UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Use of CPT in Geotechnical Earthquake Engineering

Prof. Scott M. Olson, PhD, PE

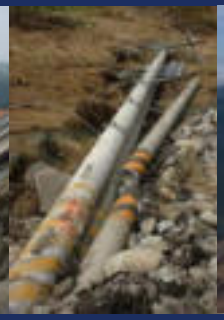
Use of Cone Penetration Test for Foundation Analysis and Design
2006 Annual Meeting
Transportation Research Board

www.uiuc.edu

Geotechnical Earthquake Engineering

- Ground shaking
- Structural hazards
- Liquefaction
- Landslides
- Retaining structure failures
- Lifeline hazards
- Tsunamis & seiches

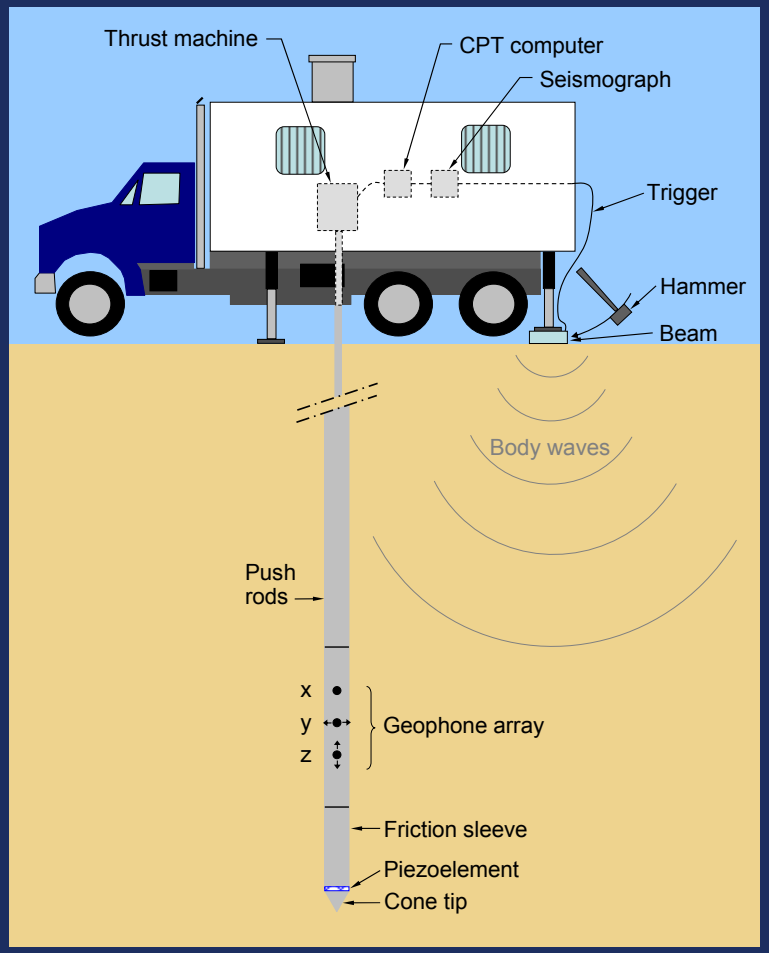



Ground Shaking & Site Response

- Code based
  - Vs profile
- Site-specific
  - Soil profile
  - Small strain shear modulus

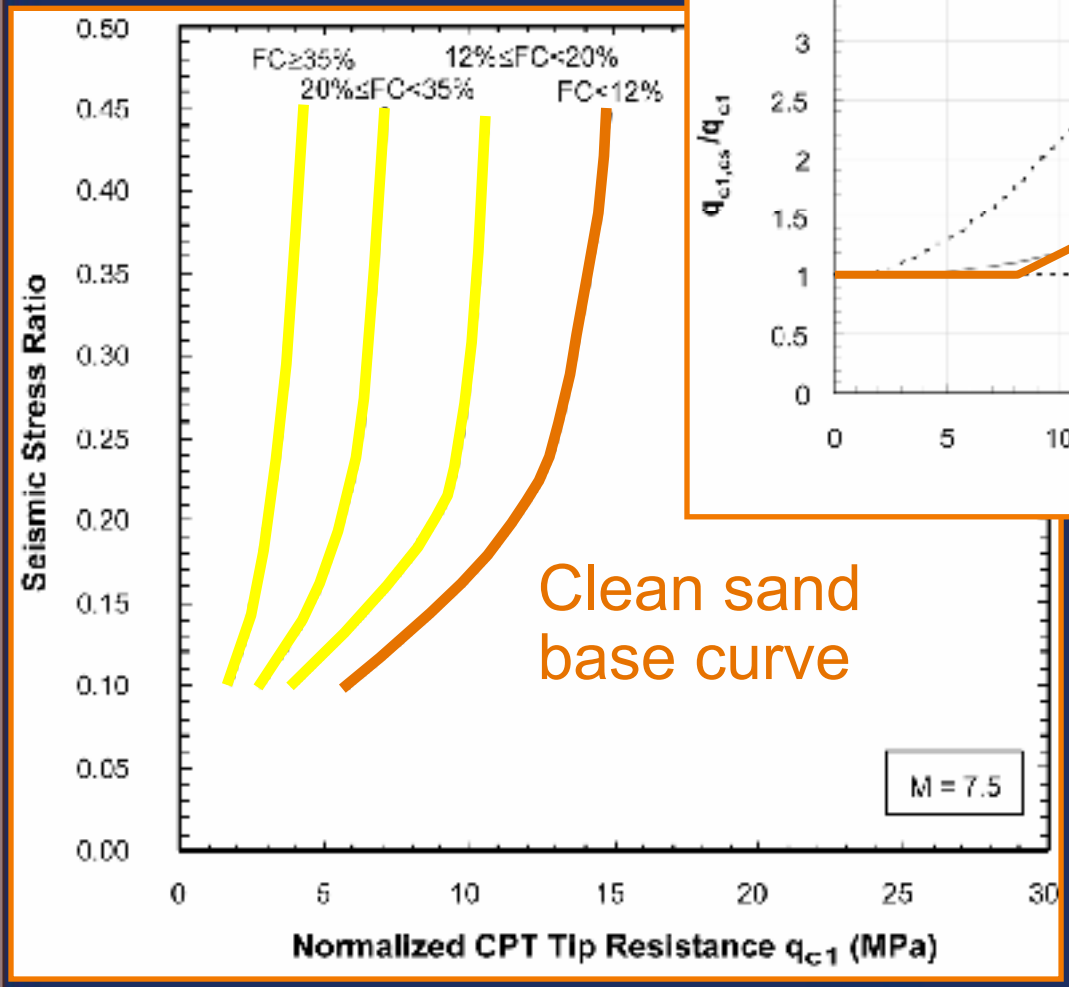
Seismic CPT



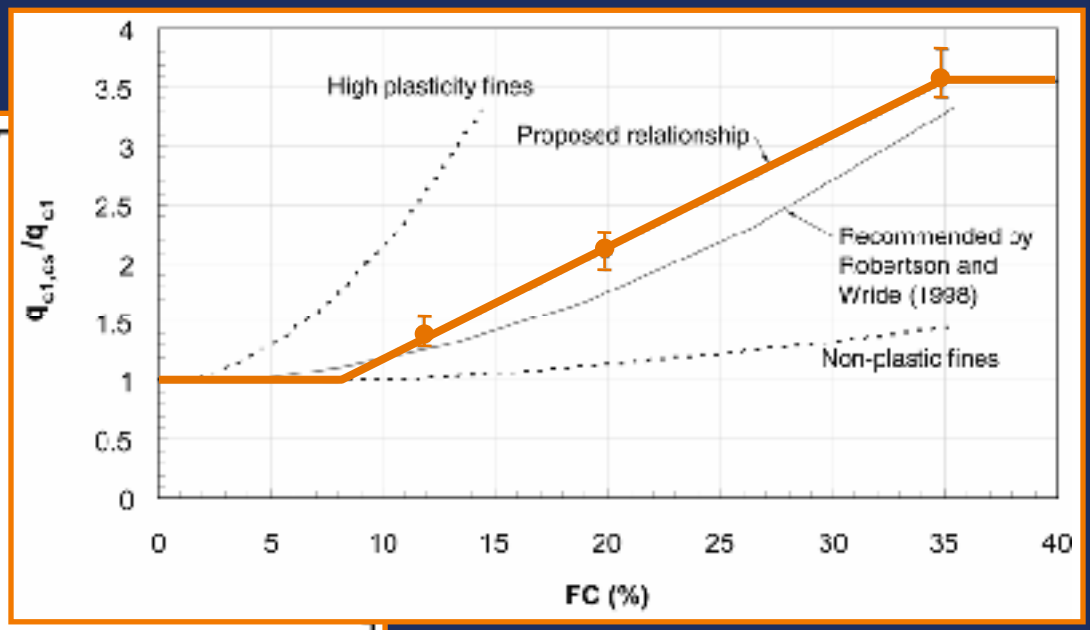
Liquefaction

- Level ground (cyclic liquefaction)
- Liquefaction-induced settlement
- Flotation of buried structures
- Lateral spreading
- Sloping ground / flow failure

Level Ground Liquefaction



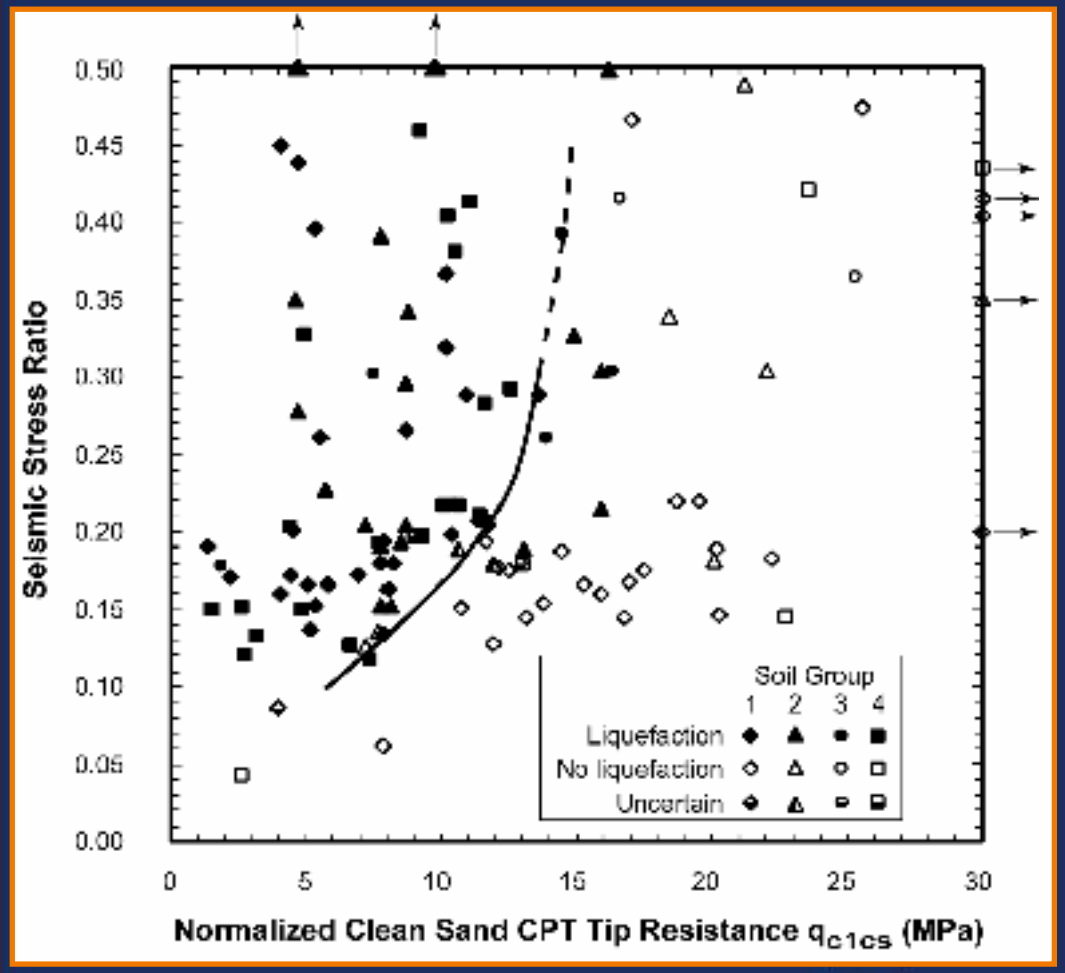
Clean sand base curve



$$q_{c1,cs} = C_{FC} \cdot q_{c1}$$

Newman, Stark, & Olson (in review)

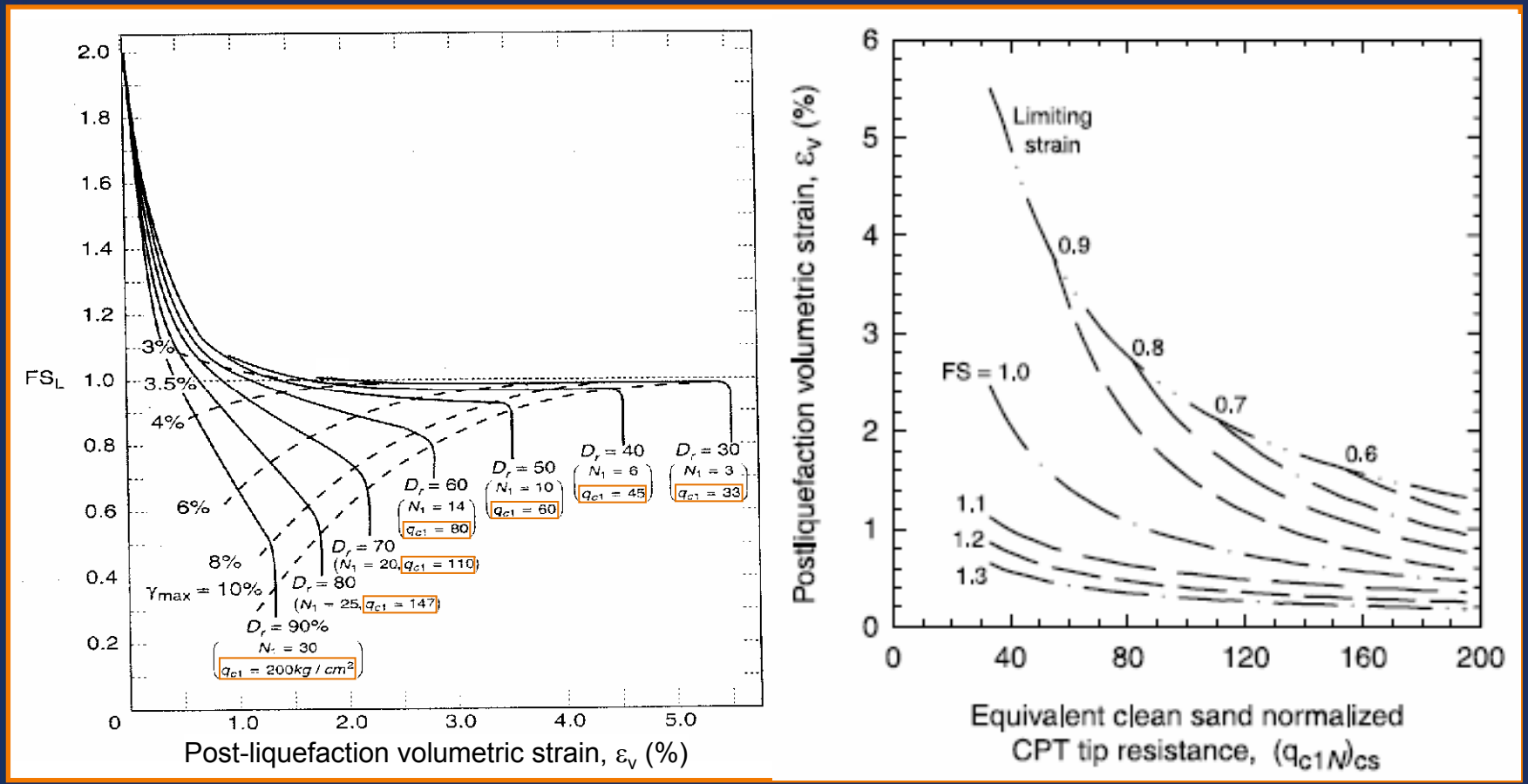
Level Ground Liquefaction



$$FS_L \approx \frac{\text{Resistance}}{\text{Demand}} \approx \frac{\text{CRR}}{\text{CSR}} \approx \frac{\text{CRR}}{0.65 \frac{a_{max}}{g} \frac{\sigma_v}{\sigma'_v} r_d} \Big/ MSF$$

Newman, Stark, & Olson (in review)

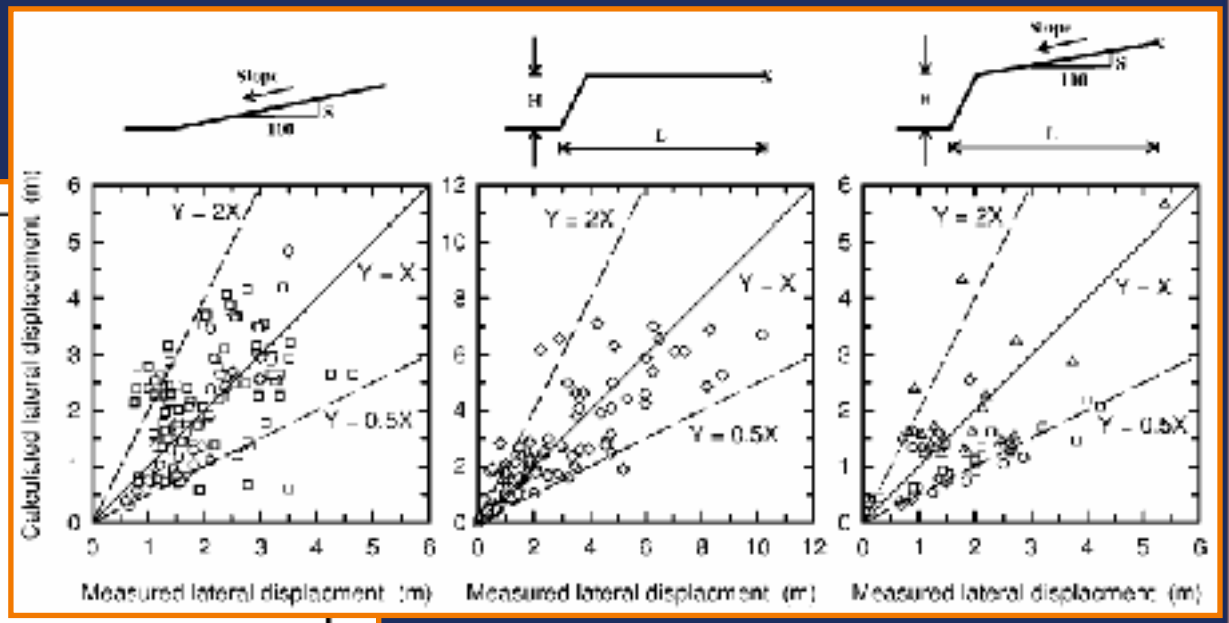
Liquefaction-induced Settlement

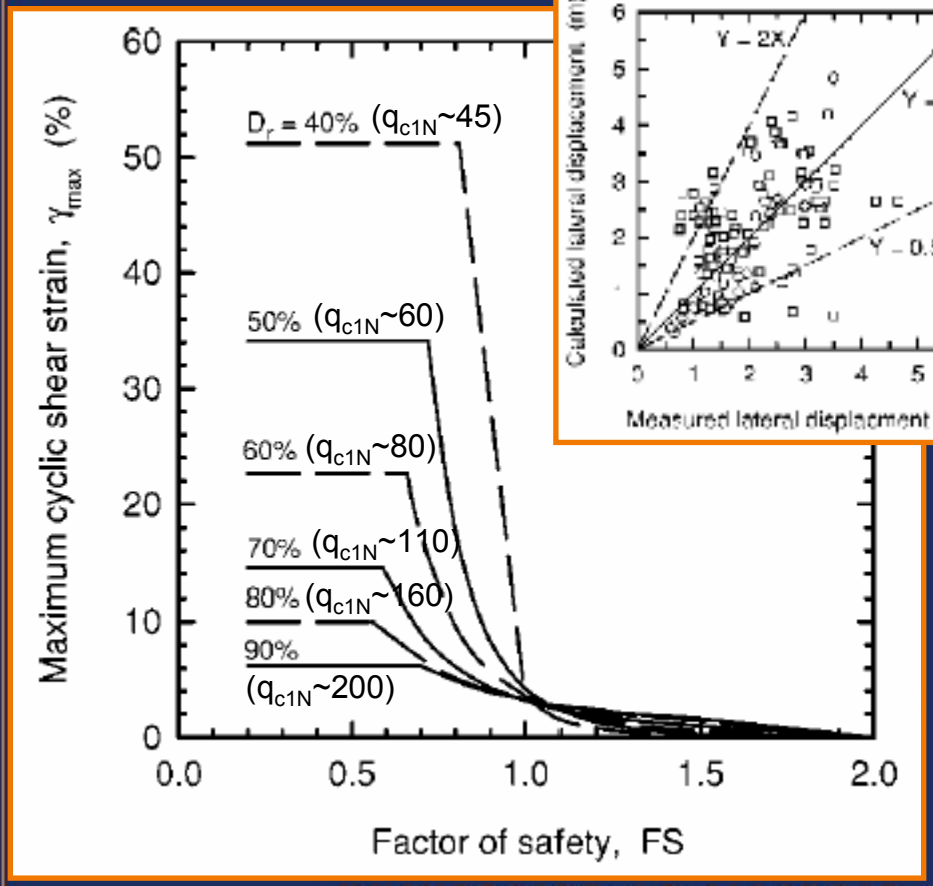


Ishihara & Yoshimine (1992)

Zhang, Robertson, & Brachman (2002)

Lateral Spreading



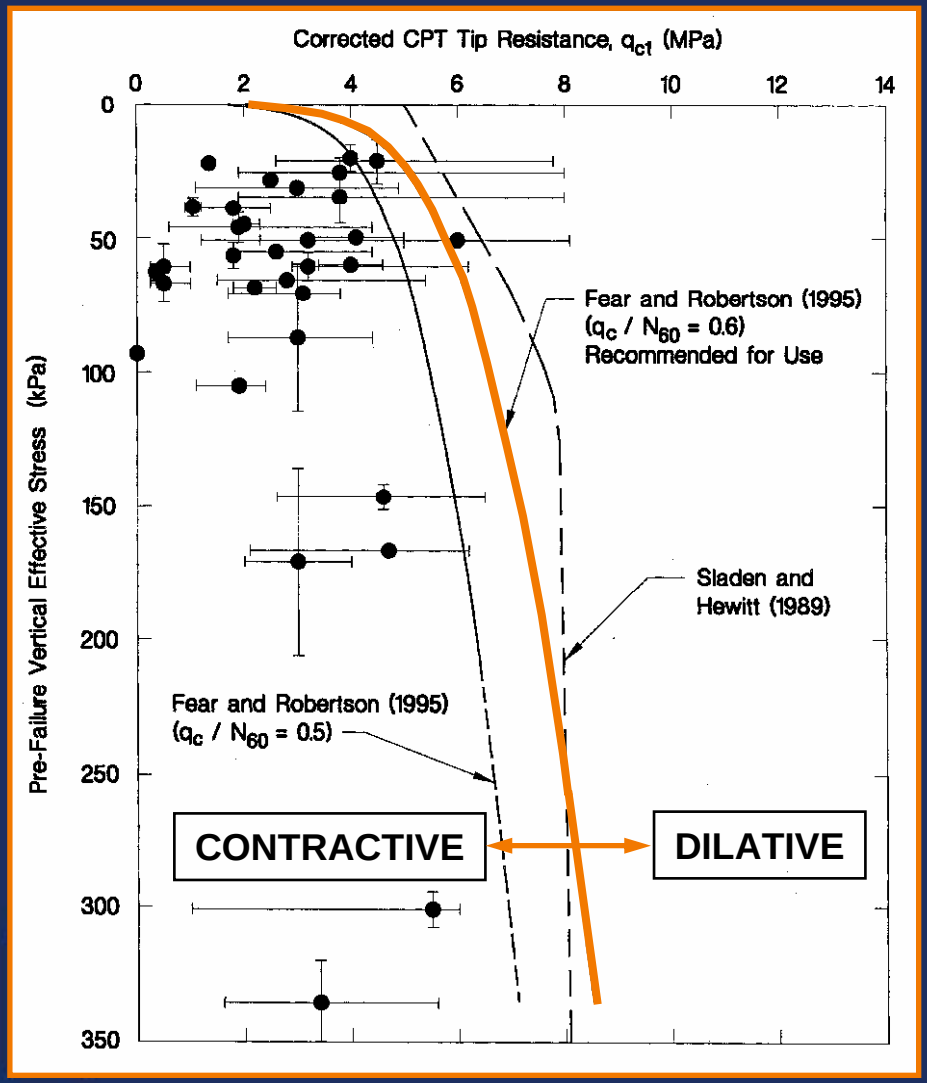


Zhang, Robertson, & Brachman (2004)

modified from Ishihara & Yoshimine (1992)

Sloping Ground / Flow Failure

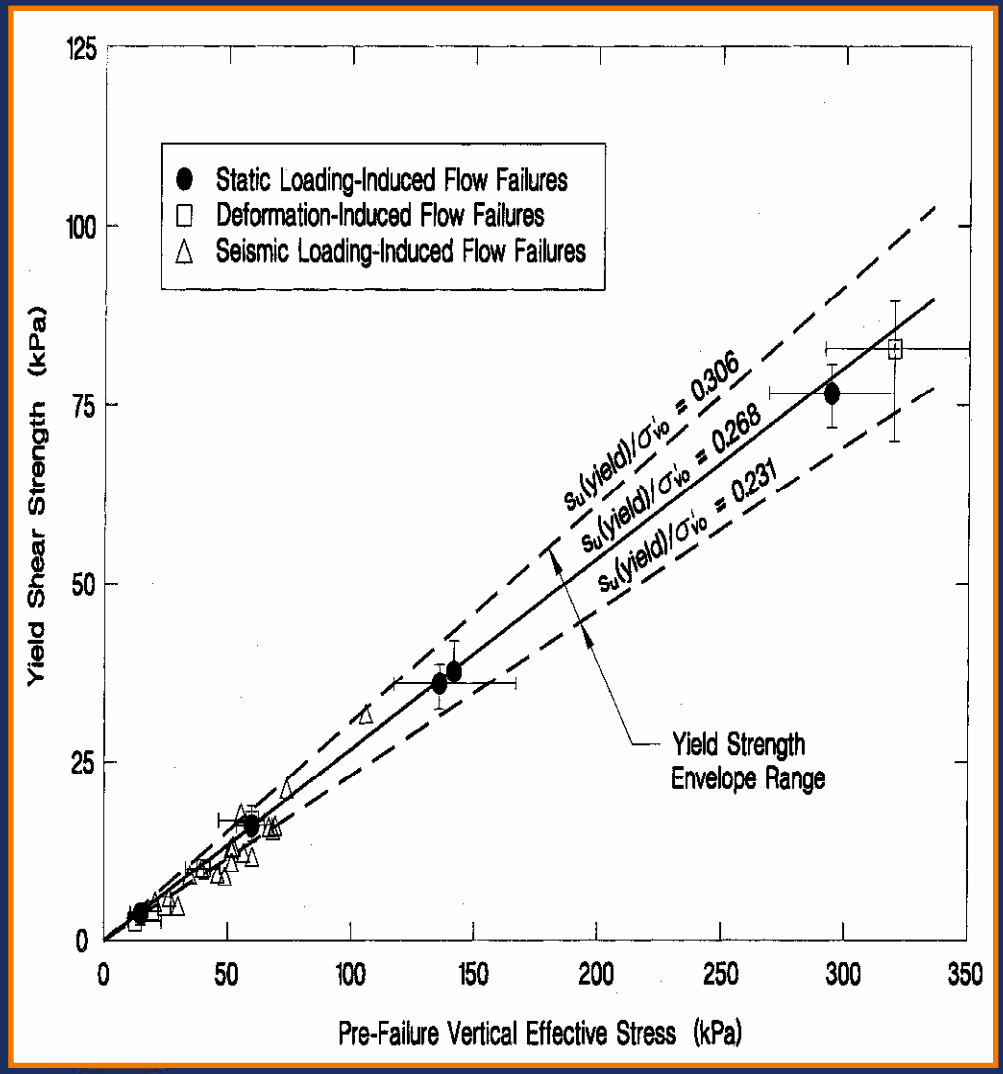
- Susceptibility
- Triggering
- Post-triggering stability



Olson & Stark (2003)

Sloping Ground / Flow Failure

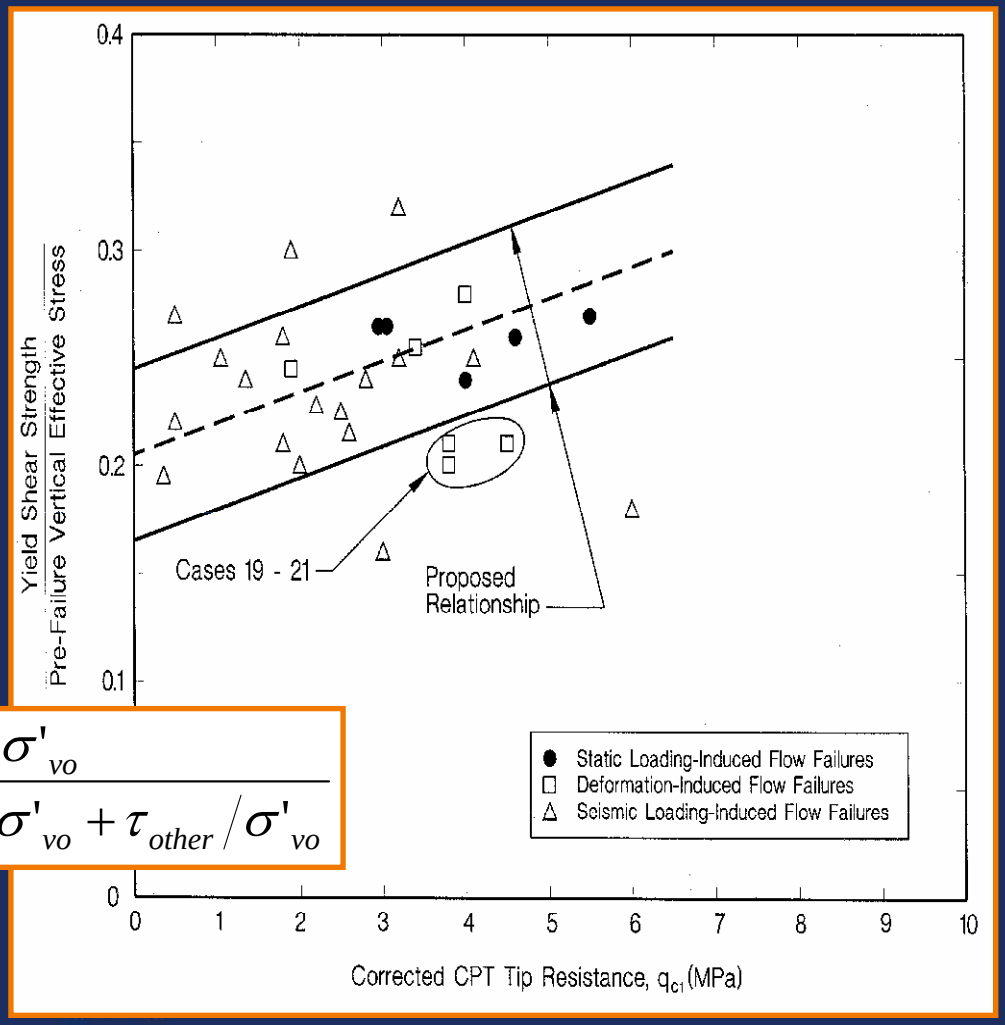
- Susceptibility
- Triggering
- Post-triggering stability



Olson & Stark (2003)

Sloping Ground / Flow Failure

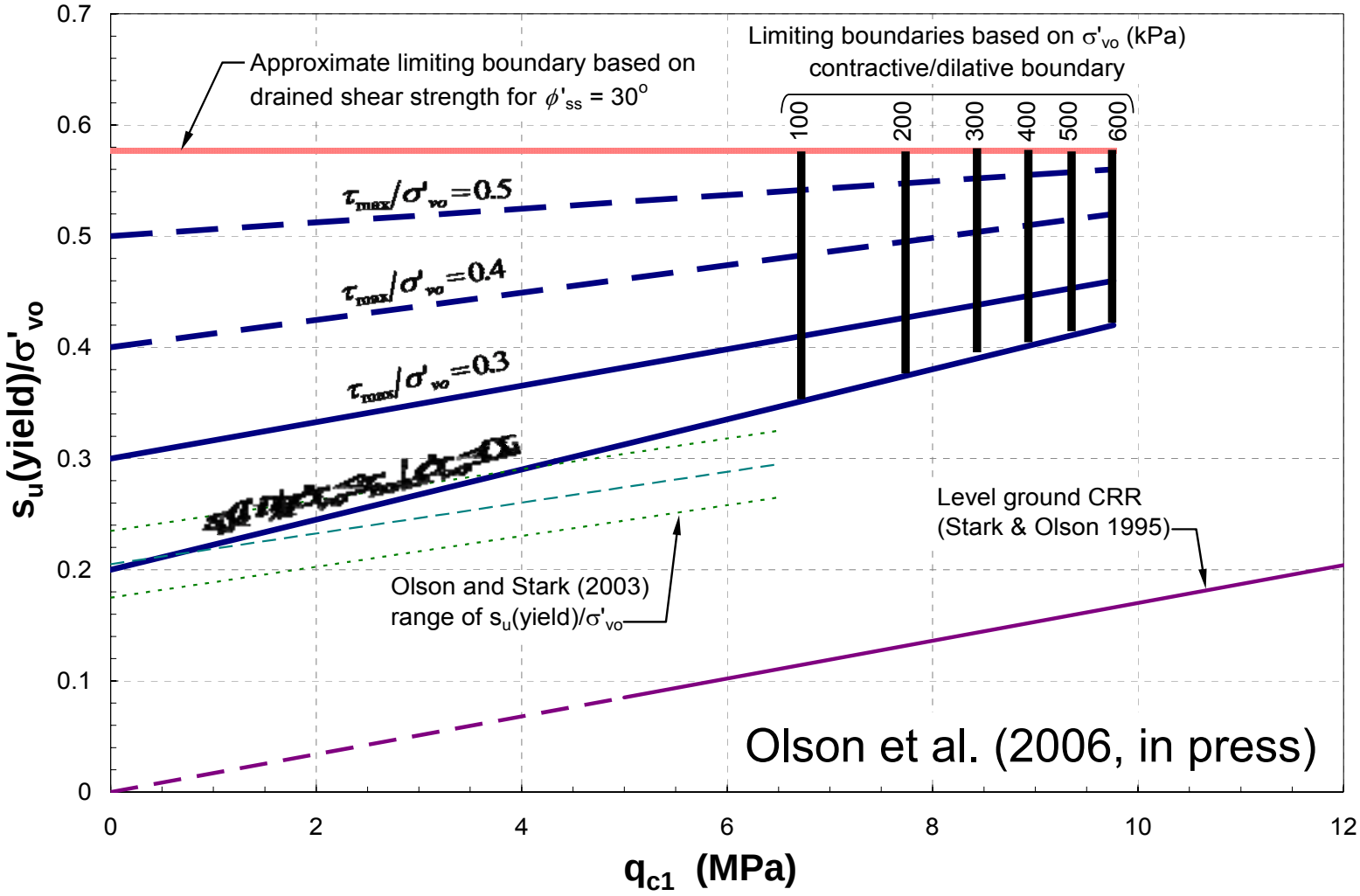
- Susceptibility
- Triggering
- Post-triggering stability



$$FS_{Triggering} \approx \frac{s_u(yield)/\sigma'_{vo}}{\tau_{static}/\sigma'_{vo} + \tau_{avg,seismic}/\sigma'_{vo} + \tau_{other}/\sigma'_{vo}}$$

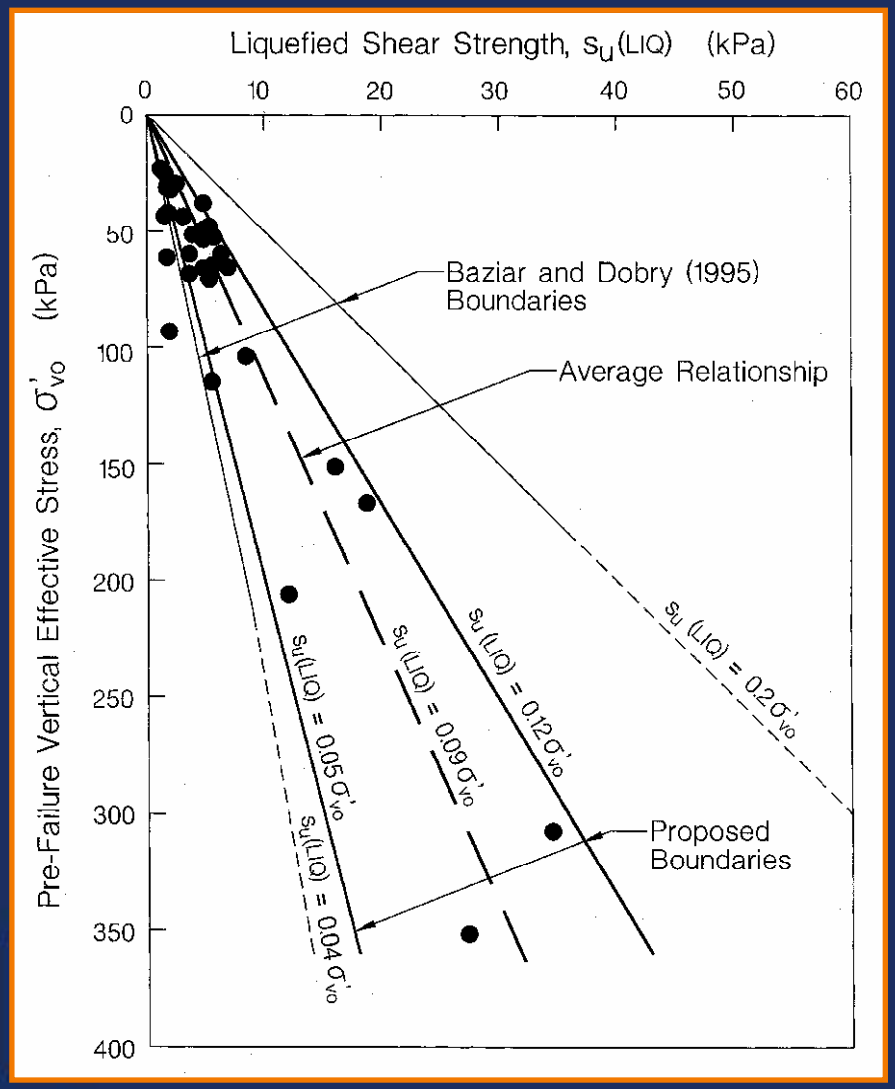
Olson & Stark (2003)

Sloping Ground / Flow Failure



Sloping Ground / Flow Failure

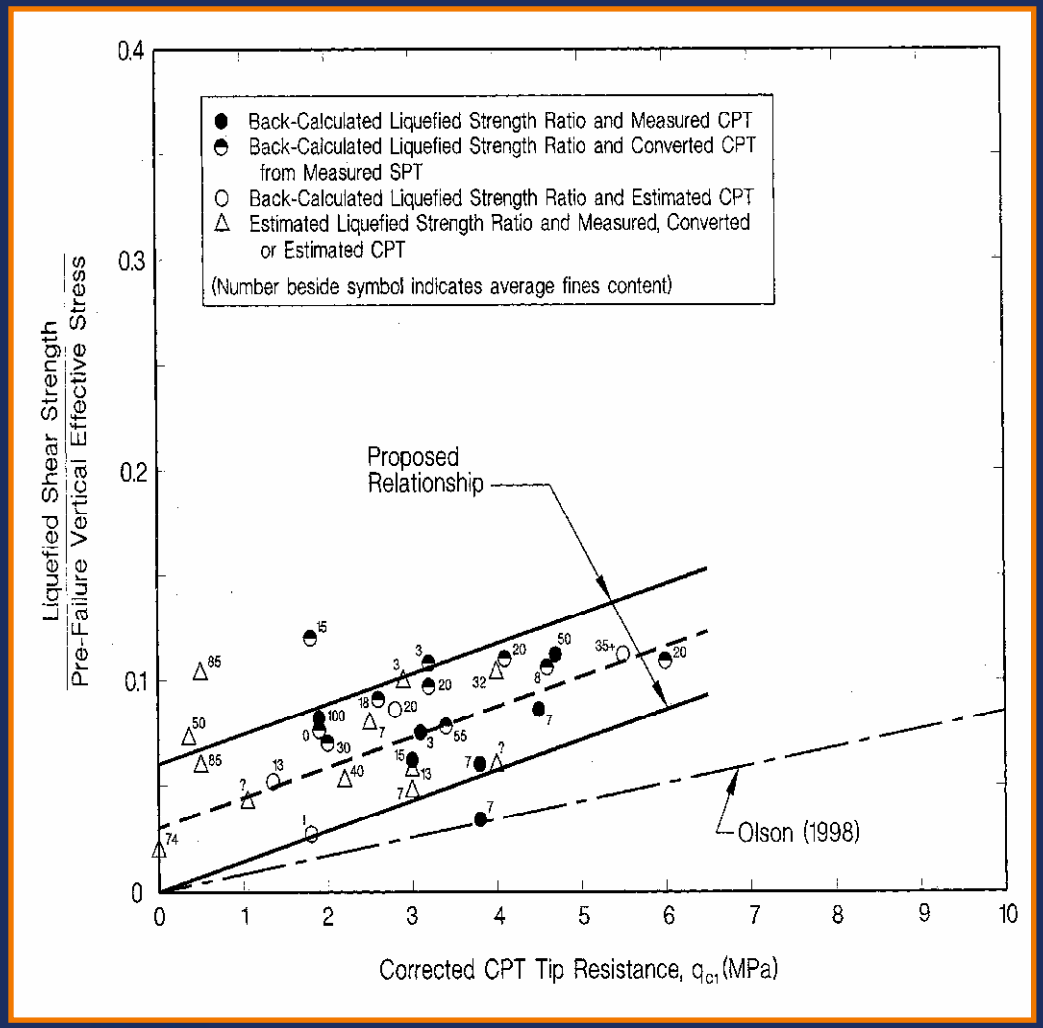
- Susceptibility
- Triggering
- Post-triggering stability



Olson & Stark (2002)

Sloping Ground / Flow Failure

- Susceptibility
- Triggering
- Post-triggering stability



Olson & Stark (2002)

Great River Bridge

- 22,550 ft of bridge
- 1400 ft cable stay main span
- Elevated crossings over levees
- Foundations
  - piles
  - drilled shafts
  - hydraulic caissons

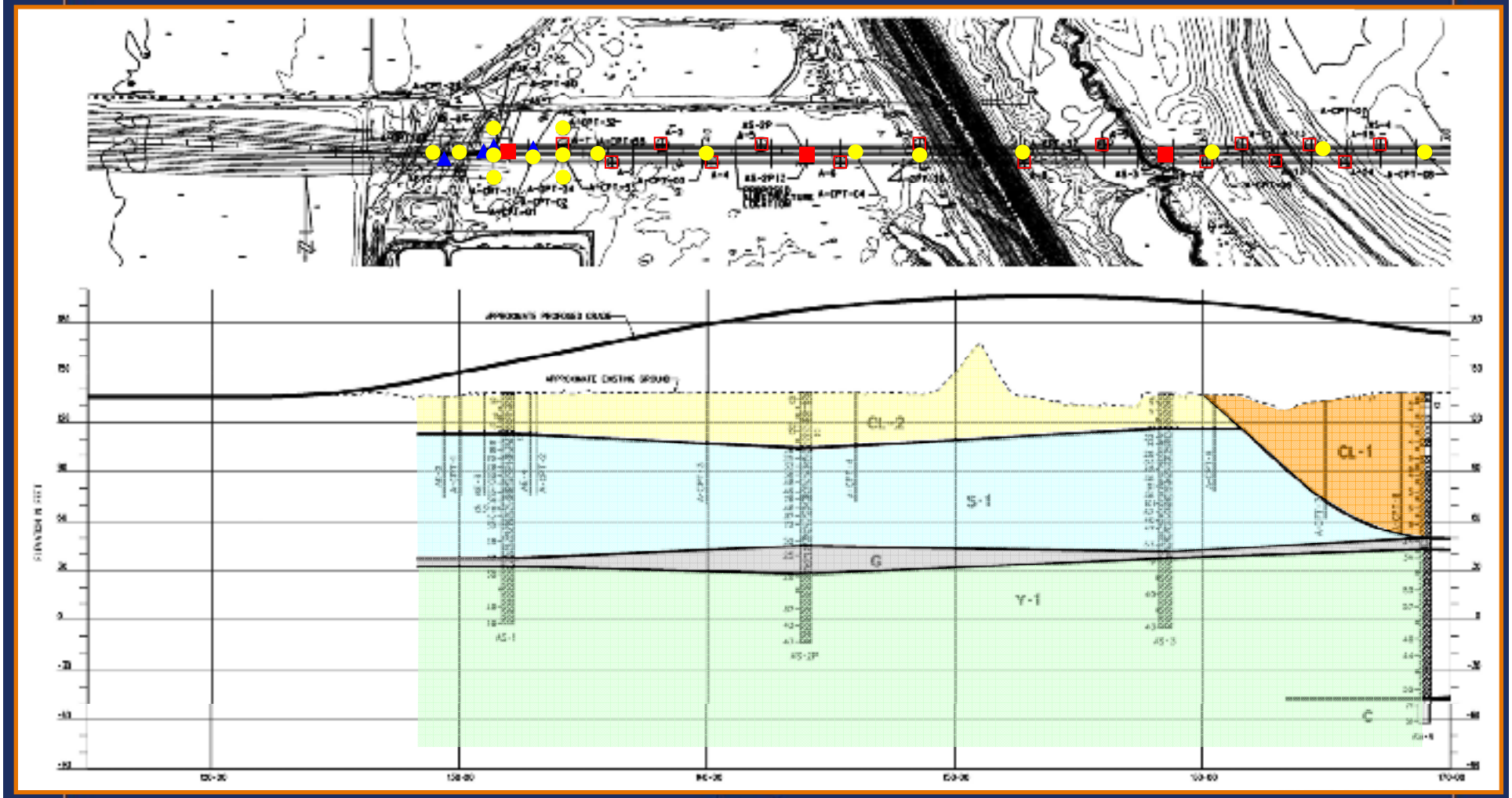
GRB Seismicity

- 2% PE in 50 years
- B/C pga = 0.14g
- Design EQ controlled by NMSZ
  - M_W 7.7
  - R = 200 km

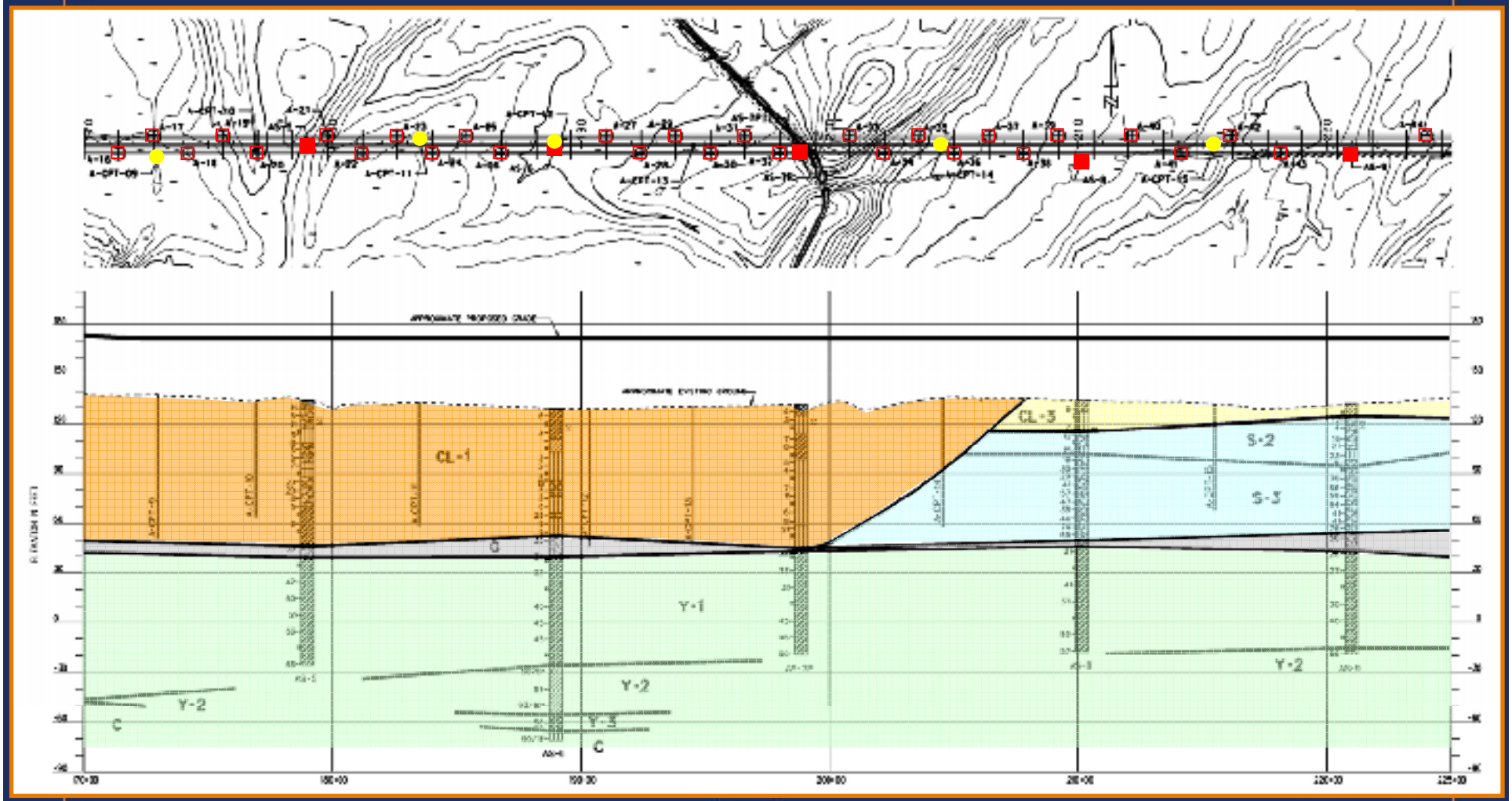
Uses of sCPTu at GRB

- Detailed stratigraphy
- Soil properties
  - static
  - dynamic (Vs)
- Liquefaction analysis
  - level ground / settlement
  - lateral spreading
  - sloping ground / flow failure

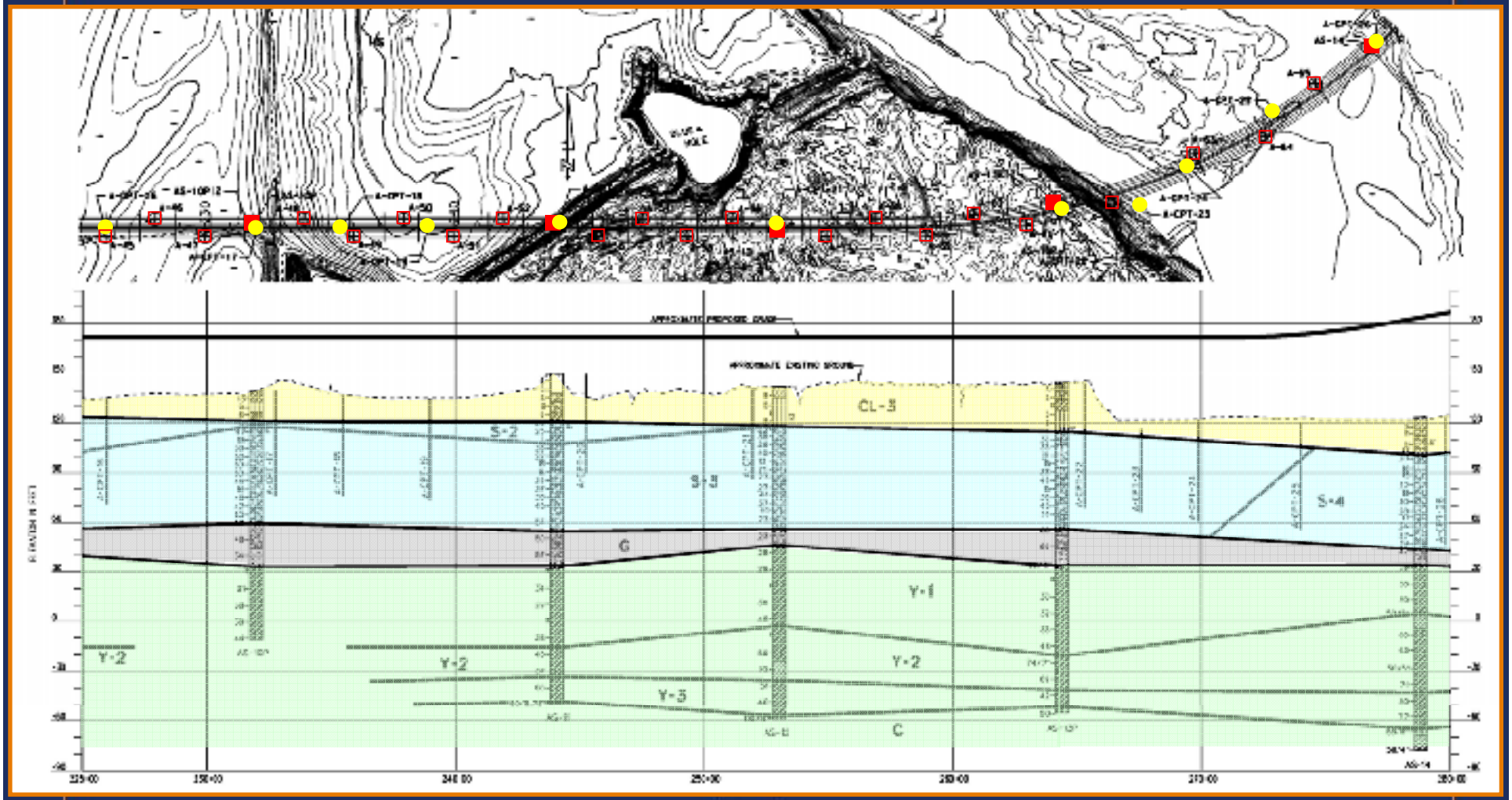
GRB Subsurface Profile



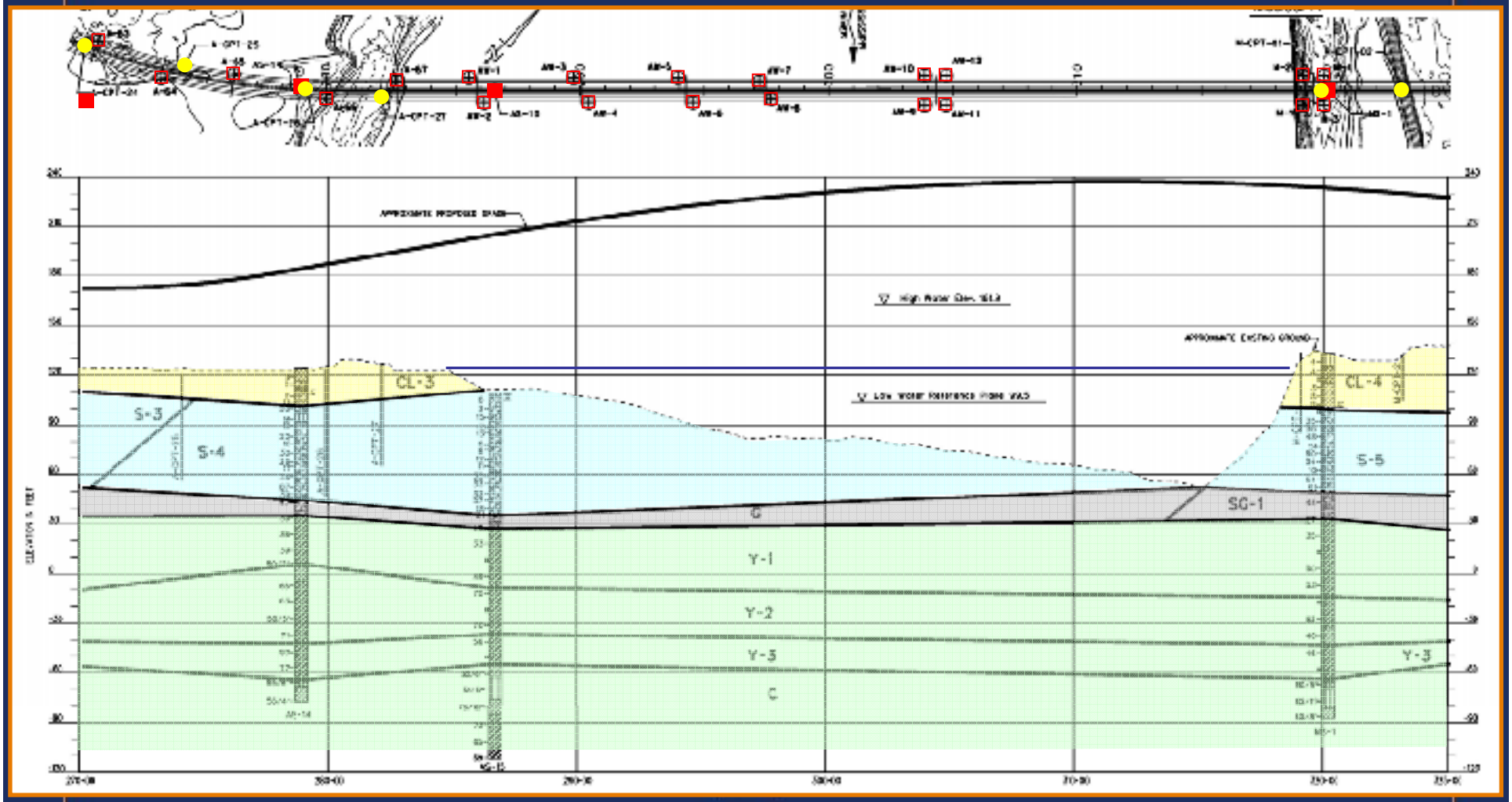
GRB Subsurface Profile



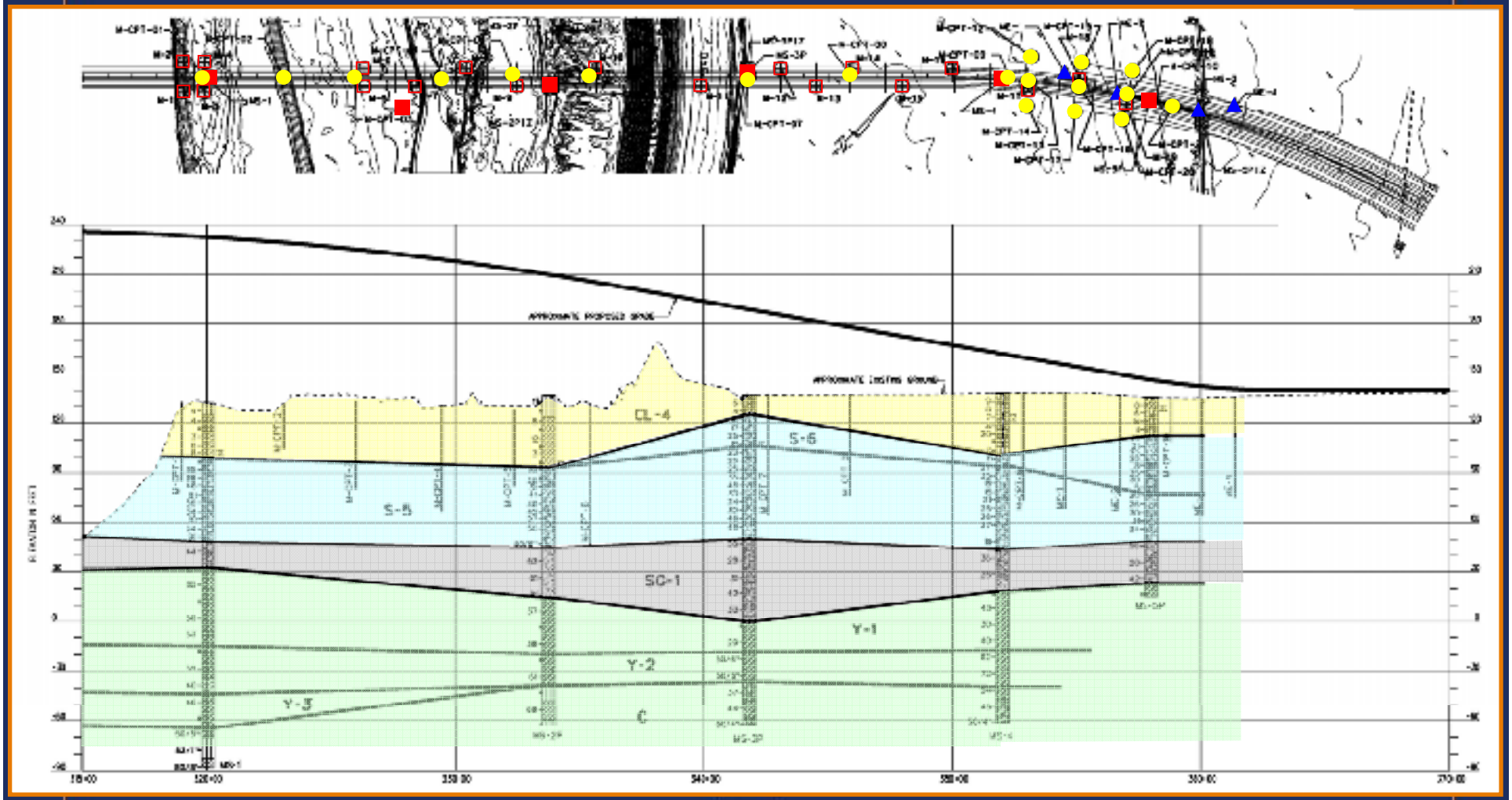
GRB Subsurface Profile



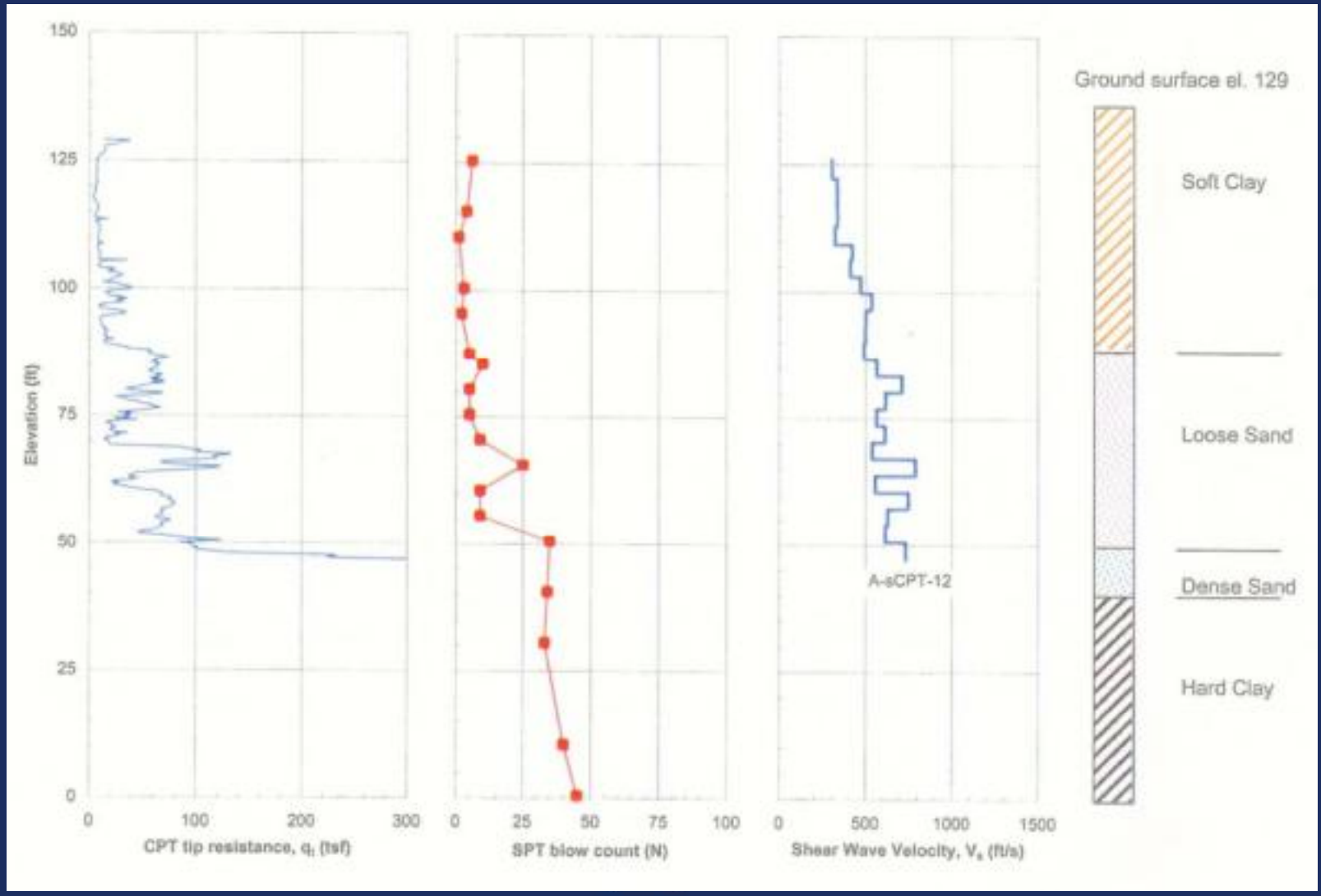
GRB Subsurface Profile



GRB Subsurface Profile



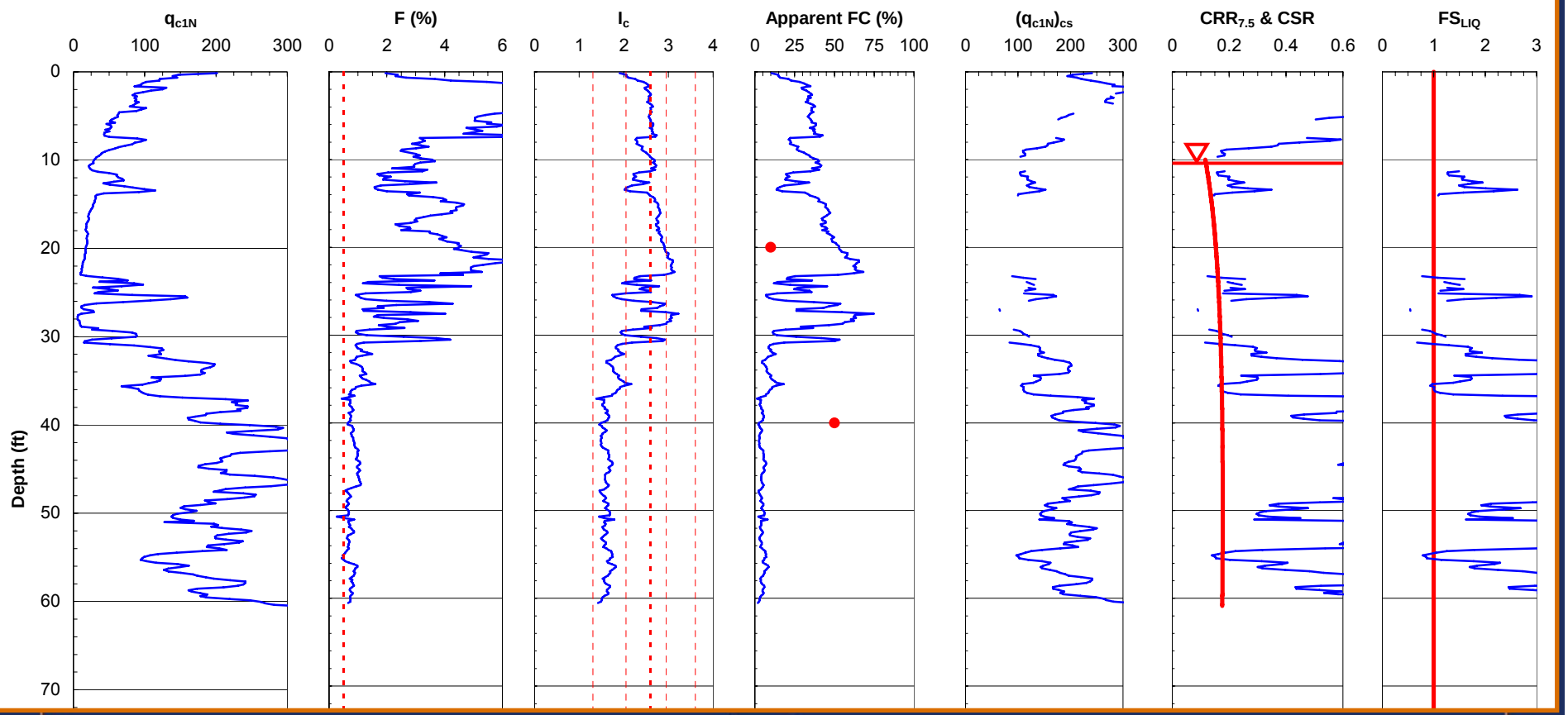
GRB Dynamic Soil Properties



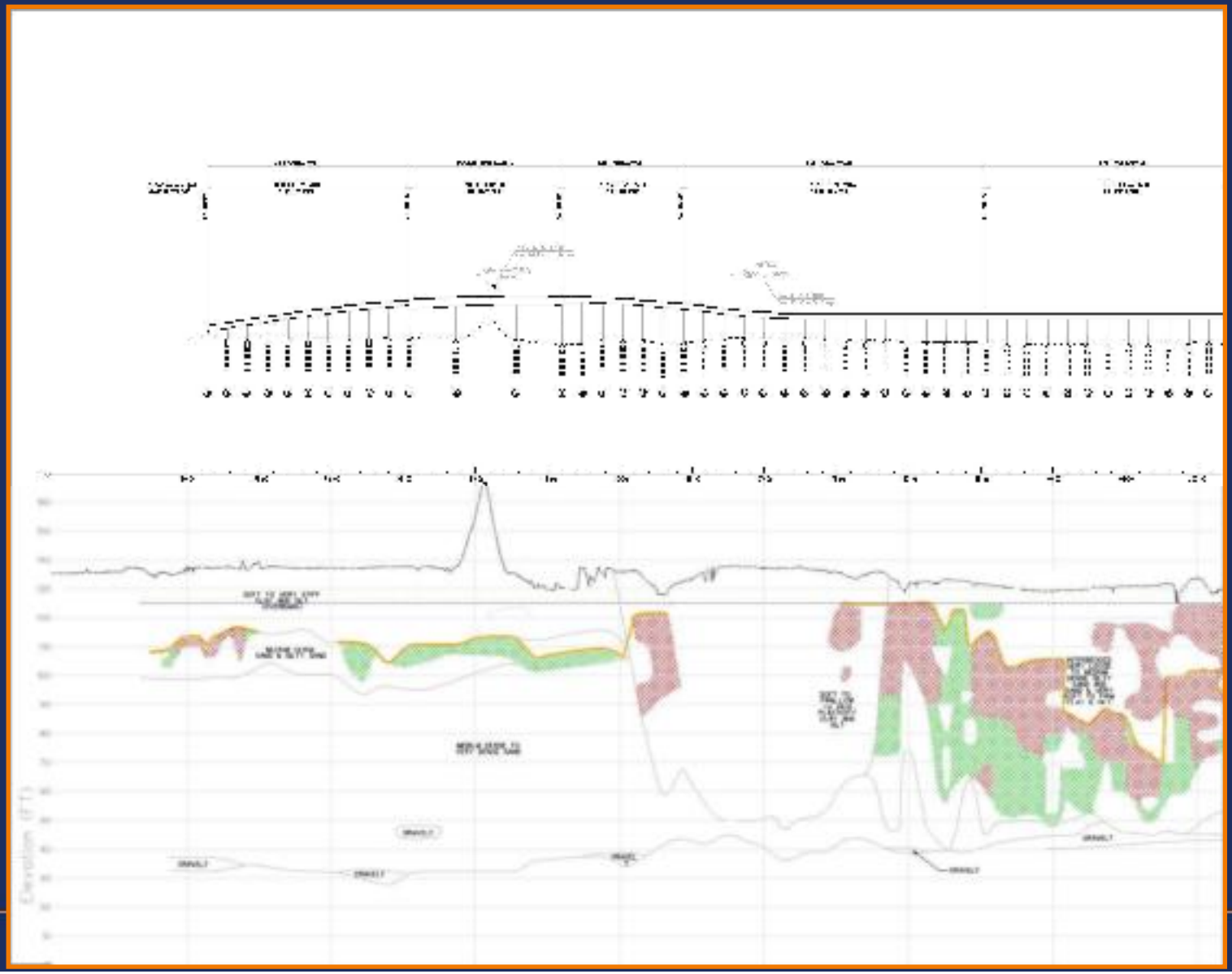
GRB Level Ground Liquefaction

General Information		Soil Information			Earthquake Information		Analysis Information	
Location:	Arkansas City, AR	Average γ_t:	120	pcf	M_W:	8.1	FC relation:	FC calculated from Ic (Robertson & Wride 1997)
Project No.	23-20010054.00	GWT depth:	10	ft	a_{max}:	0.18 g	MSF:	0.85 Idriss (1999) TRB presentation
Date:	08/10/01						r_d relation:	Idriss (1999) TRB presentation

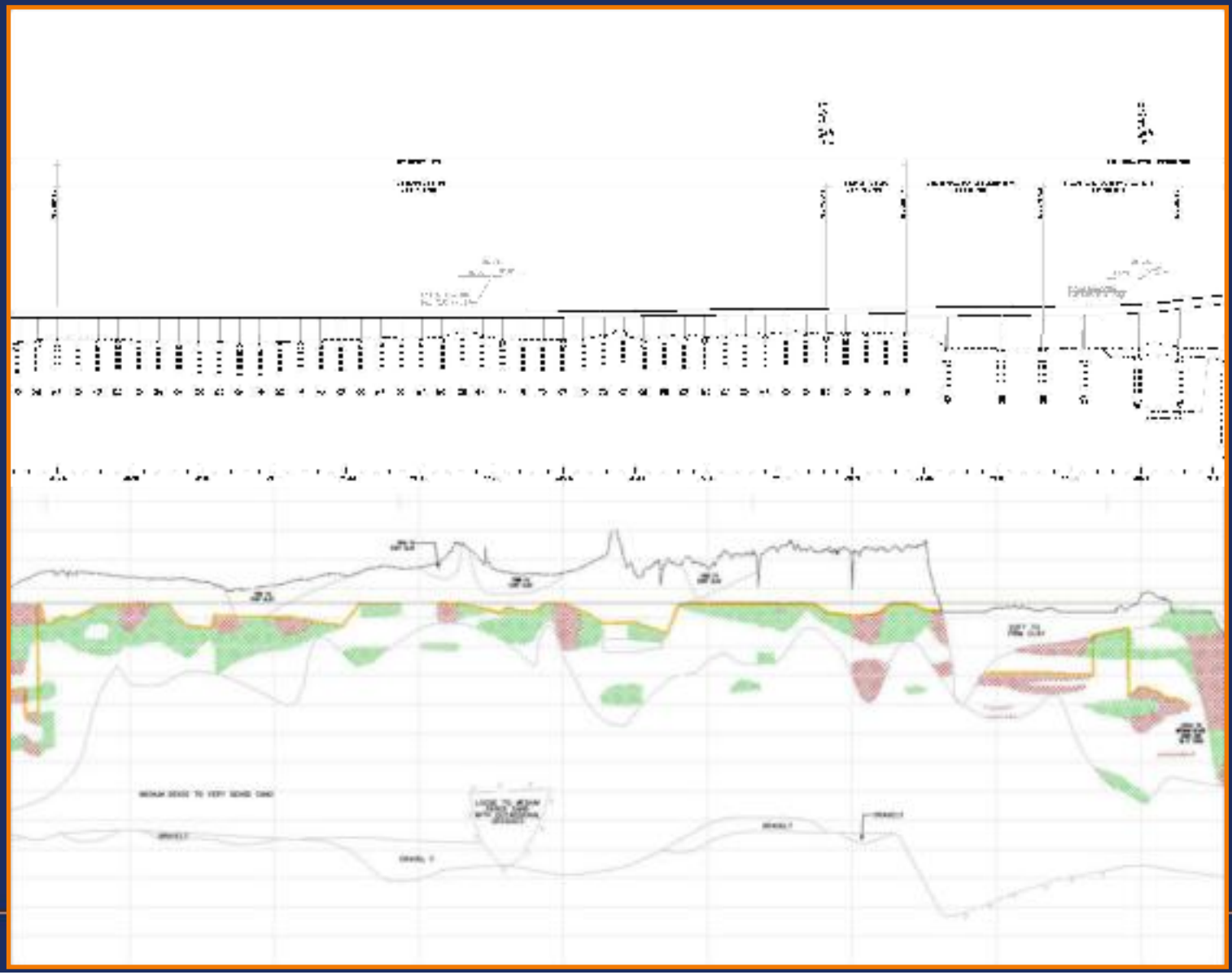
Sounding A-CPT-1



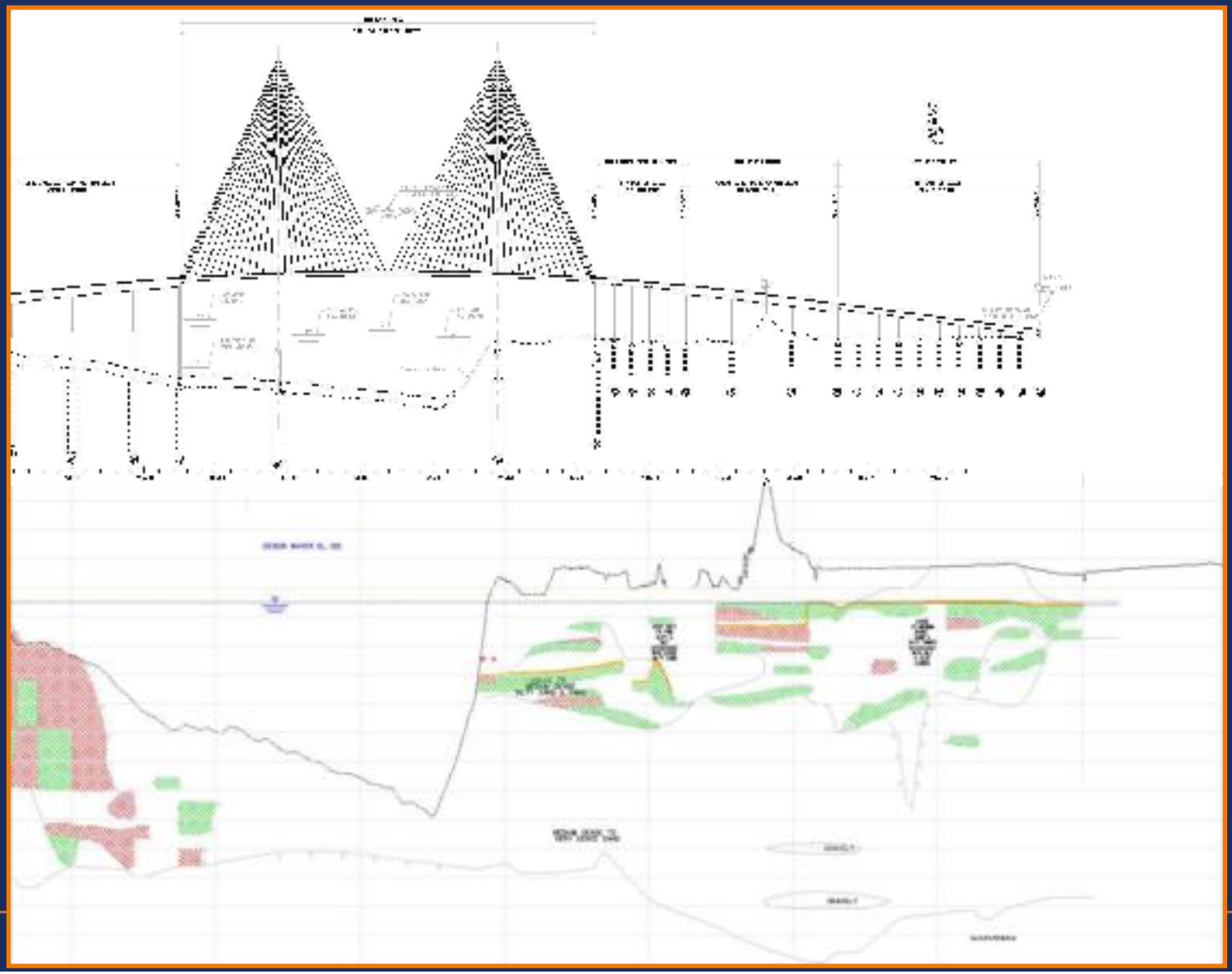
GRB Level Ground Liquefaction



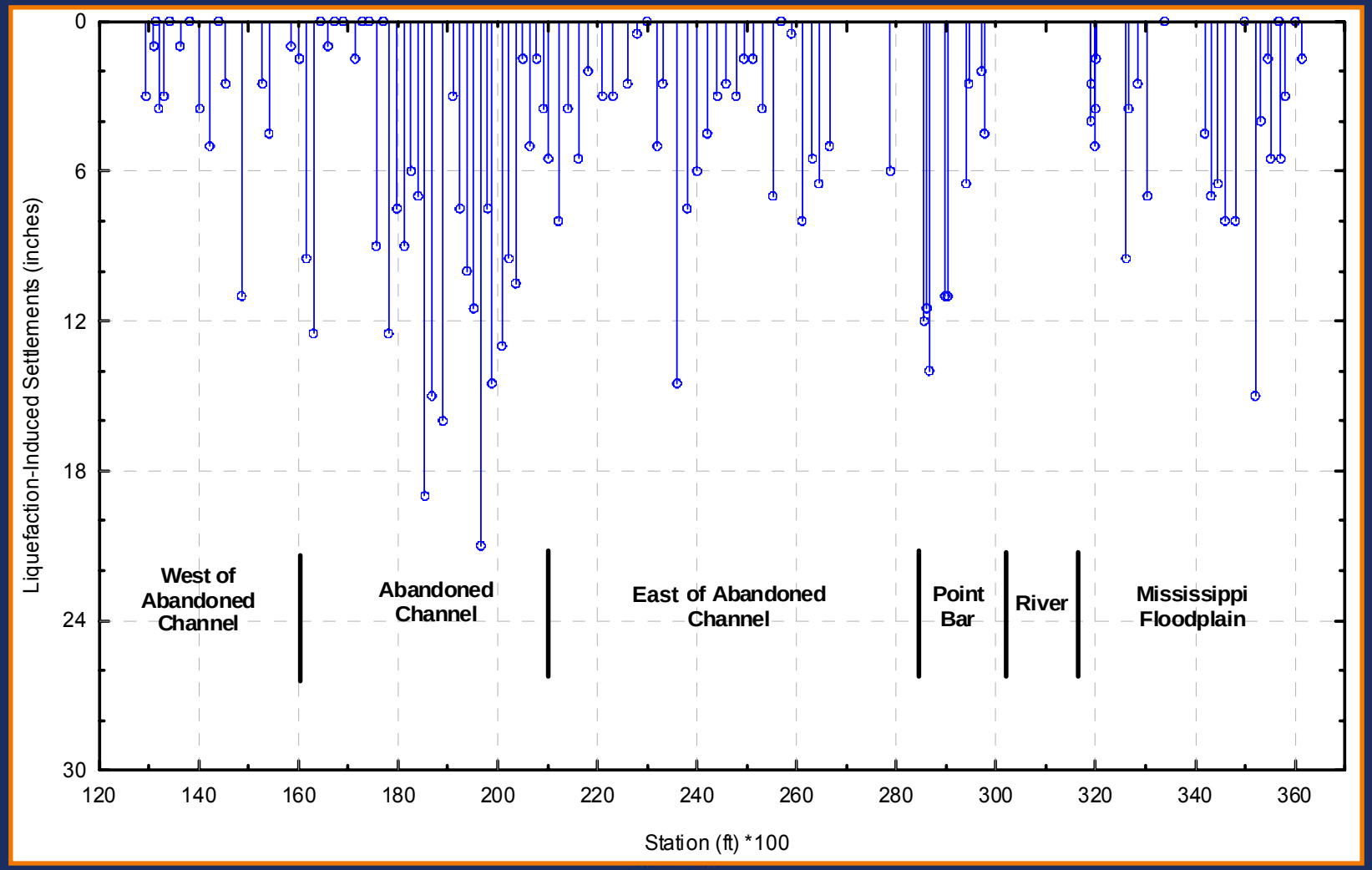
GRB Level Ground Liquefaction



GRB Level Ground Liquefaction

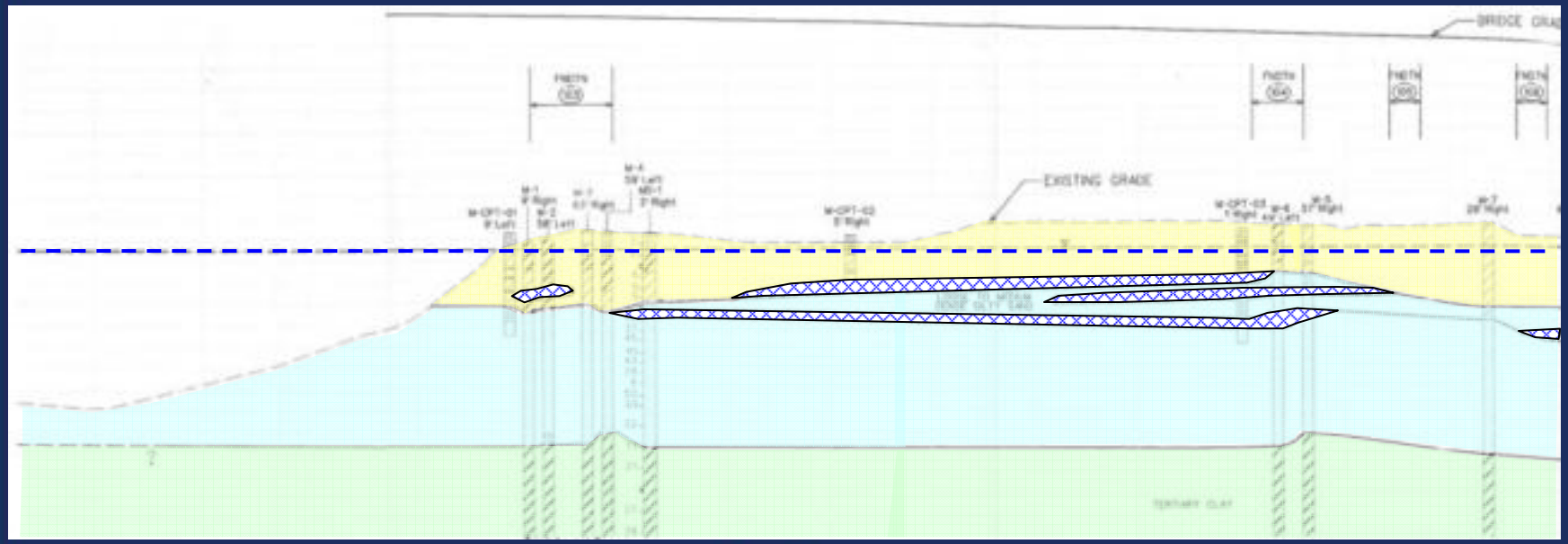


GRB Liquefaction Settlement

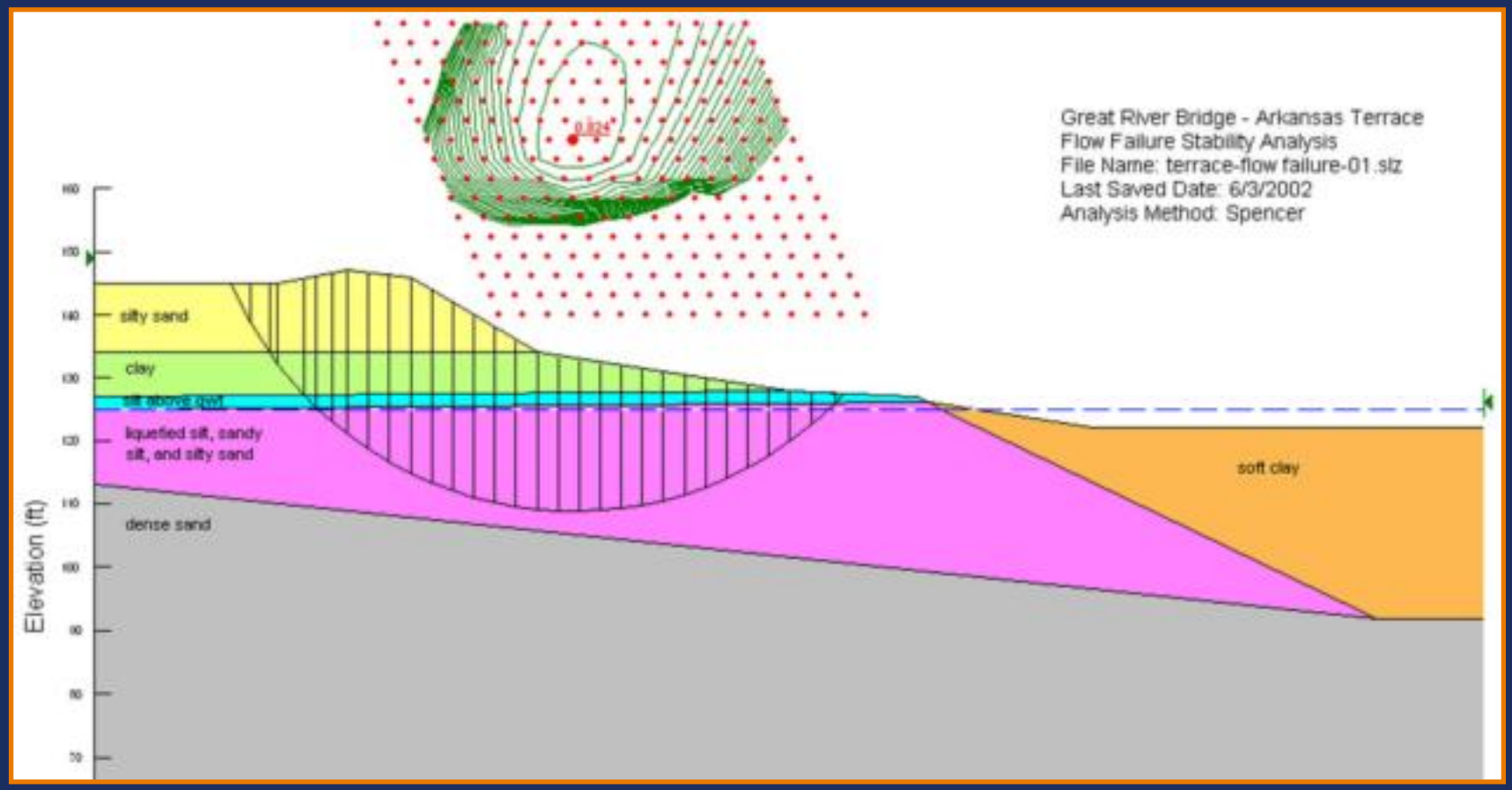


GRB Lateral Spreading

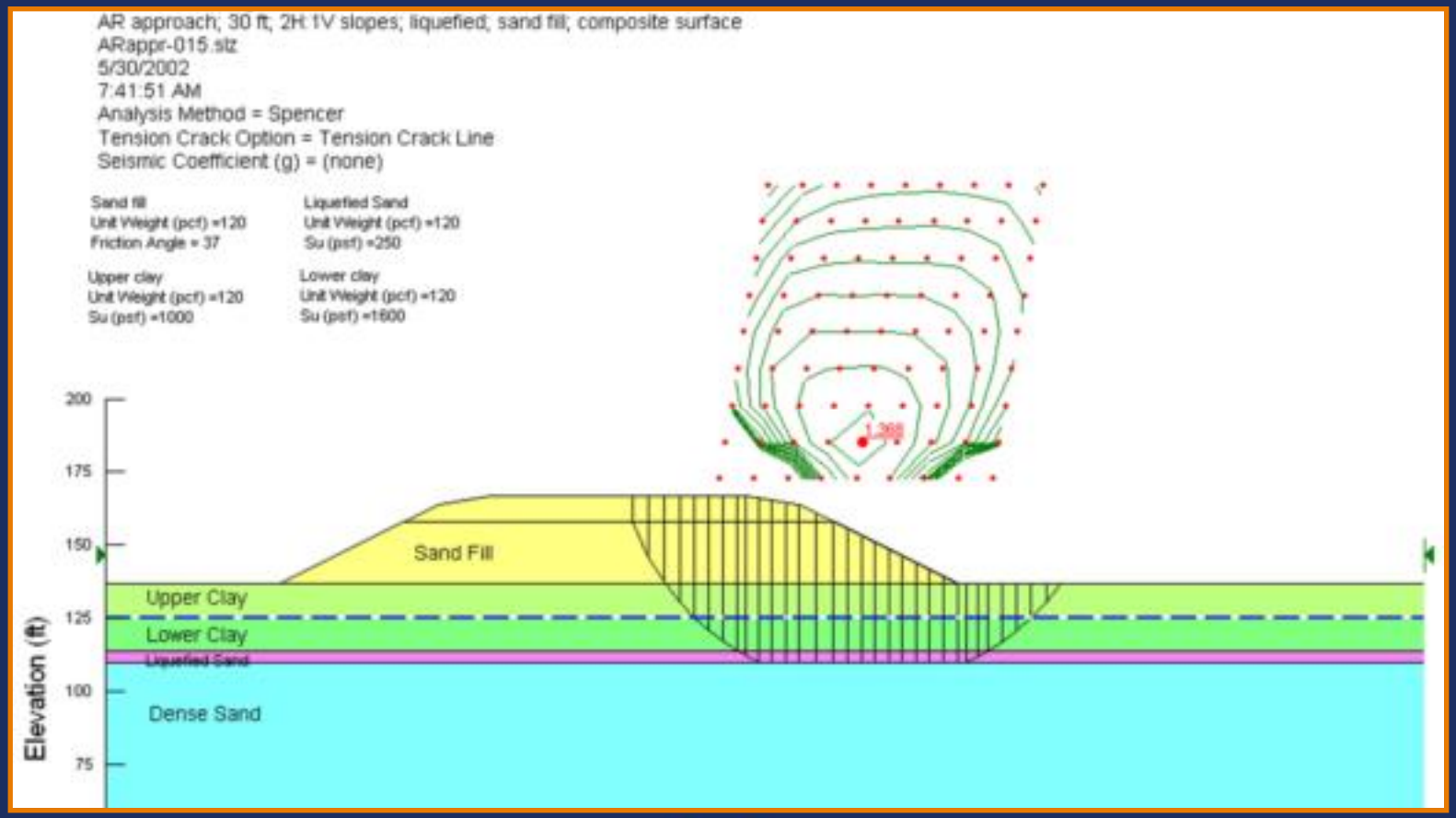
- Arkansas pointbar → 3 to 13 ft
- Mississippi cutbank → negligible



GRB Sloping Ground / Flow Failure



GRB Sloping Ground / Flow Failure



Conclusions

- sCPTu is an excellent site investigation tool when conditions are appropriate
  - quality & quantity of data
  - rapid & versatile
  - cost-effective
  - repeatable

Conclusions

- sCPTu is a versatile design tool well-suited to geotechnical earthquake engineering
  - site response (ground shaking)
  - liquefaction engineering
  - site characterization & soil properties for:
    - landslides (seismic slope stability)
    - seismic foundation & retaining structure design
    - lifeline engineering

Conclusions

- sCPTu works particularly well for liquefaction engineering
  - loose & soft materials
  - thin layer identification
  - level ground liquefaction, settlement, flotation
  - lateral spreading
  - sloping ground & flow failure

Thank You!

Questions???