# Stability Thresholds and Performance Standards for Stream Restoration Materials and Methods


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# Stability Thresholds for Stream Restoration Materials

*by Craig Fischenich*[1]

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- Description of primary hydraulic and non-hydraulic factors influencing stream stability thresholds and erosion potential, with calculations
- Discussion and summary of permissible shear stress and velocity for selected channel boundary materials
- Iterative procedure for determining hydraulic conditions, channel stability, erosion potential, threshold conditions and appropriate channel lining materials

Table 2. Permissible Shear and Velocity for Selected Lining Materials[1]

| Boundary Category | Boundary Type | Permissible Shear Stress (lb/sq ft) | Permissible Velocity (ft/sec) | Citation(s) |
|---|---|---|---|---|
| Soils | Fine colloidal sand | 0.02 - 0.03 | 1.5 | A |
| | Sandy loam (noncolloidal) | 0.03 - 0.04 | 1.75 | A |
| | Alluvial silt (noncolloidal) | 0.045 - 0.05 | 2 | A |
| | Silty loam (noncolloidal) | 0.045 - 0.05 | 1.75 – 2.25 | A |
| | Firm loam | 0.075 | 2.5 | A |
| | Fine gravels | 0.075 | 2.5 | A |
| | Stiff clay | 0.26 | 3 – 4.5 | A, F |
| | Alluvial silt (colloidal) | 0.26 | 3.75 | A |
| | Graded loam to cobbles | 0.38 | 3.75 | A |
| | Graded silts to cobbles | 0.43 | 4 | A |
| | Shales and hardpan | 0.67 | 6 | A |
| Gravel/Cobble | 1-in. | 0.33 | 2.5 – 5 | A |
| | 2-in. | 0.67 | 3 – 6 | A |
| | 6-in. | 2.0 | 4 – 7.5 | A |
| | 12-in. | 4.0 | 5.5 – 12 | A |
| Vegetation | Class A turf | 3.7 | 6 – 8 | E, N |
| | Class B turf | 2.1 | 4 - 7 | E, N |
| | Class C turf | 1.0 | 3.5 | E, N |
| | Long native grasses | 1.2 – 1.7 | 4 – 6 | G, H, L, N |
| | Short native and bunch grass | 0.7 - 0.95 | 3 – 4 | G, H, L, N |
| | Reed plantings | 0.1-0.6 | N/A | E, N |
| | Hardwood tree plantings | 0.41-2.5 | N/A | E, N |
| Temporary Degradable RECPs | Jute net | 0.45 | 1 – 2.5 | E, H, M |
| | Straw with net | 1.5 – 1.65 | 1 – 3 | E, H, M |
| | Coconut fiber with net | 2.25 | 3 – 4 | E, M |
| | Fiberglass roving | 2.00 | 2.5 – 7 | E, H, M |
| Non-Degradable RECPs | Unvegetated | 3.00 | 5 – 7 | E, G, M |
| | Partially established | 4.0-6.0 | 7.5 – 15 | E, G, M |
| | Fully vegetated | 8.00 | 8 – 21 | F, L, M |
| Riprap | 6 – in. $d_{50}$ | 2.5 | 5 – 10 | H |
| | 9 – in. $d_{50}$ | 3.8 | 7 – 11 | H |
| | 12 – in. $d_{50}$ | 5.1 | 10 – 13 | H |
| | 18 – in. $d_{50}$ | 7.6 | 12 – 16 | H |
| | 24 – in. $d_{50}$ | 10.1 | 14 – 18 | E |
| Soil Bioengineering | Wattles | 0.2 – 1.0 | 3 | C, I, J, N |
| | Reed fascine | 0.6-1.25 | 5 | E |
| | Coir roll | 3 - 5 | 8 | E, M, N |
| | Vegetated coir mat | 4 - 8 | 9.5 | E, M, N |
| | Live brush mattress (initial) | 0.4 – 4.1 | 4 | B, E, I |
| | Live brush mattress (grown) | 3.90-8.2 | 12 | B, C, E, I, N |
| | Brush layering (initial/grown) | 0.4 – 6.25 | 12 | E, I, N |
| | Live fascine | 1.25-3.10 | 6 – 8 | C, E, I, J |
| | Live willow stakes | 2.10-3.10 | 3 – 10 | E, N, O |
| Hard Surfacing | Gabions | 10 | 14 – 19 | D |
| | Concrete | 12.5 | >18 | H |

[1] Ranges of values generally reflect multiple sources of data or different testing conditions.

A. Chang, H.H. (1988).
B. Florineth. (1982)
C. Gerstgraser, C. (1998).
D. Goff, K. (1999).
E. Gray, D.H., and Sotir, R.B. (1996).
F. Julien, P.Y. (1995).
G. Kouwen, N.; Li, R. M.; and Simons, D.B., (1980).
H. Norman, J. N. (1975).
I. Schiechtl, H. M. and R. Stern. (1996).
J. Schoklitsch, A. (1937).
K. Sprague, C.J. (1999).
L. Temple, D.M. (1980).
M. TXDOT (1999)
N. Data from Author (2001)
O. USACE (1997).

- Step 1. Estimate Mean Hydraulic Conditions.
- Step 2. Estimate Local/Instantaneous Flow Conditions.
- Step 3. Determine Existing Stability.
- Step 4. Select Channel Lining Material.
- Step 5. Recompute Flow Values.
- Step 6. Confirm Lining Stability - Apply FS calculations for performance criteria

# How Has This Reference Been Used?

- NY, ID, CA, MN, NH, ME, Ontario and Australia, 2003-2008
- References to stream process to project design using full 6-step process
- Fishery enhancement, flood and watershed studies, hydroelectric projects, urban expansion and stormwater control
- Table itself reproduced at least four times

# What Has Changed Since 2001?

- Regulations updated – US EPA CWA, 2003 NPDES Phase II stormwater management
- New materials – woven HPTRMs, “eco-concrete”, ACBs, others…
- New installation methods, hybrid designs, riprap “systems”
- Additional data, especially field applications
- Recognition of additional factors influencing performance

# Does This Reference Need Updating?

- Single-variable testing, typically proprietary
- Typically initial values – little “aging” data
- Little field application testing data
- New materials and methods, particularly rolled erosion control products (RECP)
- Additional performance criteria beyond hydraulics
- Additional hard armoring techniques

# Updating Fischenich (2001)…

- New Materials, Methods and Stability Thresholds in all categories
- Erosion Control Technology Council (2008):
  - "Installation Guide for Rolled Erosion Control Products (RECPs) Including Mulch Control Nettings (MCNs), Open Weave Textiles (OWTs), Erosion Control Blankets (ECBs), and Turf Reinforcement Mats (TRMs)"

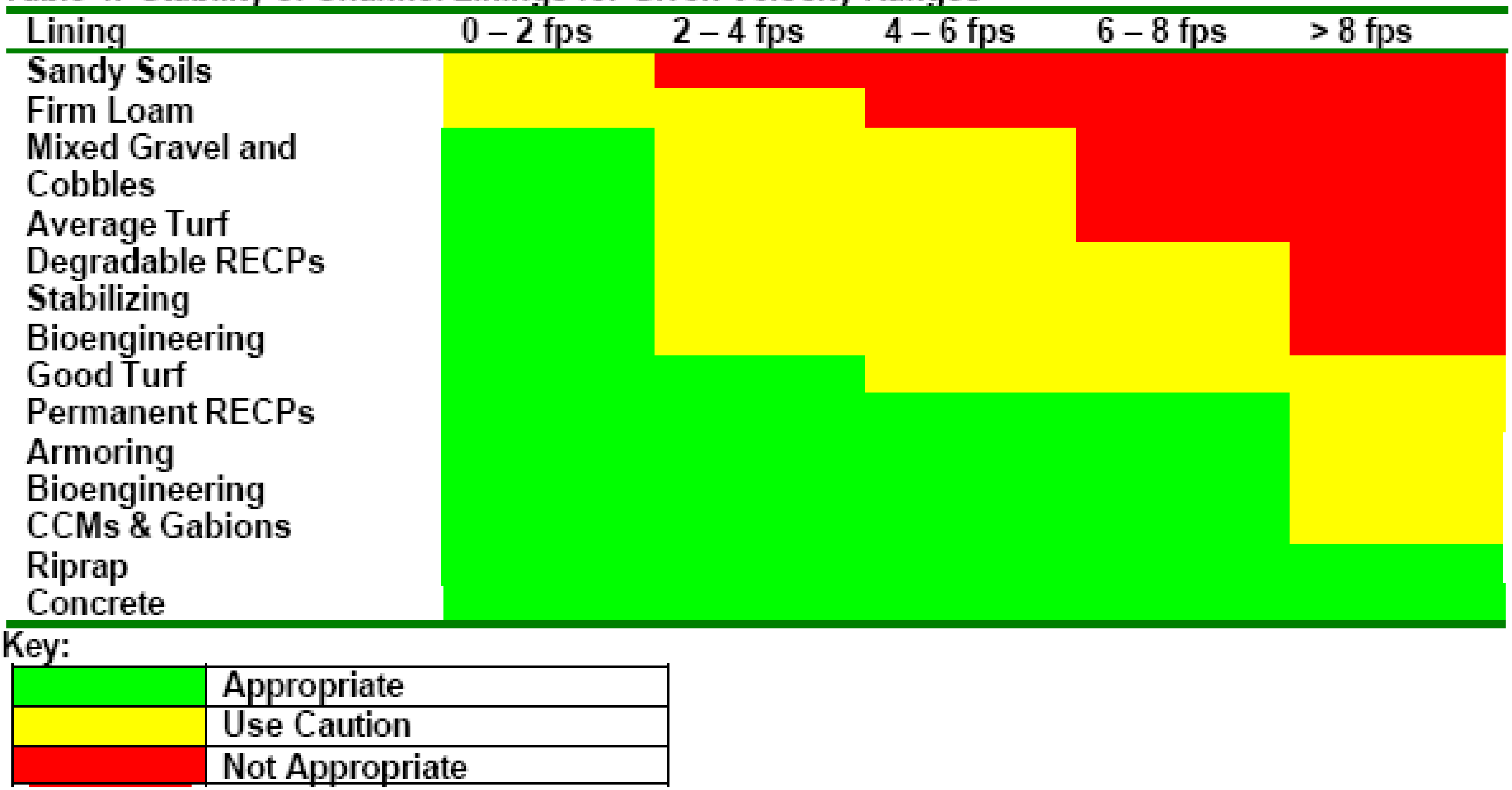
# Performance – Hydraulic Stresses

- Velocity and Shear Stress (tractive force)
  - Maximum permissible, critical, limiting
  - Still the most commonly used performance thresholds
- Stream Power
- Flow Duration
- Wave Action
- Overtopping

Colorado State University
Engineering Research Center
Dr. Chris Thornton

# Expand Data Ranges

Table 4. Stability of Channel Linings for Given Velocity Ranges



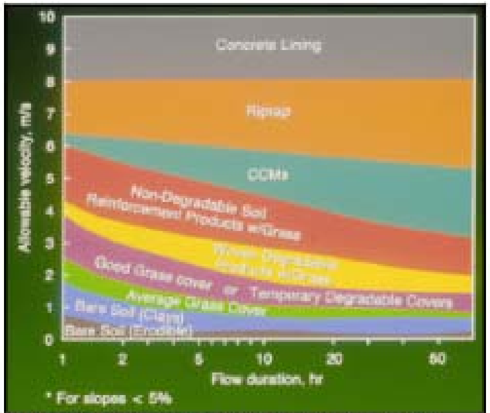



Figure 2. Erosion limits as a function of flow duration (from Fischenich and Allen (2000)).


Figure 3. Limiting values for bare and TRM protected soils (from Sprague (1999))

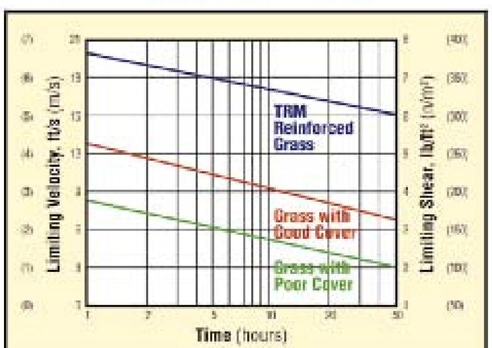
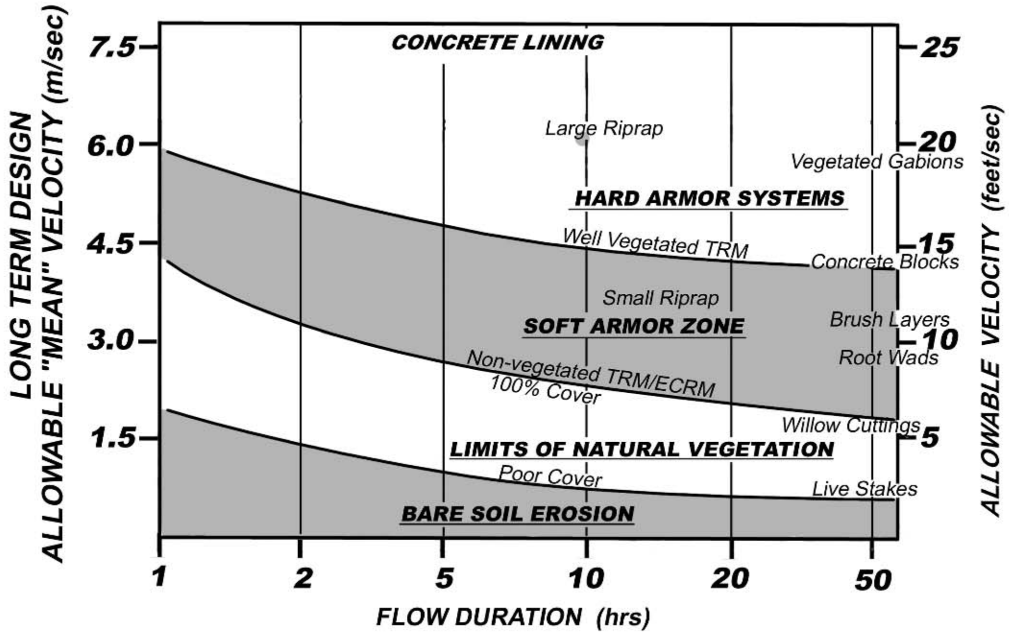



Figure 4. Limiting values for plain and TRM reinforced grass (from Sprague (1999))




*NOTES:*

1. ***Hard Armor -*** *includes Concrete, Riprap, Gabions, Concrete Blocks, etc.*
2. ***Soft Armor -*** *includes Turf Reinforcement Mats (**TRM**), Erosion Control Revegetation Mats (**ECRM**), Vegetated Geocells, and many Biotechnical Treatments.*
3. *Available data shows considerable variability in limit velocities.*

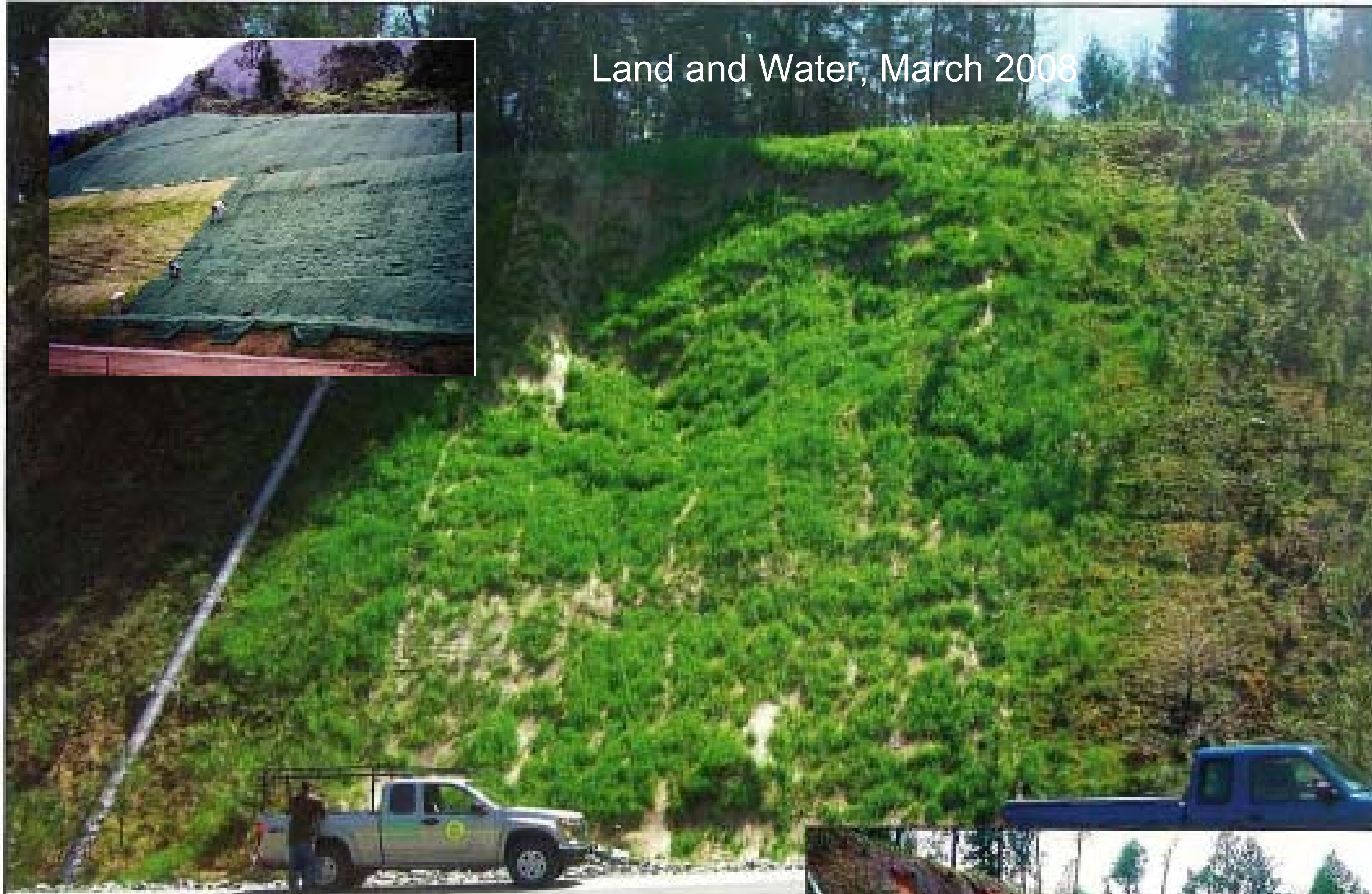
*Adapted from Thiesen (1992)*
*Used with permission of Synthetic Industries, Inc.; Fischenich and Allen (2000); McCullah and Gray (2005) (NCHRP 544)*

# ALLOWABLE VELOCITIES AND FLOW DURATION FOR VARIOUS EROSION AND BANK PROTECTION MEASURES

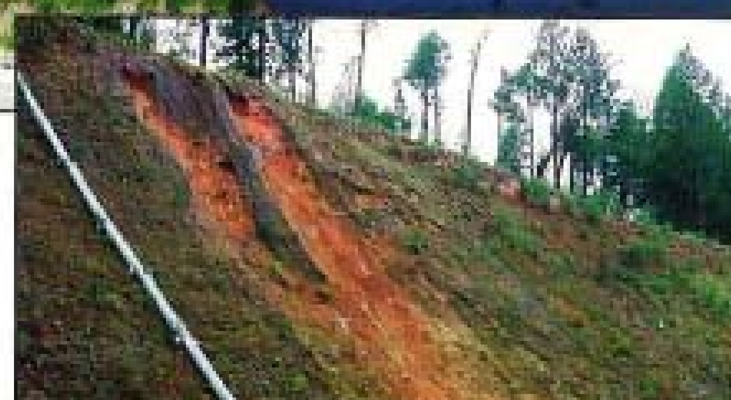
# Additional Performance Factors and Application Considerations

- Debris Loads
- Wetting/drying
- Temperature
- Traffic Loads
- UV Exposure
- Biological Activity
- Precipitation
- Environmental Considerations
- Geotechnical applications
- Chemical Stresses – Acidity, Corrosives, Salinity

M.H. Li and S. Khanna, 2008. Aging of rolled erosion control products for channel erosion control




**Above: After the HPTRM installation, the slope was hydroseeded with a native seed mix and a bonded fiber matrix product. Six months after installation, the slope has 80-90% vegetative cover. Inset: Erosion was prevalent on the 1:1 slope next to Highway 26 in Calaveras County, California.**



*by Brian Baker*

***DURING*** the heavy rainy season of

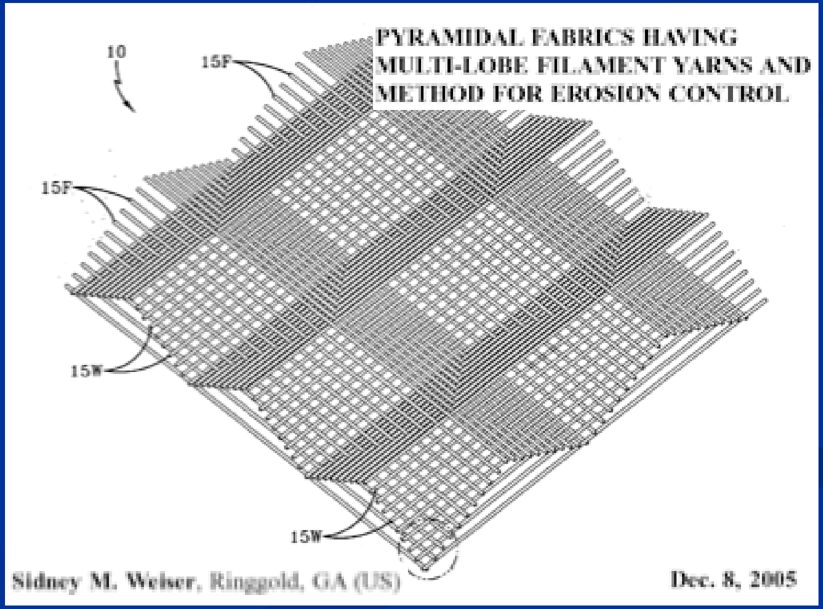
come throughout the repair. First, the failed slope is next to Highway 26, which meant

# Application – The Six+-Step Process for Selecting Lining Materials

- *Step 1. Estimate Mean Hydraulic Conditions.*
- *Step 2. Estimate Local/Instantaneous Flow Conditions.*
- *Step 3. Determine Existing Stability.*
- ***Step 3.5. Determine Additional Conditions Affecting Performance***
- *Step 4. Select Channel Lining Material.*
- *Step 5. Recompute Flow Values.*
- *Step 6. Confirm Lining Stability.*
  - *Apply FS calculations for **ALL** performance criteria*

- New Materials and Methods summaries
- New threshold data on current standards and properties
- New threshold data on new standards
- New data on used materials… actual performance in field conditions under combined stresses

Stitch-bonded polypropylene tested by Khanna (2005)

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# Thank You!


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