~~Draft~~ Final Report

Geomorphic Assessment of Stevens, Rugg and Jewett Brooks in Franklin County, Vermont

Prepared By:
Mike Winslow
Staff Scientist
Lake Champlain Committee

Prepared For:
Vermont Agency of Natural Resources
Department of Environmental Conservation
River Management Program

Grant Agreement Number: 2005-RCG-1-09

Table of Contents

Abstract

Stevens, Rugg and Jewett Brooks collectively drain 70% of the St. Albans Bay watershed and all are listed as impaired by the state of Vermont. In order to better understand the causes of impairment and identify projects that might improve the streams, the Lake Champlain Committee undertook geomorphic assessments on the streams following Vermont Department of Environmental Conservation Protocols. Phase I assessments were conducted for all streams and reaches; Phase II assessments were conducted for nine reaches on Stevens Brook and four reaches on Rugg Brook. Extensive channel straightening and land-use changes have modified the streams' sediment storage and transport regimes. Potential projects and problem areas are discussed in the report.

Introduction

St. Albans Bay in Lake Champlain does not meet water quality standards for phosphorus concentrations. Improvements at the St. Albans waste water treatment facility during the 1980's were expected to reduce nutrient loading to the Bay enough so that water quality standards could be achieved. However, those expectations were tempered by the observation that, "TP (total phosphorus) levels in the water column and bottom sediments of the Bay/Wetland system are highly sensitive to the assumption made for nonpoint source TP loading" (Martin et al., 1994). A comprehensive assessment of nonpoint source phosphorus loading to St. Albans Bay has not been undertaken, but in recent years extensive development in the vicinity of St. Albans City has occurred. Developed land is estimated to produce two to three times more phosphorus per unit area than agricultural land in the Champlain Basin (Hegman et. al, 1999)

Stevens, Rugg, and Jewett Brooks account for over 70% of the St. Albans Bay watershed (Figure 1). Jewett Brook is a low-gradient stream that empties into St. Albans Bay after draining a primarily agricultural basin of approximately 8 mi^2. Stevens and Rugg Brooks drain a mixture of agricultural, urbanized, and suburbanized land. Combined, these two watersheds are approximately 20.8 mi^2. Both streams originate in the hills east of St. Albans. All three waterbodies are listed on the state of Vermont's 303d list of impaired waters. Jewett Brook and portions of Rugg and Stevens Brooks are considered impaired due to agricultural runoff, while other portions of Rugg and Stevens Brook are considered impaired due to urban stormwater runoff and, in portions of Stevens Brook, fuel spills (VT DEC, 2004b).

In recent years, the Vermont Department of Environmental Conservation (VTDEC) has been using their geomorphic assessment procedure to gather measurable, field data that document the condition, quality, and departure from a natural state of fluvial systems. This work provides a science-based foundation for initiatives to preserve, protect and restore fluvial systems and address potential human conflicts with those systems (VTDEC 2001).

The Lake Champlain Committee (LCC) applied Vermont's Phase I Geomorphic Assessment Protocols to Stevens, Rugg and Jewett Brooks, and the Phase II Protocols to selected reaches in Stevens and Rugg Brooks. LCC is a non-profit environmental organization dedicated to protecting the natural resources and scenic beauty of Lake Champlain and the Champlain Valley. LCC has identified St. Albans Bay as a high priority lake segment requiring particular attention due to excessive nutrient concentrations. We anticipate that projects identified through the application of Geomorphic Assessment protocols will reduce the generation and transport of sediment in the river system and improve aquatic habitat thus facilitating water quality improvements in the Bay as well as the streams themselves.

Methods

For the Phase I portions of the assessment, we utilized procedures set forth by the Vermont Department of Environmental Conservation in their Phase I Geomorphic Assessment Handbook (VTDEC 2004a) including application of the Stream Geomorphic Assessment Tool (SGAT) version 3.0. Sub-watersheds were digitized from digital topographic maps supplied by the Northwest Regional Planning Commission (NRPC). Soils data were also supplied by NRPC. Land use/Land Cover data were supplied by the Vermont Center for Geographic Information and converted to a shapefile by Judy Bond of GrassRootsGIS. Step seven, windshield surveys, were deferred on those reaches where Phase II assessments took place. For Jewett Brook, windshield survey occurred on July 26, 2005. Windshield surveys of remaining reaches occurred on October 20, 2005.

During the Phase I analysis each reach was assigned an impact score (0-32) related to land-use and the extent of modification that had occurred in the channel and the floodplain. Reaches with high scores were more likely to physically respond to disturbances. Reaches with very low scores could be used to define reference conditions for other similar reaches. (VTDEC 2004a)

Phase II portions of the assessment followed the most recently available protocols (VTDEC 2005). Phase II assessments were conducted on Stevens Brook (main stem reaches one through nine, except reach four, plus tributary one reach one) and Rugg Brook (main stem reaches five through eight). Field work was conducted between June 27, 2005 and September 21, 2005 by Mike Winslow and Jim McKenzie. Mike had undergone VTDEC Phase II training on the Tweed River between May 24 and May 26, 2005. Jim had undergone abbreviated Phase II training on June 16, 2005.

All data from Phase I and Phase II assessments were entered into the VTDEC data management system. Quality assurance checks at various times throughout the project were conducted by Staci Pomeroy of VTDEC.

Results and Discussion

Phase I Jewett Brook

For the Phase I analysis, Jewett Brook was divided into six reaches. Reaches were labeled from downstream to upstream M01 through M06. Reach breaks were established due to changes in valley width (M01/M02, M02/M03), changes in slope (M03/M04, M04/M05), and at the confluence with agricultural ditches draining a substantial watershed area (M05/M06).

The six reaches shared some common characteristics. All were classified as C-type streams – slightly entrenched but with access to a floodplain, moderate to high width to depth ratios, and gentle slopes. There was very little topographic relief in the watershed (lowest point 97 feet, highest point 206 feet), and reach slopes ranged from 0.04% (M01) to 0.26% (M04). The dominant land cover in all reaches was agricultural – either crop or field. Glacial lake sediments were the dominant soil parent material in all reaches except M04 where lake sediments were sub-dominate to glacial till.

Impact scores increased from downstream to upstream except reach M06 scored lower than reach M05 (Table 1). High impact scores due to land-use variables (step 4) for all reaches can be attributed to the absence of forest and wetlands, and their replacement by cropland and fields. Changes in the width of buffers and the ratio of fields to cropland accounted for variation between reaches. Impact scores related to channel modifications (step 5) were related to the number of stream crossings (public roads and agricultural roads) and straightening. Extensive channel straightening was most notable in reaches M03 (27.5% straightened), M05 (61.2%), and M06 (99.8%) and also led to higher floodplain modification impacts (step 6) due to low meander-width ratios and low wavelength ratios. High floodplain modification impacts for reach M04 were related to an active stream channel; meander migrations, avulsions and flood chutes could be seen in aerial photos. Channel activity here may be a response to extensive historic upstream straightening.

Numerous potential water quality and habitat impacts can be linked to impact scores. Loss of wetlands reduces the watersheds ability to store water. Loss of forest cover leads to an increased stream temperatures, due to an absence of shading. Cropland generates more sediment than forested land or fields. The absence of wooded riparian buffers reduces stream bank resistance to lateral migration. Also, narrow riparian buffers can not effectively filter overland runoff. Straightening a channel increases the slope and erosive power of a stream. That erosive force can be expressed downstream in meander migrations and avulsions which become sources of sediment and nutrients.

Most stream reaches in Jewett Brook should have the capacity to store fine sediments while retaining equilibrium with production and transport of coarse sediments. Gentle slopes suggested the stream would not have the power to move much sediment. Some potential exceptions include M03, M05, and M06 where greater than 30% of the stream had been straightened. Resulting increased stream power would allow these reaches to transport more sediment, and thus store less.

Phase I Stevens Brook

Stevens Brook was the largest of the three waterbodies assessed, draining 14.71 mi^2. The Phase I assessment dived the Brook into 11 main stem reaches (M01-M11 labeled downstream to upstream), two tributaries with four (T1.01-T1.04) and three (T2.01-T2.03) reaches, and one sub-tributary (T1S1.01). Reaches M01 through M04 passed through agricultural land. Reaches M05 through M10 passed through St. Albans City and continued across I-89. Reach M11 was principally a mountain stream on the east of St. Albans City. Tributary, T1 joined the main stem of Stevens Brook upstream of Kellogg Rd. and formed the reach break between M03 and M04. T1's watershed included the developed area around Exit 20 of I-89 including Parah Drive and Franklin Parkway. It also included the sub-tributary T1S1 which drained agricultural fields on both sides of I-89 south of Exit 20. Tributary, T2 was Grice Brook on the south side of St. Albans City.

The Stevens Brook watershed was much more diverse than the Jewett Brook watershed. Land-cover along the main stem corridor varied from wetlands (M01), to predominately agricultural lands (M02), to forests and low-density residential areas (M03-M04), to highly urbanized (M05-M10), and to second growth fields (M10-M11). Elevations in the watershed ranged from 97 feet to 1240 feet. Channel slopes in reaches ranged from 0.03% (M01) to 12.14% (M11). The predominant geologic parent material was glacial till, however alluvium dominated M02 and M10, while muck dominated M01.

Reference stream types in the lower watershed (M01 and M02) were Es – slightly entrenched with low width to depth ratios and very gentle slopes. The reference stream type for four reaches (M08, M11, T1.04, and T2.03) was A – entrenched with low width to depth ratios, low sinuosity and steep slopes. Four other reaches (M03, M07, M09, T2.01) had a reference type of B – moderately entrenched with moderate width to depth ratios, low to moderate sinuosity, and moderate slopes. The remaining reaches were Cs –slightly entrenched with moderate to high width to depth ratios, moderate sinuosity, and low slopes. Impact scores in the watershed ranged from 4 (M04) to 20 (T1.03) (Table 2). Every reach's impact score increased due to land-use issues in the watershed, and 17 of 19 scores increased due to land-use issues in the stream corridor.

M04, the least impacted reach in the Stevens Brook system, began at the confluence of the main stem and an unnamed tributary, and ended at a wetland complex just downstream of the wastewater treatment facility. M04 was one of only two reaches where stream corridor land-use did not affect impact scores; the stream passed through one of the more wooded areas of the watershed. However, cropland and some urbanization in the larger watershed did affect the impact score. Other variables increasing the impact score were depositional features noted from aerial photographs and a low meander width ratio (i.e. fewer, narrower meanders than expected given the calculated channel width). There were no in-stream channel modifications.

Seven reaches had impact scores of 16 or greater (of a possible 32). In order from highest to lowest scores they were T1.03, M05, T2.02, T1.02, M02, M06, and M10. Each of these reaches, plus an additional seven reaches, scored fives or six out of six for potential impacts due to land use (Table 2). In other words they had extensive development or cropland in both their watersheds and riparian corridors, and they had at best minimal buffers. Development of the watershed tends to result in higher peak flows and lower base flows. In-stream modifications were not a driving factor in high impact scores for most reaches. Two exceptions were M05 and M09, both of which scored six out of ten in this category. Over 70% of M05 had been straightened, 12 bridges and culverts were noted in the Phase I analysis (two additional crossings were added in the Phase II analysis). Furthermore, during high flows, water is diverted from Stevens Brook, at M05, into Rugg Brook. Reach M09 also had been straightened and had high impacts from bridges and culverts, but in addition this reach had been repeatedly dredged. Removal of bed materials from M09 has likely increased the downstream power of the brook. Extensive floodplain modification drove the high impact scores for all seven heavily impacted reaches.

Based upon the Phase I analysis, most reaches in Stevens Brook were expected to generate and transport sediment. Generation and transport was expected in those reaches that were moderately sloped B type streams or C and E streams that had been extensively straightened. Sediment transport without much generation was predicted for reaches with steep slopes and cohesive soils – M11 and T2.03. A few reaches with gentle slopes and minimal straightening could be expected to store sediments - M01, M02, M04, and T1.01. Phase II analyses forced different conclusions about sediment transport regimes in reaches M02, M03, M05, M08, and M09 however.

Phase II Stevens Brook

Reaches M01 through M09 (except M04) and T1.01 were evaluated using Phase II protocols. Large portions of the assessed reaches, particularly within St. Albans City, were impacted by bank armoring, straightening, grade controls, rip rap, and roads and berms (Figure 2). By contrast, the principal impact along reach M02 in the farmland downstream of the city was bank erosion.

Reach M01 ran from the confluence of Stevens and Jewett Brooks in the St. Albans Bay wetlands, upstream to the first agricultural bridge crossing. It had a deep well defined channel winding through an extensive wetland. Under high lake conditions, water levels in the stream were determined by lake levels rather than by watershed inputs. This reach showed little need for projects to improve water quality. The surrounding riparian corridor and wetlands appeared essentially intact, and could serve to dissipate high flows from Stevens Brook as well as buffering the lower reaches of the stream from surrounding agricultural land.

Reach M02 began just upstream of the wetlands at the mouth of Stevens Brook and continued almost to Jewett Ave. It was by far the longest reach in the system. The reach's watershed was principally agricultural with a mixture of crop and pasture land. Some land was being newly development in the watershed. M02 was divided into three sections. The section most downstream (M02A) was straightened and heavily influenced by high lake levels causing back flow. Stream banks in this section were quite low, and pastured cattle had access to the water.

The other two upstream sections of M02 (B and C) were both highly sinuous and had high entrenchment ratios (good connection to their floodplain) E-type reaches, as predicted in Phase I. Only at very high flows would the stream access its floodplain, meaning potentially diminished sediment storage capacity. Meanwhile, sediment generation may have increased as there was extensive erosion at each meander bend with banks up to eight feet high. The bed of M02 was composed principally of sand particles with a riffle-dune stream type. In the upper reach (M02C), neck cutoffs appeared likely, and some avulsions had occurred. The stream appeared incised and had definitely experienced active and historic planform adjustments. There was little human infrastructure in the floodplain threatened by these adjustments.

M03 straddled Kellogg Rd., starting below powerlines downstream from the road and extending upstream to the confluence with T1. M03 had two sections, a downstream portion (M03-1) characterized by a B-type stream with steep bedrock controlled ledges and low sinuosity and a C-type upstream portion (M03-2) with more floodplain access, more sinuosity and no grade controls. The bedrock in M03-1 prevented downward incision. High flows spread across a widened stream channel, which remained largely dry during low flow periods. However, obvious signs of active widening, such as leaning trees, were absent. M03-2 was designated a sub-reach, because the minimal entrenchment and gentle slope did not reflect the B reference type. Debris jams and steep riffles indicated some aggradation may be occurring, potentially leading to future planform adjustments. There was no human infrastructure in this segment that would be threatened by such adjustments.

M05 was divided into two sections with the St. Albans waste water treatment facility (WWTF) near the boundary. Downstream of the WWTF (M05A) a deep channel wound through wetlands; low banks meant good access to the floodplain during high flows thus a high width to depth ratio and a C-type stream just as in the reference condition. M05A was one of the few reaches where sediment storage can easily occur. This segment was further characterized by old beaver ponds, riffle dunes, and sandy substrate. The wetlands and beaver ponds have the potential to mitigate many of the effects of the upstream inputs from urbanized portions of the watershed. However, any additional flooding in this area would threaten the WWTF.

M05B passed through the most heavily urbanized portion of the watershed. This segment of Steven's Brook was entirely straightened and was crossed by numerous bridges and culverts;

upstream scour and deposition were often noted in the vicinity of bridges. The increased slope caused by channelization has led to channel incision, a decrease in the width to depth ratio, and a stream-type departure from C to E. The bed of the stream was principally sand with some larger materials further upstream. In places where debris in the channel impeded water flow, sand accumulated quickly creating nascent meanders. One example was downstream of LaSalle St. where branches from stream-side cedar trees collected sediment, creating a side bar that diverted current against the right hand bank. Sediment accumulation had also led to blockage of culverts at Newton Ave. The origin of the sediment was unclear since there is little bank erosion in this reach. Two candidates were road sanding and erosion of bed material.

Heavy investment in infrastructure in the riparian zone of this segment of M05 and the entrenchment of the river system limited opportunities for meaningful attempts to manage the geomorphology of the stream. Areas where some semblance of riparian connection remained, such as the rail yard, were listed as impaired due to contamination of soils. There was a small area of potential floodplain connection in a private back yard downstream from LaSalle Street.

During high flows, water is diverted from the upper portions of M05 into Rugg Brook at the diversion structure. The diversion of flows, potentially affects all reaches downstream of M05, and reaches in Rugg downstream of the diversion structure outlet. The area in the immediate vicinity of the diversion structure had potential to act as a wetland and absorb and hold high flows thus providing for base flows between storms.

M06 extended from the confluence with Grice Brook to just below Main Street. This had been an area of extensive interest due to flooding. In the absence of human influence, this stream segment would likely be very active as it sits at the base of a steep rise, and thus could be characterized as an alluvial fan. The upper portion of the reach was dominated by a floodwall and earthen berm which forced the stream channel to make an abrupt turn. The area behind the floodwall and berm was below flood-prone depth, and the base of the floodwall was severely scoured in places. The geologic and topographic constraints of this area made the floodwall and berm at best a temporary solution to flooding issues. Flooding in the area behind the floodwall and berm should be expected during higher flows. The Phase II assessment suggested that M06 still retains its reference c-typing, at least downstream from the floodwall and berm.

There was a possibility that during precipitation events some water utilized the streets as a channel, avoiding M06, and thus bypassing the diversion structure. Sheet flow across Main St. and down Weldon St. was observed on one day during this project. The sheet flow may have reentered Steven's Brook along Weldon St. or it may have entered the storm sewer system and been discharged at the Weldon St. bridge into M05B. This possibility must be acknowledged when considering modifications of the diversion structure.

M07, which extended upstream from Main St. to Lincoln Ave., was a B-type step-pool stream in a steep valley. Large bed materials limited the ability of the stream to cut downward and leaning trees indicated that some widening was occurring. From reach M07 upstream through M08 and to a lesser extent in M09 instances of residents dumping lawn clippings and debris into the stream became prolific. Lawn clippings in particular likely contributed to high phosphorus loading of downstream areas (Waschbusch et al.1999). Lawn clippings contain about 0.13 pounds of phosphate per 1000 ft^2 during the growing season (Spetzman et al. 2004). In addition to lawn debris there was also sofas, lawnmowers, and assorted garbage throughout M07 and M08. While none of these influenced the geomorphic condition of the stream, it was aesthetically unpleasant.

M08 is similar to M07 except that the valley was not as deep and the step-pool structure was defined by bedrock ledges. Bedrock prevented vertical migration of the stream channel. The channel width on M08-1 was greater than predicted by the Phase I analysis leading to a stream-type departure from A to F. The departure may have been due to stream widening, or perhaps because the coarse resolution of the remotely sensed data led to under prediction in Phase I. Despite the bedrock, the dominant bed material was gravel which led to the determination that M08-1 was both a source of fine sediment and a transporter. The upstream-most portion of the reach (M08-2), downstream of Barlow St. to the first ledge, was broken out as a sub-reach, because its gentle slope relative to the rest of the reach. The cross section suggested an E-type stream. This area represented one of the few opportunities within the city where the brook retained some good riparian access.

M09 extended from Barlow St. to Fairfax St. The downstream-most portion (M09A) was heavily modified with rip-rap and floodwalls dominating both sides of the stream from Barlow St. to upstream of Quentin Court. Our cross section suggested this segment has maintained its B-type. There is some floodplain connection in this section. Under low water conditions, water flowed underneath the Barlow St. culvert rather than through it. There were numerous drains in the floodwall upstream of Quentin Court that may originate at local residences. We observed repeated discharge from one such drain on the left bank during a time with no precipitation.

Incision along M09B had lead to a departure from its reference stream type of B to a current stream type of F, meaning it has become more entrenched. Typically, following incision a stream will begin to widen, accompanied by profound physical adjustments upstream and downstream (VTDEC 2005). This reach begins upstream of the floodwall near Quentin Court, where the stream made an abrupt turn. At this turn there was an accumulation of large bed material which may promote widening. Already, water flow behind the left bank floodwall had carved a deep scour hole. Upstream of this point, large slugs of sediment were found at various spots suggesting current aggradation. Two headcuts, areas of active incision, were noted on the reach sketch. Sediment generated at these headcuts is likely to be deposited downstream of the reach. There were areas of good riparian access which may be important if the stream begins to undergo planform adjustments.

The first reach of tributary one (T1.01) also underwent Phase II assessment. This segment began at the confluence with the main stem, crossed Jewett Ave., and ended just upstream of Route 7. This segment did not fit its Phase I reference type of B-step-pool, but there were insufficient indication of a stream type departure. It was determined that the appropriate stream type was a C. There was extensive bank undercutting at high flows indicating some widening and planform adjustments may be occurring. The culvert at Jewett Ave. appeared to be seriously undersized, and a large pool had been scoured downstream of that road crossing. The culvert itself hung 0.4 feet above the water surface at the time of the survey.

Stream reaches in Stevens Brook were active, with most of those assessed incising. On-going incision could result in sections of the stream losing access to their floodplain. If this happens the stream would begin to widen leading to loss of property, further stream instability, and erosion. In the Rapid Geomorphic Assessment most reaches were rated “fair” while reach M03-1 and -2 and T1.01 were “good” (Table 3). Reach M09A and B had the lowest overall score, due to historic and active degradation (both) and aggradation (M09B). Reaches M03-1 and -2 were undergoing only minimal channel adjustment. In M03-1 bedrock prevented incision. Reaches M05B through M09A were incising. Reaches M02C was undergoing planform adjustments as indicated by the presence of avulsions. Reaches M09B and T1.01 were currently widening and aggrading.

Sensitivity, the likelihood that a segment would respond to watershed or local disturbance or stressors (VTDEC 2005), was determined during the Phase II analysis (Table 3). Sensitivity of assessed segments ranged from moderate (M03-1) to extreme (M09B) but most were assessed as highly or very highly sensitive. M03-1 was in good geomorphic condition and its bedrock control and valley setting likely limited response to watershed scale stressors. M09B had undergone a stream type departure. Reaches M07 and M08-1 were located in confined valleys, thus sensitivity was categorized only as high, despite relatively low rapid geomorphic assessment scores.

In the Rapid Habitat Assessment, four segments were assessed as good, seven as fair, and two as poor (Table 3). Segment M03-1 offered the best habitat, with reference epifaunal substrate, embeddedness, riffle/step frequency, bank stability, bank vegetative protection, and minimal channel alteration. Reach M05B offered the worst habitat, with poor epifaunal substrate, pool variability, channel flow status, channel sinuosity, extensive sediment deposition, and extensive channel alteration.

The more detailed analysis provided by the Phase II assessment forced reconsideration of sediment transport regimes on many segments. In some cases adjustment processes changed the sediment regime. Phase I analysis had suggested M02 would allow fine deposition; while this suggestion held in M02A, in M02B and C, extensive erosion suggested that these segments would be sources of fine sediment instead. Armoring along segment M08B limited its ability to generate sediment as predicted. A stream type departure in M09B led to more aggradation than was predicted in Phase I. In other cases natural differences in stream type between Phase I and Phase II altered the predicted regime. Phase I predicted M03 was a confined reach that would transport sediment and act as a source; this was true for M03A, but M03B with its gentler slope appeared to be in equilibrium, perhaps even acting as an area of fine deposition. The wetlands along M05A also likely provided fine deposition, rather than the being a sediment source and transporter as predicted.

Phase I Rugg Brook

Rugg Brook drained about 6 mi^2 of mostly flat terrain in the southern part of the St. Albans Bay watershed. Extensive conversion of land from agriculture to residential uses had occurred in the watershed in recent years. Rugg Brook flowed into Mill River in Georgia before reaching the Bay. The Brook originated on Bellvue Hill southeast of St. Albans City. Eleven reaches were identified along the main stem. The diversion structure, which shunts water from Stevens Brook to Rugg Brook during high flows, discharges to reach M07, increasing the volume of storm flows for all reaches downstream. Reach M06 receives drainage from the St. Albans industrial park and Nason Drive, while M01 through M05 drained principally agricultural land. Reaches M07 through M09 passed through the most heavily developed portion of the watershed. Reach M10 ran from Quentin Court nearly to Rt. 104 and M11 was located between Rt. 104 and I-89. A single tributary with three reaches that flowed off St. Albans Hill and joined Rugg Brook just upstream of Fairfield Street was also analyzed.

The reference stream type for all but one reach was C or B - moderately to slightly entrenched with moderate width to depth ratios and gentle to moderate slopes. The single exception was T1.03

which was an A type – entrenched and steep sloped (Table 4). Elevations in the watershed ranged from 205 feet to 1320 feet; however the highest elevation west of I-89, the bulk of the watershed was 730 feet. The predominate geological parent materials were glacial till and alluvium.

Impact scores ranged from three (M03) to 21 (M07) (Table 4). The healthiest reach appeared to be M03 with impacts only from a high percentage of cropland and developed land in the watershed and a moderately high meander width ratio. M03, located upstream of Mill River Road has portions that are more heavily wooded than anywhere else in the watershed. M07 had high impacts from land-use, in-stream modification, channel modification, and conditions of the bed and bank. Over 64% of M07 has been straightened; the reach receives discharge from the diversion structure; and it passes through the most densely settled portion of the watershed.

The Phase I analysis provided an opportunity for a preliminary estimate of the sediment dynamics of Rugg Brook. The lower portions (reaches M01 to M06) were expected to transport, store and generate coarse sediments in equilibrium, and store fine sediments in the floodplains along these reaches. This expectation was based on a Phase I reference stream type of C and an absence of significant channel straightening. All other reaches in the watershed were expected to generate and transport sediment. For most, this was because of their slope, but historic straightening of reaches M07, M10, and T1.02 increased their likelihood of transporting sediment. However, Phase II analysis forced revised consideration of sediment dynamics for reaches M05, M06, and M08.

Phase II Rugg Brook

Phase II assessments were conducted on Rugg Brook on reaches M05 through M08. Assessments included the two reaches immediately downstream of the diversion structure (M05 and M06) and upstream to Fairfield St. Downstream of the diversion structure high flows have been augmented by additional water from Stevens Brook. Impacts on the assessed reaches from erosion and straightening were extensive (Figure 3)

By reference, M05 is a C type stream however degradation has decreased the width to depth ratio creating an E stream. The reach is surrounded by agricultural land. The downstream portion of the reach (M05A) was extensively straightened. Though rip-rap covered much of the banks it was overgrown and sometimes falling into the stream channel. The bed was characterized by dune ripples with sand comprising nearly half of the substrate. At fairly regular intervals, banks slumps had fallen into the channel splitting flow. The upstream portion of the reach (M05B), upstream of the gas line crossing, was very sinuous and entrenched. Extensive erosion could be seen at each meander bend and substantial bank slumps had fallen into the channel.

M06A, the downstream portion of M06, closely resembled M05B – deeply entrenched, sinuous, sandy substrate, failing banks, and erosion at meander bends. However this segment was more deeply entrenched and the stream had departed from a reference C condition to a G. In the future the stream would be expected to continue adjusting until it had established a new floodplain at a lower elevation. Indeed, the stream channel was very active and changes in meander bends could be detected between 2003 aerial photos and the time of the field work. This area and M05B have been targeted for a floodplain reconstruction project.

M06B, the upstream portion of M06, has also undergone a stream type departure, this one from C to F. It was less entrenched than M06A, but more entrenched than reference. It was also shallower than M06A. Similar to M06A the segment would be expected to continue adjusting until a new equilibrium had established, and this segment did have a number of recent avulsions. Roots of willow trees restrained migration of the head-cuts created by avulsions, at least temporarily; however the headcuts reflected instability in this portion of the stream. Where M06A approached Nason St. near the intersection with Green Mtn. Drive the brook had begun to erode the valley wall threatening to undermine the road base.

Reach M07 was divided into three segments. M07A, the most downstream segment, passed through a narrow valley and received input from the diversion structure. The setting and cross-section data suggested the reference condition for M07A was B type, rather than the original C therefore it was broken out as a separate sub-reach. A number of houses are perched atop the valley wall. Downstream of Crosby Drive the stream had recently moved creating an island and a large scour pool. M07B began upstream of Crosby Drive and had been extensively straightened within the last twenty years. The stream was attempting to regain some of its floodplain by widening and there were numerous bank slumps in the channel. Degradation in this section produced a G type stream from what had been a C stream. However, anecdotal evidence gathered after the field season suggested that the bank full depth of the stream in this section may have been underestimated and therefore the cross section and stream typing should be field checked. M07B ended at the railroad culvert where a deep pool had been established and the culvert now hangs two feet over the water surface.

The upstream segment (M07C) extended from the railroad culvert to South Main St. Again, degradation had created a G type stream from what under reference conditions was a C, setting up an expectation of future channel adjustments in the area. The lower portion of the section was entrenched and straightened. A 360’ floodwall confined the stream along the right bank, however there was no significant human infrastructure in the floodplain. Therefore, this stretch presented some opportunities for active and/or passive channel restoration. The stream flowed through a narrower valley with a more wooded riparian buffer upstream of an architecturally intriguing stone arch that spanned the brook.

Reach M08 extended from Main Street to a point upstream of the confluence with an unnamed tributary. M08 was divided into two segments; the downstream segment (M08A) meandered through an undeveloped floodplain and the upstream segment (M08B) consisted of step-pools alternating with incised plane-bed streams. Generally the brook had good floodplain access except around Fairfax Street. Such access should be maintained. Both segments of M08 had capacity for sediment storage, however M08A was very active with a head cut just upstream from Main St. and numerous flood chutes and meanders. Some project to address the head cut may be warranted. Challenges with identifying bank full along M08 led to cross-sections that should be field checked.

There were some potential problems at road crossings along reach M08. At South Main St., bank slumping on the upstream side, particularly on the right bank, partially blocked the culvert. Meander migrations in the area of Twin Courts had undermined the road there. At Fairfax St., the stream mades two sharp turns on the upstream side before entering the culvert, resulting in scour at the base of the right bank footer.

Assessed reaches in Rugg Brook were perhaps even more active than those in Stevens Brook. In the Rapid Geomorphic Assessment, all segments were rated as "fair" except M05B which was "poor" (Table 5). Segments M05A and B, M06A and B, and M07C had undergone extensive incision. Additionally, the avulsions on M06B indicated planform adjustments were occurring. M07A and M08B were aggrading, while M07B was beginning to widen. M08A was undergoing planform adjustments, though the presence of a headcut indicated incision was also occurring.

The activity of the reaches led to more designations of extremely sensitive segments than in Stevens Brook (Table 5). Segments M06A, M06B, M07B, and M07C had all undergone stream type departures and were categorized as extremely sensitive. Reach was considered highly sensitive because it was confined within a narrow valley, thus limiting its ability to adjust. All other reaches were assessed as very highly sensitive.

In the Rapid Habitat Assessment (RHA), one segment was assessed as good and the other eight were fair (Table 5). M08A was the one good segment, barely earning that designation with an RHA score of 0.645. M08A had reference conditions for epifaunal substrate and left bank vegetative cover; all other parameters were rated good. M05B had the lowest RHA score at 0.345, barely entering the fair category. M05B had poor right bank stability and good scores in the channel alteration parameter; otherwise, all scores were fair.

On three segments the Phase II analysis forced reconsideration of sediment transport regimes suggested in the Phase I analysis. Reaches M05 and M06 were initially considered in equilibrium but it became clear during the Phase II analysis that instead these reaches were sediment sources. The sediment came from the extensive erosion and deep incision, both caused by inputs of additional water through the diversion structure. Phase I analysis suggested M08 would be a sediment source, however the absence of erosion or bank armoring, a low incision ratio, and a change is assessed stream type from B to C (M08A) and E (M08B) suggest instead that the stream is in equilibrium. This initial determination must however be tempered by recognition that the cross sections on M08 need to be field checked and there is an active head-cut in M08A.

Conclusion

Many of the challenges faced in managing Stevens, Rugg, and Jewett Brooks came from systemic conditions in the watershed. The original forested land-cover has been replaced by an agricultural and urban landscape. The agricultural lands often have narrow stream buffers and cropland that can be quite erosive. Storm flows coming from the urbanized land have likely led to incision in various reaches, while infrastructure investments limit the streams ability to widen. Large portions of the stream system have been straightened in both agricultural and urbanized portions of the watershed. The inter-basin transfer of water from Stevens to Rugg Brook during high flows has caused extensive incision in Rugg Brook (M05 and M06) and may have intensified aggradation in Stevens Brook (M05B).

These systemic changes, in concert with other localized changes, have reduced the sediment storage capacity of the stream system, while in increasing its sediment generation capacity. Straightening and the increased volume of storm flow have increased the power of the streams and thus their ability to transport sediment. Armoring of stream banks, particularly in sections of St. Albans City, and incision and entrenchment of numerous reaches have further augmented transport capacity.

Erosion of bed and bank, application of winter sand, and loss of soils from croplands were factors that increased the streams' sediment loads.

Therefore, increasing the sediment storage capacity of Stevens, Rugg, and Jewett Brooks is at least as important as reducing sediment generation in maintaining and improving water quality in St. Albans Bay.

References

Hegman, W., D. Wang, and C. Borer. (1999). Estimation of Lake Champlain basinwide nonpoint source phosphorus export. Lake Champlain Basin Program Technical Report No. 31. Grand Isle, VT.

Martin, S.C., R.J. Ciotola, P. Malla, N.G. Subramanyaraje Urs, and P.B. Kotwal (1994). Assessment of sediment phosphorus distribution and long-term recycling in St. Albans Bay, Lake Champlain. Lake Champlain Basin Program Technical Report No. 7C. Grand Isle, VT.

Spetzman, J., G. Black, C. Hetzel, K. McDonald, S. Heiskary, B. Horgan, B. Mugass, C. Rosen, and R. Struss (2004). Phosphorus in lawns, landscapes, and lakes. Minnesota Department of Agriculture. http://www.mda.state.mn.us/appd/ace/phosphorusguide.pdf
Accessed 2/28/06.

VTDEC (2001). Fluvial geomorphology: A foundation for watershed protection, management and restoration. http://www.vtwaterquality.org/rivers/docs/rv_fluvialgeomorph.pdf Accessed 12/22/05.

VTDEC (2004 a). Watershed Assessment Using Maps, Existing Data and Windshield Surveys. Vermont Agency of Natural Resources: Waterbury, VT.

VTDEC (2004 b). 303d list of waters. Approved by USEPA 7/19/04. VTDEC, Waterbury, VT.

VTDEC (2005). Vermont stream geomorphic assessment Phase 2 handbook: Rapid stream assessment field protocols. www.vtwaterquality.org/rivers.htm

Waschbusch, R.J., W.R. Selbig, and R.T. Bannerman (1999). Sources of phosphorus in stormwater and street dirt from two urban residential basins in Madison, Wisconsin, 1994-95. U.S. Geological Survey Water Resources Investigations Report 99-4021.

Tables and Figures

Figure 1: Location of study watersheds within Vermont.

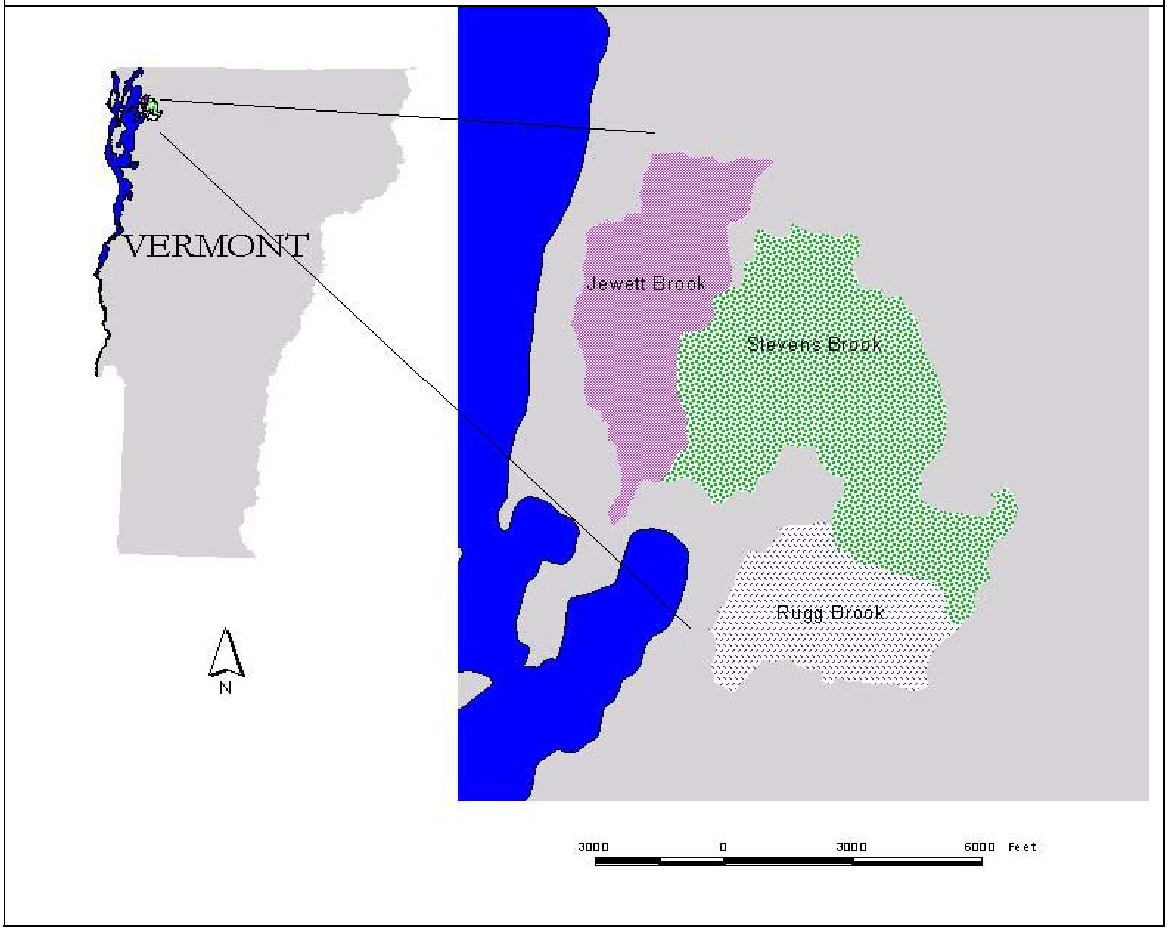

Figure 2: Impacts on the portion of Stevens Brook within St. Albans City identified during Phase I and Phase II assessments.

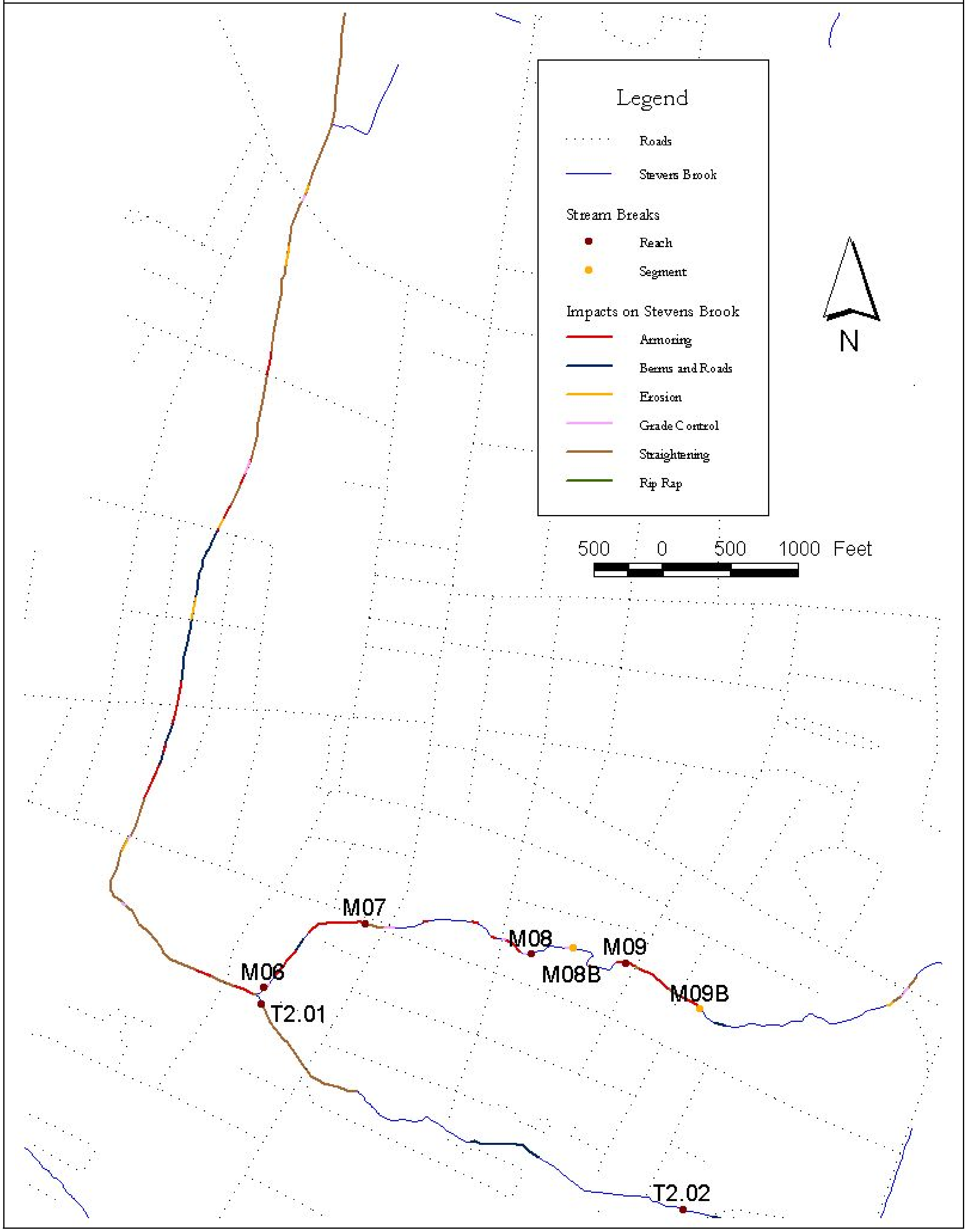

Figure 3: Impacts on Rugg Brook identified during Phase I and II assessments.

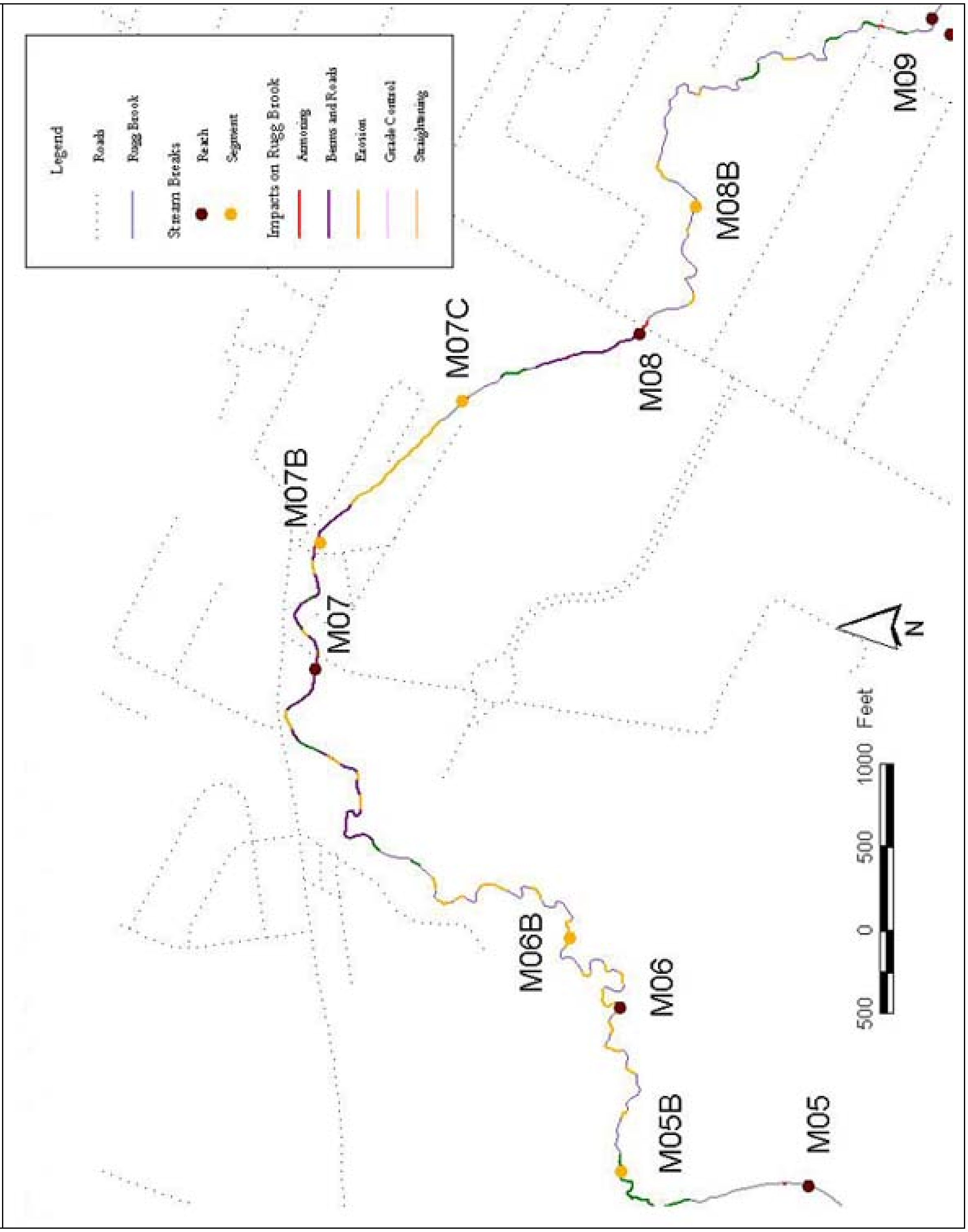

Table 1: Jewett Brook downstream to upstream impact scores from Phase I assessment. NE=not evaluated

		Stream Type				**Step 4**	**Step 5**	**Step 6**	**Step 7**
						Land	**Instream**	**Floodplain**	**Bed & Bank**
		Stream	**Bed**		**Total**	**Use**	**Modification**	**Modification**	**Survey**
Reach	**Stream**	**Type**	**Material**	**Bedform**	**(of 32)**	**(of 6)**	**(of 10)**	**(of 12)**	**(of 4)**
M01	Jewett Bk.	C	NE	Riffle-Pool	6	2	0	4	0
M02	Jewett Bk.	C	Cobble	Plane Bed	8	3	4	1	0
M03	Jewett Bk.	C	NE	Riffle-Pool	10	5	2	3	0
M04	Jewett Bk.	C	Sand	Riffle-Pool	12	4	1	6	1
M05	Jewett Bk.	C	Sand	Riffle-Pool	16	6	3	5	2
M06	Jewett Bk.	C	Sand	Riffle-Pool	13	6	3	4	0
Total Scores					65	26	13	23	3
Percent of Each Impact Category						40.0 %	20.0 %	35.4 %	4.6 %

Table 2: Stevens Brook downstream to upstream impact scores from Phase I assessment. NE = not evaluated

		Stream Type				**Step 4**	**Step 5**	**Step 6**	**Step 7**
						Land	**Instream**	**Floodplain**	**Bed & Bank**
		Stream	**Bed**		**Total**	**Use**	**Modification**	**Modification**	**Survey**
Reach	**Stream**	**Type**	**Material**	**Bedform**	**(of 32)**	**(of 6)**	**(of 10)**	**(of 12)**	**(of 4)**
M01	Stevens Bk	E		Dune-Ripple	5	2	2	1	0
M02	Stevens Bk	E	Sand	Dune-Ripple	16	6	2	6	2
M03	Stevens Bk	B	Gravel	Step-Pool	8	4	2	2	0
M04	Stevens Bk	C	Gravel	Riffle-Pool	4	2	0	2	0
M05	Stevens Bk	C	Sand	Dune-Ripple	19	5	6	7	1
M06	Stevens Bk	C	Gravel	Riffle-Pool	16	5	3	7	1
M07	Stevens Bk	B	Gravel	Step-Pool	12	5	3	2	2
M08	Stevens Bk	A	Gravel	Step-Pool	7	5	0	2	0
M09	Stevens Bk	B	Gravel	Step-Pool	13	5	6	2	0
M10	Stevens Bk	C	NE	Riffle-Pool	16	5	4	7	0
M11	Stevens Bk	A	NE	Cascade	6	5	1	0	0
T1.01	Stevens trib	C	Gravel	Riffle-Pool	13	4	2	4	3
T1.02	Stevens trib	C	NE	Riffle-Pool	17	5	4	7	1
T1.03	Stevens trib	C	NE	Riffle-Pool	20	6	3	9	2
T1.04	Stevens trib	A	NE	Step-Pool	11	6	3	1	1
T1 S1.01	Stevens subtrib	C	NE	Riffle-Pool	14	6	3	4	1
T2.01	Grice Bk	B	NE	Step-Pool	12	6	3	3	0
T2.02	Grice Bk	C	NE	Riffle-Pool	18	6	3	8	1
T2.03	Grice Bk	A	NE	Cascade	8	5	3	0	0
Total Scores					235	93	53	74	15
Percent of Each Impact Category						39.6 %	22.6 %	31.5 %	6.4 %

Table 3: Major adjustment processes, scores and condition from Rapid Geomorphic Assessment, and stream sensitivity of Stevens Brook reaches assessed in Phase II

Reach	Seg.	Phase II Type	Departure *	Adjustment Process	Geo. Score	Geo. Condition	Sensitivity	Habitat Rating	Habitat Condition
M02	B	E5	no	Degradation	0.49	Fair	Very High	0.49	Fair
M02	C	E4	no	Planform	0.64	Fair	Very High	0.71	Good
M03	1	B4	no	In Regime	0.75	Good	Moderate	0.79	Good
M03	2	C4	no	In Regime	0.74	Good	High	0.77	Good
M05	B	E5	yes	Degradation	0.44	Fair	Very High	0.23	Poor
M06	0	C4	no	Degradation	0.60	Fair	High	0.40	Fair
M07	0	B4	no	Degradation	0.45	Fair	High	0.37	Fair
M08	1	F4a	yes	Degradation	0.59	Fair	High	0.52	Fair
M08	2	E4	no	Degradation	0.58	Fair	Very High	0.47	Fair
M09	A	B4	no	Degradation	0.40	Fair	High	0.35	Poor
M09	B	F4b	yes	Degradation, Aggradation & Widening	0.40	Fair	Extreme	0.67	Good
T1.01	0	C4b	no	Aggradation & Widening	0.65	Good	Very High	0.60	Fair

* For reference stream type refer to Table 2

Table 4: Rugg Brook downstream to upstream impact scores from Phase I assessment. NE = not evaluated

		Stream Type				Step 4	Step 5	Step 6	Step 7
						Land	Instream	Floodplain	Bed & Bank
		Stream	Bed		Total	Use	Modification	Modification	Survey
Reach	Stream	Type	Material	Bedform	*(of 32)*	*(of 6)*	*(of 10)*	*(of 12)*	*(of 4)*
M01	Rugg Bk.	C	NE	Riffle-Pool	9	5	0	4	0
M02	Rugg Bk	C	NE	Riffle-Pool	8	4	1	2	1
M03	Rugg Bk	C	NE	Riffle-Pool	3	2	0	1	0
M04	Rugg Bk	C	NE	Riffle-Pool	7	3	2	2	0
M05	Rugg Bk	C	Sand	Dune-Ripple	20	6	3	8	3
M06	Rugg Bk	C	Gravel	Riffle-Pool	15	6	1	5	3
M07	Rugg Bk	C	Gravel	Riffle-Pool	21	6	4	9	2
M08	Rugg Bk	B	Gravel	Plane Bed	10	4	2	3	1
M09	Rugg Bk	B	Gravel	Riffle-Pool	11	4	3	4	0
M10	Rugg Bk	C	Gravel	Riffle-Pool	13	6	3	4	0
M11	Rugg Bk	B	Gravel	Riffle-Pool	16	6	4	5	1
T1.01	Rugg trib	B	NE	Plane Bed	8	6	2	0	0
T1.02	Rugg trib	C	NE	Riffle-Pool	13	6	3	4	0
T1.03	Rugg trib	A	NE	Step-Pool	6	3	3	0	0
Total Scores					160	67	31	51	11
Percent of Each Impact Category						41.9 %	19.4 %	31.9 %	6.9 %

Table 5: Major adjustment processes, scores and condition from Rapid Geomorphic Assessment, and stream sensitivity of Rugg Brook reaches assessed in Phase II

Reach	Seg.	Phase II Type	Departure *	Adjustment Process	Geo. Score	Geo. Condition	Sensitivity	Habitat Rating	Habitat Condition
M05	A	E4	yes	Degradation	0.48	Fair	Very High	0.36	Fair
M05	B	E4	yes	Degradation	0.33	Poor	Very High	0.40	Fair
M06	A	G4c	yes	Degradation	0.36	Fair	Extreme	0.45	Fair
M06	B	F4	yes	Degradation & Planform	0.41	Fair	Extreme	0.54	Fair
M07	A	B4c	no	Aggradation	0.45	Fair	High	0.44	Fair
M07	B	G4c †	yes	Widening	0.49	Fair	Extreme	0.37	Fair
M07	C	G4c	yes	Degradation	0.51	Fair	Extreme	0.58	Fair
M08	A	C4 †	no	Degradation & Planform	0.63	Fair	Very High	0.65	Good
M08	B	E4 †	no	Aggradation	0.64	Fair	High	0.64	Fair

* For reference stream type refer to Table 4

† Phase II types need to be field checked – inconsistencies between measurements and other observations of stream type