# Fluvial Geomorphology of Great Brook

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## ABSTRACT

Both quantitative and qualitative methods of geomorphic analysis were used to assess the mainstem and tributaries of the Great Brook watershed in Plainfield Vermont for hazard potential. On the basis of field and office assessments the results were divided into four sections:

1) The unstable lower reach; 2) the stable upper reach; 3) the tributaries, and 4) the watershed, i.e., the land that is not adjacent to the tributaries or mainstem.

The Great Brook watershed has a drainage area of 14.2 square miles and ranges in elevation from 712 to 3,352 ft. above sea level. The main channel is approximately 9 miles in length.

The lower reach flows through located in the lakebed of glacial Lake Winooski. Groundwater well logs and seismic data show that there is little bedrock control throughout the lower 5 miles of the brook.

Damage frequently re-occurs in the same area during flood events. Two houses have been washed away during the 1984 and 1989 floods. Five bridges, two additional houses and numerous sections of the road remain at risk to flood damage. Over 2 million dollars has been spent repairing roads, stream banks and bridges in the lower reach since 1984. This section of the brook has been impacted by floodplain encroachment, channelization, and other disturbances by incision, bank failure and widening. The brook has over 25 mass failures, most occur in basal till.

The upper reach is relatively stable. Although in the recent past an in-stream pond catastrophically failed. In the upper watershed and tributaries, channel avulsions, multiple channels and alluvial fans occur where the slopes flatten out and sediment transport capacity diminishes, or as a result of debris jams. Potential hazards throughout the watershed occur as a result of; stormwater concentrating flow from driveways and roads; inadequate, or poorly placed culverts; from changes in hydrology due to concentrated flow; and the geologic characteristics of the watershed, which include thick deposits of highly erodible sands. These sands have failed catastrophically, in part as a result of concentrated stormwater flow.

Data for the assessment of potential hazards is divided into three main categories, 1) geological characteristics, 2) geo-fluvial processes and 3) anthropogenic influences. The results will be used to create a hazard map to help the town to reduce impacts to public and private property from changes in channel planform, channel incision and widening. Studies have found that half of the flood damage that occurs in Vermont is "avoidable" damage (40). This study is a first step towards making recommendations on how to reduce or prevent "avoidable" damage. Hazard mapping recommendations include delineating hazard areas on the basis of the three categories, geologic geo-fluvial and anthropogenic.


Excerpts: The Great Brook shares a confined valley with the Brook Road. Thirteen narrow bridges cross the brook along a 5 mile length of the valley in which the mainstem flows. These bridges are narrower than the width at bankfull flow (1.5 – 2 year return) and generally cause the channel to be constricted. Some of the bridges are located in severe meander bends of the river, where they are most vulnerable to fluvial erosion. Accounts of floods as early as the 19th century detail the destruction of bridges along the course of the Great Brook. After a large flood in 1973, a bulldozer was used to channelize the Brook for about four miles as measured directly up the valley from the village. Several houses and roads have encroached upon the narrow floodplain that did exist in the valley for parts of the stream. Work to repair flood damage in 1984 and 1989 has resulted in further channelization and hard armoring of the Great Brook.

The most significant alterations in this section are a result of anthropogenic causes. In-stream management, channelization, removal of roughness from the watershed, hard armoring of banks, flood plain encroachment, and berming have contributed to a highly unstable river system in the lower watershed. The three main activities that have caused damage are; 1) flood plain encroachment from the Brook Road and houses, 2) channelization, and 3) channel constriction at the bridges.

The brook has been heavily armored with rip-rap in order to protect the road, bridges and houses. Due to the active degradation, much of this rip-rap is being undermined and is falling into the bed.

After the 1973 flood, the Town Annual Report listed $26,622 in flood damage on the Great Brook, compared to $1,136 on the Winooski River. That year, the Town paid $4,184 for "Channeling Great Brook." (33). Ed Letourneau, a local resident recalls riding his motorcycle up and down the channel after the bulldozer was done (42). The channel has been bulldozed several times since the 1973 flood. The bulldozing appears to include Reach 1 – 26.

River management has included removing all woody debris. Roughness was also removed from the channel when boulders were moved to the banks to serve as rip-rap. This was a common management method and on the older bridges (pre 1930), the rip-rap is primarily stream boulders.

River management has also included straightening the channel in several locations. This has reduced the sinuosity, and increased the slope, the velocity and the shear stress. The channel is still actively adjusting to these changes. The channel wants to re-establish its meanderbelt width, and reduce its slope but is constrained by the road.

TABLE 6: SUB-BASIN CHARACTERISTICS

| | **Upper Basin above Reach 31** | **Mid Basin Above Reach 18** | **Lower Basin Above confluence with the Winooski River** |
|---|---|---|---|
| Belt Width | 125 | 170 | 350 |
| Meander Wavelength | 200 | 400 | 420 |
| Meander Amplitude | 35 | 70 | 120 |
| Radius of Curvature | 30 | 80 | 90 |
| Sinuosity | 1.03 | 1.07 | 1.15 |
| Drainage Area (Sq. Miles) | 4.6 | 7.9 | 14.2 |
| Channel Slope (%) | 5.5 | 3.6 | 3.1 |
| Channel length (mi) | 2.6 | 5.4 | 8.4 |
| Low and High Elevation (feet) | 1400-3352 | 1140-3352 | 712-3352 |
| Hillslope Gradient | Steep-ext. steep | Steep – ext. steep | Moderate - ext. steep |
| Valley Confinement | Confined | Semi-confined | Confined |
| Bankfull width | 17 | 25 | 39 |
| Stream Order | 1 | 2 | 3 |

**Basin Characteristics**

| **% Hydrologic Group** | **A** | 1.1 | **B** | 32 | **C** | 44.7 | **D** | 21.8 |
|---|---|---|---|---|---|---|---|---|

**Land Use (from 1970s orthophotography, Central Vermont Regional Planning Commission)**

| | | | |
|---|---|---|---|
| **% Wetlands** | 3 | **% shrub/ abandoned Ag. Land** | 5.13 |
| **% Forest** | 77.4 | **% Agricultural** | 15.2 |
| **% Imperviousness** | 1.65 | | |

| | | | |
|---|---|---|---|
| **Channel Modification:** Location: Reach 1-26, Bermed, channelized, straightened | | | |
| **Annual Snowfall** | 100-120 inches | **Annual Precipitation** | 39 inches |

**Hydrologic Characteristics in Cfsm:**

| **Basin** | **7q10** | **10% Exceedance** | **50% Exceedance** | **90% Exceedance** | **Mean Annual Flow** |
|---|---|---|---|---|---|
| Dog | 0.1 | 3.6 | 0.8 | 0.22 | 1.6 |
| Ottaquechee | | 5.2 | 1.4 | 0.47 | 2.5 |
| Ayers | 0.06 | 3.6 | 0.9 | 0.22 | 1.6 |
| E. Orange | 0.07 | 4.5 | 0.9 | 0.26 | 1.8 |
| Sleepers | | 3.5 | 0.9 | 0.28 | 1.6 |

**Great Brook estimates in CFS (from average of all stations) (DA=14.2 sq. mi)**

| | | | | | |
|---|---|---|---|---|---|
| Predicted flows (cfs) | 1.1 | 60 | 14 | 4 | 26 |

*Bridges*

Of the 14 bridges along the Brook road with dates on them, five were built prior to the 1927 flood. Three have been standing since 1929. Five have been replaced in the last 11 years. While the older bridges have experienced floods that have outflanked and cut new channels around them, the bridges themselves remained after the flood.. Channel constriction is present at every bridge, except for the new bridge downstream of Reach 8 by the sandpit. Most are narrower than the bankfull width and floodprone width. The angle of flow is a problem on approach to five bridges including two built in the early 1990s. These bridges may have to be replaced.. One of these bridges poses an immediate hazard as both upstream and downstream wingwalls have already been outflanked. Summary information is in Table 14.

**Table 14. BRIDGE DATA, BROOK ROAD, PLAINFIELD, VERMONT**

| Location | Year built | Brook Road mileage from village | Bedrock or concrete apron | Width measured along road (feet) | Width measured square (feet) | Bankfull Width | Nearest cross-section | Height (feet) | Depth measured center to center (feet) | Angle of flow problem on approach to bridge |
|---|---|---|---|---|---|---|---|---|---|---|
| In village, near Hudson Ave. | 1929 | | N | 29 | | 44 | 3 | 7 | 28 | N |
| Brook Road in Village | 1920 | 0.09 | Y | 22 | 20.5 | 46 | 4 | 7.3 | 23 | Y |
| D/S town salt shed | 1929 | 0.38 | | 33.5 | 33 | 34 | 6 | 9.5 | 24 | N |
| u/s sand pit | 1991 | 0.9 | N | 44 | 34 | 33 | 8 | 14.5 | 38 | Y |
| Tributary | 1991 | 1.35 | Y | 13.5 | | | | 6 | 32 | N |
| d/s white trailer | 1929 | 1.78 | N | 24 | | 33 | 12 | 13 | 24 | N |
| u/s white trailer | 1991 | 1.85 | N | 24 | 23 | 34 | 13 | 13.5 | 30 | Y |
| Private bridge: | | 2.4 | N | 31 | | 26 | 17 | 9 | 12 | N |
| Bedrock tributary | | 2.47 | Bedrock | 7 | | | | 7.5 | 21 | N |
| Lee Rd. Bridge | 1991 | 3.15 | N | 23 | | 29 | 22 | 8.5 | 21.5 | Y |
| | 1919 | 3.4 | Y | 14 | | 29 | 23 | 8 | 20 | N |
| | 1923 | 3.5 | Y | 18 | 16 | 29 | 23 | 8 | 24 | |
| | 1925 | 3.6 | Y | 24 | | 29 | 24 | 9.3 | 21 | |
| Before East Hill | 1920 | 4.1 | Y | 18.5 | 14.5 | 29 | 26 | 8.9 | 25 | Y |
| Maxfield Rd | 1991 | 4.37 | Bedrock | | 16 | 19 | 29 | 11 | 17 | |
| New/Old bridge | 1919/ 1999 | 4.85 | Y | | 10 | | NA | 6.5 | 25.5 | N |
| Orange | culvert | 4.95 | n/a | | 4 | | | 4 | | |
| Driveway in Orange | culvert | 4.93 | n/a | | 4 | | | 4 | 12 | |
| Gore Rd | culvert | | n/a | | 10 | | | 10 | | |

**Discussion:** The results of the assessment are complicated due to the extreme instability within the lower portion of the watershed and the frequency of significant floods in the last 30 years. While the assessment methods reflect the processes occurring within the channel, they do not reflect the time period needed to destabilize a reach. Catastrophic failures, such as the loss of the road, bridges and houses occur quickly. However, smaller changes continue after the catastrophic failures. Channels take many years to adjust to changes in hydrology, sediment load or land use change. The adjustment "curve" is an asymmetrical bell shaped curve with active adjustment occurring rapidly in the beginning, (the first 20 years or so). It is important to remember that the stream continues to adjust its dimension, pattern and profile for up to and over a 60–100 year period. The active degradation that is still occurring in the lower reaches of the watershed indicates that it is still in the period of active adjustment.

Two examples of catastrophic failure are the houses lost during the 1984 and 1989 floods. In the case of the house lost in 1984, the channel degraded and widened during a single event. Photos and drawings from during and after the flood event show that the straightened channel may have been trying to recreate its meander belt-width. The four primary factors that contributed to the loss of the house in 1989 are: 1) The house was located in a flood plain that had been filled; 2) A debris jam re-directed flow into the former flood plain; 3) The stream channel had been bulldozed both upstream and downstream of the house, and the bed armor destroyed; 4. Mass failures upstream contributed a sediment load that filled the pools and may have contributed to a reduction in flood conveyance capacity.