Channel Design

Channel Design - Introduction

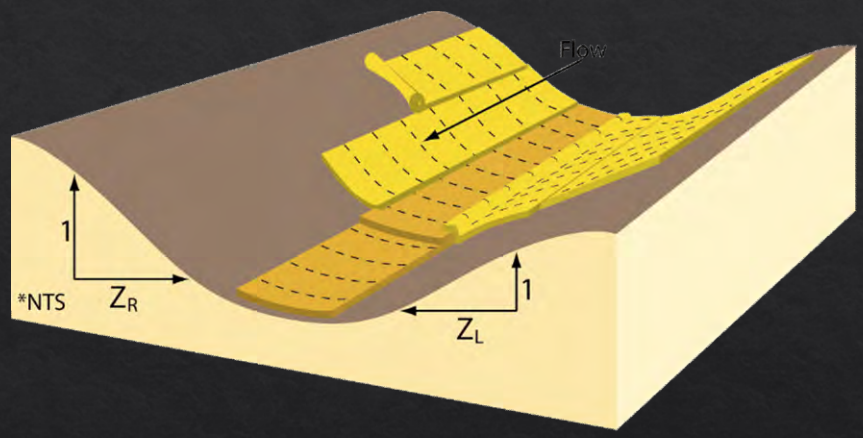
- Simple Case ->
  - Is Stability in Testing > Expected Field Conditions
  - Does not Account for Variability in On-Site Conditions
  - Can Lead to Under-Conservative Application
- Typical Hydraulic Design, HEC-RAS, Useful in Determining Hydraulic Forces, Not Stability

Channel Design - Introduction

- Regulated by Federal Highway Administration
- Hydraulic Engineering Circular (HEC) – 15, Highways in the River Environment
- Developed to Provide Method of Determining Suitable Products for Flexible Channel Lining
- Options for Many Types of Protection - Hybrid
- Utilizes Site Specific and Product Specific Data
- Heavily Reliant on Manufacturer’s Data, Maximum Permissible Shear Stress and Manning’s n
- Definition of Failure – 0.25 to 1.0 inches, CSLI

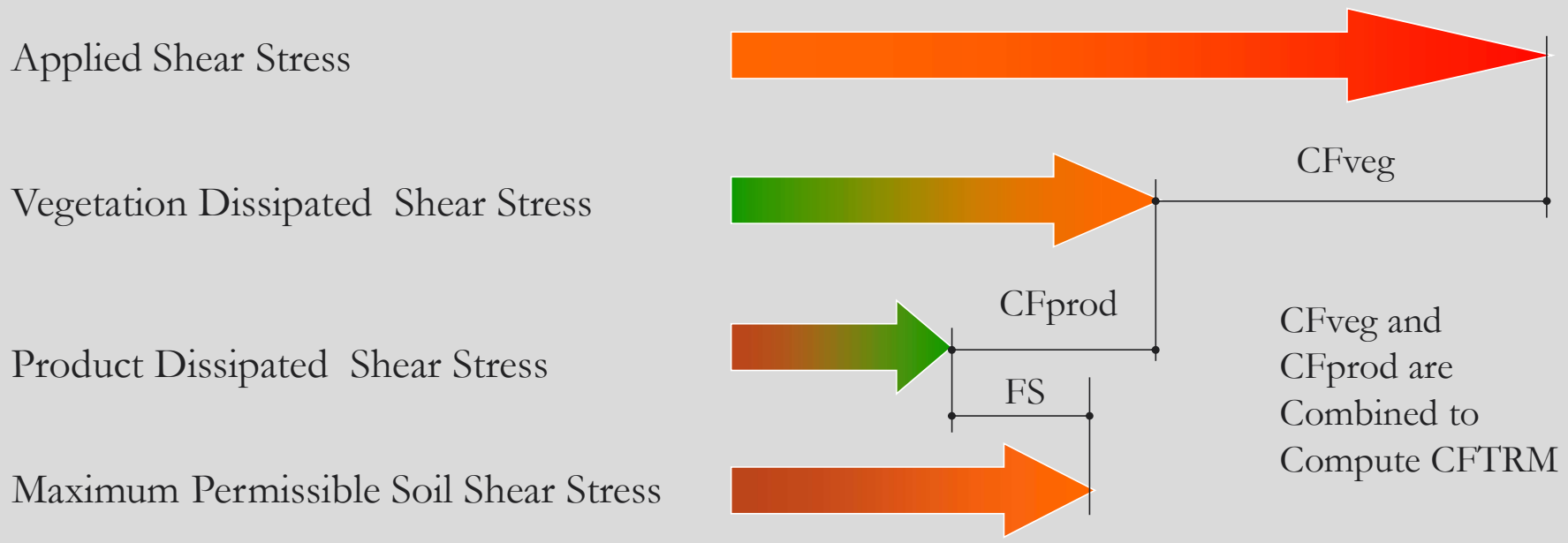
Channel Design - Introduction

- Relatively Complex
- Recently Updated
- Includes Vegetated and Unvegetated Conditions
- Iterative Procedure (Trial and Error)
- Dissipation of Shear Stress Computed Through Series of Cover Factors (C_f)



Channel Design

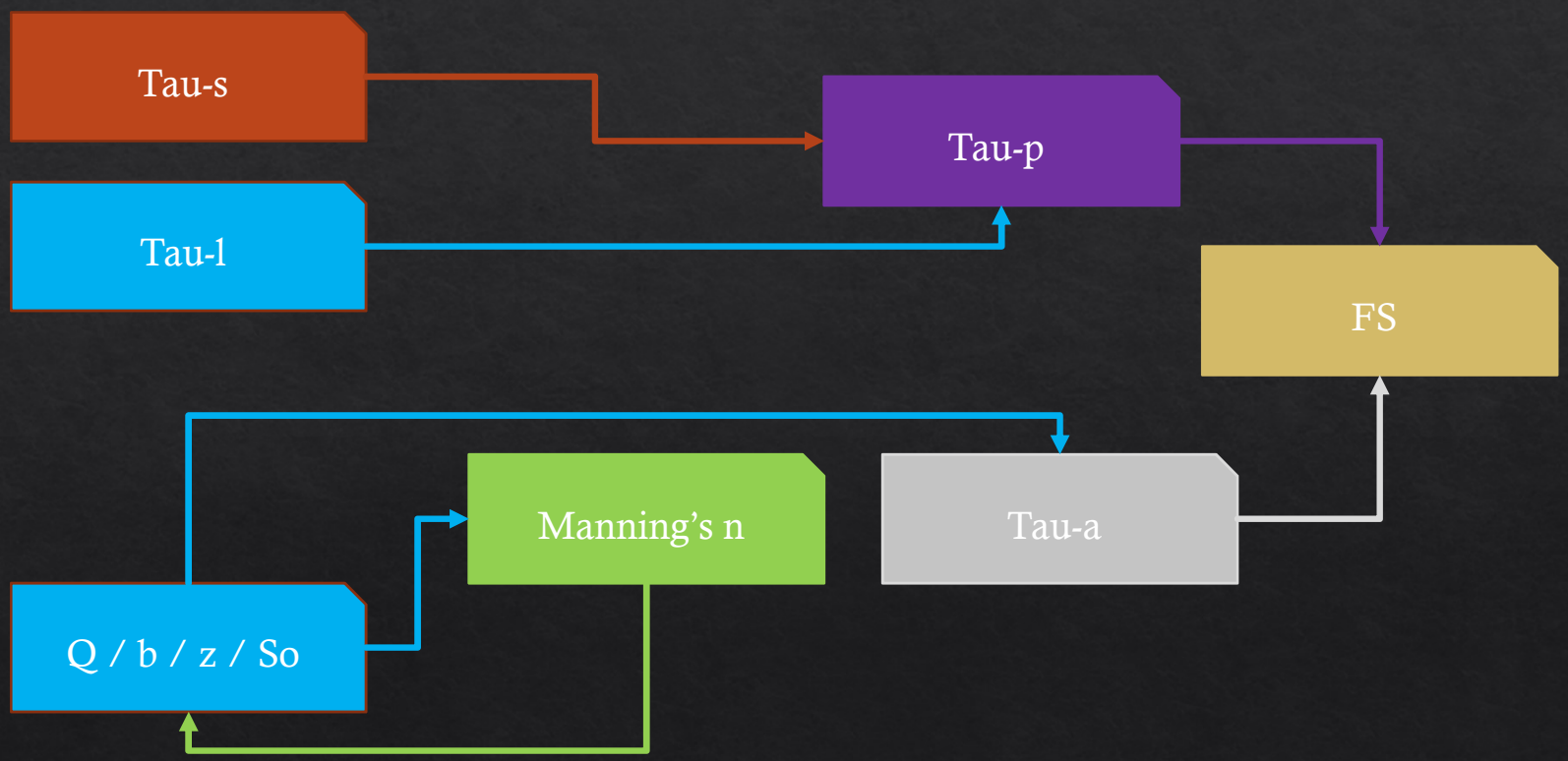
- Dissipation of Boundary Layer Shear



Channel Design – Unvegetated Procedure Specifics

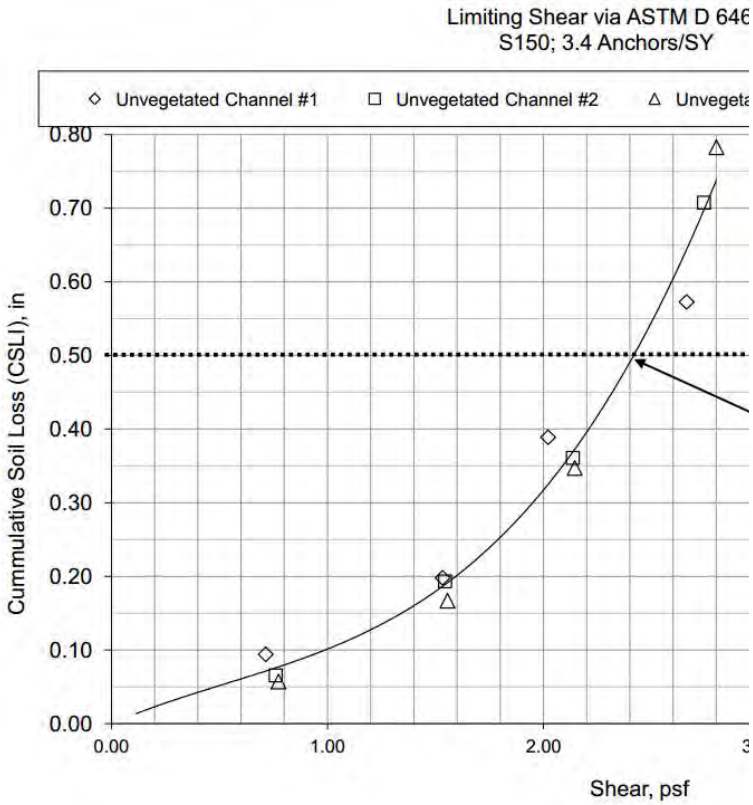
1. Compute Critical Shear Stress of Soil
2. Compute Hydraulic Conditions
   - Determine Flow Depth from Variable Roughness
   - Determine Shear Stress Applied at Equilibrium
3. Compute Shear Stress on Soil (Partially Dissipated by Product) –$C_{f\text{ - product}}$
4. Determine Stability

Channel Design – Unvegetated Procedure Specifics



Unvegetated Channelized Performance

Unvegetated Channelized Performance



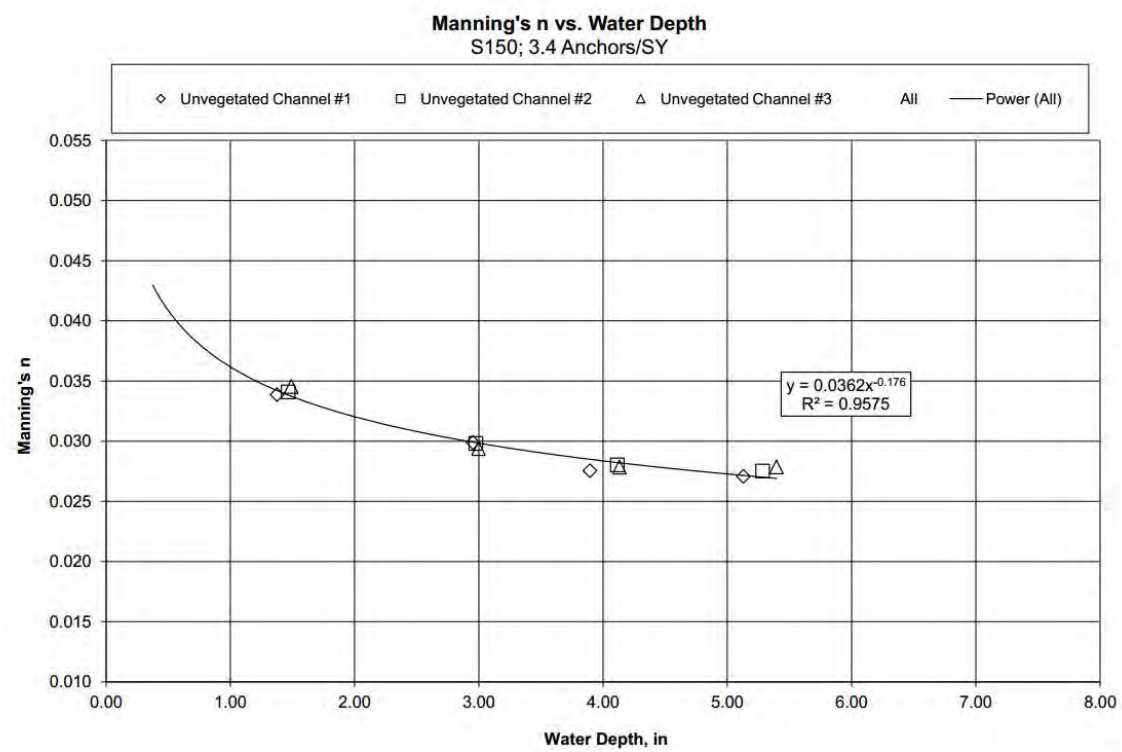
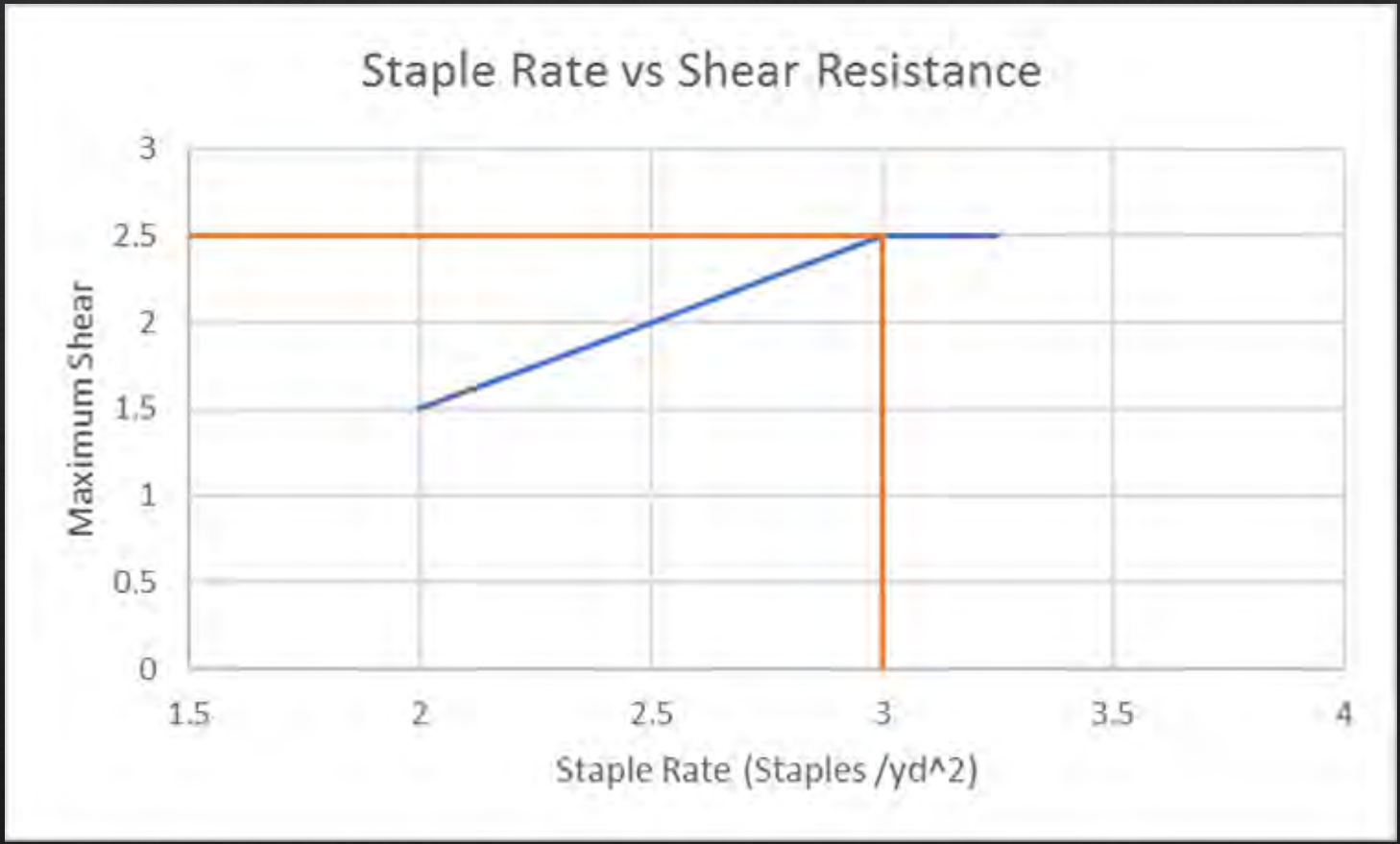


Figure 15. Flow Depth vs. Manning's "n" – Tested Product

Performance vs Pin Rate



Channel Design

- Computation Step 1 – Determine Roughness
- a, b, nmid, nupper, nlower determined from testing

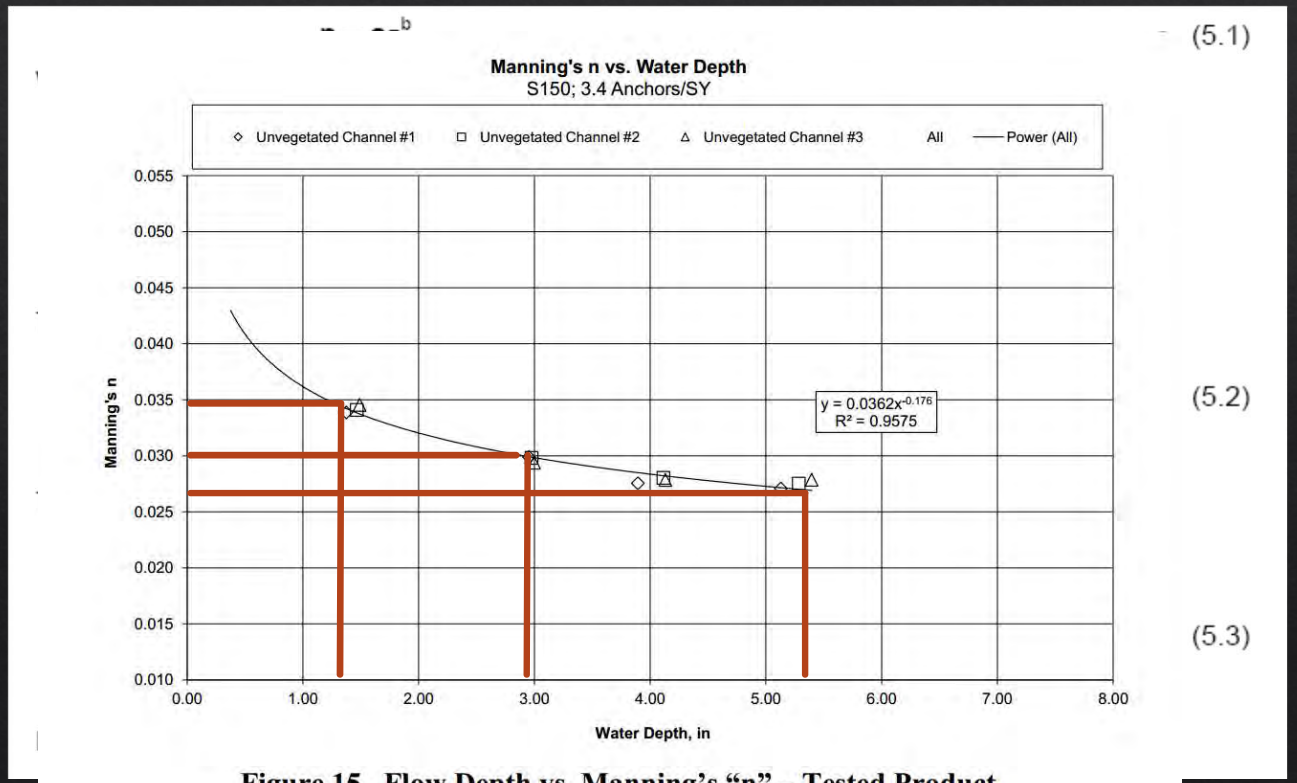


Figure 15. Flow Depth vs. Manning's "n" – Tested Product

(5.1)

(5.2)

(5.3)

Channel Design

- Computation Step 2 – Determine Acceptable Lining Shear Stress

$$\tau_p = \frac{\tau_l}{\alpha}\left(\tau_{p,soil} + \frac{\alpha}{4.3}\right) \tag{5.5}$$

where,

τ_p = permissible shear stress on the RECP lining, N/m^2 (lb/ft^2)

τ_l = shear stress on the RECP that results in 12.5 mm (0.5 in) of erosion

$\tau_{p,soil}$ = permissible soil shear stress, N/m^2 (lb/ft^2)

α = unit conversion constant, 6.5 (SI), 0.14 (CU)

- Taul = Maximum Lining Shear from Testing

Channel Design

- Computation Step 3 – Determine Shear Stress Applied by Flow
  - Iterative (Trial and Error)
  - Guess Flow Depth, Compute Shear Stress, Compute Roughness, Check for Match, Repeat
- Computation of Flow Depth Also Iterative (Double Loop)

$$Q = \frac{\alpha}{n} A R^{2/3} S_f^{1/2} \qquad (2.1)$$

where,

Q	=	discharge, m^3/s (ft^3/s)
n	=	Manning's roughness coefficient, dimensionless
A	=	cross-sectional area, m^2 (ft^2)
R	=	hydraulic radius, m (ft)
S_f	=	friction gradient, which for uniform flow conditions equals the channel bed gradient, S_o, m/m (ft/ft)
α	=	unit conversion constant, 1.0 (SI), 1.49 (CU)

Channel Design – Procedure Vegetated Overview

- Compute Stability of Vegetation
  - Follow Temple (USDA Agricultural Handbook 667)
  - $C_f - C_{f\text{ - Vegetation}}$
  - Determine Hydraulic Conditions at Equilibrium
  - Determine Stability of Vegetation in Design Conditions
- Determine Added Stability With TRM Incorporated
  - Repeat Vegetated Analysis to Determine Stability

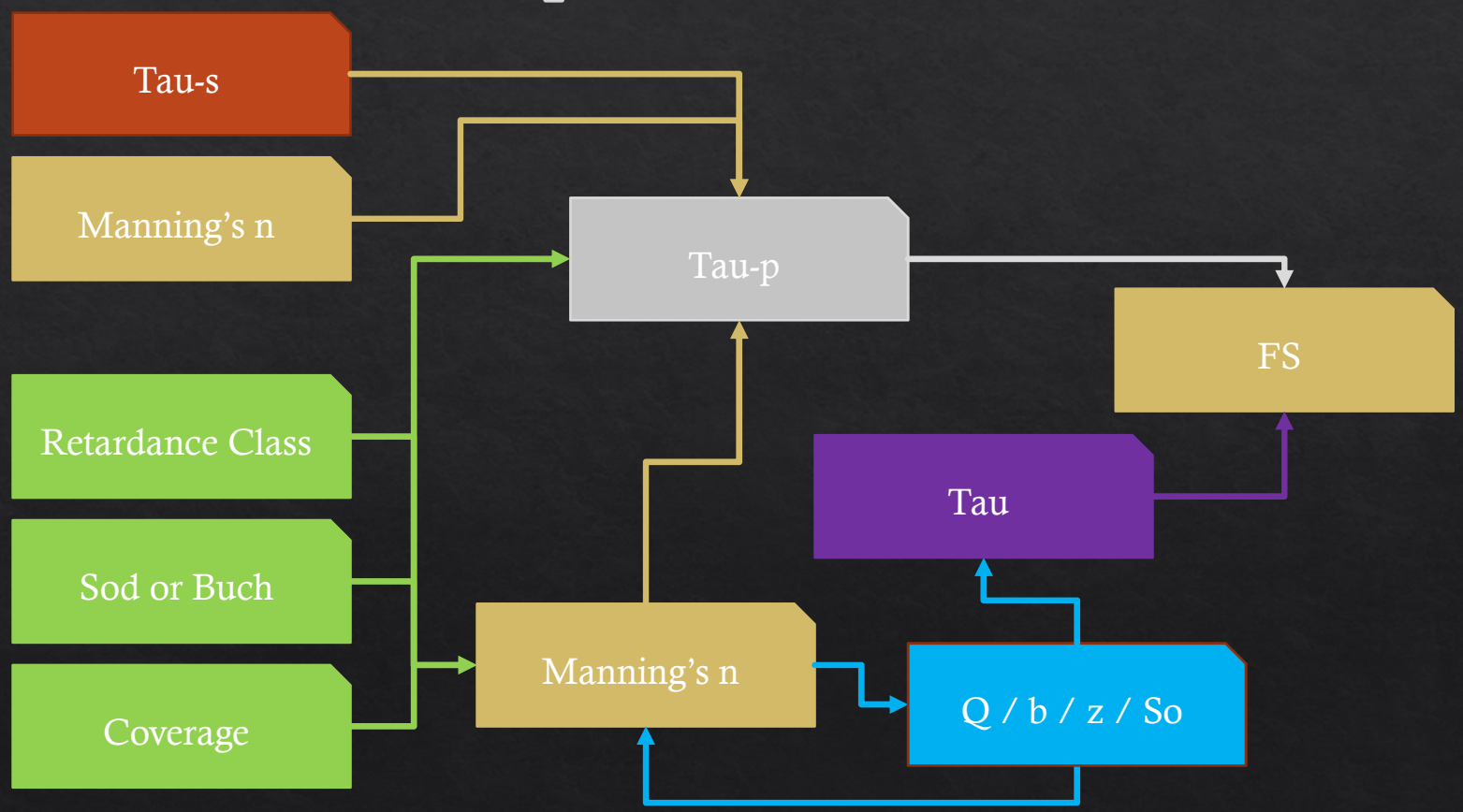
Channel Design - Vegetated

1. Determine Vegetation Parameters
2. Compute Permissible Shear Stress on Soil
3. Compute Shear Stress Applied from Flow with Vegetation Present (Roughness Variable by Vegetated Stand Established)
4. Compute Shear Stress Dissipation from Vegetated Coverage
5. Compute Shear Stress Applied to Soil Through Vegetation

Channel Design - Vegetated

- Vegetation Parameters
  - Retardance Class
  - Vegetation Type (Bunch or Sod)
  - Cover Quality
- Determine C_{fveg} - Vegetation (Temple, Agricultural Handbook 667)
- Determine C_{fTRM}

Channel Design – Vegetated Procedure Specifics



Vegetated Design - Roughness

- Roughness of Geosynthetic Lined Channel with Vegetation Assumed Solely a Function of the Vegetation
- Roughness of Vegetation Defined by Relationship with Shear Stress
- Iterative Process

$$n = \alpha C_n \tau_o^{-0.4}$$

where,

τ_o = mean boundary shear stress, N/m^2 (lb/ft^2)

α = unit conversion constant, 1.0 (SI), 0.213 (CU)

Channel Design - Vegetated

- C_{fTRM} _ Composite Cover Factor Including Vegetation and Product

$$C_{f,TRM} = 1 - \left(\frac{\tau_{p,VEG-test}}{\tau_{p,TRM-test}}\right)\left(1 - C_{f,VEG}\right) \quad (5.6)$$

where,

$\tau_{p,VEG-test}$ = permissible shear stress on the vegetative lining, N/m^2 (lb/ft^2) as reported by Manufacturer's testing

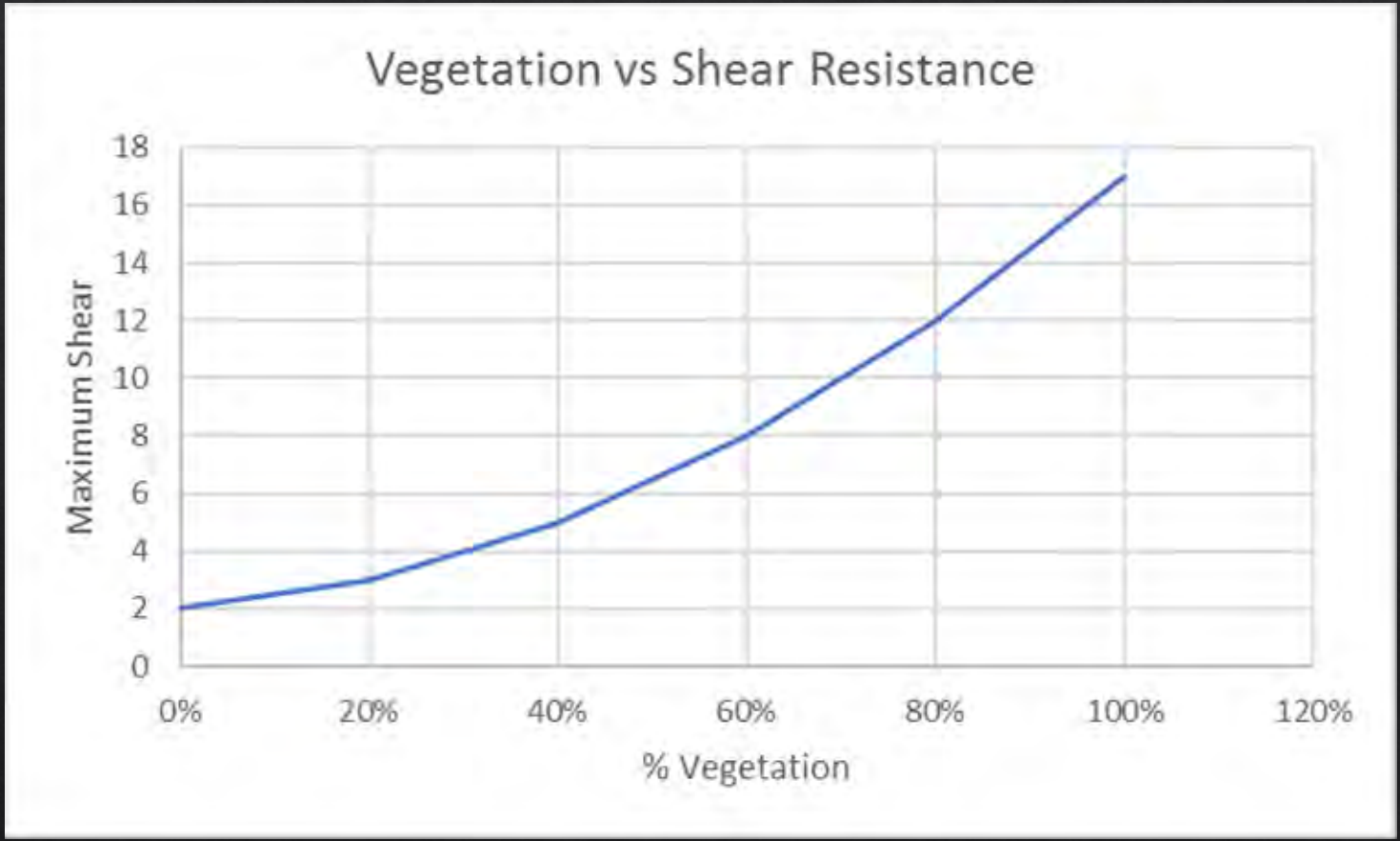
$\tau_{p,TRM-test}$ = permissible shear stress on the turf-reinforced vegetative lining, N/m^2 (lb/ft^2) as reported by manufacturer's testing

$C_{f,VEG}$ = grass cover factor (see Table 4.5)

$C_{f,TRM}$ = TRM cover factor

- Determine Stability of TRM Similar to Vegetated Channel

Example Influence of Vegetation



Vegetated Channel Performance

Vegetated Channel Performance

Vegetated Channel Performance in Design

- Product Data Shows Maximum Test Value
- Idealized Condition
- Should Reduce by Factor of 1.5 – 2.0 if Project Expected to Have Excellent Vegetation
  - Test Vegetation ~ 2X More Resilient to Flow than Natural Channels
- Lesser Vegetated States Estimated by Method
- Outstanding Vegetated Cover Situations Can be Overestimated by Method, Absolute Cap on Performance Should be the Test Value