Phase 1 Geomorphic Assessment of the White Creek/Mill Brook Watershed in Southwestern Vermont

Conducted in 2005 by

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Tables and figures

I. EXECUTIVE SUMMARY

In 2005, the Bennington County Conservation District conducted a Phase 1 Geomorphic Assessment of twenty-one reaches in the White Creek/Mill Brook watershed in the towns of Rupert and Sandgate in southwestern Vermont.

Much of the watershed has been highly altered by human activities, and this assessment quantifies many of those alterations. (Because they are what is consequential in terms of future management actions in the watershed, this report focuses on those human-induced impacts.)

- Seventeen of the twenty-one reaches received a “high” impact rating due to urban land uses in the stream corridor.
- Twelve reaches received a “high” impact rating due to straightening.
- Three reaches rated “high” due to a history of dredging.
- Fourteen reaches were rated “high” impact due to restrictions of the floodplain caused by berms and roads.
- Seven reaches received a project reach condition score of “poor” and five a project reach condition score of “fair.”

II: PROJECT OVERVIEW

Introduction

Physical features such as channel slope, width, depth and planform are essentially responses to the water and sediments a watercourse must transport. In natural systems, these geomorphic features are in a dynamic balance with sediment supply and water volume and velocity. Where systems have been disturbed, rivers are likely to be “in adjustment” – evolving toward a new, sustainable dynamic equilibrium between profile, dimension, and pattern on the one hand and watershed inputs of water and sediment on the other.

Empirical studies of rivers worldwide have enabled river scientists to characterize rivers in dynamic equilibrium according to their geomorphic features. We know, for example, that, in nature, a northeastern valley bottom stream typically occupies a wide, gently sloping valley; that the channel is a good deal wider than deep, and that sinuosity is moderate. In nature, a northeastern headwaters stream is usually steep, deeply entrenched, and often exhibits numerous cascades. For the river researcher, a red flag is raised where any feature of a stream departs in an important way from what would be typical of a watercourse in that landscape setting. Assessments of physical features of rivers are useful because, by uncovering and describing these departures, they can help us understand how and why a watercourse is changing, and guide us in managing for those changes.

Goals and objectives

In 2005, the Bennington County Conservation District conducted a geomorphic assessment of the White Creek/Mill Brook watershed in Bennington County, Vermont. The purpose of the project was to lay a foundation for future targeted field investigation of the causes of instability in the watershed and, eventually, for the design and implementation of their “cures.” The long term objective was to reduce instability and its impacts on natural and cultural resources.

The results, summarized in this report, describe the sort of rivers typical of the watershed’s geologic setting, and red-flag departures from the typical reach by reach. The assessment made use of the April 2005 Vermont Agency of Natural Resources (ANR) Vermont Stream Geomorphic Assessment Phase 1 Handbook (ANR 2005 SGA Phase 1) and the Stream Geomorphic Assessment Tool software developed for the ANR. More information on the protocols and SGAT can be found at http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassesspro.htm Study findings were uploaded to the agency's web-based Data Management System (DMS) and are available for public review at https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm.

III. PROJECT AREA AND FLUVIAL GEOMORPHIC SETTING

The Vermont portion of the White Creek/ Mill Brook watershed occupies about 22 square miles in the towns of Rupert and Sandgate. White Creek discharges to Black Creek in Salem, NY. Black Creek drains to the Batten Kill in Greenwich, NY. The Batten Kill drains to the Hudson near Clarks Mills, NY. The White Creek and Mill Brook watershed is the largest subwatershed of the Batten Kill draining to New York State. The Batten Kill and the Hoosic River watersheds are the only watersheds in Vermont which drain to the Hudson River.

Twenty-one reaches on White Creek, Mill Brook, Sandgate Brook, and three unnamed tributaries were examined.

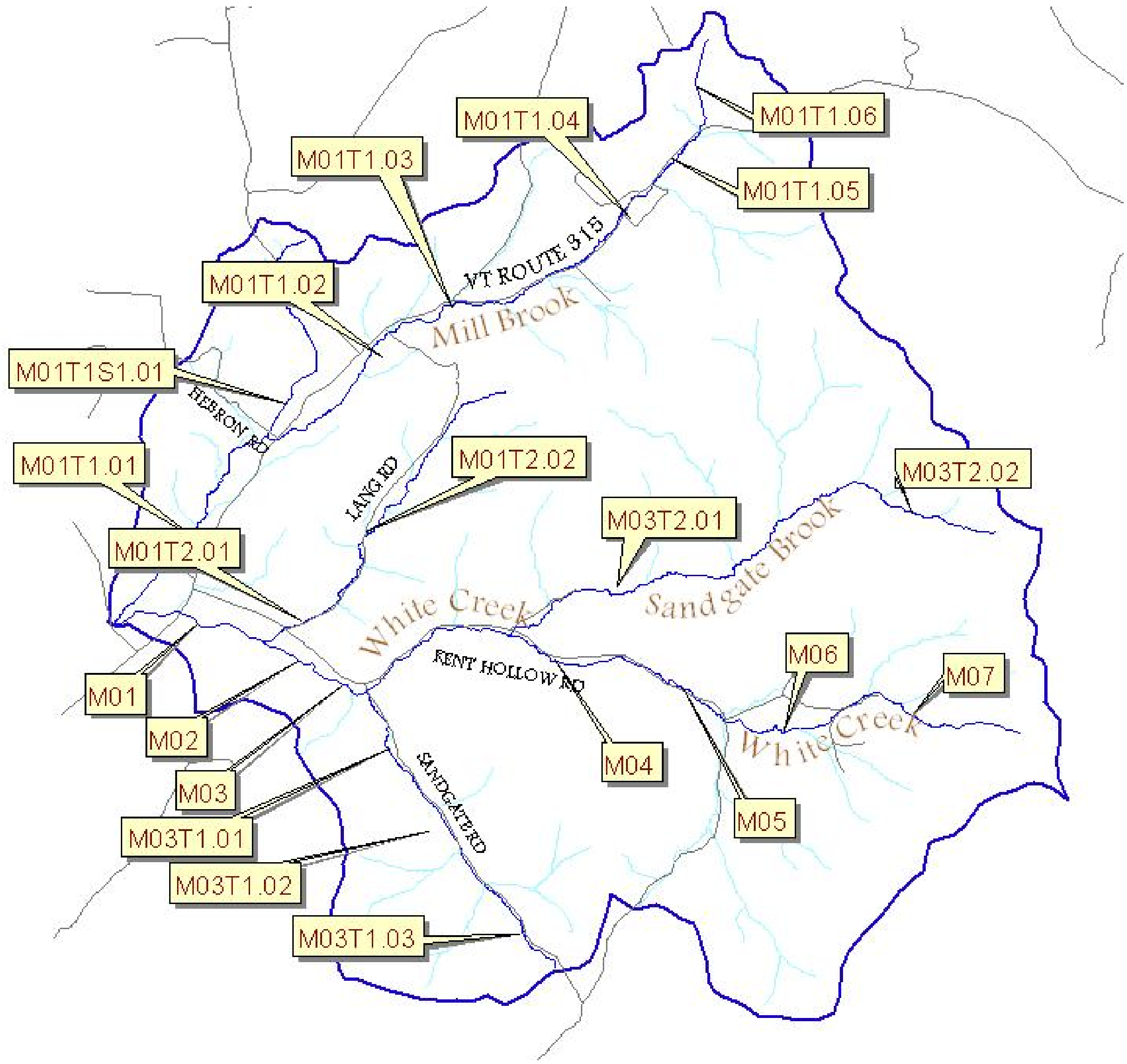
White Creek and Mill Brook and some of their tributaries are notoriously unstable watercourses. In the recent past, major floods in 1996, 1999, and 2000 in the watershed washed out public roads, farm fields, and driveways; damaged bridges; flooded numerous homes; and caused several channel avulsions.

Following the 1999 flood, USDA Emergency Watershed Protection funds totaling more than $34,000 were expended in Rupert. For the 2000 flood, after which then president Clinton declared Rupert a federal disaster area, the town of Rupert documented almost $213,000 in damage to public, commercial, and private lands and structures. (Some of those costs were incurred in the Indian River drainage.) Downstream in the village of Salem, NY, agricultural runoff carried by a flooding White Creek contaminated the community's private wells. The Village has since installed a public water supply system in response to that contamination event and others like it in earlier years.

A study by members of Trout Unlimited following the 2000 flood found collapsing banks, an overwidened and deeply entrenched channel, and erosion and aggradation in Mill Brook; occasional entrenchment in White Creek; and instability in Sandgate Brook. Trout Unlimited researchers found that instability in the watershed had likely been caused by prior and existing land uses and channel alterations. Long reaches on many streams down-valley are cleared nearly to the edge of bank, and various reaches have routinely been scalped following depositional flood events. In fact, in December 2001 the Town of Rupert was fined for an August 2001 unpermitted channelization of more than one-half mile of White Creek by Town road crews.

Map 1 illustrates the study area.

Map 1. White Creek/Mill Brook Watershed Study Area



IV. METHODOLOGY

The Phase 1 assessment of the White Creek/Mill Brook watershed used the November 2003 version of the SGAT Arcview extension, which helps automate much of the data collection and creation, the NHD Reach Indexing Tool, and the April 2005 version of the Vermont Stream Geomorphic Assessment Phase 1 Handbook. Orthophotography was flown in 2001. Study findings were uploaded to the agency's web-based Data Management System (DMS) and are available for public review at https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm.

V. ASSESSMENT RESULTS

A. Pre-intervention: the reference condition

Phase 1 stream geomorphic assessments begin by describing a watercourse's reference condition, that is, the kind of stream it most likely would have been absent human intervention. The following table illustrates the stream typing scheme used by the VT ANR (ANR 2005 SGA Phase 1, p. 28).

Table 1. Stream Typing Chart

Reference stream type	Confinement (Valley type)	Valley Slope	Bed form
A	Narrowly confined	Very Steep > 6.5%	Cascade
A	Confined	Very Steep 4.0-6.5%	Step-pool
B	Confined or semi-confined	Steep 2.0-4.0%	Step-pool
B	Confined, semi-confined, or narrow	Mod. – Steep 2.0-3.0%	Plane Bed
C or E	Unconfined	Mod. –Gentle <2.0%	Riffle-pool or Dune-ripple
D	Unconfined	Mod.-Gentle <4.0%	Braided Channel

The twenty-one reaches were found to have the following stream types.

Table 2. Study Area Reach Types

Reach number	Watercourse name	Stream type
MO1	White Creek	C Riffle-pool
M01T1.01	Mill Brook	C Riffle-pool
M01T1.02	Mill Brook	C Riffle-pool
M01T1.03	Mill Brook	C Riffle-pool
M01T1.04	Mill Brook	B Step-pool
M01T1.05	Mill Brook	A Step-pool
M01T1.06	Mill Brook	A Step-pool
M01T1S1.01	Mill Brook trib	C Riffle-pool
M01T2.01	White Creek trib	B Step-pool
M01T2.02	White Creek trib	A Step-pool
M02	White Creek	C Riffle-pool
M03	White Creek	C Riffle-pool
M03T1.01	Sandgate Brook	C Riffle-pool
M03T1.02	Sandgate Brook	A Step-pool
M03T1.03	Sandgate Brook	A Cascade
M03T2.01	White Creek trib	A Step-pool
M03T2.02	White Creek trib	A Cascade
M04	White Creek	C Riffle-pool
M05	White Creek	B Step-pool
M06	White Creek	C Riffle-pool
M07	White Creek	A Cascade

B. Post-intervention: human-induced impacts – in the watershed or stream corridor, and in the stream

The concept of dynamic equilibrium acknowledges the primacy of change in watercourses over time. Streams free of human intervention erode their banks, cut off bends, move laterally in response to new obstructions, grow deeper in one location and shallower in others, and otherwise move up and down and from side to side within their valley walls.

Although such change sometimes can be dramatic and nearly instantaneous, human intervention usually leads to comparatively greater instability (that is, more change) and generally more violent change within a watercourse. Degraded natural resources and drained public coffers can result. Vermont ANR's Phase 1 assessments collect information on anthropogenic alterations in the watershed and in or along the stream itself which might cause atypical instability in stream profile, dimension, or pattern. Such human-induced changes uncovered in the White Creek/Mill Brook watershed assessment include:

Land uses (Step 4 of the Phase 1 SGA)

- Intensive agriculture or urban development in the watershed or stream corridor
- Reduction in the width of the naturally occurring riparian buffer

Instream modifications (Step 5 of the Phase 1 SGA)

- Bridges and culverts
- Bank armoring
- Channel straightening
- Channel dredging or gravel mining

Floodplain modifications (Step 6 of the Phase 1 SGA)

- Berms and roads
- Intensive agriculture or urban development in the stream corridor

B1: Riparian land uses: forests, agricultural lands, urban areas

Land use and land cover in the stream corridor and in the riparian zone are indicators of watercourse stability and resiliency for a number of reasons. Forested corridors and buffer zones are more likely than urbanized or agricultural lands to capture precipitation. Storm-induced flows in forested streams are smaller in volume and slower in velocity – and therefore less powerful – than non-forested watercourses. Water that doesn't quickly infiltrate the soil moves more slowly over the ground in forested landscapes compared to non-forested ground because of the friction provided by downed logs and limbs, leaf litter and other large and small organic particles. And stream banks on which trees and shrubs are growing are secured by plant roots; they are less likely to erode than unvegetated banks.

Using land use/land cover data derived from LANDSAT imagery created in the early 1990s, the White Creek/Mill Brook watershed Phase 1 study looked at land uses within each reach's stream corridor – that area inside the valley walls needed by a particular watercourse of a certain type to secure dynamic equilibrium. (In the land use/land cover GIS layer, lands of at least two acres in size as pictured in the satellite images are classified as wetland, forest, shrub, field, crop, residential, commercial, industrial or several other more specific classes.) Watercourses in forested corridors are at minimum risk of land use-induced instability. Residential, commercial, and other urban uses pose the greatest risk to stream stability – a risk so significant that the Phase 1 study considers urban land uses of 10% or more of the corridor to have a high impact. The following table summarizes land use impacts within corridors on the study reaches according to this 10% threshold.

Table 3. Urbanization in reach corridors

Total number reaches	21
Number of reaches with predominantly urban land uses	6
Number of reaches with at least 10% or "high" impact: urban land uses	17

The Phase 1 study also looked more closely at the riparian zone itself. Using orthophotography from April 2001, the study determined the width of the vegetated buffer along each reach. Table 4 summarizes vegetated buffer widths by percent of each watercourse.

Table 4. Buffer Widths

Reach #/Stream Name	**Predominant buffer width, left and right bank**	
	Left bank	**Right bank**
M01/White Creek	>100	0-25
M02/White Creek	>100	51-100
M03/White Creek	0-25	0-25
M04/White Creek	>100	0-25
M05/White Creek	>100	0-25
M06/White Creek	>100	>100
M07/White Creek	>100	>100
M01T1.01/Mill Brook	0-25	>100
M01T1.02/Mill Brook	0-25	26-50
M01T1.03/Mill Brook	0-25	0-25
M01T1.04/Mill Brook	0-25	>100
M01T1.05/Mill Brook	>100	51-100
M01T1.06/Mill Brook	>100	>100
M01T1.S1.01/Mill Brook trib	0-25	0-25
M01T2.01/downstream White Creek trib	0-25	0-25
M01T2.02/downstream White Creek trib	0-25	>100
M03T2.01/upstream White Creek trib	>100	>100
M03T2.02/upstream White Creek trib	>100	>100
M03T1.01/Sandgate Brook	>100	0-25
M03T1.02/Sandgate Brook	>100	26-50
M03T1.03/Sandgate Brook	>100	51-100

B2: Channel Modifications
Phase 1 assessments of instream channel modifications look at five elements: flow regulation; the number and length of bridges and culverts; bank armoring, channel straightening; and dredging history.

a) *Flow regulation*
Except for a small impoundment on Sandgate Brook, no flow regulations were discerned on the orthophotographs nor during the windshield survey. In all cases, reaches were rated "not significant" for impacts due to flow regulation.

b) *Bridges and culverts*
At least sixteen of the twenty-one reaches studied are bridged or culverted, some in two to three locations. In every case, though, the assessor rated those impacts “low.”

c) *Bank armoring*
Neither review of the orthophotographs nor the windshield survey provided irrefutable evidence of bank armoring. For all reaches, therefore, impacts caused by armoring were rated “unknown.”

d) *Channel straightening*
Relatively poor resolution on the orthophotographs used in the assessment or inaccessibility by road made evaluation of straightening in several small tributaries and headwaters reaches problematic. Seven reaches posed this problem and were not assessed for this feature. It is clear, however, that in the other reaches, straightening has been the rule rather than the exception. Two reaches have been straightened over more than ninety percent of their length; an additional four reaches have been straightened over more than fifty percent of their length. Altogether, twelve of the evaluated reaches were ranked as “high impact” due to straightening.

Table 5: Straightening

Reach #/Stream Name	Percent of reach straightened	Straightening Impact
M01/White Creek	76	High
M02/White Creek	55	High
M03/White Creek	32	High
M04/White Creek	22	High
M05/White Creek	9	Low
M06/White Creek	Not evalutated	Not evaluated
M07/White Creek	Not evaluated	Not evaluated
M01T1.01/Mill Brook	39	High
M01T1.02/Mill Brook	61	High
M01T1.03/Mill Brook	47	High
M01T1.04/Mill Brook	43	High
M01T1.05/Mill Brook	Not evaluated	Not evaluated
M01T1.06/Mill Brook	Not evaluated	Not evaluated
M01T1.S1.01/Mill Brook trib	66	High
M01T2.01/downstream White Creek trib	96	High
M01T2.02/downstream White Creek trib	Not evaluated	Not evaluated
M03T2.01/upstream White Creek trib	16	Low
M03T2.02/upstream White Creek trib	Not evaluated	Not evaluated
M03T1.01/Sandgate Brook	39	High
M03T1.02/Sandgate Brook	93	High

M03T1.03/Sandgate Brook	Not evaluated	Not evaluated

Table 5 continued

e) *Dredging history*
Present-day evidence of dredging or reports of past dredging seem to be confined to three reaches – two on White Creek and one on Mill Brook, both in the flat valley bottom. (As recently as 2001, the Town of Rupert's road crew dredged White Creek, for which the Town was fined.) Table 6 summarizes dredging histories for impacted reaches. Table 7 summarizes instream channel modifications generally in the study area.

Table 6. Dredging History

Reach #/Reach Name	Dredging History	Impact
M01/White Creek	Yes	High
M02/White Creek	Yes	High
M01T1.01/Mill Brook	Yes	High

Table 7. Instream channel modifications

Bridges-Culverts: Impacts (# of reaches) NS=not significant			Bank Armoring: Impacts (# of reaches) NE = not evaluated			Channel Straightening: Impacts (# of reaches)			Dredging History: Impacts (# of reaches)		
High	Low	NS	High	Low	NE	High	Low	NS/NE	High	Low	NS/NE
0	16	5			21	12	2	7	3	0	18
Flow regulation impacts were all not significant.											

B3: Floodplain Modifications
A floodplain is essentially the land the stream made, primarily through accretion of alluvial deposits during times of bankfull flows or flood, or through lateral movement back and forth as the watercourse struggled to balance inputs from upstream. Valley walls limit the maximum width of a floodplain naturally; in the human-impacted setting, berms and roads along watercourses further restrict the area a watercourse might work while in bankfull stage or in flood.

Although Rupert is primarily a farming community with a fairly recent influx of second homes in its headwaters forests (corridor development impacts all rated "low" or "not significant"), most of its floodplains are impacted by roads and an abandoned rail line, now a rail-trail. Table 8, Berm and Road Restrictions, summarizes this feature.

Table 8. Berm and Road Restrictions

Berm & Road Impacts (# of reaches)		
High	Low	Unknown
14	3	4

Most of the other floodplain modification features analyzed in the Phase 1 assessment are results of modifications to the channel or the floodplain. They include depositional features, meander migration histories, meander width ratios, and wavelength ratios.

Except for on Reach M02 on White Creek, very few noteworthy depositional features were discovered.

Meander width ratios and wavelength ratios of certain ranges on C and E streams can suggest a history of floodplain encroachment, channel alterations, and other changes in the reach setting, both human-induced and natural. Several C-type reaches in the study area were rated as "high impact" in this context, but most were so rated due to straightening: where a reach is more than fifty-percent straightened, the Phase 1 protocols direct that these belt widths not be measured but are instead automatically assigned an impact of "high.".

Two reaches not so straightened but nonetheless rated "high impact" have problematic geometry and may have been assigned improperly long belt widths by the assessor (also the author of this report).

C: Impact Summary

The Phase 1 assessment of the White Creek/Mill Brook watershed first collected information on human-induced changes in the study area – on corridor land cover, riparian buffer widths, flow regulation, bridges and culverts, bank armoring, channel straightening, dredging history, berms and roads, corridor development, depositional features, meander migration, meander width ratio for C and E streams, wavelength ratio for C and E streams, bank erosion, and debris or ice jam potential. When entered into the River Management Program's web-based Data Management System (DMS), those changes were each assigned a score of "2" or "high," "1" or "low," or "0" "not significant." Those scores were then combined for a total impact score of from 0 (representing the least impact) to 32 (the most impact).

Because the DMS assigns parameters not assessed a score of 0, lack of information on a certain kind of impact can skew an impact score lower than might be warranted. In this study, flow regulation wasn't assessed on many reaches; meander migration wasn't assessed at all; bed material information was lacking for most of the reaches; and bank erosion/bank height were not evaluated. (It is hard to accurately gather this information via a windshield survey.) Had it been possible to assess those parameters, total impact scores might have been higher.

The DMS also makes use of parameter impact values to suggest which of four adjustment processes – degradation, aggradation, widening, and planform change – are most at work in any reach. A cut-off score of 4 was established to distinguish (very broadly) between streams in equilibrium and those in adjustment. In general, the two highest scores indicate the adjustment processes most active in the reach.

Finally, these scores are used to generate a reach condition score for each reach in two different contexts – within the project area (the reaches are compared to one another), and statewide (in which the study reaches are compared to adjustment statewide). In each context, "reference" (a score of 0.85-1.0) means the reach has suffered no significant channel or floodplain modifications and is well-buffered; “good” (a score of 0.65-0.84) means a stream is undergoing only minor adjustments or has adjusted to previous modifications and is nearly in balance again; “fair” (a score of 0.35-0.64) means a reach is already experiencing major or rapid changes or that those changes are imminent; and “poor” (a score of 0.00- 0.34) refers to a reach that is severely out of regime.

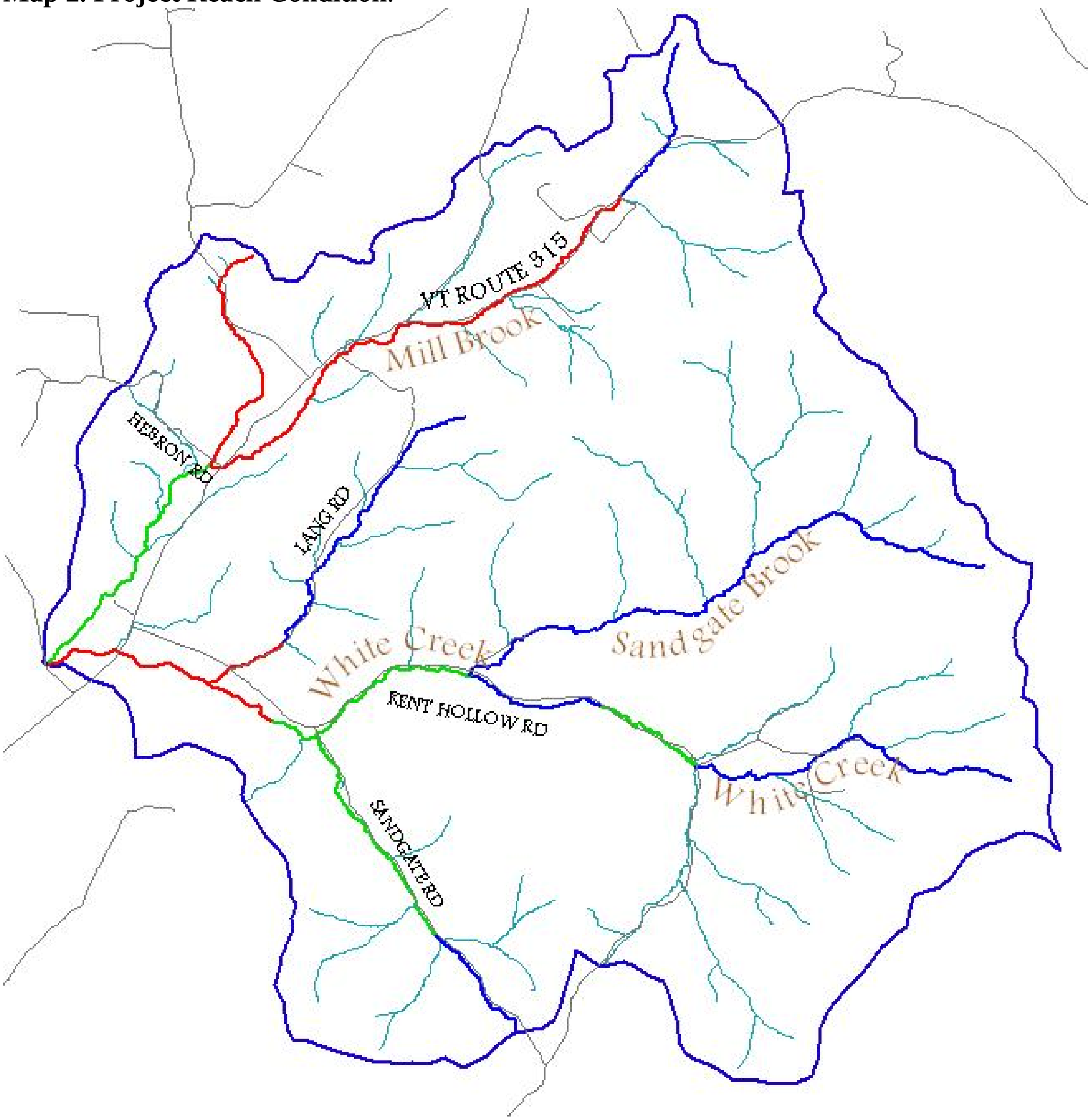
Page B-13 in Appendix B of the Phase 1 Handbook explains the process by which adjustment processes are assessed. (Because the processes are interrelated – one process entrains another – the adjustment process scores aren’t simply additive but are also weighted so as to capture that interplay phenomenon.) Page 75 in the April 2005 Phase 1 Handbook explains how reaches are assigned a reach condition.

Table 9 displays these DMS-generated findings for reaches with total impact scores equal to or greater than “9.” (It’s near this point in the descending-order impact list that project reach conditions become “good” or “reference.” No reaches rated in “poor” project reach condition are omitted from the table.) “D” signifies degradation; “A,” aggradation; “W,” widening; and “P,” planform change.

Table 9. Impact Summary, Adjustment Processes, Reach Conditions

Reach #/Stream Name	Highest adjustment processes	Total Impact Score	Project Reach Condition	Statewide Reach Condition
M01/White Creek	A 10; D&P 9	17	Poor	Fair
M02/White Creek	D 8; P 8	15	Poor	Fair
M03/White Creek	D 7; A&P 6	15	Fair	Good
M04/White Creek	D 4; A 4	11	Good	Reference
M05/White Creek	D 6; A 6	10	Fair	Good
M06/White Creek	D 3; A 3	10	Good	Reference
M01T1.01/Mill Brook	D 9; P 8	15	Fair	Good
M01T1.02/Mill Brook	A 9; D&W 7	17	Poor	Fair
M01T1.03/Mill Brook	P 9; D&A 7	17	Poor	Good
M01T1.04/Mill Brook	D 9; A 8	14	Poor	Fair
M01T1.S1.01/Mill Brook trib	D9; A&P 7	14	Poor	Good
M01T2.01/downstream White Creek trib	D 9; A 8	13	Poor	Fair
M03T1.01/Sandgate Brook	D 6; A 6	11	Fair	Good
M03T1.02/Sandgate Brook	D 7; P 5	9	Fair	Good

Map 2. Project Reach Condition.



Legend
Reach Condition Poor
Reach Condition Fair
Reach Condition Good or Reference

VI. CONCLUSIONS

This assessment of the White Creek/Mill Brook watershed in southwestern Vermont describes a system highly altered by human activities and one, in many locations, still adjusting to the impacts of those activities. Future field studies focusing particularly on “high” total impact, “poor” project reach condition reaches can help area residents and municipal officials craft short-term and long-term management plans.