WATERSHED IMPROVEMENT PLAN AND RECOMMENDATIONS FOR A TOTAL MAXIMUM DAILY LOAD (TMDL) FOR SEDIMENT

ALLEN BROOK
WILLISTON, VERMONT

Waterbody ID: 08-02

FINAL REPORT – March 30, 2003

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1.0 EXECUTIVE SUMMARY

A watershed restoration plan and recommendations for a sediment Total Maximum Daily Load (TMDL) was developed for the 37.5 square kilometer (km^2) Allen Brook watershed in the Town of Williston, Vermont. Allen Brook fails to meet the Vermont Water Quality Standards (WQS) and is in need of restoration. Allen Brook is impaired primarily due to nonpoint sources of pollution.

Field work based on the Vermont Agency of Natural Resources (ANR) Phase II protocols (2001) for river assessment was completed for 31 cross-sections, and three permanent monumented sites. The 18 km long mainstem was walked for its entire length.

The Channel Evolution Model (CEM) of Schumm. showed 19 cross-sections that were in adjustment, i.e., either the elevation of the stream bed was lowering (degradation), and/or the banks were eroding (widening/aggradation). This model can be used to identify areas that are not meeting reference conditions and can be identified as impaired and contributing excess sediment to the system.

Additional analysis included modeling of sediment loads in the watershed, which concluded that a sediment reduction of 50% of Total Suspended Solids (TSS) is required for impaired sites. Detailed recommendations on retrofit opportunities and priority rankings are made for over 100 of the stormwater management systems in the watershed. A study by ANR (1995) showed that of the 35 stormwater systems reviewed in Williston, 29% failed to be built or maintained properly. This outcome was higher than the state study average.

The Town of Williston is experiencing rapid growth. Five sub-watersheds in the lower basin (which comprise 26% of the watershed) have impervious cover ranging between 8 – 25%. The Williston Zoning Ordinance (Section 3.16) allows for a maximum lot coverage of 65% in the Commercial I and II Districts and 70% in the Industrial District. The predicted build-out of the lower Allen Brook watershed has not been reached.

Rapid growth is *also* occurring outside the Sewer Service Area. According to the 2000 Annual Growth and Development Report for the Town of Williston, the target for new dwelling units of 20% in this district has been exceeded almost every year for the past 10 years. The Town of Williston is experiencing rapid growth. While the state population grew 8% from 1990 to 2000, Williston's population grew almost 57%. This rate of growth makes Williston the fastest growing community in Chittenden County, and even one of the fastest growing communities in Vermont (U.S. Census Bureau).

This level of growth and the resulting increase in impervious surface will change the hydrology of the watershed and contribute to further impairment of Allen Brook if management of stormwater runoff is not properly controlled. The report provides recommendations on areas that may be addressed through the development of ordinances and incentives to prevent further degradation of Allen Brook. The report also provides information on "Quantifiable Controls," to reduce sediment load into the watershed. The results show that non-structural approaches, including (1) better site design, (2) erosion and sediment control, (3) maintenance and management of stormwater systems and (4) buffers are the most cost effective methods to reduce sediment loads.

Recommendations in the report include:

- **Stormwater Management and Retrofit Opportunities:** including the use of stormwater practices suitable for cold climates, in combination to achieve the maximum benefit, using infiltration only where soils are suitable, and the use of distributed runoff control for watersheds with over 8% impervious area (Center for Watershed Protection, 2000).
- **Prediction of stream adjustment based on land use:** Proposed developments should use the relaxation curve developed for Vermont streams (Center for Watershed Protection, 1999) in conjunction with landuse analysis of impervious surfaces to predict the amount of enlargement in the stream channels that will occur if attention is not paid to hydrologic changes that accompany development. This is a tool that should be used within every subwatershed, especially for any proposed development that creates large amounts of impervious surface.
- **Adopting Management and Maintenance Suggestions:** The Town of Williston should adopt the Vermont Stormwater Management Manual (2002), the New York Guidelines for Urban Erosion and Sediment Control (1997) and enforceable maintenance agreements (Watershed Management Institute, 1997).
- **Changes to local ordinances**: including zoning, planning, public works and applying the Town's riparian buffer ordinance to ephemeral and intermittent tributaries of Allen Brook. Vermont's draft riparian buffer procedure applies to all streams, including ephemeral and intermittent streams.
- **Pollution prevention:** These opportunities include regular street sweeping to remove sand, catch basin cleaning, and disconnection of roof gutters and down-spouts, among other practices.
- **Developing a stormwater utility:** This utility does not have to be a separate entity. It could be part of an existing organization and will be responsible for management and maintenance of stormwater systems. Homeowners will pay a fixed rate and commercial enterprises could have a sliding scale based on number of acres of impervious area and the number of Best Management Practices (BMP's) that are installed and maintained.
- **Best Management Practices During Construction:** Best management practices required by the Town need to be strengthened. This may involve a developer hiring trained erosion and sediment control personnel to be on-site throughout construction. Erosion and sediment control during construction is critical for reducing sediment and nutrient loads to Allen Brook. Present practices are not adequate. Erosion controls need to be incorporated and emphasized.
- **Better Site Design:** Better site design practices include designing developments to reduce road width, decrease impervious surfaces, and conserve land. Many of these practices yield economic and aesthetic benefits to both the developer and the homeowner.
- **Road Management**: Better attention to management of road runoff, especially during the construction phase of roads, will need to be implemented. Bridges should be designed with consideration to fluvial geomorphology, i.e., they should not constrict the

channel, should be a minimum of bankfull width for entrenched channels, and allow for floodprone width flows for streams that access the floodplain. Bridges/culverts located at meander bends should be even wider, and the angle of approach should be as straight as possible. Bridges/culverts should be designed using the relaxation curve (CWP, 1999) to predict channel enlargement so that bridges will not be undersized as the watershed develops. The use of culverts and double culverts should be discouraged, and other options (e.g., 1/2 bridges) explored. Street sweeping and cleaning catchbasins need to be conducted on a regular schedule and especially as soon as possible after snow-melt.

- **Best Management Practices (BMPs)**: These include the implementation of BMPs for activities such as, though not limited to, golf course management, agriculture, forestry, and construction.
- **Prevention**: It is recommended that all new projects apply all of the credits provided in the Vermont Stormwater Management Manual.

The appendices contain detailed information including: recommendations for changes to local zoning, planning and public works ordinances; the results of a literature search on quantifiable controls; an assessment of which practices are the most cost-effective; priority ranking and specific suggestions on potential retrofits for over 100 stormwater management systems; background data on the watershed; and complete results of the field work.

Public meetings, watershed tours, newspaper articles and outreach, streambank restoration with local clubs, meetings with developers, homeowners associations and employees of the Town of Williston, the Vermont Agency of Natural Resources, and the Vermont Agency of Transportation occurred throughout the course of the study.

The challenge for the Town of Williston will be to involve existing homeowners, developers, homeowners associations, public and private organizations in protecting the stream as the watershed continues to develop. Regular monitoring and implementation of a complex mix of the recommendations provided in this report will be required for the watershed to meet Vermont Water Quality Standards.

2.0 INTRODUCTION AND WATERSHED DESCRIPTION

In 2000, the Vermont Agency of Natural Resources' Department of Environmental Conservation (VTDEC) retained the services of a team of experts[1] to develop a watershed restoration plan for Allen Brook and to make recommendations for the development of a sediment Total Maximum Daily Load (TMDL). VTDEC identified Allen Brook as polluted or "impaired" – failing to meet the Vermont Water Quality Standard (WQS) – and, therefore, in need of restoration. VTDEC requested that this restoration plan take an alternative approach in restoring Allen Brook. Allen Brook is impaired primarily due to nonpoint sources. Therefore, VTDEC requested that the team develop a cost-effective means of restoring waters impaired by nonpoint sources, which could be used as a model for other waters with similar water quality problems.

Allen Brook is located in the Town of Williston in Chittenden County, Vermont (Figure 1). Allen Brook drains a land area of approximately 37.5 km^2 (14.5 mi^2) and flows northwest to join Muddy Brook just prior to its confluence with the Winooski River, which in turn flows west into Lake Champlain. The mainstem of Allen Brook is approximately 17.7 km (11 mi) long and has an average gradient of 1%. The eight tributaries shown on the USGS 7.5-minute topographic maps are mostly ephemeral, with drainage areas generally less than 2.6 km^2 (1 mi^2). Topographic relief in the watershed is low, ranging from 64 meters (m.) (210 ft) to 277 m. (908 ft) above sea level. A detailed description of the watershed is in Appendix A.

The Town of Williston is experiencing rapid growth. While the state population grew 8% from 1990 to 2000, Williston's population grew almost 57%. This rate of growth makes Williston the fastest growing community in Chittenden County, and even one of the fastest growing communities in Vermont (U.S. Census Bureau).

The 2000 Williston Town Plan is designed to direct future growth to locations with adequate town services near its commercial areas (the Sewer Service Area). This includes a major portion of the Allen Brook watershed north of I-89. But growth pressures outside this area have been significant. According to the 2000 Annual Growth and Development Report for the Town of Williston, the target for new dwelling units outside the Sewer Service Area of 20% has been exceeded almost every year for the past 10 years. This level of growth and the resulting increase in impervious surface will continue to change the hydrology of the watershed and contribute to further impairment of Allen Brook if management of stormwater runoff is not properly implemented. The rapid growth requires that extra attention be paid to erosion and sediment control, stormwater management design and maintenance, and improved site design to reduce impervious area (DNREC, 1997; Tourbier, 1994). These concerns may be addressed through the development of ordinances and incentives to prevent further degradation of Allen Brook (See Appendix F for a set of local ordinance recommendations).

[1] Lori Barg, Step-by-Step,Inc; Dr. Cully Hession, University of Vermont, Civil & Environmental Engineering (UVM-CEE); Chris Cianfrani, UVM-CEE; Kari Dolan, National Wildlife Federation; and Bob Kort, US. Department of Agriculture Natural Resources Conservation Service (USDA NRCS).

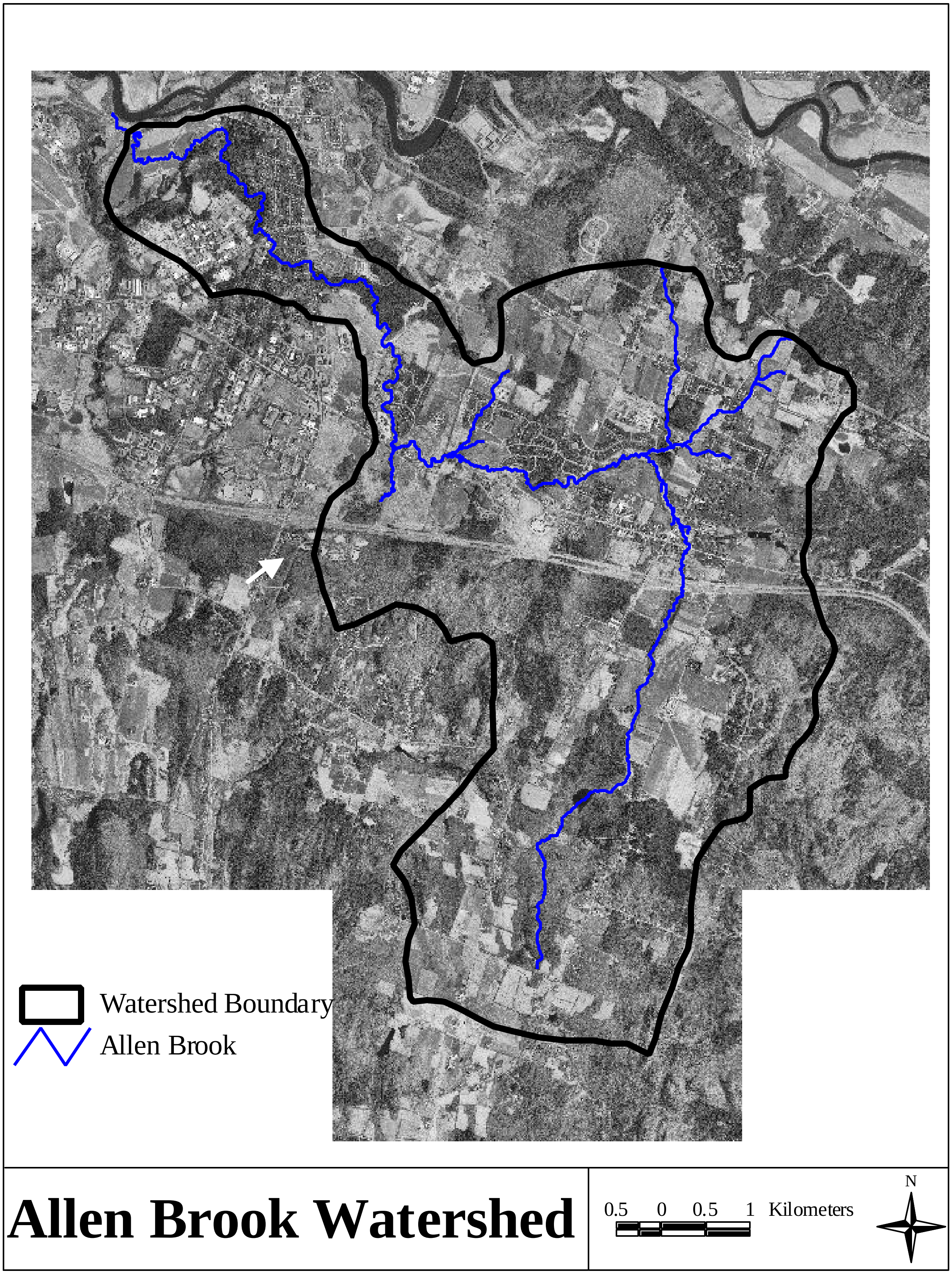

Figure 1. Allen Brook and its watershed shown on digital orthophotos.

3.0 STREAM ASSESSMENT RESULTS AND DISCUSSION

Figure 2 depicts the location of 31 rapid geomorphic assessment (RGA) sites. Stream assessment results for Allen Brook are organized by reach and site number, and include a summary of stream geometry, stream type, stage of channel evolution, Rapid Geomorphic Assessment (RGA), Rapid Bioassessment Protocols (RBP), and metrics used for analysis of the TMDL. The metrics include embeddedness and particle size distributions. An explanation of the methodologies based on the VT ANR Phase 2 River Assessment Protocols (2001) and complete results of the fieldwork are presented in Appendix G. Please refer to this section for complete results.

Allen Brook is extremely variable along its length. Wetland vegetation, narrow stream channels, low gradient and slow flow characterize parts of Reaches 1, 4, 5, 7, and 10. These areas contain many characteristics of low-gradient, warm water streams, although the Vermont WQS do not designate Allen Brook as a "warmwater" stream. Reaches 2 and 3 contain bedrock cascades and Reaches 2, 6, and 9 contain steep, step-pool systems.

While there is a riparian buffer along much of the mainstem, this does not address changes in channel morphology due to hydrologic changes in the watershed. Some factors that promote stability within the watershed include the presence of channel-spanning bedrock, boulder step-pool systems, beaver dams, and clay deposits. Some of this control, such as the bedrock, is permanent. The clay, beaver dams, and boulders can be destabilized through hydrologic changes or failure. When dams fail, large loads of sediment that have built up upstream of the dams will be released. The two boulder step-pool systems in the lower watershed both show signs of scour and degradation at the downstream end of the reach, which may be an indicator of impending instability. Flashier hydrology (higher high flows, and lower low flows), which tends to accompany increases in development, can contribute to the destabilization of these systems. Reaches 2, 3, 4, 5, 6, 7, 8, 9, and 10 all contain some kind of grade control (Table 1).

Bank erosion in the lower watershed has been partly addressed through the installation of tree revetments and bank sloping in Reach 1. Some of this has held, and some is failing. Monitoring and maintenance of these revetments should be done.

Table 1. Grade Control that Promotes Stability in the Allen Brook Watershed.

Location *	Type of Control
u/s end of Reach 2 and middle of Reach 3	Bedrock control. Lower cascades is fish migration barrier
u/s Reach 2.2 and u/s 6.2, Reach 9	Step-Pool
Reach 3, u/s 4.3, 5, 7, and 10	Beaver Dam Control
u/s Reach 8.2 under I-89 and the parallel section of South Road	Culvert control. Fish migration barrier
u/s Reach 6.1's mass failures; Reach 4.4 and 5 and the beginning of 6	Lacustrine-carved clays. Clays are plastic, cohesive, and resist erosion better than non-cohesive sediments, like sands

* u/s = upstream segment; d/s = downstream

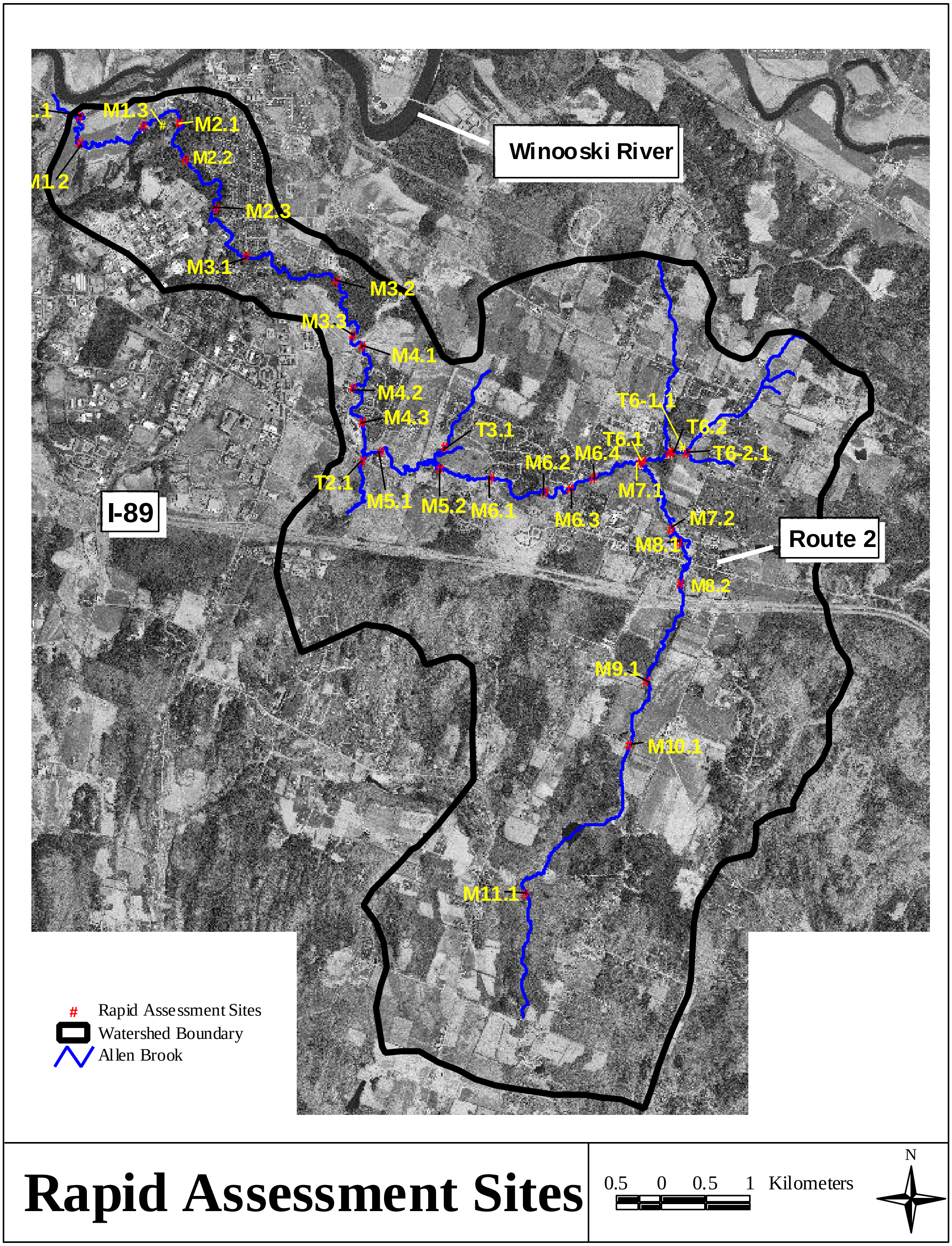

Figure 2. Location of rapid geomorphic assessment (RGA) sites. The labels indicate whether sites are on the mainstem (M) or on a tributary (T), the reach or tributary number, and the within-reach cross-section ID (after the decimal).

3.1 Results Channel Evolution Model (CEM) and Rosgen Stream Type

Table 2 summarizes the results of the channel evolution model (CEM) for Allen Brook. The channel evolution model is based on physical stream features including channel dimensions and evidence of change (active headcuts, deposited sediment etc.). The CEM is used to communicate how streams are adjusting morphologically to changes in the watershed. Changes in channel morphology can be caused by in-stream management (straightening, gravel mining, channel constriction) and changes in hydrology - such as increased runoff and decreased infiltration - due to increase in impervious area. The results show that 19 of the 35 sites are "in adjustment", i.e., they are degrading, widening, or stabilizing at a lower elevation and are not able to effectively transport water and sediment.

Simon and Kuhnle (2001) identify CEM Stages I and VI (Stage 5 in Schumm) as defining "Reference" rates for suspended sediment transport. They use the channel evolution model as a method to identify streams that are effectively transporting water and sediment (Stage 1 and 5 in Schumm). They state(2001) *"An advantage of a process-based channel-evolution scheme for use in TMDL development is that Stages I and VI [1 and 5] represent two true "reference" conditions."* CEM Stage 2 through 4 in Schumm's Channel Evolution Model are comparable to Stage 2 – 5 in Simon (1989a) and represent channels that are adjusting through the processes of degradation, widening and aggradation. The majority of cross-sections in Reaches 5 – 8 are in adjustment. The headwaters of the watershed upstream of Reach 9 were relatively stable at the time of the survey, but stormwater headcuts in the upper watershed could lead to degradation of these reaches.

The Rosgen stream type is a stream classification system that is based on entrenchment, width/depth ratio, sinuosity and slope and modified by the stream bed type (sand, gravel, cobble, boulder). Simon and Kuhnle state *"Although the Rosgen (1985) stream classification system is widely used to describe channel form, stream types D, F, and G are by the author's own definitions, unstable (Rosgen, 1996, p. 4-5). These stream reaches, therefore, would be expected to produce and transport enhanced amounts of sediment and represent impacted, if not impaired conditions. Thus, although it may be possible to define a "representative" reach of stream types D, F, and G, for the purpose of TMDL development, a "reference" condition transporting "natural" or background rates of sediment will be exceedingly difficult to find."* Table 3 lists the cross-sections with Rosgen stream types that are unstable.

While all the sites in Table 3 are listed in Table 2, the reverse is not true. This is because the CEM does not rely entirely on cross-sectional dimensions, but considers additional physical features as well.

Table 2. Channel Evolution Stage.

"Stable"Condition" Channel Evolution Stage 1, 5			"In Adjustment" Channel Evolution Stage 2, 3, 4		
Reach Number	Site Number	Channel Evolution Stage	Reach Number	Site Number	Channel Evolution Stage
1	3	1	1	1	4
2	1	1	1	2	2
2	2	5	3	1	3
2	3	1	3	3	4
3	2	1	4	3	4
4	1	1	5	1	3
4	2	1	5	2	3
5	T2.1	1	5	T3.1	2-3
7	T6-1.1	1	6	1	1-2
9	1	1	6	2	3
10	1	5	6	3	3
11	1	1	6	4	2
			7	1	2
			7	2	2-3
			7	T6.1	2
			7	T6.2	2-3
			7	T6-2.1	2
			8	1	3
			8	2	2-3

Table 3. Unstable Rosgen Stream Types.

Reach Number	Site Number	Rosgen Stream Type
4	3	F3-5
6	2	F3
6	1	G4
7	2	F5
7	T6.2	G5

3.2 Stream Geometry Measures

Cross-sectional data at monumented sites is summarized in Table 9. Complete cross-section data for each of the rapid assessment sites is contained in Appendix G. Of the 35 sites surveyed, four sites were highly entrenched (less than (<) 1.4 entrenchment ratio (ER)), 11 sites were moderately entrenched and 20 sites had flood plain access (ER greater than (>) 2.2). Of these 20 sites, most showed degradation sometime in the past (incision ratio greater than 1), while two sites showed no degradation. Of the 15 sites that were moderately to highly entrenched, three had slopes of approximately 3%, and three flowed through wetlands. Wetlands have great root-binding capacity, and the banks were generally well vegetated with grasses and showed little erosion.

Three of the entrenched sites did not show active signs of degradation due to bedrock grade control immediately downstream (a waterfall at Reach 3) Boulders provide grade control near Reach 6.2. Reach 4 and 8 showed the highest probability for continued adjustment due to the lack of grade control.

Three reaches (Reach 3.2, 6.2 and 6.3) have high bankfull width/depth ratios between 29 and 39. Two of these are forested reaches, and the third is abandoned agricultural land. High width/depth ratios are an indicator that the stream may not effectively carry the water and sediment generated within the watershed. Reduced capacity to carry water and sediment has caused increased bank erosion and failure. There is a lack of reference sites for determining the departure from normal for this stream type in Vermont. The bankfull width changes depending on buffer type (Table 4). The data gathered provides a baseline that can be used to measure future changes in stream morphology.

Table 4. Allen Brook Stream Geometry and Buffer Type

Reach No.	Site Number	Riparian Buffer Type/ forest or grass/ wetland	Bankfull Width (ft)	BF Thalweg Depth (ft)	Mean Depth (ft)	Width/ Depth Ratio	Low Bank Height (ft)	Incision Ratio (Low Bank Height/ Dmax)	Entrenchment Ratio	Cross-Sectional Area (sq. ft)	Estimated Width of Flood Prone Area (ft)	Water Surface Slope %
M1	2.1	grass	22.4	2.7	1.8	12.4	6.5	2.4	2.7	40.6	60	0.3
M1	2.2	grass	27.6	2.4	1.5	15.1	3.1	1.3	2.2	40.9	50	0.3
M1	2.3	grass	21.7	2.4	1.6	13.6	6.7	2.8	2.3	35.7	50	0.3
2	1	forest	33.5	2.5	1.7	19.7	3.7	1.5	1.5	56.5	50	1.1
2	2	forest	34.2	3.1	1.7	20.1	3.4	1.1	2.9	58.1	100	2.0
2	3	forest	42.5	3.6	1.8	23.6	3.6	1.0	2.4	76.7	100	0.7
M3	0.1	forest	24.6	1.8	1.1	22.4	4.1	2.3	1.6	28.0	40	1.4
M3	0.2	forest	24.8	1.2	0.9	27.6	3.3	2.8	1.3	22.5	31	1.4
M3	0.3	forest	28.7	1.5	1.0	28.7	2.8	1.9	1.1	28.6	33	1.4
4	1	forest	28.7	2.4	1.8	15.9	4.2	1.8	1.7	52.1	50	0.2
4	2	forest	21.5	1.6	1.3	16.5	1.8	1.1	1.9	27.3	40	1.4
4	3	forest	24.0	2.4	1.8	13.3	2.8	1.2	1.3	52.1	30	0.2
5	1	grass	12.0	1.2	0.8	15.0	2.0	1.7	1.7	9.7	20	1.5
5	2	grass	12.7	1.2	0.9	14.1	2.1	1.8	1.8	11.6	23	2.2
6	1	grass	16.7	1.6	1.0	16.7	3.7	2.3	1.6	17.5	26	0.2
6	2	forest	40.8	1.8	1	39.0	3.4	1.9	1.2	42.6	48	1.0
6	3	grass	23.7	1.7	0.8	29.6	2.7	1.6	1.9	19.1	45	1.4
6	4	grass	20.3	2.4	1.7	11.9	4.7	2.0	2.4	34.8	49	1.0
7	1	grass	8.2	1.8	1.4	5.9	3.3	1.8	1.8	11.5	15	0.3
7	2	grass	10.8	1.3	0.9	12.0	2.3	1.8	1.3	9.9	14	1.2
8	1	forest	18.7	1.8	1.0	18.7	2.5	1.4	2.7	18.4	50	1.0
8	2	grass	9.7	1.0	0.6	16.2	2.6	2.6	4.1	5.8	40	0.4
9	0.1	forest	14.3	1.3	0.9	15.9	1.50	1.1	2.0	13	29	3.0
9	0.2	forest	16.6	1.6	0.9	19.0	2.00	1.2	2.6	14.4	43	3.0
9	0.3	forest	12.4	1	0.5	24.8	1.90	1.9	1.2	6.1	15	3.0
10	1	grass	14.8	2.5	1.2	12.3	4.40	1.76	2.6	17.5	38	0.1
11	1	forest	8.5	0.7	.4	21.3	0.80	1.14	1.8	3.6	15	2.9

3.3 Rapid Stream Assessment

The EPA Rapid Bioassessment Protocols (RBP's) have been adopted by the State of Vermont and are used to:

- Determine if a stream is supporting or not supporting aquatic life.
- Characterize the existence and severity of impairment.
- Help to identify sources and causes of impairment.
- Evaluate the effectiveness of control actions and restoration activities.
- Support use attainability studies and cumulative impact assessments.

The parameters listed in the RBP's address the physical system, the bed, the banks, the vegetation, the structure of the river, and how that physical system affects the aquatic life of the stream. The results can be used to help assess habitat, stream stability and can be used as a management guide for basin planning. The parameters are scored along a scale of 0 (poor) to 20 (excellent). Higher scores not only indicate a more stable physical system, they also indicate better habitat.

The total score is added up and compared to a reference condition score. The reference condition is best if it is specific to the stream (usually in the upper watershed), regional references can be used as well.

The results of the assessment can be used either as a total score, or can be divided into categories such as floodplain/channel alterations, sediment deposition, and bank erosion/slope failure. These categories can be examined individually to evaluate the impacts on the stream.

The Vermont Rapid Geomorphic Assessment (RGA's) were developed to supplement the EPA Rapid Bioassessment Protocols (RBP). These RGA's assess channel adjustment processes and management potential. They are scored the same way as the RBP's. The RGA assesses four different adjustment processes: widening, degradation, aggradation and change in planform. One or all of these adjustment processes may be occurring within a reach. Streams adjust in response to either natural causes (floods) or human activity that changes the hydrology of the watershed. The RGA reflects some of the same adjustment processes as the Channel Evolution Model (Schumm).

The Rapid Bio-assessment Protocol (RBP) habitat scores are based on a maximum possible score of 200 points and the Rapid Geomorphic Assessment (RGA) scores have a maximum of 80 points. Results are normalized to 1. Higher scores indicate better habitat and increasing stability. Not all parameters were measured for all tributaries or reaches and the rating was adjusted accordingly. The RBP habitat assessment and RGA results are summarized in Table 5. The primary form of adjustment in the lower watershed is aggradation, essentially the accumulation of fine sediments within the channel (Table 6) The lower watershed rates much lower in terms of geomorphic stability and habitat (Table 7) than the upper watershed, indicating that it is actively adjusting to changes in hydrology and land use.

It is important to note that RGA and RBP ratings often do not correlate, particularly in unstable river systems, for a number of reasons (Figure 3) Unstable sites can contribute large amounts of large woody debris to the stream system as the channel widens and downcuts the banks collapse and large trees can fall into the river. Large woody debris provides important aquatic habitat. Moreover, bedrock control in a reach may contribute to geomorphic stability. However, in a system with excessive amounts of sediment coming from upstream, high embeddedness lowers the habitat scores regardless of the amount of bedrock control. The matrix (Table 8) summarizes the data for each reach according to Channel Evolution Model (CEM), RBP and RGA.

Table 5. Results of RBP Habitat Assessment and RGA by Site.

Reach Number	Site Number	RGA Total Score	RGA Rating	Rank	RBP Total Score	RBP Rating	Rank
1	1	46	0.58	F	109	0.55	F
1	2	42	0.53	F	129	0.65	G
1	3	60	0.75	G	174	0.87	R
2	1	64	0.80	G	175	0.88	R
2	2	50	0.63	F	135	0.68	G
2	3	43	0.54	F	134	0.67	G
3	0	63	0.79	G	149	0.75	G
3	1	62	0.78	G	154	0.77	G
3	2	57	0.71	G	158	0.79	G
3	3	53	0.66	G	138	0.69	G
4	1	60	0.75	G	102	0.51	F
4	2	68	0.85	G	158	0.79	G
4	3	54	0.68	G	116	0.58	F
5	1	45	0.56	F	158	0.79	G
5	2	30	0.38	F	106	0.53	F
5	T2.1	66	0.83	G	135	0.68	G
5	T3.U	52	0.65	G	57	0.57	F
5	T3.R	72	0.90	R	84	0.84	G
5	T3.1	22	0.28	P	81	0.41	F
6	1	49	0.61	F	140	0.70	G
6	2	46	0.58	F	141	0.71	G
6	3	67	0.84	G	158	0.79	G
6	4	39	0.49	F	139	0.70	G
7	1	39	0.49	F	110	0.55	F
7	2	40	0.50	F	120	0.60	F
7	T6.1	43	0.54	F	127	0.64	F
7	T6.2	42	0.53	F	116	0.58	F
7	T6-1.1	65	0.81	G	125	0.63	F
7	T6-2.1	60	0.75	G	99	0.50	F
8	1	33	0.41	F	111	0.56	F
8	2	52	0.65	G	151	0.76	G
9	0	67	0.84	G	164	0.82	G
9	1	73	0.91	R	166	0.83	G
10	1	72	0.90	R	160	0.80	G
11	1	72	0.90	R	177	0.89	R

Score Range	Stream Condition	Score Range	Stream Condition
0.85 – 1.00	Reference Condition (R)	0.35 – 0.64	Fair Condition (F)
0.65 – 0.84	Good Condition (G)	0.00 – 0.34	Poor Condition (P)

Table 6. Summary of Results of RGA (Lower Scores Indicate Poorer Condition).

Reach Number	Degree Of Channel Degradation (Incision)	Degree of Channel Aggradation	Over-Widened Channel	Changes in Planform
Lower watershed downstream of I-89 Reach 1 – 8	0.68	0.56	0.62	0.55
Upper watershed upstream of I-89 Reach 9 – 11	0.93	0.90	0.88	0.90
Tributaries	0.55	0.52	0.64	0.78

Table 7. Summary of Results of RBP Habitat

(Lower Scores Indicate Poorer Condition).

Reach Number	Bank Stability (both banks)	Vegetative Protection (both banks)	Riparian Vegetative Zone Width (both banks)	Sediment Deposition
Lower watershed downstream of I-89 Reach 1 – 8	0.74	0.80	0.81	0.49
Upper watershed upstream of I-89 Reach 9 – 11	0.94	0.90	0.80	0.85
Tributaries	0.63	0.89	0.97	0.33

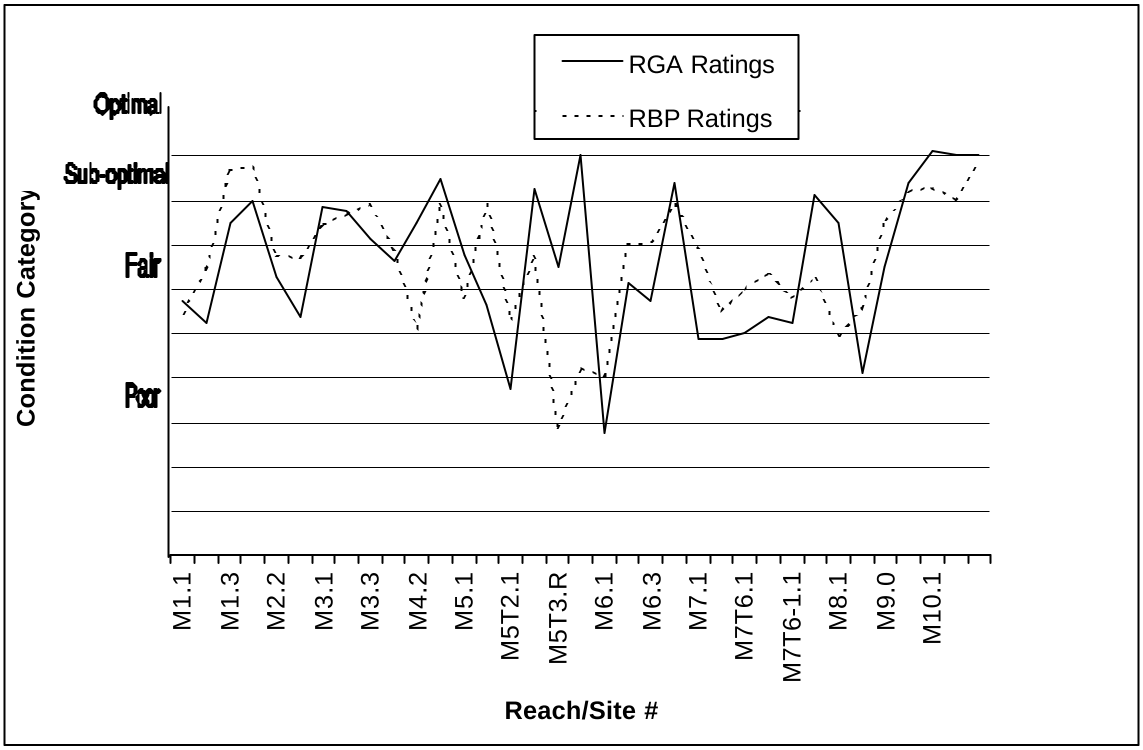

Figure 3. RGA and RBP Scores by Site.

Table 8. Summary Matrix: Streams in Adjustment.

Reach Number	Site Number	CEM in Adjust-ment	RGA: Poor or Fair	RBP: Poor or Fair	Unstable Rosgen Stream Type
1	1	x	x	x	
1	2	x	x		
2	2		x		
2	3		x		
3	1	x			
3	3	x			
4	1			x	
4	3	x		x	x
5	1	x	x		
5	2	x	x	x	
5	T3.1	x	x	x	
5	T3.U			x	
6	1	x	x		x
6	2	x	x		x
6	3	x			
6	4	x	x		
7	1	x	x	x	
7	2	x	x	x	x
7	T6.1	x	x	x	
7	T6.2	x	x	x	x
7	T6-1.1			x	
7	T6-2.1	x		x	
8	1	x	x	x	
8	2	x			

Note: Reaches, 9, 10 and 11 do not have any cross-sections that fall in the categories listed.

3.4 Detailed Stream Assessment (Includes Embeddedness)

Figure 4 shows three monumented cross-sections along Allen Brook that were chosen for detailed assessment. Two of the sites are currently used by the VTDEC Biomonitoring and Aquatic Studies Section (Reach 3 and Reach 9). Reach 9 is used by VTDEC bio-monitoring as a reference site for Champlain valley streams. The additional site (Reach 1), located downstream of Williston Village, has been used by ANR for bio-monitoring. Longitudinal profiles and the cross sections were surveyed for each reach using a laser level. Three cross sections were surveyed for each site. Detailed channel surveys were made at each site including: pebble counts to determine substrate size and embeddedness surveys to compare an impaired site with a reference site. Data for the detailed surveys are presented in Table 9, Table 10, Figure 5, and Figure 6.

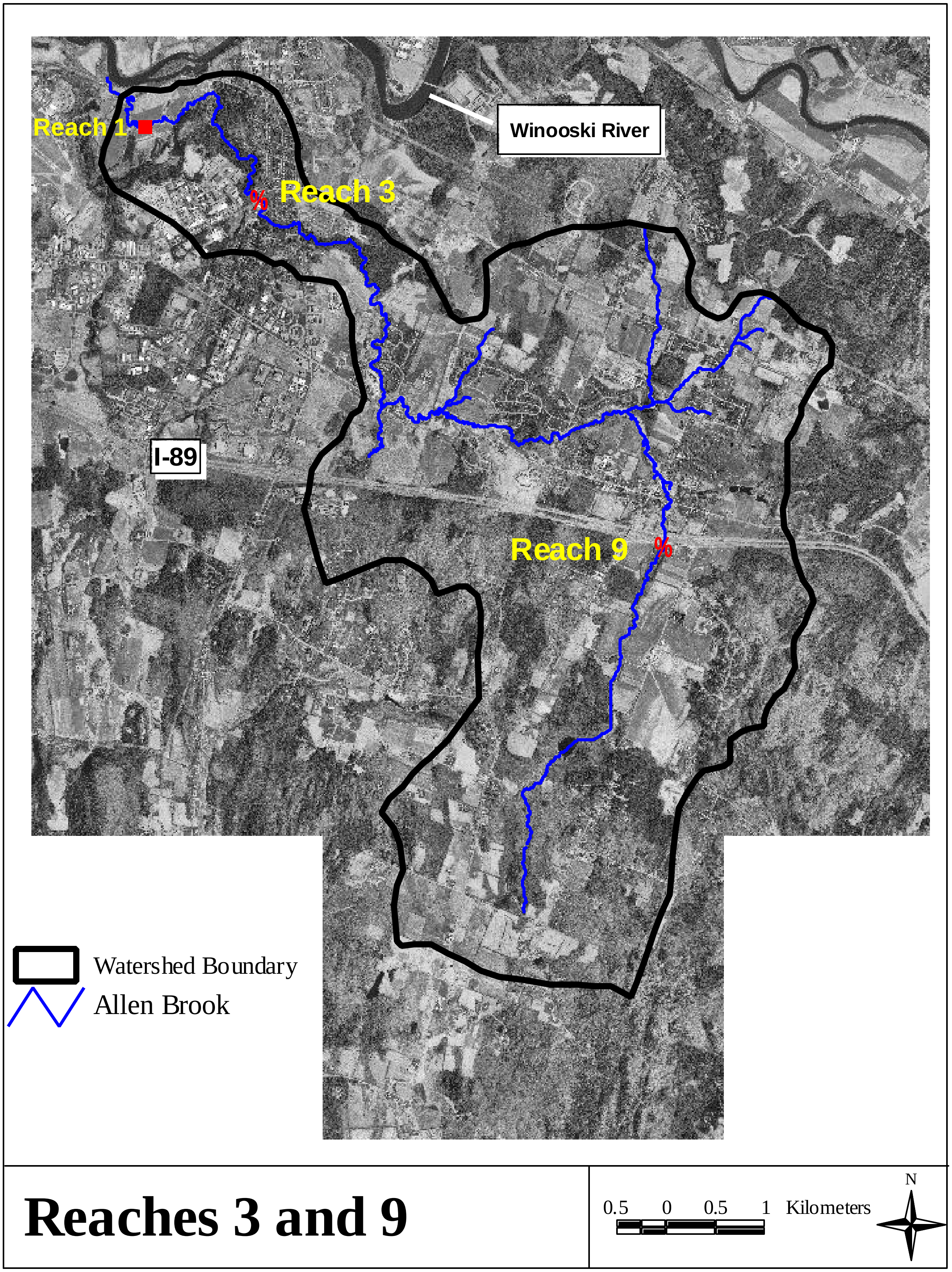

Figure 4. Location of Reach 3 (Impaired) and Reach 9 (Reference).

Table 9. Monumented Cross-Section Watershed Characteristics.

Parameter	Upper Basin Above Reach 9	Mid Basin Above Reach 3	Lower Basin Above Mouth and Reach 1
*Bankfull width (ft)	11	26	24
*Bankfull mean depth (ft)	0.7	1	1.6
* Surveyed slope (%)	3	1	0.3
Channel slope from 7.5' topographic map (%)	1.25	1.08	1.01
*Cross-sectional area (sq. ft.)	10	26	39
Predicted 2 year flow (cfs)	130	320	480
Sinuosity	1.11	1.35	1.60
Drainage area (sq. mi.)	3.9	9.8	14.5
Channel length (mi.)	3.8	8.8	11
Low elevation (ft.)	515	295	210
Valley type	Confined	Unconfined	Unconfined, abandoned terraces
Stream order	1	3	3

* = survey data

Table 10. Embeddedness Counts for Reach 3 (Impaired) and Reach 9 (Reference).

Reach	0-25%	25-50%	50-75%	75-100%	Total
3	14	11	6	0	31
9	9	17	4	0	30

3.5 Sampling for Total Suspended Solids (TSS)

Grab samples were taken at two locations (Reaches 3 and 9) in the Allen Brook Watershed (a reference site and an impaired site) for baseflow and storm events during the summer and fall of 2002 (6/12/02, 7/9/02, 8/23/02, 9/16/02, 9/28/02, and 10/17/02). Four samples for Reach 9 and six samples for Reach 3 were analyzed (Figure 5). Discharge was determined for each event either by direct measurement (at the impaired site – Reach 3) or by using the stage-discharge relationship that had been developed for the site using a staff gage. Discharge was scaled for the reference reach using the ratio of watershed areas (Reach 9).

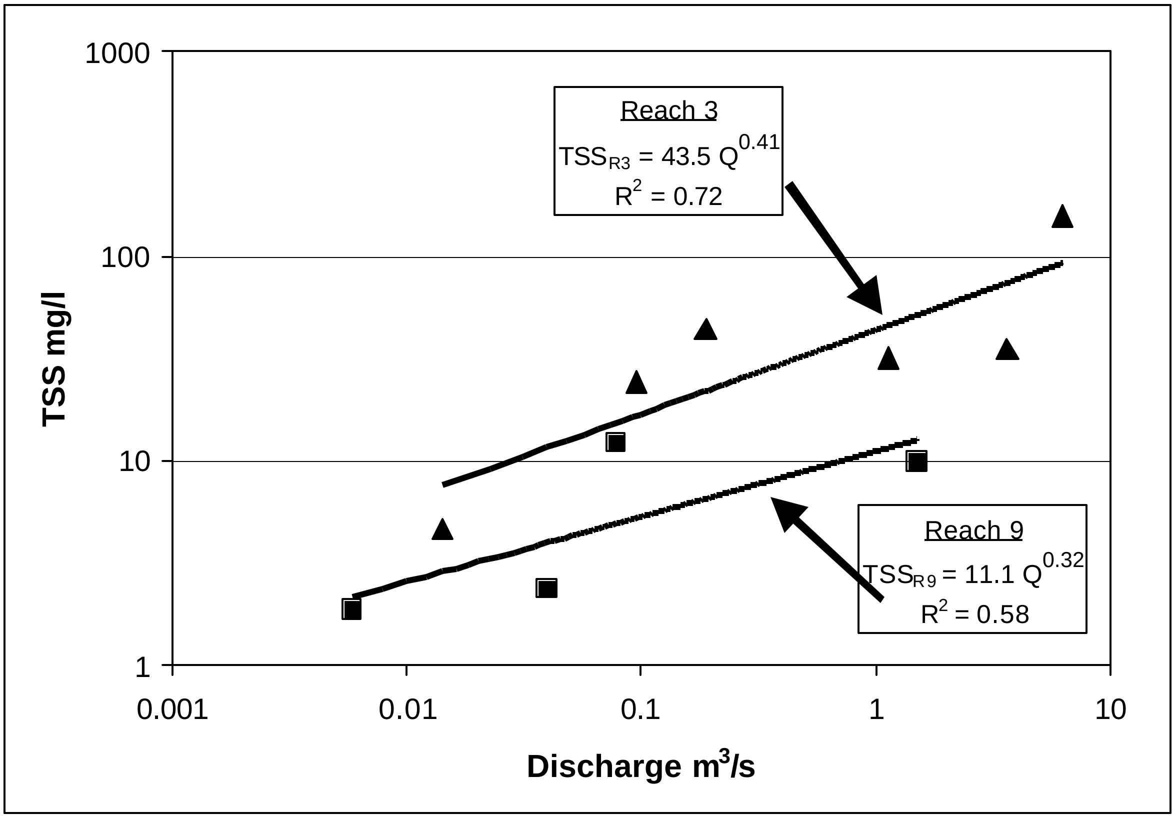

Figure 5. Total suspended solids (TSS) versus discharge (Q) for two sites in the Allen Brook watershed. Reach 9 is a reference site and Reach 3 is the impaired site.

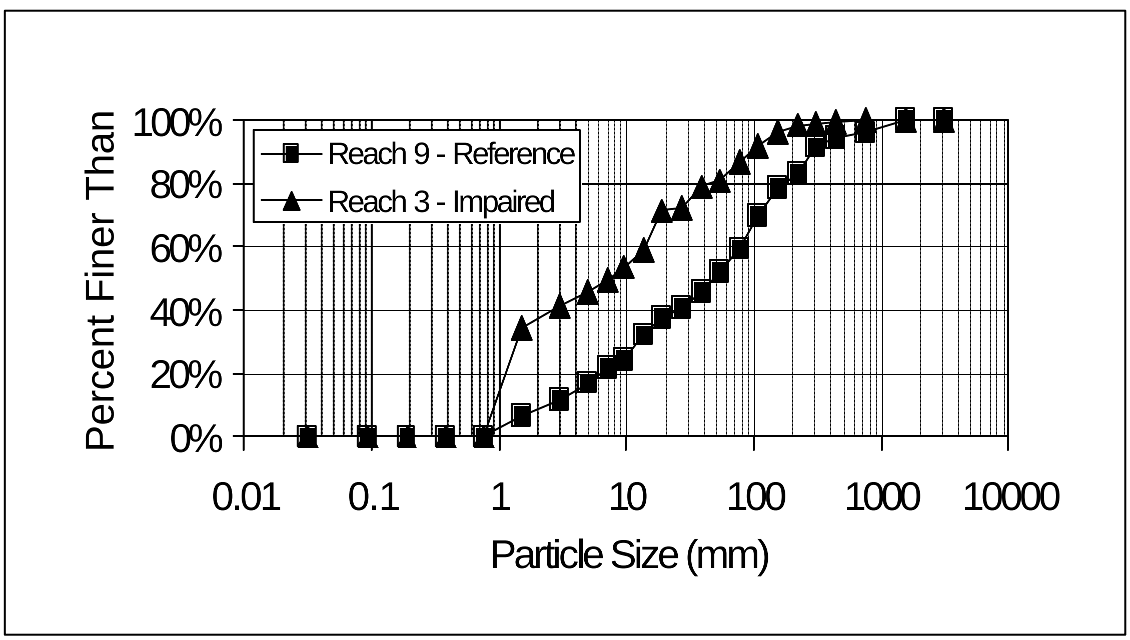

Figure 6. Pebble Count Data for Reach 3 and Reach 9.

3.6 Impervious Cover

Allen Brook watershed is experiencing rapid development. As increasing areas of the watershed become covered with roads, houses and other impervious surfaces there is an increase in runoff, and decrease in infiltration. Allen Brook is adjusting to this change in hydrology through the following adjustment processes:

- Stage 1: *over-widening,* and lose the ability to effectively transport sediment;
- Stage 2: *incision* or *degradation* – which lowers the elevation of the stream bed;
- Stage 3: *aggradation* – which raises the elevation of the streambed; and/or,
- Stage 4: changes in the *planform* (the view from the air) of the river.

A study for the Vermont Geological Survey concluded that even at low levels of imperviousness (2%) features such as loss of riffle-pool structure were occurring (Center for Watershed Protection et al., 1999b). As the percent of impervious area within a watershed increases, streams in Vermont were found to become up to two times as wide.

The impervious cover of the watershed, estimated in 1995 was found to be 5.5% (Pease, 1997a). Research has shown that watersheds that have less than 25% impervious cover can be restored (CWP 1998c). As the watershed develops to a higher percentage of imperviousness the stream will adjust geomorphically to the new hydrologic conditions. This will contribute increased sediment and nutrient loading to the watershed.

As subwatersheds achieve levels of >8% impervious cover, then more aggressive implementation of the Vermont Stormwater manual, and retrofit opportunities will be required. An updated impervious layer using orthophotography and ground-truthing has been completed. The lower watershed has a high percentage of imperviousness (Table 11, Figure 7). However, the predicted build-out of the lower watershed (maximum lot coverage of 65% in Commercial I and II Districts and 70% in Industrial District, see Town of Williston Zoning Ordinances, Section 3.16) ensures that maximum attention will need to be paid to protect the stream.

Table 11: Impervious Cover for Allen Brook Subwatersheds

SWAT Subbasins	
SUBBASIN	**AREA (m2)**
1	1015200
2	1388700
3	1274400
4	265500
5	2055600
6	1723500
7	67500
8	1090800
9	558000
10	1733400
11	1039500
12	905400
13	1291500
14	37800
15	1650600
16	2140200
17	1514700
18	1405800
19	942300
20	1305000
21	1259100
22	1029600
23	879300
24	1760400
25	2289600
Total Area	30623400

Impervious Area for Each Subbasin	
SUBBASIN	**Imperv (m2)**
1	85200
2	59500
3	92300
4	7900
5	120200
6	61100
7	2700
8	62700
9	38200
10	268800
11	49400
12	47600
13	81200
14	0
15	52600
16	64000
17	23300
18	25500
19	25300
20	322000
21	159100
22	131700
23	47500
24	69900
25	57000
Tot Imperv	1954700

SUBBASIN	% Imperv
1	**8.39%**
2	4.28%
3	7.24%
4	2.98%
5	5.85%
6	3.55%
7	4.00%
8	5.75%
9	6.85%
10	**15.51%**
11	4.75%
12	5.26%
13	6.29%
14	0.00%
15	3.19%
16	2.99%
17	1.54%
18	1.81%
19	2.68%
20	**24.67%**
21	**12.64%**
22	**12.79%**
23	5.40%
24	3.97%
25	2.49%
TOTAL	6.38%

*Bolded areas indicate subbasins with > 8% impervious

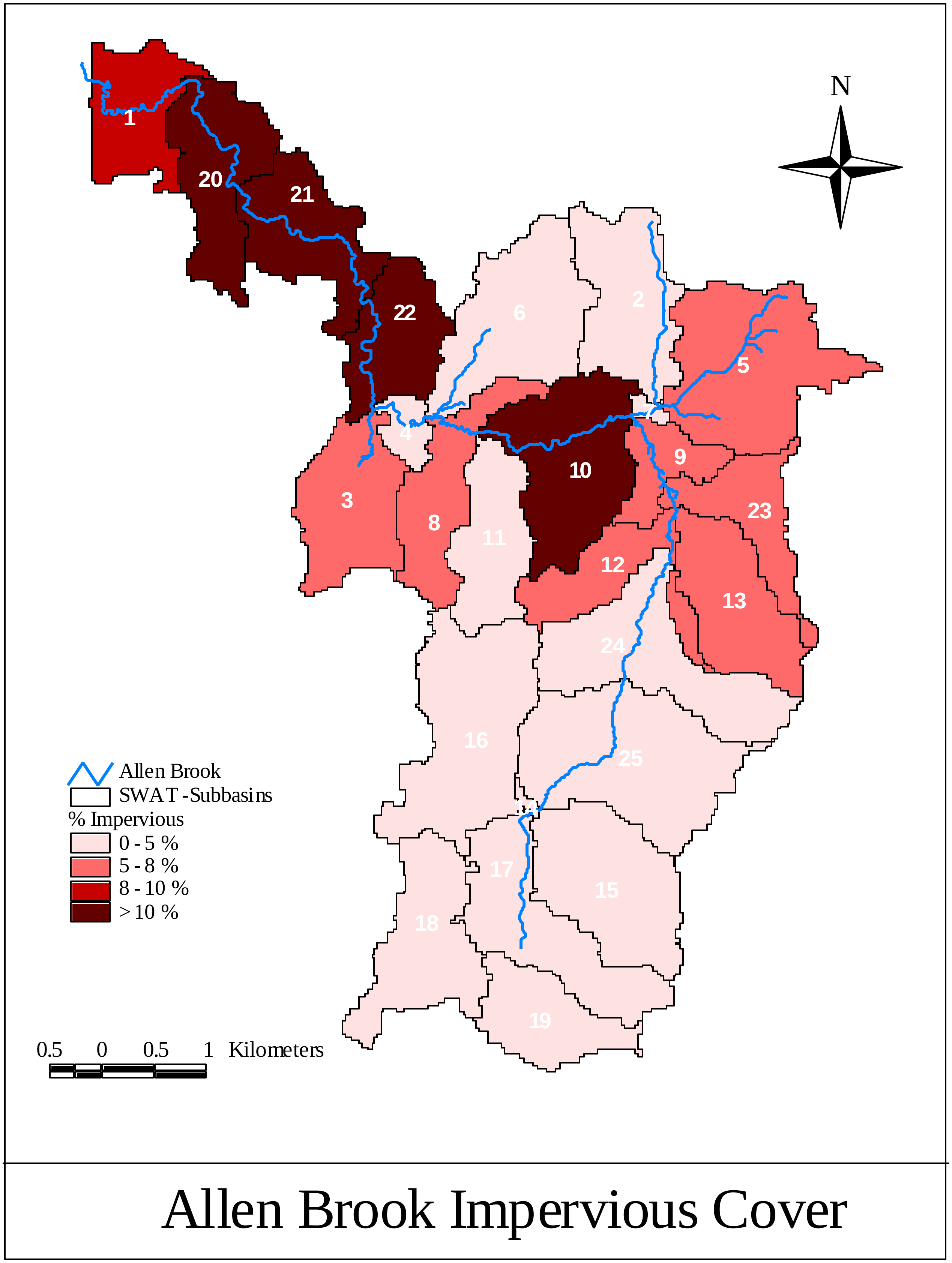

Figure 7: Allen Brook Impervious Cover

3.7 Modeling Results (SWAT)

The Soil and Water Assessment Tool (Srinivasan and Arnold 1994; SWAT - http://www.brc.tamus.edu/swat/) was used to estimate total annual average sediment loads for Allen Brook (see Appendix I for more detailed information). SWAT is considered a mid-range watershed loading model (other mid range models include AGNPS and GWLF) and provides a balance between simple empirically based models and detailed process based models. The user has the ability to use more specific data for a given watershed and to specify the time interval used. Mid-range models require more data inputs, but they also provide more detailed output and flexibility. If the data is available, completing this level of analysis is preferable to using simple methods. SWAT specifically was chosen because of its availability (free through the internet), its ease of use, and its ability to interface with ArcView (ESRI, Redlands, CA) geographic information software.

SWAT requires landuse, soils and topographical information and gives the user the ability to choose the time step for the modeling process. The 1992 Landsat Thematic Mapper landuse grid was used as the base landuse information. This data layer was first compared to 1999 orthophotos of the watershed and then ground-truthed. Soils data was obtained from the STATSGO soil database (USDA NRCS). The digital elevation model (DEM) for Allen Brook was obtained from the state GIS website (VCGI). In order to cover a broad range of conditions that occur both throughout the year (seasonal) and over multiple years, modeling was completed for a ten-year period and then averaged. The sediment loads were calculated by subbasin. The average annual sediment loading by subbasin is shown in Figure 8, and the data are found on Table 12.

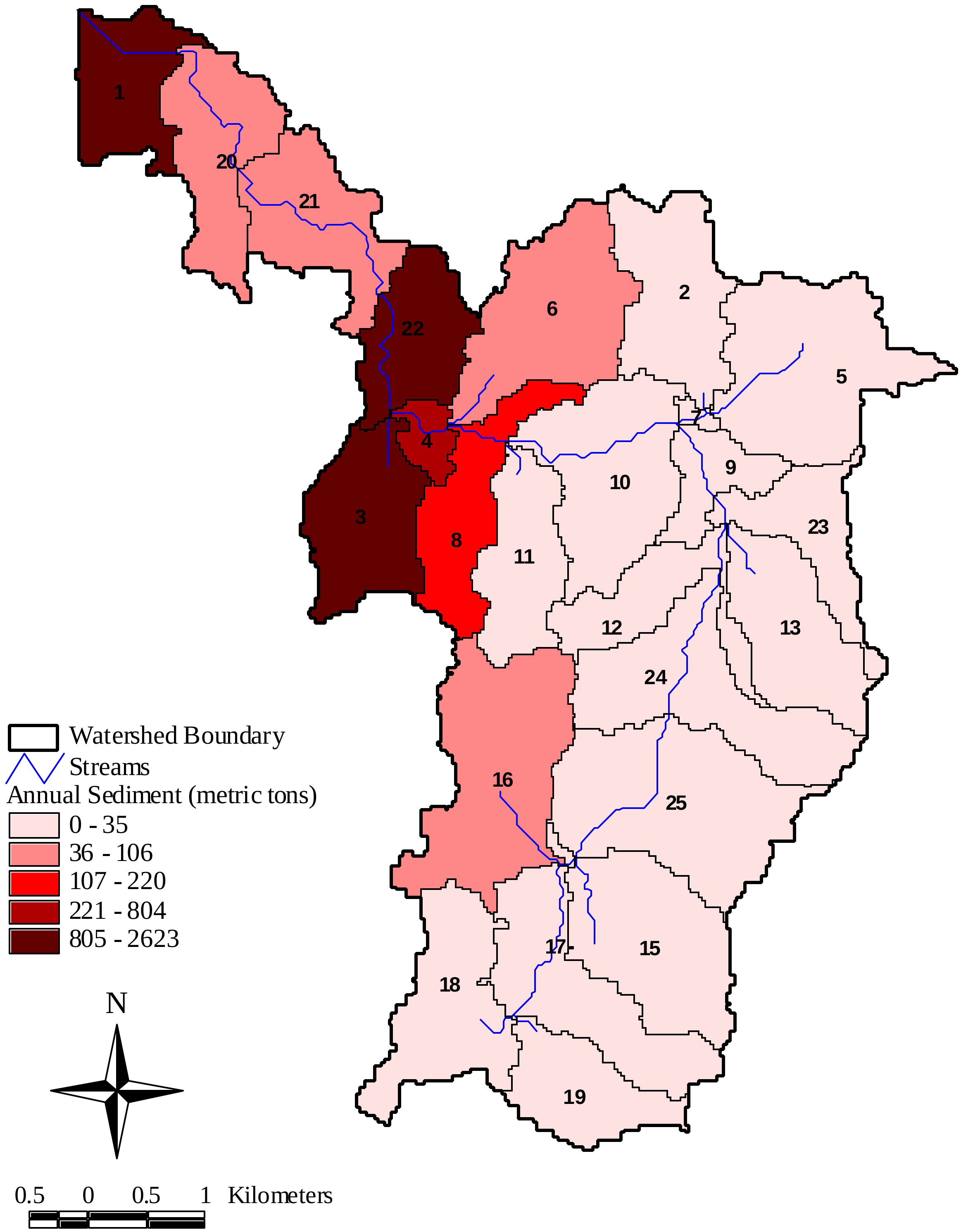

Figure 8. Average annual sediment load (metric tons/yr.) based on SWAT model outputs. Numbers on map indicate subbasins delineated for modeling purposes.

Table 12. Potential Sediment Load per Subbasin and Percent Contribution to Total Load, Based on SWAT Modeling.

Subbasin	Area (ha)	Sediment Load (metric tons)	% Total Load
1	102	2797	28.7%
2	140	32	0.3%
3	127	2623	26.9%
4	27	610	6.3%
5	206	19	0.2%
6	175	318	3.3%
7	7	3	0.0%
8	110	220	2.3%
9	56	10	0.1%
10	173	112	1.1%
11	106	57	0.6%
12	92	13	0.1%
13	131	15	0.2%
14	4	1	0.0%
15	166	16	0.2%
16	215	101	1.0%
17	154	17	0.2%
18	141	35	0.4%
19	94	23	0.2%
20	131	191	2.0%
21	127	270	2.8%
22	104	2204	22.6%
23	88	9	0.1%
24	178	22	0.2%
25	229	27	0.3%
TOTAL	3079	9744	100%

4.0 PROBLEM ASSESSMENT AND POLLUTANT SOURCES

4.1 Problem Assessment

The lower portion of Allen Brook (from 1.6 km (1 mi.) above its mouth upstream 8.8 km (5.5 mi.)) remains on the 2000 303(d) List of Impaired Waters due to pathogens and undefined-typical pollutants (which includes sediments, toxics, nutrients, and/or metals). This portion of Allen Brook has been identified on the 303(d) List of Waters since 1992. The finding of impairment of aquatic life uses in the designated section of the stream has been driven by biological conditions observed by VTDEC between 1987 and the present. Poor water quality conditions prevent Allen Brook from safely supporting two uses – aquatic life support and contact recreation.

The biological monitoring data (macroinvertebrate and fish) indicate that the principal problem pollutant is sediment and associated habitat degradation. The sources of these pollutants include land development, erosion, and urban runoff. There are also indications that nutrient enrichment may be a contributing factor to the impairment. A review of existing data is provided in Appendix B.

4.2 Sediment Loading

This water quality improvement plan is designed to address Allen Brook's sediment problem. Too much sediment in waterbodies, due to erosion, channel adjustment from hydrologic changes, and unchecked runoff, is the leading water quality problem in Vermont and nationally. Sediment increases turbidity in the water column (causing acute and chronic impairment to biota) and can degrade aquatic habitat by increasing embeddedness and altering bed particle-size distributions.

Addressing sediment loading concerns will also serve as a proxy for problems of nutrient pollution and habitat degradation. This approach is appropriate for nutrients, particularly phosphorus, because phosphorus typically binds to soil, and reaches surface water through soil erosion and stormwater runoff. In addition, it is likely easier to measure the success of management practices to control sediment, rather than to monitor phosphorus, since phosphorus can recirculate in flooding events.

Although Allen Brook is listed on the Impaired Waters List for other pollutants (e.g. pathogens, toxics), there is limited available data to characterize the extent of the problem. E. coli bacteria monitoring data, developed as part of the Vermont Indirect Discharge Permit, shows some elevated levels of pathogens at the Route 2 crossing. Bacteria loadings typically come from five general categories of sources: (1) illicit sewer connections; (2) sewer line leaks; (3) septic systems; (4) urban stormwater runoff; and (5) animal waste including wildlife, agriculture and pets. If there is a bacteria loading problem during dry weather, the assumed sources are illicit sewer connections and sewer-line breaks, since the loadings are independent of runoff from storm events. Urban stormwater runoff is typically considered a significant source of bacteria during wet weather. Some benefits may result upon controlling urban stormwater but a separate and specific investigation is required.

The only available monitoring data for toxic constituents is from a site at the mouth of the Muddy Brook (downstream of its confluence with Allen Brook), as Muddy Brook flows into the Winooski River. The existing data shows no severe problems with toxic contamination in the Allen Brook/Muddy Brook drainage system. Some toxic constituents were detected below chronic/acute levels set forth in the Vermont WQS.

4.3 Pollutant Sources/Areas of Concern

The rapid development of the watershed has caused an increase in impervious surfaces that has resulted in decreased infiltration and increased runoff. These changes in hydrologic conditions are directly contributing to the stream's impairment, both through sediment loading from stream adjustment and external sources, and resultant stream habitat alteration.

As part of this project, extensive fieldwork and modeling was conducted for the Allen Brook watershed. This included measurements of flow and total suspended solids (TSS) at selected locations; a detailed geomorphic and habitat assessment of the watershed based on the VTDEC Phase II protocols for fluvial geomorphic assessment (Appendix G); the installation of 3 monumented cross-sections, longitudinal profiles, and pebble counts (Appendix G); additional measures including large woody debris, mid-channel bars, embeddedness and percent of bank eroded (Appendix G); a review of existing data (Appendix B); a calculation of impervious surface; a survey of the watershed for pollution prevention and stormwater retrofits (Appendix J); and a watershed-level hydrologic/water quality model (Section 3.7, above).

The fieldwork resulted in specific areas of concern (listed below) and the modeling results identified subwatersheds that contribute the most sediment on an annual basis. Restoration of the watershed and implementation of a TMDL will need to address *each* of the areas listed below:

- **Tributaries**: Some tributaries are over-widened and incised due to development without stormwater control. Tributaries have not had a riparian buffer under Williston's buffer ordinance. For example, over-widened, incised tributaries, such as the one found in the South Ridge development and the stormwater ditches draining the Meadow Ridge development, have contributed to increased sediment and nutrient loads within the mainstem.
- **Encroachment into riparian buffer along mainstem**: The root structures of riparian vegetation hold the soil together, reducing stream bank erosion. The vegetation attenuates flow and sediment reducing sediment loading to the brook. When riparian vegetation is absent it can cause localized sources of sediment. For example, several houses have been built within the buffer zone in Reach 4 (Figure 2). Their location is causing instability problems in the brook and one of the adjacent streambanks is experiencing a mass failure. VTDEC has commented on engineering design for slope stabilization at this site (VTDEC, 12/7/2000). This site is contributing sediment to the Brook.
- **Lack of Stormwater Management**: Stormwater causes increased runoff and decreased infiltration, changes in peak flows, and increased duration of flows with erosion potential. Several problems included bank failures and headcuts in two developments – the Taft's Farm development and the Williston Hills development– are contributing large loads of sediment to the watershed. Conveyance of storm flows is

causing increased erosion in ephemeral tributaries in the upper watershed from Meadow Ridge and other developments.

- **Channel Enlargement:** Allen Brook adjusts to hydrologic changes in the watershed through degrading and widening causing an increase in sediment load to the brook. For example, the ephemeral and intermittent tributaries that drain the recent developments are still in active adjustment. Other examples include the deposition of soft sediment and large bars throughout the channel downstream of the crossing with I-89. Sediments generated from the bed and banks of the stream (due to hydrologic changes) will affect habitat as the channels adjust to these changes.
- **Direct Connection of Impervious Surfaces:** This alters the hydrology of the watershed, decreases infiltration and increases runoff which leads to more sediment generated from more erosive flows. Many of the new developments either directly connect impervious surfaces to the stormwater management system, or drain onto impervious surfaces.
- **Lack of Best Management Practices During Construction:** This is responsible for extremely high sediment loads as much as "*2000 times greater than on forest land*"- (Vermont Geological Survey 1987).
- **Lack of Better Site Design**: Increased impervious area causes changes in hydrology which leads to changes in channel morphology and increased stream sedimentation.
- **Nutrient Loading:** While periphyton was not measured, VTDEC has percent cover observations at the macroinvertebrate sites that indicate that attached algae are abundant. Two storm events led to high nutrient loading in the upper watershed. The Meadow Ridge development manages storm flows primarily by conveyance in ditches. On two recent occasions, high flows have overtopped a town road and flowed through the manure storage pit at the Siple Farm. These events caused significant nutrient loading to Allen Brook. As phosphorus is generally attached to sediment increased nutrient loading follows increased sediment loading.
- **Road Management**: Sediment sources include road sanding, and lack of attention to catch basin cleanout and street sweeping, concentrated flow from road ditches, undersized culverts, use of double culverts, poorly designed bridges and culverts that do not consider the fluvial geomorphology of the basin. Culverts and bridges can cause localized channel instability by causing deposition upstream and whole-scale scouring downstream. For example, one of the worst parts of the stream was downstream of Route 2 at Reach 8.1 (Figure 2). The banks are failing, the stream is degrading and aggrading, there is a foul odor, and there are many asymmetrical and haphazard point bars and mid-channel bars, which indicate an inability to effectively transport sediment. The culverts under I-89 and South Road, while providing grade control, are also barriers for fish movement.

4.4 Natural Background

In order to estimate a background sediment load and instream suspended sediments, the watershed was modeled using Soil and Water Assessment Tool (SWAT) assuming that the land use was 100% forest. . This would identify the lowest possible sediment load Allen Brook could receive. This resulted in an average annual sediment load at the outlet of 1158 metric tons/yr., an average per unit area load of 0.38 metric tons/ha/yr. throughout the watershed, and an average TSS of 26 mg/l for Reach 1 (at the outlet). Comparing this estimated natural background sediment load and TSS to current condition estimates (see Figure 5 and Section 3.5), the background load is minimal, even in comparison to the “reference” reach (Reach 9) estimates. The assumption was made that the natural loading of sediment that occurs is minimal and does not contribute significantly to the impairment.

5.0 APPLICABLE WATER QUALITY STANDARDS

5.1 State Water Quality Standards

The Water Quality Standards (WQS) for which Allen Brook has been included on the 303d List is a narrative criterion for aquatic life support. The excessive sedimentation to Allen Brook has resulted in a violation of the Vermont WQS § 3-04(B)(4)(d) (as measured through various biometrics) which states that there shall be:

No change from the reference condition that would prevent the full support of aquatic biota, wildlife, or aquatic habitat uses. Biological integrity is maintained and all expected functional groups are present in a high quality habitat. All life-cycle functions, including overwintering and reproductive requirements are maintained and protected.

Therefore, the numeric target for the TMDL would ultimately be that of the biocriteria (macroinvertebrates and fish) that guide the determination of use support. However, by definition, TMDLs are prepared on a pollutant-by-pollutant basis and require that the pollutant for which it is developed be clearly identified. TMDL guidance does allow for the use of surrogate measures that relate back to the WQSs, or in this case, aquatic life support. Other tracking options include changes in the physical nature of the substrate through embeddedness, pebble counts and TSS. Some type of loading estimate is still necessary as a target for the TMDL.

5.2 Class B Water Quality Standards

Since Allen Brook is classified as a Class B waterbody, the Vermont WQSs state in § 3-04(A) that:

Class B waters shall be managed to achieve and maintain a high level of quality, that is compatible with the following beneficial values and uses including § 3-04(A)(1):

aquatic biota and wildlife sustained by a high quality aquatic habitat with additional protection in those waters where these uses are sustainable at a higher based on Water Management Type designation.

Since macroinvertebrate and fish biomonitoring data did not meet the criteria for Class B standards, Allen Brook does not support the designated uses for Class B waters.

5.3 Antidegradation Policy

In addition to the above standards, the Vermont WQS contains, in part, the following General Antidegradation Policy in § 1-03(A):

All waters shall be managed in accordance with these rules to protect, maintain, and improve water quality.

6.0 NUMERIC WATER QUALITY TARGETS

6.1 Background

Section 303(d)(1)(C) of the Clean Water Act states that TMDLs "shall be expressed at a level necessary to implement the applicable WQSs." Without specific numeric sediment targets defining impairment in the Vermont WQS, a set of numeric biological community criteria were established to identify when conditions were not fully supporting the standards. The VTDEC uses a variety of biological indicators to identify aquatic community conditions for various stream types for both fish and macroinvertebrates. These values are the ultimate numeric targets for the Allen Brook TMDL.

The specific macroinvertebrate biometric values used to determine compliance with the Class B WQSs are provided in Table 12. Macroinvertebrates were chosen because of their frequency of use and ease in sampling. The results describing the condition of Allen Brook in 1999 and 2000 at the biomonitoring site located just above Industrial Avenue (Reach 3) are also included in Table 13. They indicate that Reach 3 failed to meet the Class B criteria for one category (biotic index) in 1999. Older data shows that fish also failed to meet Class B criteria. In all other categories it met the standard or the value was at or near the target value and passed in 2000.

As previously stated, sediment was identified as the reason for impairment of Reach 3 in 1999. Many studies have shown the link between increased sediment levels and macroinvertebrate impairment (Newcombe and MacDonald, 1991; Rosenberg and Resh, 1993; Newcombe and Jensen, 1996; Shaw and Richardson, 2001). Shaw and Richardson (2001) state that total suspended solids (TSS) concentrations of about 700 mg/l can induce responses in fish and invertebrates. In their summary paper, however, Newcombe and MacDonald (1991) cite that duration may be just as important as concentration, indicating that smaller concentrations over long periods of time may have detrimental effects. Table 14 lists the exposure effects of suspended sediment on benthic macroinvertebrates from a variety of studies.

Table 13. Aquatic Invertebrate Biometrics, Water Quality Targets and Allen Brook Results For Reach 3.

Biometric	Description	Allen Brook 1999 Assessment	Allen Brook 2000 Assessment	Class B Criterion B – WMT 2-3 (WQ Targets)
Density	Relative abundance of organisms in a sample	3990	5594	≥ 300
Species richness	Number of different taxa in a sample unit	42	51	≥ 30
EPT	Number of water quality sensitive taxa from the insect orders Ephemeroptera, Plecoptera and Trichoptera.	*16	24	≥ 16
PMA-O	Ratio of water quality sensitive EPT taxa to all taxa found in Community	66.7	64.3	≥ 45
Biotic Index	The community tolerance to organic/nutrient loading, based on the tolerances of the species found in the community	**5.69	*5.33	≤ 5.40
% Oligochaeta	A measure of the percent of the macroinvertebrate community made up of the order Oligochaeta.	0	0	≤ 12
EPT/EPT & Chironomid	Ratio of density of EPT taxa to EPT and tolerant Chironomidae	0.52	0.75	≥ 0.45
PPCS-FG	Percent of dominant genera in the community	0.45	*0.42	≥ 0.40

**Failed to meet standard.

* Indeterminate – at or near target value.

Table 14. Effects of Sediment on Macroinvertebrates (Newcombe and MacDonald, 1991).

Exposure		Effect	Source
Concentration TSS (mg/l)	Duration (hours)		
8	2.5	Lethal: increased rate of drift	Rosenberg and Wiens (1978)
1700	2	Lethal: alteration in community structure and drift patterns	Fairchild et al. (1987)
8	1440	Lethal: up to 50% reduction in standing crop	Rosenberg and Wiens (1978)
16	1440	Lethal: reduction in standing crop	Slaney et al. (1977)
32	1440	Lethal: reduction in standing crop	Slaney et al. (1977)
62	2400	Lethal: 77% reduction in population size	Wagener and LaPerriere (1985)
77	2400	Lethal: 53% reduction in population size	Tebo (1955)
390	720	Lethal: reduction in population size	Tebo (1955)
278	2400	Lethal: 80% reduction in population size	Wagener and LaPerriere (1985)
743	2400	Lethal: 85% reduction in population size	Wagener and LaPerriere (1985)
5108	2400	Lethal: 94% reduction in population size	Wagener and LaPerriere (1985)

The biological criteria are the ultimate measure for attainment of WQSs. Given the importance of sediment levels to the health of macroinvertebrates, sediment targets act as another means of tracking the effectiveness of the phased implementation measures. These targets give a relative estimation of sediment loading by evaluating resultant in-stream conditions. However, the WQS do not specify values for instream conditions. These target values must be determined by another method. EPA's "Protocol for Developing Sediment TMDLs," (1999b) outlines a number of methods for setting in-stream targets including: (1) comparison to reference sites; (2) user surveys; (3) comparison to literature values; (4) use of indicator relationships; and (5) reliance on best professional judgment. Because of the uncertainty in using any one target or any one method, a combination of these was used for Allen Brook including a reference site, comparison to literature values, and best professional judgment.

First a reference site was chosen. Ideally, a reference site is located close to the impaired site (within the same watershed if possible) and contain very similar conditions, except for the human disturbance (EPA 1999b). For Allen Brook, Reach 9 was chosen as a reference site. This site has been used as a reference site by VTDEC for Champlain valley streams. Reach 9 is located toward the top of the watershed and, like Reach 3, is used by VT DEC for biomonitoring. This location met all water quality standards (based on macroinvertebrate sampling) for 1999 and

2000. The watershed above Reach 9 has relatively low human disturbance, but includes the Siple Farm and the Meadow Ridge housing complex. This area received high rankings in both the Rapid Geomorphic Assessment and Rapid Biohabitat Assessment (all scores between 0.82 - 0.91 indicating a 'good' or 'reference' ranking).

While Reach 9 is in good condition and does not show effects of degradation, there are a number of significant differences between the two reaches that must be considered when setting numeric targets (Table 15). When looking at the longitudinal profile of Allen Brook, Reach 9 can be considered in the Headwaters Zone and Reach 3 in the Transfer Zone (Schumm 1984). Moving downstream across zones, a decrease can be expected to occur in bed material grain size, mean flow velocity, and slope. An increase can be expected in channel width, channel depth, and stream discharge. Some of these changes are evident in Allen Brook. First, Reach 3 has more than twice the contributing watershed area as compared to Reach 9. Partly as a result of being lower in the watershed (and partly as a result of disturbance), it has a larger width and cross sectional area. Second, Reach 3 is much lower in the watershed and is a lower gradient stream. Differences in substrate size composition would be expected as a result. Given these differences, Reach 3 would not be expected to look exactly like Reach 9. However, in the absence of disturbance, Reach 3 should exhibit characteristics more similar to Reach 9 than currently exist. Therefore, numeric targets can be set through comparison with Reach 9, while accounting for natural differences using best professional judgment.

Table 15. Comparison of Reach 3 and Reach 9 Characteristics.

Characteristic	Reach 3	Reach 9
Contributing Watershed	2850 ha	1200 ha
Channel Width	8.0 m.	3.4 m.
Cross Sectional Area	2.4 sq. m.	1 sq m.
Surveyed Slope	1 %	3 %

6.2 Reduction Goals

The numeric targets were determined using a three-tiered approach and are listed in the tables below. First, the target values obtained from a literature review and reference to previously completed sediment TMDLs are listed (Table 16). Second, comparisons were made between Reach 3 (impaired) and Reach 9 (reference) for in-stream TSS, substrate particle size distribution (pebble count), embeddedness and bank stability (Table 17). Finally, modeling using the Soil and Water Assessment Tool (SWAT) provided average annual sediment loading estimates and instream sediment concentrations (Table 18).

Table 16. Sediment Indices and Target Values Obtained from Literature Review.

Sediment Index	Target Value
% Fines < 2mm (sand and silt)	< 8%
% Particles < 8mm	25%
% Embeddedness	25 - 50% ('good' condition)

Table 17. Measurements and Targets for Impaired and Reference Reaches.

Sediment Index	Allen Brook Reach 9 (Reference)	Allen Brook Reach 3 (Impaired)	% Reduction to Reference Condition	% Reduction to Literature Values
% Fines < 2mm (sand and silt)	6	35	83	77
% Particles < 8mm	21.8	49.5	56	60
Median embeddedness %	25-50	25-50	0	0
TSS (mg/l)	2-12	5-44	65	NA
Bank Stability (both banks from RBP)	0.94 (watershed above Reach 9)	0.74 (watershed below Reach 9)	21	NA

Table 18. Results from Hydrologic/Water Quality Modeling (SWAT) of Allen Brook.

Sediment Index	Allen Brook Reach 9 (Reference)	Allen Brook Reach 3 (Impaired)	Target Value Background Condition	% Reduction
Sediment loading (metric tons/ha)	0.2	2.4	0.2	91
Mean annual average sediment concentration (mg/l)	21	181	21	89

Numeric targets were set for percent fines, percent particles less than 8 mm and percent embeddedness based on review of previously accepted TMDLs (e.g. the Styles Brook Sediment TMDL (VTDEC, 2001)), literature review, and by comparison with the reference reach. The targets are set to provide habitat quality suitable to meet the state requirements for benthic macroinvertebrates and fish. Percent fines and percent particles > 8 mm provide information about the suitability of the habitat given that benthic macroinvertebrates require a range of substrate sizes, including larger gravel and boulder sized particles. If the percentage of smaller size particles is great, habitat quality is decreased and a reduction in the number and a change in the type of invertebrates will occur. These particles also affect fish by reducing potential food sources. The percent reduction required to meet the literature standard for percent fines and percent less than 8 mm (77% and 60%, respectively) agrees closely with the reduction determined by comparing the impaired reach (Reach 3) in Allen Brook with the reference reach (Reach 9) (83% and 56%, respectively). These reduction values can be considered very conservative given that the literature values were used for higher gradient streams and the difference in conditions between Reach 3 and Reach 9. A more suitable reduction value would be less than the >55% - 83% range.

Embeddedness required no reduction when compared to the literature values and Reach 9. However, embeddedness is a qualitative measurement and can be difficult to measure. Therefore, we did not rely on this measure in calculating reductions.

Bank stability was measured during the stream assessment. Average bank stability ratings were generated for the area of the watershed below Reach 9 (the most impaired area) and that above Reach 9 (the reference area). Individual ratings included height and length of eroding banks within a given assessment reach. These ratings were then summed over the two divisions of the watershed. The impaired section received a 0.74 rating and the reference section a 0.94. This indicates a reduction of 21% is necessary to obtain reference conditions.

The numeric target for total suspended solids (TSS) was set based on a comparison of measured TSS values. First, both sets of TSS and discharge data were plotted and the regression equations determined (Figure 5, above). Given that the slopes of the regression lines were fairly similar, the necessary reduction was determined by calculating the percent TSS reduction in Reach 3 required to match the TSS levels (for a given discharge) for Reach 9. This calculation resulted in a 65% reduction. As recommended in the "Protocol for Establishing Sediment TMDLs" developed by the Georgia Conservancy (2002), this percent reduction was equated to a necessary percent reduction in sediment loading to the stream. As with the other measures, the TSS for Reach 3 would be expected to be larger than Reach 9. In addition, because of the small sample size taken over a short period of time this value can only provide an indication of the differences between Reach 3 and Reach 9. This data is useful in that it provides baseline data for each reach that can be used in the future.

Finally, sediment targets for loading and instream sediment concentrations were determined using modeling results. A sediment loading estimate for the reference reach and impaired reach was calculated by using the contributions from all subbasins upstream of the reach. A loading rate per hectare was then calculated. In comparing these values for the same reaches (Reach 3 and Reach 9) a 91% reduction would be needed to match the impaired reach to the reference reach loading amount. A similar reduction (89%) was calculated using the modeled results for annual average instream sediment concentration (indicating the model exhibits a one to one correlation between sediment loading and instream sediment concentration). These values indicate the highest reductions of all the methods used. While the model was able to use detailed land use and topographical information, it was necessary to make a number of assumptions when data were not available. Therefore, the modeling results are useful for relative comparisons, but cannot be expected to provide exact amounts of sediment loading. In addition, stream bank erosion is not accounted for by the model. This source of sediment was noted throughout the watershed during the stream assessment.

The various estimated target values for Allen Brook require sediment reductions that range from 21% - 91% (not including the embeddedness measures). Given the differences between the positions in the watershed of Reach 3 and Reach 9, the limitations of the sampling and the modeling efforts and best professional judgment, it was determined that a reduction of approximately 50% of the sediment load to Allen Brook would be conservative and would result in it meeting water quality standards. This reduction can be met by utilizing the quantifiable controls outlined in Section 9.7.

7.0 WATERSHED LOAD REDUCTIONS

The TMDL process requires allocation of the pollutant loadings to Wasteload Allocations (WLA) (point sources) and Load Allocations (LA) (nonpoint and natural sources) and inclusion of a Margin of Safety (MOS). The TMDL must also consider seasonal variations.

$$TMDL = WLA + LA + MOS$$

The EPA Protocol for Developing Sediment TMDLs (1999) outlines three options for determining sediment allocations: maximum allowable loads, percentage reduction targets, and performance based actions or practices. Percentage reduction targets were chosen as the most appropriate for the Allen Brook watershed. As indicated by the EPA protocol (1999), this method is suitable in dynamic watershed settings when variable nonpoint sources are the main sediment contributors.

7.1 Recommended TMDL Sediment Load Reduction

Based on the field and modeling analysis, a 50% reduction in sediment loading across the watershed is recommended. Annual average potential load contributions have been determined on a subbasin basis through modeling the entire basin (as indicated in the results section in Table 5). This information is helpful in determining where control actions may be the most useful in reducing sediment loads in the watershed.

7.2 Margin of Safety

The statute and regulations require that a TMDL include a Margin of Safety (MOS) to account for any lack of knowledge concerning the relationship between reliability of nonpoint source remediation measures and water quality. This MOS can be either implicit in the analysis by using conservative assumptions or explicit as a separate loading allocation. In the case of Allen Brook, an implicit MOS was used.

There is an inherent MOS established for the Allen Brook TMDL with the selection of a conservative values for the metrics (embeddedness, %fines, %bed < 8mm, and TSS). The values were determined based on using Reach 9 as a “reference” for Reach 3. Reach 3 is a much lower gradient stream and thus would be expected to have higher values for the metrics. With such a conservative target as the goal of the implementation measures, compliance with the Vermont WQSs should be assured.

7.3 Seasonal Variation

A sediment TMDL should account for seasonal load variations. This is to ensure that WQSs will be met throughout the year under a variety of weather and flow conditions. Seasonal variation was incorporated into the modeling effort by using annual average values for both sediment loading and instream sediment concentration levels. Loads were determined on this basis and thus include all conditions. In addition, the recommendations in this report focus on eliminating sources of sediment and thus are not seasonally dependent.

7.4 Future Growth

Sediment loading from future growth is incorporated in the recommended total watershed sediment loading reduction. In addition, the implementation measures in this report address future growth within the watershed. Strategies are identified to ensure new growth and development takes place with consideration of the potential sediment loading to Allen Brook.

8.0 MONITORING PLAN

Monitoring, which in part consists of assessing the water body and comparing it against the state's WQSs, is essential to determine whether the specific techniques or approaches employed to improve water quality are having the intended effect. Natural events such as droughts and floods may influence the results of the monitoring and should be taken into consideration.

The only on-going monitoring that is currently occurring in the watershed is done by the Vermont Agency of Natural Resources. ANR monitors aquatic biota on a 5-year cycle. There may be funds from the EPA available through the Vermont Agency of Natural Resources for post-TMDL monitoring (personal communication, Eric Perkins, 2002). Volunteer monitoring, conducted by citizens trained in quality assurance and quality control, is another option for gathering information. Table 19 contains a proposed schedule of monitoring Allen Brook to determine progress in reducing pollutants. As historical data is limited in the watershed, the results from this project can be used to compare the results of future monitoring. Recommendations on monitoring including reporting, monitoring for phosphorus and erosion and sediment control and quality control are in Appendix H.

Table 19. Recommended Monitoring and Maintenance Plan Components.

Growth	New Development	Annual Maintenance Inspection	Every 5 years, or after >10 year Return Interval storm	5-7 years
Predicted growth indicates the need for increased monitoring and enforcement. The TMDL must ensure that new development does not cause additional degradation or increase in pollutant loads.	Pre-construction, during construction, post-construction. This includes erosion and sediment control monitoring and physical and biological monitoring.	Review enforceable maintenance agreements of stormwater management systems. Use Watershed Management Institute or VTDEC Stormwater Manual Vol. 2 protocol. Require compliance.	Physical and biological assessment	Review and re-write monitoring plan

8.1 Physical, Hydrological, and Biological Monitoring

Since some of the water quality impacts are related to physical effects, periodic monitoring of the physical, hydrological and biological effects is needed. VT ANR protocols including the RGA, RHA, CEM and cross-sectional survey are methods to be used for continued monitoring. Other monitoring requirements, may include, but are not limited to: best management practices, performance objectives, narrative conditions, monitoring triggers, and action levels (e.g., monitoring benchmarks, toxicity reduction evaluation action levels). (Table 20 lists monitoring objectives and methodology.)

Table 20. Monitoring Objectives and Methodology.

	Project Objectives	Indicator	Monitoring Method	Indicators of Success
1	Enhance capacity to effectively move water and sediment. Reduce or eliminate hydrologic changes and help stream recover from long term changes in watershed hydrology. Do not increase stream power.	Design cross-section stability Native bank vegetation	Cross-sections & longitudinal profile Vegetation sampling Stream channel and bank assessment	1. Stability of channel cross-section, banks and upper slope. 2. No measurable average increase in bed slope or lowering of the channel bed. 3. No measurable average increase in bed slope or lowering of the channel bed. 4. No significant loss in vegetation on the lower banks due to erosion, over time. 5. No change in particle size or embeddedness. 6. CEM Stage 1 or 5
2	Reduce erosion as source of nonpoint source pollution	Native bank vegetation Design cross-section stability	Cross-sections & longitudinal profile Stream channel assessment	1. No adverse changes in channel geometry 2. No measurable average increase in bed slope or lowering of the channel bed 3. RHA/RGA grade Good/Reference
3	Restore stream bank lost from erosion	Design cross-section stability Native bank vegetation	Cross-sections & longitudinal profile Stream channel assessment	1. Stability of channel cross-section, banks and upper slope 2. RHA/RGA grade Good/Reference
4	Increase habitat values with the reintroduction of native plant communities	Native bank vegetation	Vegetation sampling Sampling	1. RHA/RGA grade Good/Reference 2. Meet ANR criteria for fish and benthic macro-invertebrates
5	Protect private property abutting brook	Design cross-section stability	Cross-sections	1. Stable cross-section over time 2. Minimize changes in hydrology for existing and new construction through better site design etc.
6	Minimize impacts to flood storage capacity	Design cross-section stability	Cross-sections Stream channel and bank assessment	1. Maintain and protect Class 1, 2 and 3 wetlands. 2. RHA/RGA grade Good/Reference
7	Establish vegetated buffer on mainstem and tributaries	Amount of vegetation	Vegetation sampling.	1. 100% vegetative cover along buffers of ephemeral, intermittent and perennial streams
8	Minimize soil losses from land disturbing activities: Pre-	Visible on-site or off-site erosion or sedimentation Instream sediment	Visual on-site and off-site assessment Instream monitoring (deposits) and	1. Implement erosion and sediment controls during all construction and maintenance activities 2. Monitor during storm events and dry

	construction, during construction, post-construction.	deposits or turbidity	sampling (TSS)	weather during pre-construction, during construction and post-construction.

Allen Brook should be monitored on a regular basis, or at a minimum of every five years, and/or after any major storm event (>10 year return interval) with the initial monitoring to occur by 2005. Protocols to be followed will be either those used for this assessment, or those developed by the Vermont Agency of Natural Resources Water Quality Division (Phase 2 and 3 Protocols) (ANR, 2001 & 2002). This 5 year interval is in accord with the VT ANR five year rotation for bio-monitoring.

It is recommended that this monitoring plan be implemented sooner in the event of any large-scale development projects within the watershed. Monitoring is recommended both during and after construction of any project that requires permitting through the Vermont Stormwater Management Manual, for erosion and sediment control, or as part of Phase II EPA guidelines. Monitoring should include, but not be limited to:

1. Rapid Geomorphic Assessment and Rapid Habitat Assessment. These two pieces of the ANR Phase II river assessment protocol should be completed during low flows. The results will be compared to previous results at the same (or additional) sites to show any change within the stream system.

2. Channel geometry, cross-section monitoring, and pebble counts shall be conducted to determine the extent of lateral channel migration and changes in cross section geometry. Permanent cross section markers have been installed consisting of iron rods (two per section) at three cross sections. Cross sectional geometry shall be measured, bed particle size shall be monitored (minimum sample size of 100 per section), and photographs shall be taken at these stations at the same time of year during low flow conditions.

3. Channel Evolution Model (CEM) (Schumm). Monumented sites, and Rapid Assessment sites will be placed into Schumm's CEM on the basis of cross-sectional monitoring Rapid Geomorphic and Rapid Habitat Assessment. Stream sections that are in CEM Stage 2 , 3 or 4 (degradation or over-widening) will indicate that remediation options need to be actively implemented.

4. Photo monitoring shall be conducted to determine the condition of the stream and bank. At a minimum, the monumented sites should be photographed on a regular basis. After a major (>25 – 50 year return interval (RI) storm event, 1/3 –1/4 of the rapid assessment sites should be visited. Photographs shall be taken at these stations at the same time of year during low flow conditions. Additional photographs shall be taken of locations requiring alterations or repairs necessary to restore the stream's ability to adequately transport sediment and water.

5. Fish and Benthic Macro-invertebrate surveys shall be conducted to determine the success of the project in restoring aquatic habitat. Biological surveys shall be conducted near the three monumented sites. Survey data shall include species type and abundance,

fish length (total length) and fish weight according to ANR Bio-monitoring Unit Protocols.

6. Hydrologic Monitoring. While Allen Brook is not gaged, there are observable indicators of changes in hydrology associated with watershed development. These include: (a) Increased flooding frequencies, i.e., rivers that used to overflow their banks once a year, may overflow several times a year; (b) Impacted dry weather flows: As a watershed develops, recharge is limited, and the stream may be drier during dry weather (and wetter during wet weather).

7. Temperature Monitoring. Monitoring of temperature in the stream on hot summer days before and after a storm event downstream of stormwater discharges.

It is recommended that a monitoring report shall be submitted to the Vermont Agency of Natural Resources, the Environmental Protection Agency and the Town of Williston. The progress report entitled, "Progress Report: Allen Brook Water Quality Improvement Plan and TMDL," October 22, 2001, includes copies of all photographs. Changes indicating the need for action are listed in Column 2 of Table 21.

Table 21. Monitoring Methods and Indicators.

<table>
<tr><th>Assessment Method</th><th>Indicates Need For Action</th><th>Possible Responses to Deterioration</th></tr>
<tr><td>Rapid Geomorphic Assessment</td><td>Change from Good or Reference categories to Poor or Fair categories.</td><td rowspan="8">Responses to deterioration of the watershed may include, but are not limited to:
1. initiate stormwater retrofits;
2. disconnect impervious surfaces;
3. address changes in hydrology;
4. increase erosion and sediment control during construction;
5. restore channel;
6. re-vegetation of riparian areas;
7. other suggestions made in the body of this report.</td></tr>
<tr><td>Rapid Habitat Assessment</td><td>Change from Good or Reference categories to Poor or Fair categories.</td></tr>
<tr><td>Cross-sectional geometry</td><td>Increase (over-widening) or decrease (degradation) in Width/Depth ratio, cross-sectional area, bankfull width.</td></tr>
<tr><td>Pebble count</td><td>-Decrease in particle size (D35, D50, D84), and/or
-bi-modal distribution of particles.</td></tr>
<tr><td>Erosion pins</td><td>Measurements to the bed and bank taken from erosion pins will be used to detect bank or channel bed movement. Excessive retreat or gains in bank will be used to identify unstable areas.</td></tr>
<tr><td>Channel Evolution Model</td><td>Change to Stage 2 , 3 or 4 of Schumm's CEM from Stage 1 or 5.</td></tr>
<tr><td>Fish and benthic macro-invertebrate</td><td>Per ANR protocol, inability to meet ANR bio-monitoring unit standards.</td></tr>
<tr><td>Tracking increase in impervious area</td><td>Impervious area increases placing subwatershed in higher risk category to respond to hydrological and morphological changes. Correlating impervious area with changes in channel geometry can be predicted on the basis of the relaxation curve provided in Phase II of the Watershed Hydrology Protection and Flood Mitigation Project (CWP et. al, 1999)</td></tr>
</table>

Water quality	Inability to meet Vermont Water Quality Standards.	
Photo monitoring	Increase in erosion, percent eroded bank, aggradation, unvegetated mid-channel bars, or other indicators of excessive sediment load.	

The three monumented cross-sections in the watershed have detailed pebble counts, biological data collection and fluvial geomorphic surveys. These should be monitored on a regular basis. The recommended, higher priority sites for on-going monitoring are:

- Subwatersheds that have over 8% impervious surface as determined at time of proposed build-out.
- Subwatershed that rate poor or fair in the Rapid Geomorphic Assessment (see Appendix G).
- Subwatersheds where construction is planned.
- Reaches where pebble counts show a decrease in the size classifications that are smaller than the D50 (the median size range of the pebble count), indicating an increase in embeddedness (Barg, 2002).

An important recommendation contained in this report is that stormwater facilities must be maintained on a regular basis. Therefore, Allen Brook's monitoring plan should include annual review of maintenance records of stormwater facilities

Requiring, monitoring, and enforcing maintenance agreements for all stormwater facilities are another important means of curtailing sedimentation and other impacts from stormwater runoff. Maintenance should be carried out for each system as recommended by the Watershed Management Institute (1997). Failure to regularly maintain stormwater facilities will almost certainly lead to their failure.

It is recommend that Williston adopt an *Enforceable Maintenance Agreement*. Model agreements are available from the Center for Watershed Protection in Maryland (http://www.stormwatercenter.net) and the Watershed Management Institute (1997) in Florida. Both of these resources can aid the town in developing Enforceable Maintenance Agreements for stormwater facilities. Monitoring is an integral part of these agreements.

9.0 IMPLEMENTATION PLAN

9.1 Preventive Measures

A TMDL water quality improvement plan can be very effective at achieving the anticipated environmental benefits in a cost-effective and equitable manner. However, it must comprehensively deal with the array of sources of problem pollutants while considering how to prevent new sources of pollutants from appearing sometime in the future. Retrofitting existing sources is an important strategy for dealing with the chronic contributors of problem pollutants and can result in significant decreases in loading. Appendix D summarizes the results of a literature search on costs of BMP's and maintenance. These results can act as a guide to help make decisions that are both economical and effective.

Preventing and minimizing future pollutant sources makes the best economic sense, since the cost of retrofitting sources can be significant. Moreover, water quality gains achieved though pollutant reductions can easily become overwhelmed by unchecked new sources of pollution.

Construction sites where disturbed land is left unprotected from wind and precipitation can be, in aggregate, a significant source, particularly for growing communities like Williston. Tackling major classes of potential sources, such as construction sites, can be handled efficiently with appropriate education and oversight. It is recommended that the Town adopt the erosion and sediment control manual from New York state (1997). The Town of Williston has an important opportunity, under its stormwater and erosion control programs, to apply the best available information at curbing stormwater pollution. Finally, the town of Williston has local ordinances that can be the best tool for confronting the variety of nonpoint sources that all contribute to Allen Brook's water quality problems. By using its local ordinances to address local problems, the town will be able to demonstrate local successes in protecting and restoring its natural resources for the residents and visitors alike to enjoy.

9.2 Retrofit Opportunities

Stormwater retrofits are one of the watershed restoration tools that are available to us. Installation of these structural measures in urban watersheds is designed to lessen accelerated channel erosion, provide better hydrologic balance, reduce pollutant loads, and promote conditions for improved aquatic habitat. They vary from small on-site facilities that are designed to fit in the limited space provided by the urban landscape to large multi-purpose ponds for larger drainage areas.

The type of retrofit and the benefits it provides depends on the site. Thus retrofitting urban areas has been called "the Art of Opportunity" (CWP, 2001). It often takes considerable more creativity to determine an appropriate design alternative for a retrofit site than for new development because of restrictions typically imposed by the retrofit site. Stormwater retrofits need to not only reduce pollutants in runoff to receiving waters (i.e. water quality) but also help establish a stable and predictable hydrologic water regime (i.e. water quantity). More in depth site evaluations are required to determine the suitability of any retrofits in the watershed. Elements to be considered in these evaluations include: construction and maintenance access; utilities; wetlands, forests, and sensitive streams; conflicting land uses; complementary restoration projects; permits and approvals; retrofit purpose; and cost (CWP, 1995; EPA, 1999c). Some of the more common retrofit locations and typical STPs are listed in Table 21.

Table 22. Locations for Stormwater Retrofits (Claytor, 1995; CWP. 1995).

Location	Type of Retrofit
Existing stormwater detention facilities (dry detention ponds).	Usually retrofitted as a wet pond or stormwater wetland capable of multiple storm frequency management. Perhaps the easiest retrofit option.
Immediately upstream of existing road culverts.	Often a wet pond, wetland, or extended detention facility capable of multiple storm frequency management. Typically a control structure and micropool.
Immediately below or adjacent to existing storm drain outfalls (end of pipe).	Usually water quality-only practices such as sand filters, vegetative filters or other small storm treatment facilities. Often off-line practices with flow splitter.
Directly within urban drainage and flood control channels.	Usually small-scale weirs or other flow attenuation devices to facilitate settling of solids within open channels.
Highway rights-of-way and cloverleafs.	Can be a variety of practices, but usually ponds or wetlands. Existing highways often have available space.
Within large open spaces, such as golf courses and parks.	Can be a variety of practices, but usually ponds or wetlands capable of multiple storm frequency management.
Within or adjacent to large parking lots.	Usually water quality-only facilities such as sand filters or other organic media filters (e.g. bioretention). “on-site measures”.

Retrofits can be installed in most situations, but an implementation strategy that meets watershed restoration objectives is necessary. An eight-step process has been proposed (Center for Watershed Protection, 2001; Claytor, 1995): (1) preliminary watershed retrofit inventory; (2) field assessment of potential retrofit sites; (3) prioritization of sites for implementation; (4) public involvement process; (5) retrofit design; (6) permitting; (7) construction inspections; and (8) maintenance plan. Portions of the first three steps were followed to evaluate specific Allen Brook watershed retrofit needs and opportunities.

A significant portion of the development in the Allen Brook watershed is covered by Vermont Department of Environmental Conservation (VTDEC) Stormwater Discharge Permits, and a VTDEC Watershed Improvement Permit is proposed for the watershed. The field inventory and evaluation process for existing permitted stormwater management sites included a review of the associated VTDEC permit files. Certain non-permitted development locations in the watershed were also inventoried so as to identify as many potential retrofit sites as possible and all the significant sources of pollutants.

Field observations showed certain situations to be a common problem throughout the watershed. These were often related to conditions typical for VTDEC Stormwater Discharge Permits at the time of issuance, and a lack of inspection and maintenance for the facilities. Issues include:

1. Detention basins contain significant sediment deposits that need to be removed in order to provide the storage volume designed for. Ironically the outlet structures that are partially clogged often provide better treatment/control of the stormwater. In extreme cases, a totally clogged outlet was "maintained" by breaching the embankment for the basin.

2. Detention basins provide no control or treatment of smaller storms due to the large size of the outlet structure orifice or weir. Modification of these basins to meet the 2002 Vermont stormwater treatment standards (water quality, channel protection, etc.) should be done.

3. While there were a few infiltration STPs most areas where infiltration of stormwater was noted (or attempted) happened due to natural topography and soil conditions at non-permitted sites. Areas with NRCS hydrologic soil group A or B soils should be considered for infiltration retrofits. Developed locations with infiltration of stormwater occurring should be evaluated for proper pretreatment of stormwater to address the potential for clogging and groundwater contamination concerns. Design and installation of infiltration STPs according to the 2002 Vermont stormwater management manual may be necessary for some sites.

4. "Overland flow across vegetated terrain" and "treatment in a grass-lined swale" were common permit conditions. Considerable problems with these vegetative treatment practices were evident in the field. Concentrated flows, poor vegetative cover (sparse or too short), and steep slopes often caused little or no treatment to occur. In certain cases implementation resulted in gully erosion. These areas need to be evaluated for the proper residence time, erosion problems, and condition of vegetation (for swales); and vegetation condition, erosion problems, slope, filter length, contributing area length, and sheet flow conditions (for vegetated filters/terrain). In some cases all a swale/filter may need is better vegetative cover (cool season grasses at the proper height are preferable). It is quite possible that certain sites are not suitable for these treatments and alternative measures will be needed. *"Effectiveness for STPs relying primarily on vegetation for treatment (e.g. swales, filter strips, constructed wetlands) in cold regions such as Vermont is limited by the short growing season. Measures such as dry swales and bioretention (that could be incorporated into many existing swales), and other STPs appropriate for "overland flow" sites are preferable from a water quality perspective. It is better to have vegetative treatment measures as part of a treatment train and not be the sole treatment measure."*

5. Erosion and poor vegetative cover was common in areas adjacent to roadways and parking areas.

6. Some sites require education of property owners/users and not a redesign.

A summary of the inventory and preliminary retrofit recommendations are included in Appendix J. Since changes in watershed hydrology are having significant impacts on Allen Brook, the ideal STPs for retrofits should provide better hydrologic balance and protect the stream channel from erosive discharges due to developed sites. This can be accomplished with infiltration STPs, better site design, disconnecting impervious surfaces, etc. for the hydrologic balance, and through extended detention and Distributed Runoff Control STPs for channel protection.

Site limitations and cost realities at some retrofit locations listed in Appendix J sometimes resulted in a less effective STP being recommended. An example of this is the recommendation of STPs that only stabilize an eroded area and provide conveyance of stormwater instead of recommending the more effective STPs that that provide hydrologic control.

Based upon the condition of certain reaches of Allen Brook and the results of the inventory, a few sites stood out as having the most significant impact on the brook. This ranking was based upon best professional judgment and not a formalized scoring protocol. The locations are:

1. Meadow Ridge subdivision. Uncontrolled runoff from the subdivision overtops South Road and has washed manure from the Siple farm manure pit into Allen Brook. This has contributed to high nutrient loading to Allen Brook that is evident by the presence of long strands of attached filamentous algae in Reach 9. A stormwater detention pond was never built as required by the VTDEC Stormwater Discharge Permit. Swales were not dimensioned as shown in the permit and are conveyance ditches instead that are a source of sediment.

2. South Ridge subdivision. The stream inventory of Allen Brook showed it to be in poor condition immediately downstream of this subdivision. While there are two other subdivisions in the general area, South Ridge is the largest, closest to the brook, and contains the most impervious area. Existing stormwater ponds need maintenance and retrofitting.

3. Taft's Farm subdivision. This subdivision straddles Allen Brook with very little buffer left along the stream corridor. Significant erosion from some stormdrain outfalls exists, treatment at certain discharge points to Allen Brook is insufficient or nonexistent, and basins are in need of maintenance and retrofitting.

4. Williston Hills subdivision. There is extensive gully erosion below the culvert outfall for the stormdrain collection system serving this area. A large sediment deposit exists where the flows enter Allen Brook. This is an older subdivision with no stormwater controls in place.

5. Avenue D (Whitcomb Industrial Park). Most lots were not required to have a stormwater discharge permit since provisions to infiltrate stormwater on-site were included in construction plans. Many of the proposed infiltration STPs were never built or are not functioning as intended. There is gully erosion from both permitted and non-

permitted discharge points. Groundwater impacts are a concern since this site was once a sand pit and has soils with high infiltration rates.

Among the remaining sites investigated there are some that provide opportunities to improve the health of Allen Brook, promote the goals of the watershed restoration, and educate residents and workers in the watershed. This included sites on public land such as the Williston Elementary School and Williston town offices. Grants could be pursued to make these viable projects.

There were some bright spots and they need to be recognized as well. A few residential developments were notable for the way that most of the stormwater is handled on-site. Subdivisions with swales instead of curb and gutter, or flow dispersed properly over pervious surfaces (thereby disconnecting impervious areas) provide some infiltration and pollutant removal (e.g. Old Stage Estates, Lefebvre Lane). A residential area that treated stormwater management as an integral and aesthetic part of the landscape with biofilters and a wet pond (e.g. Turtle Pond) is in the watershed.

As much as stormwater retrofits are an integral part of any watershed restoration effort, it is extremely important to remember that they are not a quick fix that will solve all the problems for Allen Brook or any other impaired stream or river. Recent research suggests that you have to do everything in order to succeed. Not just riparian buffers, or stormwater retrofits, or source controls, or stream bank restoration, or education of homeowners and businesses, or construction site erosion and sediment control, or conservation site design / low impact development – everything. A holistic approach is necessary (May, 2002).

9.3 Pollution Prevention Opportunities

9.3.1 Pollution Prevention Survey

A survey of the residential areas in the watershed was conducted in late April 2001 after snowmelt to identify areas that may be contributing to the problems identified in Allen Brook. The survey was based on the pollution prevention and preliminary retrofit surveys conducted by the Center for Watershed Protection (2001). Copies of the field sheets and the results of the surveys are in Appendix J. The survey noted:

- **Presence of salt/sand/gravel on the streets:** These materials contribute sediment to the storm system, and the brook. Some developments did not do street cleaning promptly after snowmelt, while others had already been cleaned by the end of April. Rapid cleanup of roads after snowmelt can reduce sediment loads to the stream. Street sweeping on a regular basis improves water quality.

- **Direct connection of roof gutters and downspouts:** Many developments had the rooftops directly connected to the storm drain system or to impervious surfaces such as roads or driveways. Disconnecting the downspouts from the storm drain system, and directing the stormwater from the roof to pervious surfaces to increase infiltration and recharge, and reduce runoff can modify these systems.

- **Erosion hazards:** The Town of Williston has identified two erosion problems on either side of the Allen Brook cascades at Industrial Avenue. The buffer zone on the north side of the stream has been filled with construction debris. The town is requesting stabilization and revegetation of both sites, and has requested and received advice from VTDEC wetlands and erosion control staff.

- **Encroachment into riparian buffer along mainstem:** There are several examples throughout the lower watershed of houses, which have been recently constructed within the buffer zone. This is a problem, not only for the stream, but also for the houses. For example a mass failure/erosion site has been identified in Reach 4. The house owned by Bob Salter, was built within the buffer zone. Although town zoning states that no buildings are allowed within 150' of the top of bank along the main channels, there are evidently some exceptions to this. This house, as well as several others in the watershed, appears not to meet Town zoning standards. The bank at Mr. Salter's house is eroding from above (probably due to changes in hydrology and an increase in hydraulic loading), causing a large amount of sediment to enter Allen Brook, as well as threatening the house. This instability would not have occurred if the house had been built with the appropriate setbacks from the mainstem. Please refer to Appendix F's Item #9 under the discussion of recommended ordinance changes, which describes steps to avoid encroachment into the buffer zone during construction of new developments.

9.3.2 Pollution Prevention Recommendations

The results of the survey are summarized in Appendix J. Table 23 offers recommendations that could be instituted throughout the town (using homeowners' associations for example), to lessen further impairment caused by the stormwater runoff-related problem pollutants – sediment, nutrients, bacteria, and toxics (CWP, 2001). The predicted build-out of the lower watershed (maximum lot coverage of 65% in Commercial I and II Districts and 70% in Industrial District, see Town of Williston Zoning Ordinances, Section 3.16) indicates that despite the best stormwater controls, the channel may become wider and deeper, and river restoration efforts need to consider the predicted impact of the proposed watershed development on the channel. Streams can be de-stabilized with as little as 2% impervious cover, however above 8% impervious cover it is recommended that Distributed Runoff Control (DRC) as described in the Vermont Stormwater Management Manual be implemented. Previous studies have found that streams that are managed for zero peak flow increase during the 2 year storm event actually erode *more* than streams that are not managed. DRC was developed to reduce the quantity and duration of flows to levels below the level that cause erosion (approximately 2/3 of bankfull). DRC requires a geomorphic assessment to determine the bankfull channel characteristics and thresholds for channel stability and bedload movement.

Table 23. Opportunities for Pollution Prevention (CWP, 2001).

Opportunity	Activity
Lawn care: Reduces nutrients and toxics	-Incentive-based program for individuals and homeowners associations to reduce lawn fertilizers or agricultural chemicals. -Promote soil testing as a condition of using lawn care products. - Reward citizens for using integrated pest management.
Disconnect directly connected impervious areas: Reduces sediment, toxics, thermal pollution, changes in hydrology	-Incentive-based program for downspout disconnection and rain barrel program. -Institute stormwater management fee based on directly connected impervious surface.
Street sweeping: Reduces sediment, toxics, nutrient loads	-Require or encourage street sweeping immediately after snowmelt and on a regular basis during non-winter months. -Establish a routine catch basin cleaning schedule.
Storm drain stenciling: Prevents toxic substances from entering watershed	For example, in Heritage Meadows a homeowner dumped gasoline down a storm drain and caused the evacuation of the neighborhood. Stenciling could have prevented this.
Manage pet waste: Reduces bacteria loads	Install and develop Pooper Scooper program with barrels and regulations.
Snow removal: Reduces sediment, salt	-Incentive-based program, design dedicated snow storage sites with treatment practices to reduce pollutants.
Hotspots: Reduces toxics	-Identify and map hot-spots. -Encourage the installation of stormwater management practices where needed. -Inspect and maintain.
Dumpster management / litter control: Reduces odors, trash, bacteria	-Locate dumpsters away from storm drain inlets and riparian buffers. -Promote/require use of enclosed holding areas -Stream Cleanups

9.3.3 How to Succeed in Pollution Prevention

While the ideas and activities needed to implement pollution prevention are fairly simple, it takes effort to succeed. Many people may be unaware of the impact of their actions on stream quality and aquatic habitats. Most people don't relate to terms like "stormwater" or "polluted runoff." It will take education and effort.

The Williston Whistle had an article in the spring of 2001 about a resident of Heritage Meadows who dumped his gasoline down the storm sewer. This event resulted in gas fumes moving into the neighbors' basements via footing drains. Every home in the neighborhood was evacuated, and luckily no explosion occurred. A fan to vent the fumes was set up and contaminated snow had to be disposed of. The violator was identified and was required to pay the cost of the clean-up, which was $4,000.

This is an example of how public education and storm drain stenciling might have prevented a neighborhood from being evacuated. It is clear that drains are used for improper disposal of automobile fuels (such as oil and antifreeze) and other waste.

9.4 Stormwater Utility

Stormwater utilities are an option for communities to finance a stormwater management program. Fees are billed to consumers much like water, electric, and other utilities. Funds cover costs such as maintaining public storm drain systems, street sweeping, public education, watershed planning, and maintenance of stormwater structures. Other stormwater financing options are typically one-time fees that cover the more immediate environmental impacts of development. These include government grants and loans and developer impact fees. See the web site http://www.stormwatercenter.net for more details on stormwater financing.

An interesting funding success story is how the Massachusetts city of Chicopee, a working class community with a median income of $28,000, initiated a stormwater charge ($10 per quarter for single family homes and sliding scale of $0.30 per 100 to 1000 square feet (ft^2) for commercial/industrial space (depending on which stormwater controls were implemented). Although Chicopee chose not to create a stormwater utility, they built broad public support for instituting the stormwater charge through innovative ideas for communicating their services to the community.

In Chicopee they found that the community does not care about stormwater or combined sewer overflows, but they do care about good service and what is in it for them. Innovative ideas in Chicopee that contributed to its success included:

- Addressing each complaint, regardless of the topic, with a follow-up letter to the concerned resident;
- Addressing flooded cellar problems during storm events;
- Buying a video camera and doing camera assessments for free ($200-300 value) of home sewer lines and then giving residents and businesses a list of what they need to do to solve their problem;
- Spreading their resources across several areas of the community and not focusing on any one area;
- Conducting extensive education and outreach to improve their visibility in the community; and,
- Leaving information on doorknobs of surrounding homes when they clean out catch basins which include why they performed the service, how citizens can help, and who they can turn to for more information.

Now they tend to get more compliments than complaints, and people have offered to pay higher stormwater fees because they are happy with the service and the reduction of "in-cellar" storage.

This is a good example of modifying existing resources to meet identified needs. Sometimes it is easier to modify an existing organization than to create a new one. Williston should search the community resources for organizations already present in the watershed that can assist in outreach efforts.

9.5 Vermont State Stormwater Program Implementation

The Vermont Agency of Natural Resources (ANR) has been regulating stormwater discharge into the state's surface waters since the 1980s. (Refer to ANR's stormwater website for more information: http://www.vtwaterquality.org/stormwater.htm.) To streamline the permitting process, ANR is relying on a series of General Permits (although individual permits may be required under certain circumstances). General Permits are permits based on categories of projects, rather than permits for individual projects. ANR administers four general permits under state law and three general permits required under federal law.

9.5.1 The State Stormwater Program and Relevance to Allen Brook

The ANR's state stormwater general permits will specify stormwater treatment measures the applicant would need to implement. Stormwater sources need to provide a certificate of compliance to the terms of the general permit. The four types of General Permits issued under ANR authority are listed below, however, only item 4 is relevant to Allen Brook:

1. New development and redevelopment in waters not affected by stormwater runoff. Stormwater discharges from new development and redevelopment to waters that are not principally impaired by collected stormwater runoff;
2. Expired stormwater permits. Previously permitted stormwater discharges to waters that are not principally impaired by collected stormwater runoff. ANR has a current backlog of approximately 1,000 expired permits. This permit will require that all projects with an expired permit demonstrate compliance with the terms of the original permit;
3. Permits for roads in waters not affected by stormwater runoff. Stormwater discharges from linear projects (roads and bikeways) to waters that are not principally impaired by collected stormwater runoff; and
4. Watershed Improvement Permits (WIPs). WIPs are for stormwater discharges to waters principally impaired by collected stormwater runoff. (As described earlier in this plan, impaired waters are those waters that fail to meet the state Water Quality Standards.) The WIP general permits are designed specifically for the impaired watershed. The intent of the WIP is to cost-effectively restore these waters within a reasonable timeframe. Under the WIP program, ANR is implementing a three-part strategy to restore Allen Brook and other impaired waters:
   a. Existing stormwater permit-holders need to demonstrate compliance with the terms of their existing permit;
   b. Specific stormwater sources, by virtue of their size, location, and lack of adequate treatment, will need to upgrade their stormwater treatment facilities; and,

c. All new development projects need to meet the improved standards for water quality, recharge, and channel protection requirements, which are specified in the 2002 Vermont Stormwater Management Manual.

Allen Brook is one of about two dozen Vermont surface waters impaired by stormwater pollution runoff. ANR expects to issue the WIP and accompanying compliance schedule for Allen Brook in the spring of 2003. Individual permittees will likely need to comply with the WIP by 2005.

9.5.2 Federal Stormwater Control Requirements and Relevance to Allen Brook
The Vermont ANR regulates stormwater discharges, as required for all states with delegated authority to administer the Federal Water Pollution Control Act's (Clean Water Act or CWA) discharge permitting program. In 1987, the CWA was amended requiring the Environmental Protection Agency to develop rules to address flooding, water quality problems, health threats pertaining to stormwater runoff. EPA was required to develop regulations for stormwater discharges under the existing permitting program called the National Pollutant Discharge Elimination System (NPDES).

In 1990, EPA issued stormwater "Phase I" regulations which authorized a NPDES discharge permitting system for several categories of industrial operations, cities and counties with a population of at least 100,000 that operate municipal separate storm sewer systems, and construction activities that disturb at least five acres of land.

EPA's "Phase II" regulations become effective in March 2003 and apply to publicly-operated municipal separate storm sewer systems (referred to as MS4 systems) within all "urbanized areas" (as defined by the US Census Bureau) and construction activities that disturb between one and five acres and certain industrial facilities. Thus, in addition to the WIP, there are three additional General Permits required by federal law and part of the NPDES permitting system. These permits are also administered by ANR. These three general permits include:

1. Stormwater Runoff from Construction Sites. Under Phase 1, development in Vermont that disturbs greater than five acres need to comply with this permit today. Under Phase II, development disturbing between one and five acres will be subject to stormwater control requirements beginning in March, 2003;
2. Multi-Sector General Permit (MSGP). The MSGP applies to stormwater discharges associated with industrial activity. Most industrial facilities (public and private) will need to comply with this general permit in 2003. In addition, specific private industrial facilities identified on the MSGP standard Industrial Classification (SIC) code list that have a stormwater discharge to either a municipal stormwater sewer system or waters of the state will have to comply with the requirement to develop a site plan to minimize contamination of stormwater runoff; and,
3. Phase II MS4 Permit. There are about nine Vermont municipalities with separate storm sewer systems, all within the Lake Champlain Basin that will need to comply with this permit. Williston is one of those towns. Williston will need to file a notice of intent on how they will comply with the Phase II stormwater rule by March, 2003. The Phase II communities will then have five years to fully implement the stormwater control program.

The rule requires that these communities develop a program containing six minimum measures: (a) public education and outreach; (b) public involvement and participation; (c) illicit discharge detection and elimination; (d) construction site stormwater runoff control; (e) post construction stormwater management; and (e) pollution prevention and good housekeeping.

9.5.3 Recommendations on Stormwater Credits

To assist Williston and other Vermont towns in controlling stormwater pollution, the Agency of Natural Resources offer six voluntary stormwater management credits for non-structural practices described in the *Vermont Stormwater Management Manual, Volume I-Stormwater Treatment Standards,* April 2002. We recommend that Williston strongly encourage developers doing business in the town to use all of these credits. These credits create a "win-win" situation – water quality is protected and, if applied correctly, the developer can save money by reducing the size and cost of installing structural storm treatment practices.

9.6 Local Ordinance Recommendations

Please refer to Appendix F for a descriptive set of recommendations to modify local ordinances in order to best address the need to control sediment loads and other pollutants from stormwater runoff.

Appendix C gives detailed recommendations on many methods to reduce the impacts in the watershed from site design, transportation infrastructure and maintenance, stormwater facility maintenance and other structural and non-structural opportunities. Recommendations include incorporating Better Site Design into all proposed developments. (Delaware, 1997; Tourbier, 1994; CWP 1998a and 1998b)

9.7 Construction Site and Erosion and Sediment Controls

Erosion and resultant off-site sedimentation can be major problem caused by construction sites, since land is disturbed during construction and often left unprotected from wind and precipitation. Construction is often the most damaging phase of the development process for streams such as Allen Brook. While activity may be over a short time frame, sites can erode 20 to 200 tons of soil per acre per year.

VTDEC requires construction site erosion and sediment controls for certain permitted projects and the town of Williston includes certain recommendations in its public works standards. Unfortunately both of these efforts fall short of what is required to provide meaningful protection for off-site water resources. The standards and specifications utilized by both the state and town, and follow up inspection and maintenance are insufficient. Field observations confirmed this: improper use of sediment control practices (i.e. poor design), installations not made according to plans, practices in need of maintenance, sites that rely totally on sediment control and do not utilize the more effective erosion controls, and sediment controls that were not removed after construction is finished and the site stabilized.

The report describes some opportunities to control erosion and off-site sediment in the recommendations to modify the local public works standards, described in Appendix F. It is recommended that all construction site erosion prevention and sediment controls in the watershed be designed according to the New York Guidelines for Erosion and Sediment Control (1997 & 2003) until the dated Vermont 1987 guidelines are revised. Mechanisms to ensure good design, installation, site inspection and maintenance will also need to be implemented for this to be a successful program in Williston:

- Performance bonds for erosion and sediment control should be required.
- Installation of erosion prevention and sediment controls needs to be a line item in bid estimates for projects that are constructed in Williston.
- Construction contracts should include a contingency line item for maintaining and repairing erosion prevention and sediment control practices.
- The development review process should be amended to require early review of the erosion prevention elements of the erosion and sediment control plan.
- The erosion prevention and sediment control plan designer must visit the site to certify that that practices called for on the plan were properly installed.
- A preconstruction meeting, regular inspection visits, a pre-wintering meeting, and final inspection for completed phases/projects should be mandatory.
- One individual should have overall erosion prevention and sediment control responsibility for a construction site.

ANR requires an erosion and sediment control plan when it applies its general permit for new construction.

9.8 Quantifiable Controls

The ANR Request for Proposal sought a "Quantifiable Control Approach" to TMDLs for the Allen Brook watershed. A literature search was conducted on rates and ranges of removal for nutrients, toxics, bacteria and sediment for a variety of structural and non-structural STPs. The literature review includes information on hydrologic impacts and how different land use and stormwater management practices affect the hydrograph. The results of the literature search can be applied to efforts at modeling potential reductions in the watershed.

There are very few studies that quantify reductions on non-structural Best Management Practices for agricultural, forestry, road building and other practices. The implementation of BMPs through enforceable agreements (between the town or state and the holder of a stormwater permit) is critical to prevent further degradation of the watershed. The results in Appendix C show that non-structural approaches, including (1) better site design, (2) erosion and sediment control, (3) maintenance and management of stormwater systems and (4) buffers are the most cost effective methods to reduce sediment loads.
The recommendations based on the literature search that can reduce loading are prioritized below. The numbers refer to tables in Appendix C.

9.8.1 Better Site Design

1. Require Better Site Design and BMP's for Better Site Design to be implemented in proposed developments. (Tables C-2 through C-5)

2. Require all 6 credits (Table 24) of the Vermont Stormwater Management Manual (2001) be applied in proposed developments. See Manual for application and restrictions on credits. The manual states:

"In most cases, non-structural practices will need to be combined with structural practices to meet stormwater requirements. The key benefit of non-structural practices is that they can reduce the generation of stormwater from the site; thereby reducing the size and cost of stormwater storage. In addition, they can provide partial removal of many pollutants. The six proposed non-structural stormwater credits are:

Table 24: Vermont Stormwater Manual Stormwater Credits

Credit 1: Natural Area Conservation Credit	A stormwater credit is given when natural areas are conserved at development sites, thereby retaining their pre-development hydrologic and water quality characteristics
Credit 2: Disconnection of Rooftop Runoff Credit	A credit is given when rooftop runoff is disconnected and then directed over to a pervious area where it can either infiltrate into the soil or filter over it. The credit is typically obtained by grading the site to promote overland filtering, by providing bioretention areas on single family residential lots.
Credit 3: Disconnection of Non-Rooftop Runoff Credit	Credit is given for practices that disconnect surface impervious cover runoff by directing it to pervious areas where it is either infiltrated into the soil or filtered (by overland flow). This credit can be obtained by grading the site to promote overland vegetative filtering or providing bioretention areas on single family residential lots.
Credit 4: Stream Buffer Credit	This credit is given when stormwater runoff is effectively treated by a stream buffer. Effective treatment constitutes capturing runoff from pervious and impervious areas adjacent to a stream buffer and treating through the overland flow in a grass or forested buffer.
Credit 5: Grass Channel Credit	Credit may be given when open grass channels are used to reduce the volume of runoff and pollutants during smaller storms (i.e., 0.9 inches and less).
Credit 6: Environmentally Sensitive Rural Development Credit	This credit is given when a group of environmental site design techniques are applied to low density or rural residential development.

Local jurisdictions may need to update or revise some of the local subdivision and/or zoning codes to ensure that the credit will be applicable to their jurisdiction. The application of these credits does not relieve the design engineer or reviewer from the standard of engineering practice associated with safe conveyance and drainage design."(CWP 2001)

9.8.2 Erosion and Sediment Control

Erosion and sediment control (ESC) is one of the most cost-effective and important processes for controlling sediment to streams.

Table C-6 shows increases in sediment concentrations from undisturbed sites to sites that are developed with and without Best Management Practices (BMP's) for ESC. Sediment concentrations increase from 25 mg/l from undisturbed sites to 150 mg/l to sites developed with BMP's to 4,500 mg/l for sites developed without BMP's for ESC (Environmental Protection Agency (EPA), 1993).

Since the Vermont Handbook for Soil Erosion and Sediment Control (1982) is out-dated, it is recommended that contractors adopt practices from New York Erosion and Sediment Control manual (New York Urban Erosion and Sediment Control Committee, 1997 and 2003 (at press)), as well as hiring an erosion and sediment control officer to be on-site during construction. All BMP's used should be suitable for cold-climates.

Recommendations for reducing erosion during construction are found in Table 4-7, 4-12, 4-15, 4-16 of Appendix C(EPA, 1993). BMP's include:

a) Phase construction: Limit amount of disturbance at one time.
b) During construction build check dams, berms, and trenches that follow contour and direct runoff to vegetated areas
c) Implement careful hydraulic design to avoid flow concentration during construction.
d) Deliver water into vegetated areas with level spreader so that water ponds up and spills as sheet flow. If vegetated areas not available place a slope drain at the end of the water bar with energy dissipation at bottom.
e) Manage water in small units- don't concentrate a lot of water, try to spread it out in small amounts, discourage delivering stormwater into wetlands. If unavoidable then implement pre-treatment or forebay.
f) Require sediment and erosion control officer to be present during construction.

9.8.3 Buffers

Buffers on all streams (ephemeral, intermittent, perennial) should be sized to maximize efficacy, this includes consideration of slope, length of flow path, vegetation and soil characteristics, this may be used in lieu of a minimum default width. (Table C-15).

9.8.4 Maintenance and Management

Maintenance and management are critical for successful operation of all practices including non-structural practices. According to a study by the State of Vermont (1995) almost a third (29%) of the stormwater management facilities in Williston were not maintained or constructed properly (Table C-12). Systems fail if they are not maintained properly. For example, although infiltration practices can show good removal rates, lack of proper design, construction or maintenance can cause failure:

"Infiltration basin failures are associated with:

- Inaccurate estimation of infiltration rates.
- Inaccurate estimation of the seasonal high water table.
- Excessive compaction during the construction process
- Excessive sediment loadings either from improper erosion and sediment control during the development construction process or a lack of pretreatment BMPs.
- Lack of maintenance." (Livingston, 2000)

Proper design, construction and maintenance increase the efficacy of BMP's.

Enforceable maintenance agreements such as those suggested by the Center for Watershed Protection and Center for Watershed Management are recommended on all structural and non-structural stormwater facilities. This includes regular maintenance of buffer strips. (Livingston, 2000)

9.8.5 Implementation Of BMP's

Although many BMP's do not have adequate studies on removal capacity, the Opportunities for Pollution Prevention listed in Table 23 should be implemented. Tables C-16 and C-24 list reductions from some BMP's.

Documented removal rates are found for street sweeping and catchbasin cleaning. It is recommended that catchbasins are cleaned at least twice a year, and a vacuum street sweeper is used on State and Town roads within 2-3 weeks of snowmelt, and on a regular basis throughout the year.

Snow storage, salt storage, and salt and sand spreading. Practice BMP's for snow storage, and salting, etc.

9.8.6 Infiltration Practices

Filter strips and grass swales (Table C-15) do not meet the 80% Total Suspended Sediment (TSS) reduction requirement (EPA 1993). They should not be used as stand alone practices or combined with practices that are not suitable for cold climates. Filter strips and grass swales are not effective during winter. BMP's that require infiltration should only be used in soils that are suitable (Table C-14). Bio-retention should be promoted in suitable soils.

9.8.7 Structural Treatment

An effort should be made to maintain and/or improve water quality treatment and channel protection treatment with all existing stormwater facilities.

It is recommended that practices meet cold-climate recommendations detailed in the Appendix of the Vermont Stormwater Management Manual.

Several practices are not suitable for stormwater management. The Vermont Stormwater Management Manual states:

"Section 4.3 Several practices are not recommended for providing the target water quality treatment (i.e., 80% TSS removal) as "stand alone" practices. Many of these practices have little monitoring data, or available data suggest poor pollutant removal capabilities. Some of these practices, such as dry ponds and underground storage vaults (Figures 4.20 and 4.21, respectively), can be used to meet channel protection and flood control requirements, while others can often be incorporated into a STP design as pretreatment devices, to treat a small portion of a site, or to achieve water quality credits (see Section 5). The following list of practices do not meet the water quality treatment target, but may have some applicability in a site design in conjunction with recommended practices:

- Dry Ponds/Underground Vaults/On-Line Storage in the Storm Drain Network (Designed for

Flood Control)

- Filter Strips [and grass swales]
- Deep Sump Catch Basins and Catch Basin Inserts
- Oil/Grit Separators and Hydrodynamic Structures

Limited design guidance and specifications will be provided in the Handbook for these practices".
(Center for Watershed Protection, November 2001)

Stormwater treatment systems in Williston that use the practices listed above, should be retrofitted to improve water quality treatment. Do not retrofit wetbasins to dry basins, as this will decrease water quality treatment.

9.8.8 Channel Protection

Retrofit existing stormwater facilities for 1 year Extended Detention, or Distributed Runoff Control as explained in Vermont Stormwater Management Manual (2001).

Do not permit structural stormwater that uses zero peakflow increase, or control of Two-Year or Ten year Frequency runoff event. This design degrades water quality by causing channel widening and increased sediment load.

Previously permitted facilities that use 2 or 10 year control, zero peak flow increase should be retrofitted for 1 year extended detention according to the Vermont Stormwater Management Manual. Section 9.1 of this appendix cites research (MaCrae, 1996) that shows that in alluvial channels, that control of the 2 year event (the previous Vermont stormwater procedures) promote practices that increase erosion.

9.8.9 Phosphorus Loading

The literature shows disproportionately heavy loading of phosphorus (P) from urban land. The Lake Champlain basin is under strict guidelines to reduce phosphorus loading. Table C-19 through C-24 and pages C13- C17 show methods to reduce phosphorus loading. All practices that reduce phosphorus loading should be implemented.

9.8.10 Transportation and Infrastructure

Impacts from roads in the watershed are associated with instability in Allen Brook. Consideration of the following is recommended:

Bridge design needs to take into account the following factors:

Proposed future development within the watershed. The Phase II study (CWP et al., 1999) shows a predicted enlargement curve (relaxation curve) based on percent imperviousness within the watershed for Vermont streams. Bridges should be designed with consideration of channel widening under projected build-out for the life of the structure. In some Vermont watersheds, channels can be expected to double in width as a response to hydrologic changes due to an increase in impervious area. Channel enlargement can take over 50 years, with the most rapid enlargement generally occurring in the first 20 years or so. The Williston buildout analysis can be used to predict channel enlargement and size bridges for predicted channel enlargement. The Town of Williston's Zoning Ordinance, in Section 3.16, allows for the lower watershed to reach a full build-out lot coverage of 65% in Commercial I and II Districts and 70% in the Industrial District. (Williston, 2000) Bridge sizing recommendations are consistent with Melville (2000) who recommends that allowance be made for:

- Watershed land-use changes over the life of the structure
- The past flow history in comparison with projected flows occurring over the life of the structure, the duration of floods or flows near bankfull stages probably being more important than the flood magnitudes;
- That lateral migration can fluctuate along a given reach and markedly from one period tot he next, sometimes occurring only episodically; and
- That following a disturbance, an initially stable channel typically oscillates between aggradation and degradation before the channel restabilizes."

Size bridges for geomorphic stability (Melville, Coleman 2000) considering potential build-out within the watershed

The Vermont Regional hydraulic curve (ANR, 2001), field work associated with this study, and other sources should be consulted to design to prevent increases in stream power near bridges. Bridge and culvert sizing should consider fluvial geomorphology (Simon 1995). Bridges should be a minimum of bankfull width except at meander bends, should be 1.5 times bankfull width. Streams with access to floodplain (not entrenched) should consider sizing for overflow of floodprone width. This design method also increases habitat value along the riparian corridor.

Reduce the use of culverts, and do not use double culverts (SEI, 1998, ANR 1999).

Size culverts to avoid backwater effects, channel aggradation upstream, channel constriction and downstream scour. This will reduce sediment loads into the watershed.

Attempt to restore hydrology along road corridors:

a) put in level spreaders for all drainage within corridor (from and to road)
b) disperse existing flow that has been concentrated either draining from the roads or, draining towards the roads. This could be done through the use of constructed wetlands, level spreaders etc. to disperse flow.
c) fill in swales or take other steps needed to restore hydrology.

Ensure sediment isn't swept from bridges into streams during bridge maintenance.

Develop a maintenance and management plan for culverts and other infrastructure, based on Watershed Management Institutes Operation, Maintenance and Management suggestions (Watershed Management Institute. 1997).

Use all applicable suggestions from the Vermont Better Back roads Manual (Windham Regional Commission, 1995).

10.0 FUNDING

The watershed restoration plan requires the commitment of the community and funding for the plan to work. The EPA publication, *Catalog of Funding Sources for Watershed Protection*, found on the website: http://www.epa.gov/owow/watershed/wacademy/fund/wfund, lists possible sources of federal funding. Other opportunities for funding include the Town pursuing options such as:

- Grants from organizational programs such as Partners for Fish and Wildlife, Vermont Better Backroads Small Grants Program, Lake Champlain Basin Program Local Implementation Grants, the Sustainable Future Fund, Conservation License Plate Watershed Projects, NRCS's Conservation Reserve and Wildlife Habitat Incentive programs , VT Section 319 grants, and others.

- Establishment of a stormwater utility, or incorporating stormwater management into a current town function. See section 9.3.4 above.

- A variation on Vermont's statewide "current-use-appraisal" which gives local property tax deductions for land that is in active agricultural or forest use. The town could establish a local tax incentive for protection of wide riparian buffers and other non-structural practices to protect water quality. This could be used as an incentive to limit growth in the rapidly developing upper watershed.

- Developing recreational opportunities along Allen Brook by expanding walking and biking paths, improving habitat (lunker structures), and offering river festival to increase community awareness and involvement.

- Initiate a voluntary Stormwater maintenance agreement .

- Requiring Better Site Design which not only protects the stream, but provides an economic incentive to the developer (Delaware, 1997).

- Paying for Erosion and Sediment Control through: A permit fee structure that covers the true cost of effectively implementing this program in the town of Williston. Requiring private individuals to perform site inspection work for sediment and stormwater compliance at large construction sites as is done in Delaware's Certified Construction Reviewer program (Piorko, 2000).

- A participatory approach to watershed planning that uses existing GIS maps in overlays to inform and educate stakeholders to help make management decisions.

A combination of education, incentive programs and enforceable maintenance agreements can provide reasonable assurance that water quality standards will be attained, and will be sustainable. This is especially critical as the predicted build-out of the lower watershed, and the rapid growth in the upper watershed will demand a concerted effort for the stream to meet Vermont Water Quality Standards.

11.0 PUBLIC PARTICIPATION

A number of activities were conducted to inform landowners, businesses, town and state officials, and the general public about the water quality problems of Allen Brook and restoration goals. These activities were also used to gather information from the public about where the problem sites were, and how the public could participate in preventing future problems. We completed the following activities to reach out to the public and stakeholders:

- Produced a large poster that described the project, which was displayed at Town Meeting Day and at the Dorothy Alling Library.
- Produced a questionnaire, which was distributed at Town Meeting Day, the Town offices, and the library throughout Spring 2001. The purpose was to introduce the project and hear from the public their views of the Brook and problem areas.
- Published two articles in the *Williston Whistle* to describe the project.
- Conducted an introductory meeting with Williston residents and officials. The purpose was to "kick off" the project and set a collaborative tone for the project.
- Gave a presentation to the Town Selectboard to describe the project and gather their comments.
- Organized two river walks to give an "hands-on" perspective on the health of Allen Brook and discuss priorities for restoring Allen Brook. Advertisement included posters, notices in the *Williston Whistle*, phone call invitations to residents known to be interested in the project, and mailing of postcards to Allen Brook's riparian landowners. Nine people participated in the walks.
- Held four "kitchen meetings," which were informal discussions with landowners about their concerns.
- Put together a database of 78 interested residents and Allen Brook abutters, who will receive notices of future events.
- Held two meetings with the development community – builders, engineers, developers, which was advertised in the *Williston Whistle* – to discuss the project and hear of their concerns.
- Held two meetings with the town Conservation Commission to describe the project, offer a summary of our findings, and identify future steps the Conservation Commission could take.
- Held a meeting with the town Selectboard to give them an update of the project.
- Met with the Williston Rotary Club to discuss the project and identify opportunities for their assistance.
- Organized a tree-planting and stream-side cleanup project with the Williston Rotary Club to create a 35-foot riparian buffer on a farm at the confluence of Allen and Muddy Brooks.
- Met with the homeowners' associations in Williston, organized with assistance from the Conservation Commission, to discuss the project and the state stormwater program.
- Met with the Williston Planning Commission to discuss likely recommendations to the town ordinances.
- Met with members of the Vermont Agency of Natural Resources and the Vermont Agency of Transportation to discuss possible concerns and offsets associated with the proposed development of the circumferential highway. Recommendations included:
    1. Change hydrology along corridors:
    a) Consider role of swales.

   b) Put in level spreaders for all drainage within corridor (from and to road).
   c) Disperse existing flow that has been concentrated either draining from the roads or, draining towards the roads. This could be done through constructed wetlands, level spreaders etc. to disperse flow.
2. Mitigate imperviousness:
   a) For example, if road creates 100 acres of imperviousness, mitigate 100 acres of impervious cover in the watershed through:
   b) Disconnection of impervious surfaces, roof tops, etc. They could sponsor a program in the town to disconnect impervious surfaces.
3. Reduce sediment through streetsweeping and catch-basin cleaning: Sweep all town streets as well as state roads within 2-3 weeks of snowmelt.
4. Snow storage, salt storage, and salt and sand spreading practice BMP's for snow storage, and salting, etc.
5. Bridge maintenance: Make sure sediment isn't swept from bridges into streams.
6. Better Back roads: Use all applicable suggestions.
7. Culvert and bridge sizing. Minimum of bankfull width except at meander bends, should be 1.5 x bankfull width (Melville, 2000). Streams with access to floodplain - consider overflow sizing for floodprone width. Examine enlargement curve from Phase II study (CWP, 1999), and look at Williston buildout analysis, predict channel enlargement and then size bridges for predicted channel enlargement.
8. Develop a maintenance and management plan for culverts and other infrastructure, base it on the Watershed Management Institutes (1997) suggestions.
9. Implement BMPs during construction using New York State erosion and sediment control guidelines (NYESC, 1997).
   a) Phase construction: Limit amount of disturbance at one time.
   b) During construction build check dams, berms, and trenches that follow contour and direct runoff to vegetated areas.
   c) Implement careful hydraulic design to avoid flow concentration during construction.
   d) Deliver water into vegetated areas with level spreader so that water ponds up and spills as sheet flow. If vegetated areas not available place a slope drain at the end of the water bar with energy dissipation at bottom.
   e) Manage water in small units: Don't concentrate a lot of water, try to spread it out in small amounts. Discourage delivering stormwater into wetlands. If unavoidable then implement pre-treatment or forebay.

Please refer to Appendix E to view the articles, questionnaire, and poster.

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