# Innovative Slide Repair Techniques

## A Guidebook for Missouri and Beyond

**Michael Lambert, P.E.**
**Shannon & Wilson, Inc**

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# Credit & Disclaimer

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# Outline

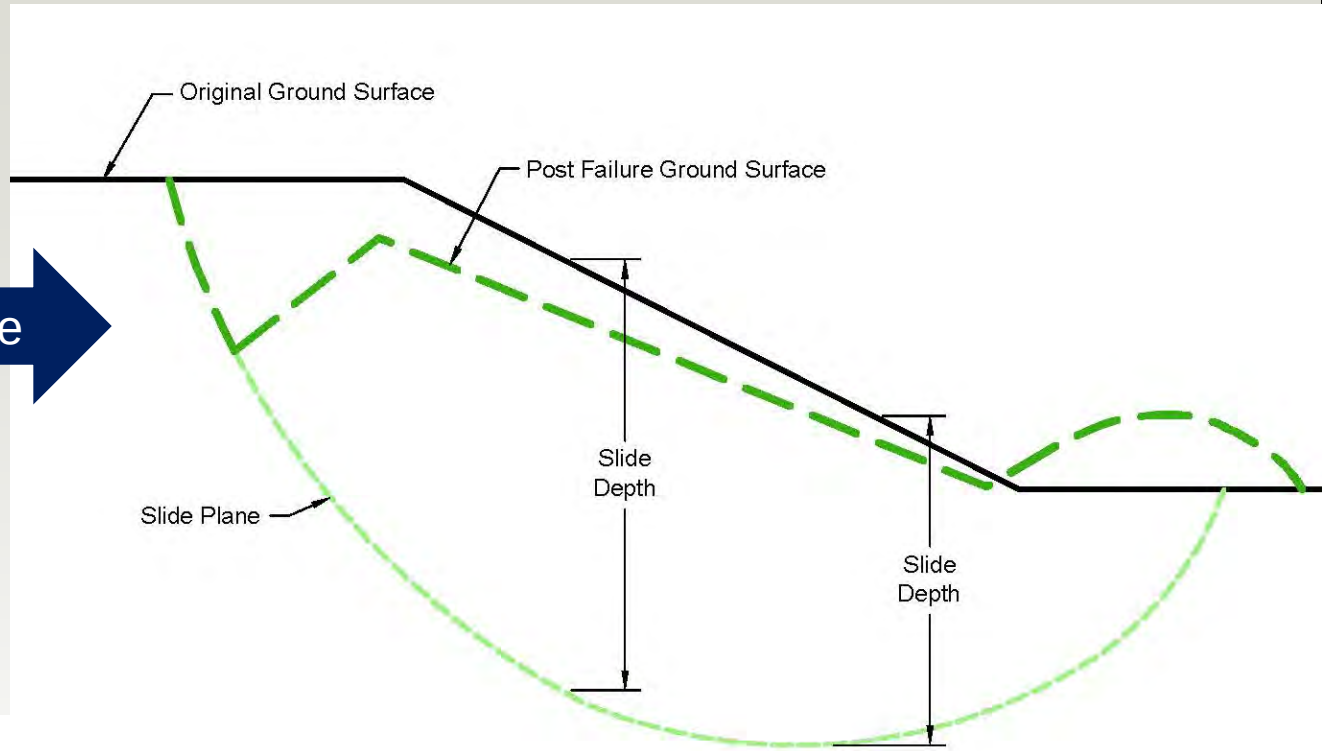
- Brief review of stability terms
- Goal of the guidebook
- Discussion of selected options included in the guidebook
- Summary

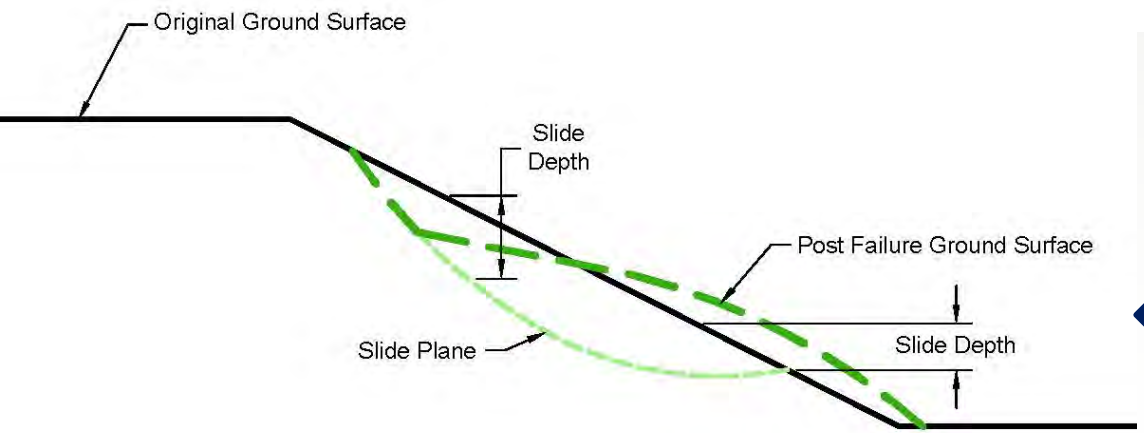
# Review of Soil Slope Instability

- Different Shapes
  - Falls, topples, flows, spreads, slides, and combinations
- Shallow or Deep Seated
  - Shallow < 10 feet deep
  - Deep > 10 feet
- Circular or Wedge (non-circular) Shaped

# Typical Circular Slides

Deep Slide




Shallow Slide

# Cause of Slides

- Slides occur when driving forces are greater than resisting forces.
- Driving or resisting forces change when:
  - Geometry changes (cut at toe or fill on top)
  - Water level increases
  - Weight added to top of slope
- Loss of vegetation

# Possible Repair Options Considered for the Guidebook

- Aggregate Drains
- Horizontal Drains
- Tire (Tyre) Bales
- Expanded Polystyrene Block Geofoam (EPS)
- Pin Piles/Micro Piles
- Soil Nails
- Rock/Soil Buttress
- Compaction Grouting
- Rammed Aggregate Piers & Stone Columns
- Soil Mixing
- Walls
  - Tied-Back Secant or Solider Pile
  - MSE
- Lime/Cement Injection

# Guidebook Goal

Document with step-by-step implementation instructions for simple to moderately complex repair methodologies.  Focused on methods that do not require extensive site investigation, testing, and analysis.

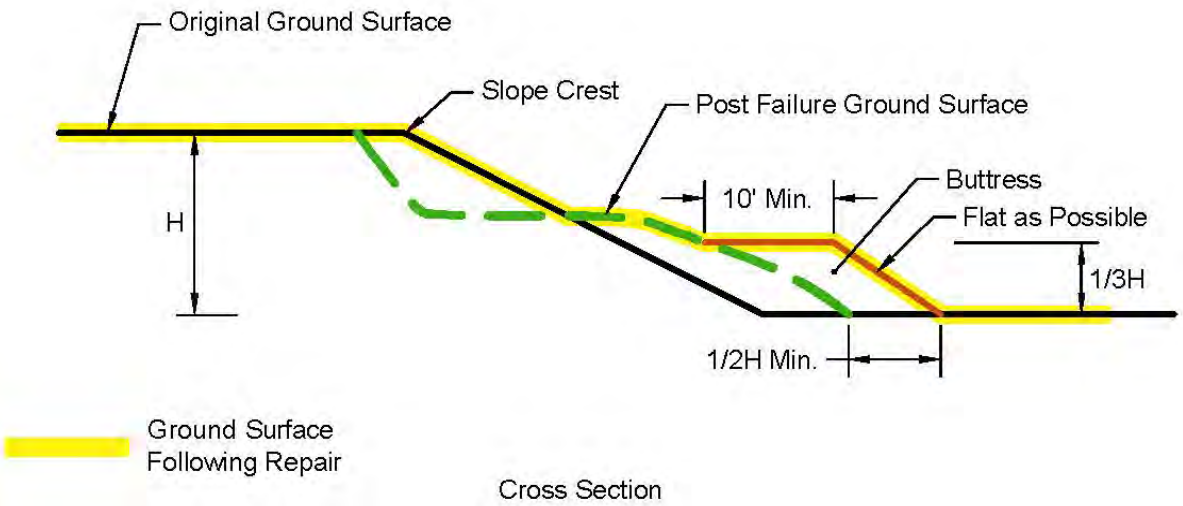
# Guidebook
# Included Repair Methods

- Rock/Soil Buttress
- Pin Pile and Micropile
- Tire Bale and Shredded Tire
- Polystyrene Block Geofoam
- Rammed Aggregate Piers and Stone Columns
- Aggregate Drain
- Horizontal Drain
- Mechanically Stabilized Earth (Wall)

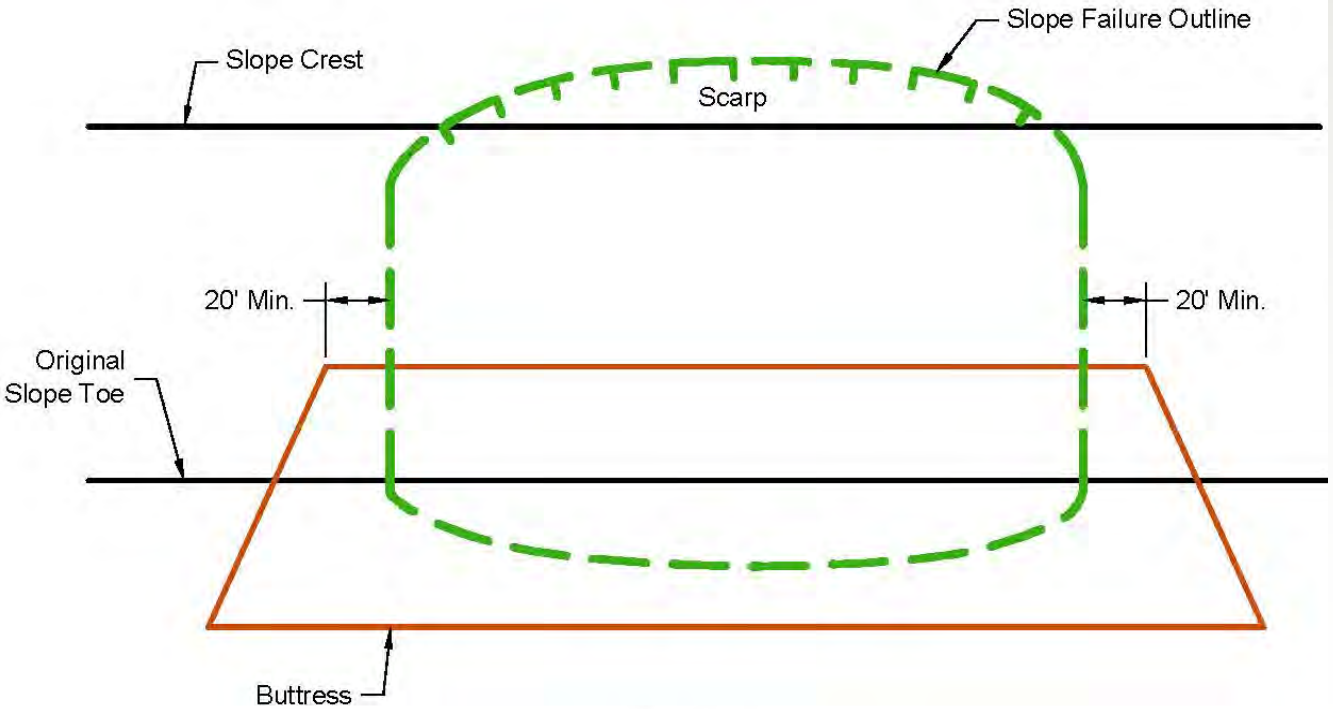
# Rock/Soil Buttress Repairs

- Consists of adding weight to the lower portion of the slide.
- Deep or Shallow Slides
- Can be completed w/o design
- Quick to start, no specialized equipment, low quality material can be used
- Large quantity of material required, toe access required, additional right-of-way may be required

# Rock/Soil Buttress Repairs




Cross Section



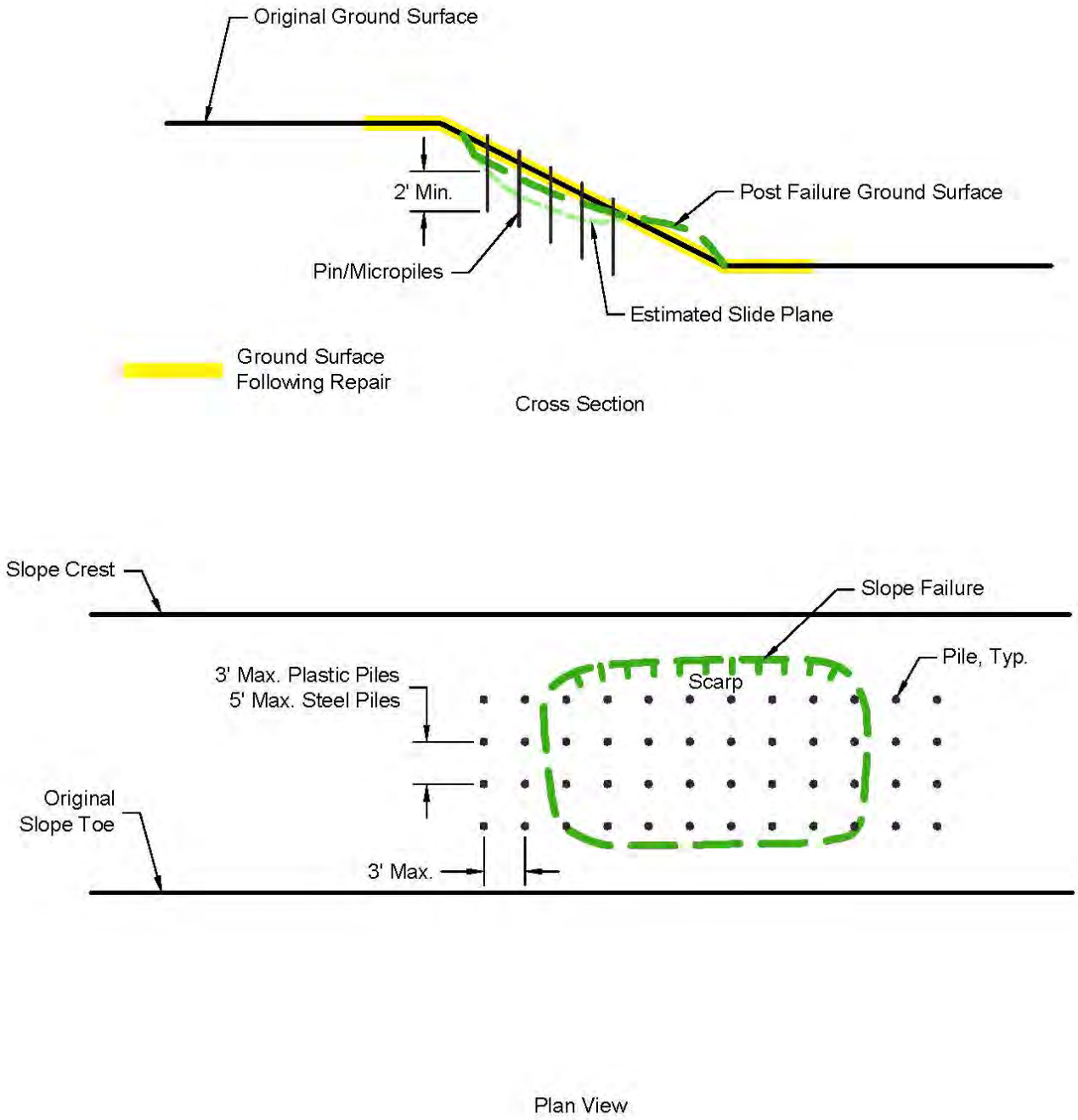

Plan View

# Rock Buttress

# Pin Pile and Micropile Repair

- Increases resistance to sliding
- Shallow Slides, ~5 ft. for plastic and unreinforced grout piles and ~10 ft. for steel and reinforced grout piles
- Can be completed w/o design, design is recommended
- Limited slope disturbance and required material, no excavation
- Specialized equipment, relatively expensive material, material may be hard to locate quickly, if slide depth is underestimated, no improvement

# Pin Pile & Micropile Repairs



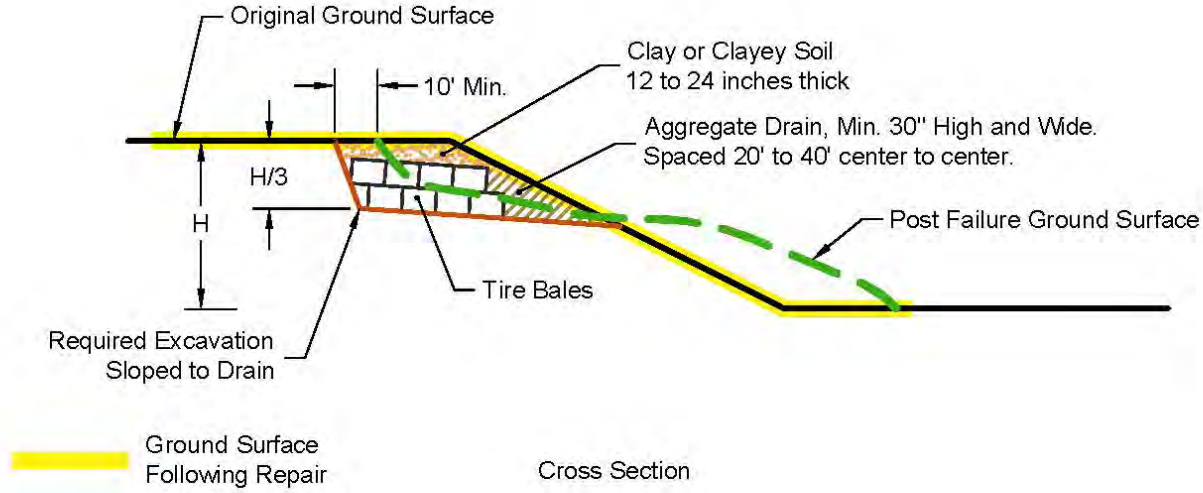
# Steel Pin Piles

# Steel Micropiles

# Tire Bale & Shredded Tire Repair

- Reduces forces driving the slide, tire bales may also increase drainage and strength
- Deep or Shallow Slides
- Can be completed w/o design
- No specialized equipment
- Material may be hard to locate quickly, unfamiliar material, small chance of internal combustion with shredded tires

# Tire Bale & Shredded Tire Repairs

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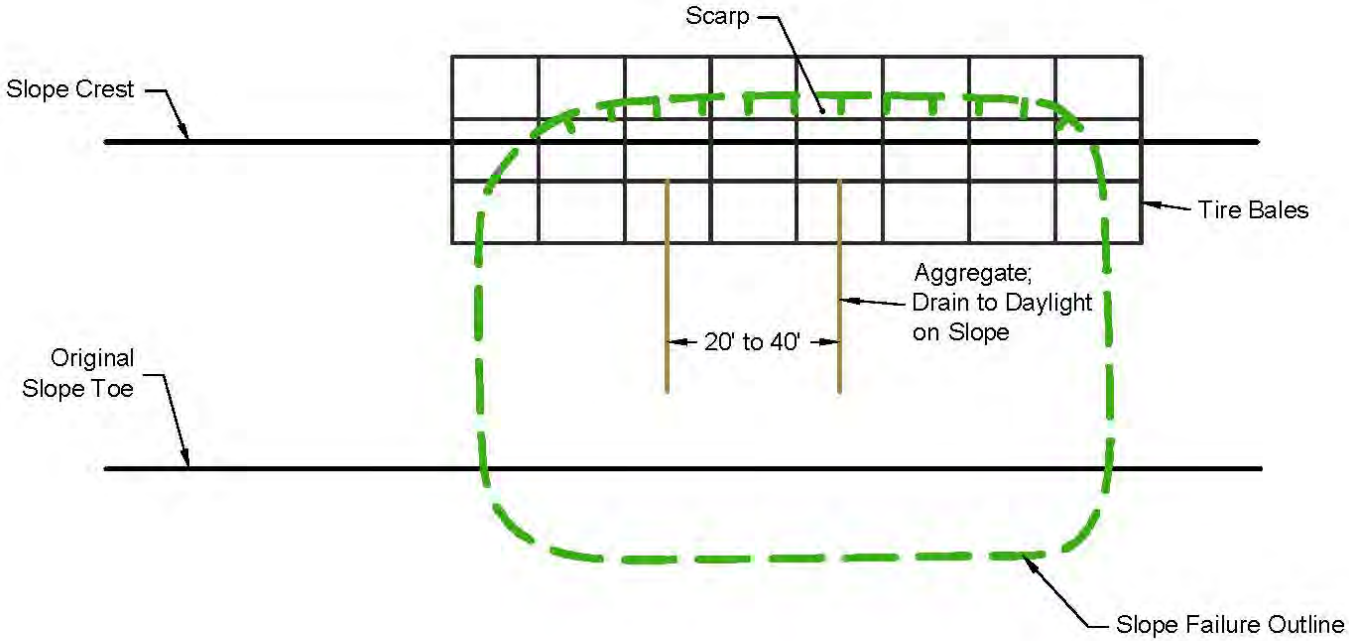



Plan View

# Example of Tire Bales

Photo from Eagle International,
www.eagle-equipment.com

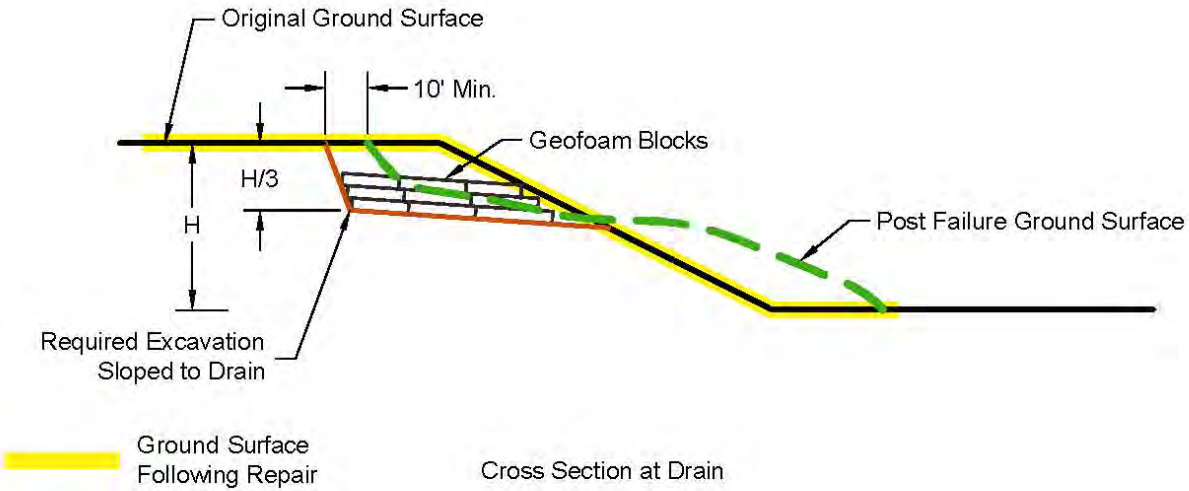
# Stacked Tire Bales

Photo from www.scrapmonster.com

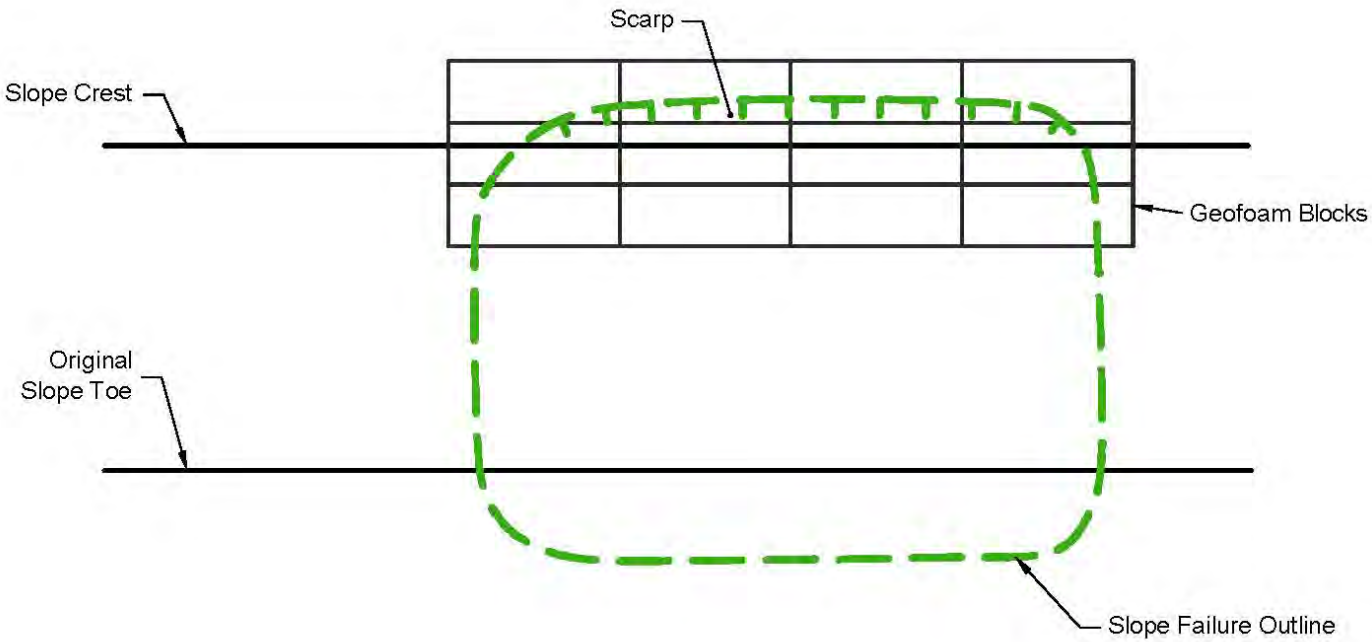
# Polystyrene Block Geofoam (EPS) Repair

- Reduces forces driving the slide
- Deep or Shallow Slides
- Can be completed w/o design; however, design recommended
- No specialized equipment
- Material may be hard to locate quickly, unfamiliar material, high material costs
- Blocks can float

# Polystyrene Block Geofoam Repairs




Cross Section at Drain



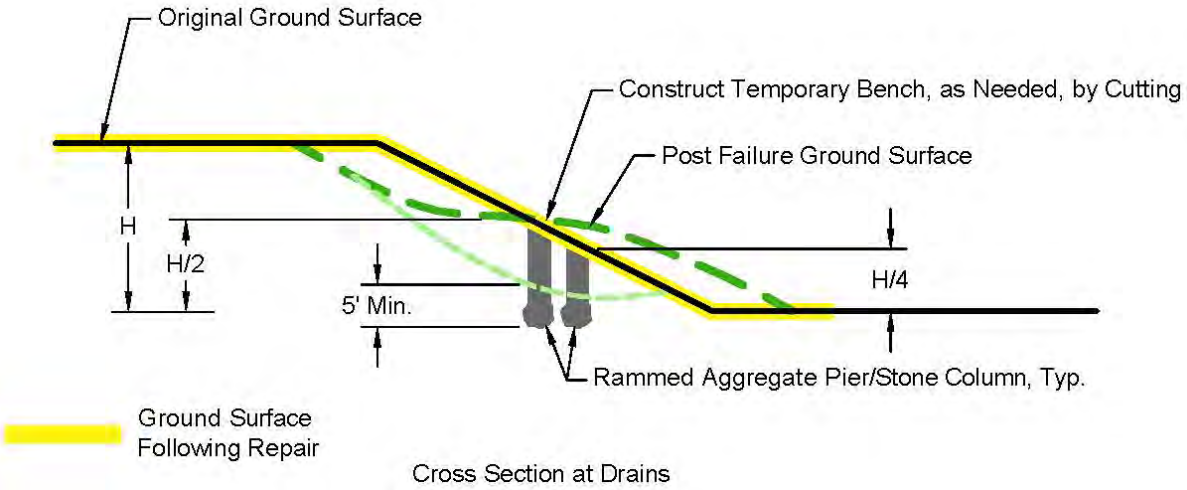

Plan View

# EPS Blocks placed as lightweight fill

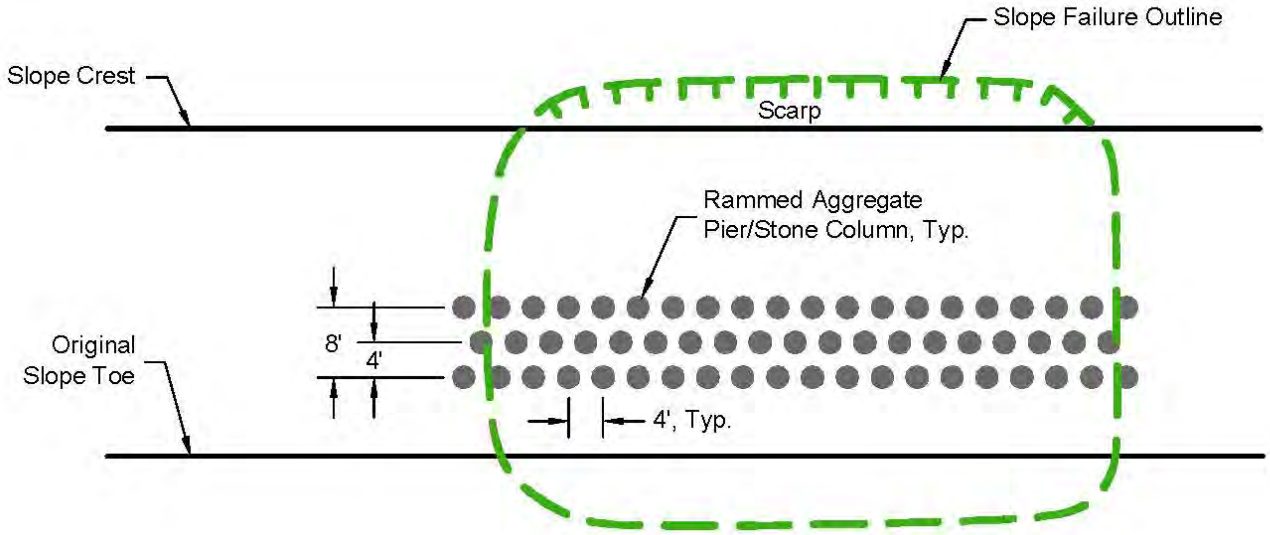
# Rammed Aggregate Piers & Stone Column Repair

- Increases strength and effective stress along slide plane
- Deep or Shallow Slides
- Can be completed w/o design; however, design recommended
- Limited site disturbance and quick installation
- Specialized equipment and personnel
- If slide depth is underestimated, no improvement

# Rammed Aggregate Piers & Stone Column Repairs




Cross Section at Drains




Plan View

# Geopier Equipment


Photo courtesy of Geopier®

# Summary & Questions

- Many options available for slide repairs
- Professional geotechnical input always valuable
- Without site-specific designs, buttress and aggregate drains are expected to have the highest likelihood of success for lower costs
- Missouri Guidebook available: http://library.modot.mo.gov/RDT/reports/TRyy1104/cmr13005.pdf
- mtl@shanwil.com

# Typical Deep Circular Slide

# Typical Deep Circular Slide

# Typical Flow Slide (Shallow Slide)

# Title for this slide?

# Rock Buttress

# Completed Soil Buttress

# Aggregate Drain

# Aggregate Drain

# Conventional Horizontal Drains

# Example of Tire Bales

Photo from Eagle International,
www.eagle-equipment.com

# Stacked Tire Bales

Photo from www.scrapmonster.com

# EPS Blocks placed as lightweight fill

# EPS Blocks placed as lightweight fill

# Stone Columns


# Geogrid Installation

# Geogrid and Wall Facing

# Questions?

mtl@shanwil.com

# MoDOT Scope of Work

- Literature Review
- Guidebook
- Presentation of Results to MoDOT
- Final Project Report
  - http://library.modot.mo.gov/RDT/reports/TRyy1104/cmr13005.pdf

# All Repairs Do One or More of the Following

- Decrease driving forces
- Increase resisting forces

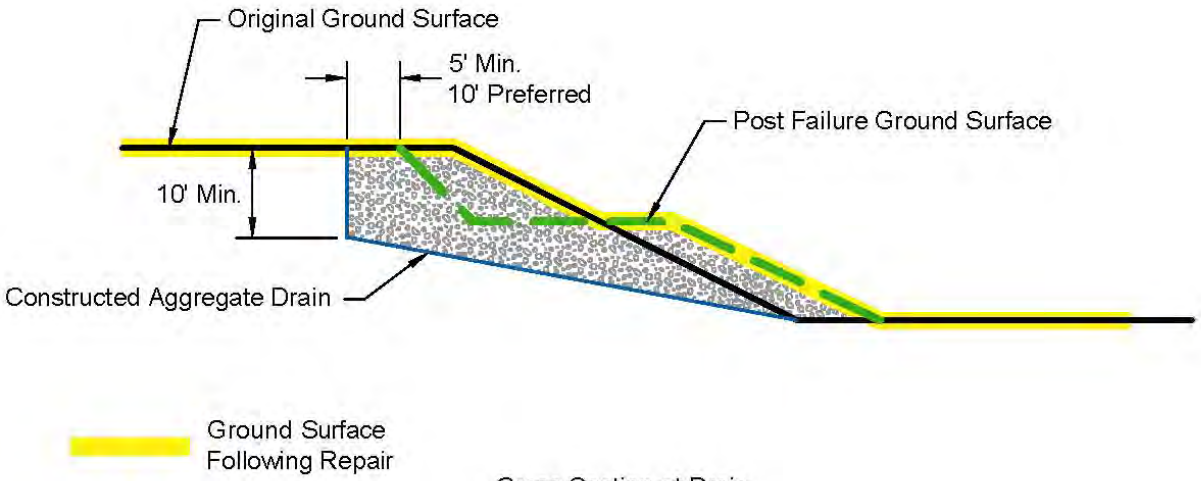
# Options that Decrease Driving Forces

- Aggregate Drains
- Horizontal Drains
- Tire (Tyre) Bales
- Expanded Polystyrene Block Geofoam (EPS)

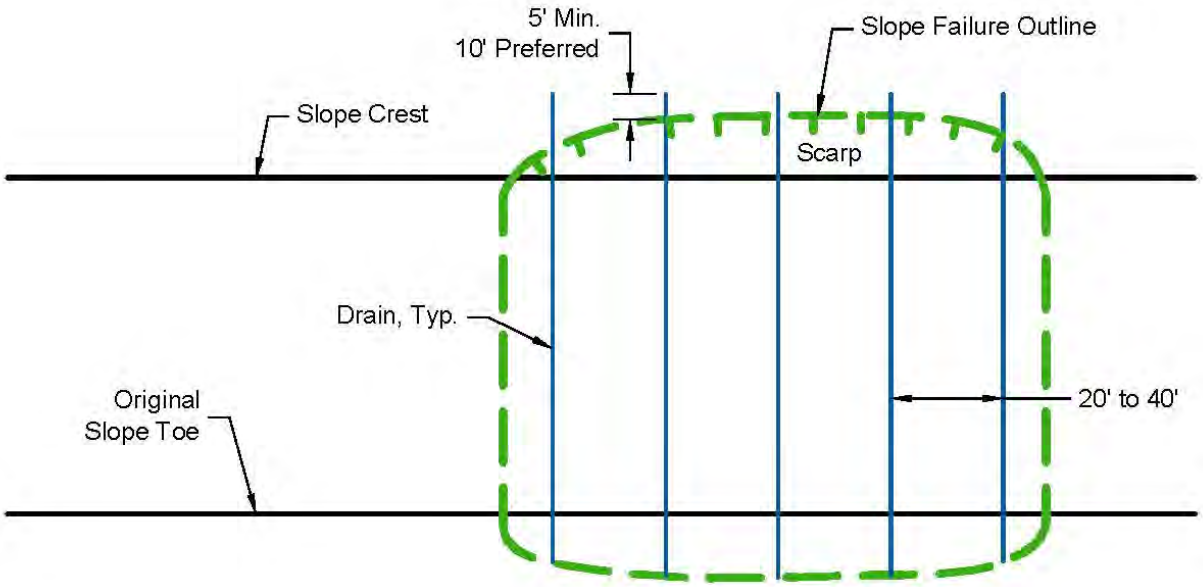
# Aggregate Drain Repair

- Decreases water (weight) & increases effective strength.
- Deep or Shallow slides
- Can be completed w/o design
- Quick to start, no specialized equipment
- If water not a significant factor in failure, minimal improvement

# Aggregate Drain Repairs




Cross Section at Drain

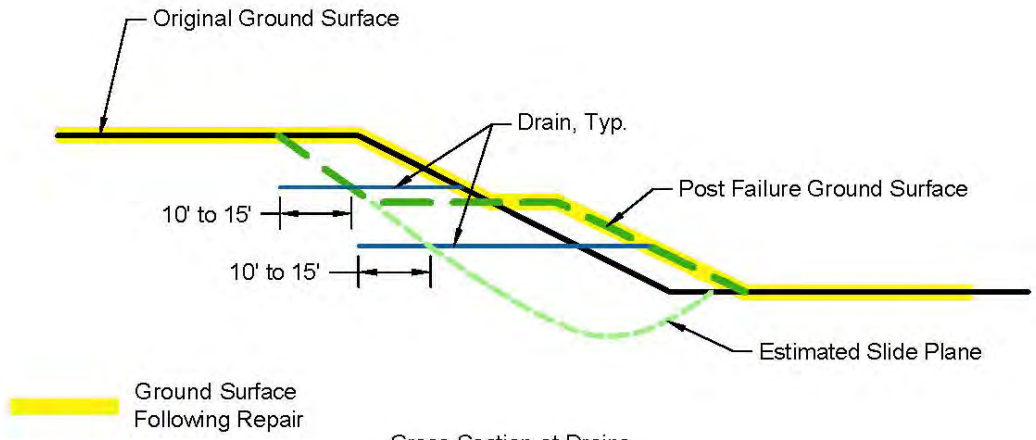



Plan View

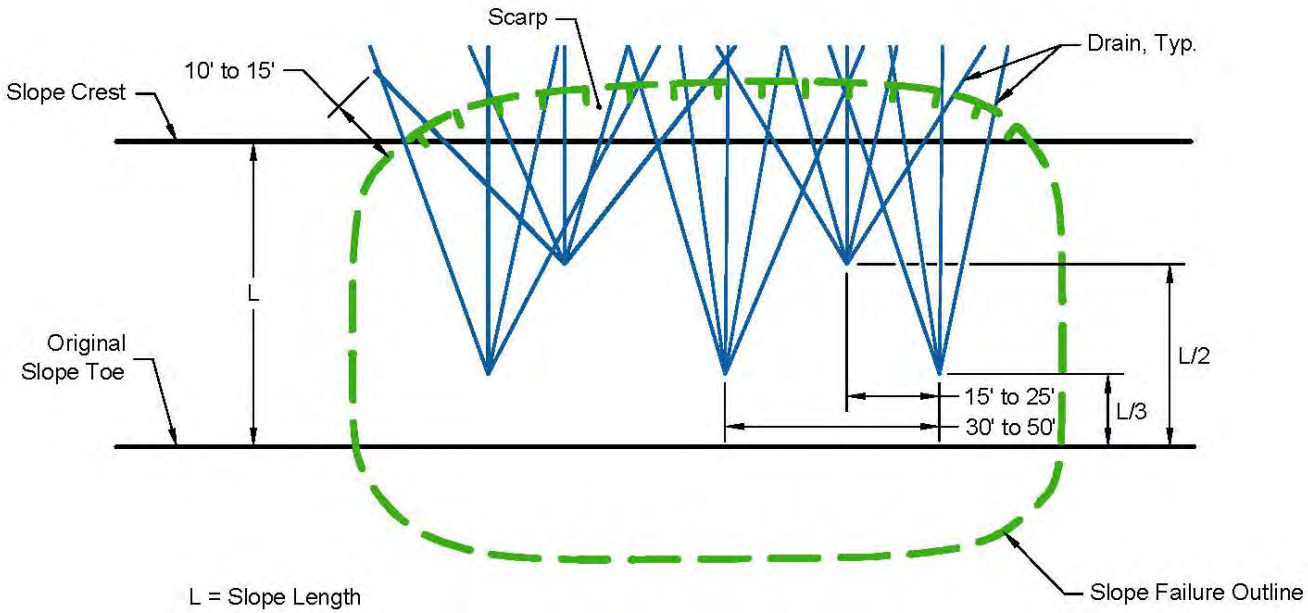
# Horizontal Drain Repair

- Decreases water (weight) & increases effective strength.
- Deep or Shallow slides
- Can be completed w/o design
- Less slope disturbance, less required material, deeper installations possible than aggregate drains
- If water not a significant factor in failure minimal improvement, specialized equipment and material, clogging, possible drain damage

# Horizontal Drain Repairs




Cross Section at Drains

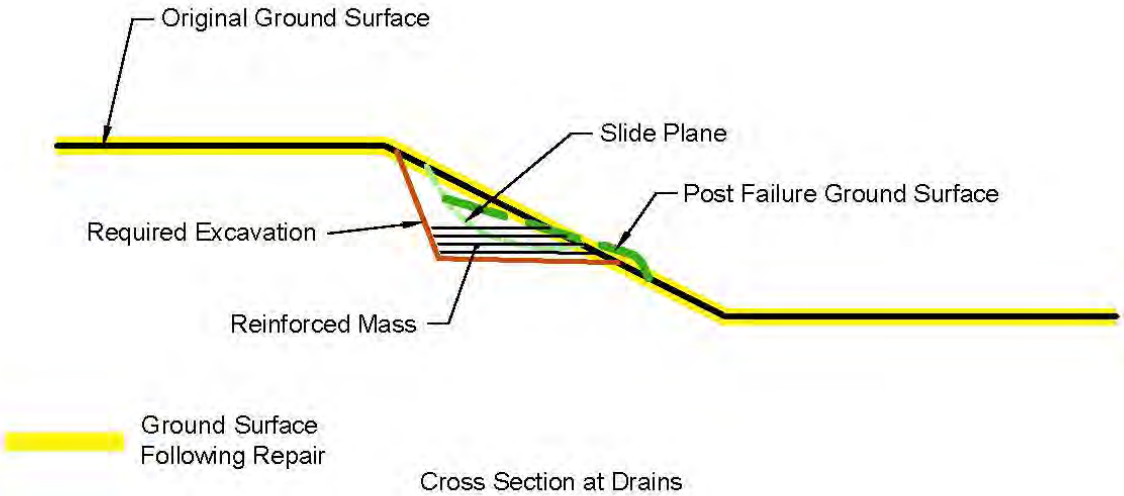



Plan View

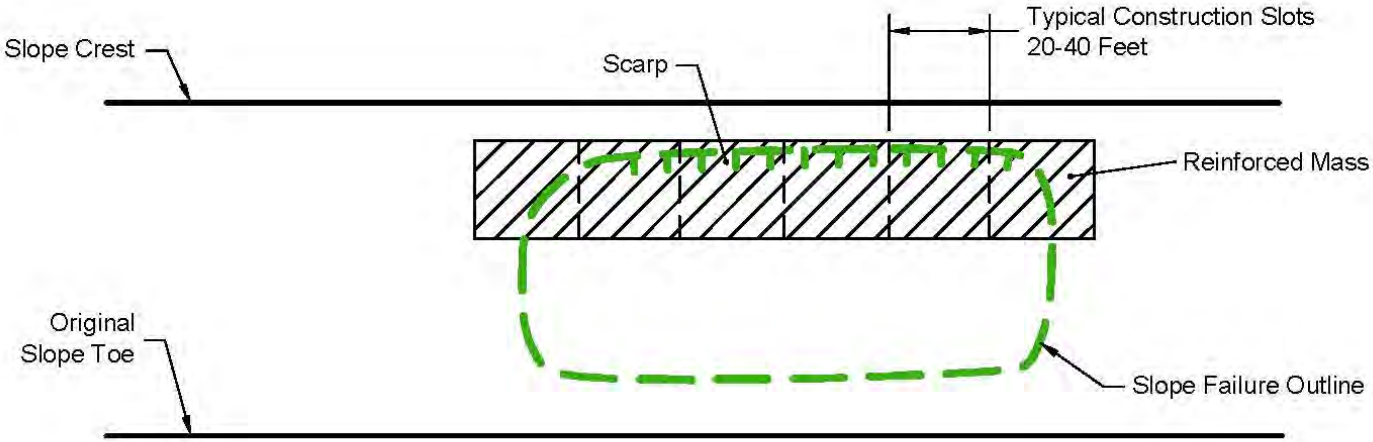
# MSE Wall Repair

- Increases strength and possibly weight in lower portion of slide
- Deep or Shallow Slides
- Site specific design required
- High degree of success, materials generally available
- Design required, significant excavation, excavation in slots required that may lead to additional movement

# Mechanically Stabilized Earth (Wall) Repairs




Cross Section at Drains




Plan View

# Who is Shannon & Wilson?

- 12 offices in 8 states
- Employee-owned
- ~280 employees
- Founded in 1954 in Seattle by Bill Shannon & Stan Wilson

# Who is Shannon & Wilson?

- Geosciences Consulting Firm
  - Geotechnical
  - Environmental
  - Natural Resources
  - Construction

# Research Objective

Soil slides often require immediate action to keep traffic moving safely. This study will focus on developing newer (innovative) approaches to evaluate slope failures and provide cost-effective repair and mitigation techniques. Typically slides are repaired by excavating the slide material and then backfilling with more stable material. However, MoDOT is looking for the researcher to review newer more innovative techniques that have been deployed nationally by other State Departments of Transportation, Geotechnical journals, Geotechnical contractors and any organization that is responsible for the repair of landslides. The goal is to find repairs that provide for long-term stabilization, but that are more cost effective than the typical excavation method. The research is to develop a listing and description of these innovative slope repair techniques. The study shall provide MoDOT with descriptions of when these innovative techniques could be deployed and what are the resources, materials, equipment and personnel needs required to accomplish such repairs.

# Literature Review

Goals

- Identify repair techniques meeting research objectives
  - Classic Literature Search
  - Specialty Contractor Interviews
- Group each technique
  - Appropriate
  - May Be Appropriate
  - Not Appropriate

# Literature Review
# Classic Literature Search

- Performed by Ms. Judy Bloch (S&W Staff Librarian)
- Total of 34 article/study abstracts published/underway since Jan. 2005 identified
- 11 articles reviewed in detail

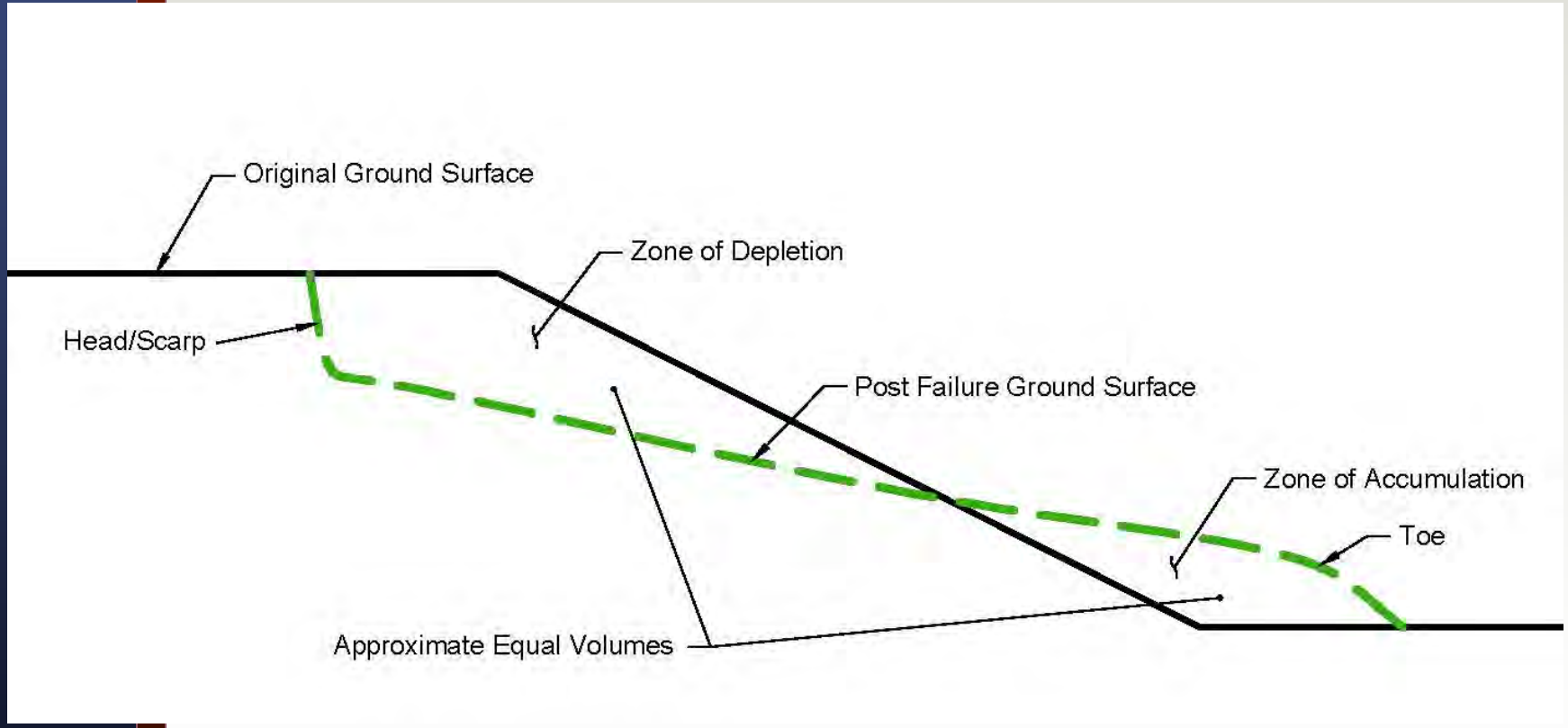
# Literature Review
# Specialty Contractor Interviews

- Mr. Matt Caskey of Geopier Foundation Company
- Mr. Jeff Hill of Hayward Baker Construction

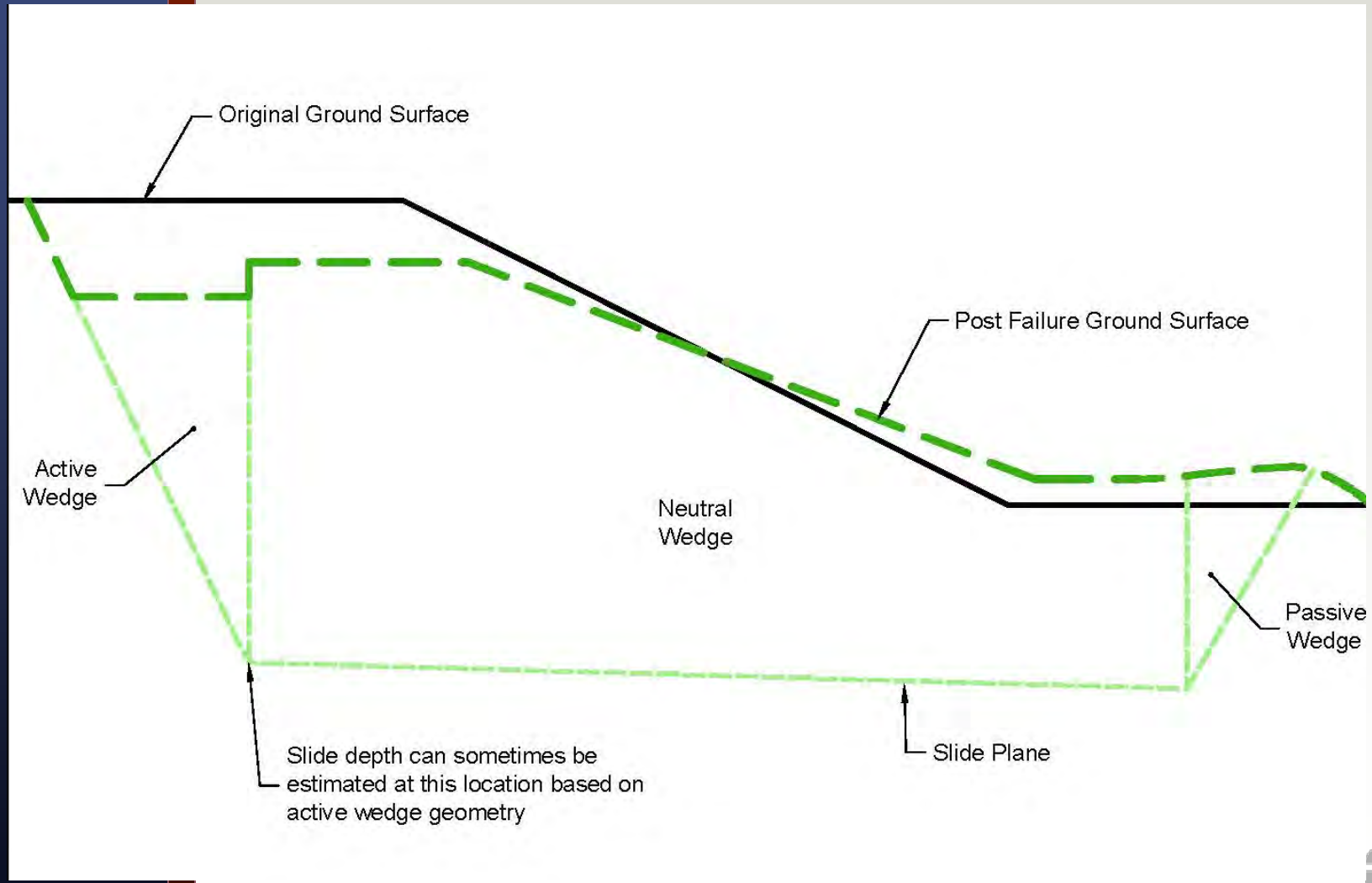
# Slide Shapes

- Falls and Topples are most common in rock and uncommon in soil.
- Flows and Spreads tend to be very shallow and are often fast moving.
- Generic slides are the most common in soil in Missouri.

# Typical Slide



# Typical Wedge Failure



# Appropriate Methods for MoDOT

- Pin Piles/ Micropiles
- Soil Nails
- Aggregate Drains
- Rock/Soil Buttress
- Tire (Tyre) Bales
- Expanded Polystyrene Block Geofoam (EPS)
- Compaction Grouting
- Rammed Aggregate Piers & Stone Columns
- Soil Mixing

# May be Appropriate for MoDOT

- Horizontal Drains
- Drilled Shafts
- Tied-Back Secant Wall or Soldier Pile and Lagging Wall
- Mechanically Stabilized Earth (MSE) Walls
- Lime/Cement Injection

# Slide Repair Activities to Avoid

- Loading or stockpiling material along the upper portion of the slope
- Unloading or excavating the lower portion of the slope
- Directing water to the failure area
- Removing vegetation
- Installation of irrigation