Environmentally Sensitive Maintenance on Agricultural Roads to Reduce Nutrient and Sediment Pollution in the Kishacoquillas Watershed

Prepared for the U.S. Department of Agriculture Conservation Innovation Grant Program

FINAL REPORT

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PENNSTATE

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NRCS68-3A75-5-167		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
Environmentally Sensitive Maintenance on Agricultural Roads to Reduce Nutrient and Sediment Pollution in the Kishacoquillas Watershed	**5. Report Date** December 31, 2009 **6. Performing Organization Code**
7. Author(s) Barry E. Scheetz and Steven M. Bloser	**8. Performing Organization Report No.** LTI 2010-08
9. Performing Organization Name and Address The Thomas D. Larson Pennsylvania Transportation Institute The Pennsylvania State University 201 Transportation Research Building University Park, PA 16802-4710	**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** 93135
12. Sponsoring Agency Name and Address U.S. Department of Agriculture National CIG Program USDA-NRCS P.O. Box 2890, Room 5239-S Washington, DC 20013-2890	**13. Type of Report and Period Covered** Final Report 9/27/2005 – 12/31/2009 **14. Sponsoring Agency Code**

15. Supplementary Notes

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16. Abstract

Sediment-laden runoff from over 20,000 miles of unpaved public roads is a significant documented source of stream pollution to the waters of the Commonwealth of Pennsylvania. The Center for Dirt and Gravel Road Studies at Penn State has established Environmentally Sensitive Maintenance Practices (ESMPs) to reduce sediment pollution from unpaved roads, and advocates the use of these practices to curtail the detrimental impact of road-related runoff. Many unpaved farm lanes are channels for runoff of sediment and nutrients from adjacent fields into nearby streams, but runoff-associated impact of private farm access roads and field lanes has yet to be quantified. The sites chosen for this study, prior to the implementation of ESMPs, were funneling sediment-laden storm runoff into streams comprising the Kishacoquillas Watershed in Mifflin County, Pa. The objective of this project was to incorporate ESMPs on five private farm lanes in the watershed to determine whether severing this conduit and reconnecting natural drainage patterns would reduce the pollution associated with these lanes. The sites that were chosen were to serve as both field data collection points as well as demonstration sites for surrounding landowners. Sediment and nutrient runoff measurements from before and after project implementation were taken in an effort to document the effectiveness of the ESMPs that were implemented and to quantify any reductions in pollution resulting from these practices. An Environmentally Sensitive Maintenance two-day training developed by the Center was held at the beginning of the project and a one-day focused training at the end of the project to introduce agriculture professionals to these low-cost and effective practices and encourage their widespread use. The successful replication of these practices on farm lanes throughout the Chesapeake Bay Watershed should provide marked non-point source pollution relief for the Bay and its tributaries.

17. Key Words	18. Distribution Statement
Nutrient, sediment, environmentally sensitive maintenance, maintenance	No restrictions. This document is available from the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	32	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENTS

This project was made possible by the USDA's Conservation Innovation Grant Program, with matching support through the PA State Conservation Commission's Dirt and Gravel Road Maintenance Program.

The authors would like to extend their thanks to several people and organizations that have contributed to this study. The entire support staff of the Center for Dirt and Gravel Road Studies has been invaluable in implementing this project, especially Dave Creamer for project oversight, training, data collection, and help with this report and Tim Ziegler for data collection and help with this report. Special thanks to the Mifflin County Conservation District for selecting the sites and gaining cooperation from the landowners, as well as their cooperation and flexibility in collecting data and getting these projects on the ground. The continued cooperation of the landowners where these practices were implemented is also greatly appreciated.

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EXECUTIVE SUMMARY

Sediment laden runoff from over 20,000 miles of unpaved public roads is a significant documented source of stream pollution to the waters of the Commonwealth of Pennsylvania. The Center for Dirt and Gravel Road Studies (Center) at Penn State University has established Environmentally Sensitive Maintenance Practices (ESMPs) to reduce sediment pollution from unpaved roads, and advocates the use of these practices to curtail the detrimental impact of road related run-off. While the run-off associated impact of private farm access roads and field lanes is similar to the problems generated by public roads, this impact has yet to be quantified. However, just as public roads act as conduits to direct concentrated storm drainage to streams and their tributaries, many unpaved farm lanes are channels for runoff of sediment and nutrients from adjacent fields into nearby streams. The sites chosen for this study meet this criteria, and prior to the implementation of ESMPs were funneling sediment laden storm runoff into streams comprising the Kishacoquillis Watershed in Mifflin County, PA. The objective of this project was to incorporate Environmentally Sensitive Maintenance practices on 5 private farm lanes in the watershed to determine whether severing this conduit and reconnecting natural drainage patterns would reduce the pollution associated with these lanes. The sites that were chosen were to serve as both field data collection points as well as to be used as demonstration sites for surrounding landowners. Sediment and Nutrient runoff measurements from before and after project implementation were taken in an effort to document the effectiveness of the Environmentally Sensitive Maintenance practices that were implemented and to quantify any reductions in pollution resulting from these practices.

Projects were undertaken on five separate farm lanes during the summers of 2008 and 2009. Runoff samples were collected from each road both before and after implementation of ESM projects. A total of six data sets were planned on being collected from each of the five sites during distinct rain events, three sets prior to the implementation of the selected ESM practices and three sets after the practices were implemented at the project sites. The initial (pre-project) sample sets were collected during the Spring and Summer of 2007 and 2008 and the post-project sampling was performed during the Spring and Summer of 2009. In addition to flow rate, samples taken prior to the implementation of ESMPs were evaluated for Total N, Total P, and Total Suspended Solids, A number of factors existed at each site that had the potential to influence the sediment load of run-off samples that were beyond the scope of the study and the control of the research team. The most notable of these factors was the annual variability of tillage practices and crop rotations within the watersheds that drained to the data collection points. Therefore, in order to minimize these influences, data was collected, quantified and analyzed for flow reduction only during post-project sampling. Sediment and nutrient loads were then calculated based on

chemical values obtained from initial sample sets and a comparison of pre-project and post-project flow reduction (data).

The ESMPs that were utilized were selected for their suitability for each specific site and focused primary on the control of surface drainage through the reduction of concentrated run-off and the use of natural drainage patterns. The practices were also chosen for their economic feasibility, in order that they might be easily replicated on farm lanes at other beneficial sites. The following practices were implemented on the projects in order to achieve the above mentioned goals:

- Raising the Profile: raising the road elevation to restore natural drainage patterns;
- Crown or Cross-Slope: establishing a road shape that effectively sheds water from the road surface with ½" to ¾" of fall per foot of road width;
- Broad Based Dips: intentional watercourses across a roadway that convey water from the uphill ditch over the road surface to a discharge area and prevent drainage from flowing linearly on the road surface for long distances;
- Grade Breaks: elongated humps in the road surface designed to shed water to both sides of the road;
- Berm Removal: elimination of unnecessary high ground or road material (berms) adjacent to the road that retains water in the road corridor and creates an unnecessary down-slope road ditch;
- French Mattress: a structure consisting of clean/coarse rock wrapped in geo-textile fabric to allow water to pass freely through the roadbed; &
- Conveyor Belt Diversions: mine conveyor belts embedded into the road at an angle to prevent run-off from flowing lengthwise on the road and to direct concentrated surface drainage to a stable outlet on the down-slope side.

An Environmentally Sensitive Maintenance Training (ESM) two-day training was held at the beginning of the project and a one-day focused training at the end of the project. This comprehensive training developed by the Center for Dirt & Gravel Roads at Penn State, focuses on innovative and effective practices to reduce maintenance costs and sediment pollution from unpaved roads. They were held within the Kishacoquillas Watershed in the Spring of 2006 and again in late Summer of 2009. The target audiences of the trainings were those individuals actively engaged in production agriculture in the area. The objective of the training was to introduce agriculture professionals to these low cost and effective practices and encourage their widespread use. It is the contention of the staff of the Center for Dirt and Gravel Road Studies and a host of other conservation professionals that the successful replication of these practices on farm lanes throughout the Chesapeake Bay Watershed would provide marked non-point source pollution relief for the Bay and its tributaries.

1. INTRODUCTION

1.1 Program Background

In 1997, the Commonwealth of Pennsylvania recognized that a substantial contribution of sediment pollution to Pennsylvania streams was carried in runoff from dirt and gravel roads (*Figure 1.1*). In response to a statewide assessment conducted between 1994 and 1996 that documented evidence of stream pollution from unpaved roads, the Commonwealth established the Dirt and Gravel Road Maintenance Program [Program] within the State Conservation Commission [SCC] in 1997. The purpose of the Program is to provide a non-lapsing funding source with the objective of identifying the sources of sediment pollution generated by unpaved public roads and implementing cost-effective solutions. The Center for Dirt and Gravel Road Studies [Center] was established at the University Park Campus of The Pennsylvania State University in 2000 to support the SCC's Program. The Center identifies Environmentally Sensitive Maintenance Practices [ESMPs] for unpaved roads, teaches these practices to public and private road owners, and participates in an outreach assistance program for townships in the Commonwealth. The Center has conducted more than 140 two-day maintenance training sessions which have been attended by over 5,000 state and township personnel. A more detailed description of the program and its accomplishments to date can be found at www.dirtandgravelroads.org.

Figure 1.1: Many farm lanes act as conduits for sediment and nutrient runoff from nearby agricultural fields to streams.

1.2 Project Background

While the Dirt and Gravel Road Maintenance Program focuses on "publicly" owned roads, the Center recognizes that countless miles of private driveways, access roads, and farm lanes exist that present many of the same sediment pollution concerns. Farm lanes are of particular concern because in addition to runoff from the road surface, they regularly act as collectors of nutrient and sediment runoff from adjacent agricultural fields. Many farm lanes simply collect this runoff and transport it to the nearest drainage channel or stream. While many agricultural "best maintenance practices" exist to reduce erosion of soils from agricultural fields, few studies have considered the role that roads play as conductors of agricultural runoff. The ESMPs implemented in this project were designed to disconnect this "rural stormwater system" and to effectively reduce sediment and nutrient pollution while encouraging infiltration.

The goals of this study were to:

- Work with landowners to implement ESMPs on farm lanes in the Kishacoquillas Watershed, and to:
    - Reduce nutrient and sediment delivery to streams,
    - Improve the condition of farm lanes, and
    - Educate the landowners about the practices used.
- Evaluate the effectiveness of the projects using sediment and nutrient sampling.
- Provide training and documentation about projects to landowners within the project area.

Seven cooperating farm owners were identified within the Kishacoquillas Watershed. Members of the Mifflin County Conservation District and the Center for Dirt and Gravel Road Studies worked closely with these landowners to develop a maintenance plan for their farm lanes. The goal of each project would be to reduce the connectivity of the road drainage to the stream, while providing a more stable road for the landowner. The practices were implemented during the summers of 2007 and 2008 under the supervision of Conservation District and Center staff.

Sampling points for runoff were established on the field sites. Runoff samples were collected both before and after ESMPs project implementation. Runoff samples were evaluated to determine the total suspended solids, sediment, nitrogen, and phosphorus that were flowing in the road corridor and entering the stream. This sampling was used to evaluate the effectiveness of the projects in reducing pollutant transport to the streams.

The projects implemented in this study were used as "case studies" to educate additional landowners about ESMPs for farm lanes. The projects were also used to create technical documentation and training material that the Center will continue to use to educate both public and private entities about environmentally sensitive road maintenance.

1.3 Project Site Selection

Projects were completed on seven farm lanes in the Kishacoquillas Watershed. Five of the seven sites were selected on which to perform sampling of road related storm runoff both before and after the implementation of ESM practices. The sites were intentionally dispersed across the catchment of the Kishacoquillas Watershed to gain a representative cross section of the area with as much variation in soil types, agricultural practices, and localized weather events as possible. While an attempt was made to include representative variation in farming practices, many similarities still exist among the sites due to regional uniformities in agricultural markets and techniques. The farm sites chosen all practice no-till, rotational cropping techniques. Four of the five farm lanes traverse this rotational cropped ground. The fifth site is influenced by permanent grass pasture upslope of the project/sampling site.

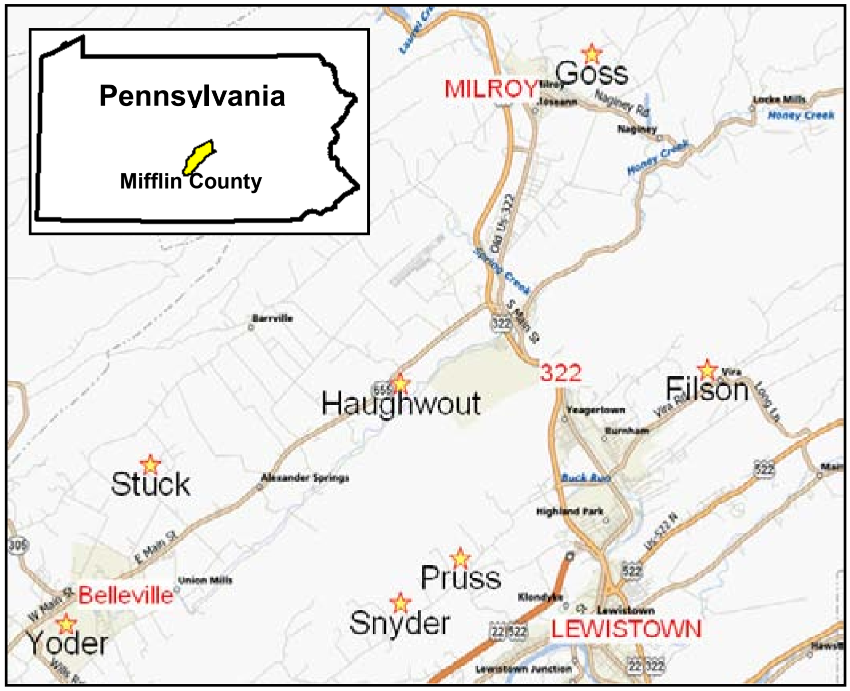

Figure 1.2: Location of each of the seven properties where ESM projects were installed on farm access lanes.

Of the 20 EQUIP-eligible farms that expressed an interest in participating in this study, only 3 of these farms were owned by Old Order Amish. Each site was visited and evaluated for research suitability by representatives of the Mifflin County Conservation District and the Center for Dirt and Gravel Road Studies. Unfortunately, none of the lanes on the Old Order Amish farms were found suitable for data collection. Therefore, no farms operated by Old Order Amish were included in this study. This is one potential shortfall of the site selection process. Mifflin County has among the highest density of Old Order Amish in Pennsylvania (approximately 3% of the county population, and a considerably greater percentage of the farm population). Since Amish are typically slower to adopt modern farming and conservation practices the majority still engage in traditional tilling practices. Therefore, it is reasonable to assume that greater reductions in stream sediment loads would be accomplished if ESM practices were incorporated on Amish farm lanes and field roads as well as on conventional farms.

2. EXPLANATION OF ESM PRACTICES

Environmentally Sensitive Maintenance practices used on the farm lanes were all designed to reduce sediment and nutrient pollution to the Kishacoquillas by preventing farm lanes from collecting and transporting sediment. A brief description of the ESM Practices used on these seven projects is presented below. Many of the practices have associated “Technical Bulletins” produced by the Center that describe each practice in detail. Any applicable bulletins are included in Appendix B.

Crosspipes and Turnouts: Turnouts (cutouts, bleeders) are intentional openings in the down-slope road bank where the downslope road ditch is outletted away from the road. Crosspipes are open structures placed under the road to provide an outlet for the water collected in the upslope ditch. One of the simplest and most effective ways to reduce the detrimental effect of road runoff is to attempt to mimic natural drainage patterns by providing more outlets for the drainage. More outlets along a road will result in less concentrated runoff at each outlet. This practice increases the potential for infiltration and decreases the distance that runoff is transported, effectively disconnecting the roadside drainage system from nearby streams.

Raising the Road: “Raising the road” is a technique used on roads that have become entrenched, or sunken, into the surrounding landscape. An entrenched road will collect and retain water from higher surrounding terrain, typically transporting it to the nearest stream. The practice of raising the road involves using fill material to elevate the road so that it is no longer entrenched. This practice reduces drainage connectivity and encourages sheet flow by eliminating the downslope ditch. In addition, the upslope ditch is elevated, which provides increased opportunity to drain the upslope ditch at more potential outlet locations, as well as provides fill for pipe cover and other drainage features.

Grade Break: A grade break is an intentional high spot in a lane that prevents water from flowing down the road surface by forcing it off to either side. Gradebreaks prevent water from building volume and velocity that will erode the road surface. Additional benefits of gradebreaks are that they provide cover for crosspipes, and will continue to function even after crown has been lost on the unpaved road surface.

Broad-Based Dip: A broad-based dip is a gradual dip and associated high spot installed diagonally across a road. The dip function similarly to a grade break to prevent water from flowing down the road, but differs from the grade break as it transports water from one side of the road to another. These structures function similar to crosspipes to outlet and disperse ditch flow from the road corridor. The bottoms of dips are typically reinforced to prevent erosion.

Conveyor Belt Diversions: Similar in function to a broad-based dip, belt diversions prevent water from flowing down the road and direct runoff to a stable filter area. They consist of a piece of mine belting attached to lumber and buried at an angle in the roadbed. The diversion is buried so that approximately 4” of belt protrudes from the road surface. This belt is flexible enough to allow vehicles to pass, but prevents water from flowing down the road.

Road Crown: Proper crown is a road’s first line of defense to effectively drain surface water. Effective road crown is a cross-sectional road shape that prevents water from flowing down the road and includes continuous fall, or slope, from the road center-line to the road edge, or ditch. Without proper crown, wheel tracks often form on the surface that can act as conduits for runoff.

French Mattress: Similar to a French Drain used for home construction, a French Mattress consists of clean stone wrapped in water-permeable separation fabric. The mattress is used in particularly wet areas and is placed under the road to provide support for the road while allowing the free movement of water through the road base.

Berm Removal: Unnecessary berms, or piles of earthen material, are present on the downslope side of many roads. This berm retains water in the road corridor and creates an unnecessary ditch that concentrates and transports runoff along the road. Simply removing this berm will eliminate the ditch, encourage sheet flow and infiltration, and reduce stream pollution.

Separation Fabric: A geotextile material used to reinforce and separate layers of soil. It is often used between different courses of road material to provide separation and support and increase road stability.

Underdrains: Underdrains are stone-filled trenches designed to collect subsurface springs and seeps in the road corridor. Underdrains increase road base stability by removing excess water. The result is less rutting, fewer potholes, and longer maintenance cycles. Underdrains also separate clean subsurface water from road runoff.

Headwalls and Endwalls: Headwalls and endwalls are constructed protection around the inlet and outlet of crosspipes and stream pipes. These structures prevent erosion around the pipe, support the road edge, and increase the flow capacity of the pipe by reducing turbulence.

Many of these practices have associated “Technical Bulletins” from the Center for Dirt and Gravel Roads that describe each practice in detail. Any applicable bulletins are included in Appendix B.

3. RUNOFF STUDY METHODOLOGY

Runoff sampling points were established on five of the seven field demonstration sites. Projects were also completed on the remaining two sites to collect visual and anecdotal evidence of runoff reduction and to have reserve sample sites should unforeseen problems arise on the selected farms. The same sample collection points on the five sites were maintained throughout the field sampling period to ensure that comparable water samples were being collected. At each site a 4” wide open grate NDS SPEE-D Channel Drain was installed on the lower end of the road section to be sampled. The drain extended across the entire road surface from ditch to ditch. The elevation of the drain was set to be lower than the road surface and parallel road ditches were plugged, effectively collecting all surface flow associated with the road. The individual sites were selected to cover the breadth of the watershed and to provide as much diversity with respect to soil type, recommended ESM practices, farming practices, etc.

The study would sample runoff from storm events both before and after ESM practice implementation to determine flow, sediment, and nutrient reductions for the five roads. When possible, three separate storm events were sampled at each site. The runoff rate for each event was determined by recording the time required to fill a bottle of a known volume. Runoff samples were taken and analyzed at a Penn State Institutes for Energy and the Environment Water Quality Laboratory for total suspended solids (sediment), nitrogen, and phosphorus. Multiple samples were taken for each storm event in an attempt to obtain a hydrograph for each site. Samples were taken at intervals of 0, 2, 4, 6, 10, 16, 23, and 30 minutes. All of the samples were analyzed by the Water Quality Laboratory for N, P and TSS following the protocols from "Standard Methods for the Examination of Water and Wastewater" a document traceable to Water Environmental Federation [WEF, 2005]. All raw sampling data are presented in Appendix D.

Figure 3.1: A sampling point is cleaned in preparation for a storm event after ESM practice implementation on Goss Lane.

Figure 3.2: A sample bottle of runoff, collected and to be analyzed for sediment and nutrients.

4. FIELD PROJECT WALKTHROUGHS

In order to maintain better continuity throughout this document, the site descriptions, project implementation, results, and discussion will be presented separately for each of the seven sites.

Site 1: Yoder Farm

Site Description, Yoder Farm

Yoder Farm

- **Location: 40°36'00"N, 77°43'55"W**
- **Sampling Point Watershed:**
  - **513 feet of farm lane drainage**
  - **2.9 acre watershed**
- **Soil Types:**
  - **Hagerstown Silty Clay Loam**
  - **Opequon Silty Clay Loam**

Additional Information for Yoder Farm

- Lane is straight (no turns) and runs perpendicular to contours with continuous downhill grade that increases as it approaches the sample point.
- Lane is maintained solely by the landowner.
- Lane is typical (very representative) of the farm lanes, field lanes, and access roads found on working agricultural operations in the area, having minimal, if any, effective road shape and few, if any, intentional drainage features to address road run-off and/or transport of storm water.
- Land use in the watershed – rotational crops of corn and hay (alfalfa).
- Watershed comprised primarily of one soil type, Hagerstown Silty Clay Loam, with 44% of the land area having slopes of 3% to 8% and 48% of the area with slopes of 8% to 15%. The balance of the area is Opequon Silty Clay Loam between 15% and 25% slope. The majority of the soils in the watershed have a moderate run-off potential.
- Approximately 20% of ground is covered by crop residue after harvest.
- A previously constructed stormwater swale exists that collects drainage from the eastern roadside channel (ditch) and directs it to flow toward Kishacoquillas Creek.
- ESM practices (features) that are inexpensive to install and require minimal maintenance can be incorporated on this road with a high potential of both reducing both the long term maintenance needs of the road as well as the sediment load delivered to the stream

ESM Practice Implementation, Yoder Farm

Pre-Project Problems: The Yoder farm lane had no drainage control features and had a very poor surface shape (lacked crown). Water from the road and surrounding field was carried on the road surface and directed into the barnyard area. The water was causing erosion and picking up additional nutrients in the barnyard area before continuing past the farm into the stream.

Figure 4.1: Grass is beginning to grow through the erosion matting in the newly constructed roadside swale.

Implemented ESM Practices: The original plan specified the installation of two new 15” crosspipes, complete with headwalls and endwalls. The intent was to divide the drainage coming to the lane and disperse it as evenly as possible into the surrounding fields. However, the landowner was greatly concerned about any additional water entering the crop fields downslope of the road. A compromise was reached that eliminated the crosspipes in favor of a more traditional approach with an emphasis on surface water control. Therefore, in an effort to employ basic ESM principles, a new grass lined swale was constructed up-slope and parallel to the road to capture water that had been previously entering the roadway and running down the surface of the road. The new swale was connected to an existing drainage feature originally built to direct field run-off away from the house and barn. PennDOT 2RC aggregate material was added to the road surface to elevate it above the new swale and to establish center-crown. Two Grade Breaks were installed on the lane to prevent water from flowing down the road surface and to disperse road surface drainage evenly into the downslope field.

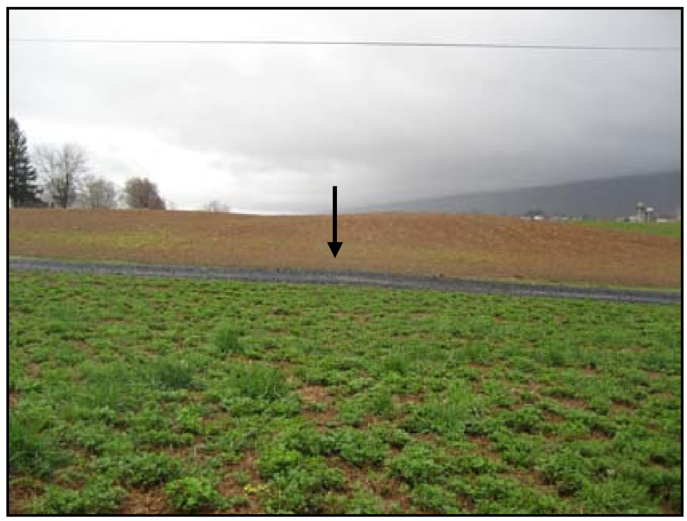

Figure 4.2: Although gradebreaks are difficult to see in still images, notice the slight rise in road elevation in the center of the image.

Results and Discussion, Yoder Farm

By preventing sediment laden field drainage from discharging directly into the main stem of Kishacoquillas Creek, the Environmentally Sensitive Maintenance Practices (ESMPs) employed on the Shawn Yoder farm lane have significantly reduced the negative impact of non-point source pollution from this farm.

Prior to the implementation of the ESMPs the field upslope of the lane was cropped to the road edge and run-off spilled onto the road surface. Wheel tracks on the lane intercepted sheet flow from a 2.9 acre watershed of rotationally cropped ground and channeled much of this drainage to an intentionally constructed swale through a pasture which terminates at Kishacoquillas Creek.

Figure 4.3: 2009 image of Yoder Farm lane and grass-lined swale.

The construction of a grass-lined swale between the field and the road, and the installation of a crosspipe to redirect this flow away from the stream and into a stable floodplain is largely responsible for a marked reduction in post project sediment delivery to the stream. This combined with a slight elevation of the road surface and the use of two grade breaks has effectively severed the conduit and now allows field drainage to infiltrate into the ground while also allowing existing vegetation to filter transported sediment.

Three storm events were sampled before construction including a 0.54" event on 4/25/07, a 0.12" event on 7/5/07, and a 0.45" event on 8/9/07. Average runoff rates at the sample point for those three events were 0.2, 0.1, and 0.1 Liters per minute, respectively with an average of 5.0mg/L of N and 0.8mg/L of P coupled with an average of 2,356mg/L of TSS. After ESM practice implementation, the site was visited during four storm events including a 0.3" event on 4/3/09, a 0.4" event on 5/4/09/, a 0.18" event on 7/29/09, and a 1.0" event on 7/31/09. The two July events did not yield any runoff at the sample point. This is attributed to the heavy crop cover and water use by plants during the peak of the growing season.

Due to the elimination of the proposed crosspipes in the original road plan, the amount of runoff at this site was not noticeably affected as evidenced by a 1% relative increase in volume. However, with the installation of the grass lined swale upslope of the road that intercepts field sheet flow, combined with road surface improvements that shed drainage that previously flowed down the road, a 92% decrease in sediment has been achieved through the use of ESM Practices.

Site 2: Goss Farm

Site Description, Goss Farm

Goss Farm

- **Location: (40° N, 77° W)**
- **Sampling Point Watershed:**
  - **280 feet of farm lane drainage**
  - **6.7 acre watershed**
- **Soil Types:**
  - **Edom Silty Clay Loam**

Additional Information for Goss Farm

- Lane is strait (no turns) and runs along the contours (parallels stream for most part).
- Lane is steeper at the top and grade lessens in flood plain along the stream.
- No notable drainage features pre-project.
- Lane has direct drainage discharge into unnamed tributary of Honey Creek.
- Farm lane acts as direct conduit to the stream for up-slope surface flow from pasture fields, the drainage from the road surface, and a significant volume of sub-surface water that daylights at the up-slope (eastern) road edge.
- Land use in the watershed is permanent pasture.
- 96% of the watershed comprised of one soil type, Edom Silty Clay Loam, with 75% of the ground from 8% to 15% slope. Edom Silty Clay Loam has a slow infiltration rate and a higher than average run-off rate.
- No crop is conventionally harvested on this ground, and the crop residue is essentially 100%.

ESM Practice Implementation, Goss Farm

Pre-Project Problems: The Goss Farm lane cuts across a small wetland stream channel. The road creates a dam on the channel and funnels the water through two concrete pipes. Because of the large amount of surface and sub-surface water present, the road base in this section of lane is always wet and susceptible to potholes and rutting, resulting in a need for higher than normal re-graveling rates and more frequent surface maintenance. Farm equipment utilizing the road has historically created ruts and disturbed settled sediment, allowing the sediment to then drain with road surface flow. Drainage is carried on the road surface and in roadside ditches until it discharges into the stream near the stream crossing.

Figure 4.4: This is the wetland stream crossing on the Goss Farm. Notice that BEFORE, water is dammed up against the right side of the road and funneled through a single pipe. The AFTER picture shows the French mattress. White pipes are visible and highlighted with black arrows. Notice also that the road's "lowpoint" has been moved away from the stream so runoff is forced to leave the road before nearing the channel

Implemented ESM Practices: A 120' long French Mattress was installed adjacent to the stream crossing on the Goss Farm lane. The mattress will provide base support for the road surface while allowing seasonally variable amounts of water to move as needed through the road profile. In addition, two 12" pipes were installed through the mattress to provide additional flow relief for future flood events that are likely to occur. The two existing concerte pipes were left in place and retrofitted with headwalls and endwalls. An additional advantage of the fill imported for the French Mattress is that it effectively moves the "low point" in the road profile away from the stream in both directions. Runoff that was formerly flowing down the road and discharging directly to the stream is now turned out approximately 100' on either side of the stream crossing. A gradebreak was also installed on the road prior to the road disending into the flood plain to further insure that water would not flow down the road surface.

Figure 4.5: 2009 image of the improved Goss Farm Lane.

<u>Results and Discussion, Goss Farm</u>

The activities on the Goss Farm clearly have had significant impact on water quality in this study. Before the road project, water emerging from a spring in the adjacent pasture would enter the road way and be conducted directly into the unnamed tributary to Honey Creek. The French mattress installed here allows the flow from the spring to pass through the base of the road without entering the roadway, keeping the road surface dry and mud free. Further, the roadway was elevated by the addition of aggregate which also served to isolate the road surface from the stream.

From the Landowner:

"The lane is definitely better. There is no longer an issue with the whole road flooding, and it no longer ruts when we cross it with heavy equipment. We can use the road year-round where we could not before. Also, water does not run down the road and into the stream like it used to."

- Linda Goss, 10/2009

Before the ESM project, a notable sediment plume was observed in the stream by those collecting data during storm events. The plume originated at the point where runoff that had been running down the farm lane discharges into the stream. Three storm events were sampled before construction including a 0.54" event on 4/25/07, a 0.21" event on 8/21/07, and a 0.67" event on 12/23/07. Average runoff rates at the sample point for those three events were 6, 3, and 24 Liters per minute, respectively with an average of 2.2 mg/L of N and 1.2 mg/L of P coupled with an average of 633mg/L of TSS. After ESM practice implementation, the site was visited during three storm events including a 0.24" event on 04/01/09, a 1.02" event on 04/03/09, and a 0.51" event on 05/04/09. In all cases, no water was observed flowing onto the road way and to the stream. Despite the fact that the storm events were more intense than pre-project events, no samples could be taken after the implementation of ESM practices on the Goss Lane. It was observed that the road no longer acted to collect and transport water to the stream.

From these observations the reduction of flow, sediment, Nitrogen, and Phosphorus load reductions resulting from the ESM practices on this lane is assumed to be 100%.

Site 3: Stuck Farm

Site Description, Stuck Farm

Stuck Farm

- **Location: 40°38'15"N, 77°41'42"W**
- **Sampling Point Watershed:**
    - **1,334 feet of farm lane drainage**
    - **4.5 acre watershed**
- **Soil Types:**
    - **Hagerstown Silt Loam**
    - **Hagerstown Silty Clay Loam**

Additional Information for Stuck Farm

- Lane is strait (no turns) and is aligned perpendicular to the contours.
- Lane has continuous fall to sample point, but is steeper at the bottom.
- No notable drainage features pre-project, and road was lower than the surrounding terrain.
- Lane drains to wetland area with multiple spring seeps that comprises the headwater of an intermittent tributary to Kishacoquillas Creek.
- Lane acts as direct conduit for run-off to the stream from rotationally cropped corn and hay fields.
- Soil types are Hagerstown Silt Loam or Hagerstown Silty Clay Loam with between 2% and 8% slope. These soils have a moderate infiltration rate with a moderate run-off potential.
- Approximately 60% of ground is covered by crop residue after harvest.

ESM Practice Implementation, Stuck Farm

Pre-Project Problems: The Stuck Farm lane was the proto-typical "entrenched road" that collected runoff from the surrounding fields, trapped it on the road surface, and transported it down the hill to the stream. This trapped drainage caused constant erosion problems for the landowner in addition to acing as a conduit for nutrients and sediment into the stream.

Implemented ESM Practices: Several practices were used to prevent water from concentrating on this lane and to encourage sheet flow. A total of 420 cubic yards of shale fill was imported in order to raise the elevation of the entire lane an average of 12" in order that the road was no longer "entrenched." An additional 6" of PennDOT 2RC aggregate was then used to surface the road. Effective road shape, or cross-slope, was established on the road surface. Center-crown is the predominant shape, although some of the lane was out-sloped. Approximately 600 feet of roadside berm that was restricting sheet flow and confining runoff to the lane was removed to

Figure 4.6: BEFORE the project, the entrenched farm lane collected field runoff and transported it down the road surface. Many practices were implemented to elevate the road, encourage infiltration, and insure that runoff could no longer use the road as a flow corridor.

restore natural drainage patterns. Four broad-based-dips were installed over the length of the lane. These dips will insure water does not flow down the road and by-pass potential outlets, even if ruts re-form on the road surface.

<u>Results and Discussion, Stuck Farm</u>

Prior to the installation of ESMPs the concentrated field/road drainage collected at an area used to store silage bags. Open silage bags produced leachate that mixed with road drainage and sediment from equipment ruts before flowing to the stream channel. A cropping regime has been typically employed that leaves 40% of the ground surface in the watershed upslope of the road exposed through winter and early spring. Since the road elevation has historically been lower than the surrounding terrain, the lane has transported sediment and nutrients to the silage storage area and the stream channel year round. By dispersing the field drainage post project and eliminating a concentrated discharge at the silage bags this situation has been corrected.

Figure 4.7: 2009 image of the improved Stuck Farm Lane.

The drainage patterns on this site were manipulated by using a combination of ESMPs, including raising the road profile, the installation of four broad-based dips, selective berm removal, and outsloping of the road surface at strategic locations. The result was to redirect the field drainage to existing swales and flow paths that required a longer, more subtle meander before reaching the floodplain of the stream. Storm water falling on, or directed to, the road no longer flows on the road and into the stream as was documented prior to the implementation of Environmentally Sensitive Maintenance Practices.

Three storm events were sampled before construction including a 0.54” event on 4/25/07, a 0.45” event on 8/9/07, and a 0.54” event on 10/26/07. Average runoff rates at the sample point for those three events were 1.4, 2.4, and 0.7 Liters per minute, respectively with an average of 5.8mg/L of N and 0.7mg/L of P coupled with an average of 893mg/L of TSS. After ESM practice implementation, the site was visited during two storm events including a 0.18” event on 7/29/09, and a 1.0” event on 7/31/09. No runoff was flowing to the sample point during the 0.18” event. Runoff during the 1.0” storm event was greatly reduced compared to pre-project runoff levels.

The Stuck Farm lane showed a 96% reduction in flow, and a >99% reduction in sediment after ESM practice implementation.

Site 4: Haughwout Farm

Site Description, Haughwout Farm

Haughwout Farm

- **Location: 40°37'36"N, 77°40'31"W**
- **Sampling Point Watershed:**
  - **410 feet of farm lane drainage**
  - **2.8 acre watershed**
- **Soil Types:**
  - **Hagerstown Silt Loam**
  - **Hagerstown Silty Clay Loam**
  - **Hagerstown Rock Outcropping**

Additional Information for Haughwout Farm

- Lane is not strait in project area (has turns) and runs diagonal to contours. It is steeper at the top where it leaves the fields and less steep at the sample point.
- A forested buffer lies between the fields at the top of the hill and the sample point – the road is primary conduit for field drainage to the sample point.
- If road had any drainage features pre-project, none were functioning.
- Land use is 80% rotational crops and 20% forested slope.
- 70% of land is Hagerstown Silt Loam with 2% to 8% slope, 10% is Hagerstown Silty Clay Loam with 3% to 8% slope and 20% is Hagerstown Rock outcrop with 8% to 25% slope. All of these soil types have a moderate infiltration rate with a moderate run-off potential.
- Approximately 60% of the ground is cover by crop residue post harvest.

ESM Practice Implementation, Haughwout Farm

Pre-Project Problems: The Haughwout Farm lane had been reduced to two deeply incised wheel tracks from years of erosion and use. The wheel tracks functioned to collect runoff from the surrounding fields and transport it to the nearby stream, by-passing many potential outlet points on the way.

Figure 4.8: The existing farm lane with incised wheel tracks.

Implemented ESM Practices: PennDOT 2RC aggregate was used to fill and re-profile the incised wheel tracks on the lane.

Geotextile separation fabric was used over much of the lane to reinforce the road base and provide support for a new road surface. In addition the geotextile fabric will help provide weight distribution for regular heavy equipment use. Center-crown was established for the entire project length in order to shed water. Several surface drainage control features were used to insure water would not run down the road surface even if crown was lost. Two conveyor belt diversions were constructed and installed and two broad based dips were also employed to control surface runoff. Stone underdrain was installed to capture a small spring that had been saturating part of the road. The underdrain was directed under the road and outletted into a wooded area.

Figure 4.9: A conveyor belt diversion is being installed across the road that will allow traffic to pass while diverting water off the road surface.

Figure 4.10: The outlet of the stone underdrain is shown here just after installation. The underdrain collects clean subsurface water before it inters the road area.

<u>Results and Discussion, Haughwout Farm</u>

The ESM practices that are demonstrated on the Haughwout Farm include the use of conveyor belt diverters and the restructuring of the farm lane with additional aggregate to move water off of the lane and discharge it into adjacent fields. As with the lane at the Raymond Snyder Farm, this road is used strictly for field access. The road is not graded, does not receive winter maintenance, and receives less routine maintenance than those lanes at other sites that also serve as driveways or through roads. Therefore, belt diverters were chosen for this application because these structures will continue to function even as the shape of the road surface changes over time, and they represent a longer term, less maintenance intensive, method to address road related drainage issues than do many alternative approaches.

Three storm events were sampled before construction including a 0.20” event on 11/26/07, a 0.67” event on 12/23/07, and a 0.17” event on 1/11/08. Average runoff rates at the sample point for those three events were 3.9, 8.5, and 5.6 Liters per minute, respectively with an average of 2.3mg/L of N and 0.8mg/L of P coupled with an average of 4,702mg/L of TSS.

This site was visited on 7/31/09 during a storm event that was 5 to 6 times larger than an event that would have produced collectable run-off prior to the implementation of ESMPs. At the time of the visit no water was entering the sampling point. Based on this observation in relation to the magnitude of the rain event, it was concluded that no additional sampling from this site would be undertaken.

The current rotational cropping scheme being employed leaves approximately 40% of the ground free of crop residue during the winter and early spring. Therefore, the ESMPs will function to reduce the sediment loading of the stream year round. From these findings the reduction of sediment, N and P load to the stream is assumed to be 100%.

Site 5: Snyder Farm

Site Description, Snyder Farm

Snyder Farm

- **Location: 40°36'05"N, 77°37'53"W**
- **Sampling Point Watershed:**
  - **810 feet of farm lane drainage**
  - **3.2 acre watershed**
- **Soil Types:**
  - **Edom-Weikert Complex**
  - **Ernest Silt Loam**
  - **Berks Shaley Silt Loam**

Additional Information for Snyder Farm

- The lane above the sample point runs up and down the hill, perpendicular to contours.
- The land use is no-till rotational crops.
- Approximately 80% of the ground is covered by crop residue post harvest.
- The lane has direct impact on the receiving stream and discharges to Buck Run, a lower end tributary to Kishacoquillas Creek.
- The sample collection point is located on the section of lane north of the stream crossing.

ESM Practice Implementation, Snyder Farm

Pre-Project Problems: Like many of the other lanes described before, the Snyder Farm lane had become lower than the surrounding fields and acted as an entrenched conduit for field drainage. The road collected runoff from fields on both sides of the stream and funneled it to a ford crossing.

Figure 4.11: The existing lane funneled runoff to the stream at the tree line in the background.

Figure 4.12: Farm runoff collected by the farm lane is shown entering a Kish tributary during a rain event.

Implemented ESM Practices: Approximately 400 tons of shale fill were imported and used to raise the elevation of the lane on both sides of the stream. A total of six conveyor belt diversions were installed on both sides of the stream to prevent water form re-establishing former flow channels down the road surface and into the stream. Two broad-based dips were also installed at strategic locations with suitable outlets to further insure water will be diverted from the road area.

Figure 4.13: A conveyor belt diversion, installed before the ford crossing, insures runoff is diverted before it can reach the stream.

Figure 4.14: Three conveyor belt diversions can be seen in series on the hill slope leading to the stream at the tree line.

Results and Discussion, Snyder Farm

The lanes on the Raymond Snyder Farm that were chosen for this study are strictly field access roads that lead to pastures and crop ground north of a ford stream crossing on Buck Run. The sections of road that were chosen lay perpendicular to the stream and discharged sediment laden field run-off directly to the stream at the site of the ford prior to the use of ESMPs.

For reasons similar to those used on the Haughwout Farm, conveyor belt diversions were selected for use at this site. The Snyder farm lane was also built up with imported shale material to elevate it higher than the surrounding fields, so the road would no longer function as a storm water channel for field run-off. Both of these practices incorporate basic and practical technologies that can be performed by the landowner, if desired, and are easily repeatable at similar problem locations. While ESMPs were implemented on the road on both sides of the stream crossing, and therefore effectively mitigated sediment delivery from two former discharge points, sampling was done only on the portion of road north of Buck Run.

On the lane entering the farm from SR4013 large volumes of sediment laden run-off could be witnessed flowing down the lane and discharging directly into a tributary of Buck Run during the same post project rain events that yielded too little flow to measure at the sampling point less than a quarter of a mile away. Sediment plumes are no longer visible in the vicinity of the ford crossing.

The landowner has already seen a significant savings in time and material needed to maintain the lane where the project was completed. He has plans to sell timber from the woods north of the project site in the near future and he plans to use ESM practices on his main entry road once the timber harvest is complete.

> **From the Landowner:**
>
> *"I am pleased with the structures. As far as run-off they are doing their job and there is no washing on the road. I especially notice how well they are working on the back on the hill, on the steep part across the creek. Almost every other year we would have to fill that section with truck loads of shale, and it doesn't look like we'll have to do that anymore. The approach leading from the barn to the creek is holding up much better also. There has definitely been an improvement in run-off. I'm thinking about using similar structures on my front lane that continues to scour during rainstorms."*
>
> **- Ray Snyder, 11/2009**

Two storm events were sampled before construction including a 0.54" event on 4/25/07, and a 0.75" event on 6/12/07. Average runoff rates at the sample point for those two events were 1.2, and 9.8 Liters per minute, respectively with an average of 7.6mg/L of N and 2.3mg/L of P coupled with an average of 3564mg/L SS. After ESM practice implementation, the site was visited during two storm events including a 0.18" event on 7/29/09, and a 0.4" event on 5/4/09. No runoff was flowing to the sample point during the 0.18" event. Runoff during the 0.4" storm event was greatly reduced compared to pre-project runoff levels.

The Snyder Farm lane showed a 99% reduction in flow, and a >99% reduction in sediment after ESM practice implementation.

Site 6: Pruss Farm

Site Description, Pruss Farm

Pruss Farm

- **Location: 40°36'46"N, 77°36'41"W**
- **Sampling Point Watershed:**
    - **225 feet of farm lane drainage**
- **Soil Types:**
    - **Edom-Weikert Complex**
    - **Atkins Silt Loam**

Additional Information for Pruss Farm

- No rain event runoff sampling done at this site.
- The site was selected and used for sampling with the Rainmaker.
- Visual observations regarding changes in run-off patterns were observed and recorded by the landowner.

ESM Practice Implementation, Pruss Farm

Pre-Project Problems: The Pruss Farm lane was a constant source of maintenance due to poor surface material and the tendency of runoff to flow down the surface of the road.

Figure 4.15: The existing lane just before construction.

Implemented ESM Practices: Because this lane is the main farm access to the public road, and the existing road surface was composed of poor quality material, a decision was made to use a quality PennDOT 2A aggregate to surface the road and establish the needed crown. This will result in a more durable driving surface and will provide functional aggregate when doing future maintenance grading. The aggregate was placed on a layer of separation fabric in the flat wet area around the stream crossing to support traffic loads and to keep the quality material from migrating into the soft sub-base. Two grade breaks were installed to prevent water from flowing down the steeper part of the lane and eroding the new surface.

The Pruss Farm lane was not used for rainfall sampling.

Figure 4.16: A broad-based dip is being constructed just before a steep part of the lane. The dip will divert water into the field instead of allowing it to flow down the road.

Figure 4.17: The same broad-based dip can be seed in action during a rain event.

Results and Discussion, Pruss Farm

Figure 4.18: 2009 image of improved surface and gradebreaks on Pruss Farm lane.

Prior to performing Environmentally Sensitive Maintenance on the lane entering the Pruss Farm from SR4013, storm run-off would flow in the wheel ruts of the lane from an area near the house and barn for a distance of more than 600' and discharge directly into the main stem of Buck Run. Along a significant length of the road lower ground exists adjacent to the road shoulder, but suitable outlet locations were not being utilized because the wheel depressions were lower than the shoulder.

The main focus of the project was to install two grade breaks on the surface of the road to correct the situation and shed storm flow from the road before reaching the stream. A Grade break is a practical surface maintenance structure that creates a relatively short reverse grade on the roadway which causes drainage to spill laterally off of the road at a predetermine outlet location. The feature is similar to a rolling grade dip routinely used in trail maintenance.

In addition to the two grade breaks a headwall and an endwall were installed at the existing stream culvert to prevent further erosion of the road bank at the road/stream interface.

No rain event sampling was done at this site, because a large portion of the sediment delivered to the stream pre-project was coming directly from the road surface and not from the surrounding farm land. The site was better suited to evaluate the potential reduction in road generated run-off with the use of ESMs using the Rainfall Simulator, and therefore, was selected for use in this portion of the study. A more detailed description of the Rainfall Simulator Process is attached as Appendix A. The data gathered from this test are also included in this report.

Even with the absence of rain event sampling, anecdotal evidence of flow reduction and sediment delivery was observed. Farm owner and local conservation district employee, Kadie Pruss, has commented on and confirmed a significant reduction in water flowing on the road surface and has seen no sediment plumes at the stream crossing as was previously noted.

Site 7: Filson Farm

Site Description, Filson Farm

Filson Farm

- **Location: 40°30'11"N, 77°32'09"W**
- **Sampling Point Watershed:**
  - **420 feet of farm lane drainage**
- **Soil Types:**
  - **Edom Silty Clay Loam**
  - **Philo Silt Loam**

Additional Information for Filson Farm

- No runoff sampling done at this site.

ESM Practice Implementation, Filson Farm

Pre-Project Problems: The Filson Farm lane, although relatively flat, still collected water in the road and transported it to the stream. There were no surface drainage features and the road surface was in poor condition. This was a concern of the landowner, as this lanes serves as the main access to the public road.

Figure 4.19: The existing lane just before construction carries water in the wheeltracks to the bridge in the distance.

Implemented ESM Practices: Like the Pruss Farm lane, a few simple practices were employed to improve the road surface and control surface drainage. 2A aggregate was used to establish crown in the road to shed water to the grass area on either side. Two Grade Breaks were installed, one on each side of the stream crossing, to in sure that water would not be able to flow down the new road surface and reach the stream. The Filson Farm lane was not used for rainfall sampling.

Figure 4.20: The gradebreak pictured here sheds water from the road surface, preventing it from flowing to the bridge and stream in the background.

Figure 4.21: The improved road surface has a good shape and in resistant to traffic and erosion.

Results and Discussion, Filson Farm

Figure 4.22: 2009 image of the improved surface and bridge on Filson Farm lane.

No rain event sampling was performed at the Filson Farm. However, the landowner granted permission to do a project at this site during the initial site selection phase. Therefore, ESMPs were installed on the lane as a reserve site in the event that unforeseen circumstances prevented data collection from any of the other project sites. Five hundred and ten feet (510’) of farm lane was included in the project area. Environmentally Sensitive Maintenance Practices were incorporated on the road on both sides of the stream crossing. 2A aggregate was used to rebuild the road surface and provide material to reshape the crown and then be able to maintain in the future. Broad based dips where constructed to direct water across the lane and Grade Brakes where installed to assure that water would no longer follow the wheel tracks increasing the effective life of the crown. Considering that the surrounding land use was either maintained yard or permanent pasture, the project was very effective at reducing road sediment loss to the stream. Prior to the project the area around the wooden bridge surface was severely eroded. Since the road surface drainage features where installed the area around the bridge is very stable with little aggregate loss.

5. EDUCATION AND OUTREACH

One of the goals of this project was to use the field sites as educational tools. This was done through landowner interactions, classroom trainings, and project brochures.

The implementaiton of projects provided education directly to the cooperating landowners. As can be seen in the landowner quotes in the dicussion above, the participants in this project have developed an appreciation for the reduced maintenance costs and sediment generation on their farm lanes.

Two classroom training sessions were held in Mifflin County during this project. The first was the Center's two-day Environmantally Sensitive Maintenance for Dirt and Gravel Roads training. This comprehensive training is directed towards road maintenance professionals to advocate practices to reduce maintenance costs and sediment pollution. This training was held on April 11, 2006 in Lewistown, Pa.

Figure 5.1 Center Staff presents Environmentally Sensitive Maintenance for Farm Lane Techniques to Mifflin County Landowners on 9/29/09.

A second one-day training was also held for the benefit of local landowners. This session incorporated a walkthrough and discussion of the seven farm lanes that were studied as part of this project. The training was tailored to educate local farm owners about better ways to maintain their lanes and access roads. This training was held on September 29, 2009 in Milroy, Pa.

In addition to direct education efforts, several educational documents were produced. These "Worksite in Focus" documents highlight specific projects in detail. They provide information about what was done on each project, why it was done, the benefits, and the costs. These documents will be made available on the Center's website and will be used in the Center's ongoing educational efforts. The documents are available in Appendix C.

6. PROJECT SUMMARY

The objective of this project was to apply and evaluate the effectiveness of ESM practices in reducing sediment and nutrient loading of surface waters by farm lanes that were directly conducting run-off from surrounding farm fields to adjacent streams. All of the sites in this study are located in the Kishacoquillas Watershed in Mifflin County, Pennsylvania. Because of the disparity in runoff collection parameters, i.e. differences in the time of year, crop cover, crop maturity and magnitude of the rain events, the study relies heavily on averaging the flow, N, P, and TSS concentration data for these analyses. Further, based on factors beyond the control of the research team such as annual variability in the application rates of organic and inorganic fertilizers, the variability in the intensity of rainfall events resulting in more or less impact erosion, and the limited time frame available for post construction sampling, only the flow and TSS data were utilized in the comparison analyses for load reduction.

6.1 Site Summaries

In addition to other criteria, sites selected from the initial group of twenty willing participants were chosen to provide as wide a representation of agricultural operations in the Kishacoquillas Watershed as possible. This deliberate choice is represented in Figure 6.1 which

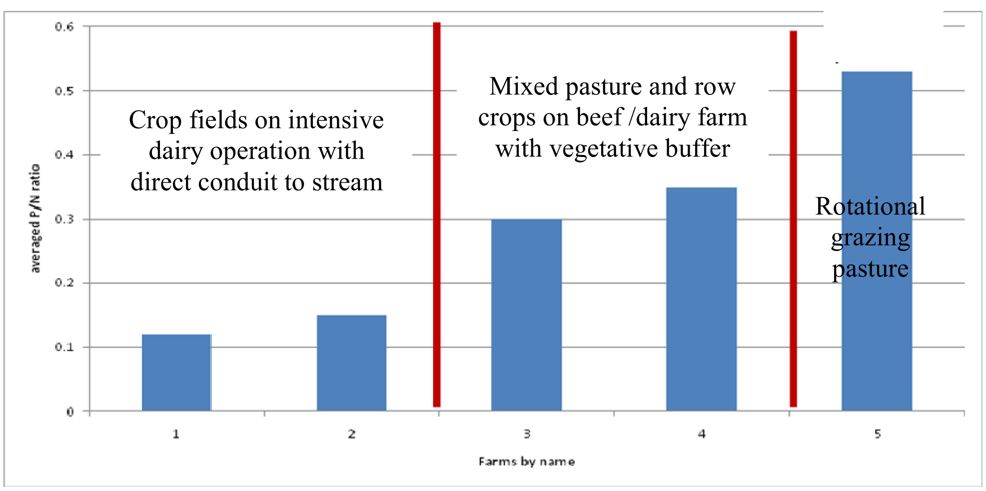

Figure 6.1. P/N ratio for the five participating farms, sampled watersheds.

correlates the measured P/N ratio to the agricultural/conservation practices and road alignment in the catchment at each site.

From this figure, the two farms that had both a high animal density per acre and the most direct conduit from the farm field to the sample point both possess a measured P/N that closely approximates the P/N ratio for cattle manure, as might be expected on an animal intensive central

Pennsylvania dairy farm where manure is spread on a limited amount of production acreage. The remaining three farms showed an appreciable reduction in nitrogen in the runoff. The Haughwout farm, while an animal intensive dairy operation, possesses a vegetated forest buffer between the crop fields and the sample point, affecting some of the overland sheet flow at this site. Both the Snyder farm and the Goss farm are beef cattle operations that utilize a rotational grazing system to feed their stock throughout the growing season. The catchment that comprises the research area at the Goss farm is located entirely within permanent grass pasture, which likely explains the very low N to P ratio at this site. The catchment at the Snyder farm encompasses no-till rotationally cropped small grain fields with some permanent grass pasture. This combination, in conjunction with high crop residues, is likely why the N to P ratio at the Snyder farm falls between the pure pasture beef scenario and the intensive managed dairy operations. On the dairy farm with a vegetated buffer and on the beef farm with a mix of crop and pasture ground the nitrogen is lower than the intensive dairy farms by almost a factor of two. On the beef operation where the entire watershed is in pasture, the reduction in nitrogen is close to a factor of four smaller than the heavily fertilized fields with a direct pathway to the adjacent streams.

All five of the farms represented a contributory influence of sediment as well as N and P to the adjacent streams as detailed in the above report. Based on the flow and TSS, the Goss and Haughwout farms exhibited a total elimination of flowing water from the farm lanes on which the ESM practices were implemented. These observations were based upon site visits during rain events which were all larger than the 0.12 inch event, which was established in the pre-construction sampling as the threshold for water collection at all of the sampling points across the Kishacoquillas Watershed. The practices implemented on the Stuck and Snyder farms were likewise estimated as reducing the flow by greater than 99%. The Yoder farm was the only site that exhibited an appreciable flow during our post-construction sampling. Recorded data showed negligible flow reduction from the implemented ESM practices. An analysis of the farm lane maintenance practices revealed that during the past winter, snow plowing activities had eliminated crown from the road thus allowing more of the flow to continue to follow the farm lane. However, the TSS measured in the runoff was reduced by 92%. This is likely the result of the newly installed grass lined swale.

The implications of this study support the observation that the ESMPs that are fostered by the Commonwealth's Dirt and Gravel Road Maintenance Program are effective measures to mitigate sediment movement into streams adjacent to roads. This study would support a greater than 95% overall reduction in sediment and nutrients transported from farm fields via farm lanes.

6.2 Overall Sediment, Nutrient, and Phosphorus Summary

The predicted annual total pounds of waterborne sediment (TSS), pounds of nitrogen (N) and pounds of phosphorus (P) delivered to the receiving streams from the sites in this study can be estimated using data collected during the study in conjunction with data and information from outside sources.

According to data from the National Climatic Data Center (NCDC) cooperative weather station at Milroy, Pennsylvania at 40.73ºN 77.63ºW and reported on Worldclimate.Com, Mifflin County receives approximately 37.3 inches of annual rainfall. A fair estimate of anticipated annual runoff from agricultural fields of this nature in a humid region of the U.S. (receiving >800mm of rain/yr) would be approximately 15% of the total annual rainfall [Elrashidi et al., 2003]. This figure is in agreement with data reported by the NRCS and derived using the EPIC model for 1997 NRI cropland sample points (see figure 6.2). By using this formula the anticipated annual runoff from a representative average of fallow agricultural ground (tilled soil or soil not under crop with no existing cover crop), ground under crop, and permanent pasture in Mifflin County, PA would be 5.6" of rainfall. The total runoff volume can then be used to determine the sediment, N and P lost using the average concentrations observed of the constituents found in the study.

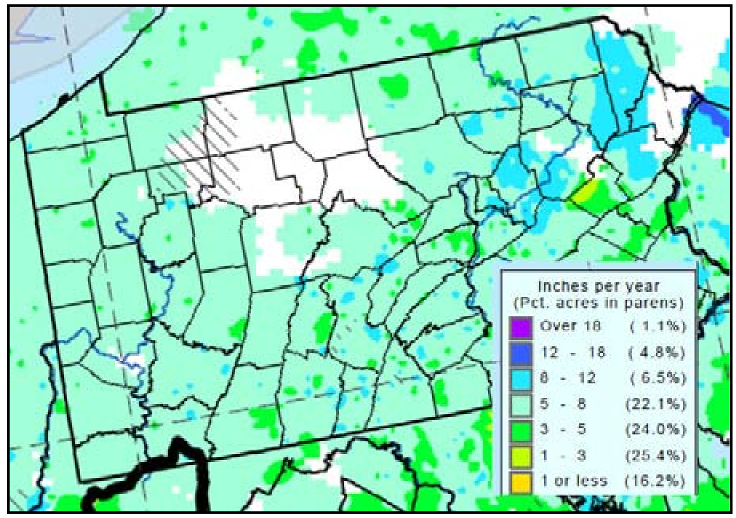

Figure 6.2. Annual runoff volumes for Pennsylvania. *[NRCS EPIC model calculations]*

Each sample taken during the pre-project phase of the study is of a known volume and all of the analyzed concentrations were reported in the same units (mg/L). Assuming an average annual runoff amount of 5.6", the annual amount, or weight, of TSS, N and P can be calculated per acre. Surveys to determine the surface watershed area draining to each sample point allow the total annual amount of each element to be calculated per site. An estimated annual increase or decrease in TSS, N and P resulting from the implemented projects can then be made by comparing flow reductions or increases during the post-project sampling period to the flow figures pre-project. The findings of the study are shown in table 6.1.

According to the findings of this study, the implemented ESMPs account for an average annual reduction in the delivery for each road of 8,238 lbs of sediment (TSS), 18 lbs of nitrogen (N) and 5 lbs of phosphorus (P) directly to streams comprising the Kishacoquillas Creek watershed in Mifflin County, Pennsylvania. Thus, it would be expected that the proper application of Environmentally Sensitive Maintenance Practices on farm lanes responsible for the direct delivery of agricultural field runoff to streams in the Kishacoquillas Creek watershed could reduce the loading of these streams by 2,049 lbs of sediment, 4.4 lbs of N and 1.3 lbs of P per acre drained by these roads. A wider estimate of totals for an individual catchment such as the Kishacoquillas Watershed, the Susquehanna River Watershed, or the Chesapeake Bay Watershed would require input of additional data such as the total amount of similar agricultural land drained by farm lanes to receiving tributaries in each of the drainages. It is the opinion of the authors of this study that the reduction in delivery of these components would be substantial watershed wide with the proper application of Environmentally Sensitive Maintenance Practices on farm lanes throughout the region.

		BEFORE					AFTER			
	Area (ac)	Runoff (L)	Sediment (lbs)	N (lbs)	P (lbs)	% Flow Reduction	Runoff (L)	Sediment (lbs)	N (lbs)	P (lbs)
Yoder *	2.9	1,667,819	8,663	18.38	2.94	-1%	1,684,497	8,749	18.57	2.97
Goss	6.7	3,853,237	5,377	18.69	10.19	100%	-	-	-	-
Stuck	4.5	2,587,995	5,095	33.09	3.99	96%	103,520	204	1.32	0.16
Haughwout	2.8	1,610,308	16,693	8.17	2.84	100%	-	-	-	-
Snyder	3.2	1,840,352	14,460	30.84	9.33	99%	18,404	145	0.31	0.09

Table 6.1. Estimates of total annual runoff, sediment, nitrogen, and phosphorus leaving the 5 test sites and entering the Kishacoquillas creek.

** The Yoder farm showed a 1% increase in flow due to several ESM Practices being removed through winter maintenance. Runoff sampling showed a 92% reduction in sediment.*

An important principle of Environmentally Sensitive Maintenance is effective education through demonstrations and practical on-site training. Each site provides a "hands-on" opportunity to work directly with the landowners as well as create documentation from the local watershed that can be shared with many landowners. A one-day classroom training was developed and presented to local farmers using the experiences gained on the field sites. The experiences and the documents created will be used in future educational opportunities provided by the Center.

The implications of this study support the observation that the ESMPs that are fostered by the Commonwealth's Dirt and Gravel Road Maintenance Program are effective measures to mitigate sediment movement into streams adjacent to roads. This study would support a greater than 95% overall reduction in sediment and nutrients transported from farm fields via farm lanes.

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APPENDIX A: RAINFALL SIMULATOR

In addition to the storm sampling described above, a rainfall simulator was used on Pruss lane to further quantify sediment reductions.

The “rainmaker” is designed to simulate rainfall on a 100’ length of road. It delivers approximately 1.1” of rainfall per hour in a highly controlled and repeatable event (Figure A1).

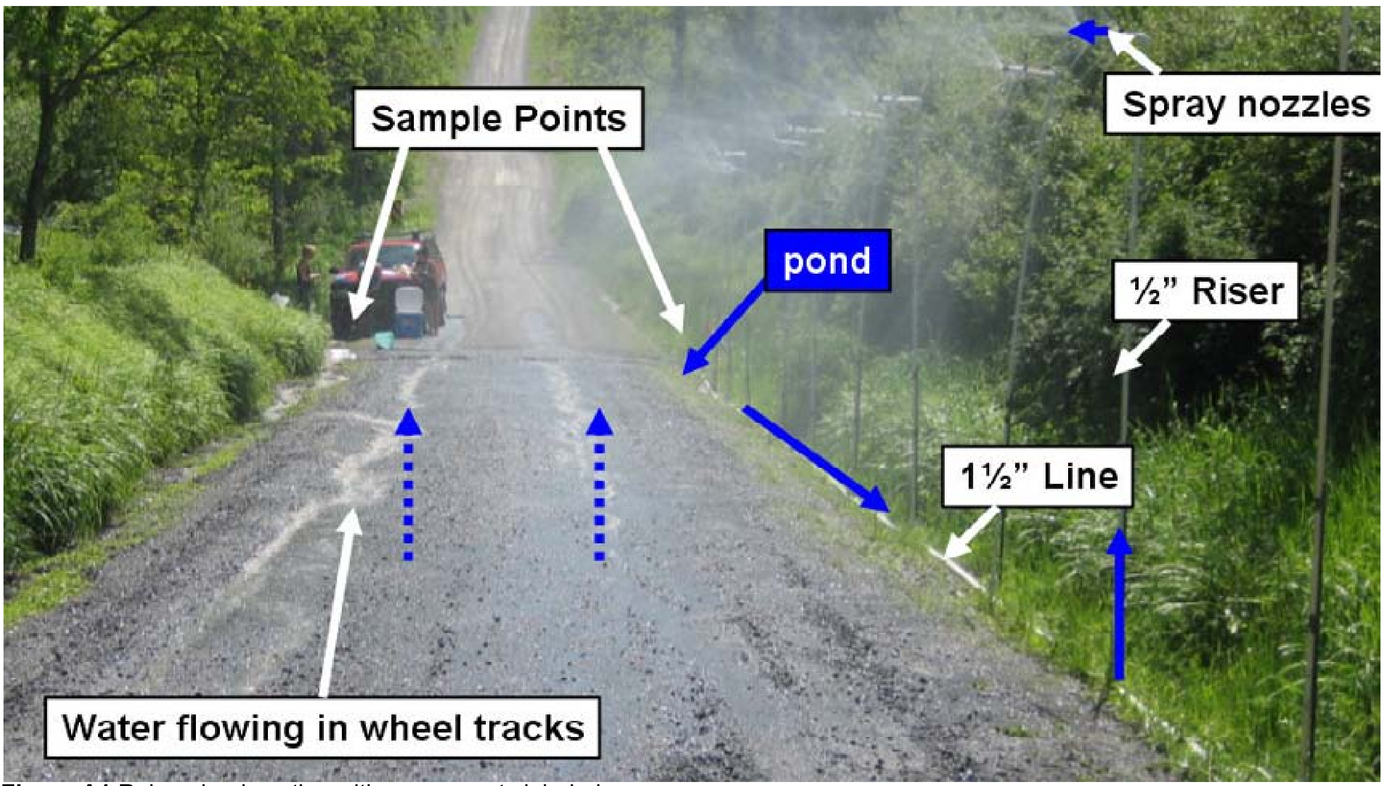

Figure A1 Rainmaker in action with components labeled.

The following setup and procedure was used to determine the sediment load generated from a farm lane in the pre-construction study. Further details on the rainmaker and related Chesapeake Bay Study can be found in *Scheetz and Bloser (2008)*.

The primary purpose of the rainmaker is to create a highly repeatable rainfall event. The repeatability of the setup was verified by collecting and measuring rainfall for three separate events on a gravel road in Huntingdon County, PA. The collection jars for repeatability testing can be seen on the road in figure A2 and graphically displayed in figure A3. The average rainfall intensity over the entire road was 1.09 inches per hour. The variability between rainfall collection jars within a single run of the rainmaker approximates the “evenness” of precipitation over the road. The standard deviation between collection jars was 0.60, or 55% of the mean intensity.

Figure A2: Collection jars for repeatability testing on a test road in Huntingdon County.

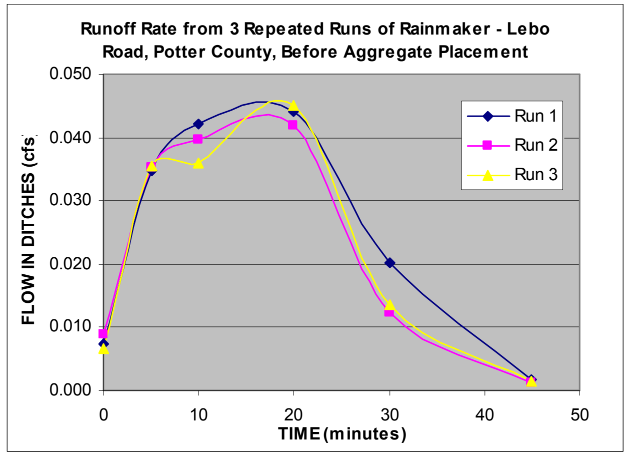

Figure A3: Example of repeatability of rainfall events. The ditch flow from three separate events are shown for Lebo Road in Potter County.

This indicates that although the average intensity of rainfall is 1.09 in/hr, rainfalls can be expected to vary between 0.49 and 1.69 in/hr for any point on the road.

Consistency between separate rainmaker runs is of a greater importance to this study than evenness of coverage over the road. The real advantage of the rainfall simulator is that it provides the same storm every time it is run. Analysis of the data indicates that the standard deviation between runs of the rainmaker is 0.19 or 17% of the mean intensity. This indicates that the average variability for any particular point on the road can be expected to be less than 17% between separate runs of the rainmaker. The results of a paired-t test indicated that there were no significant differences in rainfall intensity between the three runs. (P-values of 0.15 for for Run 1/Run2, 0.11 for Run1/Run3, and 0.59 for Run2/Run3). The excellent repeatability of the rainmaker can also be seen in runoff rate comparisons. Figure A3 shows nearly identical runoff rates for three separate runs of the rainmaker for Lebo Road as part of the Driving Surface Aggregate Study. Additional details for the rainmaker can be found in Scheetz and Bloser [2009].

Figure A4: The rainfall simulator being run on Pruss Lane in Mifflin County.

__Rainfall Simulator Results__

The rainfall simulator was run before and after the installation of a gradebreak on Pruss Farm lane, figurre A4. The gradebreak was installed at the 50' mark of the 100' length of rainfall simulator. The gradebreak directed water off the road surface and into a vegetative filter area. The gradebreak reduced the total sediment runoff by 86% for the 30 minute design rainfall event of 0.55". Nitrogen and

Phosphorus runoff was not measured for the rainfall simulator. Nutrients were not measured since the rainfall simulator only produced precipitation on the road surface. The vast majority of Nitrogen and Phosphorus runoff during natural strom events can be attributed to precipitation falling on farm fields adjacent to the road. Results from Pruss lane have been incoporated into a related research project through the Chesapeak Bay Commission.

Raw Data for the rainfall simulator is presented below:

BEFORE - PRUSS LANE (combined ditches) 10/22/2007

	Time to Runoff	Time (min)	Sample ID	Flow Measurements: Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Sediment: Lab Code	TSS (mg/l)	Lbs / min sediment
Run 1	Time to Runoff: 1:50	0		1.0	0	0.0			0.000
		1	1.01	5.6	0.36	3.8	SB 252	3000	0.096
		5	1.05	5.2	0.36	4.1	253	1000	0.035
		10	1.10	4.2	0.36	5.2	254	720	0.031
		20	1.20	6.8	0.36	3.2	255	145	0.004
		30	1.30	8.9	0.36	2.4	256	1160	0.023
		40		1.0	0	0.0			0.000
Run 2	Time to Runoff: 2:30	0		1.0	0	0.0			0.000
		1	2.01	6.8	0.36	3.2	257	2600	0.069
		5	2.05	10.3	0.36	2.1	258	1000	0.017
		10	2.10	4.2	0.36	5.2	259	800	0.034
		20	2.20	7.0	0.36	3.1	260	240	0.006
		30	3.30	8.1	0.36	2.7	261	190	0.004
		40		1.0	0	0.0			0.000
Run 3	Time to Runoff: 2:30	0		1.0	0	0.0			0.000
		1	3.01	5.3	0.36	4.0	262	1620	0.055
		5	3.05	6.6	0.36	3.3	263	470	0.013
		10	3.10	4.2	0.36	5.1	264	410	0.018
		20	3.20	4.9	0.36	4.4	265	230	0.009
		30	3.30	8.0	0.36	2.7	SB 266	830	0.019
		40		1.0	0	0.0			0.000

Average total 30 minute sediment loss = 0.72 lbs

AFTER - PRUSS LANE (combined ditches) 5/14/2008

	Time to Runoff	Time (min)	Sample ID	Flow Measurements: Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Sediment: Lab Code	TSS (mg/l)	Lbs / min sediment
Run 1	Time to Runoff: 2:00	0		1.0	0	0.0			0.000
		1	1.01	41.1	1	1.5	SB 252	3000	0.037
		5	1.05	26.2	1	2.3	253	1000	0.019
		10	1.10	70.5	1	0.9	254	720	0.005
		20	1.20	49.9	1	1.2	255	145	0.001
		30	1.30	53.1	1	1.1	256	1160	0.011
		40		240.0	0.132	0.0	avg	961.0	0.000
Run 2	Time to Runoff: 2:00	0		1.0	0	0.0			0.000
		1	2.01	33.7	1	1.8	257	2600	0.039
		5	2.05	21.4	1	2.8	258	1000	0.023
		10	2.10	19.4	1	3.1	259	800	0.021
		20	2.20	20.1	1	3.0	260	240	0.006
		30	3.30	52.7	1	1.1	261	190	0.002
		40		70.0	0.066	0.1	avg	961.0	0.000
Run 3	Time to Runoff: 1:15	0		1.0	0	0.0			0.000
		1	3.01	16.7	1	3.6	262	1620	0.049
		5	3.05	14.6	1	4.1	263	470	0.016
		10	3.10	18.6	1	3.2	264	410	0.011
		20	3.20	20.6	1	2.9	265	230	0.006
		30	3.30	57.2	1	1.0	SB 266	830	0.007
		40		65.0	0.066	0.1	avg	961	0.000

Average total 30 minute sediment loss = 0.41 lbs

APPENDIX B: TECHNICAL BULLETINS

The technical bulletins attached here detail specific Environmentally Sensitive Maintenance Practices.

Technical Bulletin

Crosspipe Installation

10/2006

CROSSPIPE INSTALLATION - This technical bulletin deals with techniques for proper crosspipe installation (drainage culverts, not stream pipes). Please see related technical bulletins for general pipe information or details of a "Shallow Pipe Installation".

Photo 1. A plastic crosspipe is shown during installation. Notice the pipe bedding material, endwall, and stone at outlet.

PIPE ELEVATION – When possible, try to outlet pipes at the elevation of the natural ground. This will eliminate the need for long "tail ditches" at pipe outlets that are a constant source of maintenance and erosion. More information on pipe elevation can be found in the "Shallow Pipe Installation" Tech Bulletin.

PIPE LENGTH AND ANGLE – Pipes should be installed at an angle across the road that lines up with natural drainage patterns. This has many advantages over installing pipes straight across a road: *(Figure 1)*

- Reduces erosion around pipe inlet and outlet that is caused when water "turns" to enter or exit the pipe.
- Pipe efficiency and flow capacity are increased when water does not have to turn 90º to enter the inlet.
- Traffic loading on the pipe is decreased since only one vehicle tire at a time is directly over the pipe.
- Often with longer pipes installed at an angle, it is possible to keep pipe joints away from wheel tracks.

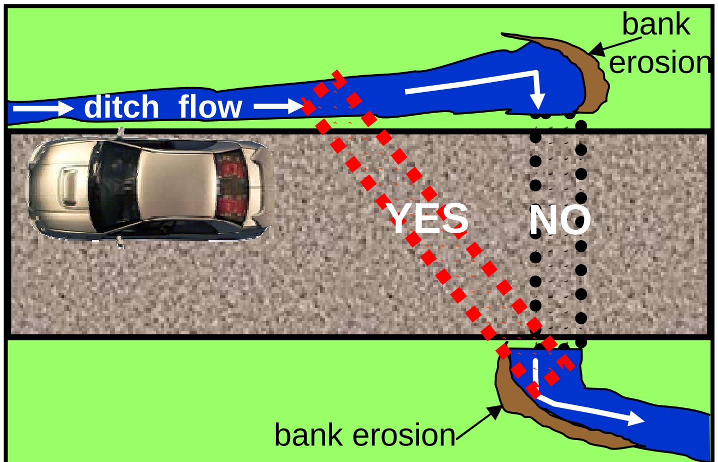

Figure 1. The crosspipe shown in black is improperly aligned straight across the road. The red pipe indicates a better pipe placement that will carry more water and cause less erosion.

BEDDING / FILL MATERIAL– In selecting a material for use as bedding and fill around a crosspipe, frost action and compaction are the two most important concerns. When possible, the material that is excavated out of the pipe trench will make the best fill material. If this material has a lot of large rock in it, it will not compact properly and new material must be imported. Keep in mind the following when selecting a bedding material:

- Imported bedding material should be as similar as possible to existing road material. This will insure that the entire road will react in the same way to cycles of freeze and thaw.
- Any bedding material needs to be slightly moist to achieve the best compaction. Compaction is crucial both above and beside the pipe to provide proper pipe support and avoid excessive flexing.
- Some common fill materials include crushed bank run gravel, shale, and PENNDOT 2RC aggregate.

OTHER CONSIDERATIONS

- When raising the road profile, fill should be placed and compacted prior to pipe placement. After road fill is in place, excavate pipe trench and proceed with installation.
- Insure that all pipes have at least a 1% fall.
- All pipes should have headwalls and endwalls to reduce erosion and improve pipe functionality.
- Drop-inlets (grates like on storm sewers) are not recommended for use on unpaved roads.

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CROSSPIPE INSTALLATION

1) **Excavate Pipe Trench:** Trench should be wide enough to fit compaction device (*shown in "D"*) on both sides of pipe. Trench depth will depend on outlet elevation. Outlet pipe at natural ground elevation whenever possible to eliminate the need for a tail-ditch. Bottom of pipe inlet should be at the same elevation as the ditch. If needed, use a level to insure bottom of pipe trench has min 1% fall across entire length. (*See photo A).*

2) **Place Pipe Bedding:** Once trench is complete, place small amount of bedding material (~3") in bottom of trench if needed. Use bedding to smooth trench bottom and achieve proper slope. Some shovel and rake work is required to spread bedding evenly. If bedding material is used to level the trench, it should be compacted before pipe placement. Use level to find any uneven spots and double-check slope (*See photo B).*

3) **Place Pipe in Trench:** Place and align first section of pipe in trench. Pipe inlet should be located in the existing ditch line, with just enough room between the pipe and the bank for a headwall. Inlets that are to close to the road pose traffic hazards. Inlets that are to far off the road cause unnecessary bank erosion. Align additional pieces and secure together using provided collars or pipe adhesive. Look under pipe to make sure it is in constant contact with the bedding. Voids under the pipe will cause sagging upon compaction. If desired, headwall and endwall can be constructed at this time. Fill will be placed against the back of the walls in next step (*See photo 1 on front).* Otherwise, headwall and endwall can be constructed after pipe installation is complete.

4) **Place and compact fill material around pipe:** Place bedding material around pipe until approximately 8" of material is on each side of pipe. Pipe may need to be held in place so fill material does not push or lift pipe *(See photo C).* Use a Jumping-Jack to compact fill on both sides of pipe. Compaction of the first layer of bedding material is crucial because it packs material down around the base of the pipe for support (See photo D). The importance of compaction cannot be overstated! Unlike metal and concrete pipes which have structural strength, plastic pipes get their strength from the material compacted tightly around them. Be careful not to puncture pipe with the foot of the Jumping-Jack while compacting. Continue to fill and compact in stages, placing approximately 8" of fill before compaction. If to much fill is placed at once, proper compaction cannot be achieved. Continue to fill and compact over top of pipe (See photo E). Be sure to provide adequate fill over pipe. Adequate fill varies with pipe size and construction. Plastic pipes up to 24" in diameter require a minimum of 12" of compacted cover.

Draft

Informational Bulletin

The Road Profile

Version 1.0 12/13/04

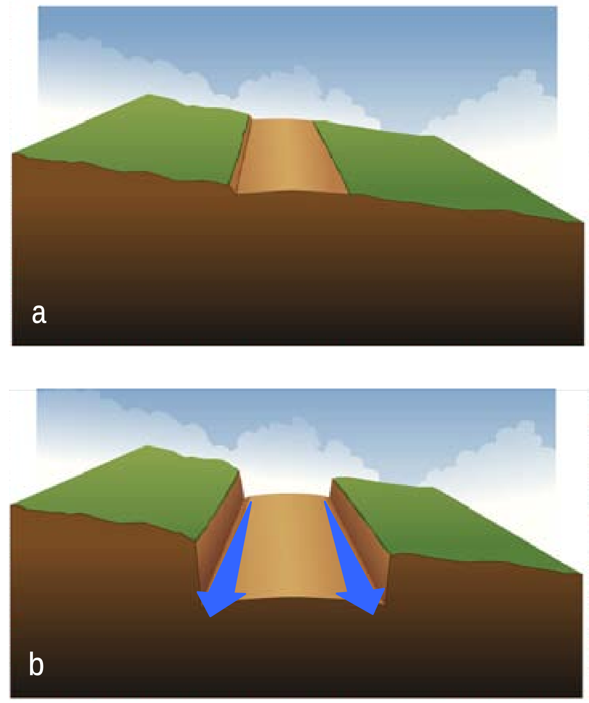
What is a Road Profile?

The road profile is the cross-sectional shape of the road surface in relation to the road corridor traversing the surrounding landscape. Road corridors that cross high meadows or forested ground encounter different environmental conditions than corridors along riparian buffer areas or streambanks. A road's profile, the shape and elevation of its surface, is critically important to the road corridor's ability to withstand the unrelenting forces of nature.

Why Raise the Road Profile?

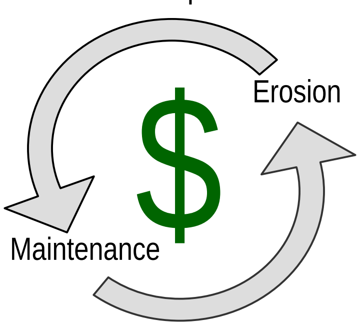
Routine road maintenance practices (surface grading, snow removal, shoulder cutting, ditch cleaning, etc.) combined with the wear and tear of traffic and natural erosive forces have the cumulative effect of lowering the elevation of the road in relation to the surrounding terrain. As the road profile drops, water draining to the road is trapped and concentrated in parallel ditches and the road begins to function as a channel for downslope water flow (see image b).

As water flows downhill, it gains volume and velocity, becoming "hungry" and aggressively erosive. It is this "hungry" water that is a roadmaster's worst enemy, robbing the road of valuable surface material as well as ditch and bank soil that supports stabilizing vegetation.



Over time, natural erosive forces, vehicle traffic, and routine maintenance practices can transform the road's original profile (a) into a deeply entrenched road (b) that is difficult to maintain without causing further soil erosion and increased maintenance costs.

With road managers ever encouraged to keep water "off of, out of, and away from" the road, the result is deeper and deeper ditches and steeper and steeper banks. The resulting depressed, or entrenched, road profiles offer increasingly difficult challenges for road managers trying to install cross pipes, turnouts, and other drainage features to shed water from the road. Raising the road profile can eliminate the persistent maintenance difficulties associated with an entrenched road.



Consequences of Entrenched Road Profiles

Erosion and maintenance which cost money, money, money!

1. Loss of road surface material
2. Soil collapsing into deep pipe or drainage inlets
3. Soil collapsing from steep banks undercut during maintenance operations and by water flowing in ditches
4. Road edges undercut by concentrated ditch flow
5. Difficulty plowing snow and finding a location to place plowed snow
6. Pipe installations with steep, unstable banks at inlets and long, difficult to maintain outlet tail ditches

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Benefits of Raising the Road Profile

- Can effectively eliminate parallel ditchflow and encourage low-volume, low-velocity sheetflow off the road
- Adds additional base support for the roadway
- Widens the road (not always a benefit)
- Allows room for snow removal
- Reduces concentrated “hungry” water flow and associated loss of surface material
- Less expensive maintenance of ditches and reduced need to armor ditches with costly rock treatments
- Raises the elevation of pipe inlets and outlets in relationship to the surrounding terrain thereby eliminating the need for long deep armored outlets and steep drop inlets which cause environmental and maintenance problems
- Eliminates/reduces the need for turnouts

This deeply entrenched road traps drainage and is a persistent source of maintenance and erosion. Additional maintenance efforts and vehicle traffic compound the problem by lowering the road elevation further.

Materials Commonly Used for Mass Filling

- Native shale; use caution where shale is known to leach acid
- Any kind of rock spoil
- Bank run gravel
- Concrete waste/demolition waste
- Tire shreds
- Spent sandblasting sand
- Ground glass
- Mining spoil
- Coal combustion waste

Special caution and permits may be required for handling some of these materials. Work with your local conservation district to determine if materials pose any danger or require special handling procedures.

Filling the road profile here, as shown above, with appropriate center-line crown, eliminates concentrated parallel ditchflow and allows water to sheet flow off the road into surrounding terrain, reducing the erosive force of “hungry” water and saving scarce maintenance funds.

General Considerations

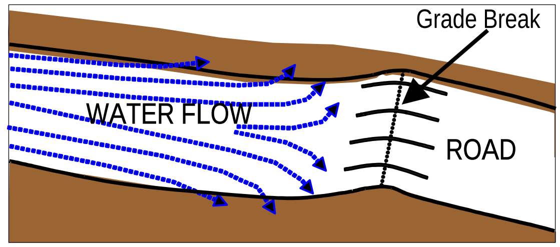
- To be cost-effective, the fill material must be low-cost and nearby. Often transportation hauling is the biggest expense. In many cases, fill can be borrowed from locations where removing material will be beneficial.
- Many property owners with vested interest in improvements to their local roads have suitable material for road filling. Municipalities can take material for roadwork without the constraints of mining permits. However, reclamation is still required. Work closely with your conservation district to establish what regulations apply. Use Dirt & Gravel Road Program funds to purchase material only from approved or permitted suppliers, not from un-permitted mines site or other locations.

Technical Bulletin

Grade Breaks

Version 2.0 2/21/04

GRADE BREAK – A small intentional increase in road elevation on a downhill slope, which causes water to flow off of the road surface to both sides into ditches or dispersal areas.



PURPOSES – The main purpose of a *grade break* is to prevent erosion of road material caused by build up of water volume and velocity in the travel lanes. They also calm traffic speeds.

NO GRADE BREAK – Water flows on road causing excess erosion and aggregate loss.

GRADE BREAK – Interruption in slope redirects flow and causes water to leave road area.

BENEFITS OF *GRADE BREAKS*:

- *Grade breaks* conserve road material and prevent eroded road surfaces
- *Grade breaks* reduce road maintenance expenses
- *Grade breaks* conserve aggregate by removing the water's erosive force from the road
- *Grade breaks* calm traffic by inducing lower driving speeds

WHERE TO USE *GRADE BREAKS*:

- On any sloping section of road that has evidence of water velocity damage to the surface.
- Before stream crossings to force road surface drainage into turnouts or vegetative filters.
- At intervals frequent enough to prevent a concentration of water to cause erosion of the road surface or of the discharge area. If ruts are forming on the driving surface or stones 1 inch or larger are being moved by concentrated water flow, some correction is needed.
- Prior to cross pipes to cause water to flow into the inlet side ditch. Discharge to the side ditches should not be located where it can erode cover off of the end of the pipe.

Grade breaks are easy to build with normal machinery. They are inexpensive, but highly effective structures to reduce and prevent erosion of dirt and gravel roads!

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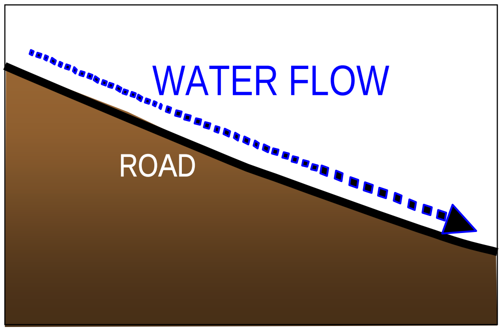
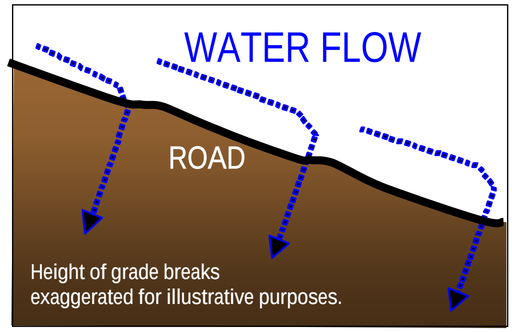
Center for Dirt and Gravel Road Studies



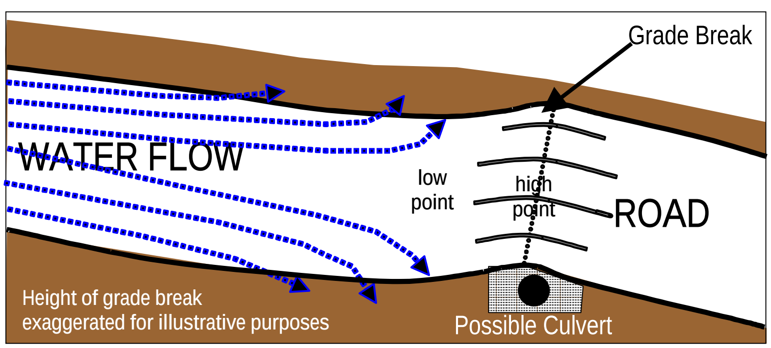
NO *GRADE BREAKS* – Water flows on road causing excess erosion and aggregate loss.



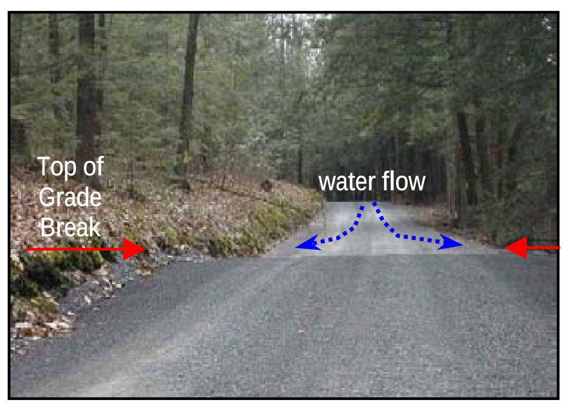
GRADE BREAKS – Increase in slope disrupts flow and causes water to leave road area.

IMPORTANT CONSIDERATIONS:

- Spacing: On a long sloped road, multiple g*rade breaks* may be used in succession to bleed water from the road and prevent the buildup of erosive volume and velocity. The degree of slope is the determining factor in *grade break* spacing. Steeper slopes require g*rade breaks* to be constructed closer together because water will build volume and velocity more rapidly.
- Equipment: Most municipalities can make a *grade break* with their own equipment. A bulldozer is preferred, but in most cases, a grader can be used.
- Transitions: It is important to gradually taper the edges of a *grade break* back into the road grade. Driving through the finished *grade break* in a car at a reasonable speed is one test of this structure. If the ride is too rough or the car "bottoms-out", the structure needs to be tapered more. The iron clad test of a *grade break* is the ability to plow snow. The plow should ride into and out of the *grade break* without cutting the road surface. A good *grade break* is very subtle.
- Maintenance: Grader operators need to be instructed to maintain crown through a *grade break* without eliminating it. Traditional grading operations strive to eliminate surface deviations. Uninformed operators may see g*rade breaks* as a source of road material for use in other areas.



Compressed illustration showing road surface water drainage patterns at grade break.



GRADE BREAK- Notice the contour of ditch on the left side of the road.

BROAD BASED DIPS:

A *broad based dip* is somewhat like a *grade break* except it conveys water from the uphill road ditch and road surface across the road and to a discharge area. *Broad based dips* are also effective structures in diverting water and will be the subject of a future technical bulletin.

Technical Bulletin

Broad Based Dips

9/2008

<u>Broad Based Dip</u>: An intentional watercourse and associated high spot created across a roadway that conveys water from the uphill ditch over the road surface to a discharge area.

Purpose:

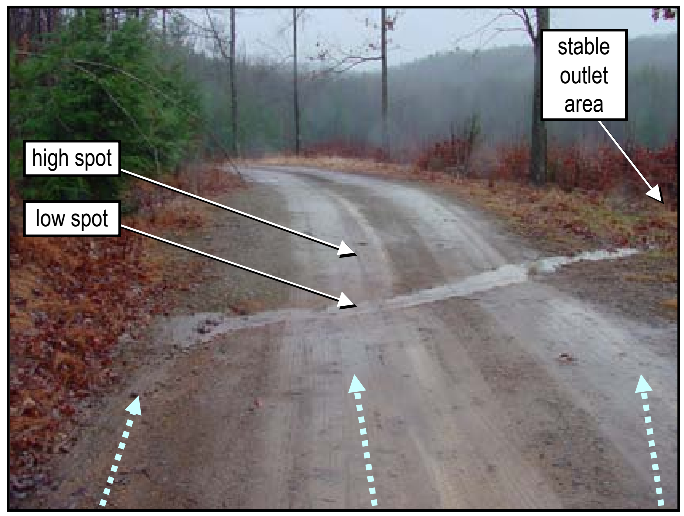
The main function of a *broad based dip* is to collect flowing water from the road surface and ditches, directing it across the road to a stable outlet. *Broad based dips* can be used in place of crosspipes in certain situations to outlet water from the uphill ditch across the road. *Broad based dips* also act as gradebreaks or water bars to prevent drainage from flowing down the wheel tracks on the road surface.

Benefits:

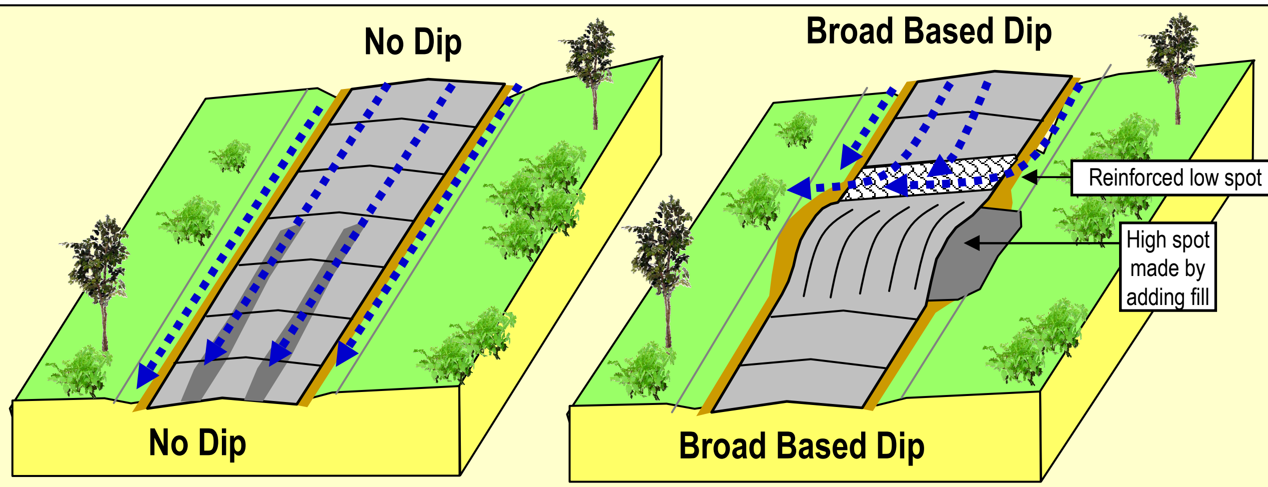
- Prevents erosion caused by water flowing down road.
- Acts as a crosspipe to outlet drainage from the uphill side of the road, reducing potential for erosion and stream pollution from long ditch runs.
- Cheap, easy, and effective on low volume roads.

Considerations:

- Use discretion when considering *broad based dips*. <u>They are only appropriate for use on low traffic roads</u>. Roads with high vehicle traffic and oversized loads may not be appropriate for *broad based dips*.
- *Broad based dips* should not be used on roads with a slope of greater than 10%.
- A *broad based dip* is designed to carry runoff across the surface of the road. It may be necessary to reinforce the bottom of the dip and dip outlet to prevent erosion, depending on site conditions.
- *Broad based dips* are not designed to accommodate continually flowing water such as springs or streams.



This *broad based dip* in Huntingdon County is located on an access road that is only open to the public for hunting season. This low-use road is ideal for *broad based dips* instead of crosspipes to reduce long term maintenance. The dip pictured here collects road and ditch water and directs it from left to right across the road.



Water is allowed to run down the roadway and ditch. This builds volume and velocity which can erode the road area and deliver sediment to streams.

The *Broad Based Dip* forces water flowing on the roadway and in the ditches to a stable outlet area to reduce erosion. Reinforcement of the outlet area may be needed, depending on site conditions.

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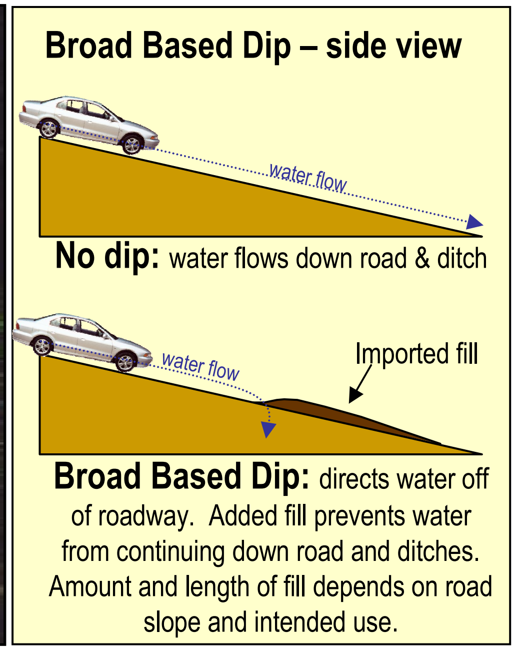


A *broad based dip* is pictured here during a heavy rainstorm. Notice how gradual the dip would be to vehicles, yet how effectively road and ditch flow is directed across the road. Without the dip, road and ditch drainage would continue to build erosive force around the corner.

Construction Considerations:

- **SPACING**: Multiple *broad based dips* can be used in sequence, similar to crosspipes, to drain a long stretch of road. Spacing for *broad based dips* depends on a variety of site-specific conditions including road slope, native soils, and hydrologic conditions.
- **SIZE & SHAPE**: Sizing for *broad based dips* will vary widely depending mostly on road slope and anticipated traffic. Dips constructed on flat roads may be relatively small (fill transitions as short as 12 feet and as low as 6 inches). Dips installed on steeper sections of road will require more "approach fill" to ease the transition into and out of the structure (fill transitions over 100 feet long and up to 18 inches deep). Be sure to take anticipated traffic into account. The dip pictured on the front of this document is on a gated access road and is much more abrupt. The dip pictured above has much smoother transitions to accommodate cars and log trucks. A relatively wide dip bottom is recommended to accommodate water and ease vehicle transitions. The upslope end of the dip should be tied into the uphill bank to insure water does not bypass the structure and continue flowing down the ditch.
- **ANGLE**: *Broad based dips* should be angled across the road at approximately 20-40 degrees, not placed at 90 degrees perpendicular to the road like a speed bump. The angle will facilitate the flow of water across the road. A dip placed straight across the road will be much more likely to fail because it forces water to turn at a right angle to flow across the roadway.
- **SLOPE**: Similar to crosspipes, the bottom of a *broad based dip* should have an elevation drop towards the outlet end. A 3% slope is recommended across the bottom of the dip
- **DIP REINFORCEMENT**: Because a *broad based dip* is designed to carry concentrated flow on the surface of the road, reinforcement of the dip bottom is recommended. Hard stone and even geo-synthetic materials can be used to reinforce the bottom of the dip to resist erosion.
- **OUTLET REINFORCEMENT:** Because a *broad based dip* outlets water similar to a crosspipe, similar outlet stability concerns apply. When possible, outlet dips into a vegetated buffer area. Depending on the amount of water and slope of the land, additional outlet stabilization with stone may be required.
- **MAINTENANCE:** A properly constructed *broad based dip* will function for years with minimal maintenance. Care must be taken not to remove the dip during any future maintenance activity.

Broad based dips are a cheap and effective means of drainage control on low volume roads. Farm lanes, camp roads, gated access roads, and other low use roads are ideal candidates for these structures. Always try to discharge dips to a stable outlet away from streams.

A **Gradebreak is a related surface drainage structure designed to divert water off the road surface, but not to carry flowing water across the road. For details about gradebreaks, see the Center's related technical bulletin at www.dirtandgravelroads.org.*

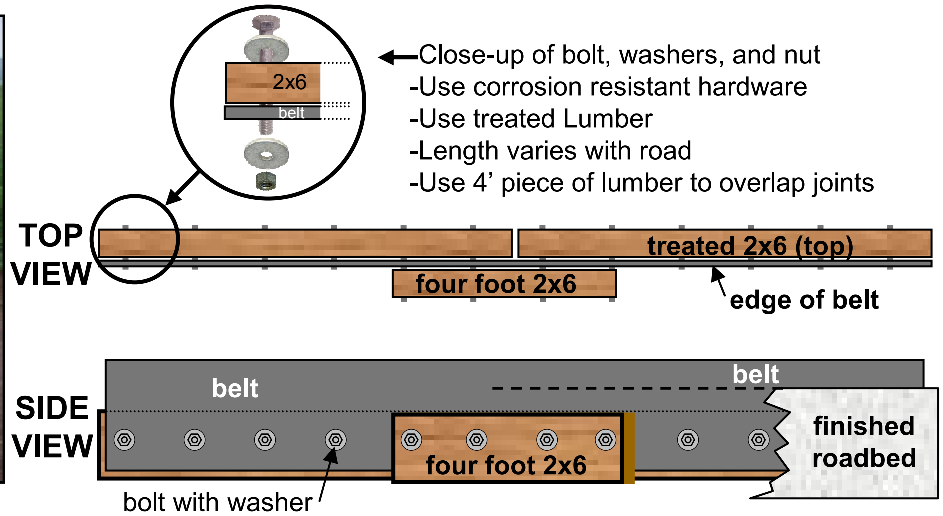
Technical Bulletin

Conveyor Belt Diversions

9/2009

CONVEYOR BELT DIVERSION – A structure used on low traffic roads to divert water off the road surface. It consists of a piece of used conveyor belt bolted to treated lumber and buried in the road.

Completed Conveyor Belt Diversion



PURPOSE – Conveyor Belt Diversions reduce erosion caused by flowing water that is trapped in wheel tracks and ruts by diverting concentrated drainage from the surface of the road while still allowing vehicles to pass. The belt diversion gives under tire pressure, then springs back to its original position (see **Pic 5** on reverse).

BENEFITS OF A CONVEYOR BELT DIVERSION:

- Forces water off the road surface similar to waterbars or grade-breaks to reduce erosion on road surface.
- Functions when road crown is lost (provided belt diversions are properly spaced).
- Will not deform or crush under heavy hauling as can be the case with earthen and aggregate structures.
- Long life expectancy and low maintenance.

WHERE TO USE A CONVEYOR BELT DIVERSION:

- **Low volume (traffic) roads** and access roads (consider for driveways, farm lanes, and camp lanes). They are NOT suitable for roads that receive high traffic volume, fast traffic, frequent grading, or snow plowing. They work well for "off right of way" water issues
- On sloping sections of low traffic roads with evidence of water velocity damage to the surface.
- On roads that do not receive sufficient surface maintenance to maintain proper crown or cross-slope.

Low volume access lanes such as this are ideal candidates for diversions.

CONSIDERATIONS:

- Large rocks should be placed at the end of the diversion to slow water and disperse flow.
- Multiple Conveyor Belt Diversions may be used to prevent the buildup of erosive volume and velocity. Spacing between the diversions is determined by the grade of the road, the stability of the surface material, available outlets, and the amount of water entering the road drainage system (including off right-of-way sources).

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TYPICAL REQUIREMENTS:

MATERIALS (to Build)

- (1) Conveyor Belt ½” x ~15” x necessary length
- Treated 2”x6” lumber. Length and number depends on road width. Overlap joints with 4’ length board (see diagram on front)
- (12) 3/8” diameter bolts and nuts. (length varies with belt)
- (24) wide diameter washers
- Tools: utility knife; drill; hammer; adjustable wrenches

EQUIPMENT (to Install)

- Backhoe, excavator, or trenching machine
- Upright tamper (Jumping Jack)
- Shovel and rake

CONSTRUCTION: *Building diversion (see diagram on front)*

Note: These instructions assume 20’ length. Yours will vary.

1. Cut conveyor belt into ~15” x 20’ piece.
2. Lay belt on two 2”x6”x10’ boards laid end to end. Leave ~8” of belt above board (4” to be buried & 4” left above road).
3. Starting at one end, drill holes through belt and lumber (~2’ spacing) and secure with bolts and washers. **(*Pic 1*)**
4. On diversions longer than 16’, a lumber joint is necessary. Longer bolts should be used to attach a 4’ piece of lumber on the opposite side of the belt at the joint (visible in **Pic 2**).

INSTALLATION: Installing diversion

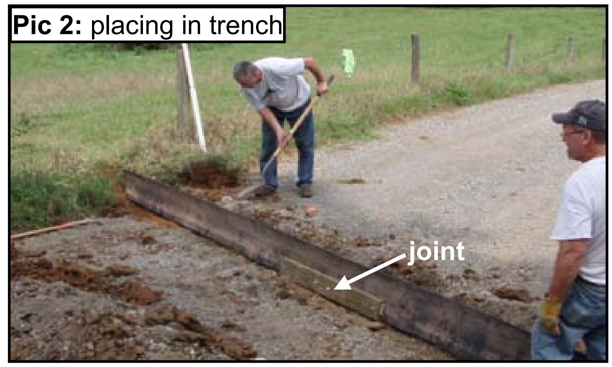
1. Excavate a trench diagonally across the road
   1. **Angle**: Dig trench at min 30% angle to road (**Pic 3**).
   2. **Fall**: Minimum of 1% of continuous fall toward the outlet.
   3. **Width**: Wide enough trench to allow for compaction equipment beside the belt diversion (typically 15” – 18”).
   4. **Depth**: The trench should be deep enough to provide 3”-4” of cover over the top of the supporting 2” x 6” board.
2. Place the diversion against bottom edge of the trench, leaving ~4” of the belt exposed above the final road surface. (**Pic 2**)
3. Backfill the trench and compact with a tamper. (**Pic 3 & 4**)
4. Place large stones at the end of the diversion to control erosion.
5. Mark the ends of the Conveyor Belt Diversion with reflective posts to avoid damage during future maintenance.

ADDITIONAL NOTES:

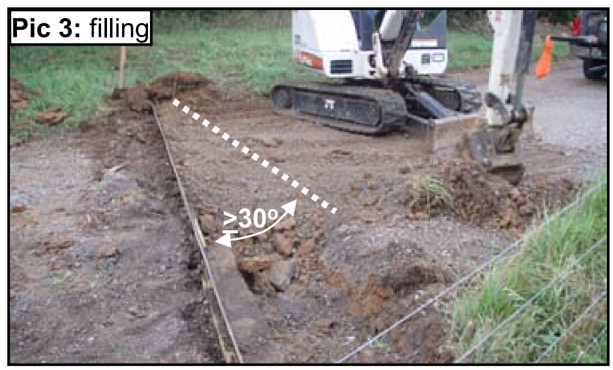
- Be sure diversion is long enough to a) be angled across roadway and b) insure that water does not flow back to the roadway around the end of the diversion.
- Used belts may be available at a local quarry or mine at low or even no cost. Belts typically come in 26”-30” widths. Unless they contain steel, most belts can be cut with a utility knife.
- Once the belt is cut in half lengthwise, it will begin to bow. You will need to adjust the belt as you secure it to the boards.
- For longer diversions. It may be easier to construct the belt, then remove the 4’ joint board. The diversion can then be folded in half for transport and reassembled on site.

This document is based on a brochure produced by PA’s Indiana County Conservation District.


Pic 1: building



Pic 2: placing in trench



Pic 3: filling


Pic 4: compacting


Pic 5: completed

Informational Bulletin

Crown & Cross-Slope

Version 1.0 1/14/05

Crown and Cross-Slope

This bulletin illustrates how to drain water from the road surface using three (3) different road surface templates. Crown describes the cross-sectional shape of a road surface. Cross-sloping, either *in*-sloped or *out*-sloped, of the road is the slope angle of the road cross-section, typically measured in percent or expressed as inches of vertical change per foot of horizontal distance.

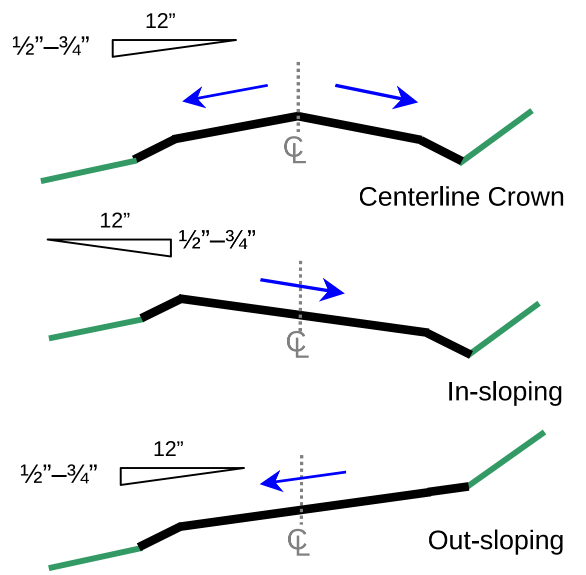
The Purpose of Draining the Road Surface

Water allowed to penetrate the road surface, by retention on flat surfaces or infiltration via puddles, weakens both the road surface and road base materials. Water flow on the road allowed to concentrate, such as in wheel tracks, causes erosive damage. The purpose of surface drainage is to cause the water to leave the road as shallow, non-erosive sheet flow in a direction and pattern chosen to suit various combinations of road material, slope, and terrain.

Types of Road Surface Templates

1. **Centerline crown**: A surface configuration that sheds water to both sides of the road from its longitudinal highpoint (1).
2. **In-sloping**: This surface configuration drains water from the entire width of the road toward the cut-bank or up-slope side. Commonly used on steep side-hills or where speed requires a banked curve, in-sloping can be useful to direct ditch water to better discharge points and also to lessen the probability of vehicles sliding on a steep side-slope.
3. **Out-sloping**: Out-sloped road surfaces drain water from the entire width of the road toward the fill-bank or down-slope side. The road is shaped to avoid collection or concentration of water in a ditch. Minor overland sheet flow is allowed to flow across the road (2). Out-sloping is useful on roads where concerns about winter icing are minimal or side-slopes are gentle.

Types of Crown



Figures not drawn to scale.

1: Centerline Crown

2: Out-sloping

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Center for Dirt and Gravel Road Studies

Maintaining Road Crown

The abrasive and compacting action of traffic, some maintenance activities, and the erosive forces of rain and flowing water wear away at the road surface. Over time, fines, which bind the coarse aggregate together, are lost and the coarse material, displaced by traffic, accumulates along the edge of the road trapping water on the traveled surface. Retained water has additional time to penetrate, saturate, soften, and lubricate the road. Road material in this condition packs more easily, or can be "pushed" to bulge up on the edges changing the shape of the surface cross-section. Additionally, water trapped on the road by the developing windrow of raveled loose stones accumulates velocity, eroding the driving surface in the wheel paths (see Illustration 1). The process starts slowly but if maintenance is not completed on a timely basis, the damage to the road can be severe.

Specific procedures for re-establishing crown during maintenance operations are detailed in the Grading Sequence with a Carbide-Tipped Blade Technical Bulletin.

Illustration 1. Centerline crown that has become misshapen over time, road drainage trapped on road by windrow of displaced aggregate. Road drainage is forced to travel on the road surface causing erosion, loss of road material, and increased maintenance. Additional methods of controlling this concentrated flow on the road surface are shown in the Grade Breaks Technical Bulletin.

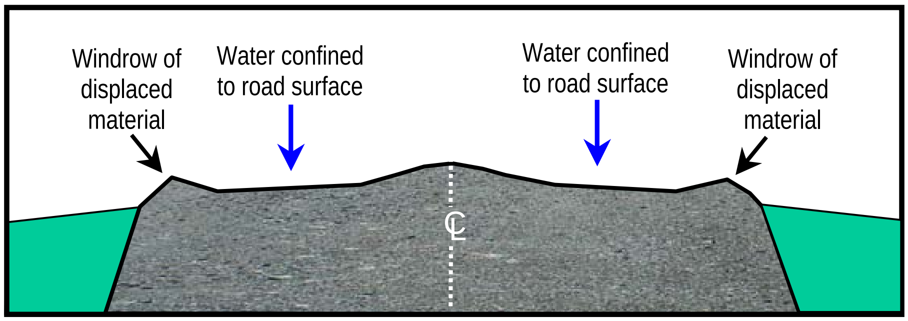
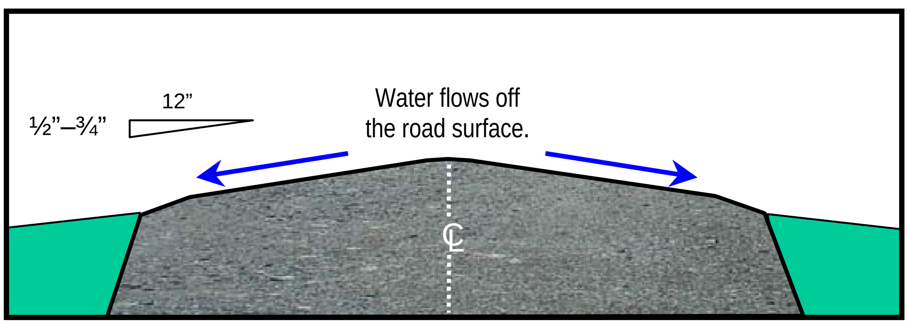


Illustration 2. Centerline crown with proper cross-slope. Road drainage flows without obstruction off the road surface into surrounding vegetation.



Crown: Paved Roads vs. Unpaved Roads

Unpaved roads must have more crown than paved ones. Pavement is not totally impervious to water but it will shed water more quickly than an unpaved surface. Pavement is typically laid at a cross-slope of 2%, or ¼" of fall per horizontal foot of road width measured from the centerline toward the ditch.

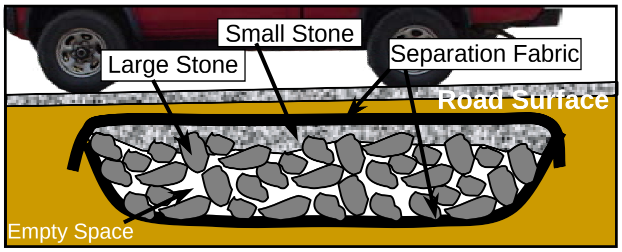
On unpaved surfaces, the recommended cross-slope is between 4% and 6%, or ½" to ¾" of fall per horizontal foot of width from the centerline toward the ditch. The steeper cross-slope means less potential for water to penetrate and weaken the road and, therefore, longer intervals between maintenance grading operations. The wear and tear of traffic will naturally 'drive-out' the crown, so no grading job will last forever! Road shoulders should be slightly steeper. Exercise caution not to grade shoulders significantly steeper on narrow roads where drivers must drive on the shoulder to allow other vehicles to pass (see Illustration 2).

Technical Bulletin

French Mattress

Version 2.0 2/21/04

FRENCH MATTRESS –A structure under a road consisting of coarse rock wrapped in fabric through which water can freely pass. A *French mattress* is basically a French drain that is used similar to a culvert to allow water passage through the roadbed.



Side view cut-away diagram of a French mattress.

Side view of an actual French mattress.

PURPOSES: The primary function of a *French mattress* is to provide load support and to establish, maintain, or equalize the subsurface water on both sides of the road. The use of *French mattresses* in road maintenance is a relatively new concept. Please contact the Center for Dirt & Gravel Road Studies with any questions or concerns.

HOW THEY WORK:

Support strength is provided by large rocks in the lower portions and by spreading the weight load with layers of progressively smaller rock near the top. Water moves into the *French mattress* from any direction through the protective geo-textile fabric, which functions to prevent migration of fine material. The water collects in the voids provided by the larger rock and moves by gravity either into the soil or subsurface drainpipes, if provided, or exits as a gentle seep on the downhill end of the structure.

BENEFITS OF A *FRENCH MATTRESS*:

- Corrects road support problems in areas where the road base has been weakened by water saturation caused when the road acts as a dam to natural water flow.
- Allows for natural equalization of subsurface water on both sides of a road.
- Requires little, if any, maintenance compared to cross-drainage culverts.
- Eliminates the need for additional cross pipes in some instances.
- Allows a gentle, non-erosive water discharge rather than concentrated flow.
- Provides an indefinite service life if not compromised by heavy flows of sediment.

WHERE TO USE A *FRENCH MATTRESS*:

- Areas where concentrated outlet flow through a pipe may be undesirable, impractical, or regulated.
- Low-lying areas near streams or wetlands where installing cross drains would be difficult.
- Areas where a road is acting as an impoundment or dam to the natural water flow by isolating subsurface water on one side of the road from the other.
- Areas where placement of a pipe at the depth necessary to provide structural cover would lower the natural water table of the area and require long term maintenance.

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IMPORTANT CONSIDERATIONS

- Materials: The core material for the mattress should be large clean stone, typically referred to as R4[1]. A general rule is that the depth of the mattress needs to be at least three times the diameter of the largest stone used. Smaller stone, such as #3's[1] should be placed on top of the large stone. Progressively smaller stone should be place on top to prevent tearing of the fabric. The structure should be wrapped in heavy-duty, non-woven separation fabric.
- Dimensions: The length of the mattress must, at a minimum, equal the width of the road, but can extend out of the road area to equalize drainage. Mattress width and stone size depend on the amount of water that needs to pass through. In wetland settings, the mattress should be as wide as possible to allow slow lateral flow and avoid concentrating the outlet drainage. Mattress depth depends on stone size, depth available, and desired drainage patterns.
- Equipment: Most mattresses can be installed easily with a backhoe and a truck to haul stone.

CONSTRUCTION: *Refer to numbered pictures on right.*

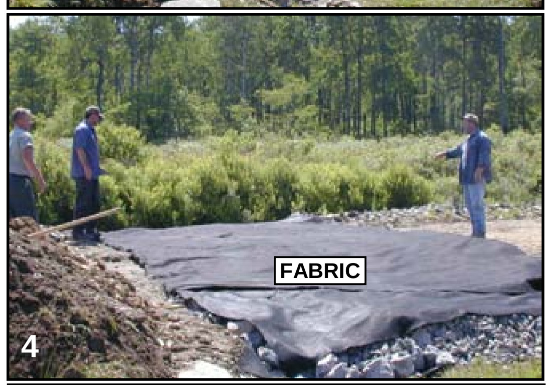
1. Excavate the section of the road where the mattress will be located to desired depth. Lay heavy-duty separation fabric in the bottom of the area after excavation and leveling. Use bedding material if necessary to protect fabric. Leave enough fabric on the ends to wrap around and overlap with top fabric later.

2. Place large stone, typically R4[1], on top of the fabric and spread out into a uniform bed.

3. Place a layer of smaller stone such as #3's[1] on top of the R4[1]. Be careful not to intermix the two stone sizes. The empty space between the large stones, and therefore flow capacity, will be reduced if the small stone is intermixed. Spread increasingly smaller stone on top to create layer that will not puncture fabric.

4. Wrap ends of lower fabric up on top of structure. Place a piece of fabric on the top if existing fabric does not completely cover mattress. All fabric "joints" should overlap by at least 18".

5. Place bedding material and fill over the mattress if necessary. Place driving surface aggregate (DSA) over the structure according to normal program specifications and procedures.



TYPICAL REQUIREMENTS:

While these figures will vary with the size of structure and individual site conditions, here is what was required for the 20´ x 12´ x 1.5´ mattress illustrated on the right:

- 3 Hours of work with a Case 580 Backhoe
- 20 tons of clean R4[1] rock (large rock)
- 8 tons of clean #3[1] rock (small rock on top)
- 85 Square yards of heavy-duty geo-textile (fabric)
- Sufficient fill and driving surface aggregate over fabric (minimum of 6 inches recommended after compaction)

[1] R4 and #3 size rock refer to PA Department of Transportation Section 408 Specifications. #3 rock ranges from 1" to 2 ½". R4 rock ranges from 3" to 18".

Informational Bulletin

Underdrains

4/2006

What is an Underdrain?

An underdrain is a drainage system installed under a road or road ditch to collect and transport subsurface water. These buried conduits come in a variety of shapes and sizes and are usually wrapped in geotextile fabric which allows water to enter the conduit while keeping sediment out.

How do Underdrains Work?

The purpose of an underdrain is to collect subsurface water before it appears on the road surface or in the road ditch. By intercepting this water, underdrains can help dry out road base, ditches, and banks that would otherwise be wet from emerging springs and seeps. Underdrains also prevent subsurface water from mixing with sediment-laden surface runoff during storm events. The clean water collected by an underdrain can then be directed to a stable outlet location separate from road surface drainage.

The ditch above carries water from roadside springs. An underdrain can collect this flow to keep the roadbed and ditch dry.

Benefits of Underdrains

-Inexpensive and easily installed
-Decrease volume of water on road surface
-Allows road bank, ditch, and base to dry out
-Separates clean subsurface water from road runoff
-Saves money by reducing maintenance time and costs associated with perennially wet roadsides

Where to Use Underdrains

-Where spring flow discharges onto the road
-Where seeps appear on the surface of the road
-Where road shoulders are continually wet and rutting
-Where road ditches have frequent standing water or active flow due to springs and seeps
-Where the cut bank is unstable and frequently fails due to excess moisture

Types of Underdrains

Conduits can be bought prefabricated and ready to put into place. They usually consist of a small plastic pipe that is perforated with holes to allow water to enter. Underdrains can also be constructed using clean stone and geotextile fabric. To maximize water collection and flow capacity, perforated pipes can be incorporated into the stone of a constructed underdrain.

Outlets

Underdrains should, if possible, be outletted separately from road drainage, particularly if the underdrain is carrying spring water. A separate underdrain outlet keeps clean spring water from getting mixed with sediment-laden surface drainage and minimizes the volume of concentrated flow at each outlet.

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Important Underdrain Considerations

Materials

Perforated Pipe: Typically available in 4” or 6” diameter, perforated pipes work well to collect and convey underground water. Other shapes of prefabricated underdrain such as trench drains are available for specific purposes (see picture at right).

Prefabricated underdrains come in a variety of shapes and sizes.

Geotextile Fabric: Fabric is a crucial part of any underdrain. Fabric around both pre-fabricated and constructed underdrains is intended to prevent clogging. The fabric allows water to pass through while blocking fine silt and clay which would eventually clog the underdrain. Consult the manufacturer to determine the appropriate fabric for your specific site conditions.

Clean Stone: In constructed underdrains, it is important to use “clean” stone. “Clean” stone is relatively uniform in size with no fine material. Typically 1”-2” diameter stone is used. Larger stones will increase the capacity of the underdrain.

Fabric and outlet protection are important to prevent clogged pipes such as this.

Surface Water

Underdrains are meant to collect clean water from springs and seeps. Never direct road surface drainage into an underdrain. The high volumes of sediment carried in surface runoff will clog the underdrain as sediment settles out (see clogged pipe at right).

Slope

Remember that underdrains function like pipes to convey water. As with pipes, underdrains should be installed at an adequate slope to ensure proper drainage. All underdrains should be installed with at least a 1% slope.

Cover

Underdrains need to be buried to function properly. Fill not only prevents road surface runoff from entering the underdrain, but protects pipes from the weight of traffic. When using a prefabricated underdrain such as a perforated pipe, make sure that there is at least 12” of fill over the pipe. Constructed stone drains are inherently stronger, but should be covered with at least 8” of fill.

Outlets

If at all possible, outlet underdrains separately from surface drainage. Since a properly installed underdrain will be carrying clean water, it can be outletted near steams and wetlands. Having seperate outlets also reduces the potential for erosion and sediment transport at any single outlet. In many cases, you may want to consider installing an animal guard on the outlet of an underdrain. Buried pipes make a perfect home for small mammals which may clog the pipe.

Additional Information

Underdrains work well when adding fill to a road to raise the road elevation and are also closely related to French mattresses. Bulletins detailing these practices and many more are available from the Center at www.dirtandgravelroads.org.

Informational Bulletin

Headwalls & Endwalls

Version 1.0 6/1/04

Headwalls and Endwalls:

A wall built at a pipe opening to support the road and protect it from the erosive forces of flowing water. A wall at a pipe inlet is called a headwall. A wall at a pipe outlet is an endwall.

Purposes

Headwalls and endwalls support the road and protect the ends of the pipe. Properly constructed headwalls and endwalls improve pipe capacity and efficiency while reducing erosion around pipe installations.

Benefits of Headwalls and Endwalls

- Provide a low-cost, long-lasting solution to erosion problems at pipe openings.
- Prevent flowing water from damaging the road structure.
- Provide structural support for the road and prevent crushing of the pipe.
- Increase the flow capacity of pipes by reducing turbulence and directing flow.
- Visually identify pipe openings and protect them from traffic and maintenance equipment.

Necessity for Protection at Pipe Openings

It is necessary to protect pipe openings for several reasons:

- Water is turbulent when it changes shape or direction, increasing its erosive potential.
- Water accelerates as it passes through a pipe creating the need for armor to prevent erosion.
- High flows erode unprotected areas directly causing soil erosion, sediment pollution, and maintenance costs.
- Physical support for the road may be necessary at pipe openings, depending on road width and pipe length.

Materials

Headwalls and endwalls can be built with many different materials. Several factors influence the choice of materials including local availability, skill and time required for construction, durability, cost, and volume and velocity of water to be handled. Materials commonly used in Pennsylvania include*:

- Native stone or boulders collected on-site
- Pre-cast concrete and cast-in-place concrete
- Molded plastic (Hartman Endwall System)
- Modular masonry products

* Construction techniques using the materials listed will be covered in future technical bulletins.

Walls can be made with a variety of materials including native stone (a), boulders (b), or molded plastic (c).

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Shape

The shape of headwalls and endwalls is important to direct water flow, to protect the road and banks from turbulent water, and improve drainage efficiency.

Headwalls and endwalls built in a rough trapezoidal/parabolic shape act to collect and funnel fast-moving water while protecting the ends of the pipe from erosion (Figure 1). At the pipe inlet, the headwall reduces turbulence, directs flow, and maximizes the flow capacity of the pipe during high flows. At the outlet, the endwall prevents erosive back eddy currents from undermining the pipe placement and the road structure.

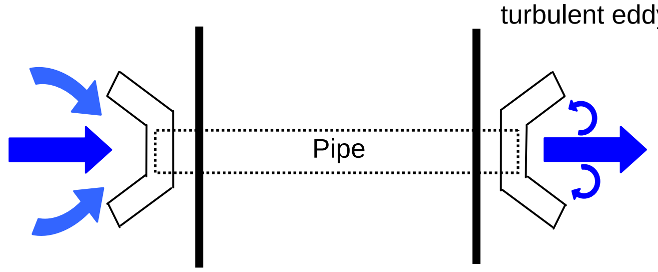


Figure 1: Plan or Bird's Eye View
Figure not drawn to scale.

Water that must change direction to enter a pipe can be very erosive. Erosion and sediment deposition cause maintenance and pollution. An angle-shaped headwall directs flow and reduces turbulence, improving pipe capacity (Figure 2).

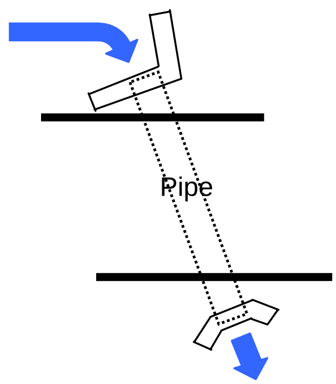


Figure 2: Plan or Bird's Eye View
Figure not drawn to scale.

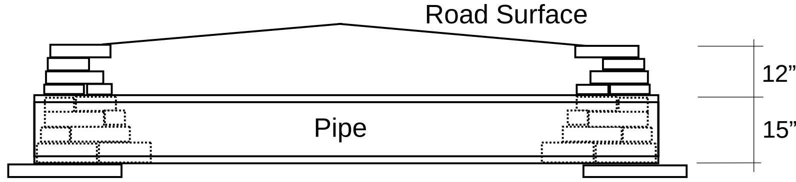


Figure 3: Longitudinal Section of Pipe Installation.
The head- and endwalls are built 12" above the pipe to ensure proper cover, support the road, and improve pipe capacity.
Figure not drawn to scale.

Important Considerations

- Headwalls and endwalls should be built high enough to support the full depth of pipe cover recommended by the manufacturer: 12" of cover for plastic and corrugated steel pipe 24" in diameter and smaller (Figure 3).
- It is critically important to anticipate the forces of drainage water under heavy storm high flow conditions. Drainage structures should be built to conduct massive flows and provision for safe over flow should be provided. Headwalls and end walls built to the proper height not only improve pipe capacity during extremely high flows but also help prevent pipe blockage, road washouts and the resulting catastrophic effects.

APPENDIX C: WORKSITES-IN-FOCUS

Goss Farm

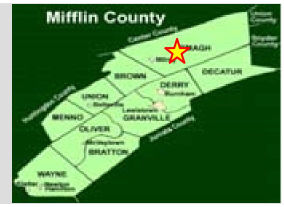
Snyder Farm

Stuck Farm

Project Summary

Mifflin County

Goss Farm Lane



Project Overview:

The Goss Farm lane traverses a small wetland stream channel, effectively damming the channel and funneling the flow through two concrete pipes. For much of the year spring water surfaces on the lane and mixes with silt and road material that is suspended in the flow by traffic utilizing the lane. This water discharges directly to a tributary of Kishacoquillas Creek. The large amount of surface and sub-surface water present saturates the road base creating potholes and rutting. This results in sediment laden run-off entering the stream that would otherwise have been clear spring flow. It also results in a need for higher than normal re-graveling rates and more frequent surface maintenance.

Project Facts

Project: Goss Farm Lane
Project Owner: Porter Township
Watershed: Kishacoquillis Creek
Project Length: 280 feet
Date Completed: 2009
Cost Estimate: $3,573

For More Information:
Center for Dirt and Gravel Road Studies
(814) 865-5355 www.dirtandgravelroads.org

Mifflin Cons. District: (717)248-4695

Project Objectives

1. Prevent road surface drainage from directly discharging to the stream.
2. Reconnect natural surface and subsurface drainage patterns in order to minimize the effect of the road related to sediment loading of the stream, and to reduce cyclical road maintenance.
3. Incorporate Environmentally Sensitive Maintenance Practices (ESMPs) that require minimal maintenance input by the landowner and can withstand heavy equipment traffic.

Project Considerations

The lane is used both as a cattle walkway and for equipment field access. Any maintenance plan had to accommodate both factors. The plan specified a lane that is wide enough for large farm machinery and includes a tight, densely packed surface that will not be problematic to cattle.

French Mattress: Similar to a French Drain used for home construction, a French Mattress consists of clean stone wrapped in water permeable separation fabric. The mattress is used in particularly wet areas and is placed under the road to provide support for the road while allowing the free movement of water through the road base.

Broad-Based Dip: A broad-based dip is a wide and shallow channel with an associated high spot that forms a reverse grade. The dip functions in a fashion similar to a grade break to prevent water from flowing down the road. However, the dip is installed diagonally across the road and differs from the grade break in that it collects drainage from the full width of the road and transports the water to a single outlet point. These structures function similar to crosspipes to outlet and disperse ditch flow from the road corridor. The bottoms of dips are typically reinforced to prevent erosion.

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Cost Summary
The Goss farm lane project was completed almost entirely by a contractor at a cost of $3,572.76. Even though the French Mattress is one of the easier ESM's to build a contractor was utilized here to expedite the process. Considering the small size of the project most of the costs reflected where consumed in stone and aggregate.

Figure 1: This is the wetland stream crossing on the Goss Farm. Notice that BEFORE, water is dammed up against the right side of the road and funneled through a single pipe. The AFTER picture shows the 120 foot French mattress. White relief pipes are visible and highlighted with black arrows. Notice also that the road's "lowpoint" has been moved away from the stream so runoff is forced to leave the road before nearing the channel. The Broad based dip at this location forces the water to the down slope side of the road.

Project Solutions:

Considering the volume of sub-surface water present at the site, the French Mattress was an ideal solution.

• Wet land flows could pass through the road with no adverse impact. This benefits not only the farm lane but the down slope wetland as well. Reattaching this subsurface hydrology will greatly improve the ecological diversity in the recently protected stream buffer.

•The heavy equipment that frequently uses the road is well supported by the combination of stone and fabric. Agricultural operations seldom have the luxury of waiting for ideal conditions to proceed. Prolonged rain events, freeze and thaw periods, and melting snow could easily destabilize the previous base and often where the cause of excessive maintenance. The mattress will adequately support both farm machinery and live stock during the entire year.

•Any road drainage trapped on the lane is also diverted into a small buffer prior to the stream due to the filling of the road profile by the material used to construct and cover the Mattress.

•The material used to cover the mattress was graded such that it had a tightly bound surface. As with all cattle walk ways the material on the surface must be agreeable with animal hooves. By design the mattress does not expose the course material that freely drains the road base and supports surface traffic.

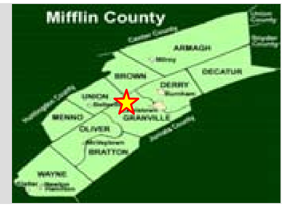
From the Landowner:

"The lane is definitely better. There is no longer an issue with the whole road flooding, and it no longer ruts when we cross it with heavy equipment. We can use the road year-round where we could not before. Also, water does not run down the road and into the stream like it used to."

- Linda Goss, 10/2009

Project Summary

Mifflin County
Snyder Farm Lane



Project Overview:

As is common with many farm lanes in Mifflin County, the Snyder Farm lane had become lower than the surrounding fields and was acting as an entrenched conduit, or direct channel, for field drainage to reach the stream. The lane collected runoff from fields on both sides of the stream and funneled it to a ford crossing.

Project Objectives

1. Prevent field drainage from directly discharging to the stream.
2. To maintain soil fertility and reduce stream pollution by Replicating natural drainage patterns as closely as possible in order to capture nutrients being lost with runoff.
3. Incorporate Environmentally Sensitive Maintenance Practices (ESMPs) that require minimal maintenance input by the landowner and can withstand heavy equipment traffic.

Project Considerations

The existing farm lane was deeply entrenched in relation to the surrounding landscape and required fill material to elevate it to a maintainable level above the surrounding fields. The Snyder farm has a shale barrow area on the property where the necessary material could be obtained.

Project Facts

Project:	Snyder Farm Lane
Watershed:	Kishacoquillis Creek
Project Length:	810 feet
Date Completed:	2009
Cost Estimate:	$3,758

For More Information:

Center for Dirt and Gravel Road Studies
(814) 865-5355 www.dirtandgravelroads.org

Mifflin Cons. District: (717)248-4695

Figure 1: The existing lane funneled runoff to the stream at the tree line in the background.

Figure 2: Farm runoff collected by the farm lane is shown entering a Kish tributary during a rain event.

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Center for Dirt and Gravel Road Studies

Cost Summary

The Snyder farm lane project was completed almost entirely by a contractor. The landowner was able to provide the shale fill material which helped to reduce the overall project cost. The installation of the drainage features and the placement of the shale fill totaled $3,757.92. The estimated cost for the shale fill if it had been delivered to the site was $10,560. This equates to a total project value for this project of $14,318.

Figure 3: A conveyor belt diversion, installed before the ford crossing, insures runoff is diverted before it can reach the stream.

Figure 4: Three conveyor belt diversions can be seen in series on the hill slope leading to the stream at the tree line.

Project Solutions

Conveyor Belt Diversions: Similar in function to a broad based dip, belt diversions prevent water from flowing down the road and direct runoff to a stable filter area. They consist of a piece of conveyor belting attached to lumber and buried at an angle in the roadbed. The diversion is buried so that approximately 4" of belt protrudes from the road surface. This belt is flexible enough to allow vehicles to pass, but prevents water from flowing down the road.

Filling the Road**:** Raising the elevation of the lane with material was required to allow water to drain from the road surface. Elevating the road surface also allowed the newly installed belt diversions and broad-based dips to function effectively. No tail ditch outlets or excavation into crop fields was required.

Broad-Based Dip: A broad-based dip is a wide and shallow channel with an associated high spot that forms a reverse grade. The dip functions in a fashion similar to a grade break to prevent water from flowing down the road. However, the dip is installed diagonally across the road and differs from the grade break in that it collects drainage from the full width of the road and transports the water to a single outlet point. These structures function similar to crosspipes to outlet and disperse ditch flow from the road corridor. The bottoms of dips are typically reinforced to prevent erosion.

From the Landowner:

"I am pleased with the structures. As far as run-off they are doing their job and there is no washing on the road. I especially notice how well they are working on the back on the hill, on the steep part across the creek. Almost every other year we would have till fill that section with truck loads of shale, and it doesn't look like we'll have to do that anymore. The approach leading from the barn to the creek is holding up much better also. There has definitely been an improvement in run-off. I'm thinking about using similar structures on my front lane that continues to scour during rainstorms."."

- Ray Snyder, 11/2009

Project Summary

Mifflin County
Stuck Farm Lane

Project Overview:

The Stuck farm lane, also known as Red Rose Lane, is bordered on both sides by rotationally cropped farm fields consisting of corn and mixed alfalfa hay. The lane is lower in elevation than the surrounding fields and runs at a right angle to the crop strips. The road elevation and alignment creates a dry stream bed that channels considerable run-off to the stream during wet weather events. The lane also collects and carries a significant amount of water from Knagy Lane to the east. On this animal intensive commercial dairy operation, that utilizes both manure and chemical fertilizers on the fields to maximize crop yields, substantial Nitrogen losses occur during run-off events. Also, the topography is such that drainage from the road flows through an area used to store ensiled feeds. Leachate from the silage bags mixes with the field drainage, further decreasing the water quality prior to discharging into the stream. Aside from the pollution issues, erosion and base saturation of the road caused notable maintenance and usability issues for the landowner.

Project Facts

Project: Stuck Farm Lane
Watershed: Kishacoquillis Creek
Project Length: 1,334 feet
Date Completed: 2009
Cost Estimate: $11,464

For More Information:
Center for Dirt and Gravel Road Studies
(814) 865-5355 www.dirtandgravelroads.org
Mifflin Cons. District: (717)248-4695

Project Objectives

1. Prevent direct discharge of road/field drainage into a tributary of Kishacoquillas Creek.
2. Reduce soil and nutrient loss from productive farm fields and reduce.
3. Reduce road related maintenance issues for the landowner and provide a more stable lane for farm equipment use during all seasons of the year.

Project Solutions

Filling the Road: The elevation of the road was raised above the surrounding fields by importing shale and filling the road cross section. The road no longer acts as a drainage channel for storm flows and field run-off. Diverting Off-ROW Drainage: By elevating Red Rose Lane at the intersection with Knagy Lane, drainage from Knagy Lane that had flowed onto Red Rose Lane is redirected into the adjoining farm fields where it was more likely to infiltrate. This reduces the volume of water flowing on Red Rose Lane and reduces saturation of the road base and erosion of the road surface.

Establishing Crown and Cross-Slope: In addition to raising the road elevation, effective surface shape was built into the road. A combinaton of center-crown and out-sloping was used. Center-crown is where the road surface slopes an average of 4% to 6% from the road center to the road edge. Out-slope is where the entire road surface slopes 4% to 6% from the up-hill road edge (a higher road bank) to the down-hill road edge (a shoulder that falls away from the road).

Installing Broad-Based Dips: Four Broad-Based Dips were constructed on the road surface at strategically locations to divert any water flowing in the road corridor to natural water courses and areas in the adjoining fields where effective drainage away from the road could be achieved.

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Project Solutions (continued)

Berm Removal: In some areas small amounts of topsoil along the down-slope road edge (generally less than 6“ in depth and no wider than 3‘) were excavated and redistributed over higher ground in the fields, so road drainage would not be restricted from draining to lower ground.

Figure 1&2: BEFORE the project, the entrenched farm lane collected field runoff and transported it down the road surface. Many practices were implemented to elevate the road, encourage infiltration, and insure that runoff could no longer use the road as a flow corridor.

Cost Summary

This project was mostly completed by a contractor. The road fill material and surface drainage features where installed for $11,464. The contractor was utilized to move the 420 cubic yards of material as well as provide proper compaction.

The landowner was able to remove most of the undesirable berm material with a skid steer. In conjunction with the contractor filling the road profile this simple activity provided a great benefit in reducing concentrated flow.

Figure 3: 2009 image of the improved Stuck Farm Lane. In the lower portion of the photo is a sampling trench.

APPENDIX D: RAW RAINFALL DATA

Yoder Farm   Pre-Construction Water Sampling

4/25/2007 0.54" rain event				7/5/2007 0.12" rain event				8/9/2007 0.45" rain event			
Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)	Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)	Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)
0.14	6.79	1.51	4,822	4.05	6.79	1.51	10,900	0.07	6.79	1.51	4,822
0.04	5.75	0.63	2,472	1.21	5.75	0.63	3,260	0.08	5.75	0.63	2,472
0.03	4.62	0.91	3,947	1.68	4.62	0.91	3,000	0.14	4.62	0.91	3,947
0.06	4.94	0.06	2,447	1.82	4.94	0.06	2,270	0.12	4.94	0.06	2,447
0.13	4.87	0.15	1,525	0.45	4.87	0.15	1,150	0.09	4.87	0.15	1,525
0.11	4.78	0.89	1,573	0.12	4.78	0.89	550	0.10	4.78	0.89	1,573
0.12	4.70	0.55	1,185	0.06	4.70	0.55	320	0.07	4.70	0.55	1,185
0.14	3.89	1.37	881	0.05	3.89	1.37	580	0.07	3.89	1.37	881

Yoder Farm   Post-Construction Water Sampling

4/1/2009 0.23" rain event		4/3/2009 0.30" rain event		5/5/2009 0.39" rain event	
Flow (L/min)	TSS (mg/L)	Flow (L/min)	TSS (mg/L)	Flow (L/min)	TSS (mg/L)
2.03	10900	0.17	2760	0.15	1260
0.60	3260	0.5	2910	0.13	1110
0.83	3000	0.65	3460	0.12	990
0.94	2270	0.73	3480	0.11	2510
0.23	1150	0.18	1670	0.12	4600
0.06	550	0.06	980	0.14	1950
0.03	320	0.1	660	0.15	1400
0.03	580	0.03	410	0.12	1180

Goss Farm Pre-Construction Water Sampling

4/25/2007 0.54” rain event				8/21/2007 0.21” rain event				12/23/2007 0.67” rain event			
Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)	Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)	Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)
3.00	3.39	2.71	1,578	1.25	3.39	2.71	1,578	17.44	3.39	2.71	1,578
3.75	2.33	1.10	623	1.50	2.33	1.10	623	17.75	2.33	1.10	623
3.75	1.82	1.02	532	2.00	1.82	1.02	532	21.74	1.82	1.02	532
10.00	2.00	1.16	581	2.31	2.00	1.16	581	28.30	2.00	1.16	581
7.50	1.91	0.95	497	2.73	1.91	0.95	497	25.86	1.91	0.95	497
7.50	1.98	0.99	455	4.29	1.98	0.99	455	26.55	1.98	0.99	455
6.00	2.32	0.90	426	4.29	2.32	0.90	426	28.30	2.32	0.90	426
6.00	2.03	0.52	406	4.29	2.03	0.52	406	26.79	2.03	0.52	406

Goss Farm Post-Construction Water Sampling

4/1/2009 0.23” rain event	4/3/2009 0.30” rain event	5/5/2009 0.39” rain event
No flow	No flow	No flow

Stuck Farm Pre-Construction Water Sampling

4/25/2007 0.54” rain event				8/9/2007 0.45” rain event				10/26/2007 0.54” rain event			
Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)	Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)	Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)
0.64	7.13	0.30	983	1.67	7.13	0.30	983	0.75	7.13	0.30	983
1.20	6.49	0.50	738	2.64	6.49	0.50	738	0.70	6.49	0.50	738
2.00	6.18	0.80	674	2.23	6.18	0.80	674	0.67	6.18	0.80	674
1.76	5.83	0.15	600	1.48	5.83	0.15	600	0.61	5.83	0.15	600
0.97	5.65	0.67	1,674	3.33	5.65	0.67	1,674	0.55	5.65	0.67	1,674
1.15	5.13	1.67	579	2.52	5.13	1.67	579	0.48	5.13	1.67	579
2.00	5.09	1.11	1,454	1.96	5.09	1.11	1,454	0.46	5.09	1.11	1,454
1.25	4.92	0.46	443	3.44	4.92	0.46	443	1.25	4.92	0.46	443

Stuck Farm Post-Construction Water Sampling

7/31/2009 1.03” rain event		7/29/2009 …..0.18” rain event	
Flow (L/min)	TSS (mg/L)	No flow	
0.14	430		
0.13	380		
0.13	290		

Haughwout Farm Pre-Construction Water Sampling

11/26/2007 0.2" rain event				12/23/2007 0.67" rain event				1/11/2008 0.17" rain event			
Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)	Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/IL)	Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)
4.10	4.53	0.20	10,530	4.42	4.53	0.20	10,530	3.57	4.53	0.20	10,530
3.97	4.51	0.08	3,686	4.50	4.51	0.08	3,686	4.07	4.51	0.08	3,686
4.02	2.50	1.12	5,250	6.11	2.50	1.12	5,250	5.22	2.50	1.12	5,250
2.28	1.67	0.08	2,763	5.51	1.67	0.08	2,763	6.56	1.67	0.08	2,763
2.87	1.27	1.19	6,830	7.33	1.27	1.19	6,830	7.26	1.27	1.19	6,830
4.40	0.82	0.84	2,380	16.57	0.82	0.84	2,380	6.99	0.82	0.84	2,380
2.29	1.92	1.63	4,020	13.89	1.92	1.63	4,020	5.88	1.92	1.63	4,020
6.94	1.19	1.25	2,163	10.00	1.19	1.25	2,163	5.68	1.19	1.25	2,163

Haughwout Farm Post-Construction Water Sampling

7/31/2009 1.03" rain event		
No flow	Elected not to sample	Elected not to sample

Snyder Farm Pre-Construction Water Sampling

4/25/2007 0.54" rain event

Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)
0.09	6.79	1.51	430
0.13	5.75	0.63	380
0.14	4.62	0.91	290
0.14	4.94	0.06	240
0.17	4.87	0.15	255
0.18	4.78	0.89	195
0.16	4.70	0.55	140
0.15	3.89	1.37	145

6/21/2007 0.75" rain event

Flow (L/min)	N (mg/L)	P (mg/L)	TSS (mg/L)
0.91	10.56	5.01	5143.00
6.00	8.99	1.18	1307.00
10.00	6.96	1.04	6403.00
6.00	6.02	2.52	4045.00
15.00	5.71	3.53	4333.00
20.00	6.02	0.57	3330.00
15.00	7.95	2.66	2172.00
6.00	8.65	1.81	1784.00

Snyder Farm Post-Construction Water Sampling

5/4/2009 0.39" rain event

Flow (L/min)	TSS (mg/L)
0.09	430
0.13	380
0.14	290
0.14	240
0.17	255
0.18	195
0.16	140
0.15	145

7/29/2009 ----0.18"rain event

No flow

7/31/2009 1.03" rain event

No flow