

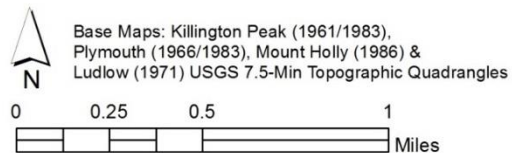
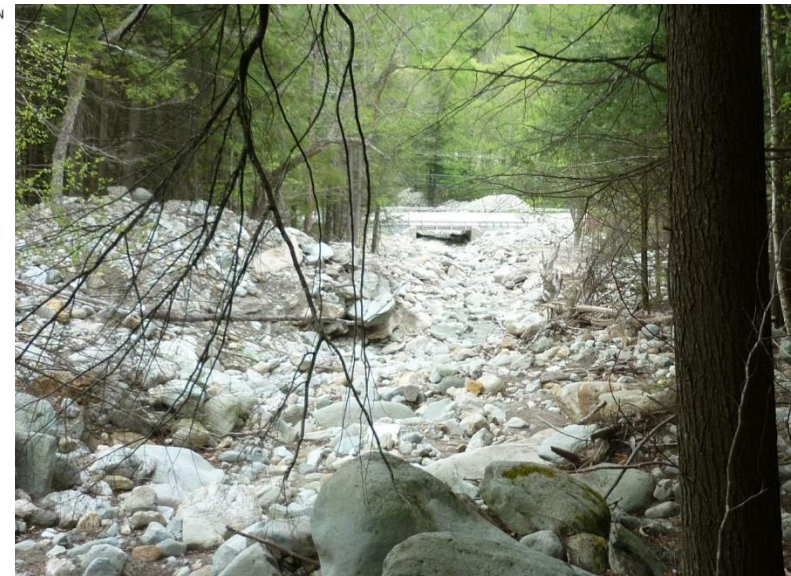
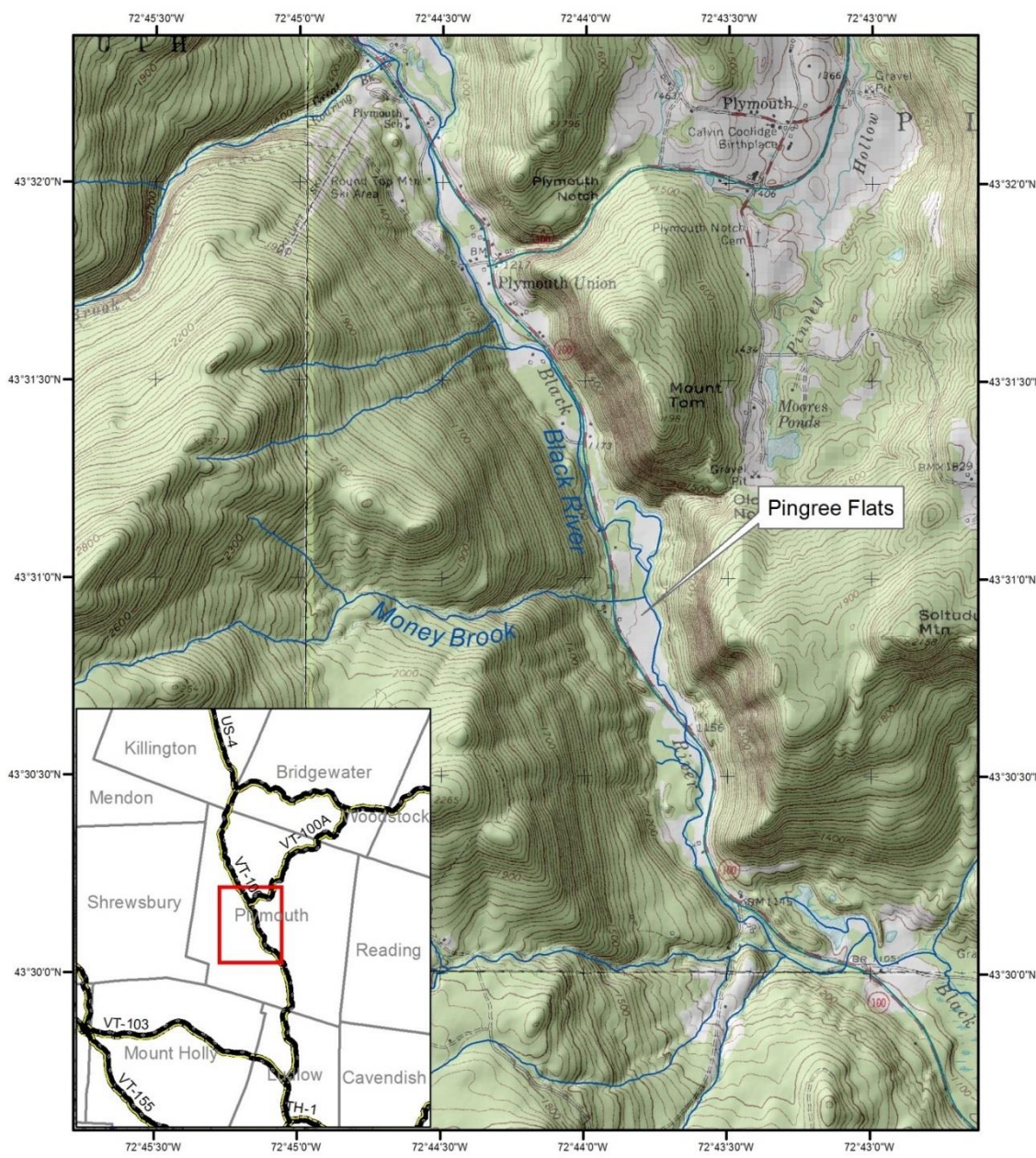
Landslide and Alluvial Fan Activity Due to Tropical Storm Irene: Examples from Money Brook, Black River Watershed, VT

*GSA Northeastern Section 50th Annual Meeting
Bretton Woods, New Hampshire
23 March 2015*

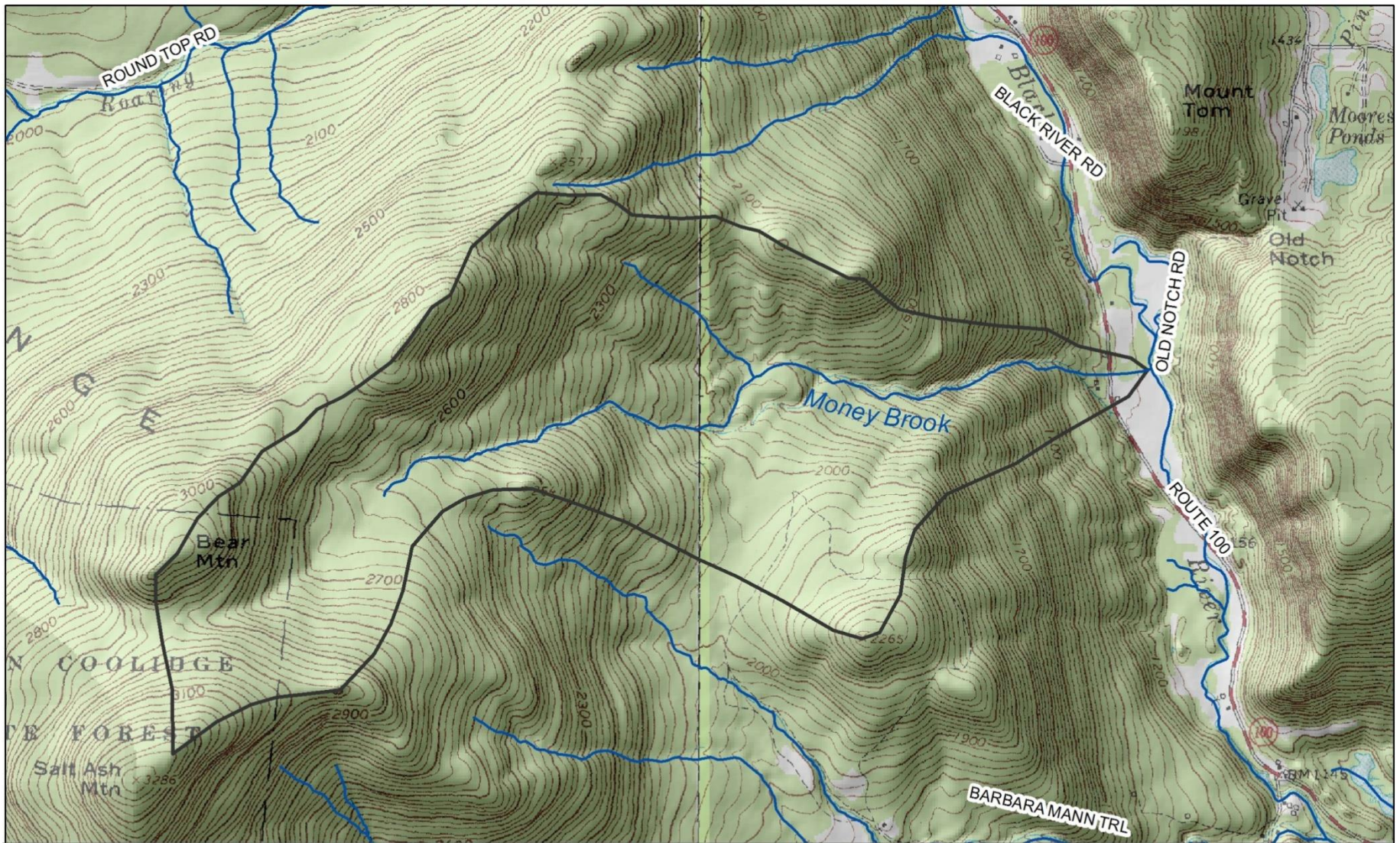
Kristen L. Underwood, South Mountain R&CS, Bristol, VT
George Springston, Norwich University, Northfield, VT



Location



Site Location Map
Money Brook/ Pingree Flats
4181 Route 100, Plymouth, VT
LAT: 43.5156; LON: -72.7323



Base Maps: Killington Peak (1961/1983),
Plymouth (1966/1983), Mount Holly (1986) &
Ludlow (1971) USGS 7.5-Min Topographic Quadrangles

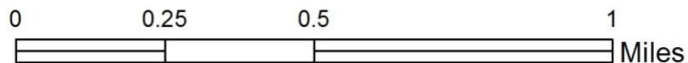
Map Prepared by: Kristen L Underwood, PG
South Mountain R&CS, September 2013

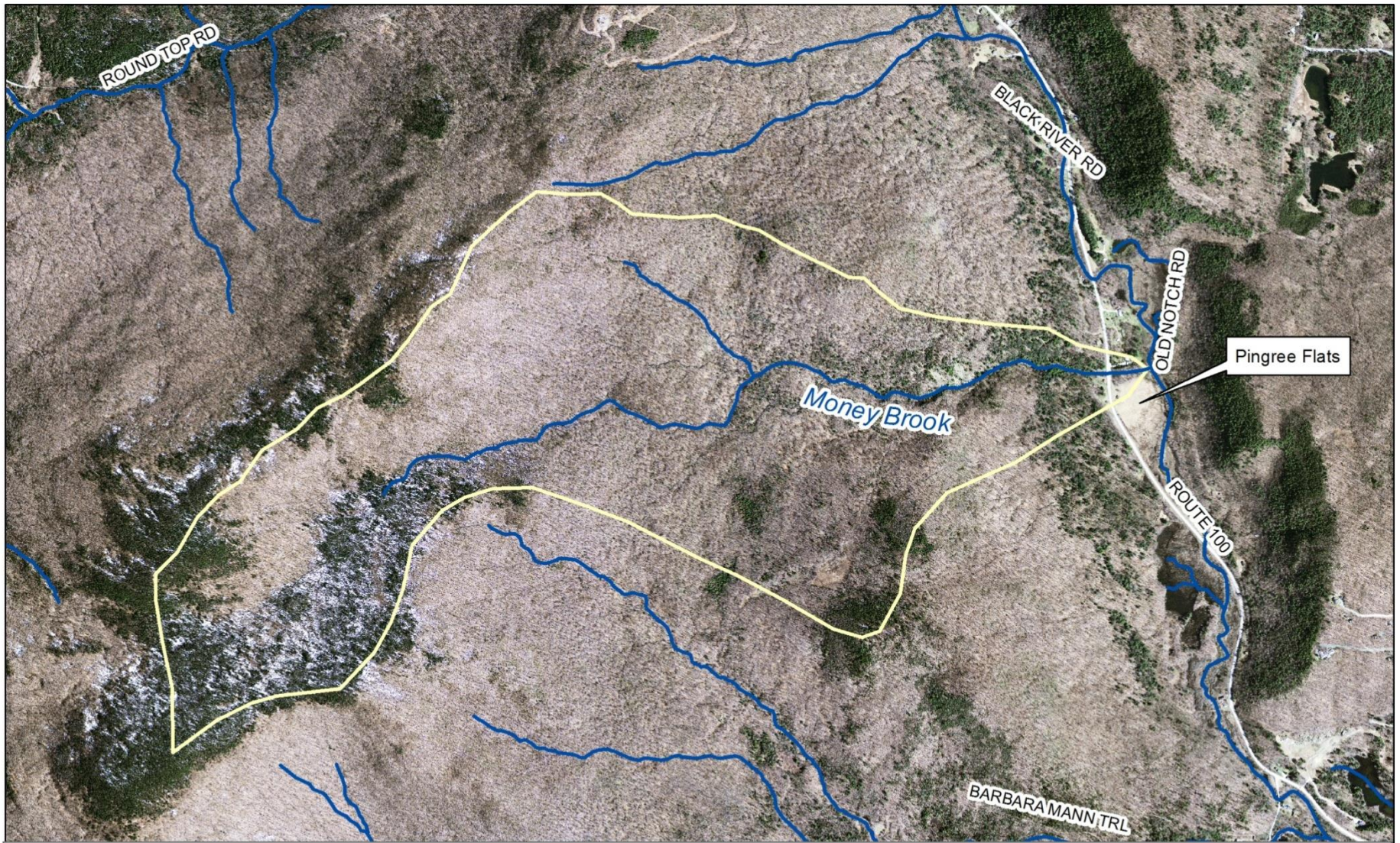
Legend

- Major Streams
- Money Brook Watershed

Watershed Delineation

Money Brook / Pingree Flats
4181 Route 100, Plymouth, VT





Base Image: May 1, 2011

Map Prepared by: Kristen L Underwood, PG
South Mountain R&CS, September 2013

Legend

- Major Streams
- Money Brook Watershed

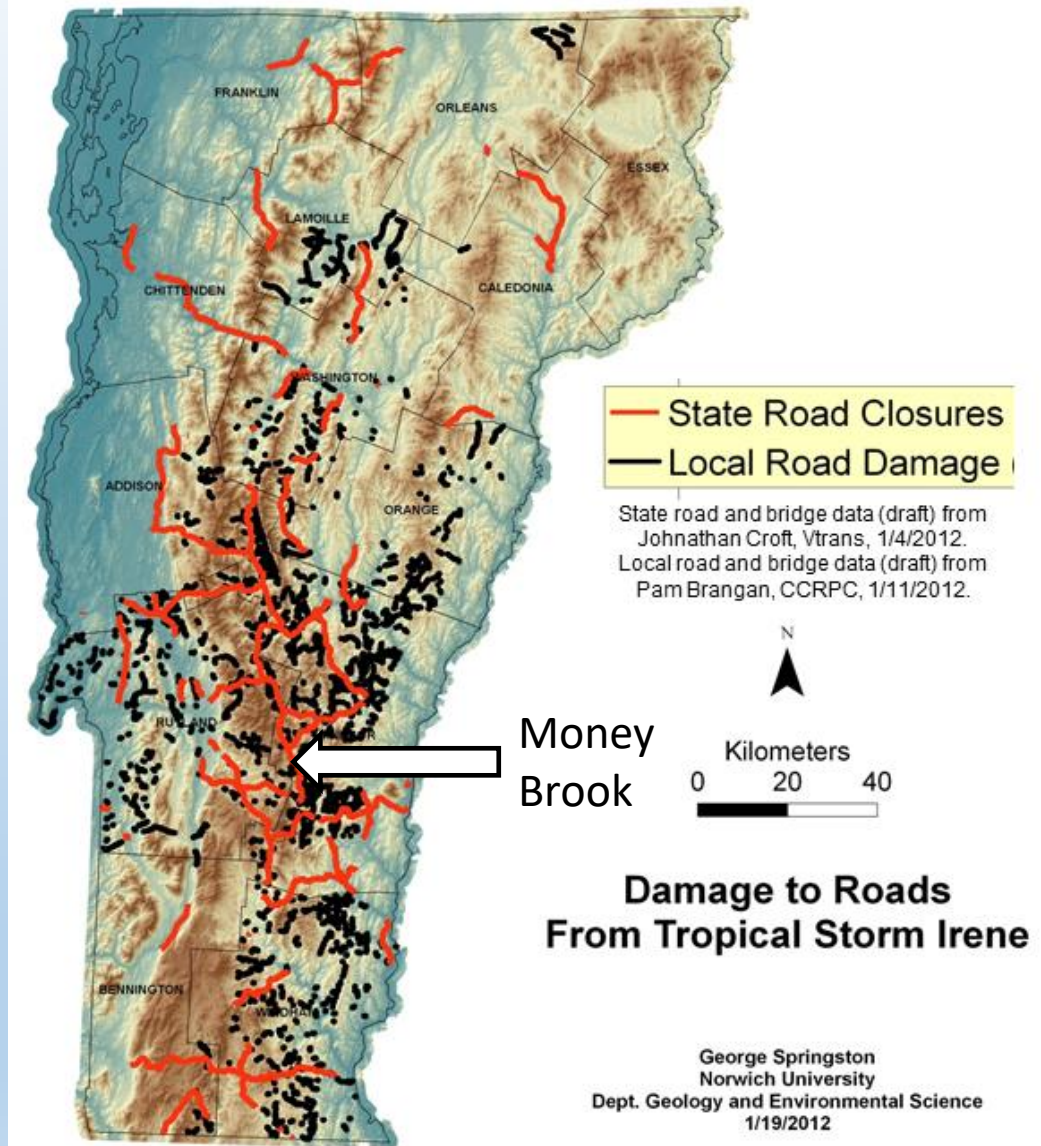
0 0.25 0.5 1 Miles

Money Brook Watershed
Money Brook / Pingree Flats
4181 Route 100, Plymouth, VT

Tropical Storm Irene

- 28-29 August 2011
- State Infrastructure damage
 - > 500 miles roads
 - > 200 bridges
- Town Infrastructure damage
 - 2,800 road segments
 - 280 bridges
 - 960 culverts

(Pealer, 2011)



Tropical Storm Irene: 28-29 August 2011

Coarse Sediment events

— 3 to 4 times per century



September 2011, Mansfield Heliflight



Midge Tucker



Historic Flood Damages and Channel Management

Table 1. Historic Floods of Significance Impacting the upper Black River over the last 100 years.

Event	AEP	Notes	Data Source
2011, August 28-29	<1%	Tropical Storm Irene: Debris over Route 100 and on <u>Pingree</u> lands west and east of <u>Rt 100</u> . Similar impacts to Tucker residence. Bridge 108 overwhelmed. Channel dredged upstream and downstream of <u>Rt 100</u> . Sediment / debris trucked from <u>Pingree</u> Flats. Channel later dredged in Fall of 2011 and again before TS Sandy in 2012.	<u>Kiah, et al., 2013</u> Town of Plymouth <u>Menees, 2013</u> <u>Pingree, 2013</u> <u>Tucker, 2013</u>
1976, August	>5%	Flood debris over Route 100 at Money Brook. Sediment "plowed" from Route 100.	VTDEC WQD, 1999 Town of Plymouth <u>Pingree, 2013</u>
1973, June	1 - 4%	Flood debris over Route 100 at Money Brook. Sediment "plowed" from Route 100. Estimated 25-year storm (Figure 12) to 100-yr storm (Appendix C).	USGS, 1990; VTDEC WQD, 1976; Town of Plymouth; <u>Pingree, 2013</u>
1952, June	7%	Estimate 15-year storm; (Figure 11)	USGS, 2013
1938, September	4%	Likely debris over <u>Rt 100</u> . Est. 25-yr storm (Fig 11, 12) "The road from Plymouth to Bridgewater Corners was heavily eroded."	USGS, 2013; USGS, 1990
1936, March	4%	Estimated 25-year storm, (Figure 11, 12).	USGS, 2013
1927, Nov 3-7	<1%	Largest flood on record in Vermont. Very likely debris over <u>Rt 100</u> . Significant damages in Ludlow, Cavendish, Springfield, <u>Plymouth</u> .	USGS, 1990; Harris, 1949; <u>Minsinger, 2003</u> ; Gay, 1927

AEP = Annual Exceedance Probability. For example, 100-year flood has an AEP of 1%, or a 1% probability of occurring in any given year.

Fine Sediment events – chronic

Lake Rescue

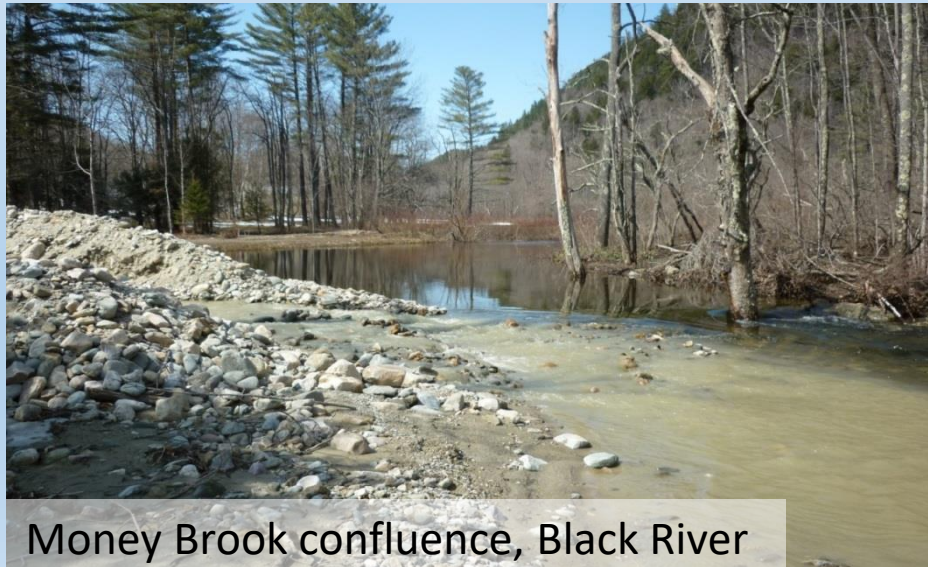


Mansfield Heliflight, September 2011



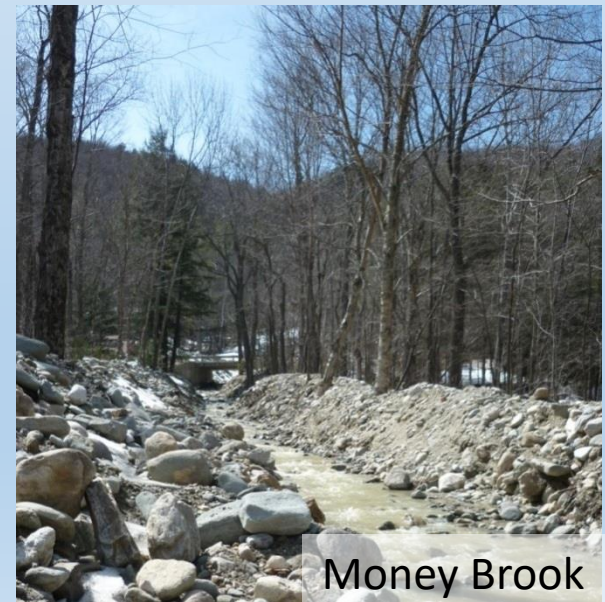
Echo Lake

Mansfield Heliflight, September 2011



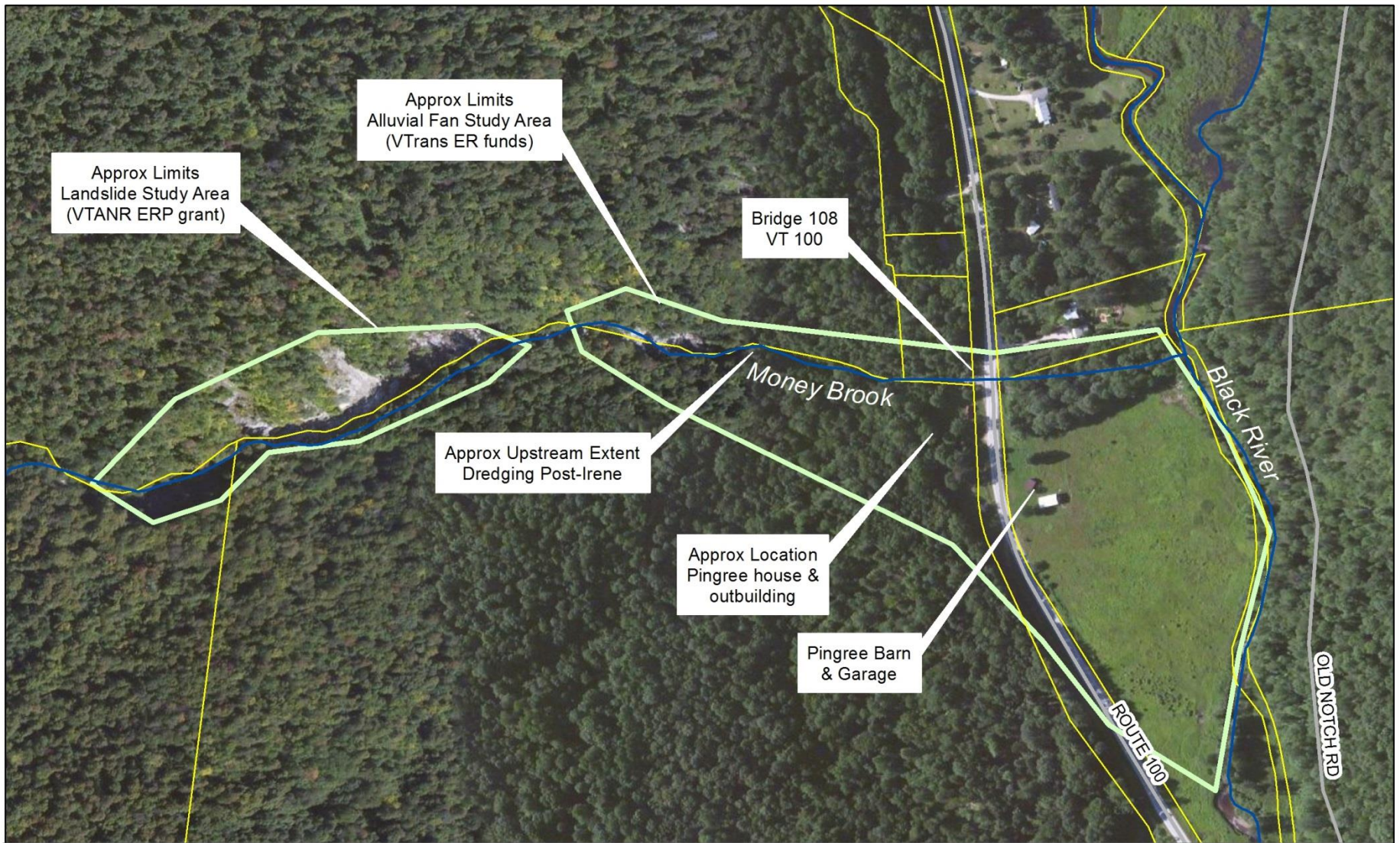
Money Brook confluence, Black River

Underwood, April 2013



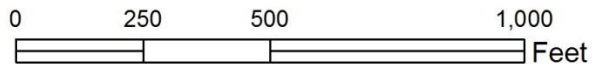
Money Brook

Underwood, April 2013



Base Image: 2011 (pre-Irene)

Map Prepared by: Kristen L Underwood, PG
South Mountain R&CS, September 2013



Legend

- Major Streams
- Parcels_Plymouth2009
- StudyArea
- Roads

Vicinity Map
Money Brook / Pingree Flats
4181 Route 100, Plymouth, VT

Longitudinal Profile

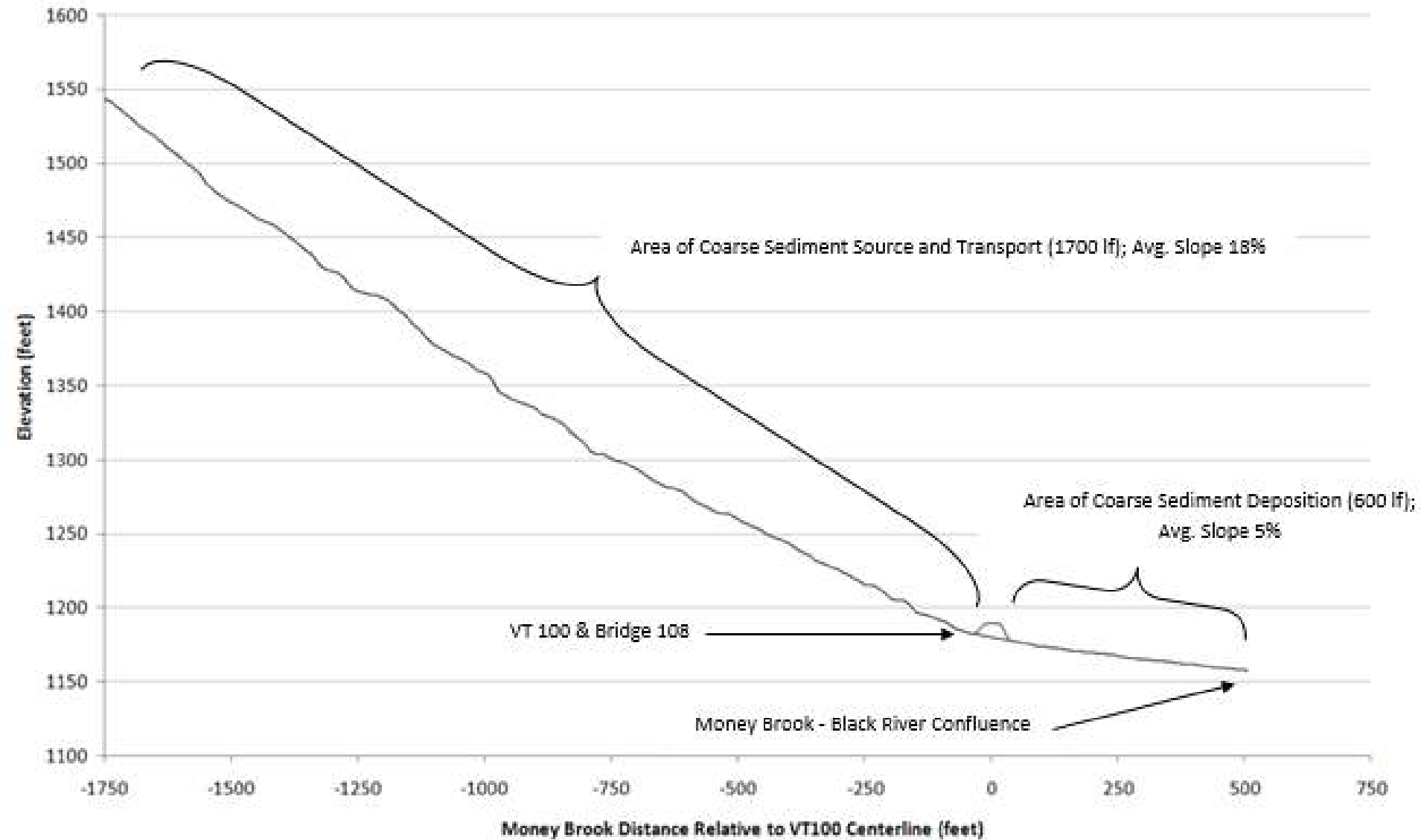


Figure prepared by Fitzgerald Environmental Associates



Money Brook Hydrology

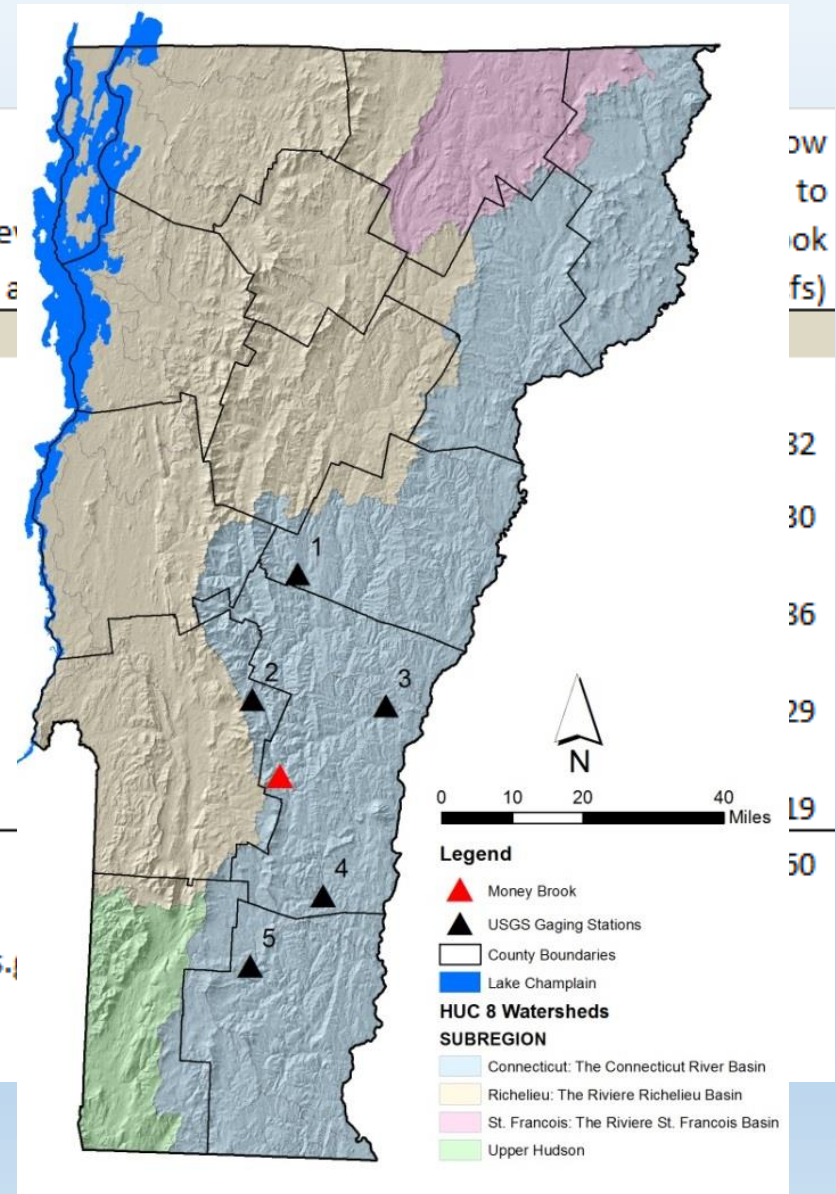
Comparison to measured peak flows from similar watersheds

- Area-adjusted flow for Money Brook = 647 cfs

No.	Station	Station Name	Drainage Area, DA (mi ²)	Elev (ft a
		Money Brook	1.2	
1	01142400	Third Branch White River Tributary at Randolph, VT	0.77	
2	01150800	Kent Brook Near Killington, VT	3.31	
3	01151200	Ottawaquechee River Tributary Near Quechee, VT	0.82	
4	01153300	Middle Branch Williams River Tributary at Chester, VT	3.16	
5	01155350	West River Tributary at Rt 30, Near Jamaica, VT	0.9	

References

- USGS, 2013, on-line surface water data, <<http://waterdata.usgs.gov>>
- Olson, 2002; Table 8
- Kiah *et al.*, 2013



Money Brook Hydrology

Comparison to measured peak flows from similar watersheds

- Area-adjusted flow for Money Brook = 674 cfs



No.	Station	Station Name	Drainage Area, DA (mi ²)	Gage Elevation (ft amsl) ¹	% Basin area above 1200 ft ²	Mean Ann Pptn (in) ²	TS Irene Peak Flow (cfs) ³	Peak Flow Adjusted to Money Brook DA (cfs)
		Money Brook	1.2	1,158	98.1			
1	01142400	Third Branch White River Tributary at Randolph, VT	0.77	690	55.3	39.6	117	182
2	01150800	Kent Brook Near Killington, VT	3.31	1,560	100	55	2,840	1,030
3	01151200	Ottawaquechee River Tributary Near Quechee, VT	0.82	670	8.7	38.8	59	86
4	01153300	Middle Branch Williams River Tributary at Chester, VT	3.16	622	56.4	43	602	229
5	01155350	West River Tributary at Rt 30, Near Jamaica, VT	0.9	1,230	100	47.3	239	319
Geometric Mean:								260

References

- USGS, 2013, on-line surface water data, <<http://waterdata.usgs.gov/vt/nwis>>. (for elevation data)
- Olson, 2002; Table 8
- Kiah *et al.*, 2013



Richelieu: The Riviere Richelieu Basin
St. Francois: The Riviere St. Francois Basin
Upper Hudson

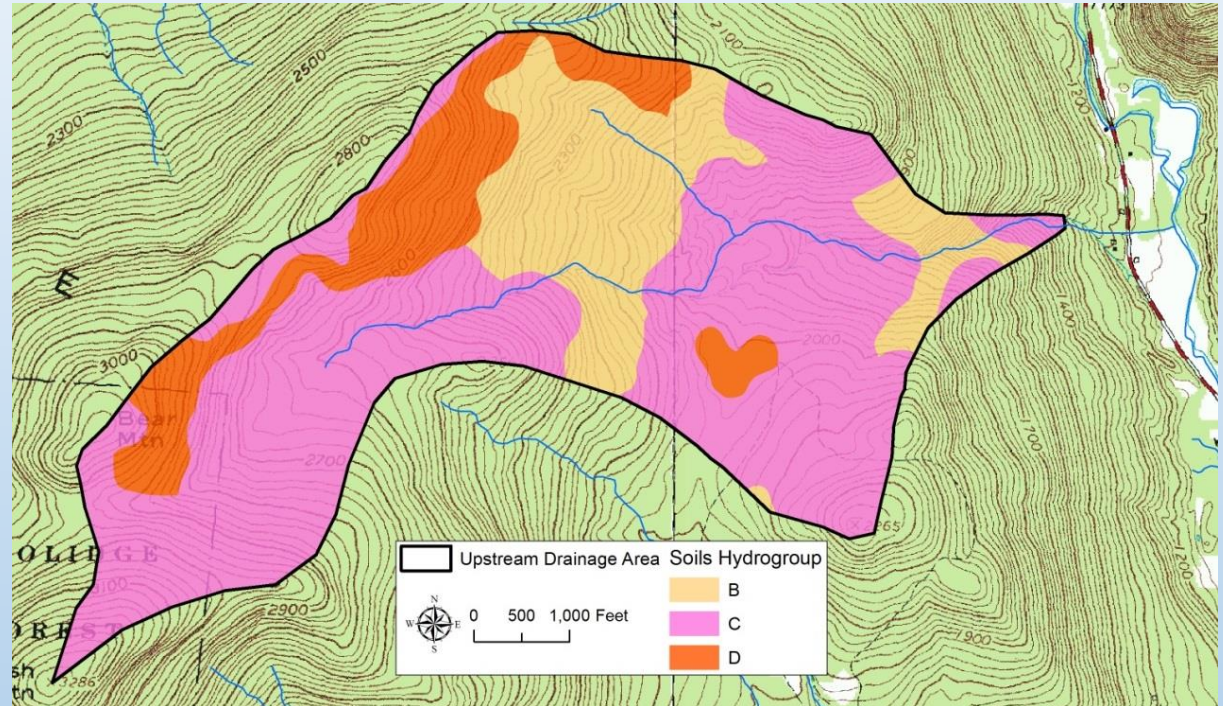
Money Brook Hydrology

HydroCad TM

Estimated Peak Flows

Rainfall Event (in)	TR20 Model	
	Short SCF	Long SCF
1-year (2.3)	64	51
2-year (2.5)	89	69
10-year (3.7)	297	225
100-year (5.9)	825	621
TS Irene (7.0)	1,124	846

Distribution of Hydrologic Soil Groups – 78% C & D soils



*Figure preparation and HydroCAD analysis by
Fitzgerald Environmental Associates, LLC*

Money Brook Hydrology

Flood Competence Estimates (after Costa, 1983)

- 7.5 m/s (25 ft/sec) peak velocity during TS Irene

$$V = 0.18 * d^{0.49}$$

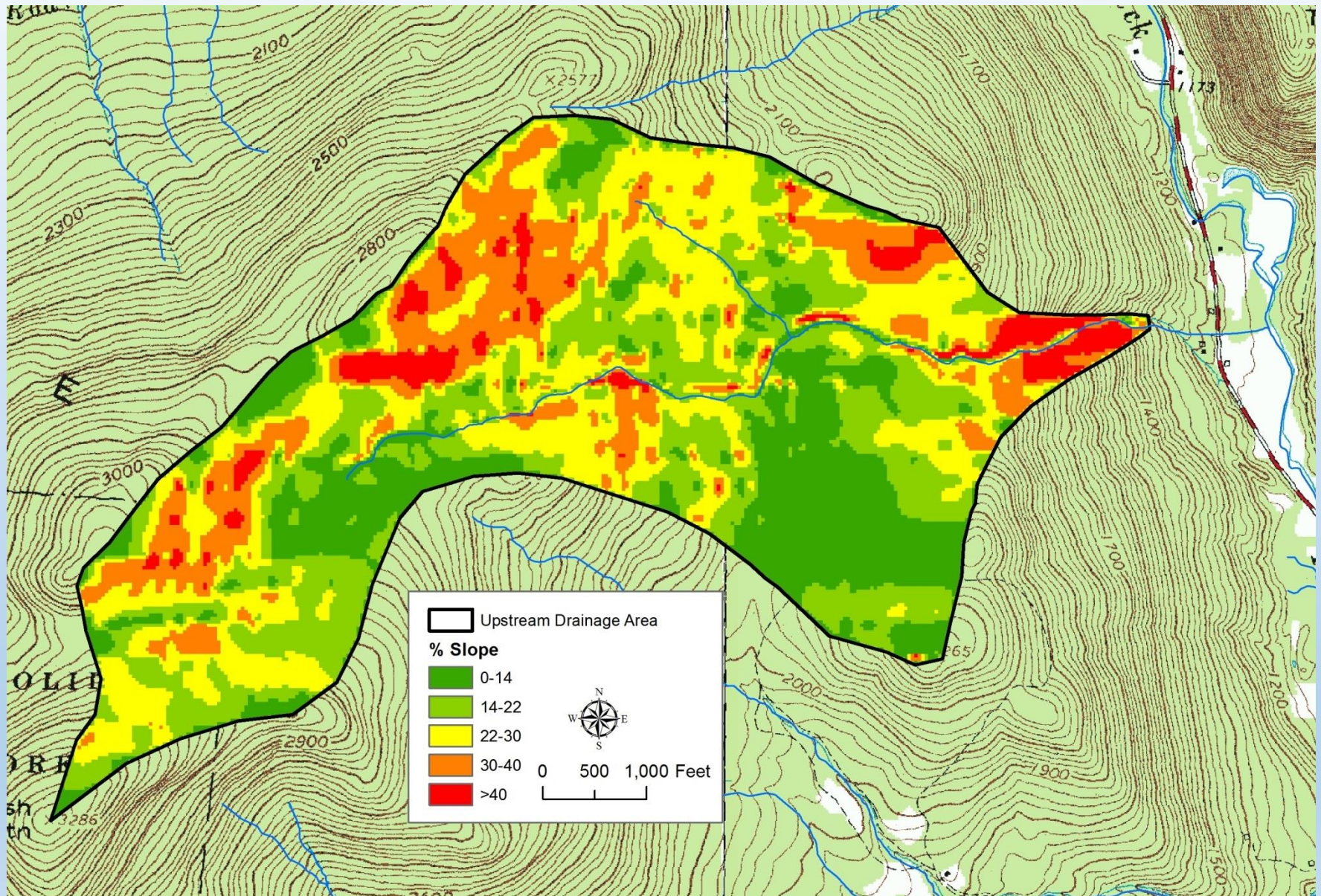
where, V = velocity, in m/s

d = median clast diameter, in mm



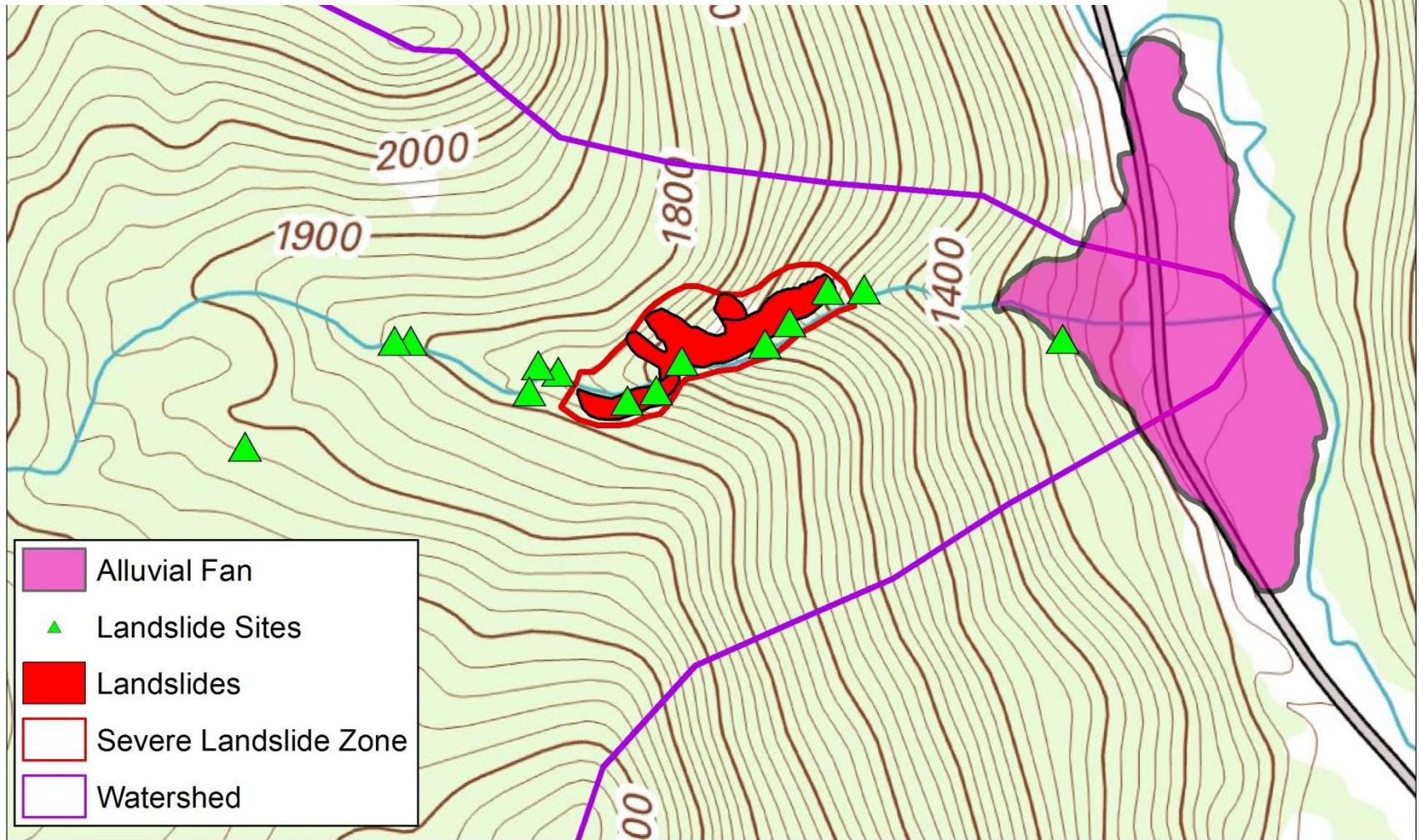
Costa, 1983. Paleohydraulic reconstruction of flash-flood peaks from boulder deposits in the Colorado Front Range: Geological Society of America Bulletin, v. 94, p. 986-1004

Money Brook hydrology – slopes, stream power



Landslide assessment

field protocol developed by Clift and Springston (2012)



Base Map from USGS Plymouth
7.5 minute quadrangle.
20 foot contours.

0 100 200 300
Meters



George Springston
Norwich University
Dept. Geology and Environmental Science
12/09/2013



Left: Looking upstream at MB-10. Bedrock can be seen on the left side of the photo (on the right side of the channel).

Right: Looking downstream at MB-10. Note abundant boulders, the source material for the boulders on the alluvial fan.

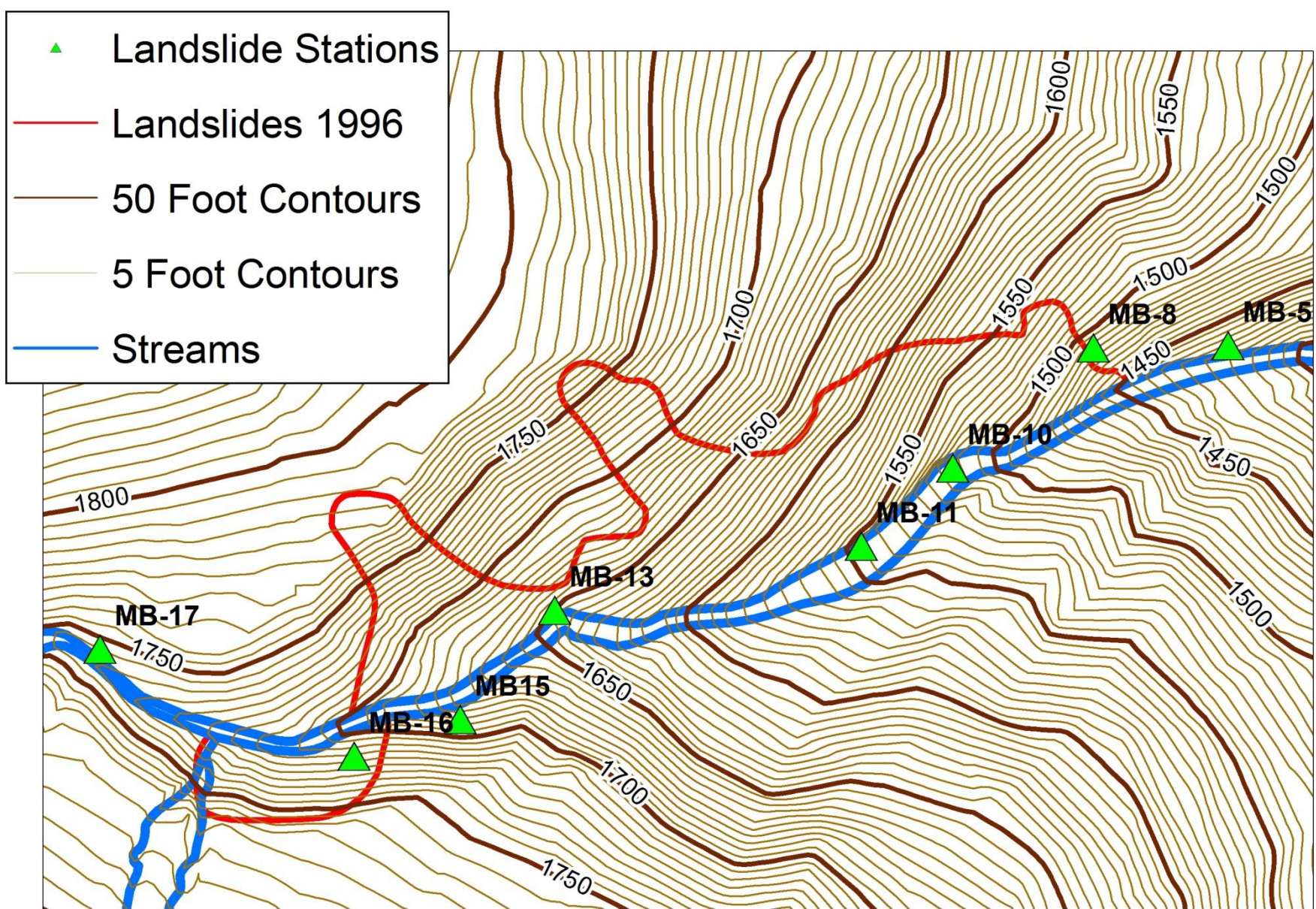


General Characteristics of Major Landslides at Money Brook

Landslide Site	Elevation of Crown (feet)	Activity	Landslide Type	Width (m)	Height (m)	Depth (m)	Aspect	Overall Slide Angle	Area Estimate (sq. m.)
MB-8	1490	Active	Complex	44.0	17.9	>3	175	46	>1000 sq. m.
MB-10	1605	Active	Complex	55.0	28.8	>3	130	37	>1000 sq. m.
MB-11	1755	Active	Complex	92.0	58.3	>3	155	31	>1000 sq. m.
MB-13	1780	Active	Complex	40.0	38.5	>3	176	37	>1000 sq. m.
MB15	1730	Active	Complex	44.0	19.2	<2	303	41	>1000 sq. m.
MB-16	1755	Active	Complex	91.0	18.4	<2	5	40	>1000 sq. m.
Sum				366.0	181.1			232	
Mean					30.2			38.7	



Looking north at landslide at MB-11. Note fresh erosion at base of slope and rilling of landslide surface.

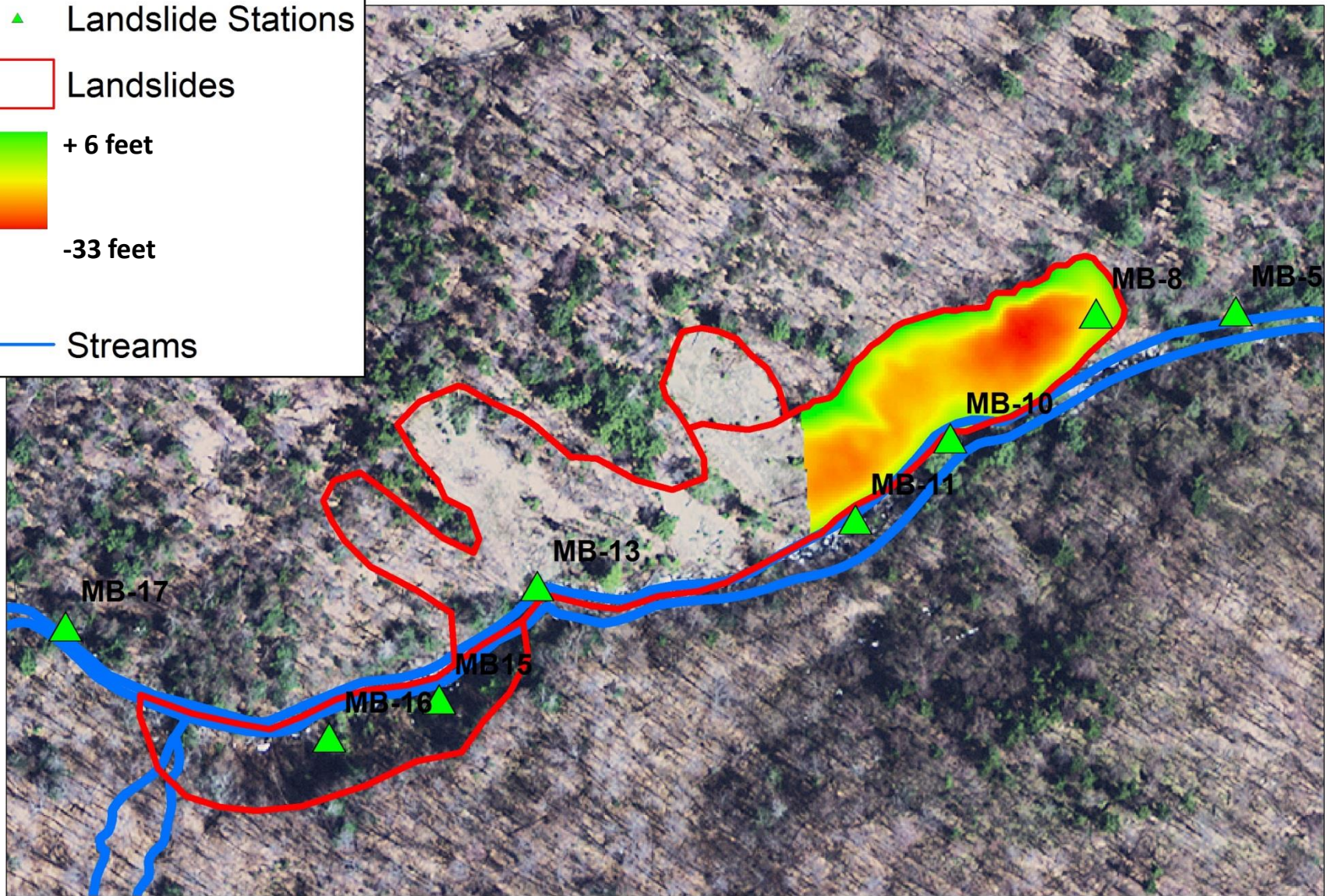
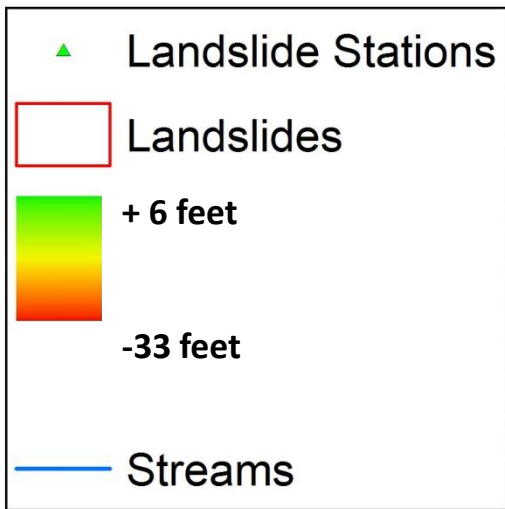


Base Map from Photogrammetry
Flown in May, 1996 for
Michael Engineering.

0 100
Meters



George Springston
Norwich University
Dept. Geology and Environmental Science
12/09/2013



Base Map from State of Vermont
Orthophoto Program, Spring, 2011.

0 100
Meters



George Springston
Norwich University
Dept. Geology and Environmental Science
12/09/2013

Estimate of Volume Change of Landslides at Money Brook from 1996 to 2012

Landslide Section	Area (sq. ft)	Depth (ft)	Volume (cubic feet)	Volume (cubic yards)
North Side, Lidar	43,551	18.2	792,628	29,356
North Side, No Lidar	76,521	18.2	1,392,682	51,581
South Side, No Lidar	35,113	9.1	319,528	11,834
Sum			2,504,838	92,771

For the landslide on the north side with lidar, depth is measured change in elevation between 1996 and 2012.

This same depth was used for the portion of the north side without lidar.

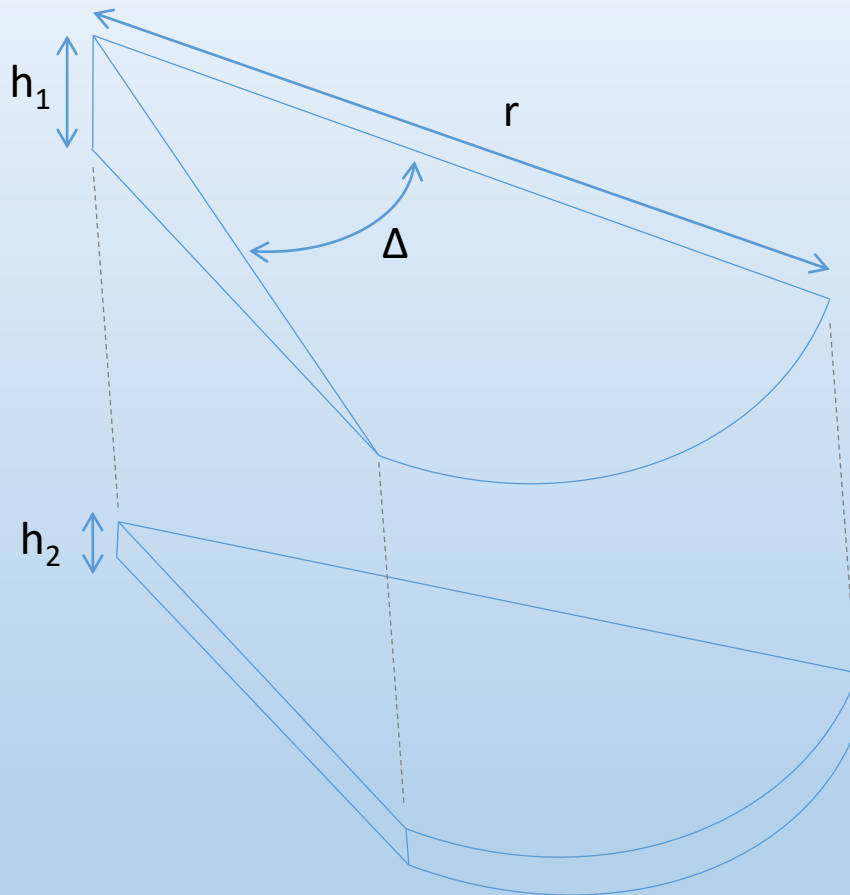
For south side without lidar, the above figure was cut in half. This is consistent with the observed depth of erosion at this landslide.

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**Total estimate for landslide volume
change = 92,772 cubic yards (71,100 m³)**

George Springston
12/09/2013

Estimate of Volume of Material Deposited on Money Brook Alluvial Fan



Volume of Sector of Cone:

$$V_1 = 1.0472 r^2 h_1 (\Delta/360^\circ)$$

V_1 = volume in cubic feet

r = radius = 1200 feet

h_1 = height of cone = 5 feet

Δ = segment of cone = 50°

$$V_1 = 1,057,284 \text{ cubic feet}$$

Volume of Sector of Disk:

$$V_2 = 0.008727 \Delta r^2 h_2$$

V_2 = volume in cubic feet

r = radius = 1200 feet

h_2 = height of disk = 1.5 feet

Δ = segment of cone = 50°

$$V_2 = 942,516 \text{ cubic feet}$$

**Total volume estimate for deposit on fan = 1,989,800
cubic feet = 73,696 cubic yards (56,600 m³)**

Debris Jam #2 (240 CY)





Acknowledgments

- Evan Fitzgerald, Fitzgerald Environmental Associates, LLC, Colchester, VT
- Roy Schiff, Milone & MacBroom, Inc., Waterbury, VT
- Chris Lathrop, DuBois & King, Inc., South Burlington, VT
- Paul Libby, Vtrans
- Marie Caduto, VTDEC Watershed Management Division
- Pingree Family
- Lake Rescue Association
- Funding from VT Agency of Natural Resources Ecosystem Restoration Grant

Questions?