Limitations in the Back Analysis of Shear Strength from Failures

NICHOLSON 50 YEARS

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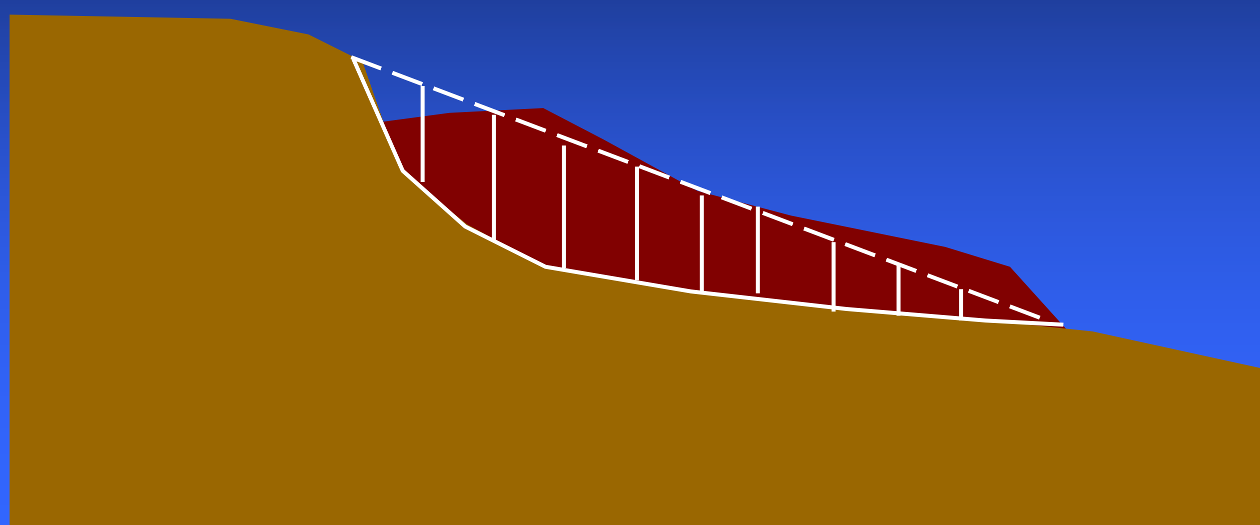
Presentation Overview

- Background
- Examples from Case Histories
  - Grandview Lake Dam
  - Marmet Lock and Dam
  - Kentucky River Lock and Dam No. 10
- Summary

Back-Analysis

- Find Strength assuming SF = 1.0



Back-Analysis of Strength

- Commonly Used by Profession
- Often Believed to Provide Best Estimate of Strength
- Can Lead to Significant Errors!!

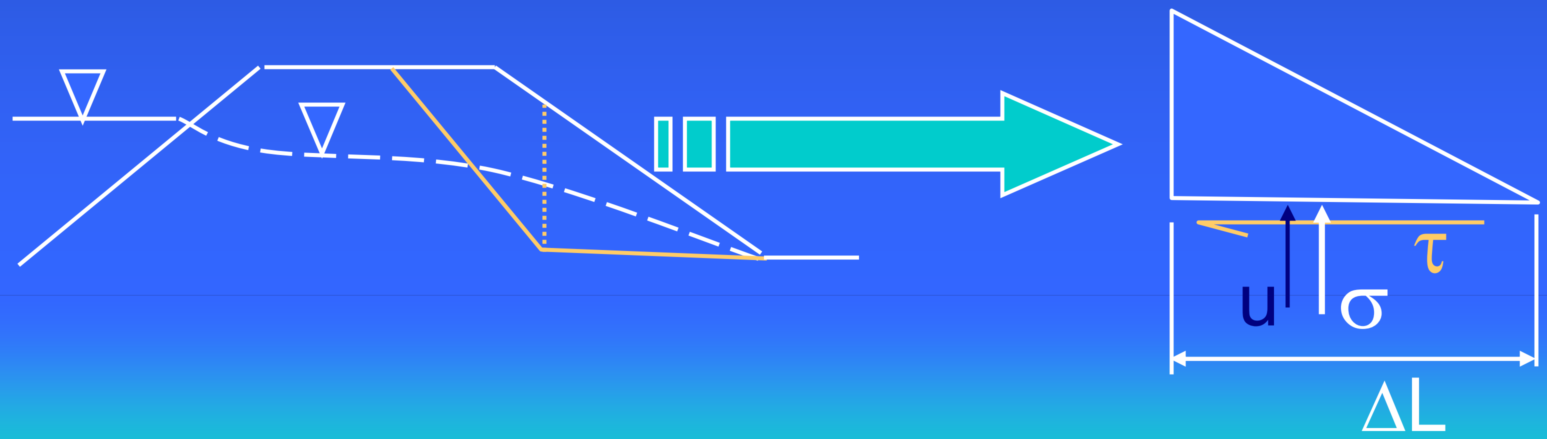
Presentation Goals

- Illustrate Limitations of Back-Analysis
- Show that Conservative Design Assumptions are Unconservative in Back-Analysis

Simple Example

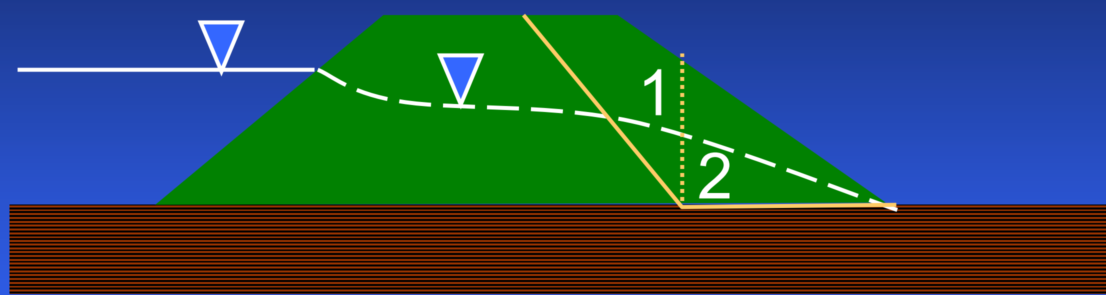
$$SF = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

$$SF = \frac{\Sigma\{c + (\sigma - u)\tan\phi\}\,\Delta L}{\Sigma\,\tau_{\text{mobilized}}\,\Delta L} = 1.0$$



Resisting Forces = Driving Forces

$$\Sigma\{ c + (\sigma\text{-}u) \tan \phi\} \Delta L = \Sigma \tau_{\text{mobilized}} \Delta L$$

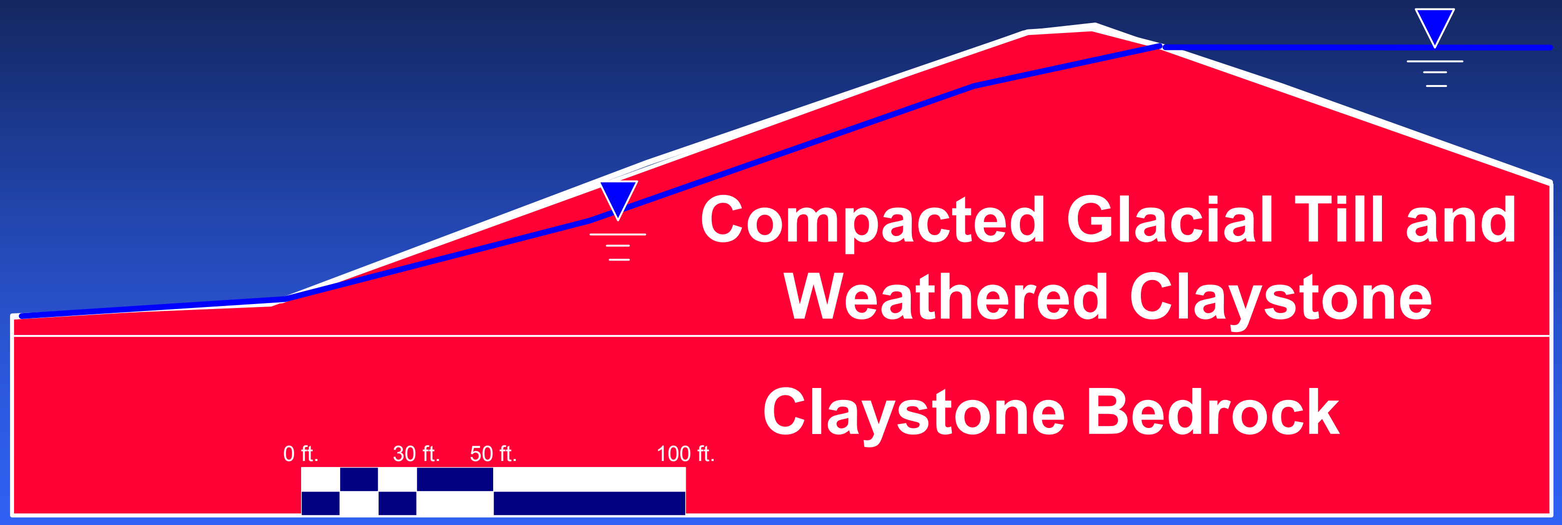


$$\{(\sigma_1\text{-}u_1) \tan \phi_1\}\Delta L_1 + \{ (\sigma_2\text{-}u_2) \tan \phi_2\}\Delta L_2 = \tau_1\Delta L_1 + \tau_2\Delta L_2$$

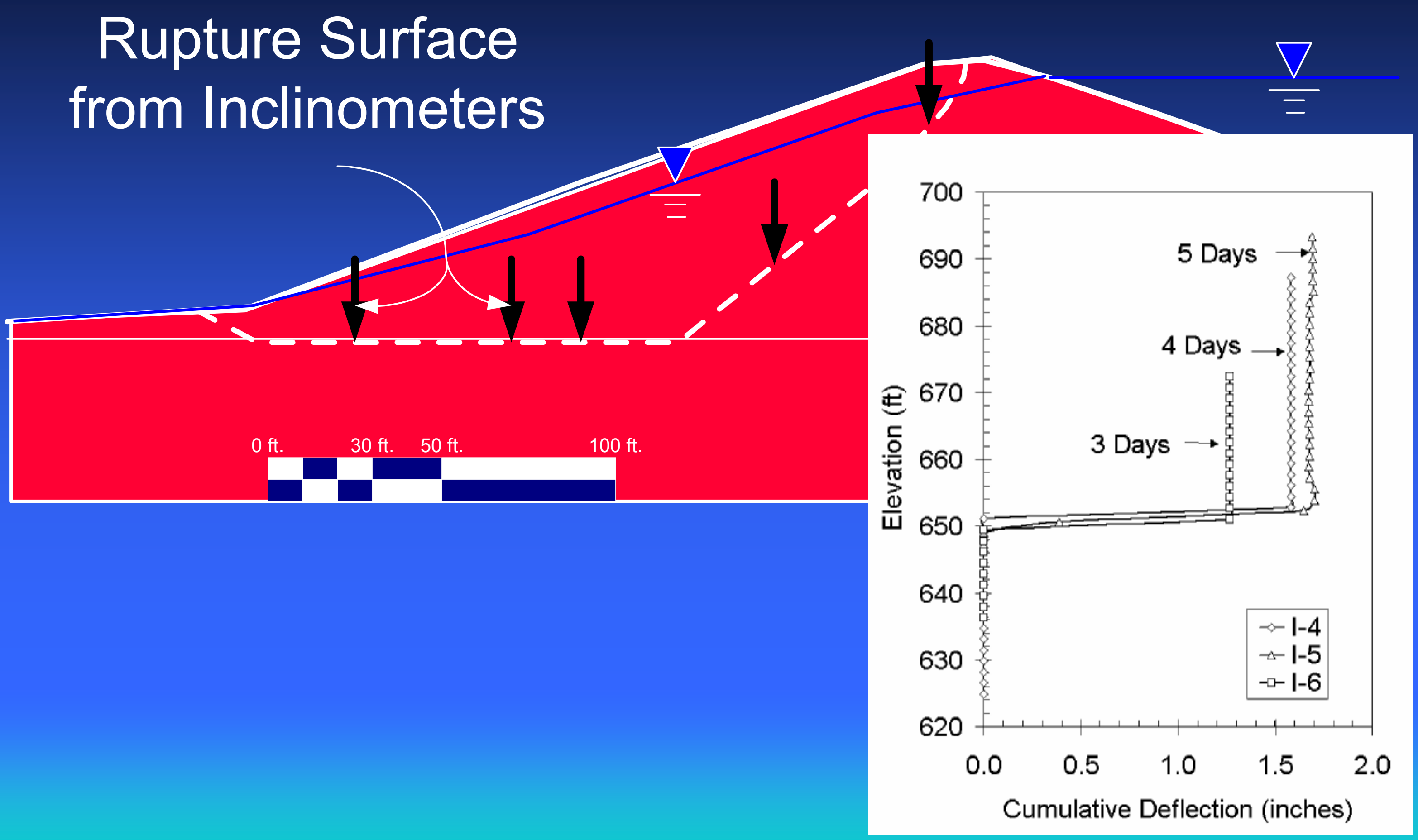
Factors Influencing Interpretation

- Strength of Various Materials ✓
- Slip Surface Location ✓
- Pore Pressure Distribution ✓
- Three Dimensional Effects ✓
- Progressive or Retrogressive Failure
- Strength in Terms of ϕ and/or c

Grandview Lake Dam

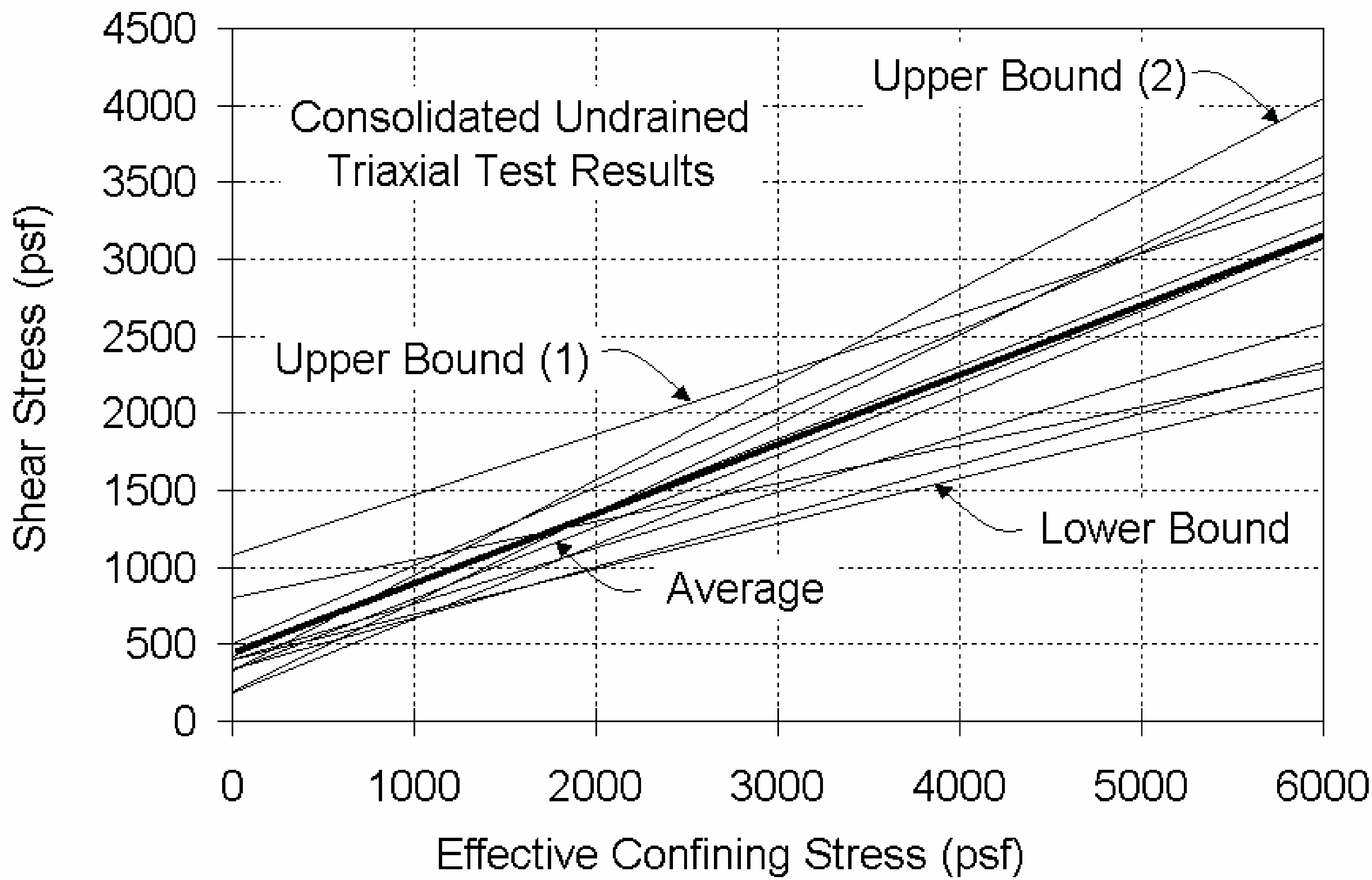


Grandview Lake Dam

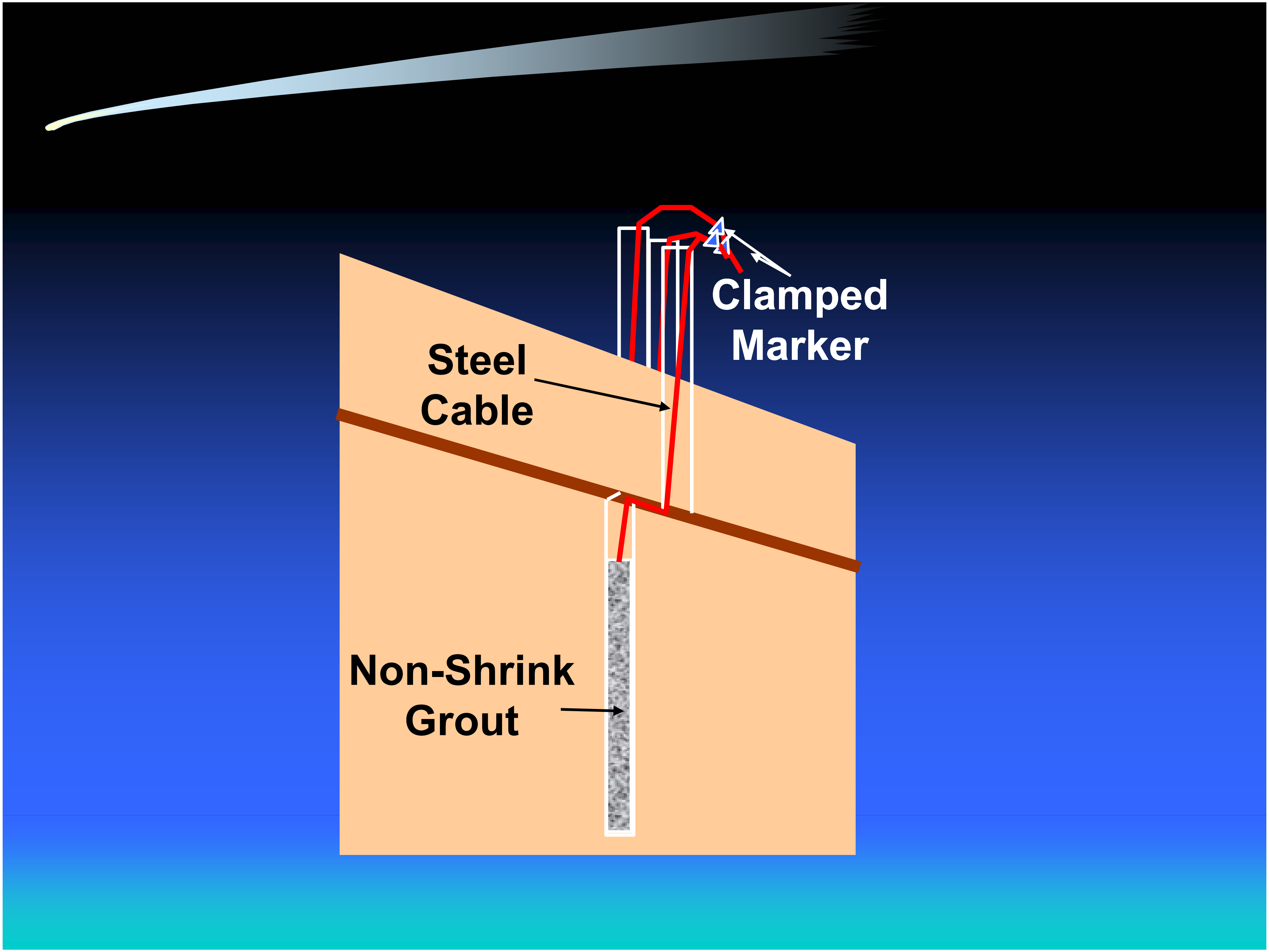


Failure in Seam in Bedrock

- What strength parameters are applicable?
- How can they be determined?

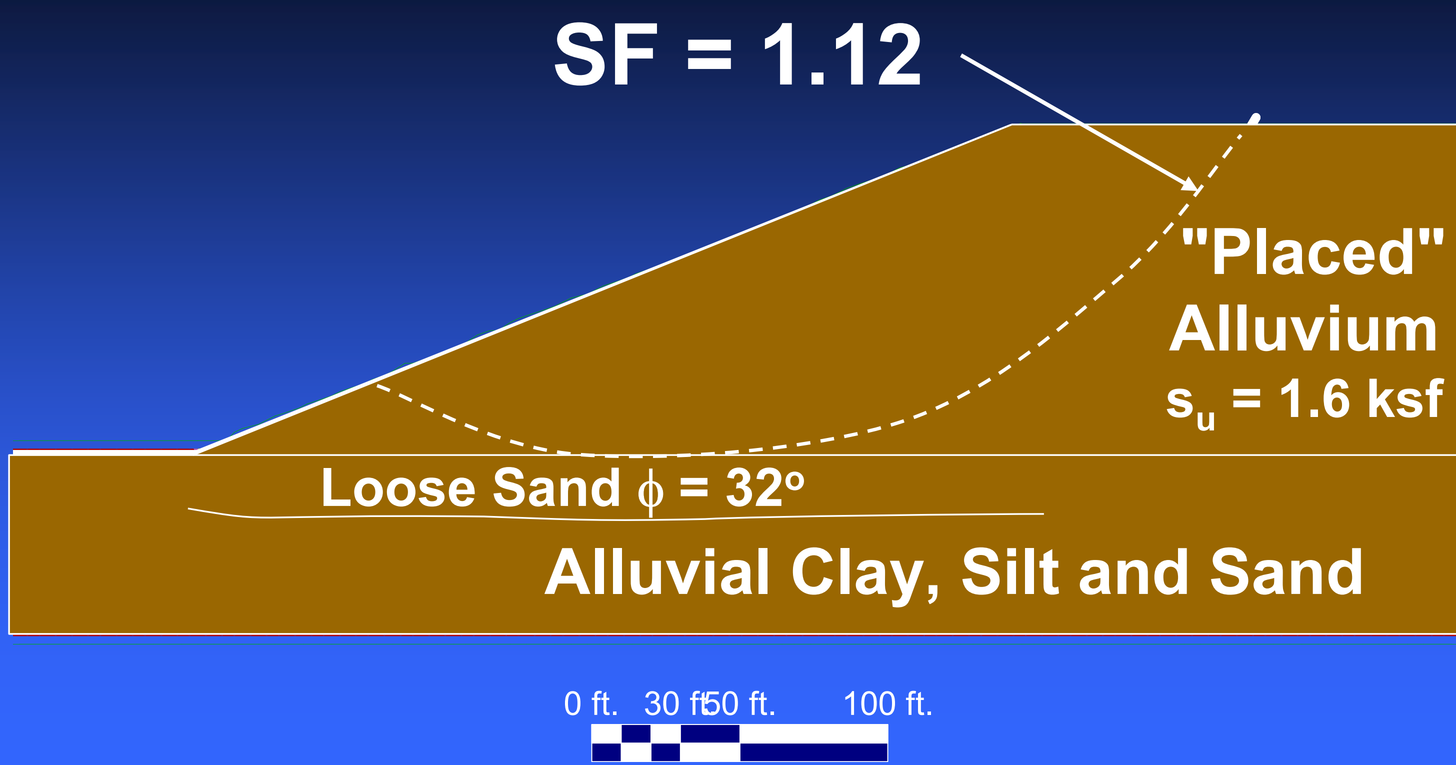

Consolidated Undrained
Triaxial Test Results
Upper Bound (2)
Upper Bound (1)
Average
Lower Bound
Shear Stress (psf)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
1000
2000
3000
4000
5000
6000
Effective Confining Stress (psf)

Back-calculated strength.	
Embankment Strength	**Back Calculated Friction Angle**
Lower Bound	23
Upper Bound (High Friction)	16
Upper Bound (High Cohesion)	11
Average	18

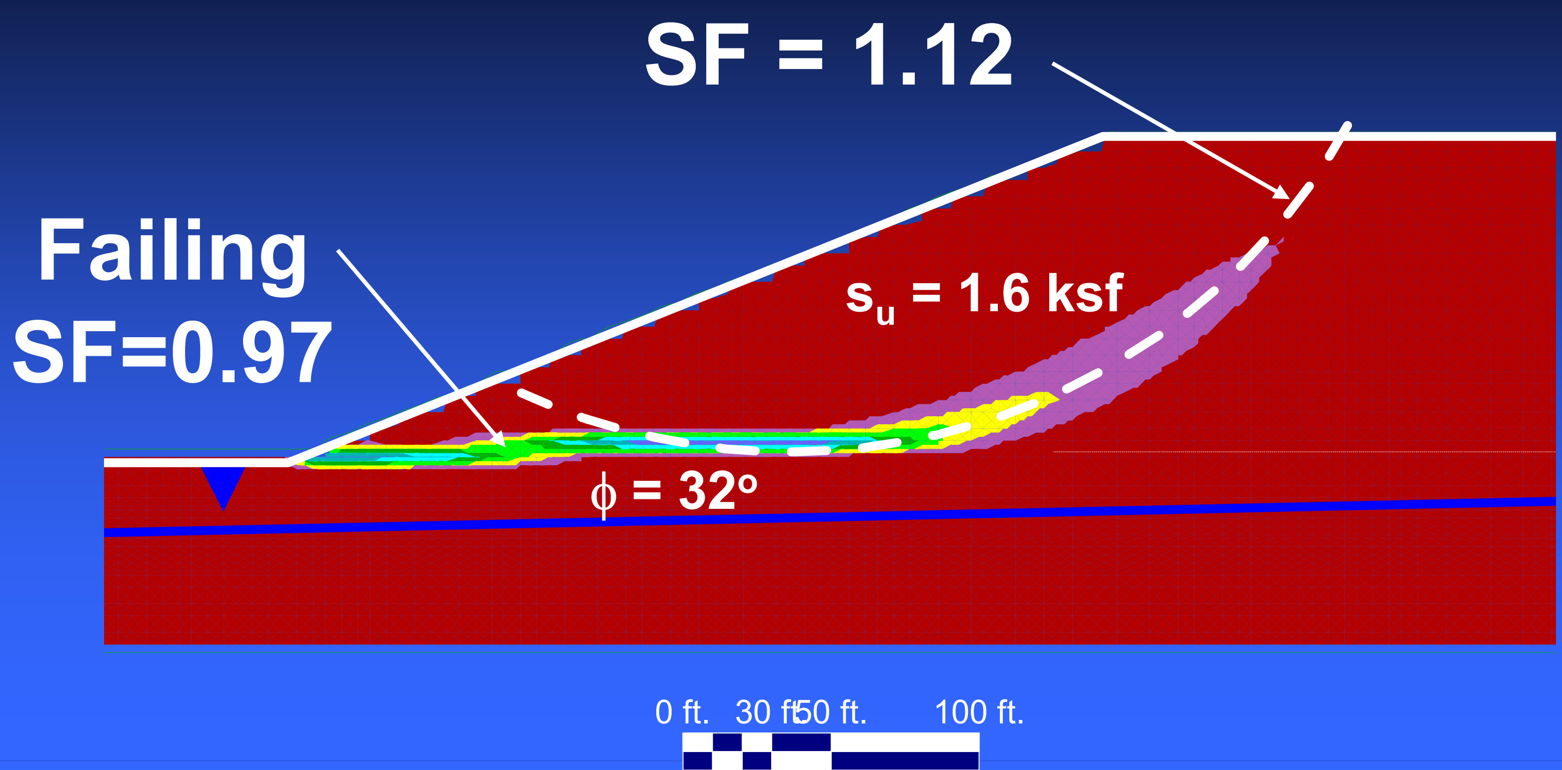

Clamped
Marker
Steel
Cable
Non-Shrink
Grout

Marmet Lock & Dam, WV

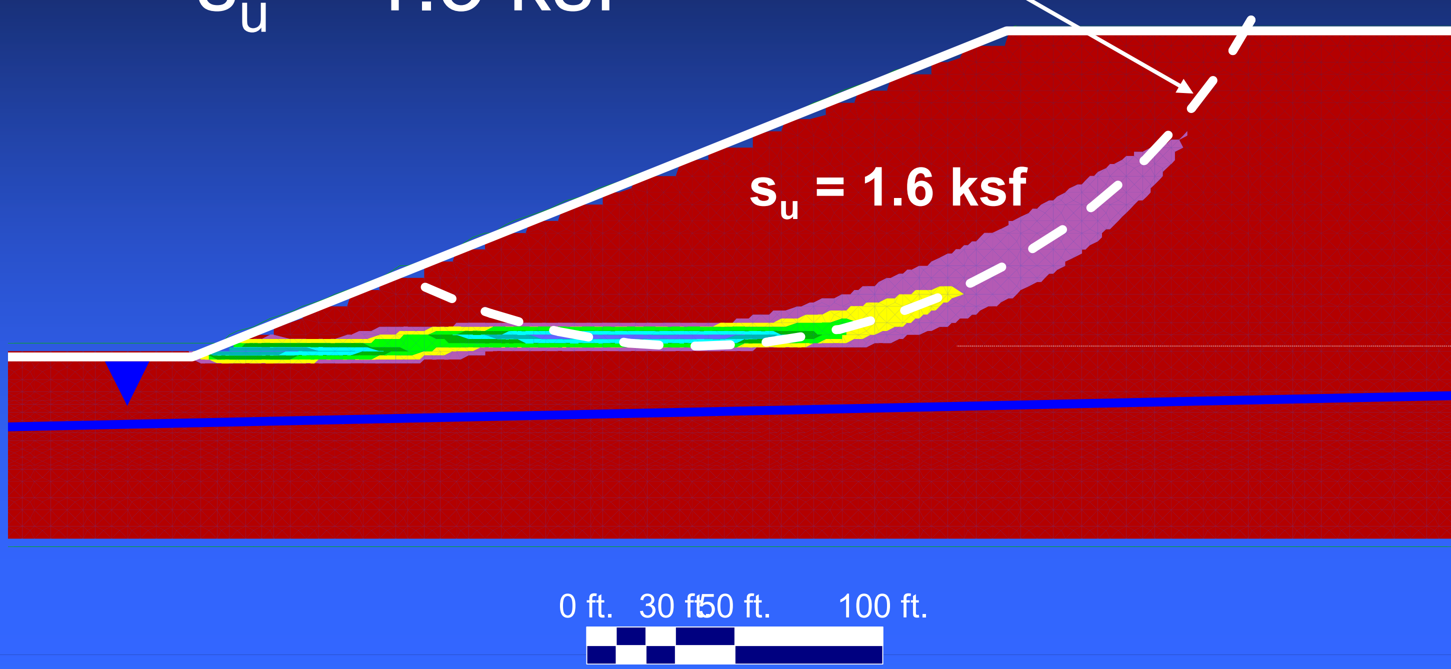
Critical Section - Design



Critical Section - Actual



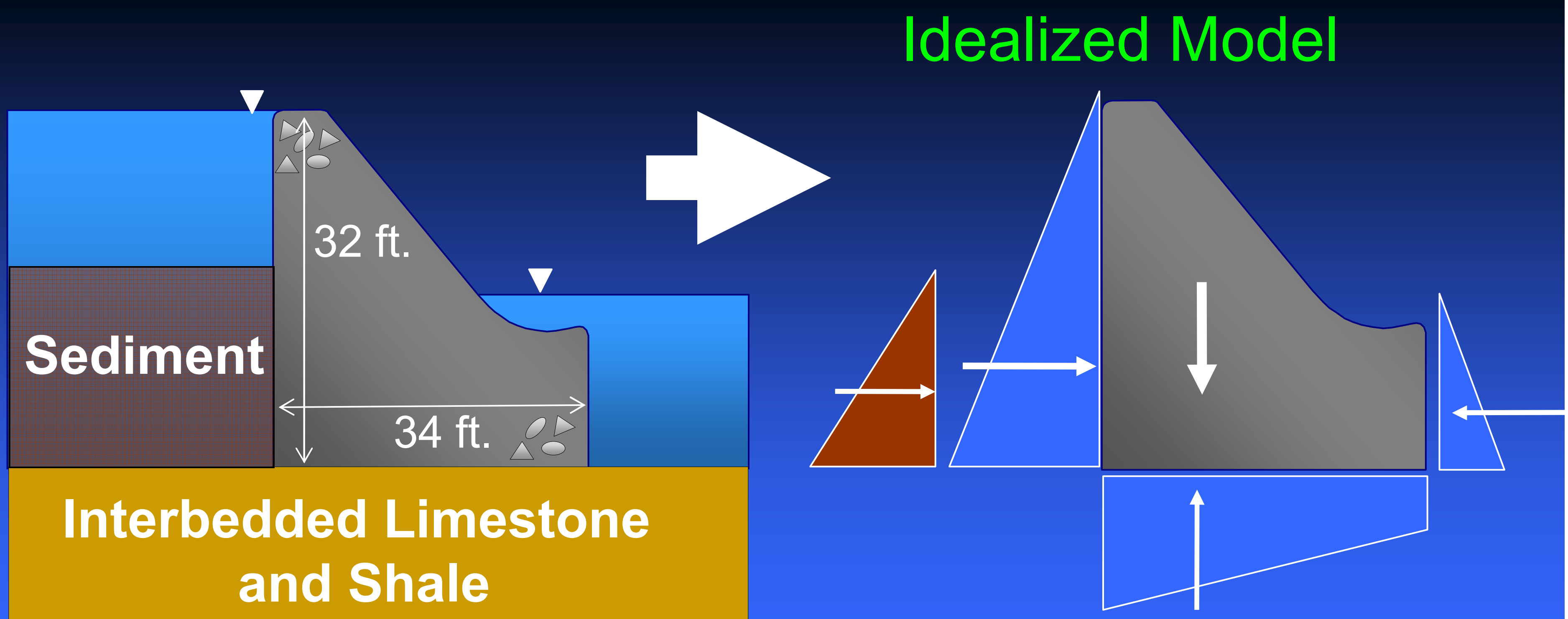
Back-calculated strength
s_u = 1.3 ksf



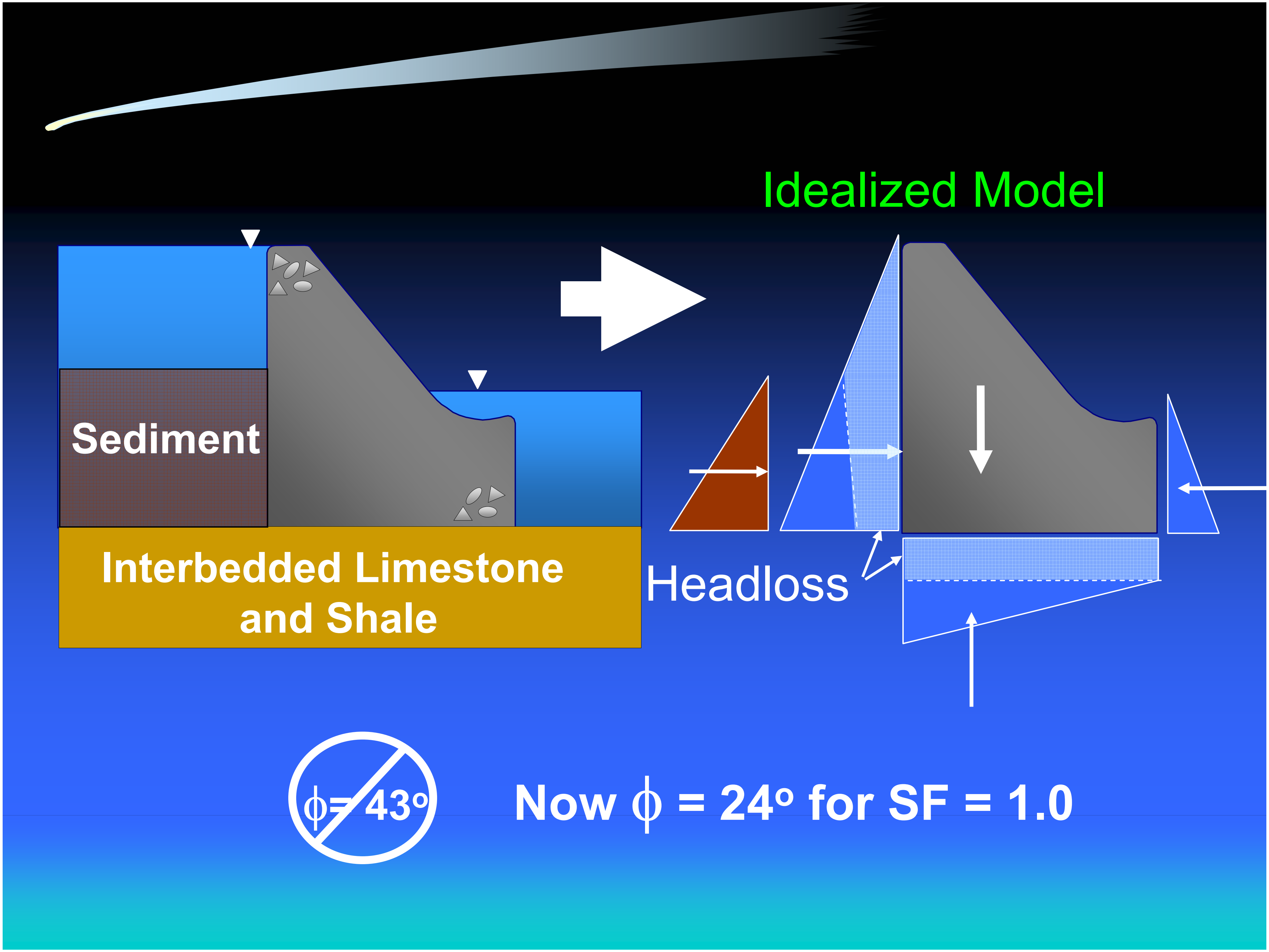
Kentucky River Lock & Dam 10

Louisville District

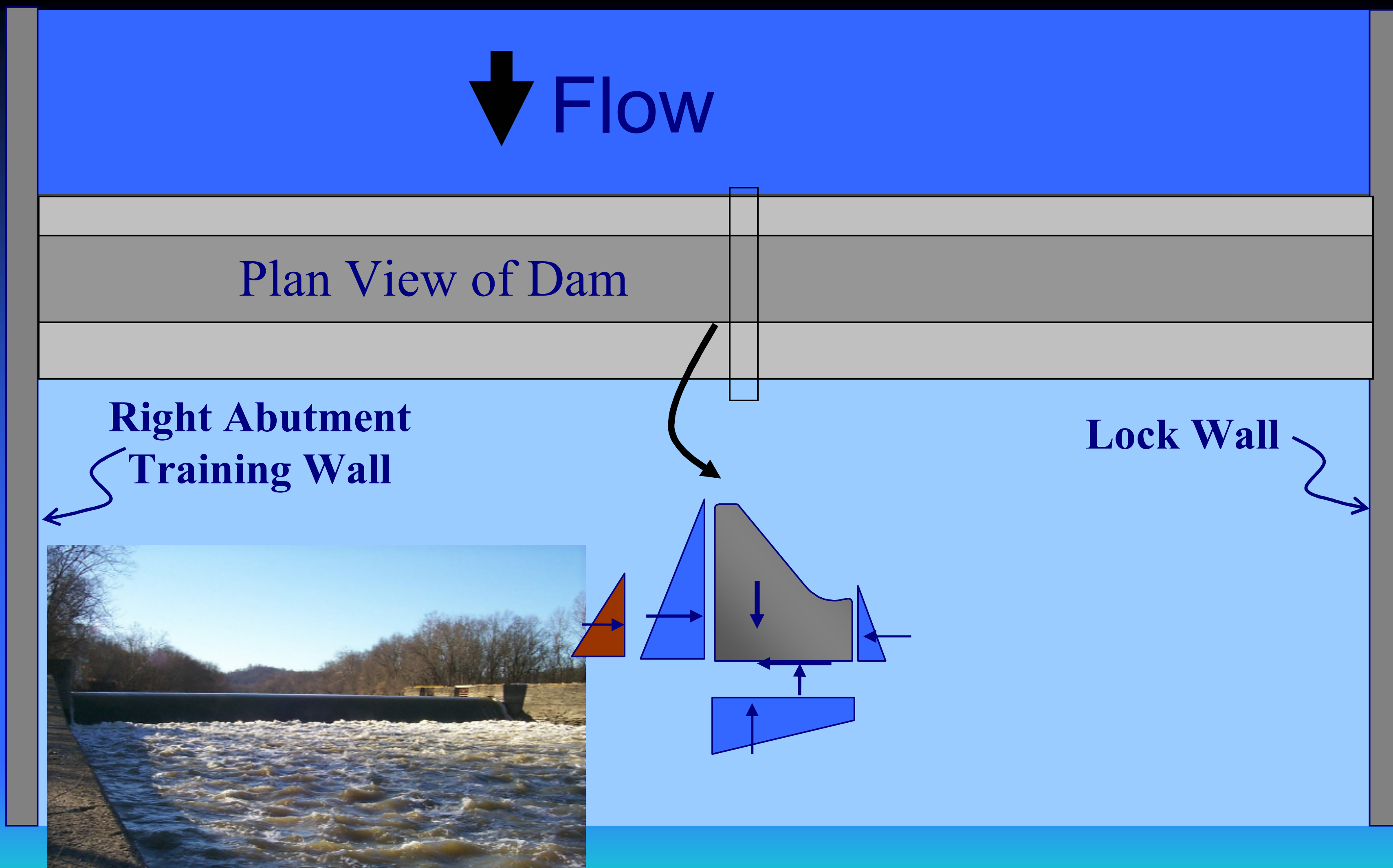
Importance of Accurate Model



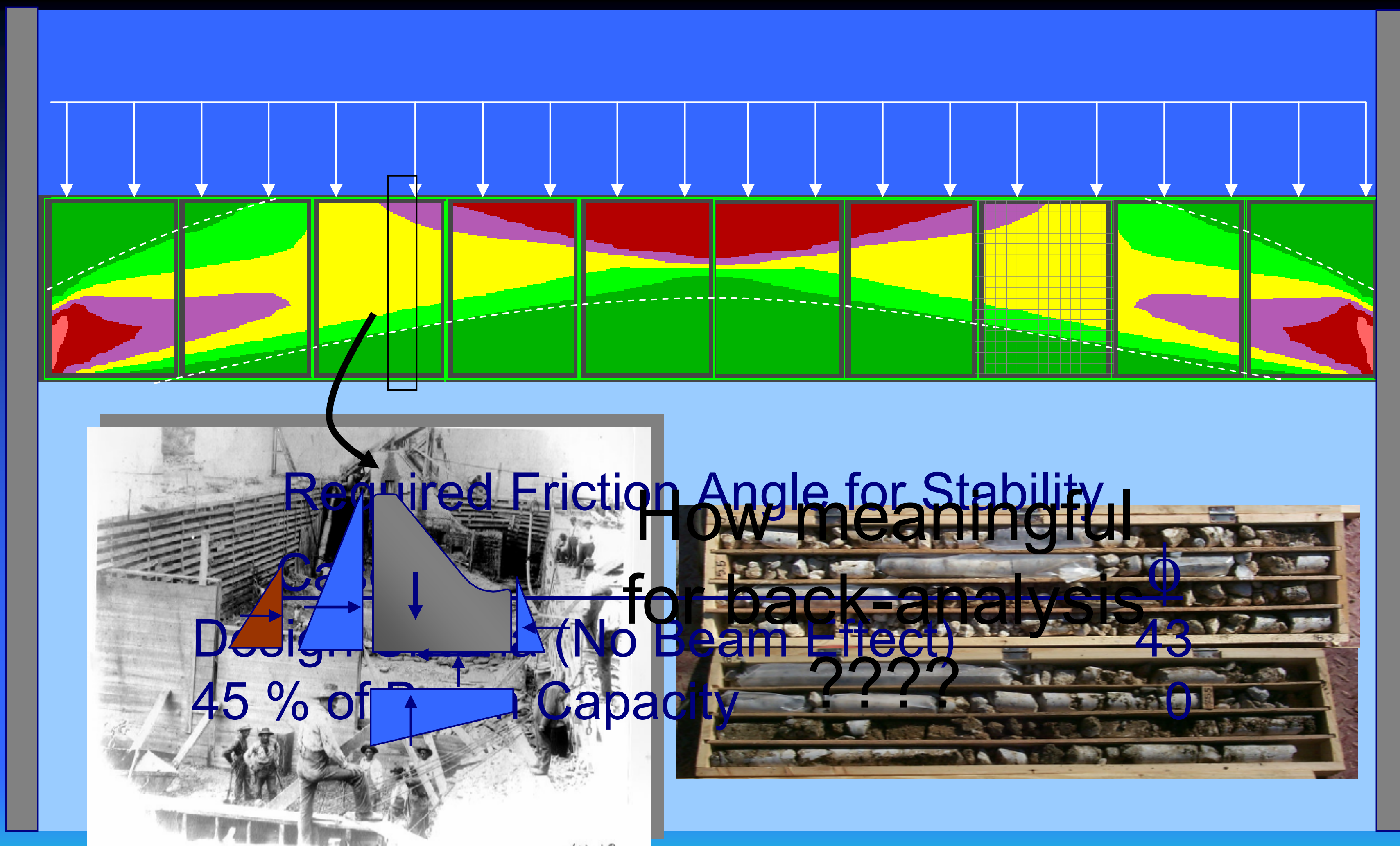
ϕ = 43° for SF = 1.0


Idealized Model
Sediment
Interbedded Limestone
and Shale
Headloss
ϕ= 43°
Now ϕ = 24° for SF = 1.0

3-D Effects


Flow
Plan View of Dam
Right Abutment
Training Wall
Lock Wall

3-D Effects (cont.)

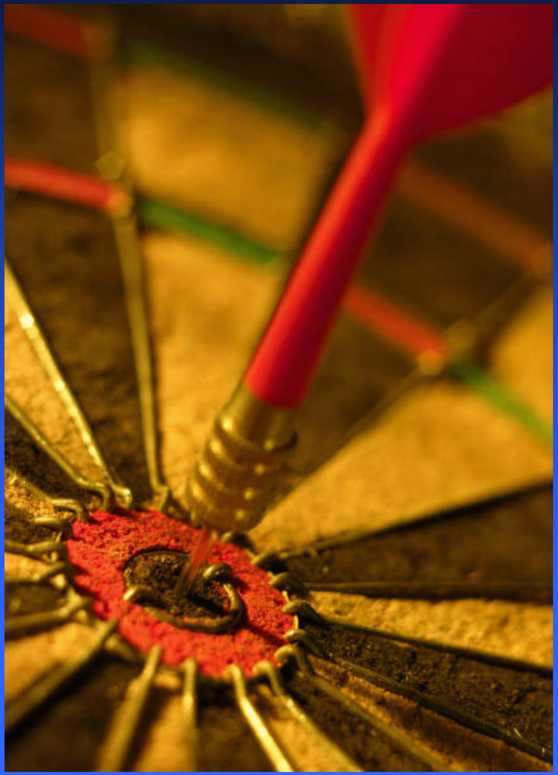


3-D Effects (cont.)

- 3D effects in soil slopes add ≈ 5 to 25 % to stability.
- This leads to overestimation of soil strength, if not accounted for somehow.

Summary

- Back-Analysis is a Useful Tool **Only** When Assumptions and Models are Accurate



Recommendations

- Narrowly Bound Input Parameters
- Account for Model Limitations
- Assess Upper and Lower Bound
- Judge Usefulness of Results

Remember

- Conservative Design Assumptions are Unconservative if used in Back-Analysis
- Inherently Conservative Models are Unconservative if used in Back-Analysis

"I am inclined to compare the functions of theory with those of a walking stick in rugged country. It reduces the risk of stumbling, but the walking has to be done with the legs."

Karl Terzaghi

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