Monitoring sediment production from forest road approaches to stream crossings in the Virginia Piedmont

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Re-opening legacy roads

Contemporary road design

Virginia road BMPs

- Location
- Grade and water control
- Surfacing of approaches

Sediment delivery at forest road approaches to stream crossings

- A primary sediment source and direct pathway for sediment transport to stream channels

- Ninth Circuit decision that ditched roads are point sources
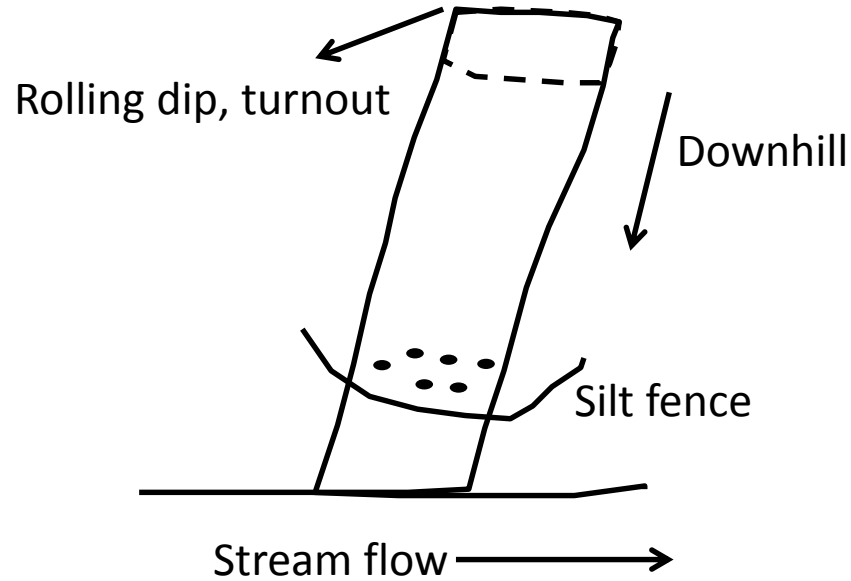
Objectives

- Measure annual rates of sediment delivery from forest road approaches to stream crossings due to road reopening in the Virginia Piedmont.

- Compare sediment delivery rates of reopened bare approaches with existing graveled approaches.

- Identify the major road approach characteristics above the stream crossing that govern rates of sediment delivery.
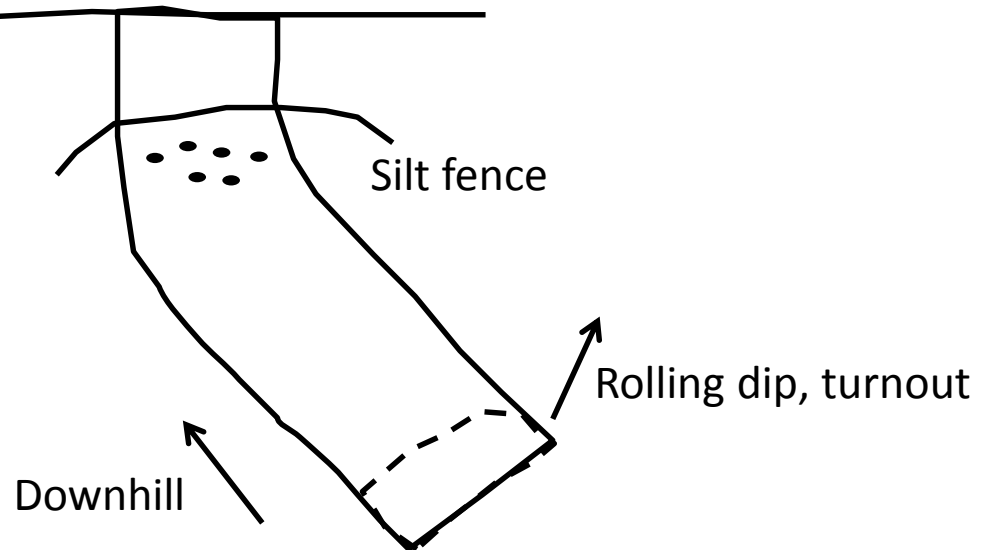
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- Compare sediment delivery rates of reopened bare approaches with existing graveled approaches.

- Identify the major road approach characteristics above the stream crossing that govern rates of sediment delivery.

- Evaluate the sediment reduction efficacy of partial and complete graveling of road approaches during storm events.

Plan view of road approach plots
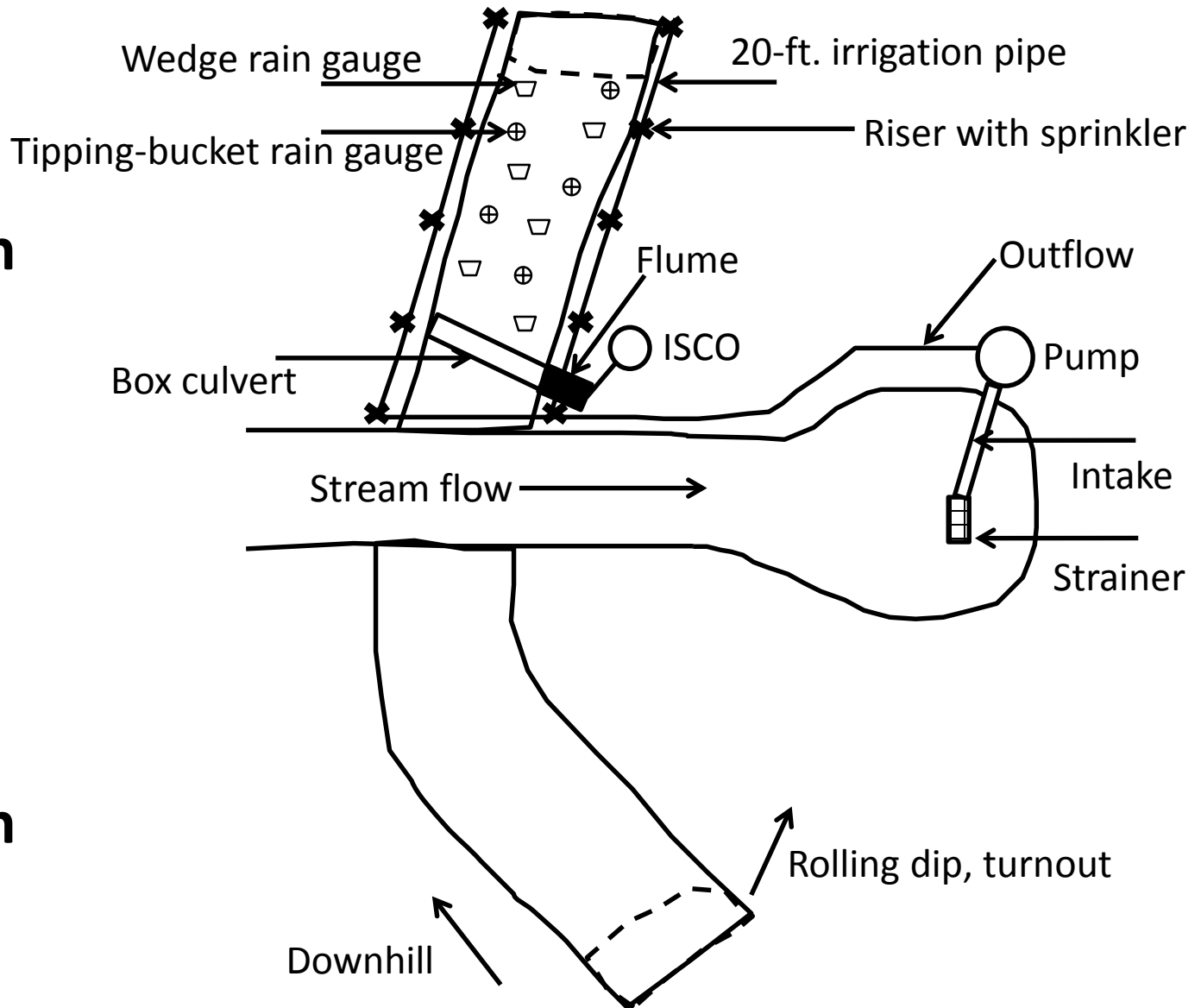
Left approach

Rolling dip, turnout

Downhill

Silt fence

Stream flow →

Silt fence

Right approach

Rolling dip, turnout

Downhill

Plan view of road approach plots

Left approach

Right approach

Wedge rain gauge

20-ft. irrigation pipe

Tipping-bucket rain gauge

Riser with sprinkler

Flume

Outflow

ISCO

Pump

Box culvert

Stream flow

Intake

Strainer

Rolling dip, turnout

Downhill

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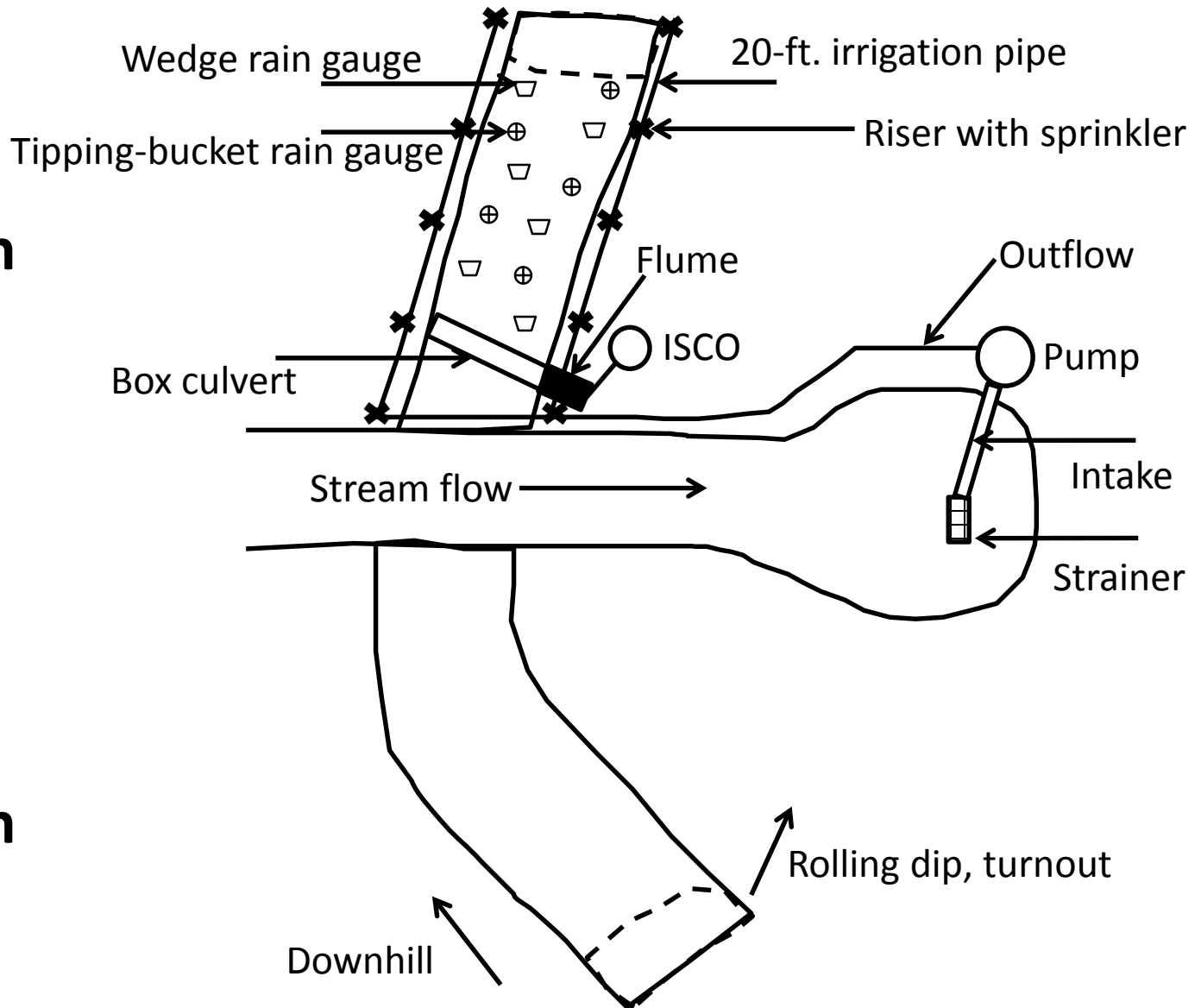
Study 1 Methods

Bulldozer blading to reopen legacy road approaches.

Silt fence barriers and erosion pin networks were installed to trap and measure sediment delivery.

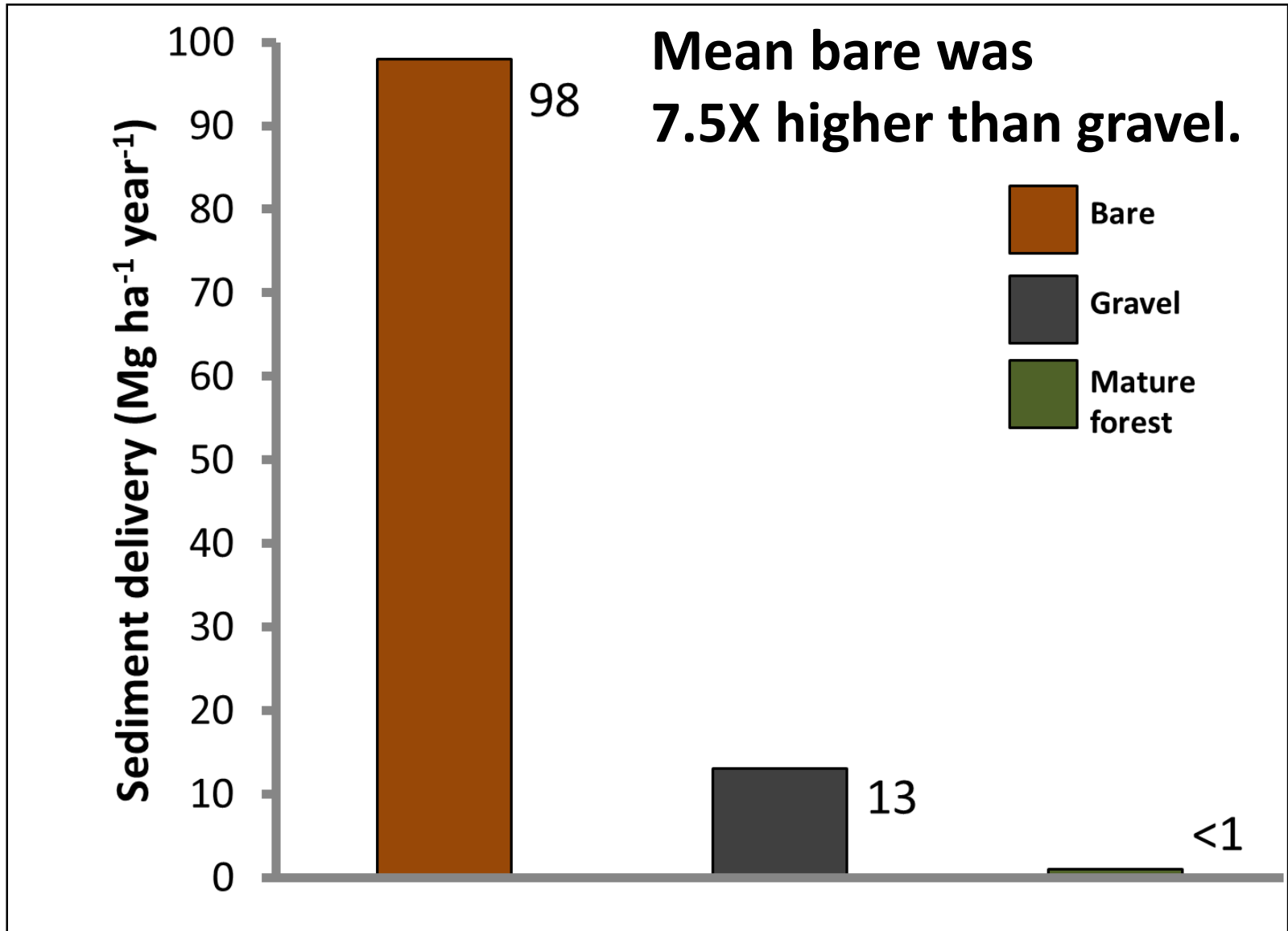Repeated measures via differential leveling with a total station were used to estimate annual sediment delivery rates.

Elevation gain (m) X Depositional area (m^2) X Bulk density of trapped sediment ($Mg\ m^{-3}$) = Sediment load (Mg)

Statistical analyses

- Tested for differences in median sediment delivery per measurement interval by road surface type (bare, graveled)

- Multiple linear regression model development to identify the most predictive road characteristics for sediment delivery
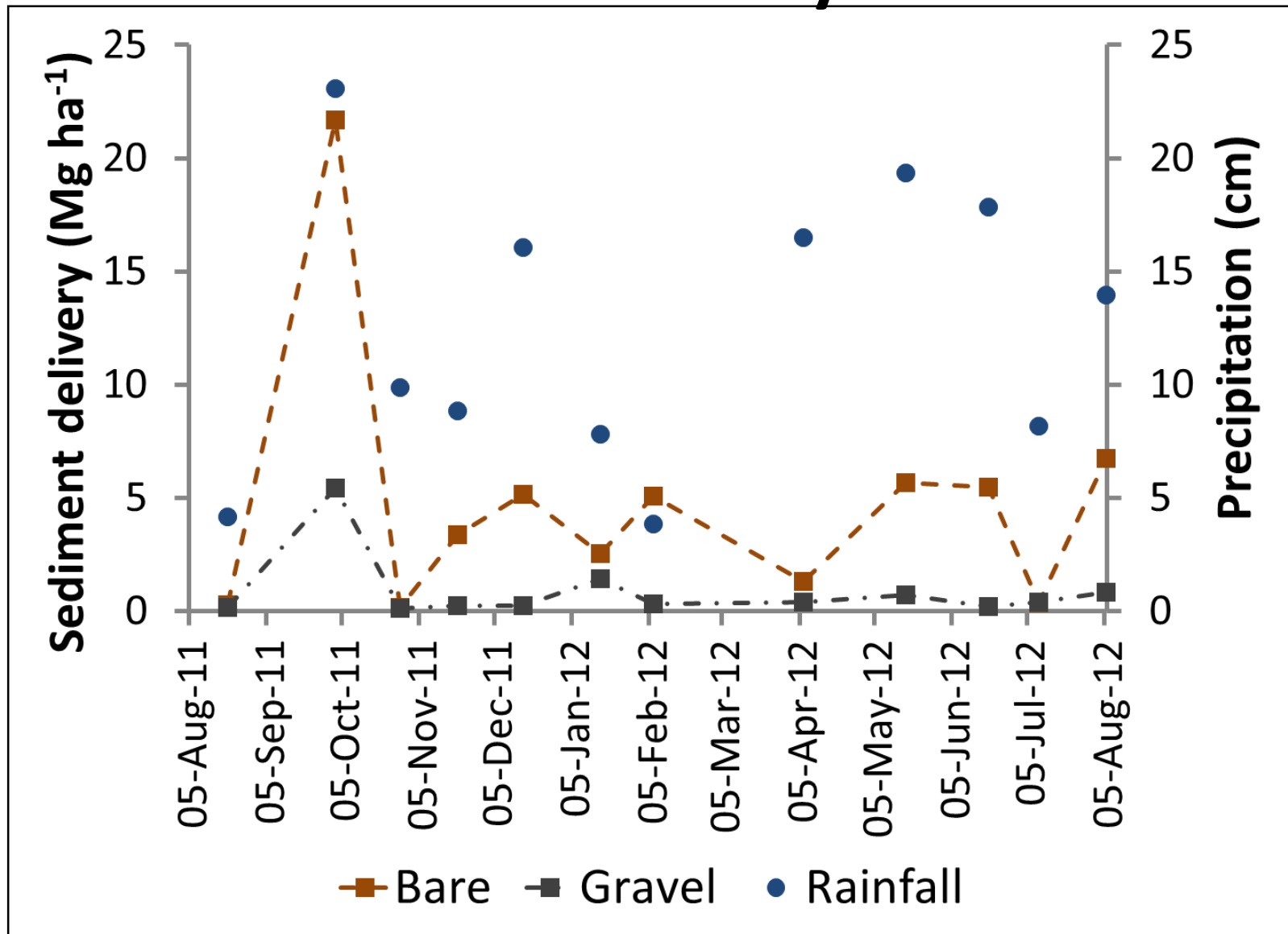
Results

Mean bare was 7.5X higher than gravel.

Problem road segments

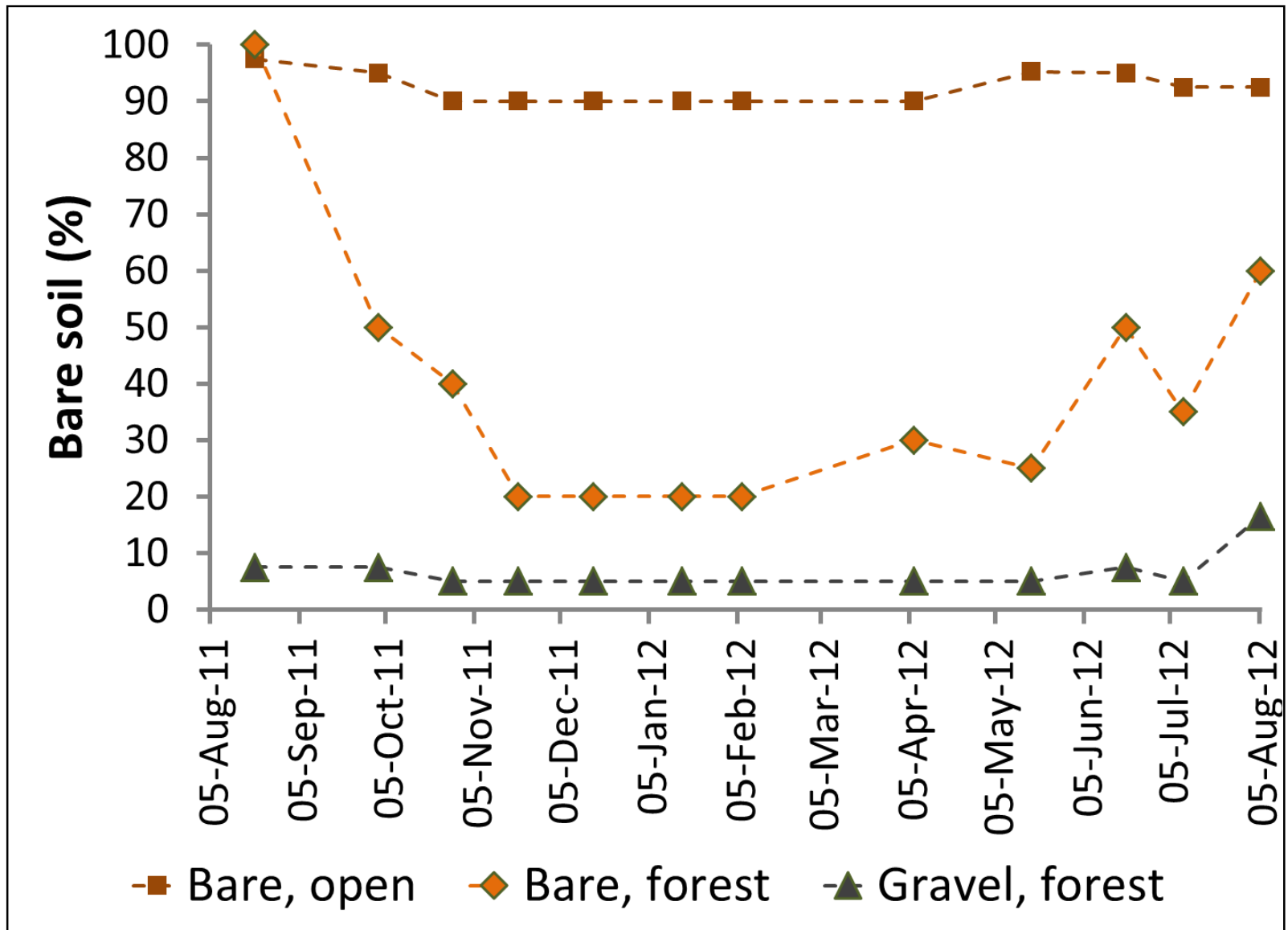287 Mg ha^{-1} year^{-1}

85 Mg ha^{-1} year^{-1}

- Surface runoff traveled between 75 and 130 m between the nearest water control structure and the silt fence

- 90 to 100% bare soil conditions throughout the year

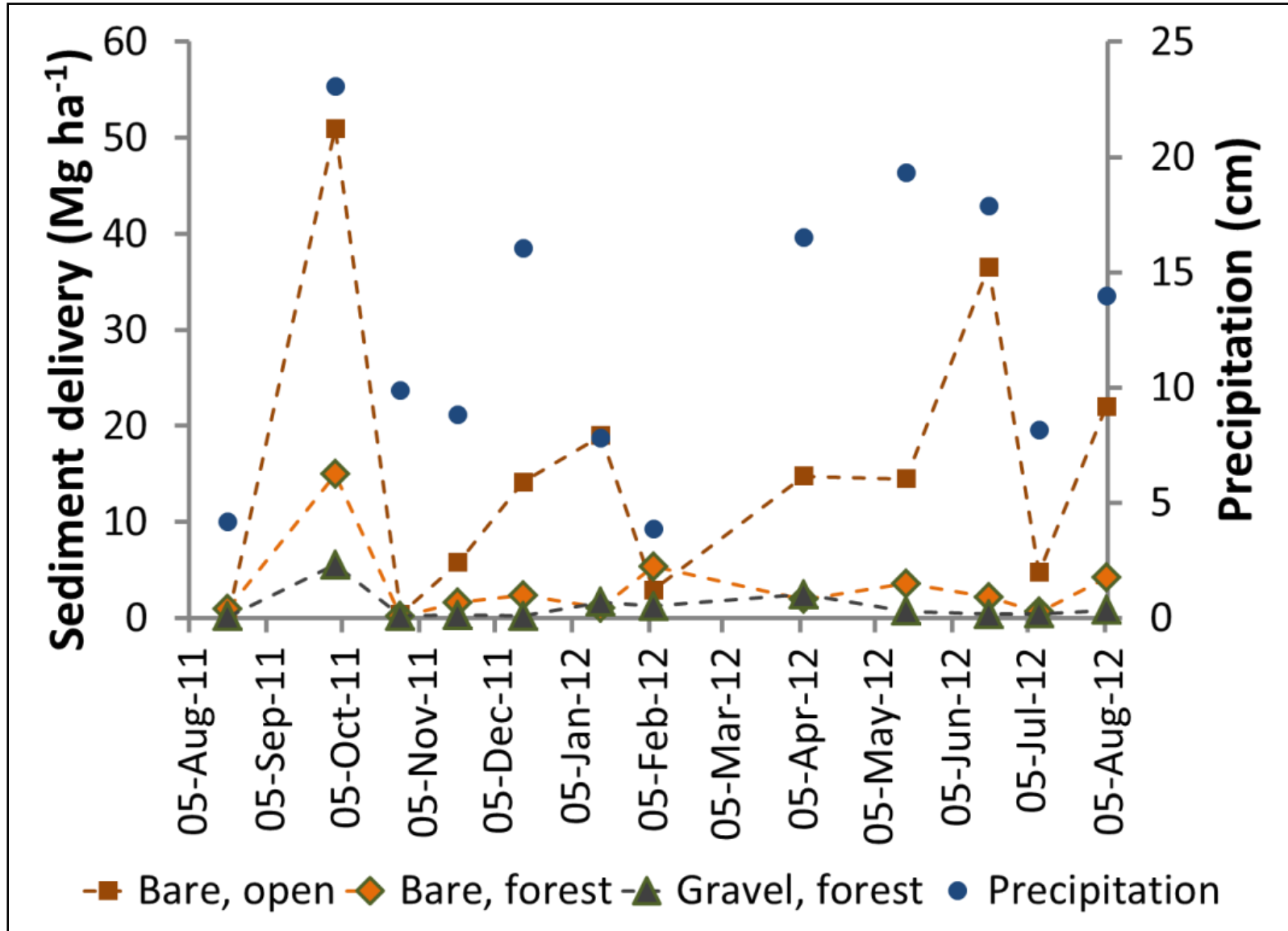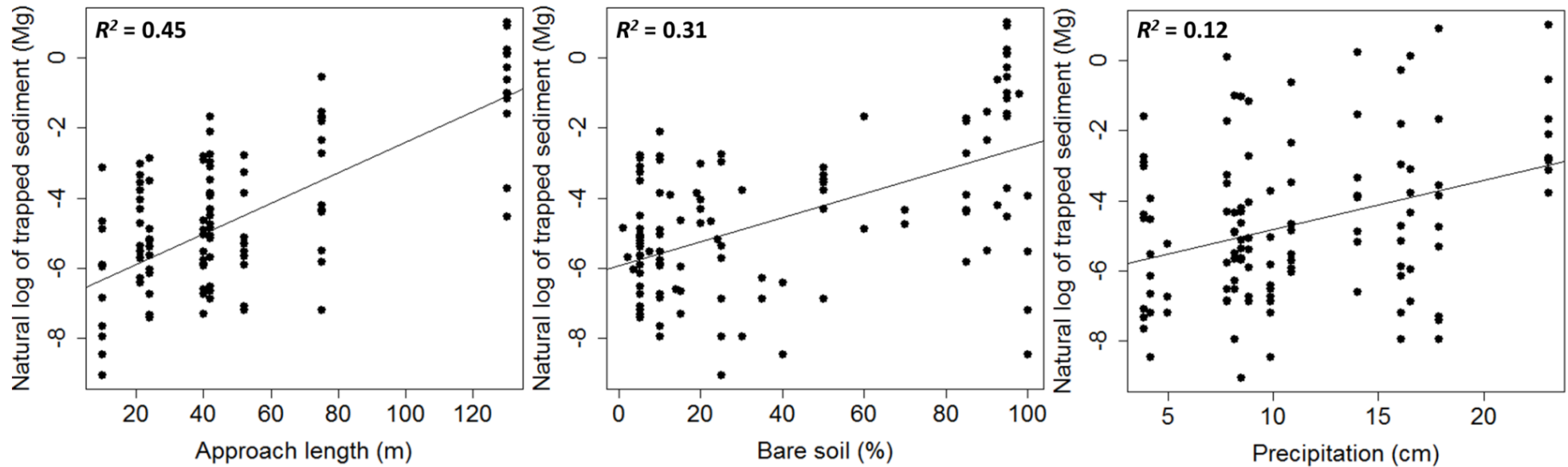# Temporal variability of sediment delivery rates

Bare soil in relation to adjacent forest cover

Sediment delivery in relation to surface type, forest cover

Relative importance of road characteristics that we can control

The highest sediment delivery rates were associated with road segments longer than 75 m and bare soil percentages greater than 50%.

Multiple regression model

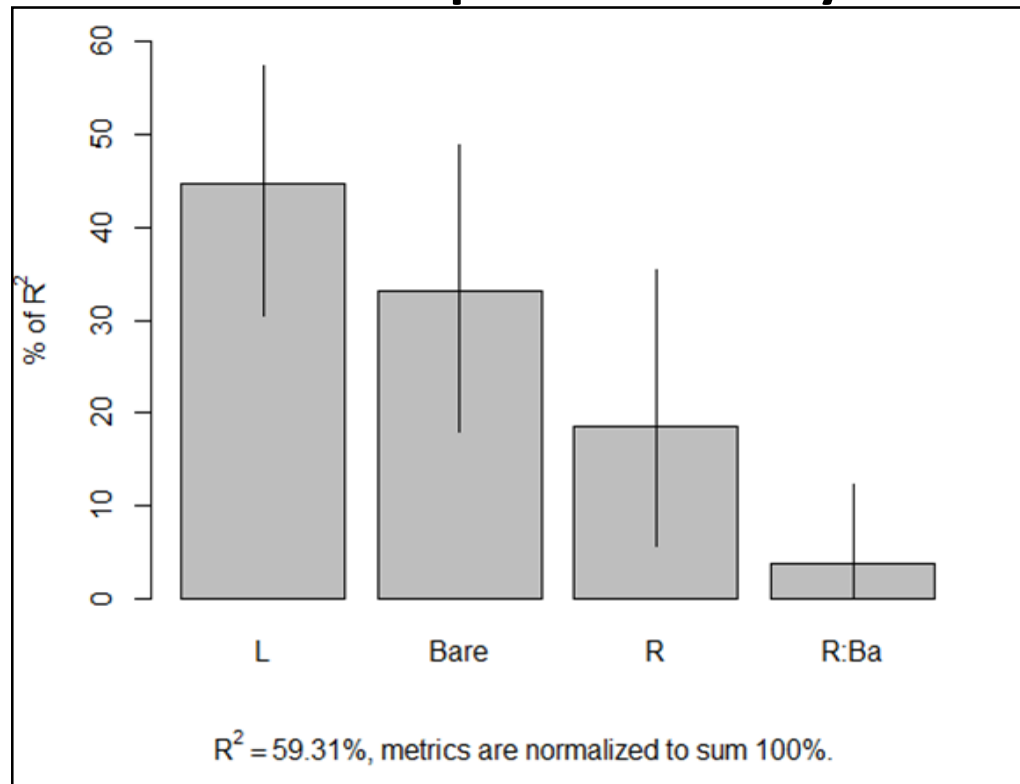$$y = 0.0714*X_1 + 0.0341*X_2 - 0.0044*X_3 + 0.0015*X_1{:}X_3$$

Sediment   **Precipitation**   **Approach length**   **Bare soil**   **Rain, bare soil interaction**

Relative importance analysis

$R^2 = 59.31\%$, metrics are normalized to sum 100%.

Research objectives revisited

- Sediment delivery rates from reopening legacy roads: **34 to 287 Mg ha^{-1} year^{-1}**

- Sediment delivery rates from existing gravel approaches: **10 to 16 Mg ha^{-1} year^{-1}**

- Important road characteristics: **Approach length, bare soil percentage, rainfall amount, and the interaction between bare soil and rainfall amount**

Application of findings

- Legacy roads may require additional measures to minimize water quality problems, especially if road approaches are steep, bare, and have inadequate water control.

- Findings support contemporary BMP recommendations to:
  - gravel road segments to the top of the approach that is contributing sediment to the stream
  - redistribute stormwater runoff from the road surface at least 7.6 m before the stream crossing

Rainfall Simulation Methods

Bare treatment

25 – 50% coverage

9.8-m gravel

50 – 100% coverage

19.6-m gravel

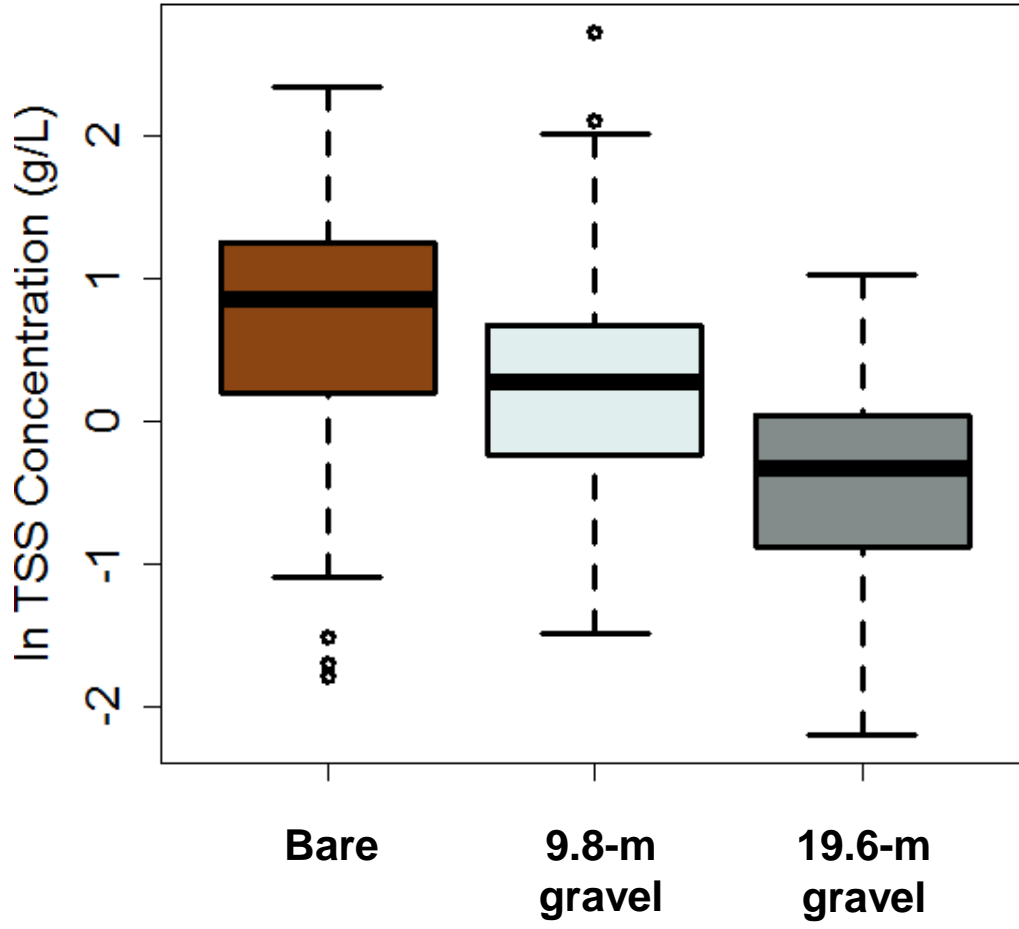Wedge type and automatic tipping bucket rain gauges

Open-top box culvert

1" X 18" cutthroat flume and ISCO stormwater sampler

Results

- Simulated rainfall events had recurrence intervals of < 1 to 5 years for Critz, VA. Surface runoff was commonly generated within the first five minutes of the onset of rainfall.

- Gravel application reduced TSS concentration.

Cost effectiveness of gravel

Median TSS concentration (g L^{-1}) by treatment

- Bare treatment (2.34 g L^{-1}) was 1.8X greater than gravel 1 (1.32 g L^{-1}) and 3.3X greater than gravel 2 (0.72 g L^{-1})

Cost for 3 in. gravel @ $25/ton

- 32 ft. X 10 ft. X 0.25 ft. X 100 lbs./ft^3 X 1 ton/2000 lbs. X $25/ton = $100
- $100/32 ft. = **$3.13/ft.**

Conclusions

Legacy roads and associated stream crossings have the potential to deliver significant quantities of sediment to streams if the roads are not properly closed or maintained.

Corrective best management practices (BMPs), such as gravel, can minimize the sediment contributions of stream crossing approaches.

Judicious BMP implementation can reduce sediment inputs to streams and strike a balance between sediment reduction efficacy and BMP implementation cost.

Road slope lengths are difficult to correct after road construction, so careful road design is an important BMP.

Questions?