



# TRB Webinar: Erosion and Sediment Control for Native and Aggregate Surfaced Roads



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# Reducing Sediment Production from Forest Roads during Wet-Weather Hauling

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Oregon State University

LVR Webinar  
April 4, 2012



# Background



*Figure 4-14. Rock road surfacing, base, and subgrade.*

(Kramer 2001)

- Forest Roads
  - Unbound aggregate pavement
  - Pavement often in layers
  - Native soil subgrade



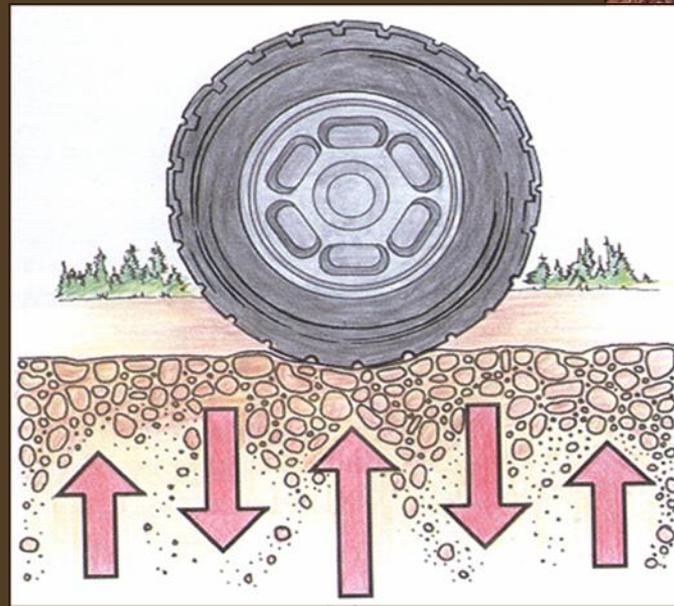
# Background

- Forest roads produce fine sediment
- Can deliver sediment to streams
  - Increase turbidity
- Changes to Pac NW state regulations
- Regulatory solution is to stop traffic
  - Ex: California, Oregon



# Background

- Where does fine sediment come from?
  - Exist in surface aggregate
  - Produced from aggregate breakdown
  - From subgrade - mixing



# Introduction

- How to reduce sediment production?
- Existing design methods:
  - Do not consider environmental failure
  - Design for specified rut depth
  - Managers use trial and error
- Future need:
  - Design for increasing regulations



# Research Objectives

Goal: To evaluate the environmental benefits of upgrading forest roads for wet-weather hauling

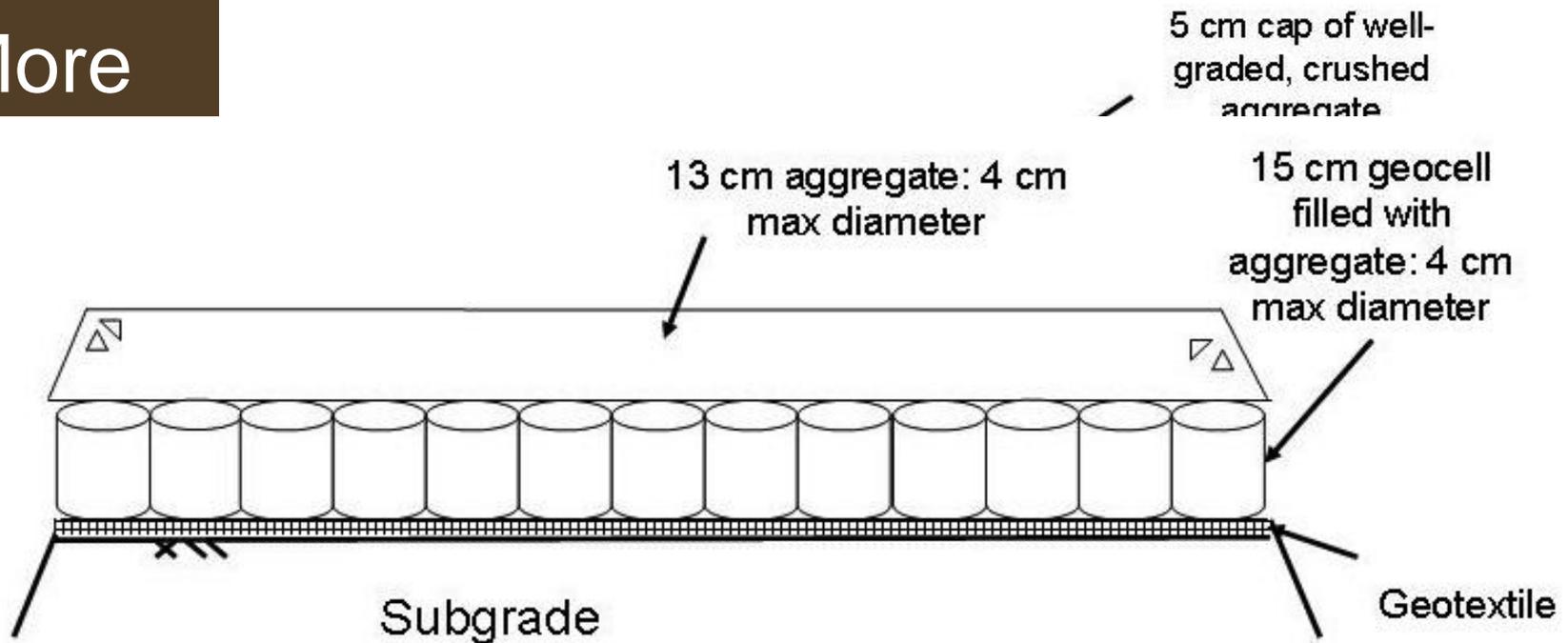
Objective: measure sediment production from alternative designs for road pavements

- Focus: Reduce subgrade mixing



# Methods

- Control
- Geotextile
- Geocell
- More



# Methods

- Three research locations
  - Crannell, California
  - South Burma, Oregon
  - Molalla, Oregon
- Constructed pavement treatments
  - “Standard” practices
- Truck traffic
- Artificial rain
- Sampled runoff
- Dug trenches

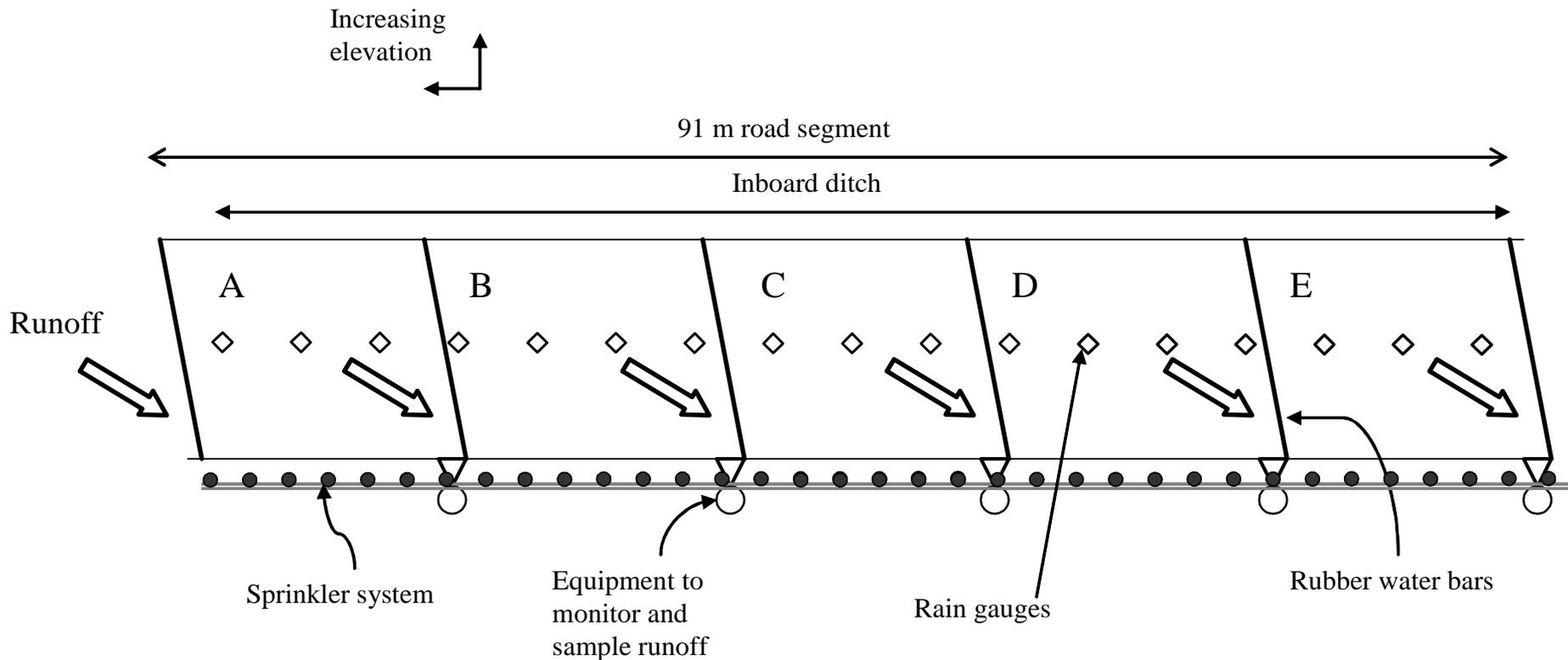


# Methods



# Methods

- Example equipment setup



# Methods



# Methods



# Methods



# Methods

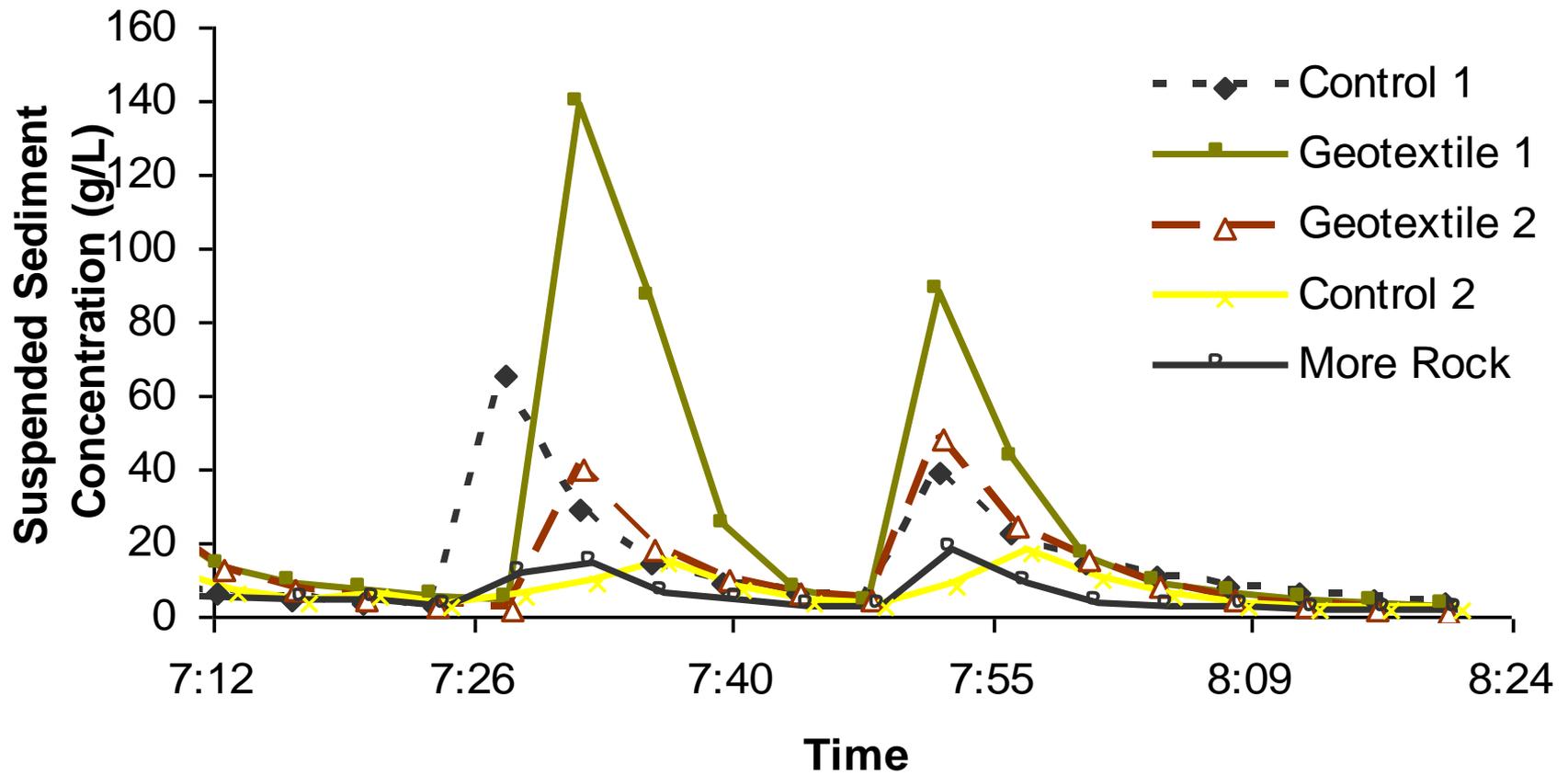


# Methods



- Analyzed runoff for Suspended Sediment Concentration (SSC)
- Compared SSC between treatments and across locations

# Methods



# Methods

- Two-way ANOVA with 5 treatments at 3 research locations
- Block effect: local aggregate and subgrade conditions

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F-Statistic	P-Value
Model	$B_{ss} + T_{ss} + I_{ss}$	11	$(B_{ss} + T_{ss})/11$	$F_{\text{Model}}$	$P_{\text{Model}}$
Block	$B_{ss}$	2	$B_{ss} / 2$	$F_{\text{Block}}$	$P_{\text{Block}}$
Treatments	$T_{ss}$	3	$T_{ss} / 3$	$F_{\text{Treatment}}$	$P_{\text{Treatment}}$
Interactions	$I_{ss}$	6	$I_{ss} / 6$	$F_{\text{Interaction}}$	$P_{\text{Interaction}}$
Residual	$R_{ss}$	3	(Standard Deviation) <sup>2</sup>		
Total	$B_{ss} + T_{ss} + I_{ss} + R_{ss}$	14			

# Results

Statistical Analysis: Repeated control, block design

ANOVA results

1. No significant difference in sediment production between pavement treatments!
  - Alternative treatments did not reduce sediment production over controls

# Results

- After hauling was completed on the roads, conducted “autopsy” of each pavement treatment



# Results: Trenches



- Clear boundary between subgrade and aggregate pavement
  - No subgrade mixing
  - Fines were produced from the pavement

# Results

## ANOVA results

1. No significant difference in sediment production between pavement treatments!
2. **Some differences in sediment production at the individual site level**

# Results

	Crannell	S. Burma	Molalla
Treatments that produced the most sediment	Geotextile, Control (1)	Geotextile	All

# Results

- Ruts!



# Results

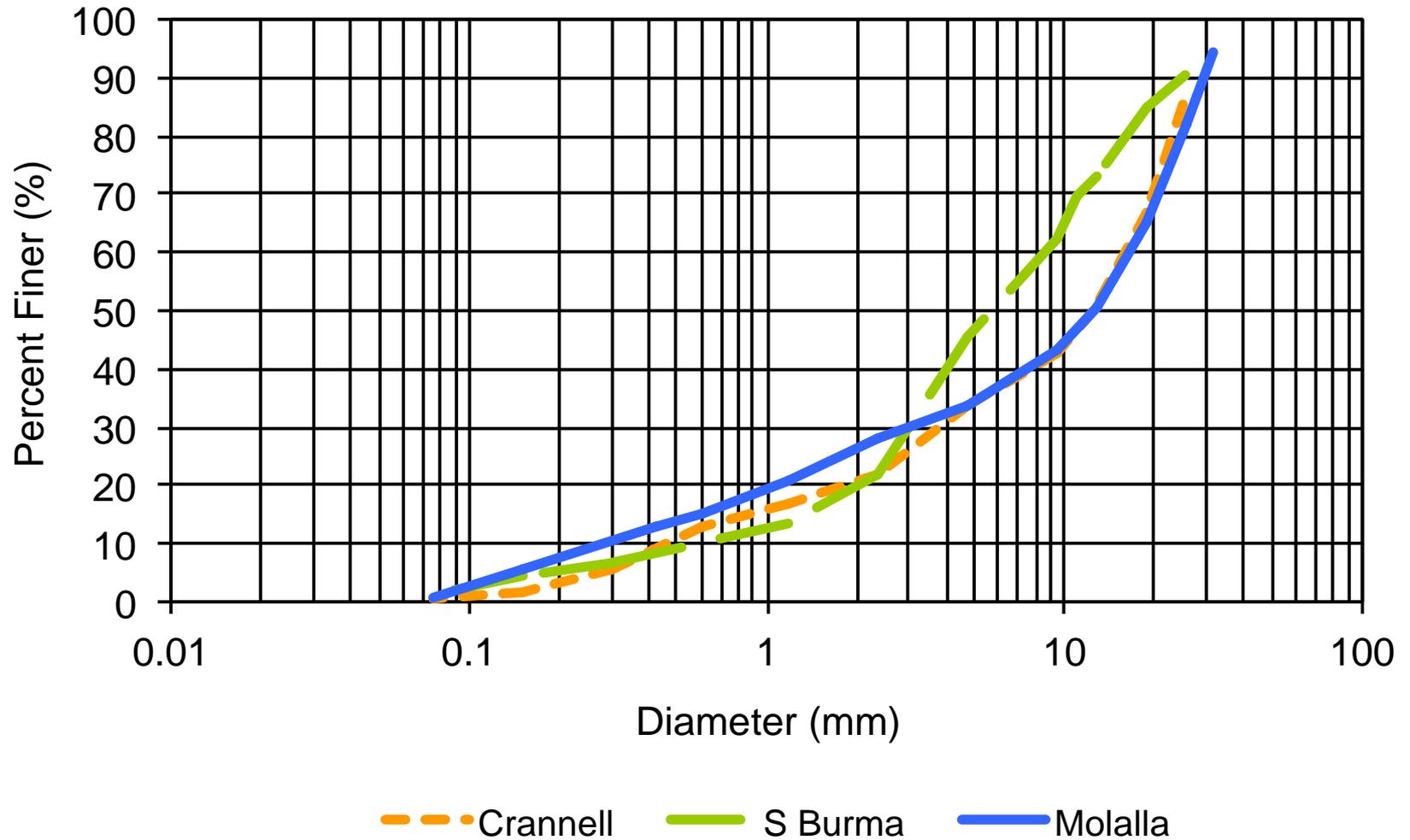
## ANOVA results

1. No significant difference in sediment production between pavement treatments!
2. Some differences in sediment production at the individual site level
3. **Significant block effect: difference in sediment production between research locations**

# Results

Avg. Peak SSC (mg/L)	Crannell	S. Burma	Molalla
Control	25,833	5,722	97,551
More Rock	13,402	12,219	68,430
Geotextile	44,273	24,899	103,485
Geocell		6,868	72,985

# Results – Surfacing Aggregate



# Results

	Crannell	S. Burma	Molalla
Fine Aggregate			
Fine Sediment			
“Fines” Foltz and Truebe			
Aggregate quality (MD)			
Truck count			

# Results

	Crannell	S. Burma	Molalla
Fine Aggregate	33.5%	44.1%	32.9%
Fine Sediment			
“Fines” Foltz and Truebe			
Aggregate quality (MD)			
Truck count			

# Results

	Crannell	S. Burma	Molalla
Fine Aggregate	33.5%	44.1%	32.9%
Fine Sediment	0.4%	1.3%	0.8%
“Fines” Foltz and Truebe			
Aggregate quality (MD)			
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# Results

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Aggregate quality (MD)			
Truck count			

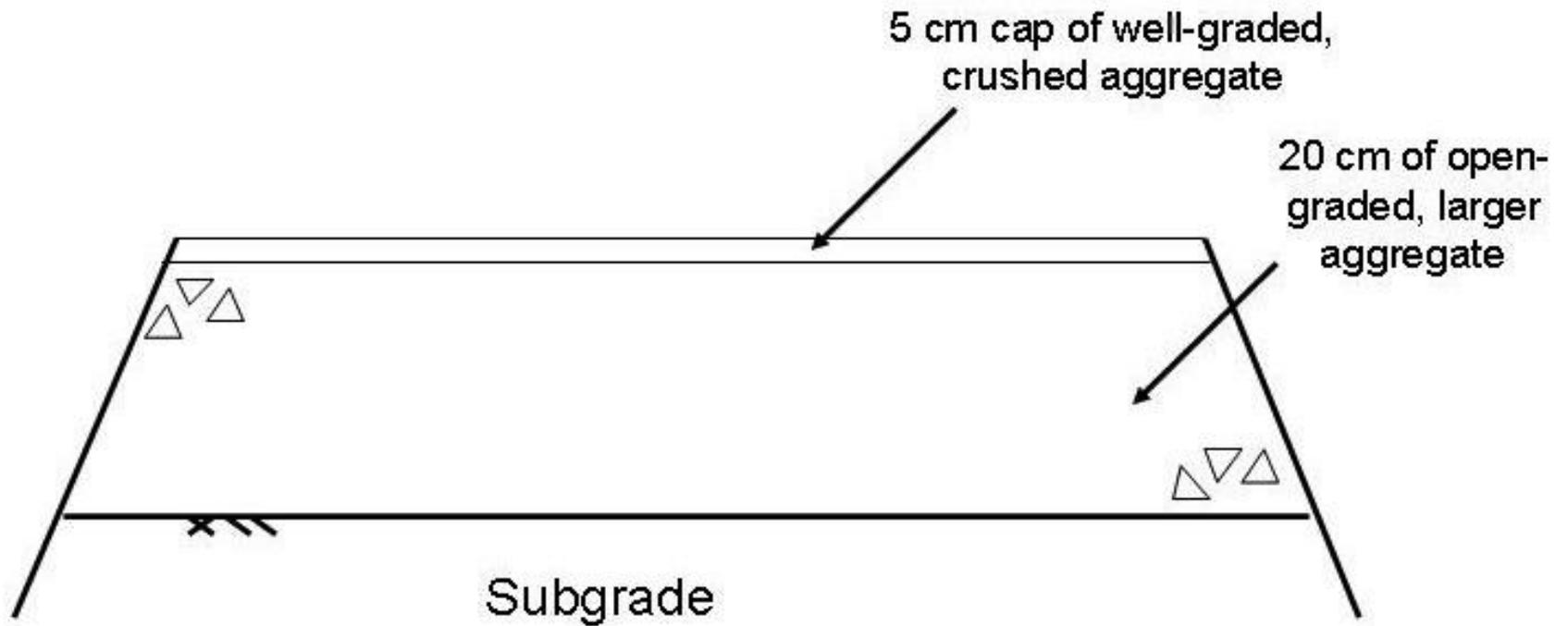
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Aggregate quality (MD)	26.9%	12.7%	19.1%
Truck count			

# Results

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Fine Aggregate	33.5%	44.1%	32.9%
Fine Sediment	0.4%	1.3%	0.8%
“Fines” Foltz and Truebe	12.6%	9.0%	15.2%
Aggregate quality (MD)	26.9%	12.7%	19.1%
Truck count	292	1,435	203

# Results



# Results



# Ruts

- Ruts create a flow pathway
- Road surface does not shed runoff as well
- As ruts collect more volume
  - More kinetic energy
  - More sediment detachment and transport



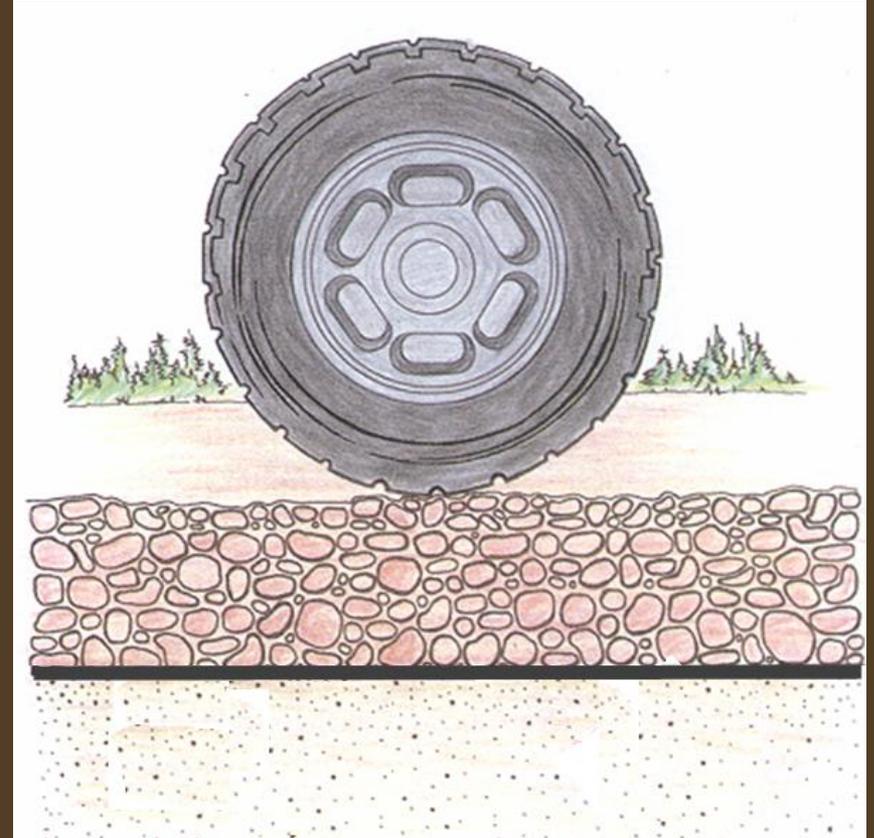
# Discussion

- Rutting (in all but one treatment) was contained within the surfacing aggregate
- Ruts did not form because of a weak subgrade

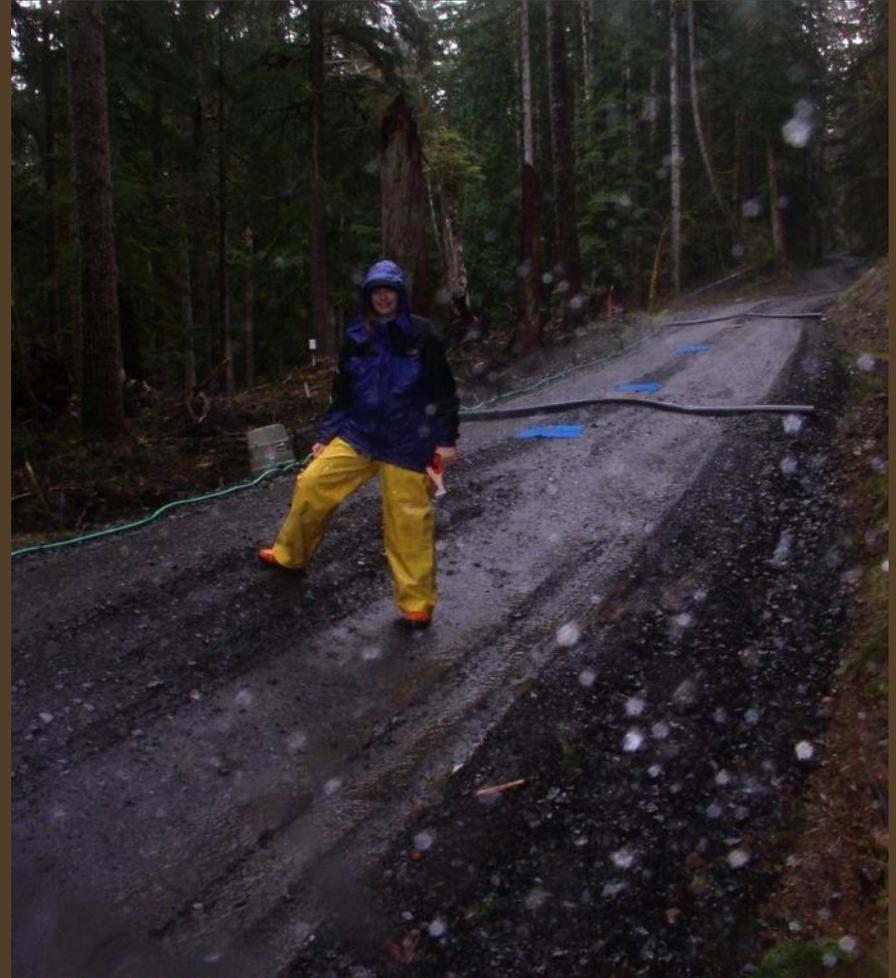


# Discussion

- Geotextile treatments were prone to rutting
  - Why?
    - Large open-graded base
    - Little aggregate interlock



# Discussion



# Discussion – Time Factor

**Subgrade August 2006**



**End of use May 2007**



# Research Conclusions

- To minimize sediment production from forest roads:
  - Focus on aggregate pavement, not subgrade
    - Subgrade mixing not a factor
  - Consider availability of fine sediments in the aggregate
  - Design and maintain the pavement to resist rutting

# Sediment Production from Unpaved Roads in Pennsylvania



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[www.dirtandgravelroads.org](http://www.dirtandgravelroads.org)

Transportation Research Board  
April 4/2012



*Photo Credit: Allegheny National Forest*

## **GOALS:**

- Realize the potential for sediment pollution from unpaved road runoff.**
- Look at potential sediment reductions possible by using quality aggregates.**

# *Presentation Outline*

## **Background**

- **Perspective**
- Driving Surface Aggregate
- Rainfall Simulator

## **Study 1: CBC, 2008**

- Overview
- Results
- Conclusions

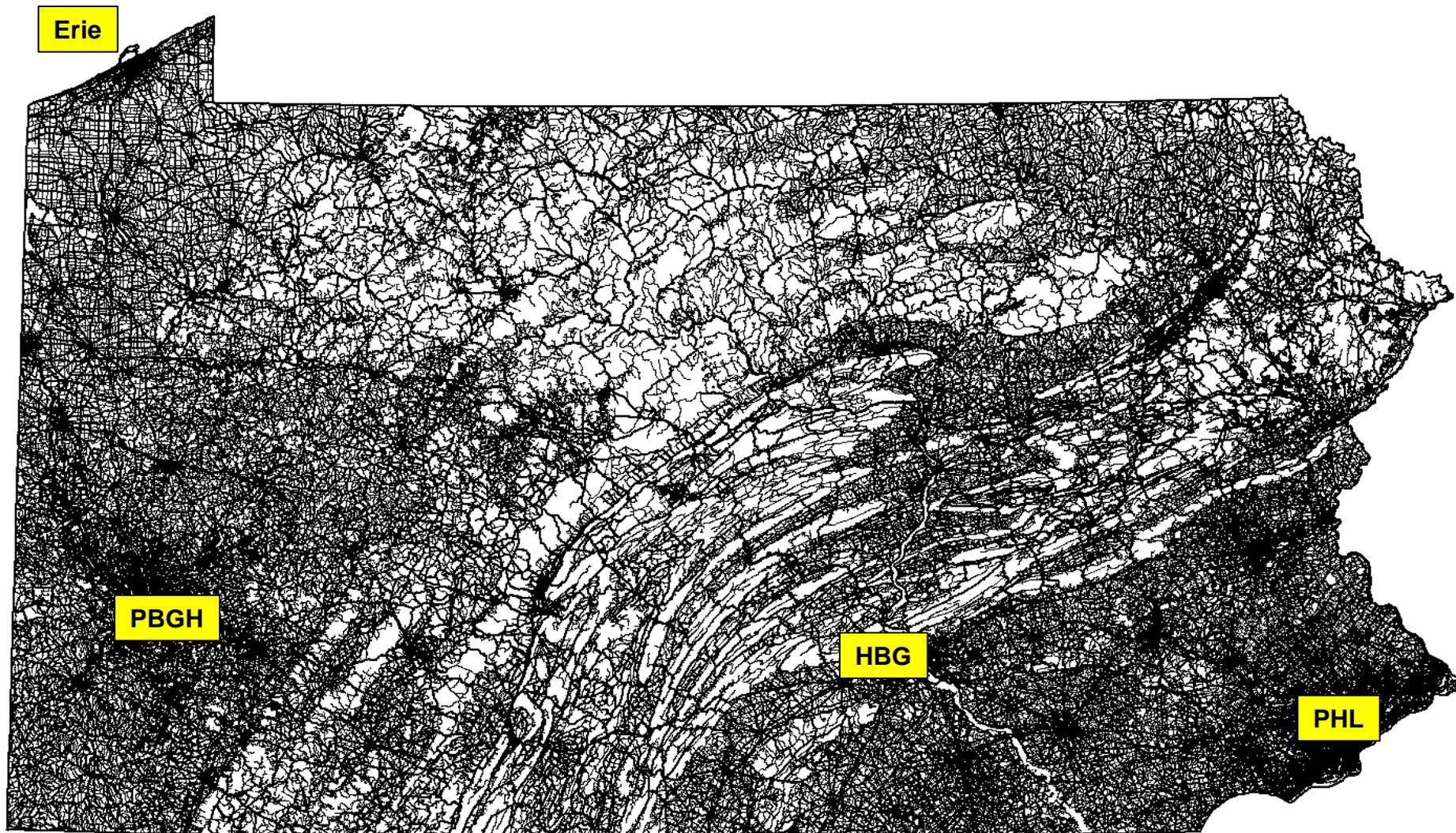
## **Study 2: ANF, 2012**

- Overview
- Results
- Conclusions

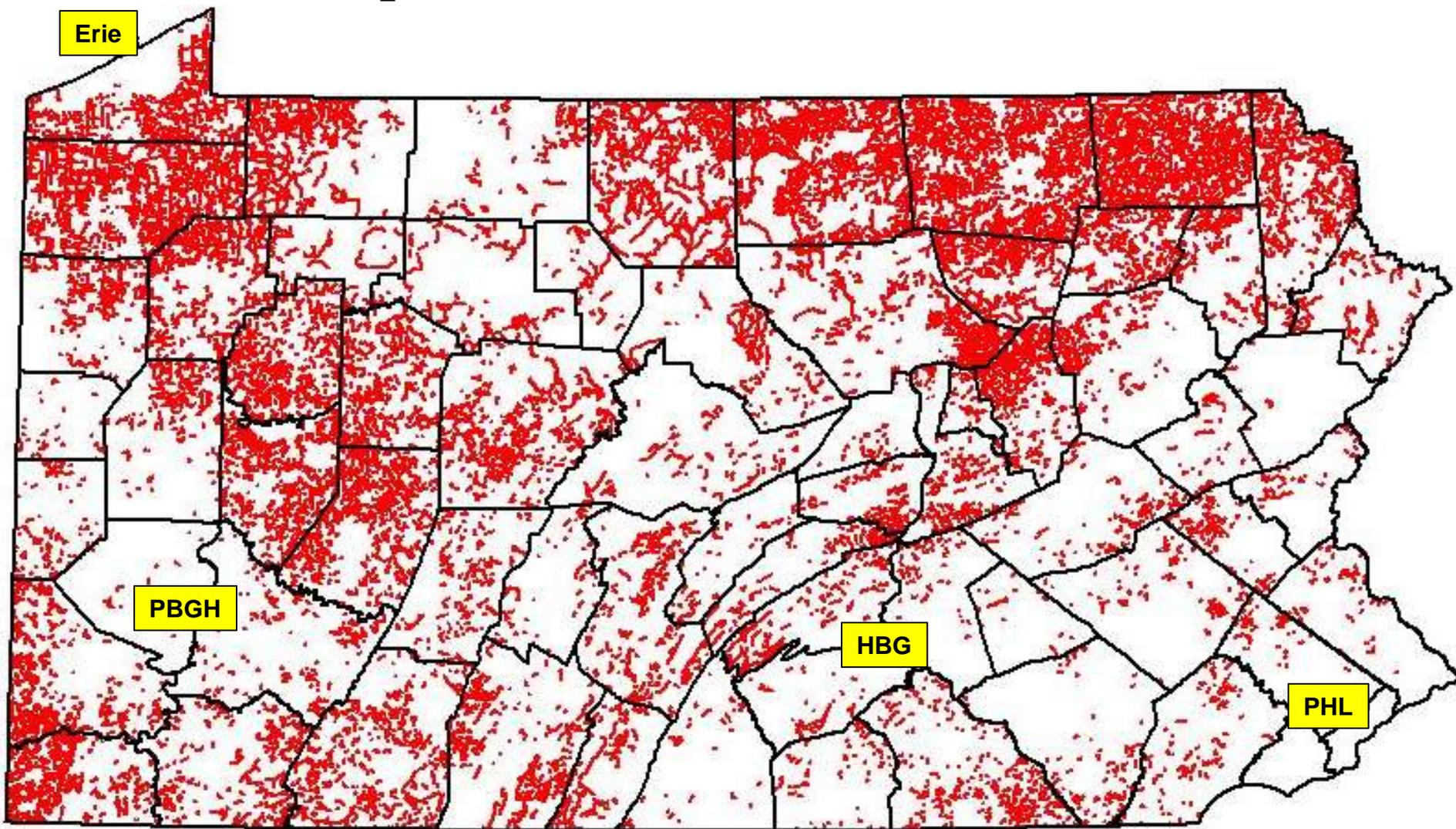




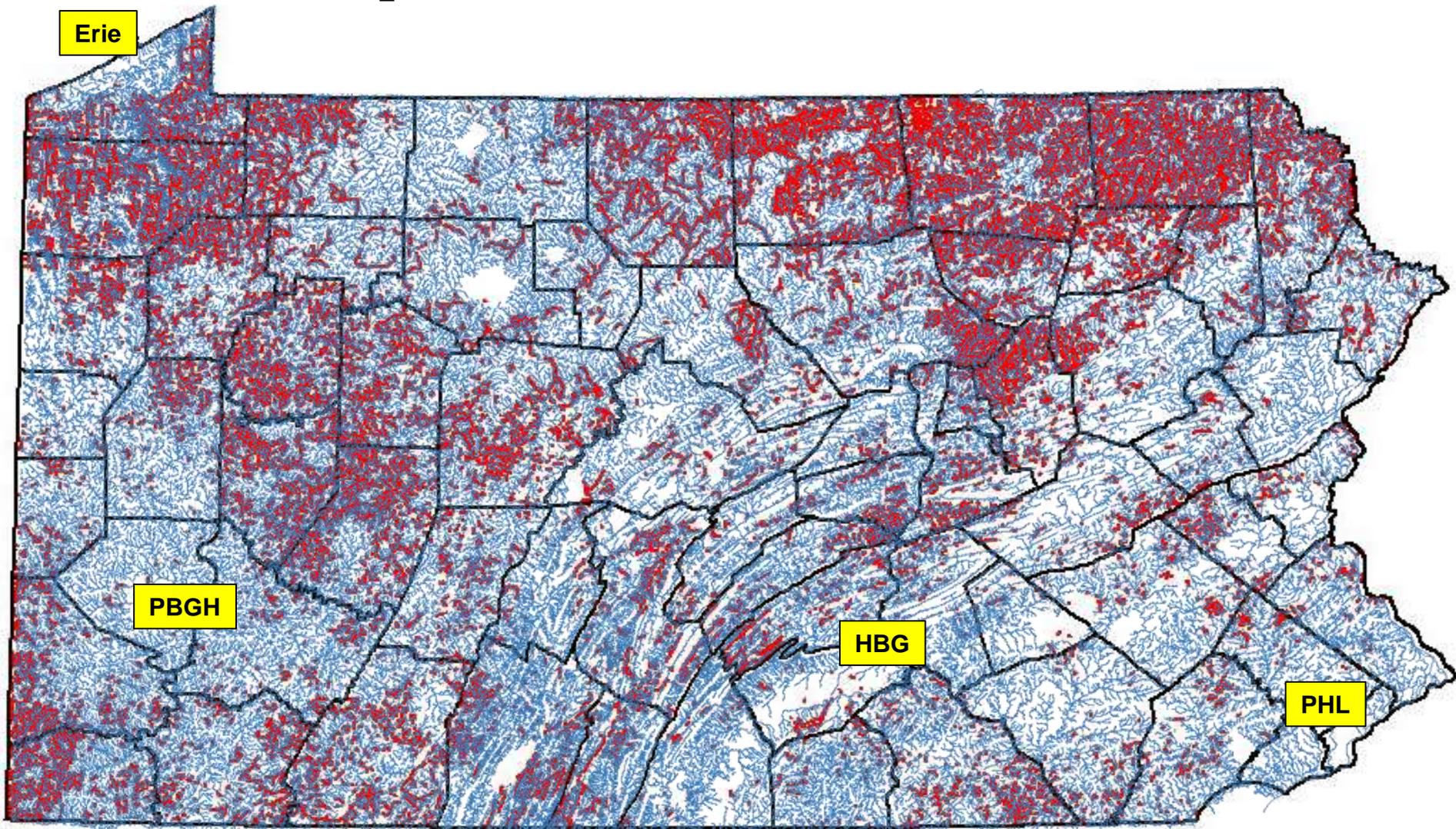
# PA: 118,000 miles of public road



# Unpaved Public Roads 20,000+ miles



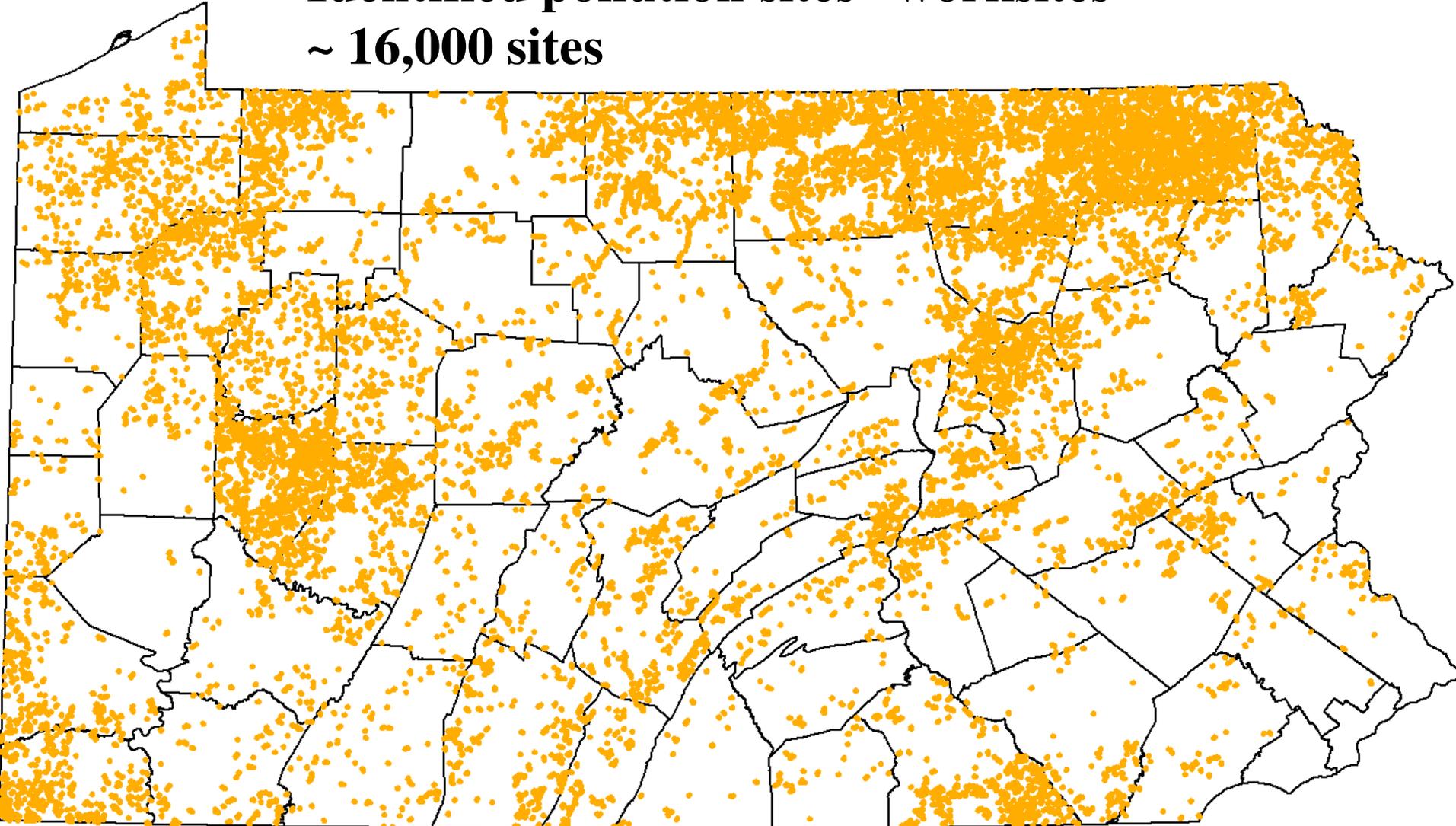
# Unpaved roads + streams



## Dirt and Gravel Road Maintenance Program

- Began in 1997 (Trout Unlimited initiative)
- Grant Program to fund “Environmentally Sensitive Road Maintenance” on local roads.
- **GOAL: Long term solutions to reduce stream pollution and maintenance costs from unpaved roads**

**Identified pollution sites “worksites”  
~ 16,000 sites**

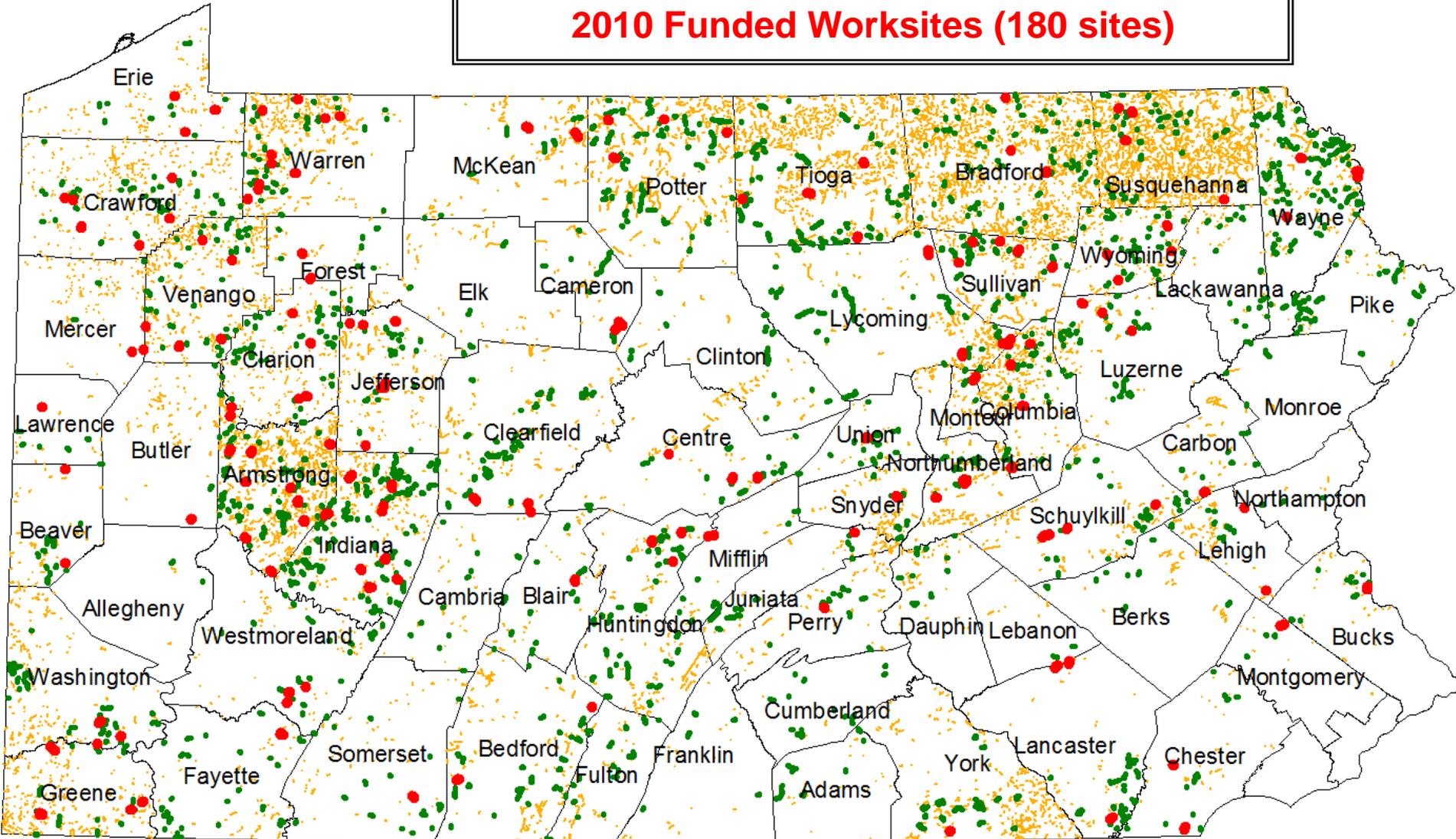


**Program Status  
as of 1/2011**

**Unaddressed Pollution Sites (14,500 sites)**

**All Funded Worksites (2,100 sites)**

**2010 Funded Worksites (180 sites)**



# Presentation Outline

## Background

- Perspective
- **Driving Surface Aggregate**
- Rainfall Simulator

## Study 1: CBC, 2008

- Overview
- Results
- Conclusions

## Study 2: ANF, 2012

- Overview
- Results
- Conclusions



## Driving Surface Aggregate

- Developed by Center in 2000 to replace “base courses” that were being used in PA.
- Well graded to achieve maximum density.
- Rock fines (-#200) of 10-15%.
- No clay or silt added.
- Hardness and pH specs.
- Placed at optimum moisture and compacted.
- Recommended paver placement.
- Dirt and Gravel Road Program promotes its use at “road/stream interactions”
- *PennDOT Publication 447 (MS-0450-0004)*

Passing Sieve	Lower %	Higher %
1½ inch	100	-
¾ inch	65	95
#4	30	65
#16	15	30
#200	10	15

# Unpaved Road Sediment Study

# Driving Surface Aggregate





# *Presentation Outline*

## **Background**

- Perspective
- Driving Surface Aggregate
- **Rainfall Simulator**

## **Study 1: CBC, 2008**

- Overview
- Results
- Conclusions

## **Study 2: ANF, 2012**

- Overview
- Results
- Conclusions

## Site Testing

- A Rainfall Simulator was used to quantify sediment production
  - Repeatability
  - Convenience



## Rainmaker:

- 100 feet long (30 m)
- 11 ten foot risers (3m)



## Rainmaker:

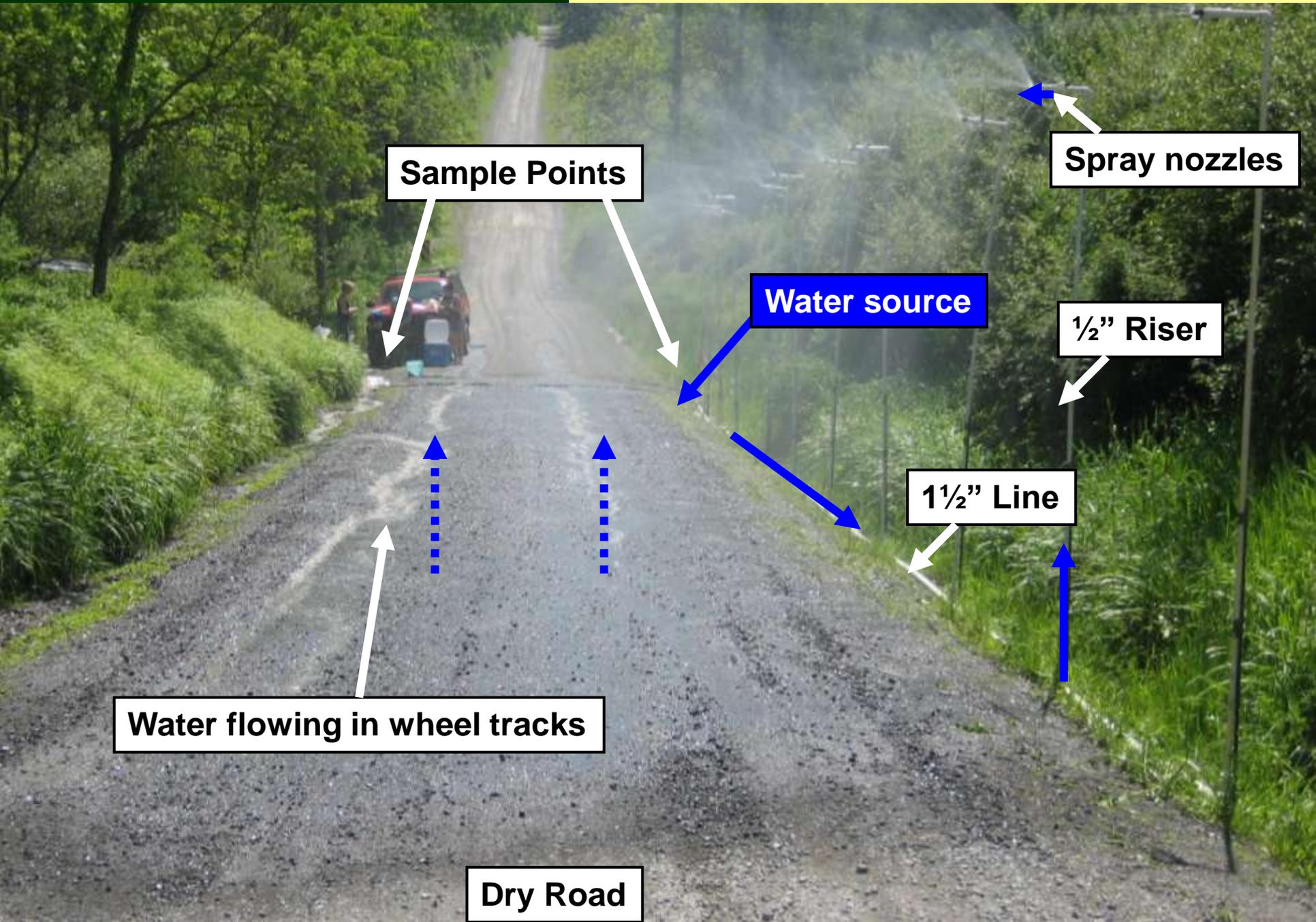
- 100 feet long (30 m)
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- 2 rotary nozzles per riser
- 3" (7.6 cm), 6hp water pump



## Rainmaker:

- 100 feet long (30 m)
- 11 ten foot risers (3m)
- 2 rotary nozzles per riser
- 3" (7.6 cm), 6hp water pump
- Equivalent to 0.6" rainfall in 30 minutes.
- Three runs: measure flow and sediment.





Sample Points

Spray nozzles

Water source

1/2" Riser

1 1/2" Line

Water flowing in wheel tracks

Dry Road



## Rainmaker:

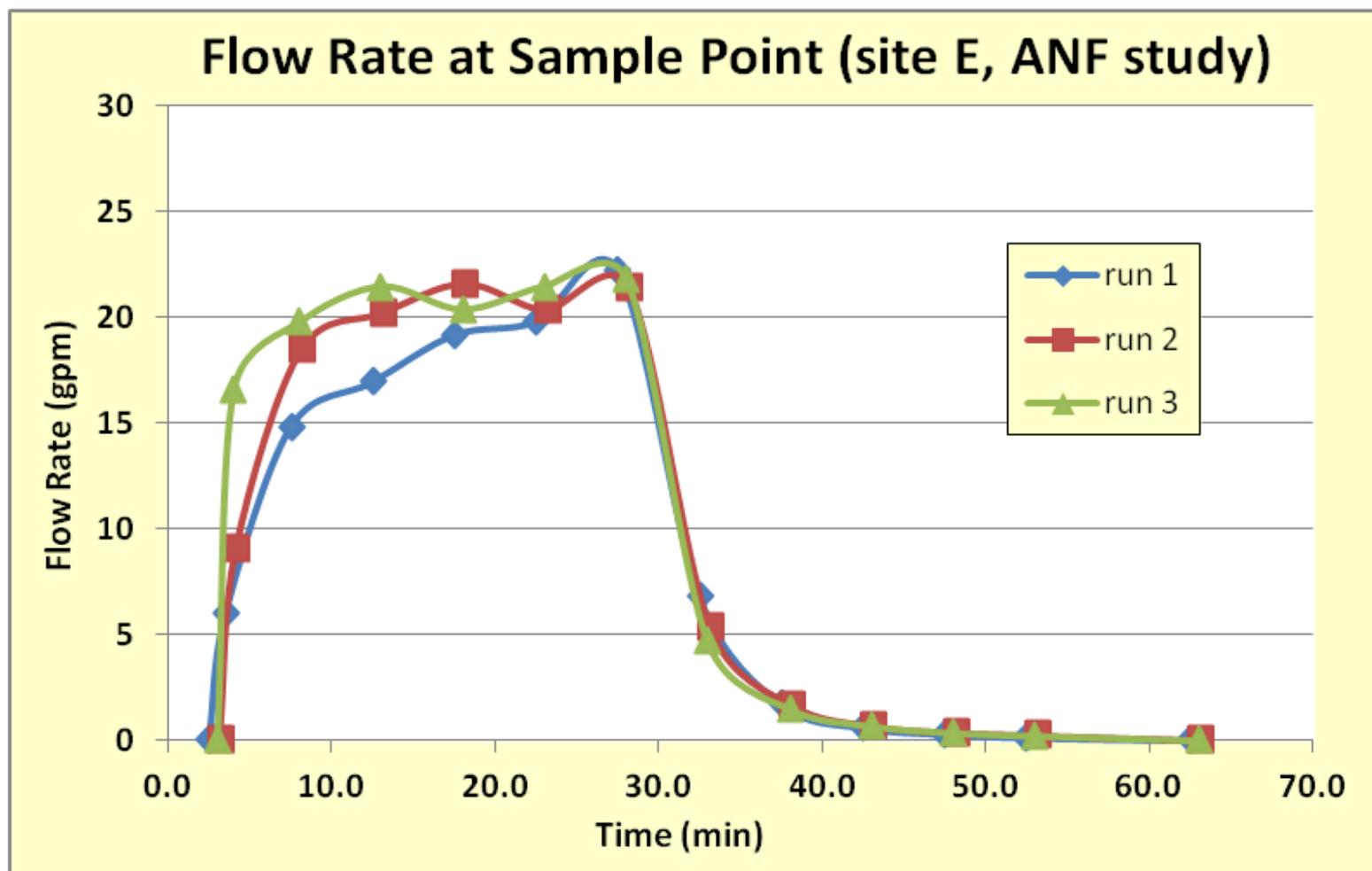
- **Grab Samples**: taken at regular intervals. Analyzed in lab for sediment.
- **Flow Samples**: timed bucket filling at regular intervals allows flow calculation.
- Flow and sediment concentration used to determine **total sediment in runoff for event.**



## Rainmaker:

- **Three 30-minute runs** are done on each site and averaged to get sediment production.
- There is a **60 minute drying time** before runs 2 and 3.
- **20 vehicle passes** are done over the site during the drying time to simulate traffic stresses.

## Convenience and Repeatability



## Rainfall Simulator note:

### Conservative sediment estimates:

- No “compounding” effects because it is only run on 100’ of road.
- No off-road water influences.
- No “bed load” measurement
- Largely measures impact erosion.

# Presentation Outline

## Background

- Perspective
- Driving Surface Aggregate
- Rainfall Simulator

## Study 1: CBC, 2008

- **Overview**
- Results
- Conclusions

## Study 2: ANF, 2012

- Overview
- Results
- Conclusions



# Study 1: CBC

# Study 2: ANF

There is a lot to cover, so presentation will move fast.

## More Information:

## Research Summaries: ➡

## Full Research Reports:

[www.dirtandgravelroads.org](http://www.dirtandgravelroads.org)  
under "research".

**Research Summary**  **Sediment Reductions from Environmentally Sensitive Maintenance Practices on Unpaved Roads**

**Research Overview:**  
Pennsylvania's Dirt and Gravel Road Maintenance Program has long advocated Environmentally Sensitive Maintenance (ESM) Practices to reduce stream pollution from unpaved roads. Penn State's Center for Dirt and Gravel Road Studies (Center) has recently completed a research project with funding from the Chesapeake Bay Commission that begins to quantify sediment reductions from several commonly used ESM practices.

**ESM Practices Tested:**  
Five Environmentally Sensitive Maintenance Practices were tested in this study:  
- **Grading Surface Aggregate:** a specific aggregate mixture designed as a wearing course for unpaved roads;  
- **Raising the Road Profile:** raising road elevation to eliminate lower ditch & curb street flow;  
- **Grass Breaks:** elongated bumps at the road surface designed to slow water to each side of the road;  
- **Additional Drainage Outlets:** creating new outlets in ditches to reduce channelized flow; and  
- **Berm Removal:** removing unnecessary berm and ditch on down slope side of road to encourage street flow.

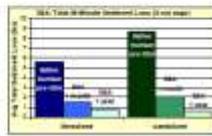
**Methods:**  
In order to determine sediment reductions of the five practices, it was necessary to collect sediment data both before and after each practice was implemented. The Rainmaker (see description below) was used to create a controlled and repeatable rainfall event on a 100' section of road. Each test consisted of three 30-minute runs of the rainmaker, both before and after ESM practice implementation. Flow and sediment samples were taken at regular intervals to determine the total sediment loss for each section of road. The three test runs were combined for each section of road to determine the average sediment loss for one 30 minute event. By comparing the flow and sediment differences before and after ESM practice implementation, the sediment reduction from each practice can be determined.

**Meet the Rainmaker, a Rainfall Simulator for Roadways...**  
The "rainmaker" is a rainfall simulator developed by the Center that creates a 0.5" rainfall event in 30 minutes over a 100' length of road. This is equivalent to a 1.5-inch return interval for a 30 minute storm for most of Pennsylvania. The rainmaker creates a controlled, repeatable rainfall event that is run both before and after ESM practices are installed on the road. By comparing runoff and sediment concentrations, sediment reductions can be calculated for the various ESM practices used in the study. Components are illustrated to the right.



**Results**  
**Runoff Rates from Existing Roads:**  
The five "existing conditions" test sites for this study showed sediment production rates ranging from 0.7-0.2 percent of sediment runoff in a single 30 minute, 0.5 inch simulated storm. The 0.7 percent was generated from a flat and inactive farm lane with grass growing between the wheel tracks. The 0.2 percent event was generated from a road, located immediately adjacent to a 4.5% slope. This highlights the great variability in erosion rates based on specific site conditions. Using the average sediment runoff rate of 0.5 percent, a single 30 minute 0.50 inch rain event dumping across Pennsylvania can be conservatively expected to generate over 3,000 tons of sediment from the State's 20,000+ miles of public unsealed road. This illustrative purpose only, more testing on paved roads is needed to substantiate this extrapolation.

**Driving Surface Aggregate**  
Test results OSA placements were tested on Leber Road in Potter County. The aggregate, one limestone and one sandstone, were placed according to Dirt and Gravel Road Program standards (one 8" lift, placed using a power, compacted to 2"). Rainfall simulations were run before placement, and at intervals of 1 month and one year after placement. The graphs to the right summarize the results in total sediment loss per 30 minute rainfall simulation. Compared to their respective before placement, Limestone OSA reduced sediment by 27% after one month and 66% after one year, while Sandstone OSA reduced sediment by 78% after one month and 50% after one year. Rainfall runoff did not significantly affect sediment generation.



**Drainage Control Practices**  
Limestone OSA which reduces sediment generation from the road surface, the flat remaining practices reduce sediment by reducing and controlling the volume of runoff.

**Raising the Road Profile:**  
Gravel Road in Columbia County was lifted approximately 1 foot in order to completely eliminate the ditch on the down slope side of the road. Street flow into a vegetative filter was achieved off the down slope side of the road after it was lifted. This practice reduced the amount of sediment entering the stream by 70% after one month, and 81% after one year. Some 10% of sediment runoff into the new road lift was now accumulated for the higher than expected reduction on Daniel Road.

**Grass Breaks:**  
Two grass breaks were tested in this study, one in Huntington County, and one in Millheim County. The grass breaks showed sediment reductions of 57% and 41% respectively. Note that the grass breaks were placed in the middle of the 100' test section, therefore sediment reductions of 50% indicate the grassbreak was 100% effective in eliminating upstream sediment.

**Additional Drainage Outlets:**  
The effect of adding a turnout was tested on Pine Swamp Road in Huntington County. The new turnout directed flow to vegetative filter and did not affect the stream. A turnout used instead of a culvert for road effectiveness and simplicity. The turnout showed sediment reductions of 65% for the down slope ditch and 21% when factoring in the up slope ditch that was unaffected by the turnout. Note that this was "before" the turnout was placed in the middle of the 100' test section, so a 50% sediment reduction indicates a 100% efficiency.

**Berm Removal:**  
The effect of berm removal was tested on Pine Swamp Road in Huntington County, removing the berm effectively eliminated the down slope ditch and allowed water to flow into a vegetative filter area. Berms removed showed sediment reductions of 94% for the down slope ditch alone, or 51% when factoring in the up slope ditch that was unaffected by the practice.

This is a summary only. Full report available at [www.dirtandgravelroads.org](http://www.dirtandgravelroads.org) under "research".

**Research Summary**  **Sediment Production from Shallow Oil & Gas Access Roads in the Allegheny National Forest**

**Research Overview:**  
This project quantified sediment production from 14 sections of road used by the shallow oil and gas industry within the Allegheny National Forest. In addition to these 14 "existing condition" road tests, four of the sites also had a new surface applied, after which testing was repeated. The purpose of this research was to quantify and compare sediment production rates from existing roadways, and to determine any change in sediment runoff after placement of OSA or aggregate surfaces on the road.

**Study Details:**  
Shallow oil and gas development has been occurring in the Allegheny National Forest (ANF) for most of the last century. As of 2010, there were an estimated total of 6,000 wells throughout the ANF. Many wells are still in production today and are serviced by a network of over 3,000 miles of roadway (1,300 ANF and 1,700 adjacent). New wells are still being drilled and current estimates are that this network of roads will be expanded to over 3,500 miles by 2021. Erosion and sedimentation from this extensive and increasing network of roads has become a growing concern.

**Phase 1:** 14 sections of roadway were chosen for testing in cooperation with personnel from the Allegheny National Forest (ANF). The road sections were chosen to cover a wide variety of traffic levels, slopes, and widths typical of the road network. Testing was completed on these 14 existing road segments in 2010. The purpose of this testing was to determine sediment production from these roads and attempt to identify factors affecting sediment production.

**Phase 2:** Four of the 14 road sections above had new surface aggregate placed on them in 2011. These four sites were tested again in late 2011 in order to determine any differences in sediment production compared to the 2010 tests. Two of the sites were covered with "natural" gravel. The use of a locally excavated material of varying quality that is available at a relatively low cost. Two of the sites were covered with "Driving Surface Aggregate (DSA)" (DSA is a FIDNODD aggregate specification designed to achieve maximum density for use as an untreated wearing course for unpaved roads).

**Rainfall Simulator:**  
A rainfall simulator, or "Rainmaker" was used in this study in order to create a controlled and repeatable rain event. This makes it possible to compare sediment production before and after ESM practices are implemented on a section of road. The Rainmaker is a rainfall simulator developed by the Center for Dirt and Gravel Road Studies (Center) that creates a 0.5" rainfall event in 30 minutes over a 100' length of road. The Rainmaker creates a rainfall event that is equivalent to a 1.5-inch return interval for a 30 minute storm for most of Pennsylvania.

The Rainmaker was used on each of the 100' road test segments in this study. Each one test consisted of three 30 minute runs of the rainmaker, with 10 minutes of drying time and 200 gully study volume placed between runs. Flow and sediment samples were taken at regular intervals to determine the total sediment loss for each section of road. The three test runs were combined for each section of road to determine the average sediment loss for one 30 minute event.

This is a summary only. Full report available at [www.dirtandgravelroads.org](http://www.dirtandgravelroads.org) under "research".

**Results**

**Part I: Sediment Production from Existing Roads**

Sediment production was measured on 14 existing roads in the Allegheny National Forest. The table to the right highlights the installed sites characteristics and sediment production of all 14 sites in order of increasing average sediment production.

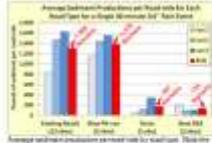
The average sediment production from the 14 test sites ranged from 0.2% to 0.7% of sediment runoff for a single 30 minute rain event of 0.5". This equates to 1,000 pounds of sediment production per mile of roadway for a single 30 minute rain event.

Site	Runoff (in)	Runoff (ft)	Slope (%)	Width (ft)	Flow (cfs)	Sediment (lb)	Sediment (%)	Flow (cfs)	Sediment (lb)	Sediment (%)
1	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
2	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
3	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
4	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
5	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
6	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
7	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
8	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
9	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
10	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
11	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
12	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
13	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000
14	0.5	0.015	0	10	0.000	0.000	0.000	0.000	0.000	0.000

**Site Details and Observations:**  
Site 1: partially covered by grass, but had best amount of sediment production.  
Site 2: significant "first flush" effect was seen on all sites where runoff of the sediment was during the first 5-15 minutes of runoff.  
Site 3: without traffic stress, the least sediment production from the roads tested were road slope combined with road width - if the road is traveled by traffic, then sediment production increases less dependent on road width and slope, and more dependent on road strength as measured by the California Bearing Ratio (CBR).

**Part II: Sediment Production After Use of New Aggregate**

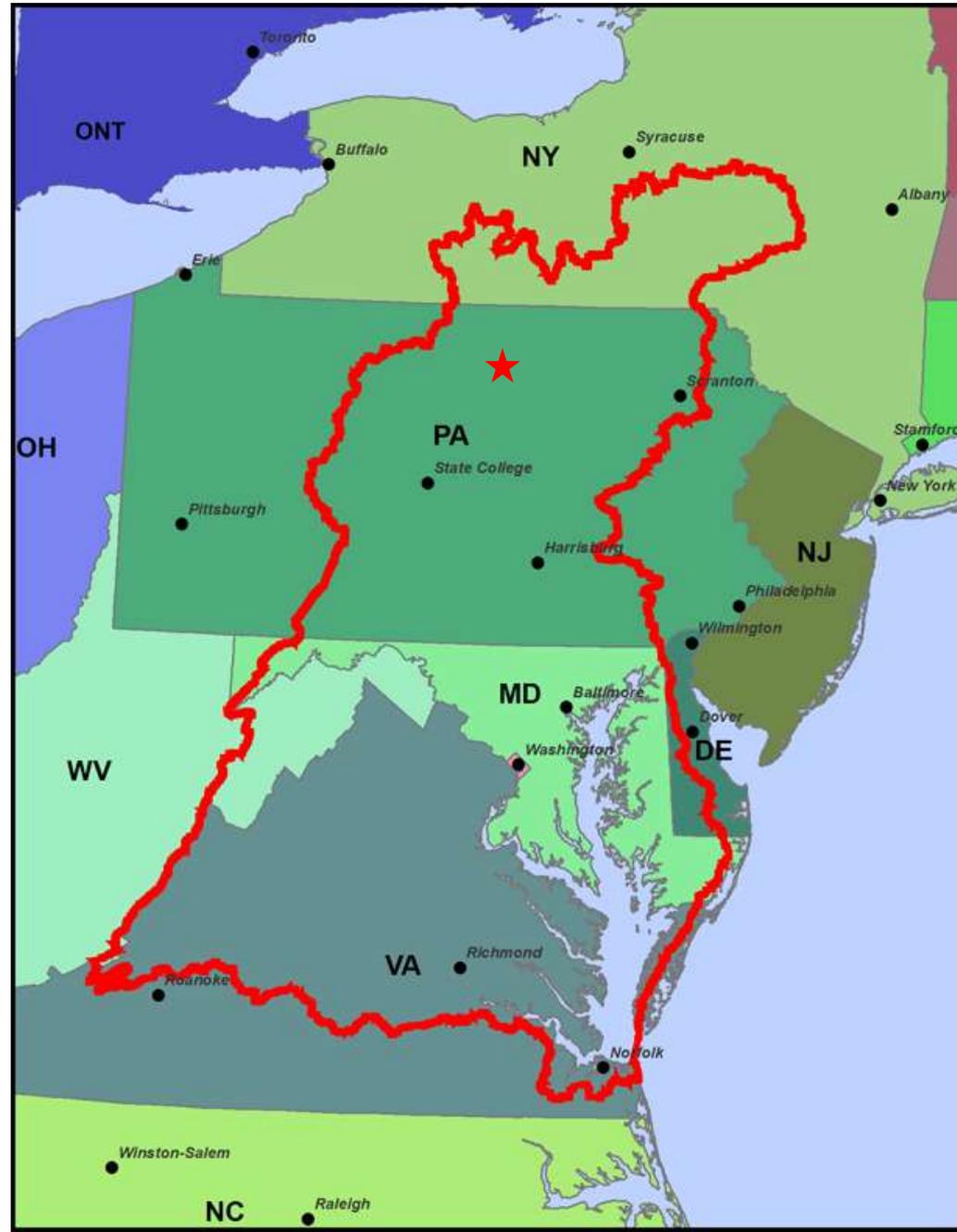
Four of the sites detailed above had a new aggregate surface placed on them in 2011 (sites 6 & 7 with "natural" aggregate, and sites 8 & 9 with Driving Surface Aggregate). The newly placed polymer material reduced sediment production by 25% and 54% (note that these two sites happened to have a large "first flush" sediment production). The newly placed Driving Surface Aggregate revealed reduced sediment reductions of 67% and 82% - a direct comparison shows that the two polymer sites produced 10 times the amount of sediment of the new DSA (average 25.1 lbs and 23.6 lbs respectively). The sediment reductions found here from DSA placement were comparable to previous studies conducted by the Center. Previous research conducted in 2007 showed sediment reductions from DSA placement of 10% after one month and 50% after one year compared to untreated roads in a similar study. DSA was also unaffected by traffic stress, as illustrated in the graph below (sediment decreases from run 1 to run 3 for DSA, increases for all other sites).



This is a summary only. Full report available at [www.dirtandgravelroads.org](http://www.dirtandgravelroads.org) under "research".

## Study Details

- Funded by Chesapeake Bay Commission.  
62,000+ sqmi watershed  
16+ Million residents
- Study completed in 2008



## Study Details

- **Purpose**: Determine sediment reductions from BMP implementation
  - Additional Drainage Outlets
  - Berm Removal
  - Raising an entrenched road
  - Grade-breaks
  - **Driving Surface Aggregate**
- Use results in Chesapeake Bay Watershed Model.

# Lebo Road (PA Forestry), Potter County, PA

ADT estimated at <20, \*usually\*



- Lebo Road DSA placements – June 2006



**Sandstone**

**Limestone**

## Study Details

- **Aggregates placed in 2006**
- **Sediment tests run:**
  - Before placement
  - 1 month after placement
  - 1 year after placement
  - 2 years after placement
- **Study completed in 2008**
- **Low traffic road**
  - Hunting season, fishing season, road rally

# Presentation Outline

## Background

- Perspective
- Driving Surface Aggregate
- Rainfall Simulator

## Study 1: CBC, 2008

- Overview
- **Results**
- Conclusions

## Study 2: ANF, 2012

- Overview
- Results
- Conclusions



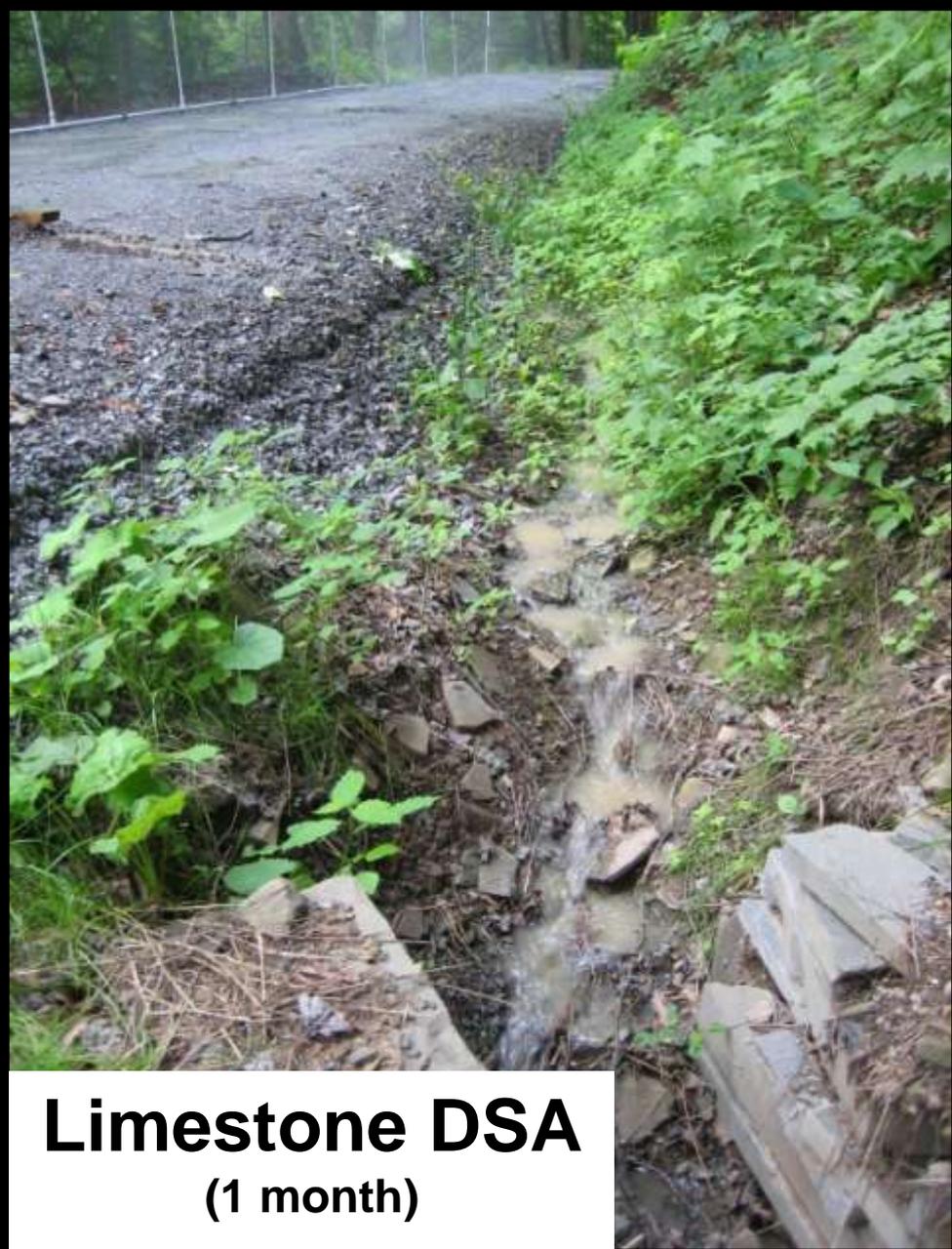


**Native Surface**

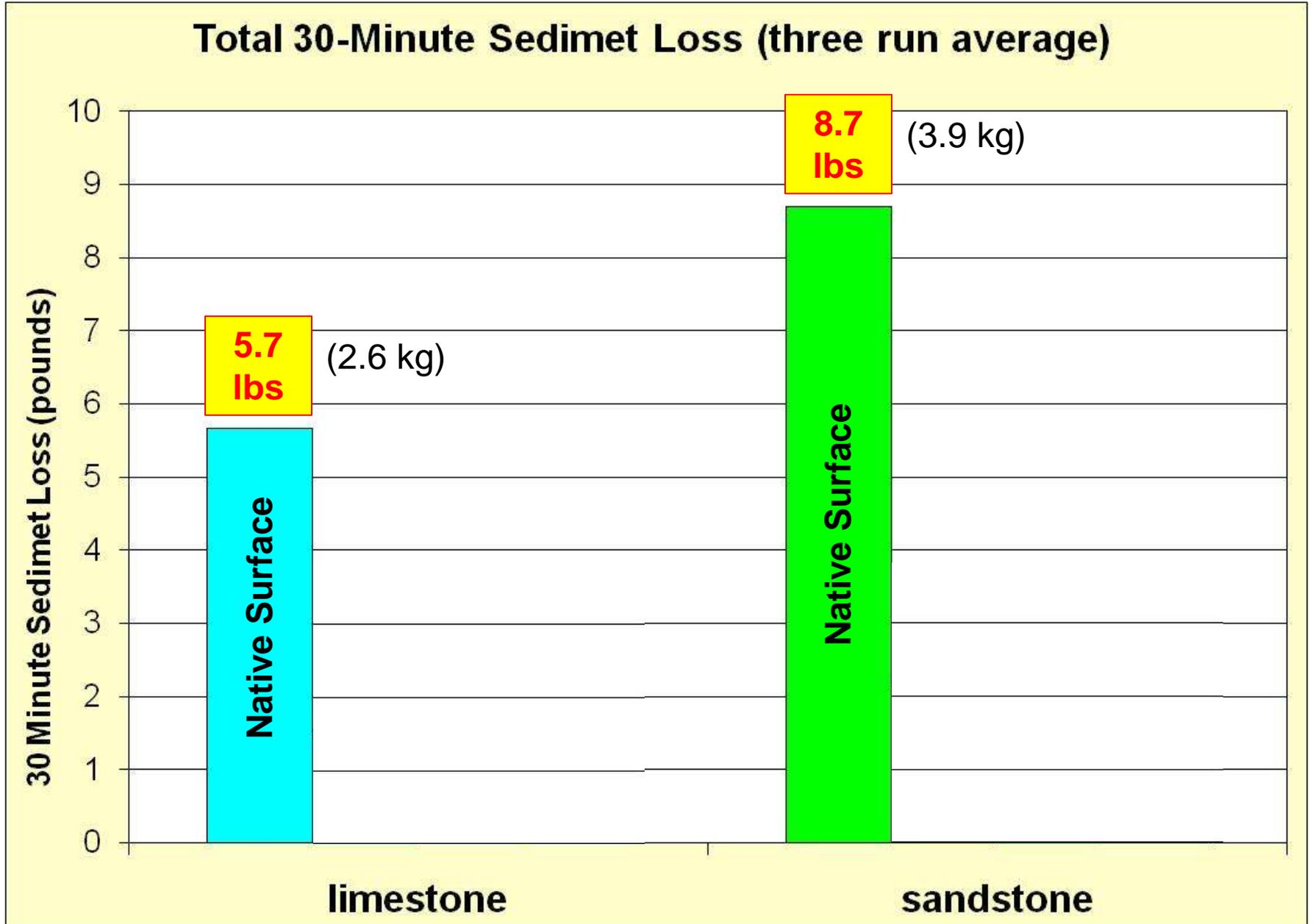
**Sandstone DSA**  
(1 month)

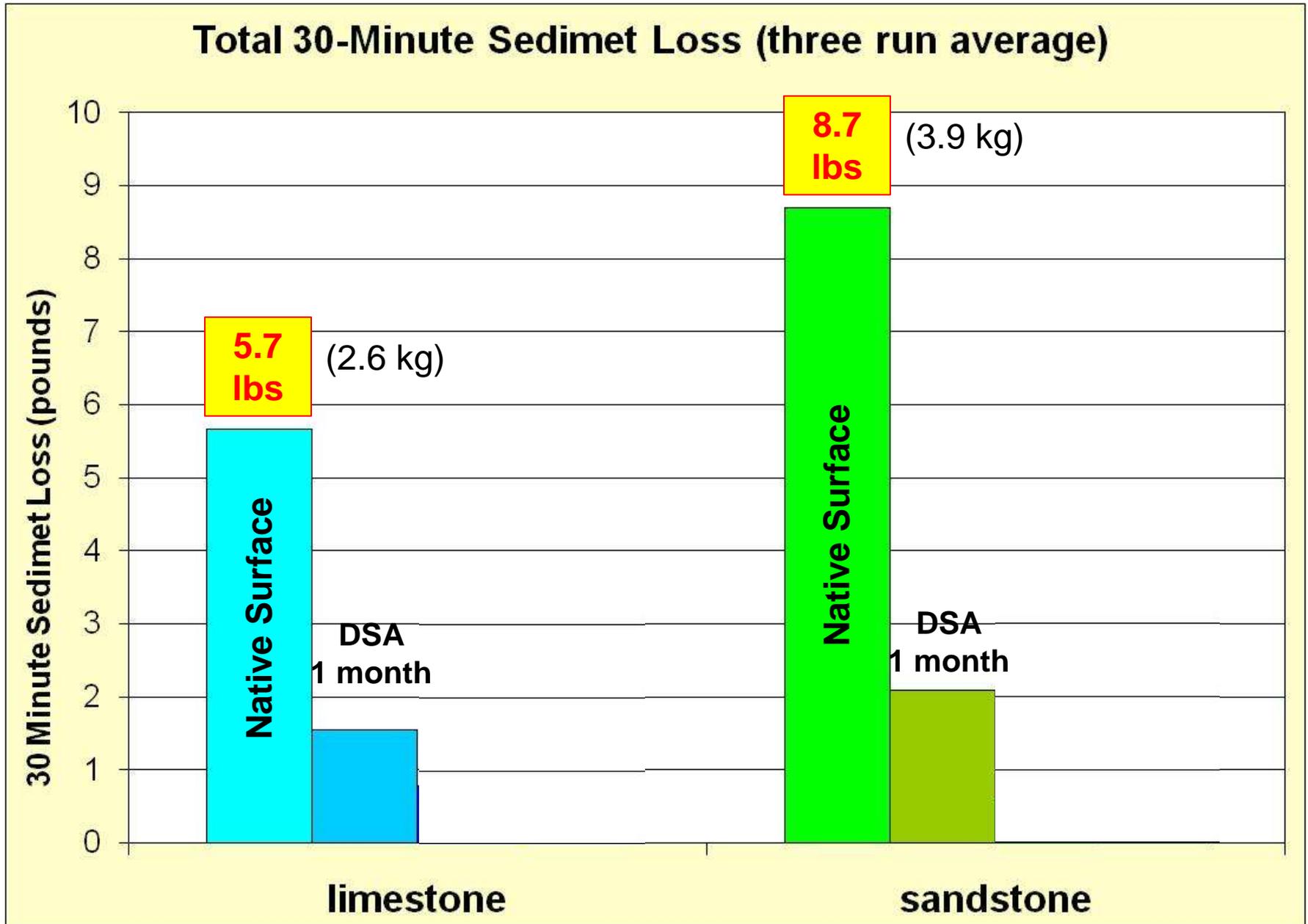


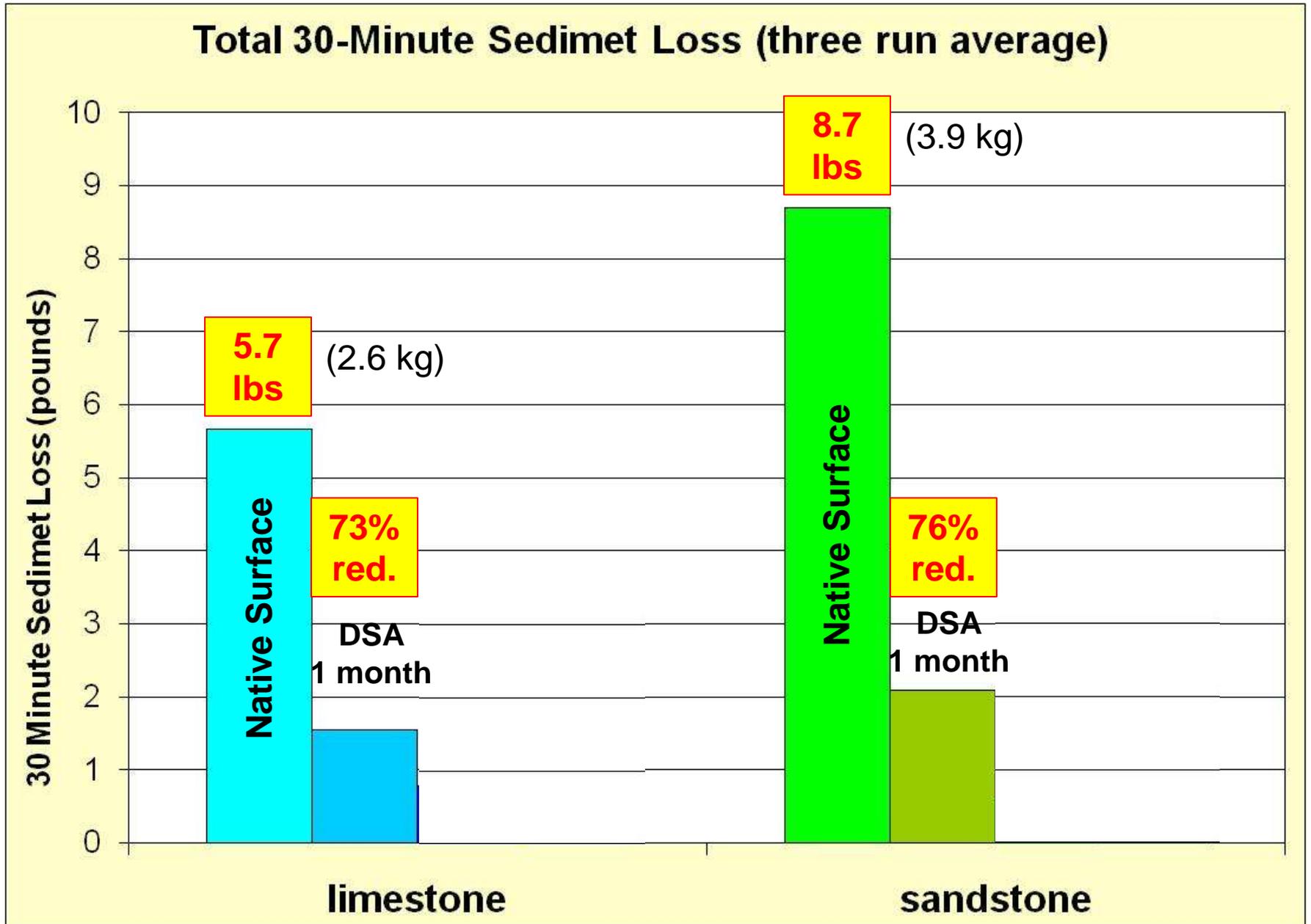
**Native Surface**

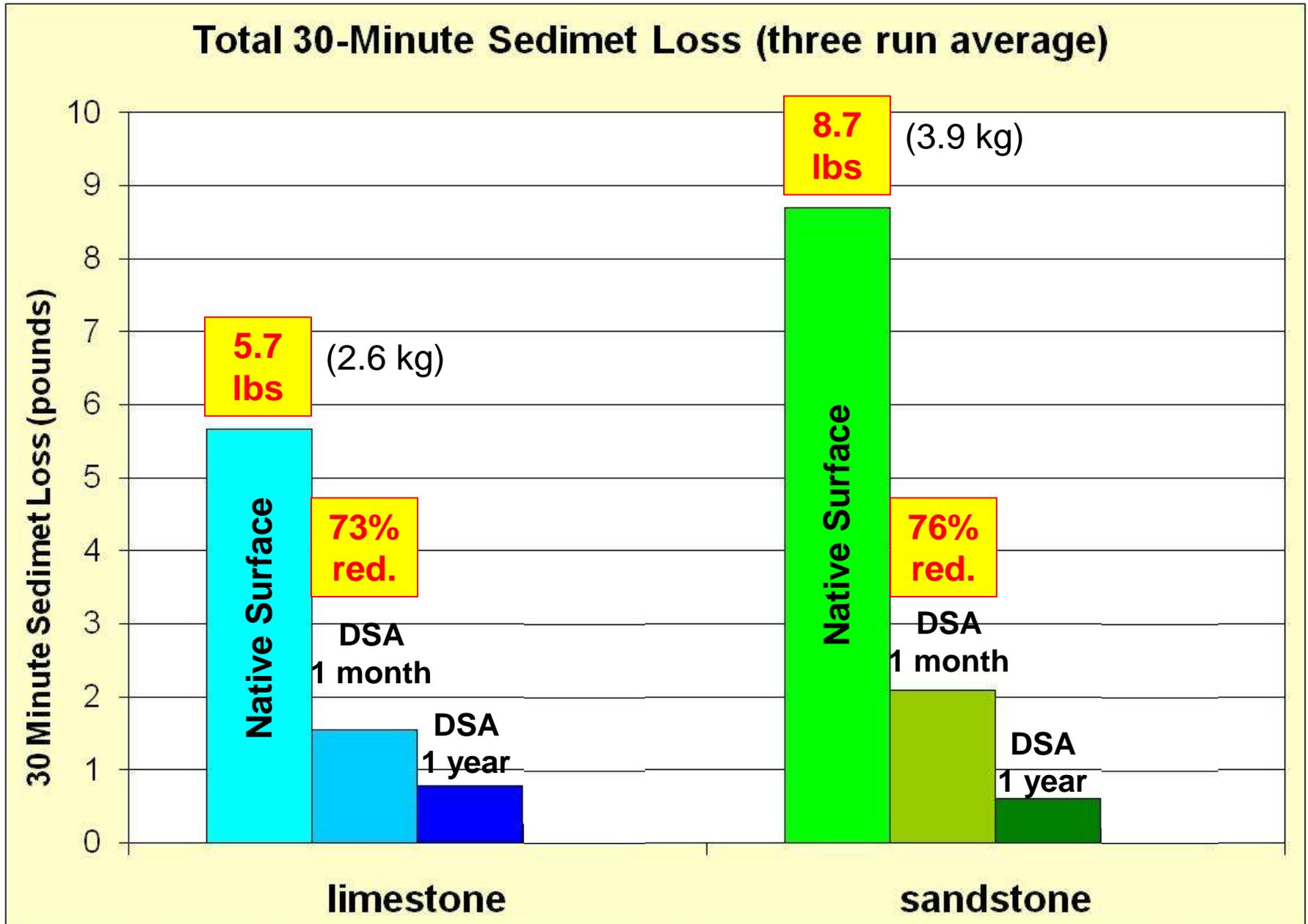


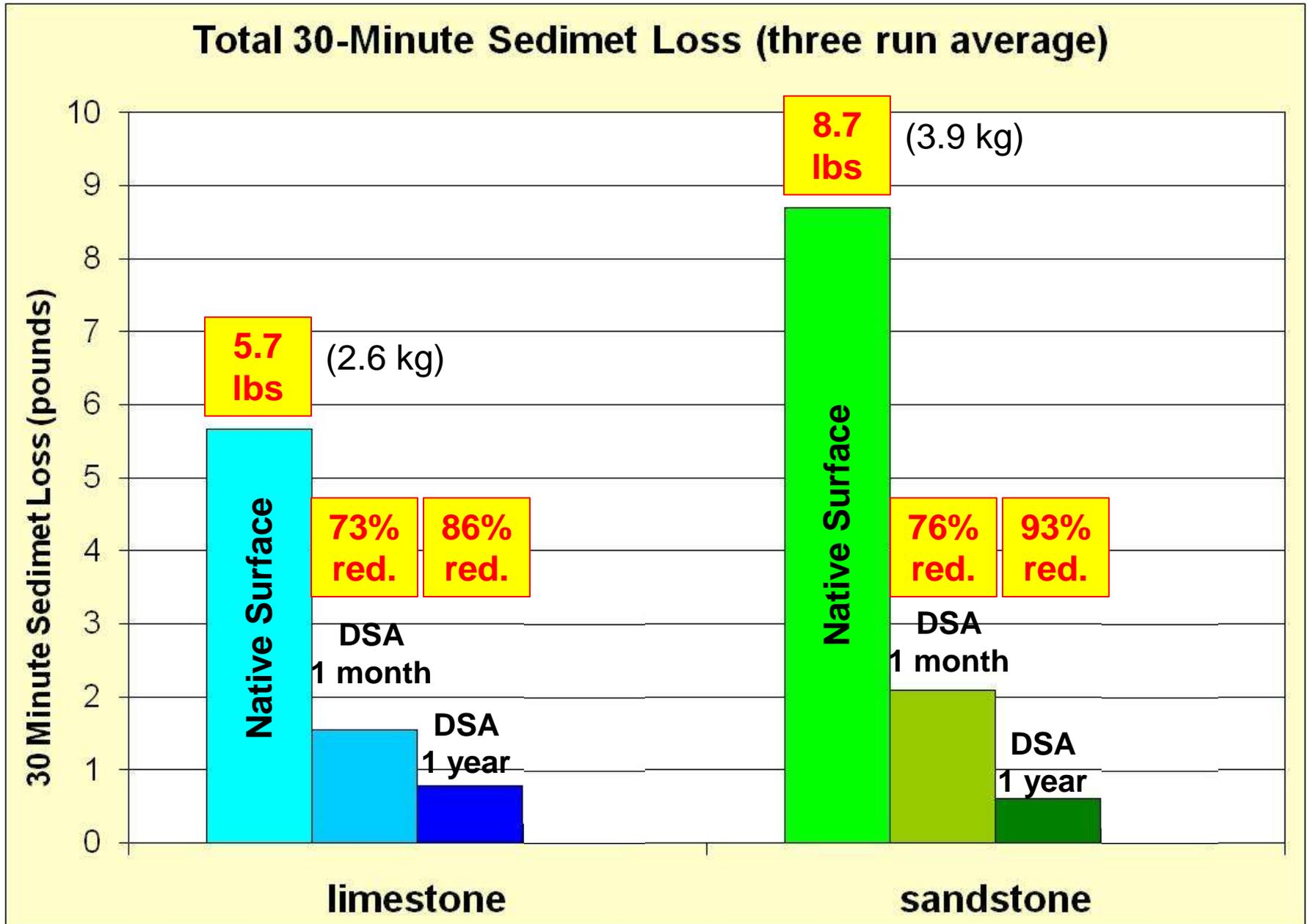
**Limestone DSA  
(1 month)**



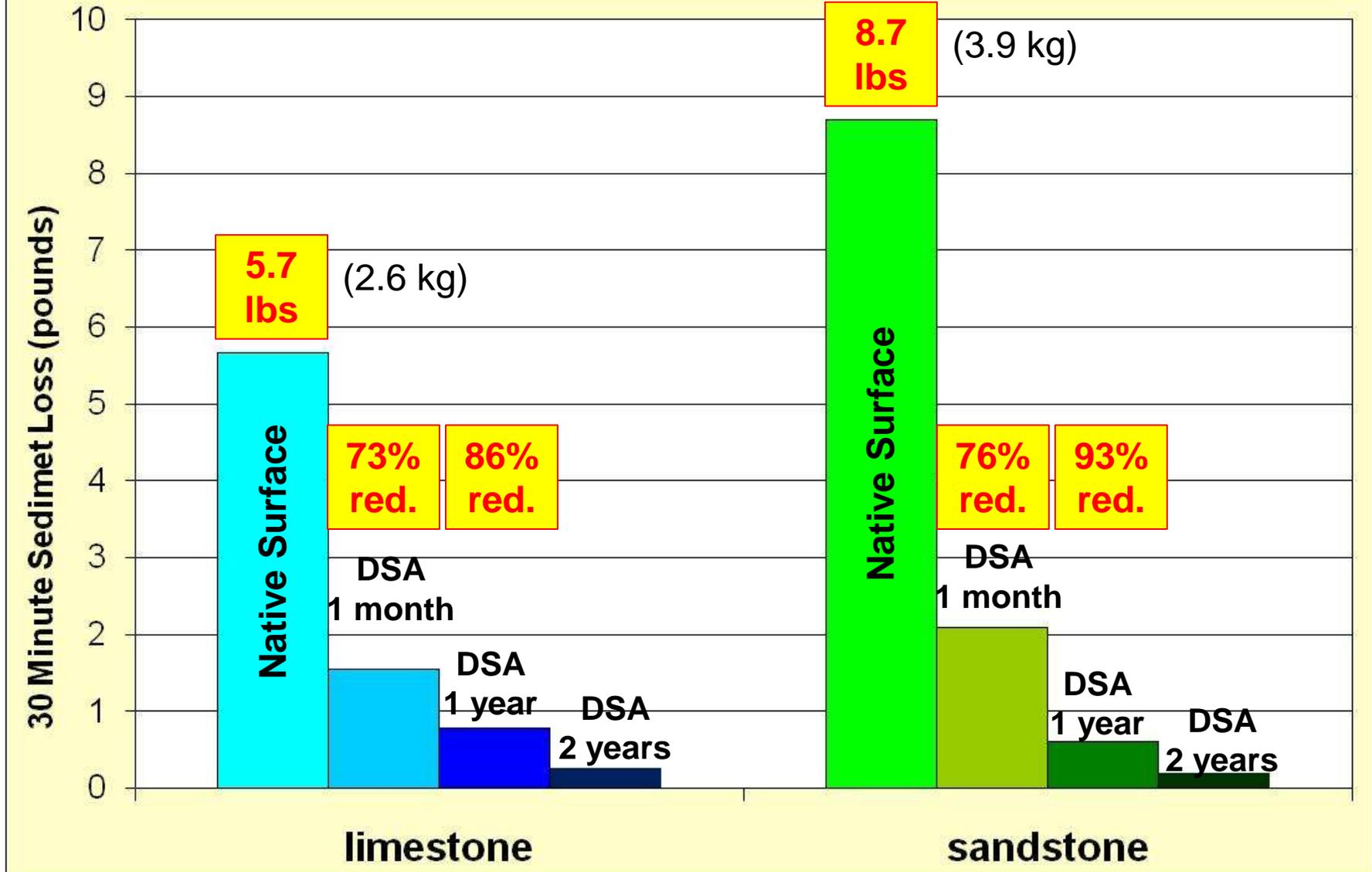




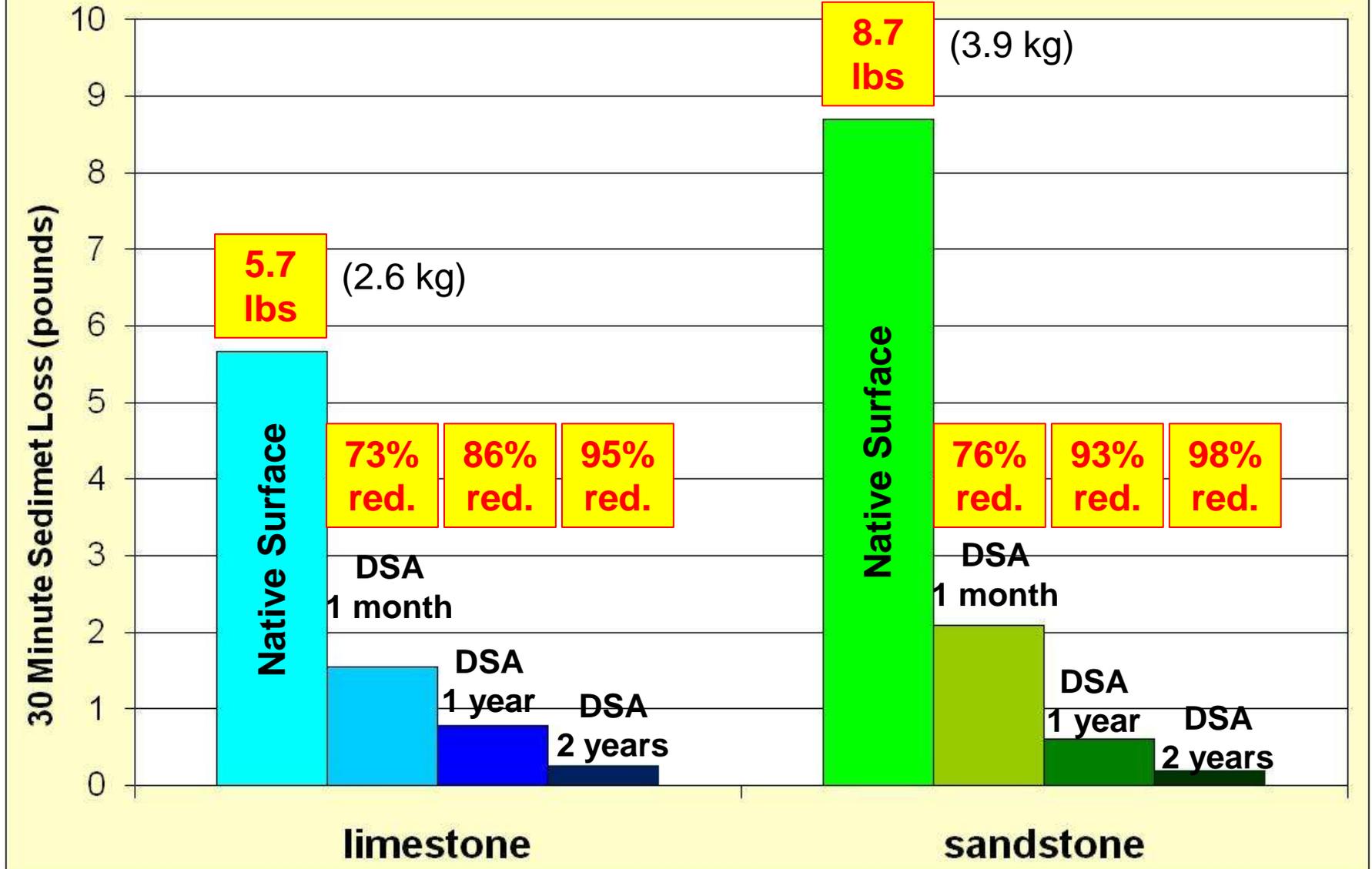




Total 30-Minute Sediment Loss (three run average)



Total 30-Minute Sediment Loss (three run average)



## Average Sediment Production (combined sites):

**Native Surface:**                      **380 lbs/mile** (107 kg/km)

**DSA 1 month:**                      **96 lbs/mile** (27 kg/km)

**DSA 1 year:**                      **36 lbs/mile** (10 kg/km)

**DSA 2 years:**                      **12 lbs/mile** (3.4 kg/km)

\*remember this is for one 30 minute storm



# Presentation Outline

## Background

- Perspective
- Driving Surface Aggregate
- Rainfall Simulator

## Study 1: CBC, 2008

- Overview
- Results
- **Conclusions**

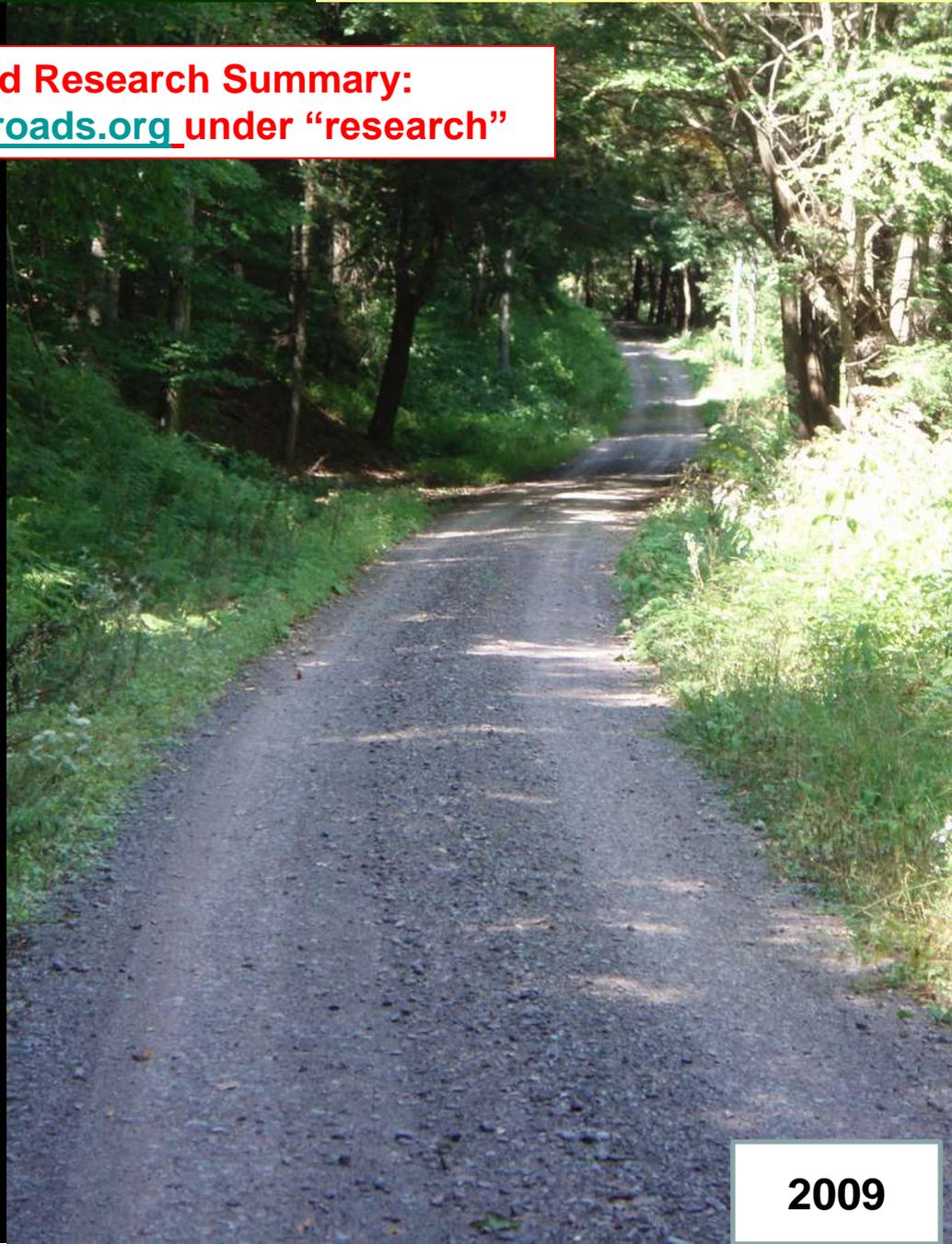
## Study 2: ANF, 2012

- Overview
- Results
- Conclusions

## Conclusions:

- DSA reduced sediment production by >90% for at least two years after placement.
- No significant difference in limestone -vs- sandstone parent material. (equal hardness)
- Road was not graded until 2011, 5 years after placement.

Full Report and Research Summary:  
[www.dirtandgravelroads.org](http://www.dirtandgravelroads.org) under "research"



2009

# *Presentation Outline*

## Background

- Perspective
- Driving Surface Aggregate
- Rainfall Simulator

## Study 1: CBC, 2008

- Overview
- Results
- Conclusions

## Study 2: ANF, 2012

- **Overview**
- Results
- Conclusions



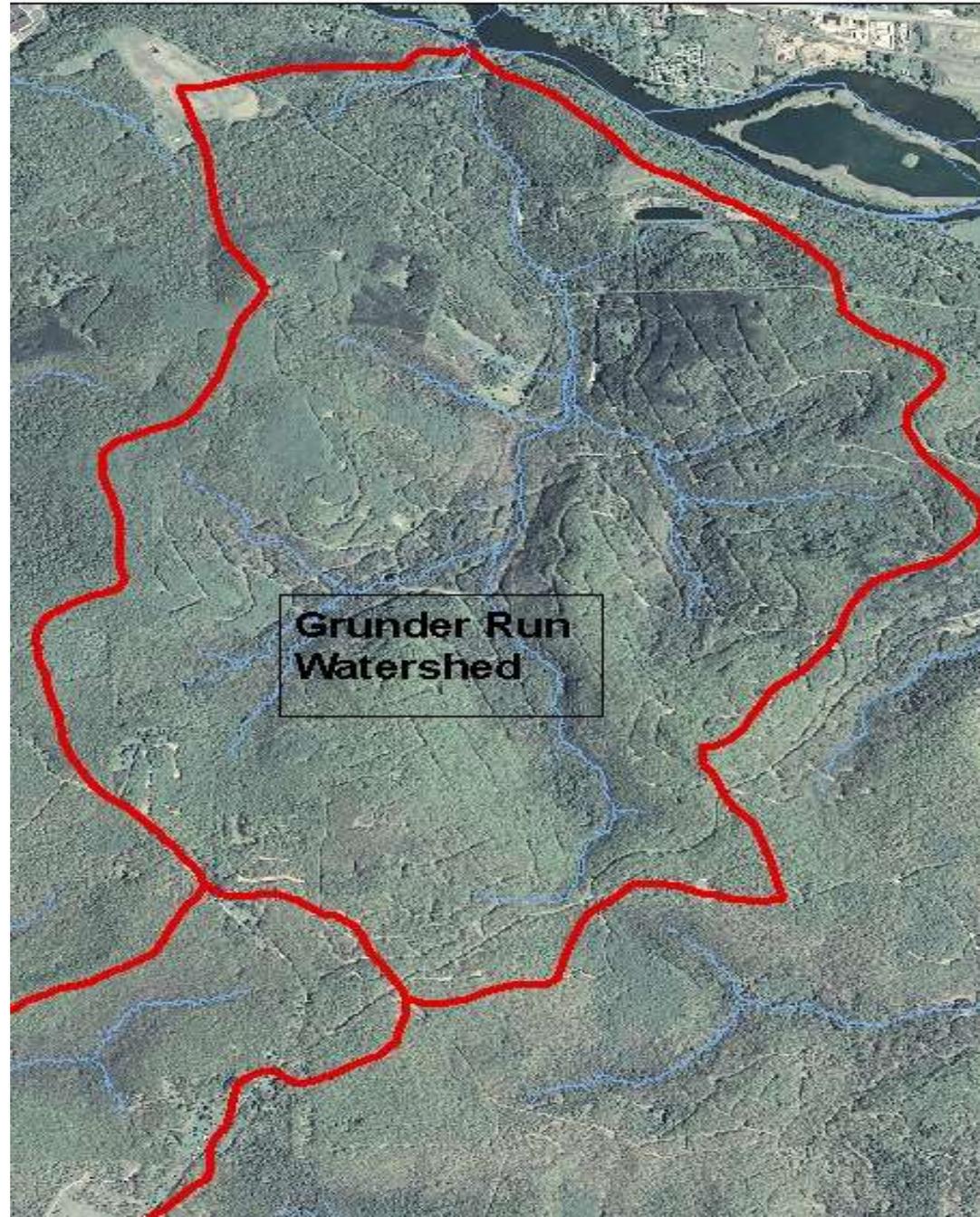
## Study Details

- Funded by: US Department of Energy, National Energy Technology Laboratory & US Forest Service, Northern Research Station
- Study completed 3/2012.



## Study Overview

- 9,800+ wells in ANF
- 1,700+ miles of access road, and growing
- Focused on Grunder Run Watershed



## Study Purpose

- Collect baseline data on sediment production from oil access roads.
- Look at various road factors such as slope, width, use, etc.
- Collect second set of data from a few sites after new aggregate was placed.





## Study Status

- 14 sites tested on “existing roads” in 2010.
- Work was done, including aggregate placement, on several of those sites.
- 4 sites re-tested on newly placed DSA or newly placed pit-run in 2011.
- Final report finished 3/2012.



# *Presentation Outline*

## Background

- Perspective
- Driving Surface Aggregate
- Rainfall Simulator

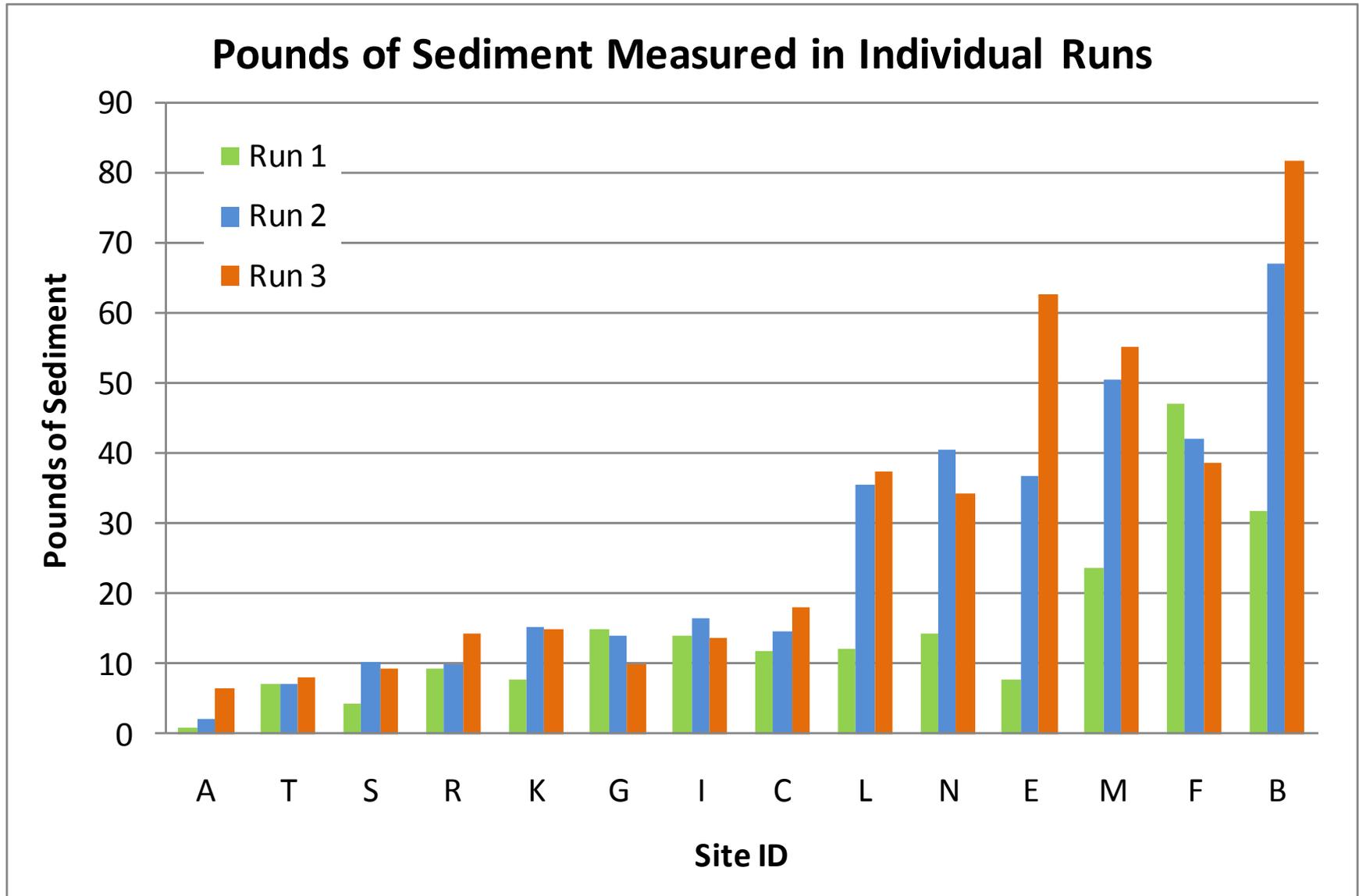
## Study 1: CBC, 2008

- Overview
- Results
- Conclusions

## Study 2: ANF, 2012

- Overview
- **Results**
- Conclusions

Sediment productions from 7.4 to 60.1 lbs (390 - 3,173 lbs/road mile)



**Site A: 3.2 pounds of sediment**

1 lbs, 2.1 lbs, 6.4 lbs ←

**Tested: 8/18/2010**

**Slope: 14.7%** ←

**Width: 13'**

**Traffic: Very Low**

**CBR(strength): 31**

**Material: Loam: 43% sand, 31% silt, 26% clay**



## **Site T: 7.4 pounds of sediment**

7.1 lbs, 7.0 lbs, 8.0 lbs

**Tested:** 8/19/2010

**Slope:** 3.3% ←

**Width:** 12' (16' with berm)

**Traffic:** High

**CBR(strength):** 141

**Material:** Sandy Loam: 75% sand, ←  
14% silt, 11% clay



**Site S: 7.9 pounds of sediment**

4.2 lbs, 10.1 lbs, 9.4 lbs

**Tested:** 7/27/2010

**Slope:** 7.6%

**Width:** 11' (11' with berm)

**Material: Sandy Clayey Loam:** 52%  
sand, 24% silt, 24% clay

**Traffic:** Med

**CBR(strength):** 91



## **Site R: 11.1 pounds of sediment**

9.3 lbs, 9.8 lbs, 14.3 lbs

**Tested:** 7/27/2010

**Slope:** 9.0%

**Width:** 11.5' (11.5' with berm)

**Traffic:** Low

**CBR(strength):** 99

**Material: Loam:** 47% sand, 29% silt,  
24% clay



**Site K: 12.7 pounds of sediment**

7.9 lbs, 15.4 lbs, 14.9 lbs

**Tested:** 6/18/2010

**Slope:** 4.4% ←

**Width:** 12' (13' with berm)

**Traffic:** Med

**CBR(strength):** 67

**Material:** Sandy Loam: 57% sand,  
27% silt, 16% clay



**Site G: 13.0 pounds of sediment**

15.1 lbs, 14.0 lbs, 10.9 lbs ←

**Tested: 7/2/2010**

**Slope: 16.2%** ←

**Width: 12.5' (12.5' with berm)**

**Traffic: High**

**CBR(strength): 126**

**Material: Loam: 41% sand, 38% silt,  
21% clay**



**Site I: 14.7 pounds of sediment**

14 lbs, 16.5 lbs, 13.7 lbs ←

**Tested:** 8/17/2010

**Slope:** 20.5% ←

**Width:** 13' (17' with berm)

**Traffic:** Low

**CBR(strength):** 81

**Material:** Loam: 43% sand, 33% silt,  
24% clay



## **Site C: 14.9 pounds of sediment**

11.9 lbs, 14.6 lbs, 18.0 lbs

**Tested:** 7/8/2010

**Slope:** 7.2%

**Width:** 10' (14' with berm)

**Traffic:** Low

**CBR(strength):** unknown

**Material:** Loam: 45% sand, 30% silt,  
25% clay



**Site L: 28.4 pounds of sediment** ←

12 lbs, 35.7 lbs, 37.5 lbs

**Tested:** 6/31/2010

**Slope:** 13.8%

**Width:** 12' (15' with berm)

**Traffic:** Low

**CBR(strength):** 71

**Material:** Loam: 51% sand, 31% silt,  
18% clay



**Site N: 29.7 pounds of sediment**

14.3 lbs, 40.5 lbs, 34.4 lbs

**Tested:** 8/18/2010

**Slope:** 5.6%

**Width:** 13' (15' with berm)

**Traffic:** High

**CBR(strength):** 103

**Material:** Loam: 49% sand, 31% silt,  
20% clay



Site E: 35.9 pounds of sediment

7.8 lbs, 36.9 lbs, 62.8 ←

**Tested:** 6/30/2010

**Slope:** 9.2%

**Width:** 13' (13' with berm)

**Traffic:** Low

**CBR(strength):** 65

**Material: Loam:** 73% sand, 14% silt,  
13% clay



**Site F: 42.7 pounds of sediment**

47.1 lbs, 42.2 lbs, 38.8 lbs ←

**Tested:** 7/2/2010

**Slope:** 13.3%

**Width:** 15' (15' with berm)

**Traffic:** High

**CBR(strength):** 133

**Material:** Loam: 46% sand, 33% silt,  
21% clay



**Site M: 43.1 pounds of sediment**

23.6 lbs, 50.5 lbs, 55.2 lbs

**Tested:** 6/31/2010

**Slope: 19.2%** ←

**Width: 10' (15' with berm)**

**Traffic:** Low

**CBR(strength):** 76

**Material: Loam:** 47% sand, 33% silt,  
20% clay



**Site B: 60.1 pounds of sediment** ←

31.7 lbs, 67.0 lbs, 81.7 lbs

**Tested:** 7/8/2010

**Slope:** 12.7%

**Width:** 11' (16' with berm) ←

**Traffic:** Med

**CBR(strength):** unknown

**Material: Loam:** 48% sand, 32% silt, 20% clay



Site ID	Slope %	Road width (ft)	rd + berm width (ft)	Strength (CBR)	traffic level	lbs Sediment per 30 min. event				Site ID
						Run 1	Run 2	Run 3	Avg	
A*	14.7	na	13	31	v. low	1.0	2.1	6.4	3.2	A*
T	3.3	12	16	141	high	7.1	7	8	7.4	T
S	7.6	11	11	91	med	4.2	10.1	9.4	7.9	S
R	9	11.5	11.5	99	med	9.3	9.8	14.3	11.1	R
K	4.4	12	13	67	med	7.9	15.4	14.9	12.7	K
G	16.2	12.5	12.5	126	high	15.1	14.0	10.0	13.0	G
I	20.5	13	17	81	low	14.0	16.5	13.7	14.7	I
C	7.2	10	14	na	low	11.9	14.6	18.0	14.9	C
L	13.8	12	15	71	low	12.0	35.7	37.5	28.4	L
N	5.6	13	15	103	high	14.3	40.5	34.4	29.7	N
E	9.2	13	13	65	low	7.8	36.9	62.8	35.9	E
F	13.3	15	15	76	high	47.1	42.2	38.8	42.7	F
M	19.2	10	15	133	low	23.6	50.5	55.2**	43.1	M
B	12.7	11	16	na	med	31.7	67.0	81.7	60.1	B

\* Site A on grass road: not used in averages.

\* Site M, run 3 extrapolated

Avg	15.8	27.7	28.6	24.7	pounds lbs/mile
Avg	836	1,463	1,511	1,306	
	Run 1	Run 2	Run 3	Average	

## Big Picture:

### Let's extrapolate:

Let's talk about one rain shower moving across the National Forest with 0.6 inches of rainfall in 30 minutes.....

## Big Picture:

### Let's extrapolate:

Let's talk about one rain shower moving across the National Forest with 0.6 inches of rainfall in 30 minutes.....

$1,320_{\text{pounds/mile}} * 1,700_{\text{miles}} / 2000_{\text{lbs/ton}} =$

**1,122 tons of sediment** from all roads in ANF

## Big Picture:

### Let's extrapolate:

Let's talk about one rain shower moving across the National Forest with 0.6 inches of rainfall in 30 minutes.....

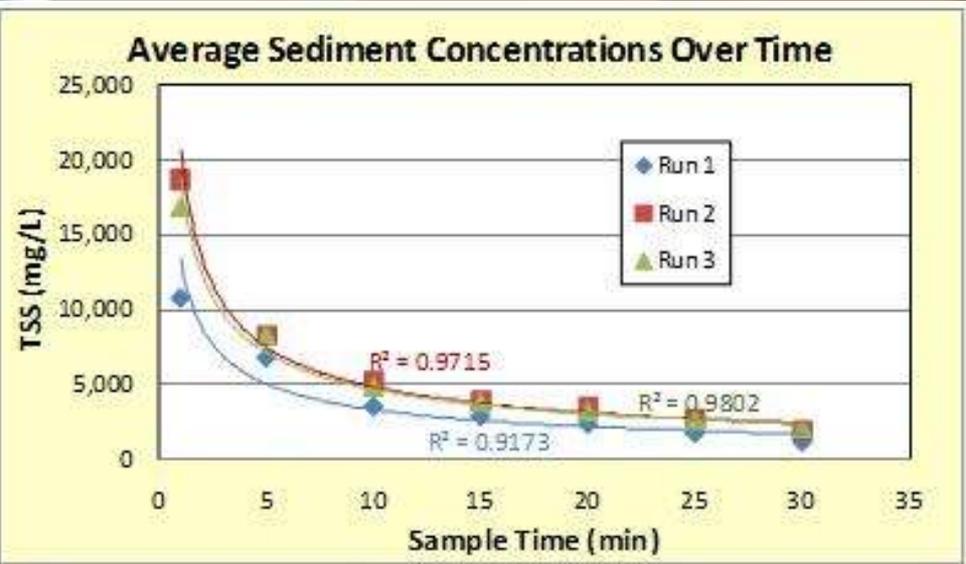
$1,320_{\text{pounds/mile}} * 1,700_{\text{miles}} / 2000_{\text{lbs/ton}} =$

**1,122 tons of sediment** from all roads in ANF

**374 tons of sediment (17 tri-axle loads) of direct stream pollution in one 30 minute, 0.6" rain event.**

- *conservative estimate and does not include ANF roads*
- *estimates are that there will be 2,260 miles of access roads by 2020*

# 2010 Testing: First Flush (grassed road)



## The rest of the study:

Look at sediment predation from **four** of the previously tested sites that have been resurfaced. Two with limestone **Driving Surface Aggregate**, two with **pit-run gravel**.

Completed in 2011



## The rest of the study:

### “Pit-Run”

- locally excavated
- no processing
- highly variable

### DSA – Driving Surface Aggregate

- must be imported to ANF
- costs 2-3 time as much
- ANF has been placing on roads within 300' of streams



**2010 – existing road**

**60.1lbs** (32, 67, 82)

**B**

**39%  
reduction**

**2011 – Pit-Run**

**36.8 lbs** (20, 41, 49)



**2010 – existing road**

**42.7 lbs** (47, 42, 39)

**F**

**64%  
reduction**

**2011 – Pit-Run**

**15.4 lbs** (23, 13, 10)



2010 – existing road

13 lbs (15, 14, 10)

**G**

67%  
reduction

2011 – DSA

4.2 lbs (6, 3, 4)



**2010 – existing road**

**14.9 lbs** (11.9, 14.6, 18 )

**C**

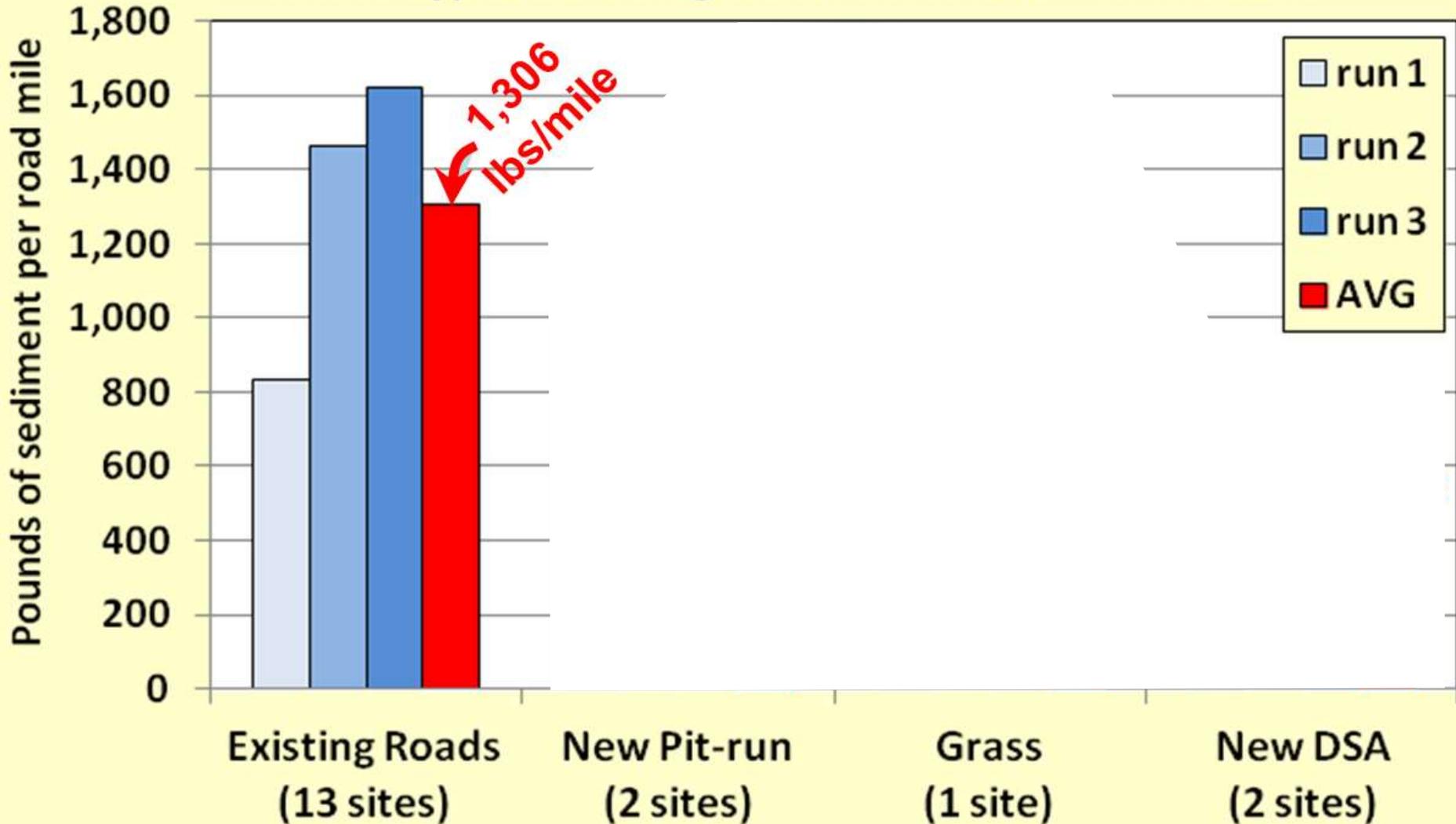
**95%  
reduction**

**2011 – DSA**

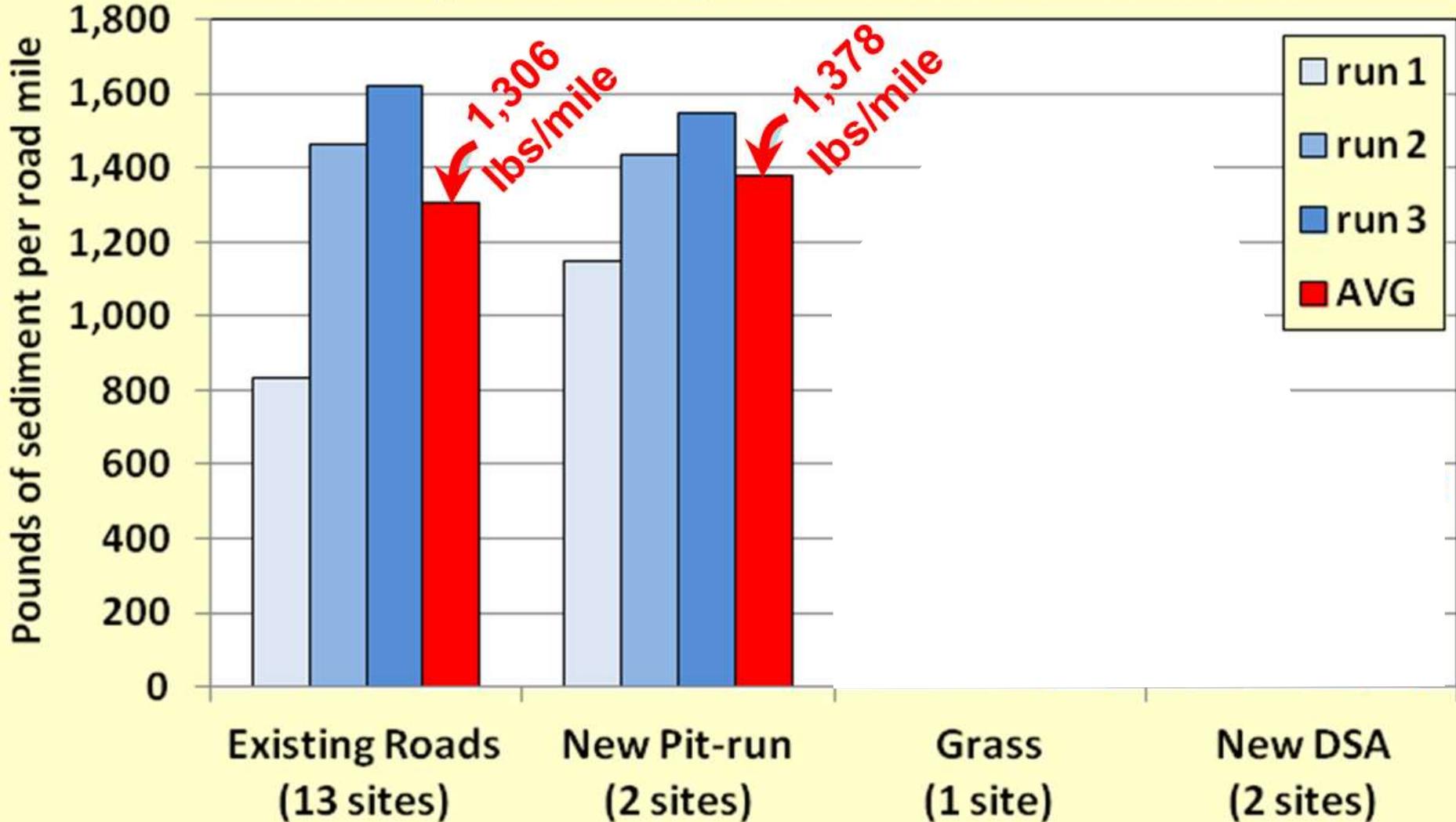
**0.8 lbs** (1.5, 0.5, 0.4)



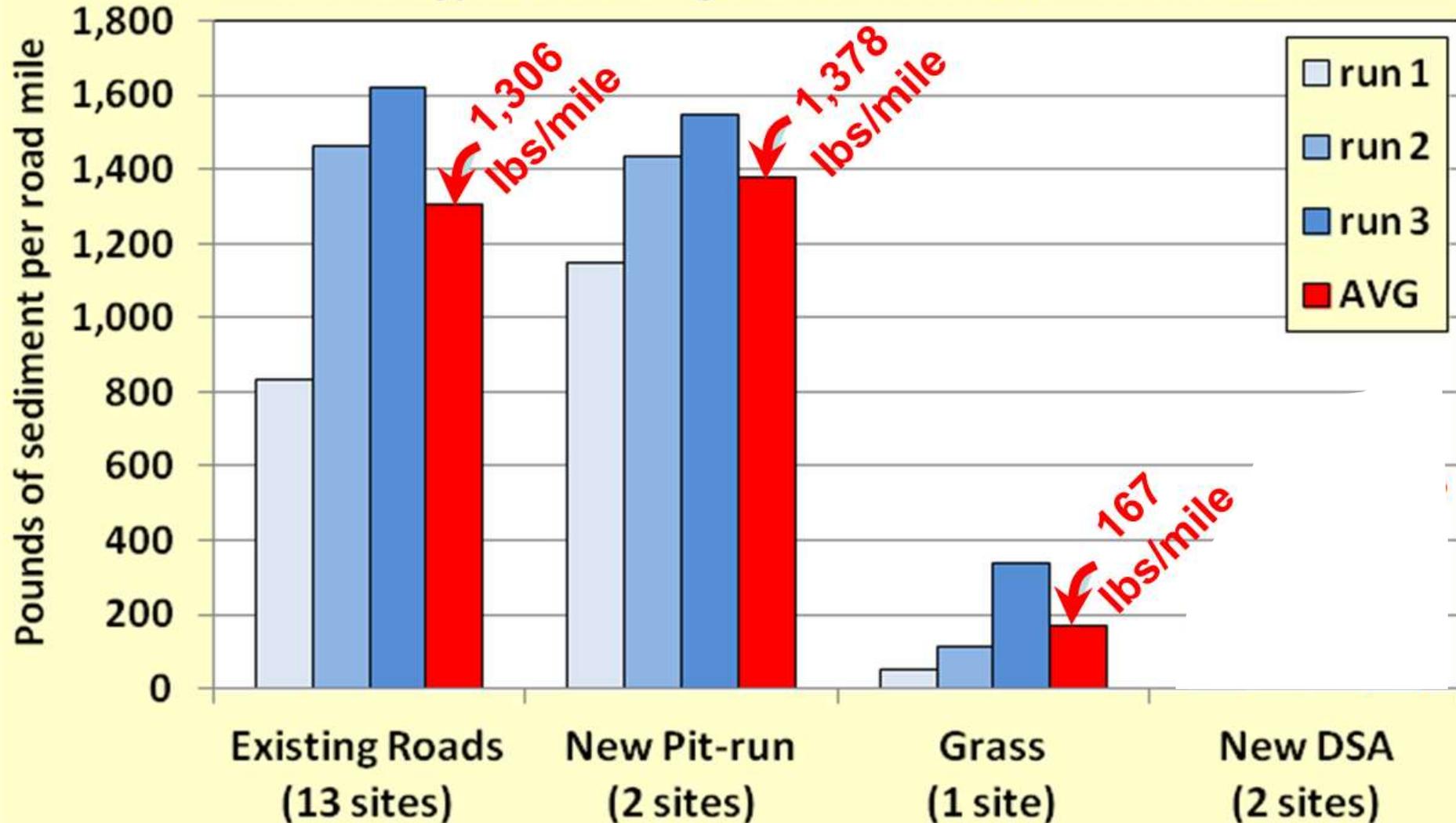
Average Sediment Productions per Road-mile for Each Road Type for a Single 30-minute 0.6" Rain Event



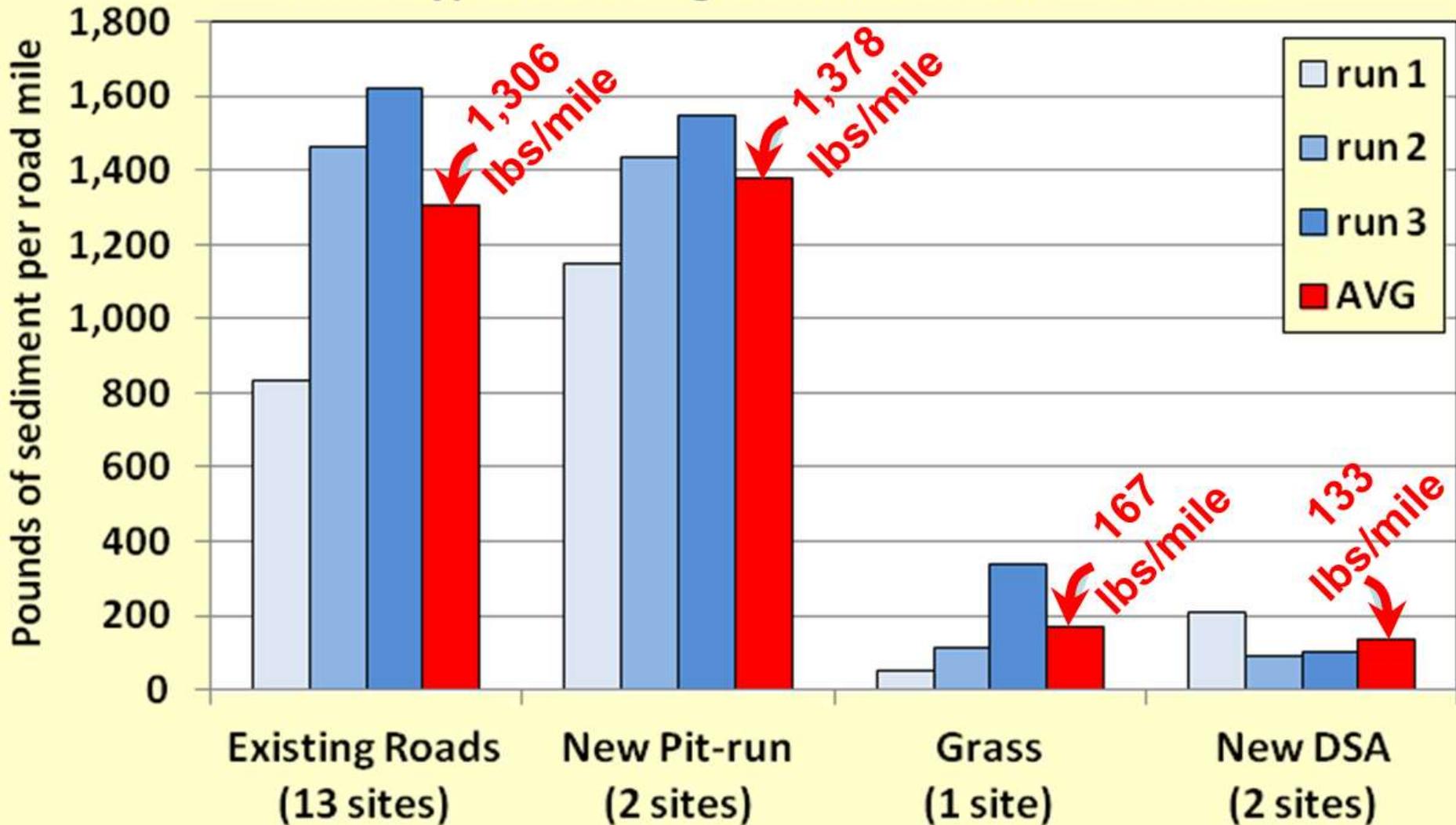
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Average Sediment Productions per Road-mile for Each Road Type for a Single 30-minute 0.6" Rain Event





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- Perspective
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- Rainfall Simulator

## Study 1: CBC, 2008

- Overview
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- Overview
- Results
- **Conclusions**

## Disclaimer:

- Use caution when drawing conclusions from this study.
- While it provided valuable data and lessons, it really only gave us a peak at the whole process going on:
  - We only looked at 1,400 feet of road (0.02% of oil/gas roads).
  - Doing one run per road only gives us “snapshots” in time.

## Results Summary for existing roads:

Avg. 1,300 lbs/mile per single 30 minute 0.6" rain event.

**Run 1:** Road slope and width were best sediment predictors, although relationship was not as strong as expected.

**Runs 2&3:** Road strength (CBR) had a large influence on how much sediment production increased over run 1.

Significant "First Flush" effect: In many cases  $>1/2$  the sediment left the site in the first 5-10 minutes of runoff.

Maintaining a grass surface significantly reduces the amount of sediment generated from seldom used roadways.

## Results Summary for new aggregate:

New pit run reduced sediment on their particular sites, but was still in range of “average” sediment production from all existing roads.

DSA significantly reduced sediment production on individual sites and produced 1/10 as much sediment as the existing or new pit-run surfaces.

Over the past few years, the ANF has been “concentrating” DSA placement into stream sensitive locations ( $\leq 300'$ ) because of cost. This appears to be an effective way to reduce road runoff pollution.

## Future Research:

- **More data points**, especially in other geographic locations.
- Additional “after” **aggregate testing**, either on new sections, or on the same sections in successive years.
- Correlation of sediment production to **road longevity**.
- Comparison of **other aggregate gradations** or varying aggregate **qualities**.
- How do maintenance activities such as **grading** affect sediment production?
- How does **traffic volume** affect aggregate performance and longevity?

### Research Summary

#### Sediment Reductions from Environmentally Sensitive Maintenance Practices on Unpaved Roads

**Research Overview:**  
Pennsylvania's Dirt and Gravel Road Maintenance Program has long advocated Environmentally Sensitive Maintenance (ESM) Practices to reduce stream pollution from unpaved roads. Penn State's Center for Dirt and Gravel Road Studies (Center) has recently completed a research project with funding from the Chesapeake Bay Commission that begins to quantify sediment reductions from several commonly used ESM practices.

**ESM Practices Tested:**  
Five Environmentally Sensitive Maintenance Practices were tested in this study:  
- **Grading Surface Aggregate:** a specific aggregate mixture designed as a wearing course for unpaved roads;  
- **Raising the Road Profile:** raising road elevation to eliminate lower ditch & water sheet flow;  
- **Grass Breaks:** elongated bumps at the road surface designed to slow water to each side of the road;  
- **Additional Drainage Outlets:** creating new outlets in ditches to reduce channelized flow; and  
- **Berm Removal:** removing unnecessary berm and ditch on down slope side of road to encourage sheet flow.

**Methods:**  
To determine sediment reductions of the five practices, it was necessary to collect sediment data both before and after each practice was implemented. The Rainmaker (see description below) was used to create a controlled and repeatable rainfall event on a 100' section of road. Each test consisted of three 30-minute runs of the rainmaker, both before and after ESM practice implementation. Runoff and sediment samples were taken at regular intervals to determine the total sediment loss for each section of road. The three test runs were combined for each section of road to determine the average sediment loss for one 30 minute event. By comparing the flow and sediment before and after ESM practice implementation, the sediment reduction from each practice can be determined.

**Meet the Rainmaker, a Rainfall Simulator for Roadways...**  
The "rainmaker" is a rainfall simulator developed by the Center that creates a 0.5" rainfall event in 30 minutes over a 100' length of road. This is equivalent to a 1-month return interval for a 30 minute storm for most of Pennsylvania. The rainmaker creates a controlled, repeatable rainfall event that is run both before and after ESM practices are installed on the road. By comparing runoff and sediment concentrations, sediment reductions can be calculated for the various ESM practices. Rainmaker layout and components are illustrated to the right.

### Research Summary

#### Sediment Production from Shallow Oil & Gas Access Roads in the Allegheny National Forest

**Research Overview:**  
This project quantified sediment production from 14 sections of road used by the shallow oil and gas industry within the Allegheny National Forest. In addition to these 14 existing "driveway" road tests, four of the sites also had a new surface applied, after which testing was repeated. The purpose of this research was to quantify and compare sediment production rates from existing roadways, and to determine any change in sediment runoff after placement of DSA and other road treatments.

**Study Details:**  
Shallow oil and gas development has been occurring in the Allegheny National Forest (ANF) for most of the last century. As of 2010, there were an estimated total of 3,000 wells throughout the ANF. Many wells are still in production today and are serviced by a network of over 3,000 miles of roadway (1,300 ANF and 1,700 adjacent). New wells are still being drilled and current estimates are that this network of roads will be expanded to over 3,500 miles by 2020. Erosion and sedimentation from this extensive and increasing network of roads has become a growing concern.

**Phase 1:** 14 sections of roadway were chosen for testing in conjunction with personnel from the Allegheny National Forest (ANF). The road sections were chosen to cover a wide variety of traffic levels, slopes, and typical of the road network. Testing was completed on these 14 existing test segments in 2010. The purpose of this testing was to determine sediment production for these roads and attempt to identify factors affecting sediment production.

**Phase 2:** Four of the 14 road sections above had new surface aggregate placed on them in 2011. These four sites were tested again in late 2011 in order to determine any differences in sediment production compared to the 2010 tests. Two of the sites were covered with "natural" gravel. The other two sites were covered with "Driving Surface Aggregate (DSA)". DSA is a FIDNOD aggregate specification designed to achieve maximum density for use as an alternate wearing course for unpaved roads.

**Rainfall Simulator:**  
A rainfall simulator or "rainmaker" was used in this study in order to create a controlled and repeatable rain event. This makes it possible to compare sediment production before, after, or to compare sediment production "before" and "after" practices are implemented on a section of road. The simulator is a rainfall simulator developed by the Center for Dirt and Gravel Road Studies (Center) that creates a 0.5" rainfall event in 30 minutes over a 100' length of road. The rainmaker creates a rainfall event that is equivalent to a 1-month return interval for a 30 minute storm for most of Pennsylvania.

**Results:**  
The addition of the surface aggregate treatments resulted in an 11% decrease in runoff for the 12 test sites. In addition, erosion control (cover for a 30-minute rain event) had the most significant effect on sediment production. The addition of DSA to the road surface had the most significant effect on sediment production. The addition of DSA to the road surface had the most significant effect on sediment production.

# More Information:

# Research Summaries:

# Full Research Reports:

[www.dirtandgravelroads.org](http://www.dirtandgravelroads.org)  
under "research".

### Results

**Runoff Rates from Existing Roads:**  
The first "existing condition" test done for this study found sediment production rates ranging from 0.7-0.2 percent of sediment runoff in a single 30 minute rainfall event. The 0.7 percent event was generated from a flat and inactive road with no grass growing between the wheel tracks. The 0.2 percent event was generated from a road with moderate to heavy grass growing between the wheel tracks. This highlights the great variability in erosion rates based on specific site conditions. Using average sediment runoff rates of 0.5 percent as an event, a single 30 minute 0.50 inch rain event during winter Pennsylvania can be conservatively expected to generate over 3,000 tons of sediment from the State's 200,000 miles of public unpaved roads. This illustrative purpose only, since testing on paved roads is needed to substantiate this assumption.

**Driving Surface Aggregate:**  
Ten separate DSA placements were tested on Leber Road in Potter County. The aggregates, one limestone and one sandstone, were placed according to Dirt and Gravel Road Program standards (one 1/8" placed using a power, compacted to 2"). Rainfall simulations were run before placement, and at intervals of 1 month and one year after placement. The goal of the right summarizes the results in total sediment loss per 30 minute rainfall simulation. Compared to their respective before placement, Limestone DSA reduced sediment by 27% after one month and 66% after one year, while Sandstone DSA reduced sediment by 78% after one month and 50% after one year. Forest material did not significantly affect sediment generation.

**Drainage Control Practices:**  
Limestone DSA which reduces sediment generation from the road surface, the flat remaining practices reduce sediment by reducing and controlling the volume of road runoff.

**Raising the Road Profile:**  
Down Road in Columbia County was filled approximately 1 foot in order to completely eliminate the ditch on the down slope side of the road. Street flow into a vegetative filter was achieved off the down slope side of the road after it was filled. This practice reduced the amount of sediment entering the stream by 70% after one month, and 81% after one year. Since 81% of sediment run off the road had 81% of it was assumed for the higher than expected reductions on Down Road.

**Grass Breaks:**  
Two grass breaks were tested in this study, one in Huntington County, and one in Millin County. The grass breaks showed sediment reductions of 57% and 41% respectively. Note that the grass breaks were placed in the middle of the 100' test section, therefore sediment reductions of 50% indicate the grassbreak was 100% effective in eliminating sediment generation.

**Additional Drainage Outlets:**  
The effect of adding a turnout was tested on Pine Swamp Road in Huntington County. The new turnout placed into a vegetative filter and did affect the stream. A turnout used instead of a culvert for road effectiveness and simplicity. The turnout showed sediment reductions of 65% for the down slope ditch alone, or 21% when factoring in the up slope ditch that was unaffected by the turnout. Note that as with the "grassbreaks", the turnout was placed in the middle of the 100' test section, so a 50% sediment reduction indicates a 100% efficiency.

**Berm Removal:**  
The effect of berm removal was tested on Pine Swamp Road in Huntington County. Removing the berm effectively eliminated the down slope ditch and allowed water to flow into a vegetative filter area. Berms removed showed sediment reductions of 90% for the down slope ditch alone, or 50% when factoring in the up slope ditch that was unaffected by the practice.

This is a summary only. Full report available at [www.dirtandgravelroads.org](http://www.dirtandgravelroads.org) under "research".

### Results

**Part I: Sediment Production from Existing Roads**

Site	Runoff (inches)	Sediment (tons)	Runoff (inches)	Sediment (tons)
1	0.7	1.2	0.2	0.1
2	0.5	0.8	0.3	0.4
3	0.4	0.6	0.2	0.3
4	0.3	0.5	0.1	0.2
5	0.2	0.4	0.1	0.1
6	0.1	0.3	0.1	0.1
7	0.1	0.2	0.1	0.1
8	0.1	0.2	0.1	0.1
9	0.1	0.2	0.1	0.1
10	0.1	0.2	0.1	0.1
11	0.1	0.2	0.1	0.1
12	0.1	0.2	0.1	0.1
13	0.1	0.2	0.1	0.1
14	0.1	0.2	0.1	0.1

The average sediment production from the 14 test sites was 0.50 inches of runoff per 30 minutes, or 0.50 percent of sediment production per 30 minutes. This is equivalent to a 1-month return interval for a 30 minute storm for most of Pennsylvania.

**Part II: Sediment Production After Use of New Aggregate**

Four of the sites detailed above had a new aggregate surface placed on them in 2011 (sites 8 & 9 with "natural" aggregate, and sites 10 & 11 with Driving Surface Aggregate). The newly placed "stone" material reduced sediment production by 29% and 54% (note that these two sites happened to have a large "before" sediment production). The newly placed Driving Surface Aggregate material showed sediment reductions of 67% and 80%. A direct comparison shows that the two DSA sites produced 70% less amount of sediment than the two DSA sites (average 25.1 tons and 23.6 tons respectively). The sediment reductions based on DSA placement were comparable to previous studies conducted by the Center. Previous research conducted in 2007 showed sediment reductions from DSA placement of 10% after one month and 50% after one year compared to untreated roads in a similar study. DSA was also unaffected by traffic stress, as illustrated in the graph below (sediment decreases from 1 to 3 on a 1 to 3 DSA increases for all other sites).

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**THANK YOU!**

**Sediment Production from Unpaved Roads in Pennsylvania**



**QUESTIONS?**

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Transportation Research Board

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