APPENDIX G

Reach Narratives

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G.1 Lewis Creek Main Stem

M23

M23 was originally assessed in 2002 by a team of VTDEC River Management Section staff and Lewis Creek volunteers. In December 2008, these data were updated to 2007 protocols relying in part on 2002 observations, as well as limited field observations and repeat cross sections completed in July of 2008.

Within this reach, Lewis Creek transitions from the Green Mountains out into the broad alluvial valley that parallels Route 116. The reach was classified as an "alluvial fan" to mark the notable change in channel gradient that occurs (from 3.95 % in M24, to 2.6% in M23, to 0.77% in reach M22) and a transitional state of valley confinement (from Semi-confined in upstream reaches to Very Broad in M22). The channel in M23 is generally bound along the RB by steep slopes of glacial till overlying bedrock. Frequently along the LB, and occasionally along the RB, the channel is closely confined by (entrenched below) terraces of glaciofluvial sediments (as mapped by USDA). Without conducting more detailed surficial geologic mapping, it is not possible to determine the origin of these terraces (depositional or erosional) or whether the Lewis Creek may have incised below these terraces in recent times (last 300 years) or in post-glacial times (1000s of years before present) – or both. The terraces range in height from approximately 8 feet to 4 feet (or 4 to 2 times the thalweg depth); terrace height generally decreases with distance downstream. Based on sediments revealed in the eroding streambanks, these terraces are comprised of unconsolidated, erodible materials. Therefore, in a conservative approach, the Phase 1 reference valley wall was mapped beyond these terraces at the approximate contact of the glaciofluvial and glacial till sediments, such that the "floodplain" of the channel is inclusive of these terraces (though it is likely that flood stages will rarely overtop these terraces except perhaps in the case of a significant debris jam). Using the mapped Phase 1 valley walls (see Figure G-1), valley confinement varies from Semi-Confined to Very Broad, with an average Broad confinement. This suggests a reference C stream type.

In reach M23, the Lewis Creek channel flows through coarse boulders and cobbles likely derived from glacial kame terraces which are mapped at this position along the eastern valley margin (Calkin, 1965). Based on pebble counts completed in the reach, it is likely that the coarser fractions encountered (perhaps up to 20% of the bedload) are larger than the bankfull-flow threshold grain size. Bedrock forms the left valley wall in a few locations mid-reach. No vertical bedrock grade controls were observed within the reach; however, channel-spanning bedrock is present immediately upstream at the reach break for M24.

The channel appears to have a similar planform on aerial photographs from 1962 and 1974. Ireland Road (gravel) encroaches along the LB for a majority of the reach. In some locations it appears to be at the same elevation as the terrace upon which it is positioned (which itself is most often above the FPW elevation). In other locations, Ireland Road appears to be elevated on fill material above the terrace surface. Encroachment of this road along LB has resulted in a human-caused change in valley width (Step 1.5 of the protocols) from average Broad confinement to average Narrow confinement; however, the status of the valley setting (Unconfined) remains unchanged. Several culverts and turnouts from ditches along this road direct stormwater and road sediment directly to the channel. A "delta" of sediment was observed in July 2008 at the confluence of a LB tributary near the upstream end of the reach - this tributary crosses Ireland Road and receives runoff from road ditches. The Beers Atlas (1871) depicts an impoundment near the intersection of Ireland Road with Meehan Road at the mid-point of the reach (a possible former mill pond). Occasional residential buildings are located

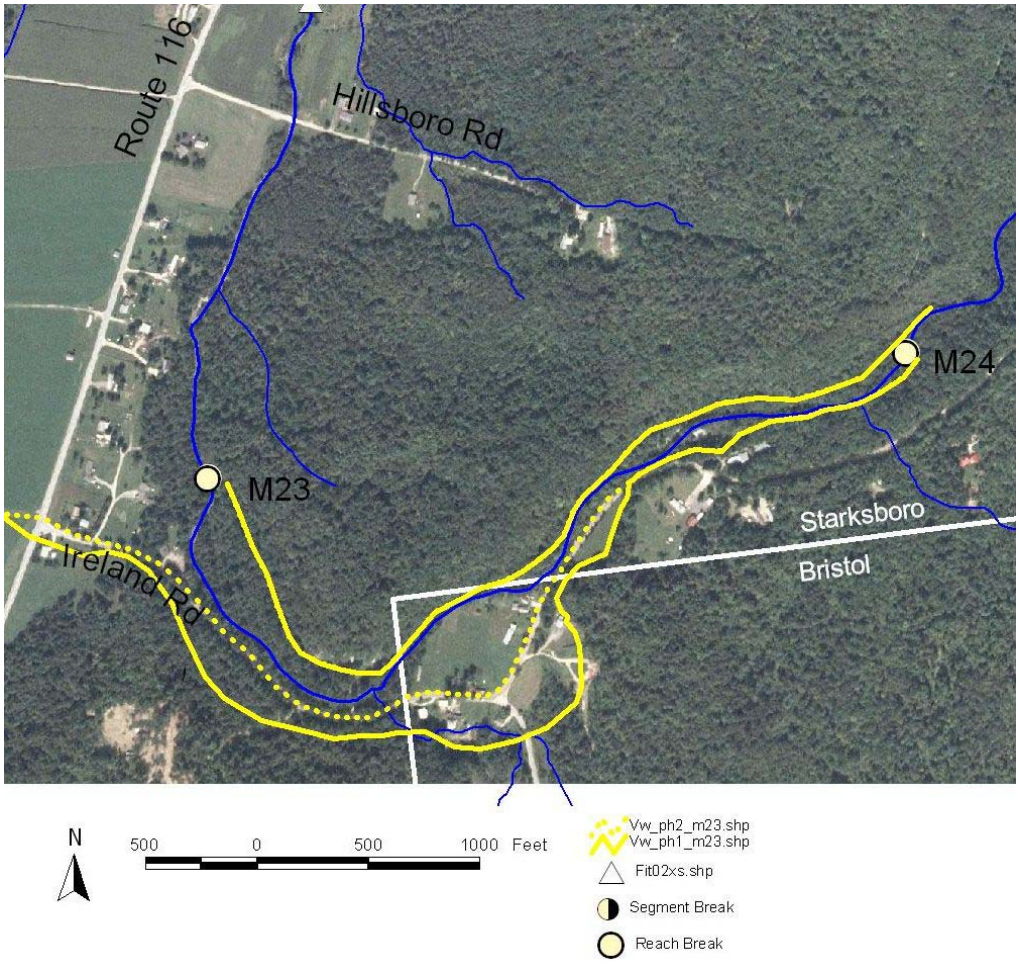


Figure G-1. Reach M23, Lewis Creek, town of Starksboro (and Bristol), VT

along the left and right banks. Rip-rap armoring protects LB house near upstream end of reach. A bankfull-constricting private bridge crosses the channel in the downstream half; just downstream of this structure is a vehicle ford. Cobble/gravel/earthen berms are present along the LB in vicinity of these crossings at a thalweg height of approximately 7 feet (or approximately 3 times the average measured bankfull thalweg).

Two representative cross sections completed in the reach indicated historic incision (IR_{RAF} = 2.3 in upstream half; IR_{RAF} = 3.95 in downstream half), and a vertical stream type departure (from Cb to Fb). It is likely that some (perhaps most) of this vertical separation of the channel from the surrounding abandoned floodplain is a result of post-glacial incision, rather than historic incision (colonial era). If a historic dam existed near the mill pond at the mid-point of the reach as indicated on the Beers Atlas, it is possible that "hungry water" effects or periodic channel management may have contributed to historic incision in the reach. Reported channelization, dredging and berming in downstream reach M22, may also have contributed to historic incision at the downstream end of reach M23. Near its upstream end, the LB berm is elevated above the LB terrace, whereas near its downstream end, the top of the berm is slightly below the terrace (see cross section XS-1). Ireland Road in this location is elevated above the terrace (RAF), thus reducing the valley width to a degree.

Dominant adjustment processes within the reach include moderate aggradation (few diagonal bars) and localized widening (at debris jams, or above boulder grade controls). Boulders and cobbles in the channel margins (likely of kame terrace origin) may offer boundary resistance that has moderated channel adjustments overall. Nevertheless the incised and entrenched reach remains susceptible to catastrophic erosion during flood events. There is a short section of step-pool bedform in the middle of the reach, and some weak riffle/pool form in the upstream end of reach; overall, a plane-bed form dominates. A "Fair" condition rating was assigned, with a sensitivity of "Extreme" due to the vertical stream type departure. A channel evolution stage of II [F] is inferred.

M22

M22 was originally assessed in August of 2002 by Lewis Creek volunteers. In the Fall of 2002, a Phase 3 assessment was completed by VTDEC on two sites within the reach (including longitudinal profile, cross sections, and pebble counts). In January 2008, these 2002 data were updated to 2007 protocols (including feature indexing) relying on the 2002 observations, and some limited 2005 observations in the area of the Meadowlark Lane bridge crossing. Updates resulted in some significant changes to RGA data since original reporting (VTDEC, 2003) and since data were last summarized in the draft 2006 River Corridor Management Plan: Reaches M19-M22. Bankfull elevations had been underestimated in some cases during the original assessment.

After transitioning out of the Green Mountains, the Lewis Creek turns northward from Ireland Road to flow through an alluvial valley along Route 116 toward Starksboro village. This is a Very Broad, unconfined setting for the Lewis Creek, which is flanked by bedrock-controlled steep valley walls on the west (Hogback Mountain) and east (East Mountain, i.e., foothills of the Green Mountains). Reach M22 is 1.5 miles in length and extends from the vicinity of Ireland Road, along the east side of this valley, crossing under Hillsboro Road; it then crosses under Route 116 to flow down the middle of the valley west of Route 116, crossing under Meadowlark Lane and ending in wetlands approximately 2,000 feet downstream of the Meadowlark Lane bridge
(Figure X-x). Sediments in this valley have a glaciolacustrine origin overlain by glaciofluvial sediments and more recent alluvium (Calkin, 1965; Stewart & MacClintock, 1969; USDA, 2007; USDA, 2006). Kame terraces of glaciofluvial origin are mapped at the western and eastern valley margins (Calkin, 1965). No bedrock grade controls were observed along the Lewis Creek channel within reach M22 (2002 assessment).

At the upper extent of reach M22, the Lewis Creek transitions from the narrower valley setting of reach M23, and flows through glacio-fluvial (kame terrace) sediments out onto the very broad alluvial valley (Calkin, 1965; Stewart & MacClintock, 1969; USDA, 2007; USDA, 2006). This transition in valley confinement is accompanied by a change in stream gradient from 3.95% in Semi-confined reach M24 and 2.64% in Narrow reach M23 to 0.77% in M22. In a broad sense, topographic contours at the downstream end of reach M23 and the upstream end of M22 suggest an alluvial fan, a feature that probably involved more active sediment deposition in earlier post-glacial environments (1,000s of years before present). A braided channel (D stream type) might be expected as the reference stream type in this setting under more intense hydrologic and sediment regimes, and prior to widespread vegetation of the landscape. This location may have seen renewed sedimentation and lateral adjustments during colonial times, during widespread deforestation of upland slopes in the 1800s. A reference stream type of C-riffle/pool is likely more appropriate under present sediment and hydrologic regimes. Similarly, the rest of reach M22 in the unconfined valley setting is inferred to have a reference C-riffle/pool stream type.

Given the highly permeable nature of the surficial deposits, the upstream portion of reach M22 is observed to dry up periodically during baseflow conditions. This condition in a "losing reach" occurs when the groundwater table drops below the elevation of the channel bed. A 2000-foot section of reach M22 spanning the Route 116 crossing was dry in late August of 2002 during the original Phase 2 assessment.

Wetlands (NWI) are mapped contiguous to the channel in localized areas downstream of Route 116. Hydric soils are also mapped in much broader areas across the valley floor (USDA, 2007; USDA, 2006). Based on positioning of crop fields, hay fields, and pasture areas, and the linear planform of tributary channels relative to mapped hydric soils, it would appear that natural wetland areas in the valley surrounding reach M22 have been previously converted to agricultural uses, as facilitated by channelization and dredging of tributary channels.

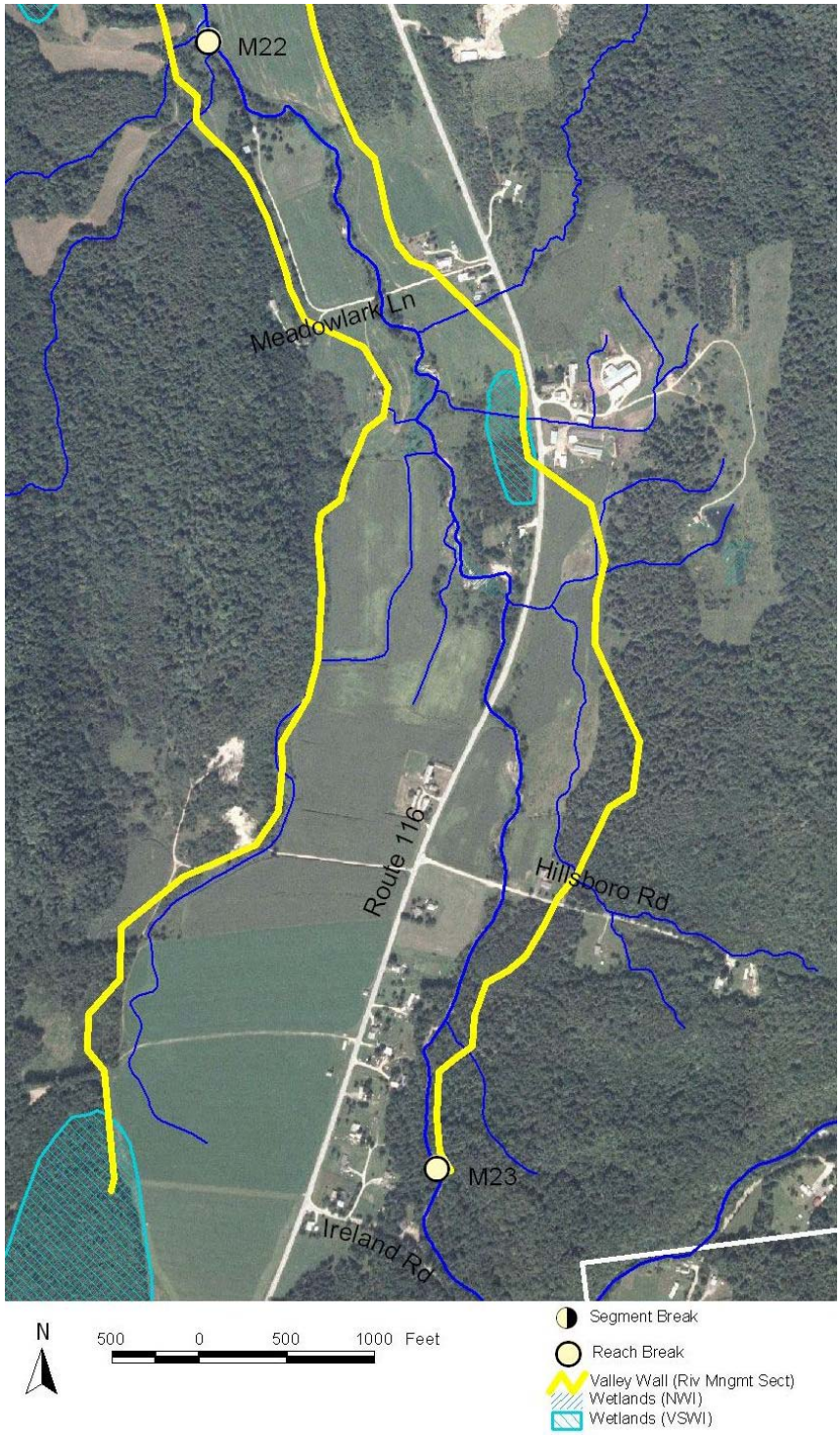


Figure G-2. Reach M22, Lewis Creek, town of Starksboro, VT.

Land uses in the valley along reach M22 are primarily low-density residential and agricultural in nature. Encroachments include:

- Route 116 – this is a State road, elevated on fill material above the floodplain; it runs parallel to the valley and reduces the floodplain width available to the channel - though not to a degree which significantly alters the entrenchment status (unconfined) or valley confinement ratio (Very Broad). Based on review of historic aerial photographs, road realignment occurred between 1942 and 1962 and increased the degree of encroachment along the channel in direct vicinity of the Route 116 bridge crossing.

- Berms –
    - Along LB upstream of Hillsboro Rd crossing to protect residences and crops;
    - Along LB downstream of Hillsboro Rd crossing to protect a crop field;
    - Along RB downstream of Route 116 crossing (i.e., fill material for Route 116);
    - Dredging spoils (unconsolidated gravel) along both banks at prominent meander bend downstream of the Route 116 crossing;
    - Along LB downstream of this meander to protect crop fields;
    - Along LB just upstream of the Meadowlark Lane bridge.

- Development (as of 2003)–
    - Three bridge crossings (bankfull constrictors);
    - A home along LB near the upstream end of the reach; and
    - A garage along LB near the downstream end of the reach.

Three bridge crossings in the reach constrict the channel to varying degrees:

- Hillsboro Rd bridge (98.6% of reference bankfull width [BFW], 103% of measured BFW)
- Vermont Route 116 bridge (80% of reference BFW, 84% of measured BFW)
- Meadow Lark Lane bridge (69% of reference BFW, 72% of measured BFW)

One ford crossing was evident near the upstream end of the reach during 2002 assessments.

Extensive historic straightening was evident from a review of 1942, 1962, 1974 and 1995 aerial photographs, especially in the upstream half of reach M22. This section is close to the point of marked slope reduction where the Lewis Creek transitions out of the Green Mountains and into the Champlain Valley.

Examples of localized dredging and berming have been reported in the vicinity of the VT Route 116 bridge crossing during realignment of this road (Hartline, 2002; Cahoon, 2005), and in the vicinity of the Meadowlark Lane bridge following a debris-induced washout in a 1980s Summer flood (Wagner, 2002). An example of recent channel management was observed during field assessments in October of 2002 at the prominent meander bend downstream of the Route 116 crossing.

Phase 3 data including longitudinal profiles, cross sections, and pebble counts were collected by the VTDEC River Management Section at two sites along reach M22 in October of 2002 - one upstream of the Route 116 crossing (LP-M22B) and one downstream of the bridge (LP-M22A) (see Figure G-3). Three riffle cross sections from these Phase 3 surveys were selected to characterize the reach for this Phase 2 assessment, along with one additional cross section performed in October of 2005 near the downstream end of the reach. Two of these four cross sections are considered representative of reach conditions overall; and two demonstrate channel dimensions at sites of localized planform adjustment (meander extension and translation). All four cross sections confirm a gravel-dominated C-riffle/pool stream type, consistent with the reference stream type. Pebble counts performed at these cross section sites indicate a fining-downstream pattern of riffle substrates. Approximately 90% of the sediments at riffles in cross sections upstream of the Route 116 bridge are mobile in the predicted bankfull event; while downstream

of the Route 116 crossing, all sediments in the bed are predicted to be mobile at the bankfull stage (and in higher flood stages).

Based on Phase 3 cross section measurements, as well as other cross sections completed in the reach for the Phase 2 assessment, the channel is moderately incised below the adjacent floodplain. Incision appears to be historic in nature, given the absence of features (e.g., headcuts, rejuvenating tributaries) that would suggest active incision processes. Generally, the degree of historic incision decreases with distance downstream in the reach – from IR_{RAF} of 1.7 between Hillsboro Rd and Route 116 to IR_{RAF} of 1.3 downstream of the Meadowlark Lane crossing. Bankfull events would be contained within the banks of the channel; but moderate to high flood stages would be expected to spill over the banks, especially downstream of the Route 116 crossing.

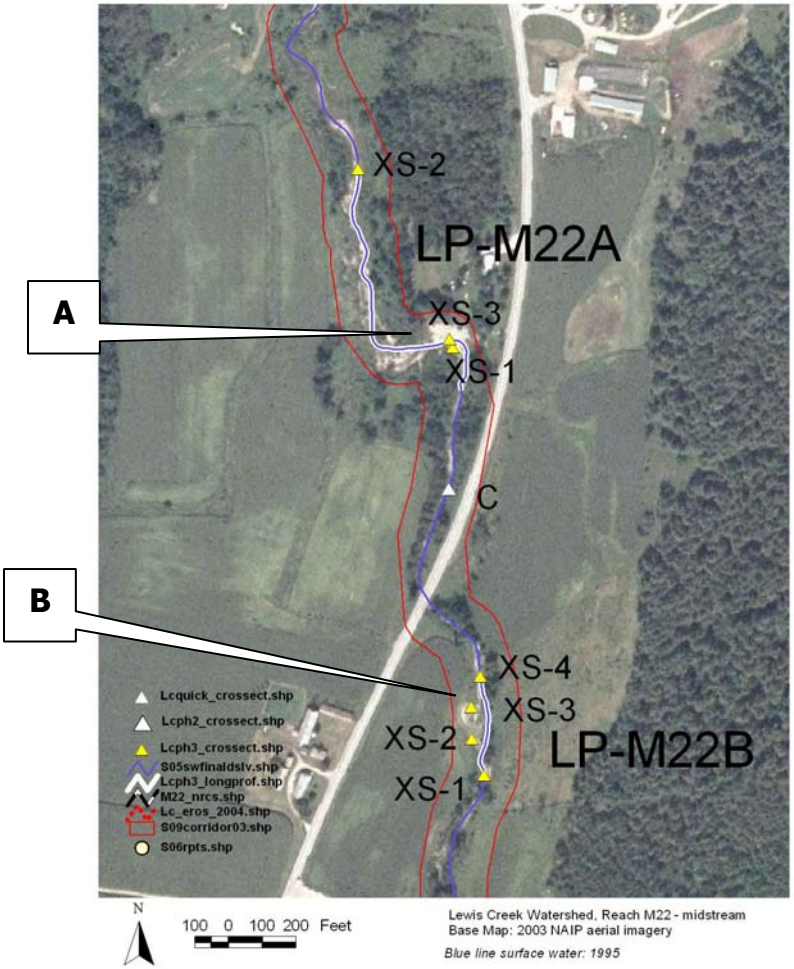


Figure G-3. Location of Phase 3 assessments, reach M22. Location of active sites of lateral adjustment (A, B).

Growing meanders along Reach M22 are at odds with cropping and pasture uses (Site B) and with Route 116, a residential lot and private driveway (Site A). (photo base dated 2003; red line is riparian corridor defined in Starksboro Valley corridor plan, 2006; blue line is position of Lewis Creek digitized from 1995 photos; flow is from south to north).

The modified (straightened, dredged, bermed) channel at the upstream end of reach M22 would be expected to have enhanced sediment transport capacity as a result of the increased slope (and increased stream power) given by historic channelization. At present, enhanced erosive energies of this segment appear to be balanced by the resisting forces of the channel margins (e.g., tree buffers, rip-rapped and bermed banks, armored cobble bed). Still, the channel remains highly susceptible to catastrophic lateral adjustments and associated fluvial erosion losses in future flood events, given its partially-incised status, unconsolidated channel sediments, the undersized bridge crossings (Hillsboro Road, VT Rt 116), and evidence of past debris jam activity.

Reach M22 appears to be undergoing significant, planform adjustments within a moderately sinuous planform as it recovers from historic channelization and encroachments. Two notable locations of active channel adjustment have developed since the late 1990s. One site (B in Figure G-3) is a meander bend which has eroded to the west through an armored streambank into the adjacent corn field just upstream of the Route 116 bridge and downstream of the Hillsboro Rd bridge (see Figure G-4). A second erosion site (A in Figure G-3) is an overwidened area where the Lewis Creek is actively depositing sediments, extending meanders to re-create sinuosity, and building a new floodplain (see Figure G-5).

Evidence of widening and aggradation elsewhere within the reach appears localized to intact and breached beaver dams and upstream of bendways. Typically, the beaver dams do not persist through bankfull or other flood events, but seem to exist long enough to influence sediment deposition / erosion cycles in a local area. Sediment builds up behind the dams during the summer and fall of each year. Once the dams breach, stream flow diverts around the accumulated sediments, resulting in sometimes significant changes in the stream's course. Examples of meander extension, meander translation, and active flood chutes are frequent and widespread. Active lateral adjustments are at odds with residential development, transportation corridors and agricultural activities in select locations along the corridor, as evidenced by the short sections of streambank armoring and berms observed through the reach. A "Fair" condition rating was assigned, along with a "Very High" sensitivity. A channel evolution stage of III[F] is inferred.

As a consequence of this geologic setting and the history of channel management that has worked counter to the natural tendencies of the channel, M22 is considered to be one of the most sensitive reaches in the Lewis Creek watershed. This a natural attenuation zone, due to the slope reduction and decreased valley confinement. Attenuation functions of the river corridor have been decreased somewhat due to historic channelization, berming, armoring and historic incision. While the channel manipulations in upstream portions of M22 have apparently served to protect the residential properties and nearby croplands during the last several years, this active management has not been without significant effort and cost. Also, there are consequences for such ongoing channel management as sediments and excess stream energies are translated to downstream sections of the creek. Through active lateral adjustments, the channel is regaining sinuosity and building an incipient floodplain. To the extent that the channel is permitted to continue its adjustments, Lewis Creek will regain more floodplain access. Reach M22 can serve an important sediment and flow attenuation function in the river network downstream of headwater sediment sources. To protect public safety and reduce the potential for fluvial erosion losses, it would be important to limit future encroachments within the stream corridor.

Figure G-4.

Site of new meander along M22 (Site B in Figure G-3) which is extending into adjacent corn fields downstream of Hillsboro Rd. Topsoil, streambank sediments and nutrients are eroding and being transported down-river.

Figure G-5. Area of active channel adjustment downstream of the Route 116 crossing (M22, view to west, Site A in Figure G-3)

M21

Reach M21 was originally assessed by Lewis Creek Association (LCA) volunteers in July and September of 2002. Additional cross sections and visual observations were recorded by SMRC in November 2006 to update the original assessment. Updates resulted in some significant changes to RGA data (including segmentation) since original reporting (VTDEC WQD, 2003a) and since data were last summarized in the draft River Corridor Management Plan for reaches M19-M22 (LCA, 2006). Bankfull elevations had been underestimated in some cases during the original assessment.

Reach M21 is a 0.9-mile reach extending from one third mile downstream of the Meadowlark Lane crossing to the High Knob tributary (T6) which joins Lewis Creek just north of the Tatro Road bridge (Figure G-6). The downstream (southern) quarter of the reach has a more narrow floodplain (Semi-confined confinement) than the upstream three-quarters of the reach and is apparently underlain by sediments of glaciofluvial origin, bounded closely on the LB by sediments of glacial till origin (USDA). In contrast, the upstream three-quarters of the reach has a wider floodplain (Very Broad confinement) comprised of alluvial sediments, bounded to the east and west by terraces of glaciofluvial sediments and an isolated pocket of glaciolacustrine sediments. Small pockets of wetlands are mapped (NWI) contiguous to the channel at the upstream end and at the middle of the reach. These differences in valley setting and soil parent materials guided reach segmentation. The downstream quarter of the reach was designated as a subreach of alternate reference stream type (Bc) in an otherwise reference C stream type.

M21 Segment	Approximate Length (ft)	Stream Type
B	3,118	C4-riffle/pool
A *	1,280	B3c-plane bed

* Subreach

Segment B

The landscape surrounding Segment M21-B has re-vegetated following more intensive agricultural uses in the early 1900s (based on review of 1942 aerial photographs). A new residential home was constructed within the RB corridor at the downstream end of the segment as of 2006. An ATV ford was observed mid-segment, and ATV activity was evident on point bars near the upstream end in 2006. Straightening of the channel occurred between 1962 and 1974 at the upstream end of the segment in vicinity of a RB crop field, based on review of historic aerial photographs.

One (non-representative) cross section (XS-2) in the downstream third of the segment, coincident with mapped wetlands, has a low width/depth ratio suggesting an E stream type. This section was deemed too short in length to warrant segmentation. A second (non-representative) cross section (XS-4) completed near the upstream (historically straightened) end of the segment indicated an incision ratio of IR_{RAF} = 2.6. The channel is overwidened at this location with high depositional bars; an incipient floodplain is apparent at a lower elevation immediately upstream and downstream of this section. This site was just upstream of a recent (post-1995; pre-2003) neck cutoff / avulsion.

Overall, Segment B has characteristics of a moderately-incised, C4-riffle/pool stream type, as indicated by the representative cross section, XS-3. Dominant active adjustment processes within Segment B include significant and recent planform adjustment (neck cutoffs, meander migration, meander translation, flood chute) and moderate aggradation (from upstream and in-segment sources). Active LWD recruitment is occurring in the wooded middle section of the segment. Debris jams and submerged LWD are contributing to bar formation and meander extension. Lateral adjustments and aggradation within the reach may be enhanced by the downstream valley pinch point (in Segment M21-A).

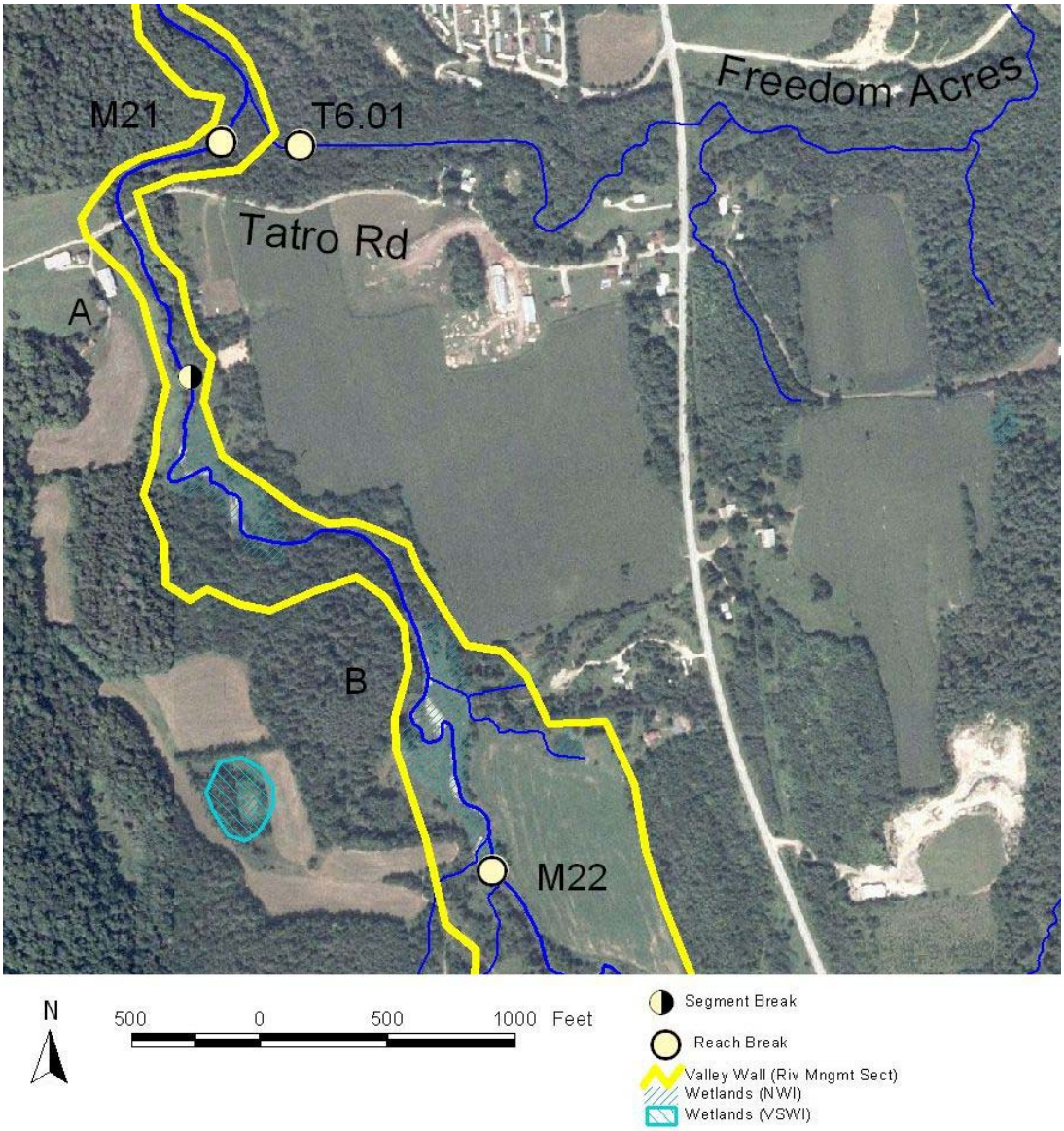


Figure G-6. Segmentation of reach M21.
(Yellow lines indicate valley walls delineated by VT River Management Section).

Segment M21-B appears to be receiving and storing sediment transported from upstream erosion sites. Meanders are forming and migrating, particularly in areas of minimal tree buffers, as the stream reasserts itself after past straightening and land-clearing. Segment M21-B is a strategic sediment attenuation area along the Starksboro corridor. A "Fair" condition rating was assigned, along with a "Very High" sensitivity. A channel evolution stage of IV[F] is inferred.

Segment A

Historic pasture uses along the LB of Segment M21-A have been abandoned and a young forested buffer has begun to regenerate. The Tatro Road (gravel) crosses Lewis Creek in this segment via a bridge. This bridge crossing is considered a bankfull constrictor, as the span of the bridge (30 ft) is undersized with respect to the upstream measured bankfull width (31.2 ft). However, negligible upstream aggradation or downstream scour were noted on observation dates. An apparent ATV trail is present along RB downstream of the Tatro Road crossing, high on the right valley wall (above the FPW elevation); this trail was indexed as an improved path. A small mass failure on the right bank was noted in 2002 in vicinity of this woods road, and associated with a debris jam and small avulsion. Stormwater inputs indexed along Segment M21-A included a LB stormwater runoff channel documented in Sept of 2002 (small "delta") and during a runoff event in May of 2006 (receiving drainage from Tatro Road and a portion of the Camp Common Ground facility). Rip-rap armoring was observed local to the bridge site.

Figure G-7.
Area of ATV use downstream from Tatro Road bridge. Vehicles use the banks and also ford the stream in this area. Trees are collapsing in the stream, and sediment is washing into the creek from this unvegetated path (M20-A, view upstream).

Photo Credit: Jennifer Turner

A cross section completed mid-segment confirmed a B3c-plane bed stream type, with moderate historic incision (IR_{RAF} = 1.4). The dominant adjustment process is a minor degree of widening. An early stage III [F] channel evolution is inferred. This channel may have persisted in this partly incised condition for some time, as boundary conditions (re-vegetating forest, erosion-resistant bank materials) appear to be moderating channel adjustments under typical flow conditions. A "Fair" condition rating was assigned, along with a "High" sensitivity rating, following the November 2008 update to sensitivity rating assignments under VTANR protocols (VTANR, 2008a).

M20

Additional cross sections and visual observations were recorded in November 2006 to update an original assessment conducted in July of 2002. Updates resulted in some significant changes to RGA data since original reporting (VTDEC WQD, 2003a) and since data were last summarized in the draft River Corridor Management Plan for reaches M19-M22 (LCA, 2006).

Reach M20 is approximately 0.8 mile long and runs from just below Tatro Road to a point about 600 feet downstream from Parsonage Road Bridge on Rublee lands (Figure G-8). The upstream (southern) half of the reach has a more narrow floodplain (Narrow confinement) than the downstream half of the reach and is apparently underlain by sediments of glaciofluvial origin, bounded closely to the west (LB) by sediments of glacial till origin (USDA). In contrast, the downstream half of the reach has a wider floodplain (Very Broad confinement) comprised of alluvial sediments, bounded to the east and west by glaciofluvial sediments and till at the downstream end of the reach. Bedrock (apparently not channel-spanning) is exposed at this local valley pinch point near the downstream end of the reach (below the Parsonage Road crossing). These differences in valley setting and soil parent materials, as well as a notable difference in buffer conditions, guided reach segmentation (although both segments were assigned a reference stream type of C-riffle/pool). In addition, channel morphology of the upstream segment indicated a vertical stream type departure (C to F) that required segmentation.

M20 Segment	Approximate Length (ft)	Stream Type
B	1,738	F3-riffle/pool
A	2,294	C4-riffle/pool

Segment B

Upstream Segment M20-B has a wide and continuous wooded riparian buffer, with limited encroachment by development, roads or agriculture. A hay field is present along the RB (beyond a minimal-width tree buffer) in the downstream 400 feet. A farm equipment and/or ATV trail is evident along the RB and was indexed as an improved path. This path does not have significant base material and is inundated at flood flows; it does not berm the channel or significantly encroach upon the floodplain. Additional ATV and foot trails were noted within the segment corridor particularly on the east side (RB). Historic straightening is inferred at the downstream end of the segment adjacent to the RB agricultural field (straightening is also apparent in downstream Segment A).

The Lewis Creek receives drainage from the High Knob tributary (T6) along the RB at the upstream end of Segment M20-B. A significant delta of sand and gravel sediments is present at the confluence of High Knob tributary (as observed on 7 November 2006). Flood chutes and channel braiding in the High Knob tributary are coincident with ATV trail crossings in vicinity of the crossing.

Sediments in the bed and banks were comprised of gravels, cobbles and boulders, with cobbles dominating. These sediments are relatively more coarse than channel sediments in upstream or downstream reaches, consistent with a glaciofluvial parent material (e.g., kame terrace deposits). It is likely that the larger cobbles and boulders are not mobile during a typical bankfull flow stage.

A cross section measured near the middle of Segment M20-B revealed an incision ratio of IR_{RAF} = 2.6, thus indicating a vertical stream type departure (C to F). Incision appears to be historic in nature, as there are no current signs of active incision (e.g., head cuts), and erosional scour of the banks is negligible. Dominant adjustment processes in the segment include moderate widening in response to the historic incision, tempered by coarse bed and bank materials and ample forest cover along the banks

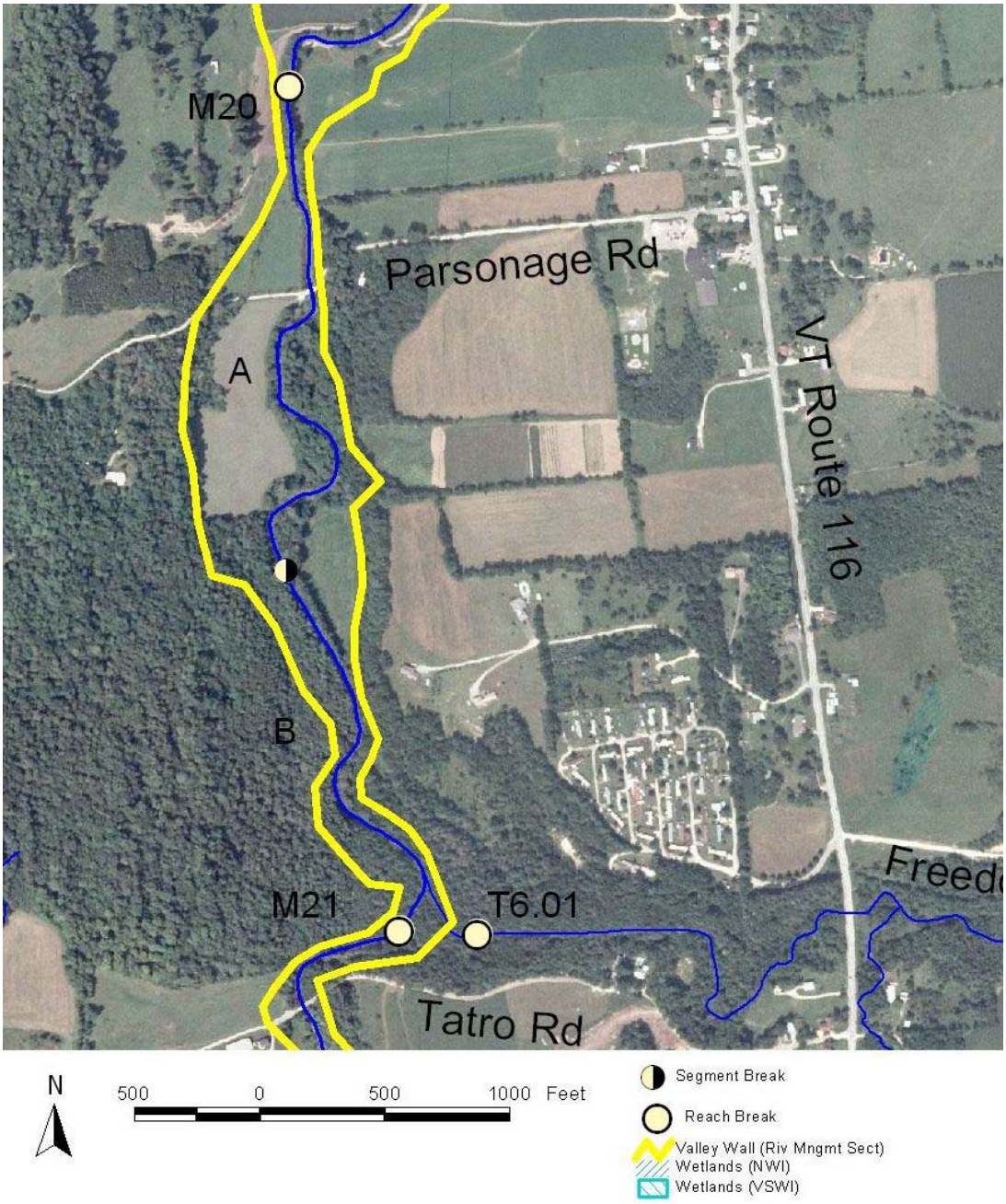


Figure G-8. Segmentation of reach M20.
(Yellow lines indicate valley walls delineated by VT River Management Section).

(which has regenerated significantly since the 1940s, based on review of historic aerial photographs). Moderate aggradation (mid-channel bar, diagonal bars, delta) is also evident, probably related to upstream erosion (M21, M22) and sedimentation from the High Knob tributary. A channel evolution stage of II[F] was assigned, along with a "Fair" condition rating and "Extreme" sensitivity.

Segment A

Segment M20-A comprises the downstream end of the reach which has incurred more extensive encroachments by agricultural and residential uses. Hay fields are present along the RB and LB in the upstream end of the segment. Pasture uses are evident in the downstream end, where a fenced crossing permits livestock to cross the Lewis Creek. Crop fields are also present at the downstream end of the segment along RB. Parsonage Road crosses the Creek via a bridge near the mid-point of the segment, and provides vehicle access to residences and farm pasture on the west side of the Creek. Recent construction of a single-family residence has occurred (post-2003) at the edge of the RB corridor downstream of the bridge.

With a span of 40 feet, the Parsonage Road bridge is considered a bankfull constrictor (approximately 80% of the measured bankfull width). A short section of Parsonage Road passes parallel to the Creek within the RB corridor, but not significantly enough to constitute a human-caused change in valley width (road quickly climbs in elevation up the valley wall). Two ATV trail fords were observed near the upstream end of the segment. Channelization is inferred at the downstream end of the segment in vicinity of the Parsonage Road bridge crossing, LB pasture, and RB crop fields, due to the linear planform, and proximity of agricultural uses and the bridge crossing. A few, short sections of rip-rap armoring were observed along LB at actively migrating bends, typically associated with minimal or absent tree buffers.

The current buffer and corridor conditions are an improvement over historic conditions (as observed on 1942 aerial photographs, which show more extensive pasture and cropland). Cows have recently been fenced away from the stream, and livestock are now confined to the one fenced crossing (and a bridge in downstream Segment M19-B).

A mid-segment cross section indicated historic incision (IR_{RAF} = 1.89). Dominant adjustment processes include moderate planform adjustment (flood chutes, meander migration) and minor aggradation in response to inferred historic channelization and incision. Upstream erosion and tributary sources are contributing to aggradation. Near the upstream end of the segment, the channel is over-widened and recent erosion, tree-fall, and deposition of gravel bars are evident. Active recruitment of large woody debris is helping this previously channelized river to recreate a meandering planform, pool and riffle diversity, and build floodplain access at a lower elevation. An early stage IV[F] CES (or late stage III [F]) is inferred. A "Fair" condition rating and "Very High" sensitivity were assigned.

M19

Portions of reach M19 were originally assessed in September 2001 during the pilot test for protocol development by VTDEC. To update the RGA for this reach to 2007 protocols, SMRC relied on limited field observations from 2001 through 2007 as well as a Sept 2001 Phase 3 assessment by VTDEC in the upper half of the reach and a Phase 3 assessment completed by VTDEC in Oct 2002 in the lower third of the reach.

Reach M19, 2.1 miles in length and runs north from the vicinity of the Parsonage Road bridge crossing downstream to town-owned land on the former Cota farm (including the Starksboro Ballfields) (Figure G-9). The downstream 2,800 feet of the reach near the Ballfields is a highly meandering stretch of the river which was identified as a subreach (Segment A) showing different channel characteristics than the remainder of the reach (Segment B).

M19 Segment	Approximate Length (ft)	Stream Type
B	8,077	C4-riffle/pool
A *	2,808	E4-riffle/pool

* Subreach

Segment B

Segment M19-B comprises the upstream 80% of the reach. The floodplain is comprised of alluvial sediments bound along the left valley wall by steep, till-covered slopes and low to moderate terraces of glaciofluvial sediments. Along the right valley wall, the floodplain is defined by higher terraces of glaciofluvial sediments (kame terrace deposits). Alluvial sediments in the downstream half of the segment are hydric in nature (USDA); a small pocket of wetlands is mapped in the LB corridor near the mid-point of the segment (NWI, VSWI).

This valley has been intensively farmed, and sections of the Lewis Creek have been channelized and armored with rip-rap. Channelization is particularly evident from 1942 and 1962 aerial photographs; a linear planform persists today along the upper half of the segment. Bar scalping was noted at a RB point bar at the upstream extent of the segment in 2001, and also in 2002.

In the past, riparian vegetation was removed right up to the riverbanks in many locations (especially visible on 1978 aerial photographs of the region). Today, there is a well-vegetated, though narrow, tree buffer along the Rublee and Bissell lands (upstream end of the segment). In the downstream half of the segment, the corridor has become fallow and riparian vegetation is re-establishing, since ownership of the Cota farm was transferred to the Town of Starksboro circa 1989. Re-vegetation is evident particularly from a comparison of the 1942 to the 1995 aerial photo. In locations where old channel armoring has begun to fail or be outflanked, meanders have re-developed in the channel. Four beaver dams were indexed in 2001; beaver activity has been frequently observed in this segment in subsequent years, and likely contributes to localized widening and aggradation.

Two bridge crossings within the segment are used for vehicle access to farm fields. Rublee maintains a farm bridge near the upstream end of the segment, which has ample vertical clearance and adequate span (148% of the measured bankfull width), such that it will likely not be a site of debris jams. A farm bridge near the downstream end of the reach provides access to the Rozendaal organic fields. This bridge is of low clearance and a somewhat narrower span (117% of the measured bankfull width). Debris jams at this crossing have been observed to contribute to upstream flooding (e.g., 6/13/2002).

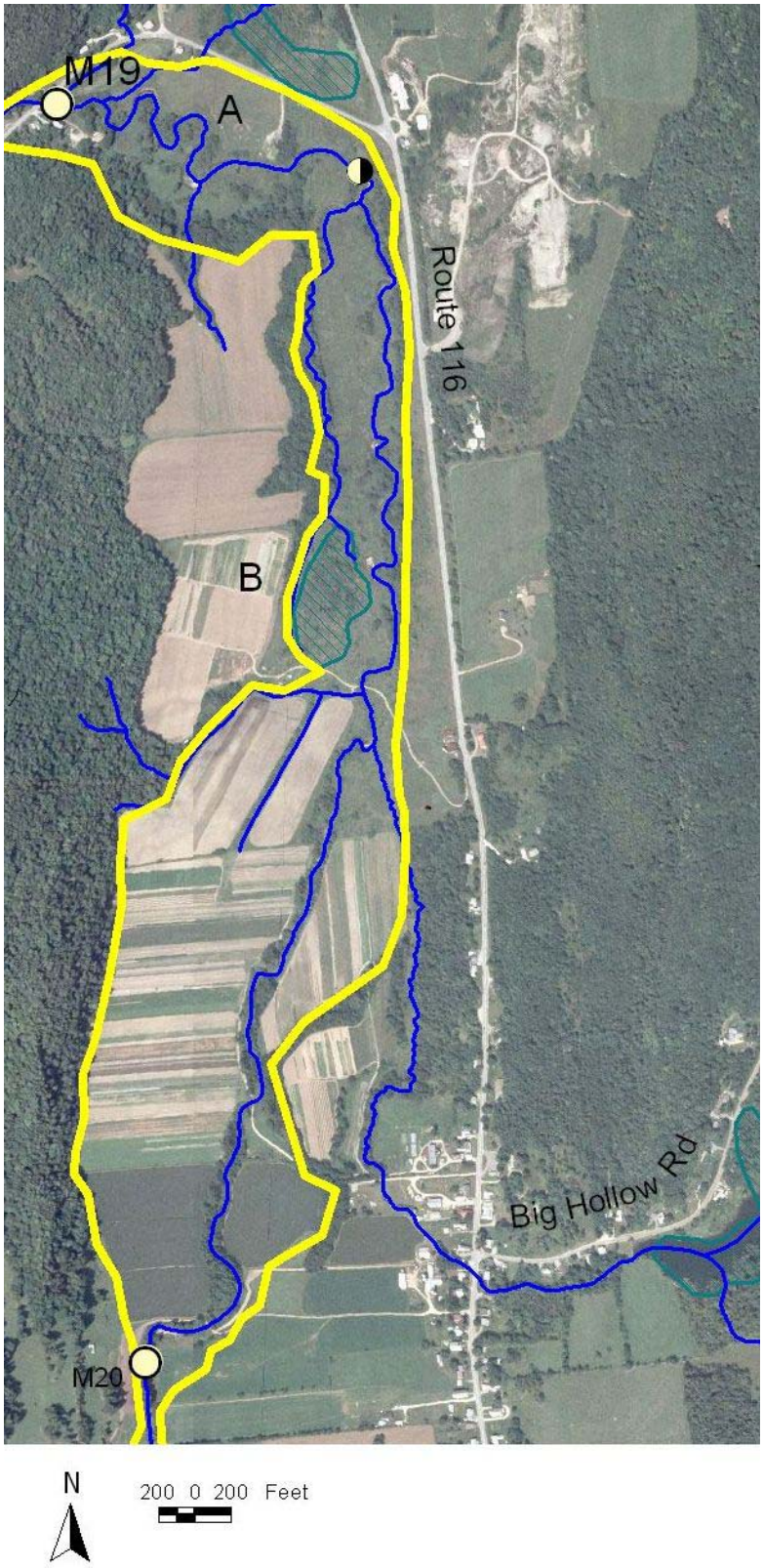


Figure G-9. Segmentation of reach M19.

Yellow lines indicate valley walls delineated by VT River Management Section.

Tractors working Lewis Creek Farm fields on the west side of the creek cross a ford mid-segment, and a small footbridge nearby provides walking access to the fields. The ford road slopes very gradually into the stream, where the bottom is reinforced with stones. Tractor use of this ford does not appear to be excessively scouring the stream bed or weakening the banks. Hank Bissell (owner, Lewis Creek Farm) describes the creek as being "flashy" during heavy rains; water overtops the banks every few years, typically during late Fall or early Spring.

Figure G-10. Lewis Creek near "bank full" during early spring. Fields often flood briefly at this time. Old brussell sprout stalks are still standing (M19-B).

Photo Credit: Jennifer Turner

Other than these agricultural uses, there have not been many encroachments on the channel in Segment M19-B. Route 116 occasionally passes within the RB corridor, but at an elevation well above the FPW. A narrow, gravel recreational trail was installed along the right valley wall by the Town of Starksboro on the former Cota lands in the downstream half of the segment; this trail is also elevated on the valley wall above the FPW. Farm roads pass within the corridor but do not significantly constrain the floodplain (flood flows inundate the roads).

Cross sections completed in Segment M19-B by VTDEC in 2001 suggested a C4-riffle/pool stream type with a low to moderate degree of historic incision (IR_{RAF} = 1.26). Dominant adjustment processes include moderate planform adjustment (neck cutoff, meander extension) and minor aggradation in response to past channelization. Lateral adjustments appear more pronounced in the downstream half of the segment, where the channelized planform is no longer being actively maintained. The segment was classified in "Fair" geomorphic condition, with a sensitivity of "Very High". A channel evolution stage of early III [F] is inferred for the segment as a whole. In recent years (since the 2001- 2002 VTDEC assessments) the degree of lateral adjustments developing in the downstream (fallow) half of the segment, suggest a later stage III [F] or stage IV [F] of channel evolution. A series of discontinuous pockets of incipient floodplain appear to be forming at a lower elevation in locations of meander extension.

Segment A

Segment M19-A comprises the downstream 20% of the reach in vicinity of the Starksboro Ballfields off States Prison Hollow Road. The channel meanders through a wide alluvial valley of Very Broad confinement, which narrows considerably near the downstream end of the segment at a valley pinch point defined by a steep bedrock falls at reach M18. The floodplain is bounded by low to moderate terraces of glaciofluvial sediments in the upstream end of the segment and steep, till-covered, bedrock slopes near the downstream end of the segment. Alluvial soils of the floodplain are characterized as hydric (USDA); a small pocket of wetlands is mapped (NWI, VSWI) to the north side of States Prison Hollow Road. The VTDEC mapped the right valley wall on the river side of the States Prison Hollow Road (see Figure G-9). This is effectively a human-modified valley wall, as the natural valley wall in this location is actually farther to the north encompassing the wetland area. While the States Prison Hollow

Road cuts off a significant portion of this natural floodplain, the encroachment of this road within the RB floodplain is not significant enough to change the confinement status of the channel (Unconfined, Very Broad). A reference E stream type is suggested by the natural valley setting, low gradient and high sinuosity of the channel in Segment M19-A.

The Starksboro Ball fields are developed within the RB corridor of Segment M19-A. Aside from the recreational fields, infrastructure at this site includes a gazebo with concrete slab and picnic tables, a small kiosk, and gravel parking areas. Rip-rap armoring has been installed along the RB of the Lewis Creek in two main areas to protect the ball fields. Historic straightening is evident at the upstream end of segment in 1962 and 1974 photographs.

Historic lateral migration of the Lewis Creek channel is evident from comparison of 1942, 1962, 1974 and 1995 aerial photographs (Figure G-11) – comprising a 400-foot wide channel migration zone over this recent 70+ year period. It is likely that the fixed elevation and position of the Lewis Creek channel at the bedrock falls below the States Prison Hollow Rd bridge has enhanced lateral adjustments of the channel in this location.

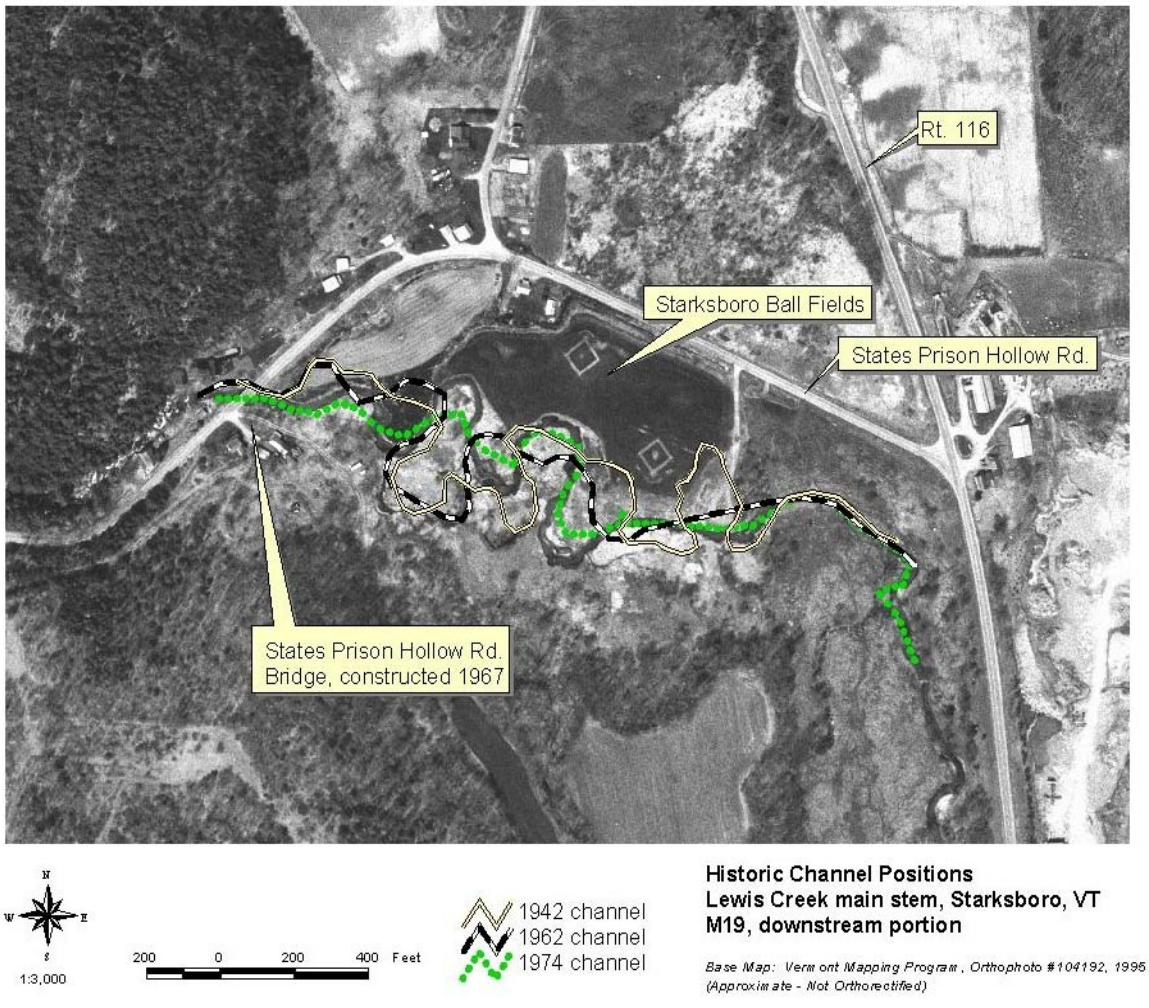


Figure G-11. Aerial photograph of the Cota ball field area from 1995 showing earier channel positions superimposed. Segement M19-A, Starksboro.

Cross sections completed by VTDEC in 2002 in Segment M19-A suggest an E4-riffle/pool stream type. A minor degree of historic incision is indicated (IR_{RAF} = 1.17). Current adjustment processes include a minor to moderate degree of planform adjustment (meander extension, meander translation) and minor aggradation (local to breached beaver dams). Segment M19-A appears to be serving as an attenuation area immediately upstream of the bedrock grade control of States Prison Hollow gorge (reach M18). A "Good" condition rating (indicating minor active adjustments) and "High" sensitivity were assigned, following protocols. A channel evolution stage of I [D] is inferred.

M18

Reach M18 was originally assessed by VTDEC River Management Section and Lewis Creek Association volunteers in August of 2002. Assessment data has been updated to 2007 standards relying on: (1) observations from 2002; (2) limited observations on 9/18/2007 during landowner outreach at the downstream end of the reach; and (3) observations on 7/7/2007 associated with the States Prison Hollow Road washout and repair.

Within this quarter-mile reach (Figure G-12), the Lewis Creek cuts sharply west to cross a narrow exposure of bedrock near the eastern flanks of Hogback Mountain. The channel bed consists of a series of cascading bedrock waterfalls and alternating bedrock and boulder steps and pools. Bedrock is also exposed occasionally along the banks of the channel, providing lateral grade controls. Till-covered bedrock walls form the valley walls which closely confine the channel (Semi-Confined). The channel gradient is 6.9%. A reference Ba-step/pool stream type is inferred. At the very downstream end of reach M18, Lewis Creek transitions from the semi-confined bedrock gorge to an unconfined, low-gradient channel meandering through a wide valley setting (downstream reach, M17).

A historic mill site operated near the top of the gorge (Beers, 1871). Today this property is operated as a Bed & Breakfast and includes structures founded on bedrock in both the LB and RB corridors. One residence is also located along the RB corridor at the downstream end of the reach. Encroachments within the corridor of reach M18 include the States Prison Hollow Road along the LB. The elevation of this road is well above the flood prone width elevation of the channel; therefore it is not considered to represent a human-caused change in valley wall. However, a recent washout of this road in 2006 was associated with mass failures that extended down to the stream elevation and resulted in sediment volumes introduced to Lewis Creek. A local resident has noticed marked sedimentation in pools in the years since this event (Paskiewicz, 2007). This alignment of the States Prison Hollow Road is relatively new – occurring post-1974 and pre-1995 based on a review of historic aerial photographs. Previously the road crossed the Lewis Creek just below the downstream end of the reach and followed the current alignment of States Prison Hollow Road Extension.

Lewis Creek is crossed by States Prison Hollow Road at the upstream end of reach M18. This bridge was constructed in 1967, according to VTrans database records. The span of this bridge is recorded as 75 feet (R.J. Turner bridge & culvert survey recorded in Vtrans database). A wooden footbridge crosses the channel approximately 220 feet downstream of the States Prison Hollow Road crossing and has a span of 60 feet. The measured spans of these two bridges compare favorably to the nearest measured bankfull width of 50 feet, and are also larger than the predicted bankfull width of 47.2 feet (VT Regional Hydraulic Geometry Curves; VTDEC WQD, 2006). These bridges are not considered to be constrictors of the bankfull flow event, but may restrict flows during a 10-year to 50-year event and higher.

A CES of I[D] is inferred for reach M18. A "Good" condition rating and "Very Low" sensitivity were assigned.

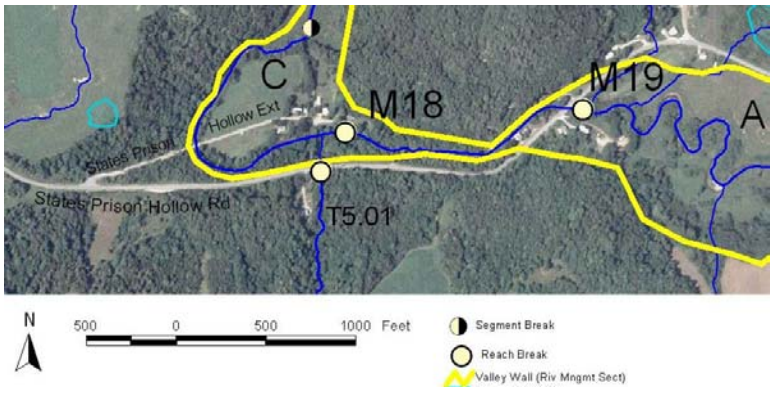


Figure G-12. Reach M18, Lewis Creek main stem, Starksboro.

M17

Reach M17 is approximately 14,003 feet (2.7 miles) long and flows from the bedrock gorge along States Prison Hollow Road (reach M18) downstream to the confluence of minor tributary M16S1 which joins the Lewis Creek along the RB between the Kelly and Clifford farms (Figure G-13). This reach was originally assessed in September of 2002, and has been updated through limited field-based evaluation (including repeat cross sections) and preparation of an updated RGA based on 2007 protocols in September of 2007. Previous estimates of bankfull elevations were determined to be too low; original cross sections and revisited cross sections were reviewed to update bankfull widths, maximum depths, and incision ratios. Revisions to these values, as well as more well-defined RGAs, have resulted in revised stream types and RGA conditions for reach segments.

Reach M17 was segmented to capture a subreach of alternate stream type in the upstream end of the reach, as well as a difference in buffer conditions and land uses between two downstream segments of the reach:

M17 Segment	Approximate Length (ft)	Stream Type
C *	2,005	C4-riffle/pool
B	8,552	E4-riffle/pool
A	3,446	E4-riffle/pool

* Subreach

Segment C

Within the upstream-most 2005-ft segment of reach M17, Lewis Creek transitions from the semi-confined, steep, bedrock gorge of upstream reach M18 to a unconfined, low-gradient channel meandering through a wide valley setting (downstream segments, M17-B, M17-A). Segment M17-C was classified as an "alluvial fan" to capture the significant slope change that occurs within this segment (from approximately 7% to less than 2%). Segment C has a slightly steeper slope than the remainder of the reach (estimated 0.8%). The size of dominant bed materials decreases with distance downstream - from cobbles and gravels to gravels and sands. Natural valley width varies from 400 ft to 700 ft, with an overall valley confinement approximately 10 times the channel width. A reference stream type of C-riffle/pool is estimated for the segment.

Encroachments within the valley include the gravel States Prison Hollow Road Extension along the RB, which provides access to residential homes within the RB corridor. This road bed is slightly elevated above the floodplain and reduces the reference valley width somewhat. While the reference valley confinement (Very Broad) is somewhat reduced (to Broad), the general confinement status of the segment (Unconfined) remains unchanged. The paved States Prison Hollow Road also passes alongside the channel in Segment C (within the LB corridor), but at an elevation well above the floodplain. This alignment of the States Prison Hollow Road is relatively new – occurring post-1974 and pre-1995 based on a review of historic aerial photographs. Previously the road crossed the Lewis Creek near the upstream end of the reach and followed the current alignment of States Prison Hollow Road Extension. The old abutment for this previous alignment was observed during 2002 assessments, and had a measured span of approximately 45 feet. The States Prison Hollow Road Extension bridge crossing further downstream in the segment, was constructed in 1938 and repaired in 1993 according to VTrans databases. This bridge has a measured span of 50 ft (2002 measurement) which compares favorably to the nearest measured bankfull width of 33.7 feet, and is also larger than the predicted bankfull width of 47.2 feet (VT Regional Hydraulic Geometry Curves; VTDEC WQD, 2006). This bridge and the old abutment are not constrictors of the bankfull flow event, but may restrict flows during a 10-year to 50-year event and higher.

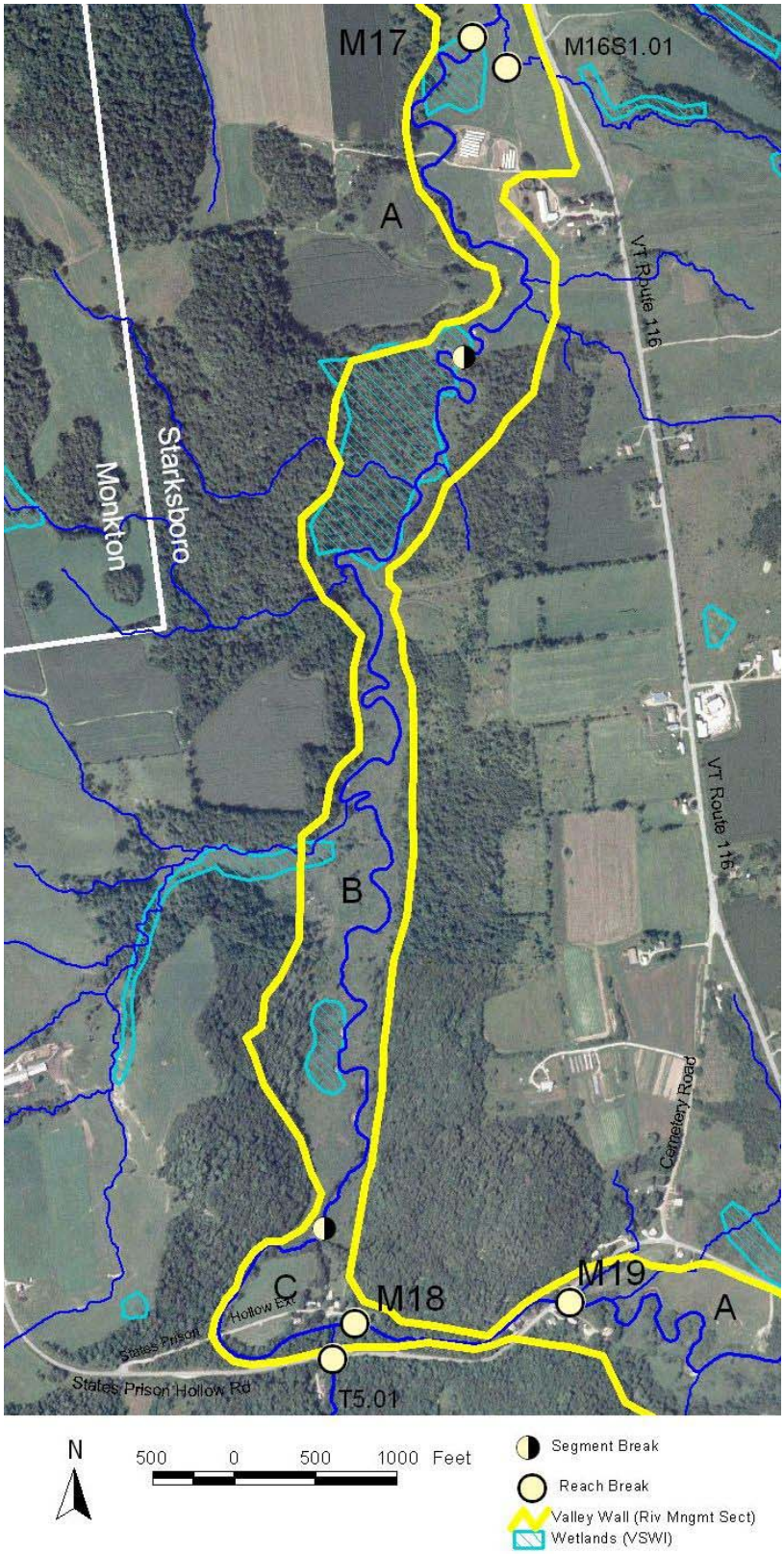


Figure G-13. Segmentation of reach M17.

Residential development encroaches on the floodplain along the RB in the upstream third of the segment. Large boulder/cobble/earthen berms are present along both LB and RB at the transition point from the bedrock gorge out into the valley in order to protect several residential lots at this location. The 1938 flood resulted in a major avulsion that cut off the broad meander that comprises this segment; flood flows eroded residential lots (Jennings, 2002), including the front porch of the upstream-most house (Paskiewicz, 2007). Straightening with windrowing is inferred associated with this post-flood response, based on a picture recorded in *Bertha's book: a view of Starksboro's history* (Hanson, 1998).

Agricultural encroachments include a hay field in the RB corridor downstream of the bridge crossing, which appears to have been protected by a low-profile berm along 310 feet of the RB. Channelization from the bridge site downstream to the full extent of the hay field is suggested by the linear planform. This RB berm is only slightly higher than the floodplain and does not substantially reduce floodplain connection.

A cross section performed downstream of the bridge crossing confirmed a gravel-dominated C-riffle/pool stream type. The channel is partly incised below the floodplain (IR_{RAF} = 1.4); locally, floodplain access is further reduced by the presence of the berm along right bank (IR_{HEF} = 1.46). Incision appears historic in nature, given the absence of headcuts, undercut banks, or other signs of active vertical scour. Signs were observed of minor to moderate widening (streambank erosion, fractured streambanks, and select leaning trees) and planform adjustment (small flood chutes) in response to this historic incision. Despite a 11.6 W/D ratio measured at the cross section site, the segment was typed as a C stream considering the +/- 2 units for W/D ratio allowable under protocols (VTANR, 2007a, Table 2.3). This cross section is at the downstream end of the segment where the creek is transitioning into an E stream type. Further upstream in the segment, visual observations suggest a slightly higher W/D ratio (>12). Low W/D ratio at the cross section may also be due to cohesive soils, and past inferred straightening with berm encroachment.

Dominant adjustment processes include minor widening and planform adjustment in response to inferred historic channelization and incision. Bedrock grade controls in the upstream reach would have limited upstream migration of incision, historically. Lateral channel adjustments appear to have been moderated by cohesive streambank sediments and well-developed buffer vegetation (particularly along the LB). Overall, Segment C was rated in Fair condition with an assigned sensitivity of "Very High". An early channel evolution stage of III [F] is suggested.

Habitats are compromised in the segment, due to the limited buffer widths along the RB, minimal availability of epiphaunal substrates, and the reported history of channelization/dredging.

Segment B

Segment B comprises the majority of reach M17 (8,552 ft). Originally assessed in September of 2002, this segment assessment was updated with observations on 10 September 2007, relying in part on cross sections from 9/21/2002. The original assessment underestimated bankfull elevation (and overestimated incision). Stream type and condition have been updated accordingly.

The Segment M17-B channel meanders through a Very Broad valley of shallow gradient (approximately 0.2%). Soils of alluvial origin are mapped within the floodplain (USDA). Till-derived soils shallow in thickness with exposed bedrock comprise the valley walls along the RB; whereas, soils of glacio-lacustrine, till, and glacio-fluvial origin are mapped along the LB valley wall. A network of minor tributaries drains forested and agricultural slopes to the west of the valley and join the Lewis Creek within Segment B; tributaries draining the eastern slopes are nearly absent. (The drainage area of Lewis Creek increases by 26% within reach M17 from 18.4 square miles to 23.1 square miles). Hydric soils are mapped along the western valley slopes and are located contiguous to the Lewis Creek channel near the downstream end of the reach. Channel-contiguous wetlands are mapped in the downstream third of the

segment by VSWI, and in the downstream two-thirds of the segment by NWI. No bedrock was observed exposed in the channel bed or banks.

Encroachments within Segment M17-B are fairly limited. Historically, the floodplain was farmed (pasture, hay; LaRue, 2007). Apparent historic pasture use spanning the channel was evident on the 1962 and 1942 photographs. Historic channelization is inferred from the 1942 photograph and present-day field-stone rip-rap in these linear sections, occasionally outflanked by meander extension. Trees have revegetated the corridor considerably in subsequent years. Presently the corridor is fallow. The RB (eastern) corridor at the upstream end of the segment is owned by the Town of Starksboro and is conserved (VT Land Trust). In the downstream end of the segment, hay and corn fields are located farther up the valley slopes to the west and east of the channel.

One private bridge (LaRue) is located mid-segment. The approximate bridge span is 18 ft, and clearance to the stream bed is approximately 6.3 ft (as measured September 2002). This crossing is significantly undersized with respect to the reference bankfull width (52.2 ft) and the measured bankfull width (33.7 feet). A downstream scour pool was observed in September 2002. Beavers are active in this segment. Six beaver dam sites were observed in September 2007 and September 2002. In 2007, four beaver dams impounded a total length of approximately 1,750 feet of channel.

Cross sections indicated a fine-gravel-dominated E-riffle/pool stream type. The riffle-pool bedform is not well developed; runs are prevalent, perhaps due to the influence of beaver-dam impoundments. The channel has good access to the floodplain (IR_{RAF} = 1.0). Anecdotal evidence from the nearby landowner indicates that the river overflows its banks regularly with spring runoff events (LaRue, 2007). The potential for historic incision and widening (associated with inferred channelization) may have been moderated by the cohesive nature of sediments in the streambanks and bed, as well as offset by aggradation locally induced at beaver-dam impoundments. Dominant active adjustment processes include moderate planform adjustment and minor (localized) aggradation. Examples of meander extension and meander migration are prevalent; flood chutes were noted crossing the inside of meander bends. Recent neck cutoffs were revealed by a comparison of current planform to that represented on historic aerial photographs. Old meander scars are visible in the floodplain on 1995 orthophotographs. One avulsion (double-neck cutoff) was apparent near the mid-point of the segment.

Habitat features include excellent buffers of greater than 100 feet on both banks (comprised of herbaceous vegetation), absence of encroachments on the floodplain, and diversity of depth and flow regimes which provide reference-quality features. Habitat conditions were somewhat tempered by erosion from unstable (migrating) banks and lack of trees in the buffer for future recruitment of large woody debris. Freshwater mussels were observed in 2002 assessment. Also noted were multiple fish, heron, deer tracks, raccoon tracks. A riparian landowner has observed black bear, deer, beaver, porcupine, wild turkey, ducks, and geese in this valley (LaRue, 2007).

Figure G-14. View upstream (south) from center of LaRue property; beaver dam in foreground; Hogback Mountain in background.

Segment A

The assessment for Segment M17-A was updated generally to 2007 standards, relying on the original 9/21/2002 assessment data from Lewis Creek Association volunteers and SMRC. The original bankfull elevation was underestimated (and therefore incision ratio was overestimated). Phase 2 stream type and condition have been updated accordingly. Also, the reference stream type was revised from a C channel to an E channel.

Segment A comprises the downstream 3,446 feet of reach M17, with an estimated gradient of 0.1%. Valley and channel dimensions for this reach were very similar to Segment B. However, segmentation was warranted, due to the stark difference in buffer and corridor conditions and land use, which will likely suggest different management objectives than upstream segments of this reach. The A/B segment break is coincident with a transition from fallow land to actively-farmed land. Cows are pastured along the full length of Segment A, with minimal fencing to prevent the cows from accessing the stream directly. Substantial bank slumping and healed scars are evident. Zero- to 5-foot herbaceous (pasture) buffers dominate, with the LB having slightly wider buffers than the RB. NWI wetlands mapped at the downstream end of the segment.

A private road (Kelly farm) crosses the river in this segment, providing access to farmlands further to the west. This farm access road was historically a town road that connected to States Prison Hollow Road to the west (Beers, 1871; USGS, 1905). A span of 25.5 feet was recorded for the farm road bridge over Lewis Creek. Based on cross section measurements upstream and downstream of this location, the bridge will constrict flows at the bankfull event and at higher flood flows (70% of bankfull).

Near the downstream portion of Segment A, the channel moves close to the left valley wall. Along the LB in this section, a substantial debris jam was noted at the base of a somewhat healed mass failure approximately 80 feet high. A second more recent mass failure of erodible sands overlying varved clays was noted further downstream. Elsewhere in the segment, both the LB and RB stream banks are actively eroding and undercut with frequent slumping and tension cracks. Based on casual observations from Route 116 in the years since this 2002 assessment, bank erosion appears to have increased along this segment.

A cross section near the downstream end of the segment confirmed a gravel-dominated E-riffle/pool stream type. A moderate degree of incision was apparent (IR_{RAF} = 1.25). The segment is dominated by a moderate degree of planform adjustment (meander migration) and localized widening and aggradation. A channel evolution stage of I[F] was assigned, along with a "Good" condition rating (indicating a minor to moderate degree of channel adjustment) and "High" sensitivity.

Beavers are active in the segment. Three beaver dams were noted on 9/7/2002, impounding a total channel length of approximately 700 ft. Beaver dams and debris jams are contributing to local aggradation and widening. A fresh-water mussel was noted near the downstream end of the segment. Habitat conditions are compromised due largely to the absence of buffers, dominance of one vegetation class in those minimally existing buffers (herbaceous/ pasture), and poor bank stability. Presence of LWD is minimal within the reach, probably due to the absence of tree buffers; debris jams consist of detritus (smaller in size than LWD).

M16

Reach M16 was originally assessed in August of 2001 (VTDEC WQD, 2003a), and has been updated through limited field-based evaluation (including Phase 3 cross sections and pebble counts conducted in 2005) and preparation of an updated RGA based on 2007 protocols in January of 2008. Revisions have resulted in a reinterpretation of Phase 2 stream type and identification of a stream type departure from E to C stream.

Reach M16 is approximately 1.2 miles long and runs along the west side of Route 116 in northwestern Starksboro to end near the confluence of the Hollow Brook (Figure G-x). The reach corridor is dominated by recent alluvium, while the floodplain beyond the corridor is dominated by sediments of glaciolacustrine origin. Locally higher grounds of the Green Mountains to the east and Hogback Mountain to the southwest are comprised of shallow till over bedrock (USDA, 2007; USDA, 2006; Stewart & MacClintock, 1969; Stewart, 1966). No bedrock exposures were observed in the banks or bed of Lewis Creek within the reach. Wetlands (NWI) are mapped contiguous to the channel through much of the reach, and in recently- and historically-abandoned meander bends. Hydric soils are mapped across the Lewis Creek channel near the upstream end of the reach, and in the upland areas surrounding the floodplain which are dominated by sediments of glaciolacustrine origin.

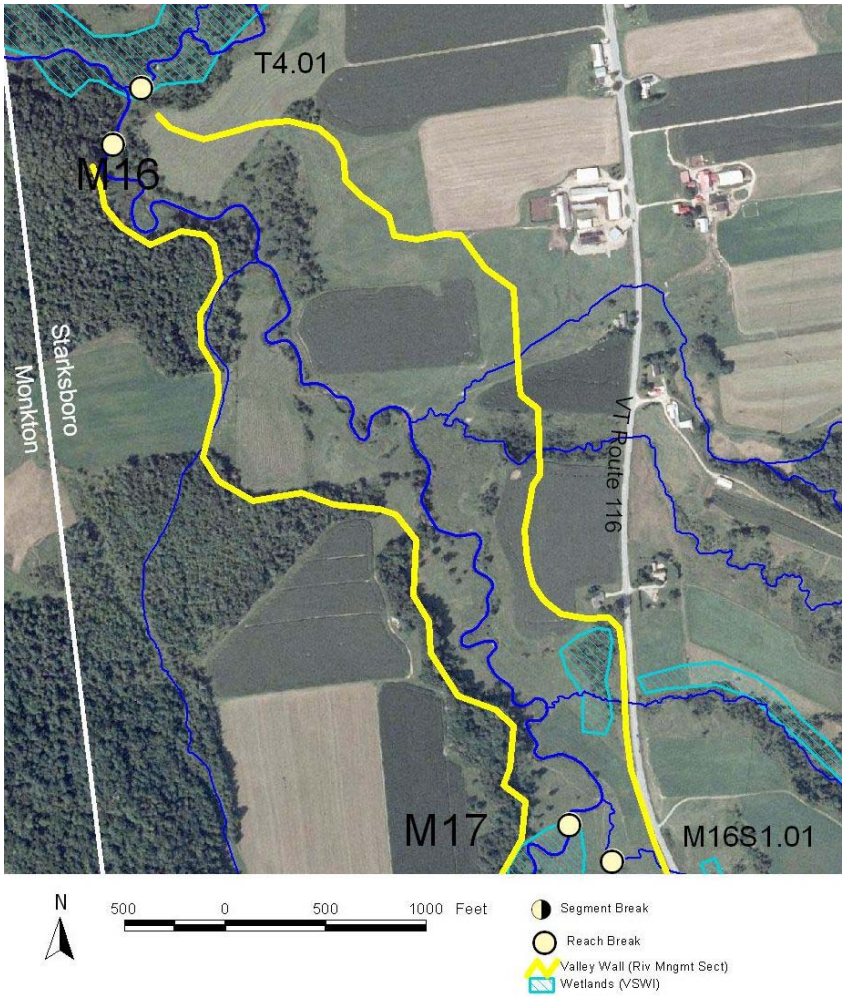


Figure G-15. Reach M16, Lewis Creek main stem.

Terraces of glaciolacustrine and glaciofluvial sediments appear to comprise the "Hilly" slopes (4 to 8% grade) of valley walls surrounding the present Lewis Creek floodplain. Valley width ranges from approximately 550 to 1000 feet, and averages 800 feet. Valley confinement is categorized as Very Broad (i.e., greater than 10 times the reference channel width of 55 feet). The unconfined valley setting, low overall valley and channel gradients (0.09 and 0.06%), and high sinuosity (1.52) suggest a reference stream type of E-riffle/pool.

Encroachments of infrastructure or development within the reach are relatively minor. Farm and residential buildings are located outside of the corridor. Route 116 encroaches slightly on the floodplain at the very southeastern (upstream) extent of the reach, but not substantially enough to result in a change of the valley confinement category. Land use within the reach corridor is dominated by agricultural fields (hay and corn) and pasture. Based on review of historic aerial photographs, forest cover which once dominated the LB corridor in the upstream half of the reach has been cleared between 1942 and 1995, and much of it is now in pasture use. Livestock crossings were historically present. On the Clifford farm in the downstream half of the reach, livestock have recently been excluded from the channel and a wide buffer area has been established surrounding the creek. One stabilized crossing remains at the mid-point of the reach. These recent efforts were accomplished with the participation of the landowner in a NRCS CREP program (see Appendix K for more details).

Three riffle cross sections were completed near the mid-section of the reach during a 2005 Phase 3 survey. The creek has reasonable access to the surrounding floodplain (IR_{RAF} values ranging from 1.0 to 1.3). Cross section data are consistent with anecdotal accounts of the nearby landowner who indicates that the Lewis Creek spills over its banks fairly frequently – perhaps every two to three years (Clifford, 2007). A very fine to medium-sized gravel-dominated bed is indicated by three riffle pebble count results. All pebbles counted were equal to or smaller than the threshold grain size calculated for the bankfull condition, suggesting a mobile bed at bankfull and higher flow stages. While sediments comprising the bed and banks are relatively cohesive due to the significant silt and clay content, stream banks are collapsing where erosion at the thalweg undermines the bank, and slabs of streambank cleave off into the channel. Cross section data suggest a lateral stream type departure from E to C stream type.

Dominant adjustment processes are planform adjustments and widening. Transient beaver dam activitiy is contributing to localized aggradation. Sediment deposition at the confluence of Hollow Brook may be contributing to aggradation and lateral adjustments at the downstream end of M16 (Figure G-16).

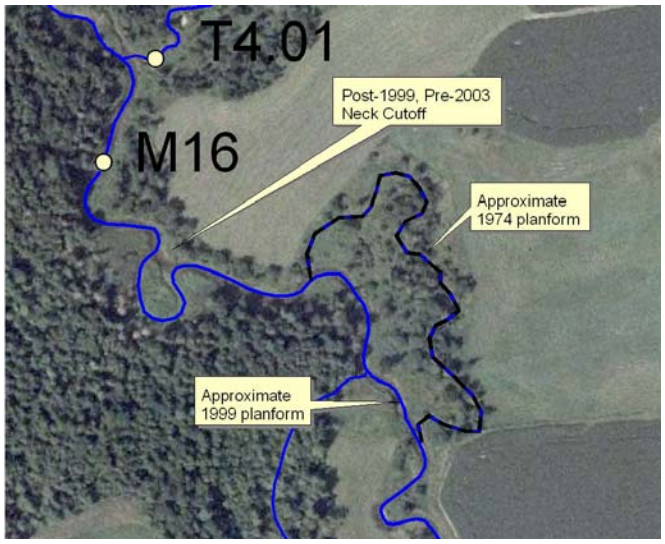


Figure G-16. Localized slope reductions related to sedimentation at the confluence of Hollow Brook tributary (T4.01) may have contributed to recent lateral adjustments in the Lewis Creek main stem. A post-1974, pre-1999 avulsion resulted in a large abandoned meander northeast of the present channel. A post-1999, pre-2003 neck cutoff has created a small oxbow south of the channel.

M15

In limited assessments during August of 2001 (VTDEC/ LCA), four separate cross sections were measured within the upstream half of reach M15 and characterized the reach as a gravel-bed C-riffle/pool stream type (VTDEC WQD, 2003a). A full-reach assessment was conducted in November 2006 to update the original assessment which had focused on select sections only. The 2006 assessment led to segmentation of the reach (Figure G-17).

Reach M15 is approximately 1.9 miles (10,151 feet) long with a shallow gradient (0.16%). This moderately sinuous channel meanders through fallow pasture and croplands from the Hollow Brook tributary confluence in Starksboro, to the northwest under Tyler Bridge Road in the northeast corner of the town of Monkton, then through southern Hinesburg toward the Lewis Creek Road. The corridor is dominated by sediments of glacial lake and alluvial origin. Wetlands are mapped contiguous to the channel throughout the length of the reach (NWI, VSWI). Hydric soils are mapped along the valley margins in the upstream 2/3 of the reach; and coincident with the channel in the downstream 1/3 of the reach (USDA). Based on field observations and review of surficial and bedrock geologic mapping for the region, channel-spanning bedrock grade controls are absent within the reach.

Reach M15 was segmented to capture a subreach of alternate stream type in the downstream end of the reach:

M15 Segment	Approximate Length (ft)	Stream Type
B	3,989	C4-riffle/pool
A *	6,162	E4-riffle/pool

* Subreach

Segment B

Segment B comprises the upstream half of reach M15. The Lewis Creek flows through a Very Broad valley of alluvial sediments bound along the southwest by moderately-steep slopes (and terraces) of glaciolacustrine, till and glaciofluvial sediments and bound along the northeast by moderate- to steep-slopes of glaciolacustrine and glaciofluvial origin (USDA). These valley wall sediments are hydric in nature. Extensive wetlands are mapped in the floodplain along the channel for the entire segment length (NWI, VSWI). A reference C stream type is inferred.

Encroachments within the corridor include a LB driveway (Cobble Creek Nursery) which parallels the channel for very short distance just upstream of the Tyler Bridge Road bridge; this driveway encroachment is not substantial enough to constitute a human-caused change in valley width. This segment is crossed by Tyler Bridge Road (paved) by means of a bridge on concrete abutments. The span of the bridge (62 feet) is slightly wider than the reference bankfull width (55.5 feet; VTDEC WQD, 2006) and the measured bankfull width (57.3 feet) of the channel. The channel is bifurcated around a large, mid-channel bar of cobbles and gravel immediately downstream of the bridge crossing. This depositional bar has been present since at least 1999, based on review of historic aerial photographs. Historic channelization is inferred from the linear planform upstream and downstream of the Tyler Bridge Rd bridge. One house is present within the river corridor along the RB upstream of the bridge. The Cobble Creek tree nursery operations are present within the LB corridor.

A gully was observed along the LB of the Lewis Creek approximately 125 feet upstream of the Tyler Bridge Road. The gully extends approximately 75 feet upstream from its confluence with Lewis Creek, and ranges in depth from approximately 5.5 feet near the confluence to 2.5 feet near the head cut (at the upper extent of the gully; see Figure G-18). The width of the gully ranges from approximately 8 to 4 feet.

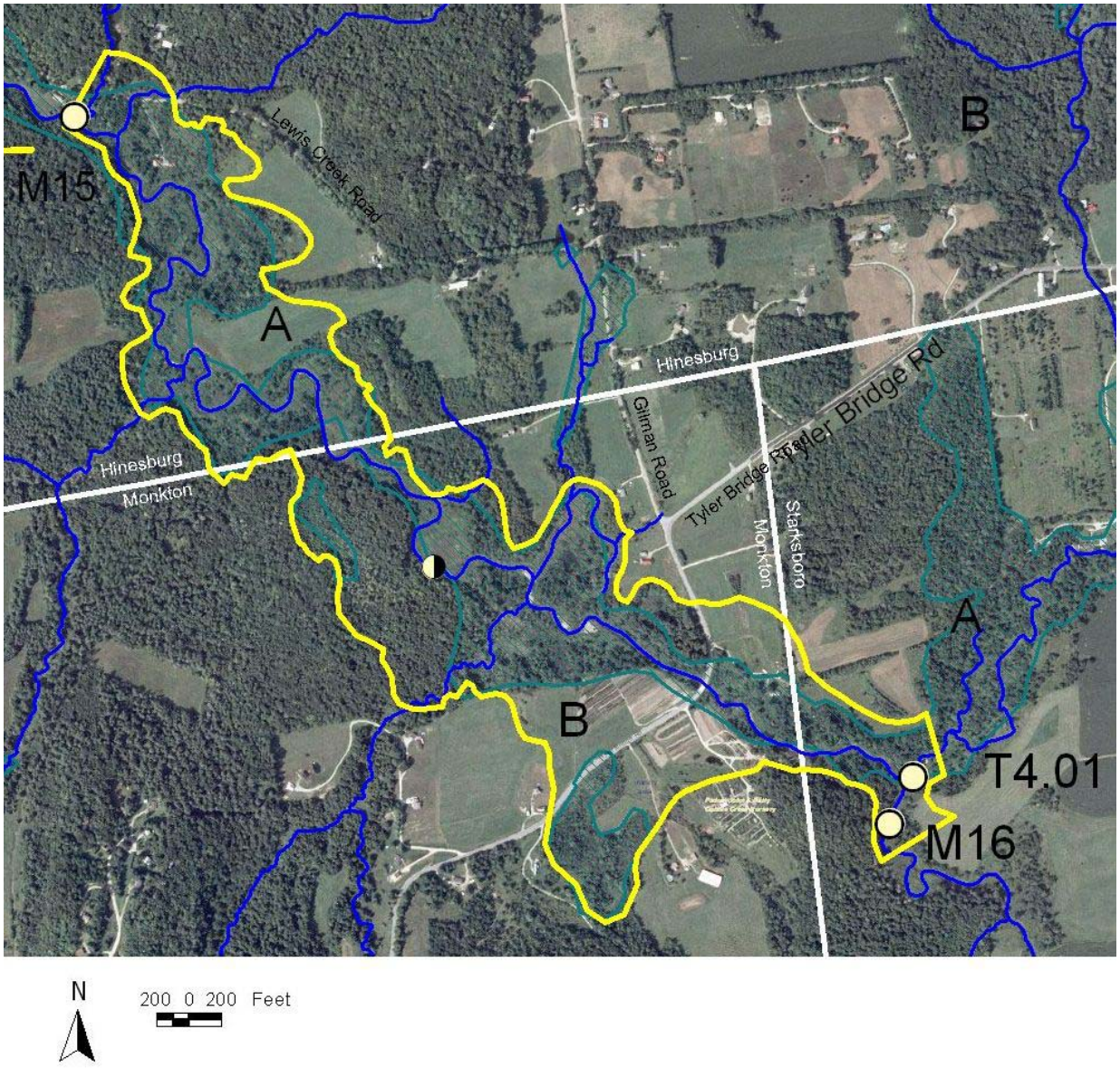


Figure G-17. Segmentation of reach M15.

Based on limited field evaluations, anecdotal evidence, and review of historic aerial photographs, it appears that a change in area drainage patterns has increased flows to a drainage swale on Cobble Creek Nursery lands to a degree that may have exceeded thresholds for erosion – contributing to the head cut and development of gully erosion. Approximately 750 feet to the southwest of this gully site, an intermittent stream drains to the northwest crossing the neighboring Frye residential property, passes under the Frye driveway through a culvert and under Tyler Bridge Road through another culvert. This stream channel has been historically ditched north of the Tyler Bridge Road on the northern Padua parcel. According to John Padua, the Frye driveway culvert has silted in over the years, and surface water from this channel now tends to pool in a marshy area along the east side of the driveway at the western edge of the Padua property and at the upstream end of a drainage swale through the Cobble Creek Nursery. A portion of the flows in this intermittent stream is now diverted to the northeast onto the Cobble Creek Nursery property. In recent wet years, the drainage swale through the nursery has conveyed more water during storms and spring runoff. The Cobble Creek Nursery driveway has been overtopped several times, washing out portions of the driveway. Accelerated head-cutting of the swale and gullying has been noted during these recent years. (Further details of this gully site and project development activities occurring in 2009-2010 are summarized in Appendix K).

Figure G-18. LB stormwater channel from commercial tree nursery in Segment M15-B just upstream of the Tyler Bridge Rd. With the addition of drainage diverted from an upstream residential property, this channel has developed into an erosional gully that has deposited gravels and sands in the Lewis Creek channel.
29 November 2006.

Between 1994 and 1995, a Lewis Creek channel avulsion occurred downstream of the Tyler Bridge Rd bridge and resulted in the loss of approximately 1000 ft of channel length as a large tortuous meander was abandoned by the Lewis Creek (Figure G-19). No bedrock grade controls exist within the reach to prevent headward migration of incision following this avulsion. However, no head cuts were observed upstream of this avulsion site in the reach (November 2006). It is possible that the low overall channel gradient (~0.1%) moderated the potential for incision. Also, recent meander extension elsewhere in the segment has added to the channel length. The potential for incision may also have been offset by active aggradation. Streambank erosion within the segment and in upstream reaches (including the Hollow Brook) is contributing coarse sediment fractions (bed load) within the segment. Aggradation is particularly evident local to beaver dams, debris jams and entrained large woody debris. The channel is locally overwidened in vicinity of these features. Discontinuous pockets of incipient floodplain are evident at a slightly lower elevation than the surrounding floodplain – being built through active channel widening and planform adjustments.

The segment cross section confirmed a C4-riffle/pool stream type with a moderate degree of incision (IR_{RAF} = 1.6). While the majority of the reach exhibits a weak riffle/pool bedform, plane bed conditions dominate the historically channelized section downstream of the bridge. A stage IV[F] (or late stage III[F]) CES is inferred. Segment M15-B was classified with a "Fair" condition rating and "Very High" sensitivity.

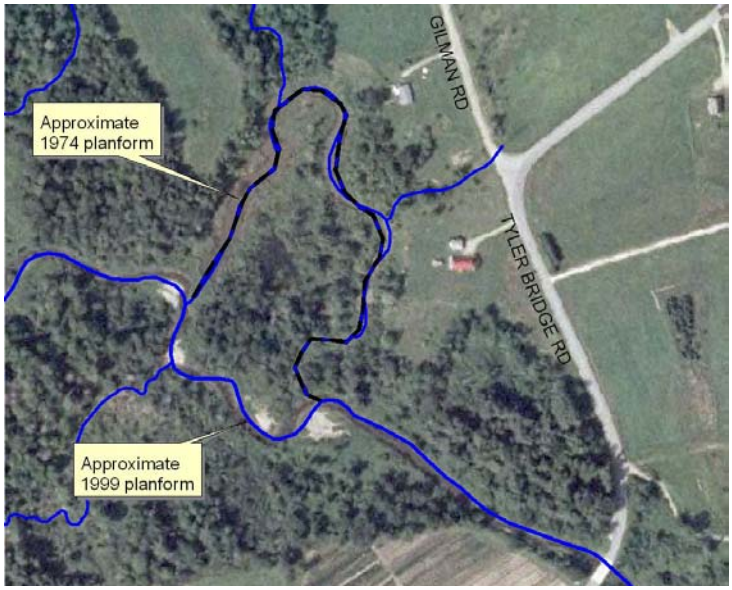


Figure G-19. Abandoned meander downstream of the Tyler Bridge Rd bridge in Segment M15-B. Review of annual fly-over images at the NRCS Middlebury office indicates that this avulsion occurred over a period of time from 1994 to 1995. Cut off of this broad meander resulted in a net loss of 1,000 ft of channel length. The avulsion and subsequent channel adjustments may have contributed to recent aggradation in downstream Segment M15-A. (Base image is dated 2003)

Beaver activity is evident in Segment B; one breached dam was indexed in November of 2006. Fresh-water mussels have been observed near the downstream segment break (November 2006) and near the confluence of Hollow Brook (August 2002).

Segment A

Segment M15-A meanders through a wide, low-gradient (0.1%) alluvial valley of Very Broad confinement, which narrows considerably near the downstream end of the segment at a valley pinch point defined by bedrock-controlled, steep valley walls in reach M14. The floodplain is bordered to the southwest by moderately-steep slopes (and terraces) of glaciolacustrine, till and glaciofluvial sediments and to the northeast by moderate to steep slopes of glaciolacustrine and till origin (USDA). These valley wall sediments are hydric in nature; alluvial sediments in the floodplain at the downstream end of the segment are also mapped as hydric (USDA). Wetlands (NWI, VSWI) are mapped contiguous to the channel throughout the segment. The unconfined valley setting, low overall gradient, and high sinuosity of the channel suggest a reference E stream type.

Encroachments within segment M15-A are relatively minor. Lewis Creek Rd encroaches within the floodplain along the downstream 10% of the segment. Historic channelization in the middle portion of the segment is apparent from a 1942 photograph in the vicinity of a former farm road crossing visible on a 1948 USGS topographic map. One single-family residence is located in the floodplain along the RB near the downstream end of the segment. Streambank armoring was recently installed (2006 construction season) to protect this RB residence (Hinesburg Lot 12-01-38); the river has since migrated toward the LB (south and southwest) to abandon its position along the rip-rap. Past streambank armoring treatments in this vicinity were also outflanked or abandoned by the adjusting river.

Between 1983 and 1999, a Lewis Creek channel avulsion occurred near the downstream end of Segment M15-A, and resulted in the net loss of approximately 510 ft of channel length (Figure G-20). Despite this avulsion, the channel has maintained excellent floodplain connection (IRRAF = 1.0). Cross section measurements indicated an E stream type, consistent with reference. Vertical adjustments may have been moderated by the low overall valley gradient, and present of relatively cohesive silt and clay sediments in the channel boundary.

Segment M15-A is dominated by moderate planform adjustment (flood chutes, meander extension & migration, recent avulsion) and aggradation in response to historic straightening and delivery of sediments from upstream sources (erosion, tributaries, stormwater inputs). Although deciduous trees are sparse in the nearbank area – some LWD recruitment is occurring where the channel bumps up against the forested, left-bank valley wall. Presence of debris jams (4) and submerged LWD (42) are contributing to lateral adjustments and aggradation that may offset a tendency for channel degradation. Lateral adjustments may also be exacerbated by natural conditions of the valley pinch point on approach to semi-confined (bedrock-controlled) downstream reach M14. Following a November 2008 update to VTANR stream sensitivity ratings (VTANR, 2008a), the sensitivity of this E4 segment in Fair condition was assigned as "Extreme".

Beaver activity was evident in the segment, including two recently breached dams (November 2006). Fresh-water mussels were also observed (November 2006).

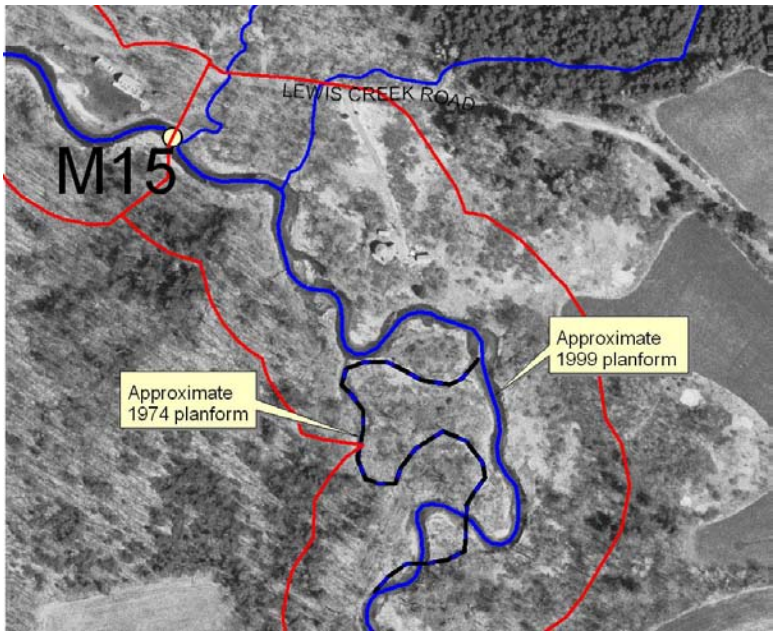


Figure G-20. Channel migration area at downstream end of reach M15 (Segment A). Based on review of orthophotos and a local landowner's aerial view, this apparent avulsion occurred post-1983 and pre-1999, and resulted in a net loss of 510 feet of channel.

(Red line is Phase 1 corridor. Base map is 1999 orthophoto).

M14

Reach M14 was originally assessed in 2001 as part of the pilot study carried out by VTDEC River Management Section and Lewis Creek Association volunteers (VTDEC WQD, 2003a). The RGA relies on observations from 2001 as well as limited observations and a cross section completed in November of 2006.

Reach M14 is a 3,003-foot (0.6-mile) long reach, located along the south side of Lewis Creek Road in Hinesburg. Here the Lewis Creek flows through lands underlain by a north-south trending band of slightly more resistant bedrock (Monkton Quartzite, Winooski Dolostone; Thompson *et al.*, 2004). Exposures of channel-spanning bedrock were observed in this reach, and bedrock was observed in several places along the steep to very steep valley walls. Valley confinement is estimated as Semi-Confined, overall, with local areas of Narrowly-Confined. The corridor is dominated by sediments of lacustrine and glacial till origin. A mix of sediment sizes, generally cohesive in nature, was observed in the stream banks. A reference Bc channel is identified for this reach, which has a low overall gradient (0.3%).

Lewis Creek Road passes within approximately 100 feet to the north along the right valley wall along the entire length of M14. However, this gravel road is elevated well above the bankfull and flood-prone-width elevations and has not significantly reduced the natural valley confinement. In addition to the road encroachment along RB, this reach is crossed by Turkey Lane (gravel) by means of a bridge on concrete abutments. The span of the bridge is undersized (41 feet) with respect to the reference bankfull width (65 feet) and measured bankfull width (52 feet) of the channel. The channel is bifurcated around a large, vegetated island of boulders, cobbles, and gravel immediately upstream of the bridge crossing. This depositional bar has been present since at least 1974, based on review of historic aerial photographs. Significant ditch and rill erosion of both the Lewis Creek Road and Turkey Lane have been observed during moderate to heavy rainfall events. Along the RB, road sediments were observed entering the Lewis Creek at discrete locations via road culverts and overland runoff (for example, Figure G-22). Although a tree buffer is maintained between the road and Lewis Creek, the steepness of the slopes and the magnitude of gravel applications on the road appears to overwhelm any potential filtering function of the vegetated buffer.

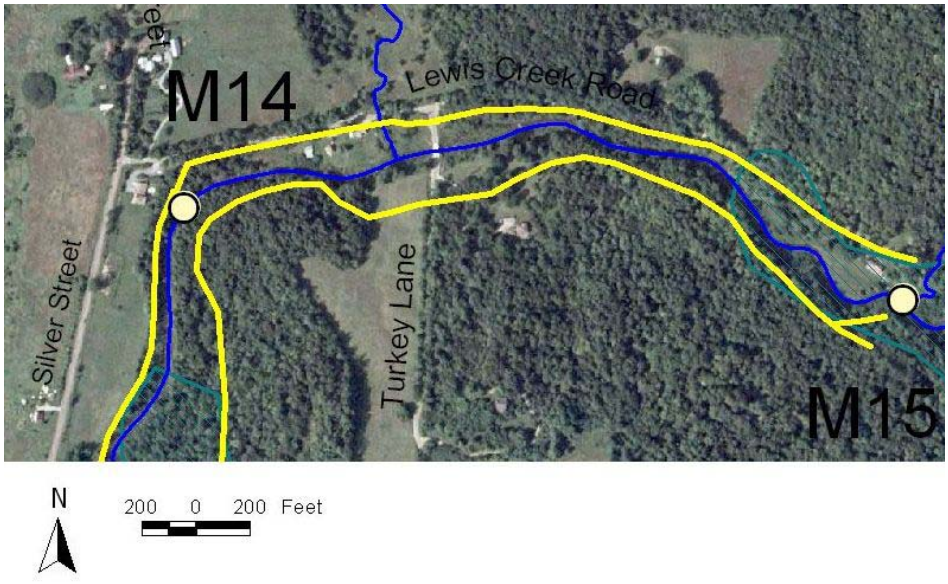


Figure G-21. Reach M14, Lewis Creek main stem, Hinesburg.

Residential development is present within the reach corridor, limited to the RB at the upstream extent of the reach and downstream of the Turkey Lane bridge. Tree buffers are absent along lawn areas at these residences and local to the bridge crossing. Rip-rap armoring is present at the upstream end of the reach along RB and at the bridge crossing. During the original reach assessment on 12 October 2001, an apparent irrigation withdrawal (1-1/4-inch black plastic pipe) was observed along the LB downstream of the Turkey Lane bridge. Also, a clear discharge was observed flowing at approximately 2 gallons per minute into Lewis Creek from a six-inch drain pipe along the RB downstream of the Turkey Lane bridge (possibly a residential gray-water drain or French drain).

A cross section performed mid-reach confirmed a Bc stream type, consistent with reference. While bedrock dominated the pebble count at the cross section site, bedrock exposures were limited to a 600-foot section of the channel mid-reach. Overall, the reach was dominated by cobbles (visual estimate). Bedforms are somewhat variable through the reach. A riffle/pool bedform (not well defined) appears to dominate the reach, although bedform within the bedrock-dominated section of the channel was more plane bed.

The channel has full access to a narrow flood plain, exhibiting negligible signs of incision. Minor evidence of aggradation is suggested by the presence of one transverse bar, the island upstream of the bridge, and two small "deltas" of fine sediment from right-bank tributaries or stormwater channels. A few trees were observed leaning into the channel from both banks at the mid-point of the reach. However, the channel margins at this location were largely stable, supported on bedrock. The width/depth ratio measured mid-reach is relatively low (21). Measured bankfull widths (52 ft at XS-2, 11/29/2006; 64 feet at XS-1 at the downstream end of the reach, 10/12/2001; and 55 feet at CS-3 in the upstream third of the reach, 10/12/2001) are consistent with expected channel width (65 feet) for a drainage area of this size (VTDEC WQD, 2006). Evidence of recent planform adjustment was limited to the pre-1974 channel bifurcation around the island upstream of the bridge. The channel appears to have a very similar planform on the 1942, 1974, 1995 and 2003 aerial photographs. Overall, reach M14 was rated in Good condition following the RGA, indicating minimal adjustments or departure from reference. A "Moderate" sensitivity rating was assigned, by protocols (VTANR, 2007a; VTANR, 2008a).

For instream habitats, a reasonable diversity of velocity/depth conditions and pool depths is available, given the alternating bedrock and cobble riffle/pool bedforms. Forested streambanks are well-developed along much of the reach, offering shading, detritus and LWD.

Figure G-22. Sediments from the Lewis Creek Road enter the Lewis Creek as a result of overland runoff along the RB, reach M14.

M13

Reach M13 was assessed in 2004 and 2005. This reach is 1.5 miles in length and extends from Lewis Creek Rd to the confluence of Pond Brook, spanning the Silver Street crossing. Within this reach, Lewis Creek is transitional from the semi-confined, bedrock-controlled reach along Lewis Creek Rd to a much broader valley setting. Valley confinement ranges from Semi-Confined, in a few locations, to Very Broad, with an average Broad confinement. The channel gradient appears somewhat steeper above the Silver Street crossing than below the bridge. Upstream of Silver Street bridge crossing, the corridor is comprised of a complex mixture of soils derived from glacial till, glaciolacustrine origins, glacial-fluvial and alluvial origins. Downstream of the Silver Street crossing, the corridor is dominated by alluvial sediments close to the channel bounded on either side by glaciolacustrine sediments with a hydric nature. A mix of sediment sizes, generally cohesive in nature, was observed in the stream banks.

Due to active beaver impoundments, the downstream half of the reach was segmented and a limited assessment was completed. While the over-riding reason for segmentation was the beaver-impounded condition, the downstream half of reach M13 also appears to have a reference stream type (E-dune-ripple) which is distinct from the upstream half of the reach. This judgment is based on the lesser gradient of Segment A, the cohesive nature of soils comprising the banks, a generally low width/depth ratio of the channel section (visual observations only), and the wetland-dominated, reference E stream type of the immediately downstream segment (M12-C).

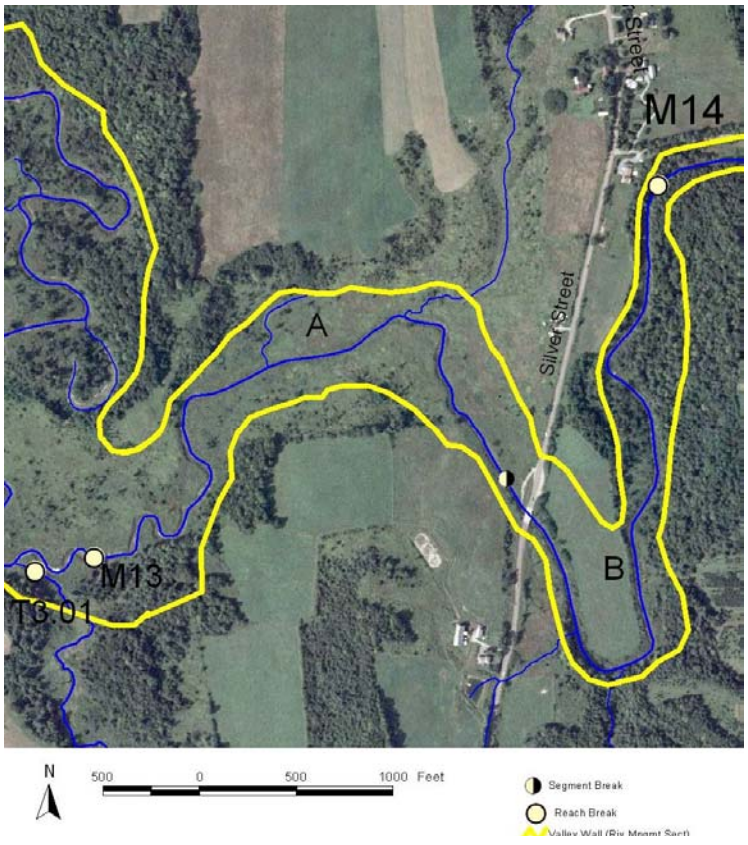


Figure G-23. Segmentation of Reach M13, southern Hinesburg.

Segment B

Segment B comprises the upstream half of the reach and ends just below the Silver Street bridge crossing. Valley confinement in Segment B ranges from Semi-confined to Broad, with an average classification of Narrow. The channel has a large meander just upstream of the Silver Street crossing. This same planform is evident on historic photographs and map images of the region dating back more than 100 years. It is likely that underlying bedrock controls as well as cohesive sediments in the bed and banks have contributed to the persistent planform.

The M13 corridor has remained largely undeveloped. Residential development is evident within the RB corridor at the very upstream end of the reach at an elevation well above the channel. Silver Street crosses the reach at the downstream end of Segment B. Historic straightening of the channel is inferred associated with this bridge crossing. The LB corridor is largely forested; while hay fields dominate the RB corridor. Following recent precipitation and high-water conditions, turbid flows were observed on 15 June 2005 from a LB tributary that joins the Lewis Creek on the prominent meander bend. A small delta of fine sediments was evident near the confluence of this tributary. Upstream reaches of this tributary flow over clay- and silt-rich sediments of glaciolacustrine and till origin; upstream land uses include forest cover, pasture and residential developments.

Silver Street bridge crossing has a span that is somewhat larger than the measured bankfull width.

Segment A

Historic aerial photographs reveal meander scars along the northern valley wall in Segment A, suggesting that the channel was more sinuous – perhaps in postglacial times. The linear planform in local sections of this segment suggest possible historic straightening.

Recent avulsion has shifted the position of the Cedar Brook confluence.

While the beaver-impounded status of the channel precluded cross section measurements, visual observations suggest a moderate degree of historic incision in Segment A. Frequent observation of this segment from the Silver Street crossing in recent years suggests that the Lewis Creek rarely overtops its banks in this section. A provisional estimate of stream type (E4-dune-ripple) and condition (Fair) has been recorded in the Data Management System for this segment. A sensitivity rating of "Extreme" is assigned following VTANR guidance.

Beaver tracks, spraints of muskrat, scat of moose.

M12

Reach M12 was assessed in October of 2004 and the update to 2007 forms, relied on this original data. Reach M12 is 2.7 miles long and extends from the Pond Brook confluence (T3.01) to the Cedar Brook confluence (T2.01) – passing under the Baldwin Road bridge mid-reach. Valley confinement varies somewhat along the length of this reach. Variable soil types and channel dimensions reveal a short subreach of alternate reference stream type mid-reach. The upper two-thirds of the reach are mapped as wetlands (NWI, VSWI). Beaver activity also impounded the lower and upper extents of the reach. For these reasons reach M12 was segmented:

- Segment C – 9,501 feet long, wetland-dominated, beaver-impounded, likely E4-dune/ripple stream type in Very Broad valley with occasional floodplain access.
- Segment B – 1,161 feet long, slightly steeper gradient, B4c-PB channel spanning the Baldwin Rd crossing, in a Semi-confined setting with historic incision (IR_{RAF} = 1.7).
- Segment A – 3,632 feet long, beaver-impounded, likely E4-dune/ripple stream type in Semi-confined to Narrow valley setting, with marginal floodplain access.

Segment C

The channel in Segment M12-C has a highly sinuous planform meandering through a Very Broad valley of low gradient (0.1%). Soils mapped close to the channel are alluvial in nature, confined by moderately to very steeply sloping valley side slopes of glaciolacustrine origin. Sediments revealed in the stream banks were comprised of cohesive silts and silty sands overlain by noncohesive fine sands. Stream bed materials were dominated by fine to very fine gravels and sand. Wetlands (NWI, VSWI) are mapped contiguous to the channel and spanning the floodplain.

Two historic neck cutoffs (oxbow channels) were noted by overlaying the current stream planform on a 1987 topographic map; oxbow channels are visible. There is a potential for future neck cutoffs at meanders with a radius of curvature tighter than regime. A beaver dam impounded nearly the entire length (7,200 ft) of this low-gradient segment.

The position of the Pond Brook tributary confluence with Lewis Creek has shifted from that depicted by the VHD (a 1999 orthophoto and 2003 aerial photograph). As a meander of the Lewis Creek channel migrated to the south, it connected with the Pond Brook channel at a point approximately 200 feet upstream of the former confluence. This new point has become the new confluence. This new confluence was first noted in October 2004 reconnaissance of the area.

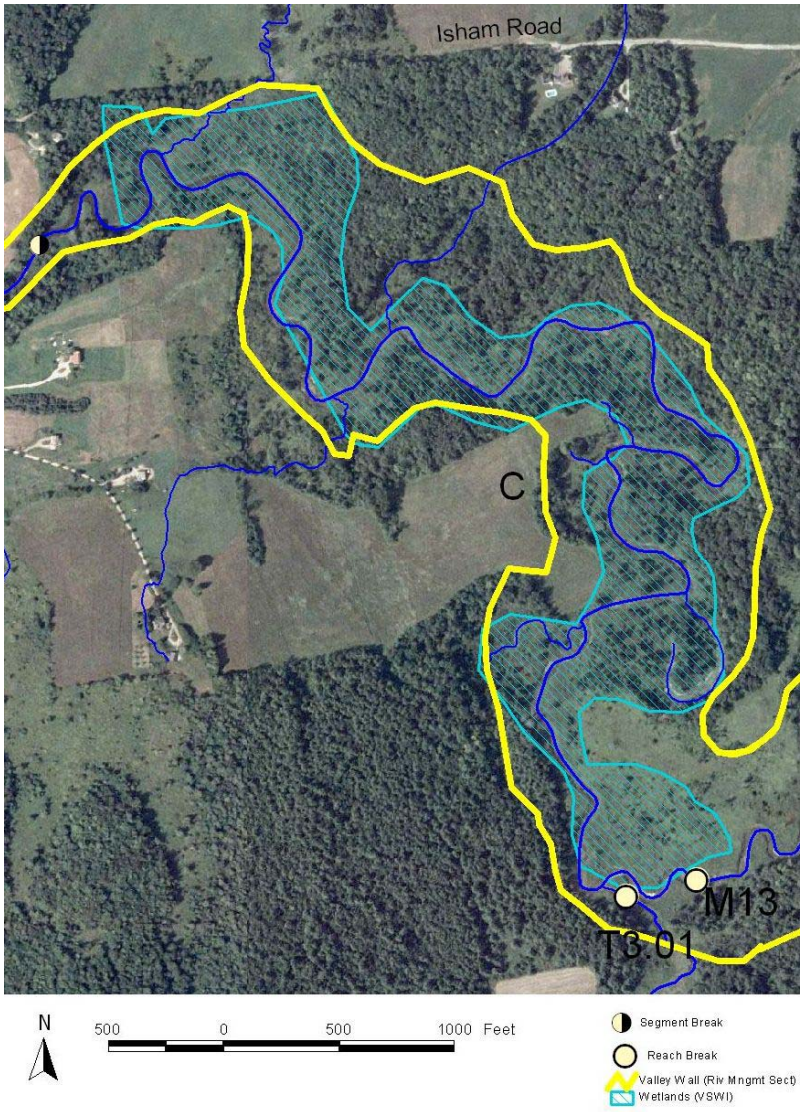


Figure G-24. Segment M12-C, Hinesburg.

Segment B

Corridor dominated by glaciolacustrine sediments, with hillsides further to the north and south comprised of glacial till sediments (USDA). Presence of cobbles and a few boulders in the stream bed, probably derived from the surrounding and underlying glacial till. The dominant bed material is classified as coarse gravel, on the cusp with small cobble.

Alternate reference stream type – C4-PB or C4-R/P – is theorized, with a vertical stream type departure to B4c-PB. Historic incision and vertical departure may have occurred prior to colonial times (post-glacial). It is also possible that a B stream type is the reference stream type, and no significant vertical departure occurred. Further study would be required.

Baldwin Rd bridge crossing is slightly wider than measured bankfull width at the upstream cross section site – therefore it has been classified as a FPW constrictor.

Condition: Good (minimal adjustment); Sensitivity (very high).

Given the uncertainty associated with the classification of reference stream type, it is possible that the sensitivity of Segment B is overstated.

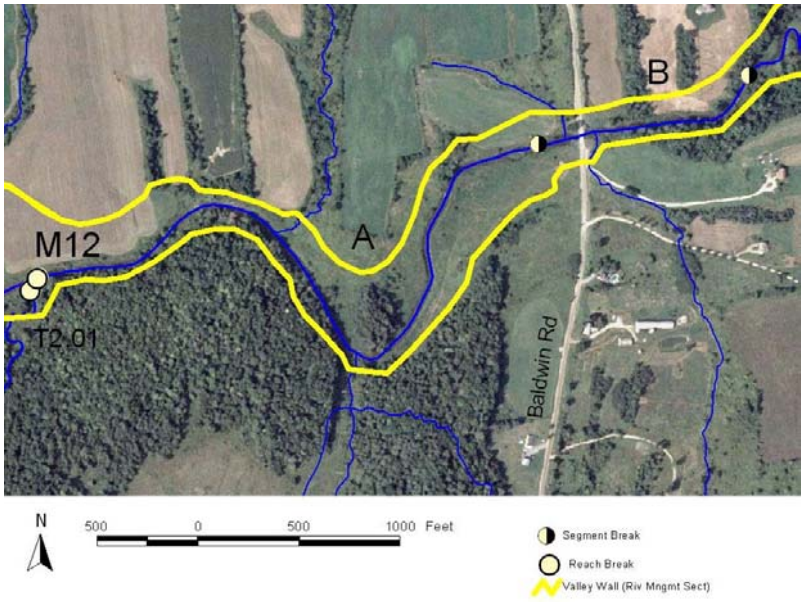


Figure G-25. Segments M12-B and M12-A, southwestern Hinesburg.

Segment A

Segment A was scheduled for assessment in 2004, but was not assessed due to extensive beaver impoundments. One beaver dam was located mid-segment and impounded a channel length of approximately 1600 feet. The remaining downstream end of the segment was impounded by a beaver dam located in downstream reach M11.

Limited extent of alluvial sediments in the upstream half of the segment in vicinity of the Baldwin Rd bridge crossing. Otherwise the corridor is dominated by glaciolacustrine sediments and glacial till (along the LB in the upstream half). Wetlands are mapped contiguous to the channel (NWI). A gradual narrowing of the valley walls is evident with distance downstream.

Figure G-26. Segment M12-A, impounded by beaver dams, 18 October 2004, Hinesburg.

M11

Assessed in October of 2004. Small pocket of alluvial sediments in the floodplain surrounded by valley walls comprised of glaciolacustrine sediments. Valley confinement generally decreases with distance downstream – from Broad to Narrow, with a short section of Semi-confined near the downstream end of the reach as the Lewis Creek passes through a short bedrock gorge just above the Seguin Covered bridge. Overall, an average Broad confinement characterizes the reach.

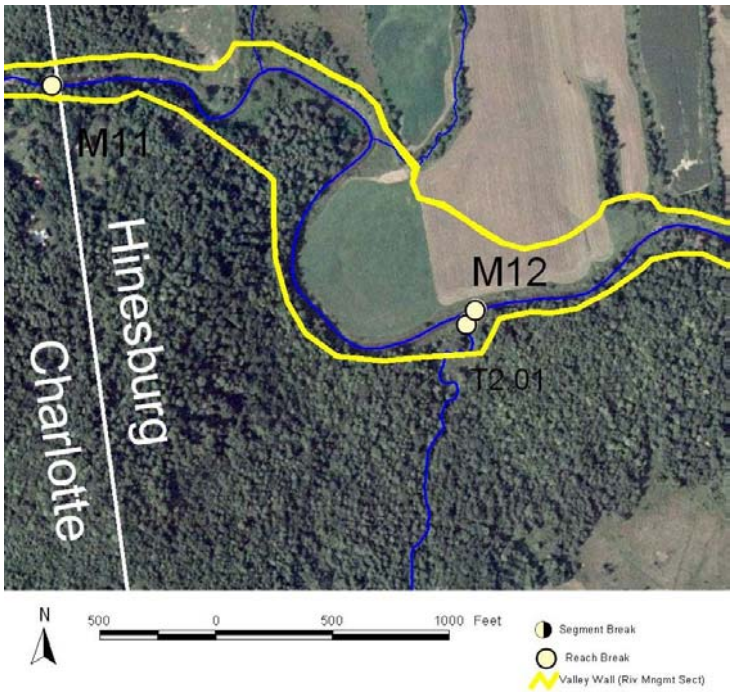


Figure G-27. Reach M11, southwestern Hinesburg.

A shallow, channel-spanning exposure of bedrock was noted in the upstream end of the reach (and near the downstream reach break in reach M10). Exposures of bedrock were also noted at several locations along the LB. Bed materials include boulders, cobbles – likely derived from surrounding glacial till and glaciolacustrine deposits.

The LB corridor is forested with a mixture of deciduous and coniferous species. The downstream end of the RB corridor is also forested, while the upstream half is encroached upon by hay fields with a residual herbaceous buffer that is generally less than 25 feet wide. Historic photographs indicate that this land use was evident in past decades (1940s and more recently).

Moderate historic incision (IRraf = 1.6) – possible contribution from breaching of historic dams reported to exist in the vicinity of the mills near Seguin Covered bridge approximately xx feet downstream of the downstream reach break. Minor aggradation local to beaver dams and infrequent debris jams.
Active channel widening has lead to an apparent lateral stream type departure from E to C stream type.

Fresh water mussels were observed near the downstream end of the reach (Oct 2004).

M10

Reach M10 is a 2.6-mile reach extending from the Hinesburg / Charlotte town line, approximately 450 feet upstream of the Roscoe Road bridge crossing (Upper Covered Bridge), downstream to the former mill pond above Scott Pond Dam. Within the reach, the Lewis Creek crosses two prominent north-south-trending ridges of till-veneered, relatively-resistant bedrock. The channel is generally confined by deposits of glaciolacustrine and till origin. Occasionally, pockets of alluvial deposits have accumulated along the channel where the valley is unconfined (USDA). Often hydric properties and/or mapped riparian wetlands (NWI, VSWI) are associated with these pockets of alluvial sediments. The valley width (as mapped by VTDEC River Management Program) varies from 600+ to 100 feet (or Broad to Narrowly-confined). Channel-spanning bedrock is exposed at the falls above the Seguin Covered Bridge (aka Upper Covered Bridge) at the upstream end of the reach. Occasionally, bedrock is also exposed along the stream banks, and likely contributes to locally narrow confinement (and low sinuosity) in sections.

Several smaller tributaries join the Lewis Creek in reach M10. One of the major tributaries, Prindle Brook (a.k.a. Pease Brook) joins the main stem in the downstream third of the reach. Variable channel planforms are depicted on historic aerial photographs in this downstream third of the reach below the Prindle Brook confluence. Historically, the downstream 1,000 feet of the reach was impounded above the Scott Pond Dam (located in reach M09). Impoundment effects and localized slope decreases, as well as a moderate decrease in valley confinement, may have contributed to a decrease in sediment transport capacity, with attendant channel braiding and lateral adjustments, in the lower third of the reach.

A portion of reach M10 was originally assessed by the VTDEC River Management Program in August of 2001. A Phase 3 survey including five cross sections and a longitudinal profile was completed in the middle portion of the reach. The full reach was walked by SMRC personnel in November of 2006 to record field observations and supplement the original August 2001 Phase 2 and 3 geomorphic assessments. Valley walls were mapped by VTDEC RMP personnel in September 2008. And three additional cross sections were completed in the reach in August of 2009 for this current update. Reach M10 was segmented to capture the significant variability in valley confinement, geology, and encroachment conditions (see also Figure x).

Segment	Length (ft)	Approx Gradient (%)	Stream Type	Notes
M10-F	564	1.8	B1c-S/P (provisional)	Subreach; Not Assessed – bedrock channel
M10-E	1,149	0.3	C3-R/P	
M10-D	4,868	0.3	C4-R/P	
M10-C	2,701	0.9	B4c-R/P	Subreach
M10-B	3,535	0.4	C4-R/P	
M10-A	1,016	0.1	N/A - Impounded	Not Assessed

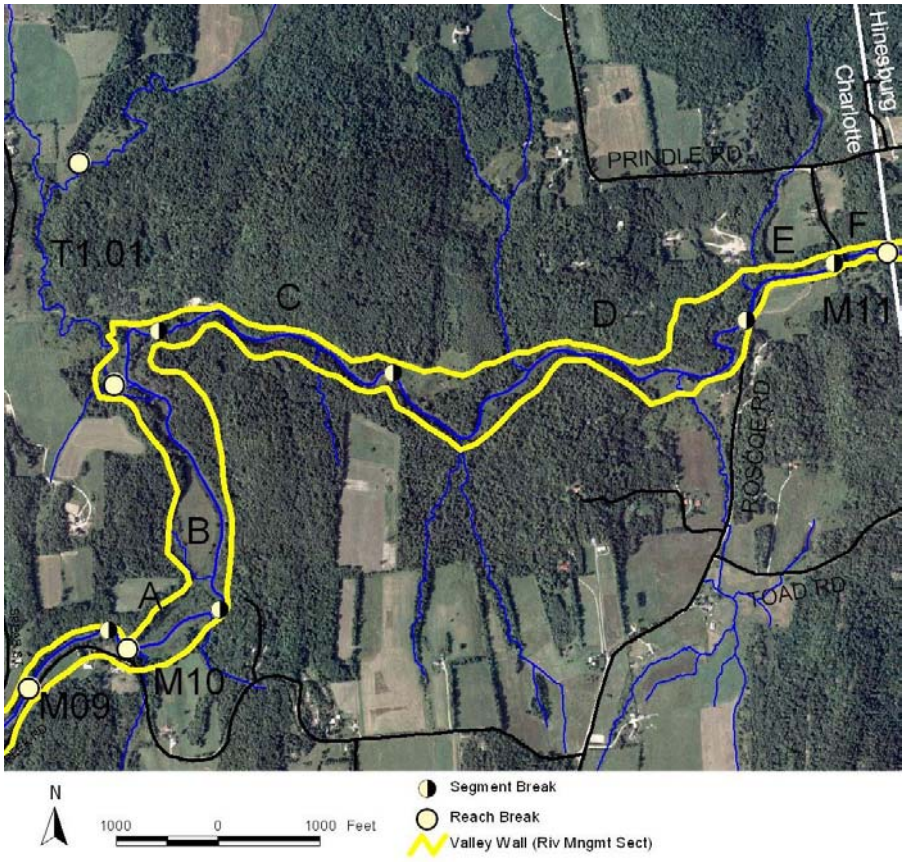


Figure G-28. Segmentation of Reach M10, southeastern Charlotte.

Segment F

Segment F is the short section of bedrock-controlled channel located upstream and slightly downstream of the Seguin Covered Bridge (c. 1850) which carries Roscoe Road over Lewis Creek. Sediments of glacial till origin are mapped along both banks of the channel and in the LB and RB corridors (USDA). Channel-spanning bedrock is exposed in a short waterfall approximately 250 feet upstream of the bridge and in a low-profile "ledge" outcropping approximately 70 ft upstream of the bridge. Vertical bedrock walls are present along RB at and downstream of the falls. Bedrock is also exposed along the LB in a more shallow profile downstream of the falls. Historically, a grist mill and black smith shop were located in vicinity of the falls (Beers, 1869). Short sections of rip-rap armoring reinforce the concrete-capped laid-up-stone abutments of the Seguin bridge, which are slightly undersized with respect to the reference channel width. Stormwater inputs were observed along the RB, both upstream and downstream of the bridge (road ditches terminating at the bridge) and along LB downstream of the bridge where a road ditch culvert is directed under Roscoe Road. Due to the bedrock nature of the channel, this segment was not assessed. A B1c-step/pool provisional stream type was assigned.

Figure G-29. Sequin Covered Bridge (aka Upper Covered Bridge) on segment M10-F of Lewis Creek.

View downstream from bedrock falls, 15 November 2006.

Segment E

Segment E of reach M10 comprises a 1,149-foot section of the channel encroached upon by Roscoe Road. Soils of glaciolacustrine origin are mapped along the RB corridor, while till and recent alluvial soils are mapped in the LB corridor. The LB terrace of alluvial soils is presently utilized for horse pasture.

The linear planform of this segment and close encroachment of Roscoe Road (along LB) suggest possible historic channelization. Rip-rap armoring has been installed in a few locations along the LB to reinforce the bank along this road; and a low berm is present between the road and the channel for an approximate length of 320 feet. High water in February 1990 reportedly overtopped the road and resulted in bank slumping near the downstream end of the segment where a small, unnamed tributary joins the Lewis Creek via a culvert under the road; concrete Jersey Barriers were placed along the road for traffic safety (Illick, 2009). Road ditch runoff along the southeast side of Roscoe Road also drains to the Lewis Creek via this LB tributary culvert. In 2000, tree revetments were installed along a 50-foot length of the LB in this location through cooperative efforts of the US Fish & Wildlife, Lewis Creek Association, and the town of Charlotte (Illick, 2009). In the 9 years since installation, sediments have accumulated along the LB and appear to have stabilized the bank in this location. Meanwhile, LB erosion has increased in a location approximately 450 ft upstream, resulting in the wooden-post guard rail along Roscoe Road slumping toward the channel.

(a)

(b)

Figure G-30. Segment M10-E at Jersey barriers along Roscoe Rd, view upstream: (a) 19 August 2009; (b) 26 January 2010 following ice jam flooding the prior evening.

Along the RB of Segment E is a terrace (RTER 1) at a thalweg height of 5.5 feet that is less than one bankfull width in extent and present at the base of a higher RB terrace (RTER 2). Based on cursory review of streambank and terrace soils, sediments comprising this terrace are silty sands and cohesive in nature, consistent with a glaciolacustrine origin (as mapped by UDSA). In the LB corridor is a terrace mapped as alluvial (USDA) and slightly higher in elevation (thalweg height of 6.9 ft) than the RB terrace, RTER 1. A conservative assumption was made that the RTER 1 represents a recently abandoned floodplain as defined in VTANR protocols, resulting in a calculated incision ratio of IR_{RAF} = 1.45. A C3-R/P stream type in Fair condition was indicated by the RGA; the median grain size for the pebble count at the cusp between cobble- and gravel-dominated. VTANR protocols assign a "High" sensitivity to a C3 channel in Fair condition.

Bankfull indicators were weak in Segment E. The measured bankfull width (63.5 ft) was less than predicted (83 ft) by VT Regional Hydraulic Geometry Curves (VTDEC, 2006). It is possible that the bankfull elevation was underestimated and the RTER 1 feature instead represents the bankfull elevation, with a calculated bankfull width of 70 ft (and bankfull depth of 5.5 ft). In this case, the LTER would become the RAF, and an incision ratio of IR_{RAF} = 1.25 would be calculated. The existing stream type would remain unchanged (C3-R/P), but the condition would be upgraded to Good (due to the lesser incision, and lower width/depth ratio). A "Moderate" sensitivity would be applicable to a C3 channel in Good condition, according to protocols. This location will continue to be monitored for a bankfull flow condition to verify bankfull elevation.

Segment M10-E persists in a partly-incised condition. Incision is historic (based on the absence of features which would suggest active incision), and may be related to operation of a historic dam or other flow regulation near the Seguin bridge. Channelization and encroachment of Roscoe Road over the years may also be a contributing factor to observed incision. Cohesive sediments in the bank may have moderated channel widening and planform adjustments, along with revetments and rip-rap armoring maintained over the years to protect Roscoe Road. A low-flow sinuosity of the channel is evident and several grassy, low-profile, narrow side bars are present – suggesting that cohesive streambank sediments may collapse and then persist along the channel margins, creating a stepped cross section.

Segment D

Segment M10D is a mostly unconfined channel section extending approximately 4,868-feet downstream of the point where Roscoe Road pulls away from the channel and climbs the valley wall. This portion of Lewis Creek is largely undeveloped and has mature forested (coniferous) buffers along both banks with occasional pockets of wetlands (NWI, VSWI). Recent alluvium and glaciolacustrine soils are mapped in the valley-bottom, which is bounded by valley slopes of till and glaciolacustrine soils (USDA). Bedrock was occasionally observed along the RB.

There is a short section of Semi-confined channel near the mid-point of Segment D, according to the valley walls mapped by River Management Section. Additional cross sections may have confirmed a more confined stream type for this short section (e.g., Bc), but the section was deemed too short for segmentation. Depending on the dominant condition, a slightly different Sensitivity may have been defined for this short Semi-confined section, yielding a different dimension of river corridor (or FEH corridor). However, it is likely that the closely-confining valley walls will ultimately determine the corridor boundary for this short section, irrespective of Sensitivity classification.

The representative cross section was completed in the upper end of Segment M10D and indicated a C4-R/P stream type with moderate historic incision (IR_{RAF} = 1.6). The channel was somewhat overwidened at the cross section site (W/D = 57). A high terrace mapped as glaciolacustrine was present at a thalweg height 2.5 times the maximum depth along the LB. The RB terrace (also mapped as glaciolacustrine) was classified as the recently abandoned floodplain, though it is possible that the Lewis Creek incised below these terraces in pre-colonial (post-glacial) times. There are several instances of incipient

floodplain developing along the channel margins, including a narrow bar along RB within the cross section site. A moderate degree of sinuosity is evident in the low-flow channel. Bank sediments are somewhat cohesive in nature and may be moderating lateral adjustments. Widening appears historic in nature, based on the absence of actively undercut banks and collapsing vegetation through riffle sections. Instead, overall widening and building of the incipient floodplain appears to be the result of active (but minor) planform adjustments (flood chutes, occasional meander migration).

Segment C

Segment M10-C is approximately 2700 feet in length with a locally steeper gradient (estimate 0.9%) – a subreach of alternate reference stream type (B4c-R/P). Large mass failures along right bank in downstream third of reach, just upstream from Prindle Brook confluence may possibly be related to right corridor sand and gravel quarrying indicated on historic aerial photographs.
Historic incision (IRraf = 1.6)
Condition: Fair; Sensitivity: Very High

Segment B

Segment M10-B is approximately 3535 feet in length. A C4-R/P reference (and existing stream type).
Possible straightening inferred along hay field.
Possible incision effects of historic breaching of the Scott Pond Dam (apparently between 1950 and 1991; and possibly during past flood events such as the 1927 or 1938 floods).
Historic incision (IRraf = 1.6)
Condition: Fair; Sensitivity: Very High

Segment A

Segment A of reach M10 consists of the apparent extent of impounded effects from downstream Scott Pond Dam, as noted during November 2006 field inspections. While the length of upstream impoundment effects may vary at different flow stages, this segment break notes the approximate extent. Historically, a mill pond of wider aerial extent existed upstream of the dam, as viewed on the 1906 topographic map (Figure G-31) and the 1869 Beers Atlas. Today, the channel appears partly incised below the former mill pond sediments. A backwater channel is visible to the north of the current channel on historic aerial photographs (e.g., 1942, 1962, 1974). Segment A was not assessed due to the impounded condition.

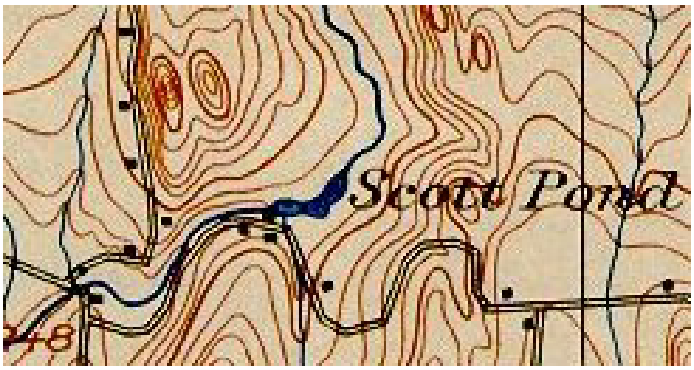


Figure G-31. Historic mill pond upstream of Scott Pond Dam, Segments M10-A, M09-B. Source: 1906 USGS Burlington, VT topographic map.

M09

The 2009 assessment update for this reach relies on field inspections from September of 2004, and limited observations from subsequent years. Reach M09 is approximately 1,305 feet in length, and flows along the Lewis Creek Road (gravel) from the Scott Pond dam and former mill pond to a point approximately 1,400 feet upstream of the Quinlan Covered Bridge. This short section of the Lewis Creek is naturally confined between bedrock-controlled, till-covered steep slopes to the north (RB) and south (LB). The valley width ranges from 2.5 to 3.5 times the channel width – classified as Semi-Confined. A LB terrace along the reach length is mapped as alluvial (USDA). Channel-spanning bedrock is exposed near the upstream end of the reach, and bedrock forms a near-vertical high bank along RB in this vicinity.

Lewis Creek Road (gravel) follows the river in the LB corridor. The road bed is slightly to moderately elevated above the LB terrace along the length. Near the upstream end of the reach, the road is elevated to the extent that it constitutes a human-caused change in valley width (under Step 1.5). A few residential properties are located along the far side of the road near the left valley wall. Scott Pond dam is present near the upstream end of the reach. The reach was segmented to account for this impoundment.

Segment B

Segment B is comprised of the Scott Pond Dam and a short upstream impounded section. This concrete dam is founded on bedrock, and operates as a run-of-river structure with a minimal upstream impoundment. At present, the dam is maintained as a barrier to the upstream migration of sea lamprey (USFW *et al*, 2001).

Over the years, variations in the dam construction and operation have undoubtedly resulted in variable elevations and profile of the river bed in this vicinity. A *History of Charlotte* indicates that a saw mill and grist mill, along with butter tub factory, were operated at this site by Winfield Scott in the 1880s (Rann, 1886). A saw mill and mill pond are identified at this site on historic maps (Beers, 1869; Walling, 1857). An impounded area and dam are depicted on the historic USGS map (1905); the impoundment appears larger in area than the present impoundment upstream of Scott Pond Dam. An April 1950 dam inspection report on file at Waterbury, VT offices of the VT Facilities & Engineering Division, indicates that the dam had deteriorated, but the dam and spillway were intact. By 1991, the dam had been breached – perhaps in the 1973 flood (Figure G-32). In records maintained by the VT Facilities Engineering Division pertaining to dam rehabilitation, a previous dam height was reportedly some 5 to 6 feet higher than the breached dam height (VTANR, 1992).

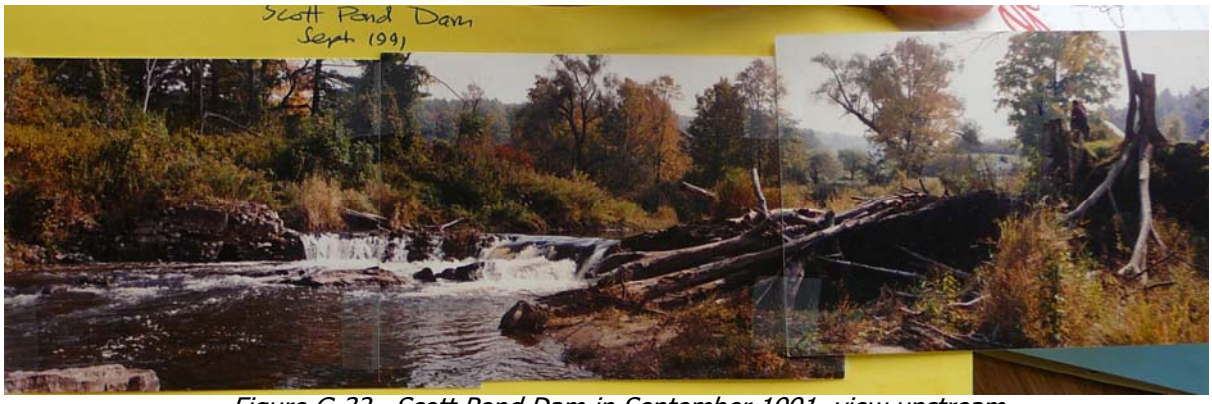


Figure G-32. Scott Pond Dam in September 1991, view upstream.
Source: VT Facilities Engineering Division.

The Scott Pond dam was refurbished between 1992 and 1994 to support its function as a sea lamprey barrier (USFW et al, 2001; VT Dam Safety Section, 1994). The current construction "is a concrete gravity structure approximately 130 feet long and 13 feet high at the end sections. The spillway is a 100' long concrete broad crested weir with 3.5' flat crest with a minimum crest elevation approximately 8 feet below the end sections. The dam appears to be founded on [bedrock] ledge for most of its length….It is provided with an overhanging steel lamprey interdiction plate and a stoplog spillway." (VT Dam Safety Section, 1994).

Figure G-33. Scott Pond Dam following refurbishment in October 1992, view downstream.

Source: M. Illick

"High flows flanked the dam around the right end in the spring of 1994 and the dam construction was extended into the right abutment in the summer of 1994." (Figure G-34). "At normal water level (low spillway crest) the dam has a surface area of approximately 1 acre and storage of 3 acre-feet… Spillway capacity is 6700 cfs." (VT Dam Safety Section, 1994).

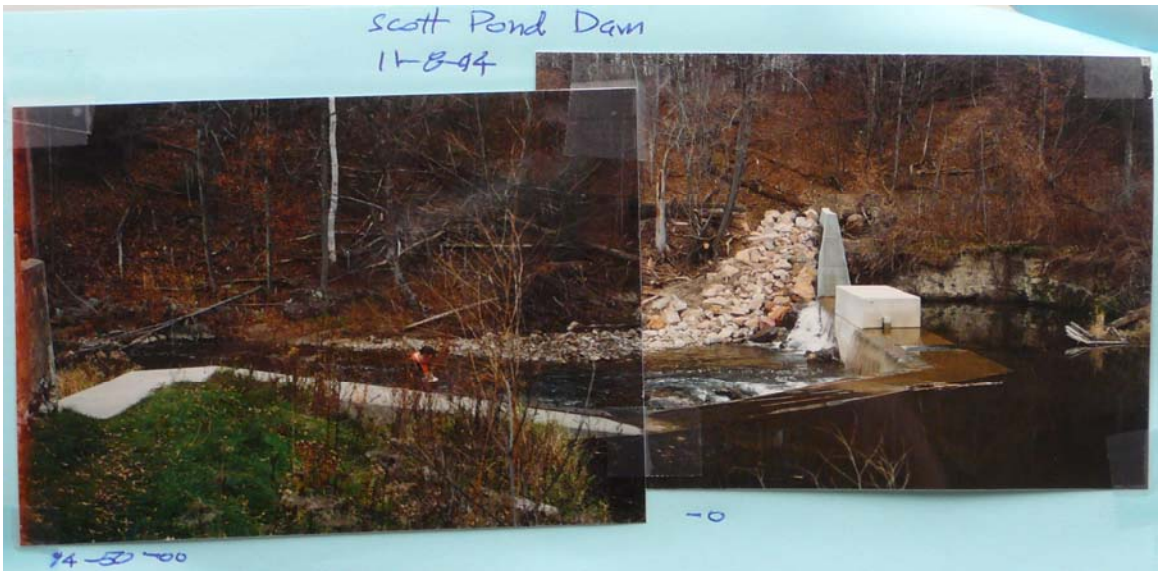


Figure G-34. Scott Pond Dam in November 1994, after extension of right abutment, view downstream. Source: VT Facilities Engineering Division

Refurbishment of the breached Scott Pond Dam in 1992 – 1994 raised the elevation of the dam by a few feet and impounded the Lewis Creek channel for a distance upstream of the dam. The present degree and extent of impoundment is inferred to be less than that associated with previous dam construction near the turn of the 19th century, based on review of the 1905 USGS topographic map.

Figure G-35. View upstream of Scott Pond Dam, Segment M09-B.

(a) No apparent impoundment associated with breached dam condition prior to refurbishment, Summer 1992. Source: M. Illick

(b) Impounded channel following dam refurbishment, October 1992. Source: M. Illick

Segment B was not assessed due to the impounded nature of flows.

Segment A

Segment A comprises the remainder of reach M09 below the dam. A reference Bc stream type was assigned due to the Semi-confined nature and low gradient of the valley setting. A cross section was completed approximately 500 feet downstream of the dam in 2004. The thalweg height of the LB terrace is approximately 2.5 to 3 times the bankfull depth. Lacking detailed surficial geologic analyses or archaeologic data for the reach, a conservative assumption was made that this terrace represents the "recently abandoned floodplain" as defined in protocols, meaning that the Lewis Creek has incised below this terrace within relatively recent history (i.e., last 300 years). The channel is now entrenched below the LB terrace, such that this feature is not overtopped except during very large flood events. Cross section measurements indicated an incision ratio (IR_{RAF}) of 2.7 and an entrenchment ratio (ER) of 1.36, suggesting a vertical stream type departure from B4c to F4.

It is possible that "hungry water" effects of the Scott Pond dam lead to historic net incision below the dam, as sediments were generally impounded above the dam site – although aggradation and widening downstream of the dam might be expected during periods of time when the dam was breached. It is also possible that channelization or gravel extraction measures along M09 (historically) have contributed to the present net degree of incision – although no specific reference to such channel management was obtained in a limited historical review. The linear nature of the channel in this reach is in part associated with the bedrock-controlled close valley confinement. To some degree, encroachment and maintenance

of the Lewis Creek Road over the years has enhanced the degree of channel entrenchment, where the road surface was elevated above the natural floodplain (especially at the upstream end of the segment and in Segment B).

The natural transport functions of this reference Semi-confined reach have been enhanced due to the incised and entrenched condition. This reach remains susceptible to catastrophic erosion in a high flood event. Depending on the operational status of the Scott Pond dam, this upstream structure may serve to impound and attenuate flows to an extent, thus reducing the peak and intensity of flows in the downstream channel. Hydrologic and hydraulic analyses would be required to understand the nature and extent of potential attenuation functions offered by the dam.

Figure G-36. View downstream from Scott Pond Dam, Segment M09-A. 3 November 2009.

M08

The 2009 assessment update for this reach relies on original field inspections from July and September of 2004, and limited observations from subsequent years. Reach M08 is approximately 6,484 feet in length, starting one-quarter mile upstream of the Quinlan Covered Bridge and ending nearly a mile downstream of the bridge. The channel flows through a Very Broad valley comprised of alluvial sediments bounded on either side by moderately-sloped terraces of glaciolacustrine origin. Hydric soils and a smaller aerial extent of wetlands (VSWI) are mapped in this valley. A reference C stream type was assigned, given the valley setting. Low-profile, channel-spanning exposures of bedrock were observed at two separate areas within the reach. North-northeast trending beds of Monkton Quartzite create steps of bedrock that cross cut the channel at an oblique angle in at least five separate locations of a bifurcated channel section upstream of the Quinlan Covered Bridge. Shallow bedrock is also exposed along the channel bed for a length of approximately 250 feet near the downstream reach break.

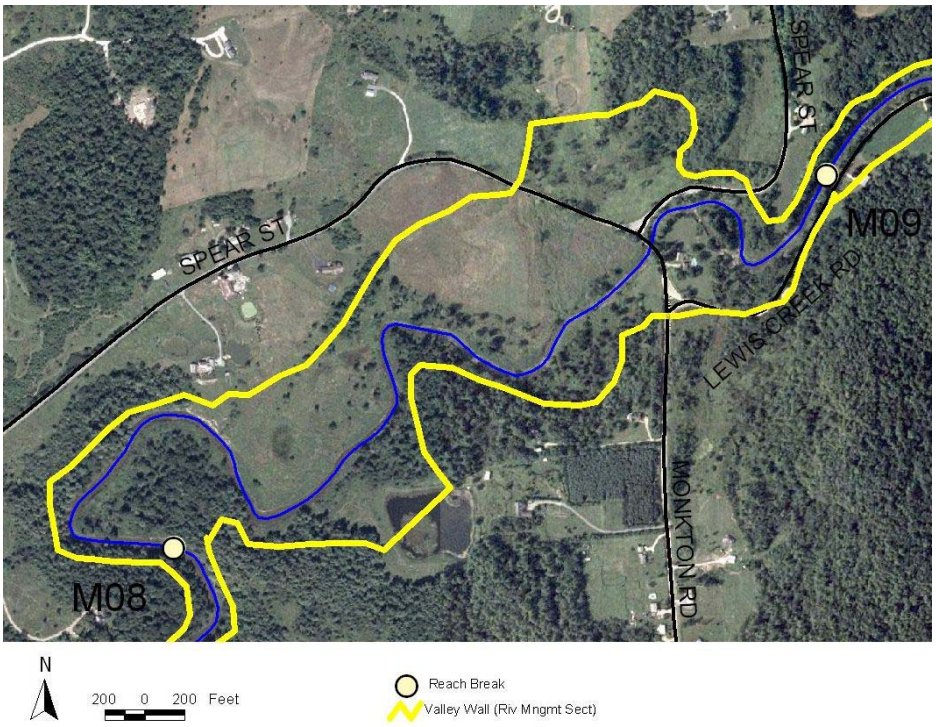


Figure G-37. Reach M08 of Lewis Creek in Charlotte; the Quinlan Covered Bridge (Monkton Road crossing) spans the channel in the upstream half of the reach. Base photo: 2003.

The historic planform (as viewed on 1942, 1962 and 1974 aerial photographs) appears similar to the present channel position. Erosion is generally occurring along the outside of meander bends, resulting in minor to moderate meander extension. Exposed streambank sediments exhibit a generally coarsening-upward sequence, with fine-grained, erodible sands overlying cohesive silts and silty-sands.

The corridor surrounding reach M08 has remained largely undeveloped over recent decades. The northwest (RB) side of the channel has been in hay and/or pasture, with an herbaceous buffer ranging from less than 25 ft to over 100 feet wide. The southeast (LB) side of the corridor is mostly forested with buffer widths most often greater than 100 feet. At the very upstream end of the reach, a residential dwelling has been located on a bedrock knob in the LB corridor near the intersection of Lewis Creek Road and Monkton Road since at least the middle 1800s.

The Quinlan Covered Bridge was originally constructed circa 1850 of timber decking / framing. Steel trusses were installed as additional supporting members and stone abutments were faced and capped with concrete during refurbishing efforts in recent decades. The measured span of the abutments is 69.2 feet, and the clearance of this structure to the channel bed is 14.8 feet. This bridge span is approximately 82% of the measured upstream (M09) bankfull width. The Lewis Creek approaches the bridge span at a moderate angle and the RB abutment protrudes into the channel.

Spear Street encroaches along the RB upstream of the Quinlan Covered Bridge; berms have been constructed and rip-rap armoring has been installed over the years to protect this road and constrain the channel on approach to the bridge. The local landowner noted that the LB of the channel upstream of the bridge was reinforced with rip-rap in the early 1970s; at about that time, the streambank along the left side of the channel downstream of the bridge was also lowered and stepped to create a more gradual overall slope (Morse, 2009).

Figure G-38. Quinlan Covered Bridge, view downstream.
Reach M08. 11 June 2009.

Following an 1850 washout of the bridge site, a second channel was reportedly blasted to the north of the original channel in an attempt to have Lewis Creek flows approach the bridge at a softer angle (Figure G-39; Morse, 2009). In recent years, the original channel of this bifurcated section has widened and deepened and now directs flow perpendicularly at the RB of the river. The upstream reach of Lewis Creek (M09) is incised and entrenched and has lost connection to the floodplain along the LB upstream of the bridge where channel-contiguous wetlands may historically have offered more flow and sediment attenuation. The entrenched condition results in concentrated, higher-velocity flows directed along Morse lands and to the bridge site. The distribution of hydric soils in vicinity of the bridge suggest that in pre-colonial times, the Lewis Creek may have meandered farther to the north and west of the Quinlan Bridge with a greater radius of curvature (Figure x).

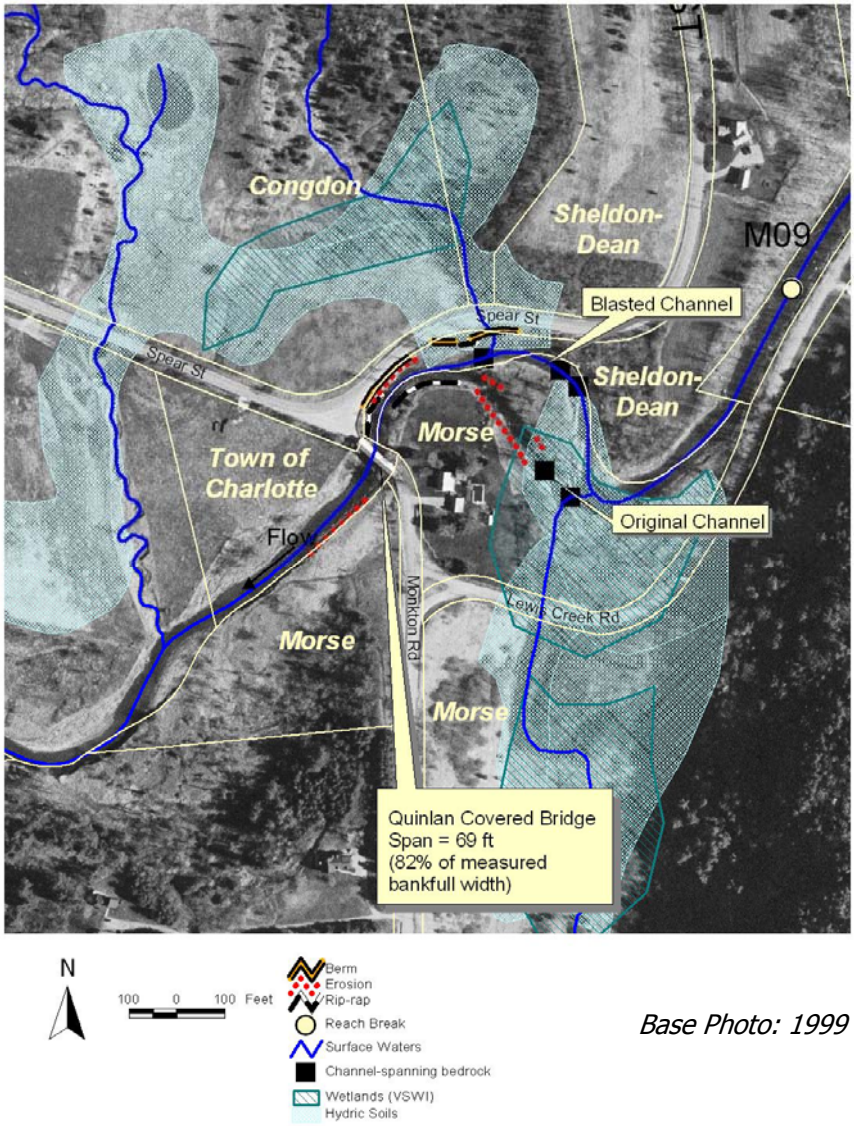


Figure G-39. The Lewis Creek channel on approach to the Quinlan Covered Bridge is constrained by Lewis Creek Road and an armored and bermed section of Spear Street. Ice jams upstream of this bankfull-constricting bridge frequently result in local inundation flooding.

A cross section measured near the mid-point of reach M08, indicated a gravel-dominated C-riffle/pool stream type, consistent with reference, and good connection to the adjacent floodplain (IR_{RAF} = 1.0). This cross section was determined to be representative of a majority of the reach length.

The measured bankfull width is less, and the bankfull depth is greater, than would be predicted by VT Regional Hydraulic Geometry Curves (VTDEC, 2006). It is likely that reach M08 is transitional between C-stream type and E-stream type characteristics, given the cohesive nature of streambank soils and high overall sinuosity of the reach (1.4). The riffle/pool bedform is not well defined – riffles are short in length and more run-like in nature, and pool depths are deep. The low-flow channel has a low width/depth ratio. If the reference stream type were classified as E-riffle/pool, the measured W/D ratio at the cross section site (20.8) would suggest a lateral stream type departure (from E to C) due to widening.

In 2004 when this reach was originally assessed, segmentation of reaches was not accommodated in SGAT or the DMS. Rather the assessments were designed to record the dominant conditions of the reach

as a whole. It is expected that encroachments in the upstream 1,600 feet of the reach have resulted in some degree of historic incision and entrenchment, and a somewhat degraded condition. Phase 3 assessments were completed in the Fall of 2009 in this upstream portion of reach M08 (under a separate project), and will likely result in segmentation of the reach to capture these site-scale variations in channel incision status, condition, and sensitivity.

Ice jams frequently cause localized flooding upstream and downstream of the Quinlan Covered Bridge (including overtopping of Spear Street), threaten the integrity of the bridge abutments, and subject the Morse residential property to inundation flooding and fluvial erosion hazards. The channel immediately downstream of the Quinlan Covered Bridge has undergone some lateral erosion associated with ice jams in the late Winter / early Spring of the year. The CRREL Ice Jam database records one of these events on 10 March 1992: "An ice jam about 400 to 600 feet long formed on Lewis Creek at a bend and caused residential and road flooding, riverbank and bed erosion, erosion of a dirt road and structural damage to pavement." Journal entries and photographic records of a nearby landowner record at least three additional ice jam events on 19 March 1986, in late February 1990, and on 21 March 2003 (Illick, 2009). Other area landowners report that ice jam flooding is a frequent occurrence, perhaps as frequently as every other year.

An ice jam event occurred during final compilation of this report on 25 January 2010. A 10-inch-thick layer of ice cover had developed in upstream sections of the Lewis Creek during a two and a half week period from 28 December 2009 through the 13 January 2010 as temperatures remained at or below freezing and snow fell almost daily (Weather Underground, 2010). For the next week, daily high temperatures climbed slightly above freezing, followed by five more days of sub-freezing temperatures and trace accumulations of snow. On 25 January 2010, temperatures warmed to the mid-50s (Farenheight), and just over one inch of steady rain fell throughout the day. Most of the precipitation ran off the frozen ground surfaces of the upstream watershed to the tributaries of Lewis Creek, resulting in a relatively rapid rise in water levels in the Creek, coupled with the break up of ice cover. USGS provisional data estimated the maximum flow at the Route 7 gage to be just over 4,000 cfs, corresponding to a 10-year to 50-year storm (Olsen, 2002). These events conspired to cause a moderate ice jam flooding event in the vicinity of Quinlan covered bridge that peaked around 8 PM on 25 January 2010 (Illick, 2010). The location of the jam was approximately 100 feet upstream of the Quinlan covered bridge (Morse, 2010). Figure G-40 shows the approximate extent of inundation flooding and ice shedding during the 25 January 2010 event. Water had just begun to overtop Spear Street in one location about 125 feet upstream of the bridge before the jam released and flood stages receded.

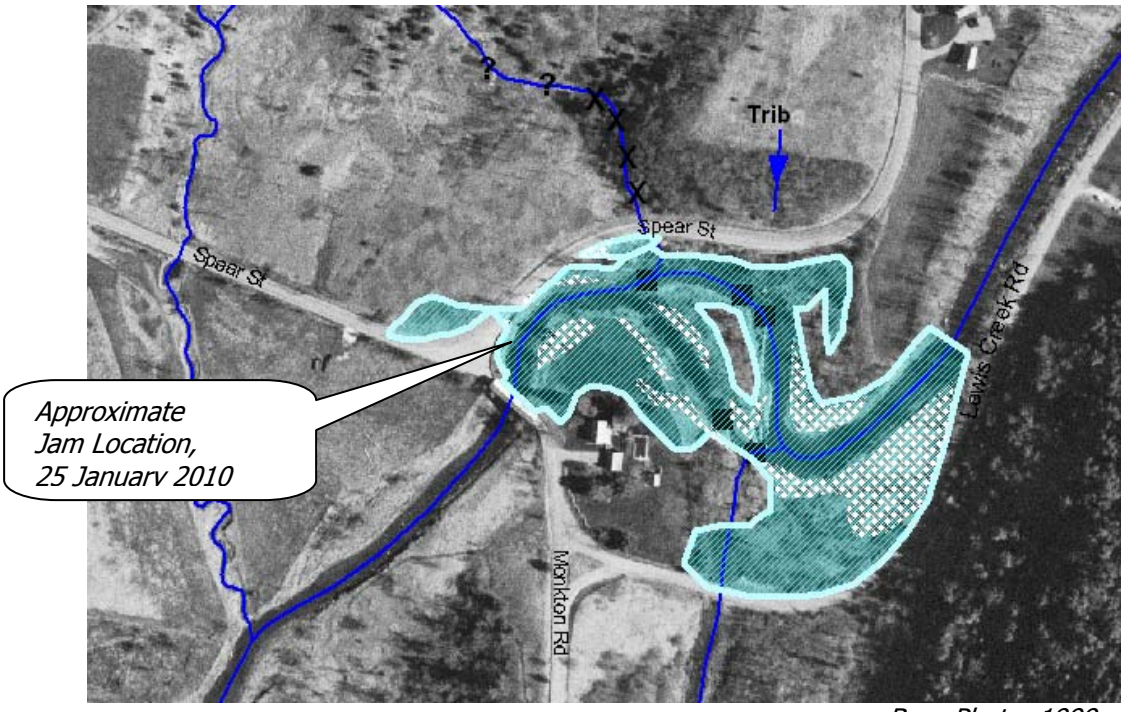


Figure G-40. Ice jam flooding event of 25 January 2010, vicinity of the Quinlan Covered Bridge (reach M08). (top) extent of inundation flooding and ice shed; (bottom left) view downstream to Morse residence from LB along Lewis Creek Rd; (bottom right) view downstream to Quinlan covered bridge from Spear Street on 26 January 2010 (receding water levels).

M07

Reach M07 flows to the southwest from a point approximately one mile downstream of the Quinlan Covered Bridge to the North Ferrisburg village, ending just below the Old Hollow Road bridge crossing. Midway along this reach the Lewis Creek crosses from the town of Charlotte into the town of Ferrisburg. The channel is Semi-confined between moderate to steep slopes of glaciolacustrine sediments. Hydric soils (and limited wetlands contiguous to the channel) are mapped in the upstream half of the reach. Two notable exposures of channel-spanning bedrock were encountered: (1) a 600-foot length of low-profile bedrock in the bed and banks with an overall control height of approximately 10 feet; and (2) a 1,400-foot long section of bedrock channel with an overall control height of approximately 30 feet, and including the North Ferrisburg falls visible upstream of Old Hollow Road bridge crossing (Figure G-41).

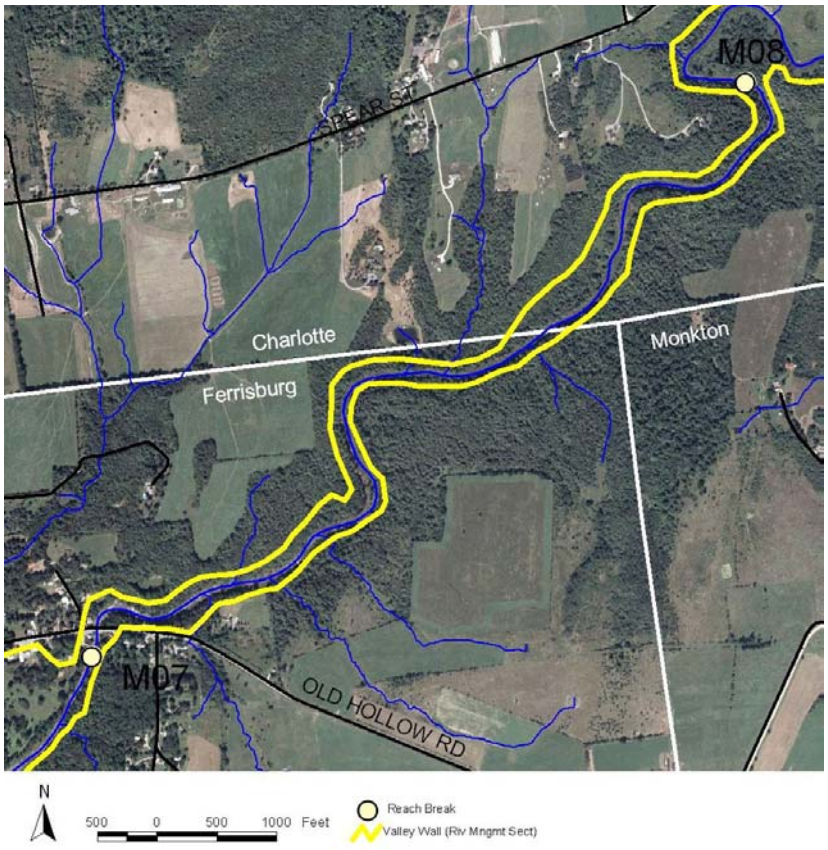


Figure G-41. Lewis Creek Reach M07. Flow is from upper right to lower left of picture. Base photo: 2003.

The full reach was walked in November of 2006 to record field observations and supplement the original August 2001 Phase 2 and 3 geomorphic assessments that were conducted along select portions of the reach only. The August 2001 cross section data were validated and determined to be characteristic of the reach. Thus, the November 2006 RGA relied on riffle cross section data from the 2001 assessment.

Floodplain encroachment by development, roads, and other infrastructure is nearly absent within reach M07, and historic channel alterations appear to be limited to the very downstream end of the reach near the Old Hollow Road crossing in North Ferrisburg village. The Beers Atlas (1871) shows several industrial enterprises at impoundments capitalizing on the series of bedrock falls upstream of the bridge crossing

including a grist mill, saw mill, and woolen mill. A historic photograph of the former covered bridge crossing of Old Hollow Road depicts a low-head dam below the bridge (Figure G-42). This dam is no longer present.

Figure G-42. Old Hollow Road crossing, North Ferrisburg, view upstream. circa 1870 to 1950. Low-head dam visible below bridge. Reach M07. Source: VT Landscape Change webpage.

Reach M07 is a gravel-dominated Bc-riffle pool stream type, exhibiting very minor adjustment. The reach has a very similar planform on the 1942 aerial photo as compared to the 1995 / 1999 orthophotographs. Channel stability is afforded by exposures of channel-spanning bedrock and occasional bedrock comprising the channel banks, cohesive streambank sediments, and continuous expanses of woody riparian buffers greater than 100 feet in width along both banks. Cross section measurements indicated that the river has good access to the narrow floodplain along this Semi-Confined channel. A minor degree of sedimentation was noted in the reach, likely originating from upstream erosion and sediment sources, as well as one in-reach mass failure along the LB.

Optimal aquatic habitat conditions are suggested by the stable streambanks, diversity of streambank vegetation types, streambank canopy cover (offering shading and detritus), and presence of variable flow regimes ranging from slow-deep to fast-shallow. The well-developed riparian buffer also offers connectivity for terrestrial habitats. Beavers are very active in the reach, as evidenced by girdled conifers and presence of a streambank den; no channel-spanning beaver dams were observed (November 2006).

M06

Reach M06 extends through a broad valley between North Ferrisburg village and the Route 7 crossing. Alluvial sediments are mapped along the channel, bounded by moderately- to steeply-sloping glaciolacustrine sediments (USDA). Wetlands are mapped in the upper half of the reach (NWI, VSWI). In the lower half of the reach, meander scars are visible on historic aerial photographs, indicating that the Lewis Creek meandered more freely across the valley in the last few hundred to thousands of years. This reach has long stretches of straight channel offset by periodic bifurcations of the channel or meander bends. Bedrock was observed along the left valley wall often coincident with the LB. This bedrock is offering lateral control to the channel in select locations, contributing to the low overall sinuosity of the reach. It is also possible that portions of the channel were straightened historically, although confirmation of this was not obtained through limited historical research. The reach has a very similar planform on the 1942 aerial photo as compared to the 1974, 1980 and 1995 photographs. Channel-spanning bedrock is present mid-reach, and several exposures of channel-spanning bedrock ledges and waterfalls are present immediately upstream in reach M07.

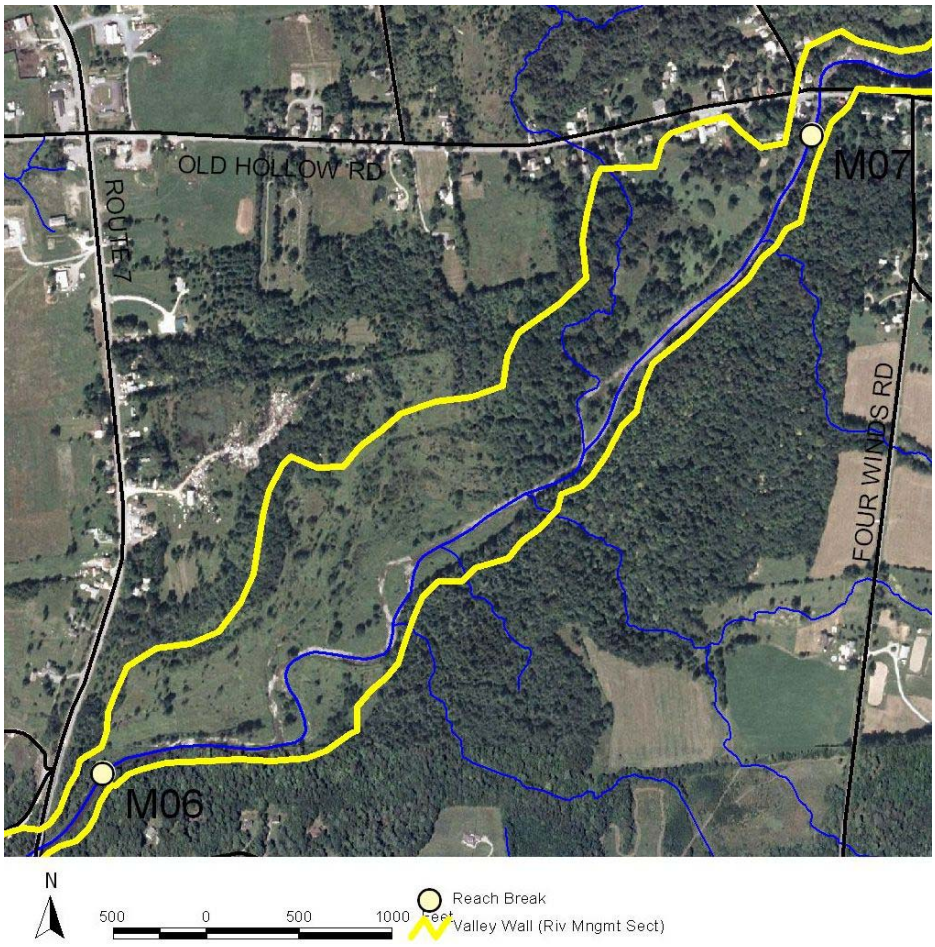


Figure G-43. Reach M06 flows from North Ferrisburg village to the southwest nearly to the Route 7 crossing. Base photo: 2003.

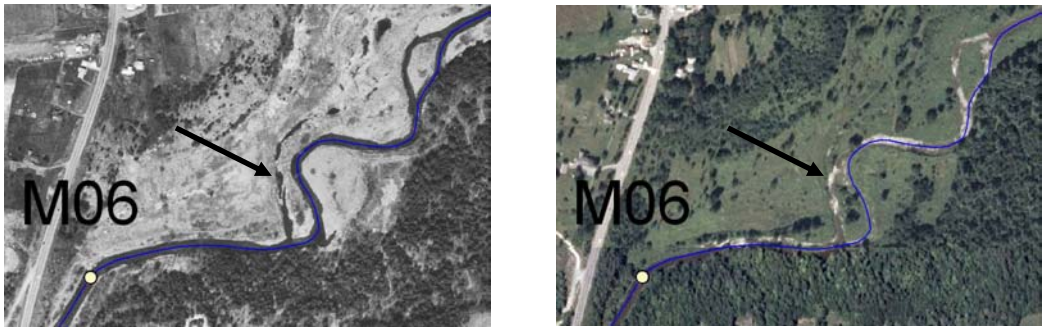
Development within the reach is very minor, with a brief section of commercial and residential properties along RB at the upstream extent in North Ferrisburg village. Floodplain encroachment by roads, railroads or other infrastructure is absent. The LB corridor is dominated by a forest of mixed coniferous and

deciduous trees. Historically, the fields along the right bank corridor at the downstream half of the reach appear to have been pastured or cropped; herbaceous buffers with saplings dominate the RB corridor in this part of the reach. The Beers Atlas (1871) and a historic photograph indicate that a dam(s) was present in North Ferrisburg just upstream of the upstream reach break.

A cross section conducted at the mid-point of the reach indicates a C3-riffle/pool stream type with a narrow floodplain width (175 feet) as compared to the estimated valley widths of 600 to 870 feet. A recent floodplain appears to have developed at a lower elevation below adjacent alluvial terraces. The Lewis Creek has good connection to the youngest floodplain (IR = 1.1), but would be incised below the older alluvial terraces (IR_{RAF}=1.96). Surficial geologic mapping work would be required to determine the age of the older terraces, which could range in age from several hundred years to several thousand years. Downstream of the cross section site, the floodplain widens considerably, and channel gradients appeared to become shallower. A second cross section was completed approximately 1,100 feet upstream of the Route 7 bridge in August of 2009. This cross section indicated a C4-PB stream type with an incision ratio of 1.97; the very-coarse-gravel median grain size (49 mm) was on the cusp with a small-cobble classification, similar to the upstream cross section. It is likely that the gradual slope decrease and the narrowing of the valley width due to bedrock grade controls in downstream reach M05 have contributed to a downstream fining in bed substrates. Ongoing lateral adjustments in reach M06 have contributed fine gravel and sandy substrates. A separate cross section conducted by the VTDEC in 2001, noted a C4 stream type near the reach break between M05 and M06 as part of a program to develop Regional Hydraulic Geometry Curves for the Vermont (VTDEC, 2001).

Between 1995 and 2003 an avulsion is evident at the downstream meander bend of reach M06 (see Figure x). A series of minor steepened riffles were observed upstream of this location in 2004. This shift in channel position has resulted in a minor reduction in channel length, which may have increased channel gradients sufficiently to initiate some localized channel incision. However, streambed sediments are fairly coarse (D50 of cobble at XS-1) and erosion thresholds are higher than if streambed materials were dominated by fine gravels; these effects may have moderated the potential for channel incision from this avulsion. The mid-reach exposure of channel-spanning bedrock and several exposures of channel-spanning bedrock ledges and waterfalls in upstream reach M07 would serve to arrest potential upstream progression of channel incision.

The above-noted avulsion, as well as evidence of meander migration, braided flows, presence of transverse riffles, and mid-channel bars, suggest that planform adjustment is the dominant condition within the reach. Relatively low width/depth ratios (24.5 in XS-2 and 27.6 in XS-1) indicate that widening is not a dominant process. Reach M06 is positioned between the somewhat steeper and bedrock-controlled reach M07 upstream and the semi-confined and bedrock-controlled channel of reach M05 downstream. The valley in M06 is a local opportunity for the Creek to freely meander and attenuate its flow and sediment loads. The active planform adjustment observed in this reach is a response of the channel to these natural variations in valley confinement and channel gradient. The channel is may also be responding to past channelization within the reach.



(a) *(b)*

Figure G-44. Channel avulsion in reach M06, Lewis Creek main stem, Ferrisburg, VT. (a) 1995 orthophotograph; (b) 2003 aerial image; blue line marks 1995 channel position; river now (2004) flows in western channel (arrow).

Habitat conditions within Reach M06 were Good as measured by the RHA (2007 protocols). Sediment deposition and embeddedness were fairly minor. Buffers were extensive along both banks, with forested cover along LB offering recruitment of large woody debris, detritus and organic matter. The newly-fallow condition along the RB will require some time for re-vegetation along right bank. Habitat conditions were compromised somewhat by active erosion along streambanks, and less than optimal depth of pools and diversity of velocity/depth patterns.

M05

Reach M05 is a one-half mile length of the Lewis Creek which exhibits different valley characteristics from either the upstream or downstream reaches. The channel is confined in a narrow valley between high silt/clay-rich (glaciolacustrine) banks. Based on the valley walls mapped by River Management Program, the valley width in this reach ranges from 1.5 to 3.3 times the channel width (reference width of 89 ft). The average valley width (230) yields a valley confinement ratio of 2.6, which is classified as Semi-Confined under Step 1.5.

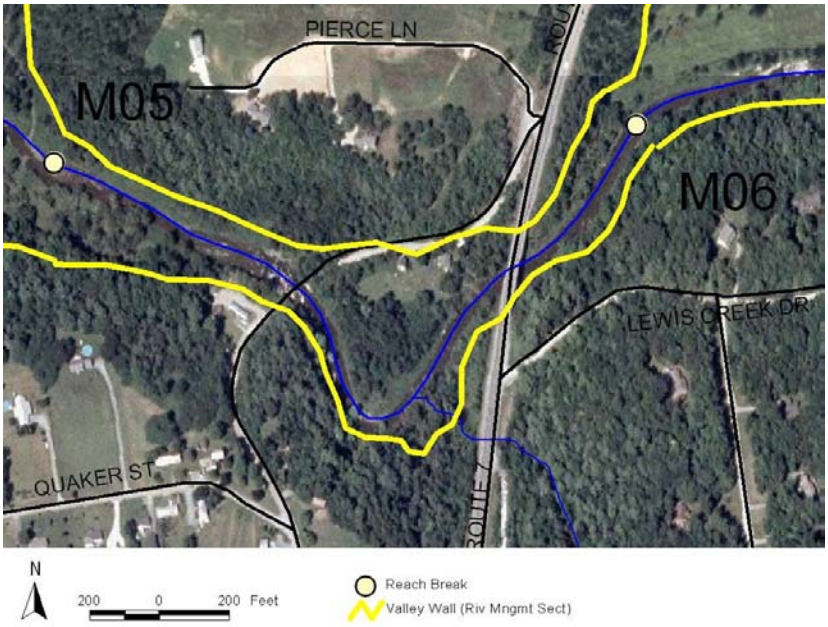


Figure G-45. Reach M05, Lewis Creek. Flow is from picture right to left.

Wetlands are mapped on the inside of the prominent meander bend (NWI, VSWI). Channel-spanning bedrock is exposed mid-reach, providing stability to the reach and offering vertical grade control to the Lewis Creek river network at this location (see Figure G-46).

Figure G-46. Channel-spanning bedrock falls upstream and downstream of the abutments of the former Route 7 alignment.

Development and other channel and floodplain encroachments are relatively minor in reach M05. Historic maps indicate that a saw mill operated at this location in the 1800s (Walling, 1857). Today there are a few residential buildings high on the valley wall approximately 50 to 140 feet above the channel. US Route 7 (and a former alignment of Route 7) crosses the Lewis Creek within the reach. The former alignment of Route 7 was constructed prior to the late 1800s, and a crossing was first sited near the head of the bedrock falls exposed mid-reach. This former alignment for Route 7 was replaced circa ____ (post-1942 and pre 1974 according to aerials) with the current alignment east of old Route 7, and a new bridge was installed spanning the reach. The roads are high in elevation above the channel. The fill for roadway approaches to the new Route 7 bridge does not appear to constrain the channel except possibly along the RB upstream of the bridge. The new Route 7 bridge is also elevated high above the channel, and does not appear to constrict the channel at either the bankfull or floodprone flow conditions (save for the influence of piers on flow, ice and debris). The abutments for the old Route 7 bridge were measured to be 62.5 feet apart, and serve to constrict both bankfull and flood prone (Q10 to Q50) flows.

Figure G-47. Cross section measured approximately 250 feet downstream of Route 7 bridge, reach M05 (view upstream).

Cross section measurements within the reach indicated a C3-riffle/pool stream type. The cross section conducted near the reach break between M05 and M06 by the VTDEC noted a C4 stream type (VTDEC, 2001). Reach M05 has a very similar planform on historic aerial photos dating back to 1942. Comparison of the 1995 ortho to the 2003 NAIP coverage indicates active meander migration into the left valley wall at the prominent meander bend in the center of the reach. A mass failure of clay/silt soils is occurring on this left bank approximately 550 feet downstream of the Route 7 bridge. Some degree of aggradation is occurring within the reach, as evidenced by presence of mid-channel bars and transverse bars, slight enlargement of point bars, and embeddedness in the 25% range. A width-to-depth ratio of 33 suggests widening, however, symptoms of active widening (for example, undercut banks, leaning trees along both banks through a straight or riffle section) were absent. Similarly, an incision ratio of 1.49 suggests channel down-cutting; however, signs of active channel incision were absent (e.g., head cuts, undercut banks). Channel incision and widening are likely historic in nature, while minor planform adjustment and aggradation are current adjustment processes.

Habitat was ranked as Good following the RHA protocol (2007 protocols). Ample forested buffers (providing shading, detritus, LWD and organic matter) are present along each bank to a width greater than 100 feet except locally at the road crossings. Compromises to habitat conditions within the reach include a less than optimal mix of epifaunal substrates (e.g., lack of submerged

logs, cobbles somewhat embedded). Also, some plane-bed channel form was noted subdominant to the riffle/pool bedform which leaves morphological diversity (frequency and depth of pools) lacking.

Figure G-48.
Wood turtles have been observed in Reach M05, 19 August 2009.

M04

The 2009 assessment update for this reach relies on original field inspections from September of 2004, and limited observations from subsequent years, including cross sections completed in September of 2006. Reach M04 is approximately 5,344 feet in length, extending from the vicinity of Route 7 at the upstream end to Greenbush Road at the downstream end. The channel flows through a Very Broad valley comprised of alluvial sediments bounded on either side by moderately- to steeply-sloped terraces of glaciolacustrine origin. Wetlands (NWI, VSWI) are mapped contiguous to the channel in the downstream half of the reach; glaciolacustrine soils mapped along the periphery of the valley are hydric in nature (USDA). A reference E stream type was assigned, given the valley setting, low-gradient and high sinuosity (1.53). Bedrock was not observed along channel margins or in the channel bed.

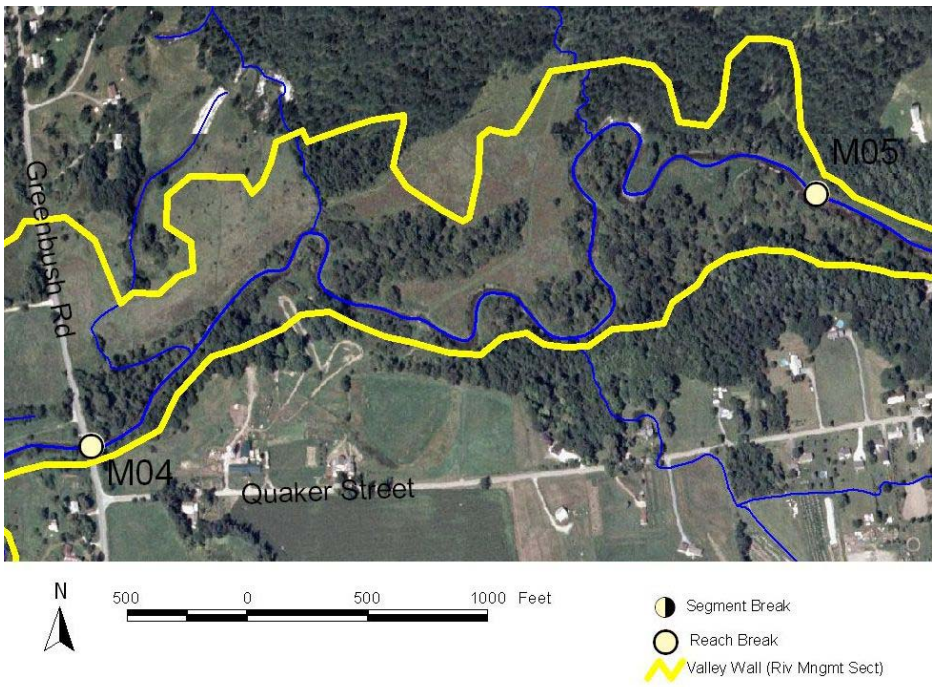


Figure G-49. Reach M04 of Lewis Creek in Ferrisburg. Base photo: 2003.

Historic planform changes (meander migration, flood chutes, avulsion) are evident from a comparison of the 2003 aerial photo to the 1995 photo and 1983 USGS topographic map. Meander scars are evident along the far northern valley wall and likely represent a past channel position from hundreds to thousands of years ago. Future neck cutoffs are possible at tortuous meander bends where the radius of curvature is tighter than regime. Erosion is generally occurring along the outside of meander bends, resulting in minor to moderate meander extension. Exposed streambank sediments exhibit a generally coarsening-upward sequence, with fine-grained, erodible sands overlying cohesive silts and silty-sands.

The corridor surrounding reach M04 has remained largely undeveloped over recent decades. Land use appears to have partially reverted from crop and pasture uses to fallow fields, and much of the river corridor has revegetated substantially since the early 1900s (based on review of a 1942 photo). The north (RB) side of the channel has been in hay or crop use, and is currently cultivated for a small retail vegetable farm operation. For a brief time in the 1980s to

1990s a small golf course was operated in the downstream half of the northern corridor. Occasional forested buffer sections along the RB (generally greater than 100 feet wide) are punctuated by sections of herbaceous buffer generally less than 25 feet wide. The southeast (LB) side of the corridor is mostly forested with buffer widths most often greater than 100 feet. High-use ATV trails were evident along the LB corridor; less-frequently-used ATV trails were also observed in the RB corridor. Two apparent fords were noted associated with these trails: one near the upstream end of the reach, and a second near the mid-point of the reach.

Multiple cross sections and two longitudinal profiles were completed within reach M04 in September of 2006 as part of a mussel habitat study by the USFW (Essex Juntion, VT). This 2009 update assessment relies on select cross sections from this study (SMRC, 2009). Cross section measurements performed at several runs through the middle of the reach indicate a sand-dominated, E-dune/ripple stream type with good floodplain connection (IR < 1.2). Width/ depth ratios varied from 9.8 to 16.7. Cross sections with width/depth ratios greater than 12 were located proximal to recently-breached or intact debris jams, suggesting localized widening. Since VT Regional Hydraulic Geometry Curves are based largely on C stream types, bankfull widths measured in this E stream were narrower than predicted, and bankfull depths were greater than that predicted. The reach is in Fair geomorphic condition (indicating a moderate degree of departure from reference). Planform adjustment is the dominant active process, following by localized, minor to moderate widening and aggradation. An "Extreme" sensitivity is assigned to an E5 channel in Fair condition, following 2007 VTANR guidance.

A Good habitat condition was assigned following the RHA. Minor to moderate deposition throughout the reach has resulted in some filling of pools. Sediment is soft underfoot in locations of aggradation above large woody debris and/or debris jams. Streambanks, particularly along the outside of meander bends, are actively eroding and contain little stabilizing vegetation. Reach M04 is a documented location of freshwater mussels.

Figure G-50. Mid-point of Reach M04, September 2006. View upstream.

Regionally, reach M04 is located between bedrock grade controls of reach M05 (near the old Route 7 alignment) and the relatively fixed base level of Lake Champlain which influences downstream reaches M01, M02, and (in a wet year) M03. There is little opportunity for the Lewis Creek to adjust its slope through vertical adjustments of the bed. Increases in sediment loading or hydrologic loading are compensated for by lateral shifts in the channel.

M03

Field observations from September 2004 and repeat cross sections and field observations recorded in September 2007 supplement the field assessments originally completed on this reach in July 2001 (VTDEC, 2003).

Reach M03 is 5,471 feet in length and extends from the Greenbush Road bridge crossing downstream to the Vermont Railway crossing (Figure G-51). As discussed in a previous section, reach M03 may be influenced by backwater effects from Lake Champlain during years of very high lake levels. Soil types in the floodplain nearest the channel are mapped as frequently-flooded Hadley very fine sandy loams, Limerick silt loams and Winooski very fine sandy loams of alluvial origin (USDA). Fine sandy loams of glaciolacustrine origin dominate the areas farther from the channel. Wetlands are mapped over an area approximately 500 to 900 feet wide and contiguous with the channel (NWI).

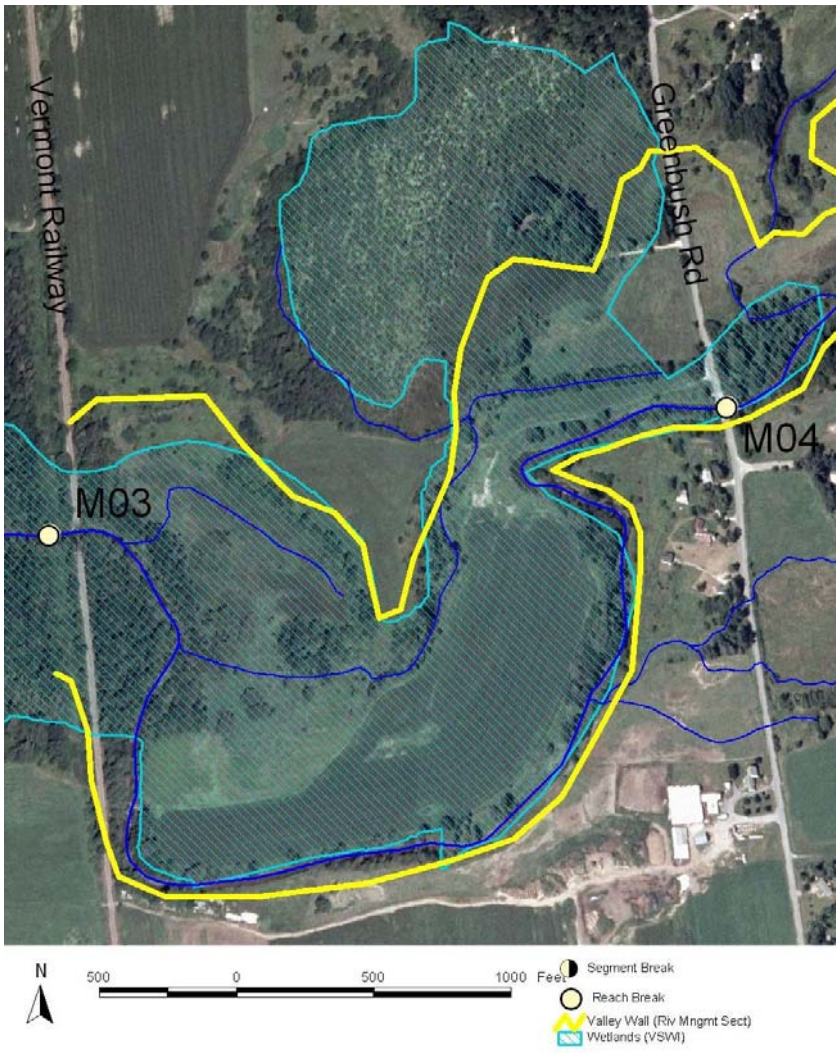
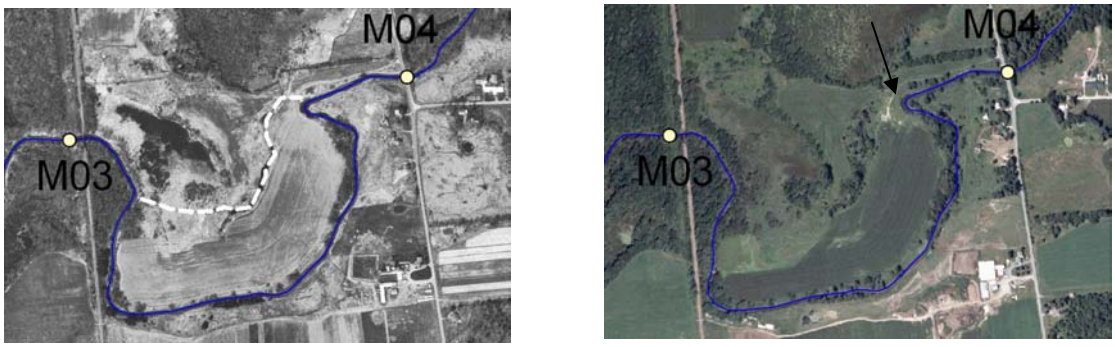


Figure G-51. Reach M03 flows west from the Greenbush Road crossing to the to the Vermont Railway railroad crossing. Base photo: 2003.

Encroachments within the reach are minimal. The railroad crosses the floodplain perpendicular to the general trend of the river valley. However, the railroad passes parallel to the river for approximately xx feet along the downstream third of the reach. The berm supporting this railroad is elevated above the floodplain and serves to constrain the channel at this downstream end. The railroad was built circa 1850 to provide connections to Burlington from the south (Amrhein, 1958). The railroad (labeled "Central Vermont") was present on an 1898 historic USGS topographic map (surveyed 1892) and the Beers Atlas dated 1871 (labeled "Rutland Railroad").

Agricultural uses within the corridor include crop fields on the inside of the prominent meander with buffer widths ranging from 0 to less than 25 ft. Hay field or fallow field land covers are evident farther from the channel. Livestock pasture is present along the LB (south) of the channel near the mid-point of the reach on a high terrace above the channel.

The VTDEC identified a potential for avulsion within the reach, which would significantly shorten the channel length, increase the channel gradient and potentially lead to channel incision within and upstream of the reach (VTDEC, 2003). This reach is very sensitive to future changes in flow and sediment regimes. NRCS project (in progress during the 2007 construction season).



(a) *(b)*

Figure G-52. Potential avulsion site, Reach M03, Lewis Creek main stem, Ferrisburg, VT.
(a) 1995 orthophoto base; white dashed line indicates potential avulsion path identified by VTDEC, 2003;
(b) 2003 aerial imagery; corn field buffer at tight meander (see arrow) increased between 1995 and 2003.

Habitat conditions within the reach were rated as Sub-optimal (good), compromised by sedimentation and streambank erosion. Riparian buffer widths and pool diversity were limited in the upstream segment (VTDEC, 2003).

Overall, the river has good access to the floodplain within the reach. A C5 ripple/dune stream type was assigned.

M02

Reach M02 was assessed in September of 2004. This reach is 4,092 feet in length, extending downstream from the Vermont Railway railroad crossing. The channel gradient is very shallow (less than 0.02%) and can not be accurately calculated at the resolution of the 1:24000 scale USGS topographic maps. This reach is influenced by backwater effects from Lake Champlain. Soil types in the floodplain nearest the channel are mapped as Limerick silt loams and Winooski very fine sandy loams of alluvial origin (USDA). Fine sandy loams of glaciolacustrine origin dominate the areas farther from the channel. Wetlands are mapped over an area approximately 600 to 1,200 feet wide and contiguous with the channel (VSWI, NWI).

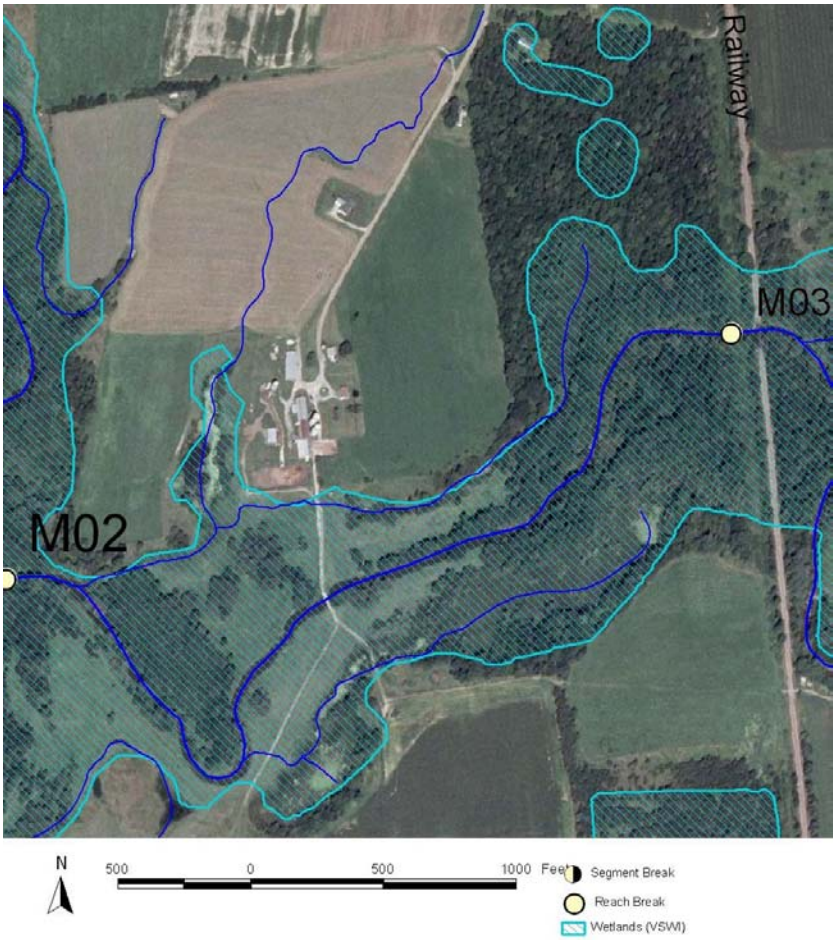


Figure G-53. Reach M02 downstream of the Vermont Railway railroad crossing. Flow is from picture right to left. Base photo: 2003.

Floodplain encroachment is limited to one farm road crossing at the mid-point of the reach. The Vermont Railway tracks cross the Lewis Creek floodplain more or less perpendicular to the trend of the channel in reach M02 and do not represent a significant encroachment in reach M02.

The upstream end of the reach flows through forested areas with ample buffers along either bank. In the mid-stream and downstream sections of the reach, agricultural uses have encroached on the channel and floodplain. Cows are pastured along either bank with direct

access to the Lewis Creek; cows were also observed within the wooded buffer areas near the downstream end of the reach along left bank. A farm road bridge crossing is located mid-reach providing access to hay and crop fields to the south of the river. The span of this bridge was measured as 61 feet, or 68% of the reference bankfull width (90.3 ft).

Reach M02 has good connection to the floodplain along most of its length, with no indications of channel incision. A cross section measured at the downstream extent of the reach indicated an E stream type (with low width/depth ratio); channel bed form was observed to be dominated by dune-ripple form. Some limited erosion was noted in the upstream half of the reach along portions of both banks. Overall, buffer widths were compromised particularly along left bank where direct pasture access to the creek is permitted.

Due to the influence of Lake Champlain on this reach, and the modified fluvial process and form, a Rapid Geomorphic Assessment and Rapid Habitat Assessment were not conducted.

Figure G-54.
Farm bridge crossing,
Reach M02,
27 September 2004.

M01

Reach M01 was assessed in September of 2004. Reach M01 is a 1.3-mile length of channel at the transition between fluvial and lake environments (see Figure G-55). Like M02, this reach is influenced by fluctuating water levels in Lake Champlain and its fluvial form and processes appear modified by backwater effects. The channel gradient is very shallow (less than 0.02%) and can not be accurately calculated at the resolution of the 1:24000 scale USGS topographic maps. Soil types in the floodplain nearest the channel are mapped as freshwater marsh and Limerick silt loams of alluvial origin (USDA). Silty clays and clays of glaciolacustrine origin dominate the areas farther from the channel. Wetlands are mapped over an extensive area contiguous with, and to the south and southwest of, the channel (NWI). Tributaries draining agricultural lands to the north of the Lewis Creek appear ditched in some sections and underlain by hydric soils, suggesting prior conversion of wetlands.

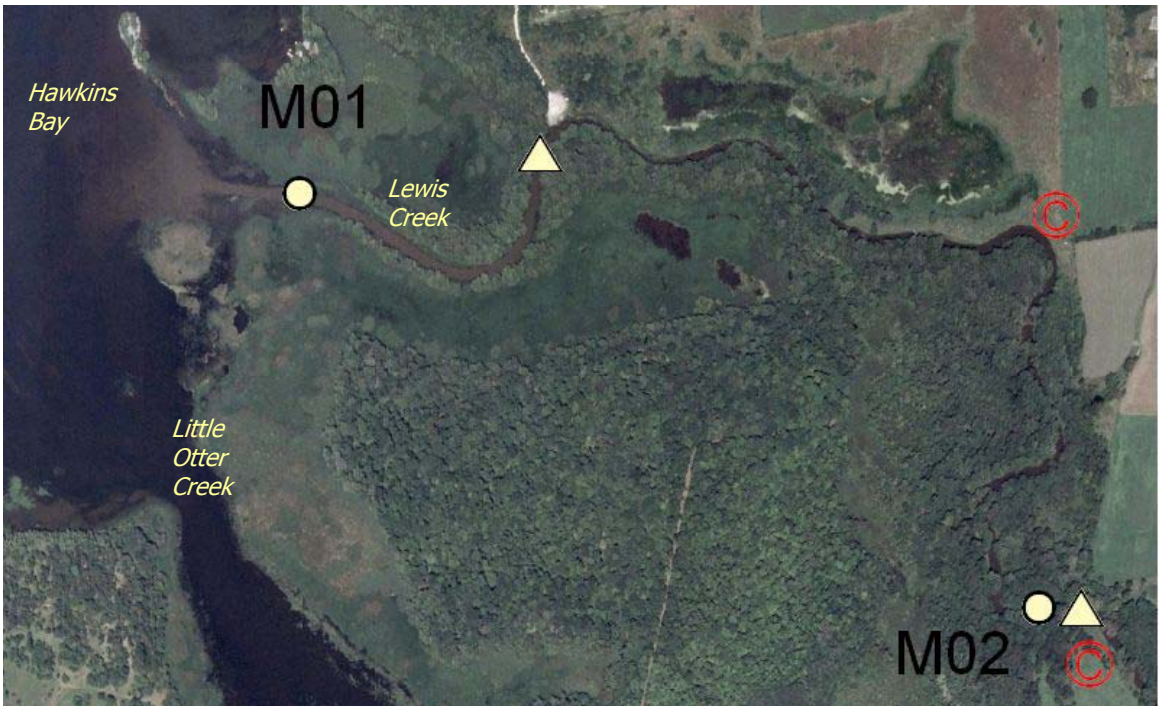


Figure G-55. Reach M01, Lewis Creek. Base photo is dated 2003. (Red "c" symbol indicates cattle observed with direct access to Lewis Creek; triangle symbols indicate location of cross sections)

The channel has ample floodplain access through out the reach for greater than 200 feet on either side. A quick cross section of the channel was measured from a canoe downstream of the boat ramp access along right bank: 103 feet. Channel depths exceeded the reach of the river staff suspended from the canoe (greater than 8.5 feet). Proceeding downstream from the boat ramp, the channel width was observed to increase gradually as the floodplain transitioned out into Hawkins Bay of Lake Champlain.

Erosion was negligible through the reach, and no channel armoring was noted. It is possible that armoring was submerged below water levels on the date of assessment. Shear stresses are likely to be quite low along this very-low-gradient reach influenced by backwater effects. The streambanks and floodplain may be influenced by erosion from ice. A limited section of development exists along right bank at the boat ramp mid-reach. Buffers of forested wetlands are present for greater than 100 feet on either bank, except in the vicinity of the boat ramp and

at pasture areas in the upper third of the reach along right bank where livestock have direct access to the Lewis Creek (see Figure G-56).

Due to the influence of Lake Champlain on this reach, and the modified fluvial process and form, a Rapid Geomorphic Assessment and Rapid Habitat Assessment were not conducted.

Figure G-56(a) - left.
Reach M01, upstream from Hawkins Bay. The Lewis Creek channel is influenced by effects of fluctuating lake levels, which have modified fluvial process and form.

Figure G-56(b) - right.
Entering Hawkins Bay at the confluence of Lewis Creek and Lake Champlain.

Figure G-57.
Cows with direct pasture access to Lewis Creek along right bank, Reach M01.

X.2 Hollow Brook (T4)

T4.05

Reach T4.05 was originally assessed by SMRC in September of 2005. In December 2008, these data were updated to 2007 protocols relying primarily on 2005 observations, as well as limited field observations and additional cross sections completed in July of 2008.

This reach flows from west to east parallel to Lincoln Hill Road (crossing from Hinesburg into Starksboro) from an approximate elevation of 1,070 feet to 660 feet above mean sea level. The upstream end of the reach is located just above the Lincoln Hill Road culvert crossing, and the downstream end is in the Lazy Brook Mobile Home Park near the intersection of Lincoln Hill Road and Hinesburg Hollow Road. Soils mapped along the channel and corridor are predominantly derived from glacial till, with some pockets of glaciofluvial sediments near the upstream end of the reach (USDA). Channel-spanning bedrock is notable near the center of the reach in a short segment of bedrock gorge.

Valley gradients and confinement are highly variable along the reach, which was segmented to document subreaches of alternate reference stream type, as well as segments at the downstream end which are estimated to have undergone a vertical stream type departure.

- Segment D: subreach of reference and existing Cb stream type with approximate gradient of 3.2%
- Segment C: bedrock gorge, provisional stream type of B1a-bedrock cascade with approximate gradient of 10.7%
- Segment B: reference B3a stream type and existing F3a stream type, approximate gradient of 8.1%
- Segment A: subreach of reference Cb channel ("alluvial fan") which has undergone a stream type departure to Fa, approximate gradient of 4.4%.

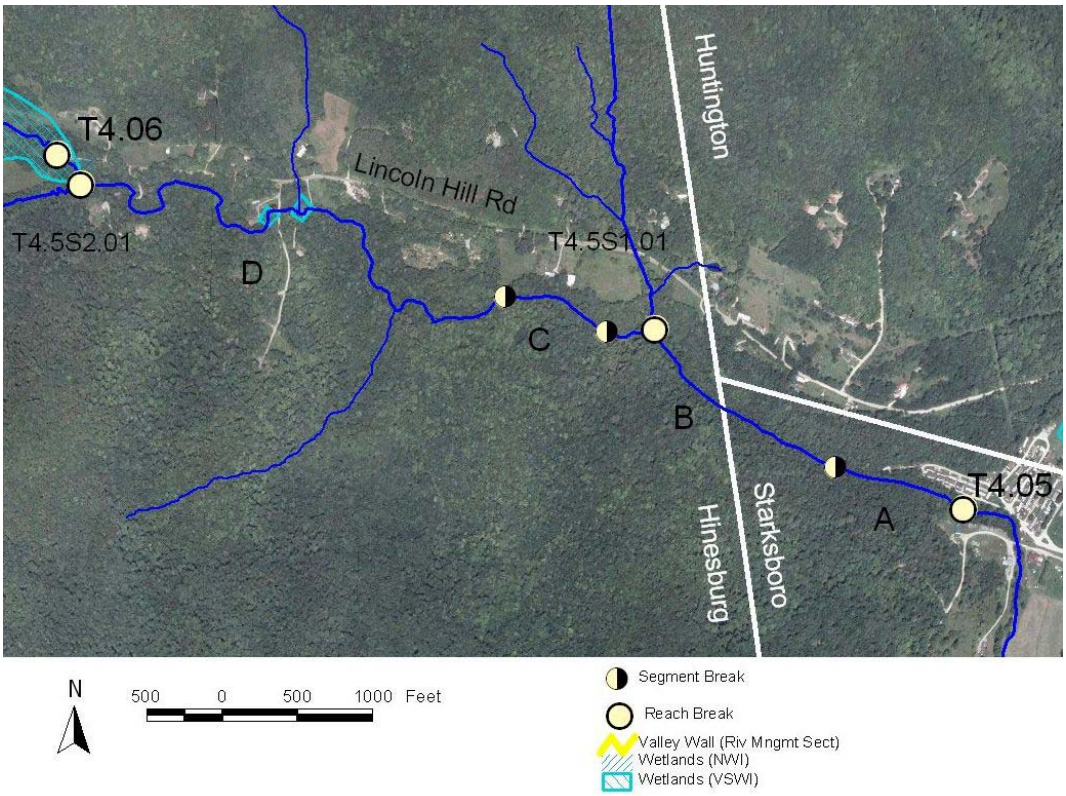


Figure G-58. Segmentation of Reach T4.05, Hollow Brook.

Segment D

Segment D is the upstream 4,373 feet of reach T4.05. Compared to the remainder of the reach, channel gradients are somewhat shallower and the valley confinement is more relaxed in this Segment D which is located upstream of the bedrock gorge (Segment C). Valley widths are variable; confinement ranges from Semi-confined to Broad, but averages Narrow. A gravel-dominated Cb–step/pool reference stream type is inferred from the valley setting and channel features. Surrounding sediments are mapped as having a glaciofluvial origin bounded by glacial till (USDA).

Lincoln Hill Road (gravel) crosses the channel at the upstream end via a culvert crossing. This road parallels the channel to the north but is typically elevated well above the channel on the left valley wall; therefore it does not result in a significant human-caused change in valley width. Several driveways cross the channel in this segment and are indexed as "roads" where they pass by the channel for short distances. Typically, these driveways are at grade and do not significantly change the valley width. (During the QA review process, VTANR instructed that even these short road segments constitute a Human-caused change in valley width). A few residential properties are developed near the channel in Segment T4.05-D. Development is sparse along an otherwise forested and scrub/shrub-dominated corridor.

Four bankfull-constricting bridge or culvert crossings of the channel were observed within the segment:

List of channel constrictions observed on segment T4.05-D; September 2005.

Constriction Type	Road	Span (ft)	% of Bankfull	Depos. Above	Depos. Below	Scour Above	Scour Below	Align-ment
Culvert	Lincoln Hill Rd	4	21	√	√		√	√
Culvert	Driveway	5	26				√	√
Bridge	Driveway	8	41	√			√	
Culvert	Driveway	2	10	√			√	

The downstream two driveway crossings are coincident with dams and small upstream impoundments of the channel:

- The bridge driveway crossing is constructed over a small dam with apparent flashboards which impounds a relatively wide, but shallow, pond at a residential property.

(a) *(b)*

Figure G-59. Bridge / dam on Hollow Brook in segment T4.05-D. (a) view downstream to the inlet. (b) view upstream to the outlet (concrete apron). 8 September 2005.

- The culvert driveway crossing is embedded in a stone and concrete structure, with a steel trap door on the upstream side (culvert inlet). Low stage flows would appear to pass through the main culvert. Moderate to high stage flows would appear to be impounded behind the stone and concrete structure when flow through the main culvert is not sufficient to pass the full discharge (such near-bankfull-stage conditions were observed on 25 July 2008). As impoundment levels rise, some flow would presumably be diverted to an overflow culvert (visible at picture right in Figure G-60 (a) below). At very high stages of impoundment, it appears that flows would pass over the top of the stone/ concrete dam and under the concrete driveway bridge that crosses over the top of the dam.

Figure G-60. Culvert / dam on Hollow Brook segment T4.05-D.

(a) View upstream to culvert outlet; ***25 July 2008.*** *Overflow culvert at picture right. Steel trap door at culvert inlet in raised (open) position. Moderate impoundment of channel flows observed in thickly vegetated wetlands area immediately upstream of dam.*

(b) View downstream to culvert inlet; ***8 September 2005****. Steel trap door at culvert inlet in lowered (closed) position.*

Two cross sections completed in Segment D indicated a gravel-dominated Cb-plane bed stream type. The upstream cross section (XS-4) was located in a somewhat narrower than average valley width; while

cross section (XS-3) was located in a somewhat wider than average valley width. Generally, they were each representative of the segment, indicating a degree of historic incision (IR_{RAF} = 1.6). Active adjustment processes include a moderate, localized degree of aggradation upstream of impoundments, constrictions, and debris jams; as well as minor to moderate planform adjustment (meander extension, flood chutes). A "Fair" condition rating was assigned, along with a "Very High" sensitivity. A early stage III [F] (or persistent, late stage II[F]) is inferred. Well-developed forested buffers may be moderating the potential for active widening. Boundary conditions appear to be balancing the somewhat enhanced erosive power of the moderately incised channel.

Segment C

Segment C is approximately 750 feet long comprising a short section of bedrock gorge, which was assigned a provisional stream type of Ba-bedrock cascade. Interpolating from contours on the USGS topographic map, the channel gradient is estimated as 10.7%. Coniferous trees provide a closed forest canopy surrounding the channel. Consistent with protocols (2007, page 77) the RGA was not completed, and a "Low" sensitivity was assigned.

Segment B

Segment B is approximately 1,851 feet long extending downstream from the bedrock gorge. Generally, the channel in Segment B is closely confined by extremely steep, forested valley walls located within one bankfull width of the channel. One occurrence of channel-spanning bedrock noted mid-segment. Occasionally, narrow terraces are present along the side of the channel – usually at a thalweg height more than 2 times the thalweg height of the channel. The cross section for Segment B was measured in one of these locations of locally wider valley width (if the terrace is ignored as a valley wall). Based on the limited available data and absence of detailed surficial geologic mapping in this location, the age of formation of these terraces is not known, and there is uncertainty as to whether these terraces represent a Recently Abandoned Floodplain created by incision occurring within the last 200 years.

At cross section XS-2, a RB terrace is present at a thalweg height of approximately 4.4. If this terrace represents a Recently Abandoned Floodplain (RAF), it would suggest a historic incision ratio of 2.59. Signs of active incision were not observed in the segment. Historically, incision may have migrated upstream from downstream straightened channel sections (Segment A). Colluvium may have moved downslope to obscure potential signs of undercut banks.

Protocols instruct to ignore high terraces that are more than 3 times the thalweg height and (generally) greater than 1 bankfull width distant from the channel when considering the RAF, as these are likely to be greater than 200 years old, forming in pre-colonial (post-glacial) times (pages 26-27, 29 of VTANR protocols, 2007).

Segment B could be classified as a B3a stream type with consideration of +0.2 permitted under protocols for Entrenchment Ratio. If this were true, the channel evolution stage would be revised to late stage IV [F]. That is the channel would have returned to a B stream type following historic incision, through minor widening, aggradation, and colluvial deposition.

In a conservative approach, and consistent with protocols, it was assumed that these terraces (RTER at XS-2) represent a RAF, since they are typically located at a height that is less than 3 times the bankfull depth, and within one bankfull width of the channel.

This classification choice has implications for the assignment of sensitivity, fluvial erosion hazard index, and dimensions of the Fluvial Erosion Hazard corridor under VTANR protocols. An F3a channel in Fair condition (inferred to have undergone a vertical stream type departure) is assigned an Extreme

sensitivity, a higher hazard index, with an FEH corridor buffered at three times the channel width on either side of the channel. In contrast, a B3a channel (in Good condition) not having undergone a stream type departure is classified with a Moderate sensitivity, a lower hazard index, with an FEH corridor buffered at two times the channel width.

Two very large mass failures were noted near the upstream end of Segment B as the channel transitions out of the upstream bedrock gorge. Frequent recruitment of LWD is occurring. Five debris jams were recorded in the segment in 2005, including a huge one immediately downstream of the mass failures.

Dominant processes of adjustment include moderate aggradation localized to mass failure sites & debris jams, along with minor planform adjustment (limited by close valley confinement).

Segment A

Segment A is a 905-foot subreach of broader valley confinement and reduced channel gradient (from 8.1 to 4.4%), where the Hollow Brook is transitioning from steep, till-covered slopes out into a broader valley comprised of glaciofluvial and alluvial sediments. Segment A was indexed as an "alluvial fan" to highlight the notable decrease in slope, though the bulk of the fan-like setting is located to the north and east of the downstream reach. Losing conditions (i.e., a section of dry channel) were noted extending from the approximate downstream reach break into reach T4.04 during the original assessment on 8 September 2005.

Development (Lazy Brook Mobile Home Park) is present along the LB corridor at the downstream end of the segment. Driveways providing access to mobile homes in the LB corridor are at grade and not significantly elevated above the floodplain. Slight berming (and likely fill / grading) is evident along the LB adjacent to the park and has encroached upon the channel which is armored in places. Historic channel straightening is inferred from the linear planform and from comparison of the 1987 topographic map and 1999 orthophoto.

A LB ephemeral tributary at the mid-point of Segment A is associated with a "delta" of sediment in Hollow Brook during the original September 2005 assessment. A small bridge provided a driveway crossing of this tributary to access a mobile home. In September 2005, this tributary channel was choked with gravel sediments. As of July of 2008, this tributary channel had been dredged and the small bridge was no longer present (see Figure X-x). This ephemeral tributary (in Starksboro) may receive stormwater runoff from ditches along Lincoln Hill Road (in Hinesburg) approximately 300 feet to the north and 140 feet upslope. The recently dredged (and now entrenched) cross section of this channel will be a source of increased sediment runoff to the Hollow Brook. It is also possible that headward incision will rejuvenate erosion and widening on upstream segments of this ephemeral tributary, leading to additional sediment delivery.

(a) *(b)*

Figure G-61. LB ephemeral tributary choked with sediment and causing damage to small driveway bridge. Hollow Brook segment T4.05-A (a) view upstream of driveway crossing. (b) view upstream from "delta" at confluence with Hollow Brook to driveway bridge outlet. 8 September 2005.

(a) *(b)*

Figure G-62. LB ephemeral tributary following dredging after bridge removal (washout?); photographed on 25 July 2008. Hollow Brook segment T4.05-A (a) view upstream from former driveway crossing. (b) view downstream to confluence with Hollow Brook.

Based on a cross section completed mid-segment (Just upstream of the confluence of the LB ephemeral tributary), the Hollow Brook channel is entrenched below RB (low bank), resulting in an inferred STD from Ca to Fa (IR_{RAF} =2.4; ER =1.2). At present the narrow tree buffer along LB and extensive forested buffer along RB (along with short sections of LB armoring/berming) appear to offer erosion resistance during typical flows. Current adjustment processes are very minor. However, this entrenched channel remains highly susceptible to catastrophic erosion in the event of very high flows and/or debris jams. A "Fair" condition rating was assigned, along with an "Extreme" sensitivity due to the vertical STD. A channel evolution stage of II [F] is inferred. Sensitivity of this channel is heightened by its topographic position of reduced slope and valley confinement.

T4.04

Not Assessed
Extensive wetlands contiguous to the channel (VSWI, NWI).
Losing conditions (dry channel in 9/2005) near upstream end.
Dominated by alluvial sediments (hydric) and muck/ peat (USDA).
Receives drainage from tributaries flowing on till covered steep slopes, primarily south of the valley.
Old bridge, culverts (candidates for removal) near upstream end in vicinity of mobile home park.

T4.3S6.01

Reach T4.3S6.01 is a small tributary draining to the north along Big Hollow Road in Starksboro to join Hollow Brook at the upstream end of reach T4.03 near the intersection of Big Hollow Road and the Hinesburg Hollow Road. This tributary reach was originally assessed in September of 2001 by VTDEC River Management Section staff and a team of LCA volunteers as part of the pilot study for protocol development. In 2007, SMRC entered assessment data from 9/5/2001 into the DMS; select parameters that were not originally measured under the 2001 version of the protocols have blank fields in the DMS. The 2007 update was primarily conducted to clarify reach segmentation due to declined property access in the upstream third of the reach (Segment B). Segment A was assessed as a cobble-dominated A-step/pool channel (reference and existing).

Cows and pigs were observed with direct access to the stream in Segment B during the 2001 assessment. Several undersized culvert crossings for roads and driveways were observed in the reach. Straightening is inferred from linear planform through pasture areas upstream of the Mason Hill N Rd (Segment B) and at select locations associated with culvert crossings elsewhere in the reach (Segment A). Several stormwater inputs from Big Hollow Road direct runoff to the LB of the channel. Indexed locations are approximate only. Forced depositional bars were observed at debris jams, submerged LWD, and boulder steps.

Dominant adjustment processes include moderate aggradation, with sediment supplied from road runoff, upstream pasturing, and high bank failures where the stream impinges on closely-confining valley walls. Lateral adjustments appear to have been moderated by reasonable-width forested buffers and relative coarseness of bed and bank material. No channel-spanning bedrock was apparently observed. Segment A was ranked in Fair condition with a "Very High" sensitivity. A channel evolution stage of I [F] is inferred.

T4.03

Not Assessed
Extensive wetlands contiguous to the channel (VSWI, NWI).
Floodplain dominated by alluvial sediments (hydric).
Receives drainage from tributaries flowing on till covered steep slopes, primarily south of the valley.

T4.02

Reach T4.02 was originally assessed in July of 2005 by South Mountain Research & Consulting. In December 2008, these data were updated to 2007 protocols relying on 10 October 2008 field observations by SMRC and Milone & MacBroom, as well as one repeat cross section completed on 25 July of 2008.

This a moderately-steep reach overall (1.9%) with a narrow floodplain confined between steep, till-covered slopes. Valley confinement generally ranges between Narrow and Broad, averaging Broad. There are a couple of instances of Semi-confined valley confinement mid-reach where the channel passes through a bedrock grade control. Glaciofluvial sediments are mapped at the upstream end of the reach and in the downstream third of the reach. Glacial till sediments are mapped in the middle of the reach, coincident with two occurrences of channel-spanning bedrock.

Reach T4.02 was segmented (Figure G-63) to capture: (1) a short upstream segment of wetland-dominated conditions (Segment C – 764 ft); (2) a middle subreach of alternate Bc stream type (Segment B – 1,746 ft); and (3) a downstream segment of apparent (C to B) stream type departure (Segment A – 4,509 ft).

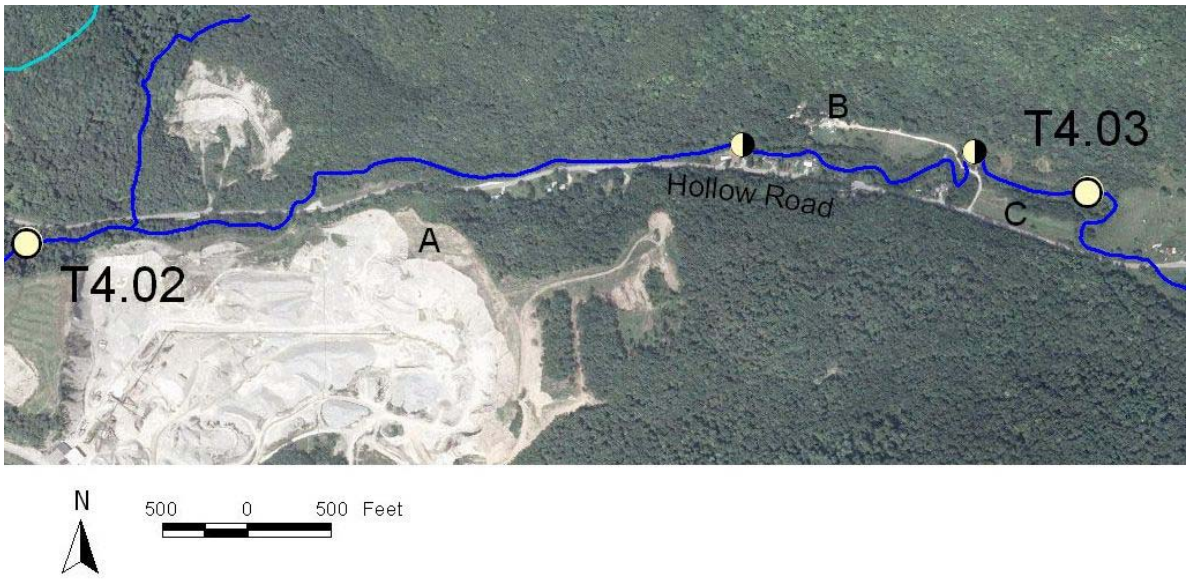


Figure G-63. Segmentation of Hollow Brook reach T4.02.

Segment C

The upper 750+ feet of reach T4.02 are similar in nature to the upstream reach, where wetland conditions dominate. The channel has a lesser gradient at this upstream end (0.9%), based on interpolated USGS topographic contours. Wetlands are mapped contiguous to the channel (NWI) in Segment T4.02-C. Two beaver dams, present on the assessment date 10 October 2008, impounded a majority of the segment length. For these reasons, the segment was not assessed.

Segment B

Segment T4.02-B is a subreach of alternate stream type in the upper third of the reach (1,746 feet) characterized by a Narrowly-confined to Semi-confined valley setting of moderate gradient (est. 1.9%). Soils of glacial till origin are mapped spanning the floodplain as well as the steep valley walls to the north and south of the channel. A series of terraces were observed within the valley, including a low-elevation set (approx. 1.3 to 2 times the thalweg height) nearest to the channel, and a moderate-elevation set (approx. 2.7 to 4 times the thalweg height). The Phase 1 (reference) valley wall was delineated at the base of the higher terraces.

Hinesburg Hollow Road parallels the channel along LB on the higher-elevation terraces, outside the delineated valley wall. Therefore, it was not considered a human-caused change in valley width. Several residential homes are present along the LB of the channel on the higher-elevation terraces. It is possible that artificial fill materials have increased the degree of channel entrenchment local to these structures. Rip-rap as well as other materials (e.g., tires, wooden cribbing, household rubbish, and debris) were observed incorporated in the stream bank next to these homes. One home was also noted on a high terrace considered to be beyond the right valley wall.

A gravel driveway crosses the channel at the upstream end of the segment to access the RB home. This crossing is undersized with respect to the bankfull width. The total span is approximately 15 ft (or 52% of the measured bankfull width) comprised of 3 separate 5-ft diameter corrugated plastic culverts installed side by side (Figure G-64). Lateral / vertical scour are evident both upstream and downstream of this structure, as well as upstream sediment deposition. Stormwater inputs were indexed at the upstream and downstream sides of this triple-culvert driveway crossing, where gravel from the driveway washes directly to the channel.

Figure G-64.
Triple-culvert driveway crossing of Hollow Brook at 1237 Hollow Rd at the upstream end of Segment T4.02-B. Reinforced with boulders and concrete blocks.
View downstream, 10 October 2008.

A cross section completed mid-segment indicated a cobble-dominated Bc-riffle/pool stream type. A degree of historic incision is inferred (IR_{RAF} = 1.4). Active adjustment processes include moderate planform adjustment (flood chutes, bifurcation) and minor aggradation. Lateral & vertical adjustments likely have been moderated by revegetating buffers and occasional lateral bedrock controls. Potential sediment delivery from upstream reaches may have been minimized by attenuation in intervening wetland-dominated reaches (T4.03, T4.04). A channel evolution stage of II [F] was assigned, with a corresponding sensitivity rating of High.

Segment A

The reference valley confinement in Segment T4.02-A varies from Semi-confined (at a valley pinch point) to Broad, and averages Broad overall. Where the channel impinges on the right or left valley wall, three mass failures have developed in high terraces of unconsolidated sands and gravels. Hinesburg Hollow Road encroaches along the LB in the upstream half of the segment, and along RB in the downstream half. This encroachment has reduced the valley confinement to an average Narrow (ranging from Narrowly-confined to Narrow).

Several homes are located along the LB corridor in the upstream half of Segment A. The Hinesburg Sand & Gravel quarry borders the LB corridor in the downstream half of the segment. An additional sand &

gravel quarry is present along the RB corridor near the middle of the segment. The aerial extent of these quarries has expanded in recent decades, based on review of historic aerial photographs. The Hollow Brook channel is positioned between quarry walls along the LB and the Hinesburg Hollow Road berm along the RB in the downstream half of the segment.
Based on comparison of 1962 and 1974 aerial photographs and review of the 1987, 1948 and 1906 USGS topographic maps, approximately 900 ft of the Hollow Brook channel was relocated from its original meander position south of Hinesburg Hollow Road to a new position (800 ft long) north of the road sometime between 1962 and 1974 (perhaps 1973 flood?) – (see Figure x). Two bridge crossings were eliminated as a result of this channelization. Dredging is inferred to have accompanied this channel relocation. Rip-rap armoring reinforces the road bed materials along LB. Within this 800 ft of relocated channel on the north side of the road, are several exposures of channel-spanning bedrock - both of small control height ("ledge") and larger control heights ("waterfall"). These were collectively indexed as one long "waterfall" with a total vertical drop of approximately 25 ft. An additional isolated exposure of channel-spanning bedrock ("ledge") was observed approximately 300 ft downstream of this relocated section.

Two culverts were observed to cross under Hinesburg Hollow Road and direct stormwater flow directly to the channel in this 800 ft section. The channel crosses under Hinesburg Hollow Road approximately 1700 ft upstream of the end of the reach. This bridge is a flood-prone-width constrictor, and a moderate scour pool has developed on the downstream side. Rip-rap armoring reinforces the abutments of this crossing structure, given the sharp approach and exit angles of the channel relative to the structure.

On 10 October 2008, the lowermost 725 ft of the segment was dry. Based on casual observations, this part of the reach and extensive sections of the next downstream reach (T4.01) are typically dry in the late Summer or early Fall of the year (i.e., "losing reach").

A vertical stream type departure (C to B) is inferred due to vertical separation of the channel thalweg from adjacent terraces (IR ranging from 2.3 to 3.5). At one cross section location (XS-3), the degree of entrenchment may have been enhanced by fill materials or regrading of the LB terrace in the vicinity of a residence. One downstream cross section (XS-1, not representative of the segment) suggests a lesser degree of incision, IR = 1.5). Incision appears historic in nature due to the absence of features that would suggest active incision. Active channel adjustments include minor (localized) aggradation, widening, and planform adjustments. A channel evolution stage of II [F] is inferred; a sensitivity of "High" was assigned due to the stream type departure.

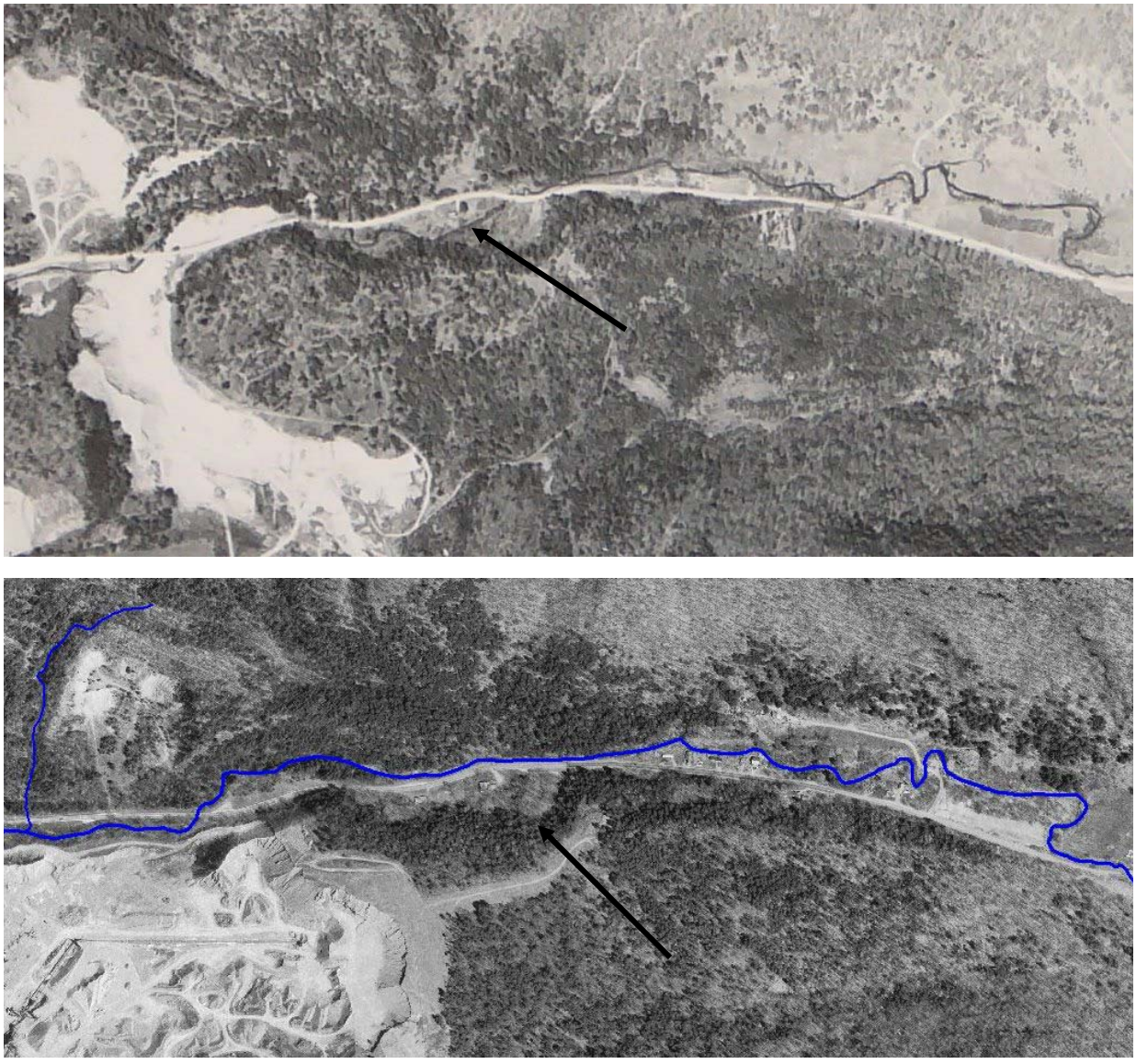


Figure G-65. Hollow Brook in Hinesburg was channelized to flow along the north side of Hinesburg Hollow Rd between 1962 (top) and 1974 based on review of aerial photographs – see arrow. (Base map of bottom image is 1999).

T4.01

Reach T4.01 was originally assessed in July of 2002 by VTANR River Management Program and a team of Lewis Creek Association volunteers. In December 2008, these data were updated to 2007 protocols relying on 18 August 2008 field observations by SMRC and Milone & MacBroom, as well as some of the 2002 data.

Reach T4.01 is the downstream-most reach of Hollow Brook and joins the Lewis Creek at the upstream end of reach M15. This 1.8-mile reach was segmented to capture a subreach of alternate reference

stream type in the downstream half:

- Segment B – 5,235 ft, est. 1.2% gradient, C4-plane bed channel (reference: C4-riffle/pool);
- Segment A – 4,415 ft, est. 0.5% gradient, subreach of E4-dune/ripple reference stream type departed to a C4-dune/ripple.

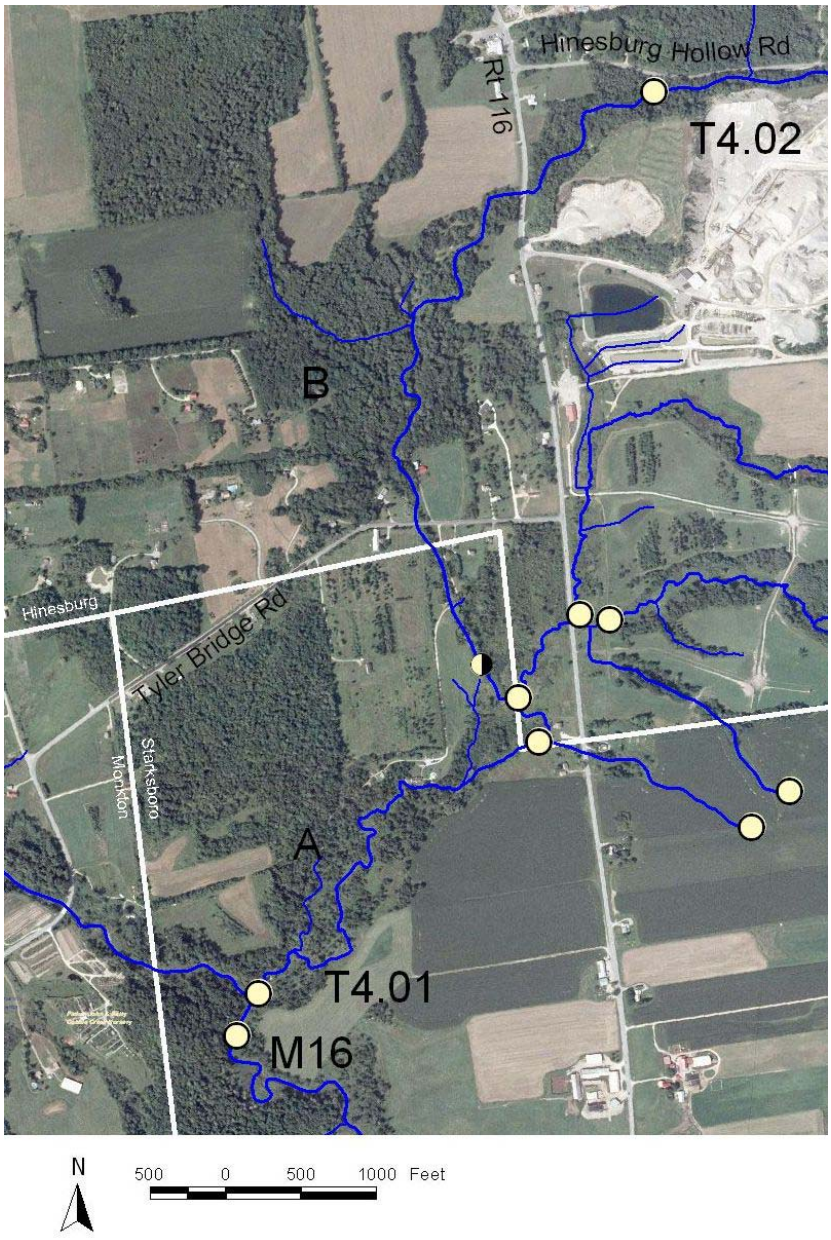


Figure G-66. Segmentation of reach T4.01, Hollow Brook.

Segment B

Segment B is the upstream half of reach T4.01 in which the Hollow Brook transitions to a Very Broad confinement, accompanied by a reduction in gradient. Accordingly, this segment was indexed as an "alluvial fan" following protocols. Sediments in the broad valley of Segment T4.01-B are generally of alluvial and glaciofluvial origin; with sediments of glaciolacustrine and till origin comprising moderately- to steeply sloped valley side slopes usually quite distant from the channel. In a few locations, the channel

impinges against these valley side slopes. On 18 July 2002, a 1,400-ft section of channel spanning the Route 116 bridge crossing was dry. Based on casual observations, this part of the segment (and sections of the upstream reach, T4.02) are typically dry (i.e., "losing reach") in the late Summer or early Fall of most years.

Road encroachments are minimal within the segment. Gravel driveways pass parallel to the channel for short sections in vicinity of the Tyler Bridge Road crossing; these are generally at grade and do not represent a significant human-caused change in valley width. Three bridge crossings are present in the segment:

- Route 116 bridge – floodprone-width constrictor with scour noted on the downstream side.
- Tyler Bridge Rd bridge – bankfull constrictor, with upstream deposition;
- Private driveway bridge – bankfull constrictor.

One equipment ford crossing connects fields in the upstream half of segment. There is sparse residential development along the segment, as well as limited encroachment by hay and crop fields. A berm is present along RB near the upstream end of segment. Berms were noted along LB in vicinity of hay fields downstream of the Route 116 crossing. Berms were also present along LB and RB in vicinity of the private driveway crossing in the downstream half of segment (possible dredging spoils). Evidence of scoop-like depressions in gravel bed of channel were observed in 2002 downstream of the private bridge (suggestive of gravel extraction). In a 1962 aerial photograph, recent channelization was evident in this 1000-foot length of channel downstream of Tyler Bridge Rd. This section continues to have a linear planform today.

A moderate to high degree of historic incision is evident at cross section sites throughout the segment, though a vertical stream type departure is not apparent. A C4 stream type was assigned, consistent with reference; however, an expected riffle/pool bedform has departed to plane bed. A weak riffle/pool form is developing in many locations throughout the segment. In a couple locations (including the representative cross section site, XS-3), berms along the low bank increase the degree of channel entrenchment, locally. The channel is building an incipient floodplain through active lateral adjustments and localized aggradation. Pockets of this incipient floodplain are evident (e.g., XS-5 upstream of the Route 116 crossing) but are not longitudinally continuous. Rip-rap and berms have been installed along driveways and agricultural fields where the laterally adjusting channel is in conflict with neighboring land uses. A channel evolution stage of IV [F] is inferred; a "Very High" sensitivity was assigned.

Segment A

Segment T4.01-A is the downstream half of the reach. Wetlands (NWI) and hydric soils are mapped contiguous to the channel. Several exposures of varved clays were observed along the outside of meander bends and at depth in pools. Presence of wetlands and hydric soils, as well as the high sinuosity and low gradient of the segment suggest an E reference stream type. Scrub/shrub and herbaceous wetland vegetation dominates the buffer areas. Abundant beaver activity noted in 2002 and 2008. One intact and one recently breached beaver dam observed on 18 Aug 2008. A network of several tributaries joins the segment near the upstream end. These tributaries drain hydric soils of glaciolacustrine origin to the east of Route 116 and pass through crop, hay and pasture areas. Some tributary segments appear ditched.

A couple of residential homes have been developed within the LB and RB corridors post-1962. One RB residence is within 50 ft of the channel, where the streambank has been reinforced by rip-rap. Recent (2002) dredging of the channel was attempted by a riparian landowner to redirect flows farther from this residence. The formerly dredged channel was observed to be largely abandoned in 2008, with flows restored to original channel. A large delta of fine and medium gravels has been noted periodically at the confluence with Lewis Creek (e.g., July 2002, Nov 2006). On 18 August 2008 this sediment deposit was

much less pronounced. One very-low-clearance and bankfull-constricting timber footbridge (possible ATV bridge) was observed mid-segment. Two fords were noted in the segment: one next to the RB residence, one downstream of the timber footbridge.

Cross sections completed in the segment indicate good floodplain access (IR = 1.0). Instead the channel appears dominated by active widening, planform adjustments and aggradation, locally enhanced at beaver dam sites and debris jams. Channel braiding (local aggradation) was noted in vicinity of a breached beaver dam on 18 August 2008. Avulsion of the channel to the west and south from the breached beaver dam has resulted in partial abandonment of the original channel position.

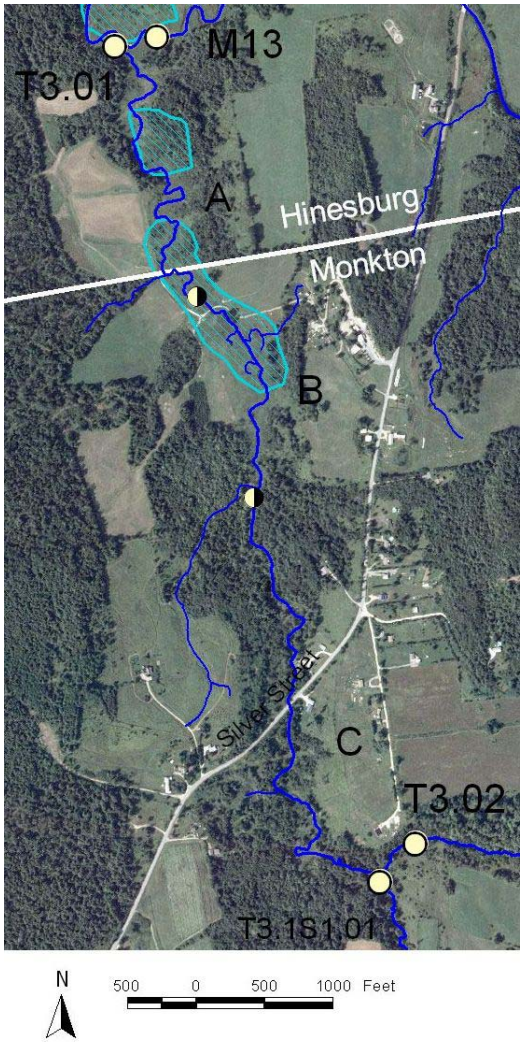
The W/D ratio (25) suggests that an E-to-C lateral stream type departure has occurred. The cohesiveness of bed sediments (e.g., varved clays) and low overall gradient may have moderated the potential for incision, despite evidence of 2002 channelization / dredging and a recent avulsion. A channel evolution stage of IIc [D] was inferred, with an associated sensitivity of "Very High".

X.3 Pond Brook (T3)

T3.01

Reach T3.01 is the downstream-most reach of Pond Brook extending from nearly half a mile upstream of the Silver Street culvert crossing to the confluence with Lewis Creek located approximately 1.3 miles downstream of Silver Street. The upstream half of this reach flows through sediments of glaciolacustrine origin; more recent alluvium is mapped in the downstream half of the reach coincident with more intensive agricultural use of the floodplain. Channel gradient decreases and valley confinement relaxes with distance downstream. Wetlands (NWI, VSWI) are mapped along the channel in the downstream half of the reach.

The upstream half of the reach is largely forested with occasional residential land use and indicators of historic pasturing (such as barbed wire fencing, and regenerating forests). While the overall reach gradient and average valley confinement would suggest a C-riffle/pool stream type, the downstream half of the reach has a much gentler gradient, finer substrates and reference sinuosity that would suggest a reference
E-dune/ripple stream type. The reach was therefore segmented to capture this subreach of alternate reference stream type. Additionally the upper portion of this downstream reference E dune/ripple channel has been extensively managed in recent decades such that a lateral stream type departure from E to C stream type is inferred. Therefore, the reach was divided into a total of three segments:



Segment C: upstream 4,363 feet,
estimated gradient of 1.4% -
reference / existing C-riffle/pool stream type;

Segment B: middle 1,840 feet,
estimated gradient of 0.1% - reference
E dune/ripple departed to C-dune/ripple;

Segment A: downstream 3,199 feet,
estimated gradient of 0.06% -
reference /existing E dune/ripple stream type.

Figure G-67. Segmentation of reach T3.01, Pond Brook tributary to Lewis Creek.

Segment C

Assessment of Segment T3.01-C was updated in 2008, relying primarily on field observations and additional cross sections collected in Sept 2008, to supplement an original October 2004 assessment. The actual planform of the channel (as measured on 8 September 2008) is different than depicted on the VHD in the upstream end of the segment.

Glaciolacustrine sediments are mapped spanning the Pond Brook channel and floodplain in this reach. An average Narrow confinement is evident as moderately- to steeply sloping valley side slopes confine a floodplain approximately 3 to 6 times the channel width.

Encroachments are minimal within the segment. Roads indexed in the segment include Silver Street which crosses the channel at an oblique angle – this does not constitute a significant human-caused change in valley width. The Silver Street culvert crossing and one timber VAST trail crossing are bankfull constrictors. Rip-rap armors the streambanks in vicinity of the Silver Street crossing. Sparse residential development is concentrated near the Silver Street crossing (RB).

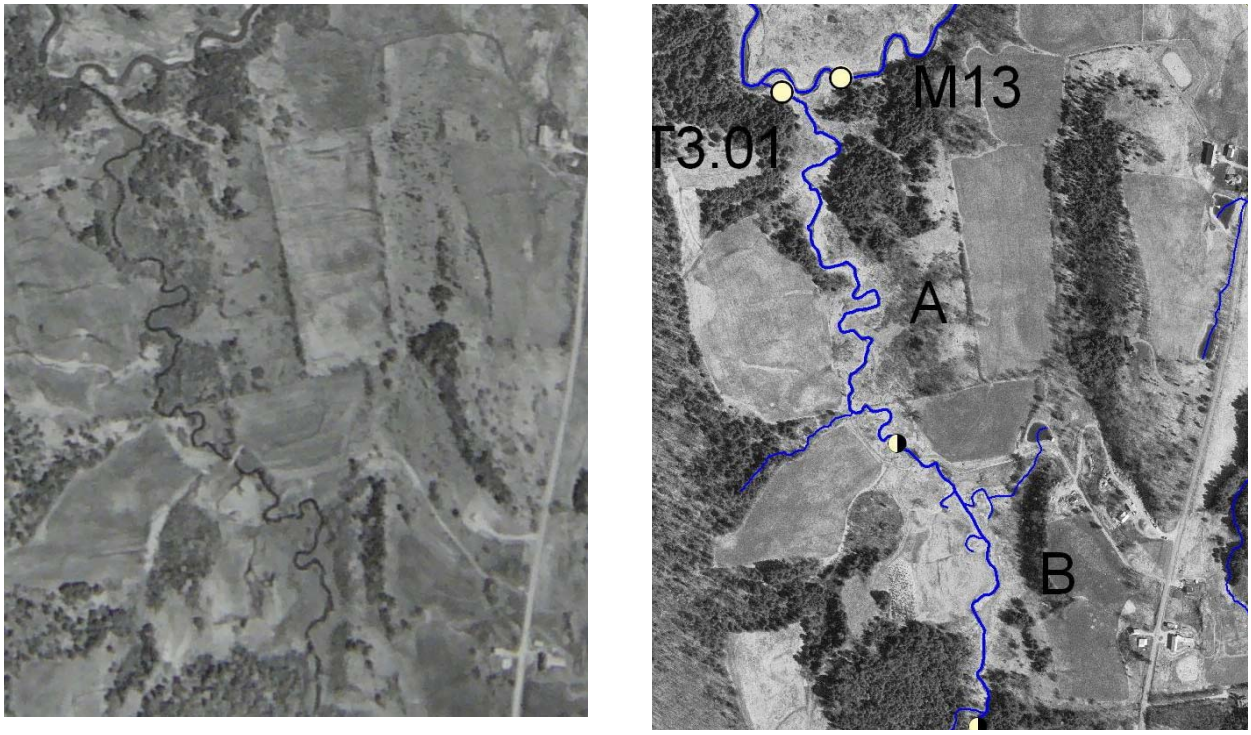
A pre-2003 and post-1999 neck cutoff at a tortuous meander upstream of the Silver Street crossing is now part of a channel-contiguous wetland. One intact beaver dam impounds a short section of channel as observed on 8 Sept 2008; nearby depositional and vegetation features suggest that this beaver dam previously impounded a larger area.

Cross sections completed within the segment indicate overall good connection to the floodplain (IR=1.0) – except for localized historic incision which was evident at the very downstream end of the segment. A stream type of C4-riffle/pool was assigned, consistent with the reference stream type. The segment is dominated by moderate planform adjustment (flood chutes, bifurcations), and moderate (localized) widening and aggradation. A I [F] channel evolution stage is inferred. The "Fair" condition rating suggests a "Very High" sensitivity of this C4 channel.

Segment B

Assessment of Segment T3.01-B was updated in 2008, relying primarily on field observations and additional cross sections collected in Sept 2008, to supplement an original Oct 2004 assessment. Wetlands (NWI) and hydric soils are mapped contiguous to the channel. An E-dune/ripple reference stream type is inferred from the narrow / deep channel, cohesive soils, and high sinuosity of the immediately downstream segment. Segment B has undergone substantial historic channelization associated with agricultural land use. Cut off meanders can be seen on either side of a straightened channel on the 1999 orthophotograph (Figure x). Dredging is inferred to have accompanied historic channelization. Pasture has recently been established in previously fallow fields within 25 ft of the LB. Fallow fields are present along the RB corridor. Occasional short lengths of rip-rap (rounded field stone) were observed along the RB adjacent to now fallow fields. One RB tile drain was observed; additional tile drains may have been present but were obscured by vegetation. A farm road culvert crossing is present near the downstream end of the segment. This instream culvert is a bankfull constrictor, and scour pools are present upstream and downstream of this structure.

The segment cross section indicates a moderate degree of historic incision (IR_{RAF} = 1.4). The channel is dominated by minor aggradation and moderate planform adjustment. Channel adjustments may have been moderated by cohesive soils and the low gradient. However, the W/D ratio (16.5) suggests that an E to C lateral stream type departure has occurred. A weak riffle/pool bedform is present where a reference dune/ripple form might be expected in a channel that was highly sinuous prior to channelization. Riffles are short in length; often riffles are sedimented (i.e., diagonal). A channel evolution stage of III [F] is inferred. The segment is in "Fair" condition, with an associated "Very High" sensitivity.



(a) *(b)*

Figure G-68. Segment B of reach T3.01 on the Pond Brook was channelized sometime after 1974 (a) and prior to 1999 (b).

Segment A

Assessment of Segment T3.01-A was updated in 2008, relying primarily on field observations and additional cross sections collected in Sept 2008, to supplement an original Oct 2004 assessment. This segment is the lower portion of the subreach of E-dune/ripple reference stream type, that has not undergone recent channelization. Wetlands (NWI) and hydric soils are mapped contiguous to the channel. Wetland vegetation is present in the floodplain surrounding the channel, while coniferous forest covers the steep valley walls. Occasionally the channel meanders to impinge upon the left valley wall.

Cross section measurements (e.g., W/D ratio < 12) support an E5-dune/ripple classification. The channel as ample access to the floodplain (IR_{RAF} = 1.0). Active meander extension and translation are apparent from comparison of a 1999 orthophotograph to 2003 aerial imagery. One small neck cutoff and short length of channel bifurcation were noted. Signs of beaver activity (slides, bank dens, chewed vegetation along valley walls) were abundant. While no intact beaver dams were observed on 8 Sept 2008, a previous assessment (October 2004) noted three beaver dams and associated impoundments. Transitory beaver impoundments have enhanced aggradation and widening (locally).

The position of the confluence with Lewis Creek has shifted from that depicted on the VHD (and 1999 orthophoto and 2003 aerial photograph). As a meander of the Lewis Creek channel migrated to the south, it connected with the Pond Brook channel at a point approximately 200 feet upstream of the former confluence. This new point has become the new confluence, as first noted in October 2004.

Many fine gravels, sands and silts are accumulating in the Pond Brook channel upstream of the Lewis Creek confluence. Sediments are very soft underfoot to a depth of more than two feet in many locations. Beaver dams were previously noted in this area on both the Pond Brook and the Lewis Creek (2004), but were absent on the 8 September 2008 assessment, and have likely contributed to the local accumulation of fine sediments. A channel evolution stage of I[F] is inferred for Segment T3.01-A. The segment is in Good condition with a "High" sensitivity.

X.4 Cedar Brook (T2)

T2.01

Reach T2.01 is the downstream-most reach of Cedar Brook tributary, and joins the Lewis Creek just below the downstream end of reach M12. The assessment of reach T2.01 was updated in November 2006, since the original assessment by VTDEC/LCA in 2001 focused on only a sub-section of the reach. Generally, the channel is located in a Semi-confined valley setting, with sediments of glaciolacustrine origin mapped in the vicinity. Several channel-spanning grade controls were indexed within the reach (Figure x), including a 450-ft-long section of bedrock waterfall with an approximate vertical drop of 35 ft. Overall, a stream type of B3-step/pool was assigned, but there are short sections of B1-cascade, as well short sections of less confined, shallow gradient (<2%) at the very downstream and upstream ends of the reach. Wetlands are mapped at the upstream end of the reach above the bedrock grade controls. A significant beaver dam with large impoundment was observed at the upstream end of the reach on 14 November 2006; there was a second beaver dam site mid-reach. Well-developed coniferous forest buffers are present along both banks. This reach functions primarily as a transport-dominated reach with little opportunity for sediment (nutrient) attenuation except where depositional bars are forced at LWD / debris jams or where flows are temporarily impounded by beavers, seasonally.

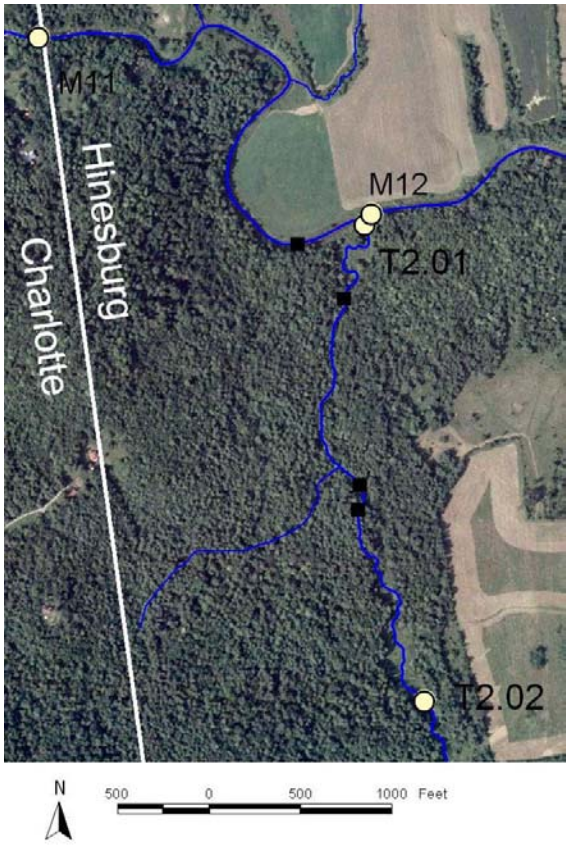


Figure G-69. Reach T2.01 of Cedar Brook tributary joins the Lewis Creek main stem just below the downstream reach break for M12. (Black dots represent downstream end of channel-spanning bedrock exposures).