Environmentally Sensitive Maintenance Practices for Unpaved Roads: Sediment Reduction Study

Prepared for

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Abstract

Sediment runoff from Pennsylvania's 20,000+ miles of unpaved public roads is a large source of stream pollution to the waters of the commonwealth. The Center for Dirt and Gravel Road Studies (Center) at Penn State has established and advocates Environmentally Sensitive Maintenance Practices (ESMPs) to reduce sediment pollution from unpaved roads. The objective of this study was to take five commonly used ESMPs and quantify sediment delivery reductions from each practice. The five ESMPs selected for this study were:

- Driving Surface Aggregate [DSA]: durable and erosion resistant road surface;
- Raising the Profile: raising road elevation to restore natural drainage patterns;
- Grade Breaks: elongated humps in the road surface designed to shed water;
- Additional Drainage Outlets: creating new outlets in ditch to reduce channelized flow; &
- Berm Removal: Removing unnecessary berm and ditch on downhill side of road to encourage sheet flow.

The experimental approach taken in this study was to use a rainfall simulation device to create a repeatable rainfall event and collect sediment load data. These data would be used as a baseline for comparison with similar sediment load data from after each ESMP was implemented. The simulated rainfall event is roughly equivalent to a 1-month return period in Pennsylvania, producing 0.55 inches of precipitation over 30 minutes.

Note that the results in this study represent only a few trials for each practice. Variations in road surface, width, crown, slope, relation to stream, etc. will alter the effectiveness of each practice, and therefore caution is advised in interpreting and applying this data to outside practices or models.

Sediment reductions form adding Driving Surface Aggregate averaged 75% after one month, and 90% after one year compared to the existing road surface for two placements. Unlike the other four ESM practices which attempt to reduce sediment by reducing runoff concentration and transport, DSA reduces sediment generation from the road surface while leaving flow pathways in place.

The four drainage control practices also showed significant sediment reductions. These practices achieve sediment reductions by reducing the amount of runoff that reaches the stream, not by reducing erosion from the road surface. Sediment reductions obtained by raising the road elevation to restore natural drainage were approximately 78% after one month, and 81% after one year. The sediment reductions obtained by installing gradebreaks on two separate roads were 43% and 57% (86% and 100% efficiencies, *see note below). The sediment reductions obtained by adding a drainage outlet were approximately 48% (96% efficiency*) when considering the down-slope ditch only and 31% (62% efficiency*) when considering the entire road area. The sediment reductions obtained by removing an unnecessary berm were approximately 94% when considering the down-slope ditch only and 59% when including the entire road area. **Note* *that sediment reductions represent the total amount of sediment reduced over 100 feet of roadway when the ESM practice is implemented at the midway or 50 foot mark. This is not equivalent to reduction efficiencies of the practice. For example, a drainage outlet placed at 50 feet within the 100 foot test section would only be expected to affect the road above the practice. The outlet would be 100% efficient if it achieved a 50% sediment reduction, since the 50 feet or roadway below the outlet is unaffected.*

This study reinforces the Center's recommendation to use Driving Surface Aggregate in places where drainage discharge to a stream is unavoidable. In other locations, such as perpendicular road/stream crossings, a combination of drainage practices can effectively eliminate much of the sediment pollution without the high cost of road aggregate. While this study has provided a valuable first look at sediment reductions, further iterations of research are needed before blanket "reduction efficiencies" can be claimed for any specific ESM practice.

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CHAPTER 1: INTROUDCTION

1.1 Background

Fifteen years ago, the Commonwealth of Pennsylvania recognized that a substantial contribution of sediment pollution to Pennsylvania streams was runoff from publicly maintained dirt and gravel roads (*Figure 1.1*). Approximately 57% of the 20,000 miles of publicly owned unpaved road in Pennsylvania are within the Chesapeake Bay watershed.

Figure 1.1: Example of the effect of road runoff on aquatic ecosystems. This image, taken in Centre County, PA, shows a clear headwater stream flowing in from the right. Drainage from an unpaved road enters the water from behind the large tree in the center.

In response to this observation of stream pollution, in 1997, the Commonwealth established the Dirt and Gravel Roads Program [Program] within the State Conservation Commission [SCC] as a non-lapsing funding source with of objective of identifying the polluting sources and implementing solutions. The Center for Dirt and Gravel Road Studies [Center] was established within the Penn State Institutes of Energy and the Environment [PSIEE] on the University Park Campus of The Pennsylvania State University in 2000 to support the Conservation Commission's Program. The Center develops environmentally sensitive road maintenance practices [ESMPs], teaches these practices to township-level roadmasters, and participates in a outreach assistance program for townships in the Commonwealth.

The Center has conducted more than 140 two-day training session which have been attended by over 5,000 state and township personnel. In the ten yeas that the DGRP has been in operation, over 1,600 individual road projects have been completed which mitigate sediment pollution into streams of the Commonwealth. More detailed description of the program and its accomplishments to date can be found at www.dirtandgravelroads.org. The organization of the DGRP is such that in its first decade it was focused on technique development, implementation, and education and less on quantification of the environmentally sensitive road maintenance practices that were being implemented.

The objective of this study was to make a preliminary attempt to quantify the sediment reductions that result from some of the Program's most commonly used Environmentally Sensitive Maintenance Practices.

1.2 Methodology

Five ESMPs were selected for study:

- Driving Surface Aggregate [DSA]: durable and erosion resistant road surface;
- Raising the Road Profile: raising road elevation to restore natural drainage patterns;
- Grade Breaks: elongated humps in the road surface designed to shed water;
- Additional Drainage Outlets: creating new outlets in ditchline to reduce channelized flow; and
- Berm Removal: removing unnecessary berm and ditch on downhill side of road to encourage sheet flow.

With the exception of DSA, the other four techniques are associated with common components of most dirt and gravel roads and represent simple, cost-effective maintenance practices which, when applied properly, can exhibit significant reductions on sediment loads moving to waterways. DSA, on the other hand, is a unique concept fostered by the Center as a means of establishing a more durable roadway. DSA is an aggregate distribution that was specifically designed as a driving surface, unlike all other aggregate distributions used as road surface, which have been developed for different purposes. These practices are detailed individually later in this report.

The experimental approach taken in this study was designed to collect sediment loads on a section of road long enough to be representative of the roadway during a simulated rain even. These data would be used as a baseline for comparison once each ESMP was implemented and the testing repeated. To ensure an accurate comparison, a device was constructed that would deliver water to the test site in a uniform manner. The details of the "rainmaker", its performance characteristics, and testing protocol follow.

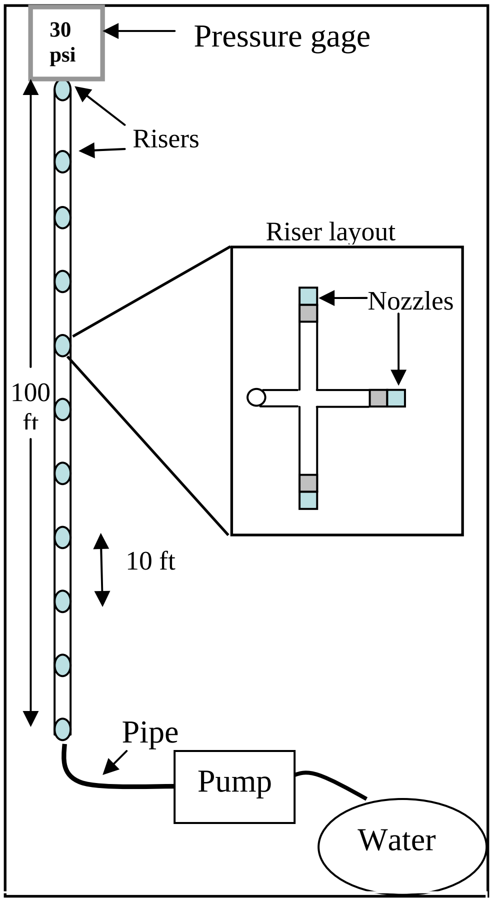


Figure 1.2: Rainmaker plan view.

1.3 Rainmaker

The "rainmaker" was designed by the Center particularly for this study. *Figure 1.2* shows a plan view of the rainmaker setup from above. The rainmaker is ideally suited to sediment monitoring because of the convenience and repeatability that cannot be achieved by sampling natural events.

The rainmaker is designed to simulate rainfall on a 100’ length of road. It delivers approximately 1.1 inches of rainfall per hour in a highly controlled and repeatable event. The rainmaker was run before and after Environmentally Sensitive Maintenance Practice implementation to determine the sediment reductions of each practice. *Figure 1.3* shows the rainmaker in action with components labeled.

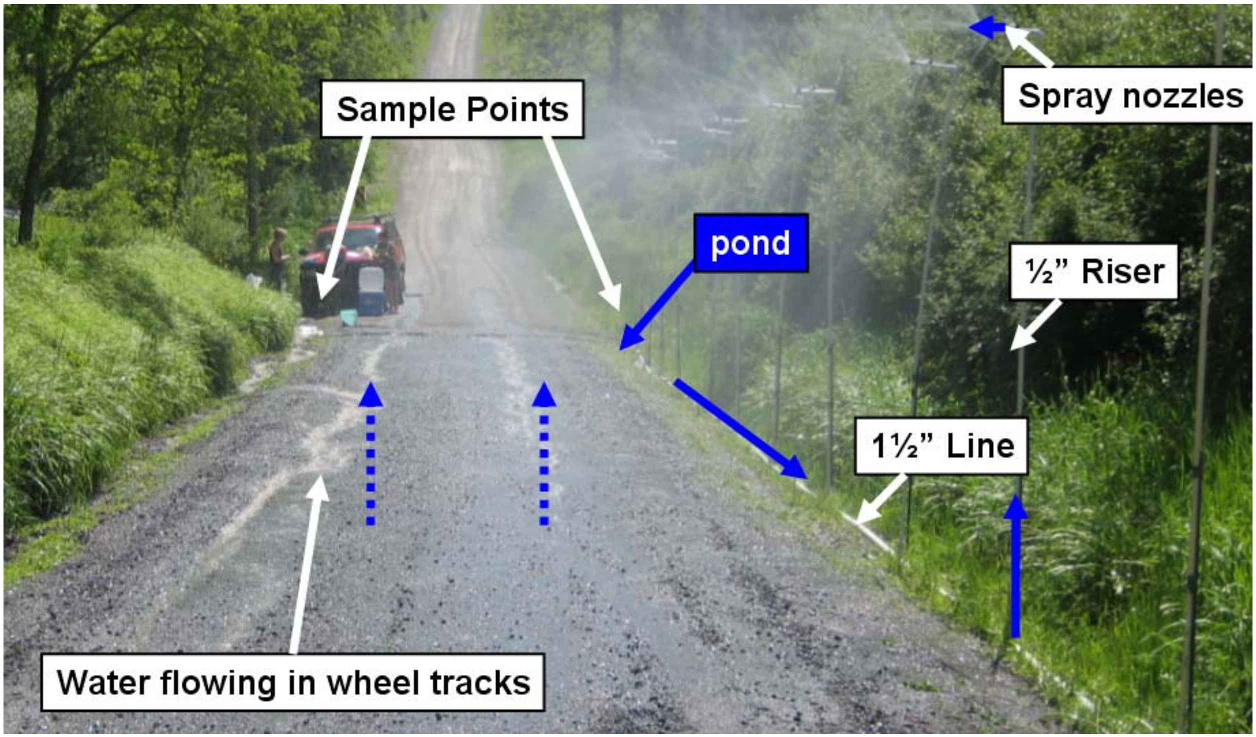


Figure 1.3: Rainmaker in action in Columbia County with components labeled.

1.3.1 Rainmaker Design Specifications

- **water source**: nearby stream, lake, or pond
- **pump**: 3” 5hp Honda water pump
- **body**: 100’ x 1½” PVC pipe (in 10’ sections)
- **risers**: 11 PVC risers at 10’ intervals, each ½” in diameter and 10’ tall with three nozzles
- **nozzles**: 3 nozzles in a “T” configuration on each riser (Rainbird 22-series MPR nozzles)
- **pressure**: 30 psi as measured on gauge at far end of setup
- **rainfall rate**: averages 0.55 inches in 30 minutes (1.1 inches per hour)

Figure 1.4: Collection jars for repeatability testing on a test road in Huntingdon County.

1.3.2 Rainmaker Calibration

Sample Container	**Rainfall Intensities** (inches per hour)				**Std. Dev. between runs**
	Run 1	**Run 2**	**Run 3**	**Mean**	
1	1.21	1.15	1.15	1.17	*0.04*
2	0.45	0.48	0.45	0.46	*0.02*
3	1.38	1.05	1.21	1.21	*0.16*
4	2.58	2.66	2.38	2.54	*0.15*
5	0.98	1.39	1.14	1.17	*0.21*
6	0.97	1.11	1.48	1.19	*0.27*
7	1.36	1.51	1.67	1.51	*0.16*
8	0.60	0.54	0.56	0.57	*0.03*
9	1.56	1.28	1.65	1.50	*0.19*
10	0.39	0.53	0.71	0.54	*0.16*
11	0.43	0.65	0.51	0.53	*0.11*
12	0.82	1.13	1.15	1.03	*0.18*
13	1.69	1.26	1.12	1.36	*0.30*
14	0.51	0.85	0.81	0.72	*0.19*
15	1.28	1.71	1.65	1.55	*0.23*
16	0.79	2.29	1.19	1.42	*0.77*
17	0.10	0.17	0.18	0.15	*0.04*
Average	**1.01**	**1.16**	**1.12**	**1.09**	***0.19***
Std. Dev.	**0.61**	**0.64**	**0.55**	***0.60***	

Standard Deviation between collection points in one run = 0.60 or 55% of mean
Standard Deviation between sample runs (consistency) = 0.19 or 17% of mean

Table 1.1: Results of repeatability testing for the rainmaker. 17 rainfall collection jars were randomly placed on the roadway and subjected to three **runs of the rainmaker.**

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 1.4*. Rainfall intensities from the repeatability testing can be found in *Table 1.1*. 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. This indicates that although the average intensity of rainfall is 1.09 in/hr, rainfall rates 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 event every time it is run. Analysis of the data presented in *Table 1.1* 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

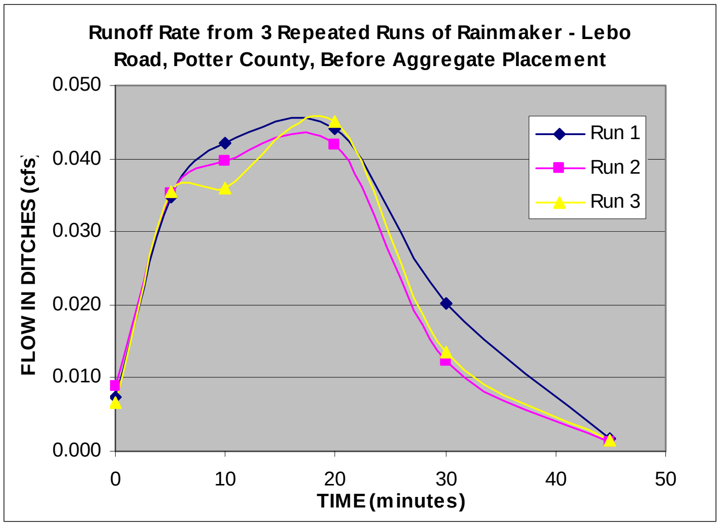


Figure 1.5: Example of repeatability of rainfall events. The ditch flows from three separate events are shown for Lebo Road in Potter County.

less than 17% between separate runs of the rainmaker. A paired-t test was also run on the data presented in *Table 1.1* to test the statistical significance of the repeatability of the separate runs. The results of the paired-t test indicated with a 95% confidence that there were no significant differences in rainfall intensity between the three runs. (P-values of 0.15 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 1.5* shows nearly identical runoff rates for three separate runs of the rainmaker for Lebo Road as part of the Driving Surface Aggregate Study.

In summary, while the rainmaker may not provide even coverage over the entire road (SD of 0.6 inches within a run), it does an excellent job of providing repeatability by providing the same rainfall intensity at the same points on successive tests (SD of 0.19 inches between runs).

1.3.3 Rainmaker Testing Procedure

- **General Considerations**
  - Rainmaker was run after at least 2 days of dry weather to avoid saturated conditions.
  - A 100-ft stretch of road was evaluated.
  - Runoff was simulated three times before the ESMP was in place and three times after the ESMP was implemented.
  - In order to insure excellent repeatability, new nozzles were installed on the rainmaker before each three-run test.
- **Step-by-step procedure**
  - Set up rainmaker on test section. Test section was identified with stakes to insure rainmaker was set up in exactly the same spot for future tests. Water was drawn from nearby stream or pond. A background source water sample was taken for reference. Background sediment concentrations for all test were negligible (avg < 5 mg/l TSS).
  - Insure sample points are ready for collection. This procedure was site-specific, but included activates such as digging sampling holes (see *Figure 1.6*), installing sheeting to make sampling easier, and insuring no runoff bypasses sampling point.
  - Turn the rainmaker on and run until flow reaches sample points. This was done to reduce infiltration on the initial run, and to test the collection system.

Figure 1.6: This is an example of a rainmaker collection point. Plastic and aluminum sheets are used to concentrate water at sample point.

- **Rainmaker Run 1**
  - Pump was turned on and adjusted for 30psi at the gauge on far end of the rainmaker. The pump ran for a total of 30 minutes in each run.
  - Sampling:
    - Timing: The first sample was collected one minute after the wetting front initially reached the sampling point (T=0). A total of six samples were

    collected at each sample point. Samples were collected at one (T=1), five (5), ten (10), twenty (20), thirty (30), and forty (40) minutes after runoff reached the sample point (T=0).
        - <u>Sediment</u>: At each sampling time described above, a one-liter sample of runoff was collected for later analysis *(Figure 1.7)*. This was used to determine the Total Sediment Load in the runoff.
        - <u>Flow</u>: Immediately after taking a sediment sample, the flow was calculated by recording the amount of time it took to fill a container of known volume.
    - After running for 30 minutes, the pump was turned off.
- **Drying Time 1**
    - After the pump was turned off and all samples were taken from the first rainmaker run, the road was allowed to dry for a period of one hour.
    - Approximately 30 minutes into the 60 minute drying cycle, a vehicle was driven a total of 20 passes over the entire test section. This was done to simulate traffic and further stress the road surface before the next rainmaker run.
- **Rainmaker Run 2**
    - After the 60 minute drying time, the pump was turned back on for 30 minutes at 30psi. The sampling procedure outlined in “rainmaker run 1” above was repeated.
- **Drying Time 2**
    - Another 60 minute drying cycle with 20 vehicle passes was completed.
- **Rainmaker Run 3**
    - After the 60 minute drying time, the pump was turned back on for 30 minutes at 30psi. The sampling procedure outlined in “rainmaker run 1” above was repeated.

1.3.4 Rainmaker Summary

By collecting sediment samples and flow volumes at each sample point, total sediment loading can be calculated. Each time the rainmaker is run, it is run for three 30-minute sample periods as described in the “rainmaker procedure” above. The flow rates and sediment concentrations for these three runs are then combined to obtain the average sediment and flow rates for each section of road.

Figure 1.7: A sediment sample is taken at a sample point, in this case a culvert outlet on Lebo Road in Potter County.

1.3.5 Rainmaker ‘Return Period’ Equivalence

The “rainmaker” simulates a 1.1 inches per hour rainfall on a 100’ length of road. The magnitude of the simulated rainfall was chosen to represent a ‘modest’ but not an extraordinary event for each of the two regional locations where ESMP testing was conducted. The applied rate of 0.55 inches for one half-hour in these regions of northern and central Pennsylvania is equivalent to approximately a one and a quarter month rain event (return period = 0.1 years). *Figure 1.8* indicates the approximate location of each test sites in Region #2 and #4 located on the PennDOT Storm Intensity-Duration-Frequency Charts [Aron et al. 1986].

The return period for 0.55 inches of rainfall in 30 minutes was extracted from Aron et al. [1986] and extrapolated from the data presented in *Figure 1.9*. Although Regions #2 and #4 exhibit subtle differences in the amount of rainfall that occurs at fixed time intervals, for the purposes of this activity, these differences were small and the equivalent Return Period is effectively reported as one month.

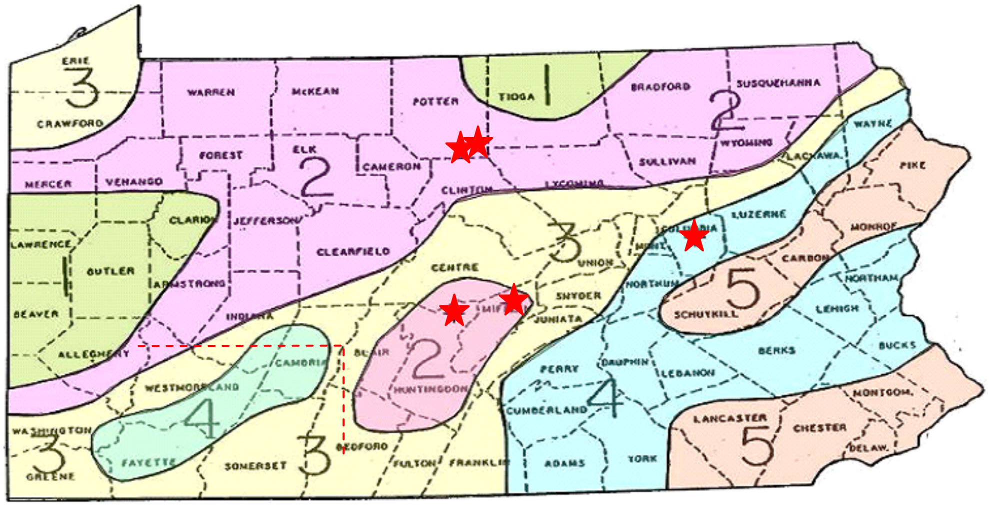


Figure 1.8: Locations of ESMP testing (red stars) in relationship to ‘delineated regions with uniform rainfall’ from PennDOT field manual. (Aron et al. 1986)

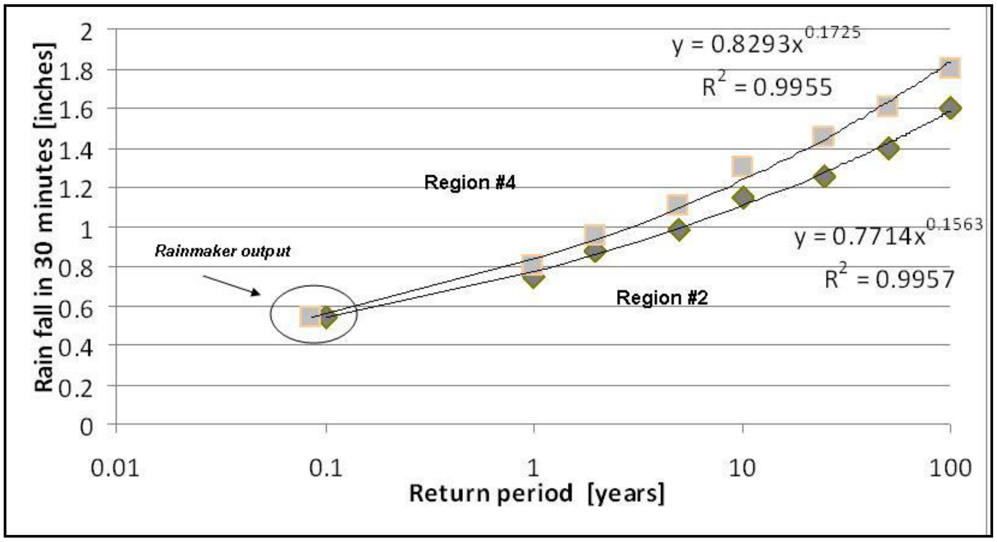
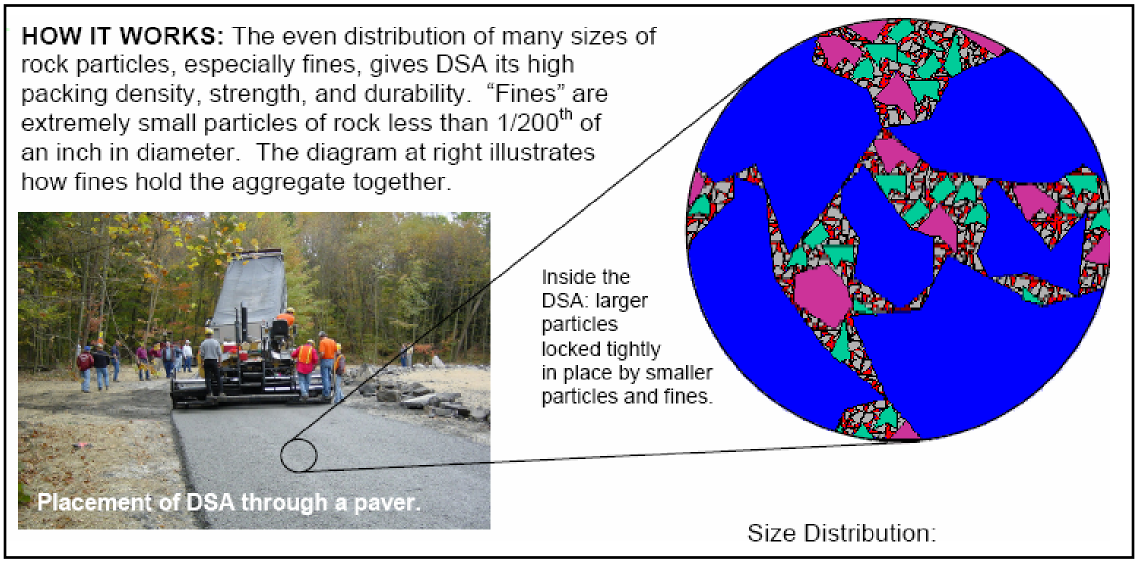


Figure 1.9: ‘Return Period’ estimate for a 0.55 inch 30-minute rainfall is slightly over one month (0.1 years). (Aron et al. 1986)

CHAPTER 2: ESMP # 1: Driving Surface Aggregate

2.1 Definition

Driving Surface Aggregate (DSA) is a specific gradation of crushed stone developed by the Center for Dirt and Gravel Road Studies specifically for use as a surface wearing course for unpaved roads.



HOW IT WORKS: The even distribution of many sizes of rock particles, especially fines, gives DSA its high packing density, strength, and durability. "Fines" are extremely small particles of rock less than 1/200th of an inch in diameter. The diagram at right illustrates how fines hold the aggregate together.

Inside the DSA: larger particles locked tightly in place by smaller particles and fines.

Figure 2.1: This graphic demonstrates how DSA works by incorporating a wide array of stone sizes, including fine material, for maximum compaction.

2.2 Background

The DSA specification has many beneficial attributes that help to make a stronger, more erosion resistant road including:

- A unique and specific particle size gradation specification consisting of many graded sizes of crushed rock designed to maximize packing density. *Figure 2.1* further explains this size gradation. *Table 2.1* details the DSA gradation specification.
- A minimum abrasion resistance requirement (L.A. Abrasion $\leq$ 40%) to insure aggregate hardness and resistance to breakdown.
- Restriction on the amount of clay or silt fines that can be contained in the aggregate. The fine material (passing #200 sieve) must be derived from the crushed rock, not the addition of clay or silt fines.
- It is highly recommended that this material be placed using a motor-paver and compacted. The paver is used to place aggregate in one 8" lift (compacted to 6") and avoid aggregate segregation that can

Passing sieve	**Lower %**	**High %**
1 ½ inches	100	
¾ inches	65	95
#4	30	65
#16	15	30
#200	10	15

Table 2.1: DSA gradation specification.

occur with typical "dump and spread" methods of aggregate placement.

- DSA has minimum and maximum pH requirements, unlike traditional aggregates.

As a result of these strict specifications, DSA produces a stronger, more consistent, and longer lasting driving surface for unpaved roads. The purpose of Driving Surface Aggregate is to obtain a longer lasting road surface that will be more resistant to traffic and erosion, and reduce the long term maintenance costs and runoff pollution associated with the road.

Driving Surface Aggregate has been used by the Dirt and Gravel Road Maintenance Program (Program) for the last ten years. Over 400 miles of public unpaved road have been surfaced with DSA since the Program began in 1997. The Program has always operated under the belief that improving the road surface near waterways will greatly reduce the amount of sediment that enters nearby stream. This is the first time a quantitative study has attempted to determine sediment reductions from DSA placement. The purpose of this section of the study is to determine sediment reduction characteristics of Driving Surface Aggregate compared to existing road surfaces.

2.2.1 Location

The DSA testing in this study was done on two separate sections of Lebo Road in Potter County, PA (41° 29.9' latitude, 77° 38.7' longitude). Lebo Road is owned and maintained by the Pennsylvania Bureau of Forestry, Susquehannock District. Lebo Road is a fairly low gradient road (<3%) that is surrounded entirely by mature forests. The existing surface of Lebo Road consisted of varied old aggregates that had mixed with the native road base over time. The road is typically graded by the Bureau of Forestry once or twice annually. Existing road width varied from approximately 11 to 14 feet.

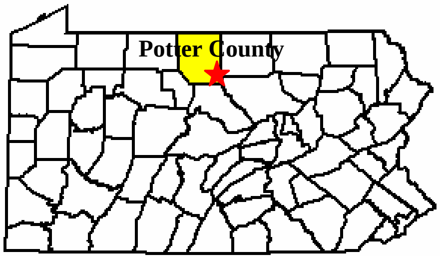


Figure 2.2: Location of Lebo Road DSA study in Potter County, PA.

2.2.2 Methodology

Funding for DSA placement came from the PA Bureau of Forestry through the Dirt and Gravel Road Maintenance Program. As part of a separate study, the Bureau of Forestry was interested in determining performance difference between limestone and sandstone derived aggregates. The Bureau covered approximately one mile of Lebo Road with DSA, half limestone based, and half sandstone based. In order to compliment this study with Forestry's sandstone/limestone study, it was decided that two test sections would be set up, one on each parent material. The gradation and hardness of both Aggregates were kept as similar as possible so the variable of parent material could be tested. Both sections met all of the specifications for DSA.

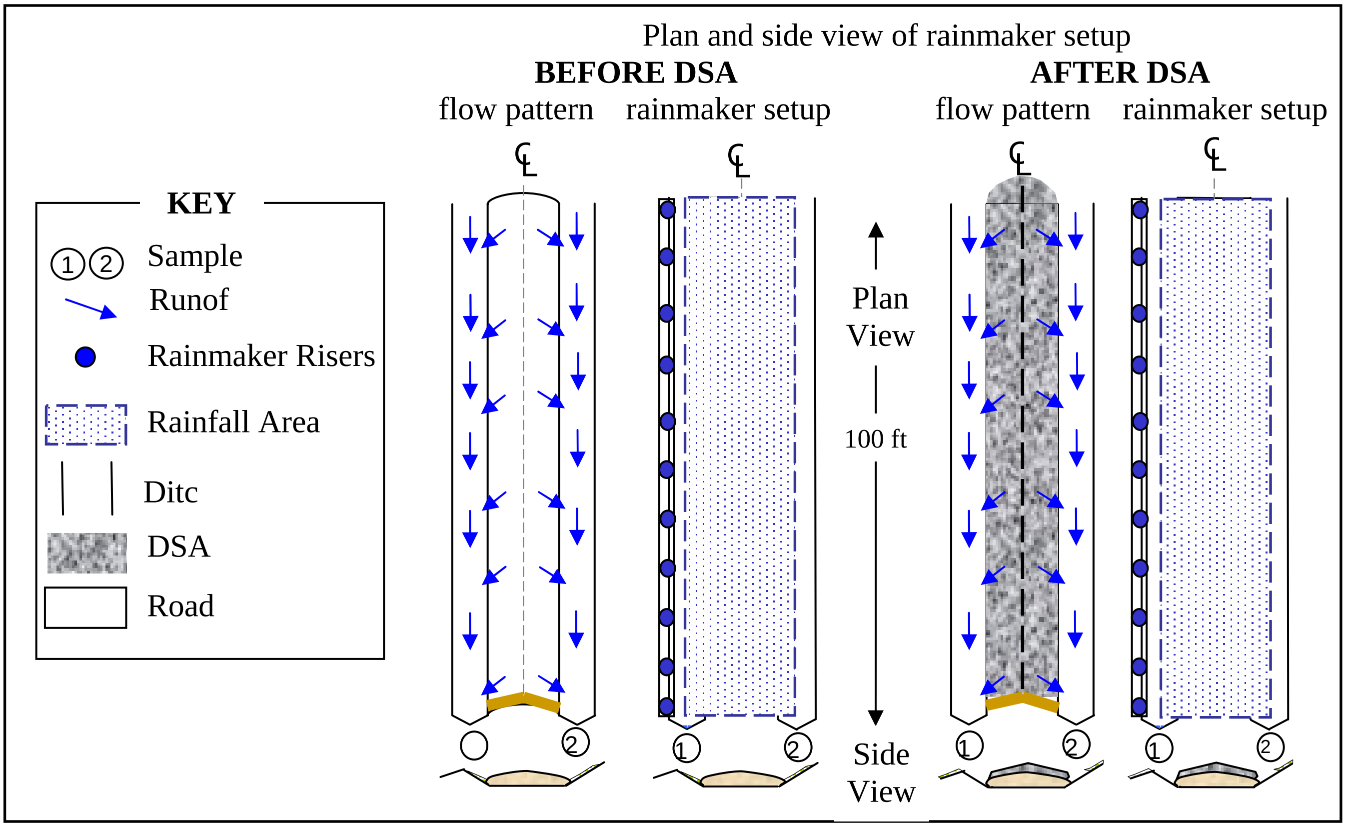


Figure 2.3: Plan and side views of rainmaker setup for testing Driving Surface Aggregate.

The procedures outlined in section 1.3 of this document were used for each run of the rainmaker. *Figure 2.3* illustrates a plan and side view of the rainmaker setup for this test. Approximately two weeks before aggregate placement, the rainmaker was run on the existing road sections (one where sandstone DSA would be placed, and one where limestone DSA would be placed). This data are used to provide a baseline for each section or road in order to determine the sediment reductions from the DSA surfaces.

Figure 2.4: A motor-paver places DSA on Lebo Road in Potter County. Lighter colored limestone DSA is in foreground, while reddish sandstone DSA is being placed by the paver.

Driving Surface Aggregate was placed on both sections of Lebo Road in May of 2006. A contracted crew placed both sections of DSA using the motor-paver pictured in *Figure 2.4*. Both sections were placed at a uniform depth of 8 inches across the road profile with a crown of approximately ½" per linear foot across the roadway. The aggregate was then compacted using a 10 ton vibratory roller. The average width of DSA placement was approximately 14 feet. Both aggregates were in place one month before any further testing was done. Approximately one month after aggregate placements, on May 22 & 23, 2006, the rainfall simulation was run on each aggregate section. Approximately one year after aggregate placements, on June 11 & 12, 2007, the rainfall simulation was run for a third time on both aggregates. The position of the rainmaker was monumented in the field to insure it was placed at the same location for each rainfall simulation. *Figure 2.5* illustrates the visual differences between runoff from the two sections of road before and after aggregate placement.

Figure 2.5: Photographs taken during rainfall simulator events for both native and DSA surfaces.

2.3 Results

For both the limestone and sandstone Driving Surface Aggregates used on Lebo Road, there was a significant reduction in sediment that was collected during the rainfall simulation events. Flow volumes remained consistent throughout the testing, indicating that sediment reductions were caused by a decrease in the erosion and transport of fine material from the road surface.

Figure 2.6 shows the sediment loss per minute (average of 3 runs) for each rainfall simulation. In order to determine sediment reductions for the aggregates, it is useful to compare the average total sediment loss for each 30 minute run of the rainmaker as illustrated in *Figure 2.7*. *Table 2.2* summarizes the total sediment loss and sediment reductions from each aggregate. Detailed results data can be found in Appendix A. It should be noted that sediment reduction calculations are highly

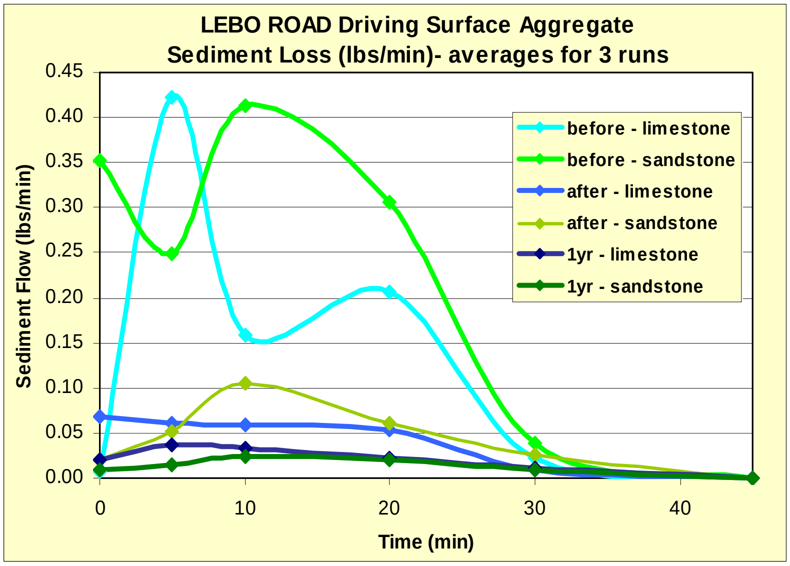


Figure 2.6: Sediment loss rate averages (3 rainfall simulations averaged) for 30 minute rainfall events before aggregate placement and at time periods of one month and one year after placement.

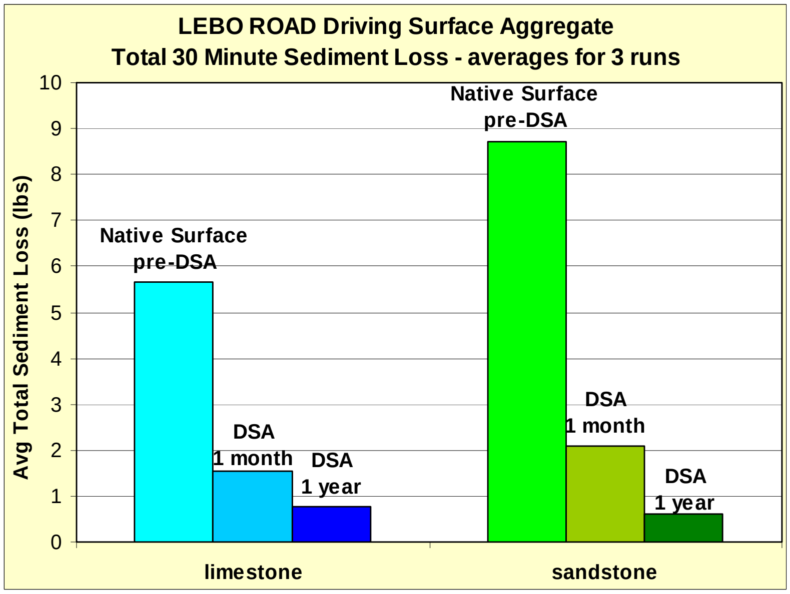


Figure 2.7: Average total sediment loss (3 rainfall simulations averaged) for 30 minute rainfall events before aggregate placement and at time periods of one month and one year after placement.

	Total Sediment Loss (lbs per 30 minute event)		**% Sediment Reduction**		**Sediment Reduction (lbs/acre)**	
	Limestone	Sandstone	Limestone	Sandstone	Limestone	Sandstone
Native Surface	5.67	8.7	na	na	na	na
DSA - 1 Month After Placement	1.55	2.09	73%	76%	120	192
DSA - 1 Year after Placement	0.78	0.6	86%	93%	142	235

Table 2.2: Results of sediment sampling and associated sediment reductions for the two sections of DSA. All data is averaged from three rainfall simulations and represents one thirty-minute event with a 1-month return frequency.

dependant on the stability of the native surface (see discussion). The average sediment reduction for the Lebo Road DSA applications was 283 pounds per mile after one month and 342 pounds per mile after one year for the simulated 1-month recurrence rainfall event.

2.4 Discussion

Both of the DSA aggregates placed on Lebo Road showed significant sediment reductions when compared to the existing material on the roadway. It is important to consider, however, that sediment reductions (percentage or lbs/acre) will be highly dependant on the existing surface. If the existing surface material is poor, a greater reduction in sediment can be expected by placing DSA on the road. In other cases where the existing road surface is stable, lower sediment reductions can be anticipated by placing aggregate. *Table 2.3* summarizes the data that has been collected to date for existing or native surface roads. There is a very high degree of variability in sediment production from the 5 native surface road used as “befores” in this study.

Sediment (lbs)	Road Location	Existing Surface Composition	Road Use Characteristics	Road Slope
0.7	Mifflin County	hard packed limestone	narrow farm road, grass in median	1-2%
1.0	Huntingdon County	hard packed limestone	narrow forest road, low-med use	1-2%
5.7	Potter County (Lebo)	native soil with limestone remenants	narrow forest road, low use	1-2%
8.7	Potter County (Lebo)	native soil with limestone remenants	narrow forest road, low use	1-2%
12.0	Columbia County	limestone and soil mixture	wide township road, high use	5-6%

Table 2.3: Summary of rainmaker testing on existing (native) road conditions. Sediment figures are average losses from three 30 minute rainmaker tests.

2.5 Conclusions

Placement of the two Driving Surface Aggregates onto Lebo Road in Potter County resulted in an average sediment reduction of 75% after one month, and 90% after one year compared to the native surface for the 30 minute simulated 1-month storm event. The amount of sediment reduction in other locations will be highly dependant on the stability of the existing or native road surface. More data is needed before a general sediment reduction figure for DSA can be given with any significant confidence.

CHAPTER 3: ESMP # 2: Raising the Road Profile

3.1 Definition

Raising the road profile involves importing material to raise the elevation of an unpaved road. It is typically practiced on roads that have become entrenched (lower than surrounding terrain). Raising the elevation of the road is designed to restore natural drainage patterns by eliminating the down-slope ditch and providing cover for pipes to drain the up-slope ditch.

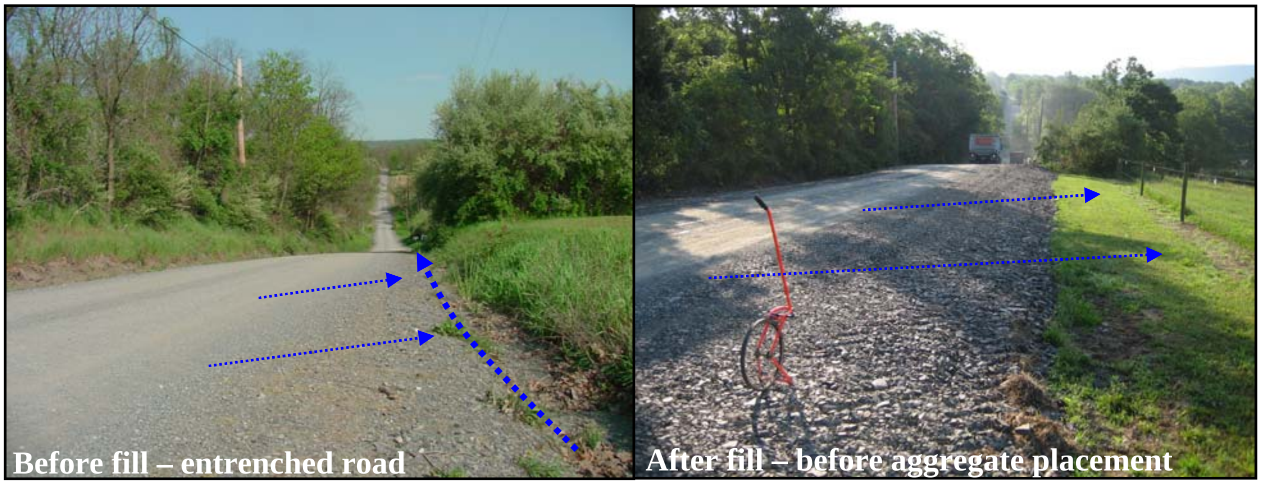


Figure 3.1: An example of "raising the road profile" on Diehl Road in Columbia County. Before, water was trapped in the sunken road and carried over 1,500 feet directly to a small stream in the distance. After, the road elevation has been raised and the ditch on the right has been eliminated. The additional fill material also provides the necessary cover to add crosspipes to drain the ditch on the left before it reaches the stream. Blue arrows indicate runoff flow. This photo was taken just above the test section.

3.2 Background

Over long periods of time, unpaved roads have a tendency to experience a decrease in surface elevation. This occurs because of many factors, both natural and manmade including surface compaction, rainfall erosion, dust, maintenance activities, and traffic wear. When this happens, the road becomes entrenched or "sunken" as illustrate in *Figure 3.2.* Entrenched roads present many maintenance problems because it is difficult to get rid of any water coming to the roadway. Often entrenched roads act as streams by collecting and trapping runoff and overland flow. Entrenched roads create longer, more erosive ditch flows that typically outlet at low points near a stream.

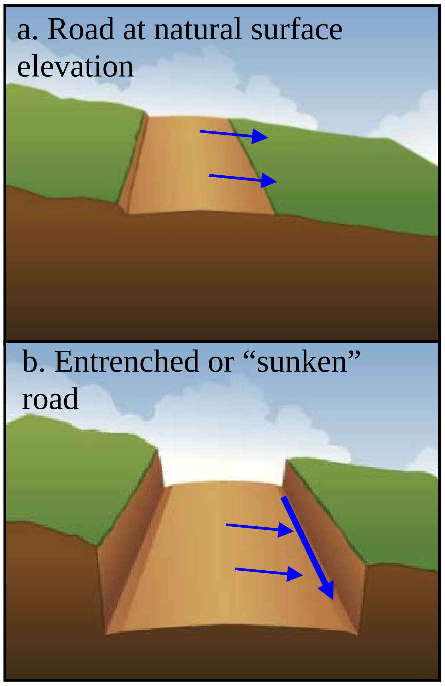


Figure 3.2: Entrenched or "sunken" roads trap drainage on the roadway.

Practices such as rock lining ditches and bank stabilization often attempt to treat the erosive "symptoms" of entrenched roads. However, the only long-term solution to the chronic problems associated with entrenched roads is to raise the road profile. Raising the road profile involves importing fill material to raise the elevation of the roadway up to the elevation of the surrounding terrain. The road is filled to a sufficient depth as to eliminate the ditch on the down-slope side of the road and encourage sheet flow as illustrated in *Figure 3.1 and 3.2.* Achieving sheet flow off the roadway instead of concentrating water in a roadside ditch solves most of the maintenance problems common to entrenched roads. The fill material also provides the much needed cover for installing cross-pipes to drain the up-slope road ditch. A wide array of materials can be used to fill the road. Shale and gravel are the most common fill materials for roads. Other potential recycled fill materials include ground glass, waste sand, automobile tires, clean concrete rubble, etc.

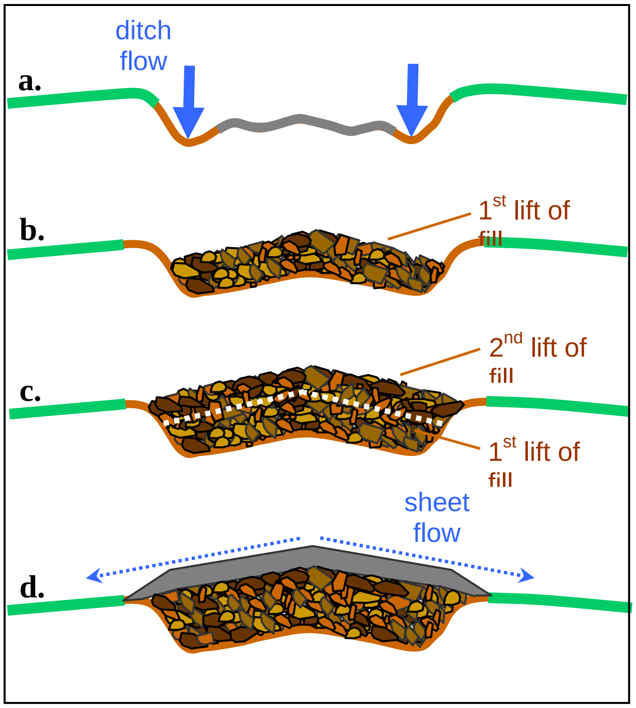


Figure 3.3: Sequence of filling the road profile: **a.** existing entrenched road; **b.** first layer of fill material; **c.** final layer of fill material; **d.** finished road elevation with new driving surface.

3.2.1 Location

The testing for raising the road profile in this study was done on Diehl Road in Madison Township, Columbia County, PA (41° 5.28' latitude, 76° 36.76' longitude). Diehl Road is owned and maintained by Madison Township. The section of Diehl Road used for this study had a slope of approximately 5% and was in a mixed use landscape of forest and meadow. The existing surface of Diehl Road was mostly limestone with a fine silt component. There are approximately 10 residences on the road and traffic volume is relatively low, although higher than other roads used in this study. Average road width was approximately 16 feet.

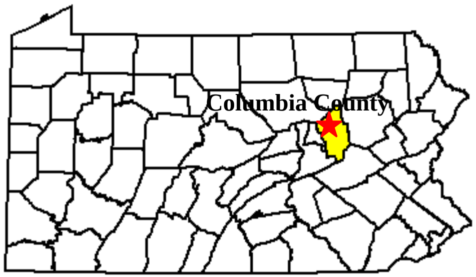


Figure 3.4: Location of Diehl Road project in Columbia County, PA.

3.2.2 Methodology

Funding for Diehl Road project came from the Department of Environmental Protection in the form of a Growing Greener Grant. Approximately one half mile of Diehl road was raised with a combination of materials. The 100' section of road used in this study was raised approximately 5 feet above the starting surface elevation. *Figure 1.3* used in the introduction of this report illustrates the rainmaker setup on Diehl Road.

The procedures outlined in section 1.3 of this document were used for each run of the rainmaker. Water was drawn from a nearby farm pond. *Figure 3.5* illustrates a plan and side view of the rainmaker setup for this test. Approximately one week before fill material was placed on the road, the rainmaker was run on the existing road section. This data was used to provide a baseline for Diehl Road in order to determine the sediment reductions from raising the road profile.

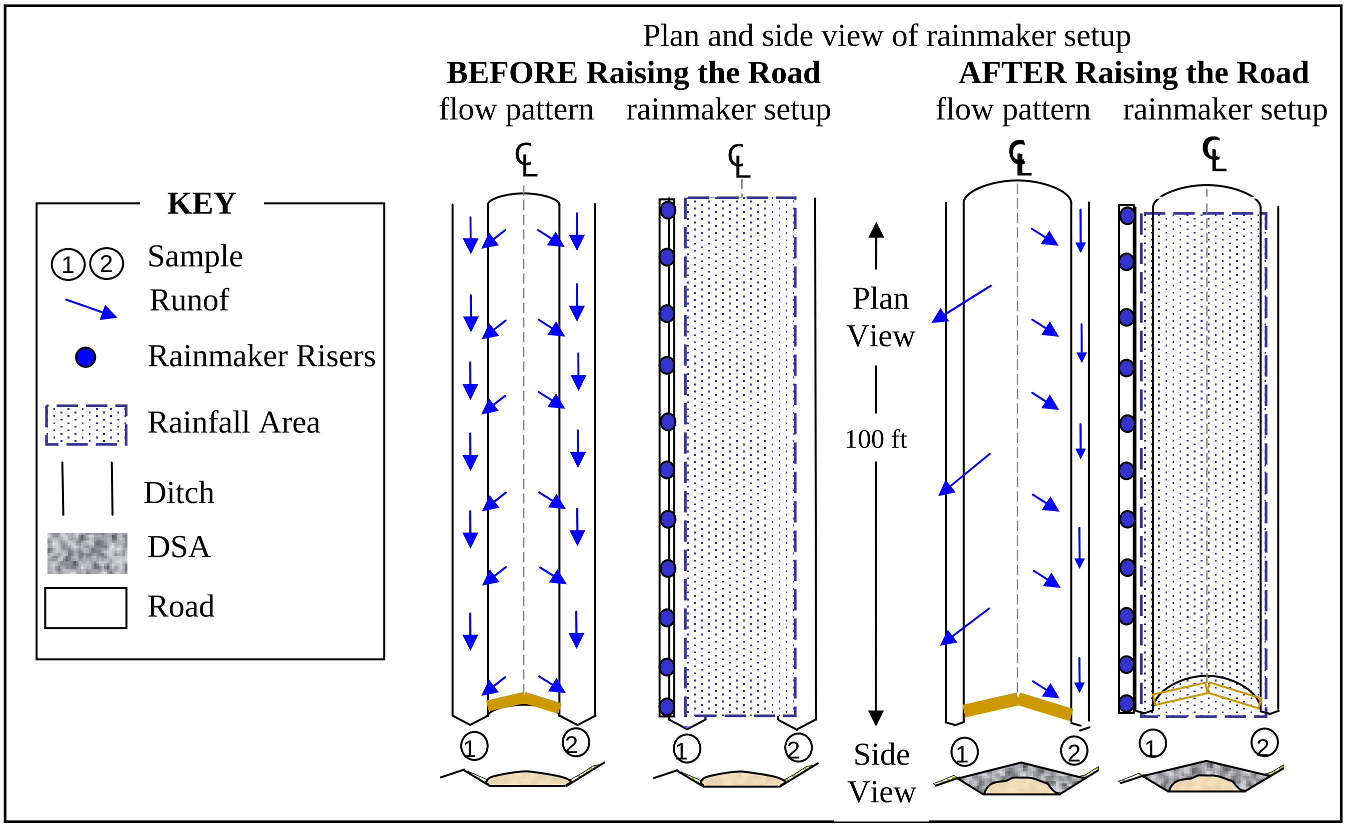


Figure 3.5: Aerial and plan view of rainmaker setup for Raising Road Profile

Approximately five feet of fill material was placed on Diehl Road in June of 2006. All fill material was compacted in eight inch lifts as it was placed to maximize fill density. The final elevation of the road was sufficient to eliminate the ditch on the down-slope side of the road. Drainage that was previously collected in the down-slope ditch now left the road as sheet flow. Approximately one month after filling the road, on July 17, 2006, the rainfall simulation was run again on Diehl Road. A surface aggregate was placed on the road in August of 2006. Approximately one year after aggregate placement, on June 1, 2007, the rainfall simulation was run for a third time on the same section of Diehl Road. The position of the rainmaker was monumented in the field to insure it was placed at the same location for each rainfall simulation.

**** important analysis consideration***

Unlike the ESM practice of placing Driving Surface Aggregate which achieves sediment reductions by reducing erosion, Raising the Road Profile achieves sediment reduction by controlling and reducing the volume of road runoff. One of the inherent problems with attempting to quantify sediment reductions from raising the road profile is that because of the nature of the practice, the surface material of the road will also be changed. In the "before" simulation, the native surface consisted mostly of limestone and silt fines. The "1 month after" simulation was run on shale material that was used as fill. The "one year after" simulation was run on a limestone aggregate. In order to eliminate any sediment generation differences caused by the change in surface materials, the sediment concentrations from the "before" simulations will be used in all calculations for the "after" simulations. The distinct runoff rates for each of the three separate events will be used to calculate respective flows, but sediment concentrations from the "before" will remain constant throughout the three simulations. This methodology will assume the sediment generation rate from the road surface was constant; therefore any reduction in total sediment can be attributed to a reduction in flow at the sample points due to raising the road elevation. This is the only way sediment reductions achieved by raising the road elevation can be separated from the effects of changing the road surface characteristics.

3.3 Results

All results and conclusions use the same sediment concentrations found in the "before" simulation in order to eliminate surface material as an influencing factor, see note above.

The practice of raising the road profile is intended to reduce the volume of water concentrated and carried by the road and ditch system. Since the sediment concentrations were kept constant in the calculations, any sediment loading differences can be attributed to changes in runoff volume due to raising the road profile.

Figure 3.6 shows the sediment loss per minute (average of 3 runs) for each rainfall simulation. In order to determine sediment reductions for the aggregates, it is useful to compare the

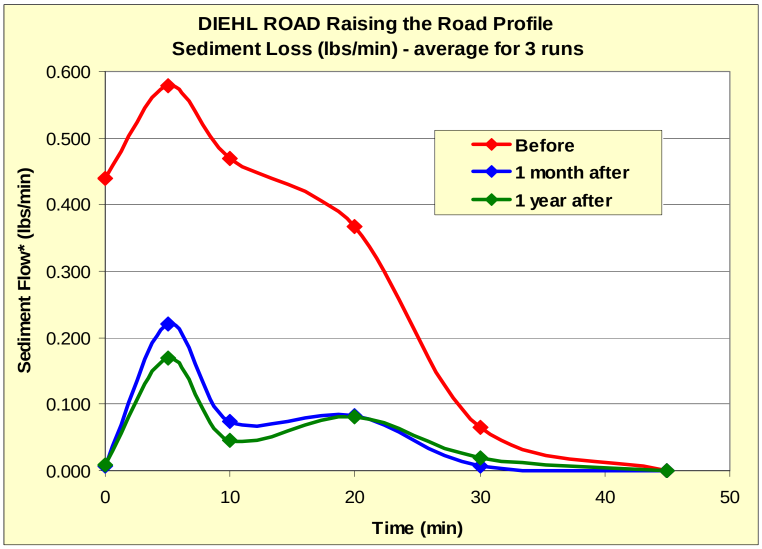


Figure 3.6: Sediment loss rate averages (3 rainfall simulations averaged) for 30 minute rainfall events before aggregate placement and at time periods of one month and one year after placement. **Sediment concentrations from "before" used for all samples, see "important analysis consideration" in methodology.*

average total sediment loss for each 30 minute run of the rainmaker as illustrated in *Figure 3.7.* *Table 3.1* summarizes the total sediment loss and sediment reductions from each simulation. Detailed results data can be found in Appendix B. It should be noted that sediment reduction calculations are highly dependant on the stability of the native surface (see discussion). The average sediment reduction from raising the road profile on Diehl Road was 496 pounds per mile after one month and 512 pounds per mile after one year for the simulated 1-month recurrence rainfall event.

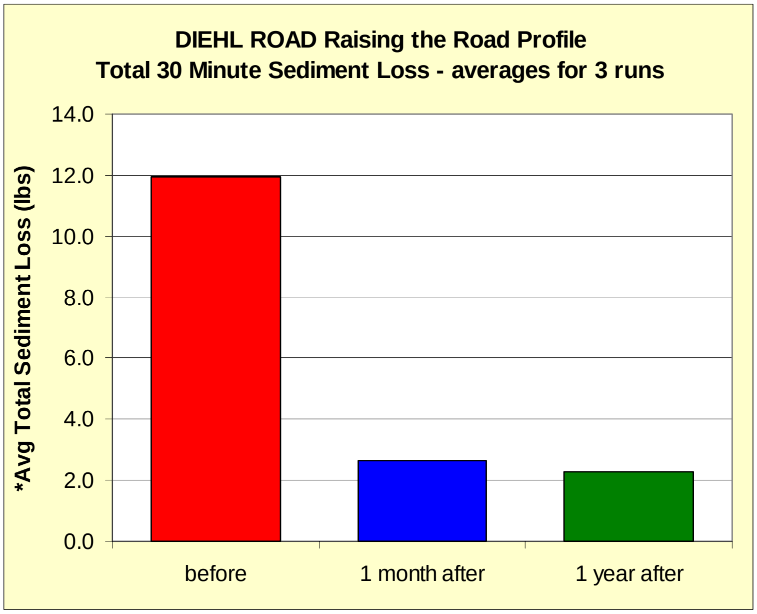


Figure 3.7: Average total sediment loss (3 rainfall simulations averaged) for 30 minute rainfall events before raising road elevation and at time periods of one month and one year afterwards. **Sediment concentrations from "before" used for all samples, see "important analysis consideration in methodology*

	Total Sediment Loss (lbs per 30 minute event)	**% Sediment Reduction**	**Sediment Reduction** (lbs/road mile)
Native Surface	12	na	na
1 Month After Raising Road	2.6	78%	496
1 Year After Raising Road	2.3	81%	512

Table 3.1: Results of sediment sampling and associated sediment reductions for raising the road profile on Diehl Road. All data is averaged from three rainfall simulations and represents one thirty-minute event with a 1-month return frequency.

3.4 Discussion

The intent of raising the road elevation is to reduce concentrated flow that is trapped in the roadside ditches and encourage sheet flow. Sediment reductions are achieved not by reducing the erosion rate of the road surface, but by eliminating the concentration and delivery of road runoff. Because of this, raising the road profile also has the added benefit of encouraging infiltration and reducing peak flow to waterways. Since sediment concentrations were kept constant, the reductions of 78% and 81% also represent water volume reductions in road runoff reaching the stream.

Two factors must be taken into consideration when looking at the sediment reduction results. First, the rainfall simulator will cause an underestimation of sediment savings due to raising the road profile. This is because the rainmaker only creates precipitation on the road and ditches. Factors that bring water to the road during natural rain events such as springs, seeps, and overland flow are not accounted for by the rainmaker. Raising the road profile will alter the flow characteristics of water from these sources as it did for water from the rainfall simulation. Raising the road profile also provides the cover necessary to install crosspipes to drain the up-hill road ditch. The sediment reductions from the addition of drainage outlets will be covered separately in this study. The second factor that must be taken into consideration is that after the road profile was elevated, some of the runoff generated by the rainmaker infiltrated into the fill material. Although the fill material was compacted to the maximum extent possible, some infiltration was noticed on the roadsides and in the ditchlines. The ultimate destination of water that infiltrates into the road fill material is unknown. The amount of infiltration is expected to decrease over time as the fill settles and compacts. This could lead to slightly higher runoff rates in the future for this study site.

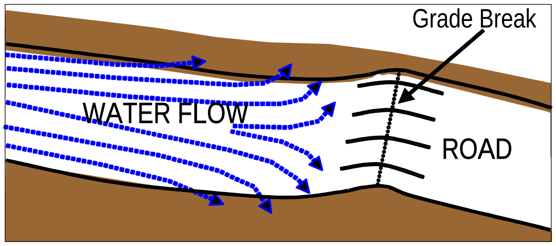
3.5 Conclusions

Raising the road profile on Diehl Road in Columbia County resulted in an average flow and sediment reduction of 78% after one month, and 81% after one year compared to the original entrenched road for the 30 minute simulated 1-month storm event. The amount of flow and sediment reduction seen on other roads will be highly dependant on site conditions such as road slope, amount of overland and underground water coming to the road, the fill material used, fill depth, fill compaction, and the nature of the finished road surface.

CHAPTER 4: ESMP # 3: Grade Breaks

4.1 Definition

A "grade break" is an intentional increase in road elevation on a downhill grade which causes water to flow off of the road surface. It is designed to reduce erosion on the road surface by forcing water into the ditches or surrounding terrain.



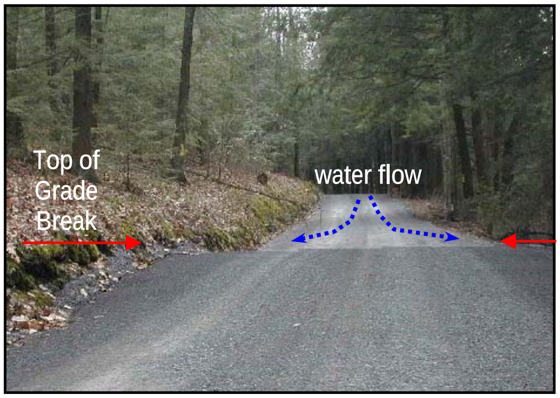


Figure 4.1: Illustration and picture of a grade break. The purpose of the structure is to prevent water from flowing down the roadway by forcing it to the side.

4.2 Background

As unpaved roads compact and erode over time, small indentations often form in the wheel tracks. These minor wheel ruts act as "on-road ditches" to collect runoff and transport it long distances on the road surface. This results in additional degradation of the road surface because of the concentrated flow in the wheel tracks. A grade break is designed to prevent water from running on and eroding the surface of the road. In simplified terms, a grade break can be envisioned as an elongated speed bump. The length of the grade break along the road varies with road slope, but typically stretches for over 50 feet in order to smooth transitions back into the natural road grade. The height of the grade break also varies with road slope. The grade break must be sufficiently high to prevent water from over-topping it and flowing down the roadway, instead forcing it into the road ditches. A properly installed grade break will be noticeable when driving, but should be accommodating to all traffic including small cars (and haul trucks if applicable). Grade breaks are best suited to low traffic roads where speeds are relatively low.

Figure 4.2: Grade breaks are designed to prevent erosive flows of water on the road surface like the one pictured here.

4.2.1 Location

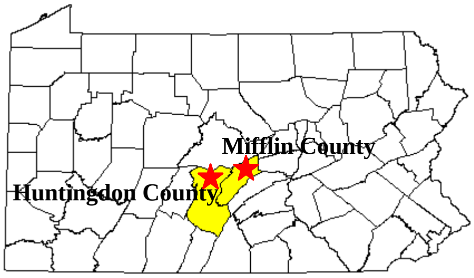


Figure 4.3: Location of the two roads used to test grade breaks in this study.

The testing for grade breaks in this study was done in two locations: on Pine Swamp Road in Barree Township, Huntingdon County, PA (40^o 42.21’ latitude, 77^o 53.18’ longitude); and on Jennie Lane in Derry Township, Mifflin County, PA (40^o 36.77’ latitude, 77^o 36.69’ longitude). Pine Swamp Road is owned and maintained by the Bureau of Forestry, Rothrock State Forest District. The section of road used for this study had a grade of approximately 1% and was in a heavily forested setting. The existing surface of Pine Swamp Road was a hard packed mixture of stone. Traffic volume is relatively low on Pine Swamp Road. Average road width was approximately 12 feet. Jeanie Lane is a private lane characterized by compacted stone wheel tracks with a strip of grass in-between. The surrounding area consists of grasses and pasture. The slope of the section of road tested was approximately 3%. Jeanie Lane is illustrated in *Figure 4.4.*

4.2.2 Methodology

The purpose of a grade break is to reduce the amount erosion on the road surface by forcing runoff laterally off the road. The water is then collected in roadside ditches or directed away from the road area. Grade breaks are typically created by importing material to create an elongated hump in road elevation. Although size varies with site conditions, a typical grade break would be approximately one foot in height and over 50 feet in length. The grade break has to be very long in order to create a smooth transition for traffic to approach and leave the structure. The need for such a long grade break presented an obstacle in this study. The material imported to create a proper grade break would cover much of the 100’ study area. Since the material used to create the grade break would undoubtedly have different erosion rates from the exiting surface, there would be no way to quantify sediment reductions. Because of this, a small “speed-bump” style grade break was installed. The small “speed-bump” grade break was approximately six inches in height and one foot in width. The “speed- bump” grade break serves the same function to force water off the road, but does not significantly alter the

Figure 4.4: Rainmaker setup and gradebreak on Jeanie Lane in Mifflin County.

surface composition of the roadway being tested.

Since the rainmaker simulates rainfall on a 100 foot section of road, the grade break was installed in the middle of the section at 50 feet. It is important to note that the grade breaks on Pine Swamp Road simply forced water into the roadside ditch, while the grade break on Jeanie Lane outletted off of the road area. In such a case as Jeanie Lane, where the grade break forces water off the road entirely, the gradebreak also serves as an additional drainage outlet.

The procedures outlined in section 1.3 of this document were used for each run of the rainmaker. Water was drawn from nearby Shavers Creek in Huntingdon County and Buck Run in Mifflin County. *Figure 4.5* illustrates a plan and side view of the rainmaker setup for this test. The grade breaks were created by small equipment using imported aggregate.

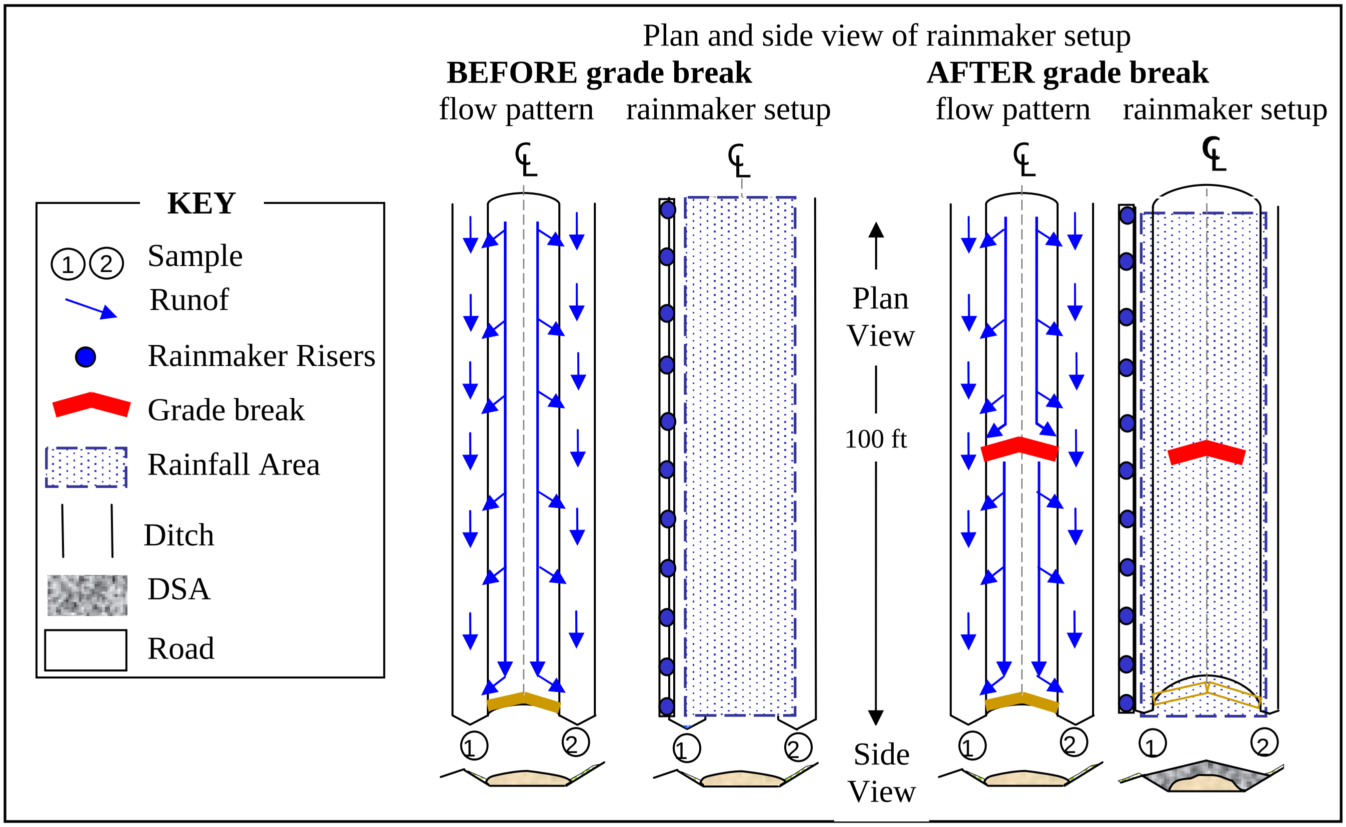


Figure 4.5: Aerial and plan view of rainmaker setup for Grade Breaks.

4.3 Results

Gradebreaks are designed to prevent water from running down the road surface. On the first site tested, Jeanie Lane, the gradebreak forced water off of the road surface and into surrounding terrain. Water from above the gradebreak was no longer collected at the sample points. The sample point on Jeanie Lane collected water from the entire road surface. On the second sample location, Pine Swamp Road, runoff from only half of the roadway runoff was sampled. This is because a ditch did not exist on the lower half of the road. The gradebreak on Pine Swamp Road diverted water into the roadside ditch which flowed to the sample point, unlike Jeanie lane where the water was dissipated. *Figure 4.6* shows the sediment flow rates for before and after gradebreak construction on each road. *Figure 4.7* shows the same scenerios in units of total sedimet loss for each 30 minute rain event. *Table 4.1* summarizes the sedimet loads and percent sediment reductions from adding a gradebreak on these two roads.

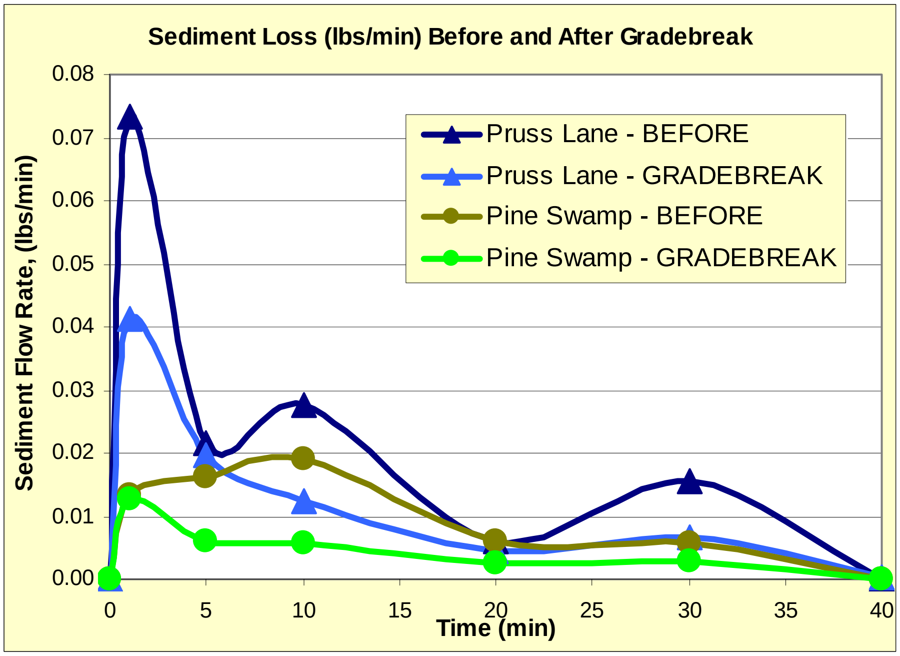
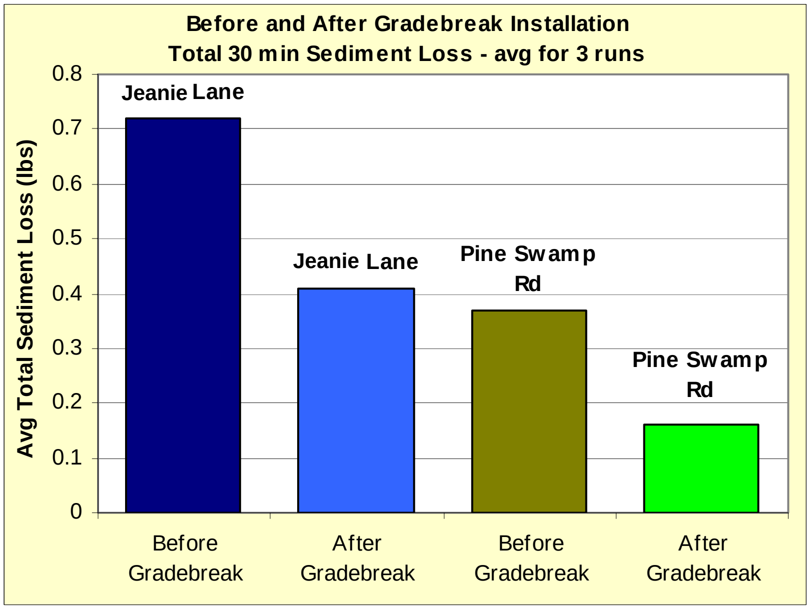


Figure 4.6: Sediment loss rate averages (3 rainfall simulations) for 30 minute rainfall events before and after installation of gradebreaks on Jeanie and Pine Swamp Road. Jeanie lane represents runoff collection from the entire road area. Pine Swamp Road represents collection from only half of the crowned road surface because sheet flow was achieved from the lower half of the road.



Figrue 4.7: Average total sediment loss (3 rainfall simulations) for before and after gradebreak installaiton for two tested roads.

		Total Sediment	**% Sediment Reduction**	**Sediment Reduction** (lbs/road mile)
Pruss Lane	Before Gradebreak	0.72	na	na
	After Gradebreak	0.41	43%	22
Pine Swamp Road	Before Gradebreak	0.37	na	na
	After Gradebreak	0.16	57%	8

Table 4.1: Results of sediment sampling and associated sediment reductions from adding a gradebreak. All data is averaged from three rainfall simulations and represents one thirty-minute event with a 1-month return frequency. Jeanie lane represents a situation where runoff from the entire road was collected and the gradebreak completely removed water from the roadway. Pine Swamp Road represents a situation where only half of the crowned road was sampled, and where the gradebreak simply diverted water into the vegetated ditch to be collected at the sample point.

4.4 Discussion

A gradebreak is designed to prevent water from flowing down the road surface by forcing flow to either side of the travel lane. Gradebreaks come in many shapes and sizes depending on road slope, crown, and layout. They may force water into parallel ditches where it will continue to flow, or cause water to leave the road area entirely, depending on site conditions. The location, road slope, run length, gradebreak size, road composition, and many more factors must be considered when trying to determine sediment reductions. The tests described here represent two gradebreaks and should not be considered to represent “universal” sediment reductions for all gradebreaks.

The Gradebreak on Pine Swamp road was effectively a “speed bump”, approximately 8 inches wide, and 4 inches tall. This artificial gradebreak still functioned to force water off of the road surface, but did not significantly alter the surface of the road which would have affected sediment generation rates. This allowed both flow and sediment data to be collected for “before” and “after” runs on Pine Swamp Road. The more natural gradebreak created on Jeanie Lane was approximately 15 feet wide and 8 inches high. Because this gradebreak changed the composition of a substantial portion of the test road, sediment concentrations from “before” were assumed to be constant and combined with “after” flow data to obtain “after” sediment loads. This was done to eliminate any changes in sediment generation as a result of the new gradebreak material. Since sediment concentrations were kept constant, any changes in total sediment on Jeanie Lane load were due to changes in the volume of runoff at the sample point.

It is also important to point out that the actual amount of sediment reduction will be highly dependant on the stability (surface material, slope, etc.) of the native road surface. Pine Swamp Road consisted of a hard-packed stone surface with a very low grade of about 1%. Jeanie Lane also consisted of hard-packed limestone and had the narrowest traveled way of any road tested in this study. Jeanie Lane was approximately 11 feet wide, and in places had small amounts of grass growing between the wheel tracks. For these reasons, Pine Swamp Road and Jeanie Lane had the two lowest overall sediment production rates of any of the native surface roads tested.

The 100 foot length of the rainmaker creates some limitations on the testing gradebreaks. Theoretically, gradebreaks will have a larger effect when used on longer runs of road because they will prevent more concentrated flow from eroding the road surface. The Center typically uses gradebreaks on long downhill runs of road. As crown is slowly driven out of the road by traffic, the gradebreaks are the only feature that forces water off the road surface. They are especially useful at grade changes to get water off the road surface before a road gets steeper and erosion potential increases.

4.5 Conclusions

It is important to note that the "% reductions in sediment" in this report are not equivalent to "sediment reduction efficiencies". For example, if a gradebreak is place at the midpoint of the 100' test section, it can only be expected to control runoff from the section of road above the grade break. For this reason, a total sediment reduction of 50% for the 100' section of tested road can be effectively equated to a 100% efficient practice.

The addition of a gradebreak on Pine Swamp Road in Huntingdon County resulted in an average sediment reduction of 57%. This is higher than expected since runoff that was diverted off Pine Swamp Road was collected in the roadside ditch and continued to the sample point. The wide, relatively flat, and vegetated ditch undoubtedly caused some of the runoff to infiltrate into the ground before it reached the sample point.

The addition of a gradebreak on Jeanie Lane in Mifflin County resulted in an average sediment reduction of 43%. This reduction was due to the fact that flow was reduced because the gradebreak dissipated runoff into the surrounding terrain. Due to site limitations the gradebreak on Jeanie Lane was situated with 5 rainmaker risers above the gradebreak, and 6 rainmaker risers below the gradebreak, instead of an even split as with all other tests. The 43% reduction in flow seen in this test is almost exactly what would have been expected by re-directing 45% of the runoff into a vegetative filter (96% reduction efficiency).

These reductions represent only the two gradebreaks tested and should not be extrapolated to universally account for all gradebreaks. The actual amount of sediment reduction seen on other roads will be highly dependant on site conditions such as road slope, run length, surface material, amount of crown, native soil characteristics, gradebreak shape and more.

CHAPTER 5: ESMP # 4: Additional Drainage Outlets

5.1 Definition

Drainage outlets are designed to capture water flowing in the roadside ditch and force it to leave the road area. There are two major types of drainage outlets. Turnouts (also called bleeders or cutouts) outlet water from the down-slope road ditch. They usually consist of relatively simple cuts in the down-slope road bank to funnel road drainage away from the road. Drainage that is carried by the up-slope road ditch is usually outletted under the roadway by the use of a crosspipe (also called culvert, sluice pipe, or tile drain). Installing additional drainage outlets is one of the core practices employed by the Center to reduce concentrated flow and sediment delivery from unpaved roads.

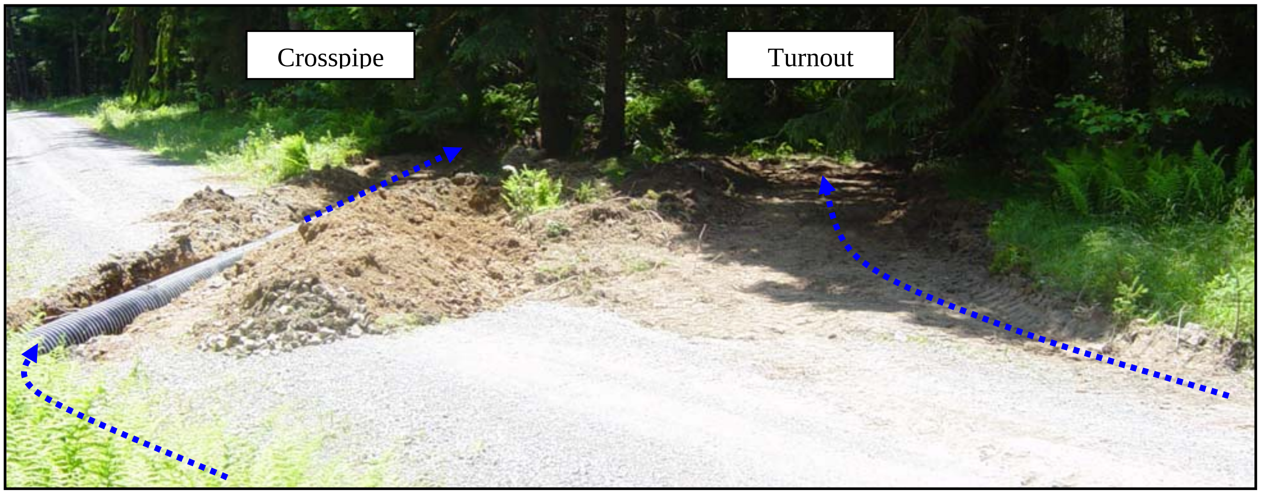


Figure 5.1: This photo from Potter County shows both a crosspipe and turnout being installed. The blue arrows indicate drainage flow. The turnout outlets water from the down-slope road ditch while the crosspipe (being installed in photo) outlets water under the road from the uphill road ditch.

5.2 Background

The addition of drainage outlets is one of the most fundamental Environmentally Sensitive Maintenance Practices employed by the Center. Adding crosspipes and turnouts is a key practice in disconnecting the roadside drainage system to reduce sediment delivery and peak flow discharges into streams. Providing additional drainage outlets for ditch flow will decrease the amount of water in the roadside ditch which leads to many environmental and economic benefits including reduced ditch erosion, reduced water and sediment delivery to streams, increased infiltration, and lower road maintenance costs. Drainage outlets are to be placed in locations that have the least likelihood of reaching streams. The frequency of drainage outlet placement depends on many site specific factors such as slope, road width, and local water table conditions.

5.2.1 Location

The testing for additional drainage outlets in this study was done on Pine Swamp Road in Barree Township, Huntingdon County, PA (40° 42.21' latitude, 77° 53.18' longitude). Pine Swamp Road is owned and maintained by the Bureau of Forestry, Rothrock State Forest District. The section of road used for this study had a slope of approximately 1% and was in a heavily forested setting. The existing surface of Pine Swamp Road was a hard packed mixture of stone including limestone. Traffic volume is relatively low on Pine Swamp Road. Average road width was approximately 12 feet.

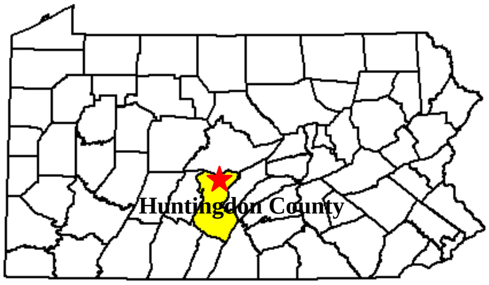


Figure 5.2: Location of Pine Swamp project in Huntingdon County, PA.

5.2.2 Methodology

Compared to many of the other practices employed by the Dirt and Gravel Road Program, the procedure of adding a drainage outlet is relatively straightforward and easy. The purpose of adding a drainage outlet is to reduce the amount of water transported in the road ditch by providing a stable outlet away from a stream. A culvert or crosspipe is an outlet under the road for water in the upslope ditch. A turnout or bleeder is an outlet to drain the down-slope ditch. A turnout was used in this study since they are much simpler and more cost effective to install. Similar sediment and flow reduction results would be expected from a properly installed culvert or crosspipe. Since the rainmaker simulates rainfall on a 100 foot section of road, the turnout was installed in the middle of the section at 50 feet. In calculating sediment and flow reductions, it is necessary to make the assumption that the new drainage outlet will not empty into the stream, as was the case on Pine Swamp Road. If a newly added turnout drains sediment to the stream, little if any sediment reductions will be obtained

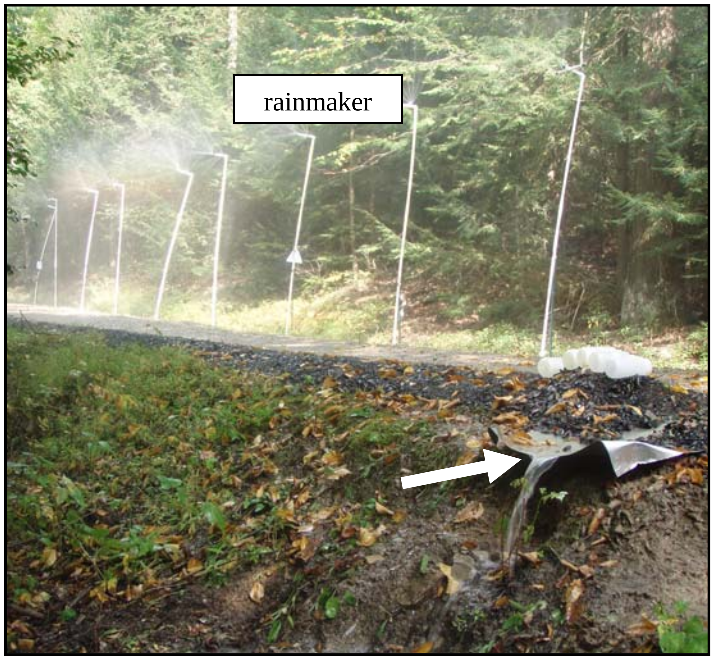


Figure 5.3: Rainmaker setup and collection point on Pine Swamp Road.

The procedures outlined in section 1.3 of this document were used for each run of the rainmaker. Water was drawn from nearby Shavers Creek. *Figure 5.4* illustrates a plan and side view of the rainmaker setup for this test. Because the process of adding a turnout is very simple, all testing and turnout creation were done the week of September 26, 2007. A turnout was created using a hand shovel in the modest berm that existed on the down-slope side of the road.

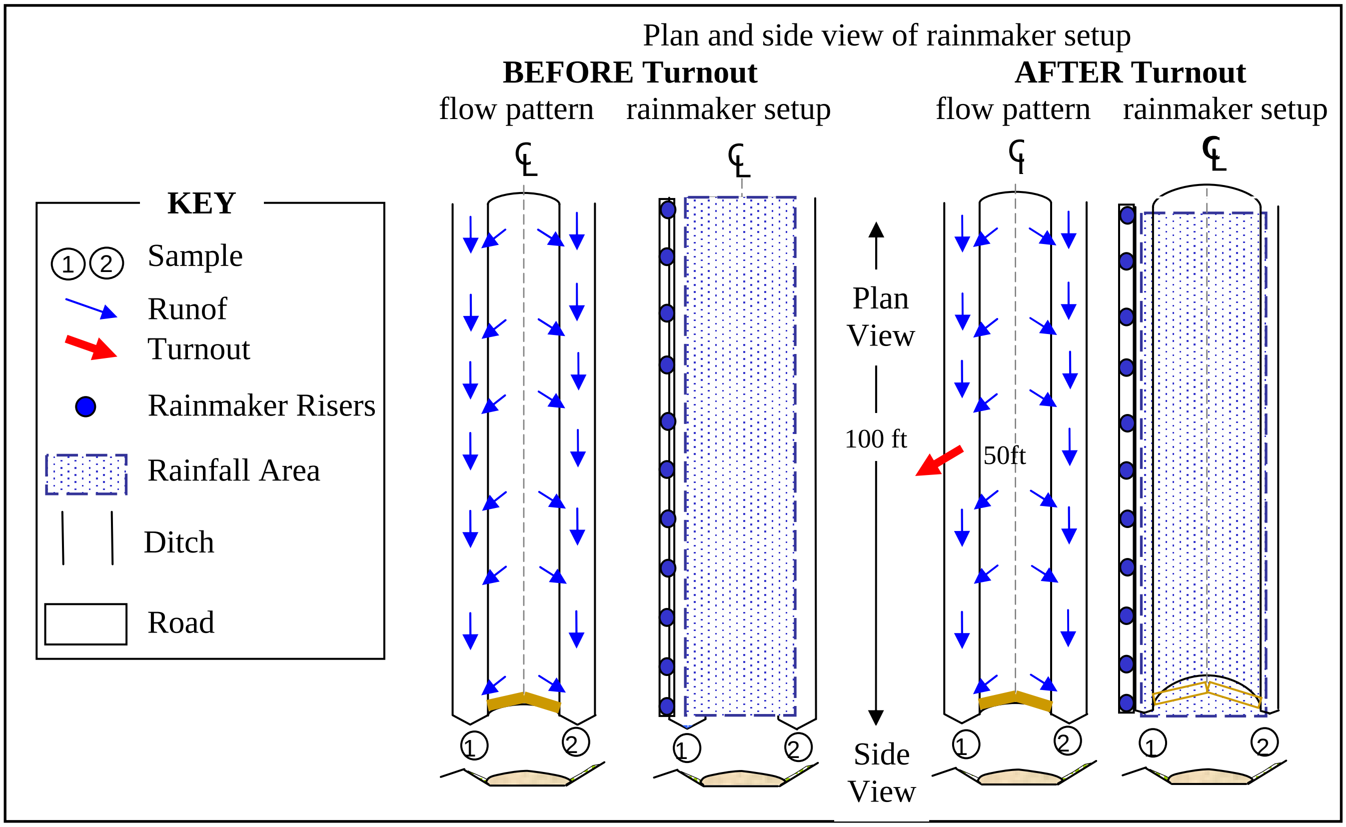


Figure 5.4: Aerial and plan view of rainmaker setup for additional drainage outlet.

5.3 Results

Similar to raising the road profile, the practice of adding a drainage outlet is designed to reduce the transport and delivery of road runoff and sediment, not to reduce erosoin rate itself. Becaue adding a turnout in the down-slope ditch does not affect sediment generation or delivery in the up-slope ditch in a crowned road, <u>all data presented here is only for the down-slope ditch unless otherwise noted</u>. *Figure 5.5* shows the sediment loss per minute (average of 3

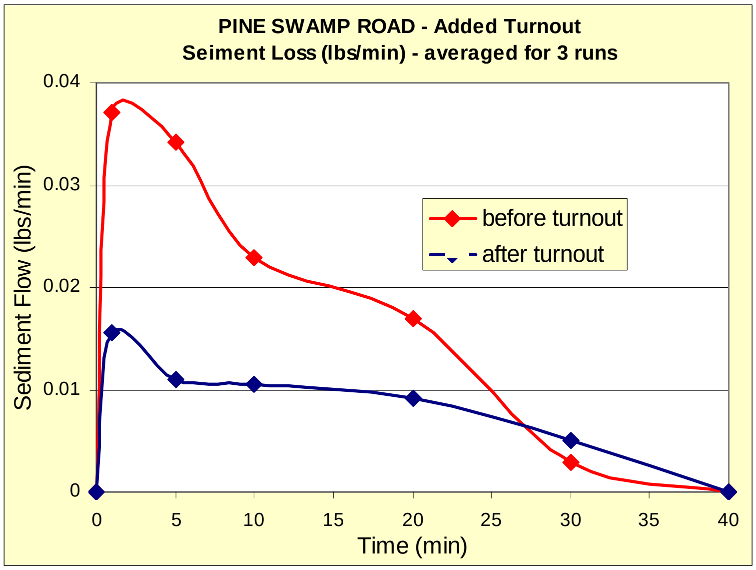


Figure 5.5: Sediment loss rate averages (3 rainfall simulations averaged) for 30 minute rainfall events before and after installation of turnout. Since the up-slope ditch is unaffected by turnout installation in the down-slope ditch, only data from the down-slope ditch is shown here.

runs) for each rainfall simulation. In order to determine sediment reductions for the practice, it is useful to compare the average total sediment loss for each 30 minute run of the rainmaker as illustrated in *Figure 5.6.*

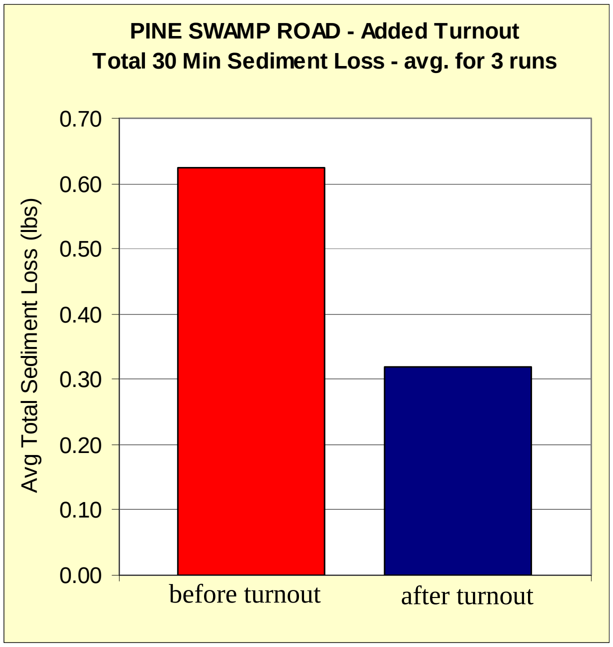


Figure 5.6: Average total sediment loss (3 rainfall simulations averaged) for 30 minute rainfall events before and after turnout construction. Since the up-slope ditch is unaffected by turnout installation in the down-slope ditch, only data from the down-slope ditch is shown here.

Table 5.1 summarizes the total sediment loss and sediment reductions from each simulation. Table 5.1 also includes the calculations when the uphill ditch in included. Detailed results data can be found in Appendix D. It should be noted that sediment reduction calculations are highly dependant on the stability of the native surface (see discussion). Pine Swamp Road was very flat and stable and produced the lowest sediment runoff rates of any native surface road tested with the rainmaker. Logic would dictate, even to those who know little about roads and erosion, that cutting the ditch run in half would reduce sediment by half. The reduction rate of 48% found in this study is very close to this expected result (96% reduction efficiency).

		Total Sediment	**% Sediment Reduction**	**Sediment Reduction** (lbs/road mile)
Down-slope Ditch Only	**Before turnout**	0.62	na	na
	After Turnout	0.32	48%	16
Considering Both Ditches	**Before turnout**	1	na	na
	After Turnout	0.69	31%	16

Table 5.1: Results of sediment sampling and associated sediment reductions adding a turnout. All data is averaged from three rainfall simulations and represents one thirty-minute event with a 1-month return frequency. Results are shown for the down-slope ditch only, and for the entire road system.

5.4 Discussion

The intent of adding drainage outlets is to reduce the amount of concentrated flow that is trapped in the roadside ditches and transported to nearby streams. Sediment reductions are achieved not by reducing erosion of the road surface, but by reducing the transport and delivery of road runoff. Because of this, adding drainage outlets also has the added benefit of encouraging infiltration and reducing peak flow to waterways.

Several factors must be taken into consideration when looking at the sediment reduction results. First, the rainfall simulator will cause an underestimation of sediment savings due to adding additional drainage outlets. This is because the rainmaker only creates precipitation on the road and ditches. Factors that bring water to the road during natural rain events such as springs, seeps, and overland flow are not accounted for by the rainmaker. Adding drainage outlets will alter the flow characteristics of water from these sources as it did for water from the rainfall simulation. Secondly, it is important to consider where outlets are placed. In this study, it was assumed that the original sample point was discharging into the stream. The turnout, located 50 feet away, was assumed not to discharge water into the stream. It is common practice when creating a turnout to maximize the distance to the stream, since placing a turnout where it will discharge into a steam will not reduce the quantity of sediment entering the water.

It is also important to point out that the actual amount of sediment reduction will be highly dependant on the stability (surface material, slope, etc.) of the native road surface. Pine Swamp Road consisted of a hard-packed stone surface with a very low grade of about 1%. For these reasons, it had one of the lowest overall sediment production rates of any of the native surface roads tested. Because adding drainage outlets reduces flow volumes, the percentage of sediment reduction provides a more reliable measure of the effectiveness of the practice in this case than the actual sediment reductions.

The 100 foot length of the rainmaker creates some limitations on the testing of adding drainage outlets. In reality, typical length of ditch runs without outlets are on the order of 200-1000+ feet. The longer the ditch run, the more effective adding an outlet will be. This is because it will reduce the amount of erosion that occurs due to scouring in the ditch. The limited 100 foot scope of the rainmaker will most likely cause an under-prediction of sediment reductions because ditch erosion is fairly minimal due to low flows.

Another important consideration is this testing is how the sediment reductions are determined. A turnout will not affect the sediment or flow characteristics of the up-hill ditch. For this reason, sediment reductions can be expected to be greater when only looking at the down-slope ditch compared to the entire road area. In this test, the turnout reduced sediment by 48% when just looking at the down-slope ditch, and 31% when considering the flow in both ditches. If a culvert is used as an additional drainage outlet, it will reduce the flow length of the up-slope road ditch. The outlet of the culvert will typically also act as a turnout for the down-slope road ditch. The Center advocates the use of a separate turnout and crosspipe outlet, as illustrated in *Figure 5.1*, to minimize water volumes at each outlet.

5.5 Conclusions

It is important to note that the “% reductions in sediment” in this report are not equivalent to “sediment reduction efficiencies”. For example, if a turnout or pipe is place at the midpoint of the 100’ test section, it can only be expected to control runoff from the section of road above the outlet. For this reason, a total sediment reduction of 50% for the 100’ section of tested road can be effectively equated to a 100% efficient practice.

The addition of a turnout on Pine Swamp Road in Huntingdon County resulted in an average flow and sediment reduction of 48% in the down-slope ditch (96% reduction efficiency). Overall road sediment reductions when considering both ditches was 31% for the 30 minute simulated 1-month storm event. Sediment reductions from natural storms may be even greater since interrupted ditch flow is longer (than the 100 foot rainmaker) and additional water sources may be present. The actual amount of sediment reduction seen on other roads will be highly dependant on site conditions such as road slope, amount of overland and underground water coming to the road, the fill material used, fill depth, fill compaction, and the nature of the finished road surface. The 48% reduction seen for the down-slope ditch in this test is very close to the 50% reduction that would be expected for reducing the length of ditch flow by half.

CHAPTER 6: ESMP # 5: Berm Removal

6.1 Definition

A berm is a mound of earthen material that runs parallel to the road on the down-slope side. Berms can be formed by maintenance practices and road erosion that lowers the road elevation over time. In many cases, the berm is unnecesary and creates a ditch on the down-slope side of the road. This berm should be removed to encourage sheet flow into surrounding lands instead of concentrated flow in an unnecessary ditch.

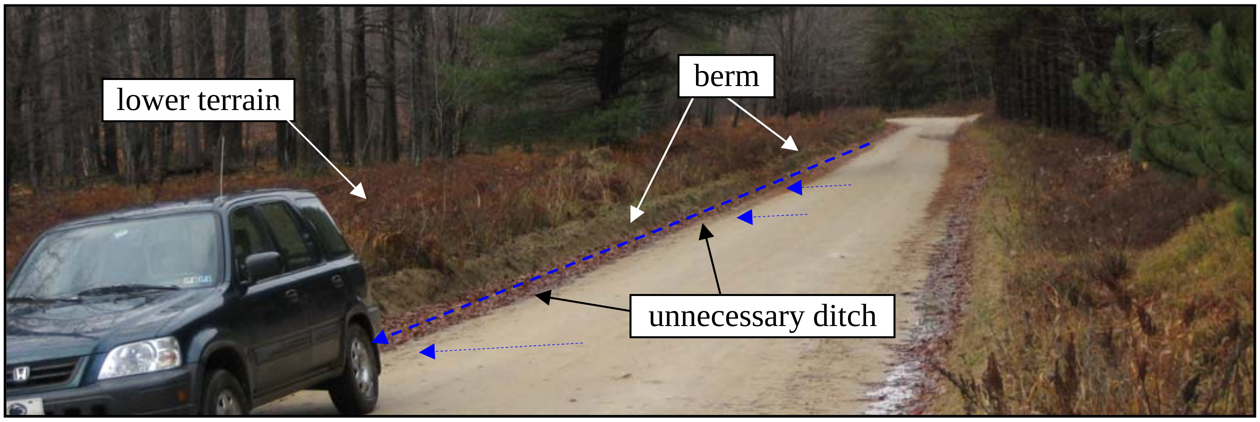


Figure 6.1: The berm pictured here is the result of various maintenance activities. The berm prevents road drainage from reaching the lower terrain on the left of the image. Road runoff and sediment are trapped in an unnecessary ditch which runs a long distance parallel to the roadway until it empties into a stream in front of the vehicle.

6.2 Background

Removing unnecessary berms on the down-slope side of roadways has many benefits including reducing both stream pollution and road maintenance costs. The most significant benefit of berm removal is the elimination of the down-slope road ditch. In many cases, the berm-ditch combination prevents water from sheet flowing off the roadway as illustrated in *Figure 6.1*. By removing the berm, the ditch is eliminated and sheet flow is restored. Restoring sheet flow results in decreased runoff and sediment transport along the roadway, increase infiltration, and reduced maintenance associated with the road drainage system.

6.2.1 Location

The testing for berm removal in this study was done on Pine Swamp Road in Barree Township, Huntingdon County, PA (40^{o} 42.21’ latitude, 77^{o} 53.18’ longitude). Pine Swamp Road is owned and maintained by the Bureau of Forestry, Rothrock State Forest District. The section of road used for this study had a slope of approximately 1% and was in a heavily forested setting.

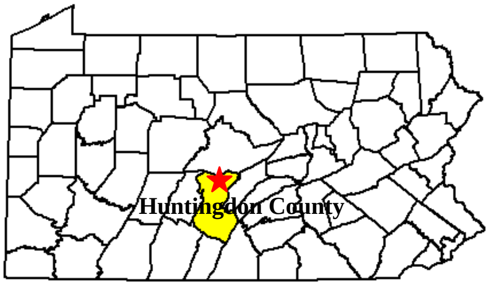


Figure 6.2: Location of Pine Swamp project in Huntingdon County, PA.

The existing surface of Pine Swamp Road was a hard packed mixture of stone including limestone. Traffic volume is relatively low on Pine Swamp Road. Average road width was approximately 12 feet.

6.2.2 Methodology

The process of removing a berm is relatively straightforward. A bulldozer, grader, or small excavator can be used depending on site conditions. The berm is removed, and the material is either hauled off-site or used as topsoil elsewhere on the site. After the berm material is removed, the existing ditch must be re-profiled along with the shoulder of the road in order to encourage sheet flow away from the road. Similar to the “additional drainage outlets” practice discussed in Chapter 5, berm removal focuses on reducing the collection and transport of road runoff instead of reducing the amount of sediment generation. In calculating sediment and flow reductions, it is necessary to make the assumptions that water was transported directly to the stream before berm removal, and that the sheet flow achieved after berm removal will not empty directly into the stream. In cases where the rod parallels the stream, this may not be true.

The procedures outlined in Chapter 1.3 of this document were used for each run of the rainmaker. Water was drawn from nearby Shavers Creek. *Figure 6.3* illustrates a plan and side view of the rainmaker setup for this test. Because the process of removing a berm is very

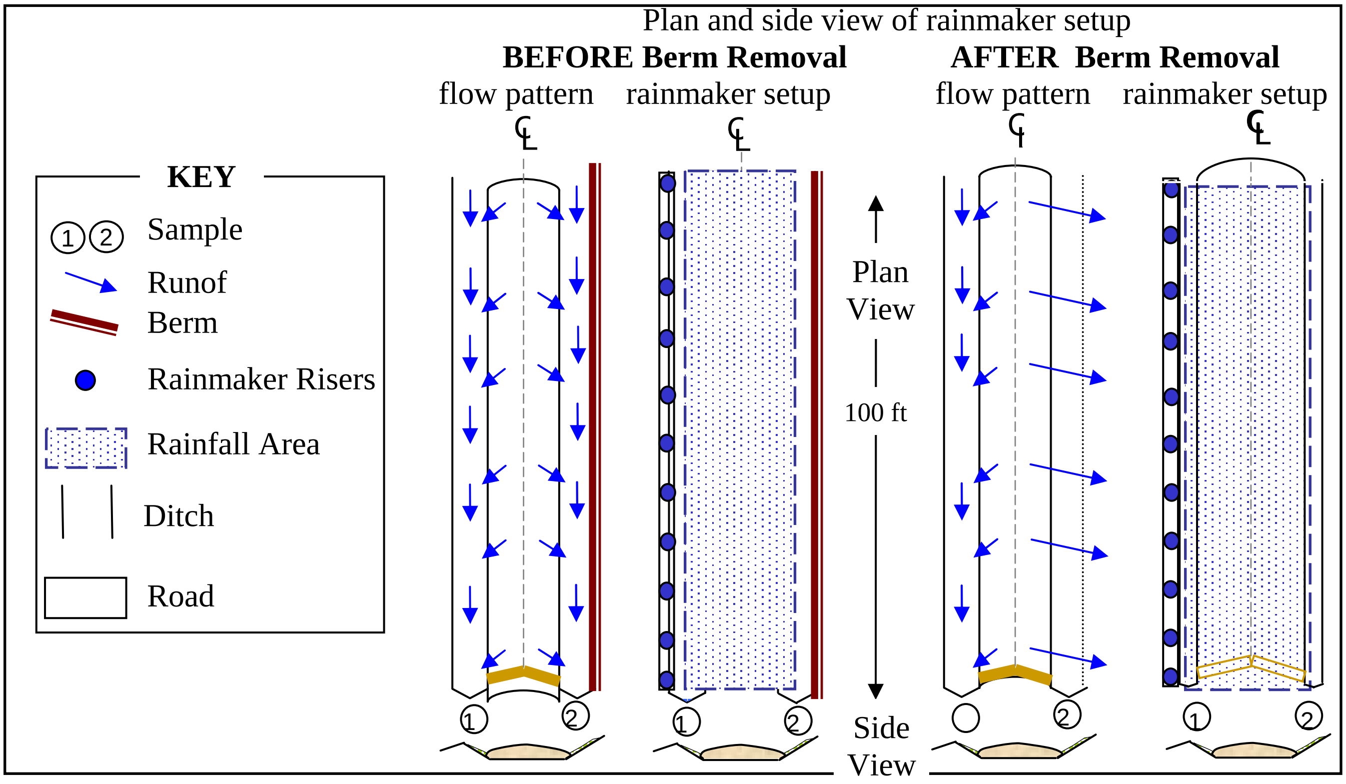


Figure 6.3: Aerial and plan view of rainmaker setup for berm removal.

simple, all testing and berm removal was done during the week of September 26, 2007. A small excavator was used to remove the berm. The sample point on the down-slope side of the road was kept at the same spot after berm removal. Since there was no berm or ditch running to the sample point, the only runoff collected at the sample point was the result of sheet flow from rainfall that ran off the road and directly to the sample point.

6.3 Results

Similar to raising the road profile and adding a drainage outlet, the practice of berm removal is designed to reduce the transport and delivery of road runoff and sediment, not to reduce erosoin rate itself. Becaue berm removal on the down-slope side of the road does not affect sediment generation or delivery in the up-slope ditch, all data presented here is only for the down-slope ditch unless otherwise noted. *Figure 6.4* shows the sediment loss per minute (average of 3 runs) for each rainfall simulation. In order to determine sediment reductions for the aggregates, it is useful to compare the average total sediment loss for each 30 minute run of the rainmaker as illustrated in *Figure 6.5*. Because the berm and ditch were eliminated in this practice, the only runoff and sediment collected at the sample point after berm removal was sheet flow that ran directly off the road surface.

Table 6.1 summarizes the total sediment loss and sediment reductions from each simulation. *Table 6.1* also includes the calculations when the uphill ditch in included. Detailed results data can be found in Appendix E. It should be noted that sediment reduction

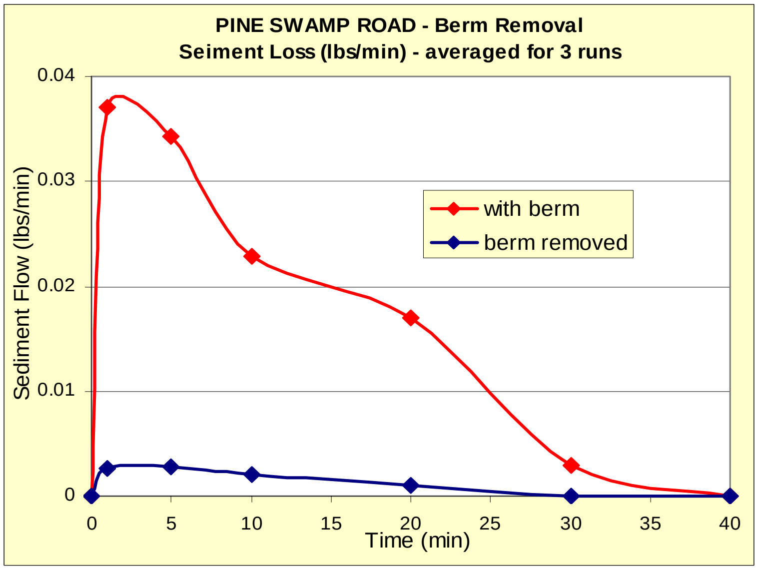


Figure 6.4: Sediment loss rate averages (3 rainfall simulations averaged) for 30 minute rainfall events before and after berm removal. Since up-slope ditch is unaffected by berm removal on the down-slope side of the road, only data from the down-slope ditch is shown here.

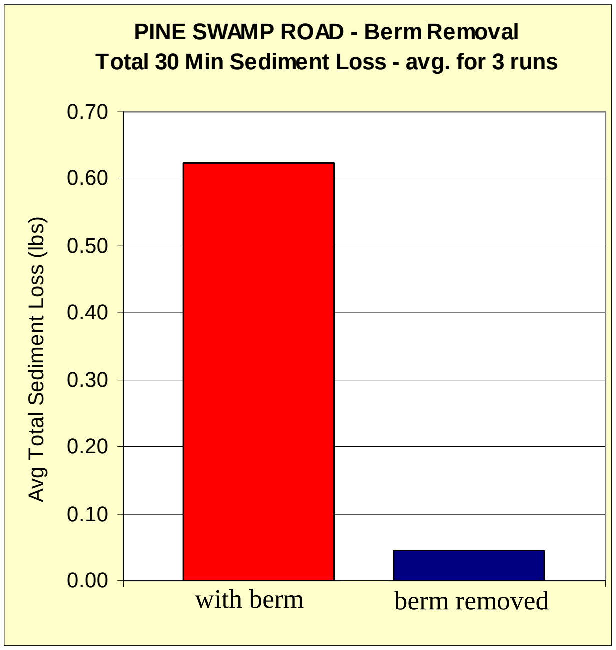


Figure 6.5: Average total sediment loss (3 rainfall simulations averaged) for 30 minute rainfall events before and after berm removal. Since the up-slope ditch is unaffected by berm removal on the down-slope side of the road, only data from the down-slope ditch is shown here.

calculations are highly dependant on achieving and maintaining sheet flow off the roadway. The actual sediment reductions are also highly dependant on the composition of the road surface. Pine Swamp Road was very flat and stable and produced the lowest sediment runoff rates of any native surface road tested with the rainmaker. The reduction rate of 94% found in this study is would result in a larger quantity of sediment being reduced on roads with a steep slope or poor driving surface.

		Sediment Loss (lbs / 30 min)	**% Sediment Reduction**	**Sediment Reduction** (lbs/road mile)
Down-slope Ditch Only	**With Berm**	0.62	na	na
	Berm Removed	0.04	94%	31
Considering Both Ditches	**With Berm**	1	na	na
	Berm Removed	0.41	59%	31

Table 6.1: Results of sediment sampling and associated sediment reductions from berm removal. All data is averaged from three rainfall simulations and represents one thirty-minute event with a 1-month return frequency. Results are shown for the down-slope ditch only, and for the entire road system.

6.4 Discussion

The intent of berm removal is to reduce the amount of concentrated flow that is trapped in the roadside ditches and transported to nearby streams. Sediment reductions are achieved not by reducing erosion of the road surface, but by reducing the transport and delivery of road runoff. Because of this, berm removal also has the added benefit of encouraging infiltration and reducing peak flow to waterways.

Several factors must be taken into consideration when looking at the sediment reduction results. First, the rainfall simulator will cause an underestimation of sediment savings due to berm removal. This is because the rainmaker only creates precipitation on the road and ditches. Factors that bring water to the road during natural rain events such as springs, seeps, and overland flow are not accounted for by the rainmaker. Berm removal will alter the flow characteristics of water from these sources as it did for water from the rainfall simulation. Secondly, it is important to consider that the sheet flow in this study was considered not to be entering or affecting the stream. In certain situations when the stream and road are in very close proximity for long distances, the assumption that sheet flow does not affect the stream is not valid.

It is also important to point out that the actual amount of sediment reduction will be highly dependant on the stability (surface material, slope, etc.) of the native road surface. Pine Swamp Road consisted of a hard-packed stone surface with a very low grade of about 1%. For these reasons, it had one of the lowest overall sediment production rates of any of the native surface roads tested. Because berm removal reduces flow volumes, the percentage of sediment reduction provides a more reliable measure of the effectiveness of the practice in this case than the actual sediment reductions.

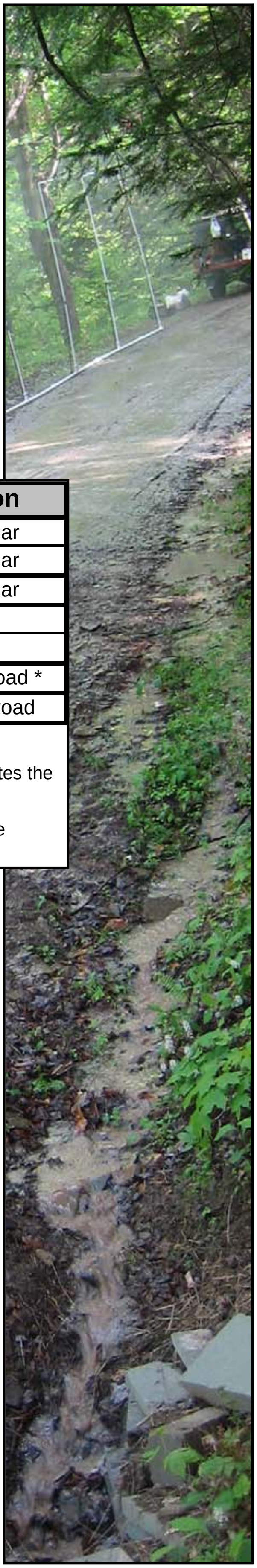
The 100 foot length of the rainmaker creates some limitations on the testing of berm removal. In reality, typical length of unnecessary berms and associated ditches are on the order of 200-1000+ feet. The longer the ditch run, the more effective berm removal will be. This is because it will reduce the amount of erosion that occurs due to scouring in the ditch. The limited 100 foot scope of the rainmaker will most likely cause an under-prediction of sediment reductions because ditch erosion is fairly minimal due to low flows.

Another important consideration of this testing is how the sediment reductions are determined. Berm removal on the down-slope side of the road will not affect the sediment or flow characteristics of the up-hill ditch. For this reason, sediment reductions can be expected to be greater when only looking at the down-slope ditch compared to the entire road area. In this test, berm removal reduced sediment by 94% when just looking at the down-slope ditch, and 59% when considering the flow in both ditches. It should be noted that berm removal is not advised by the Center in specific locations where extremely steep and dangerous drops exist on the down-slope side of the road.

6.5 Conclusions

The berm removal on Pine Swamp Road in Huntingdon County resulted in an average flow and sediment reduction of 94% in the down-slope ditch. Overall road sediment reductions when considering both ditches was 59% for the 30 minute simulated 1-month storm event. Sediment reductions from natural storms may be even greater since interrupted ditch flow is longer (than the 100 foot rainmaker) and additional water sources may be present. The actual amount of sediment reduction seen on other roads will be highly dependant on site conditions such as road slope, amount of overland and underground water coming to the road, the fill material used, fill depth, fill compaction, and the nature of the finished road surface.

CHAPTER 7: Conclusions Summary



Pennsylvania’s Dirt and Gravel Road Maintenance Program has been developing and encouraging the use of Environmentally Sensitive Maintenance Practices for over a decade. The Program has qualitatively found that the ESM practices it was advocating reduced sediment, but had no empirical evidence before this study. The results of this study indicate that all of the ESM practices used resulted in significant redutions of sediment pollution to local streams. This study is an important first step in beginning to quantify sediment generation from unpaved roads, and sediment reduction efficiencies of ESM practices. *Table 7.1* summarizes the sediment reductions found for the Environmentally Sensitive Road Maintenance Practices in this study. Remember that the results in this study are for the specific roads, practices, and conditions where they were implemented. Any attempts to make universal sediment reduction standards for these practices would not be substantiated based on the one or two data points in this study.

ESM Practice	Location	%Sediment Reduction
DSA - limestone	Lebo Rd, Potter County	73% @ 1 month; 86% @ 1 year
DSA - sandstone	Lebo Rd, Potter County	76% @ 1 month; 93% @ 1 year
Raising Road	Diehl Rd, Columbia County	78% @ 1 month; 81% @ 1 year
Gradebreak *	Jeanie Lane, Mifflin County	43% *
Gradebreak *	Pine Swamp Rd, Huntingdon Cty	57% *
Ditch Outlet * **	Pine Swamp Rd, Huntingdon Cty	48% one ditch; 31% whole road *
Berm Removal **	Pine Swamp Rd, Huntingdon Cty	94% one ditch; 59% whole road

Table 7.1: Summary of sediment reductions results form ESM Practices.

* Since these practices were placed at 50' of the 100' test section, a sediment reduction of 50% indicates the practice is 100% efficent at sediment removal. The 50' of road below the practice was not affected.

** This practices only affects half of the road and the downslope ditch. Figure are porvided for both the affected ditch, and the whole road.

The “rainmaker” proved to be a valuable tool to accurately compare the sediment loads of installed ESM practices. The rainmaker only has two significant limitations. First, it only produces rainfall on 100 linear feet of roadway. Compounding effects of longer road and ditch runs during natural rain events cannot be simulated. Second, it only produces rainfall on the immediate area around the road surface. During natural rain events, runoff from other sources typically uses unpaved road ditches as conduits for flow. These off right-of-way factors are not accounted for using the rainfall simulator. Both of these factors will lead

to the rainfall simulator underestimating the amount of runoff and sediment reaching the stream. For this reason, the runoff and erosion rates obtained in this study can be seen as a minimum. Natural rainfall events of the same intensity would most likely produce more runoff and sediment.

Erosion rates on native surface roads for the 30 minute simulated rainfall event ranged from 0.7 to 12 pounds depending on road slope and composition. The average sediment loss for a single 30 minute event with a 1-month return interval for all five roads tested is 5.6 pounds per 100' of road (individual totals in *table 2.3*). If this figure is extrapolated out to all of Pennsylvania's ~20,000 miles of public unpaved road, it can be determined that a single storm event (0.55" in 30 minutes, a 1-month event) across the State would generate approximately 3,000 tons of sediment runoff. While not all of this runoff would directly enter a stream, remember that this is a low estimate because of the lack of compounding factors and off right-of-way influences that would exist in a natural storm, but were not accounted for with the rainmaker. This figure also does not include the unknown miles of private unpaved roads such as driveways, farm lanes, mining accesses, oil and gas accesses, etc.

Driving Surface Aggregate: Adding Driving Surface Aggregate to the road surface is the practice which was best suited to rainmaker use since the major concern was erosion from the road surface, not changes in site hydrology as with other practices. DSA is also of great interest because surface aggregate is typically the most expensive and visible component of an unpaved road. Sediment loads from the two sections of DSA averaged 0.7 pounds for each 30 minute event, well below the average of 5.6 pounds for the five native surface roads. The degree of sediment reduction from placing DSA will depend greatly on the composition, width, and slope of the existing road. Before and after testing is needed on many more native surface and DSA roads before these questions and many others can be addressed. The Center will continue to advocate the use of DSA on "key areas" as it has in the past. These key areas are where the road is in close proximity to the stream where drainage controls cannot prevent the discharge of runoff to the stream. Areas with unstable existing surfaces in close proximity to streams will benefit the most from the application of DSA.

<u>Flow Control Practices</u>: While DSA is intended to reduce sediment generation, the remaining four Environmentally Sensitive Maintenance Practices (*raising the road profile, additional drainage outlet, grade break, and berm removal*) all seek to reduce sediment by reducing the concentration and transport of road runoff. Sediment reductions ranging from 43% to 94% were found after these practices were implemented. Again, as with DSA, these reductions should not be used as universal constants for each practice as many factors will effect the sediment reduction efficiencies.

The effectiveness of all of these practices will be highly dependant on the physical relationship of the road to the stream. For example, the practice of adding a drainage outlet will only reduce sediment loads if the new outlet does not also empty into the stream. In situations where the road is parallel and in close proximity to the stream, adding a pipe or turnout will not significantly reduce the amount of sediment entering the stream, it will only change the location where the sediment enters the stream. A road such as this is a good candidate for DSA to reduce the amount of sediment generated, since drainage to the stream may be unavoidable. On the other hand, a road that crosses perpendicular to a stream will be much more likely to benefit from an additional drainage outlet, since runoff will be discharged at a much greater distance from the watercourse.

The cost/benefit of ESM practices must also be considered. DSA is a very expensive practice when compared to some of the drainage control practices such as grade breaks, berm removal, and additional drainage outlets. The goal of the Dirt and Gravel Road Program has always been to reduce the amount of sediment reaching the stream. In many cases, simple drainage control practices can be combined to achieve major sediment reductions without the expense of aggregate. In some cases where drainage control options are limited, DSA can be the most effective tool to reduce sediment generation from the road.

<u>Future Research</u>: This study represents an important step in beginning to quantify sediment runoff from unpaved roads and sediment reductions achieved by Environmentally Sensitive Maintenance Practices. It also opens the door for much more research on the subject. The use of one or two sample points is not sufficient to obtain average sediment reductions for any practice. For this reason, extrapolation of the results of this study to account for sediment reductions for similar practices statewide is not advised. The Rainmaker proved to be a very valuable and successful tool for use in comparing runoff and erosion rates before and after implementation of practices. The convenience, and more importantly the repeatability, of the rainmaker made it an ideal tool for this study. The size of the rainmaker could be increased to utilize 200-300 feet of roadway, however a more powerful pump and potentially larger pipe would be required. A longer run of rainfall simulation would provide for better analysis of the ESM practices that address volume and concentration of road runoff.

Surface aggregate is typically the most expensive and visible component of an unpaved road. For this reason, and because very little literature exists, many opportunities exist for additional testing of Driving Surface Aggregate. There is a great opportunity for more study on the sediment reduction aspects of DSA. While this study provided great initial insight into the erosion process on unpaved road surfaces, many more questions exist such as:

- Does DSA produce less sediment than <u>other</u> surface aggregates?
- What effect does road slope have on DSA sediment generation?
- Do variations within the DSA gradation affect sediment generation?
- How does sediment runoff relate to road performance (longevity, need for maintenance)?
- How do maintenance activities such as grading affect sediment production?
- How is sediment generation affected by more or less intense events?
- How does traffic volume affect aggregate performance and longevity?

Expansion of this study to include more DSA placements with “before and after” sediment data would begin to paint a picture of exactly how effective the aggregate is at reducing sediment. It would also allow correlations to be made between sediment production and factors such as road slope and degree of crown. Such a study would also provide many “before” sample points in order to get a better handle on the degree and range of sedimentation that is occurring from Pennsylvania’s 20,000+ miles of varied unpaved roads.

REFERENCES

Coe, D.B.R. 2006. Sediment Production and Delivery from Forest Roads in the Sierra Nevada, California. M.S. Thesis, Colorado State University. 2006

Evans, B., S. Sheeder, K. Corradini, and W. Brown, 2003a. AVGWLF User's Guide, Version 5.0.2. Pennsylvania State University, Environmental Resources Research Institute, University Park, PA.

Food and Agriculture Organization of the United Nations, 1993. Field Measurement of Soil Erosion and Runoff. http://www.fao.org/documents/show_cdr.asp?url_file=/ docrep/T0848E/t0848e-11.htm (Last Accessed April, 2006)

Foltz, R.B. 1993. Sediment Processes in Wheel Ruts on Unsurfaced Forest Roads. Ph.D Dissertation. University of Idaho, Moscow, 1993

Kahklen, Keith, 2001. A Method for Measuring Sediment Production from Forest Roads. USDA, Forest Service.

MacDonald L.H., R.W. Sampson, and D.M. Anderson. 2001. Runoff and Road Erosion at the Plot and Road Segment Scales, St. John, US Virgin Islands. Earth Surface Processes and Landforms.

Novotny, V., 2003. Water Quality: Diffuse Pollution and Watershed Management. John Wiley & Sons, Inc., New York.

Pennsylvania Department of Transportation, 1999. Criteria for Applicability of Hydrologic and Hydraulic Methodologies. http://www.dot.state.pa.us/bridge/standards/Pubs/ 4319911.pdf (Last Accessed April, 2005)

Pennsylvania Department of Environmental Protection, 2004. Pennsylvania's Chesapeake Bay Tributary Strategy. http://www.dep.state.pa.us/hosting/pawatersheds/chesapeakebay/ docs/TribStrategy (Last Accessed July, 2007)

Ziegler A.D., R.A. Sutherland, and T.W. Giambelluca. 2000. Partitioning Total Erosion on Unpaved Roads into Splash and Hydraulic Components: The roles of Interstorm Surface Preparation and Dynamic Erodibility. Water Resources Research.

APPENDIX A – Rainmaker Data for ESMP #1 Driving Surface Aggregate

BEFORE - LEBO LOWER - Limestone

5/22/06 STREAM TSS = 5 mg/l

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment Measurements		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 4:00	0	LL 1.1-1	63.22	3.5	3.3	SB 1	337	0.009
		5	LL 1.1-2	13.50	3.5	15.6	2	1,996	0.259
		10	LL 1.1-3	11.09	3.5	18.9	3	1,167	0.184
		20	LL 1.1-4	10.62	3.5	19.8	4	955	0.158
		30	LL 1.1-5	23.22	3.5	9.0	5	182	0.014
		45	LL 1.1-6	21.37	0.264	0.7	6	84.4	0.001
Run 2	Time to Runoff: 5:50	0	LL 1.2-1	53.43	3.5	3.9	7	250	0.008
		5	LL 1.2-2	13.28	3.5	15.8	8	2,630	0.347
		10	LL 1.2-3	11.81	3.5	17.8	9	1,653	0.245
		20	LL 1.2-4	11.18	3.5	18.8	10	1,020	0.160
		30	LL 1.2-5	37.97	3.5	5.5	11	506	0.023
		45	LL 1.2-6	26.09	0.264	0.6	12	80.0	0.000
Run 3	Time to Runoff: 5:35	0	LL 1.3-1	69.15	3.5	3.0	13	215	0.005
		5	LL 1.3-2	13.16	3.5	16.0	14	4,962	0.661
		10	LL 1.3-3	13.03	3.5	16.1	15	340	0.046
		20	LL 1.3-4	10.38	3.5	20.2	16	1,771	0.299
		30	LL 1.3-5	34.75	3.5	6.0	17	527	0.027
		45	LL 1.3-6	22.97	0.264	0.7	18	261	0.002

Average total 30 minute sediment loss = 5.67 lbs

BEFORE - LEBO UPPER - Sandstone

5/23/06 AM TSS = 5 mg/l

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 5:30	0	LS 1.1-1	30.87	3	5.8	19	14,700	0.715
		5	LS 1.1-2	12.72	3	14.2	20	1,194	0.141
		10	LS 1.1-3	15.47	3	11.6	21	1,347	0.131
		20	LS 1.1-4	9.00	3	20.0	22	1,145	0.191
		30	LS 1.1-5	51.97	3	3.5	23	794	0.023
		45		1.00	0	0.0		0	0.000
Run 2	Time to Runoff: 5:37	0	LS 1.2-1	19.85	3	9.1	24	1,966	0.149
		5	LS 1.2-2	15.72	3	11.5	25	1,183	0.113
		10	LS 1.2-3	11.97	3	15.0	26	3,099	0.389
		20	LS 1.2-4	10.12	3	17.8	27	2,194	0.326
		30	LS 1.2-5	59.34	3	3.0	28	1,238	0.031
		45		1.00	0	0.0		0	0.000
Run 3	Time to Runoff: 4:20	0	LS 1.3-1	42.47	3	4.2	29	5,350	0.189
		5	LS 1.3-2	14.97	3	12.0	30	4,894	0.491
		10	LS 1.3-3	9.65	3	18.7	31	4,605	0.717
		20	LS 1.3-4	9.28	3	19.4	32	2,489	0.403
		30	LS 1.3-5	25.65	3	7.0	33	1,068	0.063
		45		1.00	0	0.0		0	0.000

Average total 30 minute sediment loss = 8.70 lbs

APPENDIX A – Rainmaker Data for ESMP #1 Driving Surface Aggregate

1 MONTH - LEBO LOWER - Limestone

7/7/2006 AM TSS = 2 mg/l

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 6:30	0	LL 1.1-1	18.79	3	9.6	SB 71	270	0.022
		5	LL 1.1-2	12.94	3	13.9	72	783	0.091
		10	LL 1.1-3	12.34	3	14.6	73	658	0.080
		20	LL 1.1-4	12.63	3	14.3	74	587	0.070
		30	LL 1.1-5	54.69	3	3.3	75	561	0.015
		45	LL 1.1-6	60.53	0.264	0.3	76	122.0	0.000
Run 2	Time to Runoff: 8:40	0	LL 1.2-1	19.16	3	9.4	77	1,932	0.151
		5	LL 1.2-2	11.85	3	15.2	78	470	0.060
		10	LL 1.2-3	12.60	3	14.3	79	591	0.070
		20	LL 1.2-4	12.50	3	14.4	80	206	0.025
		30	LL 1.2-5	96.31	3	1.9	81	380	0.006
		45	LL 1.2-6	81.75	0.264	0.2	82	246.0	0.000
Run 3	Time to Runoff: 8:40	0	LL 1.3-1	19.03	3	9.5	83	425	0.034
		5	LL 1.3-2	11.93	3	15.1	84	270	0.034
		10	LL 1.3-3	13.03	3	13.8	85	243	0.028
		20	LL 1.3-4	10.78	3	16.7	86	471	0.066
		30	LL 1.3-5	80.22	3	2.2	87	303	0.006
		45	LL 1.3-6	73.60	0.264	0.2	88	268	0.000

Average total 30 minute sediment loss = 1.55 lbs

1 MONTH - LEBO UPPER - Sandstone

7/6/2006 AM TSS = 2 mg/l

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 3:40	0	LS 1.1-1	113.06	3	1.6	89	1,080	0.014
		5	LS 1.1-2	17.90	3	10.1	90	799	0.067
		10	LS 1.1-3	14.13	3	12.7	91	671	0.071
		20	LS 1.1-4	9.97	3	18.1	92	473	0.071
		30	LS 1.1-5	17.22	3	10.5	93	370	0.032
		45	LS 1.1-6	104.18	0.264	0.2	94	297	0.000
Run 2	Time to Runoff: 3:50	0	LS 1.2-1	104.06	3	1.7	95	1,464	0.021
		5	LS 1.2-2	21.59	3	8.3	96	454	0.032
		10	LS 1.2-3	9.62	3	18.7	97	1,098	0.171
		20	LS 1.2-4	8.9	3	20.2	98	515	0.087
		30	LS 1.2-5	15.09	3	11.9	99	342	0.034
		45	LS 1.2-6	62.13	0.264	0.3	100	412	0.001
Run 3	Time to Runoff: 3:56	0	LS 1.3-1	104.25	3	1.7	101	1,588	0.023
		5	LS 1.3-2	17.69	3	10.2	102	644	0.055
		10	LS 1.3-3	10.13	3	17.8	103	495	0.073
		20	LS 1.3-4	7.72	3	23.3	104	137	0.027
		30	LS 1.3-5	14.75	3	12.2	105	106	0.011
		45	LS 1.3-6	61.97	0.264	0.3	106	250	0.001

Average total 30 minute sediment loss = 2.09 lbs

APPENDIX A – Rainmaker Data for ESMP #1 Driving Surface Aggregate

1 YEAR - LEBO LOWER - Limestone

6/12/2007 AM TSS = 3 mg/l

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 5:40	0	LL 1.1	48.00	2	2.5	158	297	0.006
		5	LL 1.2	9.40	2	12.8	159	318	0.034
		10	LL 1.3	8.40	2	14.3	160	245	0.029
		20	LL 1.4	8.60	2	14.0	161	173	0.020
		30	LL 1.5	14.40	2	8.3	162	132	0.009
		45	LL 1.6	54.15	1	1.1	163	61.2	0.001
Run 2	Time to Runoff: 6:40	0	LL 2.1	38.10	2	3.1	164	1,169	0.031
		5	LL 2.2	11.70	2	10.3	165	549	0.047
		10	LL 2.3	9.30	2	12.9	166	313	0.034
		20	LL 2.4	8.70	2	13.8	167	224	0.026
		30	LL 2.5	10.10	2	11.9	168	157	0.016
		45	LL 2.6	62.80	1	1.0	169	90.0	0.001
Run 3	Time to Runoff: 5:52	0	LL 3.1	38.10	2	3.1	170	979	0.026
		5	LL 3.2	14.10	2	8.5	171	427	0.030
		10	LL 3.3	11.80	2	10.2	172	406	0.034
		20	LL 3.4	8.60	2	14.0	173	185	0.022
		30	LL 3.5	16.50	2	7.3	174	141	0.009
		45	LL 3.6	58.10	1	1.0	175	67	0.001

Average total 30 minute sediment loss = 0.78 lbs

1 YEAR - LEBO UPPER - Sandstone

6/11/2007 AM TSS = 3 mg/l

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 5:00	0	LS 1.1	106.00	2	1.1	SB 140	399	0.004
		5	LS 1.2	17.40	2	6.9	141	285	0.016
		10	LS 1.3	12.00	2	10.0	142	249	0.021
		20	LS 1.4	10.60	2	11.3	143	199	0.019
		30	LS 1.5	12.80	2	9.4	144	170	0.013
		45	LS 1.6	21.90	0.132	0.4	145	91	0.000
Run 2	Time to Runoff: 6:00	0	LS 2.1	99.1	2	1.2	146	1,200	0.012
		5	LS 2.2	37.5	2	3.2	147	491	0.013
		10	LS 2.3	11.9	2	10.1	148	305	0.026
		20	LS 2.4	9.5	2	12.6	149	195	0.021
		30	LS 2.5	19.5	2	6.2	150	130	0.007
		45	LS 2.6	18.3	0.132	0.4	151	119	0.000
Run 3	Time to Runoff: 5:20	0	LS 3.1	106	2	1.1	152	1,135	0.011
		5	LS 3.2	29.4	2	4.1	153	391	0.013
		10	LS 3.3	10.3	2	11.7	154	285	0.028
		20	LS 3.4	7.5	2	16.0	155	141	0.019
		30	LS 3.5	12	2	10.0	156	106	0.009
		45	LS 3.6	22.7	0.132	0.3	157	88	0.000

Average total 30 minute sediment loss = 0.60 lbs

APPENDIX B – Rainmaker Data for ESMP #2 Raising the Road Profile

BEFORE - DIEHL - native material - UPHILL DITCH

5/24/2006

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment Measurements		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 4:00	0		66.56	3.5	3.2	SB 1	337	0.009
		5		15.13	3.5	13.9	2	1,996	0.231
		10		18.16	3.5	11.6	3	1,167	0.113
		20		16.04	3.5	13.1	4	955	0.104
		30		38.59	3.5	5.4	5	182	0.008
		45		110.00	0.264	0.1	6	84.4	0.000
Run 2	Time to Runoff: 5:50	0		45.22	3.5	4.6	7	250	0.010
		5		21.09	3.5	10.0	8	2,630	0.219
		10		15.12	3.5	13.9	9	1,653	0.192
		20		12.66	3.5	16.6	10	1,020	0.141
		30		35.53	3.5	5.9	11	506	0.025
		45		120.00	0.264	0.1	12	80.0	0.000
Run 3	Time to Runoff: 5:35	0		54.53	3.5	3.9	13	215	0.007
		5		16.78	3.5	12.5	14	4,962	0.519
		10		14.10	3.5	14.9	15	340	0.042
		20		15.09	3.5	13.9	16	1,771	0.206
		30		61.88	3.5	3.4	17	527	0.015
		45		122.00	0.264	0.1	18	261	0.000

BEFORE - DIEHL - native material - PONDSIDE DITCH

5/24/2006

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment Measurements		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 5:30 No flow at 45min	0		24.25	3	7.4	19	14,700	0.911
		5		13.18	3	13.7	20	1,194	0.136
		10		9.56	3	18.8	21	1,347	0.212
		20		12.09	3	14.9	22	1,145	0.142
		30		26.53	3	6.8	23	794	0.045
		45		36.84	0.264	0.4		0	0.000
Run 2	Time to Runoff: 5:37 No flow at 45min	0		34.82	3	5.2	24	1,966	0.085
		5		12.69	3	14.2	25	1,183	0.140
		10		13.16	3	13.7	26	3,099	0.354
		20		14.82	3	12.1	27	2,194	0.223
		30		27.66	3	6.5	28	1,238	0.067
		45		46.00	0.264	0.3		0	0.000
Run 3	Time to Runoff: 4:20 No flow at 45min	0		26.94	3	6.7	29	5,350	0.298
		5		15	3	12.0	30	4,894	0.490
		10		13.91	3	12.9	31	4,605	0.498
		20		13.03	3	13.8	32	2,489	0.287
		30		45.18	3	4.0	33	1,068	0.036
		45		48.62	0.264	0.3		0	0.000

APPENDIX B – Rainmaker Data for ESMP #2 Raising the Road Profile

1 MONTH AFTER - DIEHL - Shale fill material - UPHILL DITCH

7/7/2006

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment Measurements		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 6:30	0	D2-1.1	74.13	3	2.4	SB 108	337	0.007
		5	D2-1.2	28.80	3	6.3	109	1,996	0.104
		10	D2-1.3	24.80	3	7.3	110	1,167	0.071
		20	D2-1.4	25.80	3	7.0	111	955	0.056
		30	D2-1.5	14.50	0.264	1.1	112	182	0.002
		45		1.00		0.0		84	0.000
Run 2	Time to Runoff: 8:40	0	D2-2.1	48.50	3	3.7	113	250	0.008
		5	D2-2.2	20.44	3	8.8	114	2,630	0.193
		10	D2-2.3	19.75	3	9.1	115	1,653	0.126
		20	D2-2.4	20.47	3	8.8	116	1,020	0.075
		30	D2-2.5	19.80	0.264	0.8	117	506	0.003
		45		1.00		0.0		80	0.000
Run 3	Time to Runoff: 8:40	0	D2-3.1	62.00	3	2.9	118	215	0.005
		5	D2-3.2	20.50	3	8.8	119	4,962	0.364
		10	D2-3.3	20.40	3	8.8	120	340	0.025
		20	D2-3.4	22.70	3	7.9	121	1,771	0.117
		30	D2-3.5	4.80	0.264	3.3	122	527	0.015
		45		1.00		0.0		261	0.000

1 YEAR AFTER - DIEHL -- UPHILL DITCH

6/1/2007

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment Measurements		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 2:30	0	1.1	27.00	2	4.4	SB 124	337	0.013
		5	1.2	21.20	2	5.7	125	1,996	0.094
		10	1.3	23.50	2	5.1	126	1,167	0.050
		20	1.4	15.00	2	8.0	127	955	0.064
		30	1.5	18.80	2	6.4	128	182	0.010
		45	1.6	1.00		0.0		84	0.000
Run 2	Time to Runoff: 2:15	0	2.1	38.60	2	3.1	129	250	0.006
		5	2.2	16.25	2	7.4	130	2,630	0.162
		10	2.3	22.30	2	5.4	131	1,653	0.074
		20	2.4	18.60	2	6.5	132	1,020	0.055
		30	2.5	19.30	2	6.2	133	506	0.026
		45	2.6	1.00		0.0		80	0.000
Run 3	Time to Runoff: 2:35	0	3.1	37.10	2	3.2	134	215	0.006
		5	3.2	19.90	2	6.0	135	4,962	0.250
		10	3.3	21.10	2	5.7	136	340	0.016
		20	3.4	14.20	2	8.5	137	1,771	0.125
		30	3.5	21.70	2	5.5	138	527	0.024
		45	3.5	1.00		0.0		261	0.000

Before sediment concentrations used for after calculations – see section 3.2.2 for details

No pond side or down-slope ditch after road was filled. Sheet flow was achieved

APPENDIX C – Rainmaker Data for ESMP #3 Grade Breaks

JEANIE LANE, MIFFLIN COUNTY (Site 1 of 2)

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

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
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			Sediment		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
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

Before sediment concentrations used for after calculations – see section 4.2.2 for details

APPENDIX C – Rainmaker Data for ESMP #3 Grade Breaks

PINE SWAMP ROAD, HUNTINGDON COUNTY (Site 2 of 2)

BEFORE - PINE SWAMP (Uphill Ditch)

9/26/2007

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 1:30	0		1.00	0	0.0			0.0000
		1	UB 1.01	80.00	2	1.5	215	950	0.0119
		5	UB 1.05	31.00	2	3.9	216	650	0.0210
		10	UB 1.10	31.00	2	3.9	217	460	0.0149
		20	UB 1.20	23.00	2	5.2	218	190	0.0083
		30	UB 1.30	23.00	2	5.2	219	145	0.0063
		40	UB 1.40	10.00	0.264	1.6	220	10.0	0.0001
Run 2	Time to Runoff: 1:30	0		1.00	0	0.0			0.0000
		1	UB 2.01	93.00	2	1.3	221	1,210	0.0130
		5	UB 2.05	31.00	2	3.9	222	420	0.0136
		10	UB 2.10	27.00	2	4.4	223	245	0.0091
		20	UB 2.20	18.00	2	6.7	224	85	0.0047
		30	UB 3.30	20.00	2	6.0	225	135	0.0068
		40	UB 2.40	12.00	0.264	1.3	226	12.3	0.0001
Run 3	Time to Runoff: 1:30	0		1.00	0	0.0			0.0000
		1	UB 3.01	101.00	2	1.2	227	1,550	0.0154
		5	UB 3.05	33.00	2	3.6	228	460	0.0140
		10	UB 3.10	29.00	2	4.1	229	960	0.0332
		20	UB 3.20	25.00	2	4.8	230	120	0.0048
		30	UB 3.30	18.00	2	6.7	231	80	0.0045
		40	UB 3.40	13.00	0.264	1.2	232	3	0.0000

Average total 30 minute sediment loss = 0.37 lbs

AFTER GRADEBREAK - PINE SWAMP (Uphill Ditch)

9/26/2007

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 1:30	0		1.00	0	0.0	0	0	0.0000
		1	UD 1.01	118.00	2	1.0	233	1,530	0.0130
		5	UD 1.05	64.00	2	1.9	234	570	0.0089
		10	UD 1.10	51.00	2	2.4	235	265	0.0052
		20	UD 1.20	23.00	2	5.2	236	110	0.0048
		30	UD 1.30	22.00	2	5.5	237	150	0.0068
		40	UD 1.40	7.00	0.264	2.3	238	4.3	0.0001
Run 2	Time to Runoff: 1:30	0		1.00	0	0.0	0	0	0.0000
		1	UD 2.01	106.00	2	1.1	239	1,700	0.0161
		5	UD 2.05	85.00	2	1.4	240	330	0.0039
		10	UD 2.10	55.00	2	2.2	241	270	0.0049
		20	UD 2.20	35.00	2	3.4	242	36	0.0010
		30	UD 3.30	22.00	2	5.5	243	13	0.0006
		40	UD 2.40	100.00	2	1.2	244	4.8	0.0000
Run 3	Time to Runoff: 1:30	0		1.00	0	0.0	0	0	0.0000
		1	UD 3.01	113.00	2	1.1	245	1,040	0.0092
		5	UD 3.05	52.00	2	2.3	246	260	0.0050
		10	UD 3.10	49.00	2	2.4	247	320	0.0065
		20	UD 3.20	21.00	2	5.7	248	30	0.0014
		30	UD 3.30	23.00	2	5.2	249	26	0.0011
		40	UD 3.40	6.00	0.264	2.6	250	6	0.0001

Average total 30 minute sediment loss = 0.16 lbs

APPENDIX D – Rainmaker Data for ESMP #4 Additional Drainage Outlet

BEFORE -Streamside Dtich

9/25/2007

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment Measurements		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 1:30	0		1.00	0	0.0	0	0	0.000
		1	SA 1.01	53.00	2	2.3	SB 177	3800	0.072
		5	SA 1.05	33.50	2	3.6	178	1660	0.050
		10	SA 1.10	37.00	2	3.2	179	1020	0.028
		20	SA 1.20	33.00	2	3.6	180	740	0.022
		30	SA 1.30	20.50	0.264	0.8	181	900	0.006
		40	SA 1.40	1.00	0	0.0	0	0	0.000
Run 2	Time to Runoff: 1:30	0		1.00	0	0.0	0	0	0.000
		1	SA 2.01	50.00	2	2.4	182	1180	0.024
		5	SA 2.05	31.00	2	3.9	183	630	0.020
		10	SA 2.10	31.50	2	3.8	184	550	0.017
		20	SA 2.20	37.00	2	3.2	185	450	0.012
		30	SA 3.30	38.50	0.264	0.4	186	280	0.001
		40	SA 2.40	1.00	0	0.0	0	0	0.000
Run 3	Time to Runoff: 1:40	0		1.00	0	0.0	0	0	0.000
		1	SA 3.01	72.00	2	1.7	187	1140	0.016
		5	SA 3.05	31.00	2	3.9	188	1010	0.033
		10	SA 3.10	32.00	2	3.8	189	750	0.023
		20	SA 3.20	31.00	2	3.9	190	500	0.016
		30	SA 3.30	21.00	0.264	0.8	191	330	0.002
		40	SA 3.40	1.00	0	0.0	0	0	0.000

TURNOUT - Streamside Ditch

9/26/2007

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment Measurements		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 1:50	0		1.00	0	0.0	0.0	0.0	0.000
		1	SC 1.01	75.00	2	1.6	192.0	970.0	0.013
		5	SC 1.05	45.00	2	2.7	193.0	630.0	0.014
		10	SC 1.10	46.00	2	2.6	194.0	550.0	0.012
		20	SC 1.20	41.00	2	2.9	195.0	520.0	0.013
		30	SC 1.30	9.00	0.264	1.8	196.0	290.0	0.004
		40	SC 1.40	1.00	0	0.0	0.0	0.0	0.000
Run 2	Time to Runoff: 1:35	0		1.00	0	0.0	0.0	0.0	0.000
		1	SC 2.01	72.00	2	1.7	197.0	1200.0	0.017
		5	SC 2.05	48.00	2	2.5	198.0	340.0	0.007
		10	SC 2.10	46.00	2	2.6	199.0	390.0	0.008
		20	SC 2.20	48.00	2	2.5	200.0	310.0	0.006
		30	SC 3.30	10.00	0.264	1.6	201.0	275.0	0.004
		40	SC 2.40	1.00	0	0.0	0.0	0.0	0.000
Run 3	Time to Runoff: 1:39	0		1.00	0	0.0	0.0	0.0	0.000
		1	SC 3.01	66.00	2	1.8	202.0	1120.0	0.017
		5	SC 3.05	45.00	2	2.7	203.0	530.0	0.012
		10	SC 3.10	44.00	2	2.7	204.0	480.0	0.011
		20	SC 3.20	48.00	2	2.5	205.0	400.0	0.008
		30	SC 3.30	9.00	0.264	1.8	206.0	500.0	0.007
		40	SC 3.40	1.00	0	0.0	0.0	0.0	0.000

APPENDIX E – Rainmaker Data for ESMP #5 Berm Removal

BEFORE -Streamside Dtich

9/25/2007

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment Measurements		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 1:30	0		1.00	0	0.0	0	0	0.000
		1	SA 1.01	53.00	2	2.3	SB 177	3800	0.072
		5	SA 1.05	33.50	2	3.6	178	1660	0.050
		10	SA 1.10	37.00	2	3.2	179	1020	0.028
		20	SA 1.20	33.00	2	3.6	180	740	0.022
		30	SA 1.30	20.50	0.264	0.8	181	900	0.006
		40	SA 1.40	1.00	0	0.0	0	0	0.000
Run 2	Time to Runoff: 1:30	0		1.00	0	0.0	0	0	0.000
		1	SA 2.01	50.00	2	2.4	182	1180	0.024
		5	SA 2.05	31.00	2	3.9	183	630	0.020
		10	SA 2.10	31.50	2	3.8	184	550	0.017
		20	SA 2.20	37.00	2	3.2	185	450	0.012
		30	SA 3.30	38.50	0.264	0.4	186	280	0.001
		40	SA 2.40	1.00	0	0.0	0	0	0.000
Run 3	Time to Runoff: 1:40	0		1.00	0	0.0	0	0	0.000
		1	SA 3.01	72.00	2	1.7	187	1140	0.016
		5	SA 3.05	31.00	2	3.9	188	1010	0.033
		10	SA 3.10	32.00	2	3.8	189	750	0.023
		20	SA 3.20	31.00	2	3.9	190	500	0.016
		30	SA 3.30	21.00	0.264	0.8	191	330	0.002
		40	SA 3.40	1.00	0	0.0	0	0	0.000

BERM REMOVAL - Streamside Ditch

	Time to Runoff	Time (min)	Sample ID	Flow Measurements			Sediment Measurements		Lbs / min sediment
				Sample Fill Time (sec)	Sample Volume (gal)	Flow (gpm)	Lab Code	TSS (mg/l)	
Run 1	Time to Runoff: 2:25	0		1.00	0	0.0	0.0	0.0	0.000
		1	SE 1.01	71.00	0.264	0.2	207.0	2100.0	0.004
		5	SE 1.05	67.00	0.264	0.2	208.0	2400.0	0.005
		10	SE 1.10	60.00	0.264	0.3	209.0	1430.0	0.003
		20	SE 1.20	82.00	0.264	0.2	210.0	900.0	0.001
		30	SE 1.30	1.00	0	0.0	0.0	0.0	0.000
		40	SE 1.40	1.00	0	0.0	0.0	0.0	0.000
Run 2	Time to Runoff: 2:10	0		1.00	0	0.0	0.0	0.0	0.000
		1	SE 2.01	124.00	0.264	0.1	211.0	1380.0	0.001
		5	SE 2.05	131.00	0.264	0.1	SB 212	780.0	0.001
		10	SE 2.10	106.00	0.264	0.1	SB 213	710.0	0.001
		20	SE 2.20	119.00	0.264	0.1	214.0	460.0	0.001
		30	SE 3.30	1.00	0	0.0	0.0	0.0	0.000
		40	SE 2.40	1.00	0	0.0	0.0	0.0	0.000