ENGINEERING GEOLOGY'S ROLE IN REOPENING VERMONT'S TRANSPORTATION INFRASTRUCTURE IN RESPONSE TO CLIMATE CHANGE

JAY R. SMEREKANICZ, P.G., C.P.G.
SENIOR ENGINEERING GEOLOGIST
SCARPTEC, INC.
MONUMENT BEACH, MASSACHUSETTS
JAY@SCARPTEC.COM

ETHAN J. THOMAS
AOT GEOLOGIST III
ETHAN.THOMAS@VERMONT.GOV

JULIE SOPHIS
AOT GEOLOGIST I
JULIE.SOPHIS@VERMONT.GOV

VERMONT AGENCY OF TRANSPORTATION (VTRANS)
HIGHWAY DIVISION | CONSTRUCTION & MATERIALS BUREAU
GEOTECHNICAL ENGINEERING SECTION | GEOLOGY UNIT

Climate Change's Effects on Vermont's Roadway Slopes

- Roadway slopes – located in easiest terrain for road construction, i.e., weakest rocks. Slope failures lead to road closures, sometimes for days to weeks, affecting safety, travel, commerce & tourism

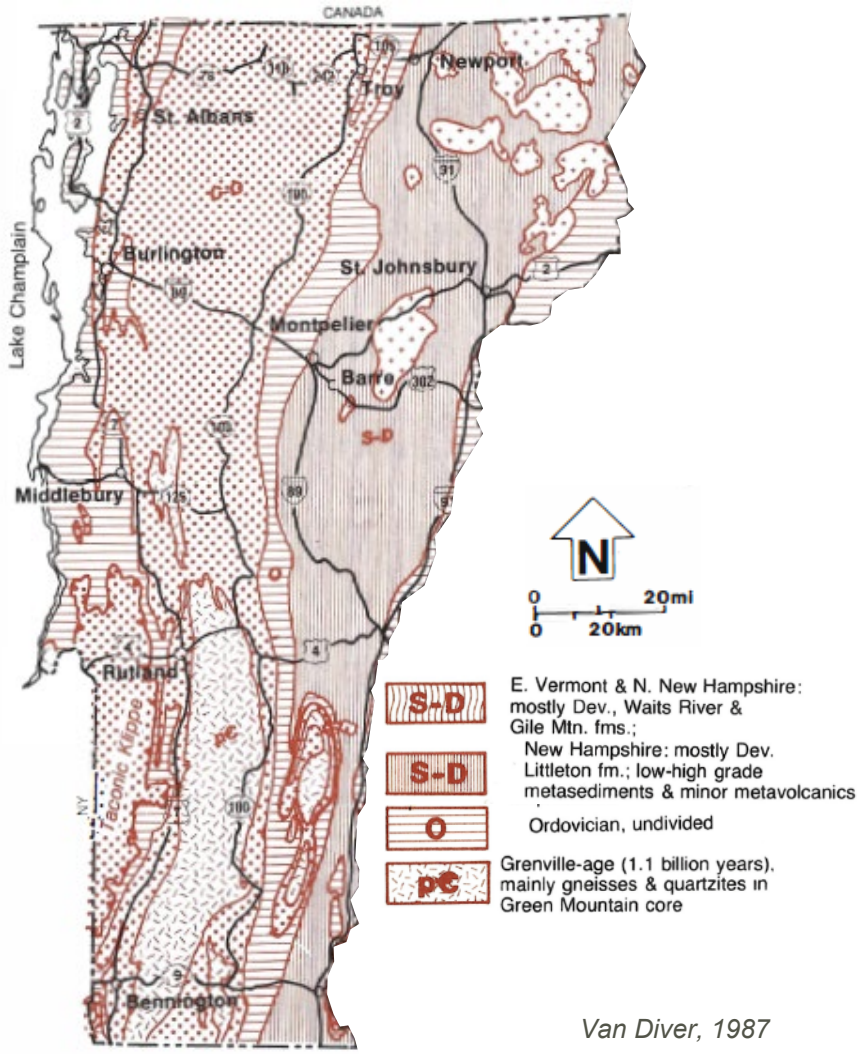
- In the past ~15 years in VT, more intense rainfall events of longer duration, too much water, not enough time to drain

- Temperature swings more intense

- Engineering geologists and their skills are vital in addressing climate change effects

VT Rt 5A, Westmore (VTrans, 2007)

Vermont's Roadways



Van Diver, 1987

- Roadway slopes – located in easiest terrain for road construction, i.e., weakest rocks (rivers→trails→roads)
- Most notorious formations are Silurian/Devonian metasediments & metavolcanics (Waits River & Gile Mtn Fms (slates, phyllites and schists)
- These weak rocks ideal for development of roadways
- VTran's robust hazard rating system updated regularly to identify and mitigate slopes with highest risk (10-year plan)

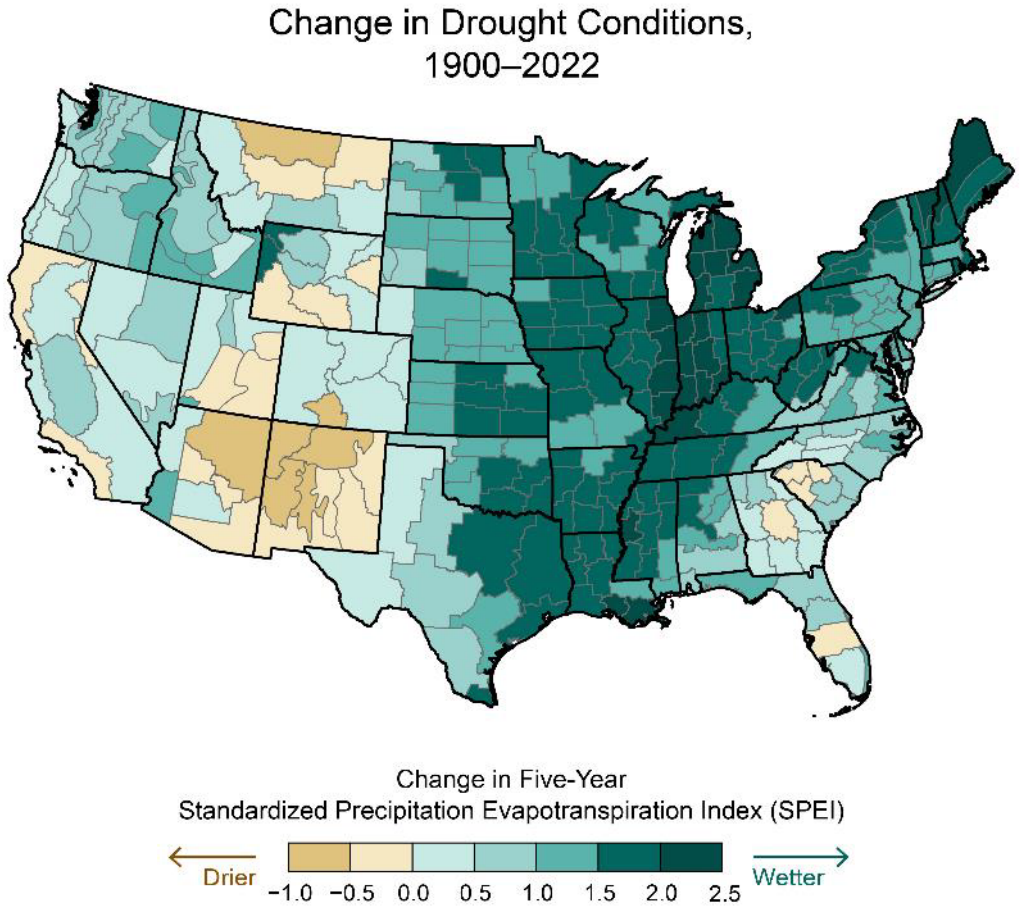
Effects of Slope Failures

- Slope failures lead to road closures, sometimes for days to weeks, even months
- Emergency remediation strains budgets and delays existing projects

Elm St. Rockslide, Montpelier, December 2005 (VTrans)

I-91 SB, Fairlee, August 2023 (VTrans)

Increasing Precipitation

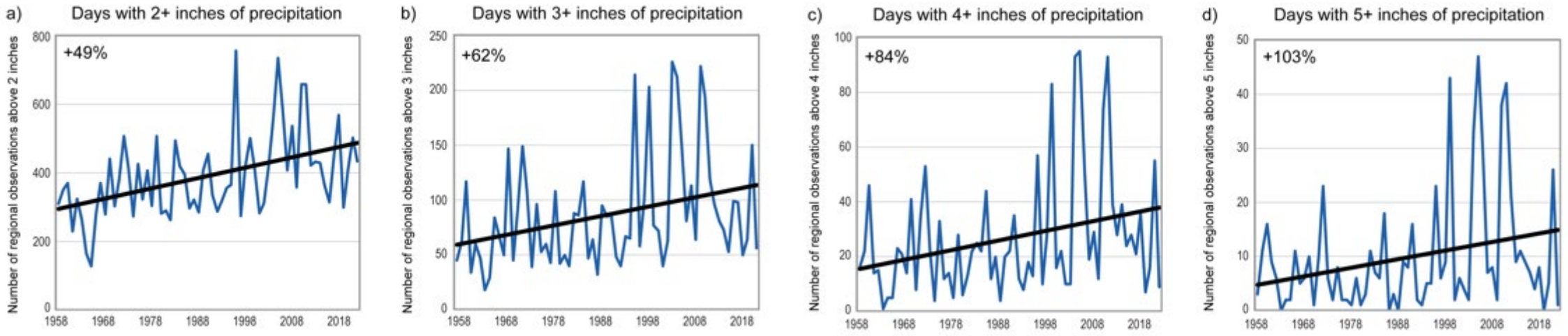


Crimmins et al., 2023 (NAC5)

I-89 NB, Berlin, July 2012 (VTrans)

Slope Failures Likely Increasing Due to More Intense Storms

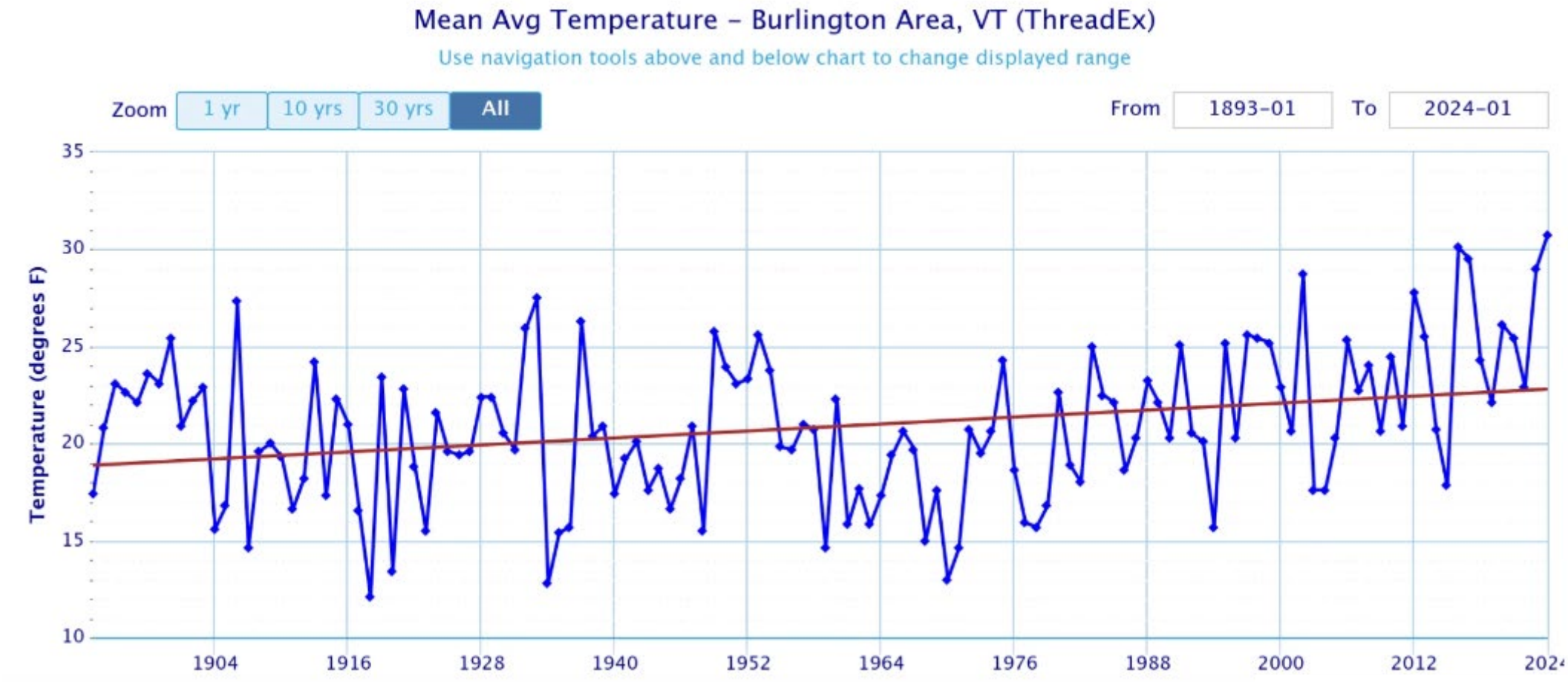
- Slope failures and their severity increasing in past ~15 years
- Increasing persistence of precipitation events and increasing magnitude of high-intensity precipitation events (Guilbert et al., 2015)
- Magnitude of 2-day storms increasing (Douglas & Fairbank, 2011)
- Number of days with extreme precipitation increasing (Jay, et al. 2023 [5th National Climate Assessment])
- More extreme weather also leads to larger volume slope failures



Crimmins et al., 2023 (NAC5)

Slope Failures Likely Increasing Due to Increasing Temperatures

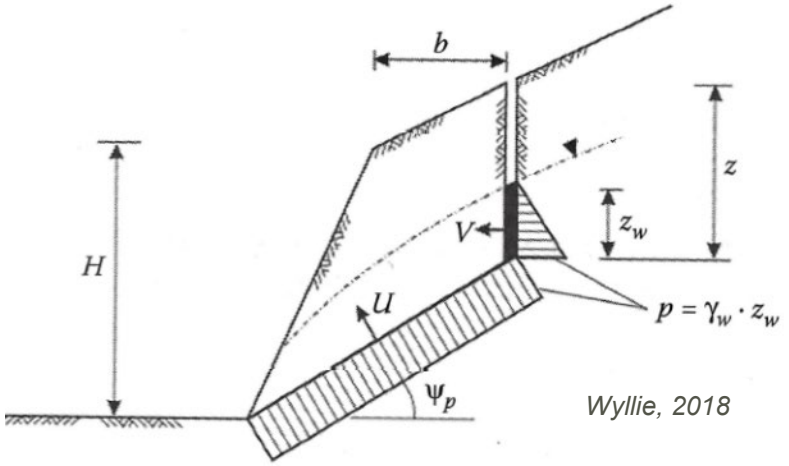
- Increases in temperature near freezing point leads to more freeze-thaw induced slope failures



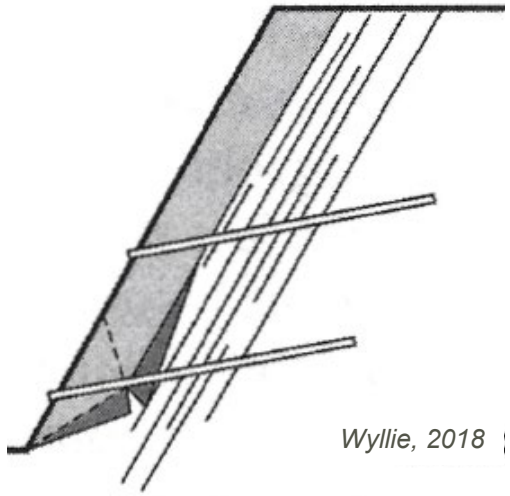
Northeast Regional Climate Center, 2024

Engineering Geology Response

- From 2000 to 2019 extreme rainfall events increased 75% (DeGaetano & Tran, 2022)
- Engineering design standards for drainage systems, dams and other infrastructure rely on analyses of precipitation extremes (DeGaetano & Tran, 2022)
- In engineering geology/rock mechanics, we routinely now apply worst-case scenarios driven by these climate change effects
- Assume full saturation of tension cracks, saturated pore water pressures, ice jacking, tree root jacking (wind), etc.
- Including more drainage and reinforcement in slope designs, which increases remedial costs



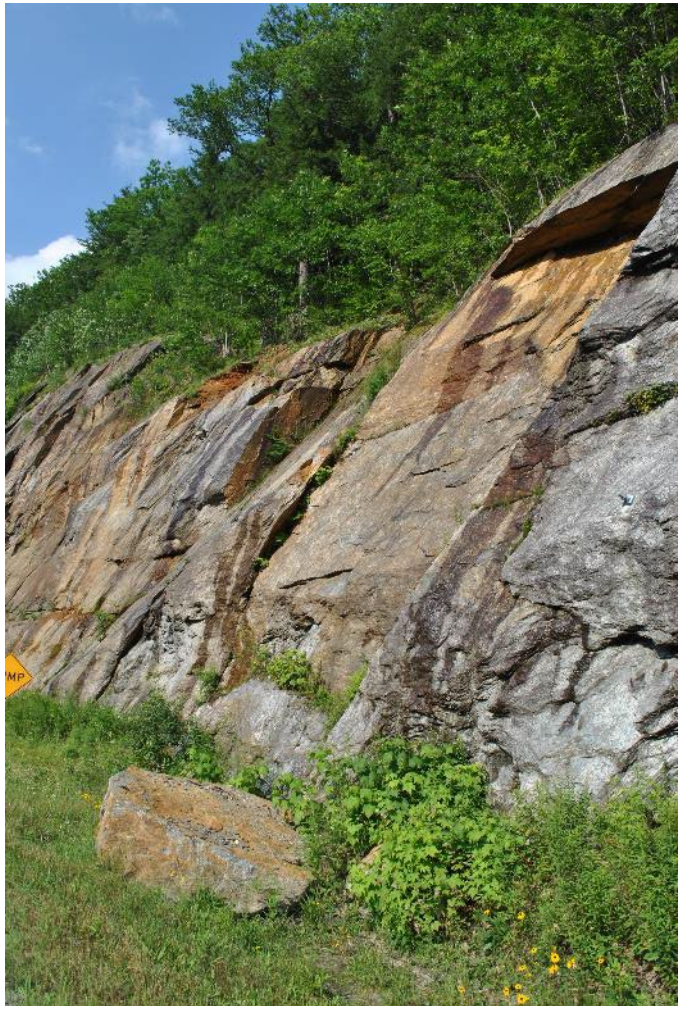
Wyllie, 2018


Wyllie, 2018

Old Rock Slope Designs – Effects of Climate Change

- Some rock slopes date from late 1800s
- Most from 1950s/1960s during interstate construction boom used a standard 4V:1H slope angle regardless of geology
- Constructed prior to widespread use of controlled perimeter blasting (i.e., presplitting)
- Failure of aging, poorly designed and constructed rock slopes exacerbated by accelerated weathering and higher hydrostatic forces

Rockslide I-89 NB, Exit 6, Berlin, July 2012 – note metalimestone bed between phyllite/schist layers (Waits River Fm; VTrans)



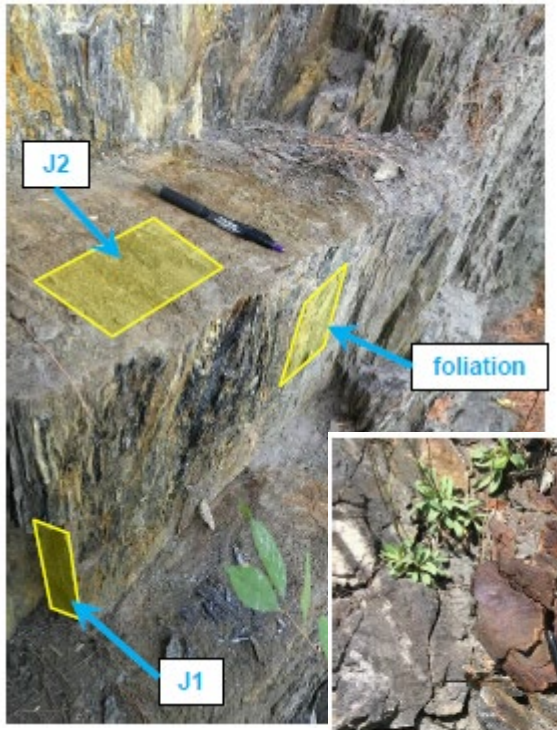
Rock fall VT Rt 103 Chester – note wet/weathered foliation planes (Gassetts Schist; Golder WSP, 2023)

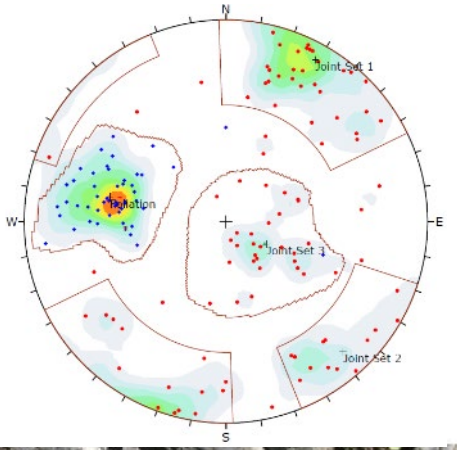
The Role of the Engineering Geologist

Rock dowel pull testing, Fairlee (Scarptec, 2024)

- What is an engineering geologist? Specialist in planning, designing, operation and maintenance of civil works
- Assess rock & soil slopes in VTrans system
- Map slopes for geologic/geotechnical characterization for rockfall, landslide and debris flow hazard analyses
- Allocate risk to public, assign remedial priorities
- Design mitigation/remedial activities to reduce rockfall/landslide risk
- Emergency response (24/7/365), assess conditions as to when roads can be reopened (even partially)

The Role of the Engineering Geologist - Disciplines



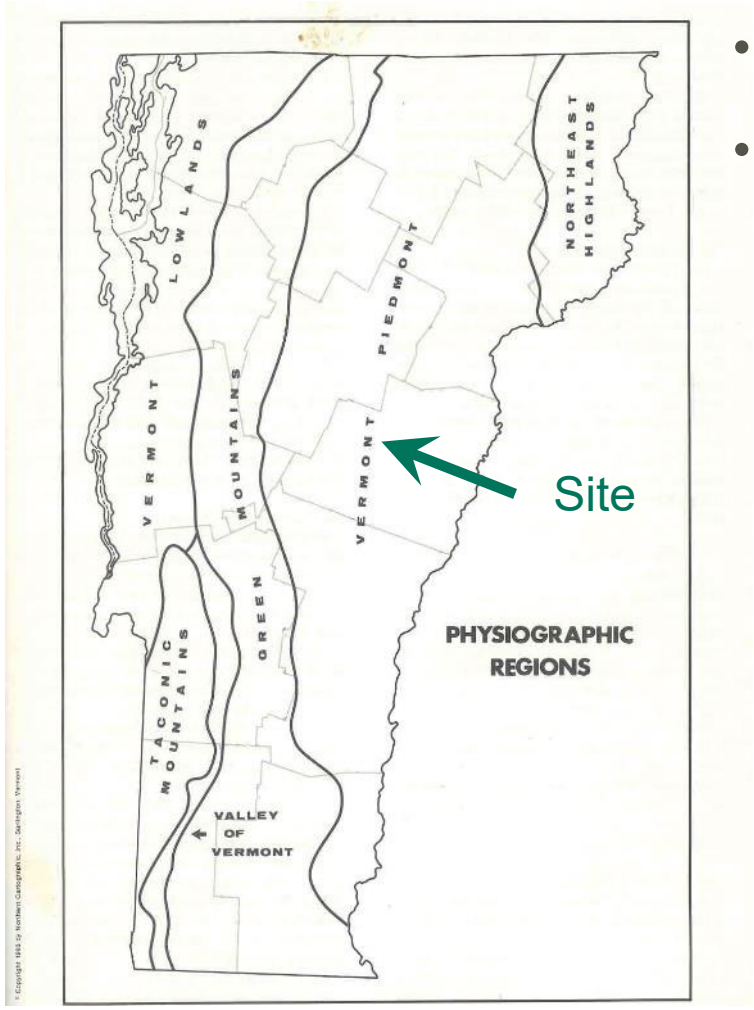


Stowe & St. Johnsbury (Golder WSP/VTrans 2018/2019)

- Desk top studies (regional mapping, aerial LiDAR)
- Field mapping (drones/terrestrial LiDAR)
- Structural & surficial geology
- Geohazards mapping
- Geotechnical engineering/physics
- Mineralogy
- Petrology
- Hydrogeology
- Meteorology
- Health & Safety (traffic hazards)

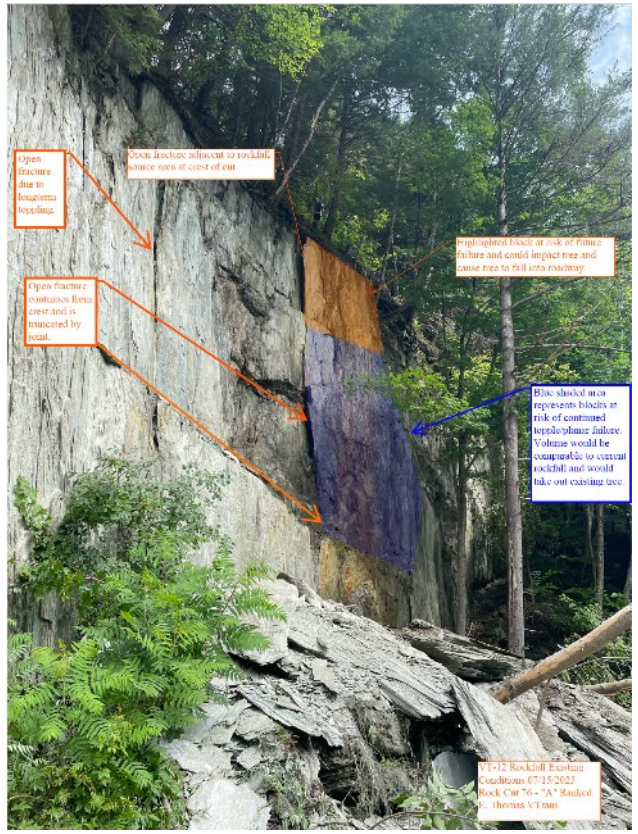
(Smerekanicz)

Case History 1: VT Rt 12 Rockslide, Berlin



Northern Cartographic, Inc., 1986

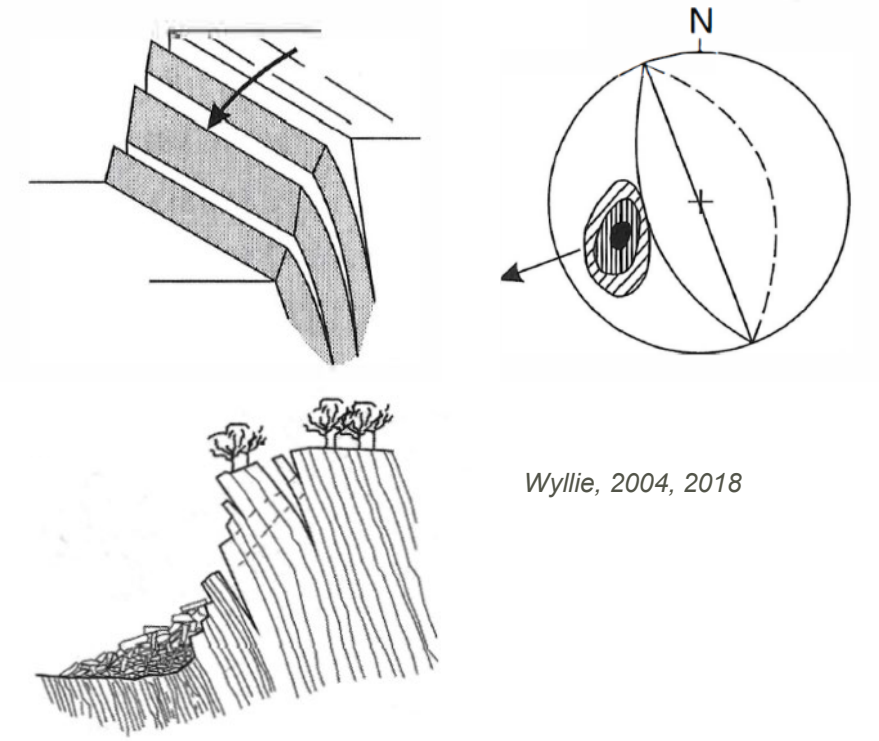
- July 10-11, 2023 rainfall event, ~5 in.
- Geology: Devonian-Silurian Northfield Fm, quartz-sericite slate/phyllite



VTrans, 2023

Case History 1: VT Rt 12 Rockslide, Berlin

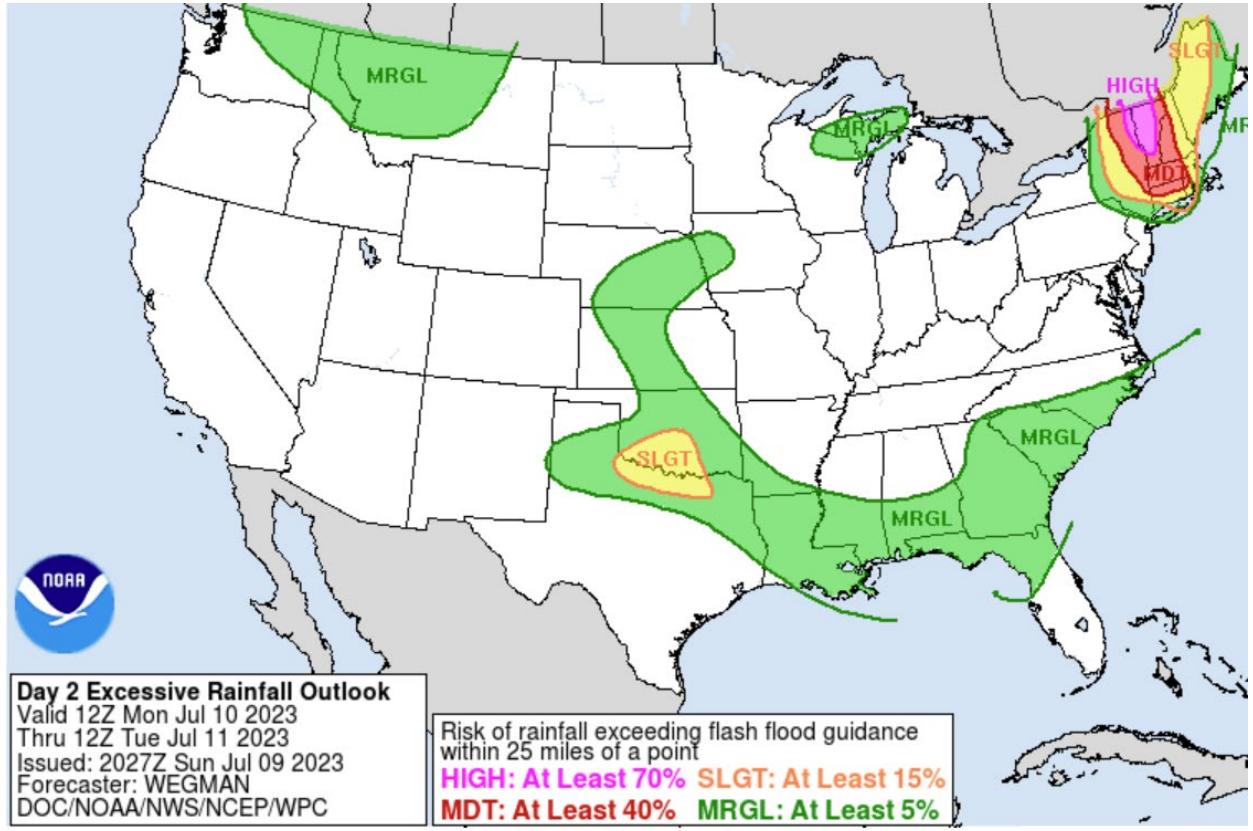
- Cause = Nearly vertical foliation on strike with roadway saturated from intense rainfall, lead to toppling
- Fairly common in VT



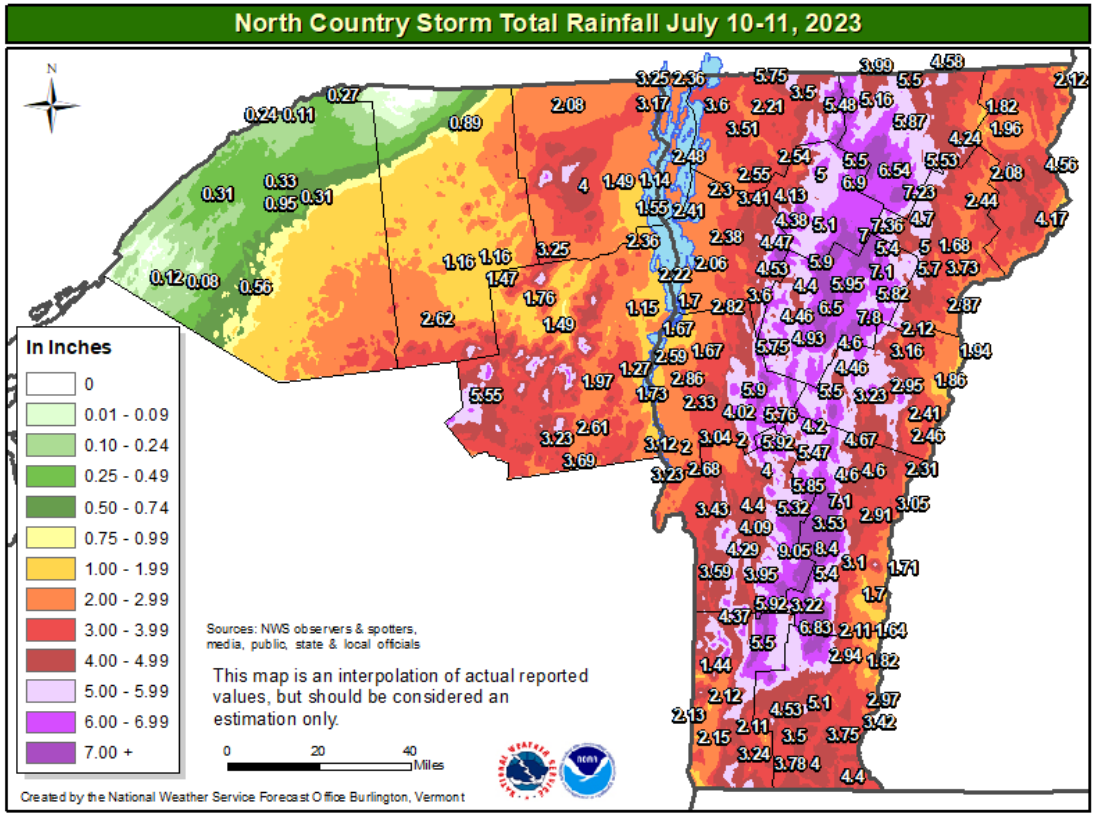
Wyllie, 2004, 2018

VTrans, 2023

Case History 1: VT Rt 12 Rockslide, Berlin



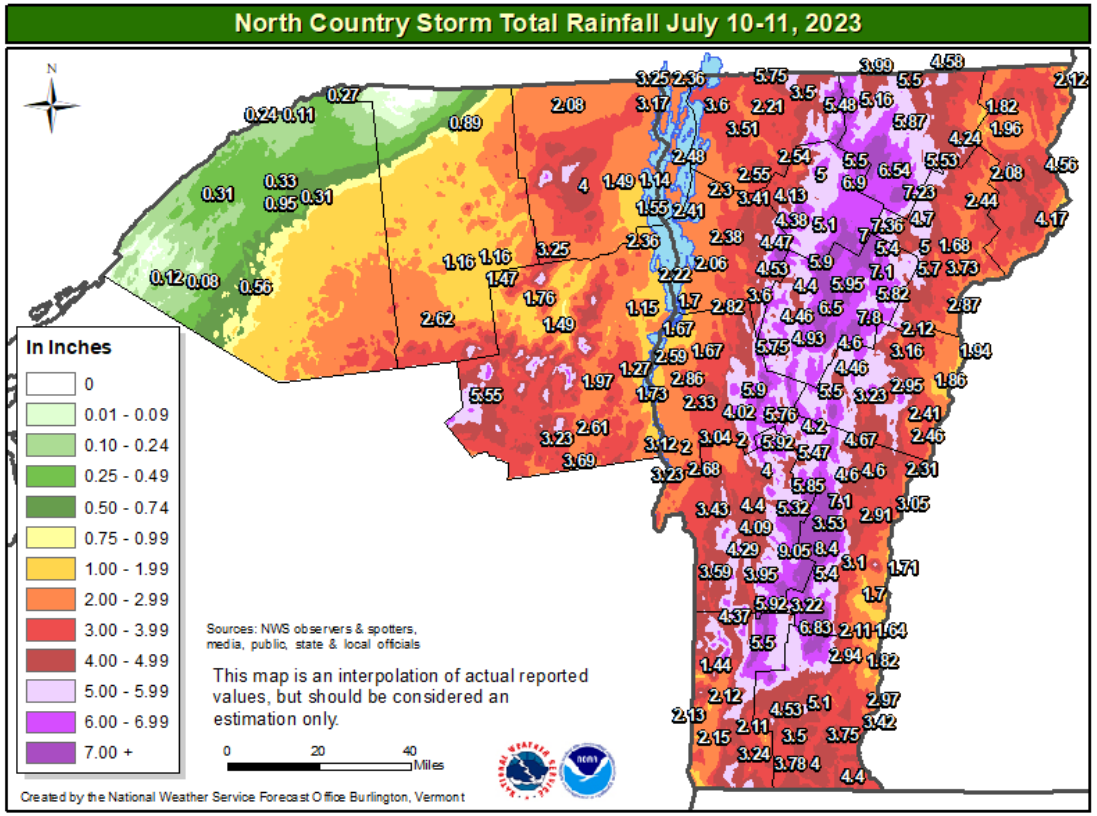
NOAA, 2023



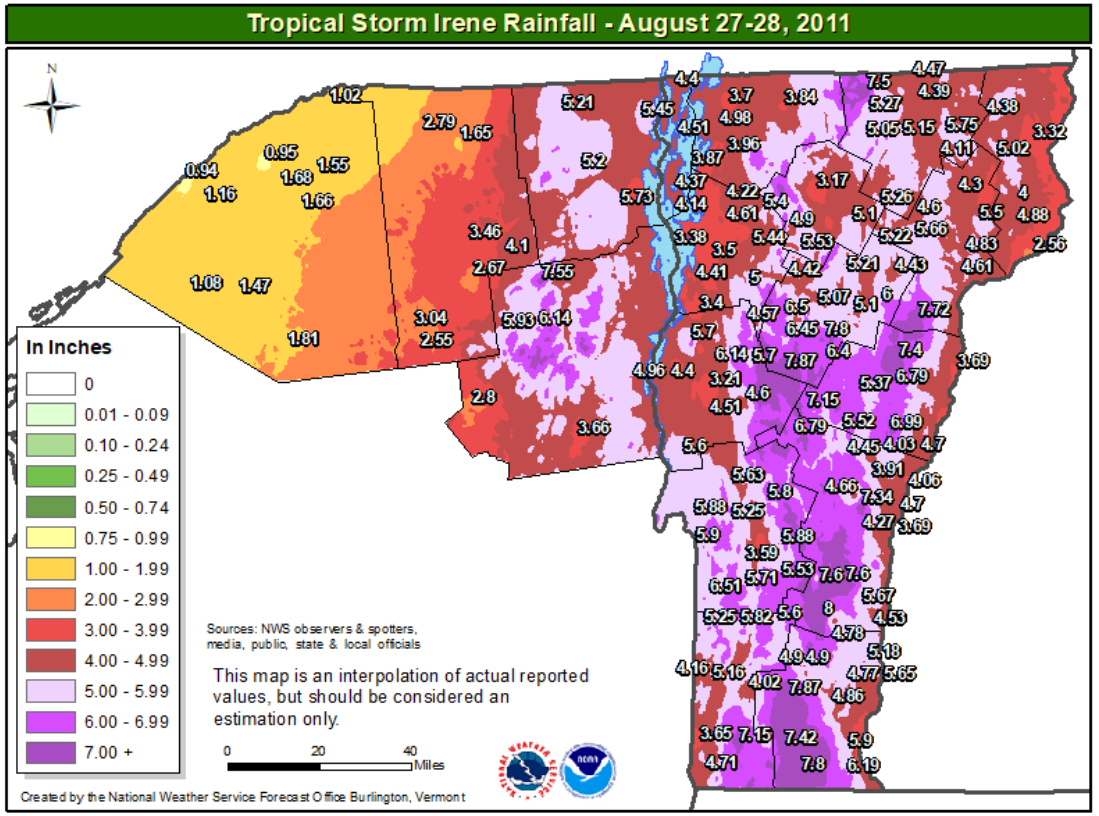
NOAA, 2023

- Intense, long precipitation event predicted

Case History 1: VT Rt 12 Rockslide, Berlin



NOAA, 2023



NOAA, 2023

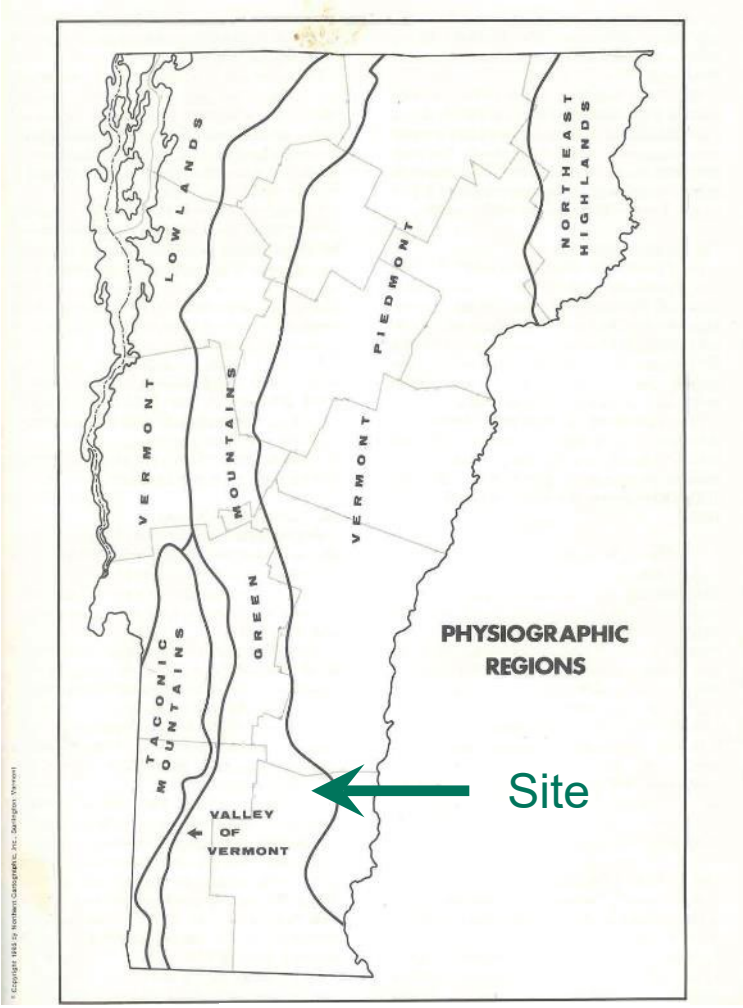
- While not as widespread as Tropical Storm Irene in 2011, July 10-11, 2023 total amounts comparable in mountainous areas

Case History 2: VT Rt 103 Proctorsville Gulf Debris Flow, Chester

- "Gulf" (deep valley), steep slopes of forested/protected land, 3-lane road, outside of VTrans right-of-way, ~1,000 ft runout starting at +40º headslope
- July 10-11, 2023 rainfall event
- Bedrock geology complex (slate, phyllite, schist, gneiss, amphibolite – Ordovician Missisquoi & Silurian-Devonian Northfield Fms), overlain by thin mantle of colluvium developed from glacial till

VTrans, 2023

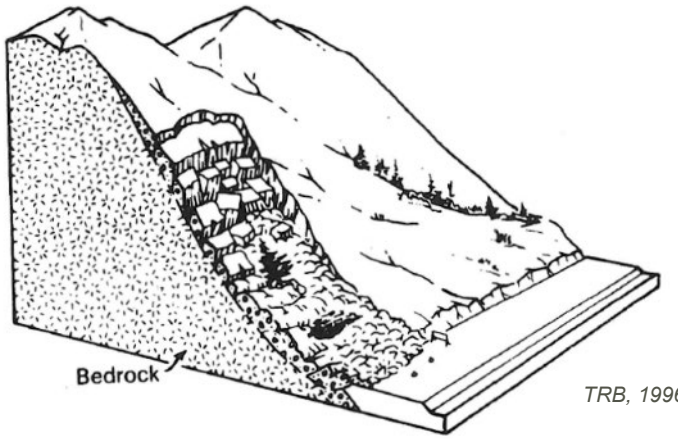
- Natural event (?), possibly influenced by past foresting activity, uprooted trees from prior storms
- Scars of past similar events evident (LiDAR)
- 100's of similar steep slopes with thin colluvium over bedrock



Northern Cartographic, Inc., 1986

Case History 2: VT Rt 103 Proctorsville Gulf Debris Flow, Chester

VTrans/Golder WSP, 2023 (photos)

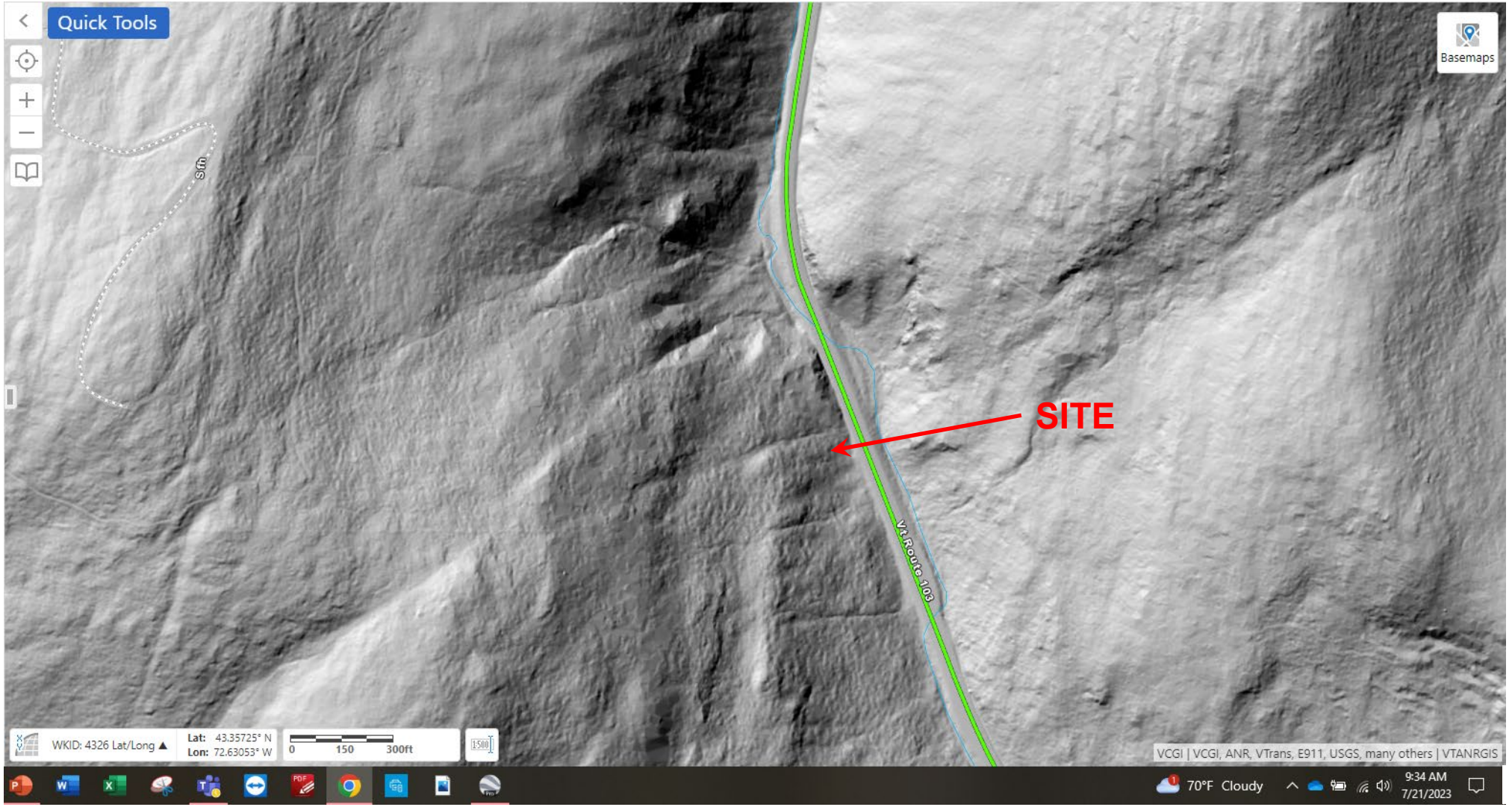


TRB, 1996

Case History 2: VT Rt 103 Proctorsville Gulf Debris Flow, Chester

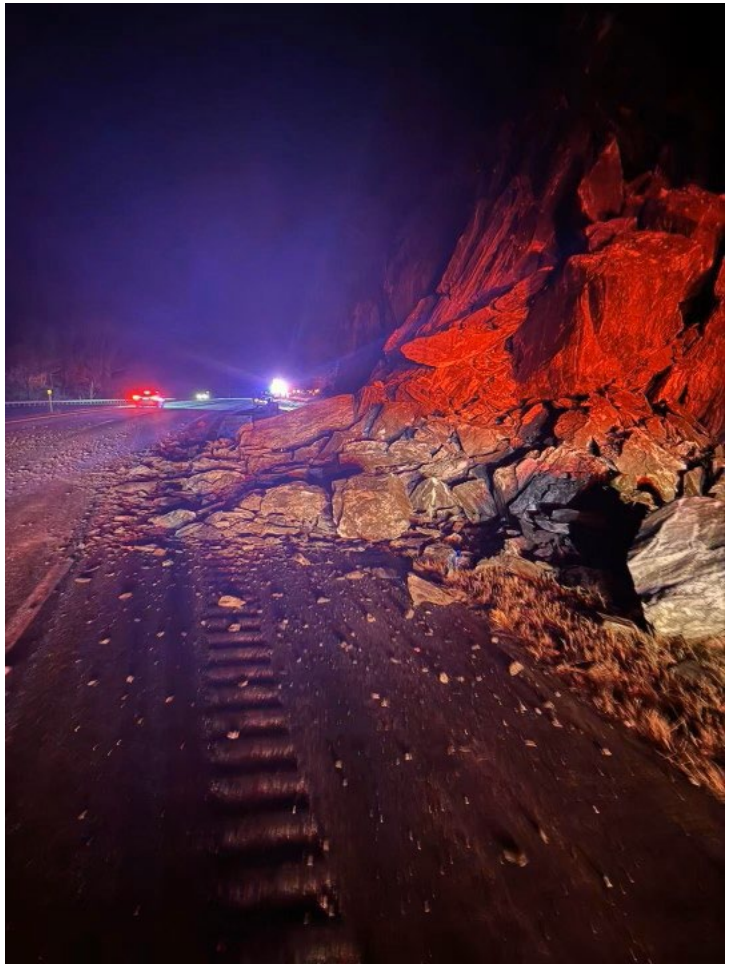
VTANR, 2023

Case History 2: VT Rt 103 Proctorsville Gulf Debris Flow, Chester



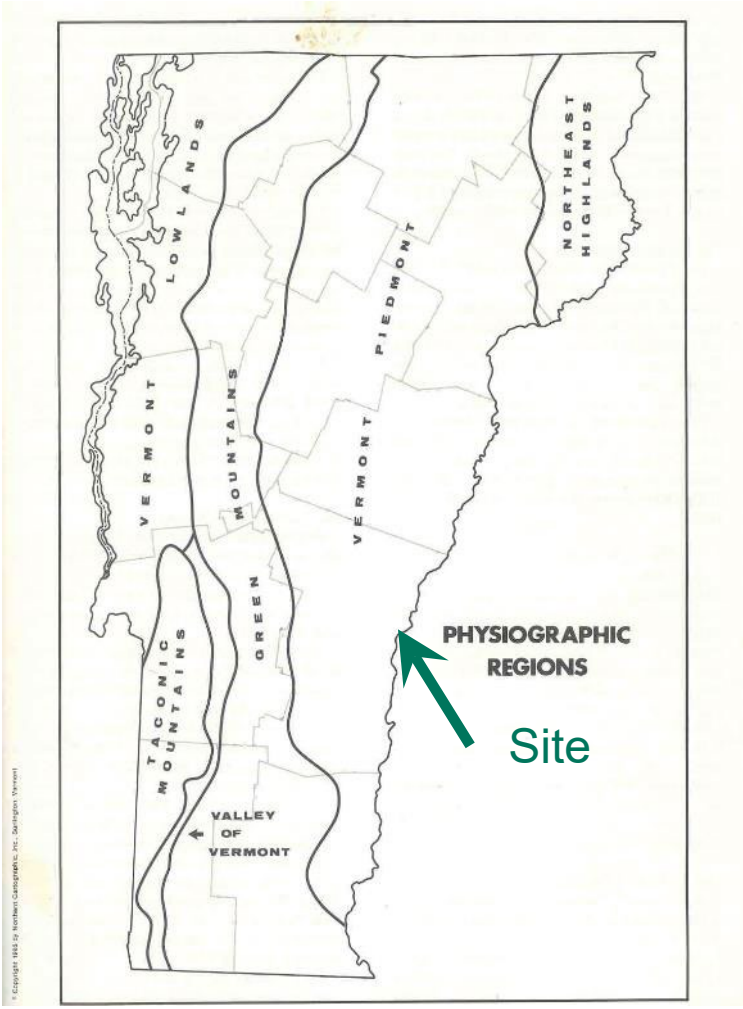
VTANR, 2023

Case History 3: I-91 MM67.25 SB Rockslide, Hartland



VTrans, 2023

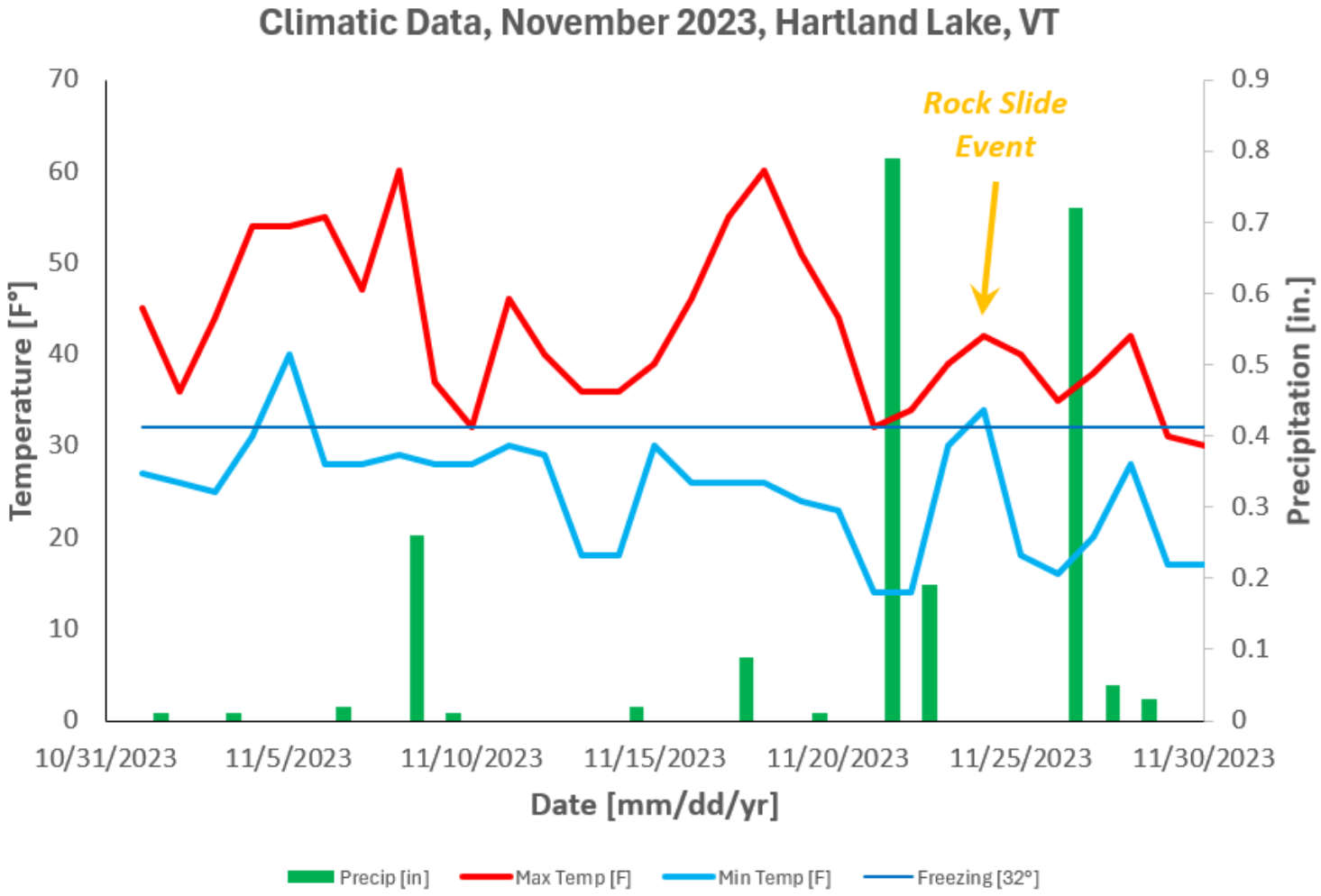
- November 23, 2023 (Thanksgiving) evening
- At least 15 vehicles damaged
- Gile Mountain Fm metavolcanics (phyllite) with several discontinuity sets
- VTrans watching slope, programmed for additional mitigation but slide occurred first
- Limited resources to remediate before sliding occurs, very hard to predict when failure will occur



Northern Cartographic, Inc., 1986

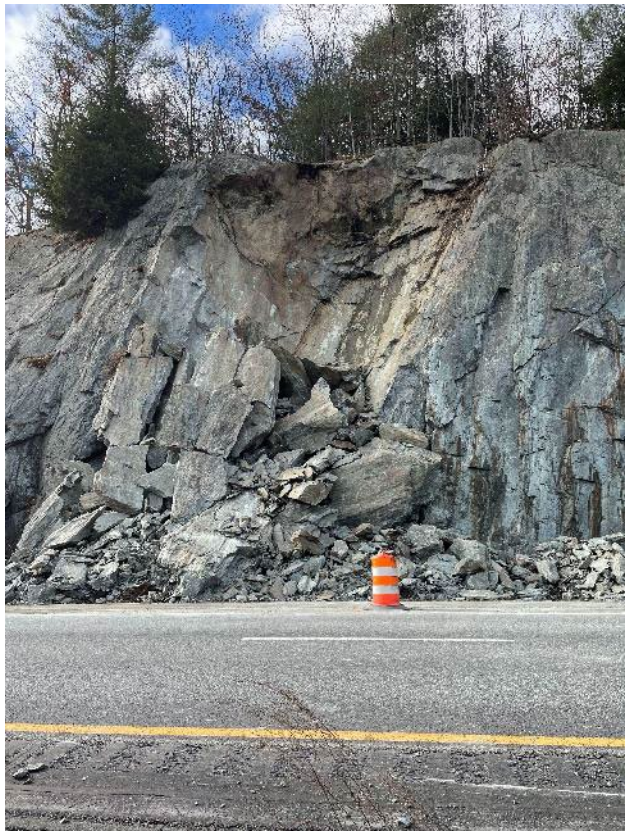
Case History 3: I-91 MM67.25 SB Rockslide, Hartland

- Precipitation event November 22
- Followed by thawing November 23, with temperature reaching 42°F



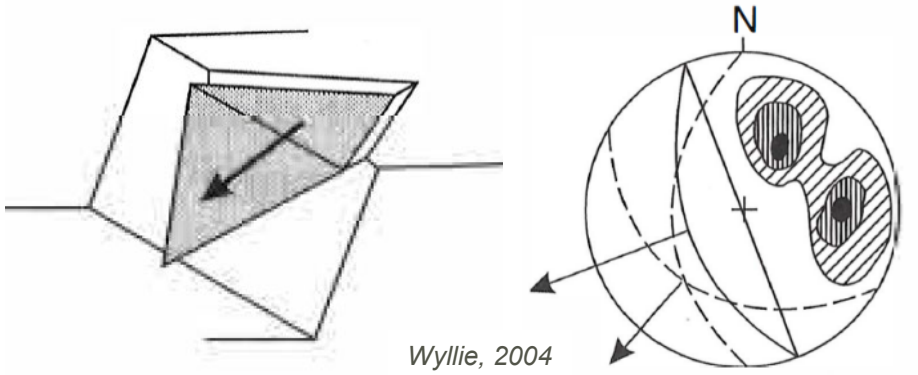
NRCC, 2024

Case History 3: I-91 MM67.25 SB Rockslide, Hartland



Scarptec, 2023

- Cause = wedge sliding due to ice-jacking
- Intersection of two joints, with line of intersection “daylighting” on rock face
- Emergency mitigation initiated to address large blocks in ditch and unstable overhang
- Mitigation = vegetation removal, scaling (removal of remaining loose rock), and securing overhang with rock dowels

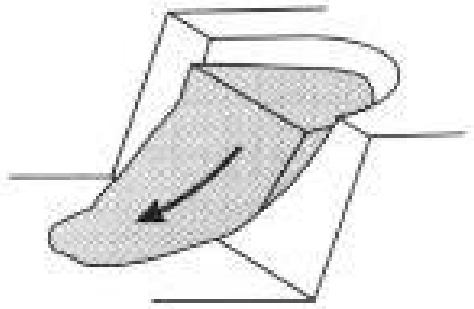


Wyllie, 2004

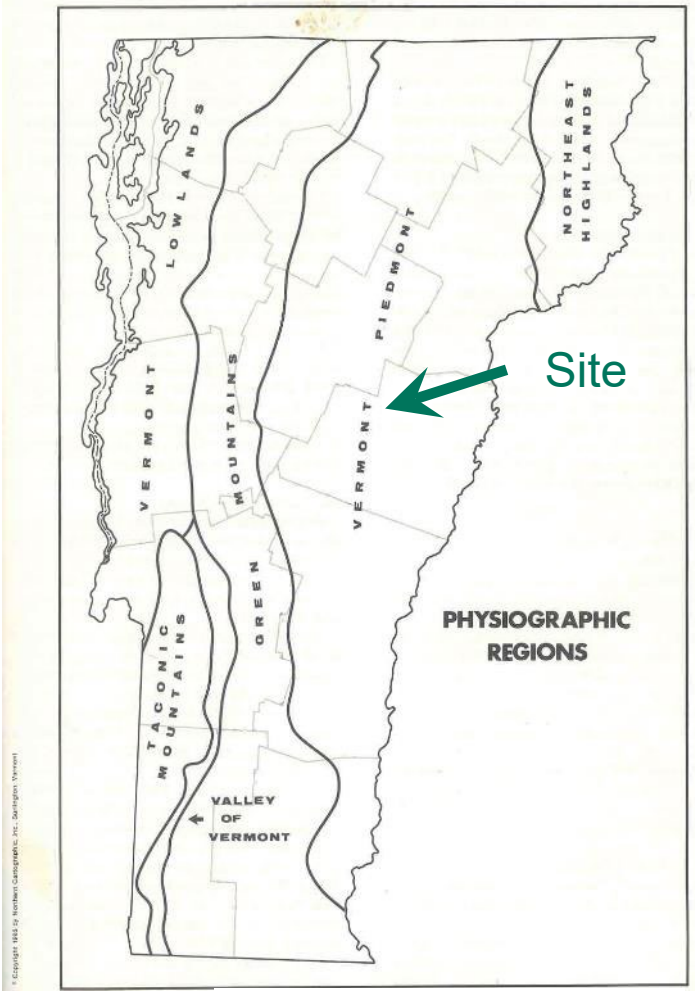
GEODesign, 2024

Case History 4: Railroad Switchback Slope Failure, Barre

- State-owned railway servicing Rock of Ages granite quarry
- July 2011 heavy rains caused small landslide, with a small head scarp in railbed (~1 ft)
- Even a fraction of an inch movement will cause railways to shut down
- Geology consists of fill materials over glacial till/colluvium
- Cause = circular failure within unconsolidated materials



Wyllie, 2018



Northern Cartographic, Inc., 1986

Case History 4: Railroad Switchback Slope Failure, Barre

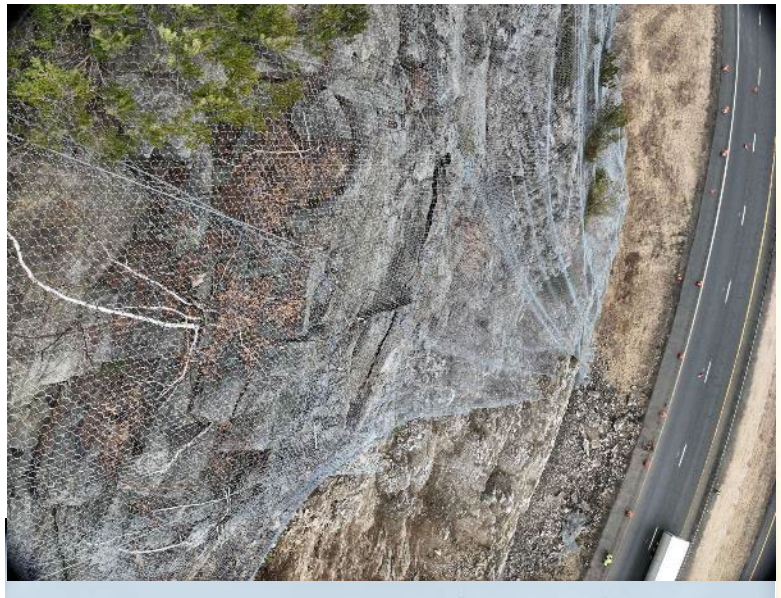
- Mitigation consisted of full slope repair, with tied-back retaining wall and rip rap slope armor (very $$$)

VTrans/Golder, 2013

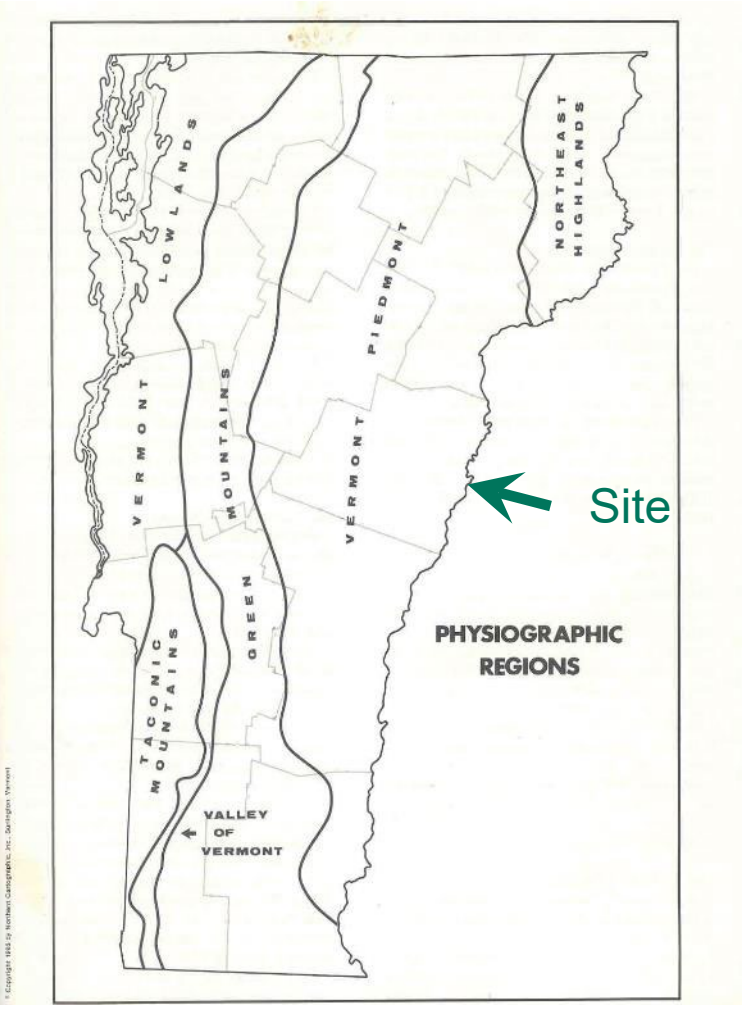
VTrans/Golder, 2013

Case History 5: I-91 MM92.6 SB Rockslide, Fairlee

- February 28, 2024 evening *(2nd biennial rockslide season)*
- Closed both directions of interstate due to rocks in road
- Very high and steep rock slope, +270 ft above roadway (“The Palisades”)
- Early Devonian Fairlee Pluton Quartz Monzonite (weakly foliated, highly fractured & faulted)
- VTrans last mitigated slope with rock removal, rock dowels and wire mesh in 1996, minor tears repaired 2022



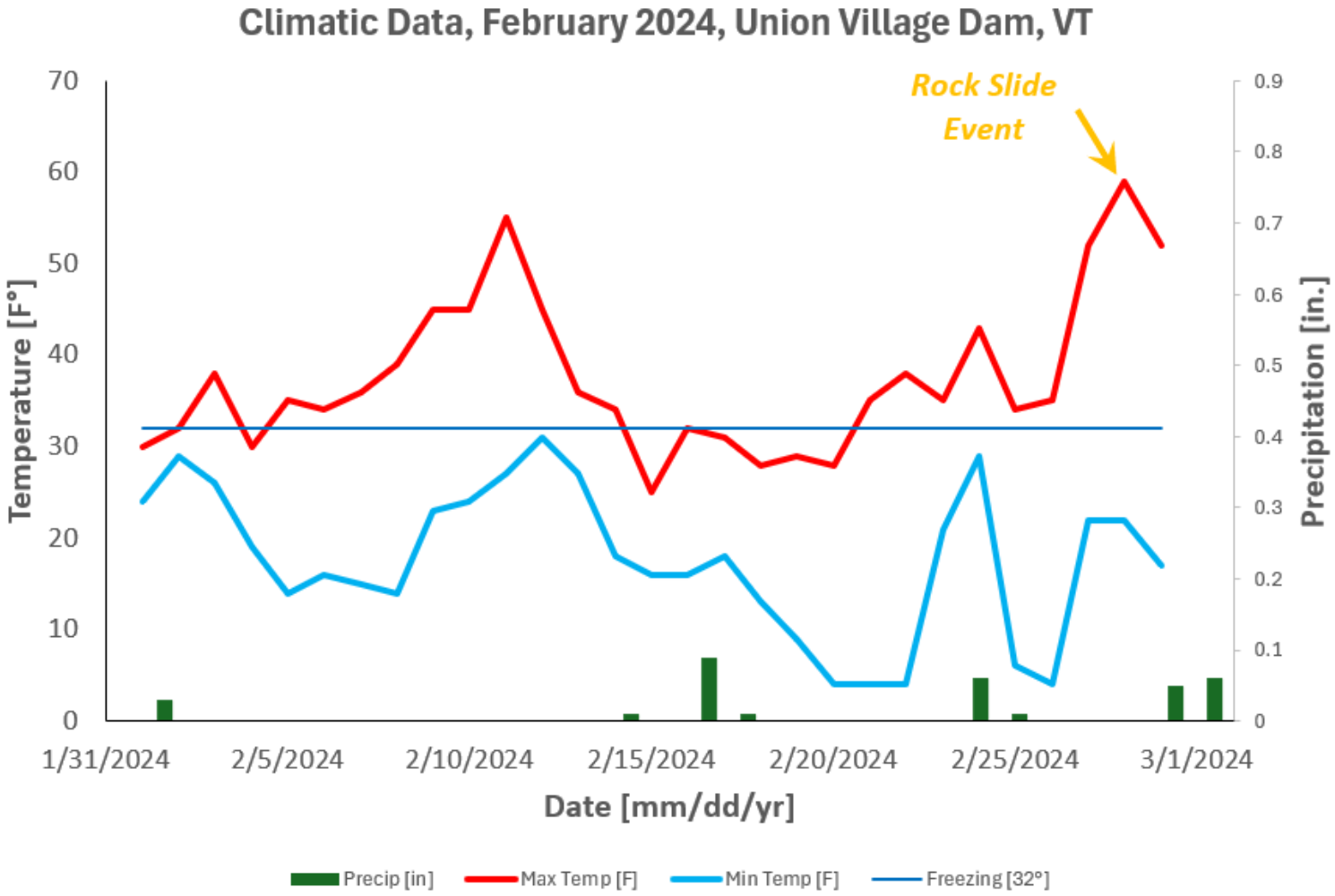
VTrans, 2024



Northern Cartographic, Inc., 1986

Case History 5: I-91 MM92.6 SB Rockslide, Fairlee

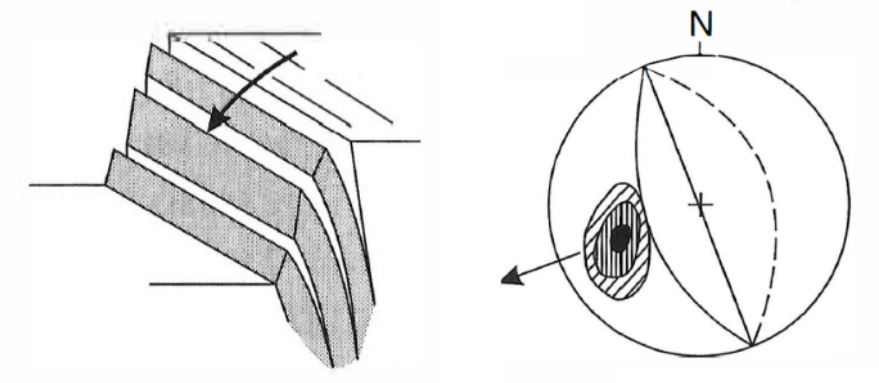
- Cause related to prolonged sub-freezing period followed by sudden thawing event starting on February 26
- Temperature reached 59°F on February 28



NRCC, 2024

Case History 5: I-91 MM92.6 SB Rockslide, Fairlee

- Cause = toppling of large pillars, blocks and slabs exacerbated by melting of adfreeze (melting of ice acting as a temporary “glue” after ice jacking occurs)



Wyllie, 2004

- Emergency mitigation on going, consisting of scaling remaining loose rock and repair of draped mesh

VTrans, 2024

Case History 5: I-91 MM92.6 SB Rockslide, Fairlee

- Numerous other areas identified behind mesh at risk of failing and overwhelm netting
- Intends to program and mitigate these 2025

VTrans, 2024

Case History 5: I-91 MM92.6 SB Rockslide, Fairlee

VTrans, 2024

Conclusions

- Slope failures have huge impact, becoming more common due to climate change
- VTrans' hazard rating system to prioritize mitigation limited by resources and funding
- Lag time increasing between mitigation of priority slopes and slopes not programmed yet
- Suspected hazards are known and monitored (system always deteriorating), but more intense, longer lasting precipitation events and temperature swings stressing slope mitigation program
- Slopes being reprioritized – proactive due to a reactive, rapidly changing climate
- Field engineering geology vital to increasing slope mitigation needs - VTrans needs more engineering geologists!

VTrans, 2024