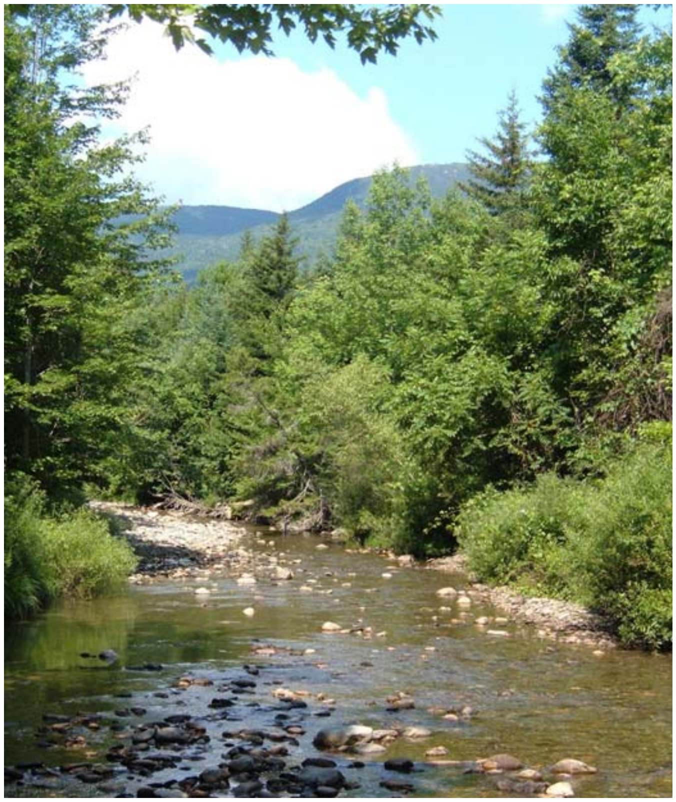
Mad River Headwaters
Phase 2 Stream Geomorphic Assessments

January 31, 2008



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1.0 Executive Summary

Fitzgerald Environmental Associates, LLC (FEA) and Lisa C. Godfrey, LLC were retained by Friends of the Mad River (FMR) to conduct Stream Geomorphic Assessments (SGA) in the headwaters zone of the Mad River watershed. This report summarizes Phase 2 SGA data collected on 18 stream reaches. FMR intends to use geomorphic data collected throughout the watershed to better understand stressors and adjustments in stream channel equilibrium. The headwaters reaches were selected for Phase 2 assessments by FMR to better understand 1) the changes in channel stability brought on by the 1998 flood, and 2) how instability in the headwaters impacts the sediment supply to the lower reaches in the valley.

In addition to the data collection and summary effort, an analysis of stressors to the hydrologic and sediment regimes and riparian and boundary conditions was conducted. This included the mapping of channel features identified during the field surveys. The data and mapping formed the basis for developing a list of potential restoration and protection projects using a step-wise procedure developed by the Vermont Agency of Natural Resources (VTANR). The following is a brief summary of findings from the Phase 2 data, and the stressor and project identification effort:

- The Mad River mainstem reaches have been historically impacted by Route 100 and the associated berming and armoring. Four of the eight assessed segments had “Fair” geomorphic stability. Two of these segments, M21 and M23-A, remain in an incised state with limited floodplain access (CEM Stage II) due to road encroachment and bank armoring. Segments M20-B and M23-C have limited floodplain access and are currently aggrading coarse substrate and widening (CEM Stage III).

- Lincoln Brook reaches appeared to be less affected by direct impacts to the floodplain and channel boundaries than the mainstem reaches. Sections of segments T12.03-B and T12.2-S2 are incised (CEM stage II) due to undersized culverts which appeared to cause excessive downcutting and sediment export during the 1998 flood. Segment T12.02-B experienced severe lateral migration during the flood (e.g., flood chutes) and continues to adjust towards an equilibrium planform. Segment T12.2-S4 had a high degree of sedimentation of sand that appeared to originate from poorly controlled road runoff from Hanks Road.

- Stetson Brook reaches appeared to be experiencing widening and aggradation with some lateral migration (F-type; CEM Stage III) following the 1998 flood. Bedrock grade controls provided some bed stability, although historical incision was indicated by terraces. A tributary to Stetson Brook also appeared affected by the 1998 flood, with minor aggradation and migration (D-type; CEM Stage IIc).

- Overall aquatic habitat conditions are “Good” along the mainstem, with only three segments receiving scores of “Fair”. Those areas assessed as “Fair” (Segments M21, M23-A, M23-C) have only limited feature formation (e.g., pools and riffles) with reduced bank vegetation. Habitat conditions on Lincoln Brook are generally “Good” to “Reference”, with the exception of the two incised channels described above. Habitat conditions in Stetson Brook appeared “Good” overall, however the downstream most reach had an RHA score of “Fair” due to road encroachments, resulting loss of buffer vegetation, and reduction of instream habitat (pools and mixed substrate types).

- The stressor identification mapping revealed that encroachment, armoring, and historical straightening associated with Route 100 has caused a departure from the reference sediment regime for six of the eight mainstem segments. Numerous grade controls were noted in the Lincoln Brook reaches, which appear to be controlling vertical adjustments on some of the impacted reaches. On Stetson Brook, road encroachment and historical berming (Stetson Hollow Road) have caused a departure from the reference sediment regime on three of the four assessed reaches, despite the abundance of natural grade controls.

- Only one of the 16 structures assessed in this study met the RMP recommended width for stream crossings (1.25-1.5 bankfull width). The remaining 15 structures ranged in size from 36% - 79% of bankfull width. Several of the structures were derelict or inaccessible and could be removed to improve stream function and habitat. Other structures are recommended to be resized and replaced.

- Options for floodplain restoration and protection along the mainstem reaches are limited due to Route 100 sharing the narrow valley with the river. The few floodplain areas that remain along the mainstem should be protected with any possible enhancement efforts to attenuate some flow and sediment upstream of the Town of Warren. Stetson Brook is a source of sediment mobilized during the 1998 flood. Enhancement of floodplain areas could be achieved through removal of road berms and bridges as Stetson Hollow Road has washed out.

- High priority projects identified in Section 7.0 of the report include:
  1. Address sizing and placement of stream crossings.
  2. Protect and look for ways to enhance high priority floodplain areas such as in M20, M22, M23 and along Lincoln Brook.
  3. Address stormwater problems in M23-B, M23-C (on a tributary) and T12.2S4.01.
  4. Remove road berms and bridges along Stetson Brook as the road has washed out and is no longer accessible.

- Two additional tributary reaches draining to the mainstem are recommended for future Phase 2 assessments. Tributaries M23-S1.01 and M23-S2.01 are delivering large quantities of fine and coarse sediment to the Mad River, resulting in degraded habitat for native trout in segment M23-C. The increased sediment supply may be resulting from channel incision caused by high road densities and wetland loss in the upslope drainage areas.

2.0 Introduction

Friends of the Mad River (FMR) received a grant from the Vermont Department of Environmental Conservation (DEC) River Management Program (RMP) to complete Phase 2 Stream Geomorphic Assessments (SGA) in the headwaters of the Mad River and on Lincoln Brook and Stetson Brook in 2007. Phase 2 SGAs were previously completed for the lower mainstem of the Mad River and for Pine Brook in 2006. FMR aims to collect geomorphic data throughout the watershed where feasible in order to better understand stressors and adjustments in stream channel equilibrium. These headwaters reaches were selected for Phase 2 assessments by FMR to better understand the changes in channel stability brought on by the 1998 flood, and how instability in the headwaters impacts the sediment supply to the lower reaches in the valley. FMR was also interested in the extent to which roads and development in the watershed have impacted the headwaters.

Through this stream assessment, FMR has increased its information base of channel conditions, adjustments, and impacts in the upper Mad River mainstem and Lincoln and Stetson Brooks. This data can now be used to plan and complete projects in the watershed and to guide development of a River Corridor Plan (RCP) to assist town planning and zoning in and near the river and riparian areas. Information from this assessment has been used to identify high risk areas and areas in need of restoration to help reduce sediment and nutrient loading of the Mad River and ultimately Lake Champlain. Phase 2 data can also be used to create Fluvial Erosion Hazard (FEH) Zone maps. Please see the RMP website for a description of FEH zones and delineation.

3.0 Background

The following information serves as a brief introduction to the scientific background of the study area with respect to its physical forms, land use history, hydrology, and ecosystems. Further, more detailed information can be found in the references cited throughout this section.

3.1 Geographic Setting and Land Use

The Mad River drains a 144 square mile watershed spanning the towns of Duxbury, Fayston, Moretown, Waitsfield, Warren, and Granville. The Mad River is a tributary to the Winooski River, eventually draining to Lake Champlain. The Mad River headwaters, the study area for the Phase 2 assessments, encompass the towns of Warren, Granville, Lincoln, and Roxbury (Figure 3.1). The topographic relief of this area ranges from an elevation of 940 feet in Warren to over 4,000 feet on Lincoln Peak.

Prior to the forest clearing associated with human settlement, logging, and farming, the watershed would have been a mixture of deciduous forest on the valley floors, coniferous forest along the mountain spines, and a mixture of both along the slopes. Deforestation and grazing, largely from sheep farms, likely left over 90 percent of the watershed devoid of trees at one time or another (Albers, 1998). This landscape change had a tremendous impact on waterways like the Mad River. Exposed soils on steep slopes eroded and was carried to the valley floors where it aggraded on river bottoms; a legacy that still influences the way Vermont's rivers are managed today.

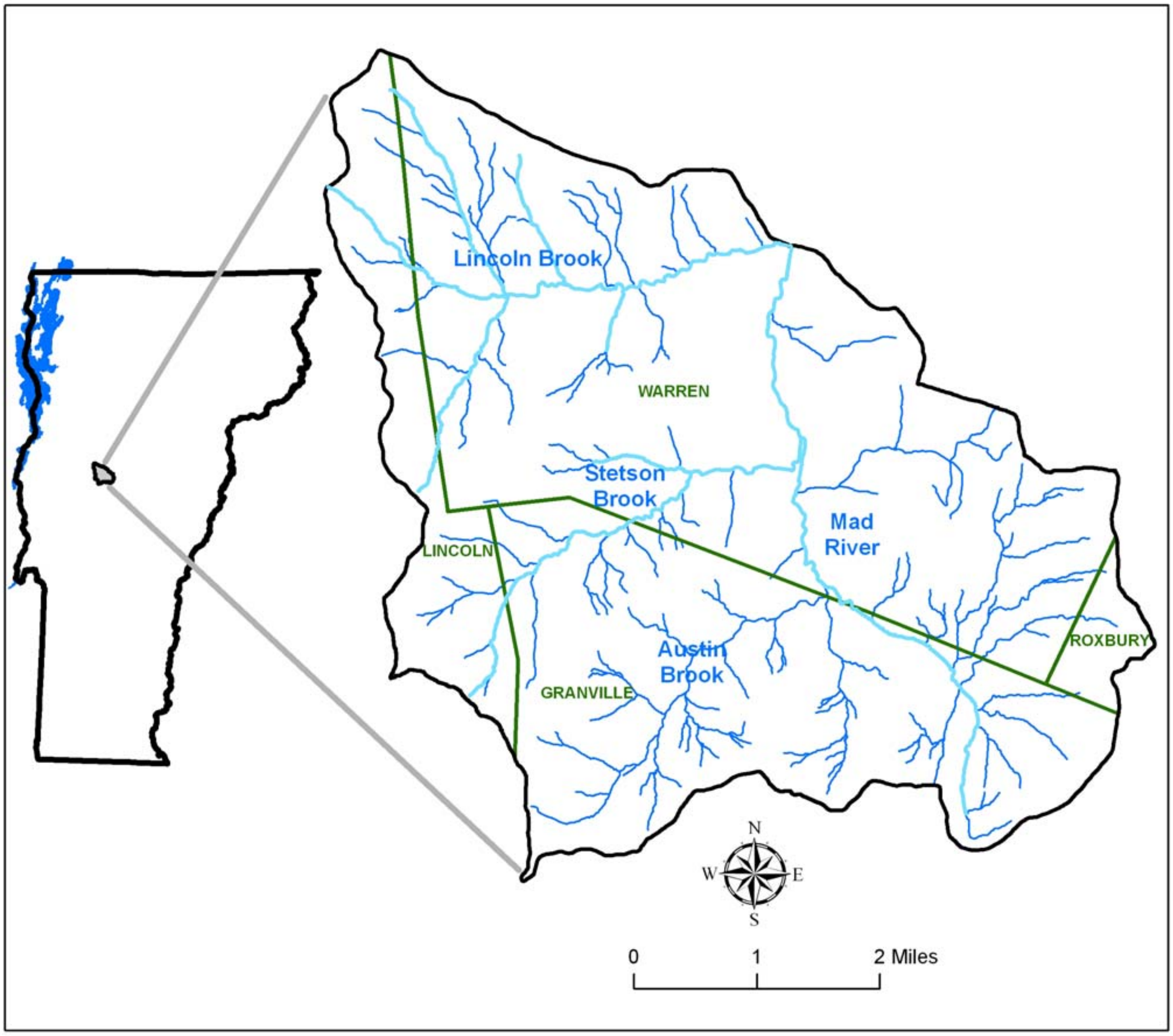

Figure 3.1 Mad River headwaters study area and town boundaries.
Study reaches are highlighted in light blue.

As Vermont's farmers began to move to the Midwest in search of more productive farmland in the mid to late 1800's, the deciduous forests along the mountain slopes began to recover (Albers, 1998). Throughout the early and mid 1900's, as more family farms found on marginal lands were given up, the forests continued to recover. Today, approximately 90 percent of the headwaters watershed is covered by forest. With the increasing tourism sector in the state, and the need for hardwood lumber for second-homes, forestry has replaced agriculture in the rural hill slopes of the valley. Only 3.4

percent of the headwaters watershed is occupied by agricultural land today, much of this in the Lincoln Brook watershed.

3.2 Geologic Setting

The Mad River watershed is found in the Northern Green Mountain Biophysical Region (Thompson and Sorenson, 2000). The bedrock of this region dates back to the Cambrian and Ordovician time, but was metamorphosed during the geologic events that formed the Taconic Mountains. The metamorphic rocks present in today's Northern Green Mountains include schists, phyllites, gneisses, and quartzites (Field, 2007).

During the Wisconsin glaciation, glaciers a mile in thickness extended across New England, reaching their maximum extents approximately 20,000 years ago. This glacial event left the Northern Green Mountains with a physical imprint that is evident today. In the Mad River watershed, features such as kame terrace deposits (i.e., Lincoln gravel pit) moraines and outwash areas (i.e., Irasville area), and lake sediments represent the dynamic nature with which glaciers shaped the landscape. However, most of the surifical geology of the Mad River watershed is dominated by glacial tills. The resulting soils are dominated by rocky tills in the sloped areas. On the valley floors, fine sandy loams and silty loams associated with recent alluvium provide good to excellent soils for agriculture. In the headwaters study area, vast areas of surficial bedrock are found along the ridgelines of the Green Mountains. One area of swamp peat is found north of Alpine Village along Mills Brook.

3.3 Geomorphic Setting

The river reaches included in the Phase 2 headwaters study are found upstream of Warren Village in the towns of off Warren, Granville, and Lincoln (Figure 3.1). These reaches were defined as part of the Phase 1 assessments carried out by Field Geology Services during 2006 (Field, 2007). The drainage area of the study area, measured at Reach M20, is 19.2 square miles. Detailed site location maps including reach breaks, cross-section locations, and roads are found in Appendix 1.

The Mad River mainstem reaches (M20 through M23) are located along Route 100 in a valley that varies in width from confined to very broad. Numerous grade controls are found in reaches M20, M22, and M23. The presence of bedrock has constricted the lateral migration of the channel in many locations, containing it within a confined setting. B and C-type channels with step and riffle-pool bedform morphologies are reference conditions for these reaches. During the Phase 2 surveys, division of the mainstem reaches resulted in a total of 8 segments, which are described in detail in section 5.

Lincoln Brook (T12) confluences with the Mad River at the Bobbin Mill upstream of Warren Village. The valley width of the mainstem of the brook varies from confined to broad. In reach T12.02, the channel is found in a wide, alluvial valley surrounded by steep topography. This unconfined area, which is an exception in the watershed, supports many areas with C-type channel dimensions. Bedrock is found throughout this valley, providing grade control and causing channel constrictions. The steep, bedrock controlled reaches which descend from the surrounding mountains all have slopes greater than 4 percent, with A and B-type channel geometry. During the Phase 2 surveys, reach divisions resulted in a total of 9 segments, which are described in detail in section 5.

Table 3.1 Mad River Headwaters Reference Stream Characteristics

Reach ID	Watershed Area (sq. mi.)	Channel Length (mi.)	Channel Slope (%)	Channel Width (ft.)	Sinuosity	Valley Type	Stream Type*	Bedform†
M20	19.2	1.8	1.2	52.8	1.07	Narrow	B	Step-Pool
M21	12.3	0.5	2.0	35.7	1.32	Broad	C	Riffle-Pool
M22	10.6	0.9	2.0	46.2	1.15	Narrow	C	Riffle-Pool
M23	5.2	2.7	1.3	23.2	1.11	Very Broad	C	Riffle-Pool
T12.01	7.7	0.9	3.4	41.0	1.12	Semi-Confined	C	Plane Bed
T12.02	7.1	1.9	2.4	27.1	1.22	Very Broad	B	Riffle-Pool
T12.03	1.0	1.9	2.6	20.0	1.07	Narrowly-Confined	A	Step-Pool
T12.2-S1.01	0.6	0.5	13.7	20.0	1.00	Narrowly-Confined	A	Cascade
T12.2-S2.01	0.5	1.2	6.1	9.0	1.05	Semi-Confined	B	Step-Pool
T12.2-S3.01	1.6	1.9	13.5	18.0	1.07	Narrowly-Confined	A	Cascade
T12.2-S4.01	1.7	0.6	8.1	19.0	1.06	Narrowly-Confined	A	Step-Pool
T13.01	4.9	0.4	4.2	32.0	1.02	Semi-Confined	B	Step-Pool
T13.02	4.9	1.0	4.7	49.0	1.07	Narrowly-Confined	B	Step-Pool
T13.03	3.4	0.9	5.0	51.0	1.17	Narrow	B	Step-Pool
T13.04	2.3	0.7	5.5	36.0	1.09	Broad	B	Step-Pool
T13.2-S1.01	0.7	0.9	12.1	13.3	1.07	Narrow	B	Step-Pool

* per Rosgen (1994)
† per Montgomery and Buffington (1997)

Stetson Brook (T13) confluences with the Mad River at the mainstem reach break between M20 and M21. Most of the Stetson Brook reaches are found in confined to narrow valley settings, and have numerous grade controls. Under reference conditions, we would expect to find B-type channel morphology with step-pool bedform in this setting. During the Phase 2 surveys, a total of 5 reaches were assessed, which are described in detail in section 5.

3.4 Hydrology and Flood History

The USGS has maintained a streamflow gauging station on the lower Mad River since 1928. The station is located north of the Village of Moretown, and records the river stage at 15-minute intervals. A hydrograph of the annual peak streamflow values compiled by Field Geology Services is provided below in Figure 3.2.

The largest flood measured on the Mad River since the installation of the gauging station was in 1938. During this event, extensive damage occurred throughout the valley, including the destruction of a covered bridge spanning Old Route 100 at the current location of the Lareau Farm (Schenk personal communication, 2007). Prior to that, the 1927 flood, which caused massive damage across northern and central Vermont, had an estimated discharge of 23,000 cubic feet at the gauging station.

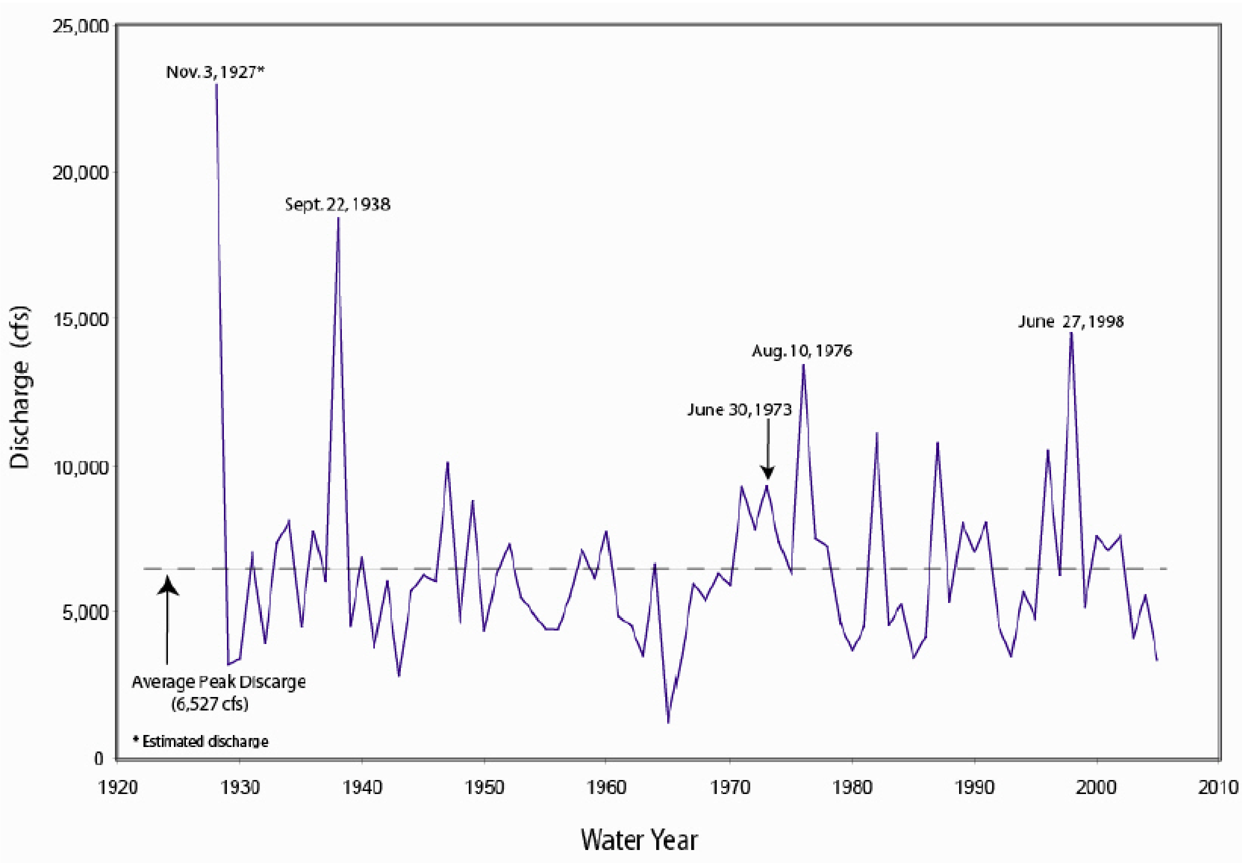

Figure 3.2 Annual Peak Discharges at USGS gauge from 1927 through 2005 (from Field, 2007)

In more recent times, two floods in the 1970's also caused extensive damage and led to increased channel management efforts (e.g., bank armoring and channel straightening) on the Mad River. The flood of 1973 caused extensive damage to infrastructure and agricultural lands in the lower watershed. Three years later, the 1976 flood was of greater magnitude than the 1973 event, but was not as destructive as a result of the channel management efforts following the 1973 flood that likely allowed higher discharges to be contained within the channel banks (Field, 2007). The most recent large flood event occurred in 1998, which was the second largest ever recorded at the gauging station. The structural damage caused by this event was concentrated in the headwaters areas around Warren, where numerous homes were destroyed by the flooding of the narrow valley through the Village.

3.5 Ecological Setting

An extensive natural heritage survey was recently conducted by Arrowwood Environmental in the Towns of Waitsfield and Fayston (Arrowwood, 2007). Although the study did not encompass headwaters area, the general findings are applicable to the entire Mad River watershed. Wetlands, wildlife habitats, and rare communities were all mapped as part of the survey. Within the survey area, nearly 1000 acres of wetlands were identified (versus 200 acres previously mapped through the National Wetlands Inventory), highlighting the importance and lack of accurate mapping of this landcover type in the basin. Two of the four large wetland complexes (wetlands with more than one community type) noted in the area are found along Shepard Brook and an unnamed tributary north of Pine Brook. No rare, threatened, or endangered species were noted in the survey area.

The study noted the high degree of fragmentation and disturbance of floodplain forests within the basin due mainly to historical clearing for agriculture. In addition, because of the recurring natural disturbance typical of these ecosystems (i.e., spring floods), they tend to be more susceptible to invasive species. Japanese knotweed (*Polygonum cuspidatum*) is particularly problematic along the banks and gravel bars of the Mad River, often colonizing new areas via propagules carried downstream during flood events. Two significant tracts of undisturbed floodplain forest were noted in the study area with mature forests and limited invasive species (Arrowwood, 2007), and these areas were recommended for further study as potential conservation sites. Due to the diverse ecological functions and recreation opportunities provided by floodplain forests, their value for conservation is generally very high.

The fishery of the Mad River watershed varies significantly along the channel network, depending on the channel gradient, bed substrate, streambank vegetation, and other factors. In the upper headwaters area above Warren Village, excellent habitat conditions support healthy wild brook trout (*Salvelinus fontinalis)* populations. Below Warren, where the channel gradient decreases and scour and depositional features are better formed, wild brook and rainbow trout (*Onchorynchus mykiss*) are present, as are brown trout (*Salmo trutta*) in lesser numbers. Below Waitsfield Village, all trout populations diminish in density, likely due to the degradation of physical habitat and elevated water temperatures. A fisheries summary of the watershed, including further information on non-trout species and other stocking and monitoring activities, is included in Appendix 4.

4.0 Methods and Data QA/QC

The Vermont River Management Program (RMP) has invested many person-years of effort into developing a state-of-the-art system of Stream Geomorphic Assessment (SGA) protocols. The SGA protocols are intended to be used by resource managers, community watershed groups, municipalities and others to identify how changes to land use affect hydro-geomorphic processes at the landscape and reach scale, and how these changes alter the physical structure and biotic habitat of streams in Vermont. The SGA protocols have become a key tool in the prioritization of restoration projects that will 1) reduce sediment and nutrient loading to downstream receiving waters such as Lake Champlain, 2) reduce the risk of property damage from flooding and erosion, and 3) enhance the quality of instream biotic habitat. The protocols are based on defensible scientific principles and have been tested widely in many watersheds throughout the state. Data collected for the Mad River watershed using the protocols forms the basis for the stressor identification and project prioritization carried out for the headwaters reaches.

The SGA protocols include three phases (VTDEC, 2006). Phase 1 assessments employ remote sensing techniques, along with limited field verification, to identify background conditions in the watershed. The Phase 1 approach results in watershed-scale data about the landscape (e.g., soils and land cover) and the stream channel (e.g., slope and form), providing a basis for understanding the natural and human-impacted conditions within the watershed. The Phase 2 approach builds upon Phase 1 data through the collection of reach-specific data about the current physical conditions. Characterization of reach conditions utilizes a suite of quantitative (e.g., channel geometry, pebble counts) and qualitative (e.g., pool-riffle habitat) measurements to calculate two indices: Rapid Geomorphic Assessment (RGA) Score; Rapid Habitat Assessment (RHA) score. Using the RGA scores in conjunction with knowledge about the background or "reference" conditions, a sensitivity rating is developed to describe the degree to which the channel will adjust to human impacts in the future. Phase 3 surveys involve the collection of detailed, reach-scale survey data for use in project development and monitoring.

Phase 1 data for the Mad River headwaters reaches were collected by Field Geology Services in 2006 and were summarized in a final report submitted to FMR (Field, 2007). During the 2007 field season, 18 headwaters reaches selected by FMR were assessed by the Project Team using the Phase 2 approach. A total of 22 segments were assessed, and data were entered into the Data Management System (DMS). All major human impacts and natural features noted during the Phase 2 surveys were indexed in a GIS using the Feature Indexing Tool (FIT; VTDEC, 2006). Reach summary statistics and DMS reach sheets are included in Appendix 2. Bed substrate histograms and cross-section plots are included in Appendices 5 and 6, respectively. Scanned field sketches with field notes are included in Appendix 7.

RMP staff shared responsibility with the Project Team for the Quality Assurance and Control (QA/QC) of the Phase 1 and 2 datasets. The DMS database for Phase 2 reaches was finalized in early January, 2008. A QA/QC summary is included in Appendix 3.

5.0 Results

The following section summarizes the results of the field observations and data analysis. Section 5.1 provides narratives of reach-scale conditions and adjustment processes. Section 5.2 includes the stressor identification analysis using mapping of the hydrologic and sediment regimes and channel boundary conditions as a basis for identifying reference stream conditions and human-caused departures.

5.1 Reach Summaries

Mad River Reaches

M20-A

M20-A is found from the confluence with Lincoln Brook (T12) at the Bobbin Mill up to a break in channel slope approximately 500 feet upstream of Warren Falls. This segment is 0.7 miles long and has an overall channel slope of approximately 2.0%. Most of the segment has B-type channel geometry with riffle-pool bedform (reference condition; Figure 5.1), however there are numerous grade controls throughout where very short sections of A-type geometry was noted. Much of the elevation loss is located at the upper end of the segment where numerous grade controls (ledges and waterfalls) are found. During the field survey, little additional information would have been gained through further segmentation in this area, and the features found in the upper segment are well described by the data and narrative in the DMS. There are numerous large depositional features above and below bedrock constrictions (Figure 5.2). These cobble and gravel features are likely associated with the 1998 event and are working their way through the segment, causing some widening and planform changes mid-segment.

Figure 5.1 B-type geometry in Segment M20-A

Figure 5.2 Large gravel bars in Segment M20-A

There is good floodplain connectivity in the alluvial areas of this segment where the entrenched valley setting (ratio = 1.5) confines the stream to a narrow floodplain. The bed substrate is dominated by cobble (46%) with a slight increase in fine sediments (14%). The channel is mostly stable (RGA condition “Good”, CEM stage I) with some evidence of widening and planform change following the 1998 flood. There is good habitat diversity due to the many bedrock features in the upper segment, and a sinuous planform in the alluvial areas where numerous pools, undercut banks, and stable riffles and runs were noted (RHA condition “good”). The LWD count for this reach was below the average for mainstem reaches (27 pieces/mile). This may be due to the high boundary resistance of much of the reach (bedrock) and limited recruitment since the 1998 flood.

M20-B

M20-B is located from a break in channel slope approximately 500 feet above Warren Falls upstream to a change in valley setting back to confined. This segment is 0.5 miles long and has an overall channel slope of approximately 1.3%. Upstream of Warren Falls the valley becomes wide and unconfined, and numerous large depositional features are found at the river bend 700 feet upslope of the waterfall (Figure 5.3). This segment has C-type channel geometry with plane bedform, representing a departure from reference bedform conditions for this reach. At the sharp channel bend in the lower segment severe channel widening and bank erosion is occurring in the vicinity of a large, mid-channel bar (Figure 5.4). This widening extends upstream on the right bank where the channel parallels Route 100. Upstream of this area, numerous diagonal bars were noted, indicating the continued aggradation of coarse material following the 1998 flood. The lack of grade control in this reach has allowed for the channel adjustments to migrate and affect the entire reach. In the upper segment there is a beaver pond located on a high terrace above the left bank. During the field survey in August 2007, the beginnings of a channel spanning beaver dam were noted near the upstream segment break, however given the stream power of the Mad River in this area long-term damming and ponding is not likely.


Figure 5.3 Vegetated gravel bar in M20-B


Figure 5.4 Severe bank erosion in Segment M20-B

Some channel incision was noted in the upper segment where the cross section was taken approximately 300 feet downstream of the segment break. Floodplain connectivity was fair in the middle and lower sections of the segment, however the bank erosion indicated that infrequent channel forming events below bankfull stage are contained well within the channel. Decreased floodplain access will continue until the channel aggrades enough coarse substrate to allow for these flow events to access a broad terrace along the left bank. The bed is dominated by cobble (55%), and the plot of substrate classes indicates the bed material is well distributed with only a minimal increase in fine sediments (6%).

The majority of the channel is moderately stable (RGA condition "Fair", CEM stage III), however there is significant aggradation and widening in the lower segment as noted above. There is good habitat diversity due to numerous pools and undercut banks (RHA condition "Good"); however bank instability may compromise habitat quality in the future with the increase of fine sediment inputs. The LWD count for this reach was slightly below the average for mainstem reaches (38 pieces/mile).

M20-C

M20-C is located from a change in valley setting up to the reach break with M21 at the confluence with Stetson Brook (T13). This segment is 0.6 miles long and has an overall channel slope of approximately 1.4%. At the downstream segment break the valley tightens and the channel is found in a narrow valley setting. Grade controls, which were absent in segment B, are once again common in this segment. This segment has B-type channel geometry with step-pool bedform, although much variability in bedform was noted throughout. The presence of numerous grade controls and channel constrictions has resulted in aggradation of coarse substrate upstream of these features (Figure 5.5). The large bars may have formed (or increased in size) following the 1998 event, since there is good evidence that Stetson Brook supplied a large amount of sediment to the mainstem channel. One area of corridor development is located in the lower bank on the right bank, however the bank vegetation is intact and the development (single house) did not appear to be negatively impacting the channel boundary conditions. A minor amount of armoring associated with the upstream Route 100 crossing does not extend downstream of the crossing and confluence with Stetson Brook.

Figure 5.5 Large gravel bar and debris in M20-C

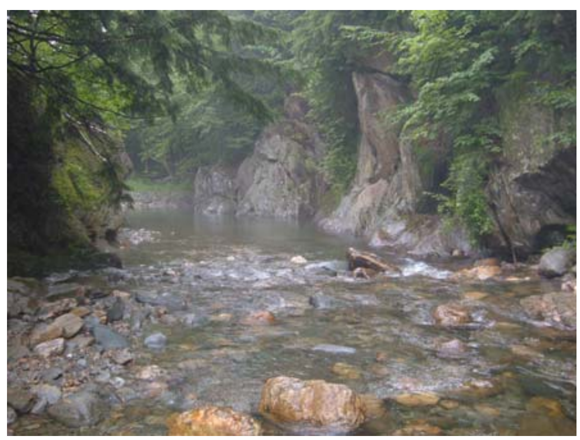

Figure 5.6 Bedrock constriction and pool in M20-C

Channel incision was noted where the cross-section was taken (incision ratio = 1.7). This incision resulted from a historic road adjacent the channel that raised the floodplain elevation above its natural location. Overall floodplain connectivity was good throughout the lower segment, and there was limited bank erosion. The bed is dominated by cobble (44%), and the plot of substrate classes indicates the bed material is very well distributed. The channel is moderately stable (RGA condition "Good", CEM stage II), but there are areas of significant aggradation and widening associated with the channel constrictions. Alternatively, the channel constrictions create excellent habitat where the bed material is scoured and deep, well-covered pools are found (Figure 5.6). There is very good habitat diversity due to abundant well-formed pools, limited embeddedness, and good diversity of velocity-depth patterns (RHA condition “Good”). The LWD count for this reach was below the average for mainstem reaches (23 pieces/mile). This may be due to the high boundary resistance of much of the reach (bedrock) and limited recruitment since the 1998 flood.

M21

M21 is located from the confluence with Stetson Brook (T13) at the Route 100 crossing up to the confluence with Mills Brook (T14). This reach is 0.5 miles long and has an overall channel slope of approximately 1.9%. At the downstream reach break the valley width increases and the channel is found in a broad valley setting. Route 100 parallels the channel and encroaches upon the corridor for nearly the entire reach, resulting in a reduced floodplain width and limited habitat features. Under reference conditions we would expect a C-type channel with riffle-pool or planebed features, however the floodplain encroachment has resulted in an entrenched channel (ratio = 1.3) with F-type channel geometry (Figure 5.7). Approximately half of the reach length contains hard bank armoring on the left bank adjacent Route 100, resulting in limited canopy cover and reduced recruitment of wood. One old bridge (crossing no longer in use) in the middle of the reach has abutments that are failing and being undermined by the channel, putting this structure at risk of collapse (Figure 5.8). In the upper reach there is a large island where the flow splits around a bedrock outcrop that constricts the channel. The high-flow channel on the left side adjacent Route 100 is accessed during moderate flow events below bankfull level.


Figure 5.7 Plane bedform with limited habitat in M21


Figure 5.8 Undermined bridge abutment in M21

Channel incision has been noted for M21, resulting from the road encroachment upon the channel that has raised the floodplain elevation well above its natural location (ratio = 3.0). Overall floodplain connectivity was poor throughout the segment. Bank erosion is limited due to the armoring along the left bank. The bed is dominated by cobble (50%), and the plot of substrate classes indicates the bed material is very well distributed. Despite the stream type departure, the channel is mostly stable in a state of quasi-equilibrium (CEM stage II). The habitat diversity is limited due to the homogenous bed features, lack of undercut banks and limited canopy cover (RHA condition “Fair”). The LWD count for this reach was the lowest of any of the mainstem reaches (12 pieces/mile). This is mainly due to the high boundary resistance of much of the reach (armoring) resulting in limited recruitment potential.

M22

M22 begins at the confluence with Mills Brook (T14) and extends upslope to the confluence with Austin Brook (T15). This reach is 0.9 miles long and has an overall channel slope of approximately 2.1%. M21 is found in a narrow valley setting with a small but well-defined floodplain. Route 100 parallels the channel and encroaches upon the corridor for approximately 15% of the reach. In these areas, hard bank armoring is present and the floodplain area is reduced considerably. The reach had C-type channel dimensions and a riffle-pool bedform (Figure 5.9). A high degree of bank erosion was observed around the Route 100 crossing midway up the reach. Armoring was present around the structure, but the bank erosion extended approximately 100 feet below the crossing on the right bank (Figure 5.10). Minor aggradation and widening were noted near the cross-section location (width to depth ratio = 26). Grade controls are present in the lower and upper sections of the reach, and may be limiting the migration of channel adjustments observed in the middle section. Upstream of a 90-degree bend in the upper reach, two large grade controls were noted before the channel slope lessens near the confluence with Austin Brook. Approaching the confluence, the right bank is influenced by the rest area where woody vegetation has been removed (minor impact).

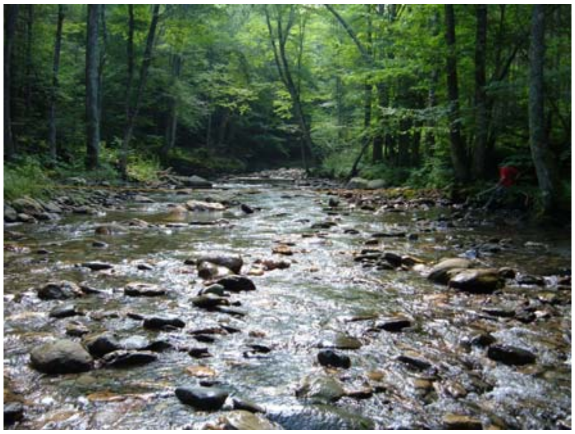
Figure 5.9 Channel cross-section in M22


Figure 5.10 Bank erosion below Route 100 in M22

Moderate channel incision (ratio = 1.6) was noted in the reach at the cross-section below the Route 100 crossing, however the floodplain was well-connected in most of the reach. Bank erosion was severe below the road crossing (as noted above), but limited throughout. The road encroachment does not appear to have a strong influence on the channel stability at present (RGA = good; CEM = III). The bed is dominated by cobble (56%), and the plot of substrate classes indicates a slight increase in sand substrate (7%). The habitat diversity is good as a result of heterogeneous bed features, a diversity of velocity and depth patterns and good canopy cover (RHA condition “Good”). The LWD count for this reach was moderate (47 pieces/mile), however there is high potential for recruitment given the healthy riparian buffer and limited bank armoring.

M23-A

M23-A begins at the confluence with Austin Brook (T15) and extends upslope to a change in slope and valley confinement at the break with segment B. This segment is 0.8 miles long and has an overall channel slope of approximately 1.0%. The segment is found in a very broad valley setting, and under reference conditions we would expect to find a C-type channel with riffle-pool bedform. However due to the straightening along Route 100 and encroachment upon the corridor (72% of reach length), a majority of this reach exhibits planebed morphology with limited habitat diversity (Figure 5.11). In these areas, hard bank armoring is present and the floodplain area is reduced considerably. Much of the armoring was intact, however one area of failing riprap was noted (Figure 5.12) downstream of the confluence with a small tributary entering from the north.

Figure 5.11 Planebed morphology in M23-A

Figure 5.12 Failing rip-rap along Route 100 in M23-A

Although no channel incision (due to bed lowering) was noted at the cross-section mid-reach, the floodplain has been elevated on the left bank due to the road encroachment. Accounting for this impact, a high degree channel incision (ratio = 2.4) was noted where the floodplain area has been significantly reduced. The road encroachment and resulting decrease in floodplain area is the greatest stressor on geomorphic stability in this segment, resulting in a reduced score for degradation and an overall assessment of fair (CEM stage II). The bed is dominated by coarse gravel (44%) with the other classes well-distributed around the mean. The physical habitat is highly impacted (RHA condition “Fair”) by the simplified channel planform, with limited pool development and a low availability of LWD (36 pieces/mile).

M23-B

M23-B is a short, high-gradient segment that begins at a break in slope at the segment division with M23-A and extends up to another break in slope approximately 400 feet upstream of the confluence with a small tributary entering from the north. This segment is 0.3 miles long and has an overall channel slope of approximately 3.4%. The channel is found in a semi-confined valley, which is the natural setting expected under reference conditions. However in some areas where the road has encroached upon the channel the valley width has been artificially narrowed by fill and bank armoring. B-type channel morphology with step-pool bedform was observed (Figure 5.13), and one large grade control (waterfall) was noted in the middle of the reach. There are four stormwater inputs that convey runoff to the channel collected from road ditches along the south side of Route 100. The abundant natural and artificial armoring (rip-rap common on left bank) provides resistance to channel incision from these impacts, however a large amount of fine and coarse deposition was observed below 2 of the outfalls (Figure 5.14). Immediately below the outfalls increased embededdness and habitat degradation was noted.

Figure 5.13 Step-pool morphology in M23-B

Figure 5.14 Stormwater-conveyed sediments in M23-B

Due to the high boundary resistance in this segment, limited vertical adjustments were noted. The road encroachment and associated stormwater impacts are the greatest stressors to geomorphic stability, however the overall channel conditions was stable (RGA condition “Good”; CEM stage I). The bed is dominated by boulder (24%) and cobble (32%) substrate, with an increase in coarse gravel (36%) that may be attributable to the stormwater inputs along the left bank. The overall physical habitat conditions were good, with many high-quality pools with good vegetation cover observed throughout. This segment had a very high density of LWD (133 pieces/mile), as well as a high recruitment potential despite the armoring on the left bank.

M23-C

M23-C is found from a break in valley slope at the division with segment B up to parking lot pull-off on the west side of Route 100. Upstream of this point, the channel is interrupted by a series of beaver dams along Route 100. The Phase 2 assessment for the mainstem ended at the parking lot where the channel dimensions were altered by historical beaver activity. This segment is 1.6 miles long and has an overall channel slope of approximately 1.0%. The channel is found in a very broad valley setting, and under reference conditions we would expect to find a channel dominated by C-type morphology and riffle-pool bedform. However, as in segment A, straightening along Route 100 and encroachment upon the corridor (95% of reach length) has resulted in a simplified channel with planebed morphology and limited habitat diversity (Figure 5.15). Where the channel has not been impacted by the road, riffle pool morphology was observed (Figure 5.16), however this bedform type was observed for less than 10% of the overall channel length.

One short section of entrenched channel was observed in the lower part of segment C where road fill has significantly reduced the floodplain area. The channel geometry of this section was indicative of F-type classification, however its short length and borderline entrenchment ratio (1.4) did not warrant segmentation. The overall impacts of channel straightening and road encroachment are pervasive throughout, and have been considered in the scoring of the segment. One area of braiding associated with a beaver dam was noted below the Route 100 crossing. Large volumes of sediment are being supplied to this area from a small tributary (M23-S2.01) entering the mainstem from the northeast. This tributary originates along Prickly Mountain Road and travels to the southwest, crossing Plunkton Road before descending through a large waterfall to the northeast of Route 100. Much of this gravel sediment appears to be originating from erosion along the fore mentioned roads, and this stressor is described in further detail in sections 5.2 and 7.2.

Figure 5.15 Plane bedform in lower M23-C

Figure 5.16 Riffle pool morphology in M23-C

No channel incision was noted at the cross-section mid-reach, but there were significant impacts to this reach from floodplain elevation associated with the adjacent road (see M23-A description for similar setting). In accounting for this impact some channel degradation was noted where the floodplain area has been significantly reduced. As in segment A, road encroachment and a decrease in floodplain area is the greatest stressor on geomorphic stability in this segment. The geomorphic stability was assessed as fair, with some areas of severe aggradation and widening indicating the latter stages of channel adjustment processes (CEM stage III). The bed is dominated by coarse gravel (33%) with the other classes well-distributed around the mean. The physical habitat is impacted by the channel straightening and simplified channel planform (RHA condition "Fair"), with poor pool development and a very low LWD density (17 pieces/mile).

Lincoln Brook Reaches

T12.01

T12.01 is found from the confluence with the mainstem at the Bobbin Mill up to the first stream crossing at Lincoln Brook Road. This reach is 0.9 miles long and has an overall channel slope of 3.9%. The majority of the reach exhibits C-type channel geometry with plane bedform (reference condition; Figure 5.17). Much of the elevation loss is located at the lower end of the reach where numerous grade controls (ledges and waterfalls) are found. Here, A or B-type channel geometry was observed through short sections in a confined setting. However, little additional information would have been gained through the segmentation of the reach, and the features found in those areas are well described by the data and narrative in the DMS. One large mass failure that was enlarged during the 1998 flood (Shayne Jaquith, 2007) has become partially revegetated since the event (Figure 5.18). A small area of development has encroached on the stream corridor in the upper reach on the right bank downstream of the road crossing, but has not affected the immediate buffer vegetation.

There is good floodplain connectivity in the alluvial areas of the upper reach (no incision) where the moderate entrenchment (entrenchment ratio = 2.7) confines the stream to a narrow floodplain. The substrate data show that the bed is dominated by cobble substrate (40%) with a slight increase in fine sediments (14%). The channel is largely stable (RGA condition “Good”, CEM stage I) with some evidence of minor adjustments following the 1998 flood. There is good habitat diversity due to the many bedrock features in the lower reach and a sinuous planform in the upper reach with heterogeneous features in the form of pools, undercut banks, and stable riffles and runs (RHA condition “Good”). However, the LWD count for this reach was below average for the tributary reaches (31 pieces/mile), perhaps due to the high transport capacity of the channel and reduced recruitment following the 1998 flood.

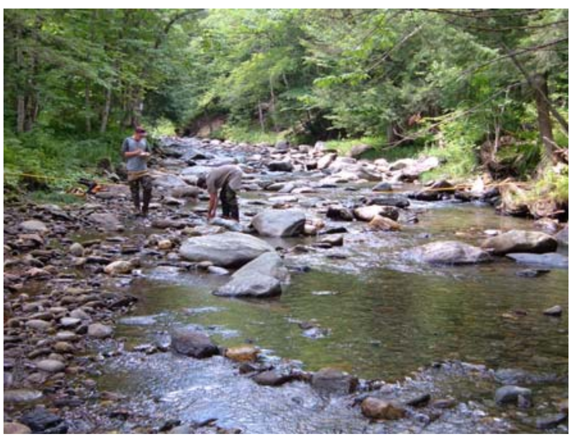

Figure 5.17 Cross section in upper T12.01

Figure 5.18 Large mass failure mid-reachT12.01

T12.02.A

Segment A of reach T12.02 begins at the channel intersection with Lincoln Brook Road and extends 0.8 miles upstream to the segment break near Thayer Road. The slope of this segment is 3.0%. This reach was segmented because the valley is narrower in segment A, than in segment B. The valley width is approximately 120 feet and 300 feet for segments A and B, respectively. The majority of the segment exhibited B-type channel geometry with riffle-pool bedform, and the bed is composed largely of cobble substrate. The upslope end of this segment has many mass failures, some exceeding 50 ft. high and 70 feet wide (Figure 5.19). These mass failures were observed in succession at the outside edges of several meanders. Failures in this segment act to supply large amounts of sediment. Angular, freshly exposed rocks are found throughout the channel downstream of these features and large depositional features were noted at the downstream end of the segment. No other development or buffer encroachment was noted except at the downstream end of this segment.

Channel geometry in this segment is indicative of a B-type channel. The width to depth ratio (W/D = 19.3) and moderate sinuosity supports this classification. There was some incision observed on tributaries to Lincoln Brook, but little on the main channel. The floodplain is accessible throughout the lower portion of the segment. Aggradation of sediments and planform changes were the main adjustment processes for this segment (RGA condition “Good”). Widening was also observed, placing the channel in stage III of the channel evolution process. The habitat conditions are consistent throughout the reach, yet several pools have sedimentation (RHA condition “Good”). Large woody debris counted in the segment was lower than expected (26 pieces/ mile).

Figure 5.19 Large mass failure in T12.02-A

T12.02.B

Segment B of reach T12.02 begins just upslope of the confluence with tributary T12.02.S1, near Thayer Road. The segment ends 1.2 miles upstream at the confluence with two tributaries near Lincoln Gap Road. Segment B has a lower slope of about 2.0%, and is set in a wider alluvial valley. Some stretches of this segment have a plane bedform, yet the majority of the channel is riffle-pool. The segment exhibited C-type channel geometry and the substrate is largely cobble (43%). A large channel avulsion was observed about halfway up the segment; a feature that was likely formed from high flows during the 1998 flood. Debris and sediment piled up at a catch point, and the channel migrated to its current location on the right side of the channel (Figure 5.20). Freshly exposed roots and rocks were noted on the right bank, indicating that this adjustment process is still active.

A slight degree of incision was observed throughout the segment (incision = 1.37), along with very low entrenchment (entrenchment = 7.3). The broad span of the valley (valley width = 300 feet) at the location of the cross-section yielded the low entrenchment value. However, this low entrenchment was not consistent in the whole segment, as other areas appeared to be slightly entrenched. The width to depth ratio (W/D = 23.5) was fairly high for a riffle-pool bedform, indicating moderate widening processes. Debris jams and fallen trees acted as catch points for sediment (Figure 5.21), resulting in additional widening and aggradation of fine sediment. The channel seemed to be migrating laterally to find a new equilibrium after the 1998 flood and is fairly active (RGA condition “Fair”; CEM = IV). The debris jams and larger rocks that were common in this segment provided a wide variety of habitat for a stream biota. The lack of deep pools caused by sedimentation reduced the overall score (RHA condition "Good"). The actively managed hay field on the left bank of the upstream end of this segment may be an area of concern, resulting in a buffer width is less than 25 feet in some places. This area has been highlighted in the project identification table (Table 6.2).

Figure 5.20 Location of 1998 channel avulsion

Figure 5.21 Large debris jam in lower T12.02-B

T12.03.A

This segment begins at the reach break by Lincoln Gap Road and travels upstream ending about 400 feet downstream of the first incoming tributary. The segment is approximately 0.4 miles long and has a slope of about 2.6%. The majority of the reach exhibits C_b-type channel geometry with plane bedform (Figure 5.22). Extending up through an active sugarbush the segment has many noticeable human impacts. Several stream crossings and access roads (for logging and sugaring) have acted as conduits for shallow concentrated flow during runoff events (Figure 5.23). Eyewitness accounts of the 1998 flood recall channel avulsions in the lower part of the reach; the avulsions have since been remediated to allow for access to the woodlot. In the downstream area of the reach at the McCuin property, sediment deposition on a sharp bend and an undersized culvert caused one avulsion during the flood. A new culvert was installed after the flood damaged the smaller culvert on the driveway that crosses the stream. Berming on the right and left banks of the channel upstream of the new culvert currently extends about 100 feet upstream to prevent future avulsions.

Figure 5.22 Plane bed morphology in T12.03-A

Figure 5.23 Old logging road along T12.03-A

The high flows during the 1998 flood have slightly incised areas of the channel that are not underlain with bedrock (incision ratio = 1.36). Some incised areas have lost access to their floodplain, leaving the raw banks as a source of sediment. This segment has a normal distribution of channel substrates, but it is predominately composed of cobble (32%). The width-to-depth and entrenchment ratios are 10.4 and 6.1, respectively. The slope and substrate size combined are responsible for the subclass C_b classification for this segment. Incision and changes in planform, where the channel migrated into adjacent logging roads during the 1998 event, have made the segment very dynamic (RGA condition “Fair”; CEM = II). The segment’s lack of epifaunal substrate, limited hydraulic diversity and geomorphic instability decreased its habitat score (RHA condition “Fair”).

T12.03.B

Figure 5.24 Bedrock grade controls in T12.03-B

Segment T12.03.B is one of the headwater segments for Lincoln Brook. It begins where the confinement changes from broad to narrow about 400 feet downstream of the first tributary and extends upslope for approximately 1.4 miles. The segment is much steeper than segment A, with cobble-sized sediment accruing in areas where the slope lessens. Given the slope and bed features this segment shows characteristics of an A-type channel with step-pool bedform. The segment had several bedrock ledges and cascades that restricted any vertical change in the channel (Figure 5.24). Not far upstream of the segment break is a large gully that formed on the right bank (Figure 5.25). The alluvial material that has moved from this 15-foot gully is a large source of sediment aggradation further downstream. The headwaters of this segment have largely not been impacted by human activities besides some areas of historic logging along riparian corridor, with minimal affects. The substrate is predominately cobble (35%), but bedrock features are also frequent (27%). The entrenchment of the channel (Entrenchment = 1.4) suggests A-type characteristics, and the segment is not incised (Incision = 1). Despite a few active features (e.g., gully), this segment is very stable (RGA condition “Reference”).

Figure 5.25 Large gully entering right bank in upper T12.03-B

Considering the bedrock grade controls there is little opportunity for vertical movement through incision or lateral planform change (CEM stage = I). The pools at the lower end of the bedrock cascades provide prime habitat for fish and other organisms (RHA condition "Reference"). Many brook trout were observed in excellent habitat in middle part of segment where pools are abundant.

T12.02.S1

Tributary T12.02.S1 begins at the confluence with the mainstem of Lincoln Brook reach by Thayer Road. The reach extends precipitously 0.5 miles upstream off the right bank of the channel into a dense forest grove (slope = 13.7%). The majority of the reach exhibits A-type channel geometry with cascade bedform (reference condition; Figure 5.26). Exposed bedrock substrate is the predominate substrate found in this reach. However, colluvium has accumulated in areas where the slope lessens, mostly towards the confluence with the mainstem. Several old skidder paths cross the reach and a log crossing acting as a channel constriction was observed in the lower reach. Some bank erosion was found where high flows stripped the banks down to the bedrock in the lower reach.

Figure 5.26 Headwaters bedrock cascade

This reach acts a conduit for the transport of sediment and debris down into Lincoln Brook. The high entrenchment of the reach (entrenchment = 1.3) is characteristic of the A-type channels, as is the low width to depth ratio (W/D = 11.8). Throughout the reach the channel has limited floodplain development; most high flows will be contained within the bedrock banks. The upper portion of this reach has less of a canopy in a hardwood grove that was recently logged. This reach is currently very stable, and future channel adjustments are unlikely because of the bedrock substrate (RGA condition "Reference"; CEM stage = I). Good habitat is abundant in this reach (RGA condition "Reference"). Many debris jams provide epifaunal cover, and very low embeddedness was observed. However, the high slope of the reach including a ~20 foot cascade on the downstream end may render the channel impassable for spawning fish.

T12.02.S2

T12.02.S2 branches from the left bank of the mainstem, crosses under Lincoln Gap Road and follows Camp Road upstream. The reach is 1.2 miles long and has an overall channel slope of 6.1%. This tributary has G-type channel characteristics with step-pool bedform (Figure 5.27). Substrate found in this reach is a mixture of cobble (36%) and coarse gravel (16%), with a significant increase in sand (27%). There is a perched culvert at Lincoln Gap Road that constricts the channel, catching sediment above and creating a pool below. Several areas of bank erosion were observed upstream of the Lincoln Gap Road crossing along Camp Road, yet the roadway doesn't appear to have a significant impact on channel.

Figure 5.27 Step-pool morphology in T12.02-S2

Figure 5.28 Channel incision in upper T12.02-S2

Under reference conditions this reach would have B-type channel geometry with a confinement ratio ranging between 3 and 5. However, it was characterized as a G-type channel because of downcutting and some areas of incision (Figure 5.28), which have led to a lower width-to-depth ratio (W/D = 7.2) and semi-stable bed. Above the road crossing (where cross-sections were taken), the reach has some floodplain development resulting in an entrenchment ratio atypical of this steep setting (entrenchment = 3.9). Areas of active channel incision (CEM = II) are now resulting in channel widening and aggradation of fine sediments. Bank erosion is the dominant input of fine sand, which has affected the habitat quality (RHA condition "Fair"). Limited numbers of fish were observed above and below the perched culvert under Lincoln Gap Rd.

T12.02.S3

T12.02.S3 begins where the reach intersects the mainstem near Lincoln Gap Road and extends upgradient for 1.9 miles. The reach has an average slope of over 10% and ends in the Breadloaf Wilderness Area. The majority of the channel is set in a dense forest of coniferous and deciduous trees with some evidence of historical and recent logging. Geometry resembles an A-type channel with cascade bedform (Figure 5.29). Bed substrate is predominately bedrock (56%) with some areas of cobble (21%) towards the lower and upper ends of the reach. Bedrock outcrops and grade controls were found throughout the reach but were most densely concentrated in the middle of the reach. This area is also where the majority of the slope change occurred. A 20-foot waterfall is located about 0.5 miles upstream of the reach break (Figure 5.30). This grade control is set in a bedrock gorge and has deposition of fine sediment both up and downstream.

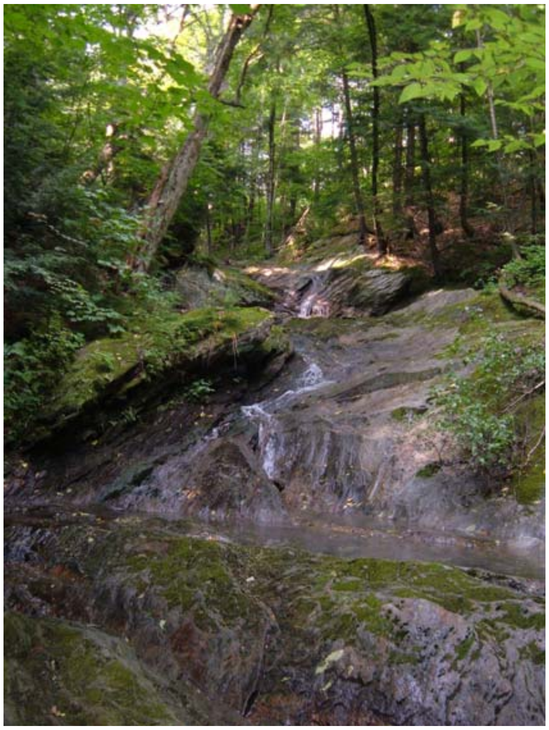
Figure 5.29 Headwaters cascade bedform

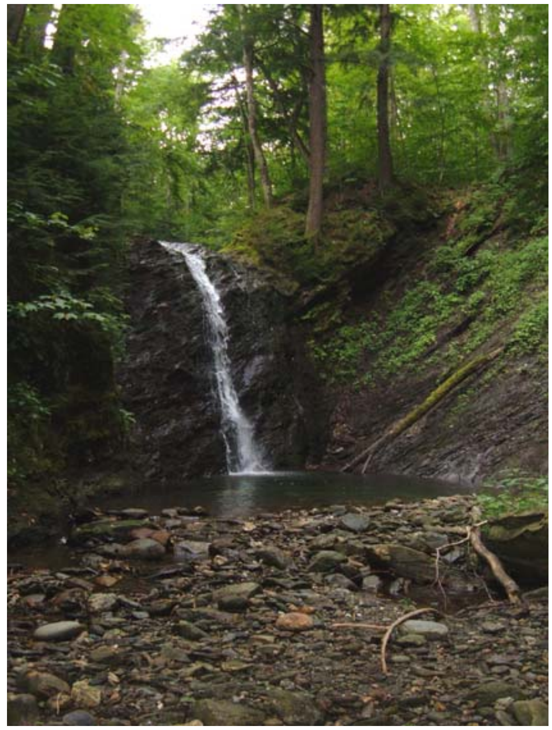
Figure 5.30 Large waterfall in T12.02.S3

The reach is narrowly confined and the underlying bedrock prevented any incision where the slope was steeper (incision = 1). The channel is moderately entrenched (ratio = 1.8) and has low width-to-depth ratio (W/D = 10.98). Upstream in the Breadloaf Wilderness Area, a small section of the reach changed to a more alluvial setting, having a wider valley and deposition of cobble and gravel sized sediment. However, limited discharge (due to small upstream drainage area) and protection from vertical movement from the bedrock below made it unnecessary to further segment this reach. Bedrock ledges and cascades give this reach a tremendous amount of vertical and lateral stability (RGA condition “Reference”; CEM = I). Few areas of aggradation of sediment were found where the channel was constricted or the slope changed. Many fish were observed through the majority of the reach and excellent habitat was readily available (RHA condition “Reference”).

T12.02.S4

Reach T12.02.S4 intersects the mainstem, crosses under Lincoln Gap Road, and extends 0.55 miles upstream along Hanks Road. This tributary parallels a semi-developed mountain road and has an average slope of over 15%. The majority of this reach demonstrates A-type channel characteristics with step-pool bedform (Figure 5.31). Some variability of bed substrate was noted throughout, although bedrock (25%) and cobble (21%) are most abundant. About midway up the reach the footers of an old logging bridge remain. This channel constriction is one of many, which has led to a large amount of aggradation immediately upstream of the structure. Upstream of the houses, the channel widens significantly and becomes braided in a short depositional section (<200 feet) with a lower slope. Encroachment is prevalent in several areas on the left bank where Hanks Road and houses occupy the corridor. Some bank erosion is found on the left bank the reach where the channel has cut into the road berm. Segments of the road berm have been armored (left bank) to prevent further lateral migration.

Figure 5.31 Step-pool morphology in T12.02-S4

Figure 5.32 Channel widening above Lincoln Gap Rd.

The encroachment of the road on the lower half of this reach has reduced the floodplain width in some areas (entrenchment ratio = 1.4), and the width-to-depth ratio is higher than normal for an A-type channel due to minor channel widening (W/D = 14.6). Bedrock channel constrictions have prevented any incision in this reach (incision = 1). The Lincoln Gap Road culvert at the bottom of the reach acts as a major site for deposition of sediment. Upstream, a large amount of cobble-sized material has been deposited causing localized widening (Figure 5.32). The lower reach is much more susceptible to geomorphic adjustments and was the main source of instability for the reach (RGA condition “Fair”; CEM = III). Fish migration up the channel may be limited at low flows because the Lincoln Gap Road culvert is perched. The overall habitat quality of the reach is in jeopardy because the reach has a high degree of embeddedness throughout (RHA condition “Good”) resulting from road runoff from Hanks Road.

Stetson Brook Reaches

T13.01

Reach T13.01 of Stetson Brook begins at the confluence with the Mad River, just north of where Stetson Hollow Road meets Route 100. The reach extends up along Stetson Hollow Road for a total reach length of 0.4 miles. The slope of the channel was 4.2% with geometry resembling a B Step-Pool type system (Figure 5.33). Bed substrate was dominated by cobbles (34%) with some increase in sand (11%). Toward the downstream end of the reach, the left bank is composed of bedrock, with some visible in the channel bed. Bedrock was not observed on the right bank in this area, so it is unknown whether this bedrock provides grade control. Another area of bedrock does provide grade control further upstream in the reach. The right bank at the downstream end of the reach was heavily riprapped and bermed to create the roadbed for Route 100 (Figure 5.34). It is possible that Stetson Brook joined the Mad River further upstream before the construction of Route 100, and was moved to its current location to eliminate a road crossing for the brook.

Channel incision from older upper terraces appeared historical, with a lower terrace developed in relation to the channel (Incision ratio = 1.65, entrenchment = 2.3) providing floodplain area. At the downstream end of the reach, the bedrock left bank and Route 100 confine the channel, but the length was too short to be valuable as a segment and was captured in the DMS notes. Current channel adjustment processes appeared to be widening with some sediment buildup in pools (CEM stage III, RGA condition "Fair"). It is possible that the 1998 flood contributed significantly to the widening observed. Route 100 and Stetson Hollow Road as well as one area of development had affected right bank buffer. Few pools and low woody debris count (30 pieces/mile) counteracted the high riffle/step frequency and vegetated buffers resulting in "Fair" habitat condition. This reach appeared to have a high transport capacity due to its slope and low sinuosity, evidenced by low woody debris counts and relatively low sediment deposition as compared to upstream reaches of Stetson Brook.

Figure 5.33 Cross section in T13.01.

Figure 5.34 Downstream section along Route 100.

T13.02

Reach T3.02 runs along Stetson Hollow Road, crossing from side to side through 3 bridges. Reach length is slightly over 1 mile with a 4.7% slope to the channel. The steep slope combined with a Narrowly Confined valley setting (Entrenchment = 1.3) signals a Ba Step-Pool type stream (with "a" subscript due to steep slope). Multiple mass failures add significant sediment to the reach and, coupled with sediment inputs from upstream, have led to extreme aggradation in the reach (Figure 5.35). Degradation and channel widening appeared historical with bedrock grade controls frequent along the reach, limiting further channel incision (Figure 5.36). Given the vertical constraints and extreme aggradation however, additional widening is possible. Bank erosion was fairly low except for some areas where mass failures had occurred. Some flood chutes and minor planform adjustments were present, although the confinement and large boulders have likely moderated planform adjustment. Three bridges for Stetson Hollow Road constricted the bankfull width, with minor deposition and scour observed. A portion of Stetson Hollow Road had washed out downstream of the third bridge, isolating an old cabin.

Floodplain area was small, due to valley confinement (Entrenchment = 1.3) and some channel incision (ratio = 1.2) was measured. Current channel adjustments appeared to be extreme aggradation (CEM stage III, RGA condition "Fair") largely in the form of coarse sediment, likely mobilized in the 1998 flood. Pools were filling with fine and coarse sediments and multiple bar features were noted. Habitat condition appeared “Good” with mixed substrate and velocity types and vegetated buffers. Habitat was affected by sediment deposition and the large bar features. 104 pieces per mile of LWD also created good habitat.


Figure 5.35 Large bar and failed road in T13.02.


Figure 5.36 T13.02 cross section with boulders, pool.

T13.03

Reach T13.03 began upstream of the old red cabin and extended into the Breadloaf Wilderness area. Channel length was 0.9 miles with a slope of 5%. This reach was slightly less confined (Narrow) than T13.02, and had taken the form of a Ba-Type channel (with “a” subscript due to steep slope). Bed substrate was dominated by cobbles, creating Step-Pool bed features. The reach had access to floodplain, but had signs of old incision with 3 terrace levels visible in some areas (Entrenchment = 2.5, Incision = 1.6). The channel appeared to have new bankfull benches, although they were fairly small. Multiple mass failures were present, some appeared old and were revegetated, and some were new with bare soil exposed (Figure 5.37).

Extreme aggradation and planform were the dominant adjustment processes (CEM stage III, RGA condition “Fair”). The channel appeared overwidened but it was difficult to determine if this adjustment was historical or if there was potential for future widening, especially given the high sediment deposition. Bar features were abundant throughout the reach, especially where debris jams or boulders acted as sediment catches. Sediment also built up at sharp meander bends, leading to channel avulsions and active flood chutes. An amazing 232 pieces of large woody debris were counted in the nearly one-mile reach, many from mass failure sites. Well-vegetated buffers provided shade, habitat and a source for the LWD. Bed substrate was largely cobble (41%) with an increase in sand and fine gravel (23%) leading to fairly embedded cobbles, which affected habitat scores. Habitat was also affected by the extreme sediment deposition but had an overall RHA condition of “Good”.

Figure 5.37 Large mass failure with exposed soil

T13.04

Reach T13.04 is the uppermost reach of Stetson Brook located in the Breadloaf Wilderness area. The reach was 0.7 miles long, with an overall slope of 5.5%. The valley had a broad confinement ratio with several levels of old terraces. The channel had floodplain areas alternating from side to side with the valley walls in between. Overall, the channel appeared to be a Ba Step-Pool stream type (with a slope subclass of “a” due to steep slope; Figure 5.38). A few areas lacked floodplain and were confined by the valley walls. Signs of old channels and flood chutes were visible on the terraces as well as old sediment deposits. Channel degradation appeared historical with no recent incision (incision ratio = 1.16). Multiple mass failures were present, adding sediment and woody debris to the system. Many debris jams and channel spanning logs trapped sediment. As much as 1-3 feet of sediment could be trapped behind fallen logs in areas.

Figure 5.38 T13.04 cross-section area.

Figure 5.39 Avulsion and sediment deposition.

Aggradation was the dominant adjustment process (CEM stage III, RGA condition "Fair") with some planform adjustment as well (Figure 5.39). Some active widening was observed in areas where the valley walls pinched close to the channel. Recent channel avulsions were observed, but could be related to the 1998 flood and sediment buildup from mass failures. Habitat condition was "Good," having mixed substrate types and reference buffer conditions. Habitat was affected by sediment deposition causing some embeddedness and filling of pools.

T13.2-S1.01

Reach T13.2-S1.01, an unnamed tributary to Stetson Brook, began just downstream of the third bridge on Stetson Hollow Road. The reach began with a series of waterfalls having about a 90-foot drop. The reach was 0.9 miles long, with an average slope of 12%, although much of this slope was over ledges and falls. The stream type appeared to be a Ba Step-Pool with cobble substrate. A few headcuts and avulsions were present, however these were likely flood-related due to the reference setting and bedrock controls of the channel. Sediment deposited upstream of boulders and logs as well as along the channel in bar features (Figure 5.40). The area appeared to have been logged in the past, with an old road present, but had revegetated and did not appear recently disturbed.

Minor aggradation and planform adjustments appeared to be dominant but flood-related and overall the reach appeared to be in "Good" condition (D-Type CEM stage IIc, RGA condition "Good"; Figure 5.41). Some minor localized widening was also observed. Only 2 mass failures and a few areas of erosion were noted. The sediment in the channel was therefore likely flood-related and moving slowly through the system. Habitat was "Good" and only affected by sediment deposition and some filling of pools. High woody debris count (76 pieces per mile), vegetated buffers and no channel alteration contributed to the good habitat.


Figures 5.40 and 5.41, Sediment trapped by a debris jam (left) and cross section view (right).

5.2 Departure Analysis

5.2.1 Hydrologic Regime Stressors

The following description of the hydrologic regime of a watershed, and the general response to watershed-scale land use changes and stressors is included from the most recent version of the VTANR River Corridor Planning Guide (VTANR, 2007).

> The hydrologic regime may be defined as the timing, volume, and duration of flow events throughout the year and over time. The hydrologic regime may be influenced by climate, soils, geology, groundwater, watershed land cover, connectivity of the stream, riparian, and floodplain network, and valley and stream morphology. The hydrologic regime, as addressed in this section, is characterized by the input and manipulation of water at the watershed scale and should not be confused with channel and floodplain "hydraulics," which describes how the energy of flowing water affects reach-scale physical forms and is affected by reach-scale physical modifications (e.g., bridges modify channel and floodplain hydraulics).
>
> When the hydrologic regime has been significantly changed, stream channels will respond by undergoing a series of channel adjustments. Where hydrologic modifications are persistent, the impacted stream will adjust morphologically (e.g., enlarging when stormwater peaks are consistently higher) and often result in significant changes in sediment loading and channel adjustments in downstream reaches.

The land cover within Mad River watershed is dominated by natural vegetation following the recovery of forest cover in the late 1900's. Currently, approximately 90 percent of the headwaters watershed from Warren up to Granville Notch is covered by a mixture of deciduous and coniferous forest (Table 5.1). A very small amount of agricultural land is still found in the watershed, mostly along Lincoln Gap Road in the Lincoln Brook watershed.

Table 5.1 Mad River Headwaters Watershed Land Cover†

Land Cover Type	Percent Cover
Forested	89.1%
Agriculture	3.4%
Barren Land	0.1%
Water & Wetland	4.4%
Residential	1.5%
Transportation	1.5%

† UVM Spatial Analysis Data (SAL, 2005)

The current day stressors to the hydrologic regime have been mapped using the variables extracted from the Phase 2 field assessments (indexed using FIT), watershed-scale loss of wetlands, and the road density at the subwatershed scale (Figure 5.42). An analysis of the percent impervious cover of the Mad River watershed was completed using methods specific to Vermont from Fitzgerald (2007). Percent impervious cover and road density

Mad River Headwaters Phase 2 Analysis
Hydrologic Alterations Map

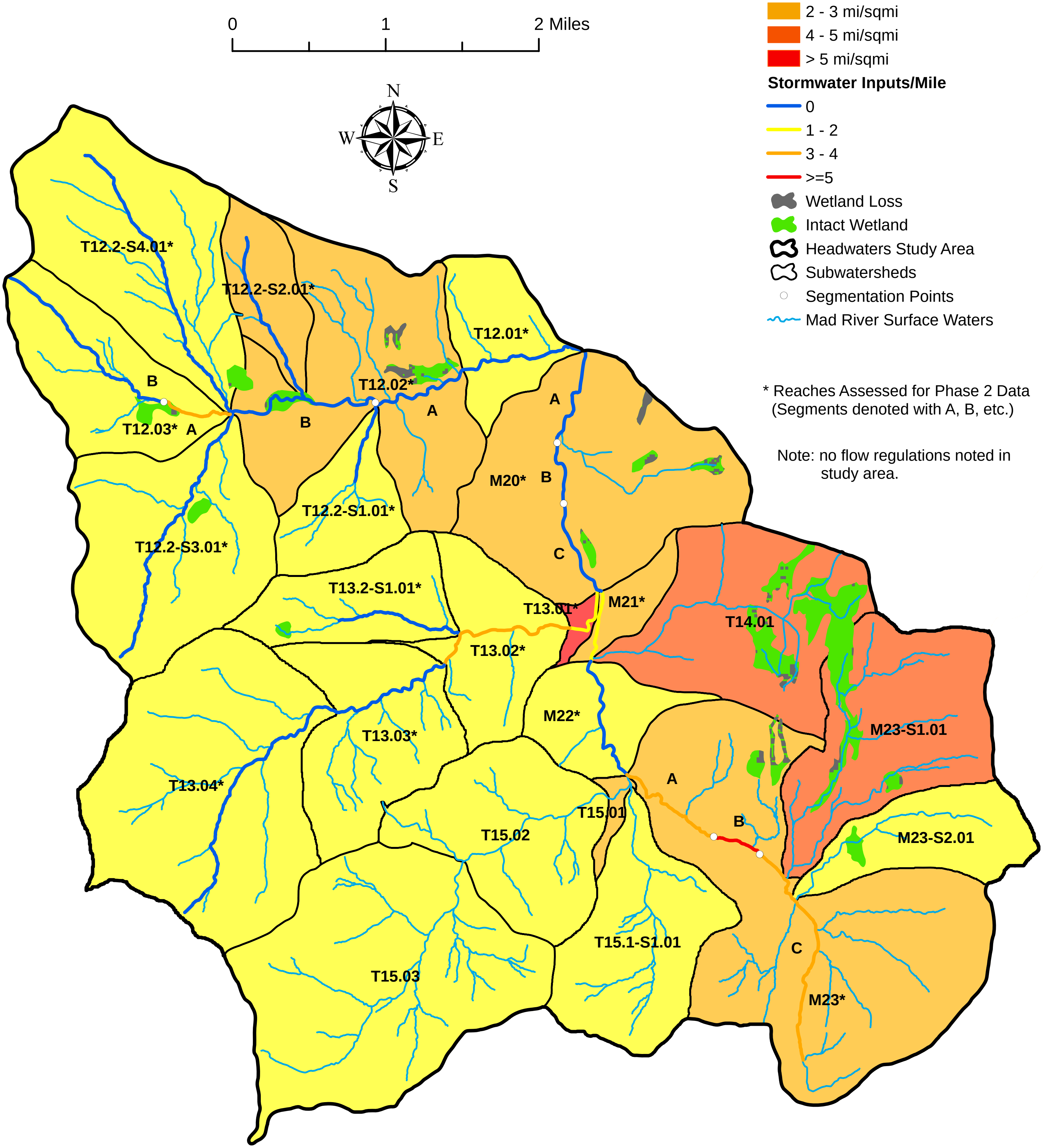

Figure 5.42 Hydrologic Alterations

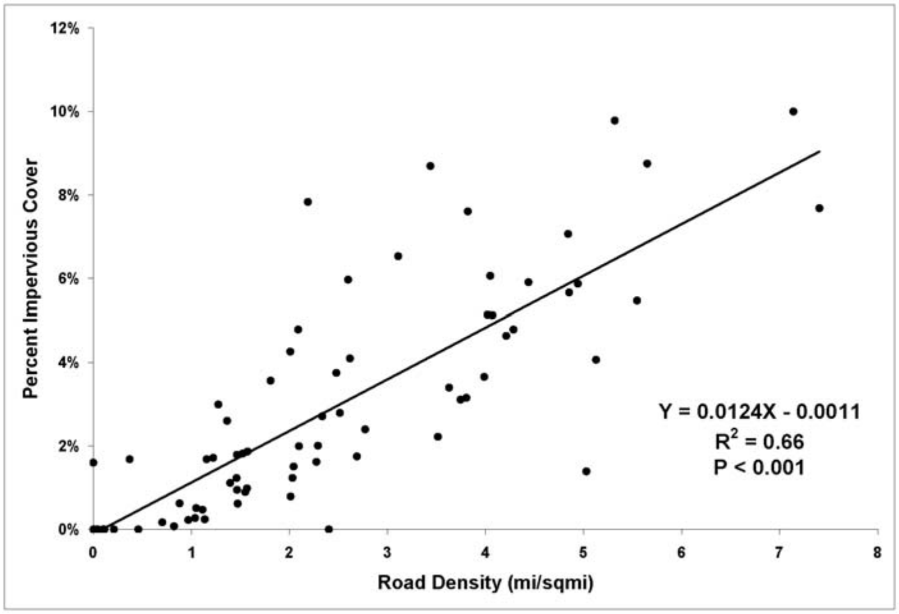

Figure 5.43 Correlation between road density and percent impervious cover for the Upper Mad River Watershed

at the subwatershed scale in the Mad River watershed was analyzed for strength of correlation. This analysis revealed that in the Mad River watershed road density is positively correlated with percent impervious cover (Figure 5.43), and that a road density of approximately 4 miles per square mile corresponds to 5 percent impervious cover. This level of impervious cover is associated with decline of channel stability and biotic integrity in watersheds in Chittenden County (Fitzgerald, 2007). A total of 4 classes of road density were mapped in Figure 5.1 to depict the relative impact of the road network and impervious cover on the hydrologic regime. Wetland loss was mapped as the area where hydric soils intersect with urban or agricultural land uses in the watershed, with the remaining areas assumed to be intact wetland (the majority found in forested conditions). This approach allows for the interpretation of loss of hydrologic attenuation of surface runoff at the reach and watershed scale. In addition, stormwater outfall densities mapped during the Phase 2 assessments are included to depict areas of increased stormflows and decreased baseflows. No dams or diversions were observed in the study area. A summary of the local (reach-scale) and upslope impacts to the hydrologic regime for each mainstem reach based on Figure 5.43 is provided in Table 5.3.

5.2.2 Sediment Regime Stressors

The following description of the sediment regime of a watershed, and the general response to watershed-scale land use changes and stressors is included from the most recent version of the VTANR River Corridor Planning Guide (VTANR, 2007).

> The sediment regime may be defined as the quantity, size, transport, sorting, and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and valley, floodplain and stream morphology. Understanding changes in sediment regime at the reach and watershed

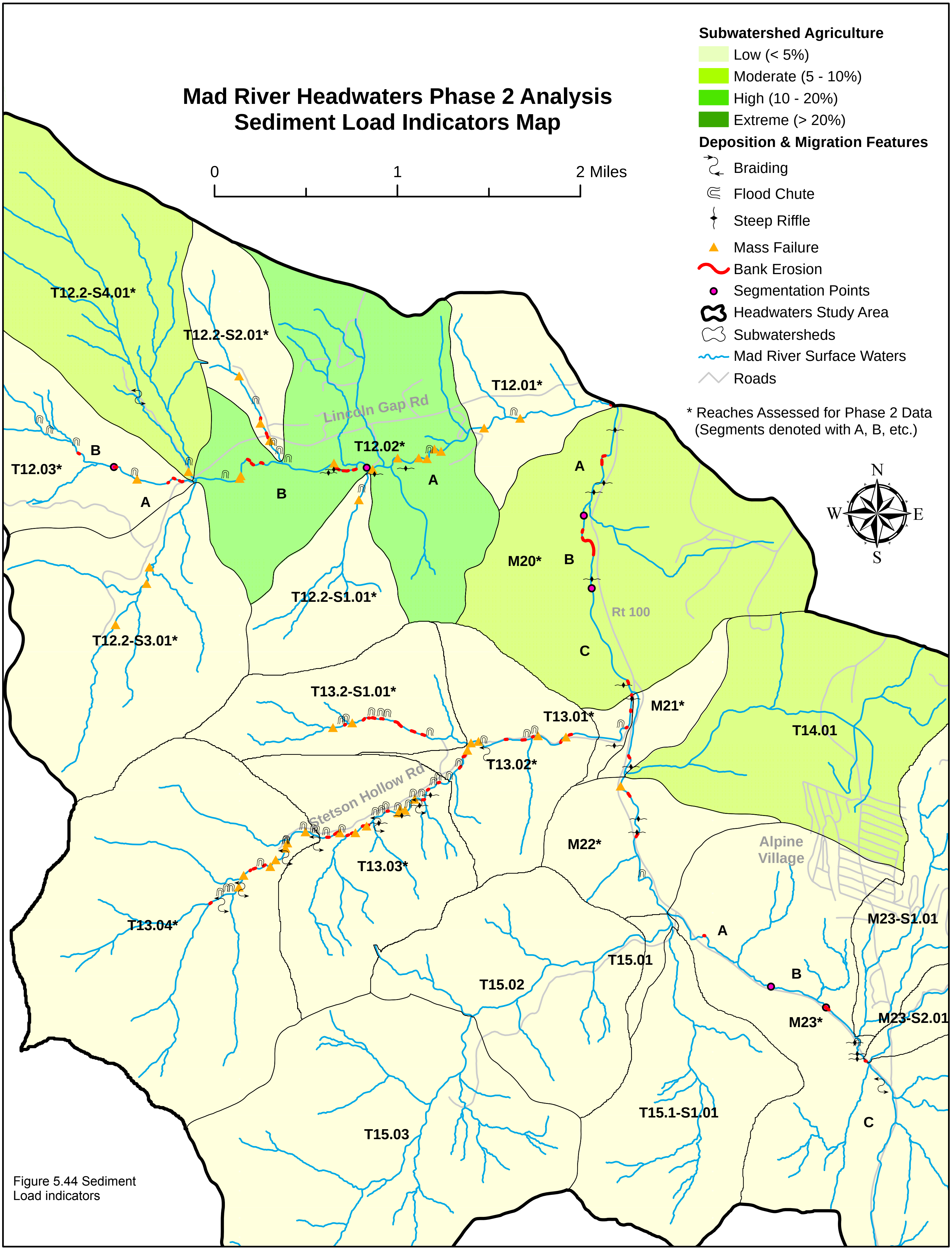

Figure 5.44 Sediment
Load indicators

scales is critical to the evaluation of stream adjustments and sensitivity. The sediment erosion and deposition patterns, unique to the equilibrium conditions of a stream reach, create habitat. In all but the most dynamic areas (e.g., alluvial fans), they provide for relatively stable bed forms and bank conditions.

The current day stressors to the sediment regime have been mapped using the variables extracted from the Phase 2 field assessments, and the percent of agriculture within each subwatershed (Figure 5.44). Four classes of percent agriculture were mapped to depict the relative impact of sediment delivery from agricultural lands at the reach and watershed scales. In addition, depositional and migration features mapped during the Phase 2 assessments are included to depict areas of increased vertical and lateral channel adjustments due to aggradation. Mass failures and bank erosion depict where sediment delivery from the channel boundaries is occurring. A summary of the local and upslope impacts to sediment loading for each mainstem reach based on Figure 5.44 is provided in Table 5.3 at the end of this section.

5.2.3 Channel Slope and Depth Modifiers

Many of Vermont's alluvial rivers have been historically manipulated and straightened to maintain an unnaturally steep slope in a state of sediment transport, allowing for a short term sense of security from flooding and subsequent encroachment of infrastructure in the floodplain. Over time, alluvial rivers seek to redevelop a sinuous planform through the deposition of sediments in unconfined valleys. Following flood events when alluvial rivers have become energized enough to transport large amounts of coarse sediment into depositional zones of the watershed, lateral channel migration ensues and further channel straightening is required to protect infrastructure found in the floodplain. Straightening and channelization typically ranges between 25 and 75 percent of the total river channel length in Vermont (VTANR, 2007).

In addition to historic alterations to channel slope in Vermont's alluvial rivers, the lowering of stream beds (e.g., dredging) and the raising of floodplains (e.g., berming) have resulted in an increase in channel depth (VTANR, 2007). Channel depths have typically been increased through the encroachment on the floodplain by roads and railroads and subsequent filling and armoring required to construct and maintain this infrastructure. Increases in impervious cover have also led to the deepening and eventual widening of channels throughout urbanized areas of Vermont (Fitzgerald, 2007).

Alterations to channel slope and depth in the Mad River headwaters have been mapped using the variables extracted from the Phase 2 field assessments (Figures 5.45 and 5.46). Channel straightening, found mainly along the upper Route 100 corridor, was mapped during the Phase 2 assessments and is included to depict areas of increased channel slope. Corridor encroachment data highlights where roads and development have reduced the floodplain area, typically resulting in increased stream power and channel deepening. Additional data showing the location of natural channel features (e.g., ledges) depict areas that have a resistance to vertical channel change. A summary of the local and upslope impacts to channel slope and depth for each mainstem reach based on Figures 5.45 and 5.46 is provided in Table 5.3 at the end of section 5.0.

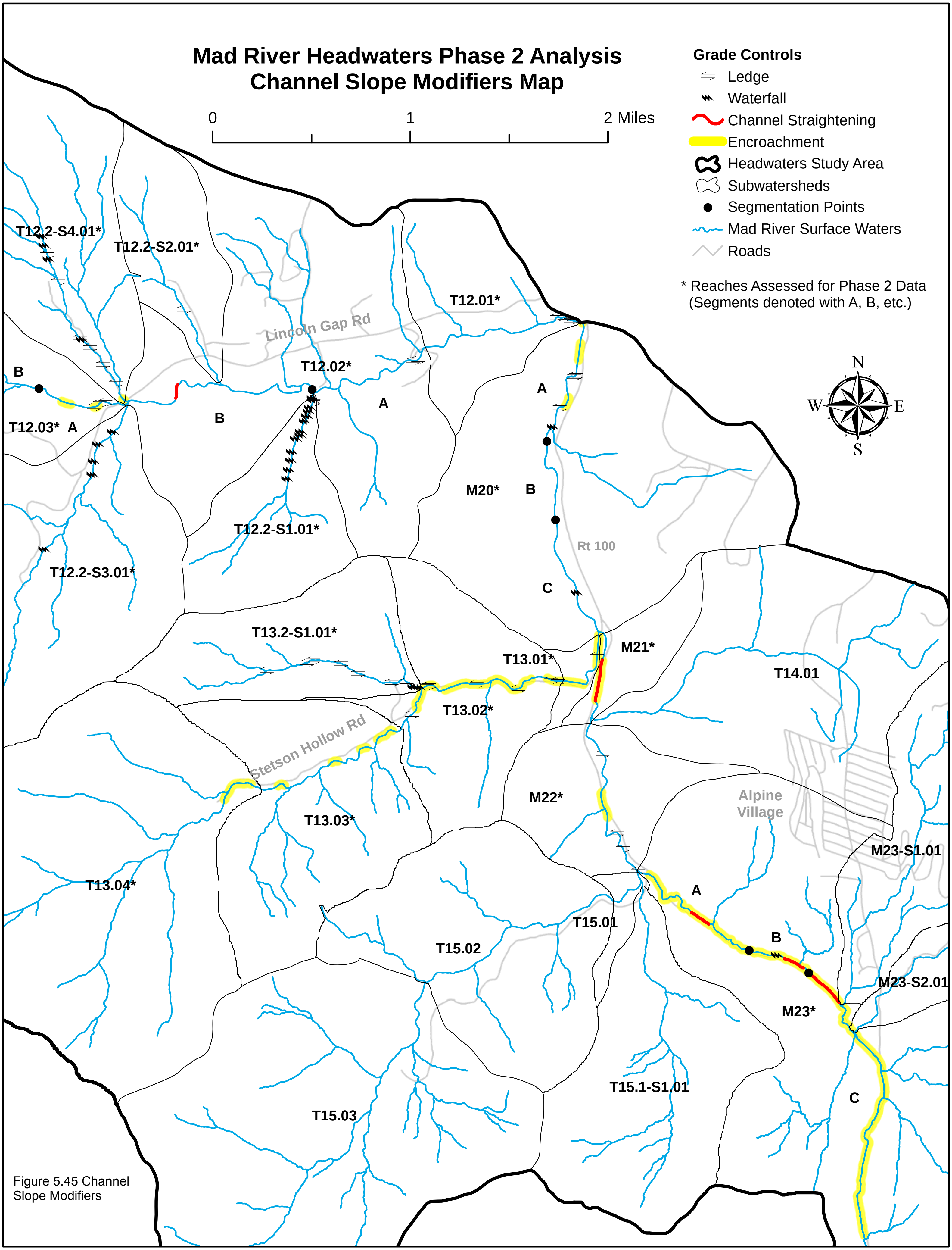

Figure 5.45 Channel Slope Modifiers

Mad River Headwaters Phase 2 Analysis
Channel Depth Modifiers Map

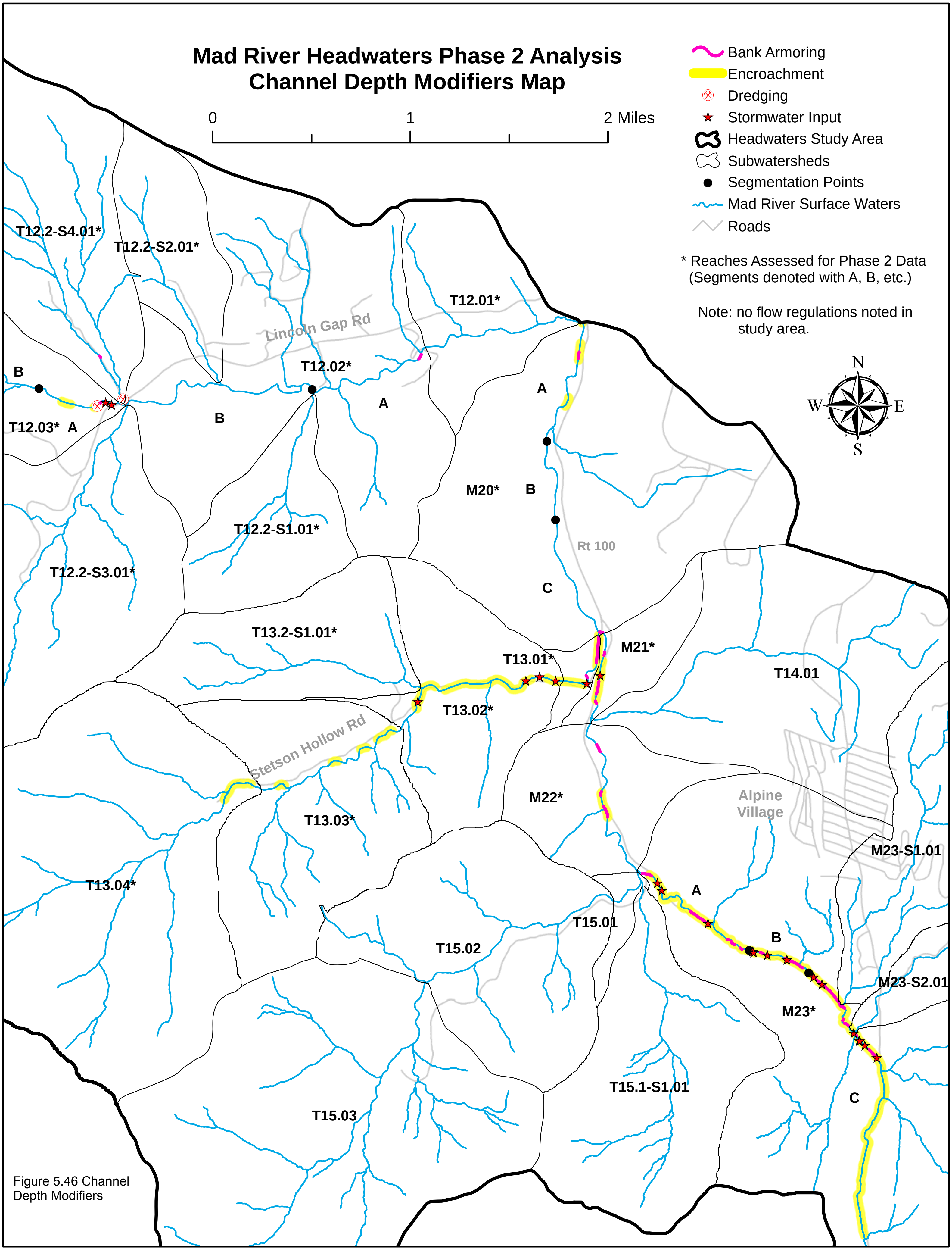

Figure 5.46 Channel Depth Modifiers

5.2.4 Modifications to Channel Boundary and Riparian Conditions

The boundary conditions of a river encompass the bed and bank substrate, and the vegetation and root material found along the riverbank. Human alterations to the river boundary conditions are often made to increase the resistance of the banks and bed to reduce lateral and vertical adjustments. In addition, the removal of riparian vegetation can cause a decrease in boundary resistance, and lead to increased lateral migration. Other natural and human-installed features within the channel, such as bedrock ledges and dams, affect boundary resistance in an upstream and downstream direction by controlling vertical adjustment processes.

In the Mad River headwaters, a majority of the reaches not found in bedrock-controlled settings have non-cohesive bank materials consisting of gravel, cobbles and boulders. Numerous natural grade controls exist along the channel network in the form of bedrock ledges and waterfalls, especially along the Lincoln and Stetson Brook channels.

Alterations to the channel boundary conditions and riparian areas in the Mad River headwaters have been mapped using the variables extracted from the Phase 2 field assessments (Figure 5.47). Relative bank armoring (e.g., riprap) highlights areas of increased resistance to lateral migration, whereas relative bank erosion highlights reaches where significant lateral adjustments are found. Additional data showing the location of natural channel features (e.g., ledges) depict areas that have a resistance to channel change. Five segments had areas of reduced riparian vegetation (at least 10% of channel length for one bank), including: M23-A, M23-C, T12.02-B, T13.01, and T13.02. However, even in segments where reduced riparian vegetation is high (as in M23-A, M23-C, and T13.02) any decreases in boundary resistance from this impact are offset by increases in boundary resistance from bank armoring, as depicted in Figure 5.47. A summary of the local impacts to channel boundary conditions for each mainstem reach based on Figure 5.47 is provided in Table 5.3 at the end of this section.

5.2.5 Sediment Regime Analysis

Many years of research has shown that alluvial river channels in wide valleys will adjust their geometry and planform to accommodate changes in the discharge and sediment loading from the upslope watershed (Dunne and Leopold, 1978). This concept was summarized by Lane (1955) to show that stream power and sediment (size and distribution) will seek a dynamic equilibrium condition in the absence of anthropogenic disturbance or catastrophic natural storm events. Slight environmental changes from one year to another at the watershed scale, such as variation in rainfall amounts (and a resulting variation in discharge), may cause subtle changes in channel form. However the shape and profile of a river is typically stable under reference watershed conditions, and predictable given knowledge about 1) the geologic conditions of the watershed and corridor, 2) the topography of the watershed, and 3) the regional climate.

Analysis of a watershed's sediment regime is a useful approach for summarizing the reach and watershed-scale stressors (described previously in Section 5.0) affecting the equilibrium conditions of river channels. Sediment regime mapping provides a context

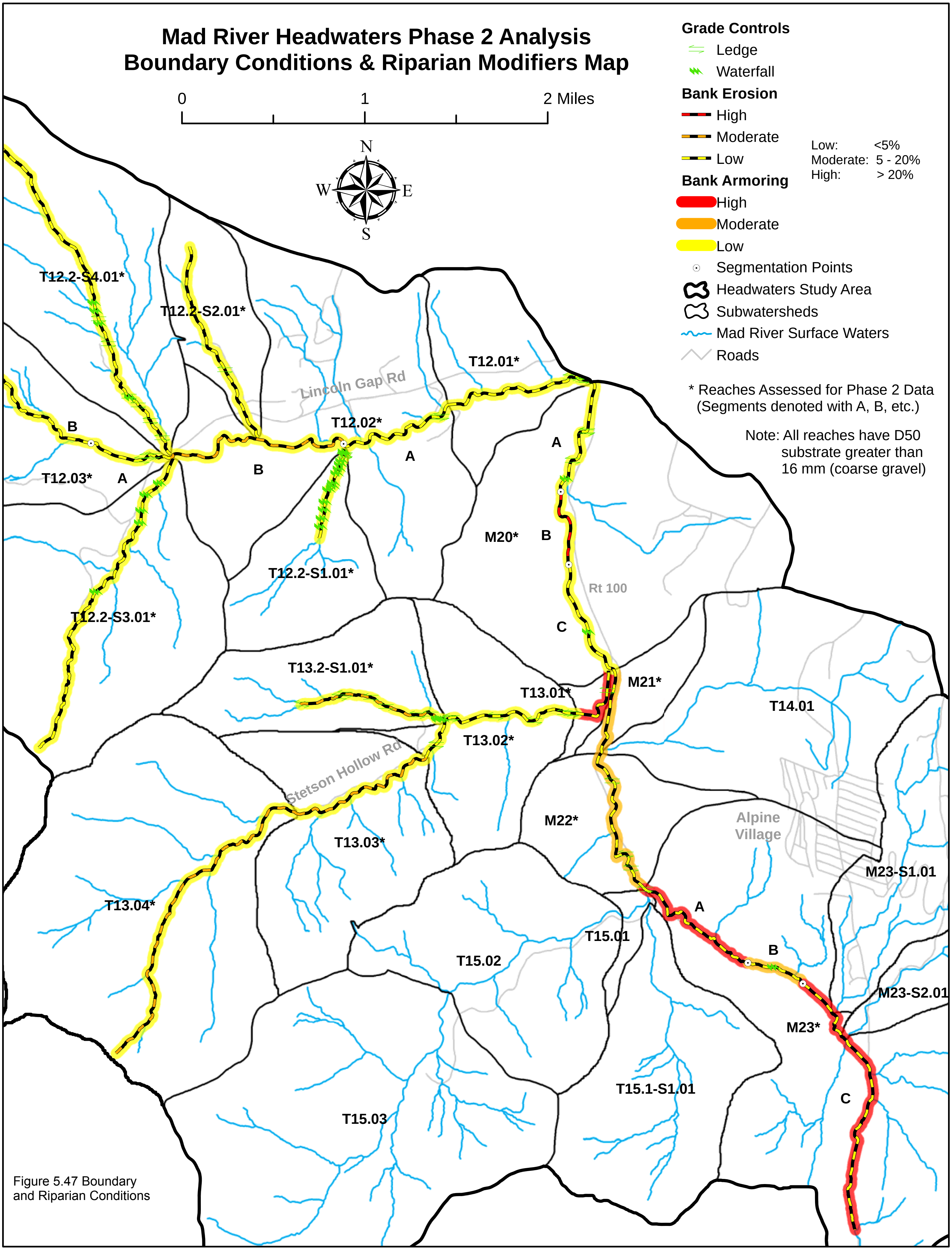

Figure 5.47 Boundary and Riparian Conditions

for understanding sediment transport and channel evolution processes (Schumm, 1984) which govern changes in geometry and planform for river channels in a state of disequilibrium. The VTANR River Corridor Planning Guide (2007) outlines a methodology for understanding the reference and altered sediment regimes of reaches according to data collected during the Phase 2 field assessments. The sediment regime types used in this analysis are summarized below in table 5.2.

Table 5.2 Sediment Regime Types (VTANR, 2007)

Regime	Narrative Description
Transport	Steeper bedrock and boulder/cobble cascade and step-pool stream types; typically in more confined valleys, do not supply appreciable quantities of sediments to downstream reaches on an annual basis; little or no mass wasting; storage of fine sediment is negligible due to high transport capacity derived from both the high gradient and/or natural entrenchment of the channel.
Confined Source and Transport	Cobble step pool and steep plane bed streams; confining valley walls, comprised of erodible tills, glacial lacustrine, glacial fluvial, or alluvial materials; mass wasting and landslides common and may be triggered by valley rejuvenation processes; storage of coarse or fine sediment is limited due to high transport capacity derived from both the gradient and entrenchment of the channel. Look for streams in narrow valleys where dams, culverts, encroachment (roads, houses, etc.), and subsequent channel management may trigger incision, rejuvenation, and mass wasting processes.
Unconfined Source and Transport	Sand, gravel, or cobble plane bed streams; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to entrenchment or incision and associated bed form changes; these streams are not a significant sediment supply due to boundary resistance such as bank armoring, but may begin to experience erosion and supply both coarse and fine sediment when bank failure leads to channel widening; storage of coarse or fine sediment is negligible due to high transport capacity derived from the deep incision and little or no floodplain access. Look for straightened, incised or entrenched streams in unconfined valleys, which may have been bermed and extensively armored and are in Stage II or early Stage III of channel evolution.
Fine Source and Transport & Coarse Deposition	Sand, gravel, or cobble streams with variable bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to vertical profile and associated bed form changes; these streams supply both coarse and fine sediments due to little or no boundary resistance; storage of fine sediment is lost or severely limited as a result of channel incision and little or no floodplain access; an increase in coarse sediment storage occurs due to a high coarse sediment load coupled with the lower transport capacity that results from a lower gradient and/or channel depth. Look for historically straightened, incised, or entrenched streams in unconfined valleys, having little or no boundary resistance, increased bank erosion, and large unvegetated bars. These streams are typically in late Stage III and Stage IV of channel evolution.
Coarse Equilibrium (in = out) & Fine Deposition	Sand, gravel, or cobble streams with equilibrium bed forms; at least one side of the channel is unconfined by valley walls; these streams transport and deposit coarse sediment in equilibrium (stream power—produce as a result of channel gradient and hydraulic radius—is balanced by the sediment load, sediment size, and channel boundary resistance); storage of fine sediment as a result of floodplain access for high frequency (annual) floods. Look for unconfined streams, which are not incised or entrenched, have boundary resistance (woody buffers), minimal bank erosion, and vegetated bars. These streams are Stage I, late Stage IV, and Stage V of channel evolution.

Figures 5.48 and 5.49 summarize the sediment regime types for reference and existing conditions for the headwaters reaches. The analysis of sediment regime types indicates that the headwaters of the Mad River have experienced many areas of departure from the reference regime conditions. Approximately half of the headwaters channels had background valley and slope conditions that supported coarse-bottomed streams in

Mad River Headwaters Phase 2 Analysis
Reference Sediment Regime Types

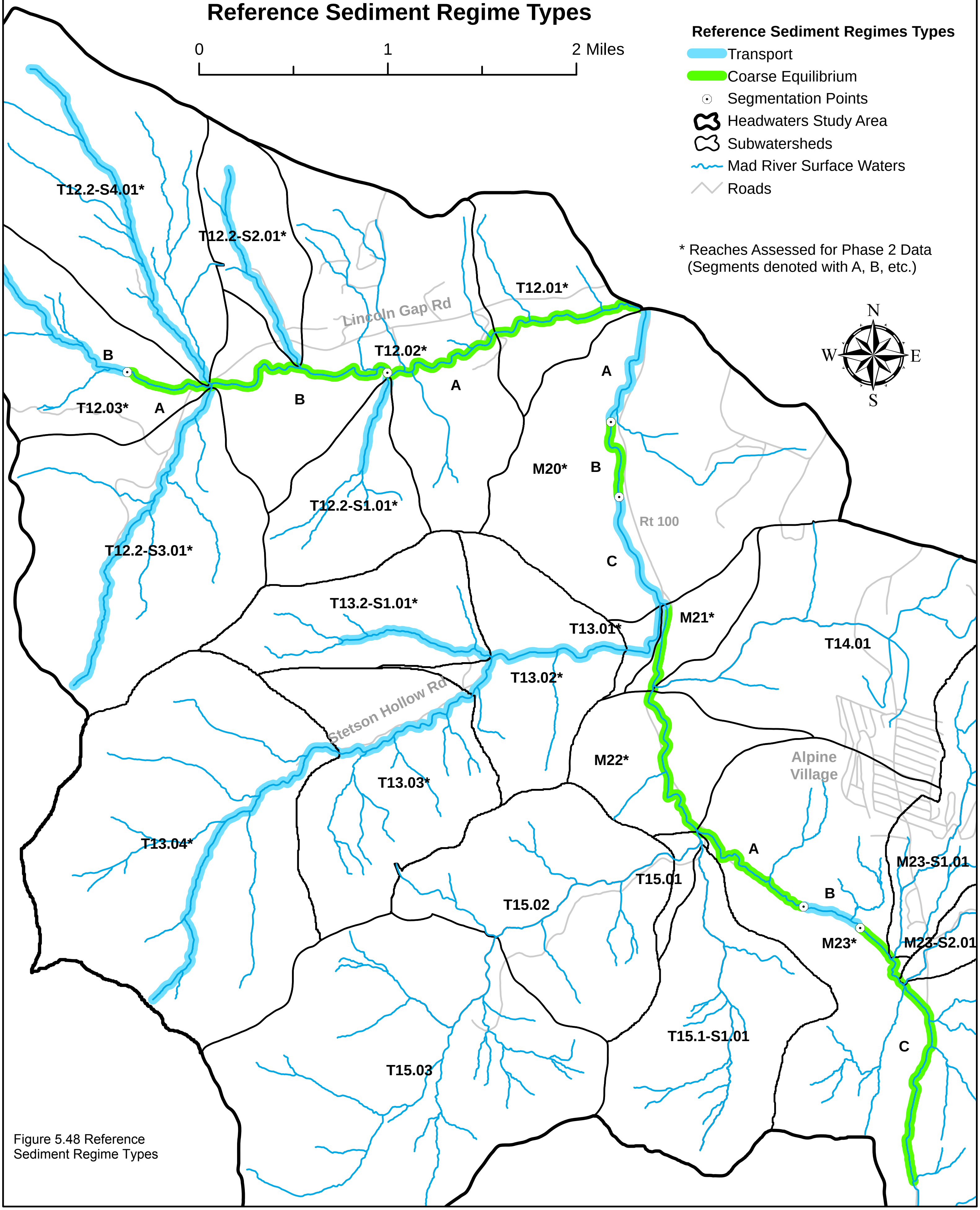

Figure 5.48 Reference Sediment Regime Types

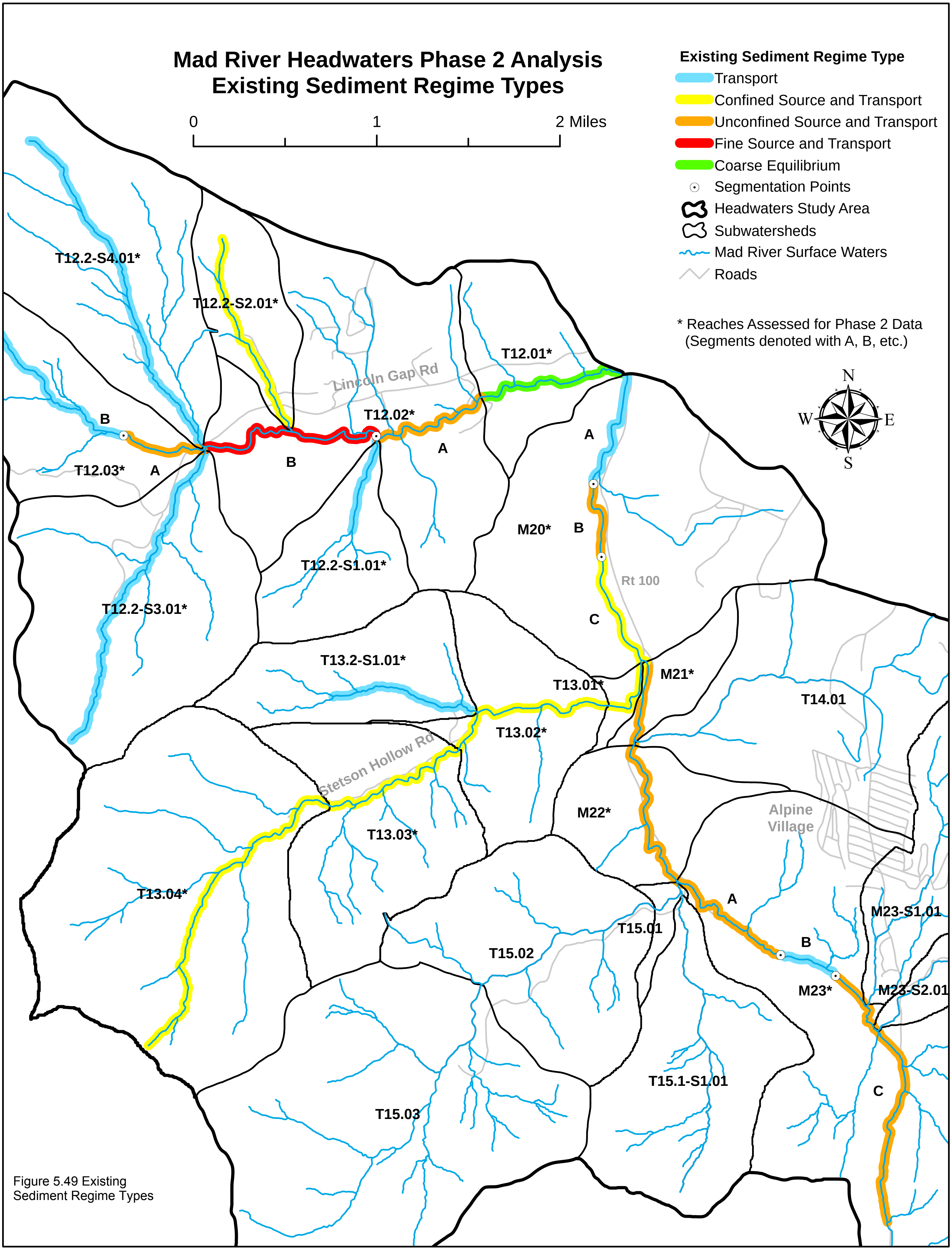

Figure 5.49 Existing
Sediment Regime Types

equilibrium; there was a balance between sediment transport and supply. Segments M20-B, M21, M22, M23-A, M23-C, T12.01, T12.02-A, T12.02-B, and T12.03-A are characterized by this regime under reference conditions. However, with the exception of a single reach (T12.01), all experienced a departure to source and transport regimes due mainly to incision and other channel evolution processes brought on by human impacts. Along the mainstem, segments M20-A, M20-C, and M23-B have confinement and channel slope characteristics that support sediment transport channels. Only segment M20-C has experienced a sediment regime departure from reference conditions due to channel incision. Within the Lincoln and Stetson Brook watersheds, many transport reaches have become significant sources of sediment due mainly to historic impacts to the channel boundary conditions (e.g., straightening, encroachment and armoring). Table 5.3 summarizes both the departure of sediment regime conditions based on the transport and storage capacity, as well as the constraints to 1) the connectivity of the adjustment processes along the channel network, and 2) the redevelopment equilibrium conditions in the reach.

Table 5.3 Mad River Headwaters Departure Analysis Summary

River Segment	**Constraints**		**Transport**		**Floodplain Sediment and Flow Attenuation (Storage)**		
	Vertical	**Lateral**	**Natural**	**Converted**	**Natural**	**Increased**	**Asset**
M20-A	Ledges; Waterfalls (N)		X			X	
M20-B		Roads (H)		X	X	X	X
M20-C	Ledges; Waterfalls (N)	Armoring; Roads (H)	X				
M21		Armoring; Roads (H)		X			
M22	Ledges; Waterfalls (N)	Armoring; Roads (H)		X	X	X	X
M23-A	Ledge (N)	Armoring; Roads (H)		X	X		
M23-B	Waterfall (N)	Armoring; Roads (H)	X				
M23-C		Armoring; Roads (H)		X	X	X	X
T12.01	Ledges; Waterfalls (N)				X		X
T12.02-A	Ledges (N)			X	X	X	X
T12.02-B				X	X	X	X

River Segment	Constraints		Transport		Attenuation (Storage)		
	Vertical	Lateral	Natural	Converted	Natural	Increased	Asset
T12.03-A	Ledges (N)			X	X		X
T12.03-B	Ledges; Waterfalls (N)		X				
T12.2-S1.01	Ledges; Waterfalls (N)		X				
T12.2-S2.01	Ledges (N)		X				
T12.2-S3.01	Ledges; Waterfalls (N)	Roads (H)	X				
T12.2-S4.01	Ledges; Waterfalls (N)	Roads (H)	X				
T13.01	Ledges (N)	Roads (H)	X				
T13.02	Ledges (N)	Roads (H)	X			X	X
T13.03		Roads (H)	X			X	X
T13.04		Roads (H)	X			X	X
T13.2-S1.01	Ledges; Waterfalls (N)		X				

N = Natural
H = Human Constructed

5.2.6 Stream Sensitivity Analysis

The following description of the sensitivity of stream types to adjustments in the context of sediment transport processes and human-induced stressors is included from the most recent version of the VTANR River Corridor Planning Guide (VTANR, 2007).

> Certain geomorphic stream types are inherently more sensitive than others, responding readily through lateral and/or vertical adjustments to high flow events and/or influxes of sediment. Other geomorphic stream types may undergo far less adjustment in response to the same watershed inputs. In general, streams receiving a large supply of sediment, having a limited capacity to transport that sediment, and flowing through finer-grained, non-cohesive materials are inherently more sensitive to adjustment and likely to experience channel evolution processes than streams with a lower sediment supply, higher transport capacity and flowing through cohesive or coarse-grained materials (Montgomery and Buffington, 1997). The geometry and roughness of the stream channel and floodplain (i.e., the width, depth, slope, sediment sizes, and floodplain relations) dictate the velocity of flow, how much erosive power is produced, and whether the

> stream has the competence to transport the sediment delivered from upstream (Leopold, 1994). If the energy produced by the depth and slope of the water is either too little or too great in relation to the sediment available for transport, the stream may be out of equilibrium and channel adjustments are likely to occur, especially during flood conditions (Lane, 1955).

The methods outlined in the Corridor Planning Guide have been used to describe the stream sensitivities of the headwaters reaches of the Mad River. Using the stream geometry and substrate data (Rosgen, 1994) collected during the 2007 field season, as well as the overall geomorphic stability of the reach (RGA score), stream sensitivity ratings have been assigned. In addition, the active adjustment processes described during the field effort have been summarized. An adjustment process was considered “active” if it received a score in the fair to poor range during the RGA scoring process. Figure 5.50 summarizes the current stream sensitivities and adjustment processes for the Mad River headwaters.

Stream channels with steeper slopes and more confined valleys (transport reaches) tend to have a lower sensitivity to human impacts due to their natural armoring and grade controls. However, where roads have encroached upon the channel, the floodplain width is often reduced, resulting in channel incision and greater export of sediments to downstream reaches. In addition, gravel roads found in these steep settings often act as an unnatural source of fine sediment to the channel, resulting in the filling of pools and degradation of aquatic habitat. Two headwaters segments in the Lincoln Brook watershed having sensitivities of “very high” or “extreme” are summarized below.

- Subtributary S2.01 is found along Camp Road and enters the mainstem of Lincoln Brook in the middle of segment T12.02-B. This steep segment has been impacted by historic agricultural land uses (grazing and perhaps straightening), and is currently experiencing channel incision. The observed stream geometry is different from what we would expect under reference conditions, and further channel incision and export of sediment is likely. Due to the stream type departure, this segment has an extreme sensitivity to further human impacts.

- Subtributary S4.01 is found along Hanks Road and enters the mainstem just below the Lincoln Gap Road crossing. This segment has a steep slope and numerous grade controls. It is experiencing aggradation of fine sediment due to runoff from the adjacent road, which is leading to channel widening and degradation of aquatic habitat. Due to the increased sedimentation in the segment, which is atypical in this setting, the reach has a very high sensitivity to future human impacts.

In addition, 3 segments on the mainstem channel have been converted from depositional to transport reaches due to historical straightening and road encroachment. The response of meandering, gravel-bed rivers to human impacts is typically more severe than steeply sloped transport reaches. In the case of the three mainstem segments, the channel adjustment processes are in their early stages, where deposition and widening processes

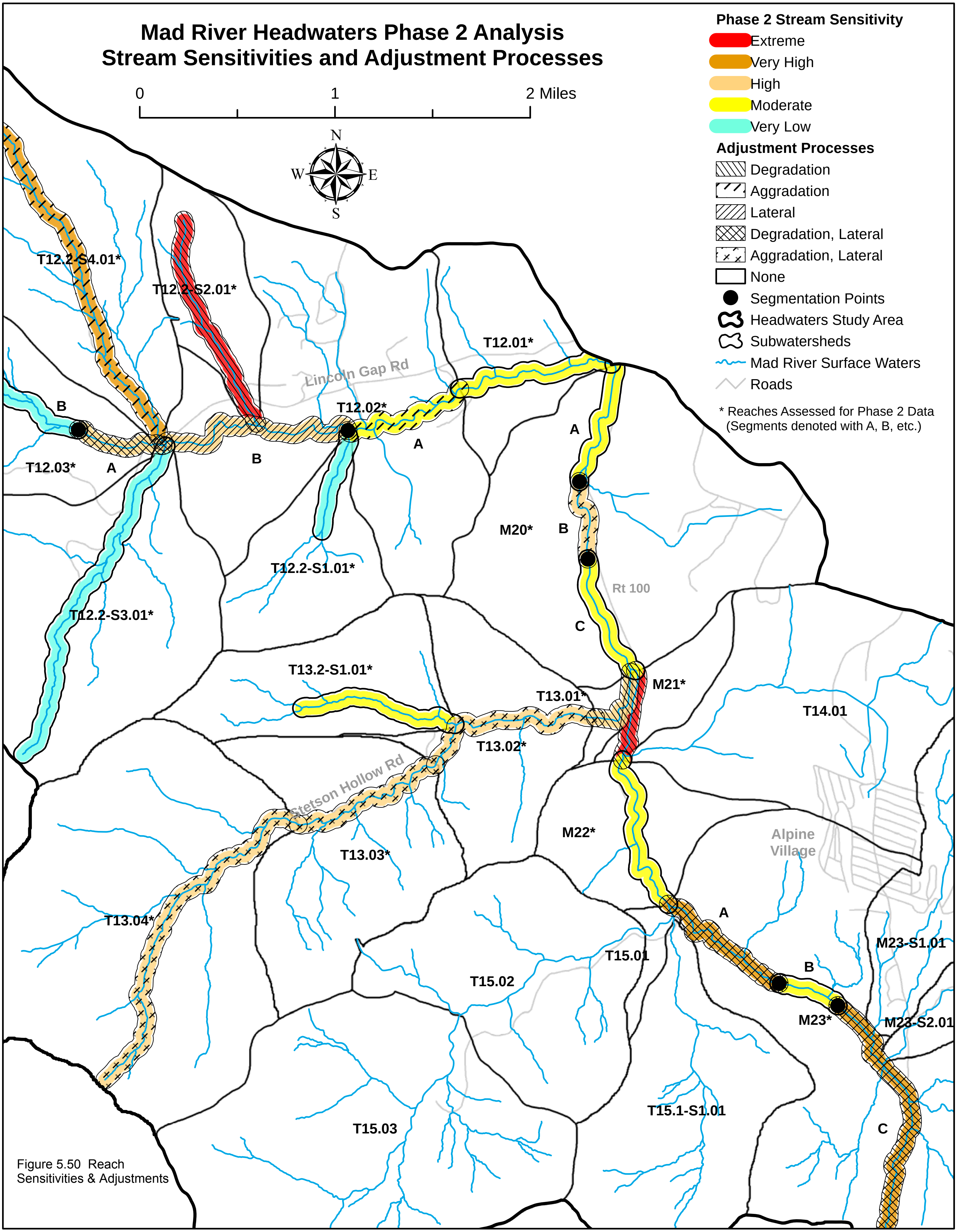

Figure 5.50 Reach Sensitivities & Adjustments

are being held in check by extensive bank armoring. The three headwaters segments on the Mad River mainstem having sensitivities of “very high” or “extreme” are summarized below.

- Reach M21 is a moderate-gradient channel (~2% slope) found in an unconfined valley setting. Under reference conditions, this reach would have C-type channel geometry and sediment deposition processes with a well-defined, albeit narrow floodplain. Due to channel straightening and bank armoring along the road, this reach has experienced a departure from reference geometry, and is now a quasi-stable transport reach. Due to the propensity of reaches in this condition to laterally adjust to the supply of sediment from upslope areas, this reach has an extreme sensitivity to further adjustments.

- Segments M23-A and M23-C are low-gradient channels that would have sediment depositional processes under reference conditions. However, due to significant road encroachment and bank armoring, the channel geometry of both reaches has been altered and sediment transport processes prevail. Despite the armored condition of these two segments, the large supply of coarse sediment from upslope tributaries will likely cause both areas to widen in the future. Due to the likelihood for further lateral adjustments, both segments have a very high sensitivity to future human impacts.

6.0 Preliminary Project Identification

6.1 Stream Crossings

Most crossing structures in the study reaches are currently undersized and causing various problems such as upstream deposition, excessive erosion, downstream bed degradation, wildlife passage problems, etc. As such structures come up for replacement, resizing them to accommodate the flow and sediment loads of the streams and placing them in proper alignment with stream channels is recommended. The RMP has begun recommending sizing structures at 1.25-1.5 times the bankfull width (Shayne Jaquith, personal communication 2007). Streams undergoing significant adjustments may require larger structures than streams in an equilibrium state. Towns can adopt bridge and culvert standards for appropriate crossing width. Adopting such standards can help with pre-disaster mitigation planning and can help towns receive state incentives for taking a proactive approach. A new Fish and Wildlife document for appropriately sized crossings is due out in Spring 2008 and can provide additional guidance on structure sizing and placement.

Table 6.1 shows structures assessed during Bridge and Culvert Assessments in the study reaches in 2007. Only 1 structure met the recommended 1.25 times stream width: The Route 100 Bridge in M22. Please refer to Table 6.2 for potential projects related to stream crossings for each reach.

Table 6.1 Summary of Stream Crossings

Reach/ Struct Type	**Road**	**Road Type**	**Stream**	**Location**	**Struct Height**	**Struct Span**	**Stream Width**	**% Span/ Stream Width**	**Floodplain Filled**	**Stream Approach**	**Comments**
M21 Bridge	Route 100	Paved	Mad River	Upstream of confluence with Stetson Brook	17.0	35.0	46.0	**76**	Partially	Mild Bend	Armoring on upstream right bank is partially failing. No other major problems.
M21 Bridge	Unknown	Paved	Mad River	Old stream crossing across Route 100 from Stetson Hollow Road	12.0	36.0	46.0	**78**	Not Significant	Channelized Straight	Old derelict bridge that is sloped to right bank and being undermined at footers and wing walls. No apparent severe damage from '98 flood. Structure should be removed in future before it fails completely. Stepped footers.
M22 Bridge	Route 100	Paved	Mad River	First crossing in M22 at Route 100 pull-off	10.0	70.0	46.0	152	Partially	Sharp Bend	Significant bank erosion downstream of structure where mid channel bar is causing widening.
M23-C Culvert	Route 100	Paved	Mad River	Next to a make shift moose crossing sign.	4.0	4.0	8.3*	**48**	Entirely	Channelized Straight	Inlet is totally blocked by sediment and debris. Pond up and down of culvert. Outflow at grade. Pool downstream.
M23-C Culvert	Route 100	Paved	Mad River	Two ponds, one on the right, the other is on the left.	4.0	6.0	8.8*	**68**	Entirely	Sharp Bend	Inlet is a pond and the outlet is a marsh that turns into a pond. Inlet blocked by sediment and debris. Outflow a cascade. Pool downstream.
M23-C Culvert	Route 100	Paved	Mad River	Just north of the intersection with Plunckton RD.	7.0	10.5	19.1	**55**	Entirely	Sharp Bend	Steep riffle upstream. Outflow at grade. Pool downstream.
M23-A Bridge	Austin Hollow Rd	Gravel	Mad River	Austin Hollow Rd. Crossing	5.0	24.0	34.0	**71**	Partially	Mild Bend	No serious problems with deposition or bank erosion, but structure appears to be very small to accommodate size of channel and respective drainage area.
M23-A Bridge	Route 100	Paved	Mad River	Route 100	7.5	17.0	34.0	**50**	Partially	Mild Bend	Severe undermining of upstream wing wall on right bank. Upstream aggradation is causing changes in planform for ~500 feet upstream.
T12.02-A Bridge	Lincoln Brook Rd	Gravel	Lincoln Brook	Lincoln Brook Road Crossing	9.5	29.5	46.0	**64**	Partially	Mild Bend	Bridge survived 1998 flood without damage. Pronounced channel/floodplain constriction. Wood Footings for road (not bridge) are deteriorating.
T12.03-A Culvert	McCuin Driveway	Gravel	Atkins Brook-Trib to Lincoln Brook	McCuin driveway off Lincoln Gap Rd.	6.0	6.0	16.7	**36**	Partially	Mild Bend	Previous culvert washed out during the 1998 flood. Homeowner has never seen depth in culvert greater than half full. Significant gravel extraction and berming above inlet post '98 flood. Outflow at grade. Significant erosion downstream.

Reach/ Struct Type	Road	Road Type	Stream	Location	Struct Height	Struct Span	Stream Width	% Span/ Stream Width	Floodplain Filled	Stream Approach	Comments
T12.03-A Culvert	Lincoln Gap Rd	Paved	Lincoln Brook	Just above Hanks road.	5.8	8.3	17.0	**49**	Entirely	Mild Bend	Deposition and steep riffle upstream. Outflow at grade. Pool downstream.
T12.2-S2.01 Culvert	Lincoln Gap Rd	Gravel	Trib to Lincoln Brook	Just up from Camp Road junction.	5.1	4.8	9.0	**53**	Entirely	Naturally Straight	Brook may be dry some years, locals say. Deposition and steep riffle upstream. Outflow a free fall. Pool downstream. Significant erosion downstream.
T12.2-S4.01 Culvert	Lincoln Gap Rd	Paved	Trib to Lincoln Brook	Just above intersection with Hanks RD.	7.0	11.0	19.0	**58**	Entirely	Naturally Straight	Deposition and steep riffle upstream. Outflow a free fall. Significant erosion downstream.
T13.02 Bridge	Stetson Hollow Rd	Gravel	Stetson Brook	Upstream most bridge of Stetson brook reach T13.02	5.9	28.5	49.0	**58**	Not Significant	Naturally Straight	Uppermost bridge on reach had no significant problems, some erosion on the roadways and a mass failure upstream on the left bank. Deposition upstream. This bridge is inaccessible as the road has washed out and therefore should be removed.
T13.02 Bridge	Stetson Hollow Rd	Gravel	Stetson Brook	Mid-reach Bridge that crosses over Stetson Brook.	5.9	29.5	49.0	**60**	Partially	Mild Bend	Mass failure on the left bank just upstream of structure, high erosion could be a problem in the future. Pool downstream.
T13.02 Bridge	Stetson Hollow Rd	Gravel	Stetson Brook	The downstream most bridge on Stetson Hollow Bridge.	6.0	29.8	49.0	**61**	Partially	Mild Bend	This bridge appeared to have not been damaged by the 1998 flood, but large rain events may wash over the top of the bridge because it is a very tight constricting point.

* Channel width data collected by USF&W surveyors at structure location.

6.2 Potential Project List

In addition to completing Phase 2 SGAs and Bridge and Culvert assessments, the project team was asked to compile a list of potential projects for the study reaches. Using the Step-wise procedure from the River Corridor Planning Guide (VTANR, 2007), the project team identified potential restoration and protection projects that would support stream dynamic equilibrium conditions and reduce potential future conflicts between human investments and stream channels and their associated expenses. Results from the Step 6 Step-wise Procedure process are presented in Table 6.2.

Table 6.2 included project prioritization based on guidelines in Step 6 of the River Corridor Planning Guide. Overall, there is little opportunity to attenuate sediment in these headwaters reaches, a condition that has been exacerbated by the presence of roads sharing the narrow valleys with the streams. Therefore areas with small floodplains, such as in M20, M22 and M23, become very high priority areas to protect the corridor to allow for some sediment and flow attenuation. Looking downstream, M19B also rises in priority, as it is the last possible attenuation area before the Town of Warren.

Table 6.2 Preliminary Project Identification

Project #	Site Description	Project Description	Priority
M20A-1	Bedrock constrictions with sediment deposition and steep riffles, likely 1998 flood related. Road in 693 of the total 3912 feet, riprap on 177 ft of right bank. No other development, no incision, in regime and “good” condition. Erosion on 75 ft of left and 133 ft of right bank.	Protect River Corridor, especially in the areas with adjacent floodplain.	Very high priority at the alluvial sections of this reach that have floodplain areas to attenuate sediment from upstream reaches and Stetson Brook. Low priority at bedrock gorge areas.
M20A-2	A very small area of bank/corridor vegetation was lacking near the house on the right bank up near the segment break.	Plant woody vegetation in the corridor in this area to strengthen stream banks and improve habitat.	Low priority due to the small area lacking woody vegetation.
M20B-1	Stage III Fair condition, Aggradation and widening, No grade controls or constrictions. 1.23 incision, some erosion, no mass failures, no armoring. Bank instability may affect habitat with fine sediments. No encroachments.	Protect River Corridor to allow for continued channel adjustments where not in conflict w the road. (Ideally, remove the road, but that is not likely to happen) and for passive floodplain and meander redevelopment.	Very high priority due to the current adjustments and the location downstream of confined, straightened and armored reaches along Route 100 and Stetson Brook.
M20C-1	Stage II good condition, bedrock constrictions and grade controls. One house on left bank had good vegetation and was not affecting the channel. Some incision caused by roads, low erosion and riprap.	Protect stream corridor to allow for continued adjustment and passive restoration of floodplain.	Very high priority in the areas with floodplain due to the sensitivity and the location downstream of confined, straightened and armored reaches along Route 100 and Stetson Brook.
M21-1	STD C to F, Stage II fair condition, “armored, stable, quasi-equilibrium.” Road along most of corridor resulting in entrenchment, riprap along half of reach, straightening. Stressors appeared to be localized from straightening and berming. The reach is currently incised and straightened with increased stream power as well as confinement by the road, the road is only on one side of the channel, but occupies the valley and the stream is up against the valley wall on the other side.	No opportunities to restore floodplain without removing the road. Pursue High Priority River Corridor Protection at a downstream reach to attenuate the flow and sediment transported by this reach.	
M21-2	2 bridges constricting the channel, a) One with deposition above, b) One failing and no longer in use.	a) Replace downstream structure with appropriately sized structure. b) Remove failing structure that is no longer in use.	a) As it is up for replacement, b) High priority due to the fact that the one structure is no longer used.
M21-3		Investigate installing habitat structures to	Medium priority as

Project #	Site Description	Project Description	Priority
		improve/create some habitat in the middle and upper part of reach.	geomorphology cannot be improved, but habitat value could be increased.
M22-1	Stage III good condition, widening and some planform, bedrock ledge grade controls, some road in corridor, incised, low erosion, some riprap, steep riffles, bars.	Protect Stream Corridor to allow for continued adjustment and passive restoration.	High to attenuate flow and sediment from upstream, especially in the lower portion of the reach.
M23A-1	Stage II Fair condition, degradation and straightening. One ledge grade control, road along most of length, low erosion, much riprap, incision due to road, some bars, vegetation impacted.	Removing the road is not likely feasible, so Protect the corridor where there is floodplain and pursue high priority river corridor protection at the next downstream attenuation area.	Very high priority corridor protection in floodplain areas to attenuate flow and sediment from straightened areas along the road and upstream.
M23A-2	2 bridges constrict the channel: a) One with deposition upstream, b) Route 100 crossing with extreme deposition above and below.	Replace structures with appropriately sized structures.	High priority due to sediment discontinuity, especially the Route 100 crossing.
M23A-3		Investigate habitat improvement structures and native vegetation planting in artificially confined areas of this segment.	Medium priority as geomorphology cannot be improved, but habitat value could be increased in these areas.
M23B-1	Stage I Good condition, bedrock gorge and bank armoring providing stability and preventing adjustment. Road in corridor along all of reach with revetments, low erosion. Stormwater runoff from the road causing increased flow and sediment loading and road encroachment were the main impacts to geomorphology and habitat.	Not much can be done here because of the road. However the stormwater outfalls delivering sediment to channel should be remediated (see below). Pursue high priority river corridor protection at the next downstream attenuation area (M23A, M22, M20).	
M23B-2		Address the stormwater issue through best practices such as swales, sediment traps, etc. to minimize impacts to the river.	High priority to reduce sediment loading of the stream and associated geomorphic and habitat impacts.
M23C-1	Stage III Fair condition, aggradation and widening. Many bars, rip rap. Low erosion. Road along most of corridor, as in segment A. Road and loss of floodplain appear to be the main stressors.	Not much can be done here because of the road, which is likely to persist, so Protect the River Corridor in areas where there is floodplain, and Pursue high priority river corridor protection at the next downstream attenuation area (M23A, M22, M20).	High priority to attenuate flow and sediment from impacted areas along the road.

Project #	Site Description	Project Description	Priority
M23C-2	One culvert constriction with deposition upstream and downstream.	Replace structure with appropriately sized structure.	High priority due to sediment discontinuity.
M23C-3		Investigate habitat improvement structures and native vegetation planting for this segment.	Medium priority as geomorphology cannot be improved, but habitat value could be increased.
M23C-4		Address sediment entering from tributaries with road improvements and/or sediment traps on the back roads. The Better Backroads program could help. Collect Phase 2 data for tributary reaches.	High priority to reduce sediment loading of the stream and associated geomorphic and habitat impacts.
T12.01-1	Stage I good condition, bedrock ledges at downstream end by Bobbin Mill, low erosion, no riprap, only one small area of development, some bars.	Protect the River Corridor to allow for continued stream function.	Low priority because development pressure is low and the reach is steep and relatively stable.
T12.02A-1	Stage III good condition, ledges, many mass failures.	Protect stream corridor to allow for continued adjustment.	High priority due to the current adjustments.
T12.02A-2		Pursue high priority corridor protection at downstream mainstem reaches to attenuate the sediment inputs from the mass failures.	The next attenuation area would be M19B, although it is incised, because there is not much potential for attenuation along Lincoln Brook.
T12.02B-1	Stage IV Fair condition, low development, low erosion, no riprap, aggradation and planform following 1998 flood, hay field in upper portion of segment.	Protect River Corridor to allow for continued adjustment and passive restoration.	High priority due to sensitivity and depositional areas.
T12.02B-2		Plant stream buffer where lacking (the hay field).	High priority due to relative channel stability and potential to improve habitat.
T12.03A-1	Stage II Fair condition, incision following 1998 flood, ledges, Some erosion, low riprap and development. Two areas with berms, a) One in the lower reach above a culvert for the McCuin driveway, and b) 3 areas of berm toward the upstream end of the segment.	Remove berms. a) Remove berm in conjunction with replacing the undersized culvert for the McCuin driveway to restore some floodplain upstream of the culvert, b) Remove berms to allow for channel to regain meandering profile and depositional areas.	Lower priorities due to the fact that the stream would remain incised even after berm removal.
T12.03A-2	2 culverts: a) One with deposition upstream, scour below, b) One with deposition below.	Replace culverts with appropriately sized structures and proper placement to reduce flooding and erosion hazards, address runoff issues from old logging roads and stream crossings,	High priority to reduce erosion hazards and sediment and habitat discontinuity.

Project #	Site Description	Project Description	Priority
T12.03A-3		Protect River Corridor to allow for continued adjustment and passive restoration of floodplain areas.	Priority depends on level of development pressure in this area.
T12.03A-4	There are some areas in the lower part of the reach by the house where woody vegetation is lacking.	Plant native vegetation where lacking.	Medium priority to improve habitat and strengthen banks.
T12.03B-1	Reference condition, one gully adding sediment. Reference habitat.	Protect River Corridor to protect stream function and quality habitat.	Low priority due to low development pressure in this area, but may be higher to protect valuable habitat.
T12.02S1.01-1	Stage I reference condition, multiple falls and ledges, no encroachments, no erosion or riprap.	Protect River Corridor to move logging practices out of the corridor and therefore protect the habitat. Ensure any future logging practices/roads do not contribute sediment to the system.	Low priority due to the wooded corridor and low encroachment potential, but may be higher to protect valuable habitat.
T12.2S2.01-1	Stage II fair condition, widening and aggradation, some incision, but one ledge and coarse substrate help protect the bed. No encroachments, some bank erosion, no riprap.	Protect River Corridor to allow for passive restoration.	Medium priority due to the wooded corridor but possible encroachment potential.
T12.2S2.01-2	Perched culvert at Lincoln Gap Rd with deposition above and scour below.	Replace Lincoln Gap Rd culvert with one of appropriate size and placement.	High priority due to the sediment discontinuity and erosion hazard created by the current structure.
T12.2S2.01-3	A pasture extends into the corridor in the downstream part of the reach.	Plant native vegetation in the pasture area in the corridor.	Low priority due to the small area of encroachment.
T12.2S3.01-1	Stage I Reference condition, multiple falls, no encroachments, erosion, or riprap. Nearly entire reach is controlled by bedrock.	Protect the River corridor to prevent logging in the corridor to protect the valuable habitat.	Low priority due to low development pressure and current wooded corridor.
T12.2S4.01-1	Stage III Fair condition. Multiple ledges and falls. One old abutment with deposition above constricts the channel. Some riprap. Aggradation of fines from road runoff. Encroachment of road with berm and houses by Hanks Rd.	Remove old abutment as this is an unnatural sediment trap and could erode in a high flow.	High priority to reduce erosion hazards and sediment discontinuity.
T12.2S4.01-2	One perched culvert for Lincoln Gap Rd with scour below constricts the channel.	Replace the culvert with one of appropriate size and orientation to alleviate the sediment and habitat discontinuity issues.	High priority to reduce erosion hazards and sediment and habitat discontinuity.
T12.2S4.01-3		Protect the River Corridor to prevent further encroachments and development in the corridor and to allow for passive restoration.	Medium priority due to stability of channel but possible continued development pressure.
T12.2S4.01-4		Plant woody vegetation where possible in the	Low priority due to small areas.

Project #	Site Description	Project Description	Priority
		residential area.	
T12.2S4.01-5	The major problem in this reach appeared to be the sedimentation originating from the road.	Address the runoff and sediment loading from the road with better road management. The Better Backroads program could help.	High priority to reduce sediment loading of the stream and associated geomorphic and habitat impacts.
T13.01-1	Stage III Fair condition, incision historical, related to road construction and 1998 flood. Roads, berms, and one area of development encroach.	Not much can probably be done here, as Route 100 is likely to persist in its current location, preventing significant channel adjustment. Possibly investigate some habitat improvement measures for this reach and Protect the River Corridor at a downstream (M20, M22, M23A) attenuation area as a high priority.	Medium priority as geomorphology cannot be improved, but habitat value could be increased.
T13.02-1	Stage III Fair condition, extreme aggradation. Multiple ledge grade controls, 3 bridges constricting the channel are decaying and may not be used, especially since the road has washed out just upstream of the second bridge (before the old cabin, which did not appear used recently). Road encroaches in most of corridor. Some incision and erosion, no riprap.	Remove road and associated berm and three bridges to restore narrow floodplain area and reduce erosion hazards. At the least, remove the third (upstream most) bridge, as it is no-longer accessible due to the road washout.	High priority to reduce erosion hazards and sediment and habitat discontinuity.
T13.02-2		Protect the River Corridor to allow for continued adjustments and passive restoration.	Low priority if development is not possible.
T13.03-1	Stage III Fair condition, extreme aggradation and planform adjustment. Road encroachment in part of the corridor, road can no longer be accessed due to washout downstream. Some incision. Upper portion in Breadloaf Wilderness.	Protect the River Corridor (that part not in Breadloaf) to allow for continued adjustments and passive restoration.	Low priority because corridor is wooded and the road washed out so access is limited at this time.
T13.03-2		Remove road, as it is not accessible or discontinue maintenance.	High priority to restore limited floodplain areas and remove the encroachment.
T13.04	Stage III fair cond, aggradation and some localized widening. In the Breadloaf Wilderness area, so presumably the corridor is already protected.	No recommendation other than to keep this area protected from encroachments or future logging efforts.	Low priority as this area is apparently already protected.
T13.2S1.01-1	Stage IIc (F model) Good condition, multiple falls and ledges, some aggradation and widening, recovering to the 1998 flood. Bedrock controls at upstream and downstream ends.	Protect River Corridor to prevent any future logging or road building within the corridor.	Low priority as this area is wooded and currently inaccessible due to the road washout.

7.0 Recommendations

7.1 Future River Corridor Planning

The data collection, analysis, stressor mapping, and preliminary project identification completed as part of this Phase 2 project have significantly advanced the corridor planning efforts for the Mad River headwaters reaches. Landowner outreach to identify social constraints to project implementation was beyond the scope of the current project. Below we have highlighted four high priority project approaches that should be considered for future corridor planning efforts. These general projects were selected according to compatibility with a corridor approach to geomorphic restoration and immediacy of possible action, and would require further investigation and landowner outreach prior to being prioritized for implementation. Projects details can be referenced in Table 6.2.

1. Address stream crossing issues throughout the entire study area. Work with Better Backroads or WHIP to replace those structures in need of replacement. Work with towns to adopt the RMP recommended structure sizing criteria for those structures recommended for resizing when they come up for replacement.
2. Protect and look for ways to enhance high priority floodplain areas such as in M20, M22, M23 and along the mainstem of Lincoln Brook.
3. Address stormwater issues in M23-B, M23-C (on a tributary) and T12.2S4.01.
4. Remove road berms and bridges along Stetson Brook as the road has washed out and is no longer accessible.

7.2 Additional Phase 2 Surveys

The Phase 2 assessments carried out in this study covered the headwaters areas most impacted by the 1998 flood event. However, one additional area that was not heavily impacted by the epicenter of the rainfall event should be considered for Phase 2 assessment. Two tributaries draining to Segment M23-C from the northeast (M23-S1.01 and M23-S2.01) appear to be supplying high sediment loads to the Mad River mainstem. Tributary S1.01 has a high road density associated with Alpine Village and other low density residential development stemming from Chatfield and Prickly Mountain Roads (see Figure 5.42). In addition, large, contiguous wetland areas have been impacted in this upslope area. The combination of these two factors has likely led to increased stormwater runoff and decreased flood attenuation, and may be leading to increased sediment export due to channel evolution processes (i.e., stage II). Cursory field observations along lower Plunkton Road indicated that Tributary S2.01 is incising and has reduced floodplain access due to encroachment from Prickly Mountain Road. Numerous aggradational features (i.e., steep riffles and flood chutes) were observed along Segment M23-C at the confluence with the Tributaries (see Figure 5.44), indicating that they are delivering large quantities of fine and coarse sediment to the Mad River. This sediment supply has degraded some areas of important habitat for native trout in lower M23-C (RHA = fair).

Given the observations summarized above, we recommend Phase 2 assessment of reaches M23-S1.01 and M23-S2.01 (Figure 7.1). The total channel length for the tributaries, according to the Phase 1 dataset, is 1.9 miles. However, the inclusion of additional subtributaries draining to the main channels in S1.01 would aid in future project identification efforts, and would likely result in a total of 3 to 4 stream miles for this area.

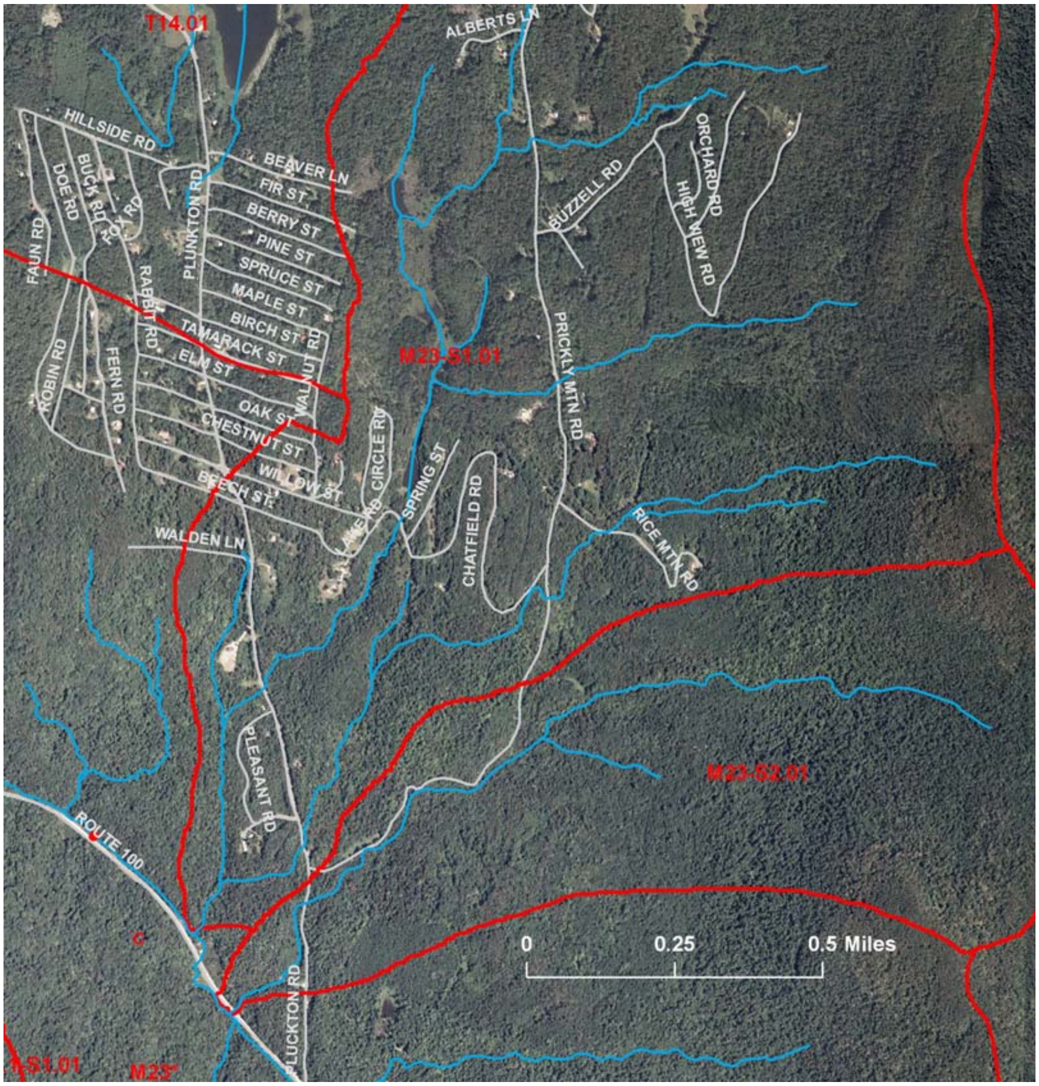

Figure 7.1 Tributaries recommended for future Phase 2 assessments.

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Acronym List

DMS – Data Management System (Developed by the DEC)
FEH – Fluvial Erosion Hazard zone or corridor
FIT – Feature Indexing Tool in SGAT for data input
FMR – Friends of the Mad River
GIS – Geographic Information System
GPS – Global Positioning System
LWD – Large Woody Debris
MF – Mass Failure (stream banks)
RCP – River Corridor Plan
RGA – Rapid Geomorphic Assessment
RHA – Rapid Habitat Assessment
RMP – River Management Program
SGA - Stream Geomorphic Assessment
SGAT – Stream Geomorphic Assessment Tool
VT ANR DEC – Vermont Agency of Natural Resources Department of Environmental Conservation

Glossary of Terms

Aggradation - The build up of sediment in a streambed.

Avulsion – A change in a river's course; a section of channel that has moved laterally from its bed to create another segment of channel some distance from the previous bed location.

Bankfull width - The width of the channel at a height corresponding to the level of stream flow that would overtop the natural banks in a reference stream system, occurring on average 1.5 to 2 years.

Bankfull maximum depth – The depth of the channel from the bankfull elevation to the thalweg (see below).

Confinement – Referring to the ratio of valley width to channel width. Unconfined channels (confinement of 4 or greater) flow through broader valleys and typically have higher sinuosity and area for floodplain. Confined channels (confinement of less than 4) typically flow through narrower valleys.

Debris jam - A collection of large woody debris that has lodged in a stream channel and spans the channel from bank to bank.

Degradation or incision - Down cutting of the streambed by erosion of bed material.

Embedded – Larger bed substrate particles (gravels, cobbles, boulders) surrounded by fine sediment, reducing the oxygen in the substrata and the ability of organisms to retreat into the substrata for cover.

Entrenched - A state where a channel has lowered significantly and floodwaters can no longer overtop the banks and access the floodplain.

Flood chute - A small side channel crossing the inside of a meander bend where flood waters will bypass the main channel, taking a shorter route through the chute.

Floodprone width - The area outward from the channel that is at an elevation that could be inundated by a flood, measured in Phase 2 SGA as at an elevation of 2 times the bankfull maximum depth.

Grade control – A fixed surface on the streambed that controls the bed elevation at that point, effectively fixing the bed elevation from potential incision, typically bedrock or culverts.

Head-cut – A sharp change in slope, almost vertical, where the streambed is being eroded from downstream to upstream.

High gradient streams - Typically found in steep, narrow valleys, these streams have steep slopes and are usually fast moving with many riffles or steps and low sinuosity.

Impervious surface – A hard surface, such as concrete or a rooftop, which prevents water from infiltrating the soil.

In Regime – Referring to a stream that is in an equilibrium state, one that would be expected given the stream setting.

Large woody debris - Pieces of wood in the active channel (within the bankfull width) usually from trees falling into the channel and with minimum dimensions of 12 inches in diameter (at one end) by 6 feet long.

Low gradient streams – Typically found in wide valleys, these streams have shallow slopes and are usually slow and meandering.

Meander – A bend in a stream, or referring to the way a stream winds down its valley.

Sinuosity - The level of bends or turns in a stream, calculated by dividing the stream length by the valley length.

Thalweg – Deepest point along the length of the stream, as if the deepest point of all cross sections were connected. The thalweg of a meandering channel typically alternates from right to left bank connecting pools.

Width/depth Ratio – The ratio of channel bankfull width to the average bankfull depth. An indicator of channel widening or aggradation.

Windrowing - Digging material from the channel bed and piling it on the bank, creating berms.

List of Resources/Links:

- River Corridor Planning Guide from ANR River Management Program - http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_rivercorridorguide.pdf
- Flood hazard management information from ANR River Management Program - http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_floodhazard.htm
- Alternatives for River Corridor Management (RMP paper) - http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_managementAlternatives.pdf
- Municipal Guide to Fluvial Erosion Hazard (from RMP) – http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_municipalguide.pdf
- ANR Buffer Guidance – http://www.anr.state.vt.us/site/html/buff/BufferGuidanceFINAL-120905.pdf