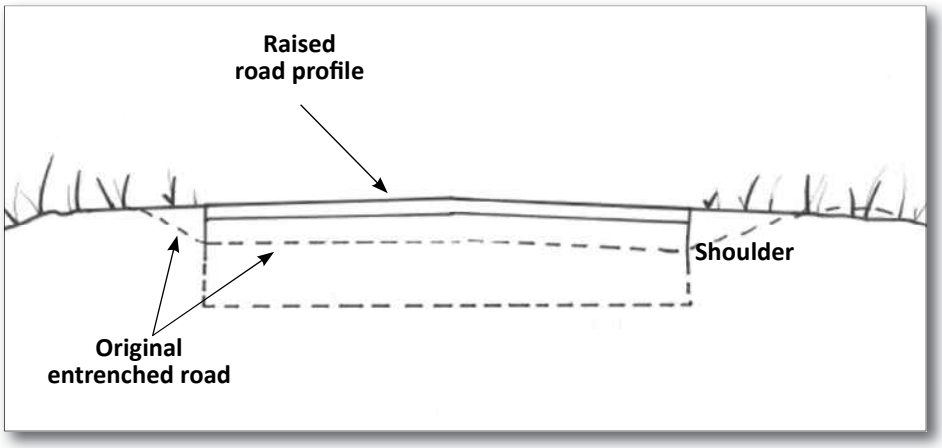
RAISE THE ROAD PROFILE

Road Type

Adjacent to wetland
Entrenched

BMP Function

Road surface drainage



Road cross-section: Filling in an entrenched road to the original elevation restores the ability for runoff to drain off the sides of the road. A ditch can then be added.

Description and Purpose

» The addition of fill and reconstruction of the road surface to the point where the road is at grade with or above the shoulder elevation.

» Allows water to drain naturally off of the road.

Criteria for Use and Site Considerations

» Consider using as soon as entrenchment has begun to occur, before the road is so entrenched that the road material required is cost prohibitive.

» Use adjacent to wetland to allow for drainage infrastructure to be properly installed below the road.

Benefits

» Prevents concentrated road drainage.

» Improves subsurface drainage.

» Increases potential for stormwater infiltration.

» Creates opportunity for drainage ditches.

» Stabilizes road banks.

» Improves motorist visibility.

Planning and Design

» Elevate the road enough so that drainage is restored to a natural condition, eliminating the need for a ditch on at least one side of the road.

» Add fill in 6 or 8 inch lifts.

» Allow time for settling of the subbase, if possible.

» Cap the new fill with proper road surface materials.

RAISE THE ROAD PROFILE

» Raising the road profile works well with the installation of a French mattress or geogrid in the case of a soft road base.

» If requiring fill, carefully select material that will not shift over time.

» Add proper specifications for subbase, surface aggregate and cross culverts as needed.

» Add moisture if needed.

Material and Equipment

» Dump truck

» Bulldozer

» Grader

» Vibratory roller

Maintenance

» Same as all unpaved roads.

In this series of photos from Pennsylvania, 3 feet of native shale was used to fill the road to an elevation where the roadside ditches were no longer necessary.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

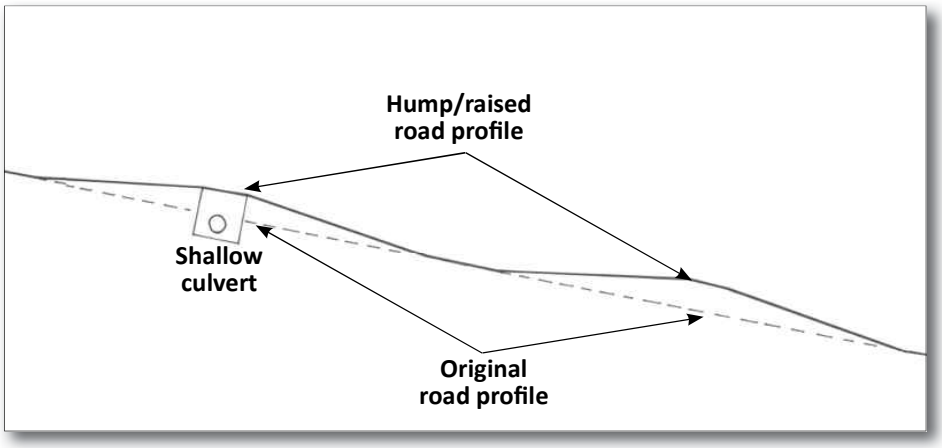
GRADE BREAK

Road Type

Steep grade
Steep private driveway

BMP Function

Road surface drainage



Road profile: A grade break helps shed all runoff on a road towards the shoulder and can provide necessary cover where shallow stormwater drainage culverts are desired or required.

Description and Purpose

» An intentional increase in road elevation (as in a hump), or a change in road grade to create an undulating road profile (rolling grade).

» Designed to reduce potential road-surface erosion by shortening the contributing drainage area and forcing water off the road surface. Water will no longer run down the slope of the road.

» Sheds water toward the shoulders and is not meant to carry concentrated flow across the road.

Criteria for Use and Site Considerations

» Use on infrequently maintained roads.

» Use on low-volume or low-speed roads.

» Use on gentle-to-moderate sloped roads (less than 10%).

» Use on sloping section of road where crown cannot be adequately maintained.

» Use before stream crossings to direct water into stable, vegetated areas.

» Use on side roads or private driveways that intersect the main road from upslope to reduce run-on flow.

The two grade breaks pictured here prevent water from flowing down the road.

Benefits

» Reduces surface material loss.

» Continues to shed water even when a proper crown is lost.

» Can provide necessary cover where shallow stormwater drainage culverts are desired or required.

» Inexpensive to install and maintain.

» Can calm traffic by naturally lowering driving speeds.

GRADE BREAK

Planning and Design

» Requires 40 to 60 tons of material to create; more on steeper roads or roads used by long vehicles.

» Multiple grade breaks may be used in succession to help prevent the buildup of erosive volume and velocity of runoff. Space 125 feet apart for road grades below 5%, space 150 feet apart for road grades 5.1% to 10%.

» When possible, locate grade breaks to align with existing high points/low points and turnouts.

» Use grade breaks in conjunction with stormwater drainage culverts. Grade breaks can be used to direct runoff into the pipe inlet while providing necessary pipe cover.

» Grade transitions to gradually taper up to grade break crest and back down to the roadway grade.

» Grade so as to not hinder traffic, yet still function to divert water off the roadway.

» Consider using signs after installation to notify road users of the grade breaks.

Material and Equipment

» Use ¾-inch dense graded crushed stone

» Bulldozer

» Grader

» Vibratory roller (compaction)

Maintenance

» Educate road crew about the grade break. Instruct grader operators on how to maintain the centerline crown through a grade break without eliminating the crown or the grade break. An un-informed operator can remove it in a single grading.

» Consider marking the ends of the grade break to alert maintenance crews where the grade break is located.

» Remove any grader berm left on the roadside from grading and plowing to allow proper road drainage.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

GRADE BREAK

CRITERIA FOR USE:

1. USE ON INFREQUENTLY MAINTAINED ROADS.
2. USE BEFORE STREAM CROSSING TO DIRECT WATER INTO VEGETATIVE FILTERS AND REDUCE HYDROLOGIC CONNECTIVITY.
3. USE ON ROADS WITH GENTLE-TO-MODERATE GRADES (LESS THAN 1V:10H, 10%).
4. USE ON LOW-VOLUME OR LOW-SPEED ROADS.
5. USE ON SLOPING SECTIONS OF ROAD WHERE CROWN CANNOT BE ADEQUATELY MAINTAINED.
6. USE JUST BEFORE ROAD GRADIENT CHANGES IN ORDER TO SHED WATER OFF OF SURFACE BEFORE IT ENTERS A STEEP SECTION.
7. USE ON SIDE ROADS OR PRIVATE DRIVEWAYS UP-GRADIENT OF INTERSECTIONS WITH THE MAIN ROAD TO REDUCE RUN-ON FLOW

DESIGN CONSIDERATIONS:

1. CONSIDER USING SIGNS AFTER INSTALLATION TO NOTIFY ROAD USERS OF THE GRADE BREAKS.
2. EDUCATE TOWN/CITY ROAD CREW ABOUT THE GRADE BREAK. AN UNINFORMED OPERATOR CAN REMOVE IT IN A SINGLE GRADING.
3. CONSIDER MARKING THE ENDS OF THE GRADE BREAK TO ALERT MAINTENANCE CREWS TO WHERE THE GRADE BREAK IS LOCATED.
4. DESIGN CONSIDERATIONS:
   - 4.1. MULTIPLE GRADE BREAKS MAY BE USED IN SUCCESSION TO HELP PREVENT THE BUILDUP OF EROSIVE VOLUME AND VELOCITY. TYPICAL GRADE BREAK SPACING SHALL BE AS FOLLOWS:

ROAD GRADE	SPACING
≤ 5% (1V:20H)	125 FEET
5.1% TO 10% (1V:10H)	100 FEET

   - 4.2. LOCATION OF GRADE BREAKS SHALL BE INFLUENCED BY SITE CHARACTERISTICS, SUCH AS AVAILABLE OUTLETS AND CURVES.
   - 4.3. USE GRADE BREAKS IN CONJUNCTION WITH DRAINAGE CULVERTS. GRADE BREAKS CAN BE USED TO DIRECT RUNOFF INTO THE PIPE INLET WHILE PROVIDING NECESSARY PIPE COVER.
   - 4.4. TRANSITIONS SHALL BE GRADED TO GRADUALLY TAPER UP TO GRADE BREAK CREST AND BACK DOWN TO THE ROAD GRADE. TRANSITION SHALL BE GRADED AS TO NOT HINDER TRAFFIC, YET STILL FUNCTION TO DIVERT WATER OFF THE ROAD.

CONSTRUCTION SPECIFICATIONS:

1. STONE: ¾" DENSE GRADED CRUSHED STONE MEETING MassDOT SPECIFICATIONS FOR DENSE GRADED CRUSHED STONE FOR SUB-BASE (M2.01.7)

CONSTRUCTION SEQUENCING:

1. CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. LOCATE AND MARK OUT THE SITE FOR EACH GRADE BREAK.
3. PLACE AND SHAPE GRADE BREAK WITH APPROPRIATE TRANSITIONS.
4. GRADER OPERATOR SHALL BE INSTRUCTED TO MAINTAIN THE CROWN OF THE ROAD THROUGH THE GRADE BREAK DURING SHAPING OPERATION.

OPERATION AND MAINTENANCE:

1. GRADE BREAKS SHALL BE INSPECTED IN THE SPRINGTIME AFTER THE WINTER SEASON AND PERIODICALLY FOLLOWING HEAVY RAIN EVENTS.
2. GRADE BREAKS SHALL BE REESTABLISHED BY A GRADER OPERATOR WHO SHALL MAINTAIN THE CROWN OF THE ROAD THROUGH THE GRADE BREAK. ADDITIONAL MATERIAL SHALL BE BROUGHT ONTO THE SITE TO REESTABLISH THE GRADE BREAK AS NECESSARY.

CONSTRUCTION COSTS:

CONSTRUCTION COST OF GRADE BREAK WILL VARY DEPENDING ON SIZE OF GRADE BREAK AND WIDTH OF ROAD. FOR A STANDARD GRADE BREAK WITH TWO 12' WIDE TRAVEL LANES AND 2' SHOULDERS, THE TYPICAL COST IS $6,600.

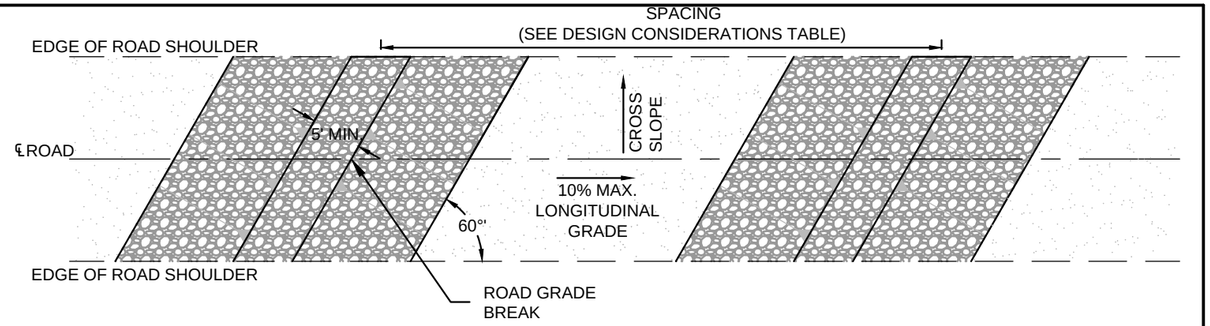
STONE: $90.00/C.Y.

EXCAVATION: $40.00/C.Y.

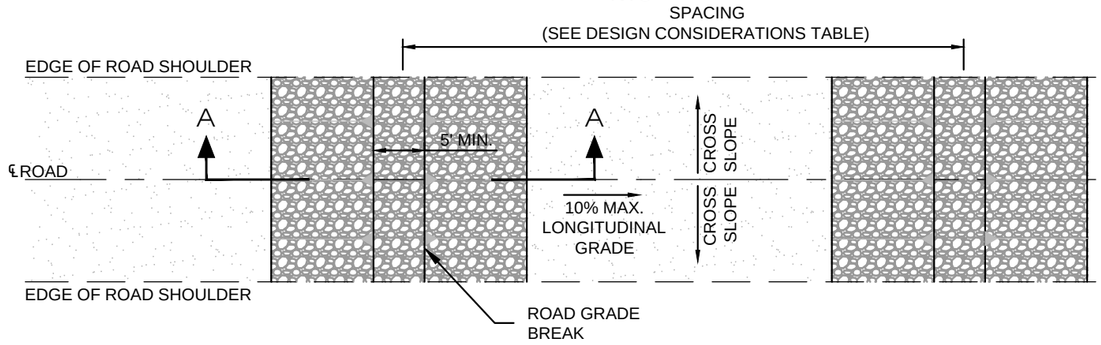
NOTES:
1. 2024 UNIT PRICES SHOWN. CONSTRUCTION COSTS FREQUENTLY VARY.

LIMITATIONS:

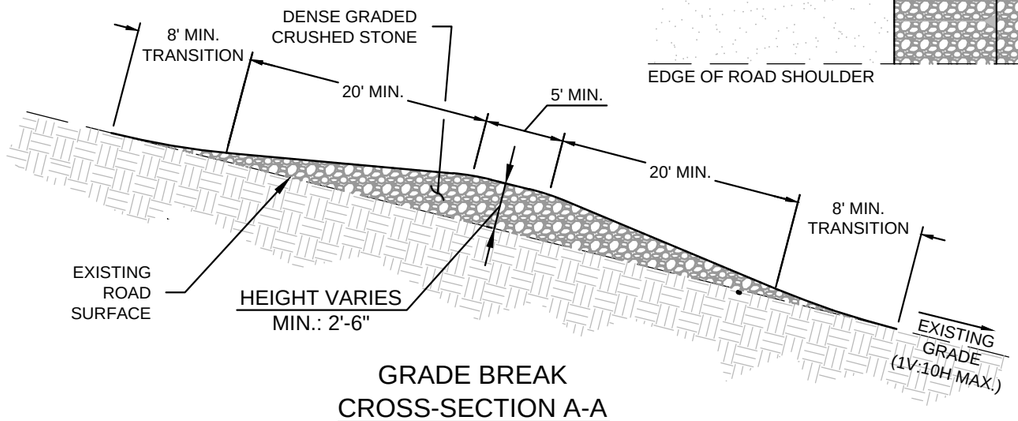
1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.



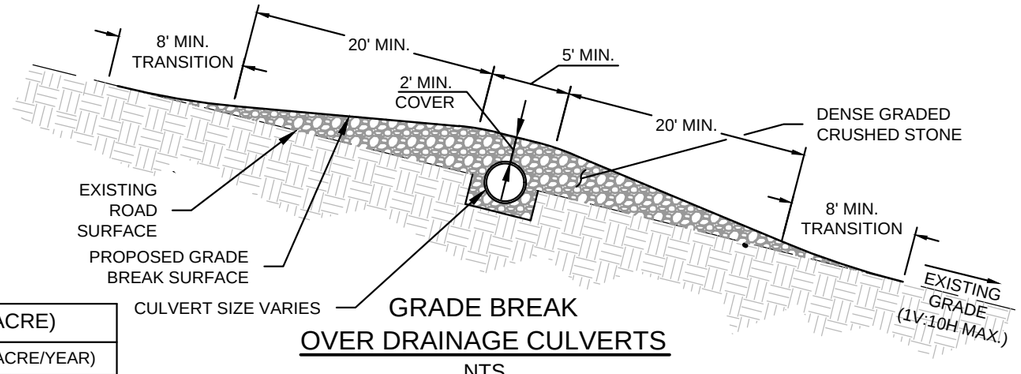
GRADE BREAK W/ CROSS SLOPE
PLAN VIEW
NTS



GRADE BREAK W/ CROWN
PLAN VIEW
NTS



GRADE BREAK
CROSS-SECTION A-A
NTS



GRADE BREAK
OVER DRAINAGE CULVERTS
NTS

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)						
GRADE BREAK	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
	44.3	50.6	0.1	0.3	0.2	2.1

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

GRADE BREAK

PREPARED BY:	REVISED BY:	PREPARED FOR:	
GZA	BSC GROUP	frcog	
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. -	FIGURE GB-1

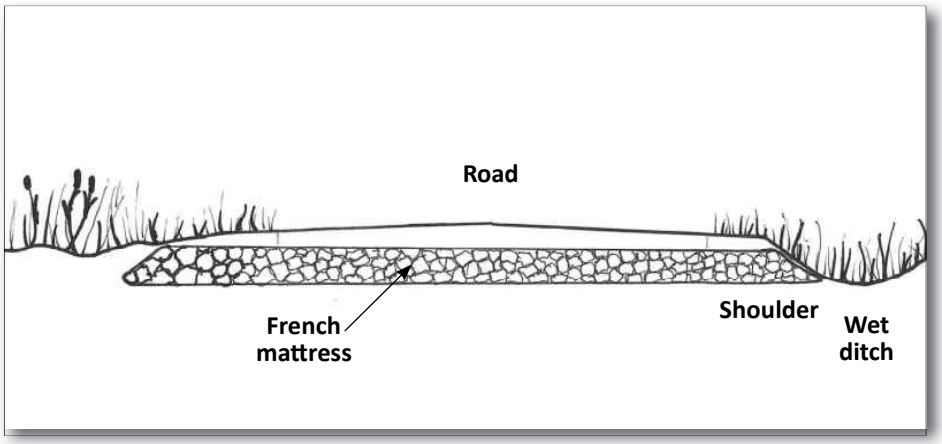
FRENCH MATTRESS

Road Type

Adjacent to wetland
Entrenched

BMP Function

Conveyance



Road cross-section: A French mattress, also known as a rock sandwich, allows water to pass underneath the road from one wet area to another.

Description and Purpose

» A structure under a road consisting of clean course rock wrapped in geotextile through which water can freely pass (can be bi-directional).

» Supports the roadbed and stabilizes the road base in areas where the road is weakened by water saturation, particularly in mud season.

Criteria for Use and Site Considerations

» Use in areas where seeps and springs result in road base saturation.

» Use in areas where low-gradient road ditches result in road base saturation.

» Use in areas where the road lays over soils with a high water table, such as near wetlands.

A small French mattress under construction.

Benefits

» Improves subsurface drainage.

» Reduces concentrated flows.

» Maintains some floodplain connectivity through a roadway.

» Suitable for wetland situations where a traditional pipe may lower the wetland water level.

» Unlike culverts, effectively reduces damming by beavers.

» Mattress size is flexible—small mattresses can be used for springs, larger mattresses can be used for large areas of saturated soils.

» Long service life.

FRENCH MATTRESS

Planning and Design

» Can be built anytime, but may be planned in conjunction with other roadwork.

» Mattresses are not suitable replacements for stormwater drainage culverts, or anywhere concentrated overland flow carries sediment; these types of flows will clog the mattress over time and should always be handled by drainage culverts.

» Mattress size is flexible, but the length should extend at least two feet beyond the driving surface of the road and should be a minimum of 4 feet wide.

» Smaller mattress size allows roadside springs to bleed through the road base while maintaining road stability. Larger mattress size creates a stable foundation for the road through an area of soft wet soils.

» Cover mattress with a minimum of 12 inches of compacted roadway material.

» Construct the mattress to be level end to end with the road alignment. Cross-slope should conform with the existing road grade.

» Mattress should provide unrestricted flow through the road. In wetland situations, the side slope may be flat or minimal. In sloped areas, a 1 to 2% fall from inlet to outlet will aid drainage.

» Mattress must be free draining at the outlet to avoid ponding water beneath.

» When placed under a raised road profile and the mattress will be above the surrounding elevation, geotextile fabric should wrap on four sides, leaving the inlet and outlet free.

» When the existing road grade is to be preserved and the mattress will be below ground, the geotextile fabric should wrap on all six sides to prevent sediment from clogging the riprap.

» Geotextile fabric joints should overlap by a minimum of 4 feet.

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» MassDOT specifications for 3 – 4-inch clean crushed stone

» Dump truck

» Excavator or backhoe

» Hand tools

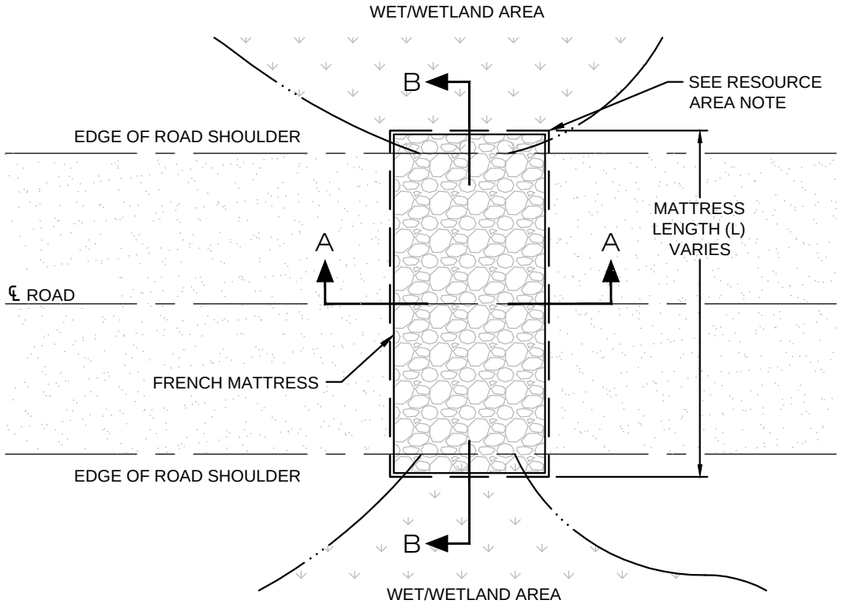
» Grader

» Vibratory roller

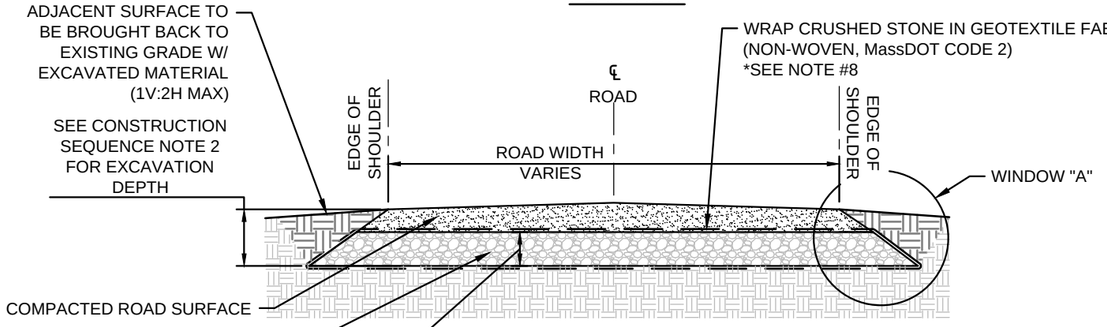
Maintenance

» None

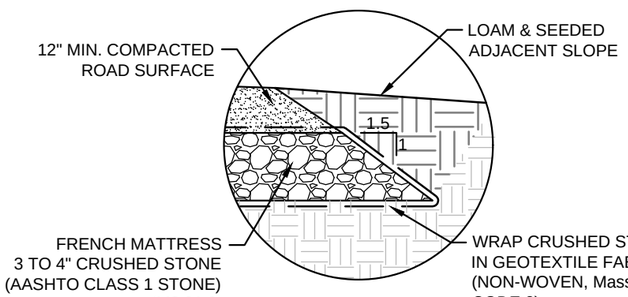
This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***



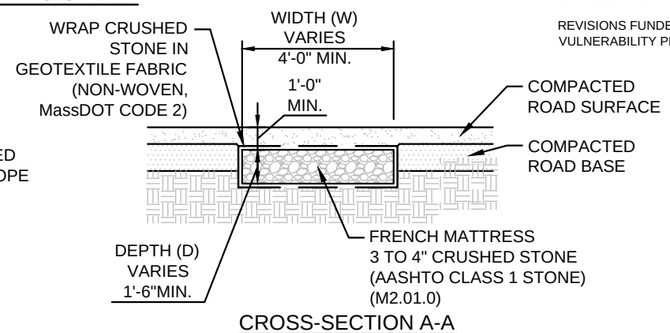
PLAN VIEW



CROSS-SECTION B-B
ROAD AT EXISTING GRADE



WINDOW "A"



CROSS-SECTION A-A

FRENCH MATTRESS

NTS

FRENCH MATTRESS

CRITERIA FOR USE:

1. AREAS WHERE ROADSIDE SPRINGS AND LOW GRADIENT ROAD DITCHES RESULT IN ROAD BASE SATURATION.
2. AREAS WHERE SPRINGS UNDER THE ROAD SATURATE THE ROAD BASE OR COME TO THE SURFACE OF THE ROAD.
3. AREAS WHERE THE ROAD LAYS OVER SOILS WITH A HIGH WATER TABLE, SUCH AS WETLANDS.

DESIGN CONSIDERATIONS:

1. MATTRESS ARE NOT SUITABLE REPLACEMENTS FOR ROAD DRAINAGE PIPES, OR ANYWHERE CONCENTRATED OVERLAND FLOW CARRIES SEDIMENT.
2. MATTRESS SIZE IS FLEXIBLE. SMALLER MATTRESS ALLOWS ROADSIDE SPRINGS TO BLEED THROUGH THE ROAD BASE WHILE MAINTAINING ROAD STABILITY. LARGER MATTRESS CREATES A STABLE FOUNDATION FOR THE ROAD THROUGH AN AREA OF SOFT WET SOILS.
3. MATTRESS SHOULD BE COVERED BY A MINIMUM OF 12 INCHES OF COMPACTED ROAD MATERIAL.
4. MATTRESS CROSS-SLOPE SHOULD CONFORM WITH THE EXISTING ROAD GRADE.
5. MATTRESS SHOULD PROVIDE UNRESTRICTED FLOW THROUGH THE ROAD. IN WETLAND SITUATIONS, THE SIDE SLOPE MAY BE FLAT OR MINIMAL. IN SLOPED AREAS A 1- TO 2% FALL FROM INLET TO OUTLET WILL AID DRAINAGE.
6. MATTRESS MUST BE FREE DRAINING AT THE OUTLET TO AVOID PONDING WATER BENEATH THE ROAD.
7. GEOTEXTILE FABRIC JOINTS SHALL BE OVERLAPPED A MINIMUM OF 2 FEET.
8. GEOTEXTILE FABRIC SHALL BE WRAPPED ON FOUR SIDES OF THE FRENCH MATTRESS WHEN DESIGNED WITH A RAISED ROAD PROFILE. FOR A FRENCH MATTRESS WHERE THE ROAD SURFACE IS AT EXISTING GRADE, THE GEOTEXTILE FABRIC SHALL BE WRAPPED ON ALL SIX SIDES.
9. NO ROUTINE MAINTENANCE REQUIRED

CONSTRUCTION SPECIFICATIONS:

1. CRUSHED STONE: FRENCH MATTRESS SHALL CONSIST OF 3" TO 4" CLEAN CRUSHED STONE. STONE SHALL MEET REQUIREMENTS OF M2.01.0 OF MassDOT STANDARD SPECIFICATIONS OR AASHTO CLASS 1 STONE
2. GEOTEXTILE FABRIC: GEOTEXTILE FABRIC SHALL BE A NON-WOVEN GEOTEXTILE FABRIC CLASSIFIED AS CODE 2 FABRIC ON MassDOT QUALIFIED CONSTRUCTION MATERIALS LIST.

RESOURCE AREA NOTE:

- WORK WITHIN 100 FT OF A REGULATORY WETLAND RESOURCE AREA AND 200 FT FROM A STREAM/RIVER MAY REQUIRE LOCAL AND/OR STATE WETLAND PERMITTING

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

CONSTRUCTION SEQUENCING:

1. CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. EXCAVATE THE AREA TO THE DESIRED DEPTH AND SLOPE (MIN. 2½ FT) TO ALLOW FOR A MINIMUM OF 12 INCHES OF COMPACTED ROAD MATERIAL OVER THE MATTRESS.
3. PLACE GEOTEXTILE FABRIC IN THE EXCAVATED TRENCH. ALLOW ENOUGH FABRIC ON THE ENDS TO OVERLAP THE TOP PIECE OF GEOTEXTILE FABRIC OVER THE FINISHED MATTRESS. GEOTEXTILE FABRIC TO BE OVERLAPPED A MINIMUM OF 2 FEET.
4. PLACE POROUS 3 TO 4" CRUSHED STONE ON TOP OF GEOTEXTILE FABRIC AND SPREAD INTO A UNIFORM BED OF DESIRED DEPTH (MIN. 18 INCH).
5. PLACE GEOTEXTILE FABRIC OVERTOP OF THE INSTALLED STONE. OVERLAP ALL FABRIC JOINTS A MINIMUM OF 12 INCHES.
6. PLACE ROAD MATERIAL COVER ON TOP OF MATTRESS, SHAPE AND COMPACT (MINIMUM OF 12 INCHES OF MATERIAL).

CONSTRUCTION COSTS:

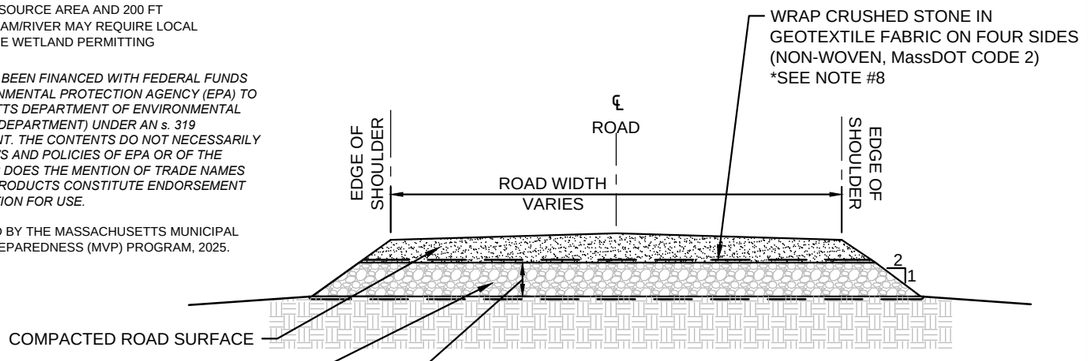
QUANTITY OF STONE = (1CY/27CF)(W' X D' X L')
QUANTITY OF GEOTEXTILE FABRIC = (2(W')+2(D')+2')X(2(D')+L'+2')X1SY/9SF

PRICE OF EXCAVATION:	$40.00/CY[1]
PRICE OF STONE:	$65.00/CY[1]
PRICE OF GEOTEXTILE FARBIC:	$3.00/SY[1]

NOTE: 2024 CONSTRUCTION DOLLARS. CONSTRUCTION PRICES FREQUENTLY VARY.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.



CROSS-SECTION B-B
RAISED ROAD PROFILE

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)						
	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
FRENCH MATTRESS	LOW	HIGH	LOW	HIGH	LOW	HIGH
	50.6	56.9	0.2	0.3	0.9	2.0

FRENCH MATTRESS

PREPARED BY:	REVISED BY:	PREPARED FOR:	
GZA	BSC GROUP	frcog	
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. -	FIGURE FM-1

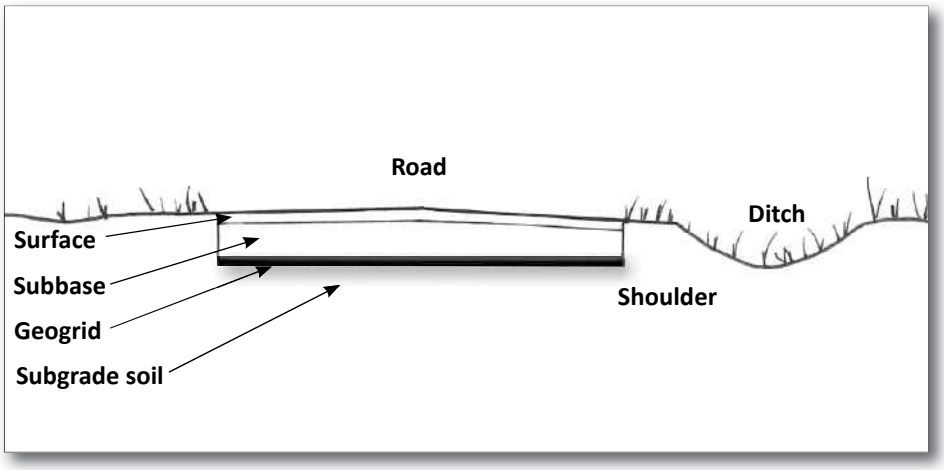
GEOGRID

Road Type

Adjacent to stream
Adjacent to wetland
Entrenched

BMP Function

Stabilization
Infiltration



Road cross section: Geogrid is a polymer gridded mat installed between the road subgrade and subbase to stabilize a wet or unstable road.

Description and Purpose

» A grid mat made of polymer material with large regular-sized openings.

» Stabilizes the road by separating and preventing the base course aggregate from migrating sideways or sinking into the subgrade soils.

Criteria for Use and Site Considerations

» Can be used at any site, but benefits are most obvious on unstable roads resulting from wet subbase.

Benefits

» Reduces rutting and other issues found on roads with wet subbase.

» On soft ground, distributes vehicle loads more widely, improving the effective bearing capacity.

» On firm ground, confines aggregate particles, interlocking itself with the fill materials, which will reduce the breakdown of the aggregate layer over time.

» Extends the service life of a road.

» Can be a solution to roads with heavy vehicle traffic that are not a candidate for paving.

Planning and Design

» Overlap ends of geogrid based on strength of subgrade: 3 – 4 feet when subgrade soils are soft, 1 – 2 feet when subgrade soils are strong.

» Gravel subbase should be at least 18 inches deep.

» Mesh size should be chosen based on the stability requirements of the road. Smaller mesh size is required for more stability.

GEOGRID

Material and Equipment

» Geogrid (for selection, refer to product specifications provided by manufacturer)

» Excavator or backhoe

» Dump truck

» Bulldozer

» Grader

» Vibratory roller

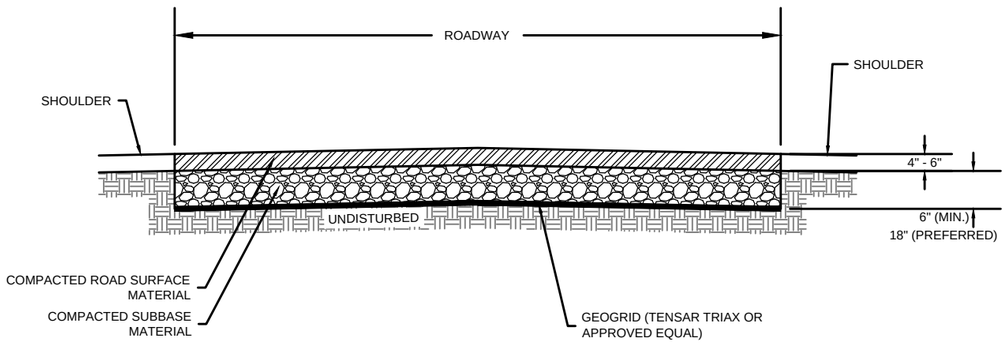
Maintenance

» Inspect road to ensure proper cover over geogrid is maintained.

Geogrid being laid on a wet section of road in early winter.

Project funded by the Massachusetts Municipal Vulnerability Preparedness (MVP) Program, 2025.

GEOGRID



CRITERIA FOR USE:

1. GEOGRID CAN BE USED TO IMPROVE COMPACTION OF SUBGRADE IN A ROADWAY PROFILE AND EXTEND THE SERVICE LIFE OF THAT ROADWAY.
2. GEOGRID IS USED TO AID ROADWAY STABILIZATION ISSUES.

DESIGN CONSIDERATIONS:

1. COMPACTED SUBBASE MATERIAL SHALL BE A MINIMUM OF 6" AND PREFERABLY, 18" OR MORE IN DEPTH.
2. WHEN CONSTRUCTED OVER SOFT GROUND, GEOGRID WILL DISTRIBUTE APPLIED LOADS MORE WIDELY, IMPROVING THE SUBGRADE SOIL'S EFFECTIVE BEARING CAPACITY.
3. WHEN CONSTRUCTED OVER FIRMER GROUND, GEOGRID WILL CONFINE AGGREGATE PARTICLES, INTERLOCKING ITSELF WITH THE FILL MATERIALS WHICH WILL REDUCE THE BREAKDOWN OF THE AGGREGATE LAYER OVERTIME.
4. GEOGRID OVERLAP VARIES DEPENDING ON THE STRENGTH OF THE SUBGRADE. FOR LOCATIONS WHERE THE SUBGRADE IS SOFTER, OVERLAPPING OF GEOGRID SHALL BE BETWEEN 3 AND 4 FT. WHEN THE SUDBGRADE IS STRONGER, THE REQUIRED OVERLAP SHALL BE BETWEEN 1 AND 2 FT.
5. THE PREFERRED GRADATION FOR PAVED BASED REINFORCEMENT APPLICATIONS IF WELL-GRADED CRUSHED AGGREGATE FILL WITH A MAXIMUM PARTICLE SIZE OF 1.5" AND LESS THAN 10% FINES. SEE TABLE.
6. FOR UNPAVED SUBGRADE IMPROVEMENT APPLICATIONS, ANY CLEAN GRANULAR FILL MAY BE ACCEPTABLE.
7. MESH SIZING SHOULD BE CHOSEN BASED ON THE STABILITY REQUIREMENTS OF THE ROADWAY. LOCATIONS WHICH REQUIRE MORE STABILITY SHALL USE GEOGRID WITH A SMALLER MESH SIZE. LARGER MESH SIZES CAN BE USED WHEN LESS STABILITY IS REQUIRED.

PREFERRED FILL GRADATION	
SIZE	% PASSING
1 1/2"	100
3/4"	50-100
#4	25-50
#40	10-20
#100	5-15
#200	LESS THAN 10

CONSTRUCTION SPECIFICATIONS:

1. GEOGRID

   THE PROPERTIES SHALL BE IN ACCORDANCE WITH ASTM D4759-02.
   REFER TO PRODUCT SPECIFICATION PROVIDED BY GEOGRID MANUFACTURER.

CONSTRUCTION SEQUENCING:

1. CONTACT DIG SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK,
2. CLEAR & GRUB & EXCAVATE (IF NECESSARY) TO THE DESIGN SUBGRADE ELEVATION.
3. REMOVE AND REPLACE ANY UNSUITABLE MATERIALS FOUND.
4. PLACE THE GEOGRID OVER THE PREPARED SURFACE IN THE DIRECTION OF TRAVEL.
5. ANCHOR THE BEGINNING, CENTER, AND THE CORNERS OF THE ROLL WITH SMALL PIECES OF AGGREGATE BEFORE FULLY UNROLLING.
6. ONCE GEOGRID IS TIGHTENED AND ALIGNED IN PLACE, AGGREGATE MAY BE DUMPED DIRECTLY ONTO GEOGRID. COMPACT AGGREGATE FILL ACCORDING TO GUIDANCE PROVIDED IN "COMPACTION OF ROAD AFTER GRADING" SECTION OF THE UNPAVED STORMWATER MANAGEMENT TOOLKIT.

OPERATION AND MAINTENANCE:

1. ROADWAY SHOULD BE INSPECTED TO ENSURE PROPER COVER OVER GEOGRID IS MAINTAINED. REFER TO "PROPER ROAD STRUCTURE" GUIDANCE PROVIDED IN TOOL 7 OF THE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT.

CONSTRUCTION COST:

UNIT COSTS:

EXCAVATION -	$40.00/CY
GEOGRID -	$15.00/SY

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OR UNPAVED ROADS, AND REDUCE SEDIMENTATION ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE THE LIMITS PRESENTED.

NOTE:
PROJECT FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

GEOGRID

PREPARED BY:	PREPARED FOR:
BSC GROUP BUILD | SUPPORT | CONNECT	frcog

DATE:	REVISION NO.	FIGURE
APRIL 2025	-	G-1

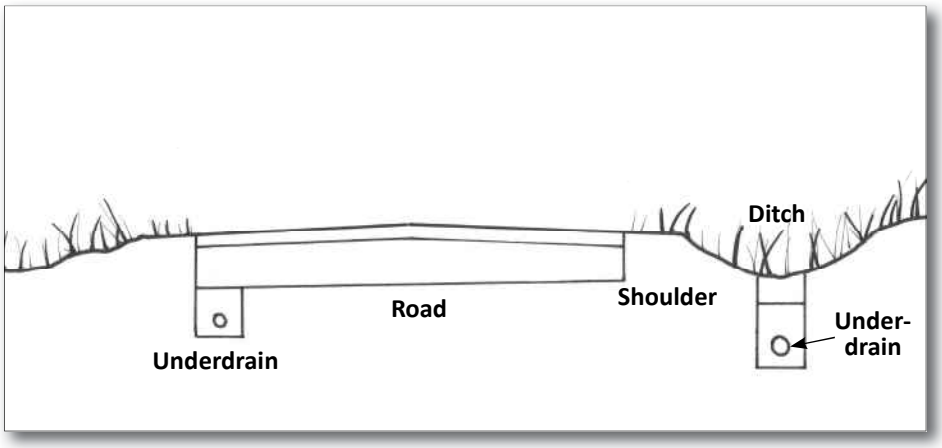
UNDERDRAIN

Road Type

Steep bank slope
Adjacent to stream
Adjacent to wetland
Entrenched

BMP Function

Conveyance



Road cross-section: Underdrain under road (left) and under ditch (right).

Description and Purpose

» A pre-fabricated perforated pipe installed under the drainage ditch or road shoulder in a bed of clean washed stone wrapped in geotextile fabric that allows water, particularly groundwater, to drain quickly through the pipe.

» Stabilizes soft road base, roadside ditches, and banks.

Underdrain under construction.

Criteria for Use and Site Considerations

» Use in areas where road ditches have standing water or active flow due to springs and seeps in the road or adjacent banks.

» Use in areas where the cut bank or road shoulder is unstable and frequently fails due to bank springs or a saturated ditch.

» Use in areas where subsurface water is suspected of causing stability problems in the road.

» Use in areas where road shoulders are wet, soft, and rutting.

Underdrain outlet with crush resistant drain pipe, animal guard to prevent clogging, and large rocks and posts to keep vehicles from damaging the pipe.

Benefits

» Improves subsurface drainage.

» Prevents subsurface water from mixing with sediment-laden surface runoff.

» Can be sized to handle site-specific flow volumes.

» Inexpensive and easy to install.

» Long service life.

UNDERDRAIN

Planning and Design

» Do not direct road surface runoff into an underdrain. Underdrains are meant to collect clean water from spring or seeps or to drain the subbase. Sediment and debris carried in surface runoff will clog the underdrain and make it nonfunctional.

» Install at an adequate slope to ensure proper drainage, at least 1% slope.

» Typical underdrain pipe size is 6 inches in diameter. Consider using a larger diameter pipe (12-inch diameter) if the length between outlets of underdrain is long (>300 feet) or the slope is under 1%.

» Install a minimum 2-foot-wide trench for perforated pipes under 12-inch diameter. For perforated pipe sizes over 12-inch diameter, install a trench with the minimum width of the diameter of the pipe plus 6 inches on each side of the pipe.

» Install trench deep enough for a minimum of 22 inches of stone below the pipe and 3 inches of stone above the pipe.

» Install a minimum of 12 inches of cover over the wrapped fabric structure to protect the integrity of the underdrain and prevent damage to the geotextile wrap.

» Do not use fine soils, such as clay, for cover directly above the drain.

» If possible, outlet underdrain separately from road drainage to keep it from mixing with sediment-laden stormwater runoff and to minimize the volume of concentrated flow.

» For long stretches of underdrain, consider installing an access point for flushing the pipe.

» Where outlet is exposed, consider installing animal guard to prevent small animals from nesting in the pipe during no-flow conditions and clogging.

Material and Equipment

» Minimum 4-inch-diameter perforated pipe, 6 inches is preferable

» MassDOT specifications for ½-inch or ¾-inch crushed stone

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» Dump truck

» Excavator or backhoe

Maintenance

» Check outlets for indication of blocked flow; flush if possible.

» Check animal guards if installed.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

UNDERDRAIN

CRITERIA FOR USE:

1. AREAS WHERE THERE ARE SPRINGS OR SEEPS IN THE ROAD OR IN THE ROAD DITCH.
2. WHERE ROAD DITCHES HAVE STANDING WATER OR ACTIVE FLOW DUE TO SPRINGS AND SEEPS.
3. WHERE THE CUT BANK IS UNSTABLE AND FREQUENTLY FAILS DUE TO BANK SPRINGS OR A SATURATED TOE.
4. WHERE SUBSURFACE WATER IS SUSPECTED OF CAUSING STABILITY PROBLEMS IN THE ROAD.

DESIGN CONSIDERATIONS:

1. SURFACE WATERS:
   - 1.1. ROAD SURFACE DRAINAGE SHOULD NOT BE DIRECTED INTO AN UNDERDRAIN. UNDERDRAINS ARE MEANT TO COLLECT CLEAN SPRING OR SEEPS, AND DRAIN THE SUBBASE. SEDIMENT AND DEBRIS CARRIED IN SURFACE RUNOFF WILL CLOG THE UNDERDRAIN AND MAKE IT NONFUNCTIONAL.
2. SLOPE:
   - 2.1. UNDERDRAINS SHOULD BE INSTALLED AT AN ADEQUATE SLOPE TO ENSURE PROPER DRAINAGE. AT LEAST A 1% (1V: 100H) SLOPE.
3. PIPE SIZE:
   - 3.1. TYPICAL UNDER DRAIN PIPE SIZE IS 6" DIA. CONSIDER USING A LARGER DIAMETER PIPE (12" DIA.) IF THE DISTANCE BETWEEN OUTLETS OF UNDERDRAIN IS LONG (300') OR THE SLOPE IS UNDER 1% (1V:100H).
4. TRENCH:
   - 4.1. TRENCH WIDTH:
     - 4.1.1. PIPE DIAMETER UNDER 12 INCHES: UNDERDRAIN TRENCH SHALL BE A MINIMUM OF 2 FEET IN WIDTH WHEN THE DIAMETER OF THE PERFORATED PIPE IS UNDER 12 INCHES.
     - 4.1.2. PIPE DIAMETER OVER 12 INCHES: UNDERDRAIN TRENCH SHALL BE A MINIMUM WIDTH OF THE DIAMETER OF THE PIPE PLUS 6 INCHES ON EACH SIDE OF THE PIPE.
   - 4.2. TRENCH DEPTH:
     - 4.2.1. UNDERDRAIN TRENCH SHALL BE DEEP ENOUGH TO PROVIDE A MINIMUM OF 2 INCHES OF BEDDING FOR THE PIPE AND A MINIMUM OF 3 INCHES OF STONE ABOVE THE PIPE. RECOMMEND 12 INCHES OF STONE ABOVE THE PIPE.
5. COVER:
   - 5.1. THE COVER OVER THE UNDERDRAIN SHALL PROTECT THE INTEGRITY OF THE UNDERDRAIN AND PREVENT DAMAGE TO THE GEOTEXTILE WRAP. COVER SHALL ALSO PROTECT PIPE FROM THE WEIGHT OF TRAFFIC. THE COVER OVER THE PIPE SHALL MEET THE REQUIREMENTS OF THE MANUFACTURER OR SHALL BE 12" AT A MINIMUM. DO NOT USE FINE SOILS, SUCH AS CLAY, FOR COVER DIRECTLY ABOVE THE DRAIN.
6. OUTLETS:
   - 6.1. IF PRACTICABLE, OUTLET UNDERDRAINS SEPARATELY FROM SURFACE DRAINAGE.
   - 6.2. IF THE OUTLET PIPE IS VULNERABLE TO CRUSHING OR EQUIPMENT DAMAGE AT THE SURFACE OUTLET, CONSIDER ENDING THE DRAIN WITH A SHORT PIECE OF HEAVIER CRUSH RESISTANT PIPE.
   - 6.3. WHERE OUTLET IS EXPOSED, CONSIDER INSTALLING ANIMAL GUARDS TO PREVENT CLOGGING.
   - 6.4. IF NO STRUCTURE IS TO BE PLACED AT THE ENDS OF THE UNDERDRAIN, THE UNDERDRAIN TRENCH SHALL BE EXTENDED A DISTANCE OF 3 FEET BEYOND THE STRUCTURE END OF THE PIPE AND FILLED WITH STONE.
7. MAINTENANCE
   - 7.1. FOR LONG STRETCHES OF UNDERDRAIN, RISERS SHOULD BE CONSIDERED FOR CLEANOUT ACCESS POINTS.
   - 7.2. UNDER DRAINS THAT DAYLIGHT AT THE OUTLET SHOULD BE DESIGNED WITH ANIMAL GUARDS TO PREVENT ANIMALS FROM ENTERING THE PIPE. A SWING GATE OR A SCREEN MESH CAN BE USED AS AN ANIMAL GUARD. THE MINIMUM SIZE FOR A SCREEN MESH IS 1-INCH.

CONSTRUCTION SPECIFICATIONS:

1. CRUSHED STONE: STONE FOR UNDERDRAIN SHALL MEET MASSDOT SPECIFICATIONS FOR ½ INCH (M2.01.5) OR ¾ INCH (M2.01.4) CRUSHED STONE.
2. GEOTEXTILE FABRIC: GEOTEXTILE FABRIC SHALL BE A NON-WOVEN GEOTEXTILE FABRIC CLASSIFIED AS CLASS 2 FABRIC ON MassDOT QUALIFIED CONSTRUCTION MATERIALS LIST.
3. UNDERDRAIN PIPE: PIPE USED FOR UNDERDRAIN SHALL BE SLOT PERFORATED CORRUGATED PLASTIC PIPE. PIPE SHALL MEET MassDOT MATERIAL SPECIFICATION M5.03.9. MINIMUM PIPE SIZE SHALL BE 4 INCHES. TYPICAL PERFORATED PIPE SIZE IS 6 INCHES.
4. INLET & OUTLET PROTECTION: INLET AND OUTLET SHALL BE COVERED WITH A #23 GAUGE GALVANIZED WIRE SCREEN OF ¼ INCH MESH SATISFACTORILY FASTENED TO THE PIPE.

CONSTRUCTION SEQUENCING:

1. CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. UNDERDRAIN SHALL BE INSTALLED IN ACCORDANCE WITH SUBSECTION 260 OF THE 2025 MassDOT STANDARD SPECIFICATIONS FOR HIGHWAYS AND BRIDGES. SEQUENCE SHALL BE AS FOLLOWS:
   - 2.3. UNDERDRAIN TRENCH SHALL BE EXCAVATED TO THE DEPTH REQUIRED TO PROVIDE ADEQUATE COVER OF THE UNDERDRAIN OR TO A STRATUM OF IMPERVIOUS MATERIAL. TRENCH SHALL BE EXTENDED 3 FEET PAST END OF UNDERDRAIN WHERE NO OUTLET STRUCTURE IS PROPOSED.
   - 2.4. GEOTEXTILE FILTER FABRIC SHALL BE PLACED ALONG THE SIDES AND BOTTOM OF THE TRENCH. ENOUGH FABRIC SHALL BE LEFT TO LAY OVER THE TOP OF THE STONE ONCE TRENCH IS BACKFILLED. OVERLAP BETWEEN ANY ADJOINING PIECES OF FABRIC SHALL BE AT LEAST 2 FEET.
   - 2.5. PLACE PERFORATED PIPE IN THE CENTER OF THE TRENCH ON A BED OF 2 INCHES OF CRUSHED STONE.
   - 2.6. INSTALL OUTLET STRUCTURE AND INLET AND OUTLET WIRE SCREEN.
   - 2.7. FILL TRENCH, AND 3 FEET BEYOND THE END OF PIPE WITH CRUSHED STONE IF NO OUTLET STRUCTURE IS TO BE USED. CHINK STONE AROUND PERFORATED PIPE.
   - 2.8. BRING TRENCH TO FINISH GRADE. MINIMUM 12" OF COVER.

CONSTRUCTION COSTS:

COST PER LINEAR FOOT OF SUBDRAIN WILL VARY DEPENDING ON SIZE OF PERFORATED PIPE. CONSTRUCTION COST FOR TYPICAL UNDERDRAIN INSTALLED IS $75.00/L.F.

STONE:	$112.00/C.Y.
GEOTEXTILE FABRIC:	$10.00/S.Y.
PERFORATED PIPE:	PRICE VARIES PER PIPE DIAMETER

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

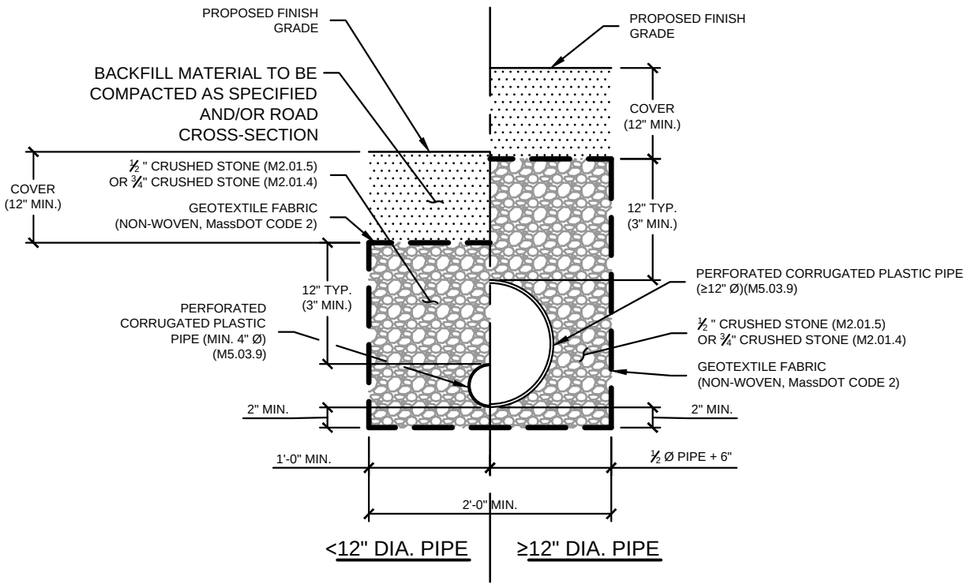
OPERATIONS AND MAINTENANCE:

1. INSPECT UNDERDRAINS BIANNUALLY AND AFTER MAJOR STORM EVENTS TO ENURE WATER IS FLOWING FREELY.
2. IN CASES WHERE THE UNDERDRAIN'S OUTLET IS DAYLIT, INSPECT THE OUTLET FOR ANY BLOCKAGES. UNDERDRAIN SHALL BE FLUSHED IF ANY BLOCKAGES ARE FOUND

LIMITATIONS:

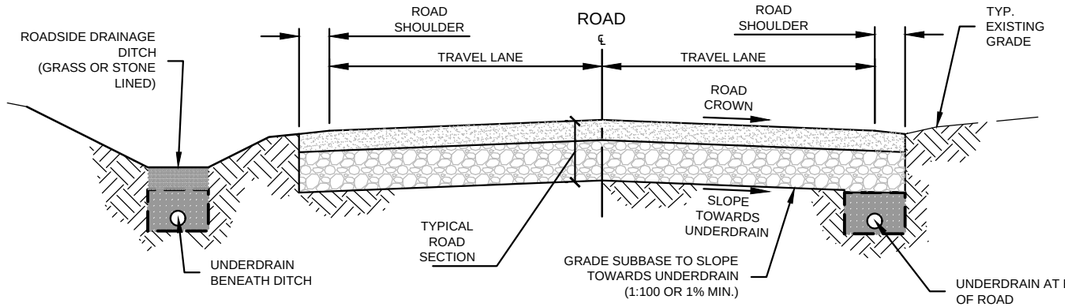
1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)						
	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
UNDERDRAIN	LOW	HIGH	LOW	HIGH	LOW	HIGH
	38.0	50.6	0.1	0.2	0.5	1.9



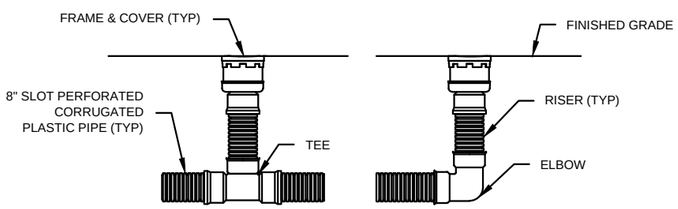
UNDERDRAIN CROSS-SECTION DETAIL

NTS



TYPICAL UNDERDRAIN LOCATION ALONG ROAD

NTS



RISER INSTALLATION OPTIONS

NTS

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

UNDERDRAIN			
PREPARED BY: GZA	REVISED BY: BSC GROUP	PREPARED FOR: frcog	
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. -	FIGURE UD-1

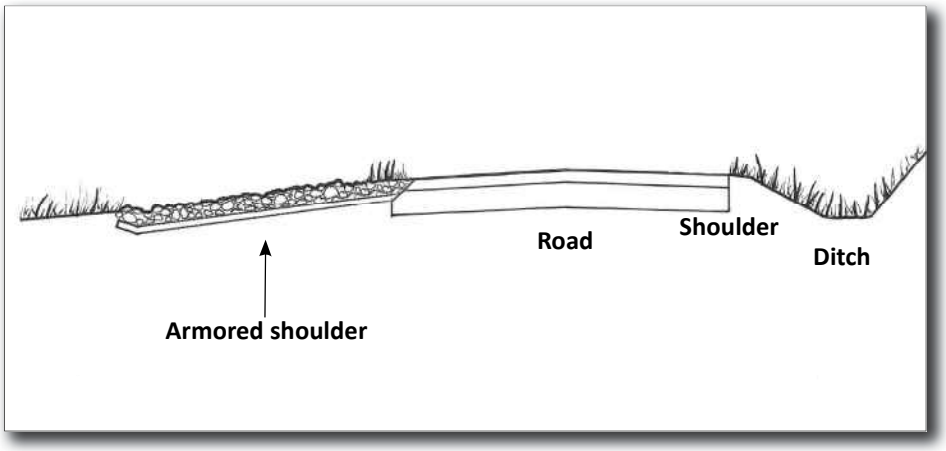
ARMORED SHOULDER

Road Type

Steep bank slope
Stream crossing

BMP Function

Velocity Control
Stabilization
Infiltration



Road cross-section: Armored shoulder downslope from road to stabilize shoulder and protect nearby waterbody. Pay attention to wetland regulations and distance from waterbodies.

Description and Purpose

» Stone placed along the road shoulder to prevent erosion where there is dispersed runoff flow down steep slopes.

» Prevents bank slides and erosion on adjacent slopes when grading, seeding, and other mechanical techniques cannot be implemented.

Criteria for Use and Site Considerations

» Use where steepness of slope causes shoulder and bank stabilization issues.

» Use where springs or seeps are causing shoulder and bank stabilization issues.

» Use where vegetation does not adequately check erosion and filter sediment.

» Use on outer edge of curving road experiencing instability.

» Use on shoulders with slopes less than 1.5H:1V (66%). Stabilization for steeper slopes should be designed by a professional engineer.

Benefits

» Road subbase is reinforced immediately below the road surface.

» Road shoulder will not erode during heavy rains.

Planning and Design

» Can be built anytime.

» Can be used with centerline or cross-sloped crown.

» Riprap size will be determined by the slope of the shoulder.

» Use angular stone riprap, not rounded stone.

» Install riprap armor thickness at 1.5 x maximum rock size.

» Install riprap armor on geotextile fabric and a bed of ¾-inch crushed stone.

ARMORED SHOULDER

» Where riprap armor is keyed in under the road shoulder and driving surface, cover with 6 inches of road surface material.

» Consider planting among the riprap to add stability, attractiveness, and habitat value.

» Pay attention to wetland regulations and distance from waterbodies. Any road work within 200 feet of a waterbody may trigger wetlands regulations.

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» Angular riprap stone as follows:
- For slope ≥2H:1V (≤ 50% slope), follow MassDOT specifications for dumped riprap
- For slopes 1.5H:1V (66% slope), follow MassDOT specifications for riprap

» ¾-inch crushed stone for bedding

» Live stakes (optional)

» Excavator or backhoe

Maintenance

» Inspect yearly and after large storms for any erosion or sliding of riprap material.

» Trim vegetation if needed and remove any invasive vegetative species growing within the riprap armor.

» Repair any damage that occurs to the shoulder while removing vegetation.

» Remove any grader berm left on the roadside from grading and plowing to allow proper road drainage.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

ARMORED SHOULDER

CRITERIA FOR USE:

1. ARMORED SHOULDERS SHOULD BE USED AS A SOLUTION TO PREVENT BANK SLIDES ON ADJACENT SLOPES TO THE ROAD WHEN GRADING, SEEDING AND OTHER MECHANICAL TECHNIQUES CANNOT BE IMPLEMENTED.
2. ARMORED SHOULDERS SHOULD BE USED WHERE VEGETATION DOES NOT ADEQUATELY CHECK EROSION AND FILTER SEDIMENT.
3. ARMORED SHOULDERS SHOULD BE USED WHERE THERE IS INSUFFICIENT AREA TO INSTALL BANK BENCHES OR INTERCEPTOR DITCHES TO REDUCE EROSION ALONG ROAD SHOULDER.
4. ARMORED SHOULDERS SHOULD BE USED WHERE THE ROAD SHOULDER BANK ENCOUNTERS WEEPING/SEEPAGE OF GROUNDWATER OUT OF THE SLOPE.
5. ARMORED SHOULDERS SHOULD BE USED ON SHOULDERS WITH SLOPES >1.5H:1V. STABILIZATION FOR STEEPER SLOPES SHOULD BE DESIGNED BY A PROFESSIONAL ENGINEER REGISTERED IN THE COMMONWEALTH OF MASSACHUSETTS.

DESIGN CONSIDERATIONS:

1. RIPRAP SIZE SHALL BE DETERMINED BY THE SLOPE OF THE SHOULDER.
2. RIRAP SHALL BE ANGULAR STONE, ROUNDED STONE SHOULD NOT BE USED.
3. STONE ARMOR THICKNESS SHALL BE AS FOLLOWS: 1.5 X MAX. ROCK SIZE = ARMOR THICKNESS. RIPRAP ON 1.5H:1V SHALL BE MIN. 18" THICK. DUMPED RIPRAP ON ≥2H:1V SHALL BE MIN. 24" THICK.
4. CONSIDER PLANTING AMONG THE RIPRAP TO ADD STABILITY, ATTRACTIVENESS AND HABITAT VALUE.
5. STONE ARMOR SHALL BE UNDERLAIN BY GEOTEXTILE FABRIC AND A BED OF ¾" CRUSHED STONE (6" MIN. DEPTH).

CONSTRUCTION SPECIFICATIONS:

1. STONE:
   - 1.1. RIPRAP:
     - FOR SLOPE ≥2H:1V - STONE SHALL MEET MassDOT SPECIFICATIONS FOR DUMPED RIPRAP (M2.02.2)
     - FOR SLOPES 1.5H:1V - STONE SHALL MEET MassDOT SPECIFICATIONS FOR RIPRAP (M2.02.0)
     - STONE SHALL HAVE A D_{50}=12 INCHES AND MEET THE MassDOT SPECIFICATIONS FOR MODIFIED ROCKFILL (M2.02.4).
   - 1.2. CRUSHED STONE:
     - CRUSHED STONE FOR BEDDING SHALL MEET THE MassDOT SPECIFICATIONS FOR ¾" CRUSHED STONE (M2.01.4)
2. GEOTEXTILE FABRIC:
   - GEOTEXTILE FABRIC SHALL BE A NON-WOVEN GEOTEXTILE FABRIC CLASSIFIED AS CLASS 2 FABRIC ON MassDOT QUALIFIED CONSTRUCTION MATERIAL LIST (QCML).

CONSTRUCTION SEQUENCING:

1. CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. CLEAR & GRUB ROAD SHOULDER WHERE ARMORING IS TO BE PLACED.
3. EXCAVATE SHOULDER TO DEPTH AND REQUIRED SLOPE.
4. INSTALL GEOTEXTILE FABRIC OVER SHOULDER AND PLACE ¾" CRUSHED STONE BED.
5. DUMP RIPRAP MATERIAL WITH THE USE OF MACHINERY, BEGINNING AT THE BOTTOM OF SHOULDER SLOPE, WORKING UPSLOPE TO THE TOP IF SLOPE IS GREATER THAN 2H:1V. HAND CHINK RIPRAP MATERIAL TO FORM A STABLE UNIFORMED SURFACE.
6. WHERE SLOPE IS 1.5H:1V TO 2H:1V, PLACE RIPRAP BY MACHINERY OR HAND, BEGINNING AT THE BOTTOM AND WORKING UPSLOPE. CHINK RIPRAP MATERIAL TO FORM A STABLE UNIFORMED SURFACE.
7. INSERT LIVE STAKES WHILE PLACING RIPRAP ONTO SHOULDER SLOPE IF UTILIZED.

OPERATION AND MAINTENANCE:

1. INSPECT ARMORED SHOULDER YEARLY AND AFTER LARGE STORMS FOR ANY EROSION OR SLIDING OF RIPRAP MATERIAL.
2. TRIM VEGETATION GROWING, REMOVE ANY INVASIVE VEGETATIVE SPECIES WHICH MAY BE GROWING WITHIN THE RIPRAP ARMOR AND REPAIR ANY DAMAGE WHICH MAY OCCUR TO THE SHOULDER WHILE REMOVING VEGETATION.

CONSTRUCTION COSTS:

UNIT COSTS:

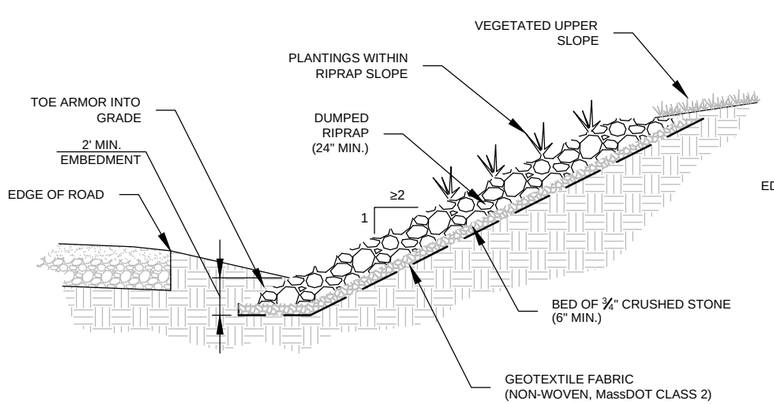
EXCAVATION -	$40.00/CY
STONE -	
¾" CRUSHED STONE -	$84.00/CY
RIPRAP -	$120.00/CY
DUMPED RIPRAP -	$135.00/CY
GEOTEXTILE FABRIC -	$3.00/SY
CLEARING & GRUBBING -	$60,000.00/AC
LIVE STAKES -	$100/LF

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

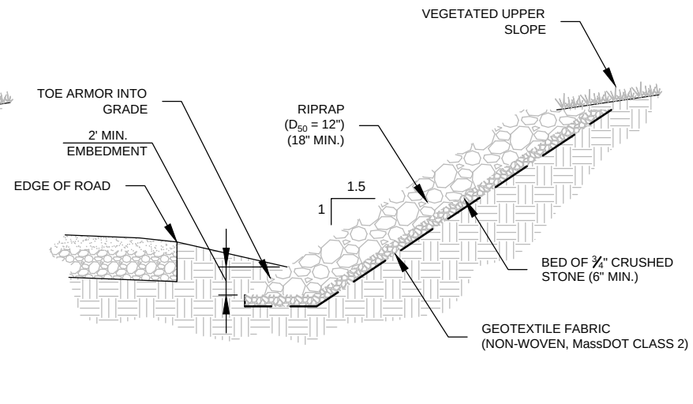
LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.

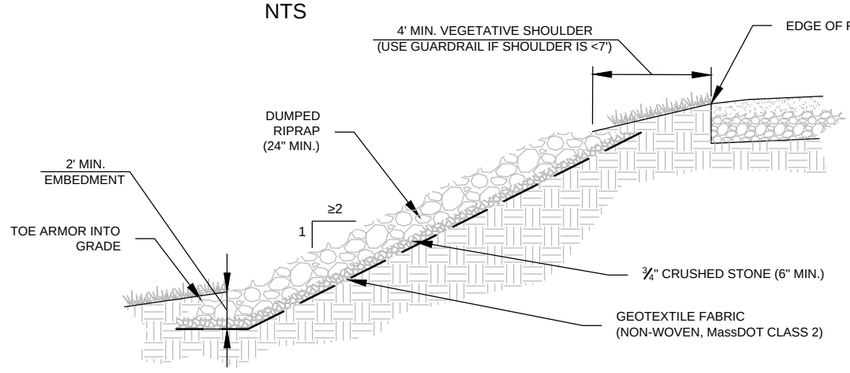
BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)						
ARMORED SHOULDER	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
	44.3	56.9	0.2	0.2	1.2	1.6



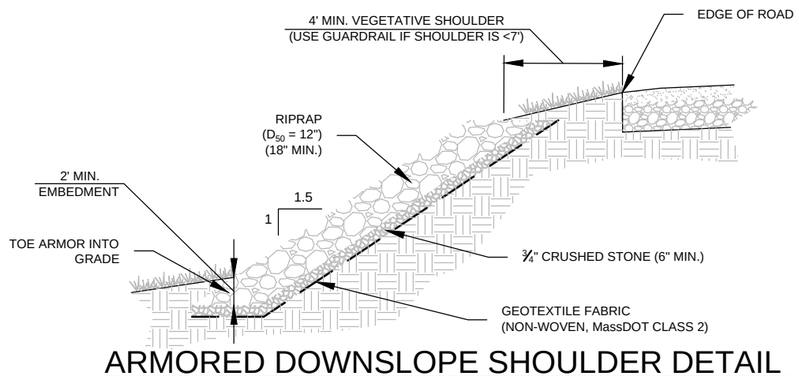
ARMORED UPSLOPE SHOULDER DETAIL
≥2H:1V SLOPE
NTS



ARMORED UPSLOPE SHOULDER DETAIL
1.5H:1V SLOPE
NTS



ARMORED DOWNSLOPE SHOULDER DETAIL
≥2H:1V SLOPE
NTS



ARMORED DOWNSLOPE SHOULDER DETAIL
1.5H:1V SLOPE
NTS

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

ARMORED SHOULDER			
PREPARED BY: GZA	REVISED BY: BSC GROUP	PREPARED FOR: frcog	
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. 1	FIGURE AS-1

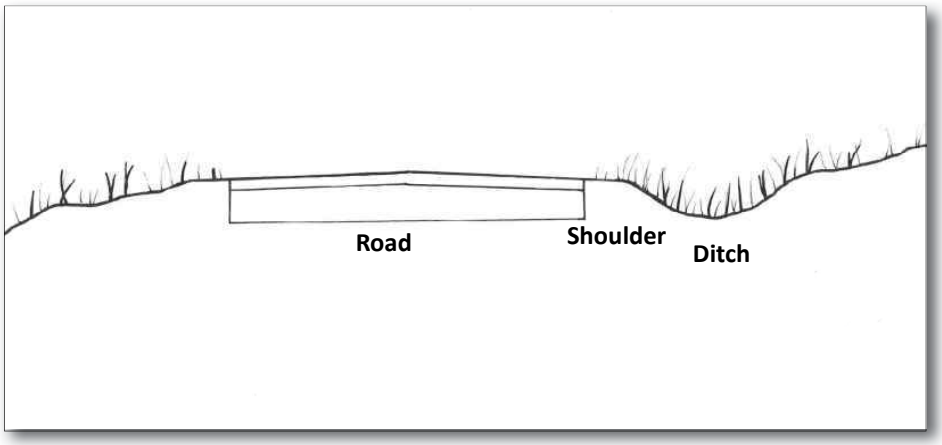
VEGETATED DITCH

Road Type

Steep bank slope
Stream crossing
Adjacent to stream
Adjacent to wetland
Steep private driveway
Entrenched

BMP Function

Stabilization
Infiltration
Conveyance



Road cross-section: All ditches should be thickly vegetated to hold soil in place, unless the ditch is steep enough that a stone-lined ditch is needed.

Description and Purpose

» Vegetated roadside trench that collects and carries surface runoff from roads, roadside banks, springs, or seeps in a controlled manner.

» Vegetation controls and slows the flow of runoff.

Criteria for Use and Site Considerations

» Install along any road where water cannot shed off the edge as dispersed flow and there is room for a ditch.

» Use for roads with a slope less than 5%. The addition of check dams is recommended for vegetated ditches between 5% and 8%.

» Grass mix should consist of native species that produce fine, uniform, and dense cover that can withstand variable moisture conditions. Consider wetland adapated species for ditches in areas of poorly drained soils.

» The ditch should not be dug below the water table. If this is not possible, more frequent stormwater drainage culverts, turnouts, or French mattresses will be needed.

Benefits

» Allows path of runoff to be controlled.

» Reduces erosion on travel lanes.

» Collects debris and allows sediment to settle out.

Ditch profiles

Proper ditch construction is considered to be trapezoidal or rounded (not square), at minimum 1 foot deep, 1 foot wide at the base, with maximum 2H:1V (50%) ditch side slopes or 3H:1V (33%) for roads with a speed limit of 40 MPH or higher.

Where there is plenty of space, consider 3-foot deep ditches for drainage. In cases where there is not enough space to construct the ideal ditch dimensions, the ditch shape can be asymmetrical.

VEGETATED DITCH

» Allows road subbase to drain.

Planning and Design

» Can be built anytime the ground is not frozen.

» Construct ditch with a U or parabolic shape; ditches with a V shape are not recommended.

» Ditch depth from road shoulder should be minimum 1 foot, ideally 2 to 3 feet for drainage.

» Construct ditch side slopes at a maximum 2H: 1V (50%); steeper side slopes are unstable and have a tendency to erode and collapse, creating maintenance problems.

» If possible, size ditch so that it is large enough to handle runoff from the contributing drainage area during a major storm, together with any contributions from uphill driveways or seeps and springs.

» Do not extend ditch depth below the groundwater table; if this is not possible, more frequent stormwater drainage culverts or French mattresses will be needed to drain the ditch.

» Runoff in the ditch should be turned out frequently (see Turnout BMP) or moved to the other side of the road (see Round Stormwater Drainage Culvert BMP) where it can drain.

» Seed ditch with seed mix appropriate for erosion control and wildlife habitat (see MassDOT guidance).

Material and Equipment

» Rubber-tire excavator with an articulated bucket (preferred)

» MassDOT specified loam and seed

Maintenance

» Inspect after major storm events for major obstructions, erosion, or collapsed banks.

» Remove sediment, leaves, and debris to prevent overflows and washouts.

» Preventing erosion from uphill slopes can lengthen the time needed between ditch cleanings.

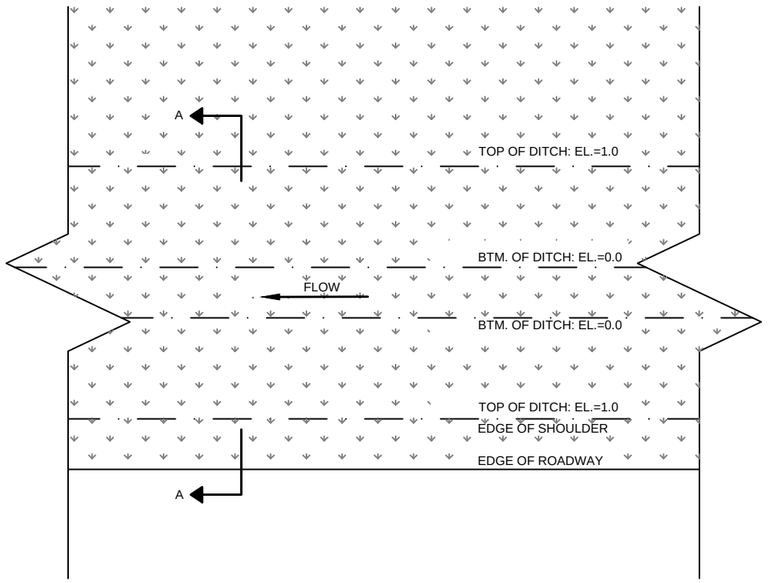
» Reseed as soon as possible after cleaning.

» Remove any grader berm left on the roadside from grading and plowing to allow proper road drainage.

Recommended ditch types by road grade

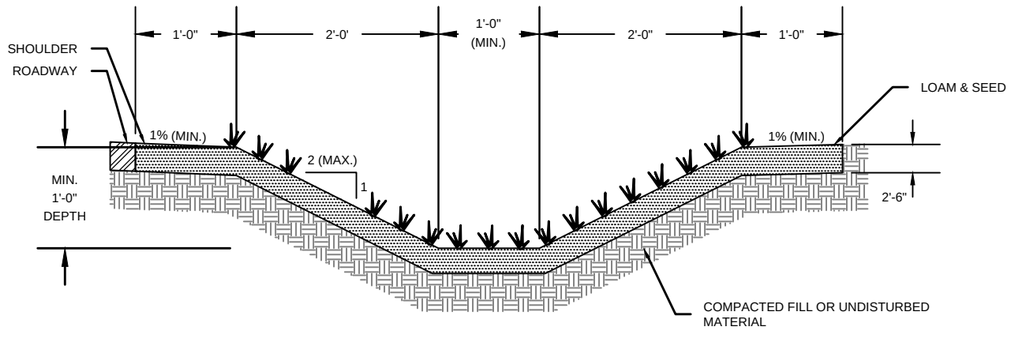
Grade	Ditch type
0 – 5%	Vegetated
5 – 8%	Vegetated with stone check dam
Greater than 8%	Stone-lined
As needed up to 10%	Stone-lined with stone check dam

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. *Revised with funding from MVP June 2025.*



TRAPEZOIDAL DITCH PLAN VIEW

NTS



CROSS-SECTION A - A

NTS

VEGETATED DRAINAGE DITCH

CRITERIA FOR USE:

1. VEGETATED DITCHES SHOULD BE INSTALLED ALONG ANY ROAD WHERE WATER CANNOT SHED OFF THE EDGE AS SHEET FLOW.
2. VEGETATED DITCHES SHOULD BE USED FOR ROADS WITH A SLOPE LESS THAN 5%. THE ADDITION OF CHECK DAMS ARE RECOMMENDED FOR SLOPES GREATER THAN 5%.
3. STONE-LINED DITCHES SHOULD BE USED FOR SLOPES REATER THAN 8%.

GRADE	DITCH TYPE
0 - 5%	VEGETATED
5 - 8%	VEGETATED WITH STONE CHECK DAM
GREATER THAN 8%	STONE-LINED
AS NEEDED	STONE-LINED WITH STONE CHECK DAM

DESIGN CONSIDERATIONS:

1. GRASS MIX SHOULD CONSIST OF SPECIES THAT PRODUCE FINE, UNIFORM AND DENSE COVER THAT CAN WITHSTAND PREVAILING MOISTURE CONDITIONS. CONSIDER WETLAND ADAPTED SPECIES FOR SWALES IN AREAS OF POORLY DRAINED SOILS).
2. CONSIDER THE USE OF GEOTEXTILE FABRIC TO STABILIZE SIDE SLOPES WHEN STEEPER THAN 3:1.
3. DO NOT EXTEND DITCH DEPTH BELOW THE GROUNDWATER TABLE; IF THIS IS NOT POSSIBLE, MORE FREQUENT STORMWATER DRAINAGE CULVERTS, TURNOUTS, OR FRENCH MATTRESSES WILL BE NEEDED.
4. RUNOFF IN THE DITCH SHOULD BE TURNED OUT FREQUENTLY (SEE TURNOUT BMP) OR MOVED TO THE OTHER SIDE OF THE ROAD (SEE ROUND STORMWATER DRAINAGE CULVERT BMP).
5. GEOTEXTILE FILTER FABRIC SHOULD BE CONSIDERED WHEN THE DITCH SIDE SLOPES ARE 2:1.

CONSTRUCTION SPECIFICATIONS:

1. LOAM

   LOAM FOR DITCH AND SHOULDERS SHALL MEET THE M1.05.0 MASSDOT SPECIFICATIONS.

2. SEED

   SEED MIXES FOR DITCH AND SHOULDERS SHALL MEET THE M6.03.0 MASSDOT SPECIFICATIONS.

CONSTRUCTION SEQUENCING:

1. CONTACT DIG SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK,
2. CLEAR & GRUB ROAD SHOULDER WHERE DITCH IS GOING TO BE LOCATED.
3. EXCAVATE SHOULDER TO DEPTH AND REQUIRED SLOPE.
4. AFTER DITCH HAS BEEN CLEARED AND EXCAVATED, LOAM AND SEED SIDE SLOPES AND BOTTOM.

OPERATION AND MAINTENANCE:

1. INSPECT AFTER MAJOR STORM EVENTS FOR MAJOR OBSTRUCTIONS, EROSION, OR COLLAPSED BANKS.
2. CLEAN DITCHES OUT WHEN THEY BECOME FILLED WITH SEDIMENT OR DEBRIS TO PREVENT OVERFLOWS AND WASHOUTS.
3. PREVENTING EROSION FROM UPHILL SLOPES CAN LENGTHEN THE TIME NEEDED BETWEEN DITCH CLEANINGS.
4. CLEAR AND REGRADE DITCH BEFORE SEDIMENT IS FILLED TO HALF THE HEIGHT OF THE DITCH AND RESEED AS SOON AS POSSIBLE.
5. VEGETATED DITCHES SHALL BE MOWED AT LEAST ONCE PER YEAR. THE GRASS SHALL BE CUT TO 3 OR 4 INCHES MINIMUM, AND SHALL NOT EXCEED 6 INCHES IN HEIGHT.

CONSTRUCTION COST:

UNIT COSTS:

EXCAVATION -	$40.00/CY
LOAM -	$90.00/CY
SEED -	$3.50/SY
GEOTEXTILE FABRIC -	$3.00/SY

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OR UNPAVED ROADS, AND REDUCE SEDIMENTATION ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE THE LIMITS PRESENTED.

NOTE:
PROJECT FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

VEGETATED DITCH

PREPARED BY: BSC GROUP BUILD | SUPPORT | CONNECT

PREPARED FOR: frcog

DATE:	REVISION NO.	FIGURE
APRIL 2025	-	VD-1

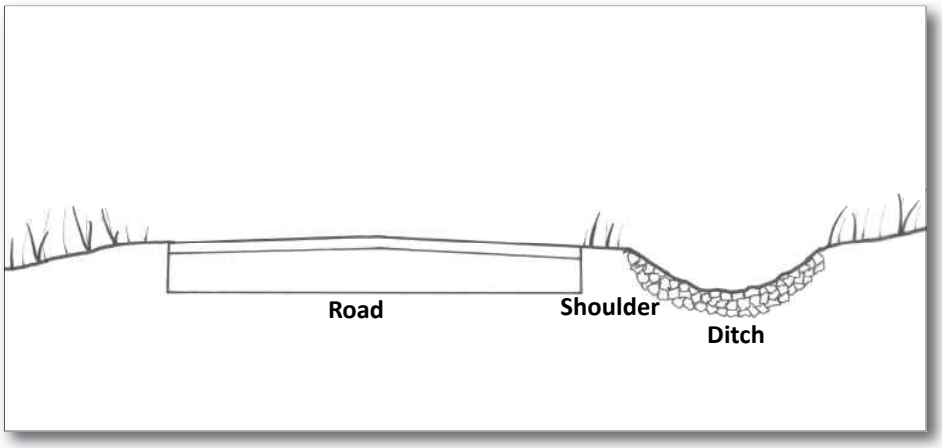
STONE-LINED DITCH

Road Type

Steep grade
Steep private driveway

BMP Function

Velocity Control
Stabilization
Infiltration
Conveyance



Road cross-section: Stone-lined ditches may be needed when the grade of the ditch is greater than 8%.

Description and Purpose

» Stone-lined roadside trench that collects and carries surface runoff from roads, roadside banks, springs, or seeps in a controlled manner.

» Controls and slows the flow of higher velocity road runoff.

Criteria for Use and Site Considerations

» Install along any road where water cannot shed off the edge as dispersed flow and there is room for a ditch.

» Use on steep stretches of roads (a slope greater than 8% or where stone check dams on vegetated ditches are not performing well).

A stone-lined ditch (left side of road) ends in a stone-lined turnout.

Benefits

» Prevents erosion in the ditch.

» Collects debris and allows sediment to settle out.

» Allows road subbase to drain.

Planning and Design

» Can be built anytime the ground is not frozen.

» Construct ditch with a U or parabolic shape; ditches with a V shape are not recommended.

» Ditch depth from road shoulder should be minimum 1 foot, ideally 2 to 3 feet for drainage.

» Construct ditch side slopes at a maximum 2H: 1V (50% slope); steeper side slopes are unstable and have a tendency to collapse, which erodes soil and creates maintenance problems.

» If possible, size ditch so that it is large enough to handle runoff from the contributing drainage area during a major storm, together with any contributions from uphill driveways or seeps and springs.

STONE-LINED DITCH

» Stone should be placed lower than the elevation of the shoulder so that water can flow from the road into the ditch and so that grading and other maintenance operations do not impact the stone lining.

» A minimum of 1 foot must be maintained from the top of the stone in the bottom of the ditch to the road shoulder. Do not fill the ditch with stone.

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» ¾-inch crushed stone for bedding

» Riprap:
- Road slopes 8 – 10%: 6 – 8-inch stone or the equivalent
- Road slopes greater than 10%: 12-inch minus stone, also referred to as stone fill
- Largest dimension of the stone can vary from 1 – 12 inches; at least 50% of the volume of the stone in-place should have a minimum dimension of 4 inches

» Dump truck

» Rubber-tire excavator with an articulated bucket (preferred)

» Skeleton bucket on an excavator to support separation of stone from sediment on-site

Maintenance

» Inspect and repair twice yearly at minimum for major obstructions, erosion, or collapsed banks. Prioritize fall and spring when plants are dormant and after major storm events.

» Remove sediment, leaves, and debris to prevent overflows and washouts.

» Preventing erosion from uphill slopes can lengthen the time needed between ditch cleanings.

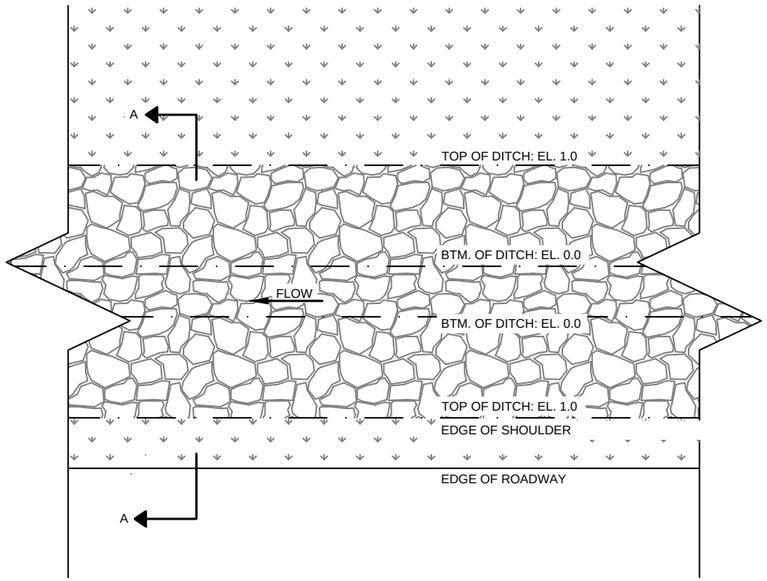
» Highway staff are understandably cautious about lining ditches with stone because the spaces between the stone will inevitably fill with silt. If a skeleton bucket is not available to clean the stone or replacement is not possible, an alternative is to scrape accumulated sediment off the top of the stone and add loam and seed it with a grass mix, maintaining the ditch as a vegetated ditch.

» Remove any grader berm left on the roadside from grading and plowing to allow proper road drainage.

Recommended ditch types by road grade

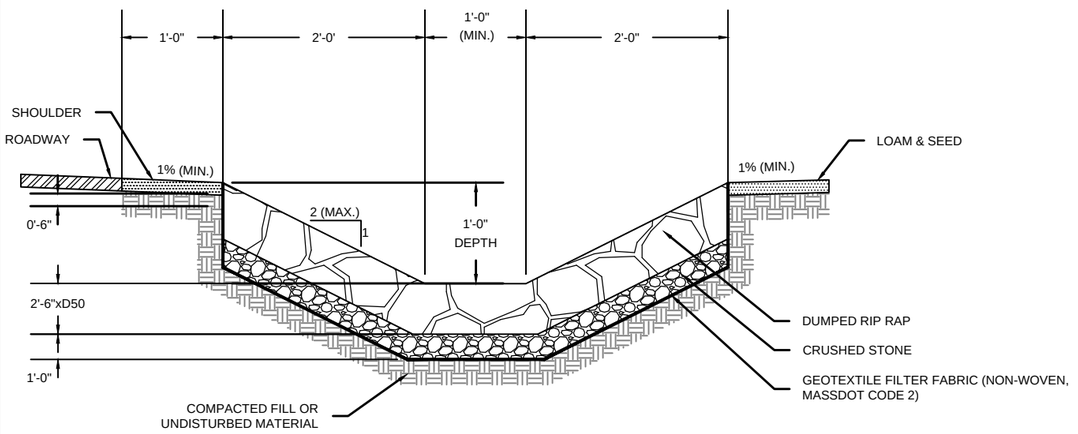
Grade	Ditch type
0 – 5%	Vegetated
5 – 8%	Vegetated with stone check dam
Greater than 8%	Stone-lined
As needed up to 10%	Stone-lined with stone check dam

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***



TRAPEZOIDAL DITCH PLAN VIEW

NTS



CROSS-SECTION A - A

NTS

STONE-LINED DRAINAGE DITCH

CRITERIA FOR USE:

1. STONE-LINED DITCHES SHOULD BE USED FOR ROADS WITH A SLOPE GREATER THAN 8% WHERE STONE CHECK DAMS ARE NOT PERFORMING WELL, WHERE WATER CANNOT SHED OFF THE EDGE AS SHEET FLOW.

DESIGN CONSIDERATIONS:

1. FOR ROAD SLOPES 8-10%, USE 6 - 8-INCH STONE OR THE EQUIVALENT. FOR ROAD SLOPES GREATER THAN 10%, USE 12-INCH MINUS STONE, ALSO REFERRED TO AS STONE FILL, TYPE 1 FOR DITCH LINING. THE LONGEST DIMENSION OF THE STONE CAN VARY FROM 1 - 12-INCHES , AND AT LEAST 50% OF THE VOLUME OF THE STONE IN-PLACE SHOULD HAVE MINIMUM DIMENSION OF 4-INCHES.
2. STONE SHOULD BE PLACED LOWER THAN THE ELEVATION OF THE SHOULDER SO THAT WATER CAN FLOW FROM THE ROAD INTO THE DITCH AND SO THAT GRADING AND OTHER MAINTENANCE OPERATIONS DON'T NEGATIVELY IMPACT STONE LINING.
3. DO NOT FILL DITCH WITH ROCKS, RUNOFF FLOWING OFF OF THE ROADWAY MUST BE ABLE TO FLOW FROM THE ROADWAY AND INTO THE DITCH.
4. A MINIMUM OF 1' MUST BE MAINTAINED FROM THE TOP OF STONE TO THE ROADWAY ELEVATION.

GRADE	DITCH TYPE
0 - 5%	VEGETATED
5 - 8%	VEGETATED WITH STONE CHECK DAM
GREATER THAN 8%	STONE-LINED
AS NEEDED	STONE-LINED WITH STONE CHECK DAM

CONSTRUCTION SPECIFICATIONS:

1. STONE
   - 1.1. DUMPED RIPRAP
     STONE SHALL MEET MASSDOT SPECIFICATIONS FOR DUMPED RIPRAP (M.02.2). FOR ROAD SLOPES 8-10%, 25 LB STONES SHALL BE USED. FOR ROAD SLOPES GREATER THAN 10%, 75 LB STONES SHALL BE USED (SEE TABLE M2.02.2-1 FOR GRADATION REQUIREMENTS).
   - 1.2. CRUSHED STONE
     CRUSHED STONE FOR BEDDING SHALL MEET THE MASSDOT SPECIFICATIONS FOR $\frac{3}{4}$" CRUSHED STONE (M2.01.4).
2. GEOTEXTILE FABRIC:
   GEOTEXTILE FABRIC SHALL BE A NON-WOVEN GEOTEXTILE FABRIC CLASSIFIED AS A CLASS 2 FABRIC ON MASSDOT QUALIFIED CONSTRUCTION MATERIALS LIST (QCML).

CONSTRUCTION SEQUENCING:

1. CONTACT DIG SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. CLEAR & GRUB ROAD SHOULDER WHERE DITCH IS GOING TO BE LOCATED.
3. EXCAVATE SHOULDER TO DEPTH AND REQUIRED SLOPE.
4. INSTALL GEOTEXTILE FABRIC INTO THE DITCH AND PLACE $\frac{3}{4}$" CRUSHED STONE BED.
5. DUMP RIPRAP MATERIAL WITH THE USE OF MACHINERY, BEGINNING AT THE DOWNGRADIENT END OF THE DITCH. FILL GAPS OF THE RIPRAP MATERIAL WITH SMALLER STONE TO FORM A STABLE UNIFORMED SURFACE.
6. WHERE DITCH SIDE SLOPES ARE 2H:1V, PLACE RIPRAP BY MACHINERY OR HAND, BEGINNING AT THE BOTTOM AND WORKING UPSLOPE. CHINK RIPRAP MATERIAL TO FORM A UNIFORMED SURFACE.

OPERATION AND MAINTENANCE:

1. INSPECT AFTER MAJOR STORM EVENTS FOR MAJOR OBSTRUCTIONS, EROSION, OR COLLAPSED BANKS.
2. CLEAN DITCHES OUT WHEN THEY BECOME FILLED WITH SEDIMENT OR DEBRIS TO PREVENT OVERFLOWS AND WASHOUTS.
3. PREVENTING EROSION FROM UPHILL SLOPES CAN LENGTHEN THE TIME NEEDED BETWEEN DITCH CLEANINGS.
4. TO CLEAN SEDIMENT BETWEEN STONE USE ONE OF TWO METHODS:
   A. DIG UP THE STONE, HAUL IT TO A LOCATION WHERE IS CAN BE SIFTED AND CLEANED, AND REPLACE IT.
   B. SCRAPE THE SEDIMENT OFF THE TOP OF THE STONE, AND LOAM AND SEED IT WITH A GRASS MIX; THIS STRATEGY REQUIRES DITCH CLEANING AND RESEEDING WHEN NEEDED, SIMILAR TO MAINTENANCE OF A VEGETATED DITCH.

CONSTRUCTION COST:

UNIT COSTS:

EXCAVATION -	$40.00/CY
STONE -	
$\frac{3}{4}$" CRUSHED STONE -	$84.00/CY
RIPRAP -	$120.00/CY
LOAM -	$90.00/CY
SEED -	$3.50/SY
GEOTEXTILE FABRIC -	$3.00/SY

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OR UNPAVED ROADS, AND REDUCE SEDIMENTATION IN ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE THE LIMITS PRESENTED.

NOTE:
PROJECT FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

STONE-LINED DITCH

PREPARED BY: BSC GROUP BUILD | SUPPORT | CONNECT

PREPARED FOR: frcog

DATE: APRIL 2025

REVISION NO.: -

FIGURE: SLD-1

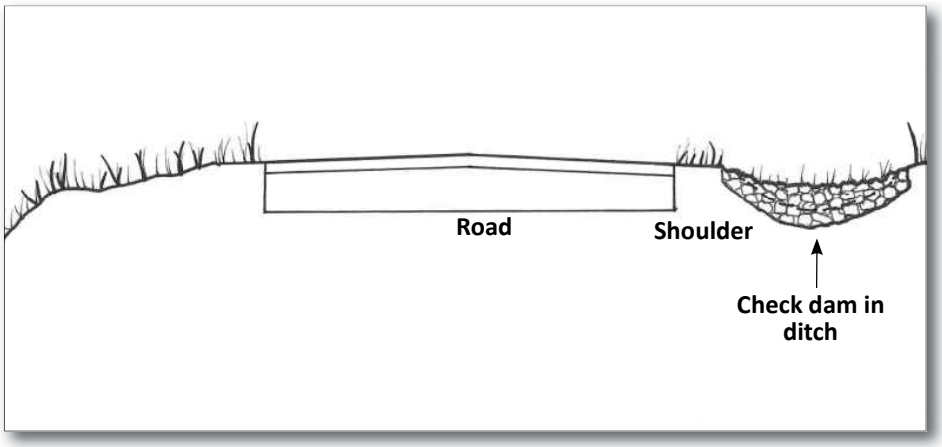
STONE CHECK DAM

Road Type

Steep grade
Steep private driveway

BMP Function

Velocity control
Detention
Accessory



Road cross-section: Stone check dams are useful in vegetated or stone-lined ditches with 5 – 10% grade where additional velocity control is needed.

Description and Purpose

» Stone dam constructed across the ditch, usually as a series.

» Designed to slow the flow velocity of runoff in a ditch to reduce erosion and allow sediment to settle out.

Criteria for Use and Site Considerations

» Use in ditches that drain 10 acres or less.

» Use in ditches with a 5 – 10% grade.

» Use in stone-lined ditches where additional velocity control is needed.

Benefits

» Inexpensive and easy to install and remove.

Planning and Design

» Can be added to a ditch anytime.

» First check dam should be installed 15 feet from nearest upgradient outlet and at regular intervals thereafter.

» Installed at a distance and a height to allow small pools to form behind them.

» The minimum spacing between the dams is variable and should be such that the bottom of the up-stream dam is at the same elevation as the top of the next downstream dam.

» Install maximum check dam height of 2 feet when draining less than 5 acres and 3 feet when draining 5 to 10 acres.

» The height of the check dam should be approximately two thirds of the ditch depth.

» Set the center of check dam approximately 6 inches lower than the outer edges to form a weir.

STONE CHECK DAM

» Side slopes not to exceed 2H:1V in slope (50% slope).

» Check dams should be keyed into the ditch bottom and abutments (sides) to a minimum depth of 6 inches, or up to 12 inches.

» Use 4- to 6-inch stone for check dams, or larger if needed.

» The rock must be placed by hand or mechanical placement (do not dump rock to form dam) to achieve complete coverage of the ditch and to ensure that the center of the dam is lower than the edges.

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» MassDOT specifications for modified rockfill, or minimum 2-inch dense graded crushed stone

» Excavator or backhoe; final placement will be manual

» Skeleton bucket on an excavator to support separation of stone from sediment on-site

Maintenance

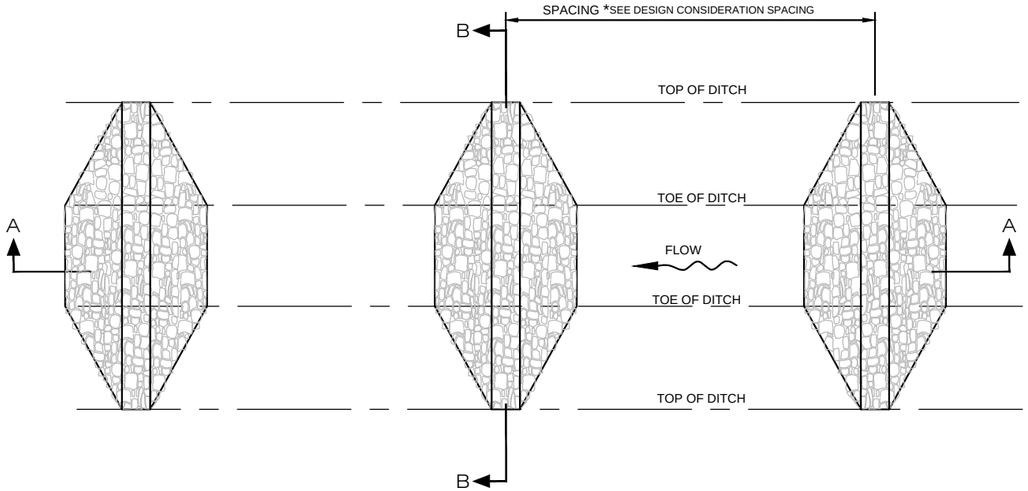
» Inspect and repair twice yearly at minimum for major obstructions, erosion, or collapsed banks. Prioritize fall and spring when plants are dormant and after major storm events.

» Remove sediment, leaves, and debris to prevent overflows and washouts.

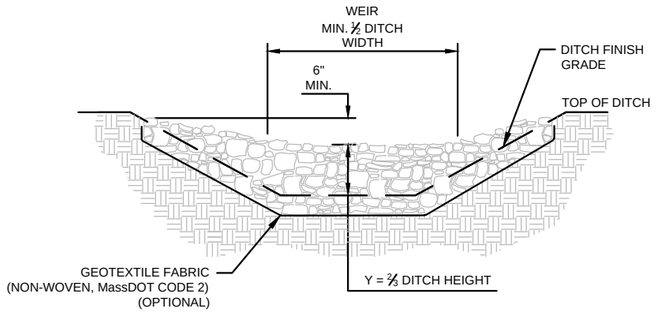
» Because a smaller amount of rock is needed for check dams, can be cost-effectively maintained by completely removing and replacing the rock when it becomes filled with silt; this is in contrast to rock-lined ditches, which require extensive amounts of hauling to clean or replace rocks.

» Alternatively, a skeleton bucket attachment can help separate stone from sediment on site.

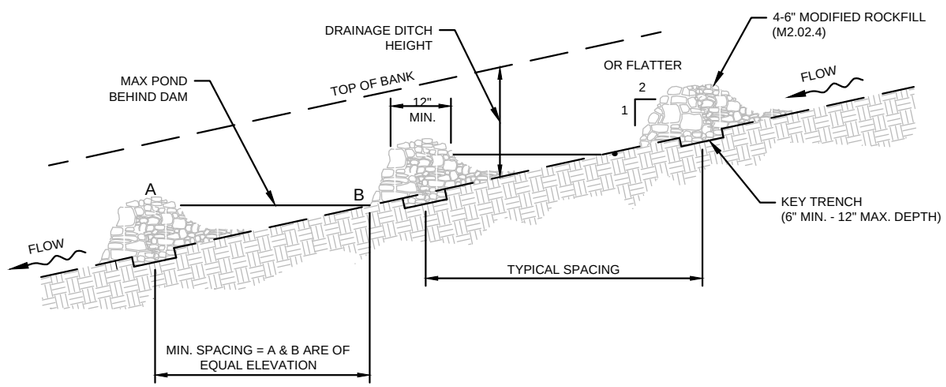
This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***



TRAPEZOIDAL DITCH PLAN VIEW
NTS



CROSS SECTION B-B
NTS



DITCH PROFILE A-A
NTS

STONE CHECK DAM
NTS

STONE CHECK DAM

CRITERIA FOR USE:

1. CHECK DAMS SHOULD BE USED IN SMALL OPEN DITCHES WITH THE FOLLOWING CHARACTERISTICS:
   - 1.1. CHECK DAMS SHOULD BE USED IN DITCHES THAT DRAIN 10 ACRES OR LESS.
   - 1.2. CHECK DAMS SHOULD BE USED IN DITCHES WITH SLOPES ≤10% (1V:10H). DITCHES WITH SLOPES STEEPER THAN 8% SHOULD BE STONE LINED.
2. CHECK DAMS SHOULD BE UTILIZED IN GRASS LINED DITCHES TO REDUCE FLOW VELOCITY TO 1 FOOT PER SECOND.
3. CHECK DAMS CAN BE UTILIZED WITHIN STONE LINED DITCHES TO REDUCE FLOW VELOCITY IN DITCHES WITH SLOPES >8%. CHECK DAMS INSTALLED WITHIN STONE LINED DITCHES SHALL FOLLOW CONSTRUCTION OF CHECK DAMS IN GRASS LINED DITCHES.

DESIGN CONSIDERATIONS:

1. CHECK DAM TYPICAL SPACING SHALL BE AS FOLLOWS:

SLOPE	SPACING*
2% OR LESS	80 FEET
2.1% TO 4%	40 FEET
4.1% TO 7%	25 FEET
7.1% TO 10%	15 FEET
> 10%	STONE LINED DITCH

2. MINIMUM CHECK DAM SPACING SHALL BE THE DISTANCE WHEN THE MAX POND BEHIND A DAM (POINT A IN PROFILE (A-A) MEETS THE TOE OF STONE OF THE UPGRADIENT CHECK DAM (POINT B IN PROFILE A-A).
3. MAXIMUM HEIGHT (Y) OF A CHECK DAM SHALL BE AS FOLLOWS:
   - 3.1. 2 FEET IN HEIGHT WHEN DRAINING LESS THAN 5 ACRES
   - 3.2. 3 FEET IN HEIGHT WHEN DRAINING 5 TO 10 ACRES.
   - 3.3. THE HEIGHT OF CHECK DAM SHALL BE LOWER THAN THE ADJACENT EDGE OF ROADWAY.
4. CENTER OF CHECK DAM SHALL BE APPROXIMATELY 6 INCHES LOWER THAN THE OUTER EDGES TO FORM A WEIR.
5. CHECK DAM SIDE SLOPES SHALL NOT EXCEED 2H:1V IN SLOPE.
6. CHECK DAMS SHOULD BE KEYED INTO THE DITCH BOTTOM AND ABUTMENTS (SIDES) TO A DEPTH OF 6" (MIN.) TO 12" (MAX.).
7. STONE MATERIAL SHALL BE SIZED APPROPRIATELY FOR THE ANTICIPATED FLOWS.
8. THE INSTALLATION OF CHECK DAMS IS NOT RECOMMENDED FOR SLOPES EXCEEDING 10%.

CONSTRUCTION SPECIFICATIONS:

1. STONE:
   - 1.1. 4-6" MODIFIED ROCKFILL (MINIMUM) (M2.02.4).
2. GEOTEXTILE FABRIC:
   - 2.1. NON-WOVEN GEOTEXTILE SEPARATION FABRIC. FABRIC MUST BE ON MassDOT QUALIFIED CONSTRUCTION MATERIAL LIST (QCML) AS A NON-WOVEN CODE 2 FABRIC.

CONSTRUCTION SEQUENCING:

1. CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. DETERMINE THE EXACT LOCATION, SIZE, TYPE, ETC. OF ALL UTILITIES THAT MAY BE AFFECTED BY THE WORK.
3. LOCATE AND MARK OUT THE SITE FOR EACH CHECK DAM TO AVOID UTILITIES AND OPTIMIZE EFFECTIVENESS OF EACH CHECK DAM.
4. REMOVE DEBRIS AND OTHER UNSUITABLE MATERIALS THAT WOULD INTERFERE WITH THE PLACEMENT OF CHECK DAM MATERIAL.
5. EXCAVATE A SHALLOW KEY TRENCH (6"-12" DEEP AND AT LEAST 12" WIDE) ACROSS THE CHANNEL.
6. PLACE GEOTEXTILE FABRIC WITHIN KEY TRENCH AND ALONG BASE BOTTOM OF THE DITCH.
7. PLACE CRUSHED STONE UPON GEOTEXTILE FABRIC VIA MACHINE AND/OR HAND. CRUSHED STONE SHALL NOT BE DUMPED INTO DITCH.
8. WORK AND SHAPE CHECKDAM TO DESIGNED DIMENSIONS.

OPERATION AND MAINTENANCE:

1. INSPECT CHECK DAMS AT LEAST TWICE ANNUALLY, PRIORITIZING FALL AND SPRING WHEN PLANTS ARE DORMANT. REMOVE ANY DEBRIS FROM BEHIND CHECK DAMS AS NECESSARY.
2. INSPECT CHECK DAMS AFTER MAJOR STORMS. LOOK FOR EVIDENCE OF SOIL EROSION, EXCESSIVE PONDING, AND SEDIMENT ACCUMULATIONS.
3. REMOVE SEDIMENT WHEN IT REACHES 1/2 THE HEIGHT OF THE CHECK DAM.
4. REPAIR CHECK DAMS AS NECESSARY.

CONSTRUCTION COST:

CONSTRUCTION COST OF CHECK DAM WILL VARY BASED ON DITCH DEPTH AND WIDTH. THE COST OF A CHECK DAM BASED ON A 2'-6" DEEP BY 2'-0" WIDE DITCH IS $200.00/CHECK DAM.

MODIFIED ROCKFILL:	$175.00/C.Y.
GEOTEXTILE FABRIC:	$10.00/S.Y.

STONE: NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)

	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
STONE CHECK DAM	LOW	HIGH	LOW	HIGH	LOW	HIGH
	44.3	50.6	0.1	0.3	0.2	2.1

STONE CHECK DAM

PREPARED BY:	REVISED BY:	PREPARED FOR:	
GZA	BSC GROUP	frcog	
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. -	FIGURE SCD-1

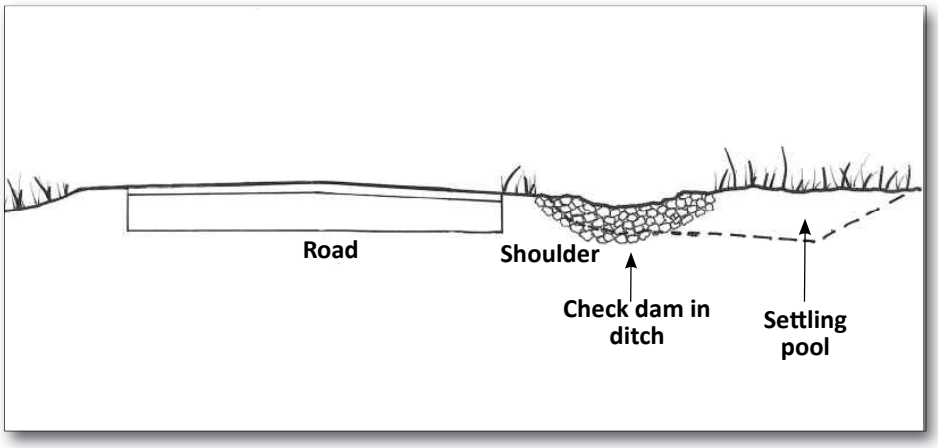
DITCH SETTLING POOL

Road Type

Steep grade
Stream crossing
Adjacent to stream
Steep private driveway

BMP Function

Detention
Velocity control
Filtration



Road cross-section: Runoff traveling along a ditch can be redirected (via a check dam and regrading) into a settling pool where it can slow down, infiltrate water, and settle out sediments.

Description and Purpose

» A basin within a ditch or at the end of a turnout with a check dam to slow the flow of runoff.

» Slows, infiltrates, and filters runoff flowing along the ditch.

Criteria for Use and Site Considerations

» Use in ditches where the existing grade is under 10% slope.

» Use in ditches that drain 5 acres or less.

» Settling pools should be located and constructed so that mechanized cleaning is possible.

» For simplest construction, use in ditches with a natural grade break.

» Use on roadsides with at least 10 feet of useable space off the shoulder.

Benefits

» Can capture a greater amount of sediment than a check dam alone.

» Sediment can be more easily removed from a settling pool than from a ditch.

Planning and Design

» Can be built anytime the ground is not frozen.

» Does not control the volume of runoff.

» Make settling pool as large as site constraints allow.

» Excavate settling pool into existing grade with a check dam discharging to a vegetated buffer or a ditch. If a settling pool uses elevated embankments, the embankments should be designed to meet applicable safety standards.

» Design pool side slopes no steeper than 3H:1V (33% slope).

» Design pool discharge or outflow velocity to control the 2-year peak discharge without scour.

DITCH SETTLING POOL

» Set the bottom of the pool at least 2 feet above the seasonal estimated high water table.

» An effective pool should dewater within 72 hours.

» Design settling pool to make maintenance accessibility easy.

» Pool sides and floor should be seeded with grass.

» Pool floor may be stabilized with stone to aid maintenance. The flatter the bottom of the pool, the easier the removal of sediment.

» Include sediment depth markers to gauge sediment accumulation during inspections and maintenance.

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» MassDOT specifications for stone for pipe ends, or minimum 2-inch dense graded crushed stone

» MassDOT specified loam and seed

» Dump truck

» Excavator or backhoe

Maintenance

» Frequent maintenance is required.

» Inspect and repair four times per year and after major storms.

» Remove sediment when it reaches one third the depth of the pool. Remove sediment, leaves, and debris to prevent overflows and washouts.

» Reseed as soon as possible after cleaning.

» Mow grass as needed.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

SEDIMENT SETTLING POOL
IN DITCH

CRITERIA FOR USE:

1. SETTLING POOLS SHOULD BE USED IN DITCHES WHERE THE EXISTING GRADE IS UNDER 10% (1V:10H).
2. SETTLING POOLS SHOULD BE USED IN DITCHES WHICH DRAIN 5 ACRES OR LESS.
3. SETTLING POOLS SHOULD BE LOCATED AND CONSTRUCTED SO THAT MECHANIZED CLEANING IS POSSIBLE.

DESIGN CONSIDERATIONS:

1. SEDIMENT SETTLING POOLS IN DITCH REQUIRE A MINIMUM OF 200 FT ^{2} OF SPACE ADJACENT TO THE ROAD.
2. AT A MINIMUM, SETTLING POOL SHALL BE SIZED TO HOLD 0.1-INCH/ACRE DRAINAGE AREA TO OBTAIN THE TARGET TOTAL SUSPENDED SOLIDS (TSS) REMOVAL. ADDITIONAL SETTLING POOLS MAY BE REQUIRED ALONG DITCH TO TO REDUCE DRAINAGE AREA TO REMOVE THE TARGETED TSS VOLUME.
3. SETTLING POOLS SHOULD BE EXCAVATED INTO EXISTING GRADE WITH A CHECK DAM DISCHARGING TO A VEGETATIVE BUFFER, OR TO A DITCH. IF A SETTLING POOL USES ELEVATED EMBANKMENTS, THE EMBANKMENTS SHOULD BE DESIGNED TO MEET APPLICABLE SAFETY STANDARDS.
4. DESIGN SETTLING POOLS TO MAKE MAINTENANCE ACCESSIBILITY EASY. BOTTOM OF POOL FLOOR MAY BE STABILIZED WITH STONE TO AID MAINTENANCE.
5. DESIGN POOL SIDE SLOPES NO STEEPER THAN 3:1.
6. DESIGN POOL DISCHARGE OR OUTFLOW VELOCITY CAN CONTROL THE 2-YEAR PEAK DISCHARGE WITHOUT SCOUR.
7. SET THE BOTTOM OF THE POOL AT LEAST 2 FEET ABOVE THE SEASONAL ESTIMATED HIGH WATER TABLE.
8. SETTLING POOL SHALL DEWATER WITHIN 72-HOURS.

CONSTRUCTION SPECIFICATIONS

MATERIAL:

1. STONE CHECK DAMS:
   1.1. 2" DENSE GRADED CRUSHED STONE (M2.01.7)

CONSTRUCTION SEQUENCING:

1. CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. DETERMINE THE EXACT LOCATION, SIZE, TYPE, ETC. OF ALL UTILITIES THAT MAY BE AFFECTED BY THE WORK.
3. LOCATE AND MARK OUT THE SITE FOR EACH SETTLING POOL TO AVOID UTILITIES AND OPTIMIZE EFFECTIVENESS OF EACH SETTLING POOL.
4. EXCAVATE THE AREA TO THE REQUIRED DIMENSIONS TO PROVIDE THE REQUIRED STORAGE VOLUME.
5. STABILIZE EARTH SLOPES AND BOTTOMS USING APPROPRIATE GRASS SEED. USE ONLY GRASSES AS OTHER VEGETATION WILL REDUCE STORAGE VOLUME WITHIN POOL.
6. INSTALL OUTLET CHECK DAM WITHIN OUT GOING DITCH PER CHECK DAM FIGURE.

OPERATION AND MAINTENANCE:

1. FREQUENT MAINTENANCE IS REQUIRED.
2. INSPECT SETTLING POOLS MONTHLY.
3. MOW GRASS AT LEAST TWICE A YEAR AND REMOVE ANY SAPLINGS AND UNWANTED VEGETATION.
4. CLEAN SETTLING POOLS FOUR TIMES A YEAR AND WHEN SEDIMENT DEPTH IS ⅓ DEPTH OF POOL. AFTER REMOVING THE SEDIMENT, REPLACE ANY DAMAGED GRASS.
5. REPLACE DAMAGED GRASS BY EITHER RE-SEEDING OR RE-SODDING.
6. INCLUDE SEDIMENT DEPTH MARKERS TO GAUGE SEDIMENT ACCUMULATION DURING INSPECTIONS AND MAINTENANCE.

CONSTRUCTION COSTS:

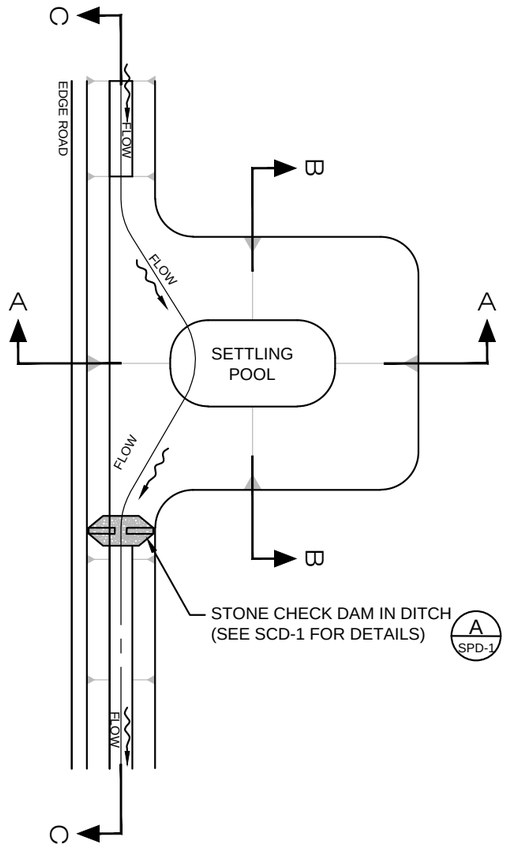
CONSTRUCTION COST OF SETTLING POOL WILL VARY BASED ON DIMENSIONS OF POOL. THE COST OF A MINIMUM SIZED IS $700/POOL.

EXCAVATION:	$40.00/C.Y.
LOAM:	$90.00/C.Y.
SEED:	$3.50/S.Y.
STONE CHECK DAM:	$125.00/C.Y.

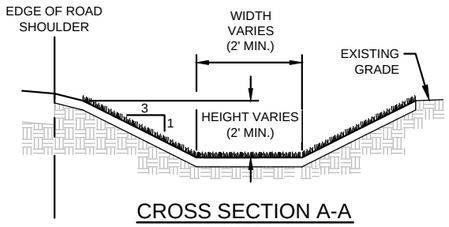
NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

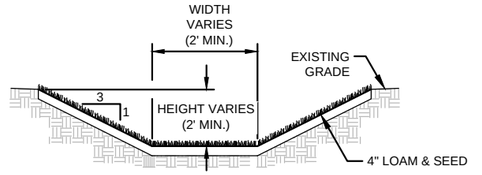
1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.



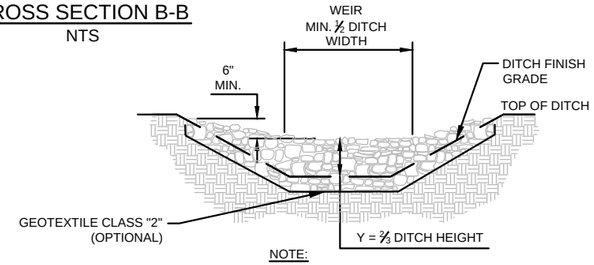
SETTLING POOL IN-LINE WITH DITCH
PLAN VIEW
NTS



CROSS SECTION A-A
NTS



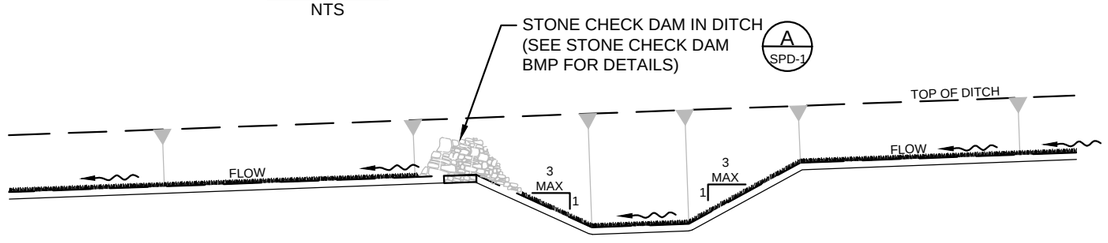
CROSS SECTION B-B
NTS



NOTE:

1. SEE FIGURE SCD-1 FOR ADDITIONAL NOTES AND INFORMATION REGARDING STONE CHECKDAM WITHIN A DITCH.

A SPD-1 STONE CHECKDAM
NTS



CROSS SECTION C-C
NTS

TYPICAL SETTLING POOL IN-LINE WITH DITCH
NTS

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)						
SEDIMENT SETTLING POOL IN DITCH	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
	44.3	50.6	0.1	0.1	0.2	0.9

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

SEDIMENT SETTLING POOL IN DITCH			
PREPARED BY: GZA	REVISED BY: BSC GROUP	PREPARED FOR: frcog	
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. -	FIGURE SP-1

SEDIMENT SETTLING POOL
AT END OF DITCH

CRITERIA FOR USE:

1. SETTLING POOLS SHOULD BE USED FOR DITCHES WHERE THE EXISTING GRADE IS UNDER 10% (1V:10H).
2. SETTLING POOLS SHOULD BE USED FOR DITCHES WHICH DRAIN 5 ACRES OR LESS.
3. SETTLING POOLS SHOULD BE LOCATED AND CONSTRUCTED SO THAT MECHANIZED CLEANING IS POSSIBLE.

DESIGN CONSIDERATIONS:

1. SEDIMENT SETTLING POOLS AT THE END OF A DITCH REQUIRE A MINIMUM OF 200 FT ^{2} OF SPACE ADJACENT TO THE ROAD.
2. AT A MINIMUM, SETTLING POOL SHALL BE SIZED TO HOLD 0.1-INCH/ACRE DRAINAGE AREA TO OBTAIN THE TARGET TOTAL SUSPENDED SOLIDS (TSS) REMOVAL. ADDITIONAL SETTLING POOLS MAY BE REQUIRED ALONG DITCH TO TO REDUCE DRAINAGE AREA TO REMOVE THE TARGETED TSS VOLUME.
3. SETTLING POOLS SHOULD BE EXCAVATED INTO EXISTING GRADE WITH A CHECK DAM AND WEIR DISCHARGING TO A VEGETATIVE BUFFER, OR TO A DITCH. IF A SETTLING POOL USES ELEVATED EMBANKMENTS, THE EMBANKMENTS SHOULD BE DESIGNED TO MEET APPLICABLE SAFETY STANDARDS.
4. DESIGN SETTLING POOLS TO MAKE MAINTENANCE ACCESSIBILITY EASY. BOTTOM OF POOL FLOOR MAY BE STABILIZED WITH STONE TO AID MAINTENANCE.
5. DESIGN POOL SIDE SLOPES NO STEEPER THAN 3:1.
6. DESIGN POOL DISCHARGE OR OUTFLOW VELOCITY CAN CONTROL THE 2-YEAR PEAK DISCHARGE WITHOUT SCOUR.
7. SET THE BOTTOM OF THE POOL AT LEAST 2 FEET ABOVE THE SEASONAL ESTIMATED HIGH WATER TABLE.
8. SETTLING POOL SHALL DEWATER WITHIN 72-HOURS.

CONSTRUCTION SPECIFICATIONS

MATERIAL:

1. STONE CHECK DAMS:
   1.1. 2" DENSE GRADED CRUSHED STONE (M2.01.7)

CONSTRUCTION SEQUENCING:

1. CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. DETERMINE THE EXACT LOCATION, SIZE, TYPE, ETC. OF ALL UTILITIES THAT MAY BE AFFECTED BY THE WORK.
3. LOCATE AND MARK OUT THE SITE FOR EACH SETTLING POOL TO AVOID UTILITIES AND OPTIMIZE EFFECTIVENESS OF EACH SETTLING POOL.
4. EXCAVATE THE AREA TO THE REQUIRED DIMENSIONS TO PROVIDE THE REQUIRED STORAGE VOLUME.
5. STABILIZE EARTH SLOPES AND BOTTOMS USING APPROPRIATE GRASS SEED. USE ONLY GRASSES AS OTHER VEGETATION WILL REDUCE STORAGE VOLUME WITHIN POOL.
6. INSTALL OUTLET CHECK DAM WITHIN OUT GOING DITCH PER CHECK DAM FIGURE.

OPERATION AND MAINTENANCE:

1. FREQUENT MAINTENANCE IS REQUIRED.
2. INSPECT SETTLING POOLS MONTHLY.
3. MOW GRASS AT LEAST TWICE A YEAR AND REMOVE ANY SAPLINGS AND UNWANTED VEGETATION.
4. CLEAN SETTLING POOLS FOUR TIMES A YEAR AND WHEN SEDIMENT DEPTH IS ⅓ DEPTH OF POOL. AFTER REMOVING THE SEDIMENT, REPLACE ANY DAMAGED GRASS.
5. REPLACE DAMAGED GRASS BY EITHER RE-SEEDING OR RE-SODDING.
6. INCLUDE SEDIMENT DEPTH MARKERS TO GAUGE SEDIMENT ACCUMULATION DURING INSPECTIONS AND MAINTENANCE.

CONSTRUCTION COSTS:

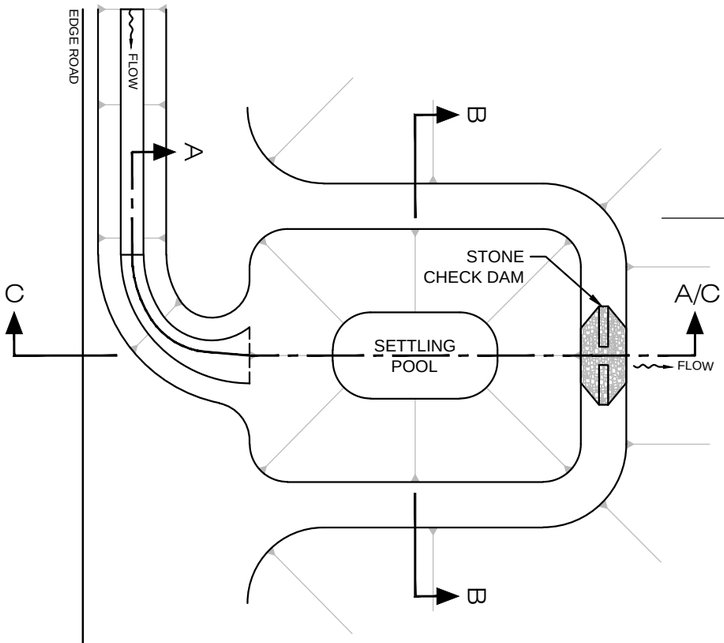
CONSTRUCTION COST OF SETTLING POOL WILL VARY BASED ON DIMENSIONS OF POOL. THE COST OF A MINIMUM SIZED IS $700/POOL.

EXCAVATION:	$40.00/C.Y.
LOAM:	$90.00/C.Y.
SEED:	$3.50/S.Y.
STONE CHECK DAM:	$125.00/C.Y.

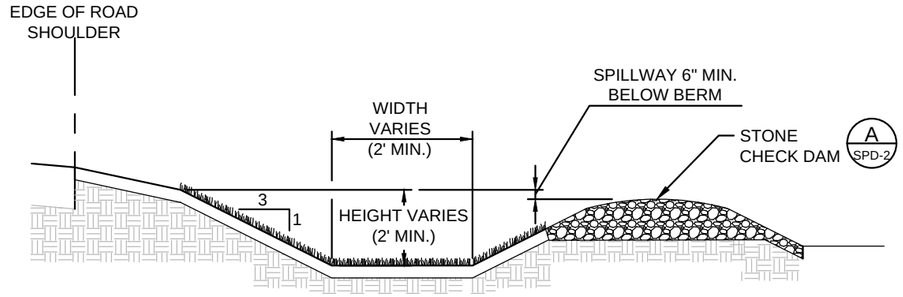
NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

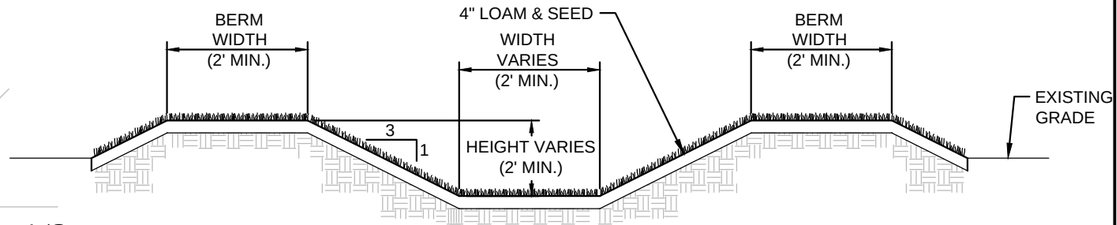
1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.



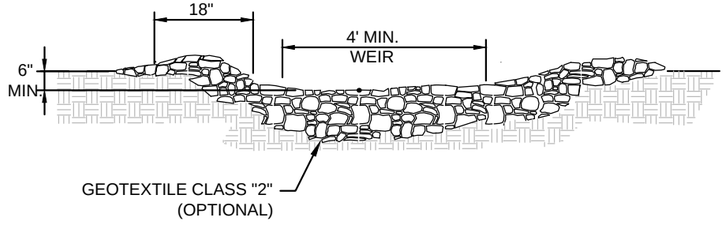
SETTLING POOL AT END OF DITCH PLAN VIEW
NTS



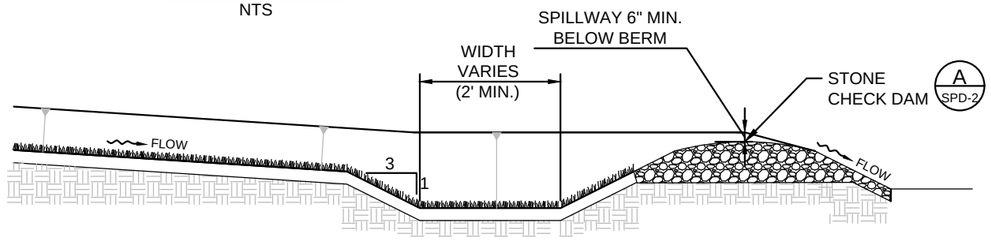
CROSS SECTION C-C
NTS



CROSS SECTION B-B
NTS



A SPD-2 STONE CHECK DAM OUTLET
NTS



CROSS SECTION A-A
NTS

TYPICAL SETTLING POOL AT END OF DITCH
NTS

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

SEDIMENT SETTLING POOL AT END OF DITCH			
PREPARED BY: GZA	REVISED BY: BSC GROUP	PREPARED FOR: frcog	
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. -	FIGURE SP-2

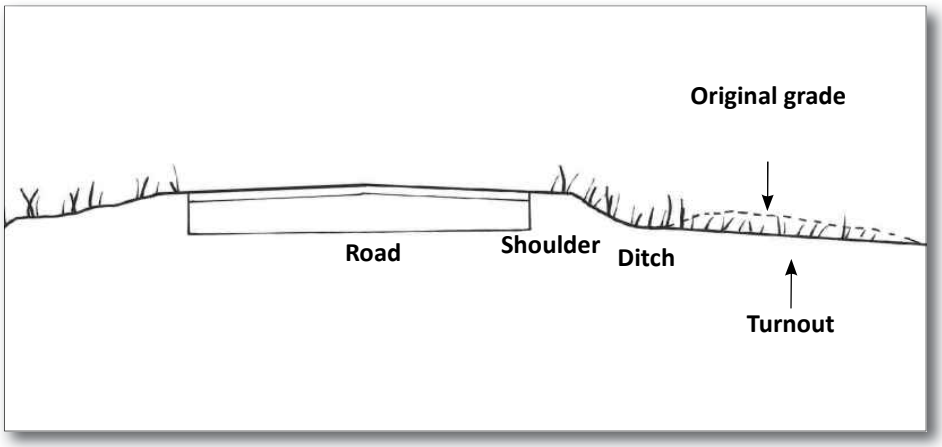
TURNOUT

Road Type

Steep grade
Steep bank slope
Stream crossing
Adjacent to stream
Adjacent to wetland
Steep private driveway

BMP Function

Conveyance



Road cross-section: Like culverts, turnouts are needed frequently along unpaved roads. Turnouts are also known as bleeders, diversion ditches, tail ditches, and by other names.

Description and Purpose

» A swale, typically an extension of the ditch, that directs runoff to a stable vegetated area.

» Designed to direct concentrated flow of runoff off of the road or out of the ditch, transforming it to dispersed flow in a place where it can slow and infiltrate and road material can settle out.

Criteria for Use and Site Considerations

» Good for all roads that are not entrenched; use frequently on roads with steep grade or steep slope to the waterbody.

» On roads without ditches, still necessary for directing runoff off the road into a stable vegetated area.

» Use frequently when runoff volume is eroding the ditch or downstream infrastructure, or ditch is otherwise showing that it cannot handle volume of runoff.

» Use turnout outlet protection in cases where velocity of runoff tends to erode turnout or where turnout outlets near a waterbody.

This wide turnout helps direct runoff off of the road to where it can infiltrate into the adjacent forest.

Benefits

» Controls the volume and velocity of runoff in the road drainage system.

» Reduces ditch erosion and maintenance by outleting runoff in a timely manner.

» Preserves the road base by draining water from ditches along the road, keeping the road subbase dry.

» Inexpensive and easy to install and remove.

TURNOUT

Planning and Design

» Can be built anytime.

» Locate turnouts to use the natural contours of the adjacent land where the runoff will flow away from the road.

» Locate turnouts where there is available right-of-way space and discharge will not adversely impact abutting property. Check with the abutting property owner to ensure the water will not adversely impact their property. Consider mentioning that the road may wash out more frequently if turnouts are not placed frequently enough.

» Because it is easier to disperse smaller volumes of water at a time, turnouts should be constructed as often as possible.

» The frequency of turnout placement is site specific and depends on several factors—the contributing drainage area and the topography of this area, road slope, soil infiltration rate, and rainfall intensity. Generally, turnouts should be placed at intervals close enough to prevent large volumes of water moving fast enough to cause erosion of the road surface and shoulder. Recommended minimum spacing between turnouts:

Road grade	Distance
2 – 5%	135 – 250 feet
6 – 10%	80 – 135 feet
10 – 15%	60 – 80 feet
16 – 20%	45 – 60 feet

Source: Massachusetts Unpaved Roads BMP Manual, 2001 and BSC Group, 2025.
Note: With climate change, distance between turnouts may need to be reduced to accommodate more frequent flash flooding.

» Turnout angle will vary depending on road grade and adjacent land slopes. Typical turnout angles are between 15 and 45 degrees.

» Look for opportunities to create a new turnout above the point where the ditch starts to erode.

» If possible, outlet ditches before curves or steeper sections of road to help reduce ditch erosion.

» Install turnout with a similar cross-sectional shape as the contributing ditch so that berms are not needed to direct the runoff.

» To avoid standing water, size and depth of turnout may depend on the soil's ability to drain water and the frequency of turnouts.

» Larger turnouts capture more sediment and require less frequent cleaning.

» For proper stabilization measures, see guidelines for vegetated and stone-lined ditches.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

TURNOUT

» Use outlet protection if slope of turnout is greater than 5% or if road runs close to a stream or waterbody.

Material and Equipment

» Hand shovel, excavator or backhoe

Maintenance

» Inspect and repair twice yearly at minimum for major obstructions, erosion, or collapsed banks. Prioritize fall and spring when plants are dormant and after major storm events.

» Remove sediment, leaves, and debris to prevent overflows and washouts.

» Remove any grader berm left on the roadside from grading and plowing to allow proper road drainage.

Cut Out

Turnouts are different from cut outs. A cut out is the cutting of a high shoulder or entrenched road to direct water off the road. Cut outs should only be used as a last resort, when regular ditch and turnout systems are not possible.

Curving Turnout

Ditches that lead straight to waterbodies must be disconnected.

In cases where there is enough space, ends of ditches can be curved to direct runoff away from the waterbody.

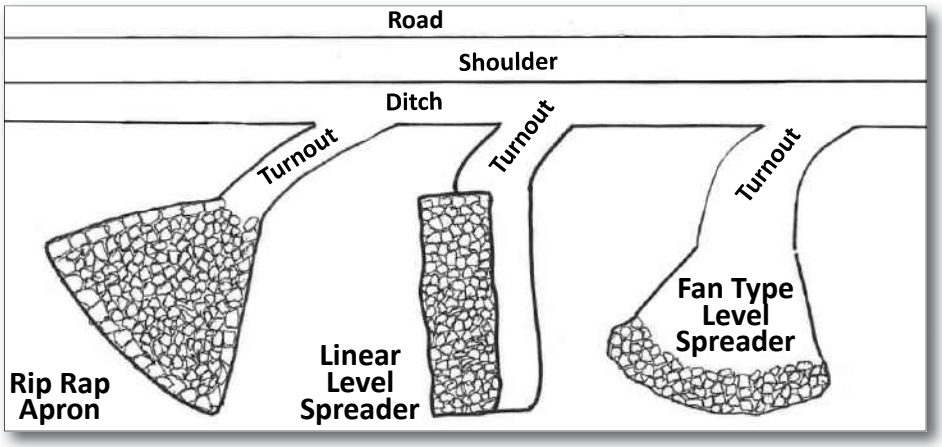
OUTLET PROTECTION FOR TURNOUT

Road Type

Steep grade
Steep bank slope
Stream crossing
Adjacent to stream
Adjacent to wetland

BMP Function

Velocity control
Detention
Accessory



Road plan view: Three types of outlet protection for turnouts.

Description and Purpose

» A structure, typically made of stone, at the end of a turnout.

» Designed to slow velocity, reduce erosion, and convert concentrated flow to dispersed flow where runoff exits turnout.

This fan-shaped turnout could be reinforced by a stone berm for greater outlet protection.

Criteria for Use and Site Considerations

Level spreader (linear or fan type)

» Linear level spreaders are oriented with the countours of the land, so runoff spreads out over the structure.

» Fan-type level spreader is used on areas with gentle adjacent slopes (3% maximum).

» Use where adequate vegetative filter strip is available (50 feet minimum) between outlet and waterbody.

» Use when slope of the ditch is 1% or less for approximately 20 feet prior to the level spreader to reduce flow velocity.

Riprap apron

» Use at the end of turnouts where the ditch slope is >5% and the water discharge velocity is high.

» Use when adjacent slope grade is >5%.

» Use where adequate vegetative filter strip is available (50 feet minimum) between outlet and waterbody.

OUTLET PROTECTION FOR TURNOUT

Benefits

» Controls the velocity of discharges from a ditch and turnout.

» Allows for trapping of sediment in stormwater runoff.

» Reduces bank erosion.

Planning and Design

» Consider using a linear level spreader where adjacent land slopes with the road grade and there is adequate right-of-way.

» Consider using the fan-type level spreader if space is limited and the adjacent land slopes down from the road.

» Consider using a riprap apron with steep road grade and steep slopes.

» Extend the length of outlet protection if adjacent slope is greater than 10% to adequately reduce flow velocities.

» Design outlet protection with minimal or no grade along its length.

» Do not berm the end of the level spreader or riprap apron.

» Discharge runoff from outlet protection structures into a vegetated area.

» Refer to design typicals TOP-1, TOP-2, and TOP-3 for additional dimensional considerations.

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» Level spreaders: 2-inch dense graded crushed stone and rocks, lumber, or curbing for weir structure; refer to design typical TOP-2 or TOP-3 for required stone sizing based on flow rate

» Rip rap apron: Minimum D_{50}= 6 inches; refer to design typical TOP-1 for suggested stone sizing based on flow rate

» Excavator or backhoe

Maintenance

» Inspect and repair twice yearly at minimum for major obstructions, erosion, or collapsed banks. Prioritize fall and spring when plants are dormant and after major storm events.

» Remove sediment, leaves, and debris to prevent overflows and washouts.

» Repair any eroded areas or low spots within the level spreaders.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

TURNOUT WITH OUTLET PROTECTION

CRITERIA FOR USE:

1. TURNOUTS MUST DISCHARGE TO VEGETATED BUFFERS.
2. TURNOUTS SHALL NOT BE USED IN VERY WET, FLAT AREAS. DISCHARGED STORMWATER MUST FLOW AWAY FROM THE OUTLET TO THE VEGETATED BUFFER.
3. TURNOUTS SHALL NOT BE USED IF ABUTTING PROPERTY WILL BE ADVERSELY IMPACTED.
4. TURNOUTS SHALL BE LOCATED TO USE THE NATURAL CONTOURS OF THE ADJACENT LAND WHERE THE WATER WILL FLOW POSITIVELY AWAY FROM THE ROAD.
5. TURNOUT SHALL NOT DISCHARGE DIRECTLY INTO ADJACENT SURFACE WATERS.

DESIGN CONSIDERATIONS:

1. TURNOUTS SHALL BE EXCAVATED INTO AND LOCATED TO USE THE NATURAL SLOPES OF THE ADJACENT LAND SO THE DISCHARGED WATER WILL FLOW AWAY FROM THE ROAD.
2. TURNOUTS SHOULD HAVE A SIMILAR CROSS SECTIONAL SHAPE TO THE CONTRIBUTING DITCH.
3. TURNOUT OUTLET SHOULD BE LOCATED BASED ON AVAILABLE RIGHT-OF-WAY SPACE.
4. CONSIDER ARMORING DOWNGRADIENT DITCH SLOPE AT TURNOUT LOCATION IF DITCH SLOPE IS >5%.
5. TURNOUTS SHALL DISCHARGE TO ADEQUATE OUTLET PROTECTION. TYPICAL OUTLET PROTECTION SHALL CONSIST OF ONE OF THE FOLLOWING:
   - 5.1. LEVEL SPREADER
   - 5.2. RIPRAP APRON
   - 5.3. SETTLING POOL (SEE FIGURE SP-2 SEDIMENT SETTLING POOL AT END OF DITCH)
6. TURNOUT SPACING REQUIREMENTS:

ROAD GRADE (%)	DISTANCE (FT)
2 - 5	250 - 135
5 - 10	135 - 80
10 - 15	80 - 60
15 - 20	60 - 25

7. TURNOUT ANGLES SHALL VARY DEPENDING ON ROAD GRADE AND ADJACENT LAND SLOPES. TYPICAL TURNOUT ANGLES ARE BETWEEN 15-45° AWAY FROM THE ROAD SHOULDER.
8. MINIMUM RADII OF TURNOUTS SHALL BE DEPENDANT ON WIDTH OF DITCH. TYPICAL TURNOUT RADIUS IS 5 FEET.

CONSTRUCTION SPECIFICATIONS:

CONSTRUCTION MATERIAL WILL VARY DEPENDING ON OUTLET BMP SELECTED. SEE TOP-2 AND TOP-3 FOR BMP MATERIAL.

CONSTRUCTION SEQUENCING:

1. CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. DETERMINE THE EXACT LOCATION, SIZE, TYPE, ETC. OF ALL UTILITIES THAT MAY BE AFFECTED BY THE WORK.
3. LOCATE AND MARK OUT THE SITE FOR EACH TURNOUT TO AVOID UTILITIES AND OPTIMIZE EFFECTIVENESS OF EACH TURNOUT.
4. REMOVE DEBRIS AND OTHER UNSUITABLE MATERIALS THAT WOULD INTERFERE WITH THE INSTALLATION OF TURNOUT.
5. EXCAVATE FOR TURNOUT AND SELECTED OUTLET BMP.
6. CONSTRUCT OUTLET BMP.

OPERATION AND MAINTENANCE:

1. TURNOUTS AND ASSOCIATED OUTLET BMP SHALL BE INSPECTED AT MINIMUM TWICE ANNUALLY. PRIORITIZING FALL AND SPRING WHEN VEGETATION IS DORMANT.
2. CHECK TURNOUTS DURING AND AFTER LARGE STORM EVENTS FOR EROSION OR ACCUMULATION OF DEBRIS.
3. REMOVE ANY DEBRIS OR SEDIMENT FOUND WITHIN TURNOUTS. REPAIR DITCH AND TURNOUT WITH MATERIAL IN-KIND.
4. REPAIR EROSION FOUND IN THE DITCH TURNOUT WITH MATERIAL IN-KIND.
5. INSPECT OUTLET BMPs PER BMP REQUIREMENTS.

CONSTRUCTION COSTS:

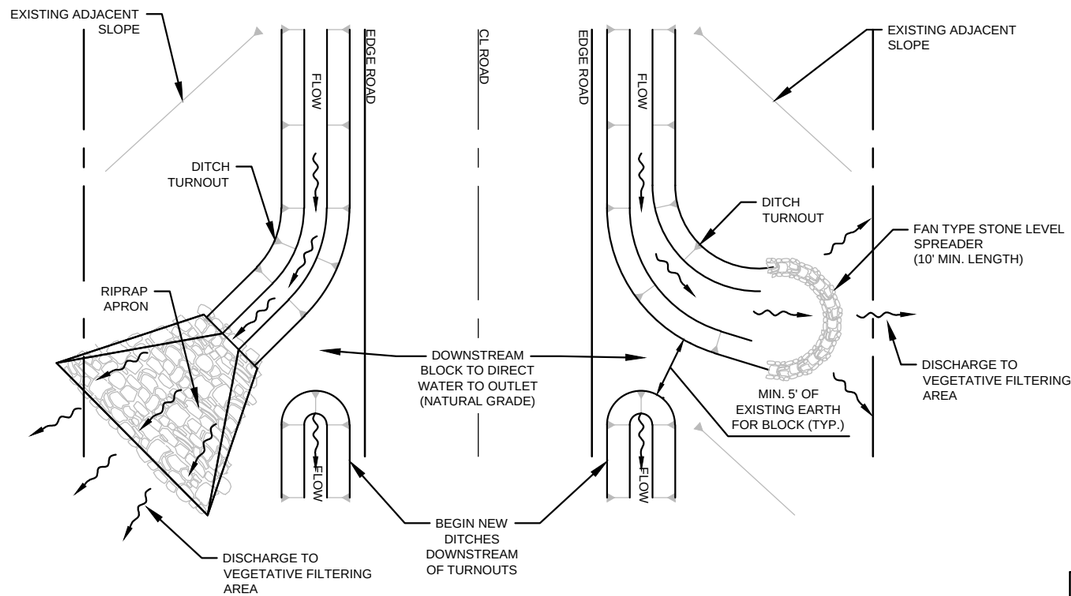
CONSTRUCTION COST OF DITCH TURNOUT WILL VARY DEPENDING ON THE OUTLET BMP CHOSEN. REFER TO OUTLET BMP INFORMATION REGARDING TYPICAL COSTS ASSOCIATED WITH EACH OUTLET BMP.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)						
TURNOUTS WITH LEVEL SPREADER	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
	12.7	56.9	0.0	0.2	0.1	1.2

SUGGESTED STONE SIZE FOR PEAK FLOW RATE	
PEAK FLOW RATE (CFS)	REQ. STONE SIZE (D50)
8.00 - 13.00	6"
13.01 - 15.75	10"
15.76 - 20.50	14"
20.50 - 22.00	20"
>22.00	22"



TURNOUT W/ RIP RAP APRON OR LEVEL SPREADER

NTS

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

TURNOUT WITH OUTLET PROTECTION

PREPARED BY:	REVISED BY:	PREPARED FOR:	
GZA	BSC GROUP	frcog	
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. -	FIGURE TOP-1

TURNOUT WITH OUTLET PROTECTION

LEVEL SPREADER

CRITERIA FOR USE:

1. LINEAR LEVEL SPREADER SHALL BE ORIENTATED IN PARALLEL TO ADJACENT LAND CONTOURS. FAN/ARC LEVEL SPREADER CAN BE USED ON AREAS WITH GENTLE ADJACENT SLOPES (3% MAX).
2. SLOPE AT OUTLET OF THE LEVEL SPREADER SHALL BE 5% OR LESS.
3. USE WHERE ADEQUATE VEGETATIVE FILTER STRIP IS AVAILABLE (MIN. 50 FT) BETWEEN OUTLET AND WATER BODY.
4. USE WHEN SLOPE OF THE DITCH FOR APPROXIMATELY 20 FEET PRIOR TO LEVEL SPREADER CAN BE 1% IN ORDER TO REDUCE FLOWS TO APPROXIMATELY 2 FEET PER SECOND

DESIGN CONSIDERATIONS:

1. LEVEL SPREADER CAN BE CREATED OUT OF ROCKS, LUMBER, CONCRETE OR GRANITE CURBING. LEVEL SPREADERS WHICH USE CONCRETE OR GRANITE CURBING CAN HELP LOWER MAINTENANCE REQUIREMENTS , BUT AT A LARGER CONSTRUCTION COST.
2. DEPTHS OF FLOW AND PONDING BEHIND A LEVEL SPREADER SHOULD RANGE BETWEEN 6 TO 12 INCHES.
3. HEIGHT OF SPREADER IS BASED ON DESIGN FLOW, ALLOWING THE SEDIMENT AND DEBRIS DEPOSITION.
4. SPREADER WEIR LENGTHS SHALL BE AS FOLLOWS:

DRAINAGE AREA SIZE (AC)	MIN. SPREADER WEIR LENGTH (FT)
1	10
2	10
3	15
4	18
5	20

5. LEVEL SPREADER WEIR SHALL BE GRADED TO BE ABSOLUTELY LEVEL ACROSS THE ENTIRE LENGTH OF WEIR. A SMALL DEVIATION CAN CAUSE EROSION AT THE WEIR LOW POINT.
6. MAX SLOPE OF STONE FOR OUTLET WEIR SHALL BE 2H:1V
7. CONSIDER THE USE OF THE LINEAR LEVEL SPREADER WHERE ADEQUATE RIGHT-OF-WAY IS AVAILABLE. IF ADJACENT LAND SLOPES WITH THE ROAD GRADE, CONSIDER USING THE LINEAR LEVEL SPREADER. WHERE RIGHT-OF-WAY SPACE IS TIGHT AND THE USE OF A LINEAR SPREADER IS NECESSARY, OBTAIN A EASEMENT FROM ABUTTER.
8. CONSIDER THE USE OF A FAN TYPE LEVEL SPREADER IF THE RIGHT-OF-WAY SPACE IS LIMITED AND THE ADJACENT LAND SLOPES AWAY FROM THE ROAD.

CONSTRUCTION SEQUENCING:

1. EXCAVATE AREAS TO THE REQUIRED DIMENSIONS.
2. IF UTILIZING PRECAST CONCRETE OR GRANITE CURB WEIR, EXCAVATE FOR WEIR, PLACE WEIR IN DESIRED LOCATION, LEVEL WEIR AND POUR IN PLACE CONCRETE SADDLE.
3. PLACE STONE FOR WEIR WITH 2H:1V MAX SLOPES.
4. STABILIZE EARTH SLOPES AND BOTTOM USING APPROPRIATE GRASS SEED. USE ONLY GRASSES.

OPERATION AND MAINTENANCE:

1. INSPECT LEVEL SPREADERS REGULARLY, ESPECIALLY AFTER LARGE RAINFALL EVENTS. NOTE ANY EROSION OR LOW SPOTS WITHIN THE LEVEL SPREADER AND REPAIR.

CONSTRUCTION COSTS:

CONSTRUCTION COST OF LEVEL SPEADER WILL VARY DEPENDING ON DIMENSIONS OF SPREADER AND TYPE OF WEIR USED. FOR A TYPICAL LEVEL SPREADER IS $1,000.

UNIT COSTS:

EXCAVATION:	$40.00/CY
STONE:	$90.00/CY
GEOTEXTILE FABRIC:	$3.00/SY
CURB:	
PRECAST:	$65.00/L.F.
GRANITE:	$110.00/L.F.

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

SUGGESTED STONE SIZE FOR PEAK FLOW RATE	
PEAK FLOW RATE (CFS)	REQ. STONE SIZE (D50)
8.00 - 13.00	6"
13.01 - 15.75	10"
15.76 - 20.50	14"
20.50 - 22.00	20"
>22.00	22"

CONSTRUCTION SPECIFICATIONS:

MATERIAL:

STONE:

2" - DENSE GRADED CRUSHED STONE (M2.01.7)

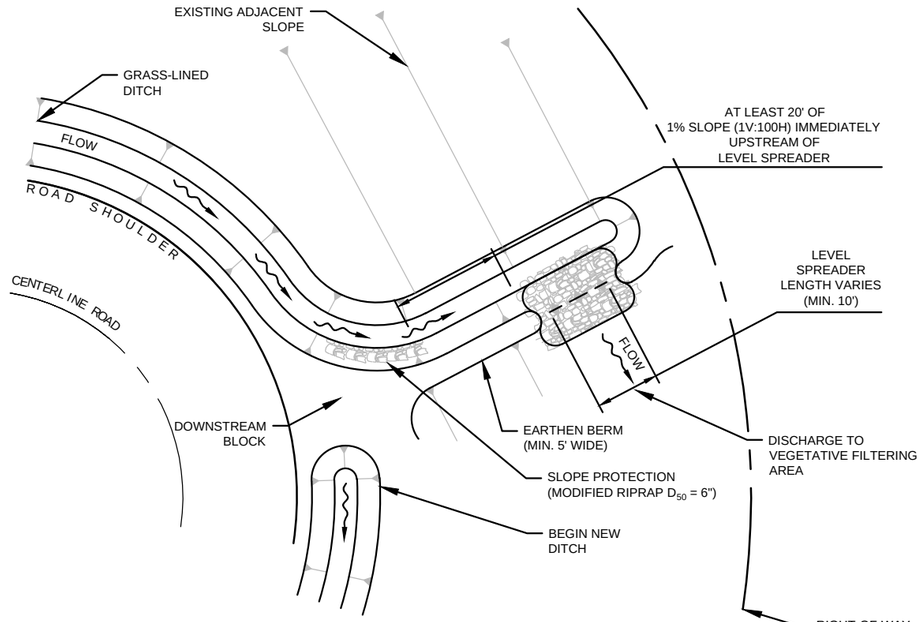
GEOTEXTILE FABRIC:

NON-WOVEN GEOTEXTILE SEPARATION FABRIC (NON-WOVEN MassDOT CLASS 2)

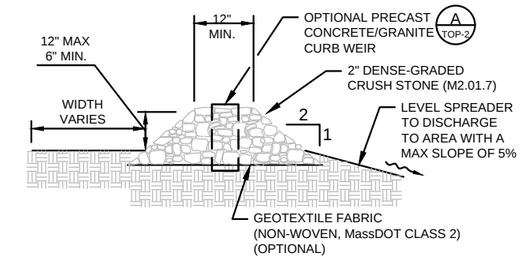
WEIR/CURB:

PRECAST CURB - STRENGTH: 5,000 PSI
WEIGHT - 135 LB/FT
DIMENSIONS: 20" H X 6" W (TOP) X 7" W (BASE)

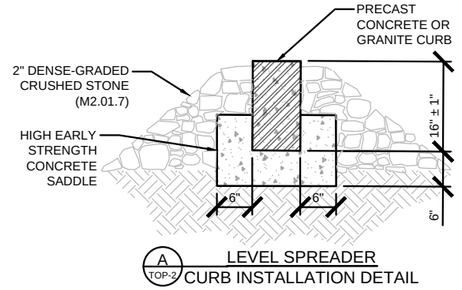
GRANITE CURB - GRANITE CURB TYPE VA5 (M9.04.1-1)



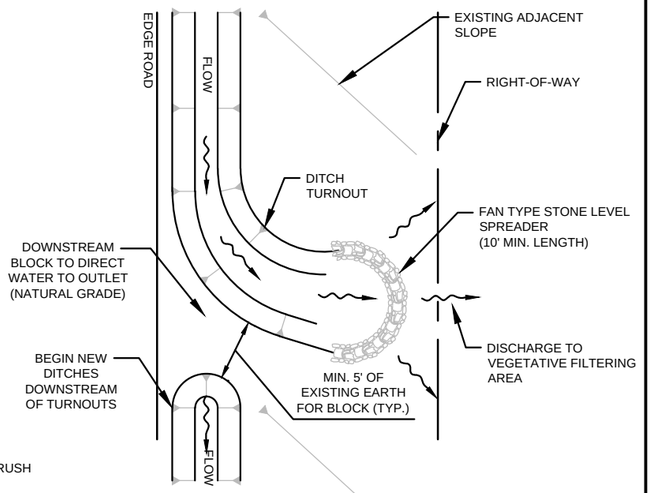
TURNOUT WITH LINEAR LEVEL SPREADER
STEEP ADJACENT GRADE
NTS



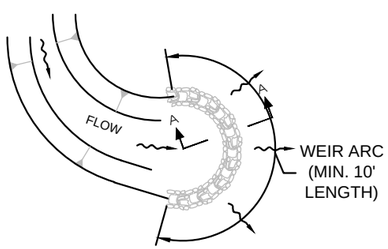
LEVEL SPREADER WEIR
(FAN TYPE & LINEAR)
CROSS SECTION A-A



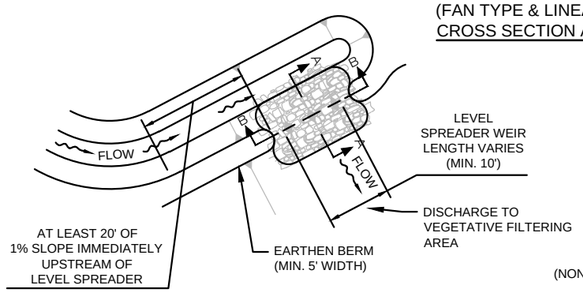
A TOP-2 LEVEL SPREADER
CURB INSTALLATION DETAIL



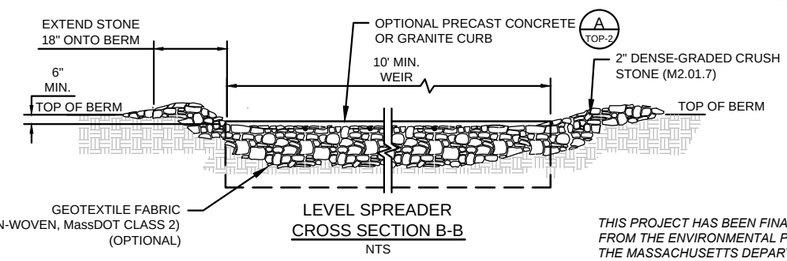
TURNOUT W/ FAN LEVEL SPREADER
NTS



FAN TYPE LEVEL SPREADER
PLAN VIEW



LINEAR LEVEL SPREADER
PLAN VIEW



LEVEL SPREADER
CROSS SECTION B-B
NTS

LEVEL SPREADER DETAILS
NTS

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

TURNOUT WITH OUTLET PROTECTION LEVEL SPREADER			
PREPARED BY: GZA	REVISED BY: BSC GROUP	PREPARED FOR: frcog	
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. -	FIGURE TOP-2

TURNOUT WITH OUTLET PROTECTION

RIPRAP APRON

CRITERIA FOR USE:

1. RIPRAP APRON SHALL BE USED AT THE END OF TURNOUTS WHERE THE DITCH SLOPE IS >5% SLOPE AND WATER DISCHARGE VELOCITY IS HIGH.
2. USE WHEN ADJACENT GRADE IS >5%.
3. USE WHERE ADEQUATE VEGETATIVE FILTER STRIP IS AVAILABLE (MIN. 50 FT) BETWEEN OUTLET AND WATER BODY.

DESIGN CONSIDERATIONS:

1. USE WHERE THERE IS ADEQUATE VEGETATIVE FILTER STRIP (MIN. OF 50 FT) BETWEEN TURNOUT AND WATER BODY.
2. RIPRAP APRON AT END OF DITCH SHALL EXTEND A MINIMUM OF 1' UP THE DITCH BANKS TO CONTAIN STORMWATER AND GUIDE THE FLOW OVER THE APRON.
3. LENGTH OF APRON MAY BE EXTENDED IF ADJACENT SLOPE IS >10% TO REDUCE FLOW VELOCITIES ADEQUATELY.
4. APRON DIMENSIONS AND STONE SIZING SHALL BE ADEQUATE TO HANDLE THE ANTICIPATED RUNOFF FLOWS. SEE TABLE FOR SUGGESTED STONE SIZE FOR PEAK FLOW RATE FOR REQUIRED STONE SIZING BASED ON FLOW RATE. RIPRAP APRON SHALL HAVE THE FOLLOWING MINIMUM DIMENSIONS:

STONE SIZE (D_{50}):	6 INCHES
UPGRADE WIDTH (W_0):	DITCH BOTTOM WIDTH + 2 FEET
LENGTH (L):	10 FEET
DOWNGRADE WIDTH (W_F):	W_0 + L

CONSTRUCTION SPECIFICATIONS:

MATERIAL:

RIPRAP:

RIPRAP SHALL BE SIZED FOR ANTICIPATED RUNOFF VOLUME AND VELOCITY. MINIMUM D_{50} SHALL BE 6 INCHES. ALL RIPRAP SHALL MEET MassDOT SPECIFICATION M2.02.3 STONE FOR PIPE ENDS

GEOTEXTILE FABRIC:

GEOTEXTILE SEPARATION FABRIC SHALL BE A NON-WOVEN GEOTEXTILE FABRIC LISTED ON THE MassDOT QCML FOR NON-WOVEN CLASS 2 FABRIC.

CONSTRUCTION SEQUENCING:

1. EXCAVATE AREAS TO THE REQUIRED DIMENSIONS.
2. PLACE LAYER OF GEOTEXTILE FABRIC DOWN WITHIN THE LIMITS OF RIPRAP APRON.
3. PLACE RIPRAP ON TOP OF GEOTEXTILE FABRIC. HAND CHINK RIPRAP STONE INTO PLACE TO FORM A UNIFORM SURFACE WITHOUT STONE MOVEMENT.

OPERATION AND MAINTENANCE:

1. ROCK APRONS SHALL BE INSPECTED YEARLY OR AFTER SEVERE STORMS.
2. REPOSITION ANY DISTURBED RIPRAP STONES TO CREATE A UNIFORM SURFACE.
3. REMOVE ANY DEBRIS FOUND IN THE RIPRAP APRON.
4. CUT AND/OR REMOVE ANY WOODY VEGETATION GROWING IN THE RIPRAP APRON.
5. REPAIR ANY SCOURING OCCURRING AROUND THE RIPRAP APRON.

CONSTRUCTION COSTS:

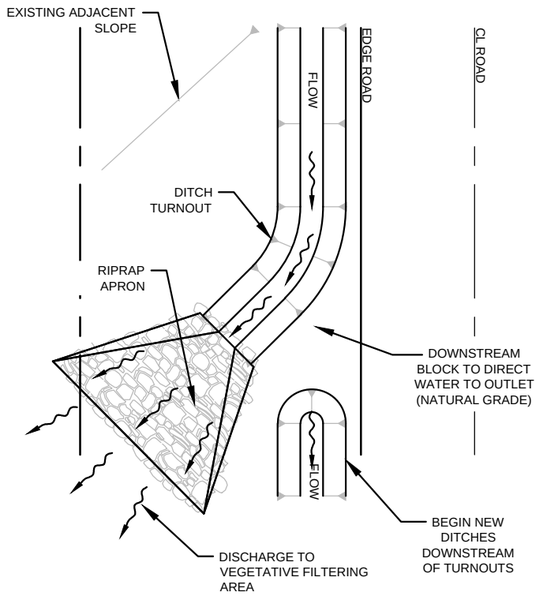
CONSTRUCTION COST OF RIPRAP APRON WILL VARY DEPENDING ON DIMENSIONS OF APRON. FOR A RIPRAP APRON AT THE END OF A 2' WIDE DITCH AND THE MINIMUM DIMENSIONS SHOWN HEREON IS $750.

UNIT COSTS:

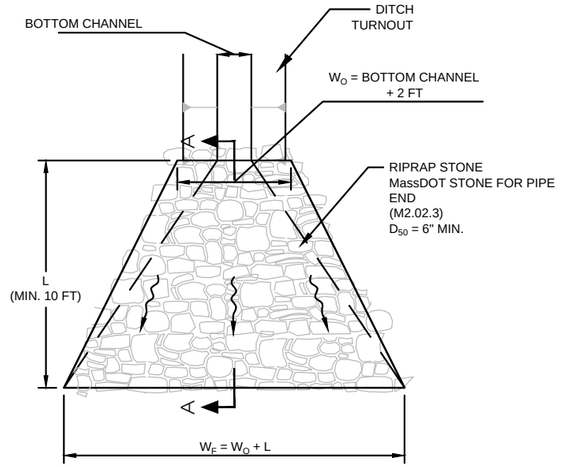
EXCAVATION:	$40.00/CY
RIPRAP STONE:	$35.00/CY (PRICE MAY VARY BASED ON REQUIRED D50)
GEOTEXTILE FABRIC:	$3.00/SY

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

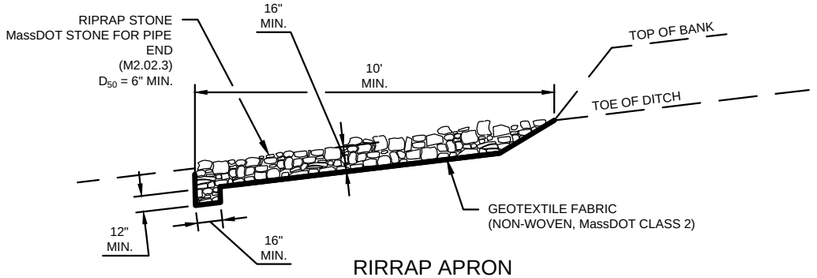
SUGGESTED STONE SIZE FOR PEAK FLOW RATE	
PEAK FLOW RATE (CFS)	REQ. STONE SIZE (D50)
8.00 - 13.00	6"
13.01 - 15.75	10"
15.76 - 20.50	14"
20.50 - 22.00	20"
>22.00	22"



TURNOUT W/ RIP RAP APRON
NTS



RIRRAP APRON
PLAN VIEW
NTS



RIRRAP APRON
CROSS SECTION A-A
NTS

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

TURNOUT WITH OUTLET PROTECTION
RIPRAP APRON

PREPARED BY:	REVISED BY:	PREPARED FOR:	
GZA	BSC GROUP	frcog	
DATE:	REV DATE:	REV NO.	FIGURE
SEP. 2024	JUN. 2025	-	TOP-3

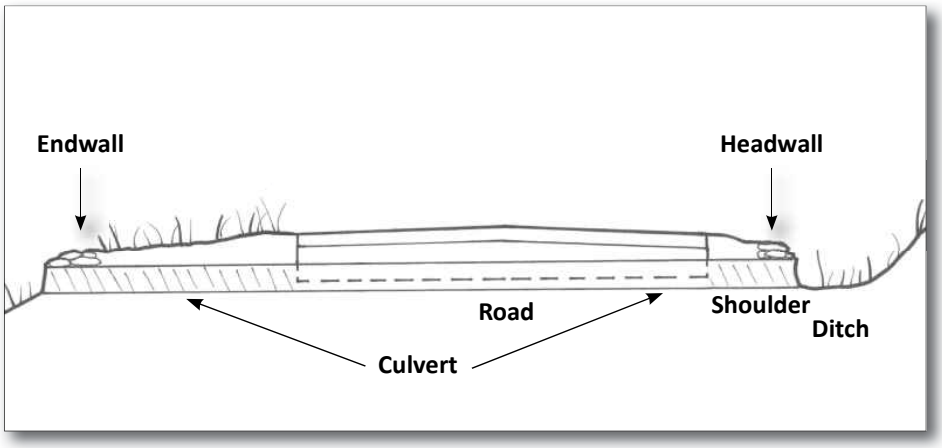
ROUND STORMWATER DRAINAGE CULVERT

Road Type

Steep grade
Steep bank slope
Stream crossing
Adjacent to stream
Adjacent to wetland
Steep private driveway

BMP Function

Conveyance



Road cross-section: Like turnouts, round stormwater drainage culverts are needed frequently along unpaved roads.

Description and Purpose

» A closed pipe or other conduit used to convey runoff from one side of a road to the other.

» Creates a way for stormwater runoff to flow to the other side of the road in a controlled manner that does not impact the surface of the road.

Criteria for Use and Site Considerations

» Use to direct runoff from one side of road to the other.

» Do not discharge directly to a waterbody.

» Culverts that convey a stream under a road are not drainage culverts and should instead meet MA Stream Crossing Standards.

Round stormwater culvert outlet.

Benefits

» Controls the volume and velocity of discharges in the road drainage system.

» Reduces ditch erosion and maintenance by outleting runoff in a timely manner.

» Preserves the road base by draining water from ditches along the road, keeping the road subbase dry.

ROUND STORMWATER DRAINAGE CULVERT

Planning and Design

» The frequency of culvert placement is site specific and depends on several factors—the contributing drainage area and the topography of this area, road slope, soil infiltration rate, and rainfall intensity. Generally, culverts should be placed at intervals close enough to prevent large volumes of water moving fast enough to cause erosion of the road surface and shoulder. Recommended minimum spacing between culverts:

Road grade	Distance
2 – 5%	135 – 250 feet
6 – 10%	80 – 135 feet
10 – 15%	60 – 80 feet
16 – 20%	45 – 60 feet

Source: Massachusetts Unpaved Roads BMP Manual, 2001 and BSC Group, 2025
Note: With climate change, distance between culverts may need to be reduced to accommodate more frequent flash flooding.

» Correctly sizing drainage culverts will help in preventing flooding problems that can lead to erosion and repairs. See FRCOG's Round Stormwater Culvert Right-Sizing Methodology, or use the shorthand sizing recommendations below, which were derived using FRCOG's right-sizing methodology on culverts in several Franklin County towns:

Watershed size	Culvert pipe size
0 – 1.5 acres	12* inches
1.5 – 4 acres	18 inches
4 – 8 acres	24 inches
8 – 15 acres	32 inches
15 – 20 acres	36 inches
Greater than 20 acres	Greater than 36 inches is likely a stream that will need to follow MA Stream Crossing Standards

Source: Franklin Regional Council of Governments
**Some road manuals, such as the 2024 Vermont Better Roads Manual, recommend a minimum of 18 inches for any stormwater culvert, and a minimum of 15 inches for any driveway culvert.*

ROUND STORMWATER DRAINAGE CULVERT

» On roads with steep grade, install at an angle to line culvert up with natural drainage patterns and to more efficiently move runoff through the road. Angled installation reduces the erosion around stormwater drainage culvert inlet and outlet that results when runoff "turns" to enter or exit the pipe; increases the efficiency of runoff entering the culvert; protects the culvert from traffic loading, since only one vehicle tire at a time is directly over the pipe; and reduces the amount of sediment collected in the culvert.

» Attempt to outlet pipes at the elevation of the natural ground whenever possible. This will eliminate the need for long "tail ditches" at pipe outlets, which are an ongoing source of maintenance and erosion.

» Install with a minimum slope of 0.5%.

» Cover with at least 2 inches of subgrade material, followed by the surface materials (at least 12 inches).

» Install headwalls and endwalls to reduce erosion, improve function, and protect the culvert inlet and outlet.

» Culvert length should be the roadway embankment from toe to toe. See the chart below for determining **culvert length** based on the width of the road and depth of fill:

Depth of fill (feet)	**Width of road at culvert location including any shoulders (assuming 2H:1V ditch side slopes) (feet)**									
	12	14	16	18	20	22	24	26	28	30
	Recommended Culvert Length (feet)									
2	20	22	24	26	28	30	32	34	36	38
3	24	26	28	30	32	34	36	38	40	42
4	28	30	32	34	36	38	40	42	44	46
5	32	34	36	38	40	42	44	46	48	50
6	36	38	40	42	44	46	48	50	52	54
7	40	42	44	46	48	50	52	54	56	58
8	44	46	48	50	52	54	56	58	60	62
9	48	50	52	54	56	58	60	62	64	66
10	52	54	56	58	60	62	64	66	68	70

Source: UMass Baystate Roads class "Basics of a Good Road" (2023)

Material and Equipment

» Backfill material free from large rocks, sod, or frozen earth

» Excavator or backhoe

» Compactor

» Culverts come in several different materials that have pros and cons (see table on following page).

ROUND STORMWATER DRAINAGE CULVERT

Culvert material	Advantages	Disadvantages
Steel	Strong Lightweight Easy to place Comes in 20-foot sections Readily available Less expensive	Subject to corrosion Subject to abrasion Shorter life (30 years)
Aluminum	Very lightweight Long life Resists corrosion Comes in 20-foot sections	Easily damaged Requires special care backfilling Subject to abrasion Weaker than steel
Plastic	Lightweight Comes in 20-foot sections Resists corrosion Long life	Requires special care backfilling High deflection Degrades from ultraviolet exposure Subject to impact damage at low temperatures
Concrete	Strong Resists abrasion Resists corrosion Long life (75+ years) Efficient inlet Superior hydraulics	Requires special handling Requires special placing Comes in maximum of 8-foot sections Not readily available in all areas

Source: UMASS Baystate Roads "Basics of a Good Road" class slide deck (2023)

Maintenance

» Inspect and repair twice yearly at minimum for major obstructions, erosion, or collapsed banks. Prioritize fall and spring when plants are dormant and after major storm events.

» Remove sediment, leaves, and debris to prevent overflows and washouts.

» Check culvert inlet for erosion and to ensure runoff is flowing in the pipe and not around it, if some runoff goes around the culvert it can undermine the bedding and the culvert will fail (e.g. piping).

» Modify if not performing adequately. Replace culverts with the same size pipes if it already meets the sizing requirements; increase culvert size if properly constructed culvert repeatedly washes out, as development along the road increases, or as sizing guidelines change.

» Mark or keep an inventory of culverts so that they do not get missed during inspections.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

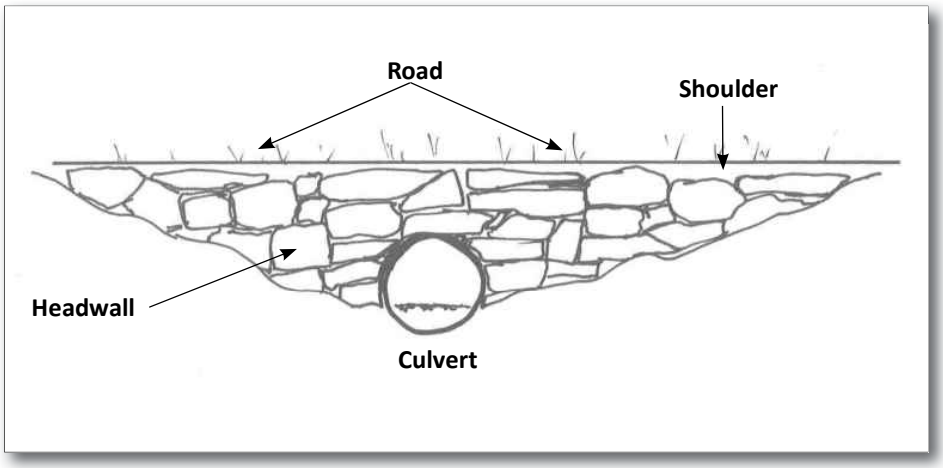
STONE HEADWALL

Road Type

All Road Types

BMP Function

Stabilization
Accessory



Culvert headwall cross-section (road in profile): A stone headwall is a rock wall placed on each side and above the culvert to to stabilize the culvert, bank, and road.

Description and Purpose

» A retaining wall made of field or masonry stone constructed around the end of a culvert pipe (called headwall at the inlet and endwall at the outlet).

» Keeps the culvert in place and controls erosion of the bank around the culvert.

Criteria for Use and Site Considerations

» All stream crossing culverts require a headwall, but can also be made of other materials such as poured or pre-cast concrete.

» All drainage culverts benefit from a headwall.

» Drainage culverts with a slope of 5% or greater require a headwall.

» Culvert movement or bank erosion indicate need for a headwall.

» If culvert replacement is needed, culvert should be replaced prior to installing headwall.

Benefits

» Stabilizes culvert.

» Stabilizes bank and road.

» Armors against erosion around the pipe.

» Can protect the end of the culvert from damage if inlet is installed flush with the headwall.

Fieldstone headwall on a stream-crossing culvert.

STONE HEADWALL

Planning and Design

» The height of the headwall should meet the pipe cover requirements (see Round Stormwater Drainage Fact Sheet).

» Angle top of wall slightly towards the road.

» Use the largest available stones for the base of the wall and smaller stones to fill in gaps.

» Fit stone tightly to ensure stability. Stagger joints and secure secure stones into compacted soil on the ground and in the bank. Install longer stones sporadically perpendicular to the wall.

» Backfill and compact behind the wall as each layer is constructed.

» Place larger capstones across the top of the wall.

» Headwall construction on stream crossing culverts is within a resource area and may require review by the Conservation Commission.

Material and Equipment

» Stone: MassDOT specifications for granite rubble blocks, stone masonry walls, or equivalent

» Gravel borrow backfill

» Large capstones: MassDOT specifications for granite rubble blocks

» Dump truck

» Excavator or backhoe

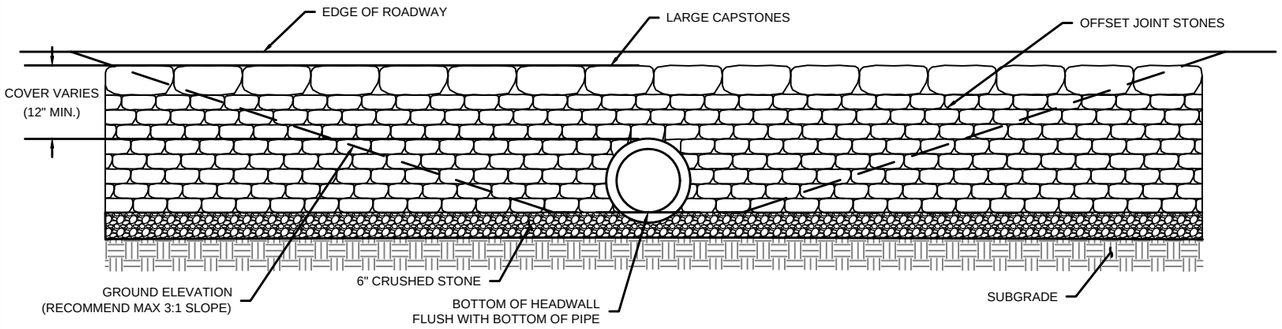
» Hand tools

Maintenance

» Inspect yearly and after major storm events for damage.

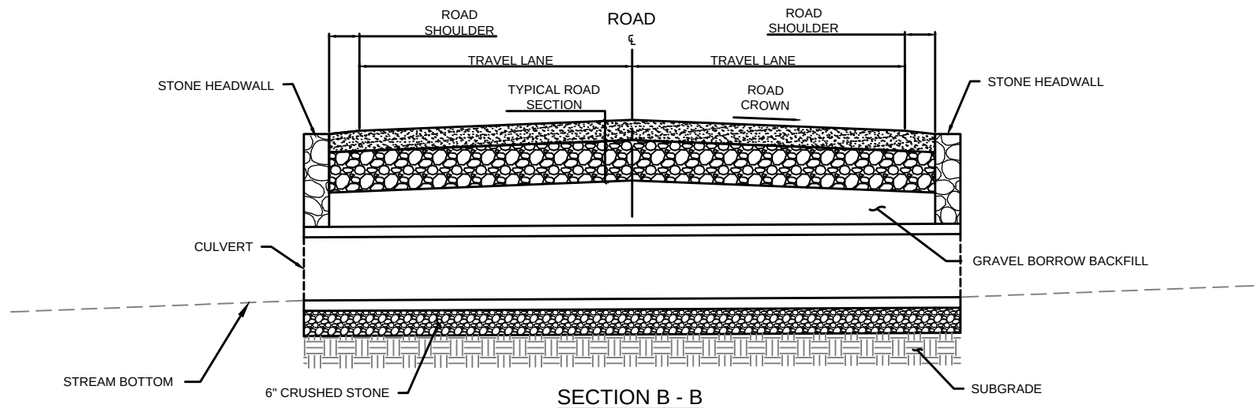
» Repair any cracks or loose stones to prevent futher damage.

Project funded by the Massachusetts Municipal Vulnerability Preparedness (MVP) Program, 2025.



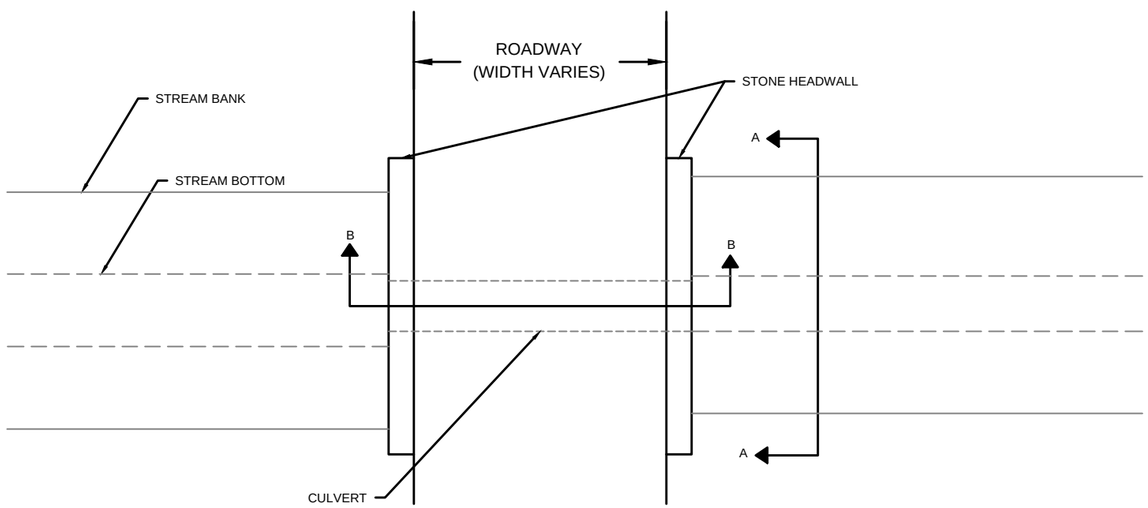
SECTION A - A

NTS



SECTION B - B

NTS



PLAN VIEW

STONE HEADWALL

CRITERIA FOR USE:

1. A HEADWALL SHOULD BE CONSIDERED IF RILL OR GULLY EROSION IS SEEN AT THE BANK OF A CULVERT INLET/OUTLET.
2. A HEADWALL SHOULD BE CONSIDERED IF THERE IS MOVEMENT OF THE CULVERT.
3. NEW CULVERTS TO BE PLACED AT A SLOPE OF 5% OR GREATER REQUIRE THE INSTALLATION OF A HEADWALL.
4. ALL STREAM CROSSING CULVERTS REQUIRE A HEADWALL.

DESIGN CONSIDERATIONS:

1. TO ENSURE THE STABILITY OF THE STONE HEADWALL, STONE MUST BE TIGHTLY FITTED, THE JOINTS MUST BE STAGGERED AND METHODS OF SECURING STONES INTO THE COMPACTED SOIL MUST BE IMPLEMENTED.
2. THE HEIGHT OF THE HEADWALL SHOULD MEET THE PIPE COVER REQUIREMENTS (SEE ROUND STORMWATER DRAINAGE FACT SHEET). HEADWALLS BUILT PROPERLY WILL IMPROVE THE PIPE'S EFFICIENCY DURING HIGH FLOWS AND MAY PREVENT EROSION, SCOUR, ROADWAY WASHOUTS, AND FLOW BY-PASS.
3. ANY PROPOSED WORK WITHIN RESOURCE AREAS WILL ENTAIL PERMITTING IMPLICATIONS.
4. IF FIELD STONE IS USED IN PLACE OF STONE FOR HEADWALL, CONSIDER USING MORTAR TO HELP STABILIZE THE WALL.

CONSTRUCTION SPECIFICATIONS:

1. LARGE CAPSTONE

   BALANCED STONE USED FOR HEADWALL SHALL MEET THE M2.03.0 MASSDOT SPECIFICATIONS FOR GRANITE RUBBLE BLOCKS.

2. STONE

   2.1. CRUSHED STONE
   CRUSHED STONE FOR BEDDING SHALL MEET THE MASSDOT SPECIFICATIONS FOR $\frac{3}{4}$" CRUSHED STONE (M2.01.4).

   2.2. STONE FOR HEADWALL
   OFFSET JOINT STONES SHALL MEET MASSDOT MATERIAL SPECIFICATION M2.03.0 FOR GRANITE RUBBLE BLOCKS, M9.04.4 FOR STONE MASONRY WALLS OR EQUIVALENT.

3. GRAVEL BORROW BACKFILL

   GRAVEL BORROW SHALL MEET MASSDOT MATERIAL SPECIFICATION M1.03.0.

CONSTRUCTION SEQUENCING:

1. CONTACT DIG SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK,
2. EXCAVATE AROUND THE PIPE AS NECESSARY. THE BASE OF THE WALL SHALL BE LEVEL WITH THE PIPE INVERT.
3. THE BASE OF THE WALL SHOULD CONSIST OF THE LARGEST AVAILABLE STONES WITH SMALLER STONES TO FILL IN ANY GAPS. THE JOINTS SHOULD BE STAGGERED AND THE WALL SHOULD BE ANGLED SLIGHTLY TOWARD THE ROAD. LONGER STONES SHOULD BE INSTALLED SPORADICALLY PERPENDICULAR TO THE WALL. THESE STONES ARE TO BE COMPACTED INTO THE WALL BACKFILL TO ENSURE STABILITY.
4. BACKFILL AND COMPACT BEHIND THE WALL AS EACH LAYER IS CONSTRUCTED.
5. ONCE THE WALL HAS BEEN BUILT TO THE TOP OF THE PIPE AND MEETS COVER REQUIREMENTS, LARGE CAPSTONE SHALL BE PLACED ON TOP OF THE PIPE TO CONNECT THE WALL ON EACH SIDE OF THE PIPE (SEE DETAIL).

OPERATION AND MAINTENANCE:

1. INSPECT ANNUALLY AND AFTER MAJOR STORM EVENTS FOR ANY SIGNS OF DAMAGE SUCH AS CRACKS IN THE STONE OR WEAKENED STABILITY.
2. REPAIR ANY CRACKS OR LOOSE STONES TO PREVENT THE OCCURRENCE OF ANY FURTHER DAMAGE.

CONSTRUCTION COST:

UNIT COSTS:

EXCAVATION -	$40.00/CY
GRAVEL BORROW BACKFILL -	$75.00/CY
STONE -	
$\frac{3}{4}$" CRUSHED STONE -	$84.00/CY

STONE FOR HEADWALL - $2,000.00/SY

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OR UNPAVED ROADS, AND REDUCE SEDIMENTATION ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE THE LIMITS PRESENTED.

RESOURCE AREA NOTE:

- WORK WITHIN 100 FT OF A REGULATORY WETLAND RESOURCE AREA AND 200 FT FROM A STREAM/RIVER MAY REQUIRE LOCAL AND/OR STATE WETLAND PERMITTING

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

STONE HEADWALL		
PREPARED BY: BSC GROUP BUILD | SUPPORT | CONNECT		PREPARED FOR: frcog
DATE: APRIL 2025	REVISION NO. -	FIGURE SH-1

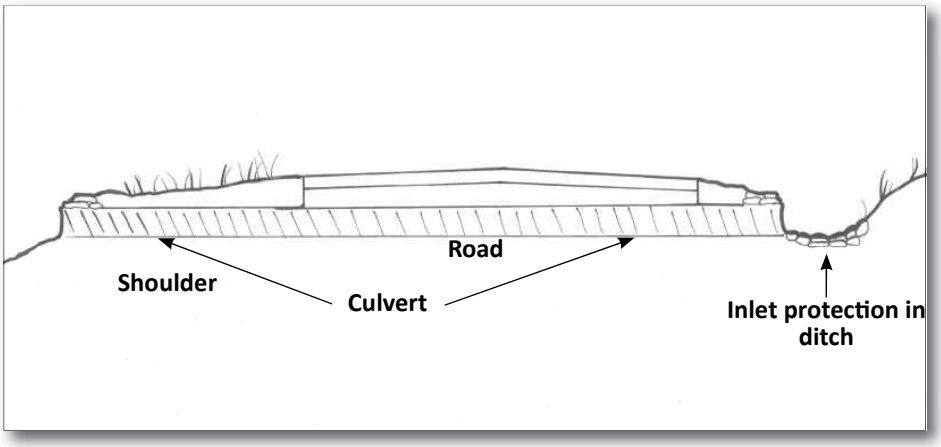
INLET PROTECTION

Road Type

Steep grade
Steep bank slope
Adjacent to stream

BMP Function

Stabilization
Accessory



Road cross-section: Stone-lining the inlet basin at a culvert inlet reduces erosion around the culvert and can reduce sedimentation in culverts.

Description and Purpose

» Stone armoring of the ditch and inlet basin prior to the inlet of a stormwater drainage culvert.

» Reduces erosion in ditch and around a stormwater drainage culvert.

Criteria for Use and Site Considerations

» Use for inlets experiencing scour, erosion, or piping around a stormwater drainage culvert.

Stone-lined inlet to culvert.

Benefits

» Reduces sedimentation in culverts.

» Lowers maintenance time and costs.

Planning and Design

» The top elevation of the stone should not sit any higher than the bottom of the culvert inlet.

» Inlet protection may be used in conjunction with sediment settling pools. Sediment settling pools should be located upstream of the inlet protection.

Material and Equipment

» Dump truck

» Rubber-tire excavator with an articulated bucket (preferred)

» For 8 – 10% ditch grade, use 2 – 6-inch diameter stone; for greater than 10% ditch grade, use 6 – 10-inch diameter stone

» Skeleton bucket on an excavator to support separation of stone from sediment on-site

INLET PROTECTION

Maintenance

» Inspect and repair twice yearly at minimum for major obstructions, erosion, or collapsed banks. Prioritize fall and spring when plants are dormant and after major storm events.

» Remove sediment, leaves, and debris to prevent overflows and washouts.

» Highway staff are understandably cautious about lining ditches with stone because the spaces between the stone will inevitably fill with silt. If a skeleton bucket is not available to clean the stone or replacement is not possible, an alternative is to scrape accumulated sediment off the top of the stone and add loam and seed it with a grass mix, maintaining the ditch as a vegetated ditch.

» Excessive sediment deposition may indicate issues upstream that could be addressed with other BMPs, such as more frequent turnouts, culverts, or stone check dams/rock-lined ditches.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

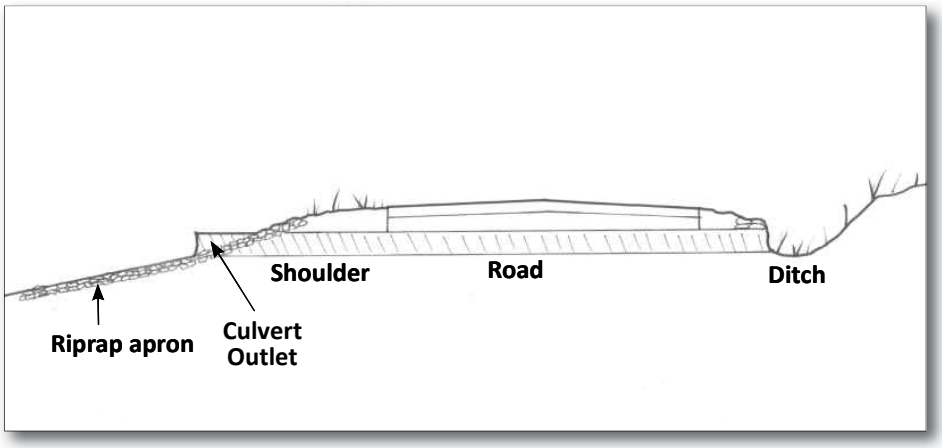
OUTLET PROTECTION: RIPRAP APRON

Road Type

Steep grade
Steep bank slope
Stream crossing
Adjacent to stream
Adjacent to wetland

BMP Function

Stabilization
Accessory



Road cross-section: The riprap apron is appropriate for outlets with bank slopes up to 5%.

Description and Purpose

» Stone or riprap pad armoring the outlet of a stormwater drainage culvert, turnout, or through-the-bank pipe in the case of an entrenched road.

» Converts channelized flow to dispersed flow as it travels perpendicular to the road.

Criteria for Use and Site Considerations

» Use at outlets where runoff discharge velocity is high.

» Use at outlet areas with up to 5% slope.

» Use where adequate vegetated buffer (minimum 50 feet) is available between the outlet and waterbody.

Benefits

» Inexpensive and easy to install.

» Provides some roughness that decreases the velocity of flow and encourages settling of sediment.

» Reduces impacts to streams if downhill from road.

Planning and Design

» Use the following minimum dimensions to adequately handle the anticipated flows:

- Upgrade width (W_0) = culvert diameter + 2 feet (for steep slopes W_0=3x culvert diameter).
- Length (L) = 10 feet for an 18-inch culvert and 14 feet for a 24-inch culvert
- Downgrade width (WF) = W_0 + L
- Depth: Minimum 18 inches

» Extend the length of apron if adjacent slope is greater than 10% to adequately reduce flow velocities.

» Design apron with minimal or no grade along its length.

» Do not berm the end of the apron.

OUTLET PROTECTION: RIPRAP APRON

» Discharge runoff from apron into a vegetated area.

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» For riprap, use minimum D_{50} = 6 inches; refer to design typical OP-1 for suggested stone sizing based on flow rate

» Dump truck

» Excavator or backhoe, hand shovel

Maintenance

» Inspect yearly and after large storms for any erosion or sliding of riprap material.

» Reposition any disturbed riprap stones.

» Remove any debris found in the riprap apron.

» Cut and/or remove any woody vegetation growing in the riprap apron.

» Repair any scouring occurring around the riprap apron.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

DRAINAGE CULVERT OUTLET PROTECTION

RIPRAP APRON

CRITERIA FOR USE:

1. RIPRAP APRON SHALL BE USED AT THE OUTLET OF A CULVERT OUTLET WHERE THE WATER DISCHARGE VELOCITY IS HIGH.
2. USE WHEN SLOPE ADJACENT TO ROAD IS ≥ 5% (1V:20H).
3. USE WHERE ADEQUATE VEGETATIVE FILTER STRIP IS AVAILABLE (MIN. 50 FT) BETWEEN OUTLET AND WATER BODY.

DESIGN CONSIDERATIONS:

1. LENGTH OF APRON MAY BE EXTENDED IF ADJACENT SLOPE IS ≥10% (1V:10H) TO REDUCE FLOW VELOCITIES ADEQUATELY.
2. WHEN USED AT END OF A DITCH, RIPRAP APRON SHALL EXTEND A MINIMUM OF 1' UP THE DITCH BANKS TO CONTAIN STORMWATER AND GUIDE THE FLOW OVER THE APRON.
3. APRON DIMENSIONS AND STONE SIZING SHALL BE ADEQUATE TO HANDLE THE ANTICIPATED RUNOFF FLOWS. SEE TABLE FOR SUGGESTED STONE SIZE FOR PEAK FLOW RATE. RIPRAP APRON SHALL HAVE THE FOLLOWING MINIMUM DIMENSIONS:

STONE SIZE (D_{50}):	6 INCHES
UPGRADE WIDTH (W_0):	CULVERT DIAMETER + 2 FEET
	BOTTOM OF DITCH WIDTH + 2 FEET
LENGTH (L):	10 FEET
DOWNGRADE WIDTH (W_F):	W_0 + L
DEPTH:	MIN. 18 INCHES

4. WHEN USED AT END OF A CULVERT, STONE SHALL EXTEND UP THE BANK A MINIMUM OF 2 FEET ABOVE THE CULVERT AT A MINIMUM DEPTH OF 6 INCHES.
5. FOR STEEP SLOPES ≥20% (1V:5H) UPGRADE WIDTH OF APRON SHALL BE A MINIMUM OF 3X THE CULVERT DIAMETER.
6. RIPRAP APRON SLOPE SHOULD BE FLAT OR MINIMALLY SLOPED WHERE FEASIBLE.

CONSTRUCTION SPECIFICATIONS:

MATERIAL:

RIPRAP:

RIPRAP SHALL BE SIZED FOR ANTICIPATED RUNOFF VOLUME AND VELOCITY. MINIMUM D_{50} SHALL BE 6 INCHES IN DIAMETER. ALL RIPRAP SHALL MEET MassDOT SPECIFICATION M2.02.3 STONE FOR PIPE ENDS

GEOTEXTILE FABRIC:

GEOTEXTILE SEPARATION FABRIC SHALL BE A NON-WOVEN GEOTEXTILE FABRIC LISTED ON THE MassDOT QCML FOR NON-WOVEN CODE 2 FABRIC.

CONSTRUCTION SEQUENCING:

1. EXCAVATE AREAS TO THE REQUIRED DIMENSIONS.
2. PLACE LAYER OF GEOTEXTILE FABRIC DOWN WITHIN THE LIMITS OF RIPRAP APRON.
3. PLACE RIPRAP ON TOP OF GEOTEXTILE FABRIC. HAND CHINK RIPRAP STONE INTO PLACE TO FORM A UNIFORM SURFACE WITHOUT STONE MOVEMENT.

OPERATION AND MAINTENANCE:

1. ROCK APRONS SHALL BE INSPECTED YEARLY OR AFTER LARGE STORMS.
2. REPOSITION ANY DISTURBED RIPRAP STONES TO CREATE A UNIFORM SURFACE.
3. REMOVE ANY DEBRIS FOUND IN THE RIPRAP APRON.
4. CUT AND/OR REMOVE ANY WOODY VEGETATION GROWING IN THE RIPRAP APRON.
5. REPAIR ANY SCOURING OCCURRING AROUND THE RIPRAP APRON.

CONSTRUCTION COSTS:

CONSTRUCTION COST OF RIPRAP APRON WILL VARY DEPENDING ON DIMENSIONS OF APRON. FOR A RIPRAP APRON AT THE END OF A CULVERT AND THE MINIMUM DIMENSIONS SHOWN HEREON, THE AVERAGE COST IS $750.

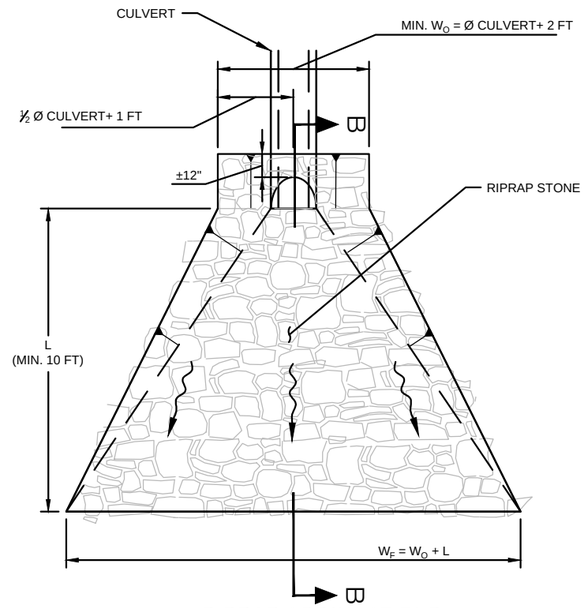
UNIT COSTS:

EXCAVATION:	$40.00/CY
RIPRAP STONE:	$35.00/CY (PRICE MAY VARY BASED ON REQUIRED D50)
GEOTEXTILE FABRIC:	$3.00/SY

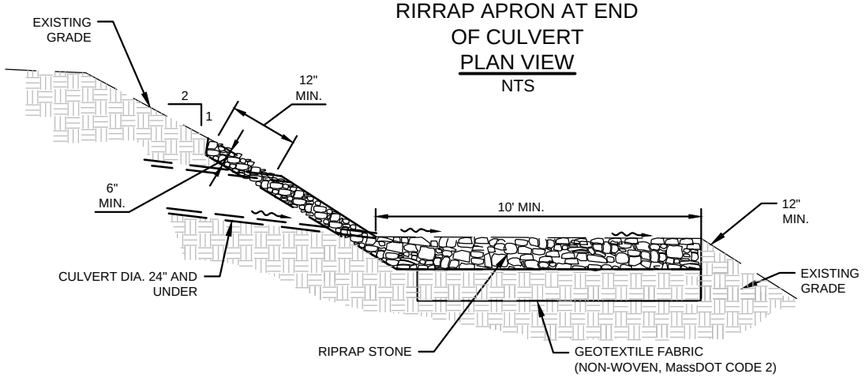
NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.



RIRRAP APRON AT END OF CULVERT
PLAN VIEW
NTS



RIRRAP APRON AT END OF CULVERT
CROSS SECTION B-B
NTS

SUGGESTED STONE SIZE FOR PEAK FLOW RATE	
PEAK FLOW RATE (CFS)	REQ. STONE SIZE (D50)
8.00 - 13.00	6"
13.01 - 15.75	10"
15.76 - 20.50	14"
20.50 - 22.00	20"
>22.00	22"

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)						
	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
OUTLET PROTECTION	LOW	HIGH	LOW	HIGH	LOW	HIGH
	-	6.3	-	0.0	-	0.0

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

DRAINAGE CULVERT OUTLET PROTECTION
RIPRAP APRON

PREPARED BY:	REVISED BY:	PREPARED FOR:	
GZA	BSC GROUP	frcog	
DATE:	REV DATE:	REV NO.	FIGURE
SEP. 2024	JUN. 2025	-	OP-1

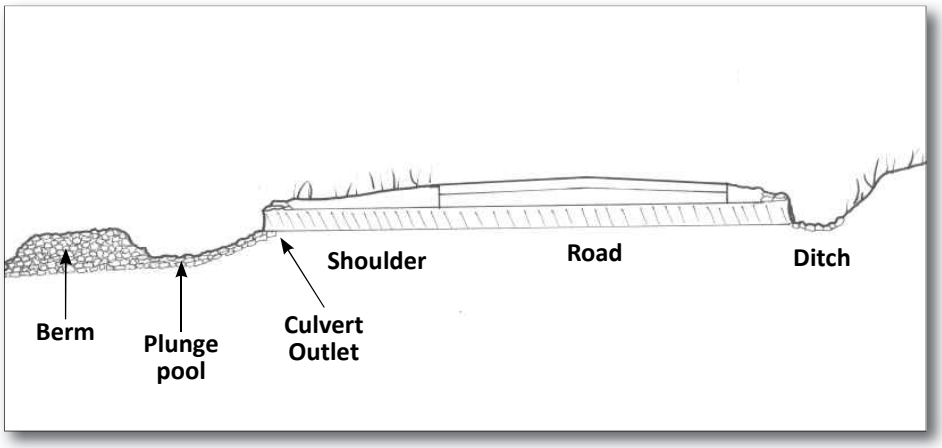
OUTLET PROTECTION: PLUNGE POOL

Road Type

Steep grade
Steep bank slope
Stream crossing
Adjacent to stream
Adjacent to wetland

BMP Function

Velocity control
Stabilization
Detention
Accessory



Road cross-section: The plunge pool is appropriate for outlets where runoff discharge velocity is high with bank slopes up to 10%.

Description and Purpose

» Stone or riprap-lined basin armoring the outlet of a stormwater drainage culvert, turnout, or through-the-bank pipe (in the case of an entrenched road).

» Designed to capture and store runoff and to settle out sediment.

Criteria for Use and Site Considerations

» Use at outlets where runoff discharge velocity is high.

» Use at outlet areas with up to 10% slope.

» Use where adequate vegetated buffer (minimum 50 feet) is available between the outlet and waterbody.

Plunge pool at outlet of culvert in woods.

Benefits

» Consolidates sediment for easier removal.

» Can allow for groundwater recharge.

» Reduces impacts to streams if downhill from road.

Planning and Design

» Construct a pool berm a minimum of 5 feet in width.

» Construct elevation of berm a minimum of 3 inches below the bottom of the culvert outlet.

» Place riprap to a minimum depth of 18 inches.

OUTLET PROTECTION: PLUNGE POOL

» Pool berm slopes not to exceed 2H:1V (50%).

» Use the following minimum dimensions to adequately handle the anticipated flows:

- Width (W) = 2 x culvert diameter
- Deep (D) = 1 x culvert diameter (3-feet minimum)
- Long (L) = 4 x culvert diameter

» Sizing:

Distance between culverts (feet)	Pool capacity			
	Crowned road		Cross-slope road	
	Depth (feet)	Diameter (feet)	Depth (feet)	Diameter (feet)
500	4.75	9.5	6	12
400	4.5	9	5.5	11
350	4.5	9	5	10
300	4	8	5	10
250	4	8	4.75	9.5
200	3.5	7	4.5	9

Source: Vermont Better Roads Manual, 2024

» Place where mechanized cleaning is possible from roadway.

» Discharge runoff from pool into a vegetated area.

» Include sediment depth markers to gauge sediment accumulation during inspections and maintenance.

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» Use minimum D_{50}=6 inches; refer to design typical OP-2 for required stone sizing based on flow rate

» Dump truck, excavator or backhoe, hand shovel

Maintenance

» Inspect yearly and after large storms for any erosion or sliding of riprap material.

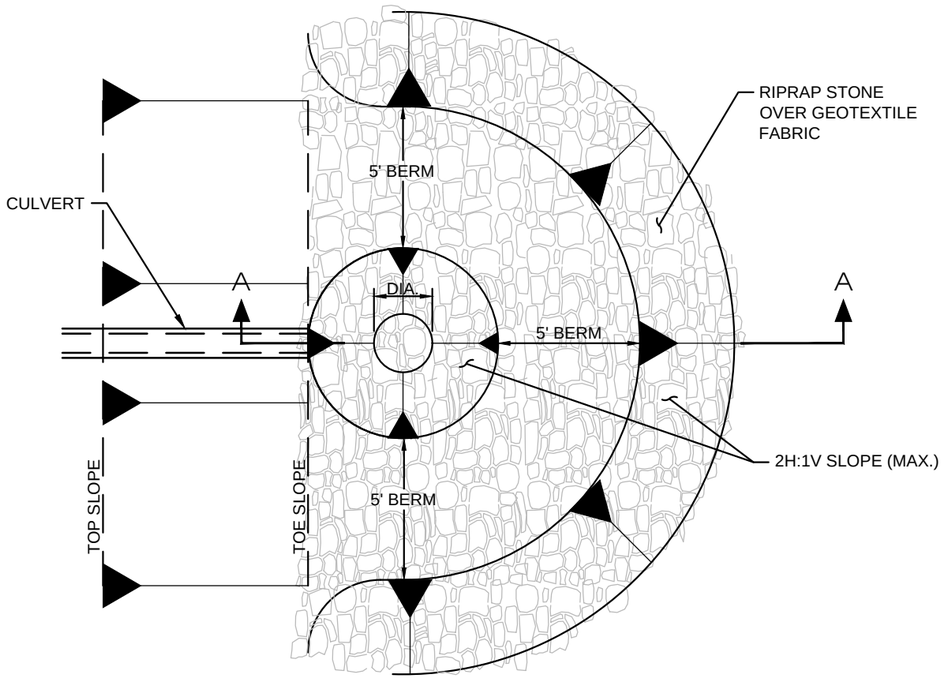
» Reposition any disturbed stones to restore the pool's original dimensions and create a uniform surface.

» Remove any debris found in the pool.

» Clean accumulated sediment when pool is one third full.

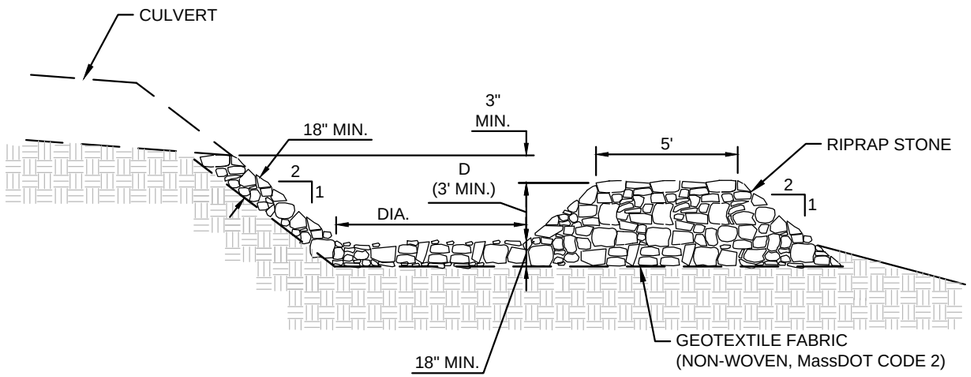
» Repair any scouring occurring around the pool.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***



PLUNGE POOL PLAN VIEW

NTS



PLUNGE POOL
CROSS-SECTION A-A

NTS

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)						
	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
OUTLET PROTECTION	LOW	HIGH	LOW	HIGH	LOW	HIGH
	-	6.3	-	0.0	-	0.0

DRAINAGE CULVERT OUTLET PROTECTION

PLUNGE POOL

CRITERIA FOR USE:

1. PLUNGE POOLS SHOULD BE USED IN AREAS WHERE ADEQUATE SPACE IS AVAILABLE WITHIN THE RIGHT-OF-WAY AND THE EXISTING ADJACENT SLOPE IS UNDER 10% (1V:10H).
2. PLUNGE POOLS SHOULD BE LOCATED AND CONSTRUCTED SO THAT MECHANIZED CLEANING IS POSSIBLE FROM ROADWAY.
3. PLUNGE POOLS SHOULD BE USED WHERE ADEQUATE VEGETATIVE FILTER STRIP IS UNAVAILABLE.

DESIGN CONSIDERATIONS:

1. ELEVATION OF BERM SHALL BE A MINIMUM OF 3 INCHES BELOW PIPE OUTLET INVERT.
2. RIPRAP DEPTH SHALL BE A MINIMUM OF 18 INCHES.
3. POOL BERM SHALL BE A MIN. OF 5 FEET IN WIDTH.
4. POOL BERM SLOPES SHALL BE NO STEEPER THAN 2H:1V.
5. POOL DIMENSIONS:
   MIN. DIMENSIONS:
   WIDTH (W) = 2 X CULVERT DIA.
   DEEP (D) = 1 X CULVERT DIA. (3' MIN.)
   LONG (L) = 4 X CULVERT DIA.
6. TYPICAL POOL CAPACITY REQUIREMENTS

	POOL CAPACITY			
DISTANCE BETWEEN	CROWNED ROAD		BANKED ROAD	
CULVERTS (FT.)	DEPTH (FEET)	DIAMETER (FEET)	DEPTH (FEET)	DIAMETER (FEET)
500	4.75	9.5	6	12
400	4.5	9	5.5	11
350	4.5	9	5	10
300	4	8	5	10
250	4	8	4.75	9.5
200	3.5	7	4.5	9

CONSTRUCTION SPECIFICATIONS:

MATERIAL:

RIPRAP:

RIPRAP SHALL BE SIZED FOR ANTICIPATED RUNOFF VOLUME AND VELOCITY. MINIMUM D_{50} SHALL BE 6 INCHES. ALL RIPRAP SHALL MEET MassDOT SPECIFICATION M2.02.3 STONE FOR PIPE ENDS

GEOTEXTILE FABRIC:

GEOTEXTILE SEPARATION FABRIC SHALL BE A NON-WOVEN GEOTEXTILE FABRIC LISTED ON THE MassDOT QCML FOR NON-WOVEN CODE 2 FABRIC.

CONSTRUCTION SEQUENCING:

1. EXCAVATE AREAS TO THE REQUIRED DIMENSIONS.
2. SMOOTH THE SURFACE OF THE EXCAVATED POOL AND REMOVE ANY PROTRUDING ROCKS AND ROOTS.
3. LINE POOL WITH NON-WOVEN GEOTEXTILE FABRIC AND PLACE A MINIMUM OF 12 INCHES OF RIPRAP (M2.02.3) ON TOP OF FABRIC. CHINK RIPRAP TO MAKE A SOLID UNIFORM SURFACE WITH MINIMAL VOIDS.
4. CREATE POOL BERM USING RIPRAP (M2.02.3). BERM TO BE MINIMUM 5' IN WIDTH AND HAVE 2'H:1'V SLOPES. CHINK RIPRAP TO MAKE A SOLID UNIFORM SURFACE WITH MINIMAL VOIDS.
5. RE-ESTABLISH VEGETATION WITHIN THE DISTURBED AREAS.

OPERATION AND MAINTENANCE:

1. POOL TO BE INSPECTED YEARLY OR AFTER LARGE STORMS.
2. REPOSITION ANY DISPLACED STONES TO RESTORE THE POOL'S ORIGINAL DIMENSIONS AND UNIFORM SURFACE.
3. REMOVE ANY DEBRIS WITHIN THE POOL AT LEAST ONCE A YEAR AND CLEAN ACCUMULATED SEDIMENT WHEN POOL IS ONE THIRD FILL.
4. CUT AND/OR REMOVE ANY WOODY VEGETATION GROWING WITHIN THE POOL.

CONSTRUCTION COSTS:

CONSTRUCTION COST OF PLUNGE POOL WILL VARY DEPENDING ON DIMENSIONS OF SPREADER AND TYPE OF WEIR USED. FOR A TYPICAL PLUNGE POOL COST IS $1,500.

UNIT COSTS:

EXCAVATION: $40.00/CY
STONE: $35.00/CY
GEOTEXTILE FABRIC: $3.00/SY

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.

SUGGESTED STONE SIZE FOR PEAK FLOW RATE	
PEAK FLOW RATE (CFS)	REQ. STONE SIZE (D50)
8.00 - 13.00	6"
13.01 - 15.75	10"
15.76 - 20.50	14"
20.50 - 22.00	20"
>22.00	22"

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

DRAINAGE CULVERT OUTLET PROTECTION PLUNGE POOL

PREPARED BY:	REVISED BY:	PREPARED FOR:	
GZA	BSC GROUP	frcog	
DATE:	REV DATE:	REV NO.	FIGURE
SEP. 2024	JUN. 2025	-	OP-2

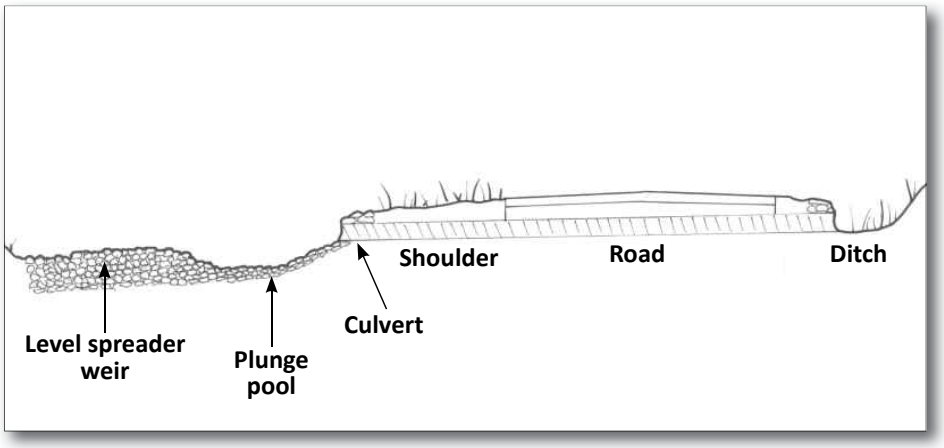
OUTLET PROTECTION: LEVEL SPREADER

Road Type

Steep grade
Steep bank slope
Stream crossing
Adjacent to stream

BMP Function

Velocity control
Stabilization
Detention
Accessory



Road cross-section: The linear level spreader is appropriate for areas with minimal bank slopes and is best used as a continuation of a plunge pool.

Description and Purpose

» Small plunge pool that discharges to a linear trench with a stone berm that can be overtopped via a weir when pool and trench are filled.

» Allows for infliltration.

» Converts any channelized over-flow to dispersed flow, i.e., levels and spreads the flow of the runoff.

Criteria for Use and Site Considerations

» Use at outlets where runoff discharge velocity is high.

» Linear level spreader should be oriented with the contours of the land, so runoff spreads out over the structure.

» Use at outlet areas with up to 5% slope.

» Use where adequate vegetated buffer (minimum 50 feet) is available between the outlet and waterbody.

Benefits

» Inexpensive and easy to install.

» Provides some roughness that decreases the velocity of flow and encourages sediment settling.

» Reduces impacts to streams if downhill from road.

Planning and Design

» Begin level spreader with a plunge pool with the following dimensions: width = 2 x diameter of culvert, depth = 1 x diameter of culvert, and length = 4 x diameter of culvert.

» Place riprap to a minimum depth of 18 inches. Cut level spreader into the existing adjacent slope, parallel with countours.

OUTLET PROTECTION: LEVEL SPREADER

» The level spreader mechanism includes a weir. The maximum slope of stone for the weir outlet shall be 2H:1V (50% slope).

» The weir should be graded to be level across the entire length, otherwise erosion will happen at the low point.

» Level spreader can be created out of rocks, lumber, or curbing (concrete or granite). Using curbing is more expensive, but can require less maintenance.

» Level spreader depth should range 6 – 12 inches.

» Level spreader length varies with drainage area size, ranging from 10 ft long for 1 acre to 20 ft long for 5 acres (see design typical OP-3 for more details).

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» Use minimum D_{50}=6 inches minimum [12 inches deep at pipe end and 18-inch deep at weir]; refer to design typical OP-3 for required stone sizing based on flow rate

» Dump truck

» Excavator or backhoe, hand shovel

Maintenance

» Inspect yearly and after large storms for any erosion or sliding of riprap material.

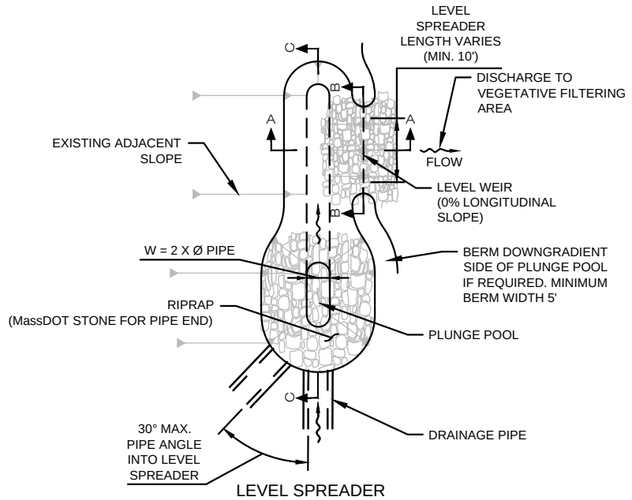
» Reposition any disturbed riprap stones.

» Remove any debris found in the level spreader.

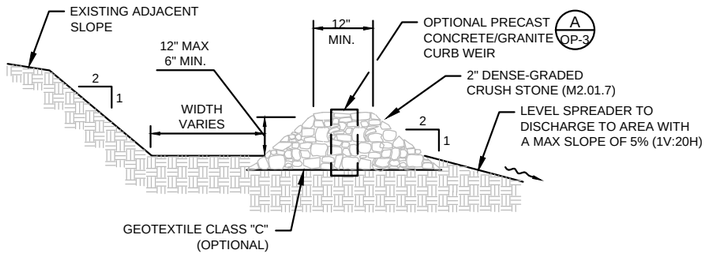
» Cut and/or remove any woody vegetation growing in the level spreader.

» Repair any scouring occurring around the level spreader.

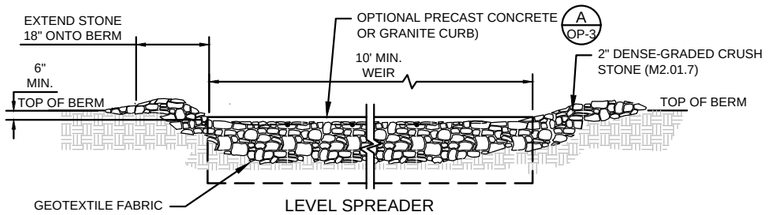
This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***



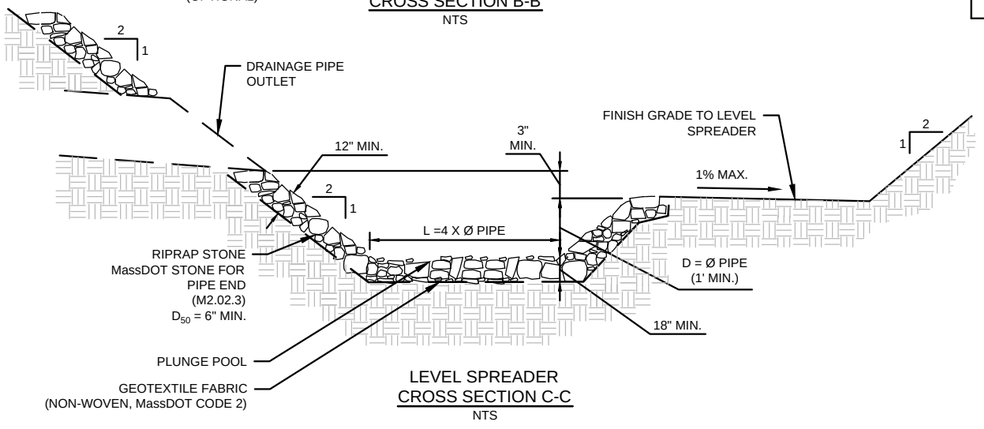
LEVEL SPREADER
OUTLET PROTECTION PLAN VIEW
NTS



LEVEL SPREADER
CROSS SECTION A-A
NTS



LEVEL SPREADER
CROSS SECTION B-B
NTS



LEVEL SPREADER
CROSS SECTION C-C
NTS

DRAINAGE CULVERT OUTLET PROTECTION

LEVEL SPREADER

CRITERIA FOR USE:

1. LINEAR LEVEL SPREADER SHALL BE ORIENTATED IN PARALLEL TO ADJACENT LAND CONTOURS.
2. SLOPE AT OUTLET OF THE LEVEL SPREADER SHALL BE 5% OR LESS.
3. USE WHERE ADEQUATE VEGETATIVE FILTER STRIP IS AVAILABLE (MIN. 50 FT) BETWEEN OUTLET AND WATER BODY.
4. CULVERT SHALL DISCHARGE TO A SMALL PLUNGE POOL PRIOR TO DISCHARGING TO THE LEVEL SPREADER.

DESIGN CONSIDERATIONS:

LEVEL SPREADER

1. LEVEL SPREADER SHALL BE CUT INTO THE EXISTING ADJACENT SLOPE.
2. LEVEL SPREADER CAN BE CREATED OUT OF ROCKS, LUMBER, CONCRETE OR GRANITE CURBING. LEVEL SPREADERS WHICH USE CONCRETE OR GRANITE CURBING TYPICALLY REQUIRE A LOWER MAINTENANCE, BUT AT A LARGER CONSTRUCTION COST.
3. DEPTHS OF FLOW AND PONDING BEHIND A LEVEL SPREADER SHOULD RANGE BETWEEN 6 TO 12 INCHES.
4. SPREADER WEIR LENGTHS SHALL BE AS FOLLOWS:

DRAINAGE AREA SIZE (AC)	MIN. SPREADER WEIR LENGTH (FT)
1	10
2	10
3	15
4	18
5	20

5. LEVEL SPREADER WEIR SHALL BE GRADED TO BE ABSOLUTELY LEVEL ACROSS THE ENTIRE LENGTH OF WEIR. A SMALL DEVIATION CAN CAUSE EROSION AT THE WEIR LOW POINT.
6. MAX SLOPE OF STONE FOR OUTLET WEIR SHALL BE 2H:1V

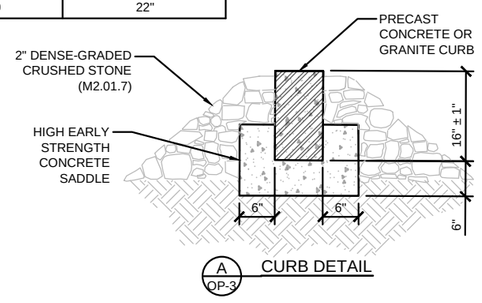
PLUNGE POOL

1. OUTLET WEIR SHALL BE MIN. 3 INCHES BELOW INLET ELEVATION.
2. OUTLET WEIR SHALL BE A MIN. OF 5 FEET IN WIDTH.
3. RIPRAP SHALL BE A MINIMUM DEPTH OF 18 INCHES.
4. POOL DIMENSIONS:

MIN. DIMENSIONS:

WIDTH (W) =	2 X CULVERT DIA.
DEEP (D) =	1 X CULVERT DIA. (3' MIN.)
LONG (L) =	4 X CULVERT DIA.

SUGGESTED STONE SIZE FOR PEAK FLOW RATE	
PEAK FLOW RATE (CFS)	REQ. STONE SIZE (D50)
8.00 - 13.00	6"
13.01 - 15.75	10"
15.76 - 20.50	14"
20.50 - 22.00	20"
>22.00	22"



A
OP-3
CURB DETAIL

CONSTRUCTION SPECIFICATIONS:

MATERIAL:

STONE:
2" - DENSE GRADED CRUSHED STONE (M2.01.7)

RIPRAP:
RIPRAP FOR OUTLET PROTECTION SHALL MEET THE MASSDOT MATERIAL SPECIFICATION M2.02.3.

GEOTEXTILE FABRIC:
GEOTEXTILE SEPARATION FABRIC (NON-WOVEN MassDOT CODE 2)

WEIR/CURB:

PRECAST CURB:	STRENGTH:	5,000 PSI
	WEIGHT:	135 LB/FT
	DIMENSIONS:	20" H X 6" W (TOP) X 7" W (BASE)
GRANITE CURB:	GRANITE CURB TYPE VA5 (M9.04.1-1)	

CONSTRUCTION SEQUENCING:

1. EXCAVATE AREAS TO THE REQUIRED DIMENSIONS.
2. IF UTILIZING PRECAST CONCRETE OR GRANITE CURB WEIR, EXCAVATE FOR WEIR, PLACE WEIR IN DESIRED LOCATION, LEVEL WEIR AND POUR IN PLACE CONCRETE SADDLE.
3. PLACE STONE FOR WEIR WITH 2H:1V MAX SLOPES.
4. STABILIZE EARTH SLOPES AND BOTTOM USING APPROPRIATE GRASS SEED. USE ONLY GRASSES.

OPERATION AND MAINTENANCE:

1. INSPECT LEVEL SPREADERS REGULARLY, ESPECIALLY AFTER LARGE RAINFALL EVENTS. NOTE ANY EROSION OR LOW SPOTS WITHIN THE LEVEL SPREADER AND REPAIR.

CONSTRUCTION COSTS:

CONSTRUCTION COST OF LEVEL SPEADER WILL VARY DEPENDING ON DIMENSIONS OF SPREADER AND TYPE OF WEIR USED. FOR A TYPICAL LEVEL SPREADER COST IS $1,500.

UNIT COSTS:

EXCAVATION:	$40.00/CY
STONE:	$90.00/CY
GEOTEXTILE FABRIC:	$3.00/SY
CURB:	
PRECAST:	$65.00/L.F.
GRANITE:	$110.00/L.F.

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)

	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
OUTLET PROTECTION	LOW	HIGH	LOW	HIGH	LOW	HIGH
	-	6.3	-	0.0	-	0.0

DRAINAGE CULVERT OUTLET PROTECTION LEVEL SPREADER

PREPARED BY:	REVISED BY:	PREPARED FOR:	
GZA	BSC GROUP	frcog	
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. -	FIGURE OP-3

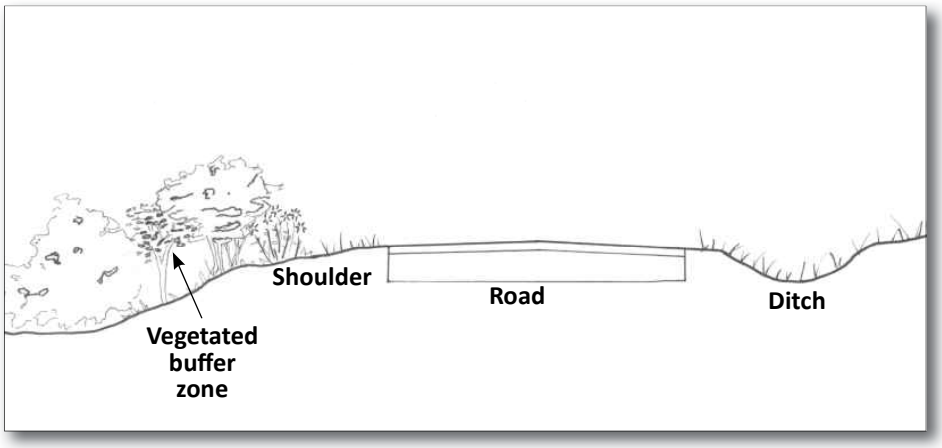
VEGETATED BUFFER ZONE

Road Type

Steep bank slope
Stream crossing
Adjacent to stream
Adjacent to wetland

BMP Function

Stabilization
Velocity control
Filtration



Road cross-section: A vegetated buffer, also know as a plant buffer, riparian buffer, or filter zone, functions as natural erosion control and a sediment trap.

Description and Purpose

» Undisturbed vegetated area that separates road from waterbody.

» Functions as natural erosion control and sediment trap as the roughness of the vegetation slows stormwater flow and reduces erosion, and filters sediments in runoff.

Criteria for Use and Site Considerations

» Use on roadsides and downslope banks.

» Use when road is close to a stream or wetland.

» If there is little or no vegetation between the road and stream, vegetated buffers must be created or enhanced.

» Not for treatment of channelized flow.

Benefits

» Inexpensive when allowing existing vegetation to grow.

» Provides shade and habitat for wildlife.

» Can help stabilize banks and absorb floodwaters from nearby waterbodies.

Planning and Design

» Encourage a mix of native grasses, shrubs, trees, and biomass (decaying plant material).

» The benefits of the buffer increase with width. Ideal width is minimum 50 feet.

» Keep excavation outside the drip line of trees and shrubs as much as possible during road work to prevent damage to roots.

» If runoff is eroding or excessive sediment is accumulating in the buffer zone, it is a sign that other types of BMPs are needed upstream.

VEGETATED BUFFER ZONE

Material and Equipment

» Seed mix appropriate for erosion control and wildlife habitat following current MassDOT guidance

» Native tree and shrub seedlings

» Shovel and rake

» Mulch

Maintenance

» Allowing a buffer zone to grow requires very little maintenance.

» Manage vegetation to discourage invasive plant species and encourage success of desired plants.

» Inspect yearly to make sure erosion is not occurring.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

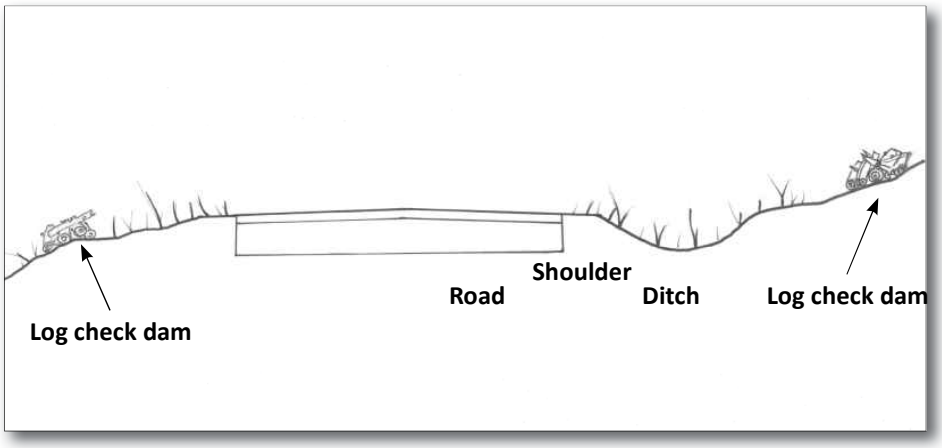
LOG CHECK DAM

Road Type

Steep bank slope
Adjacent to stream
Adjacent to wetland

BMP Function

Velocity control
Filtration



Road cross-section: Log check dams help slow down stormwater runoff and can be made from woody debris on the forest floor.

Description and Purpose

» Woody debris placed on an adjacent bank to capture and slow down stormwater runoff.

» Designed to slow flow coming into the ditch or discharging out of the road drainage system to reduce erosion and allow sediment to settle out.

Criteria for Use and Site Considerations

» Roadside slopes where vegetation does not adequately check erosion and filter sediment.

» Use on steep slopes with concentrated or dispersed flows, particularly those adjacent to waterbodies.

Benefits

» Inexpensive and easy to install and remove.

» Materials can be collected onsite or nearby in wooded areas.

» Can be installed quickly to improve an emerging erosion problem.

Planning and Design

» Can be built anytime snow cover does not obscure drainage and wood sources.

» Place logs in interlocking formation for stability; use wooden stakes to keep logs in place, if desired.

» Planning and design can be done at little cost by observation of where water is draining.

LOG CHECK DAM

Material and Equipment

» Logs and branches from fallen trees.

» Wood can be moved into place by hand or with equipment.

Maintenance

» Inspect yearly and after large storms for any collapse or if sediment needs to be cleaned out.

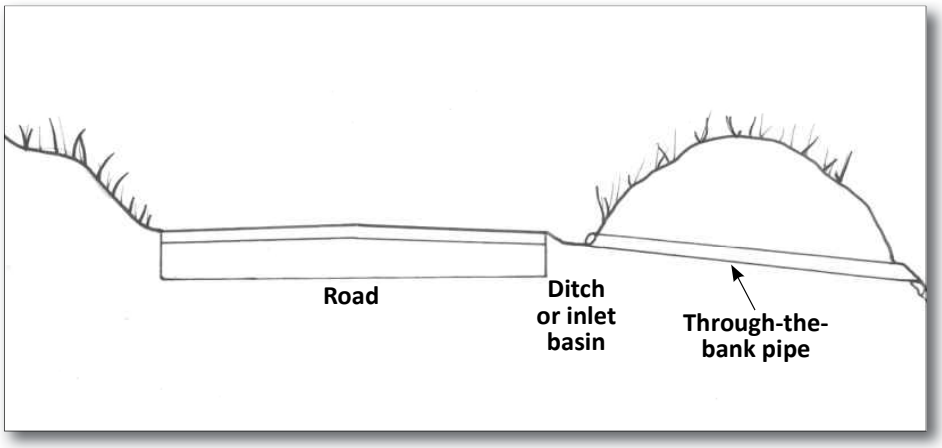
» Inspect yearly to see if check dams are placed where runoff is flowing.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

THROUGH-THE-BANK-PIPE

Road Type
Entrenched

BMP Function
Conveyance



Road cross-section: A through-the-bank pipe is used on entrenched roads where water is trapped on the road.

Description and Purpose

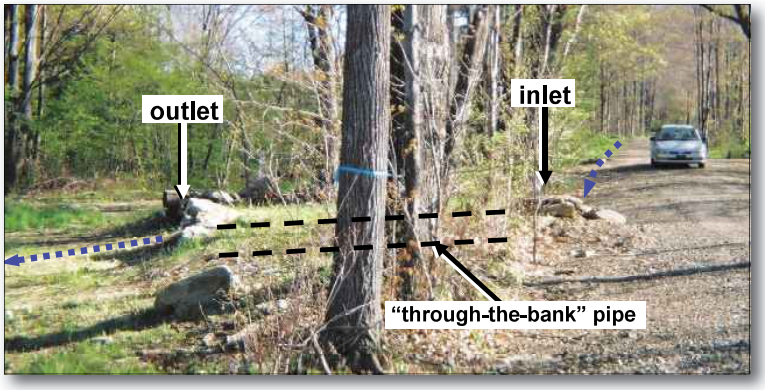
» A pipe (culvert) placed through a roadside berm or small bank to carry runoff out of an entrenched road.

» Provides an outlet for runoff that is trapped in the road corridor by road banks.

Criteria for Use and Site Considerations

» Use on roads where a berm, mounded shoulder, or bank is trapping drainage and shoulder removal is not possible.

» Use only where an appropriate drainage area exists downgradient of the culvert outlet.



A through-the-bank pipe diverts water from the road under a raised treeline.

Benefits

» Low maintenance.

» More aesthetically pleasing than open trenches.

» Can help preserve historic stone walls and mature trees.

Planning and Design

» Locate culvert inlet in the road ditch.

» Locate culvert outlet at natural ground level to reduce erosion.

» Install culvert at a 1% slope and make sure water will not flow back into the road from the outlet; use a level to determine if the structure is feasible, as often times the level will show that there is sufficient slope in locations where the naked eye thinks the outlet of the culvert might be higher than the inlet.

» Install culvert with a headwall and endwall.

THROUGH-THE-BANK-PIPE

» Install culvert at a 30 to 90 degree angle from the ditch, depending on road grade.

» Where applicable, berm the ditch immediately below the culvert inlet to prevent drainage from bypassing the culvert and flowing down the road.

» Choose a culvert with a diameter large enough to handle runoff from the contributing drainage area during a major storm. See Round Stormwater Drainage Culvert BMP fact sheet for more information.

» Use outlet protection and/or settling BMPs if high flows are expected.

» Consider installing a cross culvert or grade break just above the through-the-bank-pipe to drain the opposite road ditch as well.

» Compaction and quality of fill material is not an issue because the culvert is not under the road and therefore not expected to carry heavy loads.

Material and Equipment

» Corrugated metal or plastic culvert pipe

» Dump truck

» Excavator or backhoe, or tunneling/boring device to dig the culvert trench

» Material for outlet protection structure, if needed

Maintenance

» Inspect and repair twice yearly at minimum for major obstructions, erosion, or collapsed banks. Prioritize fall and spring when plants are dormant and after major storm events.

» Remove sediment, leaves, and debris to prevent overflows and washouts.

» Check inlet for erosion and to ensure runoff is flowing in the culvert and not around it, if some runoff goes around the culvert it can undermine the bedding and the culvert will fail (e.g. piping).

» Modify if not performing adequately. Replace culvert with the same size culvert if it already meets the sizing requirements; increase culvert size if properly constructed culvert repeatedly washes out, as development along the road increases, or as sizing guidelines change.

» Include in any inventory of culverts so that they do not get missed during inspections.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

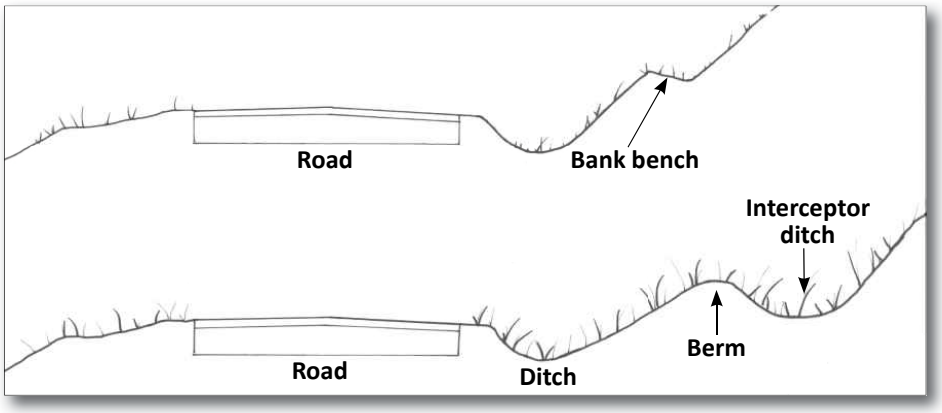
BANK BENCH & INTERCEPTOR DITCH

Road Type

Steep bank slope

BMP Function

Conveyance
Velocity control
Stabilization



Road cross-section: A bank bench (top) is a grade reversal on a bank and an interceptor ditch (bottom) is a ditch in a bank that that forces runoff to flow along the bank's contour. Both can also be used on the downslope side (not pictured).

Description and Purpose

» A step (bank bench) or swale (interceptor ditch) built into a sloped bank (either upslope or downslope of the road) to slow and divert runoff before reaching the road or waterbody.

Criteria for Use and Site Considerations

General

» Use where a stable outlet area exists nearby to drain the swale or ditch.

» Use with abutting property owner's approval if located outside the right-of-way.

Bank Bench

» Use on bank slopes that are contributing runoff to the roadside ditch, road, or waterbody, particularly if evidence of rill erosion exists on bank.

» Use on steeper bank slopes.

» Bank bench may not be suitable in areas of excess runoff because the bench has limited capacity to contain a high volume of runoff.

Interceptor Ditch

» Use on gentler bank slopes.

» Use when the longitudinal slope is gentle enough to prevent erosion in the ditch.

Benefits

» Controls and redirects stormwater runoff and sediment coming from uphill sources, such as an unvegetated bank or uncontrolled runoff from a driveway.

» Protects banks and roadside ditches from erosion.

» Can create a stable soil and moisture area that promotes plant growth on the bank.

BANK BENCH & INTERCEPTOR DITCH

Planning and Design

Bank Bench

» Typically built with equipment positioned on the roadway.

» Outlet to flat, stable, and well-vegetated areas. Use stone only if the outlet requires stabilization.

» Longitudinal slope should be minimal (5% or less).

» Construct bench to be 3 – 7 feet in width.

» Cross-sectional shape of bench can be flat, or have a slight grade reversal towards the upslope bank.

» Stabilize and revegetate with seed mix (see MassDOT guidance), mulch, and erosion control matting.

» Multiple bank benches may be necessary to slow and divert flow on steep or high banks.

Interceptor Ditch

» Can be built from the roadway, but may be large enough that it requires positioning equipment in an area outside the road right-of-way with permission from abutting landowners.

» Can be used at the top of a steep slope to prevent erosion on the slope below, or use across long slopes to break up the slope or to redirect water.

» Longitudinal slope should be minimal (5% or less); otherwise follow guidance for stone lining.

» Stabilize and revegetate with seed mix (see MassDOT guidance), mulch, and erosion control matting.

» Outlet may require stone outlet protection to reduce erosion.

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» Use D_{50} = 4 inches stone for bank slopes 5 – 10%

» Use D_{50} = 8 inches stone for bank slopes greater than 10%

» Loam

» Seed mix (see MassDOT guidance for slopes and shoulders), mulch, and erosion control matting

» Excavator or backhoe

Maintenance

» Inspect bank bench and interceptor ditch yearly and after major storm events.

» Remove sediment, leaves, and debris found within benches or ditches to prevent overflows and washouts.

» Repair any scouring, erosion, or bank collapses.

» Re-grade benches and ditches as necessary. Reseed (or stone) as soon as possible.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

BANK BENCH AND INTERCEPTOR DITCH

CRITERIA FOR USE:

BANK BENCH CRITERIA FOR USE:

1. USE ON STEEPER BANK SLOPES.
2. USE ON CUT SLOPES SUBJECT TO RELATIVELY LOW SURFACE FLOWS.
3. USE IF STABLE FILTER AREA EXISTS NEARBY TO DRAIN BANK BENCH.
4. USE IF EVIDENCE OF RILL EROSION EXISTS ON BANK.

INTERCEPTOR DITCH CRITERIA FOR USE

1. USE ON GENTLER BANK SLOPES. USE ON CUT SLOPES WITH EXCESSIVE OVERLAND FLOW.
2. USE IF STABLE OUTLET AREA EXISTS NEARBY TO DRAIN INTERCEPTOR DITCH.
3. USE WITH ABUTTING PROPERTY OWNER'S APPROVAL IF LOCATED OUTSIDE THE RIGHT-OF-WAY.
4. USE WHEN THE LONGITUDINAL SLOPES ARE GENTLE ENOUGH TO PREVENT EROSION IN THE DITCH.

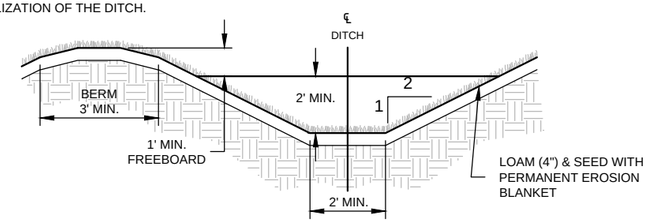
DESIGN CONSIDERATIONS:

BANK BENCH CONSIDERATIONS:

1. BUILT FROM THE ROADWAY.
2. BANK BENCHES SHOULD OUTLET TO FLAT, STABLE, AND WELL-VEGETATED AREAS. USE MATERIAL ONLY IF THE OUTLET REQUIRES STABILIZATION.
3. LONGITUDINAL SLOPE OF THE BENCH SHOULD BE MINIMAL, LESS THAN 5%.
4. BANK BENCH SHOULD BE BETWEEN 3 TO 7 FEET IN WIDTH.
5. CROSS-SECTIONAL SHAPE OF A BANK BENCH CAN BE FLAT, OR SLIGHTLY PARABOLIC, WITH A SLIGHT SLOPE TOWARDS THE CUTSLOPE BANK.
6. BANK BENCHES MAY NOT BE SUITABLE IN AREAS OF EXCESS RUNOFF.
7. IMPERATIVE TO USE MassDOT SPECIFIED SEED FOR GRASS SLOPES AND SHOULDERS TO VEGETATE BANK BENCH FOR STABILIZATION. CONSIDER THE USE OF A HYDROMULCH FOR TEMPORARY EROSION CONTROL WHILE VEGETATION GROWS.
8. MULTIPLE BANK BENCHES MAY BE NECESSARY TO SLOW AND DIVERT FLOW ON STEEP OR HIGH-REACHING BANKS.
9. CONSIDER THE USE OF PERMANENT EROSION CONTROL MATTING TO ASSISTS IN RE-VEGETATION AND STABILIZATION OF THE BANK BENCH.

INTERCEPTOR DITCH CONSIDERATIONS:

1. CAN BE BUILT FROM THE ROAD; HOWEVER, INTERCEPTOR DITCHES MAY REQUIRE AREA OUTSIDE OF THE ROAD RIGHT-OF-WAY. THEREFORE, MAY REQUIRE PERMISSION FROM ABUTTING LANDOWNERS.
2. INTERCEPTOR DITCHES MAY BE USED AT THE TOP OF A STEEP SLOPE TO PREVENT EROSION ON THE SLOPE BELOW, OR INTERCEPTOR DITCHES CAN BE USED ACROSS LONG SLOPES TO BREAK UP THE SLOPE OR REDIRECT WATER BELOW.
3. LONGITUDINAL SLOPE SHOULD BE MINIMIZED, LESS THAN 5%. HOWEVER, WITH PROPER CHANNEL ARMORING SLOPES GREATER THAN 5% MAY BE USED.
4. DITCHES WITH A LONGITUDINAL SLOPE SHALL BE LINED AS FOLLOWS:
   - 4.1. WITH SLOPE ≤5% SHALL BE GRASS-LINED (NEW ENGLAND EROSION CONTROL/RESTORATION MIX FOR DRY/WET SITES).
   - 4.2. WITH SLOPE 5%-8% SHALL BE ARMORED WITH 12 INCHES OF 2 TO 6 INCH STONE
   - 4.3. WITH A SLOPE >8% SHALL BE ARMORED WITH 12 INCHES OF 6 TO 10 INCH STONE
5. USE OUTSIDE OF THE RIGHT-OF-WAY MUST CONSIDER UPSLOPE LAND USE.
6. STONE REINFORCEMENT MAY BE REQUIRED TO STABILIZE THE OUTLET.
7. USE ON SITE CONDITIONS THAT CAN ACCOMMODATE A DITCH 6 TO 12 FEET WIDE (BANK TO BANK). MORE GENTLE BANK SLOPES ALLOW FOR WIDER DITCHES TO REDUCE EROSION.
8. CROSS-SECTIONAL SHAPE OF THE DITCH SHALL BE SHALLOW AND TRAPEZOIDAL OR PARABOLIC.
9. CONSIDER THE USE OF PERMANENT EROSION CONTROL MATTING TO ASSISTS IN RE-VEGETATION AND STABILIZATION OF THE DITCH.



A GRASS LINED DITCH
NTS

CONSTRUCTION SPECIFICATIONS:

1. STONE:
   FOR SLOPE 5-10% - STONE SHALL HAVE A D_{50}=4 INCHES AND MEET THE MassDOT SPECIFICATIONS FOR MODIFIED ROCKFILL (M2.02.4).
   FOR SLOPES >10% - STONE SHALL HAVE A D_{50}=8 INCHES AND MEET THE MassDOT SPECIFICATION FOR MODIFIED ROCKFILL (M2.02.4).
2. GEOTEXTILE FABRIC:
   GEOTEXTILE FABRIC SHALL BE A NON-WOVEN GEOTEXTILE FABRIC CLASSIFIED AS CLASS 2 FABRIC ON MassDOT QUALIFIED CONSTRUCTION MATERIAL LIST (QCML).
3. LOAM:
   LOAM SHALL MEET THE MassDOT SPECIFICATIONS FOR LOAM BORROW (M1.05.0)
4. SEED:
   SEED SHALL MEET THE MassDOT SPECIFICATIONS FOR GRASS SLOPES AND SHOULDERS (M6.03.0-2)
5. PERMANENT EROSION MATTING:
   PERMANENT EROSION CONTROL MATTING SHALL CONSIST OF TURF REINFORCEMENT MATS (TRM) SUCH AS TMAX BY NORTH AMERICAN GREEN, OR EQUAL.

CONSTRUCTION SEQUENCING:

1. CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. DETERMINE IF EXCAVATION EQUIPMENT CAN REACH FROM THE ROAD. IF BANK BENCH OR INTERCEPTOR DITCH CANNOT BE REACHED FROM THE ROAD, EXCAVATION ACTIVITIES SHALL BE CONDUCTED FROM ATOP THE SLOPE. PERMISSION FOR TEMPORARY CONSTRUCTION ACCESS SHALL BE OBTAINED FROM ABUTTING PROPERTY OWNER/S.
3. EXCAVATE BENCHES AND DITCHES TO THE DIMENSIONS AND SLOPES REQUIRED.
4. FOR GRASS DITCHES, INSTALL PERMANENT EROSION MAT, LOAM AND SEED. FOR STONE LINED DITCHES, INSTALL GEOTEXTILE FABRIC AND PLACE STONE OVER FABRIC.
5. INSTALL SELECTED OUTLET PROTECTION BMP AT THE END OF THE BENCH AND/OR DITCH.
6. INSTALL TEMPORARY EROSION & SEDIMENTATION CONTROL (SEED, MULCH AND/OR FIBER MATS) TO ASSIST IN RE-VEGETATION.

OPERATION AND MAINTENANCE:

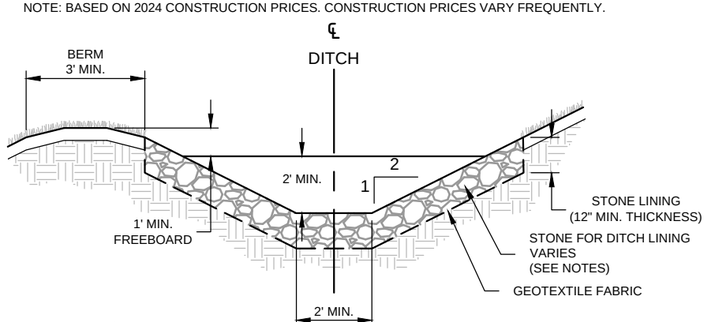
1. INSPECT BANK BENCH AND INTERCEPTOR DITCHES ANNUALLY AND AFTER A MAJOR STORM EVENT.
2. REMOVE ANY DEBRIS OR SEDIMENT FOUND WITHIN BENCHES OR DITCHES.
3. REPAIR ANY SCOURING, EROSION, OR BANK COLLAPSES.
4. RE-GRADE BENCHES AND DITCHES AS NECESSARY. REPAIR WITH LOAM AND SEED (OR STONE). USE SEED, MULCH, AND FIBER MATS TO ASSIST IN RE-VEGETATION.

CONSTRUCTION COSTS:

UNIT COSTS:

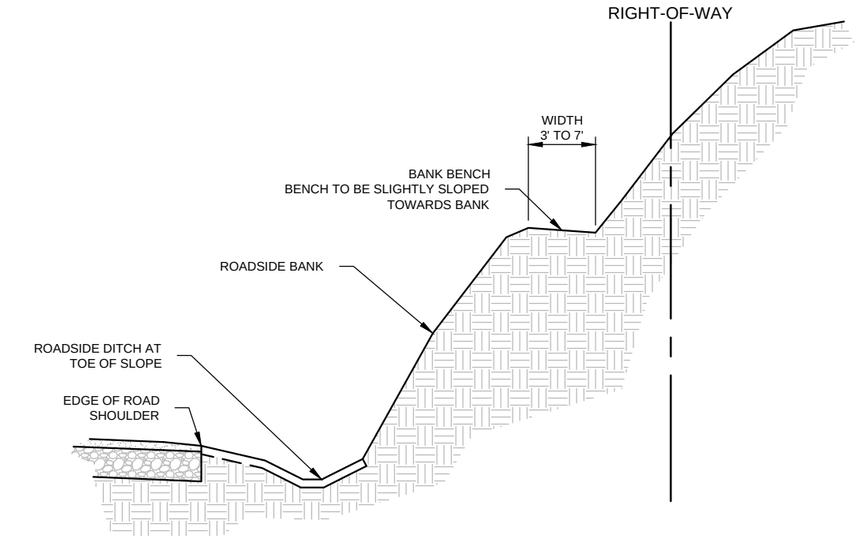
EXCAVATION -	$40.00/CY
STONE -	$90.00/CY
GEOTEXTILE FABRIC -	$3.00/SY
TURF REINFORCEMENT MATS -	$5.00/SY
LOAM -	$90.00/CY

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

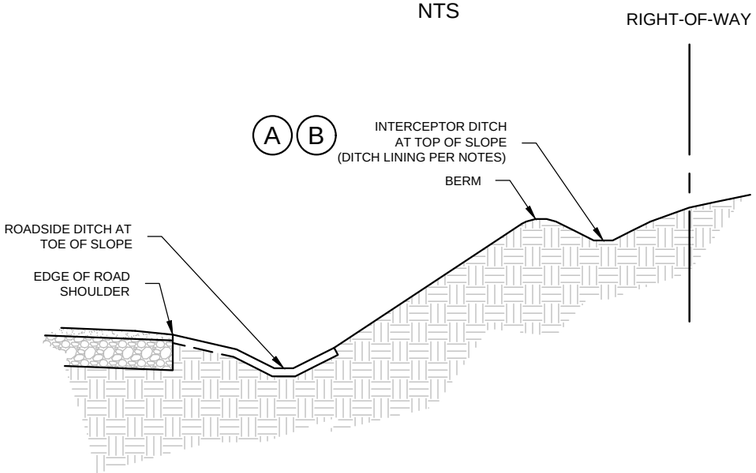


B STONE LINED DITCH
NTS

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)						
BANK BENCH/INTERCEPTOR DITCH	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
	LOW	HIGH	LOW	HIGH	LOW	HIGH
	44.3	50.6	0.1	0.3	0.2	2.1



BANK BENCH
NTS



INTERCEPTOR DITCH
NTS

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROAD STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

BANK BENCH AND INTERCEPTOR DITCH

PREPARED BY:	REVISED BY:	PREPARED FOR:	
GZA	BSC GROUP	frcog	
DATE:	REV DATE:	REV NO.	FIGURE
SEP. 2024	JUN. 2025	-	B/I-1

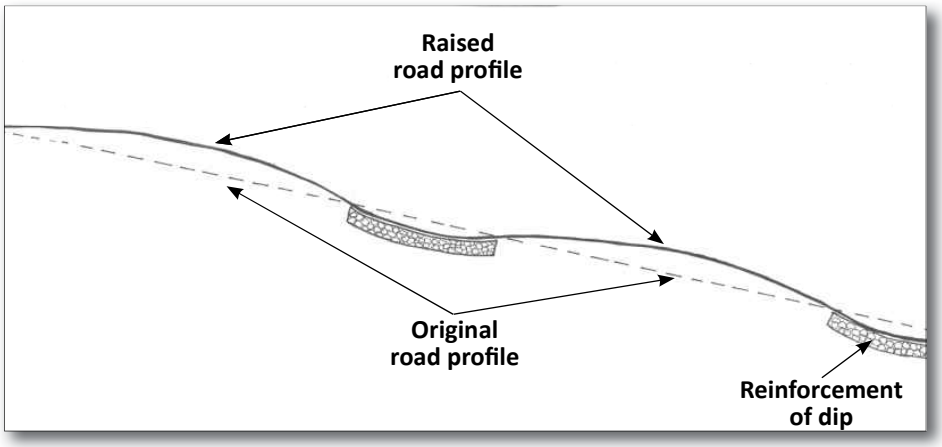
BROAD-BASED DIP

Road Type

Steep private driveway

BMP Function

Road surface drainage
Conveyance



Road profile: Used on low-volume roads and combined with a cross-slope crown, a broadbased dip directs runoff to a turnout.

Description and Purpose

» An intentional reverse grade built into a roadway that diverts runoff from the road surface and the upslope ditch across the road to a turnout and discharge area.

» Designed to reduce potential road-surface erosion by shortening the contributing drainage area.

» Broad-based dips differ from grade breaks by having more of an undulating form and by conveying runoff fully across the road.

Criteria for Use and Site Considerations

» Use on low-traffic, low-volume roads such as driveways, seasonal roads, or roads with few houses.

» Use on roads and driveways with grades up to 10%.

» Use before stream crossing to direct water into vegetative filters and reduce hydrologic connectivity.

» Use to shed water off of the road surface just before it enters a steep section.

» Most useful on long, continuous steep slopes.

» Not to be used to manage drainage problems from springs or streams.

Benefits

» Inexpensive and easy to install.

» Can be used in place of or to supplement drainage culverts.

» When properly located and installed, can shed runoff for years with little maintenance.

Planning and Design

» Does not maintain a centerline crown; all water is diverted to one side.

» The road profile (vertical alignment) is changed by simultaneously constructing a dip and raising the grade by placing fill material in the road below the dip.

» Create a relatively wide channel in the dip bottom to spread flow and to ease vehicle transitions.

BROAD-BASED DIP

» Tie the upslope end of the dip into the uphill bank to ensure water does not bypass the structure.

» Reinforce the bottom of the dip with a minimum of 1 foot of crushed stone under laid with geotextile fabric.

» Use the following minimum spacing to adequately handle runoff and traffic:
- Minimum spacing between broad-based dips = 400/(slope %) + 100 feet; additional spacing may be needed based on site specific considerations.
- When road is within 25 feet of a stream and runs parallel to a stream for more than 300 feet, decrease the spacing by a minimum of 25%.

» Angle dip across the road at approximately 20 to 40 degrees. A dip placed straight across the road is more likely to fail, since it forces water to turn at a right angle to cross the roadway.

» Maintain a cross-slope in the dip of 2 to 4%.

» Because a broad-based dip encourages concentrated flow, consider reinforcing broad-based dip outlet with an outlet protection BMP such as Riprap Apron, Plunge Pool, or Level Spreader.

» Consider using signs after installation to notify road users of the broad-based dip.

Material and Equipment

» Non-woven geotextile fabric (geotextile is a best practice for stabilizing added materials)

» May require up to 40 tons of material to create if cut material is not sufficient fill

» ¾-inch clean dense graded crushed stone to reinforce the bottom of the dip where water will flow

» Dump truck

» Bulldozer

» Vibratory roller or tamper

Maintenance

» Educate road crew about broad-based dip.

» Consider marking the ends of the broad-based dip to alert plow crews where the broad-based dip is located.

» Inspect in the springtime after the winter season and after major storm events.

» Remove debris and sediment from the broad-based dip.

» Maintain the cross-slope crown of the road when grading.

» Bring additional material to the site to reestablish the berm as necessary.

» Ensure outlets are stable, repair as necessary.

» A properly constructed broad-based dip will function with minimal maintenance.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

BROAD BASED DIP

CRITERIA FOR USE:

1. USE ON INFREQUENTLY MAINTAINED ROADS.
2. USE BEFORE STREAM CROSSING TO DIRECT WATER INTO VEGETATIVE FILTERS AND REDUCE HYDROLOGIC CONNECTIVITY.
3. USE ON GENTLE-TO-MODERATE SLOPED ROADS (LESS THAN 10%).
4. USE ON LOW-VOLUME OR LOW-SPEED ROADS.
5. USE JUST BEFORE ROAD GRADIENT CHANGES IN ORDER TO SHED WATER OFF OF SURFACE BEFORE IT ENTERS A STEEP SECTION.
6. USE WHERE TRADITIONAL CROSS-CULVERTS ARE NOT APPLICABLE OR DESIRED.

DESIGN CONSIDERATIONS:

1. DIP LOW POINT SHALL BE BETWEEN 6-12 INCHES BELOW EXISTING ROAD GRADE, WHEREAS DIP BERM SHALL BE BETWEEN 6-18 INCHES ABOVE EXISTING ROAD GRADE.
2. CONSIDER TYPES OF VEHICLES TRAVELING THE ROAD WHEN GRADING THE TRANSITIONS. TRANSITIONS SHALL HAPPEN OVER A MINIMUM OF 10 FEET. LONGER TRANSITIONS SHALL BE USED IF THE TRACTOR TRAILERS UTILIZE ROAD.
3. MINIMUM SPACING BETWEEN DIPS:
   - 3.1. MIN. SPACING = 400/(SLOPE %) + 100 FEET; ADDITIONAL SPACING MAY BE NEEDED BASED ON SITE SPECIFIC CONSIDERATIONS.
   - 3.2. WHEN ROAD IS WITHIN 25 FEET OF A STREAM AND RUNS PARALLEL TO A STREAM FOR MORE THAN 300 FEET, DECREASE THE SPACING BY A MINIMUM OF 25%.
4. BROAD BASED DIP SHALL BE ANGLED ACROSS THE ROAD AT APPROXIMATELY 20 TO 40 DEGREES.
5. BROAD BASED DIP SHALL MAINTAIN A CROSS-SLOPE IN THE DIP OF 1 TO 4%.
6. CONSIDER REINFORCING BROAD-BASED DIP OUTLET WITH AN OUTLET PROTECTION BMP.
7. A MINIMUM OF 12 INCHES OF CRUSHED STONE SHALL BE INSTALLED, OVER NON-WOVEN GEOTEXTILE FABRIC, UNDER THE ROAD SURFACE COURSE TO REINFORCE ROAD AT DIP LOW POINT.

CONSTRUCTION SPECIFICATIONS:

1. STONE:
   - 1.1. DENSE GRADE:
     ¾" DENSE GRADED CRUSHED STONE MEETING MassDOT SPECIFICATIONS FOR DENSE GRADED CRUSHED STONE FOR SUB-BASE (M2.01.7)
   - 1.2. CRUSHED STONE:
     3" TO 4" CLEAN CRUSHED STONE (MassDOT M2.01.0 OR AASHTO CLASS 1 STONE)
2. GEOTEXTILE FABRIC:
   GEOTEXTILE FABRIC SHALL BE A NON-WOVEN GEOTEXTILE FABRIC CLASSIFIED AS CLASS 2 FABRIC ON MassDOT QUALIFIED CONSTRUCTION MATERIALS LIST (QCML).

CONSTRUCTION SEQUENCING:

1. CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK.
2. LOCATE AND MARK OUT THE SITE FOR EACH BROAD-BASED DIP.
3. EXCAVATE FOR DIP AND STONE REINFORCEMENT.
4. PLACE GEOTEXTILE FABRIC WITHIN EXCAVATION. PLACE CRUSHED STONE WITHIN EXCAVATION TO REINFORCE DIP.
5. CREATE DOWN GRADIENT BERM WITH ROADBED MATERIAL. TIE BERM INTO THE ROADBED GRADE.

OPERATION AND MAINTENANCE:

1. CONSIDER USING SIGNS AFTER INSTALLATION TO NOTIFY ROAD USERS OF THE DIPS.
2. EDUCATE TOWN/CITY ROAD CREW ABOUT THE DIP. AN UNINFORMED OPERATOR CAN REMOVE IT IN A SINGLE GRADING.
3. CONSIDER MARKING THE ENDS OF THE DIP TO ALERT MAINTENANCE CREWS TO WHERE THE DIP IS LOCATED.
4. BROAD-BASED DIPS SHALL BE INSPECTED IN THE SPRING TIME AFTER THE WINTER SEASON AND PERIODICALLY FOLLOWING HEAVY RAIN EVENTS.
5. REMOVE DEBRIS AND SEDIMENTS FROM THE BROAD-BASED DIP.
6. BROAD-BASED DIPS SHALL BE REESTABLISHED BY A GRADER OPERATOR WHO SHALL MAINTAIN THE CROSS-SLOPE OF THE ROAD THROUGH THE DIP. ADDITIONAL MATERIAL SHALL BE BROUGHT ONTO THE SITE TO REESTABLISH THE BROAD-BASED DIP BERM AS NECESSARY.
7. ENSURE OUTLETS ARE STABLE, REPAIR AS NECESSARY.

CONSTRUCTION COSTS:

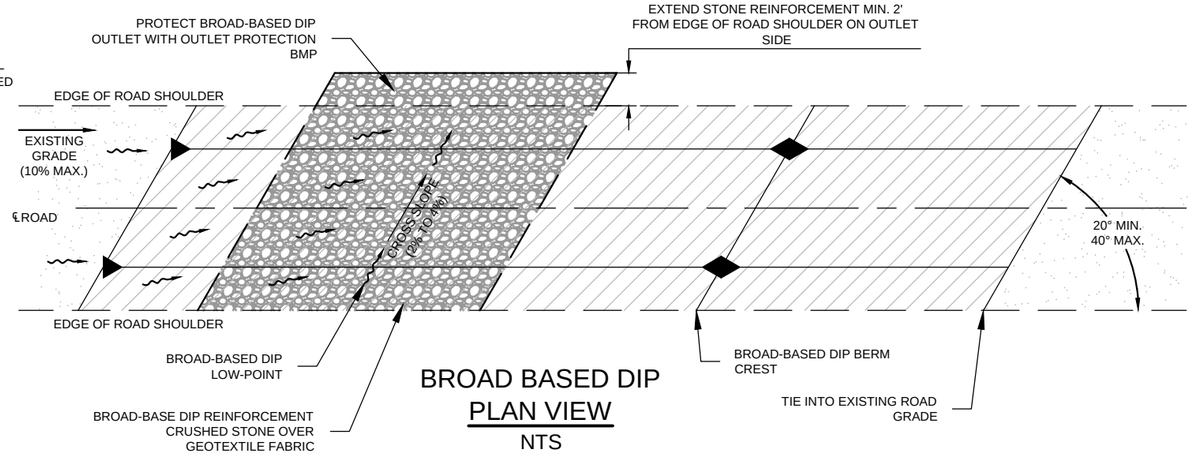
CONSTRUCTION COST OF GRADE BREAK WILL VARY DEPENDING ON SIZE OF GRADE BREAK AND WIDTH OF ROAD. FOR A STANDARD GRADE BREAK WITH TWO 12' WIDE TRAVEL LANES AND 2' SHOULDERS, THE TYPICAL COST IS $6,600.

STONE:	$90.00/C.Y.
GEOTEXTILE FABRIC:	$4.00/S.Y.

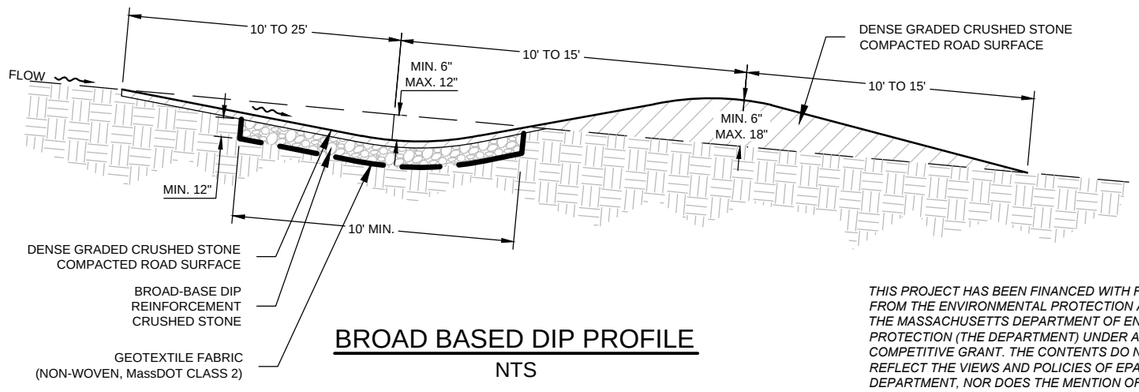
NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.



BROAD BASED DIP
PLAN VIEW
NTS



BROAD BASED DIP PROFILE
NTS

BMP ANNUAL STORMWATER POLLUTANT REDUCTION (LBS PER ACRE)						
	TSS (LBS/ACRE/YEAR)		TP (LBS/ACRE/YEAR)		TN (LBS/ACRE/YEAR)	
BROAD BASED DIP	LOW	HIGH	LOW	HIGH	LOW	HIGH
	44.3	50.6	0.1	0.3	0.2	2.1

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

REVISIONS FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

BROAD BASED DIP

PREPARED BY:	REVISED BY:	PREPARED FOR:		
GZA	BSC GROUP	frcog		
DATE: SEP. 2024	REV DATE: JUN. 2025	REV NO. -	FIGURE BBD-1	

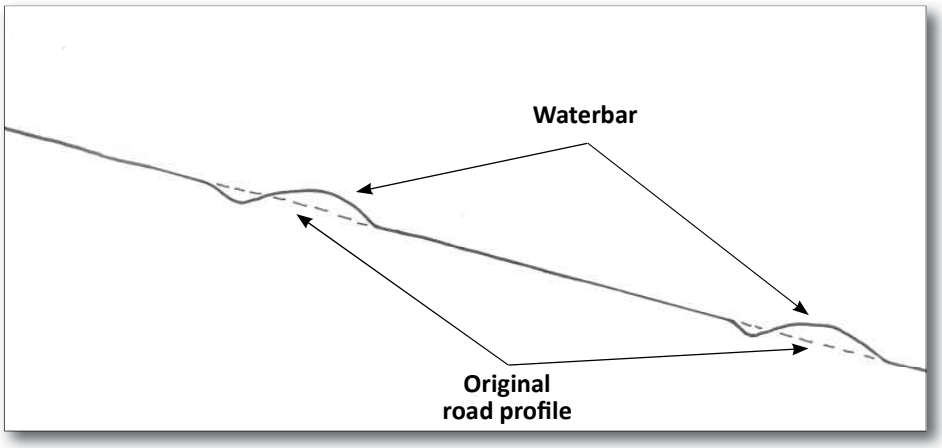
WATER BAR

Road Type

Steep private driveway

BMP Function

Road surface drainage
Conveyance



Road profile: Like a broad-based dip, a waterbar diverts water across a driveway to a discharge area.

Description and Purpose

» An intentional reverse-grade ridge (bar) and trench that together divert runoff from the road surface and the upslope ditch across the road to a discharge area. The bar and channel of a water bar are significantly smaller than in broad-based dips with a proportionately deeper dip, shaped more like a speed bump.

» Designed to reduce potential road-surface erosion by shortening the contributing drainage area and forcing water off the road surface.

Criteria for Use and Site Considerations

» Appropriate for steep driveways.

» Can be used for very low-traffic, low-volume roads such as seasonal roads or camp roads.

Benefits

» Inexpensive and easy to install.

» Trench may be shallow or deep, depending on anticipated runoff volumes.

Planning and Design

» Use the following minimum dimensions to adequately handle flows and traffic:

- Base width of bar: 6 feet minimum.
- Bar height: 18 inches from channel bottom to top of settled bar.
- Bar side slopes: 2H:1V (50% slope) or flatter.
- Channel: 12 inches wide and 6 inches deep.
- Bar and channel grade: Constant or slightly increasing, not to exceed 2%.
- Angle: Install at about a 30 degree angle down slope.

WATER BAR

» Stone can be laid in the bottom of the trench for reinforcement, as long as the trench remains 6 inches deep.

» Place water bars at frequent intervals to prevent significant water flow on the road surface. Spacing recommendations:

Road grade	Space between waterbars
Less than 5%	125 feet
5 – 10%	100 feet
10 – 20%	75 feet
20 – 35%	50 feet
Greater than 35%	25 feet

Source: Massachusetts Unpaved Roads BMP Manual, 2001.

» Be sure trenches and bars extend to shoulders and ditches on each side of the road.

» Ensure adequate drainage at the outflow and install outlet protection if needed.

Material and Equipment

» Fill, if needed

» Stone lining, if needed

» Shovel

Maintenance

» Inspect water bars periodically for vehicle wear and rebuild when needed. Inspect for erosion and sediment deposition after heavy rains and major storm events.

» Remove debris and sediment from trench and outlets.

» Repair ridge to positive grade and cross section.

» Add gravel at crossing areas and stabilize outlets as needed.

» If erosion appears in trench, consider realigning water bar to reduce the grade.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***

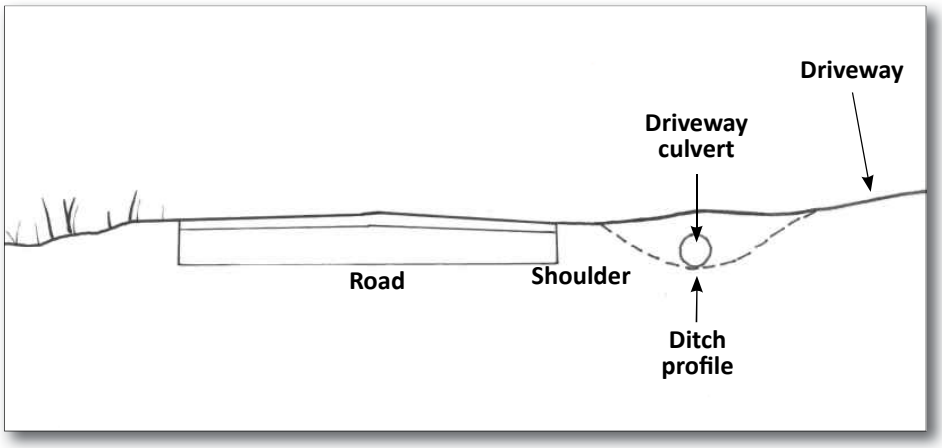
DRIVEWAY INTERSECTION CULVERT

Road Type

Steep private driveway

BMP Function

Conveyance



Road cross-section: A driveway culvert conveys runoff from one side of a driveway to the other.

Description and Purpose

» A closed conduit under a driveway at a private driveway–road intersection within the municipal right-of-way.

» Used to convey runoff from one side of a driveway to the other, providing connection to a municipal drainage ditch.

Criteria for Use and Site Considerations

» Use where roadside ditch intersects with a driveway.

Stone headwall on a driveway culvert.

Benefits

» Protects road and driveway from erosion.

» Possible to install by hand.

Planning and Design

» Select a culvert with minimum diameter of 15 inches. An 18-inch pipe is easier to clean if it becomes plugged.

» Use the following minimum dimensions to adequately handle flows and traffic:

- Culvert length: Width of driveway + width of side slopes.
- Culvert grade: minimum of 0.5%. Backfill may be necessary in small increments to keep the grade accurate.
- Cover: 12 inches, or at least half of the culvert's diameter for larger culverts.

» The culvert outlet should meet the roadside drainage ditch at grade. If this is not possible, the slope from the culvert outlet to ditch bottom should be a minimum of 6H:1V (16.6%).

DRIVEWAY INTERSECTION CULVERT

» The culvert should be covered with soil to a depth of at least 12 inches. The cover also helps spread the weight of vehicle wheels over a larger area, which can prevent the pipe from collapsing.

» It is recommended to install a grade break or broad-based dip at the bottom of the driveway before the driveway culvert to direct water into the roadside ditch and prevent it from flowing into the public road.

» Typically installed by private driveway owner, but in some towns by Highway staff. Highway staff can consider working with homeowners to properly install and maintain driveway culverts.

Material and Equipment

» Culvert pipe, typically plastic and corrugated metal are recommended for driveways (refer to the culvert materials table included in the Round Stormwater Drainage Culvert BMP fact sheet for pros and cons for each material)

» Flared end (optional)

» MassDOT specifications for ¾-inch crushed stone for bedding

» Stone for headwall: MassDOT specifications for granite rubble blocks, stone masonry walls, or equivalent

» Gravel borrow backfill

» Excavator or backhoe

» Compactor

Maintenance

» Avoid clogging, collapsing, washouts, and settlement by practicing preventative maintenance.

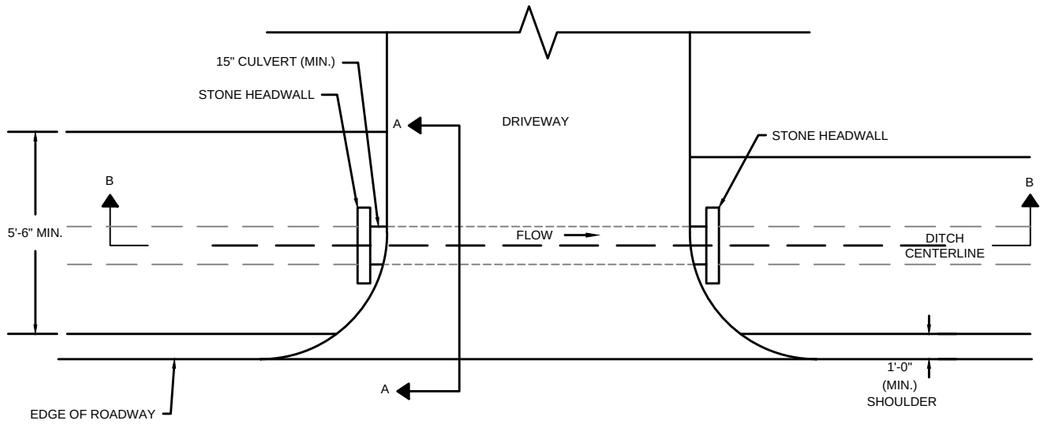
» Inspect and repair twice yearly at minimum. Prioritize late fall after leaf-off and spring after the winter season, and after major storm events for major obstructions, erosion, or collapsed banks.

» Remove any debris or sediment.

» Check culvert inlet for erosion and to ensure runoff is flowing in the culvert and not around it, if some runoff goes around the culvert it can undermine the bedding and the culvert will fail (e.g. piping).

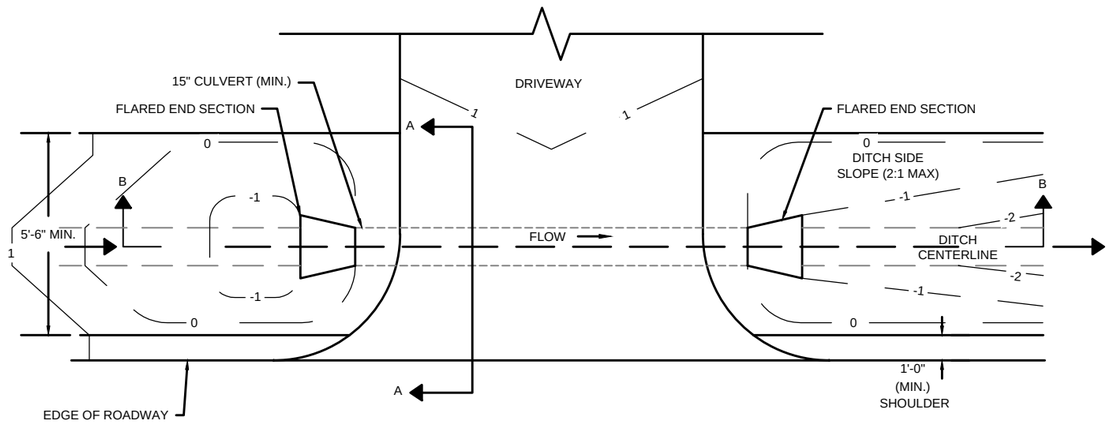
» Modify if not performing adequately. Replace culverts with the same size culvert if it already meets the sizing requirements; increase culvert size if properly constructed culvert repeatedly washes out, as development along the road increases, or as sizing guidelines change.

This project has been financed with federal funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MASSDEP) under a §319 competetive grant (project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendations for use. ***Revised with funding from MVP June 2025.***



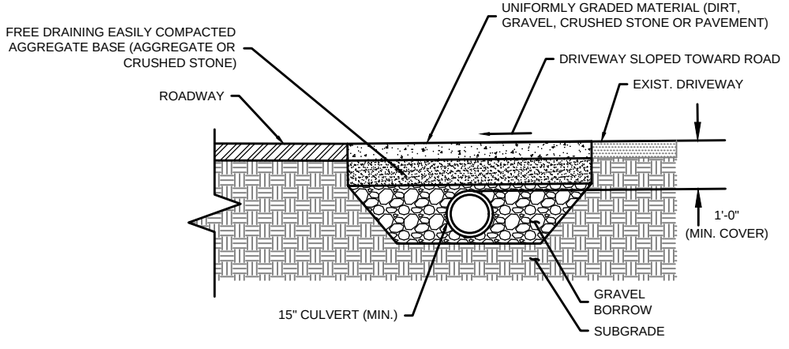
PLAN VIEW (HEADWALL)

NTS



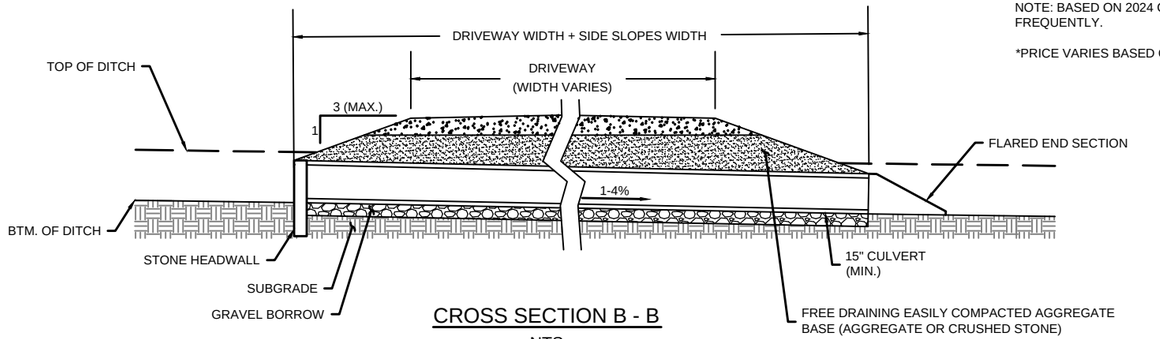
PLAN VIEW (FLARED END SECTION)

NTS



CROSS SECTION A - A

NTS



CROSS SECTION B - B

NTS

DRIVEWAY INTERSECTION CULVERT

CRITERIA FOR USE:

1. CULVERTS SHOULD BE USED WHEN A ROADSIDE DITCH INTERSECTS WITH A DRIVEWAY.
2. CONVEYS RUNOFF FROM ONE SIDE OF THE DRIVEWAY TO THE OTHER, PROVIDING CONTINUITY TO A DRAINAGE DITCH.
3. TYPICALLY INSTALLED BY PRIVATE DRIVEWAY OWNER, OR BY TOWN HIGHWAY STAFF.

DESIGN CONSIDERATIONS:

1. A CULVERT WITH A MINIMUM DIAMETER OF 15-INCHES SHOULD BE USED. HOWEVER, LARGE PIPES ARE EASIER TO CLEAN IF IT BECOMES CLOGGED.
2. USE THE FOLLOWING MINIMUM DIMENSIONS TO ADEQUATELY HANDLE FLOWS AND TRAFFIC:
   - CULVERT LENGTH = WIDTH OF DRIVEWAY + WIDTH OF SIDE SLOPES
   - THE GRADE OF THE CULVERT SHALL MATCH THE GRADE OF THE DRAINAGE DITCH. CULVERT SHALL MAINTAIN A MINIMUM SLOPE OF 0.5%. BACKFILL MAY BE NECESSARY IN SMALL INCREMENTS TO KEEP THE GRADE ACCURATE.
   - COVER: 12 -INCHES, OR HALF THE CULVERT'S DIAMETER FOR LARGER CULVERTS AT A MINIMUM. COVER IS NECESSARY TO PREVENT THE PIPE FROM COLLAPSING UNDER THE WEIGHT OF TRAFFIC.
3. THE CULVERT OUTLET SHOULD MEET THE ROADSIDE DRAINAGE DITCH AT GRADE. IF THIS IS NOT POSSIBLE, THE SLOPE FROM THE CULVERT OUTLET TO THE DITCH BOTTOM SHOULD BE A MAXIMUM OF 6H:1V (16.6%).

CONSTRUCTION SEQUENCING:

1. CONTACT DIG SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK,
2. CLEAR & GRUB CONSTRUCTION AREA. REMOVE AND CONSERVE TOPSOIL FROM THE AREA.
3. PLACE THE PIPE ON AN UN-COMPACTED BEDDING LAYER THAT HAS BEEN ROUGHLY SHAPED TO FIT THE BOTTOM OF THE PIPE.
4. ONCE PIPE IS IN PLACE, PLACE AND COMPACT FILL MATERIAL, ENSURING A MINIMUM OF 12-INCHES OF COVER IS MAINTAINED.
5. SHAPE THE SUBGRADE TO A SMOOTH SURFACE AND TO THE CROSS-SECTION REQUIRED. TYPICALLY THE DRIVEWAY SHOULD BE CROWNED AT THE CENTER, SLOPING DOWN TO THE CULVERT'S INLET AND OUTLET AT 2.0%.
6. INSTALL OUTLET PROTECTION AS NEEDED.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OR UNPAVED ROADS, AND REDUCE SEDIMENTATION ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE THE LIMITS PRESENTED.

CONSTRUCTION SPECIFICATIONS:

1. CULVERT
   - 1.1. PLASTIC
     CULVERT SHALL MEET MASSDOT MATERIAL SPECIFICATION M5.03.10.
   - 1.2. CORRUGATED METAL
     CULVERT SHALL MEET MASSDOT MATERIAL SPECIFICATION M5.03.0.
2. STONE
   - 2.1. CRUSHED STONE
     CRUSHED STONE FOR BEDDING SHALL MEET THE MASSDOT SPECIFICATIONS FOR $\frac{3}{4}$" CRUSHED STONE (M2.01.4).
   - 2.2. STONE FOR HEADWALL
     STONE SHALL MEET MASSDOT MATERIAL SPECIFICATION M2.03.0 FOR GRANITE RUBBLE BLOCKS, M9.04.4 FOR STONE MASONRY WALLS OR EQUIVALENT.
3. GRAVEL BORROW BACKFILL
   GRAVEL BORROW SHALL MEET MASSDOT MATERIAL SPECIFICATION M1.03.0.
4. FLARED END
   FLARED END SHALL MEET MASSDOT MATERIAL SPECIFICATION M5.02.2.

OPERATION AND MAINTENANCE:

1. AVOID CLOGGING, COLLAPSING, WASHOUTS, AND SETTLEMENT BY PRACTICING PREVENTATIVE MAINTENANCE.
2. INSPECT AND REPAIR BIANNUALLY AND AFTER MAJOR STORM EVENTS. PRIORITIZE LATE FALL AFTER LEAF-OFF AND SPRING AFTER THE WINTER SEASON.
3. CHECK CULVERT INLET FOR EROSION AND TO ENSURE RUNOFF IS FLOWING IN THE PIPE AND NOT AROUND IT.
4. INCREASE CULVERT SIZE IF PROPERLY CONSTRUCTED CULVERT REPEATEDLY WASHED OUT, AS DEVELOPMENT ALONG THE ROAD INCREASES, OR AS SIZING GUIDELINES CHANGE.

CONSTRUCTION COST:

UNIT COSTS:

EXCAVATION -	$40.00/CY
GRAVEL BORROW BACKFILL -	$75.00/CY
STONE -	
$\frac{3}{4}$" CRUSHED STONE -	$84.00/CY
BALANCED STONE -	$2,000.00/CY
PIPE* (15") -	
CORRUGATED METAL -	$350.00/FT
PLASTIC -	$160.00/FT
FLARED END SECTION -	$1,500.00 EA
STONE FOR HEADWALL -	$2,000.00/SY

NOTE: BASED ON 2024 CONSTRUCTION PRICES. CONSTRUCTION PRICES VARY FREQUENTLY.

*PRICE VARIES BASED ON SIZE/LENGTH.

NOTE:
PROJECT FUNDED BY THE MASSACHUSETTS MUNICIPAL VULNERABILITY PREPAREDNESS (MVP) PROGRAM, 2025.

DRIVEWAY INTERSECTION CULVERT

PREPARED BY: BSC GROUP — BUILD | SUPPORT | CONNECT

PREPARED FOR: frcog

DATE: APRIL 2025

REVISION NO.: -

FIGURE: DIC-1

Tool 6: Round Stormwater Drainage Culvert Right-Sizing Guide

Introduction

Stormwater culverts are commonly used on all kinds of roads to direct surface runoff to a desirable location. Flash flooding in Massachusetts in recent years has highlighted the need for appropriately sized culverts. FRCOG developed a GIS method for delineating the contributing drainage area and other drainage area characteristics to determine the appropriate size of round stormwater drainage culverts for unpaved roads. The method uses updated precipitation statistics for climate conditions over the next 20 – 40 years, which is the approximate life span of a plastic road culvert.[21] When Highway staff are planning to install new round stormwater drainage culverts, this tool will help them select the right size for current and future storms. Note that this method is specifically geared to stormwater culverts, not stream crossing culverts, which need to follow the Massachusetts Stream Crossing Standards.[22] The GIS methods developed by the FRCOG for this right-sizing guide are described in detail in **Appendix E** and are replicable across Massachusetts.

As towns replace or install culverts, use the right-sizing tool to determine appropriate culvert sizes.

Method

FRCOG's method for developing this right-sizing guide is a GIS process based on the stream crossing culvert capacity model and drainage culvert right-sizing work developed by Trout Unlimited and others, but improves on contributing drainage area size accuracy and uses predicted future storm event data in right-sizing calculations.

FRCOG tested the right-sizing method on culverts in a subset of towns within Franklin County using the culvert inventories FRCOG has already conducted in many Franklin County towns. We

[21] Design life varies based on material. See Table 2.15 in the EEA's *Climate Resilience Design Standards and Guidance*, Chapter 2 at https://eea-nescaum-dataservices-assets-prd.s3.amazonaws.com/cms/GUIDELINES/V1.2_SECTION_2.pdf

[22] See the MA Stream Crossing Standards at https://www.nae.usace.army.mil/Portals/74/docs/regulatory/StreamRiverContinuity/MA_RiverStreamCrossingStandards.pdf and the MA Division of Ecological Restoration's MA Stream Crossings Handbook at https://www.mass.gov/files/documents/2018/08/23/Stream%20Crossings%20booklet%20Web.pdf

used the one-hour precipitation storm at the 25-year, 50-year, and 100-year frequency using the NOAA Atlas 14++ method (using 95th confidence interval itself) to compute recommended culvert sizes.

How to Use the Right-Sizing Tool

Town boards and staff in Franklin County can request assistance from FRCOG GIS staff to determine the right size of a culvert at a known location. Outside of Franklin County, a GIS practitioner can use the methods in **Appendix E** to determine recommended culvert sizes or contact your Regional Planning Agency for assistance. FRCOG also created a rule-of-thumb sizing chart (below) that can be used as a less precise way of determining culvert size, when an estimated contributing drainage area size is available.

Drainage and Right-sizing for Your Town

Any Franklin County municipality can contact FRCOG's GIS staff to request a right-sizing analysis for one or more culverts. A latitude/longitude location of each culvert inlet is needed. FRCOG can also assist with sizing a stream crossing culvert.

The *Massachusetts Unpaved Roads BMP Manual* (2001) recommends that the sizing of culverts with contributing drainage areas exceeding 20 acres should be determined by an engineer. Field observations bear out that culverts with contributing drainage areas exceeding 20 acres typically correspond with intermittent streams or perennial streams (for larger contributing drainage areas), and these would need to comply with Massachusetts Stream Crossing Standards. Table 6-1 below provides an update to the recommendations available in the *Massachusetts Unpaved Roads BMP Manual*.[23]

Table 6-1. Rule-of-thumb sizing chart for right-sized drainage culverts

Contributing Drainage Area (acres)	Culvert diameter needed (inches)
0 – 1.5	12*
1.5 – 4	18
4 – 8	24
8 – 15	32
15 – 20	36
Greater than 20	Greater than 36 is likely a stream that will need to follow MA Stream Crossing Standards[24]

**Some road manuals, such as the 2024 Vermont Better Roads Manual, recommend a minimum of 18 inches for any stormwater culvert, and a minimum of 15 inches for any driveway culvert.*

[23] Pages 27 and 28 in the 2001 Massachusetts Unpaved Roads BMP Manual include a sizing table and method.
[24] See the MA Stream Crossing Standards at https://www.nae.usace.army.mil/Portals/74/docs/regulatory/StreamRiverContinuity/MA_RiverStreamCrossingStandards.pdf and the MA Division of Ecological Restoration's MA Stream Crossings Handbook at https://www.mass.gov/files/documents/2018/08/23/Stream%20Crossings%20booklet%20Web.pdf

Tool 7: Treatment Trains

Introduction

To effectively manage stormwater runoff from unpaved roads, multiple BMPs can be installed on a road that all work together as "treatment trains," often better than just one stand-alone BMP. A treatment train is a sequence of stormwater BMPs strategically arranged so that runoff flows through the drainage system in a way that maximizes the ability to prevent erosion and control sedimentation. Treatment trains use combinations of BMPs to improve the effectiveness of each individual BMP. For example, when sediment is captured upstream of a stormwater drainage culvert, it is more likely the culvert will function as intended without getting clogged or eroded around the inlet.

The initial cost of installation of treatment train BMPs may be higher, but a systems approach that manages several problems at once can be a more sustainable and climate resilient approach to stormwater management.

How to Use the Treatment Train Tool

This tool includes three design typicals of several example treatment trains. These examples mirror common conditions found on unpaved roads in Franklin County. The designs are suggestions and are to be used as examples of the types of projects that can be done as a package to better manage stormwater on unpaved roads.

Please consult **Tool 5: Stormwater BMP Fact Sheets and Design Typicals** for more information on tailoring BMPs to a particular road for a particular design life and design storm.

Scenario 1: Road with a steep (5 – 10%) grade with a stream crossing. The road consists of a centerline crown with adequate right-of-way and gentle slopes away from the road.

BMPs shown on this design:

- Grade break
- Vegetated or stone-lined ditch
- Ditch turnout
- Level spreader
- Riprap apron

Scenario 2: Road with a steep grade (5 – 10%) running parallel to a stream. The road consists of a centerline crown cut into a steep bank with limited area.

BMPs shown on this design:

- Bank bench/Interceptor ditch
- Underdrain
- Armored shoulder
- Vegetated ditch
- Round stormwater drainage culvert

Scenario 3: Road with centerline crown, gentle gradient (greater than 5%) with adequate space along sides, and a stream in close proximity on one side of the road.

BMPs shown on this design:

- Vegetated or stone-lined ditch
- Ditch turnout
- Ditch settling pool
- Level spreader
- Plunge pool
- Riprap apron
- Round stormwater drainage culvert

TYPICAL TREATMENT TRAIN

ROAD SCENARIO 1:

ROAD WITH A STEEP GRADE (5-10%) WITH A STREAM CROSSING. THE ROAD CONSISTS OF A TYPICAL CENTERLINE CROWN WITH ADEQUATE RIGHT-OF-WAY AND GENTLE SLOPES AWAY FROM THE ROAD.

POSSIBLE BMPs FOR USE:

USE A COMBINATION OF THE FOLLOWING BMPs TO CONTROL AND TREAT RUNOFF FROM THE ROAD.

- ROAD SIDE DITCHES:

  ROAD SIDE DITCHES SHOULD BE USED TO COLLECT WATER ALONG THE EDGES OF THE ROAD. THESE DITCHES CAN BE GRASS LINED WITH STONE CHECK DAMS OR ROCK LINED TO PREVENT EROSION WITHIN THE DITCH.

  DITCHES WITH A LONGITUDINAL SLOPE SHALL BE LINED AS FOLLOWS:
  - WITH SLOPE ≤5% SHALL BE GRASS-LINED.
  - WITH SLOPE 5%-8% SHALL BE ARMORED WITH 12 INCHES OF 2 TO 6 INCH STONE
  - WITH A SLOPE >8% SHALL BE ARMORED WITH 12 INCHES OF 6 TO 10 INCH STONE

- DITCH TURNOUTS:

  TURNOUTS SHOULD BE UTILIZED AT FREQUENT INTERVALS TO DISCHARGE COLLECTED STORMWATER THROUGH A BMP TO UPLAND VEGETATED BUFFER AREA. AT A MINIMUM, A FINAL DITCH TURNOUT SHOULD BE USED PRIOR TO THE STREAM CROSSING. TURNOUTS SHALL BE SPACED AS FOLLOWS:

ROAD GRADE (%)	DISTANCE (FT)
2	250
5	135
10	80
15	60
20	45

- LEVEL SPREADERS:

  LEVEL SPREADERS SHOULD BE UTILIZED TO REDUCE THE VELOCITY OF WATER EXITING THE DITCH TURNOUTS AND CREATE A SHEET FLOW DISCHARGE TO THE VEGETATIVE BUFFER. LEVEL SPREADER SHOULD BE USED IF THE REQUIRED LENGTH OF VEGETATIVE BUFFER IS AVAILABLE.

- RIPRAP APRON:

  RIPRAP APRON SHOULD BE USED AT THE FINAL DITCH TURNOUT PRIOR TO THE STREAM CROSSING. RIPRAP APRON SHOULD BE USED IF THE REQUIRED VEGETATIVE BUFFER IS UNAVAILABLE AND THE DITCH TURNOUT WILL BE DIRECTING WATER DIRECTLY TO THE STREAM.

- GRADE BREAKS:

  GRADE BREAKS CAN BE USED TO DIRECT WATER FROM THE ROAD TO THE DITCH TURNOUTS. AT A MINIMUM, A GRADE BREAK SHOULD BE USED PRIOR TO THE STREAM CROSSING TO DIRECT WATER TO THE FINAL DITCH TURNOUT.

DESIGN CONSIDERATIONS:

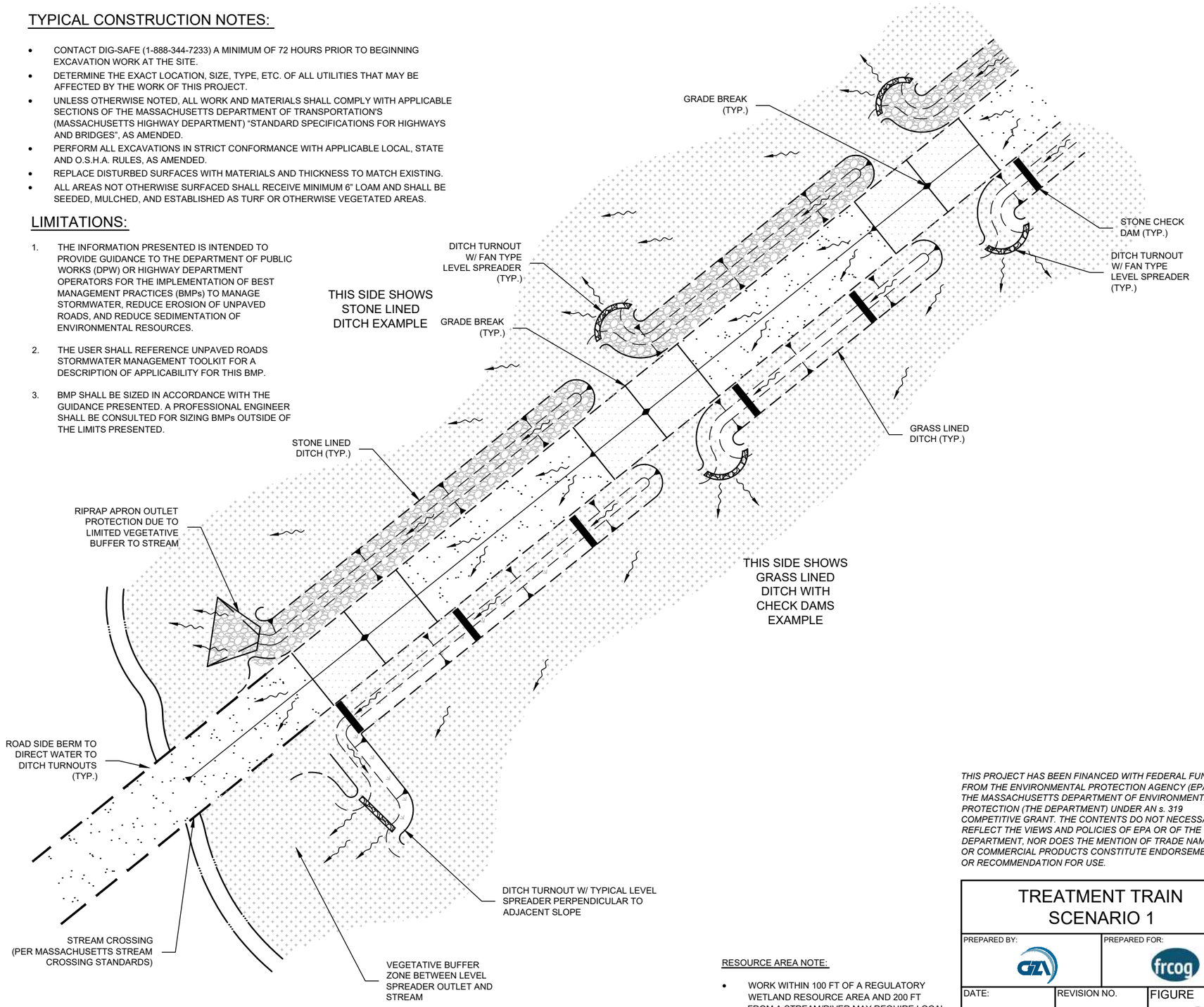
- CONSIDER THE ABUTTING PROPERTIES IN LOCATING AND INSTALLING DITCH TURNOUTS AND LEVEL SPREADERS.
- CONSIDER ANY IMPACTS ON WETLAND RESOURCE AREAS, AND THE ASSOCIATED LOCAL AND STATE PERMITTING.
- CONSIDER CREATING A LOW POINT CLOSEST TO AND UPSTREAM OF THE STREAM CROSSING.
- CREATE A BERM ALONG THE EDGE OF THE ROAD OVER THE STREAM CROSSING TO DIRECT WATER BACK TO THE DITCH TURNOUT PRIOR TO THE STREAM CROSSING.
- CONSIDER LENGTH OF VEGETATIVE BUFFER FROM LAST DITCH TURNOUT TO STREAM. SEE TURNOUT OUTLET BMP DESIGN.

TYPICAL CONSTRUCTION NOTES:

- CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 HOURS PRIOR TO BEGINNING EXCAVATION WORK AT THE SITE.
- DETERMINE THE EXACT LOCATION, SIZE, TYPE, ETC. OF ALL UTILITIES THAT MAY BE AFFECTED BY THE WORK OF THIS PROJECT.
- UNLESS OTHERWISE NOTED, ALL WORK AND MATERIALS SHALL COMPLY WITH APPLICABLE SECTIONS OF THE MASSACHUSETTS DEPARTMENT OF TRANSPORTATION'S (MASSACHUSETTS HIGHWAY DEPARTMENT) "STANDARD SPECIFICATIONS FOR HIGHWAYS AND BRIDGES", AS AMENDED.
- PERFORM ALL EXCAVATIONS IN STRICT CONFORMANCE WITH APPLICABLE LOCAL, STATE AND O.S.H.A. RULES, AS AMENDED.
- REPLACE DISTURBED SURFACES WITH MATERIALS AND THICKNESS TO MATCH EXISTING.
- ALL AREAS NOT OTHERWISE SURFACED SHALL RECEIVE MINIMUM 6" LOAM AND SHALL BE SEEDED, MULCHED, AND ESTABLISHED AS TURF OR OTHERWISE VEGETATED AREAS.

LIMITATIONS:

1. THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
2. THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A DESCRIPTION OF APPLICABILITY FOR THIS BMP.
3. BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.



RESOURCE AREA NOTE:

- WORK WITHIN 100 FT OF A REGULATORY WETLAND RESOURCE AREA AND 200 FT FROM A STREAM/RIVER MAY REQUIRE LOCAL AND/OR STATE WETLAND PERMITTING

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

TREATMENT TRAIN SCENARIO 1

PREPARED BY:	PREPARED FOR:		
GZA	frcog		
DATE: SEP. 2024	REVISION NO. -	FIGURE TTS-1	

GZA–J:\0 167300 – 0 167399\15.0167304.00 FRCOG ENGINEERING FOR UNPAVED ROADS\15.0167304.00 CAD\DWG\167304.00–TREATMENT TRAIN.DWG TTS–1 SEPTEMBER 20, 2024 MARK STADNICKI

TYPICAL TREATMENT TRAIN

ROAD SCENARIO 2:

ROAD WITH A STEEP GRADE (5-10%) RUNNING PARALLEL TO A STREAM. THE ROAD CONSISTS OF A TYPICAL CENTERLINE CROWN AND HAS BEEN CUT INTO A STEEP (1V:≥2H) BANK WITH LIMITED RIGHT-OF-WAY AREA.

POSSIBLE BMPs FOR USE:

USE A COMBINATION OF THE FOLLOWING BMPs TO CONTROL AND TREAT RUNOFF FROM THE ROAD.

- BANK BENCH/INTERCEPTOR DITCH :

  BANK BENCHES/INTERCEPTOR DITCHES SHALL BE USED TO INTERCEPT FLOW FROM THE SLOPE AND/OR TOP OF SLOPE TO PREVENT EROSION OR BANK FAILURE ONTO THE ROAD. BANK BENCHES/INTERCEPTORS SHALL CARRY FLOW FROM THE BANK AND/OR TOP OF THE BANK TO A DITCH AT THE TOE OF THE SLOPE OR TO A DRAINAGE CULVERT TO DISCHARGE THE FLOW ON THE DOWN GRADIENT SIDE OF THE ROAD.

- UNDERDRAIN:

  UNDERDRAINS SHOULD BE USED WHERE GROUNDWATER MAYBE MOVING ACROSS THE ROAD BASE. THE GROUNDWATER MAYBE DUE TO SHALLOW LEDGE OR HIGH GROUNDWATER WITHIN THE AREA.

- ARMORED SHOULDER:

  ARMORED SHOULDER SHOULD BE USED TO STABILIZE STEEP BANKS, BANKS WITH SIGNS OF GROUNDWATER WEEPING, AT SHARP TURNS WITHIN RIVERS AND STREAMS WHERE THE WATER VELOCITY IS HIGH. BANKS SHALL BE ARMORED AT THE INLET AND OUTLET OF BRIDGES AND LARGE CULVERTS.

- DITCH:

  A DITCH SHALL COULD BE USED ALONG THE UPSLOPE SIDE OF THE ROAD TO COLLECT STORMWATER AND CONVEY THE FLOW IN A CONTROLLED MANNER. THE DITCH COULD BE VEGETATED WITH STONE CHECK DAMS SPACED ACCORDINGLY (SEE CHECK DAM BMP FOR SPACING REQUIREMENTS) OR COULD BE STONE LINED. DITCHES SHALL BE PERIODICALLY DISCHARGED UNDER THE ROAD THROUGH A CULVERT (80 TO 135 FEET BETWEEN DISHCARGES).

- CULVERT:

  - CULVERTS SHOULD BE USED TO DISCHARGE COLLECTED STORMWATER, FROM THE UPSLOPE ROADSIDE DITCH, UNDER THE ROAD TO THE DOWNSLOPE BANK.
  - CULVERT SHOULD DISCHARGE TO A OUTLET PROTECTION BMP SUCH AS A RIPRAP APRON, PLUNGE/SPLASH POOL, OR PLUNGE POOL WITH LEVEL SPREADER OUTLET.

DESIGN CONSIDERATIONS:

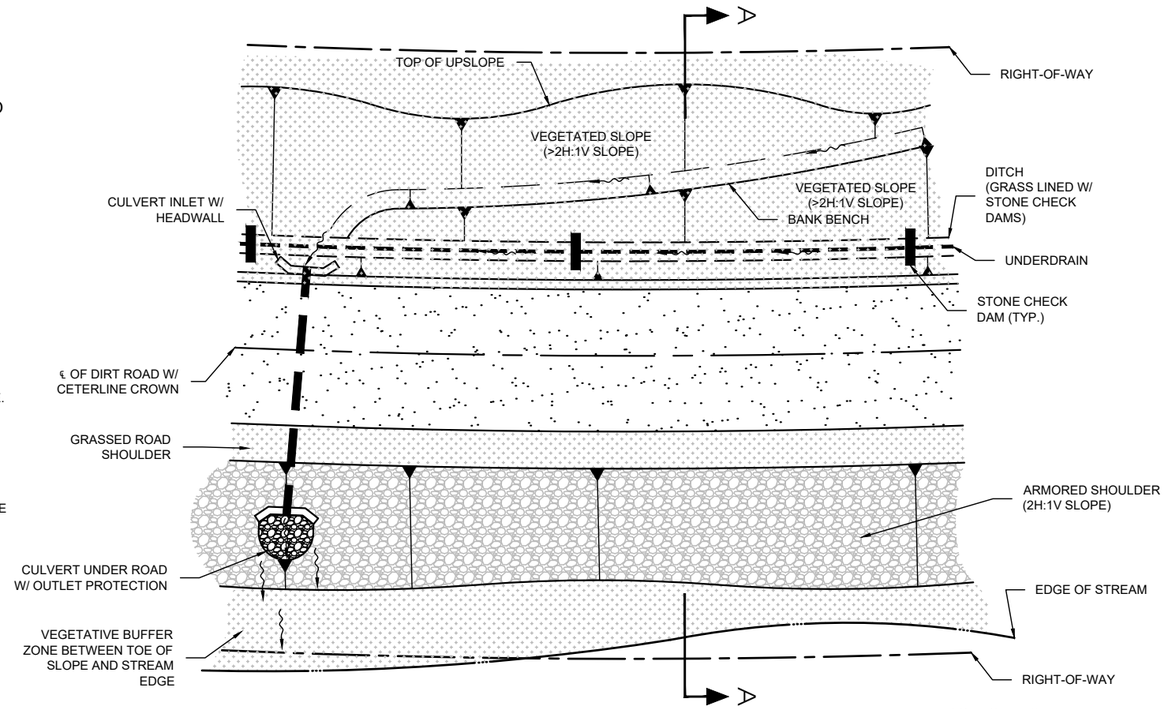
- CONSIDER THE ABUTTING PROPERTIES IN LOCATING AND INSTALLING DITCH TURNOUTS AND LEVEL SPREADERS.
- CONSIDER ANY IMPACTS ON WETLAND RESOURCE AREAS, AND THE ASSOCIATED LOCAL AND STATE PERMITTING.
- CONSIDER GROUNDWATER ELEVATION AND CHECK BANK IF WATER IS SEEPING.
- CONSIDER THE LENGTH OF NATURAL VEGETATIVE BUFFER ZONE ALONG THE STREAM. IF THE VEGETATIVE BUFFER IS ADEQUATE (50 FT IN LENGTH) CONSIDER DISCHARGING THE CULVERT TO A PLUNGE/SPLASH POOL OR A PLUNGE POOL WITH LEVEL SPREADER.
- CULVERTS SHOULD BE SIZED PER THE TOOLKIT RECOMMENDATIONS. TYPICAL CULVERT DIAMETER SIZES PER DRAINAGE AREA ARE AS FOLLOWS:

DRAINAGE AREA	CULVERT DIAMETER NEEDED
0-1.5 ACRES	12"*
1.5-4 ACRES	18"
4-8 ACRES	24"
8-15 ACRES	32"
15-20 ACRES	36"
> 20 ACRES	>36" IS LIKELY A STREAM THAT WILL NEED TO FOLLOW MA STREAM CROSSING STANDARDS

* - SOME ROAD MANUALS, SUCH AS THE 2024 VERMONT BETTER ROADS MANUAL, RECOMMEND A MINIMUM OF 18 INCHES FOR ANY STORMWATER CULVERT, AND A MINIMUM OF 15 INCHES FOR ANY DRIVEWAY CULVERT.

TYPICAL CONSTRUCTION NOTES:

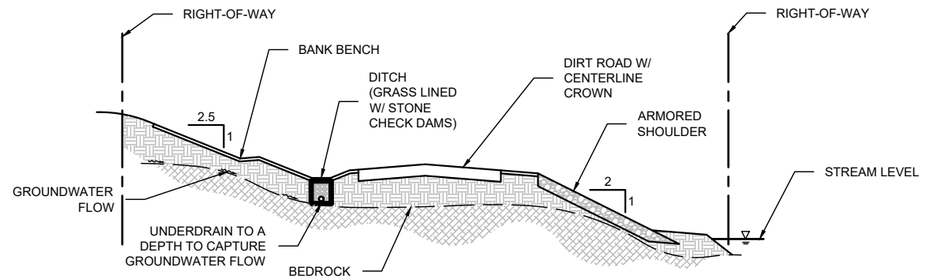
- CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK AT THE SITE.
- DETERMINE THE EXACT LOCATION, SIZE, TYPE, ETC. OF ALL UTILITIES THAT MAY BE AFFECTED BY THE WORK OF THIS PROJECT.
- UNLESS OTHERWISE NOTED, ALL WORK AND MATERIALS SHALL COMPLY WITH APPLICABLE SECTIONS OF THE MASSACHUSETTS DEPARTMENT OF TRANSPORTATION'S (MASSACHUSETTS HIGHWAY DEPARTMENT) "STANDARD SPECIFICATIONS FOR HIGHWAYS AND BRIDGES", AS AMENDED.
- PERFORM ALL EXCAVATIONS IN STRICT CONFORMANCE WITH APPLICABLE LOCAL, STATE AND O.S.H.A. RULES, AS AMENDED.
- REPLACE DISTURBED SURFACES WITH MATERIALS AND THICKNESS TO MATCH EXISTING.
- ALL AREAS NOT OTHERWISE SURFACED SHALL RECEIVE MINIMUM 6" LOAM AND SHALL BE SEEDED, MULCHED, AND ESTABLISHED AS TURF OR OTHERWISE VEGETATED AREA S.



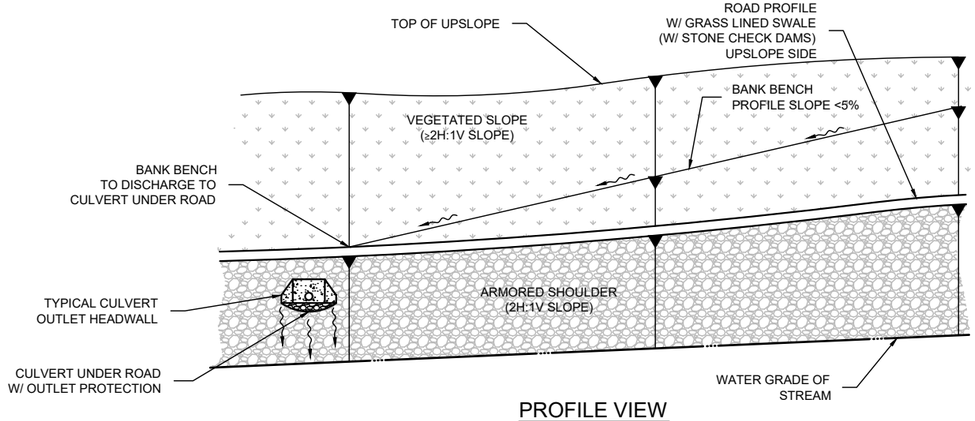
PLAN VIEW
NTS

RESOURCE AREA NOTE:

- WORK WITHIN 100 FT OF A REGULATORY WETLAND RESOURCE AREA AND 200 FT FROM A STREAM/RIVER MAY REQUIRE LOCAL AND/OR STATE WETLAND PERMITTING



CROSS-SECTION A-A
NTS



PROFILE VIEW
NTS

THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

TREATMENT TRAIN SCENARIO 2

PREPARED BY:	PREPARED FOR:		
GZA	frcog		
DATE: SEP. 2024	REVISION NO. -	FIGURE TTS-2	

GZA–J:\0 167300 – 0 167399\15.0167304.00 FRCOG ENGINEERING FOR UNPAVED ROADS\15.0167304.00 CAD\DWG\167304.00–TREATMENT TRAIN.DWG TTS–2 SEPTEMBER 20, 2024 MARK STADNICKI

TYPICAL TREATMENT TRAIN

ROAD SCENARIO 3:

ROAD WITH CENTERLINE CROWN, GENTLE SLOPES (2-4%) WITH ADEQUATE SPACE ALONG SIDES, AND A STREAM IN CLOSE PROXIMITY ON ONE SIDE OF THE ROAD. ROAD GRADE AROUND 5%.

POSSIBLE BMPs FOR USE:

USE A COMBINATION OF THE FOLLOWING BMPs TO CONTROL AND TREAT RUNOFF FROM THE ROAD.

- DITCHES:

  ROAD SIDE DITCHES SHOULD BE USED TO COLLECT WATER ALONG THE EDGES OF THE ROAD. THESE DITCHES CAN BE GRASSED LINED WITH STONE CHECK DAMS OR ROCK LINED TO PREVENT EROSION WITHIN THE DITCH.

  DITCHES WITH A LONGITUDINAL SLOPE SHALL BE LINED AS FOLLOWS:
  - WITH SLOPE ≤5% SHALL BE GRASS-LINED.
  - WITH SLOPE 5%-8% SHALL BE ARMORED WITH 12 INCHES OF 2 TO 6 INCH STONE
  - WITH A SLOPE >8% SHALL BE ARMORED WITH 12 INCHES OF 6 TO 10 INCH STONE

- DITCH SETTLING POOLS:

  DITCH SETTLING POOLS SHOULD BE USED IN-LINE OF THE ROADSIDE DITCHES TO REDUCE WATER VELOCITY AND REMOVE SEDIMENTATION FROM THE STORMWATER. WHERE POSSIBLE, SETTLING POOLS SHALL BE USED PRIOR TO CULVERT INLETS TO ALLOW SEDIMENTATION TO SETTLE PRIOR TO WATER FLOWING THROUGH CULVERT.

- DITCH TURNOUTS:

  TURNOUTS SHOULD BE UTILIZED AT FREQUENT INTERVALS TO DISCHARGE COLLECTED STORMWATER THROUGH A BMP TO UPLAND VEGETATED BUFFER AREA. AT A MINIMUM, A FINAL DITCH TURNOUT SHOULD BE USED PRIOR TO THE STREAM CROSSING.

- LEVEL SPREADERS:

  LEVEL SPREADERS SHOULD BE UTILIZED TO REDUCE THE VELOCITY OF WATER EXITING THE DITCH TURNOUTS AND CREATE A SHEET FLOW DISCHARGE TO THE VEGETATIVE BUFFER. LEVEL SPREADER SHOULD BE USED IF THE REQUIRED LENGTH OF VEGETATIVE BUFFER IS AVAILABLE.

- RIPRAP APRON:

  RIPRAP APRON SHOULD BE USED AT THE FINAL DITCH TURNOUT PRIOR TO THE STREAM CROSSING. RIPRAP APRON SHOULD BE USED IF THE REQUIRED VEGETATIVE BUFFER IS UNAVAILABLE AND THE DITCH TURNOUT WILL BE DIRECTING WATER DIRECTLY TO THE STREAM.

- CULVERTS:

  CULVERTS SHOULD BE USED TO ROUTE STORMWATER UNDER THE ROAD TO STREAM/RIVER SIDE OF THE ROAD. CULVERTS SHALL UTILIZE OUTLET PROTECTION BMPs TO PREVENT EROSION AND SCOURING.

- VEGETATIVE BUFFER:

  VEGETATIVE BUFFER SHOULD CONSIST OF AT LEAST 50 FEET OF NATURAL VEGETATION.

DESIGN CONSIDERATIONS:

- CONSIDER THE ABUTTING PROPERTIES IN LOCATING AND INSTALLING DITCH TURNOUTS AND LEVEL SPREADERS.
- CONSIDER ANY IMPACTS ON WETLAND RESOURCE AREAS, AND THE ASSOCIATED LOCAL AND STATE PERMITTING.
- CONSIDER THE GRADE AWAY FROM THE ROAD. UTILIZE DITCH TURNOUTS, CULVERTS AND OTHER OUTLET BMPS TO DISCHARGE ROADSIDE DITCHES WITHIN AREAS WHERE THE WATER CAN DRAIN AWAY FROM THE ROAD.
- CONSIDER THE LENGTH OF NATURAL VEGETATIVE BUFFER ZONE BETWEEN ROAD AND STREAM. IF THE VEGETATIVE BUFFER IS ADEQUATE (≥50 FT) THAN DRAINAGE CAN BE DISCHARGED USING THE PROPER BMP. IF VEGETATIVE BUFFER IS NOT ADEQUATE (<50 FT) THAN CONSIDER DISCHARGING COLLECTED STORMWATER AWAY FROM THE STREAM ON OPPOSITE SIDE OF THE ROAD. IF ADJACENT TOPOGRAPHY HAMPERS DISCHARGE ON THE SIDE OF THE ROAD, DISCHARGE DITCHES IN A DIFFERENT LOCATION, OR DISCHARGE USING A SETTLING POND THAT DISCHARGES VIA STONE WEIR TOWARDS THE STREAM.
- CULVERTS SHOULD BE SIZED PER THE TOOLKIT RECOMMENDATIONS. TYPICAL CULVERT DIAMETER SIZES PER DRAINAGE AREA ARE AS FOLLOWS:

DRAINAGE AREA	CULVERT DIAMETER NEEDED
0-1.5 ACRES	12"*
1.5-4 ACRES	18"
4-8 ACRES	24"
8-15 ACRES	32"
15-20 ACRES	36"
> 20 ACRES	>36" IS LIKELY A STREAM THAT WILL NEED TO FOLLOW MA STREAM CROSSING STANDARDS

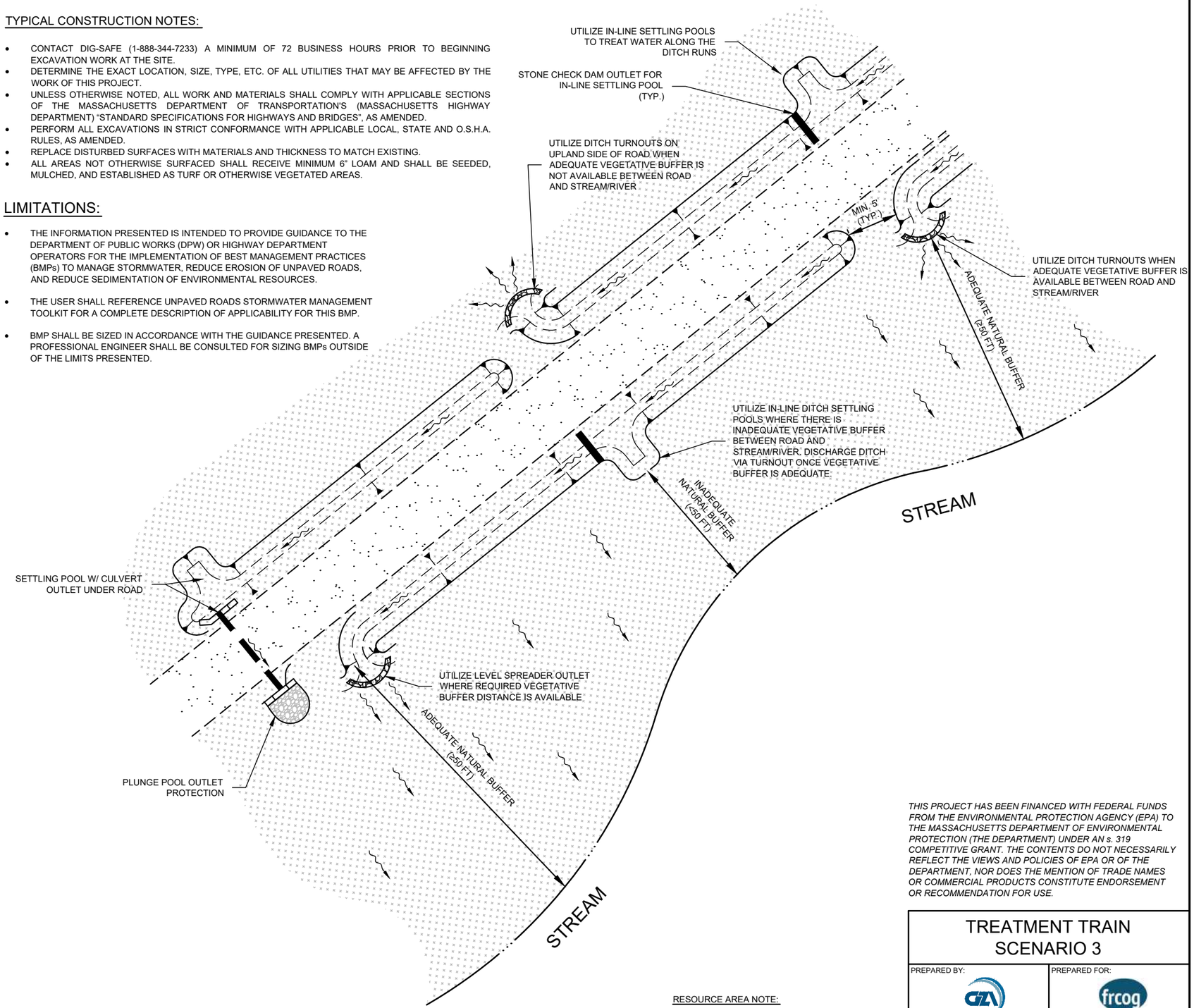
* - SOME ROAD MANUALS, SUCH AS THE 2024 VERMONT BETTER ROADS MANUAL, RECOMMEND A MINIMUM OF 18 INCHES FOR ANY STORMWATER CULVERT, AND A MINIMUM OF 15 INCHES FOR ANY DRIVEWAY CULVERT.

TYPICAL CONSTRUCTION NOTES:

- CONTACT DIG-SAFE (1-888-344-7233) A MINIMUM OF 72 BUSINESS HOURS PRIOR TO BEGINNING EXCAVATION WORK AT THE SITE.
- DETERMINE THE EXACT LOCATION, SIZE, TYPE, ETC. OF ALL UTILITIES THAT MAY BE AFFECTED BY THE WORK OF THIS PROJECT.
- UNLESS OTHERWISE NOTED, ALL WORK AND MATERIALS SHALL COMPLY WITH APPLICABLE SECTIONS OF THE MASSACHUSETTS DEPARTMENT OF TRANSPORTATION'S (MASSACHUSETTS HIGHWAY DEPARTMENT) "STANDARD SPECIFICATIONS FOR HIGHWAYS AND BRIDGES", AS AMENDED.
- PERFORM ALL EXCAVATIONS IN STRICT CONFORMANCE WITH APPLICABLE LOCAL, STATE AND O.S.H.A. RULES, AS AMENDED.
- REPLACE DISTURBED SURFACES WITH MATERIALS AND THICKNESS TO MATCH EXISTING.
- ALL AREAS NOT OTHERWISE SURFACED SHALL RECEIVE MINIMUM 6" LOAM AND SHALL BE SEEDED, MULCHED, AND ESTABLISHED AS TURF OR OTHERWISE VEGETATED AREAS.

LIMITATIONS:

- THE INFORMATION PRESENTED IS INTENDED TO PROVIDE GUIDANCE TO THE DEPARTMENT OF PUBLIC WORKS (DPW) OR HIGHWAY DEPARTMENT OPERATORS FOR THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES (BMPs) TO MANAGE STORMWATER, REDUCE EROSION OF UNPAVED ROADS, AND REDUCE SEDIMENTATION OF ENVIRONMENTAL RESOURCES.
- THE USER SHALL REFERENCE UNPAVED ROADS STORMWATER MANAGEMENT TOOLKIT FOR A COMPLETE DESCRIPTION OF APPLICABILITY FOR THIS BMP.
- BMP SHALL BE SIZED IN ACCORDANCE WITH THE GUIDANCE PRESENTED. A PROFESSIONAL ENGINEER SHALL BE CONSULTED FOR SIZING BMPs OUTSIDE OF THE LIMITS PRESENTED.



THIS PROJECT HAS BEEN FINANCED WITH FEDERAL FUNDS FROM THE ENVIRONMENTAL PROTECTION AGENCY (EPA) TO THE MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION (THE DEPARTMENT) UNDER AN s. 319 COMPETITIVE GRANT. THE CONTENTS DO NOT NECESSARILY REFLECT THE VIEWS AND POLICIES OF EPA OR OF THE DEPARTMENT, NOR DOES THE MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS CONSTITUTE ENDORSEMENT OR RECOMMENDATION FOR USE.

RESOURCE AREA NOTE:

- WORK WITHIN 100 FT OF A REGULATORY WETLAND RESOURCE AREA AND 200 FT FROM A STREAM/RIVER MAY REQUIRE LOCAL AND/OR STATE WETLAND PERMITTING

TREATMENT TRAIN SCENARIO 3

PREPARED BY:	PREPARED FOR:		
GZA	frcog		
DATE: SEP. 2024	REVISION NO. -	FIGURE TTS-3	

GZA–U:\0 167300 – 0 167399\15.0167304.00 FRCOG ENGINEERING FOR UNPAVED ROADS\15.0167304.00 CAD\DWG\167304.00–TREATMENT TRAIN.DWG TTS–3 SEPTEMBER 20, 2024 MARK STADNICKI

Tool 8: Managing Invasive Plants Along Roadsides

Understanding the Risks of Roadside Invasives

Invasive plants are non-native species that spread aggressively and cause harm to the environment, economy, or human health. They outcompete native vegetation, degrade habitats, and challenge infrastructure maintenance and public safety. According to the Massachusetts Invasive Plant Advisory Group, as of December 2022, more than 70 terrestrial and aquatic plant species have been classified as invasive, likely invasive, or potentially invasive in Massachusetts.[25] Roads are a lifeline in many communities, but they also create ideal conditions for invasive plants, with disturbed soils along the road edge. Routine maintenance like grading, mowing, and ditch clearing can unintentionally spread invasive plants such as Japanese knotweed or "Bamboo" (*Fallopia japonica*), and Asiatic bittersweet (*Celastrus orbiculatus*) along road corridors. Once established, these plants are difficult and costly to control. **Additionally, these species can cause a wide range of problems for transportation infrastructure, public safety, and surrounding ecosystems.**

Invasive plant growth can significantly impact road operations and infrastructure. Dense vegetation may reduce visibility, obscure signage, and encroach into travel lanes, compromising roadway safety. Aggressive root systems from particular species can damage pavement by pushing through road surfaces and degrading shoulders. Invasive plants often clog drainage systems, complicating storm recovery and routine maintenance. In some cases, the buildup of dry plant matter along road edges can also increase the risk of roadside fires. Nationally, invasive plants are estimated to cost over $36 billion annually in economic damages.[26]

The knotweed surrounding this culvert is contributing to the loss of soil, which threatens both the roadway and the guardrail. Photo Credit: Brian Colleran Ecological Land Management

Certain invasive plants produce chemical compounds that pose health risks to workers and the public. For example, Giant hogweed (*Heracleum mantegazzianum*) can cause photodermatitis and skin injury. Wild chervil (*Anthriscus sylvestris*) and wild parsnip (*Pastinaca sativa*) can cause severe skin burns and blistering when sap contacts skin exposed to sunlight.

[25] https://www.mass.gov/info-details/invasive-plants

[26] Pimentel, D., Zuniga, R., & Morrison, D. (2005). Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics, 52(3), 273–288. https://doi.org/10.1016/j.ecolecon.2004.10.002

When invasive plants spread from roadsides into adjacent habitats, they can disrupt local ecosystems in several ways. These species often outcompete native vegetation, reducing plant diversity and altering the natural balance. Their presence can also change soil chemistry and water availability, making it harder for native plants to thrive. These shifts hinder restoration efforts and disrupt wildlife by reducing food sources and blocking important migration corridors.

Long-term control is extremely difficult without herbicide treatment. However, in Massachusetts, herbicide use on public land or near water requires a licensed applicator and may need a vegetation management plan or permit under the Wetlands Protection Act. **Preventing spread is critical** since many Departments of Public Works (DPWs) or Highway Departments are not licensed for herbicide use and cannot legally apply it themselves.

Although state and federal agencies offer guidance on invasive plant management, these resources are often lengthy and not tailored to the day-to-day realities of rural DPWs. Most crews are focused on immediate needs such as drainage, equipment upkeep, and seasonal road work. With limited staff and tight budgets, invasive plant management can fall lower on the priority list, even when the impacts are visible and there is strong interest in improvement. Yet, routine DPW activities play a key role in either containing or accelerating the spread of invasive species.

Using This Tool in Day-to-Day Operations

This tool focuses on integrating invasive plant management into everyday DPW operations in ways that minimize additional workload while reducing long-term maintenance costs. Each section aligns with core roadway tasks that can unintentionally contribute to invasive plant spread. It offers practical strategies that are ecologically sound and operationally feasible within the realities of DPW work.

Additionally, this tool includes field-ready best practices and quick-reference sheets for crew use, adapted from the invasive plant management guidance developed by the Vermont and New Hampshire Departments of Transportation. These sheets can be printed or used digitally and are intended to complement existing routines. Departments are encouraged to distribute them before seasonal work begins, post them in garages or equipment cabs, or include them in crew binders and Standard Operating Procedures (SOPs). They may also be useful for planning, training, or internal policy discussions.

Additional resources, such as funding opportunities, identification guides, and planning references, are included at the end of this section.

While this tool provides a foundation for improved invasive plant management, sustained progress will require additional support. Long-term success depends on increased funding, hands-on training, and coordination across departments. DPW crews are already tasked with

managing complex responsibilities under tight constraints; this guidance is designed to support their efforts with realistic, actionable strategies.

Priority Invasive Plants for Roadside Management

The invasive plant species highlighted below were selected based on their prevalence in roadside environments, their ability to spread through common maintenance activities, and the long-term challenges they create for municipalities. Their common names are used in this tool.

Japanese Knotweed (*Fallopia japonica)* A fast-growing perennial that forms dense thickets along roadsides, ditches, and riverbanks. Spreads aggressively through rhizomes (underground roots) and stem fragments, which easily regenerate. Damages pavement, clogs culverts, and obscures sight lines due to its rapid growth and dense structure.

Asiatic Bittersweet (*Celastrus orbiculatus* Thunb.) A woody, deciduous vine that spreads by seed and root suckers. It rapidly climbs trees and structures, smothering vegetation and weakening host trees. Fragments can resprout, making roadside maintenance more difficult and increasing safety risks near infrastructure. Sometimes called “Oriental Bittersweet.”

Common Mugwort *(Artemisia vulgaris)* A persistent perennial herb commonly found in disturbed soils and fill along road shoulders. It spreads by both seed and rhizome and is difficult to remove once established. Although not on the Massachusetts Prohibited Plant List, it is highly prolific and can obstruct guardrails and sight lines when unmanaged.

Common Reed *(Phragmites australis*) A tall, perennial grass found in wetlands, ditches, and stormwater basins. It spreads through both rhizomes and seeds, forming dense stands that displace native plants. Blocks sight lines, clogs stormwater systems, and reduces drainage capacity.

Garlic Mustard (*Alliaria petiolate)* A biennial herb found in shaded roadsides and disturbed areas. It spreads only by seed and forms dense stands that displace native plants, contributing to erosion. Flowers and sets seed in late spring. Persistent infestations can require repeated mowing or hand removal before or when it starts to flower.

Purple Loosestrife (*Lythrum salicaria*) A tall, perennial wetland plant that spreads aggressively by seed and rhizome. Often found in roadside ditches and stormwater channels, it can clog drainage systems. Improper mowing can worsen infestations by spreading seeds.

How Invasive Plants Spread During Routine DPW Work

Below are four routine tasks most associated with the unintentional spread of invasive plants.

Road edge mowing – Mowing can break up and spread plant fragments, especially during seed production or in heavily infested areas.

Equipment Movement & Cleaning – Soil, seeds, and plant fragments can cling to blades, tracks, and undercarriages. Without cleaning, equipment can carry invasive species from one site to another, even across towns.

Soil disturbance – Grading, ditch work, and excavation can move soil containing invasive roots and seeds, spreading them to new areas. Compacted or bare soils give invasives an edge over native plants, making disturbed sites especially vulnerable.

Transportation and Disposal – Where and how plant material is moved matters. Dumping or storing materials infested with invasive plant fragments or seeds can start new populations.

Incorporating good maintenance practices will reduce the spread and help contain existing populations of invasive plants.

Road Edge Mowing

Mowing[27] is an essential roadside maintenance activity for safety, aesthetics, and operational function. It also plays a major role in the spread of invasive plants. In general, mowing should be avoided in areas heavily infested with invasive plants, unless required for safety. Effective control may require repeated mowing and is most useful when paired with other control techniques. Mowing alone is rarely a preferred eradication method because of the ongoing commitment and limited effectiveness for large infestations.

Timing of mowing can be effective in preventing invasive plant spread. After flowering, many invasive plants quickly produce seeds, increasing the risk of spread if mowed too late. Mowing during the flowering stage can reduce seed production for some invasive species. For example, *garlic mustard* can be suppressed with early mowing in May, just as it begins to flower.

Common roadside invasives garlic mustard (left): before flowering (rosettes), and (right) during the flowering stage. Timing mowing to occur during flowering helps prevent seed production and limits spread.

Raising blades to a height of six to eight inches can reduce the risk of spreading fragments and protect any remaining desirable vegetation (e.g. native grasses and groundcover).

Cleaning vehicles and equipment daily, and always before moving them offsite can reduce the spread of seeds and plant fragments. Removing soil, seeds, and plant fragments from equipment is the most practical and effective method to help prevent the spread of invasive plants and can be done with just a brush, scraper, or broom. Avoid using water to clean equipment in the field or in the DPW Yard. Uncontrolled rinsing can carry invasive plant material into ditches, storm drains, or natural areas, leading to new infestations.

In areas with high-risk species such as Japanese knotweed or common reed, avoid mowing or mechanical cutting when possible. If cutting is necessary to improve visibility or access, limit it to the minimum area required. Never mow over streams, as Japanese knotweed fragments will regrow and become established downstream. Hand tools may be appropriate for small patches or critical areas, but mechanical cutting may still be needed for larger roadside areas. In these cases, raise blades, avoid soil contact, and prioritize equipment cleaning to prevent the spread.

[27] For the purposes of this text, “mowing” refers to routine grass mowing using rotary or flail mowers. “Cutting” or refers to mechanical clearing of woody vegetation using boom arms, brush cutters, or similar equipment.

Road Edge Mowing Field Sheet

This field sheet provides practical mowing strategies to help reduce the spread of invasive plants during routine roadside maintenance. These steps are designed to fit within existing DPW operations and can be used by any crew without adding new equipment or major workflow changes.

Field Checklist

Before You Mow

- ☐ Plan Your Route
  - Skip infested areas of Japanese knotweed. Do not mow Japanese knotweed unless necessary for safety. *See guidance tips for Japanese knotweed management.*
  - If possible, use marker tape to locate invasive plant infestations during the spring or during the first mowing to help plan mowing routes for later in the season.
- ☐ Start in clean areas and end in infested zones.
- ☐ During July or August, assess whether mowing is necessary. Many invasive plants are setting seed, and mowing can spread seeds. Only mow if required for safety or visibility.
- ☐ Notice areas with repeated regrowth.
  - Note high-risk spots (e.g. knotweed, bittersweet)
- ☐ Adjust mowing height to avoid scalping grasses or shredding invasive plants.
- ☐ Use marker tape if part of your crew's process is to mark invasive plant infestations during spring or the first pass to help plan routes later in the season.

While You Mow

- ☐ Raise blades 6 – 8 inches when mowing near most invasives.
- ☐ Mowing should be limited to only the portion of the patch that is impacting safety.

After You Mow

- ☐ Use a brush, scraper, or broom to clean blades and vehicles (especially tires) before moving to the next area.

Equipment Movement and Cleaning

Routine equipment cleaning is a low-cost, high-impact strategy to prevent the spread of invasive plant species. Although full decontamination may not be feasible in most field conditions, small adjustments to cleaning habits can significantly reduce the risk of invasive plant spread. Invasive plant fragments, including seeds, stems, and underground stems known as rhizomes, can easily attach to mowers, graders, excavators, trailers, and other maintenance equipment. Seeds cling to tires and may germinate in disturbed soil. Stems can resprout when caught on blades or undercarriages. Rhizomes, the underground stem systems, regenerate aggressively from even small pieces. Images below show examples of seeds, vine stems, and rhizomes.

Examples of invasive parts that spread. From left to right: purple loosestrife seed clusters, Asiatic bittersweet stem fragments, Japanese knotweed underground stems (rhizomes).

When machinery is moved from site to site without proper cleaning, plant parts can be unintentionally transported and introduced to uninfested areas. Even small fragments can establish new populations, particularly along roadsides and drainage corridors with high disturbance and limited monitoring.

It is best to clean equipment daily during the growing season, typically May through October, especially when working in or near areas with invasive plants. Focus cleaning on areas where soil, seeds, and plant debris tend to collect, such as tires, tracks, undercarriages, and mower decks.

Dry cleaning methods such as brushes, scrapers, or compressed air should be used. If cleaning in the field is not feasible, every department should establish a designated cleaning area at the yard or garage. This area should be clearly marked, located away from drains or sensitive areas, and surfaced with gravel or pavement that allows for easy sweeping and containment. **Avoid using water. It can wash invasive seeds and fragments into ditches and wetlands, causing spread.**

Equipment Cleaning Field Sheet

This field sheet provides practical guidance for equipment inspection and cleaning to help reduce the spread of invasive plants. The steps are designed to integrate easily into existing DPW operations without requiring new equipment or major workflow changes. **Tip: Keep a brush, gloves, and a bucket in every vehicle. The bucket can collect debris or hold tools and materials for dry cleaning in the field.**

What To Clean

Focus on visible debris in these high-risk areas:

- Tires and undercarriage: clean these first because they collect the most debris
- Mower decks/blades
- Underbody and trailers
- Shovels, rakes, and other hand tools

Field Checklist

After Mowing and Before Leaving the Site

- ☐ Visually inspect equipment for plant material.
- ☐ Remove soil, stems, and seeds using a stiff brush or scraper, or compressed air.
- ☐ Always wear gloves and avoid skin contact, as some plants can burn and irritate skin.
- ☐ Never clean over ditches, storm drains, streams, or near wetlands.

Back at the DPW Yard

- ☐ Create a designated cleaning zone with a gravel base, if possible.
- ☐ Clean equipment thoroughly using a stiff brush, scraper, or compressed air.
- ☐ Dispose of collected debris in a trash bag or designated disposal area.

NOTE: Although use of water to clean off equipment is not recommended, if mowers are cleaned at the DPW yard using water, contain the runoff to a designated area and monitor the area for invasive plant growth. ***Do not allow the runoff to enter ditches, storm drains, wetlands, or adjacent property.***

Soil Disturbance

Soil disturbance is a standard part of road maintenance, whether it involves ditching, grading, shoulder work, culvert replacement, or erosion repair. This work can create ideal conditions for spreading invasive plants because it exposes soil, disrupts root structures, and can move plant fragments to new locations on and off the project site.

Best practices include minimizing disturbance, monitoring impacted areas, and stabilizing soil as quickly as possible using clean, appropriate materials. These reduce invasive plant spread, support erosion control, and protect infrastructure.

Whenever possible, excavation should be avoided in areas known to contain invasive species. If disturbance is unavoidable, efforts should be made to minimize soil disruption, and recent work sites should be monitored for at least two years for signs of invasive plant emergence. Disturbed soils should be stabilized promptly using seed, mulch, stone, or other clean materials that are free of invasive plant fragments.

Additionally, materials like fill, loam, gravel, mulch, or hay should never be brought in from locations where invasive plants are known to be present or were previously established. Species listed on the Massachusetts Prohibited Plant List, maintained by the Massachusetts Department of Agricultural Resources (MDAR), should not be used in any revegetation or landscaping. MDAR's list identifies plants that are banned from sale, propagation, or distribution because of their documented ecological harm.[28]

Soil Disturbance Field Sheet

What to Watch For

- Known invasive patches in or near your work zone.
- Spoil piles (excavated soil) or soil tracked off-site.
- Use of fill or mulch from unknown sources.
- Bare soil left unseeded or unprotected.

[28] https://www.mass.gov/info-details/massachusetts-prohibited-plant-list

Field Checklist

Before Work

- ☐ Note if invasive plants are visible in the proposed work area.
- ☐ Minimize the footprint of disturbance as much as possible.
- ☐ Mark work zone and/or protected zones with flags, fencing, tape, or paint
- ☐ If working in an infested area, plan to contain soil onsite.
- ☐ Purchase or acquire fill, mulch, and seed from clean sources only.

During Work

- ☐ Minimize soil movement. Disturb only what is necessary.
- ☐ Keep spoil piles away from waterways and wetlands.
- ☐ Avoid spreading plant materials like rhizomes (underground roots) or seeds.
    - Keep excavated soil close to where it was dug. If you must move sediment or soil contaminated with invasive plant parts, avoid relocating to a site not yet infested.
    - Use tarps or matting on which to place viable material when/where feasible.
    - Check for material or soil that may have dropped.
    - Shake off tools and buckets before moving to another location.

After Work

- ☐ Stabilize slopes with jute mesh or compost blankets.
- ☐ Seed immediately after work is complete. Consider native seed mixes if appropriate to the location.
- ☐ Monitor the area and remove any invasive sprouts. Management is cheaper and easier when plants are caught when new and small.

Transportation and Disposal

Proper transport and disposal of invasive plant material are critical to preventing unintentional spread. Even when invasive species are removed correctly, poor handling of stems, seeds, or soil can introduce them to clean areas. These practices are designed to reduce risk while remaining feasible for DPW crews.

Drying/Liquefying: For large amounts of plant material or for plants with rigid stems, place the material on asphalt in full sun to dry out and die. If there is possibility of material blowing away, place material under tarps or heavy plastic. For smaller amounts of plant material or for plants with pliable stems, bag the material in black, heavy-duty (3 mil or thicker) garbage bags. Keep the plant material covered or bagged for at least one month. Material is nonviable when it is fully dehydrated, or partially decomposed, very slimy, or brittle. Once material is nonviable, it can be disposed of in an approved landfill or brush pile. This method is recommended for Japanese knotweed and common reed.

Brush Piles: Some invasive plants, like Asiatic bittersweet and mugwort, can be piled on site to dry if cut before flowering or seed set. For common reed and Japanese knotweed, keep stems off the soil and dry fully on a tarp or pallet. Do not pile plants with seeds or fruit unless drying within the infested area, where any regrowth can be contained. If regrowth occurs, it will stay contained and will not spread to new areas.

Burying: Plant material from many invasive species can be buried at least three feet below grade, especially on job sites where soils are already disturbed. ***Burial is not recommended for Japanese knotweed unless it is at the infestation site and can be buried at least five feet deep***, with no risk of future disturbance.

Burning: Plant material should be taken to a designated burn pile. All necessary permits must be obtained before burning. Recommended but often not feasible for every invasive plant, especially Japanese knotweed and common reed.

Examples of recommended transportation and disposal strategies. From left to right: truck bed lined with tarp prevents material from falling or blowing away, brush pile left to rot in woods, and a bag of plant material to rot and avoid soil contact. Photo Credit: Grow Native Massachusetts, Woody Invasives of Michigan, Town of Concord

Transportation and Disposal Field Sheet

What to Avoid

- Loose debris or soil in truck beds, trailers, or buckets.
- Dumping plants in ditches, wetlands, or along road edges.
- Mixing invasive plants with clean brush or compost piles.
- Open transport of invasive stems, seeds,or contaminated soil.

Field Checklist

When Removing Invasive Plant Material

- ☐ Bag stems and roots in heavy-duty contractor bags.
- ☐ If bags are not available, lay cut material on plastic or asphalt to dry in full sun for at least one month.
- ☐ Keep plant material out of compost piles, roadside brush dumps, or general fill areas.
- ☐ Do not leave roots in contact with soil, especially for knotweed, loosestrife, and common reed (phragmites).

When Transporting

- ☐ Secure all plant debris and soil using tarps, closed containers, or sealed bags.
- ☐ Label bags or loads from infested areas to avoid spreading material to clean sites.
- ☐ Sweep out truck beds, trailers, and buckets at the dump or receiving site.
- ☐ Do not haul unbagged plant material in open trucks.
- ☐ Keep infested spoil separate from clean fill or root material across the site.

Final Disposal Methods

- ☐ Dry and degrade on-site (sun-dry on tarp or sealed bags until brittle/slimy).
- ☐ Bury on-site only if allowed: 3 feet minimum depth, 5 feet for knotweed.
- ☐ Burn only with proper permits and at designated locations.
- ☐ Dispose of degraded material at an approved landfill. Do not place in compost piles or general brush dumps.

Priority Invasive Plant Identification Fact Sheets

The following information highlights invasive plant species commonly encountered during roadside and public works operations. More information is provided about Japanese knotweed as it is of key concern on the roadside and in our landscape.

Knowing what to look for, including how each plant spreads and which parts can regenerate, is a critical first step in preventing the unintentional spread of invasives.

Each sheet includes key identification features and practical guidance to support better decision-making during everyday maintenance work.

For more detailed plant identification guidance and management recommendations, see the *Additional Resources and References* section at the end of this tool.

Note: Some of the linked resources include herbicide recommendations. In Massachusetts, herbicide use requires a licensed applicator and if near a wetland or waterbody, permitting under the Wetlands Protection Act. Always follow state regulations and municipal by-laws or protocols.

Japanese Knotweed (*Fallopia japonica)*

Identification

Spring (April–May): Emergence

- Shoots appear red or purplish and resemble asparagus spears
- Stems are soft, fleshy, and brittle
- Easy to miss or mow unintentionally
- Best time to detect and flag early patches

Early Summer (June): Rapid Growth

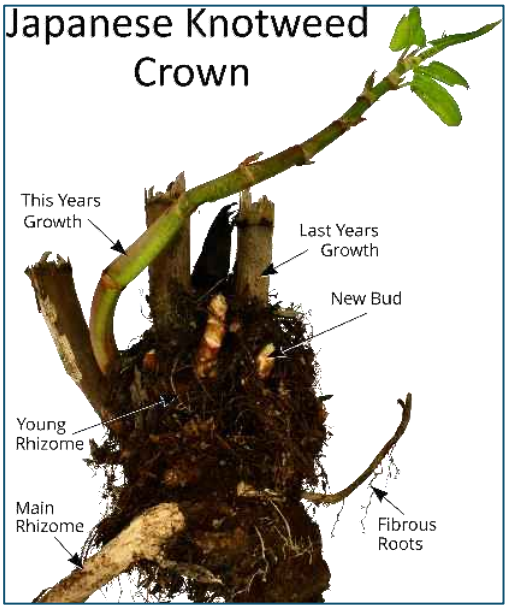
- Hollow, bamboo-like stems form dense thickets
- Leaves are **heart- or shovel-shaped**, alternating along the stem
- Plants grow 1–3 inches per day

Mid to Late Summer (July–September): Flowering

- White, plume-like flower clusters appear
- Plants reach full height (up to 10 feet)
- **Highest risk of spread if mowed**—avoid cutting during this stage
- Stems become more woody and persistent

Why Managing Japanese Knotweed Matters

Japanese knotweed is one of the most aggressive invasive plants along roadsides, especially in moist soils near riverbanks, ditches, and culverts. It ***spreads rapidly through small fragments of stems, crowns, and rhizomes,*** all of which can regrow if disturbed. Mowing and soil movement are common causes of unintentional spread.



Herbicide is often the only effective long-term control, but in Massachusetts, its use is restricted and must be done by a licensed applicator. Since most DPWs cannot apply herbicide directly, preventing spread through mowing practices and equipment cleaning is essential. Avoiding unnecessary disturbance helps limit infestations until proper treatment can be coordinated.

Do Not Mow Unless Necessary

- ☐ Only mow if the plant interferes with safety (e.g., blocking signs, sightlines, lanes).

If Mowing is Required for Safety

- ☐ Raise the mower deck 6 to 8 inches. Cutting higher avoids hitting the base of the plant or disturbing the soil, which can break off pieces that may grow back or spread to new areas.

After Mowing

- ☐ Leave material on site only if it can remain within the infested area and be fully dried in place, such as on a tarp or asphalt surface (avoid contact with soil). Do not transport, compost, or leave fresh material in clean or high-traffic areas.
- ☐ Bag and dry material in full sun until completely brown and brittle. Fully dried material may be returned to the original infestation site, but never dumped in uninfested areas or compost piles.
- ☐ Clean blades and equipment thoroughly using a brush or scraper before leaving the site.

Managing Japanese Knotweed Patches

Japanese knotweed is highly persistent and difficult to eradicate once established. The following management strategies are appropriate for public works crews when removal or containment is necessary. Always aim to prevent further spread.

Desiccation (Cut-and-Dry): Cut stems and place on a tarp or paved surface in direct sun. Let them dry completely until they turn brown and brittle.

On-Site Handling: In most mowing or roadside maintenance situations, it is best to leave Japanese knotweed material at the original infestation site rather than transporting it. Choose a location where cut stems can dry fully in the sun and where regrowth can be monitored or managed with follow-up mowing. Avoid piling plant material near wetlands, ditches, or high-quality habitat**. Equipment used in infested areas, especially mower decks, blades, and tires, should be thoroughly cleaned before leaving the site to prevent spreading fragments to new locations.**

Disposal: Dry material can be burned at proper facilities, if that is an option. Roots and rhizomes may be taken with soil to an approved landfill if other soils are being disposed of in a similar manner. **Never dump in wetlands, ditches, or roadside edges.**

Smothering: While smothering is not typically used in day-to-day DPW operations, it may be appropriate in specific situations such as isolated infestations, or in low-traffic areas where mowing is difficult or impractical. **Smothering requires effective planning, coordination, and long-term site access.** It may be best suited for collaboration with conservation staff, regional partners, or volunteer programs that can support installation and monitoring. Cover the patch with heavy-duty black plastic (7-mil or thicker) and secure it with mulch and weights. This deprives the plant of sunlight and moisture. It is low-tech but effective, especially in sensitive or hard-to-reach areas. This method takes commitment: leave the cover in place for 3 – 5 years.

Example of smothering using 7-mil black plastic and 4” mulch.

Burial: Bury rhizomes and crowns at least 5 feet deep, away from water sources and wetlands. This method should be used with extreme caution. If done improperly, buried fragments can regrow and spread, making the infestation worse.

Asiatic Bittersweet *(Celastrus orbiculatus)*[29]

Asiatic bittersweet vine with flowers.

Asiatic bittersweet vine with berries.

Asiatic bittersweet's matured berries.

Identification & Overview:

- A deciduous woody vine that can grow up to 60 feet long and form a stem 4 – 6 inches in diameter at the base.
- Climbs and strangles shrubs and trees.
- The small and greenish flowers bloom in early spring (May /June).
- The distinctive red berry like fruit is visible in the fall and persist through the winter.
- Spreads by seed and by underground roots that form new stems.

Prevent its spread:

Repeated cutting of bittersweet at 1 – 2 feet above the soil line can exhausts the plant's energy reserves and reduces the vine's ability to climb and twine around trees and shrubs.

Disposal:

Burn or bag any material that has berries on it. Discard with regular waste. Cut plants with no fruit can be left to dry in the sun or composted.

[29] Sources: https://ipm.cahnr.uconn.edu/invasive_plants_asiatic_bittersweet/ https://extension.umass.edu/weed-herbarium/weeds/celastrus-orbiculatus

Common Mugwort *(Artemisia vulgaris)*[30]

Common mugwort on a roadside.

Common mugwort flowers.

Common mugwort leaves.

Identification & Overview:

- A perennial plant (regrows each year) which grows 2 – 5 feet in height.
- Aggressively establishes and colonizes roadsides.
- Flowers are inconspicuous and bloom in late summer July – September.
- Spreads primarily by aggressive rhizomes (underground stems). Can also spread by seed.
- Seeds sprout wherever there is exposed bare ground, therefore stabilization and re-seeding of bare soil on roadsides with a grass cover will reduce establishment of mugwort populations.
- Prefers dryer soils, does not persist in wet soils.

Prevent its spread:

To prevent seed dispersal, mow roadsides from late summer to mid-September, as it flowers and before seeds have formed.

Disposal:

Bag any material that has gone to seed or plant parts that include rhizomes. Discard with regular waste. If mowing occurred after seedheads matured, collect cuttings and throw away in the trash.

[4] Sources: https://ipm.cahnr.uconn.edu/invasive_plants_common_mugwort/ https://extension.umass.edu/weed-herbarium/weeds/artemisia-vulgaris

Common Reed *(Phragmites australis)*[31]

Common reed growth habit.

Common reed flowering head is purplish.

Common reed matured seed heads.

Identification & Overview:

- Often referred to as "phragmites," this aggressive, perennial grass invades and degrades wetland habitat.
- Colonizes ditches and swales.
- Can grow 8 – 12 feet in height with long flat leaves.
- Flowers from August to September. These turn white/brown over time and persist through the winter.
- Mainly spreads through rhizomes (underground stems) which generate new plants that can be a good distance from the parent plant.

Prevent its Spread:

To prevent seed dispersal, mow roadside patches before it flowers and set the mower 6 – 8 inches or higher to prevent spreading rhizome fragments.

Disposal:

Burn or bag any material that has gone to seed or plant parts that include rhizomes. Discard with regular waste. If mowing occurred after seedheads matured, collect cuttings and throw away in the trash.

[31] Sources: https://ipm.cahnr.uconn.edu/invasive_plants_common_reed/ & https://extension.umass.edu/weed-herbarium/weeds/phragmites-australis

Garlic Mustard *(Alliaria petiolata)*[32]

Garlic mustard leaves.

Garlic mustard flowering and going to seed.

Garlic mustard matured seed pods.

Identification & Overview:

- A biennial (two years to mature and set seed) plant that can grow up to 3 feet in height.
- In the first year, just a rosette of heart-shaped leaves grow.
- Blooms in May and June during the second year of growth.
- Reproduces only by seed. A single plant can produce 600 – 7,500 seeds.
- Tolerates a variety of habitats from part sun to full shade and dry to wet soil.
- When crushed, it gives off a garlic odor.

Prevent its spread:

To prevent seed dispersal, mow roadsides as it flowers. Need to monitor the flowering to time the mowing as it varies greatly depending on the location.

Small infestations be easily hand-pulled preferably before going to seed.

Disposal:

Bag any material that has gone to flower as it can continue to grow and form seeds. Discard with regular waste. Do not compost.

[32] Sources: https://ipm.cahnr.uconn.edu/invasive_plants_garlic_mustard/ https://extension.umass.edu/weed-herbarium/weeds/alliaria-petiolata

Purple Loosestrife *(Lythrum salicaria)*[33]

Purple loosestrife growth habit.

Purple loosestrife in flower.

Purple loosestrife colonizing drainage swale.

Identification:

- A multi-stemmed perennial (plant that comes up every year) that can grow up to 10 feet tall.
- Invades wetlands, stream banks, and ditches
- Once cut, stems can float and can disperse and resprout.
- Flowers in summer (June – August).
- A single, mature plant can produce more than 2.5 million seeds annually.
- Reproduces by seed and vegetatively through plant fragments.

Prevent its spread:

Mowing is not recommended as plant fragments have the ability to grow new plants. Once purple loosestrife has matured, it is essential to not disturb the plant!

Cutting the flower heads off can dramatically slow the spread of seeds.

Young plants that have not become woody can be easily hand-pulled.

Disposal:

Bag any cut or hand removed material. Discard with regular waste.

[33] Sources: https://cipwg.uconn.edu/purple-loosestrife/ & https://www.umass.edu/agriculture-food-environment/greenhouse-floriculture/photos/invasive-plant-purple-loosestrife

Watchlist Species: Report Early, Act Fast

The following invasive plants are not yet widespread in western Massachusetts, but they are aggressive and spreading. Educate your crews about how to identify them as catching them early in your community can prevent long-term damage and reduce future maintenance needs. Print these fact sheets and keep them handy. If you spot any of these species, report the sighting immediately to the Massachusetts Department of Agricultural Resources (MDAR).

Giant Hogweed *(Heracleum mantegazzianum)* – First discovered in Massachusetts in 2002, giant hogweed is present in all three western Massachusetts counties and control efforts are underway in several western Massachusetts communities including: Blandford, Brimfield, Granville, Hinsdale, Lee, New Marlborough, Southwick, Peru, West Springfield, and Whately. The sap of Giant Hogweed can cause severe skin burns and potential blindness.[34]

Mile a Minute Vine *(Polygonum perfoliatum)* – First discovered in Massachusetts in 2006, sightings have been reported as far west as Buckland. Infestations are being managed in several western Massachusetts communities including Buckland, Deerfield, Montague, Granby, and Erving. The infestation identified in Greenfield was eradicated.

Japanese Stilt Grass (*Microstegium vimineum*) – Currently identified in all four western Massachusetts counties. Invades roadsides and drainage swales. Seeds are transported by runoff and streams to new locations.

Fact sheets for these plants are provided in the following pages.

Report sightings online at massnrc.org/pests/report.aspx or call 617-626-1779.

Early action helps protect your community and saves your crew from bigger problems later. **Don't wait—report it.**

[34] Source: https://massnrc.org/pests/pestFAQsheets/hogweed/giant_hogweed.htm & https://experience.arcgis.com/experience/a25afa4466a54313b21dd45abc34b62d/page/Dashboard

Invasive Plant Alert: Giant Hogweed

Giant Hogweed (*Heracleum mantegazzianum*) is an invasive plant that was first discovered in Massachusetts in 2002. It is most commonly found along roadsides and river banks and prefers rich, moist soil. When in flower, plants may reach 14ft or more in height. Plants die after flowering, typically after two years of growth.

Giant Hogweed is known not only for its invasive properties, but also for its poisonous "phototoxic" sap, which causes severe irritation and blistering when it comes into contact with skin that is then exposed to the sun. Because of this, care should be taken to avoid direct contact with this species.

What to look for:

1

Leaves grow in a rosette around the bottom of the stem, and can grow up to 5ft wide. Mature leaves are deeply lobed, with each lobe deeply cut into pointed teeth. Smaller leaves are also found along the stem.

2

Green stems are splotched with purple and covered with stubbly hairs. Stem nodes are prominently marked with a ring of coarse white hairs.

3

Flower heads are clusters of tiny, white flowers attached to the top of the stem in an umbrella-like shape (umbels), similar to Queen Anne's Lace but significantly larger (up to 2ft across). Plants flower from June through July.

GIANT HOGWEED LOOK-ALIKES (Do Not Report):

Cow Parsnip | Canada Lettuce | Wild Angelica

If you suspect that you have found Giant Hogweed, please photograph the plant and report it to:

http://massnrc.org/pests/report.aspx

Photo Credits: IPANE (Les Mehrhoff and others), S. Antunes-Kenyon (MDAR), Bugwood Images, Ohio ANR

MDAR
www.mass.gov/agr

WANTED

Mile-a-minute Vine ("MAM")

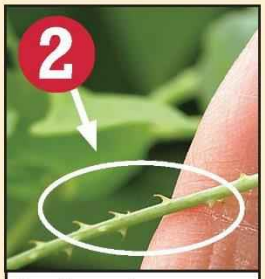
(*Polygonum perfoliatum*, also known as Devil's Tail, Asiatic Tearthumb, or *Persicaria perfoliata*)

Mile-a-minute Vine is a highly invasive annual weed, native to Asia, that was first discovered in Massachusetts in 2006. A single vine can grow up to 6 inches per day. Mile-a-minute vine climbs over trees and posts, shading out other plants. It outcompetes and overgrows native species, causing ecological and economic damage. Your help is needed to prevent this plant from becoming established in Massachusetts.

Please help us find, track, and control this invasive plant!

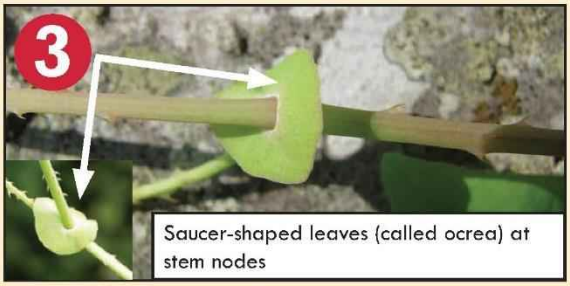
THREE IDENTIFYING TRAITS:

Triangular leaves (often nearly equilateral)



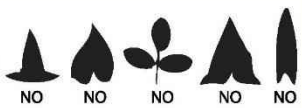
Small curved barbs along stems

In summer, MAM fruits ripen from green to metallic blue



Saucer-shaped leaves (called ocrea) at stem nodes

Leaf shapes of other vines; these species do not harm ecosystems and should **not** be reported:



If you find a plant with all 3 traits, note its location, photograph it or take a sample, and **REPORT IT**:

- **Visit http://massnrc.org/pests (click "Report MAM")**
- **Call the MDAR Plant Pest Hotline: 617-626-1779**

MDAR Massachusetts Department of Agricultural Resources

dcr Massachusetts

MassWildlife Massachusetts Division of Fisheries & Wildlife

Natural Heritage & Endangered Species Program

Based on a flyer designed by: University of Connecticut

Photos courtesy of Todd Mervosh, Les Mehrhoff, Hope Leeson, Judy Hough-Goldstein, and Renée Sullivan

Japanese Stiltgrass *(Microstegium vimineum)*[35]

Japanese stiltgrass growth habit.

Japanese stiltgrass individual plant.

Japanese stiltgrass in flower.

Identification & Overview:

- An annual grass, 1 – 3 feet in height, similar in appearance to young bamboo, that forms dense mats.
- Colonizes roadsides and drainage ditches.
- Leaves are lance-shaped and 1 – 3 inches long.
- Flowers in late summer/early fall.
- Reproduces by seed, 100 – 1,000 seeds/plant.
- Seeds float and are easily dispersed through runoff from roadside ditches to other locations and streams allowing new invasions to occur on property outside of the roadside edge.
- Leaves become purple/reddish and pale yellow in late fall.
- Tolerates a variety of habitats from part sun to full shade and dry to wet soil.
- Soil disturbance enhances germination.

Prevent its spread:

To prevent seed dispersal, mow roadsides regularly at a low height or once in late summer as it flowers before seeds are set. Monitor the plant to ensure mowing is timed correctly. Small infestations can be easily hand-pulled preferably before flowering.

Disposal:

Bag any hand-pulled or cut material that has gone to flower. Hand-pulled plants that have not flowered can be left on-site.

[35] Sources: https://ipm.cahnr.uconn.edu/invasive_plants_japanese_stiltgrass/ https://extension.umass.edu/weed-herbarium/weeds/microstegium-vimineum

Funding Resources for Invasive Plant Management

The MassWildlife Habitat Management Grant Program (MHMGP) provides funding to private and municipal landowners of conserved lands in Massachusetts to support active habitat restoration and enhancement for wildlife. Grants range from $10,000 to $50,000 and prioritize projects that improve habitat for game species and species of greatest conservation need identified in the State Wildlife Action Plan. Eligible activities include invasive plant control (mechanical or chemical), mowing, brush clearing, prescribed burning, and planting of native species. https://www.mass.gov/guides/masswildlife-habitat-management-grant-program

Community Preservation Act (CPA) funds can support invasive plant management when it aligns with eligible uses under open space, recreation, or historic preservation categories. Invasive species removal is most often funded as part of a larger natural resource restoration, trail improvement, or park revitalization project. Each municipality that has adopted CPA sets its own priorities, so eligibility and funding levels vary. Projects must typically be reviewed and recommended by the local Community Preservation Committee before going to town meeting or city council for final approval. Applicants should clearly demonstrate public benefit and alignment with community goals for open space or recreation.

Municipal Vulnerability Preparedness (MVP) Action Grants offers financial resources to communities that are seeking to advance priority climate adaptation actions. These grants support climate resilience projects, including invasive species management as part of nature-based solutions, habitat restoration, or green infrastructure. Strong fit for municipal projects that demonstrate community engagement and long-term resilience benefits. https://www.mass.gov/info-details/mvp-action-grant

The DCR Urban and Community Forestry Challenge Grant supports municipalities and nonprofits in enhancing urban tree canopy, planning for forest health, and building local forestry capacity. Projects that include invasive species removal as part of a broader urban forestry initiative, such as tree planting, developing a forest management plan, or improving canopy resilience, may be eligible. https://www.mass.gov/guides/urban-and-community-forestry-challenge-grants

Additional Resources & References

Invasive Plant Management Guidelines

Minnesota Department of Transportation. *Best Practices Handbook for Roadside Vegetation Management*, 2008: https://www.lrrb.org/pdf/200820.pdf

New England Interstate Water Pollution Control Commission. *Vegetation Management Best Management Practices for Roadsides*, 2019: https://neiwpcc.org/wp-content/uploads/2019/05/Wetlands-BMP-Manual-2019.pdf

New Hampshire Department of Agriculture. Preventing the Spread of Japanese Knotweed (*Reynoutria japonica*), 2018: https://www.mass.gov/doc/nhdot-invasive-plant-fact-sheet-2-bmps-for-knotweed/download

New Hampshire Department of Transportation. *Best Management Practices for the Control of Invasive and Noxious Plant Species*, 2018: https://www.dot.nh.gov/sites/g/files/ehbemt811/files/inline-documents/final-env-1-manual-1-invasive-species_0.pdf

New York State Department of Transportation (NYSDOT). *Invasive Species Best Management Practices for Transportation and Utility Right-of-Ways*: https://www.dot.ny.gov/divisions/engineering/environmental-analysis/repository/InvasiveSpeciesBMPs_Transp-UtilityROWs.rtf

Vermont Agency of Transportation. *Best Management Practices for Invasive Plant Management in Transportation Corridors,* 2021: https://vtrans.vermont.gov/operations/technical-services/environmental/best-management-practices

VTrans. *VTrans State Highway System Roadside Terrestrial Invasive Plants BMPs*, 2012: https://vtrans.vermont.gov/sites/aot/files/operations/documents/techservices/Invasive%20BMP.PDF

UConn. *Connecticut Invasive Plant Management Calendar*, 2018: https://cipwg.media.uconn.edu/wp-content/uploads/sites/244/2020/12/CIPWG-2018-Invasive-Plant-Management-Calendar.pdf

UMass Amherst Extension. *Invasive Plant Management Guide for Professionals:* https://www.umass.edu/agriculture-food-environment/landscape/publications-resources/professional-insect-mite-management-guide-for-woody-plants/about

Plant Identification Sources and References

Connecticut Invasive Plant Working Group (CIPWG) website and resources: https://cipwg.uconn.edu/

Cornell Cooperative Extension:

https://westchester.cce.cornell.edu/horticulture-environment/invasive-nuisance-species

Massachusetts Audubon Society: https://www.massaudubon.org/content/download/61745/file/MAInvasivesBooklet_2023.pdf?inLanguage=eng-US&version=1

Massachusetts Environmental and Economic Impacts of Invasives: https://www.mass.gov/doc/environmental-impacts-and-economic-costs-of-invasive-species/download

Massachusetts Department of Agriculture Resources (MDAR) Interactive Dashboard https://experience.arcgis.com/experience/a25afa4466a54313b21dd45abc34b62d/page/Dashboard

Massachusetts Department of Agricultural Resources (MDAR):

- Prohibited Plant List: https://www.mass.gov/massachusetts-prohibited-plant-list
- Evaluation Criteria for Invasive Plant Species in Massachusetts: https://www.mass.gov/info-details/invasive-plants\
- Publications and Additional Resources: https://massnrc.org/mipag/publications.html

National Invasive Species Information Center (NISIC), U.S. Department of Agriculture: https://www.invasivespeciesinfo.gov/what-are-invasive-species

State of Massachusetts Invasive Plants Information Page: https://www.mass.gov/info-details/invasive-plants

University of Georgia - Center for Invasive Species & Ecosystem: https://www.eddmaps.org/

USDA PLANTS Database: https://plants.usda.gov/

University of Connecticut (UCONN) Extension: https://ipm.cahnr.uconn.edu/

Vermont Invasives: https://www.invasive.org/

Appendix A: Road Maintenance Checklists

Addendum to Tool 1

UNPAVED ROADS BMP INSPECTION FORM

General Information

BMP Description			
BMP Location			
Inspector's Name			
Date of Inspection		Date of Last Inspection	
Start Time		End Time	
Type of Inspection: Regular ☐ Pre-Storm Event ☐ During Storm Event ☐ Post-Storm Event ☐			
Describe the weather conditions at time of inspection			

Specific Information

Maintenance Activity	Maintenance Frequency	Is Status of BMP Satisfactory?	Corrective Action Needed
Inspect for invasive species and remove if present	Spring/Fall	Yes ☐ No ☐	
Mow	Bi-Annually	Yes ☐ No ☐	
Clean forebays	Annually	Yes ☐ No ☐	
Clean Ditches	Annually	Yes ☐ No ☐	
Remove woody vegetation	Annually	Yes ☐ No ☐	
Repair any scouring	Annually	Yes ☐ No ☐	
Fix displaced stones	Annually	Yes ☐ No ☐	
Replace rip rap	As Needed	Yes ☐ No ☐	
Remove trash and debris	Bi-Annually	Yes ☐ No ☐	
Remove sediment from basin	At least once every 5 years	Yes ☐ No ☐	

UNPAVED ROAD MAINTENANCE TRACKING FORM

Date of Maintenance: _____

Town: _____

Road Name / Location: _____

Type of Maintenance Performed (✓ Check all that apply)

- ○ Grading
- ○ Berm Removal
- ○ Compaction
- ○ Ditch Cleaning
- ○ Culvert Inspection
- ○ Culvert Replacement
- ○ Turnout Maintenance
- ○ Dust Control Application
- ○ Pothole Repair
- ○ Snow / Ice Management
- ○ Bank Stabilization
- ○ Vegetation Clearing

- ○ Other: _____

Equipment Used (✓ Check all that apply)

- ○ Grader
- ○ Scarifier
- ○ Vibratory Roller
- ○ Excavator w/ Articulating Bucket
- ○ Dust Control Sprayer
- ○ Hydroseeder
- ○ Pickup Truck
- ○ Chainsaw / Brush Cutter

- ○ Other: _____

Materials Used (✓ Check all that apply)

- ○ Surface Gravel
- ○ Crushed Stone
- ○ Calcium Chloride ($CaCl_2$)
- ○ Magnesium Chloride ($MgCl_2$)
- ○ Lignin Sulfonate
- ○ Hydroseed Mix / Grass Seed
- ○ Culvert Pipe
- ○ Geotextile Fabric

- ○ Other: _____

Weather Conditions (✓ Check all that apply)

- ○ Clear/Dry
- ○ Light Rain
- ○ Heavy Rain
- ○ Snow
- ○ Freezing
- ○ Thawing / Mud Season
- ○ Hot / Dusty
- ○ Windy
- ○ Other: _____

Crew Members Involved:

_____

_____

Notes / Observations:

_____

_____

_____

_____

Follow-Up Required?

- ○ Yes
- ○ If yes, describe: _____
- ○ No

Unpaved Road Maintenance Activity Log

Date: _____

Road Name/Segment: _____

Maintenance Activities Performed:

- □ Grading
- □ Dust Suppression
- □ Vegetation Management
- □ Culvert/Ditch Maintenance
- □ Erosion Control
- □ Winter Maintenance (Snow/Sand)
- □ Other (specify): _____

Materials Used:

- Material Type: _____ Quantity: _____
- Material Type: _____ Quantity: _____
- Material Type: _____ Quantity: _____

Equipment Used:

- Equipment Type: _____ Hours Operated: _____
- Equipment Type: _____ Hours Operated: _____
- Equipment Type: _____ Hours Operated: _____

Personnel Involved:

- Name: _____ Hours Worked: _____
- Name: _____ Hours Worked: _____
- Name: _____ Hours Worked: _____

Additional Observations/Recommendations:

Completed By (Signature): _____

Reviewed By (Supervisor Signature): _____

Detailed Maintenance Log Template

Inspection Log:

- Date of Inspection: _____
- Inspector Name: _____
- Road Segment: _____
- Condition Observations:
  - Surface (potholes, rutting, washboarding): _____
  - Drainage and Culverts: _____
  - Vegetation Management Needs: _____
  - Recommendations: _____

Grading Log:

- Date Graded: _____
- Operator Name: _____
- Equipment Used: _____
- Hours Operated: _____
- Issues Encountered: _____

Materials Used Log:

- Date: _____
- Material Type (Gravel, Calcium Chloride, etc.): _____
- Quantity Used: _____
- Application Rate: _____
- Supplier: _____

Repair Log:

- Date of Repair: _____
- Type of Repair (Culvert replacement, erosion control, etc.): _____
- Personnel Involved: _____
- Materials and Quantity: _____
- Equipment Used and Hours: _____
- Repair Outcome/Follow-Up Required: _____

Supervisor Review and Signature: _____

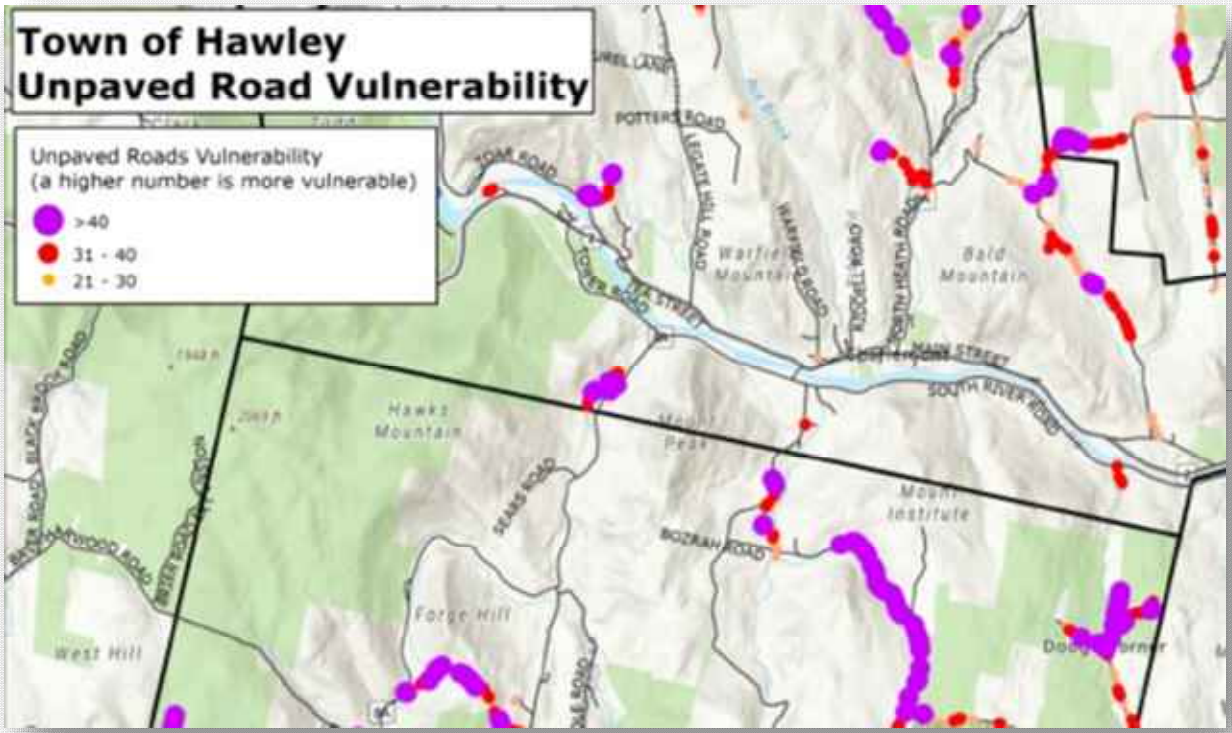
Additional Notes:

Appendix B: GIS Screening for Vulnerable Unpaved Roads

Addendum to Tool 2

If you would like to request a copy of GIS screening for unpaved roads in your Franklin County town, please contact gis@frcog.org.

If you would like to request a copy of GIS screening for unpaved roads in your Berkshire County town, please contact info@berkshireplanning.org or mmaloy@berkshireplanning.org.



GIS Screening for Vulnerable Unpaved Roads

for the Unpaved Roads Stormwater Management Toolkit

May 2025

Franklin Regional Council of Governments

Prepared by the Franklin Regional Council of Governments (FRCOG)

Introduction

This GIS screening method was developed as part of the Unpaved Roads Stormwater Management Toolkit. The goal of the GIS screening tool is to remotely identify unpaved roads that could be vulnerable to erosion during rain events and resulting in sediment loss to nearby waterbodies.

Factors used to identify vulnerability of roadway:

- Intermittent and perennial water bodies within close proximity
- Surrounding Slope
- Road Gradient
- Presence of stream crossing
- Floodzone proximity
- Wetlands proximity

Summary of Methodology:

A step-by-step GIS methodology is included in the next section of this document. The following is a general overview of the process. This can be performed in ArcGIS Pro with a spatial analysis extension.

Using a 50-foot buffer along all unpaved roads, identify all of the layers that intersect within the buffer.

Convert each of those intersections into a raster file and reclassify its values according to the level of vulnerability that they pose to an unpaved road.

Combine all of the rasters by adding them together using “Mosaic to New Raster” to obtain total vulnerability score for each cell within the 50-foot buffer of the unpaved roads. Those cells with the highest values are those with the highest vulnerability. Convert rasters to polygons and color code by total risk score.

<u>GIS screening steps:</u>

1) Identify all Dirt/Gravel Roads and create layer. Source: MassDOT Road Inventory File from MassGIS
2) Create a buffer of gravel roads by 50 feet from road centerline (creates a 100-foot wide polygon). All of the data collected will be within this polygon layer.

3) Capture surrounding slope layer using a Digital Elevation Model created from LiDAR data around gravel roads

4) Collect the road gradient of the gravel roads using the slope layer.

5) Create a stream layer with LiDAR and DEP Hydrologic Connections, to analyze the gravel roads' proximity to streams/drainage.

6) Create a stream crossing layer by intersection with gravel roads and the streams created in the previous steps.

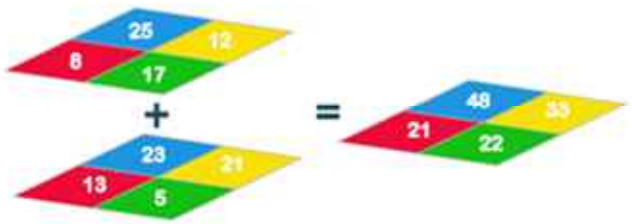
7) Create a wetlands/waterbody datalayer depicting the proximity of gravel roads to water.

8) Create a floodzone datalayer showing the gravel roads proximity to 100 year flood areas.

9) Each of the datalayers created in the previous steps should be converted to a raster with values assigned to different categories.

10) Combine the datalayers that have been created to a final raster dataset to be classified to show results.

11) The results from the combined Mosaic Raster will produce a composite raster with total scores for each cell (see demonstration image below). The highest scores indicate the highest potential vulnerability to erosion, sediment loss, and impact to water quality.



12) Convert Mosaic Raster into a polygon layer to aid in visually displaying data on a map.

Data Layers & Procedure

("town" is used as an example in the below procedure but can be replaced by a town name)

1. **Gravel Road Layer = town_rds_gravel:** create theme definition on MassDOT Road inventory file where Surface Type = 2 (*Note-this is not a perfect representation of the gravel roads in a town because the layer may not be completely up to date: some roads have been paved, are not accessible because they are not maintained, and may not be located precisely on*

the DEM because they were not created using LiDAR. In this project, some roads have been digitized to correct the location using LiDAR)

2. **Digital Elevation Model = town_DEM:** create a filled DEM raster dataset that has been clipped (use the Fill Tool on the original DEM, Spatial Analyst) get DEM from https://apps.nationalmap.gov/lidar-explorer/#/

3. **Slope = town_Slope:** create slope raster dataset from LiDAR digital elevation model using the slope tool (spatial analyst) for the town, use percent rise.

4. **Gravel Road Buffer Layer = town_buff_50:** buffer town_rds_gravel by 50 ft

5. **Surrounding slope layer = town_slope_50:** clip town_slope with town_buff_50, classify symbology into 3 categories: 0-20, 20-40 and >40

   Rationale: In our field observations, surrounding slope was a very important factor. If the slope between a road and stream is very steep, road material can travel a long way and impact streams. These categories are consistent with Penn State categories.

6. ***Raster Slope Layer = town_raster_slope_final:** reclassify(tool) town_slope_50 where 0-20 = 0, 20-40 = 5 and >40 = 15 (change no data to 0)[1]

7. **Road Gradient Layer = town_buff_4:** buffer town_rds_gravel by 5 ft

   Rationale: In our field observations, road gradient was a very important factor. A Lake Champlain Basin Program technical study also showed higher suspended sediment loading in nearby streams on steeper gradient roads.[2]

8. **Gradient Slope Layer = town_gradient_4:** clip town_slope with town_buff_4, classify symbology into 4 categories 0-3, 3-7, 7-11, >11

9. **Reclassified Gradient Layer = town_reclassify_gradient:** reclassify(tool) town_gradient_4 where 0-3 = 0, 3-7 =5, 7-11 = 15 and >11 = 20

10. ***Raster Gradient Layer = town_raster_gradient_final:** Expand(tool) town_reclassify_gradient , Number of cells = 3. Zone values = 0, 5,15,20 , morphological

[1] All steps with an asterisk in the front indicate that this is the final raster to be used in the final analysis. It is not an intermediate layer file.

[2] Lake Champlain Basin Program, Technical Report No. 74. Beverly Wemple. Assessing the Effects of Unpaved Roads on Lake Champlain Water Quality. Final Report, June 2013. Available online at https://www.lcbp.org/news-and-media/publications/technical-reports/

11. **Flow Direction Layer(D8) = town_FlowDir:** use town_DEM as input raster

12. **Flow Accumulation(D8) (archydro) = town_FlowAcc:** use town_FlowDir as input raster

13. **LiDAR Stream Raster Layer = town_Con5000raster:** use town_FlowAcc as input conditional raster, expression- "Where value is greater or equal to 5000, Input constant value = 1

14. **LiDAR Drainage Con Layer = town_Con5000:** convert town_Con5000raster to a polyline using Raster to Polyine (tool)

    Rationale: This layer captures what are likely perennial and intermittent streams based on the LiDAR elevation interpretation of drainage. These are not necessarily regulated waterbodies, but are more accurate in location since they are determined with new detailed technology.

15. **DEP Stream Layer (clipped to town) = town_hyd_conn:** DEP hydraulic connections from MassGIS (theme definition on DEP wetlands Arc_Code_D = Hydrologic connection) clipped to town)

    Rationale: This layer represents regulatory streams. The location of these lines are not as accurate as the LiDAR drainage layers, but it is a layer with regulatory protections and gets an additional score.

16. **Streams Merge Layer = town_streams:** merge town_Con5000 with town_hyd_conn

17. **Stream Buffer Layer = town_streams_50:** buffer/dissolve town_streams by 50 ft

18. **Streams within Gravel Road Buffer Layer: town_streams_gravel:** clip town_streams_50 with town_buff_50

19. **Streams in Gravel Road Buffer Raster = town_raster_streams_gravel:** Convert town_streams_gravel to raster using feature to raster use objectID for field

20. ***Raster Streams within Gravel Road Layer = town_raster_streams_final:** Reclassify town_raster_streams_gravel where 1 is now 10 and NODATA is 0

21. **Stream Crossing Layer = town_crossings:** intersect (tool) town_rds_gravel with town_streams (output = point)

    Rationale: Stream crossing areas are frequently a small area that should be looked at in the field, so we wanted this category to have a fairly high score.

22. **Stream Crossing Buffer Layer = town_crossings_50:** buffer/dissolve town_crossings by 50 ft

23. **Stream Crossing Buffer Raster = town_crossings_raster:** Convert town_crossings_50 to raster using feature to raster use objectID for field, cell size 1

24. ***Raster Stream Crossings Layer = town_crossings_final**: reclassify town_crossings_raster where 1=5, and NoData = 0

25. **Wetlands/Waterbody within Gravel Road Buffer Layer = town_water_gravel:** clip MA DEP Wetlands/Open Water with town_gravel_50

    Rationale: This layer represents regulatory wetlands and lakes. This is a layer with regulatory protections and gets an additional score.

26. **Wetlands/Waterbody within Gravel Road Dissolved Raster = town_water_gravel_dissolve:** dissolve(tool) town_water_gravel

27. **Wetlands/Waterbody within Gravel Road Raster = town_water_gravel_raster:** Convert town_water_gravel_dissolve to raster using feature to raster use objectID for field, cell size 1

28. ***Raster Wetlands/Waterbody Layer = town_water_final:** reclassify town_water_gravel_raster where 1 is now 5 and NoData is 0

29. **Floodzone within Gravel Road Buffer Layer = town_flood_gravel:** clip 100 year floodzone datalayer(FEMA) with town_buff_50

30. **Floodzone within Gravel Road Buffer Dissolved Layer = town_flood_gravel_dissolve:** dissolve(tool) town_flood_gravel

31. **Floodzone within Gravel Road Buffer Dissolved Raster = town_flood_gravel_raster:** Convert town_flood_gravel_dissolve to raster using feature to raster use objectID for field, cell size 1

32. ***Raster Floodzone within Gravel Road Layer = town_flood_gravel_final:** reclassify town_flood_gravel_raster where 1 is now 5 and NoData is 0

33. **Final Raster = town_raster_final:** Mosaic to New Raster(tool), input rasters- town_raster_slope_final, town_raster_gradient_final, town_raster_streams_final, town_crossings_final, town_water_final, town_flood_gravel_final *(note- all rasters that have * symbol are "final" and should be used in this step)* , 8 bit unsigned, cellsize = 1, bands = 1 **mosaic operator = sum(important)**, colormap mode = first

34. **Final Raster Classified for Display Purposes:** Classify town_raster_final into 6 categories 0, 1-10, 10-20, 20-30, 30-40, >40
35. **Final Polygon Layer for Display and Symbology Purposes = town_poly_final:** convert town_raster_final to a feature layer using raster to polygon to create town_Final_Poly and symbolize using graduated symbols (6) using gridcode to make the largest numbers, greater than 40 show as large circles and purple.

Appendix C: Field Assessment Form for Impacts to Waterbodies

Addendum to Tool 3

Field Assessment Form

DIRECTIONS

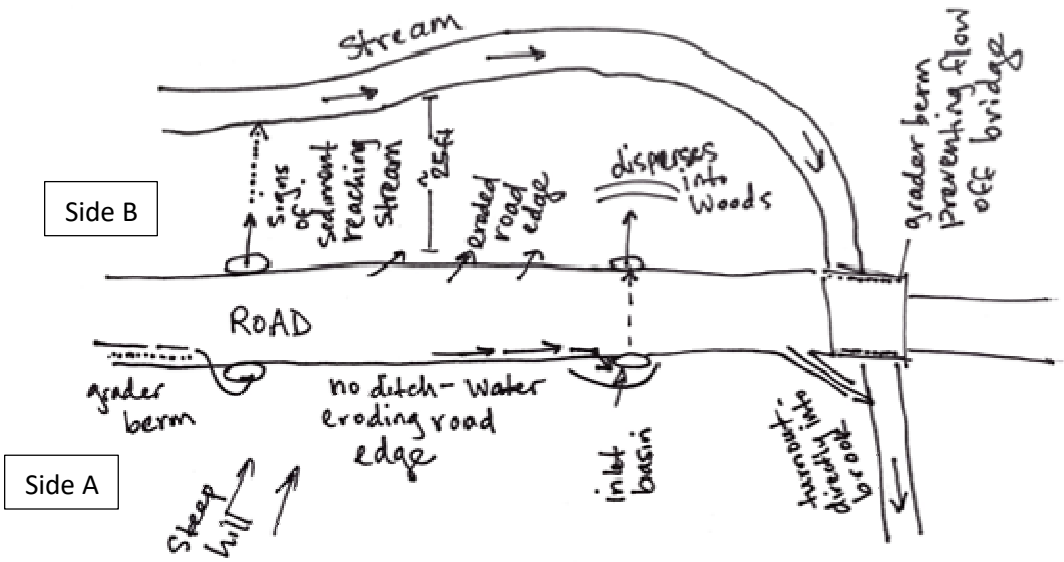
Purpose of the unpaved roads field assessment form: Road material can move off the road during storms and winter plowing. Losing dirt and gravel can be an expense for the Town in the form of material and labor. When road material makes its way to streams and waterbodies, it also impacts habitat and water quality. Grants may be available to help maintain roads and good water quality, and this form can help Towns prioritize projects for road and/or water quality grant applications.

How to use this form? The first step is to use the GIS Screening Tool to identify unpaved road segments in your town that have the potential to impact water quality through stormwater and sediment runoff to the stream. FRCOG has already done the GIS Screening for all Franklin County towns. The next step is for Town staff to visit the top-scoring sites in your town and walk the road to take a look at what is going on. This assessment cannot be done solely from a vehicle – it is essential to walk along the road to see all of the issues. These directions and the term sheet should be reviewed prior to filling out the field assessment form.

When should we do the assessment? The best time to go out is just after snowmelt in the spring or other times when conditions are wet, such as during or after a rainstorm. Observing conditions in spring *before* leaf out makes it easier to see road material that has left the road.

How much of an area should you look at and assess? Start at a low point where the road crosses or comes nearest a stream, wetland, or other waterbody. Assess the section of road where water will drain to that low point. This will be your "site." Fill out a separate field assessment sheet for each site. For roads that run alongside a stream/waterbody, use your best judgement to identify the site. There may be several sites for a road that runs alongside a stream/waterbody due to the terrain or other factors. Evaluate the entire area that scored high in the GIS screening.

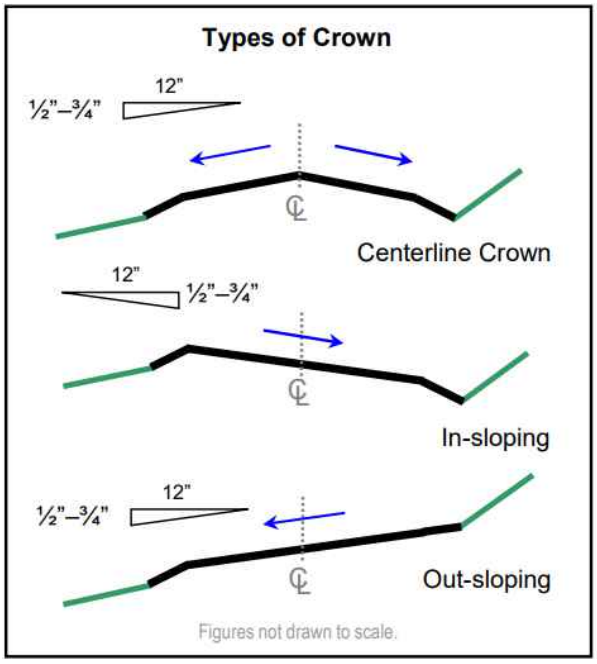
What should my site drawing include? Include the road and the waterbody and sides of the road labeled A and B (side A should be the uphill side if applicable). Show with arrows which way the runoff flows. For smaller sites, it's great to include location of ditches, culverts, turnouts and where problems are occurring.



Example Site Drawing

Field Assessment Term Sheet

Crown: Properly crowned roads shed water efficiently off both sides of the road. Proper crowning is 1/2 inch per foot of road width, with an A-shaped top, not a domed top.



Shoulder: The part of the road surface that is outside the travel lane but not part of the ditch (red arrows).

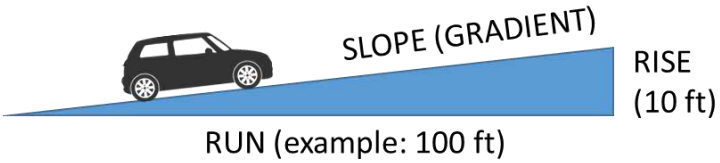
Downslope bank: Bank that is downhill of the road surface (yellow arrow).

Upslope bank: Bank that is uphill of the road surface. (blue arrow).

PERCENT SLOPE

SLOPE % = RISE/RUN x 100

Example: 10/100 x 100 = 10% slope



Gentle grade: <5% slope

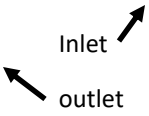
Moderate grade: 5-10% slope

Steep grade: >10% slope

Rill: Moderate erosion between 1 and 12 inches deep.

Gully: Severe erosion more than 12 inches deep.

Culvert: A closed conduit used to convey water from one area to another, usually from one side of a road to the other side.



Entrenched Road: Road surface is lower than surrounding land. There is nowhere for water to drain.

Inlet basin: A dug out basin around the inlet of a culvert (in the picture to the left, the culvert is marked by the yellow post).

Ditch: An open channel that conveys water from storm runoff to an adequate outlet without causing erosion or sedimentation.

Turnout: Extension of a ditch that directs water off the road to filtering areas. They should not drain directly into a stream.

False ditch: Ditch forming on its own from runoff, leading to road material loss. If a grader berm is preventing water from getting into a ditch, this can be called a secondary ditch.

Grader berm: A row of road material on the side of a road, created by a road grader or snow plow.

FIELD ASSESSMENT FORM

[Please see Directions and Term Sheet that accompanies this form]

Road Name: _____ Town: _____

Name of Evaluator(s): _____ Date: _____

Weather conditions: _____ Name of nearest waterbody: _____

A. SITE BASICS

Approximate length of site: _____feet OR _____miles

Describe where site begins and ends. Use telephone pole numbers if available.

Begin: _____

_____

End: _____

_____

Include GPS coordinates (latitude & longitude) here if possible:

Beginning:

End:

B. WATER FLOW and DRAINAGE

Make a rough sketch of your entire site from bird's-eye view. Draw a north arrow to show direction. Include the road and the waterbody and ***sides of the road labeled A and B*** *(side A should be the uphill side if applicable). Show with arrows which way the runoff flows. For smaller sites, it's great to include location of ditches, culverts, turnouts and where problems are occuring.*

Is runoff finding its way off the road at an unplanned location?

FIELD ASSESSMENT FORM

On side A ? (circle one) Y / N On side B ? (circle one) Y / N

How many road drainage culverts are in this site and what is the average spacing between them? (Example: 4 culverts in this site, every 400 feet). _____

_____

_____

C. GENERAL

Does the road have any of the following characteristics? *Check all that apply*

You may want to return to this question at the end of the assessment to make sure you selected all characteristics.

- ☐ Steep grade
- ☐ Steep bank slope
- ☐ Stream crossing
- ☐ Adjacent to stream
- ☐ Adjacent to wetland
- ☐ Steep private driveway
- ☐ Entrenched road

Walk the drainage route of road runoff until deposited road material is no longer visible. Be sure to look at or under leaves and on the upslope of downed logs in the drainage route.

Does the waterbody show signs of the following **problems**? Check all that apply:

- ☐ Road material in the waterbody
- ☐ Road material near the waterbody

Where is the road material coming from? Check all that apply. Revisit this question at the end of your site visit to make sure it is complete.

- ☐ Shoulder
- ☐ Ditch
- ☐ Culvert
- ☐ Turnout
- ☐ Bank

- ☐ Bridge or culvert water crossing
- ☐ Private driveway intersection
- ☐ Plow pile

D. DRIVING SURFACE of ROAD

What is the approximate road grade?

- ☐ Flat (0 – 2%)
- ☐ Slightly steep (2 – 5%)
- ☐ Moderately steep (5 – 10%)
- ☐ Extremely steep (Greater than 10%)

Measure the road crown in 3 different locations along the site (see Field Assessment Term Sheet for information about crown). Note measurements here:

1)_____(inches/ft) 2)_____(inches/ft) 3)_____(inches/ft)

Are there any surface of the road **problems**? Check all that apply:

- ☐ Erosion on the road surface in the form of rilling (<1 ft-deep grooves from flowing runoff)
- ☐ Erosion of the road surface in the form of gullying (1 ft+ deep groove from flowing runoff)

What are the likely **causes** of erosion on the road surface? Check all that apply:

- ☐ Poor original road construction
- ☐ Road is not properly crowned (proper crowning is ½ inch per foot)
- ☐ Grader berms or mounded shoulders restricting drainage

Document additional road surface issues:

- ☐ Washboarding
- ☐ Rutting (linear wheel depressions)
- ☐ Potholes
- ☐ Excessive dust

Additional observations:

_____

_____

_____

FIELD ASSESSMENT FORM

E. SHOULDER

Are there any road shoulder **problems**? Check all that apply:

- ☐ Erosion on the road shoulder
- ☐ Runoff carrying sediment directly from road shoulder into waterbody

What are the likely **causes** of erosion on the road shoulder? Check all that apply:

- ☐ Concentrated runoff breaking through grader berm
- ☐ Shoulder soil is unstable

What are the likely **causes** of runoff carrying sediment directly from the road shoulder into the waterbody? Check all that apply:

- ☐ Plow pile with road material left near waterbody
- ☐ Road material from cleaning ditches and culverts left near waterbody
- ☐ Lack of formal ditch
- ☐ Lack of runoff outlets/turnouts
- ☐ Uncontrolled bank runoff

Additional observations:

- ☐ Grader berms are <u>helping</u> keep runoff away from a waterbody

_____

_____

_____

F. DITCHS and TURNOUTS

Are there any ditches and turnouts **problems**? Check all that apply:

- ☐ Erosion in the formal ditch or turnouts
- ☐ No formal ditch
- ☐ Runoff carrying sediment directly from ditch/turnout into waterbody

If the formal ditch or any turnouts are eroding, what are the likely **causes** of these problems? Check all that apply:

- ☐ Steep ditch grade
- ☐ Ditch undersized
- ☐ Insufficient outlets

What are the likely **causes** of no formal ditch?

- ☐ No formal ditch constructed
- ☐ Road entrenched/no space for ditch

What are the likely **causes** of runoff carrying sediment directly from ditch/turnout into waterbody?

- ☐ Ditch directly connected to waterbody
- ☐ Turnout directly connected to waterbody

Additional observations:

_____

_____

_____

G. STORMWATER DRAINAGE CULVERTS

Are there any stormwater drainage culvert **problems**? Check all that apply:

- ☐ Erosion around stormwater drainage culvert (at inlet or at outlet)
- ☐ Runoff carrying sediment from drainage culvert into waterbody (directly or indirectly)

What are the likely **causes** of erosion around the stormwater drainage culvert? Check all that apply:

- ☐ Culvert undersized
- ☐ Culvert damaged
- ☐ Culvert incorrectly installed or positioned
- ☐ High velocity at inlet area
- ☐ Runoff freefalls from culvert outlet

What are the likely **causes** of runoff carrying sediment from drainage culvert into waterbody (directly or indirectly)? Check all that apply:

- ☐ Culvert directly connected to waterbody
- ☐ Culvert outlet area has no sediment traps

☐ Uncontrolled bank runoff

Additional observations:

_____

_____

H. STREAM CROSSINGS (bridge or culvert where a waterbody passes under the road)

Are there any stream crossing **problems**? Check all that apply:

☐ Erosion around stream-crossing culvert/bridge

☐ Sediment on stream-crossing culvert or bridge falling directly into waterbody

What are the likely **causes** of the erosion around the stream-crossing culvert/bridge? Check all that apply:

☐ Stream-crossing culvert/bridge undersized

☐ Stream-crossing culvert/bridge damaged

☐ Stream-crossing culvert/bridge incorrectly installed or positioned

☐ Runoff directed or concentrating around sides of culvert/bridge

What are the likely **causes** of the sediment on stream-crossing culvert or bridge falling directly into waterbody? Check all that apply:

☐ No edges on bridge or road shoulder

Additional observations:

_____

_____

_____

I. BANKS

Are there any bank **problems**? Check all that apply:

☐ Erosion of upslope bank

☐ Erosion of downslope bank

What are the likely **causes** of the erosion on the upslope bank? Check all that apply:

- ☐ Steep bank with natural erosion
- ☐ Exposed soil from excavation work
- ☐ Groundwater seep present

What are the likely **causes** of the erosion on the downslope bank? Check all that apply:

- ☐ Steep bank
- ☐ Exposed soil

Additional observations:

_____

_____

_____

J. PRIVATE DRIVEWAY INTERSECTIONS

Are there any private driveway intersection **problems**? Check all that apply:

- ☐ Erosion of private driveway intersection

What are the likely **causes** of erosion at the private driveway intersection? Check all that apply:

- ☐ Poor original road construction
- ☐ Poor original driveway construction
- ☐ Road is not properly crowned (proper crowning is ½ inch per foot; crown does not flatten to meet road)
- ☐ Grader berms or high shoulders
- ☐ Uncontrolled runoff in shoulder/ditch area
- ☐ Missing or damaged driveway culvert

Additional observations:

_____

_____

_____

FIELD ASSESSMENT FORM

Summary Assessment

On a scale of 1 to 10, based on your knowledge of all roads in town, rank the severity of road maintenance problems in this segment (1 is low road maintenance problems, 10 is high): _____

On a scale of 1 to 10, based on your knowledge of all roads in town, rank the severity of road material traveling to a waterbody in this segment (1 is low amount of road material reaching waterbody, and 10 is high): _____

Summary of road segment problems or additional comments:

Initial ideas for how to fix problem:

Appendix D: Pollutant Load Reduction Estimates for Select BMPs

Addendum to Tool 5

Known for excellence.
Built on trust.

GEOTECHNICAL
ENVIRONMENTAL
ECOLOGICAL
WATER
CONSTRUCTION MANAGEMENT

1350 Main Street
Suite 1400
Springfield, MA 01103
T: 413.726.2100
F: 413.732.1249
www.gza.com

September 12, 2024
GZA Project No. 15.0167304.00

Kimberly Noake MacPhee, P.G., CFM
Franklin Regional Council of Governments
12 Olive Street
Greenfield, MA 01301
KMacPhee@frcog.org

Re: Pollutant Load Reduction Estimates for BMPs
Unpaved Roads Toolkit Project
Franklin County, Massachusetts

Dear Kimberly:

GZA GeoEnvironmental, Inc. (GZA) prepared estimated pollutant load reductions for ten proposed best management practices (BMPs) intended for maintenance of unpaved (dirt or gravel) roads to minimize erosion and sedimentation. This Report is provided to address Task III of GZA's Agreement for Services with the Franklin Regional Council of Governments (FRCOG), dated 4/15/2024, for the Engineering for Unpaved Roads Project. GZA applied the "Simple Method," presented in the New York State (NYS) Stormwater Management Design Manual (Design Manual) to calculate pollutant load reduction from various sources within the drainage areas contributing runoff to each proposed BMP, and to estimate the reductions in pollutant loads provided by each BMP. This letter report documents the methodology, input data, assumptions, and results of the analysis.

This report is subject to the Limitations included as **Attachment 1**.

METHODOLOGY

The Simple Method from the NYS Design Manual is a spreadsheet-based model used to estimate loads from stormwater runoff, and area loading factors to calculate loads from non-urban land uses. Storm-water runoff pollutant loads are estimated on an annual basis (lbs/yr) based on land use/land cover data, watershed drainage area, assumed runoff pollutant concentrations, and precipitation. Input data are described in more detail below.

Analyses were performed for the following control measures:

- Stormwater BMP #1: Grade Break.
- Stormwater BMP #2: French Mattress.
- Stormwater BMP #3: Rock Check Dam.
- Stormwater BMP #4: Underdrain.
- Stormwater BMP #5: Turnouts with Level Spreader.

- Stormwater BMP #6: Outlet Protection.
- Stormwater BMP #7: Bank Bench/Interceptor Swale.
- Stormwater BMP #8: Broad-Based Dip.
- Stormwater BMP #9: Sediment Settling Pool in Ditch.
- Stormwater BMP #10: Armored Shoulder.

INPUT DATA AND ASSUMPTIONS

The analysis requires the following watershed input data:

- Watershed drainage area
- Watershed land use distribution
- Annual precipitation

GZA delineated the drainage areas for specific locations of observed stormwater erosion problems identified by FRCOG, utilizing USGS Streamstats and ArcGIS Pro (**Table 1**). As this analysis provides pollutant reduction estimates on a per acre basis, the actual drainage area used in the calculations is not directly relevant to the pollutant load reduction estimates. However, review of the drainage areas served to identify representative land use characteristics which are used in the calculations.

Table 1: Reference drainage areas

Simple Method		
Location	"Watershed" (Acres)	X-Y Coordinates
Steep grade roads adjacent to streams – all have steep banks as well		
Fairbanks Rd., Colrain	86	42.711885, -72.715566
Wilson Hill Rd., Colrain	29	42.704215, -72.738628
Jackson Hill Rd., Leverett	390	42.498889, -72.517792
Smith Branch Rd., Ashfield	173	42.551758, -72.807947
Steep grade roads crossing streams		
Bullitt Rd., Ashfield	79	42.502384, -72.755754
Sediment settling pool		
North Laurel Dr., Shutesbury	53	42.499326, -72.423558
Adjacent to stream roads, easy grade		
Moosehorn Rd., New Salem	64	42.517767, -72.328921
Green River Rd., Colrain	339	42.656294, -72.626241

The model provides default values for stormwater runoff pollutant concentrations, runoff coefficients, and impervious cover for the watershed based on land use. The impervious cover value (expressed as a percentage of the total area), which is used to calculate runoff coefficient for this model, was estimated based review of Landsat imagery. From this review, we estimated the impervious cover of the FRCOG identified "typical" areas to be to be around 7% considering the various types of land uses observed in the imagery, their approximate contributing area in each watershed and the value applicable to rural/agricultural areas from Smullen and Cave, 1998. It should be noted that the impervious cover estimate can be adjusted for other specific locations, as may be appropriate.

Total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) concentrations were estimated using the national median concentrations for chemical constituents in stormwater (Smullen and Cave, 1998). To verify the reasonableness of these concentrations for applicability in Franklin County watersheds, GZA reviewed the pollutant loading estimates for TSS and TP from the Lake Champlain Basin Program (LCBP) Technical Report No. 74, "Assessing the Effects of Unpaved Roads on Lake Champlain Water Quality", prepared by Beverley C. Wemple, Ph.D., University of Vermont, June 2013 (the report did not include estimates for TN). The LCBP estimates were developed for the Mad River Valley, a hilly area with possibly flashy streams and steep unpaved roads located in the northeast, similar in characteristics to Franklin County. The estimated total runoff pollutant loads based on the Simple Method and the LCBP estimates for a typical 20-acre watershed in Franklin County are presented in **Table 2**.

Table 2. Total Runoff Pollutant Load (lbs) within a Typical 20-acre Watershed in Franklin County

	TSS (lbs)	TP (lbs)	TN (lbs)
Simple Method	1077	5	40
LCBP Loading	1090	2.6	N/A

The LCBP loading estimates are within the same order of magnitude as the Simple Method estimates, which demonstrates that the Simple Method estimates are reasonable for use in Franklin County watersheds.

A value of 50.5 inches[1] was used for the annual average precipitation.

Stormwater pollutant reduction efficiencies for each BMP were determined by reviewing available literature, primarily the Massachusetts Stormwater Handbook, National Pollutant Removal Performance Database for Stormwater Treatment Practices, and Smullen and Cave, 1998. For BMPs that did not have published pollution reduction estimates in the literature reviewed by GZA, reduction estimates for similar types of BMPs ("proxy BMPs") were used. **Table 3** presents assumed pollutant reduction efficiencies for each BMP with data source and proxy BMP.

Table 3: BMP Pollutant Reduction Efficiencies

	TSS		TP		TN			
	Low	High	Low	High	Low	High	Source	Proxy BMP
Grade Break	0.70	0.80	0.20	0.90	0.10	0.90	Winer, 2000[2]	Dry swale
French mattress	0.80	0.90	0.65	0.90	0.40	0.85	Winer, 2000; Smullen and Cave, 1998[3]	Porous pavement, "filtering practices", submerged gravel wetland
Rock check dam	0.70	0.80	0.20	0.90	0.10	0.90	Winer, 2000; MA SW Handbook[4]	Dry swale
Underdrain	0.60	0.80	0.20	0.65	0.20	0.80	Winer, 2000; Smullen and Cave, 1998	"infiltration practices"
Turnouts with level spreader	0.20	0.90	0.10	0.50	0.05	0.50	PA SW BMP Manual[5]; Winer, 2000	Level spreader
Outlet protection	*	0.10	*	0.00	*	0.00	MA SW Handbook	Vegetated filter strips
Bank bench/ interceptor swale	0.70	0.80	0.20	0.90	0.10	0.90	Winer, 2000; MA SW Handbook	Dry swale
Broad-based dip	0.70	0.80	0.20	0.90	0.10	0.90	Winer, 2000; MA SW Handbook	Dry swale
Sediment settling pool in ditch	0.70	0.80	0.20	0.40	0.10	0.40	Winer, 2000; MA SW Handbook	Wet swale
Armored shoulder	0.70	0.90	0.50	0.70	0.50	0.70	EPA, 1980[6]	Crushed stone and gravel mulches

* Only one data source referenced

[1] NOAA Climate Data (Massachusetts), U.S. Climate Normals, accessed June 2024.
[2] Winer, R. March 2000. "National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition". Center for Watershed Protection.
[3] Smullen, J., and K. Cave.1998. "Updating the U.S. Nationwide Urban Runoff Quality Database." 3rd International Conference on Diffuse Pollution: August 31 - September 4, 1998. Scottish Environment Protection Agency. Edinburg, Scotland.
[4] Massachusetts Department of Environmental Protection. February 2008. Massachusetts Stormwater Handbook, Volume 2, Chapter 2.
[5] Pennsylvania Department of Environmental Protection. December 30, 2006. Pennsylvania Stormwater Best Practices Manual, Chapter 6
[6] U.S Environmental Protection Agency Region VIII. February 1980. "Upper Eagle Valley Nonpoint Source Assessment and Control Plan". EPA-908/3-80-001B Volume 2: Nonpoint Source Control Techniques.

To determine pollutant loads for the model, the following formula was used:

$$L = 0.226 * R * C * A$$

Where:
- L = Annual load (lbs)
- R = Annual runoff (inches)
- C = Pollutant concentration (mg/l)
- A = Area (acres)
- 0.226 = Unit conversion factor

To determine runoff volume, the following formula was used:

$$R = P * P_j * Rv$$

Where:
- R = Annual runoff (inches)
- P = Annual rainfall (inches)
- P_j = Fraction of annual rainfall events that produce runoff (usually 0.9)
- Rv = Runoff coefficient

To determine Runoff coefficient, the following formula was used:

$$Rv=0.05+0.9Ia$$

Where: Ia = Impervious fraction

ESTIMATED POLLUTANT REDUCTIONS

The estimated pollutant reductions in lbs/acre/year are provided below in **Table 4** for each BMP. Low and High pollutant reductions are provided for each BMP. These estimates are based on Low and High percent pollutant reduction efficiency values estimated for each BMP based on ranges observed in GZA's literature review. Output from the spreadsheet tool developed by GZA is provided as **Attachment 2** to this document.

Table 4. Pollutant Load Removed

BMP Annual Stormwater Pollutant Reduction

	TSS (lbs/acre/year)		TP (lbs/acre/year)		TN (lbs/acre/year)	
	Low	High	Low	High	Low	High
Grade Break	44.3	50.6	0.1	0.3	0.2	2.1
French mattress	50.6	56.9	0.2	0.3	0.9	2.0
Rock check dam	44.3	50.6	0.1	0.3	0.2	2.1
Underdrain	38.0	50.6	0.1	0.2	0.5	1.9
Turnouts with level spreader	12.7	56.9	0.0	0.2	0.1	1.2
Outlet protection	*	6.3	*	0.0	*	0.0
Bank bench/interceptor swale	44.3	50.6	0.1	0.3	0.2	2.1
Broad-based dip	44.3	50.6	0.1	0.3	0.2	2.1
Sediment settling pool in ditch	44.3	50.6	0.1	0.1	0.2	0.9
Armored shoulder	44.3	56.9	0.2	0.2	1.2	1.6

* Only one data source referenced

ADDITIONAL CONSIDERATIONS

The model does not estimate pollutant load reductions for BMPs in series. To determine pollutant load reductions of BMP series, the following formula can be used:

$$R = L\,[(E_1)+(1-E_1)E_2+(1-((E_1)+(1-E_1)E_2)E_3+\ldots]$$

Where:

R = Pollutant Removal (lbs)

L = Annual Load from Simple Method (lbs.)

E_i = Efficiency of the ith practice in a series

The pollutant reduction estimates presented in this report were developed using multiple simplifying assumptions and are presented as per acre of drainage area, for each BMP, assuming the installed BMP has been sized appropriately for the treatment drainage area. As such, this model should be used for a general estimation of potential pollutant load reductions that could be achieved by the BMPs evaluated. The results of this analysis should not be used to estimate actual site-specific pollutant load reductions for a specific BMP installation. For the estimation of site-specific pollutant load reductions, more advanced modeling should be utilized to account for additional variables which may be present and affect BMP effectiveness.

Please contact Rosalie Starvish at 860-550-2777 or rosalie.starvish@gza.com if you have any questions or comments concerning the information presented herein.

Very truly yours,
GZA GEOENVIRONMENTAL, INC.

Rosalie T. Starvish, P.E., CFM, CPMSM
Senior Project Manager

Nathaniel L. Russell, P.E.
Principal-In-Charge

Stephen Lecco, AICP, CEP, PWS
Consultant / Reviewer

CC: Tamsin Flanders, FRCOG
Andrea Donlon, FRCOG

Attachments:
1. Limitations
2. Input Data and Results

USE OF REPORT

1. GeoEnvironmental, Inc. (GZA) prepared this report on behalf of, and for the exclusive use of the Client for the stated purpose(s) and location(s) identified in the Report. Use of this Report, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions and we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not identified in the agreement, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

STANDARD OF CARE

2. Our findings and conclusions are based on the work conducted as part of the Scope of Services set forth in the Report and/or proposal, and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. Conditions other than described in this report may be found at the subject location(s).

3. The interpretations and conclusions presented in the Report were based solely upon the services described therein, and not on scientific tasks or procedures beyond the scope of described services. The work described in this report was carried out in accordance with the agreed upon Terms and Conditions.

4. GZA's pollutant load reduction estimates were developed in accordance with generally accepted practices of qualified professionals performing the same type of services at the same time, under similar conditions, at the same or a similar property. No warranty, expressed or implied, is made. The findings are dependent on numerous assumptions and uncertainties inherent in the process. Consequently, the findings are not an absolute characterization of pollutant load reductions.

RELIANCE ON INFORMATION FROM OTHERS

5. In conducting our work, GZA has relied upon certain information made available by public agencies, Client and/or others. GZA did not attempt to independently verify the accuracy or completeness of that information. Any inconsistencies in this information which we have noted are discussed in the Report.

COMPLIANCE WITH CODES AND REGULATIONS

6. We used reasonable care in identifying and interpreting applicable codes and regulations necessary to execute our scope of work. These codes and regulations are subject to various, and possibly contradictory, interpretations. Interpretations with codes and regulations by other parties are beyond our control.

This spreadsheet is used to calculate individual BMP's effectiveness in reducing annual stormwater pollutants (TSS, TN,TP).

Cells colored in blue can be altered

To utilize this spreadsheet, you will need the watershed area, impervious surface cover, and regional annual precipitation.

Simple Method

"watershed" (Acres)

Steep grade roads adjacent to streams – all have steep banks as well

Average acres 20.00 Acre

*acreage calculated using streamstats

(L = 0.226 * R * C * A)

L = Annual load (lbs)

R = Annual Runoff(inches)

A = Area (acres)

0.226 = Unit Conversion Factor

50.5 = Average yearly Rainfall (inches)

0.07 impervious cover estimate (%)

0.113 Runoff coefficient, or C

R= 5.13585

LBS to ton 0.0005

The Simple Method to Calculate Stormwater Loads

TSS (mg/L)*= 54.50

TP (mg/L) = 0.26

TN (mg/L) = 2.00

National Median Concentrations for Chemical Constituents in Stormwater*

*Pooled NURP/USGS (Smullen and Cave, 1998)

Table A.3 Land Use and Impervious Cover Estimates

Land Use Category	Mean Impervious Cover
Agriculture	2
Open Urban Land*	9
2 Acre Lot Residential	11
1 Acre Lot Residential	14
1/2 Acre Lot Residential	21
1/4Acre Lot Residential	28
1/8 Acre Lot Residential	33
Townhome Residential	41
Multifamily Residential	44
Institutional**	31-38%
Light Industrial	50-56%
Commercial	70-74%

* Open urban land includes developed park land, recreation areas, golf courses, and cemeteries.

** Institutional is defined as places of worship, schools, hospitals, government offices, and police and fire stations

Table A.1 National Median Concentrations for Chemical Constituents in Stormwater

Constituent	Units	Urban Runoff
TSS	mg/l	54.5[1]
TP	mg/l	0.26[1]
TN	mg/l	2.00[1]
Cu	ug/l	11.1[1]
Pb	ug/l	50.7[1]
Zn	ug/l	129[1]
F Coli	1,000 col/ ml	1.5[2]

Source:

1: Pooled NURP/USGS (Smullen and Cave, 1998)

2: Schueler (1999)

BMP Annual Total Pollutant Reduction (lbs)

	tss (lbs)		TP (lbs)		TN (lbs)	
	Low	High	Low	High	Low	High
Grade Break	886	1012	1.2	5.4	4.6	41.8
French mattress	1012	1139	3.9	5.4	18.6	39.5
Rock check dam	886	1012	1.2	5.4	4.6	41.8
Underdrain	759	1012	1.2	3.9	9.3	37.1
Turnouts with level spreader	253	1139	0.6	3.0	2.3	23.2
Outlet protection	*	127	*	0.0	*	0.0
Bank bench/interceptor swale	886	1012	1.2	5.4	4.6	41.8
Broad-based dip	886	1012	1.2	5.4	4.6	41.8
Sediment settling pool in ditch	886	1012	1.2	2.4	4.6	18.6
Armored shoulder	886	1139	3.0	4.2	23.2	32.5

* Only one datasource referenced

BMP Annual Stormwater Pollutant Reduction (lbs per acre)

	TSS (lbs/acre/year)		TP (lbs/acre/year)		TN (lbs/acre/year)	
	Low	High	Low	High	Low	High
Grade Break	44.3	50.6	0.1	0.3	0.2	2.1
French mattress	50.6	56.9	0.2	0.3	0.9	2.0
Rock check dam	44.3	50.6	0.1	0.3	0.2	2.1
Underdrain	38.0	50.6	0.1	0.2	0.5	1.9
Turnouts with level spreader	12.7	56.9	0.0	0.2	0.1	1.2
Outlet protection	*	6.3	*	0.0	*	0.0
Bank bench/interceptor swale	44.3	50.6	0.1	0.3	0.2	2.1
Broad-based dip	44.3	50.6	0.1	0.3	0.2	2.1
Sediment settling pool in ditch	44.3	50.6	0.1	0.1	0.2	0.9
Armored shoulder	44.3	56.9	0.2	0.2	1.2	1.6

* Only one data source referenced

	Total runoff pollutant (lbs) within basin		
	TSS (lbs)	TP (lbs)	TN (lbs)
Simple Method	1265	6	46
LCBP loading	1090	2.7	

Assessing the Effects of Unpaved Roads on Lake Champlain Water Quality

June 2013

Final Report

Prepared by:
Beverley C. Wemple, PhD
University of Vermont

For:
The Lake Champlain Basin Program and
New England Interstate Water Pollution Control Commission

- Estimated catchment scale pollutant production from the unpaved road network in the Mad River valley averaged 5093 kg/km/year of suspended sediment and 10 kg/km/year of phosphorus. Expressed on a unit (watershed) area basis, this equates to an average of 6120 kg/km^2/year of suspended sediment and 15 kg/km^2/year of total phosphorus, equal to approximately 17% of the annual average suspended sediment load and 28% of the annual average phosphorus load yielded from these upland catchments.

1 kg =	2.2	lb
1 km2 =	247.1	acre

Convert kg/km2 to lb/acre: 0.008903

BRPC Loac	(kg/km2)	(lb/acre)
TSS	6120	54.5
TP	15	0.13

	Reduction (%) Low-High								
	TSS		TP		TN		Source	Proxy	Notes
Grade Break	0.70	0.80	0.20	0.90	0.10	0.90	National Pollutant Removal Performance Database for Stormwater Treatment Practices	dry swale	
French mattress	0.80	0.90	0.65	0.90	0.40	0.85	National Pollutant Removal Performance Database for Stormwater Treatment Practices; Smullen and Cave, 1998	Porous Pavement; The Simple Method filtering practices (may also be considered similar to submerged gravel wetland)	This reference has 3 studies: TSS ranges from 82-97, TP from 65-94, TN from 80-85; Smullen and Cave assumes that no practice is greater than 90% efficient; The Simple method filtering practices has TSS 85, TP 60, TN 40
Rock check dam	0.70	0.80	0.20	0.90	0.10	0.90	National Pollutant Removal Performance Database for Stormwater Treatment Practices, MA Stormwater Handbook	Dry swales	
Underdrain	0.60	0.80	0.20	0.65	0.20	0.80	National Pollutant Removal Performance Database for Stormwater Treatment Practices, Smullen and Cave, 1998	"infiltration practices"	
Turnouts with level spreader	0.20	0.90	0.10	0.50	0.05	0.50	Pennsylvania Stormwater Best Management Practices Manual, National Pollutant Removal Performance Database for Stormwater Treatment Practices	level spreader	psbmp ch. 6
Outlet protection	*	0.10	*	0.00	*	0.00	MA SW Handbook	vegetated filter strips	
Bank bench/interceptor swale	0.70	0.80	0.20	0.90	0.10	0.90	National Pollutant Removal Performance Database for Stormwater Treatment Practices, MA Stormwater Handbook	Dry Swale	
Broad-based dip	0.70	0.80	0.20	0.90	0.10	0.90	National Pollutant Removal Performance Database for Stormwater Treatment Practices, MA Stormwater Handbook	Dry Swale	
Sediment settling pool in ditch	0.70	0.80	0.20	0.40	0.10	0.40	National Pollutant Removal Performance Database for Stormwater Treatment Practices; MA SW Handbook	Wet Swale	
Armored shoulder	0.70	0.90	0.50	0.70	0.50	0.70	U.S Environmental Protection Agency Region VIII. February 1980. “Upper Eagle Valley Nonpoint Source Assessment and Control Plan”. EPA-908/3-80-001B Volume 2: Nonpoint Source Control Techniques.	Crushed stone and gravel mulches	

Appendix E: Round Stormwater Drainage Culvert Right-Sizing Guide

Addendum to Tool 6

If you would like to request a right-sizing analysis for a specific culvert or set of culverts in your Franklin County town, please contact gis@frcog.org.

Methodology for Right-Sizing Round Stormwater Culverts

for the Unpaved Roads Stormwater Management Toolkit

September 2024

Franklin Regional Council of Governments

Prepared by the Franklin Regional Council of Governments (FRCOG)

This project has been financed with Federal Funds from the Environmental Protection Agency (EPA) to the Massachusetts Department of Environmental Protection (MassDEP) under a §319 competitive grant (Project 22-05/319). The contents do not necessarily reflect the views and policies of EPA or of the Department, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

Background

Through a §319 Nonpoint Source Pollution grant from the Massachusetts Department of Environmental Protection (MassDEP), the FRCOG has developed a toolbox to assess dirt roads and develop best management practices (BMPs) to minimize the impact of stormwater runoff on coldwater streams from unpaved roads in Franklin County towns. Stormwater infrastructure includes culverts, and this protocol is aimed at providing towns with a tool to determine the correct size culvert when installing a new or replacing an existing stormwater culvert. This is called "right-sizing," and our goal is to provide information based on runoff amounts projected under changing climate conditions.

The right-sizing formula should work for round culverts that are designed to carry stormwater flow only; stream crossing culverts are subject to additional regulation and the Massachusetts Stream Crossing Standards. Public Works or Highway staff should work with their local conservation commission if it is not immediately clear if a culvert is conveying a regulatory stream or stormwater.

FRCOG uses a formula originally derived by A.N. Talbots in 1887, and modified by the North Carolina Forest Service to be able to size the culvert by storm intensity. Talbot's Method solves for a square footage of drainage needed, assuming a 4-inch per hour storm event, and the North Carolina formula allows a choice of rainfall intensity and converts the square footage to a pipe diameter in inches. The formula is as follows:

$$culvert\ diameter\ (inches) = \sqrt{\frac{[\left(C\ x\ A^{\frac{3}{4}}\right)x\ \frac{R}{4}]}{0.005454}}$$

Where
C = Talbot's Coefficient
A = Area of watershed (acres)
R = Rainfall intensity (in/hr)
And
C (Talbot's Coefficient) = $C_1 + C_2 + C_3$
Where
C_1 = terrain conditions
C_2 = slope of drainage area
C_3 = shape of drainage area

This manual provides instructions on determining the variables C, A, and R for your site. This involves the following steps to determine proper culvert size:

1) Locate stormwater culverts for study area,

2) Create watersheds for culvert study area,
3) Acquire slope of watersheds,
4) Calculate length and width of watershed,
5) Determine rain intensity for your site, and
6) Input variables into provided formula.

The methodology described in the following steps has been derived from multiple sources and has been tested by the Franklin Regional Council of Governments (FRCOG) Planning Department. The method is considered valid for watersheds under 400 acres in size, but that far exceeds the size of typical stormwater catchments.[1] It can also skew high (i.e., recommend a culvert size larger than needed) when the Talbot's coefficient, C, is high.[2] The formula should be used together with other known site conditions (existing width of the drainage channel) to determine a fit that will withstand rainstorms in the climate of the next 25 years, or however long you anticipate the culvert to be in place.

Recommended Audience for this Methodology

This Methodology is geared towards GIS (Geographic Information System) practitioners who can work with town highway staff to make site-specific, detailed recommendations about culvert sizes using this methodology. Communities within Franklin County, Massachusetts can contact FRCOG GIS staff for these services. FRCOG has distilled this analysis from a sample of culverts around Franklin County to develop a "rule of thumb" recommendation in our Unpaved Roads BMP Toolkit. Using the Rule of Thumb guide does not require the detailed GIS analysis and is less site-specific.

Sources

- Flood Frequencies and Bridge and Culvert Sizes for Forested Mountains of North Carolina, *James E. Douglas, Principal Hydrologist, Coweeta Hydrologic Laboratory, Franklin, North Carolina 1974*
- Drainage Management Standards for Town Highway Access Policies, *Vermont League of Cities and Towns, Vermont Department of Environmental Conservation (VTDEC) Milly Archer, CMF Montpelier Vt. 2018*
- Right-Sizing the Hydraulic Capacity of Roadside Drainage Culverts, *Trout Unlimited, Arlington Va.*
- Extreme Precipitation in New York & New England, An Interactive Web Tool for Extreme Precipitation Analysis, *Cornell University, Cornell.edu*
- North Carolina Forestry Best Management Practices, Manual to Protect Water Quality, 2021, www.ncforestservice.gov, www.ncagr.gov
- SDW Engineering Progress, *Hattiesburg, Ms.*

[1] The 2001 Massachusetts Unpaved Roads BMP Manual recommended that engineers be consulted for culverts with drainage areas larger than 20 acres.
[2] Personal communication, A.J. Lang, Water Resources Branch Program Head, North Carolina Forest Service.

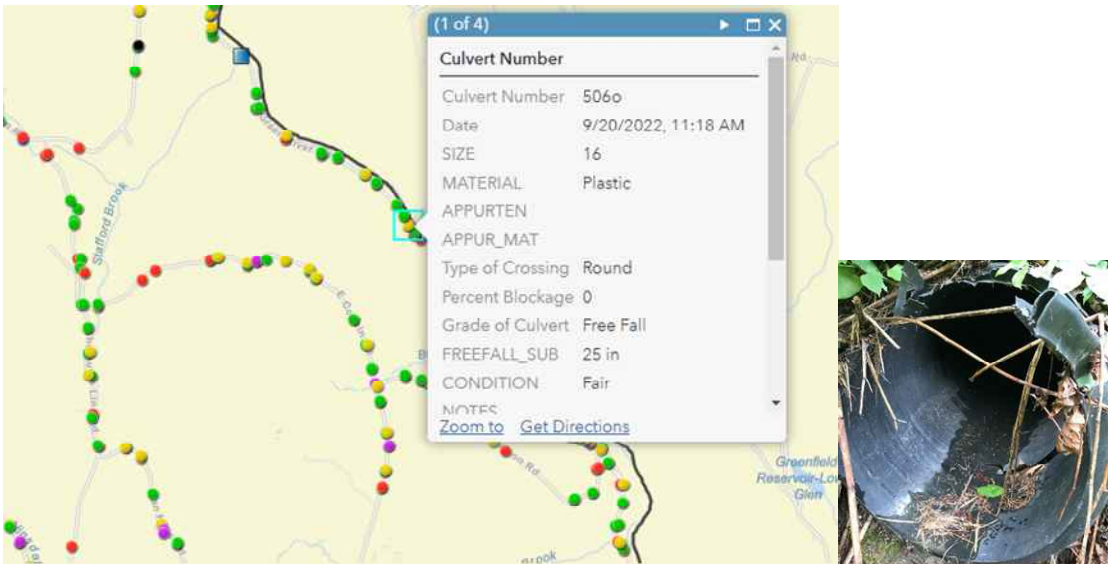
Step 1: Locate Stormwater Culvert(s)

The purpose of this step is to locate the stormwater culvert location(s) you wish to replace or install and for which you need to determine the correct size. Once you know the location of the culvert(s) to replace or install, collect the latitude/longitude using a Geographic Positioning System (GPS) and convert to a GIS data layer. Below is the methodology FRCOG used to collect culvert locations. FRCOG's methodology is not a necessary step to right-size a stormwater culvert, but can be used if you are collecting culvert data for an entire town. Please also note the part that describes the accuracy limitations of GPS data and the need to manually move your dot on a map.

FRCOG culvert inventories: The FRCOG provided several towns within Franklin County, Massachusetts with an inventory of all storm water drainage structures under municipal control. The structures have been collected using the ESRI Collector app on an iPhone 7 designed for offline use. The minimum required accuracy of the iPhone is 9 meters (approximately 27 ft.), therefore precise culvert locations might have to be manually moved once synced and downloaded from the field. FRCOG's culvert assessment work included: 1) locating every culvert and marking each inlet and outlet with GPS; 2) evaluating the physical state of each inlet, outlet, and the interior of the culvert, if visible; and 3) providing an overall condition grade of each culvert's inlet and outlet. The work can give a Highway Department and Selectboard an understanding of the location and general condition of the town's culverts in order to prioritize maintenance and capital improvement planning.

Throughout this methodology, we will use the example of a culvert project completed in Colrain.

1. Collect culvert data in your project area. This can be one site or many. The FRCOG collected culvert locations using ESRI's Collector app. Figure 1 shows a screenshot of a webmap created in ArcOnline showing culvert locations and information that was collected.
2. Sync Collector app to an ArcOnline account. Once all data is collected, create a downloadable data layer that can be used in ArcPro or ArcGIS Desktop. (ex. colr_cul)


(1 of 4)
Culvert Number
Culvert Number 506o
Date 9/20/2022, 11:18 AM
SIZE 16
MATERIAL Plastic
APPURTEN
APPUR_MAT
Type of Crossing Round
Percent Blockage 0
Grade of Culvert Free Fall
FREEFALL_SUB 25 in
CONDITION Fair
NOTES
Zoom to Get Directions
Stafford Brook

(Figure 1)

Step 2: Create Catchment Areas for Each Culvert

The purpose of this step is to determine the catchment area in acres for the stormwater culvert(s) locations that you created in step 1 above. The catchment is the area that contributes flow into the culvert. This step will determine the variable A in the equation on page 1.

Note: FRCOG has tested this procedure for Franklin County, Massachusetts. In areas where the topography is considerably flatter, catchment area mapping may be more challenging. In addition, this procedure uses both ESRI ArcPro 3.0.3 and ArcGIS Desktop 10.8.2 due to some tools running better in one or the other. To run this procedure, you must have Spatial Analyst and 3D analyst extensions and Arc Hydro tools found here https://www.esri.com/en-us/industries/water-resources/arc-hydro/downloads#arc-hydro-for-arcmap

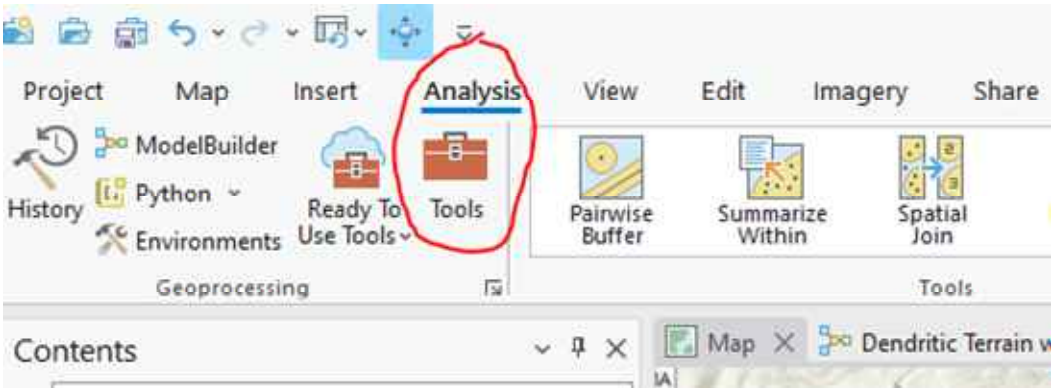
This is a list of data layers that will be created and needed in order to complete this step:

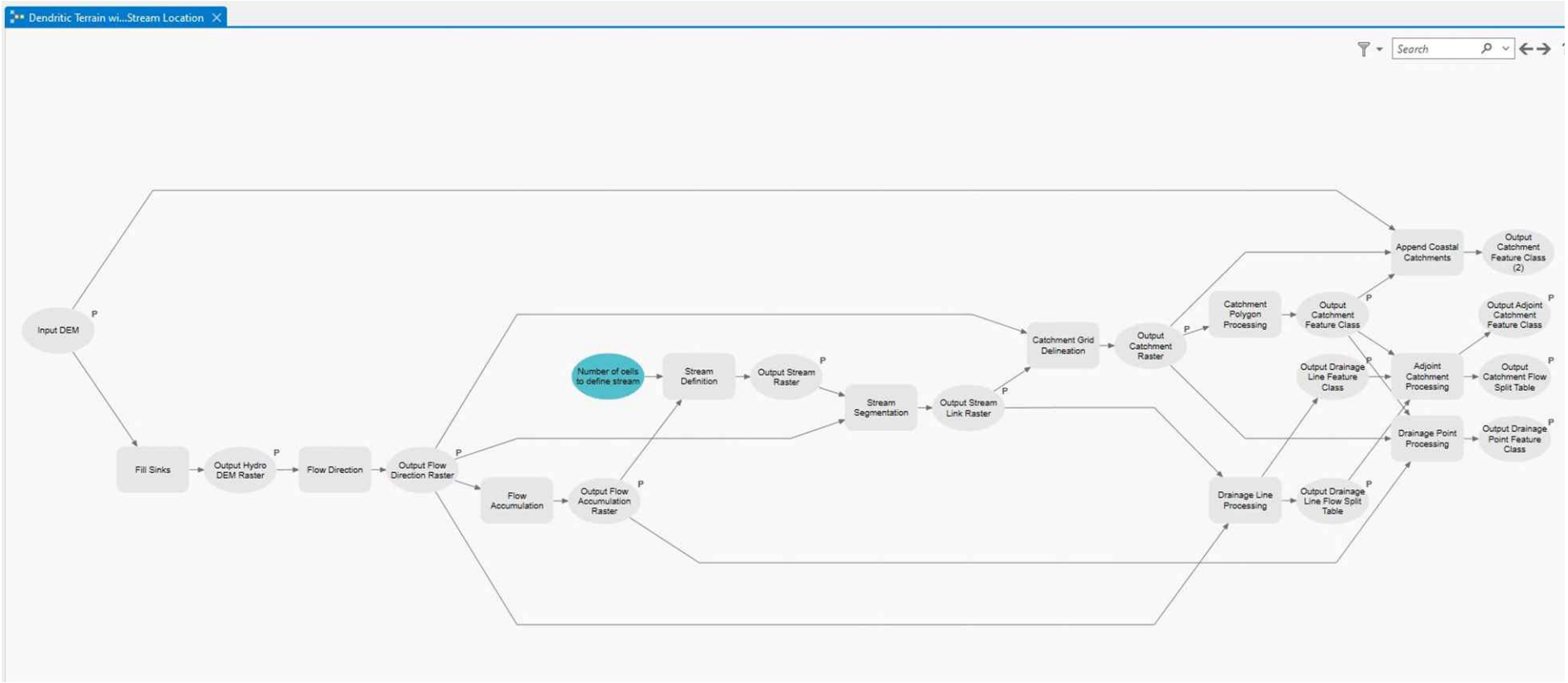
Data Layer	**Name**
Hydro Digital Elevation Model (DEM)	fil_colr *(user can determine this name)*
Flow Direction Raster	Fdr
Flow Accumulation Raster	Fac
Stream Raster	Str
Stream Link Raster	StrLnk
Catchment Raster	Cat.tif
Catchment Feature Class	Catchment
Drainage Line Feature Class	DrainageLine
Drainage Line Split Table	DrainageFS
Drainage Point Feature Class	DrainagePoint
Adjoint Catchment Feature Class	AdjointCatchment
Culvert feature class created in step 1	colrain_culverts *(FRCOG created this data)*
Local Road Feature Class	colr_rds *(this is for display purposes)*
Aerial Photo	2021 Aerial Imagery *(can add from ESRI basemap)*
Watershed Point Feature Class	WatershedPt
Watershed Polygon Feature Class	Watershed

1. Create DEM from LiDAR data of specific area where work is to be performed i.e. Colrain_DEM_clip (this will be known as your original DEM from this point forward)
2. Create new ArcPro project with Geodatabase that will be used to store all data layers created in the following steps (RS_culvert4)
3. Select all culverts collected from assessment that are going to be used in this exercise (for the FRCOG select out all the culverts that have an “I” in the name) we just want 1 point for each culvert. Select only those culverts that convey stormwater. Perennial

and intermittent stream crossings must follow the Massachusetts Stream Crossing Standards, and this right-sizing protocol is not appropriate for stream crossings.

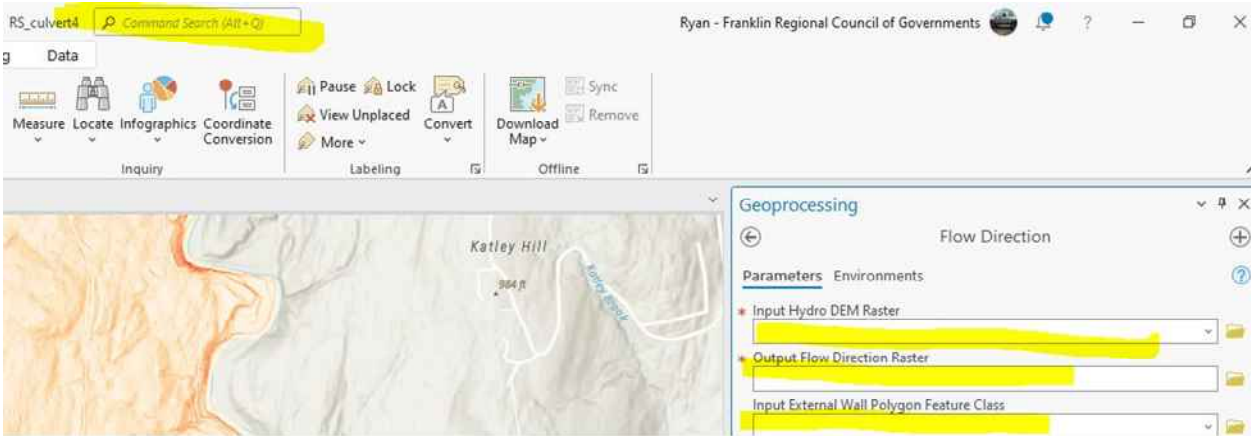
4. Perform Fill geoprocessing tool on DEM to create “fil_colr” (this will now be known as your Hydro DEM Raster to be used in various tools throughout this process.
5. Follow model below and on next page (Figure 2): Dendritic terrain with unknown stream location which can be found by selecting “Analysis” at the top , then selecting “Tools” then select “Toolboxes” tab (middle tab), select dropdown for “Terrain Preprocessing Workflows”, select “Dendritic” and right click on “Dendritic Terrain with Unknown Stream Location” and select edit.




Dendritic Terrain wi...Stream Location
Search
Input DEM
Fill Sinks
Output Hydro DEM Raster
Flow Direction
Output Flow Direction Raster
Flow Accumulation
Output Flow Accumulation Raster
Number of cells to define stream
Stream Definition
Output Stream Raster
Stream Segmentation
Output Stream Link Raster
Catchment Grid Delineation
Output Catchment Raster
Catchment Polygon Processing
Output Catchment Feature Class
Output Drainage Line Feature Class
Drainage Line Processing
Output Drainage Line Flow Split Table
Append Coastal Catchments
Output Catchment Feature Class (2)
Adjoint Catchment Processing
Output Adjoint Catchment Feature Class
Output Catchment Flow Split Table
Drainage Point Processing
Output Drainage Point Feature Class

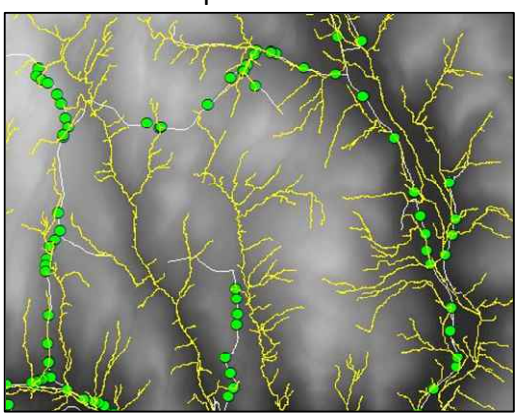
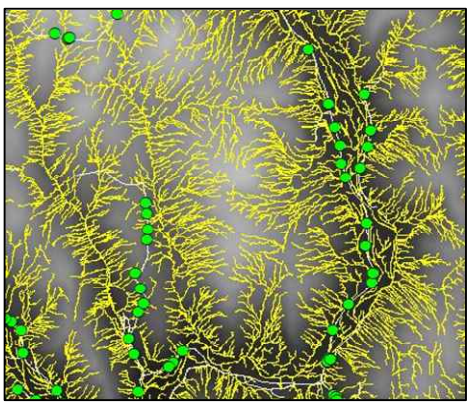
(Figure 2)

6. Instead of letting ArcPro to run the entire model, perform each of the next steps in this section (Step 2: Select Catchment Areas for Each Culvert). Do not use the pre filled options. The following steps can be performed by using the search box and filling in the information for the specified geoprocessing tools. When searching for tools make sure to select the tool that has (archydropro) listed in text. Note: within the geodatabase, feature class data will be stored in "layers" and the rasters will be stored at the base of the geodatabase.



(Figure 3)

7. Flow direction: Hydro DEM = fil_colr, Output = Fdr
8. Flow accumulation: Input = Fdr, Output = Fac
9. Stream Definition: input = Fac, number of cells to define stream = 1000, output raster = Str . Using 1000 for the number of cells results in many more drainage lines than using a larger number. The difference is illustrated below with 10,000 cells (Figure 4) and 1,000 cells (Figure 5). This will be useful later in the process (step 21) when you need to create a watershed for a particular culvert.

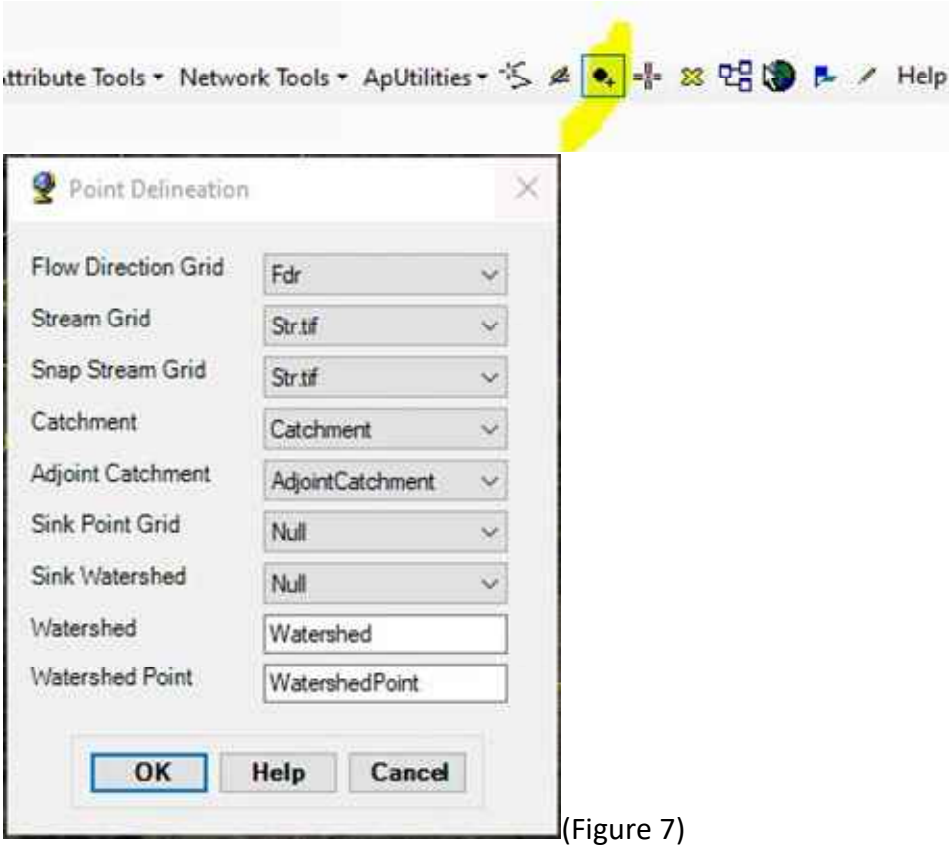
(Figure 4)   (Figure 5)

10. Stream Segmentation: Input stream raster = Str, Input Flow Direction = Fdr, Output Stream Link = StrLnk (don't use anything for the 2 options for Sinks)
11. Catchment grid delineation: Input Flow Direction = Fdr, Input Link Raster = StrLnk, Output catchment raster = Cat.tif

12. Catchment Polygon Processing: Input Catchment Raster = Cat.tif, Output catchment feature class = Catchment
13. Drainage Line processing: Input stream link = StrLnk, Input Flow Direction = Fdr, Output Drainage line = DrainageLine, Output drainage line split table = Drainage_FS
14. Drainage Point processing: Input Flow Accumulation = Fac, Input catchment raster = Cat.tif, Input Catchment Feature class = Catchment, Output Drainage Point = DrainagePoint
15. Append Coastal Catchments: Input DEM Raster = Colrain_DEM_clip (this is your original DEM from step 1), Input catchment raster = Cat.tif, Input Catchment feature class = Catchment
16. Adjoint Catchment Processing: Input drainage line = DrainageLine, Input Catchment feature class = Catchment, Output Adjoint Catchment feature class = AdjointCatchment, Output Catchment flow split table = Catchment_FS, Input Drainage line flow table = DrainageLine_FS
17. Load the original culverts (colr_cul) into ArcPro project map, select all of the culverts that have the text “i” and create feature class “colrain_culverts” (the FRCOG collected culverts using a unique identifier number with an “i” or an “o” after the number indicating the input and output of the culvert). This is the data layer you created for your culvert locations from step 1.
18. Create a new project in ArcGIS desktop and load the following from the GDB you created in ArcPro: DrainageLine, AdjointCatchment, Catchment, StrLnk.tif, Str.tif, Cat.tif, Fac, Fdr, fil_colr(Hydro DEM), Colrain Road datalayer, and latest aerial photo. Save the project “Point Delineation.mxd” (turn all layers off except for DrainageLine, Road datalayer, colrain_culverts and aerial photo as a basemap
19. Load tool bar into your project “Arc Hydro tools” that you downloaded previously from ESRI.com
20. Zoom into a culvert that is near or lies on an existing drainage line (Figure 6). This is the reason that the creation of many streams is important as shown in figure (Figure 5).

(Figure 6)

21. Select the "Point Delineation tool" from the tool bar, click OK when the dialog box below appears (Figure 7) making sure the selections are the same. Click on the drainage line that is closest to the culvert point. (culverts could be off a bit depending on the accuracy of the GPS but you need to **make sure you click on an existing drainage line**) *(using ArcMap instead of ArcPro at this step because it seems to work better in ArcMap).*

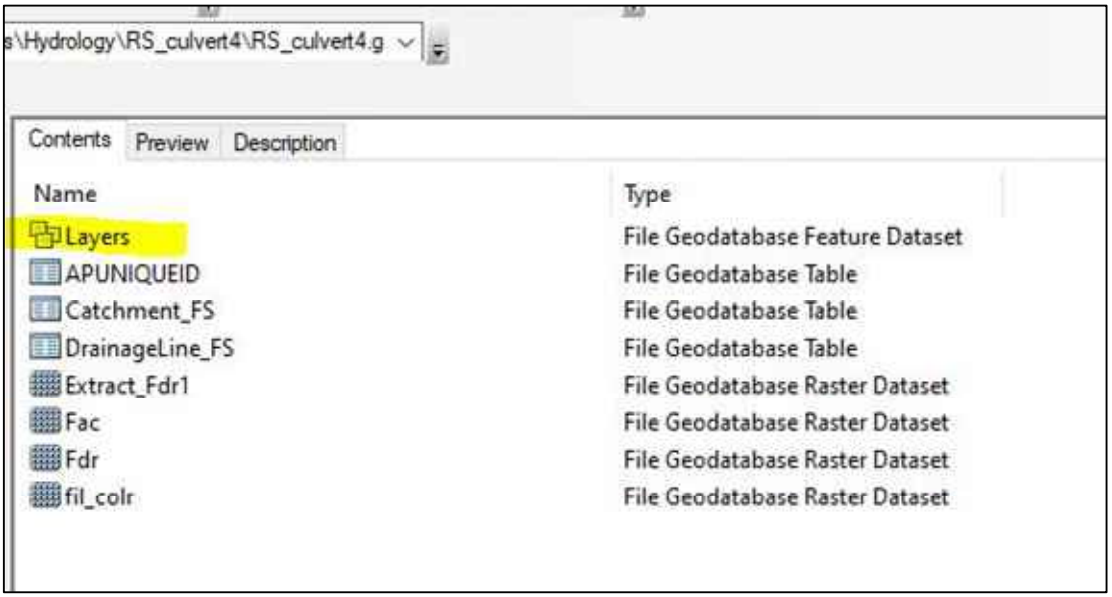


(Figure 7)

22. A red point will appear at the area you clicked representing a pourpoint and a red polygon will appear representing the catchment of that pour point, if it looks legitimate then save it with the name or number of the culvert and the road name as the description. This will then appear in the 2 datalayers that have been added to your project: WatershedPoint & Watershed- both with HydroID and DrainID within the attribute table. *(note: these 2 data layers will be stored in a temp folder on your C: Drive, you will have to export them out later)*

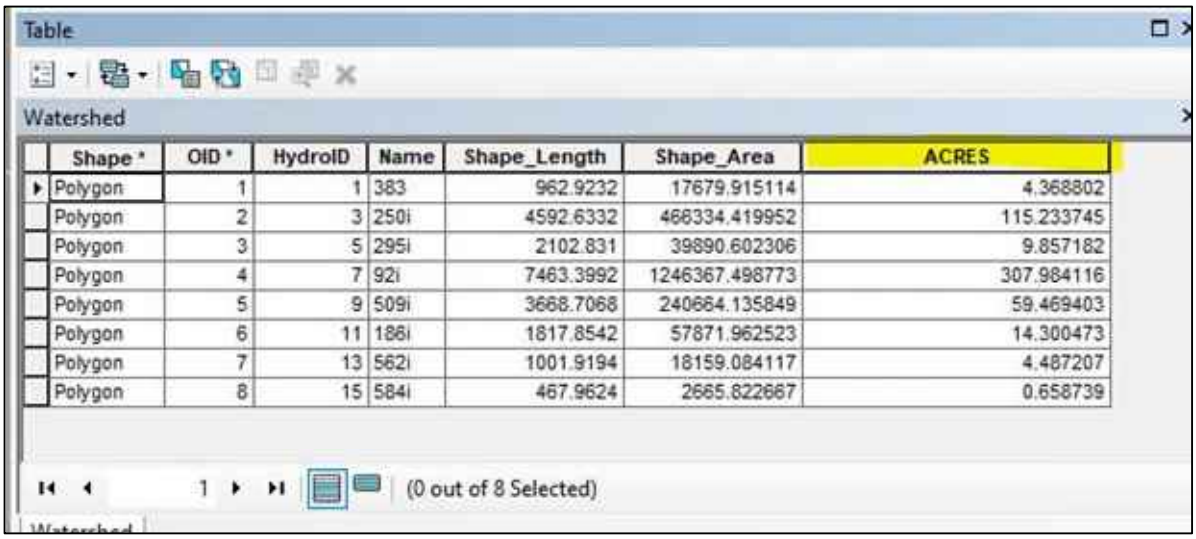
(Figure 8)

23. If the resulting polygon does not look legitimate select “no”, select your pointer tool  and select both the little red point and the red polygon and delete them, redo steps 20 and 21. Follow these steps until you have the amount of watersheds you desire. Once your Watershed layer has the correct amount of watersheds, export the WatershedPoint and Watershed layers into your Geodatabase where the rest of your files are stored under “Layers.”



(Figure 9)

24. If your Watershed layer is not already in your map, add it. Open the attribute table and add a number field "ACRES" to the table. Calculate geometry in the field options to ACRES with the correct projection/Datum. **Each of the culverts will now have a catchment area measured in acres to be entered into excel. You will need the catchment (or watershed) area for the final right-sizing step**.



Shape *	OID *	HydroID	Name	Shape_Length	Shape_Area	ACRES
Polygon	1	1	383	962.9232	17679.915114	4.368802
Polygon	2	3	250i	4592.6332	466334.419952	115.233745
Polygon	3	5	295i	2102.831	39890.602306	9.857182
Polygon	4	7	92i	7463.3992	1246367.498773	307.984116
Polygon	5	9	509i	3668.7068	240664.135849	59.469403
Polygon	6	11	186i	1817.8542	57871.962523	14.300473
Polygon	7	13	562i	1001.9194	18159.084117	4.487207
Polygon	8	15	584i	467.9624	2665.822667	0.658739

(Figure 10)

Step 3: Determine values for Talbot's Coefficient, *C*

Recall from the equation on page 1 of this manual that C (Talbot's Coefficient) = $C_1 + C_2 + C_3$

Where

C_1 = terrain conditions

C_2 = slope of drainage area

C_3 = shape of drainage area

In this step, we will be obtaining values for the three coefficients to determine C in the final step.

If you are determining the right size for many culverts, create a new excel worksheet called RightSizingCulverts.xlsx to look similar to the one in the image below (Figure 11). The table below shows an example of a completed Culvert Right Sizing worksheet. The numbers in the 2 highlighted columns are the inputs for the Talbot Formula Calculator that will be used later in the process.

	NAME	ACRES	SLOPE_Line	SLOPE_Watershed	Lenth_W	Width_W	Dnge_ratio	C1	C2	C3	C	CulvertField	CulvertRS
2	T186i	14	14	22.42	582	193	0.33	0.1	0.4	0.15	0.65	18	23
3	T250i	115	4	8.3	3676	2100	0.57	0.1	0.23	0.25	0.58	36	49
4	T295i	9.8	23	32	686	96	0.14	0.1	0.5	0.05	0.65	18	15
5	T383i	4	13	17	994	302	0.30	0.1	0.4	0.15	0.65	12	15
6	T509i	59.4	13	20	1123	287	0.26	0.1	0.4	0.15	0.65	12	40
7	T562i	4.48	16	25	277	128	0.46	0.1	0.5	0.25	0.85	16	17
8	T584i	0.65	30	23	154	26	0.17	0.1	0.5	0.05	0.65	18	7
9	T92i	307	7	21	1293	1281	0.99	0.17	0.25	0.3	0.72	60	77

(Figure 11)

Field definitions for table above:

Name: name of culvert from Step 1

ACRES: calculated number of acres from Step 2

SLOPE_Line: calculated slope (rise over run) of the longest flow path of the watershed (use this to calculate C_2). This is the more precise slope of the watershed drainage.

SLOPE_Watershed: calculated average slope of the entire watershed (this takes into account the average slope of the entire watershed polygon). This is the second way to calculate C_2, and may result in a larger or more conservative culvert size.

Length_W: estimated length of watershed at its longest point using measurement tool:  (typically feet; any units will work, just make sure you use the same units throughout the exercise)

Width_W: estimated width of watershed at it widest point (typically feet; use same units as you did in length)

Dnge_ratio: Width_W (width of the watershed) divided by Length_W (length of the watershed)

C: the Talbot's Coefficient, the sum of $C_1+C_2+C_3$

CulvertField: the size of the culvert observed in the field (inches) – this is the current culvert size, if applicable
CulvertRS: the end result of the calculations based on this method, Right Size.

Step 3a: Determine Terrain Conditions (C_1)

Use your knowledge of the site or consult online aerial imagery (for example, Google Earth) to determine the terrain conditions in the catchment or watershed area upstream of your culvert. Use the following values for C_1. If your site is a combination of the descriptions below, consider using the average of the two numbers.

0.20 = Rocky mountain with little to no vegetation, or road only
0.17 = Pasture, scattered brush
0.13 = Scattered Trees/dense brush
0.10 = Heavy Stands of Trees

Enter your C_1 value into the table as shown in Figure 11.

Step 3b: Acquire Catchment Slope (C_2)

In this step, you will use GIS to determine the slope of your culvert's watershed or catchment area that you created in Step 2. Once you have the slope, you will choose which value of C_2 your slope belongs in. Enter this C_2 value into the table as shown in Figure 11.

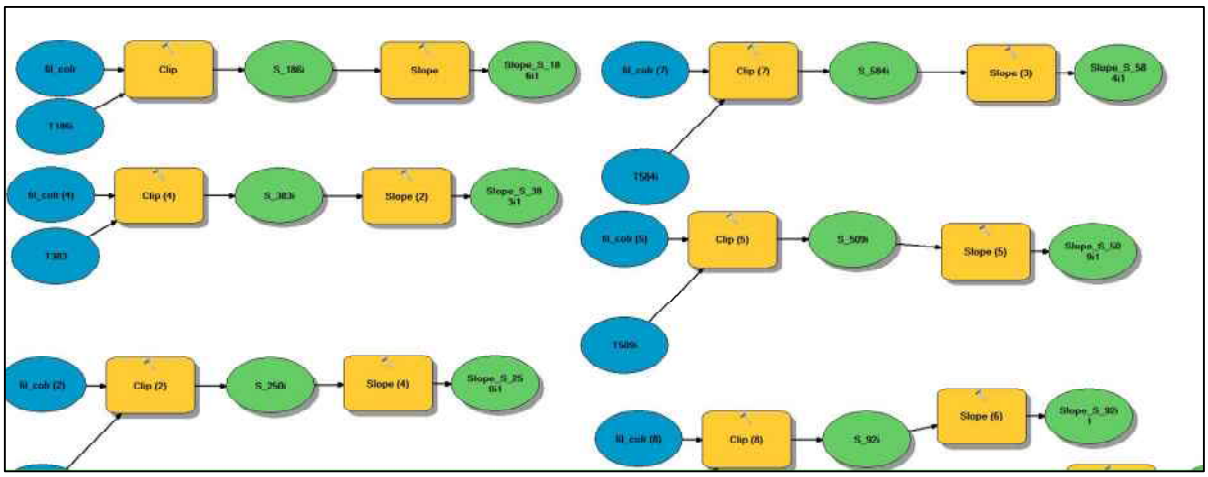
This is a list of data layers that will be created and needed in order to complete this step:

Data Layer	Name
Hydro Digital Elevation Model	fil_colr *(user can determine this name)*
Watershed Polygon Feature Class	Watershed
Individual Watershed Feature Class	T186i *(user can determine this name)*
Individual Watershed Raster	S186i *(user can determine this name)*
Slope Raster for individual Watershed	Slope_S186i *(user can determine this name)*
Longest Flpw Path	LongestFlowPath186i *(user can determine this name)*
Flow Direction Grid	Fdr
Culvert feature class created in step 1	colrain_culverts *(user can determine this name)*
Local Road Feature Class	colr_rds *(this is for display purposes)*

1. Turn all layers off except fil_colr (hydro DEM), Watershed and roads. Open tool "Split by Attribute": input = Watershed, target workspace = RS_culvert4.gdb (your main geodatabase), Split fields = Name. This process will split the watersheds layer into

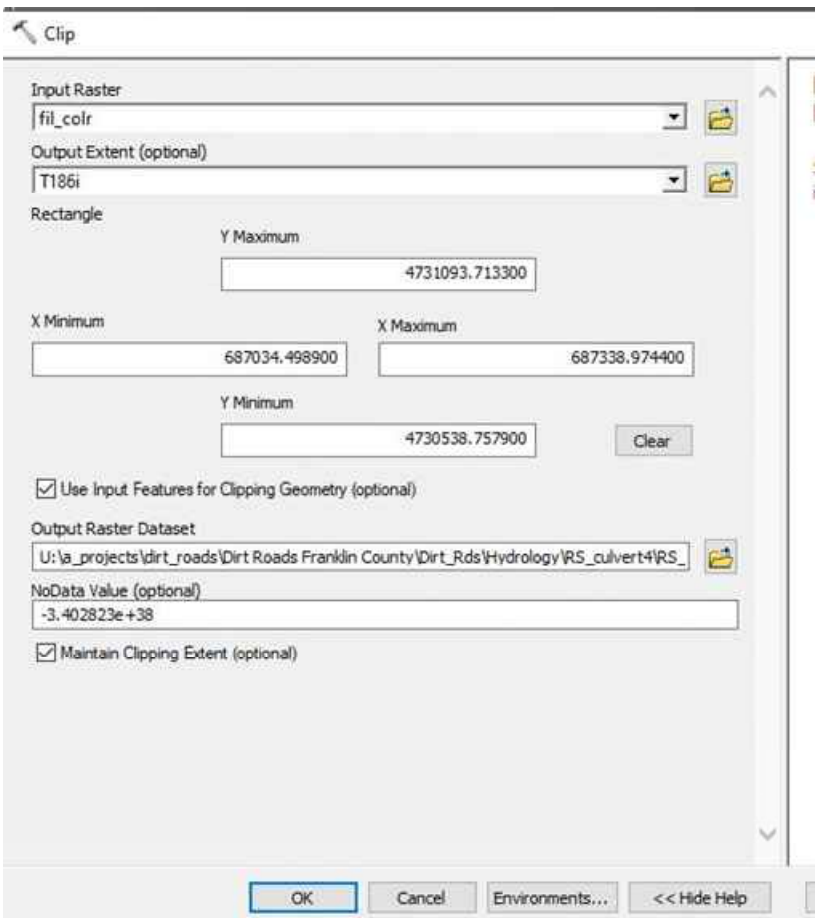
separate watersheds by the name you gave them in the last process i.e. the culvert number.

2. In this step you can either clip each of your watersheds from step 1 manually or set up a model in model builder if you plan to do this process many times (Figure 12).



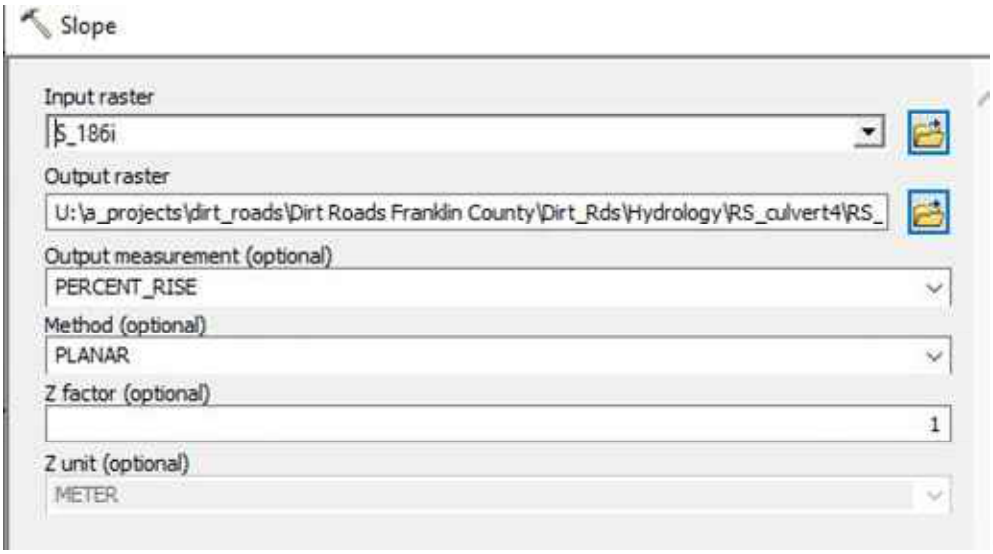
(Figure 12)

Open tool “Clip” (data management, this is a Raster Clip not an analysis clip): input features = fil_colr, Output Extent = T186i (the name of an individual watershed), Output



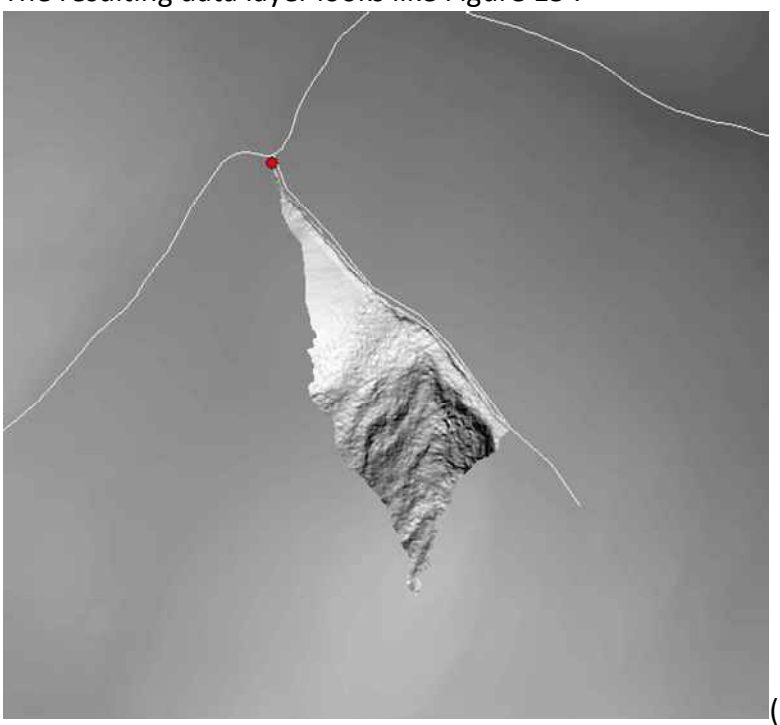
raster = S_186i. Make sure to check the boxes “Use Input Features….” and “Maintain Clipping…”
(Figure 13)

3. Slope (spatial analyst tool): input = S_186i, output = Slope_S_186i, change output measurement to “PERCENT_RISE”

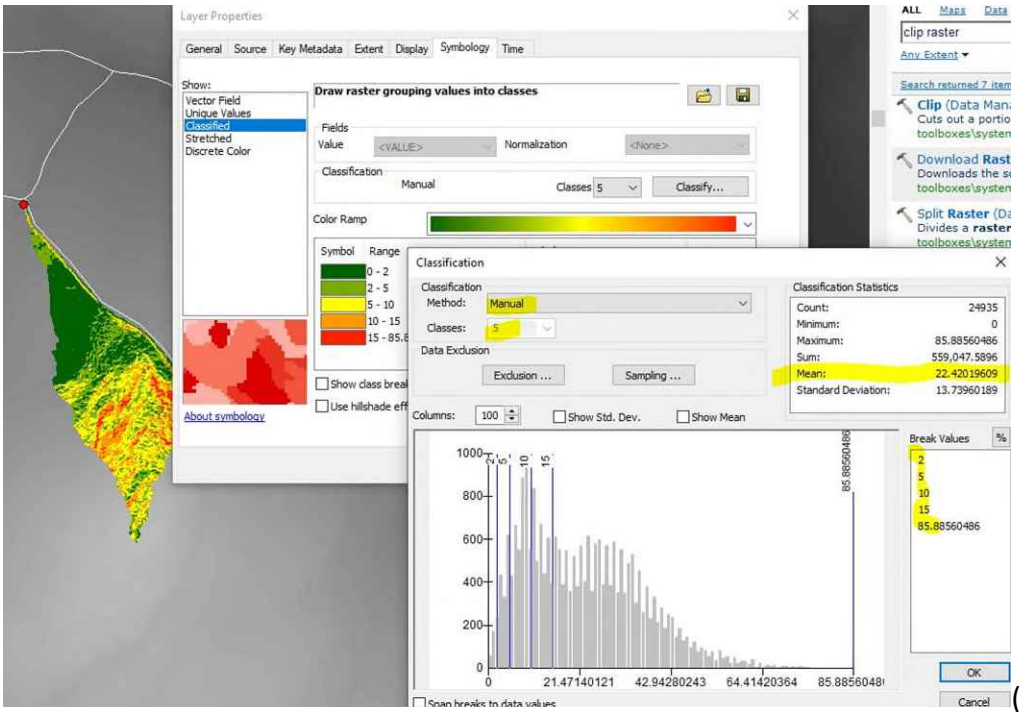


(Figure 14)

4. The resulting data layer looks like Figure 15 :

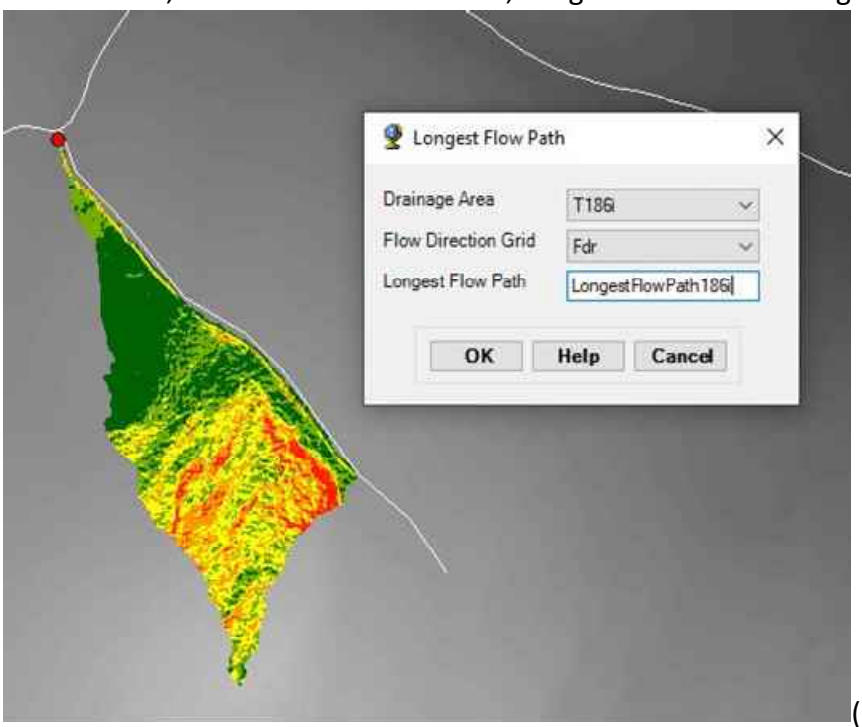

(Figure 15)

5. Open the properties for Slope_S_186i and change the symbology to Classified and green-red. Change the classes to 5 with the breaks at 2, 5, 10, 15, (Figure 16)(largest will fill automatically). Make note of the **Mean** slope (16)value and enter it into your RightSizing excel form from above in the column for “SLOPE_Watershed:



(Figure 16)

6. Open LongestFlowPath from watershed processing tools(archydro toolbar): Drainage Area = T186i, Flow Direction Grid = Fdr, Longest Flow Path = LongestFlowPath186i:



(Figure 17)

7. Turn off Slope_S_186i, add LongestFlowPath186i. Make sure to have 3D analyst toolbar. Change base layer to fil_colr. Open the tool “Add Surface Information” from 3D analyst toolbox. Input = LongestFlowPath186i, Input Surface = fil_colr, add check marks next to

avg_slope and any other fields you would like to have added. This process adds slope data to the longest flow path that was created in step 6. and select interpolate line tool from 3D analyst toolbar. Enter the number for “Avg_Slope” into excel in the “SLOPE_Line” field. See Figure 18 below.

NAME	ACRES	SLOPE_Line	SLOPE_Watershed L
T186i	14	14	22.42
T250i	115	4	8.3
T295i	9.8	23	32
T383i	4	13	17
T509i	59.4	13	20
T562i	4.48	16	25
T584i	0.65	30	23
T92i	307	7	21

(Figure 18)

8. Optional: if you are doing multiple culverts on one road or an entire town -- For a more complete culvert dataset you can join this table with your original culvert data layer using the name as your join field. Make sure to delete the “T” in the field “NAME” so that it matches with the “CULVERT_NU” field in your data layer or create a new field without the “T”.

	A	B	C	D	E	F	G	H
1	NAME	ACRES	SLOPE_Line	SLOPE_Watershed	Lenth_W	Width_W	Dnge_ratio	C1
2	T186i	14	14	22.42	582	193	0.33	0.1
3	T250i	115	4	8.3	3676	2100	0.57	0.1
4	T295i	9.8	23	32	686	96	0.14	0.1
5	T383i	4	13	17	994	302	0.30	0.1
6	T509i	59.4	13	20	1123	287	0.26	0.1
7	T562i	4.48	16	25	277	128	0.46	0.1
8	T584i	0.65	30	23	154	26	0.17	0.1
9	T92i	307	7	21	1293	1281	0.99	0.17

Table

colr_cul_in

OBJECTID *	Shape *	CUVLERT_NU	DATE	SIZE	MATERIAL	APPURTEN	APP
1	Point	1i	6/7/2022	0	Concrete	Headwall Wingwall	Conc
2	Point	2i	6/7/2022	16	Concrete	Metal Grate	
3	Point	3i	6/7/2022	16	Concrete	Metal Grate	
4	Point	4i	6/7/2022	60	Cast Iron	Headwall Wingwall	Conc
5	Point	5i	6/7/2022	16	Concrete	Metal Grate	
6	Point	6i	6/7/2022	16	Concrete	Metal Grate	
7	Point	7i	6/7/2022	16	Concrete	Metal Grate	
8	Point	8i	6/7/2022	16	Metal	Headwall Wingwall	
9	Point	9i	6/7/2022	16	Metal	Metal Grate	

1 (0 out of 616 Selected)

(Figure 19)

You can consider your watershed’s slope to be either the SLOPE_Line value (8c), which is more precise, or SLOPE_Watershed (6c), which is more conservative. Enter both values into your table, and your value for C_2. To determine the value of C_2, use the following number:

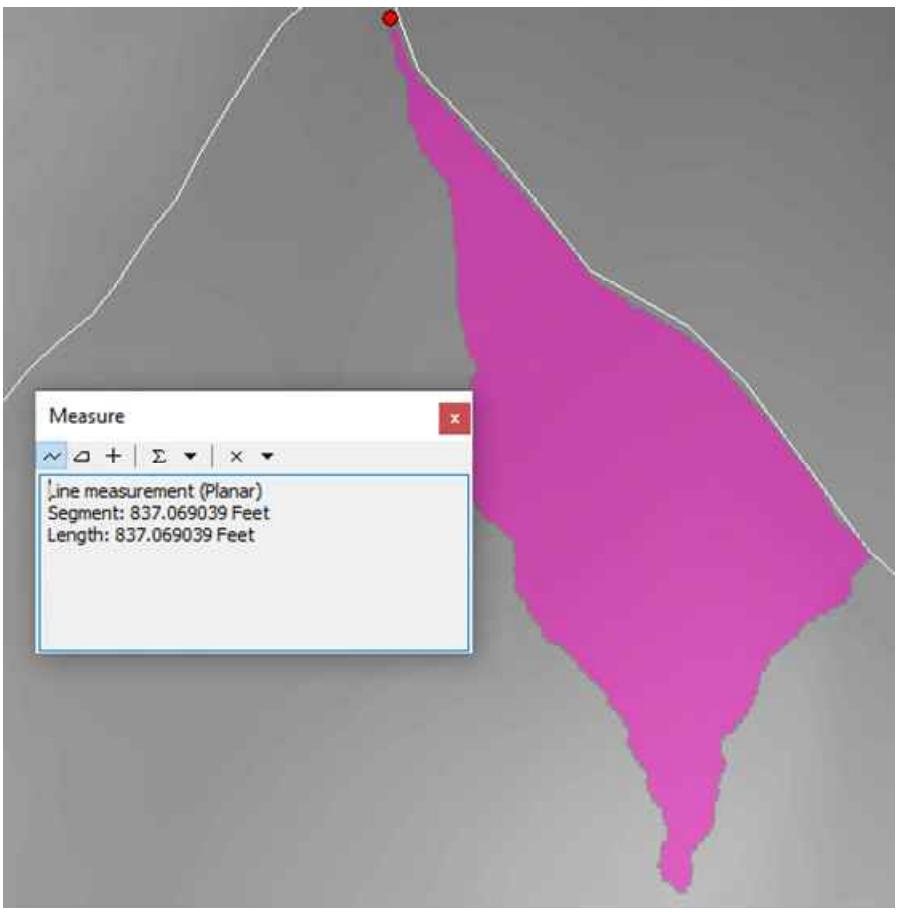
If value for SLOPE_LINE or SLOPE_Watershed (which ever one you decide to use) =

1-2, enter C_2 = 0.2
>2-5, enter C_2 = 0.23
>5- 10, enter C_2 = 0.25
>10-15, enter C_2 = 0.4
Greater than 15, enter C_2 = 0.5

Step 3c: Calculate length and width of catchment

In this step, you will use GIS to determine the length and width of your catchment/watershed. You will then calculate a drainage ratio, called **Dnge_ratio**, which is Width_W (width of the watershed in feet) divided by Length_W (length of the watershed in feet). This will be used to determine the shape of the watershed and value for C_3 in the equation.

1. Zoom to the watershed you are working on and measure the length at the farthest point to the culvert and then measure the width at the widest point using the measure tool.



(Figure 20)

Enter the length and width and value of C3 into the spreadsheet. Dnge_ratio = Width_W/Length_W.

C3: a value given representing the number in column Dnge_ratio where:

If value for Dnge_ratio =
0.5 or higher enter 0.3
0.45 enter 0.25
0.4 enter 0.2
0.3 enter 0.15
0.2 enter 0.1
Less than 0.2 enter 0.05

Step 3d: Example of Calculating C

1. In Steps 3a, 3b, and 3c, you calculated C_1, C_2, and C_3. Now add them together to get the value of C. C will never be higher than 1.0. In the example above (culvert T186i), this would be 0.1 + 0.4 + 0.15 = 0.65.

Summary: Calculating C

The following values were given in Steps 3a through 3c, and are provided together in the table below.

C_1 **Terrain Conditions**	**C_2** **Catchment Slope**	**C_3** **Drainage Ratio (catchment width/length)**
Little to no vegetation: enter 0.20 Pasture, scattered brush: enter 0.17 Scattered trees/dense brush: enter 0.13 Forest: enter 0.10	1-2: enter 0.2 >2-5: enter 0.23 >5-10: enter 0.25 >10-15: enter 0.4 >15: enter 0.5	0.5 or higher: enter 0.3 0.45: enter 0.25 0.4 enter 0.2 0.3: enter 0.15 0.2: enter 0.1

Below shows example values entered in a spreadsheet. Use your best judgement on entering values that may be in between some of the values provided.

	A	B	C	D	E	F	G	H	I	J	K	L	M	
1	TOWN	Culvert ID	Road	Culvert Condition	Catchment ACRES	SLOPE_ Watershed	Length_W	Width_W	Dnge_ratio	C1	C2	C3	C	Cul (cu in
2	New Salem	321i	Old County Rd.	good	0.550885	15.03	264	147	0.56	0.17	0.45	0.3	0.92	
3	Colrain	T584i	N. River Road	good	0.65	23	154	26	0.17	0.1	0.5	0.05	0.65	
4	Ashfield	422i	Bug Hill Road	fair	0.936163	16.99	432	126	0.29	0.1	0.5	0.15	0.75	
5	Ashfield	605i	Graves Rd	critical	1.876637	21.7	1023	121	0.12	0.1	0.5	0.05	0.65	
6	Ashfield	653i	Bellus Rd	critical	1.884856	15.64	514	213	0.41	0.13	0.45	0.2	0.78	
7	Ashfield	65i	Smith Branch Road	fair	2.019052	23.26	1082	90	0.08	0.1	0.5	0.05	0.65	
8	Ashfield	699i	Bullitt Rd.	poor	2.256737	19.25	481	265	0.55	0.1	0.5	0.3	0.9	
9	New Salem	81i	W. Moosehorn Rd	critical	3.631391	14.57	862	228	0.26	0.14	0.45	0.15	0.74	

(Figure 21)

Step 4: Determine storm intensity for right-sizing

This step shows you how to determine a storm intensity amount for the location of your stormwater culvert. We will be using the NOAA Atlas 14 ++ rainfall standards because Massachusetts Department of Environmental Protection has been leaning towards using these statistics for climate resilience design standards.

1. Go to https://hdsc.nws.noaa.gov/pfds/ and click on Massachusetts. Then click on the location information that you prefer to use – you can use a weather station, an address, a point on a map, or a latitude/longitude location. In this example, we chose the weather station at Colrain MA.

This will generate a precipitation frequency table for this site, shown below. The statistic to focus on is the precipitation frequency estimates for a **1-hour duration storm**, circled in red below in Figure 22.[3]

[3] The MA Stormwater Standards (Standard 2), 2008, as well as the MA Climate Resilient Design Standards and Guidance, Section 4, July 2022, recommend using the 24-hour storm, but the equation we use is based on a 1-hour intensity storm because the equation is set up for a 1-hour storm.

NOAA Atlas 14, Volume 10, Version 3 COLRAIN
Station ID: 19-1611
Location name: Colrain, Massachusetts, USA*
Latitude: 42.6728°, Longitude: -72.697°
Elevation:
Elevation (station metadata): 625 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.309 (0.234-0.407)	0.361 (0.273-0.476)	0.446 (0.336-0.590)	0.516 (0.388-0.687)	0.613 (0.447-0.847)	0.688 (0.492-0.966)	0.763 (0.530-1.11)	0.841 (0.563-1.26)	0.947 (0.613-1.46)	1.03 (0.652-1.62)
10-min	0.437 (0.331-0.577)	0.511 (0.387-0.675)	0.632 (0.477-0.837)	0.732 (0.549-0.975)	0.869 (0.633-1.20)	0.974 (0.697-1.37)	1.08 (0.751-1.57)	1.19 (0.797-1.78)	1.34 (0.867-2.07)	1.46 (0.923-2.30)
15-min	0.515 (0.390-0.679)	0.601 (0.455-0.794)	0.742 (0.560-0.983)	0.860 (0.646-1.15)	1.02 (0.745-1.41)	1.15 (0.820-1.61)	1.27 (0.884-1.84)	1.40 (0.938-2.09)	1.58 (1.02-2.44)	1.72 (1.09-2.70)
30-min	0.715 (0.541-0.943)	0.835 (0.632-1.10)	1.03 (0.778-1.37)	1.20 (0.897-1.59)	1.42 (1.04-1.96)	1.59 (1.14-2.24)	1.76 (1.23-2.56)	1.95 (1.30-2.91)	2.19 (1.42-3.38)	2.38 (1.51-3.75)
60-min	0.915 (0.693-1.21)	1.07 (0.809-1.41)	1.32 (0.998-1.75)	1.53 (1.15-2.04)	1.82 (1.32-2.51)	2.04 (1.46-2.86)	2.26 (1.57-3.28)	2.49 (1.67-3.72)	2.81 (1.82-4.33)	3.05 (1.93-4.80)
2-hr	1.16 (0.883-1.51)	1.36 (1.04-1.78)	1.70 (1.30-2.23)	1.98 (1.50-2.61)	2.37 (1.74-3.25)	2.66 (1.92-3.72)	2.97 (2.09-4.28)	3.30 (2.22-4.88)	3.78 (2.45-5.76)	4.16 (2.64-6.47)
3-hr	1.32 (1.02-1.72)	1.57 (1.20-2.03)	1.96 (1.50-2.56)	2.29 (1.74-3.00)	2.74 (2.03-3.74)	3.08 (2.24-4.28)	3.44 (2.44-4.95)	3.84 (2.59-5.63)	4.42 (2.87-6.69)	4.90 (3.11-7.55)
6-hr	1.67 (1.30-2.15)	1.98 (1.53-2.54)	2.48 (1.92-3.20)	2.90 (2.22-3.75)	3.47 (2.59-4.67)	3.90 (2.85-5.35)	4.35 (3.10-6.18)	4.86 (3.29-7.04)	5.61 (3.66-8.37)	6.22 (3.97-9.46)
12-hr	2.11 (1.65-2.67)	2.48 (1.94-3.15)	3.10 (2.41-3.95)	3.61 (2.80-4.62)	4.31 (3.24-5.74)	4.84 (3.56-6.56)	5.39 (3.86-7.57)	6.02 (4.09-8.60)	6.92 (4.53-10.2)	7.66 (4.91-11.5)
24-hr	2.54 (2.00-3.19)	3.01 (2.38-3.79)	3.79 (2.98-4.78)	4.44 (3.47-5.62)	5.32 (4.03-7.01)	5.99 (4.45-8.04)	6.69 (4.84-9.30)	7.50 (5.12-10.6)	8.69 (5.71-12.6)	9.68 (6.22-14.3)
2-day	2.93 (2.33-3.63)	3.54 (2.82-4.40)	4.55 (3.61-5.66)	5.38 (4.24-6.74)	6.53 (5.00-8.53)	7.38 (5.54-9.84)	8.30 (6.07-11.5)	9.41 (6.45-13.1)	11.1 (7.32-15.9)	12.6 (8.09-18.3)
3-day	3.20 (2.56-3.94)	3.90 (3.12-4.81)	5.04 (4.01-6.23)	5.98 (4.74-7.44)	7.28 (5.60-9.46)	8.24 (6.22-10.9)	9.29 (6.84-12.8)	10.6 (7.27-14.6)	12.6 (8.31-17.9)	14.3 (9.24-20.7)
4-day	3.44 (2.77-4.22)	4.19 (3.36-5.14)	5.41 (4.33-6.67)	6.43 (5.12-7.96)	7.83 (6.05-10.1)	8.86 (6.71-11.7)	9.98 (7.38-13.7)	11.4 (7.84-15.7)	13.6 (8.98-19.2)	15.5 (10.0-22.3)
7-day	4.12 (3.34-5.01)	4.95 (4.00-6.02)	6.30 (5.08-7.69)	7.42 (5.95-9.10)	8.97 (6.97-11.5)	10.1 (7.70-13.2)	11.4 (8.43-15.4)	12.9 (8.92-17.5)	15.3 (10.1-21.4)	17.4 (11.2-24.7)
10-day	4.81 (3.92-5.82)	5.68 (4.62-6.86)	7.09 (5.74-8.60)	8.26 (6.65-10.1)	9.87 (7.70-12.5)	11.1 (8.45-14.3)	12.4 (9.17-16.6)	13.9 (9.66-18.8)	16.3 (10.8-22.7)	18.3 (11.9-25.9)
20-day	7.00 (5.75-8.36)	7.91 (6.50-9.46)	9.41 (7.69-11.3)	10.6 (8.65-12.8)	12.4 (9.68-15.4)	13.6 (10.4-17.3)	15.0 (11.1-19.5)	16.5 (11.5-21.9)	18.6 (12.4-25.4)	20.2 (13.2-28.2)
30-day	8.80 (7.28-10.4)	9.76 (8.06-11.6)	11.3 (9.31-13.5)	12.6 (10.3-15.1)	14.4 (11.3-17.7)	15.8 (12.1-19.7)	17.2 (12.6-22.0)	18.6 (13.0-24.5)	20.4 (13.7-27.7)	21.9 (14.3-30.2)
45-day	11.0 (9.14-13.0)	12.0 (9.98-14.2)	13.7 (11.3-16.2)	15.1 (12.4-17.9)	17.0 (13.4-20.7)	18.5 (14.2-22.9)	20.0 (14.7-25.2)	21.3 (15.0-27.9)	23.1 (15.6-31.0)	24.3 (15.9-33.3)
60-day	12.8 (10.7-15.0)	13.9 (11.6-16.3)	15.7 (13.0-18.4)	17.2 (14.2-20.3)	19.2 (15.2-23.3)	20.8 (16.1-25.6)	22.4 (16.5-28.1)	23.8 (16.8-30.9)	25.6 (17.3-34.1)	26.8 (17.5-36.4)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Back to Top

(Figure 22)

2. Which recurrence interval to use?

Consider the typical useful life of the culvert you will install. It may be something like 20-40 years. Also consider the criticality of the road and location in which the culvert will be installed. See Section 4.8 in Climate Resilient Design Standards for further discussion. [4] While it may be advisable to review the 2-year, 10-year, and 100-year storm intervals to be consistent with MA Stormwater Standards, a medium level criticality for a design life of 11-50 years would use the 25-year design storm for a utility like a culvert (4% annual chance storm). This is consistent with the Federal Highway Administration's Project Development and Design Manual, which recommends a 25-year standard for culverts on a "low standard" road ("high standard" roads have a 50-year design storm recommendation), assuming that unpaved roads fall closer to the low standard.[5] If your town has been experiencing severe storms and the 25-year storm appears to be an underestimate, you can test out the 50-year or 100-year design storms. Evaluating multiple possible statistics to see how this impacts the resulting culvert size could help determine the desired level of protection for the physical conditions at the site. Two side-by-side culverts may also be something to consider if there is a lack of vertical space, keeping in mind that smaller culverts can get jammed with debris.

NOAA has a helpful calculator for conceptualizing the statistical risk of a certain storm event happening over a particular time period, in this case the design life of a culvert. See https://www.weather.gov/epz/wxcalc_floodperiod. For example, if you plug in 100 on the top left and 25 in the bottom left, and then click on "convert," you'll see that there's a 22.2% chance of a 100-year event happening in a 25-year period. Putting a 1 in the bottom left gives you the percent chance in any single year. As a practitioner working with or for a town, you'll need to decide if this is an acceptable level of risk.

3. Using a NOAA Atlas 14++ rainfall statistic

When you have picked a recurrence interval you would like to design the culvert for (60-minutes, 50-year interval in this example), find the 90% confidence interval in the smaller set of numbers below the current statistic. In this example, the 90% confidence interval is 2.86 inches (2.04 inches represents a statistical average). This takes into account higher storm intensities. See Figure 23 below.

[4] Also found here: https://resilientma.mass.gov/rmat_home/designstandards/, then click on the design standards under Climate Resilience Design Standards Output.

[5] Federal Highway Administration, 2012. Project Development and Design Manual, Section 7, Exhibit 7.1-A. https://flh.fhwa.dot.gov/resources/design/pddm/Chapter_07.pdf

This will be the rainfall depth to plug into the "rainfall intensity" formula on page 1.[6] You can test out different results with different rainfall amounts and see if it makes a difference in terms or recommended pipe diameter.

Duration	Average recurrence interval (year						
	1	2	5	10	25	50	
5-min	0.309 (0.234-0.407)	0.361 (0.273-0.476)	0.446 (0.336-0.590)	0.516 (0.388-0.687)	0.613 (0.447-0.847)	0.688 (0.492-0.966)	(
10-min	0.437 (0.331-0.577)	0.511 (0.387-0.675)	0.632 (0.477-0.837)	0.732 (0.549-0.975)	0.869 (0.633-1.20)	0.974 (0.697-1.37)	(
15-min	0.515 (0.390-0.679)	0.601 (0.455-0.794)	0.742 (0.560-0.983)	0.860 (0.646-1.15)	1.02 (0.745-1.41)	1.15 (0.820-1.61)	(
30-min	0.715 (0.541-0.943)	0.835 (0.632-1.10)	1.03 (0.778-1.37)	1.20 (0.897-1.59)	1.42 (1.04-1.96)	1.59 (1.14-2.24)	(
60-min	0.915 (0.693-1.21)	1.07 (0.809-1.41)	1.32 (0.996-1.75)	1.53 (1.15-2.04)	1.82 (1.32-2.51)	2.04 (1.46-2.86)	(

(Figure 23)

[6] Because we are using the 60-minute duration, the rain depth is the equivalent to a rainfall intensity in inches/hour.

Step 5: Input information into formula

At this point, you have all the information you need to calculate the culvert size you need. This process will allow a user to enter these numbers derived in steps 2 through 4 to properly size a round culvert.

1. Please download this easy to use excel formula from the North Carolina Forest Service: https://ncforestservice.gov/water_quality/documents/TalbotsformulaCalculator.xlsx . *≪Note: Our engineering consultant recommended that we supply a spreadsheet customized for us, but the benefit of this spreadsheet is that it's already available online to download in the link. FRCOG would have to provide this on a website, which we hadn't contemplated doing.≫*

   The rain intensity number (inches/hour) you determined in Step 4 is likely not represented in the table. You can "unlock" the worksheet (right-click on the name of the worksheet tab – Talbots Calc -- and choose "unprotect sheet." Add or change the rain intensity column numbers to match your precipitation statistic.
2. In Steps 3a, 3b, and 3c, we determined site-specific values for C. **Therefore, ignore or delete the box showing runoff coefficient values (see red X below).**

Culvert Sizing Calculator Using Talbot's Formula

Use this calculator to help size a culvert for your road/trail crossing.
Different culvert sizes are calculated, based on the rainfall intensity expected for the site.
Step 1: Enter your upstream watershed acres in the yellow box.
Step 2: Enter the estimated Runoff Coefficient ("C-Value") for the upstream watershed in the blue b

Key to Estimating C-Values:	More Runoff	Less Runoff
Impervious Surface:	1.0	1.0
Steep Slopes, Heavy Soils, Moderate Cover:	0.8	0.7
Moderate Slopes, Heavy-to-Light Soils, Dense Cover:	0.6	0.5
Gentle Slopes, Ag soils and Light Cover:	0.4	0.3
Flat ground with well-drained soils:	0.2	0.2

Remember : If the upstream watershed will be clearcut harvested, then you can expect more runoff for at least a few years afterwards, until the site re-grows a new stand of trees. A larger culvert may be needed.

It is recommended that the smallest size pipe on any forestry site should be no-less-than 15 inches diame

Round Culvert Sizing Calculator Using Talbot's Formula

Watershed (acres)	Runoff Coefficient (C-Value)
307	0.7

Rain Intensity (inches/hour)	One Culvert (inches diameter)	Two Culverts (inches diameter, each)	Three Culverts (inches diameter, each)
0.5	34	24	20
1.0	49	34	28
1.5	59	42	34
2.0	69	49	40
2.5	77	54	44
3.0	84	59	49
3.5	91	64	52
4.0	97	69	56

Talbots Calc

(Figure 23)

3. Input the watershed acres you determined in Step 2 into the yellow box where it says "watershed (acres): Input the the runoff coefficient (C-value) you determined at the end of Step 3 into the blue box. Remember to use the storm intensity value(s) you chose in step 4, and put those in column A, rather than the ones offered in this sheet. The number in the "one culvert" column should be the "right size" for your culvert. Round up to the nearest size that you can obtain commercially (for example, a 21-inch right size may mean you install a 24-inch culvert). In many cases, this may be a larger size pipe than you have there now. This is good – you will need to plan for potentially higher extreme precipitation. If, however, the formula does not produce a realistic number, try a smaller storm intensity or round to the next pipe size down.

   Keep in mind that high C values can lead to larger culvert recommendations. If your C-value is 0.8 or higher, give some more thought to the recommended culvert size and weigh the possibility that it may be skewing a little too high.

   Typical commercial sizes (diameters in inches) for culverts are 12, 15, 18, 24, 32, and 36. FRCOG does not recommend installing culverts smaller than 12 inches in diameter. Culverts larger than 36 inches are likely stream crossings and would need to meet MA Stream Crossing Standards.