Landslide: The downslope movement of earth, debris, or rock under the influence of gravity.

Moving Earth: Cotton Brook and other Landslides in Vermont

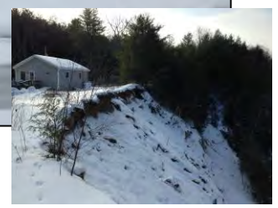
Marjorie Gale, State Geologist, DEC
George Springston, Norwich University

Lake Willoughby, 2005

Montpelier, 2005

Belvidere Mtn, 2012

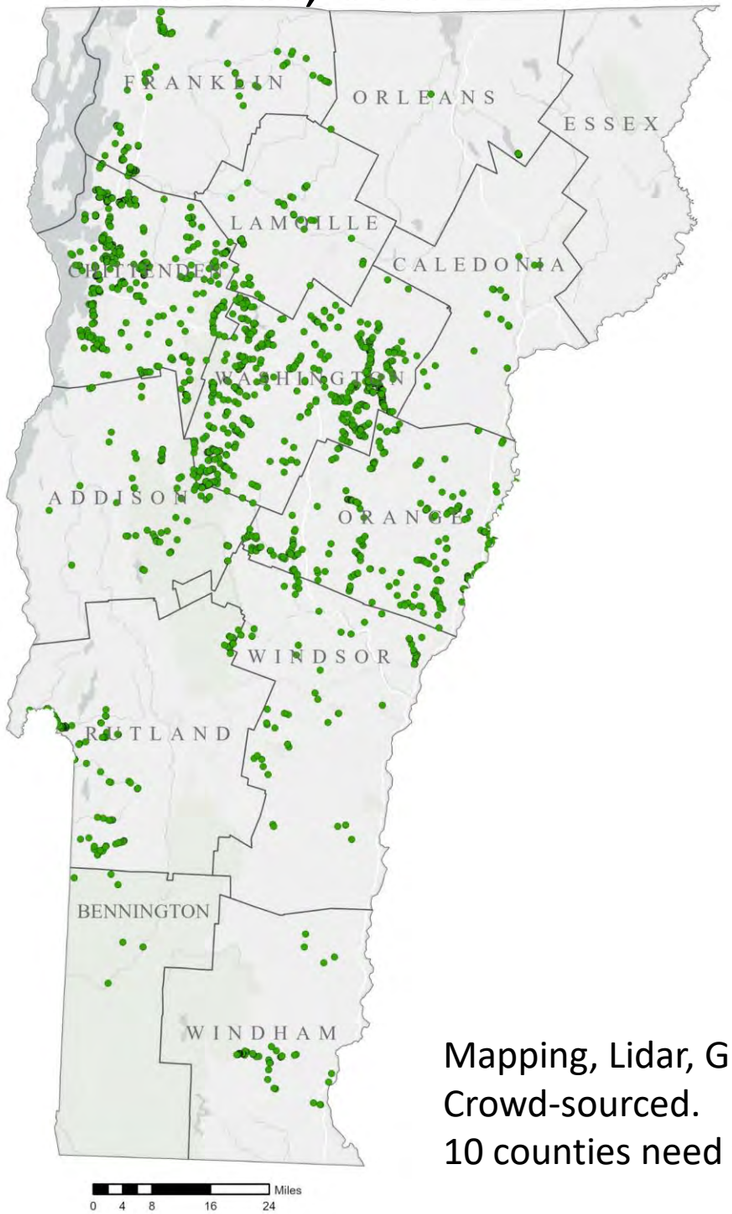
Plainfield, 2013



Huntington, 2019

Jeffersonville, 1999

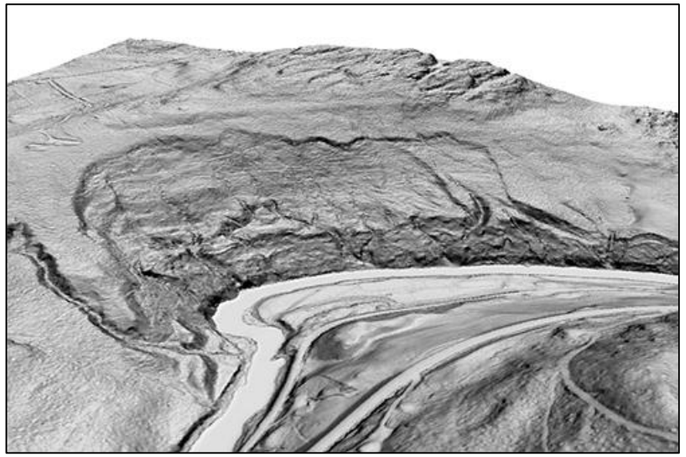
Landslide Inventory, 2020
4 counties, over 2100 sites



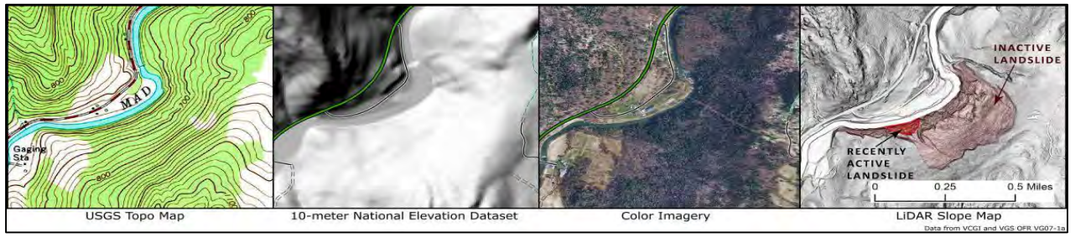
Cotton Brook, Waterbury

Smugglers Notch

ACTIVITY Text	AREA ESTIMATE Text	ASPECT Number	BANK POSITION Text	BEDROCK CONTROL Text	BEDROCK ON SLOPE Text
CAUSE 1 Text	CAUSE 2 Text	COMMENTS Text	Create_Date Date or Time	Creator Text	CROWN ELEVATION Number
DEPTH (METERS) Number	Edit_Date Date or Time	Editor Text	FAIL DATE Date or Time	FAIL STYLE Text	FIELD VISIT Text
HEADCUTS Text	HEIGHT (METERS) Number	LANDSLIDE TYPE 1 Text	LANDSLIDE TYPE 2 Text	LENGTH (METERS) Number	MATERIAL Text
OBSERVER Text	ORGANIZATION Text	OUTSIDE MEANDER Text	PIPING Text	REMEDIATED Text	SEEPS Text
SLIDE ANGLE Number	SLOPE ANGLE Number	SOURCE Text	SOURCE PUB DATE Number	SPRINGS Text	SURF OBSERVATION Text
TALUS Text	TOE CONDITION Text	TOWN Text	VISIT DATE Date or Time		



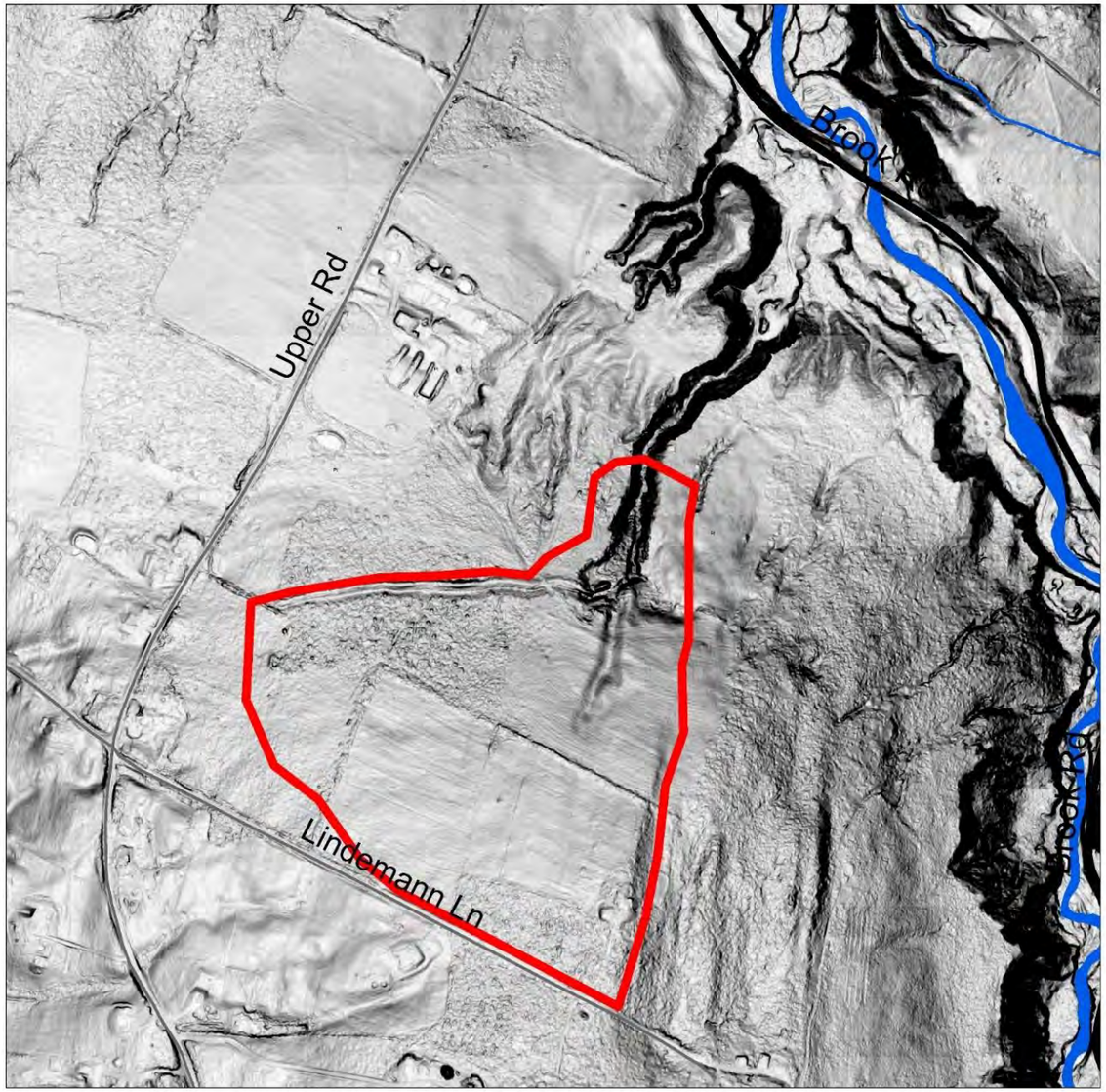
Mapping, Lidar, GIS and
Crowd-sourced.
10 counties need to be inventoried.



Impacts of land use: Gullies, Plainfield

Application of hazard mapping to management of run-off

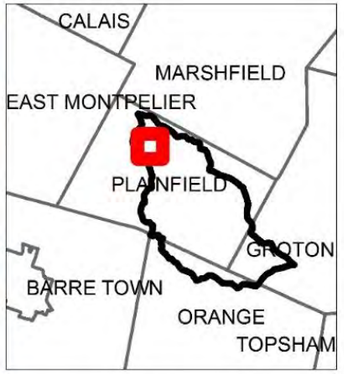
Steep slopes and gully complex on Lidar



MacLarenUpperWatershed
Minor Roads
Major Roads
Town Boundaries
Streams
Water Bodies

N

Meters
0 100 200 300



Vermont Geological Survey
3/2/2018

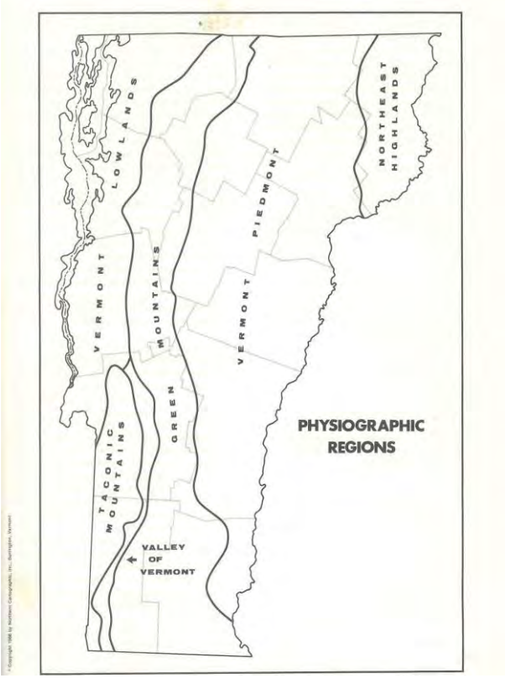
At the edge of the farmer’s field….

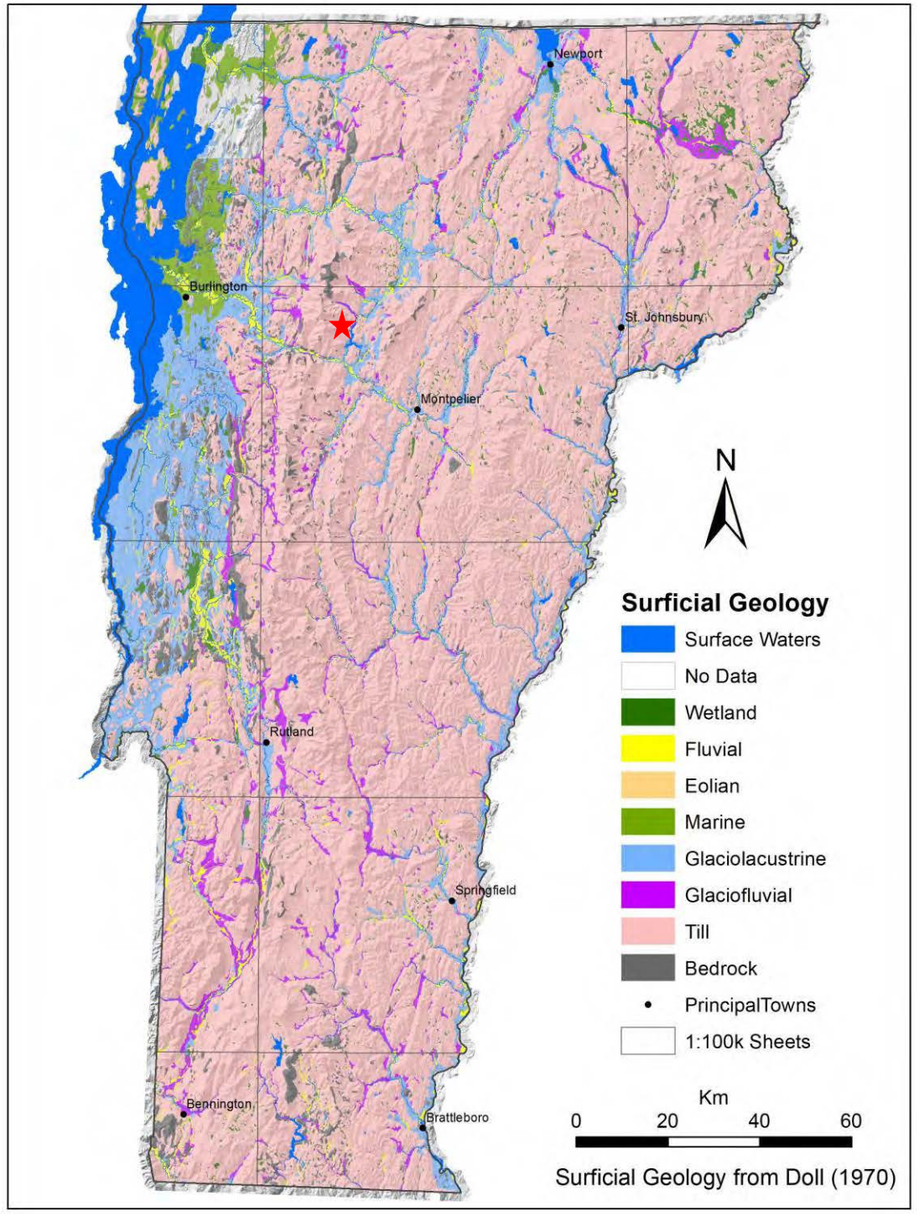
Looking up gully. Note active scour at base of slope on left.
Site GB-1010, George Springston, 7/16/2013.

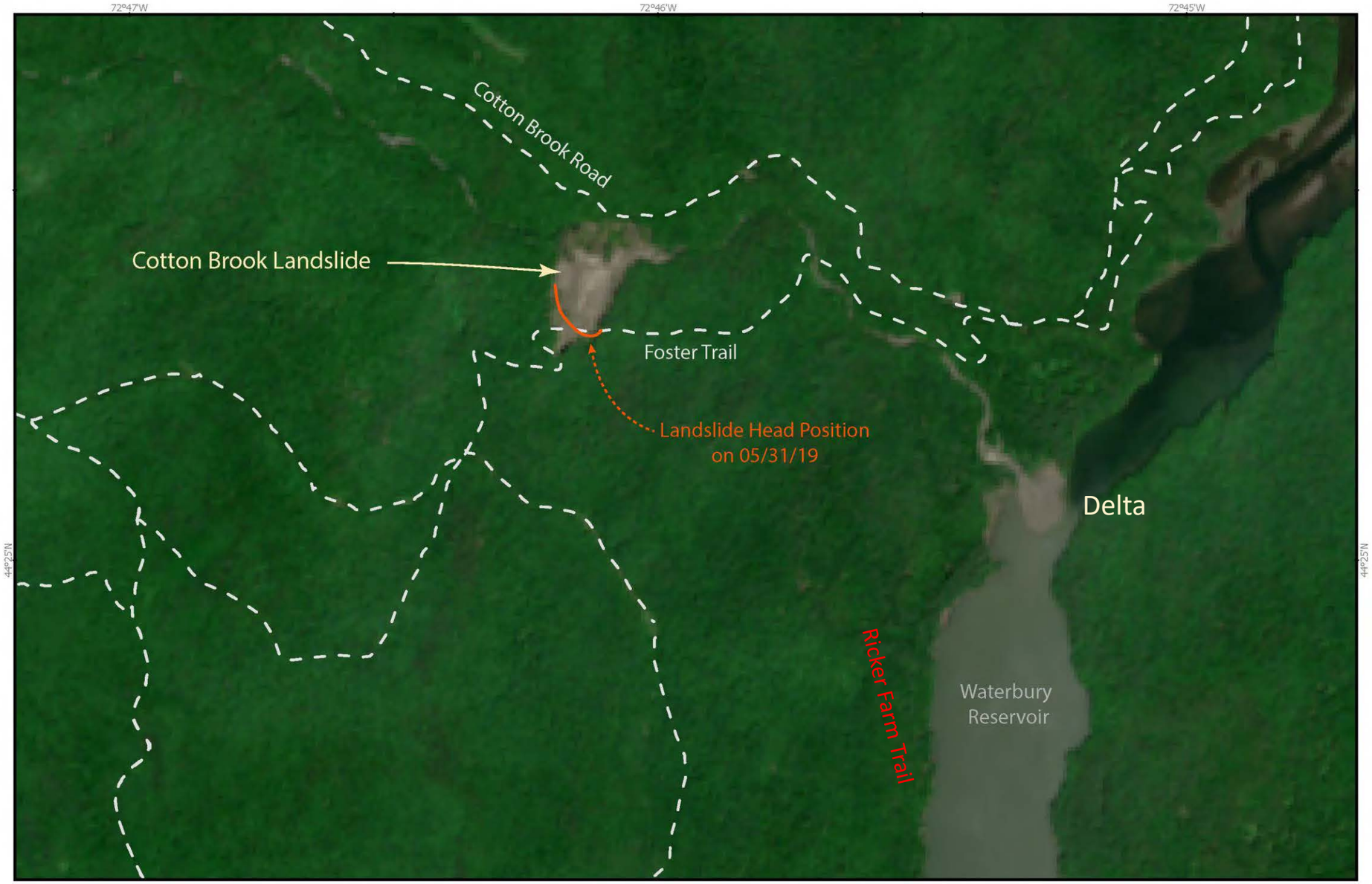
Looking down gully. Material is ice-contact fine to very fine sands and silt with gravel lenses.

Gully Erosion –cutting deep into soils
Waterfall erosion over lip
Channel erosion along bed of gully
Landslides from sides and head of gully

Landslides occur in all types of rock and surficial deposits and in all physiographic regions.

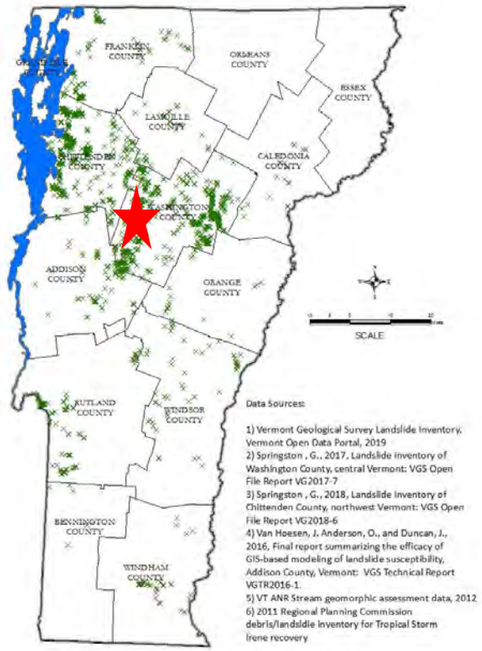






Waterbury
Landslide reported: May 31
Image: 6/17/2019

Visits: 6/4, 6/7, 6/10, 6/12, 6/24, 7/8, 7/23, 8/13, 8/14, 9/11, 10/8, 11/4



LANDSLIDES AND GULLYING SITES REPORTED TO THE VERMONT GEOLOGICAL SURVEY, 2008-2019

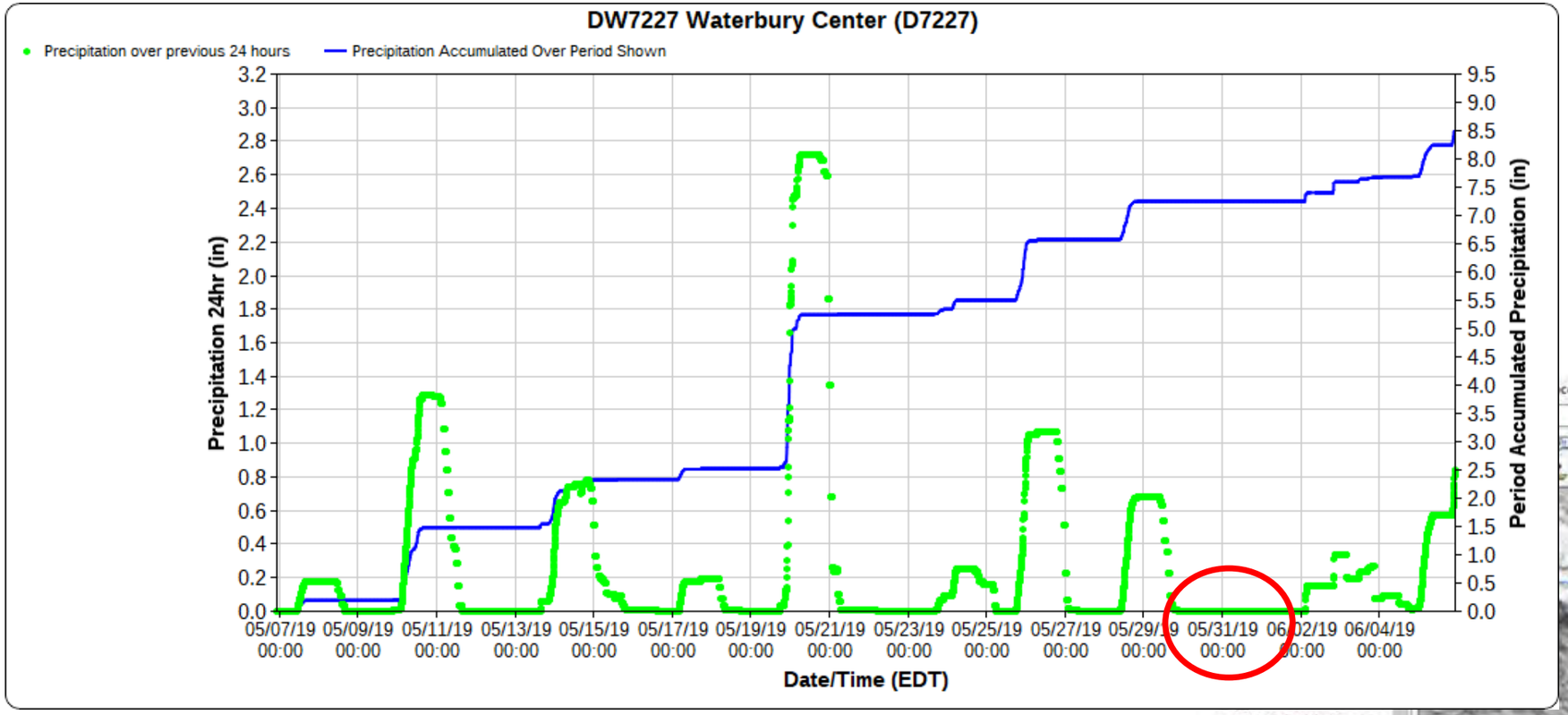
VERMONT
AGENCY OF NATURAL RESOURCES
Vermont Geological Survey

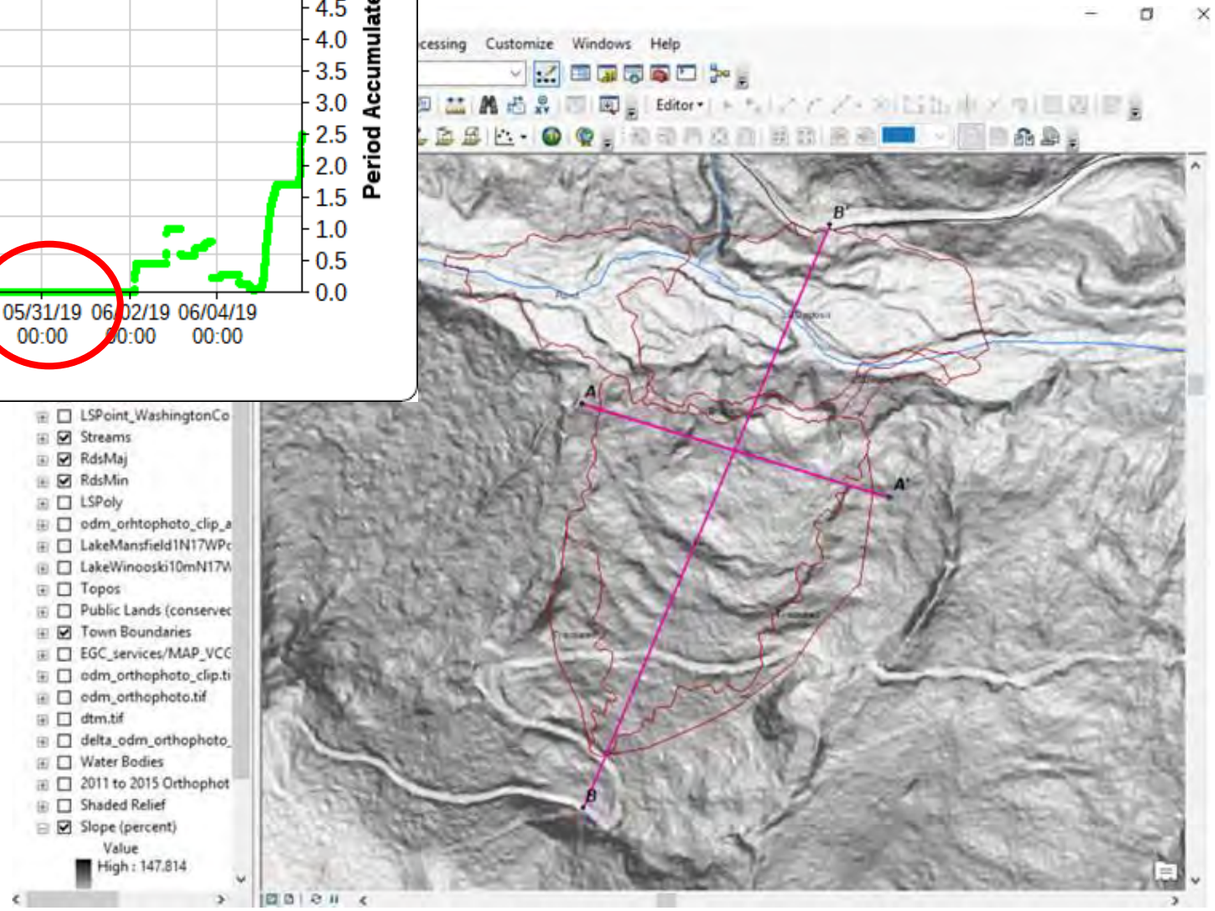
N

Scale: 1:24,000

0 500 1,000 2,000 Meters

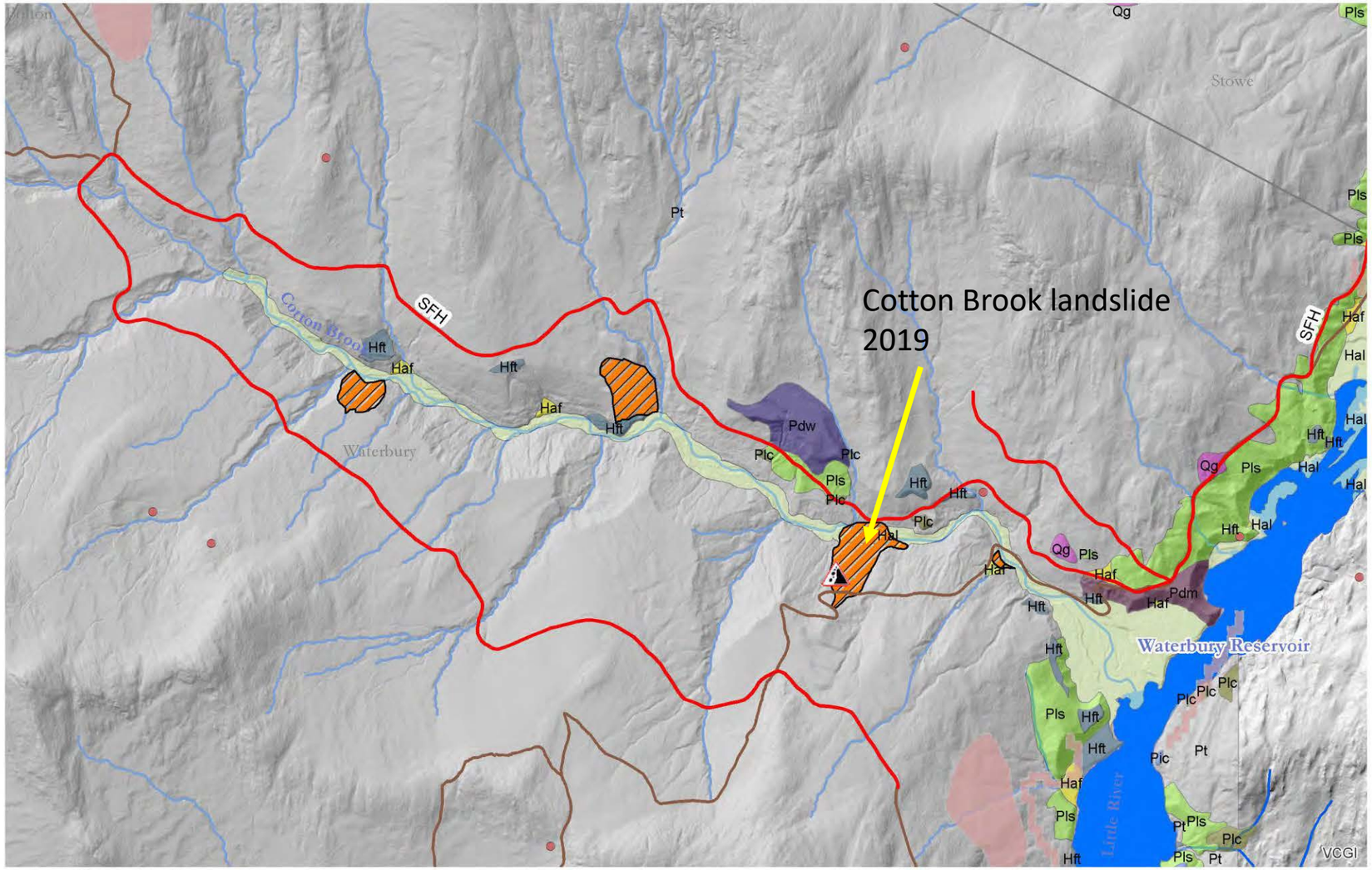
Data Sources: Imagery - Sentinel 2 LA-2 Imagery collected 06/17/19
E911 Trails (geodata.vermont.gov)





Green: Precipitation over previous 24 hours

Blue: Precipitation accumulated since 5/7/2019



Legend

- Landslide Report
- Qls Landslide
- Bedrock Outcrops (polygons)
- Bedrock Outcrops (points)

COTTON BROOK LANDSLIDE
Waterbury, VT
Map prepared 8/13/2019, Vermont Geological Survey

0.2 0.1 0 0.2 0.4 Miles
SCALE

N W E S

Bolton Mountain Quadrangle
S. Wright, 2018

Fine sands, silt and clay are sediments deposited in glacial Lake Winooski. Layers/beds dip ~ 25°

Underlain by till (shown in gray).

6/4/2019

12 acres active

2.2 acres detached

~1.8 acres impounded water

~2.8 acres delta

~200,000 cubic meters excavated

~100,000 cubic meters in brook

Seeps on surface

7/8 Flag (at arrow) was gone

June 4, 2019

June 4, 2019: Mudflows, saturated sand, boulders and trees indicated the site was still active. Water feeding the mudflows was from seeps partway down the slope, likely at a sand-silt interface or due to elevated water table.

June 4, 2019: Grooved, striated slip surface beneath sands, silt and debris near the base of the slope. No bedrock was exposed.

6/4

Left: Upper scarp at Cotton Brook landslide.

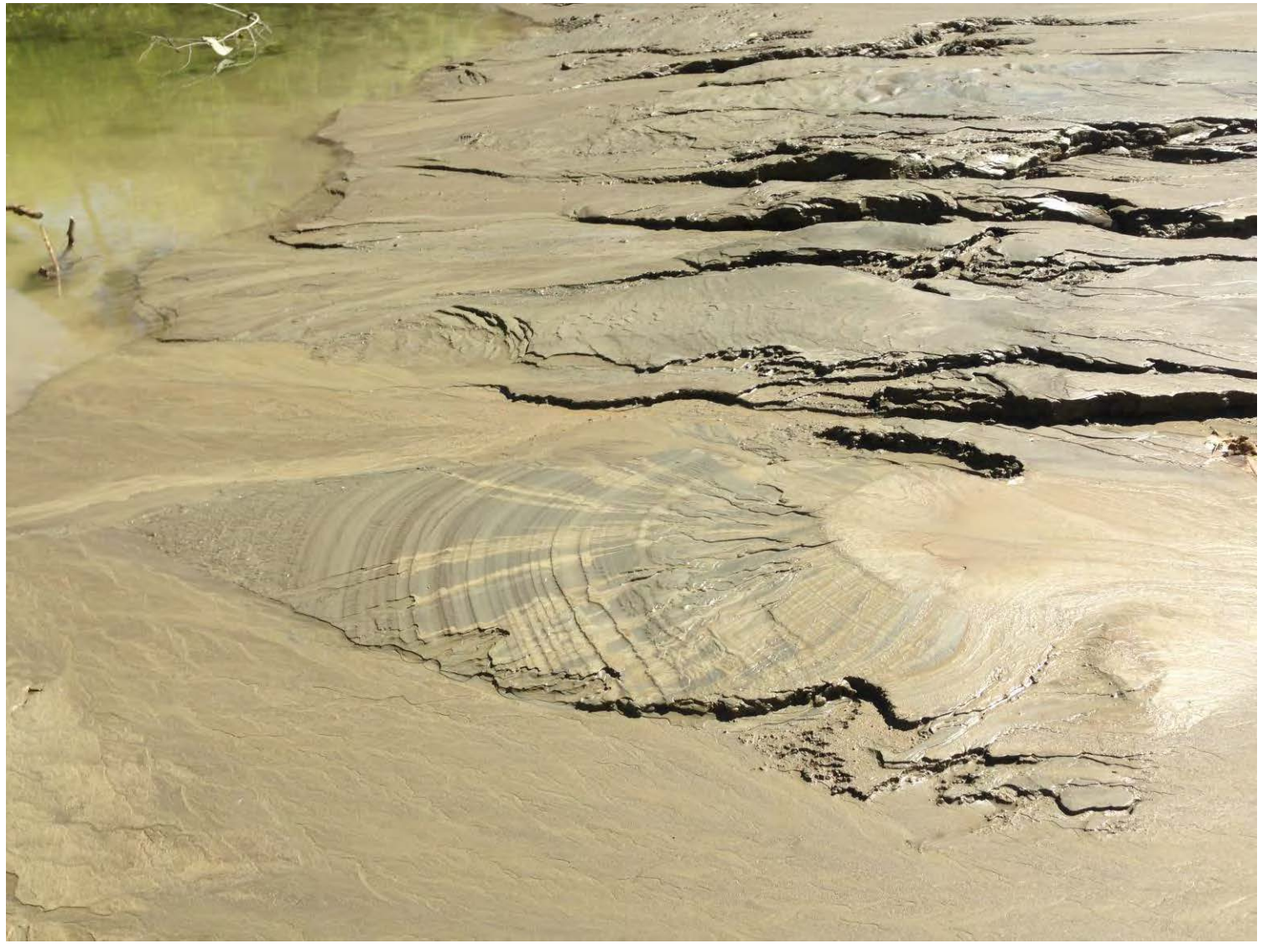
Right: Looking down from upper scarp.

6/4 Ground cracks and offset
Detached blocks continued to fail


6/12 - New delta in Waterbury Reservoir, ~2.8 acres

Delta built out into the Waterbury Reservoir.

6/10/2019



~ 12 inches

Geologic processes at all scales.

Alluvial fan (left) and delta (right)

Armored mud balls formed as pieces of mud rolled and eroded into spherical shapes, picking up sand and gravel on their soft surfaces.

Picture: Chad Ummel
Park Mgr.

Little River and
Winooski River

6/24/2019

Observations

- Slope of ~ 28 degrees which corresponds to layering in the glacial sediment.
- Materials are fine-grained silt and sand, lake bottom sediments deposited in Glacial Lake Winooski (14,100 years ago)
- Head cut of the slide roughly corresponds to the contact of the glacial lake sediment with glacial till.
- Visible slide surface of very fine silt to clay was grooved and striated by the overriding material.
- Seeps occur along the slope.

- Factors for failure include
  - saturation of unconsolidated material above the impermeable clay-silt layer or bed
  - dipping slide surface and steepness of slope
  - type of material (sand over clay),
  - height (109 m),
  - load balance, gravity, and groundwater level. Toe erosion and overland flow were less critical factors. The slope failed by translation along the clay-silt surface.
  - Fractures and grooves point to translation, like a magic carpet, as opposed to rotational failure.
  - Translational slides commonly fail along a discontinuity such as a bedding plane/surface and have high probability of recurrence. The landslide moves out and down as opposed to rotating down and up around a slope axis.

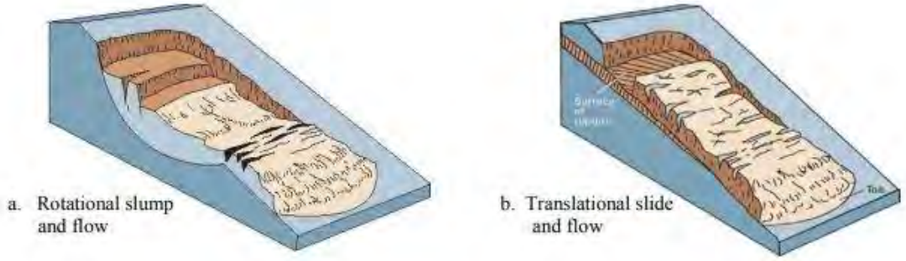


Figure 1 - Two Common Types of Landslides in Vermont. a) rotational slump and flow, b) translational slide and flow. From Highland and Bobrowsky (2008).

Cotton Brook

Influence of glacial lake sediment

The brook was blocked numerous times during the past 6 months and subsequent erosion transported sediment downstream towards the reservoir and Little River. This process repeated throughout the summer.

7/1 -7/6
sequence

8 p.m.

7/2/2019,
6 a.m.

7/2/2019,
11 a.m.

7/2/2019
2 p.m.

7/6/2019
9 a.m.

7/6/2019
5 pm

October 8, 2019: View of the impoundment and the toe deposit. The pond extended upstream and encompassed approximately 1.8 acres.

Looking upstream towards landslide area.

Nov. 4: Other signs of instability

Oct 26 – Oct 27. Change in water level in brook. Not much change in slopes.

Oct 31 - Nov 1: Considerable loss of material on both sides of brook. Debris removed.

Left: Oct 31, significant erosion of the toe deposit resulted in an ~ 11 foot drop in water level in the pond.

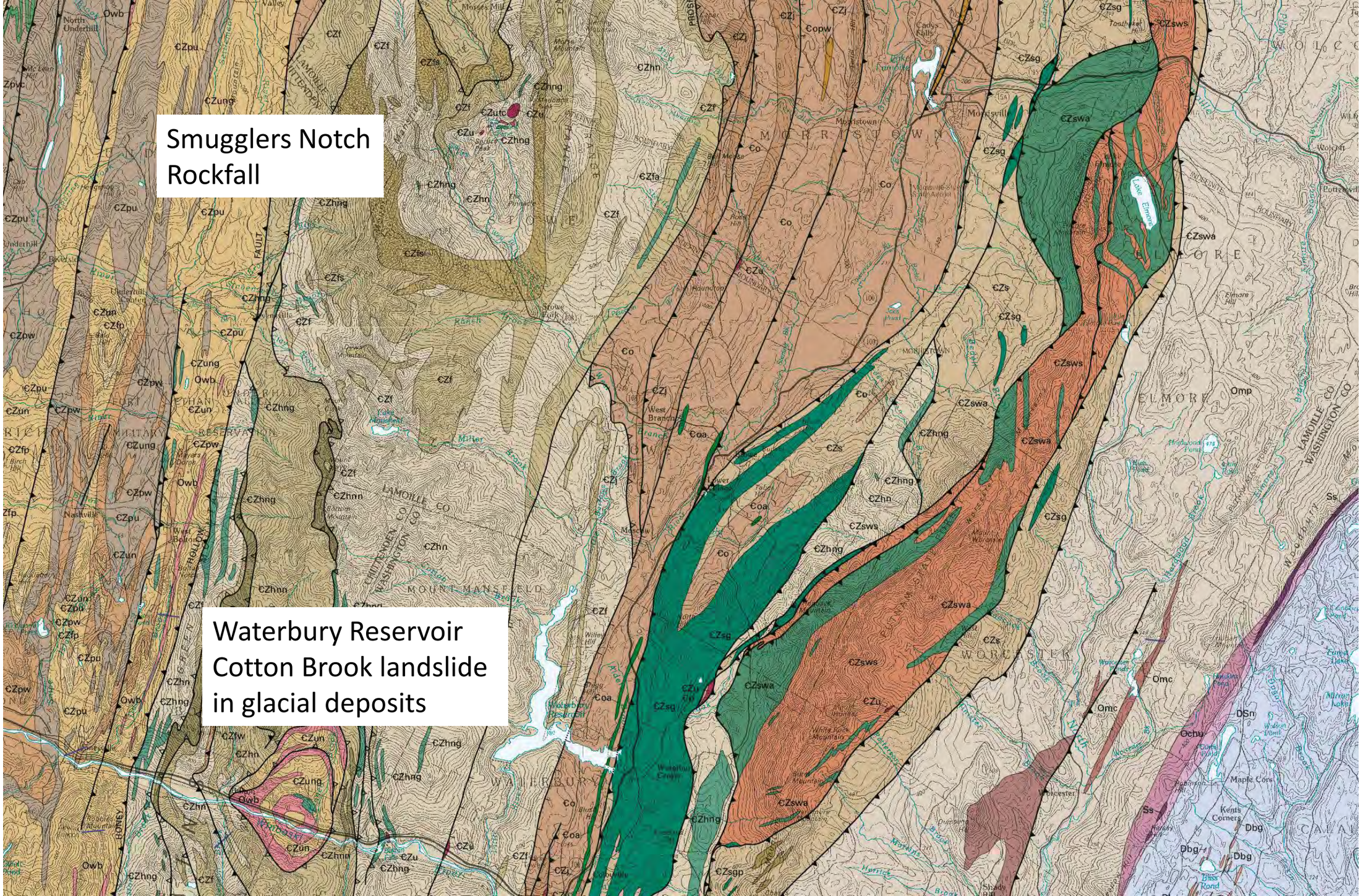
Right: August 4- Nov 3 shows erosion of toe deposit, coincident with release of water from the pond. Downstream also had significant debris, sand and cobbles which resulted in the brook moving to the north.

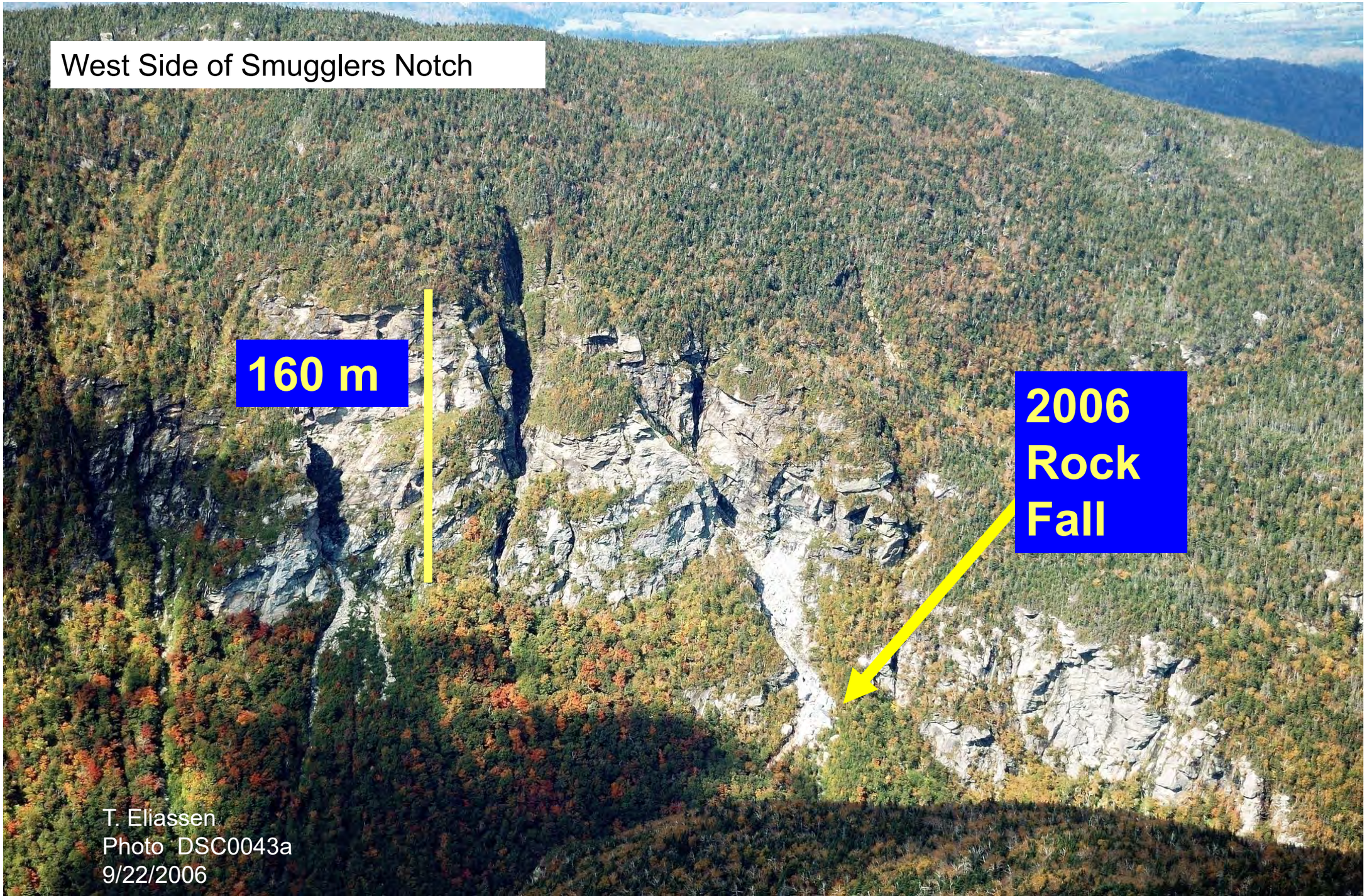
- By Nov. 4, till at the base of the slope was exposed beneath a dipping clay bed.
- We expect the site to remain dangerous due to failure of detached blocks along the sides and top of the site, trees and boulders transported on the surface, sediment and debris in the brook, saturated sand (similar to quicksand) and potential for another translational slide.

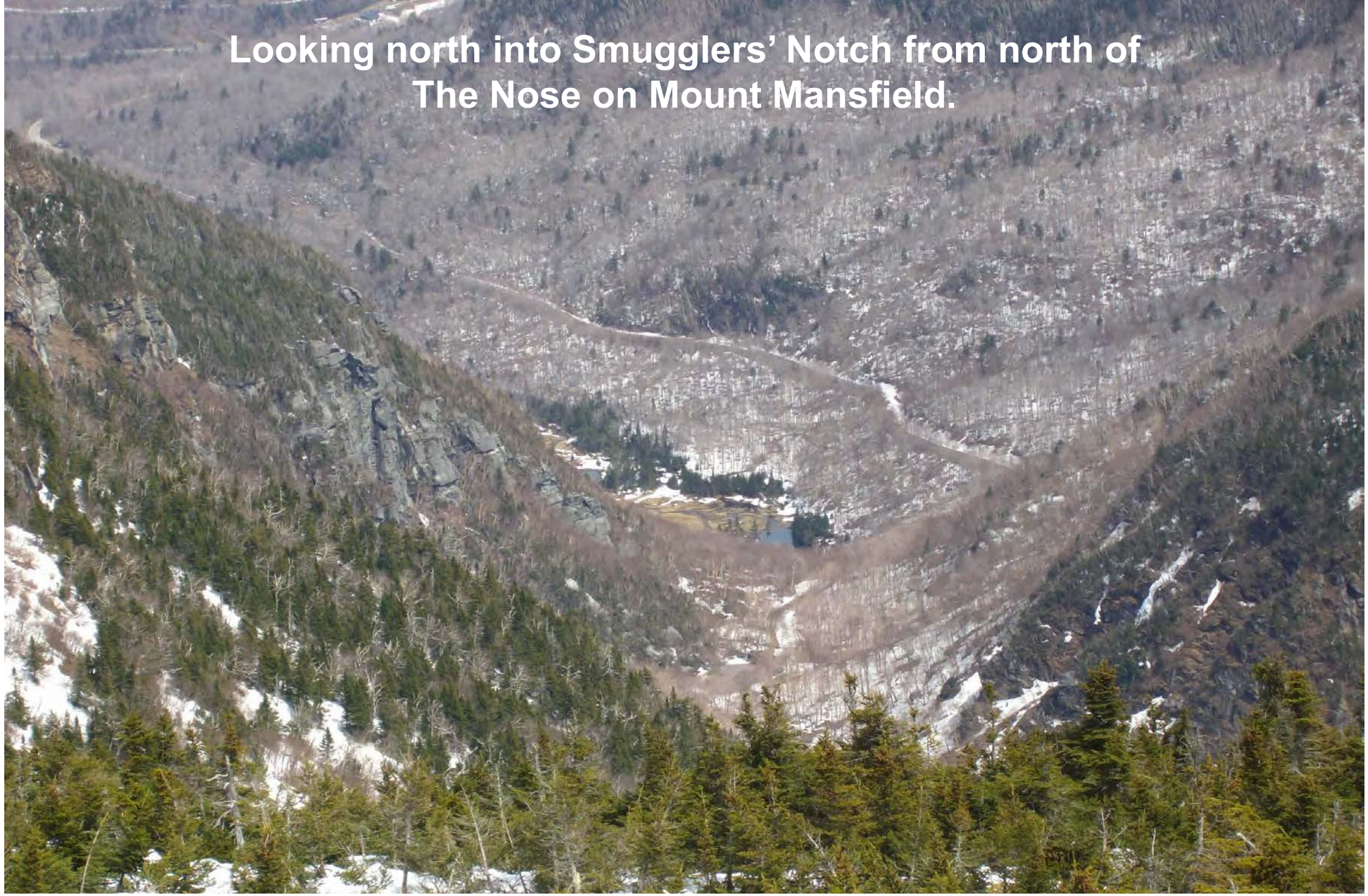
Nov. 4

On the toe with a good look at scarps, ground cracks, trees, boulders, debris.

Where will it fail next?


Smugglers Notch Rockfall
Waterbury Reservoir Cotton Brook landslide in glacial deposits
MORRISTOWN
ELMORE
WORCESTER
WATERBURY
MOUNT MANSFIELD
LAMOILLE CO
WASHINGTON CO
Lake Elmore
Waterbury Reservoir


West Side of Smugglers Notch
160 m
2006
Rock
Fall
T. Eliassen
Photo DSC0043a
9/22/2006



The Notch is a glacially scoured trough. The flanks and bottom are blanketed with thick talus and debris flow deposits.

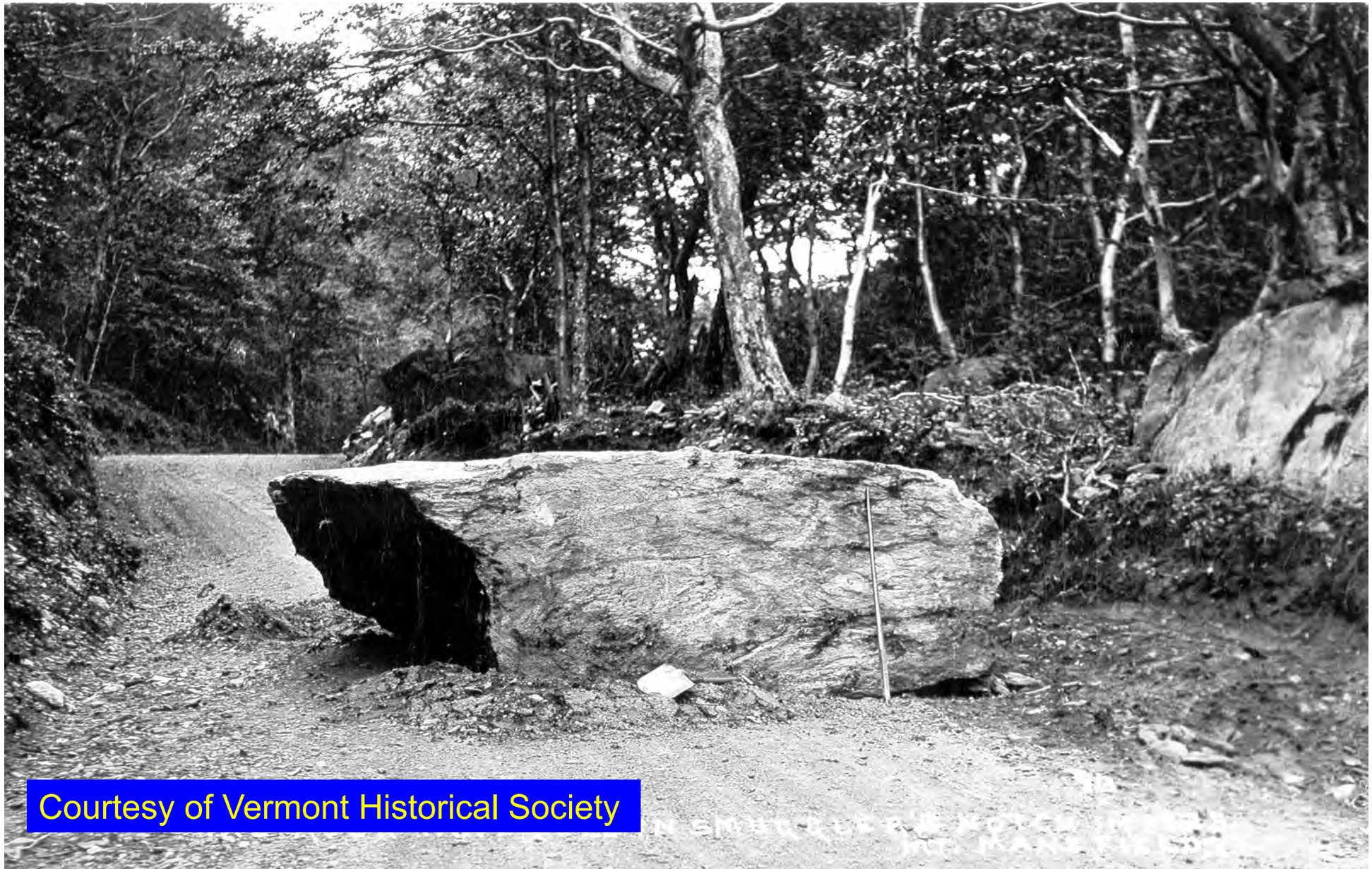
Two types of slope failures in the Smugglers Notch area: Rock falls/slides and debris flows.

Rock falls and slides involve one or more large pieces of rock detaching from a cliff and falling down a slope.

Debris flows are slurries of water, mud, pebbles, cobbles, and boulders that flow within shifting channels on the talus slopes below the cliffs. In the Notch they are activated by heavy rainstorms.

Debris flow track showing levee deposit on south side. Note scars on uphill sides of trees and boulders piled up against them. 2006

Fallen Boulder in Middle of Smugglers Notch Road, about 1925



Thank you

Landslide
Belvidere Mtn
2012