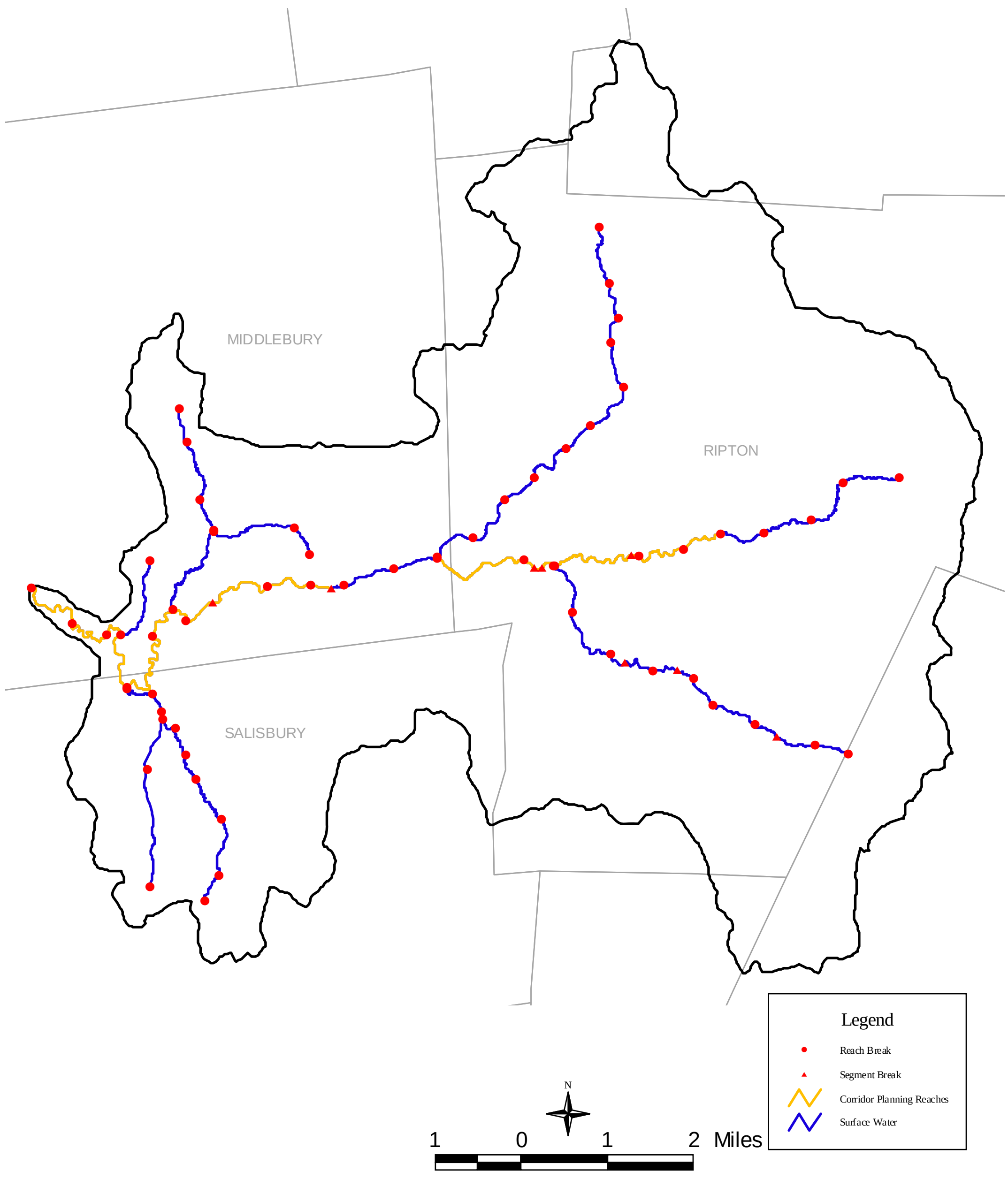
Middlebury River Watershed
River Corridor Conservation Plan
Main Stem and Middle Branch
October, 2008



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1.0 Executive Summary

Historic and present human alterations to the landscape have increased the rate and volume of water and sediment flows in the Middlebury River Watershed. In the past, almost complete deforestation at the end of the 19th century combined with damming, channel moving, straightening, berming and rip-rapping for road construction and agriculture altered the natural pattern (sinuosity), dimension (width and depth) and profile (slope) of the stream channel. These past management practices continue to increase the volume and rate of water and sediment flowing into the channel.

A river system left to its own devices will, over time, establish an “equilibrium” pattern, dimension and profile (planform) that will transport water and sediment evenly throughout the watershed. A river system that is managed to transport water and sediment through some areas (by straightening, rip-rapping flows and otherwise increasing the capacity for water and sediment movement) will gain force, increasing impacts to downstream areas.

River management at the watershed scale seeks to reduce the long-term costs and risks of erosion and flood damage to downstream reaches by identifying critical areas throughout the watershed to provide for short and long term storage of water and sediment during storm events (managing toward equilibrium). Other benefits that come from managing at the watershed scale include a reduction in the amount of sediment and nutrients entering the stream system from human land uses and improved aquatic habitat.

The main erosion hazards along the Middlebury River are human built encroachments in the river corridor. These encroachments include residential development in the villages of East Middlebury and Ripton and Route 125 between the two villages. Human land uses that have caused disequilibrium in the Middlebury Watershed include: straightening, loss of wetlands, loss of riparian buffers, eroding banks, and undersized structures.

Managing for equilibrium watershed wide will allow the river to regain a new, relatively stable planform that reduces erosion hazards and expenses related erosion and flooding. This plan identifies a list of restoration activities which, if implemented, will reduce long term conflicts between the river and human land uses, moving the stream system toward a self maintaining equilibrium condition. Restoration activities recommended in this plan are: protect the river corridor, plant stream buffers, stabilize eroding banks, arrest erosion of the stream bed, remove unnecessary berms, remove or replace undersized structures, restore access to floodplain and restore reaches that are building up large amounts of sediment.

2.0 Project Overview

2.1 Introduction

Over time and in the present climate, a river left in its natural state will maintain an equilibrium condition. A stream in a state of equilibrium will maintain a relatively stable channel, reducing erosion hazards and flood damages and providing a diverse habitat for aquatic organisms. Historically, humans have sought to control rivers by moving, straightening, hard armoring and dredging them. This has caused disequilibrium in many locations and creates expensive on-going management concerns.

The goal of river corridor planning is to utilize stream geomorphic assessment data to determine the river's current degree of departure from the reference equilibrium state and to identify existing constraints to the river evolving back to equilibrium. The analysis results in a prioritized list of restoration projects that may be implemented over the long-term by individuals and organizations interested in reducing expenses related to flood and erosion hazards, reducing sediment pollution entering the Middlebury River and in improving aquatic and terrestrial habitat within the watershed. This river corridor planning process identified potential restoration actions for each assessed reach and /or segment of the Middlebury River. The Steering Committee prioritized the top ten actions, based on both ecological and social considerations and one project has been advanced to implement at this time.

2.2 Project Partners

The Addison County Regional Planning (ACRPC), with funding from Vermont Department of Environmental Conservation (DEC), hired Landslide Natural Resource Planning Inc. to complete this River Corridor Plan. The Steering Committee was comprised of: Kevin Behm and Tim Bouton both with ACRPC, Jack Brown, East Middlebury resident, Fred Dunnington, Middlebury Town Planner, Peter Hubbard, Middlebury resident, Warren King, Ripton resident, Shannon Pytlik, River Scientist with DEC River Management Section, and Amy Sheldon, President Landslide Inc. and Ethan Swift, Basin Planner with DEC.

2.3 Background

In 2003 South Mountain Research and Consulting Services completed a Phase 2 and limited Phase 3 Stream Geomorphic Assessment study of the Middlebury River and its major tributaries, the North, Middle and South branches. In 2007 this data was updated to include parameters that were not being collected in 2003 and to double check some of the cross sections. The extensive 2003 report documents historic management practices that have altered the Middlebury River Watershed and makes recommendations for potential restoration activities within the watershed. River corridor planning utilizes the Phase 2 data and recommendations to identify specific activities that may be implemented to move a stream toward equilibrium.

Throughout this document, reference will be made to stream "reaches" and "segments". The Phase 1 SGA defined 54 sub-watersheds that comprise the Middlebury River watershed (a watershed is an area of land that all drains into the same body of water). The sub-watersheds define 54 distinct reaches of the streams within the watershed. Forty-three of these reaches were assessed during the Phase 2 SGA, 19 on the main stem, including the Middle Branch, 10 on the

North Branch and eight on the South Branch. Some of the reaches were segmented after field evaluation based on changes found within the reach. Figure 1 in Appendix A is a map of assessed reaches with reach and segment breaks shown. This corridor plan is only considering the main stem and Middle Branch, reaches M01-M15.

2.4 Geomorphic Setting

The Middlebury River is a tributary of the Otter Creek, which is located in the Champlain Valley of Vermont. It drains an area of 63 square miles or 40,207 acres and its headwaters are on the west side of the Green Mountains in Ripton. The upper watershed is typified by higher gradients and relatively narrow valleys whereas the lower watershed is characterized by broad valleys and lower gradient stream beds. The village of East Middlebury is located in an alluvial deposition area where the river transitions from the very steep Middlebury Gorge to the lower gradient Champlain Valley. This is an area where the river would naturally deposit large amounts of sediment and have multiple channels. It has been constrained by straightening, berming and hard armoring for decades through the village area, lengthening the transport zone from just downstream of the Lower Plains bridge area to down stream of the Grist Mill bridge area. The village of Ripton is similarly located in an area of high natural deposition where the Middle and South branches converge. Development of these depositional areas has reduced the area available to the river for flood and sediment attenuation (storage), thus increasing the rate and volume of water and sediment moving through the system during high flow events. The location of these settlements in areas of natural volatility makes them particularly susceptible to both inundation and erosion hazards. In addition to increased dispersed development in the headwaters of all three of the main branches, the headwaters of the South Branch contain the Middlebury College Snow Bowl ski area.

The Middlebury River Watershed was flooded during the major statewide flood events of 1927, 1938 and 1973 and it has also experienced numerous localized flood events which seem to be increasing in their frequency. Floods have occurred in: 1913, 1936, 1947, 1958, 1960, 1976, 1984, 1989, 1996, 1998, 2000 and 2006. Due to significant longitudinal changes in elevation and topography along the river, not all of these flood events affected both the upper and lower portions of the watershed (see Underwood, 2003 for details). Until the late 1980's the conventional response to a flood event was to dredge, berm and hard armor the river "in place". These conventional channel management activities have resulted in many entrenched and incised and often over-widened reaches that are contained in the channel even during high flow events. Natural channel equilibrium cannot be re-established in the Middlebury River watershed where the channel is kept straightened and hard armored and even high flows remain in the channel, not having access to the floodplain. The river will continually seek to re-establish a stable planform and continue to erode both vertically and laterally.

3.0 Departure Analysis and Stressor Identification

A stream in "equilibrium condition" will maintain a relatively stable pattern (sinuosity), dimension (width and depth) and profile (gradient). These forms are created by inputs of water, sediment and debris. Changes to the watershed inputs at the watershed or reach scale will result in a disruption of equilibrium conditions until the channel has time to adjust its pattern, dimension and profile accordingly. Human changes to the landscape create stress on the existing planform and can push the stream into disequilibrium.

The Stream Geomorphic Assessments completed on the Middlebury River and its tributaries provide an inventory of the human induced stressors that are causing disequilibrium. In Section 3, watershed and reach scale stressors have been mapped and organized to develop a “watershed story” that describes the current geomorphic condition of the watershed and individual reaches. This information is used in Section 4 to identify and prioritize the restoration activities that will be most effective in re-establishing watershed equilibrium and thus reducing flood and erosion hazards, reducing sediment and nutrient loading and improving habitat.

3.1 Watershed Scale Stressors

3.1.1 Hydrologic Stressors

The volume and rate at which water, sediment and debris flow through a stream system, combined with the resistance of the bed and bank material, work together to form the channel over the long-term. Increases or decreases to the volume and rate of water entering the stream (the natural hydrologic regime) can push a stream into disequilibrium, leading to increased flood and erosion hazards. Hydrologic stressors and physical constraints that impact the volume and rate of water and sediment moving through the stream system were analyzed to aid in our understanding of current channel adjustment processes. Hydrologic alterations within a watershed that does not have flow gauges must be evaluated indirectly using data on changes that are known to impact the hydrologic regime. Among the things that can affect the volume and rate of water entering a watershed are deforestation, dams, loss of wetlands, development and related increases in storm water runoff, and ditching related to roads, farm fields and skid ruts (VT ANR RCPG, 2007).

Deforestation affected most of the state of Vermont, with almost complete clearing occurring by the end of the 19th century and re-forestation to 75% forest cover by the end of the 20th century. Trees reduce the volume of water and sediment that flow into the channel. It is likely that the Middlebury River is still re-bounding from the loss and gradual re-growth of forest cover, and some of the historic incision and subsequent widening found in the watershed is related to the increased flows and floodplain accretion resulting from the historic loss of trees.

The presence of dams in the watershed alters the flow of water and sediment upstream and downstream of the structure. There is one historic run-of-the-river mill related dam on the assessed reaches of the Middle Branch of the Middlebury River, on M14. Run of the river dams do not alter the amount of water in the stream, but they can reduce the amount of sediment entering downstream reaches and can result in downstream bed degradation. The downstream reach, M13 is not entrenched, but it is incised and it has two grade controls on it which increase bed resistance and arrest degradation.

Wetlands provide critical storage of surface water during big storm events. They act as sponges, soaking up and holding water, reducing the volume of water and sediment entering streams at any given time. Wetlands are lost when they are drained and filled for agriculture, for road construction or other human development. Wetland loss in the Middlebury River Watershed is primarily associated with agriculture, roads and residential development. It was found to be high on reaches: M01, M04 – M06 and M13

Urban development increases surface water runoff into the streams by removing natural vegetation and creating "impermeable surfaces" (roofs and roads) that no longer absorb rainwater. Roads are related to development and also considered "urban land" in this analysis. Twenty-five percent of the assessed length of river has road directly adjacent to one side of it. This increases both impermeable surface area and results in the removal of trees within the corridor which are important for absorbing surface water runoff, stabilizing stream banks and shading waterways to reduce water temperatures for aquatic animals.

The River Management Program (RMP) considers a watershed with between 5 and 10% "urban" or developed lands to have an altered hydrologic regime. Urban development in all of the reaches of Main Stem and Middle Branch is less than 5%.

Storm water inputs are an impact associated with increased human development. Storm water inputs concentrate flows that would otherwise be spread out over land, causing them to discharge directly into the stream, thus increasing the amount of water the stream carries at a given time. There are relatively few storm water inputs in this watershed, with the highest concentration being found on reach M11. (See Figure 3 in Appendix A.)

In this analysis, hydrologic alterations were considered "Extreme" if there is significant wetland loss in the sub-watershed and if road density was found to be extreme or very high. Throughout the assessed area, development is rarely found on both sides of the river but often a road is found along one side of the river. Hydrologic impacts were considered "High" if wetland loss and road density were high. Hydrologic impacts were considered "Moderate" if road density was moderate and wetland loss was minimal, corridor development was the primary land use on one side of the corridor and urban development within the sub-watershed was between 5 and 10%. Four reaches had moderate alterations to the hydrologic regime. No reaches were found to have a "low" impact. (See Table 1 in Appendix B.)

3.1.2 Sediment Load Indicators

A stream that is in equilibrium will transport both fine and coarse sediment such that channel slope, depth and sinuosity remain stable over time. Human alterations to the landscape can act to increase or decrease the sediment load watershed wide, leading to bed degradation (downcutting) or aggradation (rising) which affects channel slope and depth. The hydrologic alterations discussed above impact the streams ability to store and move sediment. The amount and location of sediment moving through the stream channel impacts flood attenuation (storage of sediment and water), nutrient loading and aquatic habitat. Alterations to the equilibrium sediment load are not directly measured in the Phase 2 SGA, instead, observable features such as steep riffles, mid-channel bars, delta bars, flood chutes, avulsions, braiding, mass failures, gullies and length of eroding banks provide evidence to assist in the identification of stream segments that are in adjustment due to sediment load modifications. Along the main stem and Middle Branch, the left bank is 14% eroding and the right bank is 12% eroding. (See Figure 4 in Appendix A for a map of Sediment Load Indicators.)

In this analysis, sediment load impact was rated none, increased or greatly increased based on: the number of steep riffles, mid-channel bars or delta bars; the number of flood chutes, avulsions or braiding; the percent of eroding banks and the number of mass failures and gullies. Sediment load was found to be greatly increased on reaches M04, M05, M07, M11, M12 and M14. Sediment load was found to be increased on reaches M01, M02, M03, M06A&B, and M13A&B. Reach M15 had neither an increase nor decrease and M08A has a decreased sediment load. (See Table 1 in Appendix B.)

3.2 Reach Scale Stressors

Sediment transport capacity is affected at the reach scale by modifications to the valley, floodplain and channel as well as to boundary conditions. These changes alter the way that sediment is transported and sorted, affecting channel stability and in-stream habitat (RCPG, 2007). Reach scale stressors have been organized by whether they increase or decrease sediment transport as a function of slope and depth (energy grade) and boundary conditions. Boundary conditions (resistance to increases in the stream's power) can be increased or decreased in the bed or on the banks and may be natural or man made. Understanding reach scale stressors and limits assists in putting reaches into the overall watershed context.

3.2.1 Channel Slope and Depth Modifiers

Increases in channel slope and depth will increase the channel's capacity to transport sediment and water. Conversely, decreases to slope and depth will decrease the channel's ability to transport sediment and flood waters, increasing water and sediment storage capacity. Sediment transport capacity will be increased by straightening, river corridor development and encroachments (berms and roads) and in specific locations below grade controls or channel constrictions (undersized bridges and culverts), where the stream was dredged and below storm water outfalls. Sediment transport capacity can be decreased upstream of dams, channel and floodplain constrictions and at confluences and other back water areas.

Stream power in the Middlebury River Watershed was found to be increased on M06A,B, M07, M08A, M11 and M15 due to dredging, encroachments and straightening. There was no increase in stream power found on reaches M01, M02, M03 and M13B. A decrease in stream power was found on M04, M05, M13A and M14 due to deposition. Both an increase and decrease in stream power was found on reaches M12 A and C. No beaver dams were found on the assessed reaches. (See Table 1 in Appendix B.)

Channel straightening increases stream power by increasing channel gradient and flow velocity, causing a downcutting the channel bed (increasing slope) and triggering disequilibrium. Eventually, the stream banks will fail and the stream will over-widen. A total of 1.6 miles or 14% of the assessed channel length, on six reaches/segments were found to be straightened. (See Figures 5 and 6 in Appendix A.)

Development, including roads, within the corridor increases the volume of water flowing into the stream, causing bed degradation and an increase in slope. Roads occur along 25% of one side of the channel corridor with M03 being the only reach with roads on both sides for 713 feet. Development in the river corridor on the Main Stem and Middle Branch is 8% on one side only and 2% on both sides. Channel constrictions from undersized bridges and culverts, can increase channel slope down stream by concentrating flows and reducing the amount of sediment available to the stream. Reaches M01, M03, M05, M08A & B, M12A, M13A and M14 all have man made channel.

3.2.2 Boundary Condition and Riparian Modifiers

The ability of the channel bed and bank to resist the forces exerted on it by water and sediment determines whether and how a stream will undergo adjustment (RCPG, 2007). Resistance to bed and bank erosion may be increased or decreased by human alterations. Stressors that decrease bed resistance are: snagging, dredging, and windrowing and removal. Removal of riparian buffers reduces stream bank resistance. Grade control and bed armoring will increase bed resistance to erosion and bank armoring increases bank resistance to erosion, decreasing the streams ability to move laterally. (See Figures 7 and 8 in Appendix A and Table 1 in Appendix B.)

Two segments, M03 and M08A, were found to have increased bed and bank resistance due to hard armoring (rip-rap) and/or the presence of ledge or a coarse bed. All of the remaining assessed segments have decreased boundary resistance due primarily to eroding banks and, to a limited degree, a lack of riparian buffer.

3.3 Constraints to Sediment Transport and Attenuation

3.3.1 Reference and Existing Sediment Regimes

Human induced alterations to the watershed hydrologic and sediment regimes and reach based stressors can push a stream reach into disequilibrium. Past restoration efforts have applied spot fixes to erosion hazards, requiring expensive on-going maintenance at best and driving problems downstream at worst. More recently, reach scale considerations have been included in restoration planning, but still with limited success. Watershed based restoration project design includes consideration of changes to the sediment and flood attenuation (storage) and transport capacity of upstream and downstream reaches. The Vermont River Management Program has developed a procedure for organizing hydrologic and sediment regime stressor data into five different sediment regime categories that summarize existing and reference sediment and flood transport and attenuation capacity. This provides the basis for an informed restoration project selection process that accounts for departure from reference condition in upstream reaches.

Streams that are in reference sediment regime generally fall into one of two categories: Transport and Coarse Equilibrium/Fine Deposition. Transport streams are those streams that are high gradient, naturally confined and have bedrock, boulder or cobble substrates. Coarse Equilibrium/Fine Deposition are streams that are in unconfined valleys and naturally provide areas for flood and sediment storage through flood plain access. Streams in disequilibrium or undergoing channel evolution will fall into one of the following three categories: Confined Source and Transport, Unconfined Source and Transport and Fine Source and Transport. See VT ANR RCPG, 2007 for Sediment Regime Descriptions.

In the absence of human impacts, the Middlebury River main stem and Middle Branch would primarily function as a Coarse Equilibrium/Fine Deposition stream, where water and sediment entering a reach would be equal to water and sediment leaving a stream. Floodplain access would be common on these reaches. Reaches and segments M01-M08A, M13 and M15 are Coarse Equilibrium/Fine Deposition in reference condition and M11 and M14 are steeper transport streams by reference. Currently, only reach/segments M01-M06A and M13 are in Coarse Equilibrium/Fine Deposition regime and transport reaches M11 and M14 are both in regime. M06, M07, M08A, M12A & C and M13B are converted to Fine Source and Transport/Coarse Deposition and M15 is Confined Source and Transport. This means that seven formerly Coarse Equilibrium/Fine Deposition reaches/segments have been converted to Transport type streams. Streams that have been converted from Coarse Equilibrium/Fine Deposition to Transport have reduced sediment and flood attenuation (storage) capacity on that reach and reduce capacity watershed wide, increasing demand on downstream reaches for flood and erosion hazard attenuation.

3.3.2 Vertical and Lateral Constraints and Attenuation Assets

In addition to reference and existing sediment regimes, vertical and lateral constraints were analyzed as well. (See Table 2 in Appendix B.) Vertical constraints are natural grade controls and man-made channel constrictions that act to reduce the slope of the stream and prevent it from down-cutting. Constraints to lateral migration of the stream include existing rip-rap, roads, houses, development and berms. Identifying these features assists in the identification of river segments where there are few constraints to lateral migration and therefore the possibility of restoring flood and sediment storage areas exists. (See Table 3 in Appendix B.)

Attenuation assets are those segments that provide for flood and sediment storage during and between major flood events. As mentioned earlier, natural transport streams do exist in the watershed. These are areas where, even in reference condition, not much flood or sediment storage occurs. However, much of the watershed would naturally function to provide flood and sediment storage. An analysis of reference and current transport and attenuation capacity was completed to identify segments that are currently or will evolve on their own, into attenuation assets. Ten segments are currently providing flood and sediment storage and are listed in Table 2 of Appendix B. Those reaches that have few lateral constraints and are currently attenuation assets are considered a high priority for watershed scale restoration and protection of equilibrium condition.

3.3.3 Sensitivity Analysis

The Vermont DEC River management Section has developed a five level sensitivity rating for streams based on current stream type and adjustment. Sensitivity ratings attempt to predict how rapidly a given stream type is expected to adjust (move laterally) given its current geomorphic condition. The rating scale is low, moderate, high, very high, and extreme. See Figure 11 in Appendix A for a map of sensitivity and current vertical adjustment.

Sensitivity ratings were used assist in restoration project prioritization by identifying segments where rapid channel planform adjustment may occur in the presence of valuable human-built infrastructure. Table 3 in Appendix B prioritizes reaches for restoration based on sensitivity, current adjustment and potential threats to infrastructure. The results were incorporated into project identification tables discussed in the Section 4.

4.0 Preliminary Project Identification and Prioritization

An understanding of the human impacts at work throughout the Middlebury River watershed is necessary to prioritize restoration efforts. Spot fixes that do not take larger scale sediment and flow into account have historically proven expensive and unsustainable. Managing a stream toward long-term geomorphic equilibrium can be accomplished when attenuation of upstream increases in flow and sediment are accommodated. Restoration activities that seek only to address local or reach scale stressors may transfer energy and therefore, the problem, down stream.

The Vermont DEC River Management Program has developed a step wise procedure for identifying and prioritizing restoration projects. The categories of projects are: 1. Protect River Corridors; 2. Plant Stream Buffers; 3. Stabilize Stream Banks; 4. Arrest Head Cuts; 5. Remove Berms; 6. Remove or Replace Structures; 7. Restore Incised Reaches; and 8. Restore Aggraded Reaches. The first six restoration alternatives may be implemented without an extensive alternatives analysis, making them economically and technically more feasible. The final two, restoring incised reaches and aggraded reaches may require increased time and resources in the form of channel management practices and corridor land use changes.

The projects identified in Tables 4 and 5 of Appendix B provide a foundation for continued planning and restoration efforts. Table 4 identifies potential projects by reach and prioritizes them (highest priority in yellow). Table 5 examines the highest priority reaches in more detail, describing stressors and constraints and technical feasibility of the projects.

4.1 Protect River Corridors

River segments that are in equilibrium or are evolving toward equilibrium on their own, provide critical sediment and flood attenuation functions for the Middlebury River watershed. The main stem of the Middlebury River, has experienced widespread historic channel straightening, many corridor encroachments, and consequently, numerous segments have been converted from Coarse Equilibrium to Transport type streams. Due to the fact that both Ripton and East Middlebury are located in areas that would naturally store both flood waters and sediment and would likely experience regular planform adjustments and because much of the watershed has been converted to transport type streams with erosion being widespread, those reaches that are providing flood and sediment attenuation are critical to restoring equilibrium throughout the watershed.

Segments that are stable or stabilizing and have access to floodplain can provide “release valves” for the rest of the watershed, making corridor conservation along these segments the highest priority. Conservation and restoration of the attenuation assets upstream of Ripton Village and downstream of East Middlebury is critical to restoring equilibrium conditions in the watershed. Corridor conservation is a project alternative on reaches: M01, M02, M03, M04, M05, M06A & B, M12A, M12C, M13A&B, M14 and M15.

4.2 Plant Stream Buffers

Forested riparian corridors are one of the most cost effective means of providing erosion hazard protection, reducing sediment and nutrient inputs into the stream and improving habitat. Tree roots provide stability to stream banks, slowing erosion and holding onto sediment. Trees also provide shade for the stream corridor during the warmest months of the year, keeping water temperatures lower, which is important to cold water fisheries. Finally, when trees fall into the stream, they provide much needed in-stream habitat diversity by creating pools.

Because much of the Middlebury River and its tributaries are either currently forested or adjacent to roads, opportunities for tree planting are limited to the first four reaches where the river is in former floodplain forest lands that have been converted to agriculture. Much work has been done by the NRCS to restore riparian buffers in the lower portions of the watershed. Buffer planting opportunities have been identified on reaches: M01, M02, M03, M04, and M05.

4.3 Stabilize Stream Banks

Stream bank stabilization can be effective in arresting eroding banks when the stream is at or near equilibrium and the eroding banks are causing significant increased sedimentation to highly sensitive reaches or they have the potential to erode important human built infrastructure. Erosion is one of the greatest impacts in the watershed. Many of the hard armored banks along Route 125 between East Middlebury and Middlebury fail approximately every 10 years. Reaches appropriate for stream bank stabilization are: M03, M13A, M14 and M15.

4.4 Arrest Head Cuts

Head cuts are erosion of the channel bed from downstream to upstream. They can result in the rapid degradation (down cutting) of the stream bed, reducing floodplain access and transporting significant amounts of sediment to downstream reaches. There are no head cuts identified in the assessed reaches.

4.5 Removing Berms

Berms are used to keep flood waters contained in the channel. They increase channel depth, concentrating flows and lead to bed degradation. Removing historic berms that are no longer protecting homes or roads can be a cost effective way to re-establish floodplain access to incised streams. In 1989 after a major storm event a berm was built along the north side of M06 from approximately Goodro's Lumber downstream to the CVPS electric station. This berm is not adjacent to the stream channel, providing floodplain access between in and the current channel. Other berms identified for potential removal are on reaches: M04, M07 and M13A.

4.6 Remove/Replace Structures

Bridges and culverts with openings that are narrower than the bankfull channel width and are floodplain constrictions can cause deposition upstream and scour downstream and trigger disequilibrium. The concentrated flows may also scour around upstream abutments and erode banks downstream, resulting in structure failure. In instances where the road crossing is blocking the floodplain, the upstream ponding and downstream scour may be exacerbated. Additional floodplain culverts may be necessary in these circumstances.

There are numerous undersized structures on the Middlebury River that have been recommended for replacement. These structures need to be assessed to determine if the deposition above them is creating a constriction that is moving the stream toward equilibrium more quickly by re-creating gravel bars and increasing sediment and flood attenuation. In cases where the undersized structure is impeding the flow of water and sediment, leading to disequilibrium, the structure should be prioritized for replacement. A higher priority has been placed on structures that are derelict, however, there are some old abutments that may be may be historically significant, requiring another level of social consideration before their removal.

Reaches with undersized structures recommended for replacement are: M03, M08A, M12A, and M13A (multiple).

4.7 Restore Incised Reach

Incised reaches have cut down through channel bed material, reducing access to floodplain and concentrating flows. This increased flow transports sediment through the reach, disrupting channel equilibrium and depositing it at the next bend or channel constriction or when floodplain access is encountered downstream. Often habitat heterogeneity is destroyed by the scouring activity as the bed becomes dominated by larger particles that are resistant to the increased energy. From M06-M15 the Middlebury River is incised, except for M11 and M14. Some of these segments are destined to remain converted to transport, due to their relationship to roads and valley walls. However, some of the incised reaches may be restored by providing the river room to re-establish equilibrium and by re-connecting the channel to its floodplain.

Floodplain access may be accomplished by lowering the height of the existing floodplain to allow the channel to access it as widening and aggradation progresses. Floodplain access may also be accomplished by raising the channel bed through construction of a weir or by the creation of debris jams. Debris jams can be encouraged by dropping large woody debris into the channel. Finally, an incised reach may be relocated to an abandoned channel or flood chute that has access to floodplain.

Depositional reaches that have been converted to transport regimes result in an un-even distribution of energy along the channel length, increasing the chances for flood and erosion hazards. Restoring incised reaches by re-establishing floodplain access and by protecting areas that still have floodplain access will provide attenuation assets that are distributed throughout the watershed, ameliorating the impacts of watershed development. Incised reaches identified for potential restoration are: M07, M12 A and M12C.

4.8 Coordinating Restoration at the Watershed Scale

Re-establishing equilibrium at the watershed scale will reduce property damage related to flood and erosion hazards, reduce sediment and nutrient pollution and improve habitat. The allocation of resources available for river corridor restoration and flood and erosion hazard mitigation will be optimized by addressing instabilities at the reach scale that can affect improvements watershed wide. These projects have received the highest priority ranking in this plan (See Table 5 in Appendix B). Spot fixes in the downstream portion of the watershed will be met with a greater likelihood of success if the increased flow from upstream is addressed prior to attempting to stabilize eroding banks downstream.

5.0 Technical and Social Feasibility of Project Implementation

Watershed scale restoration represents a significant change from conventional river management. In the past, spot fixing eroding banks with rip-rap was thought to be the best and only solution to river conflicts. Educating landowners, town officials and others who work with the river will take time and effort but is necessary for restoration success. Projects identified and prioritized in this planning process are dependent upon willing landowners.

The towns of Middlebury and Ripton can do a lot to assist with the effort to restore the Middlebury River to equilibrium by establishing Fluvial Erosion Hazard zones. This is an area identified using SGA data that defines the extent of a river corridor that will accommodate the equilibrium condition and minimize erosion over time. FEH zones may be adopted by communities to reduce future conflicts (and costs related to those conflicts) between the river and houses. Additionally, town road crews can use the information in this plan to assist with the sizing of new and replacement bridges and culverts. As old structures are replaced, properly sizing them will be a big step toward providing for flood and sediment passage and reduced costs of structure maintenance.

6.0 Conclusions

The conservation and restoration of sediment and flood water storage areas (attenuation assets) will result in a more even distribution of water and sediment flow throughout the watershed where sediment can be stored and flow energy dissipated, reducing sediment loading and erosion hazards downstream. There are still opportunities within the river corridor to protect and restore flood and sediment attenuation areas. If development is allowed to occur in these areas, many of the highest priority restoration sites in the watershed could be permanently lost and with them, the hope of establishing equilibrium on the Middlebury River.

The primary erosion hazards and potential conflicts on the Main Stem and Middle Branch of the Middlebury River are development of the alluvial fan area in East Middlebury, development at the confluence of the Middle and South branches in Ripton, and roads, particularly Route 125, adjacent to the river. This conservation plan recommends focusing restoration resources in these areas as a priority for minimizing erosion hazards in the long term.

7.0 References

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Vermont Agency of Natural Resources. Vermont Stream Geomorphic Assessment Phase 2 Handbook – Rapid Stream Assessment Field Protocols. March, 2006.

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Middlebury River
Corridor Conservation Plan

Appendix A Maps

Figure 1. Main Stem Reaches

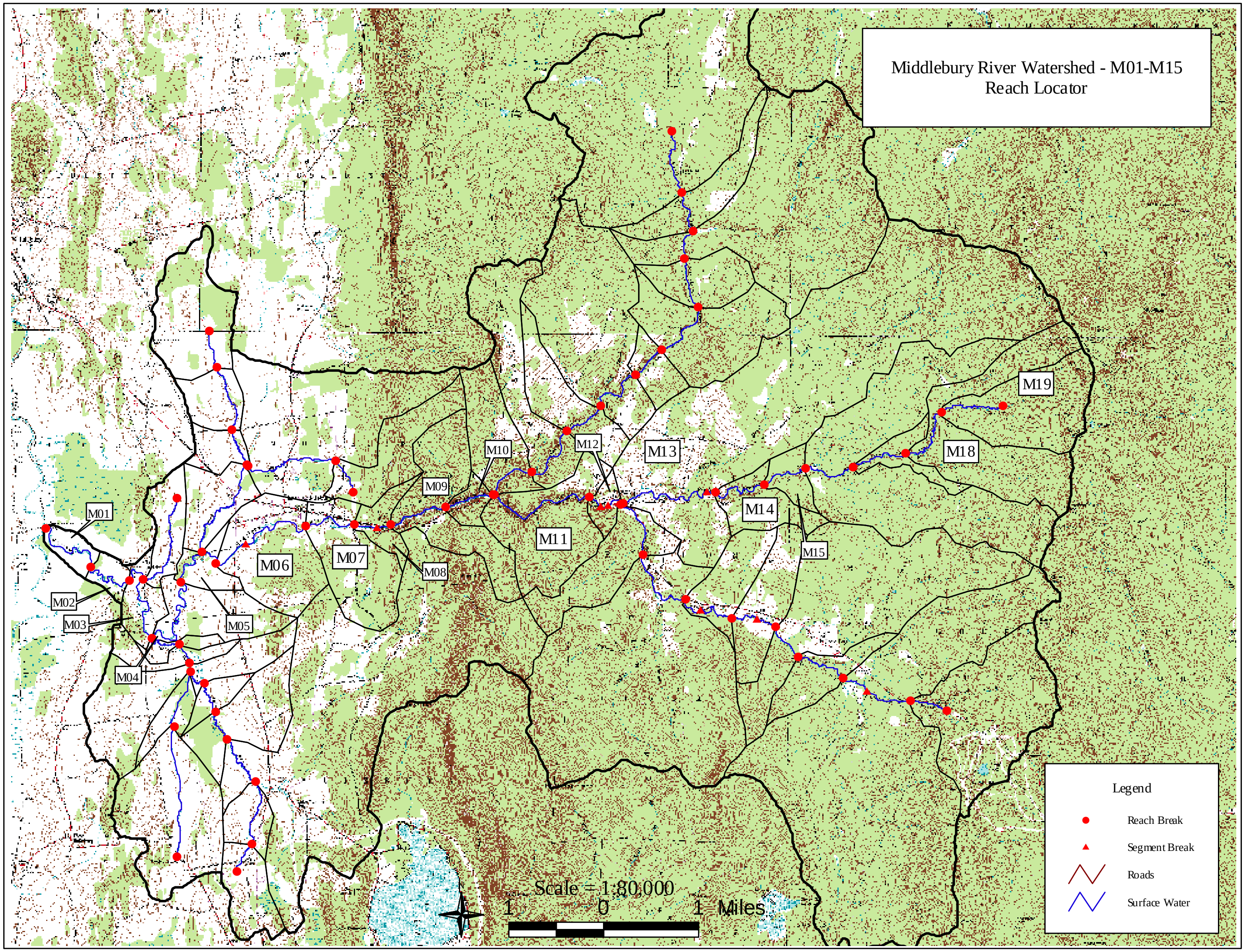


Figure 2. Historic Topographic Maps

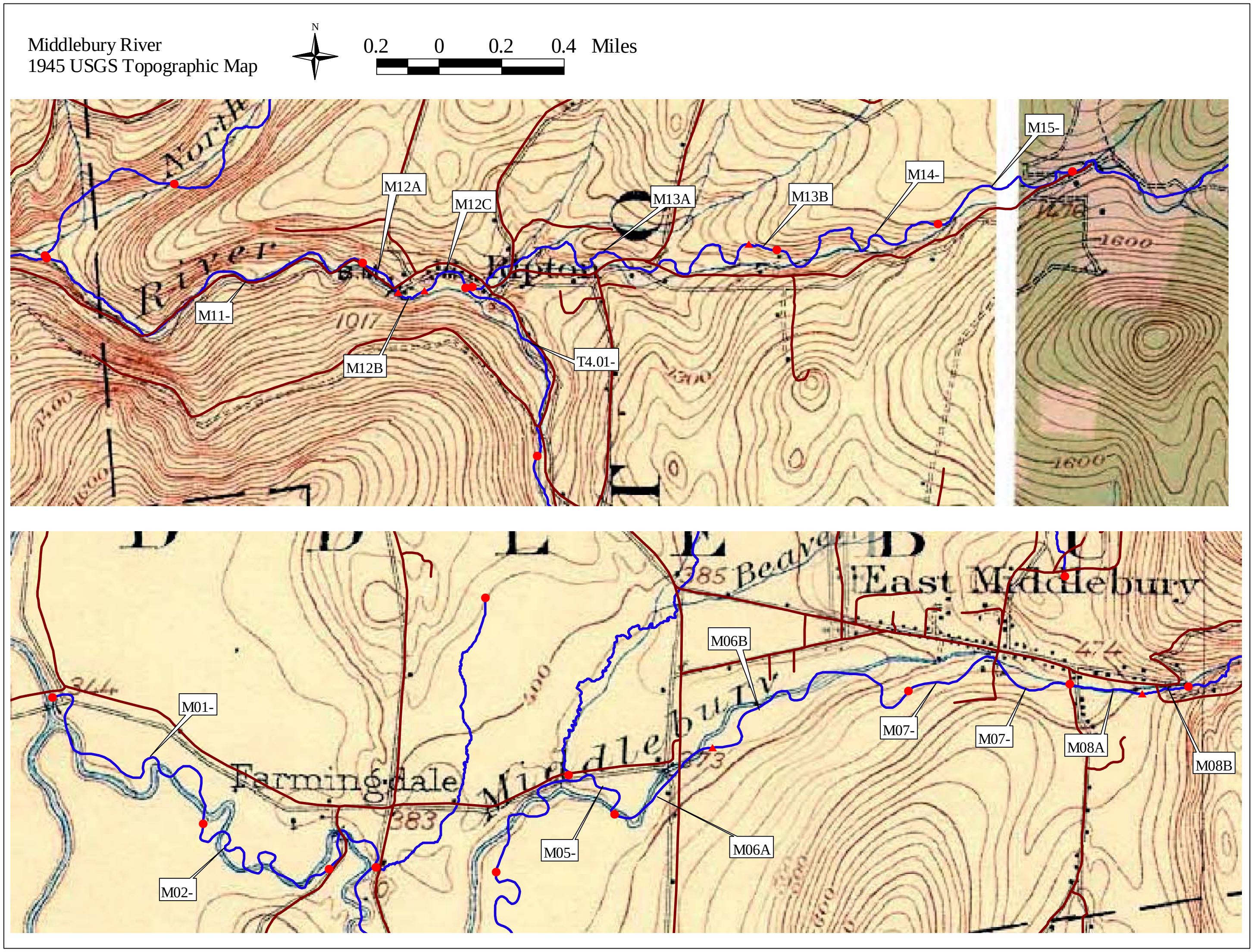


Figure 3. Hydrologic Alterations

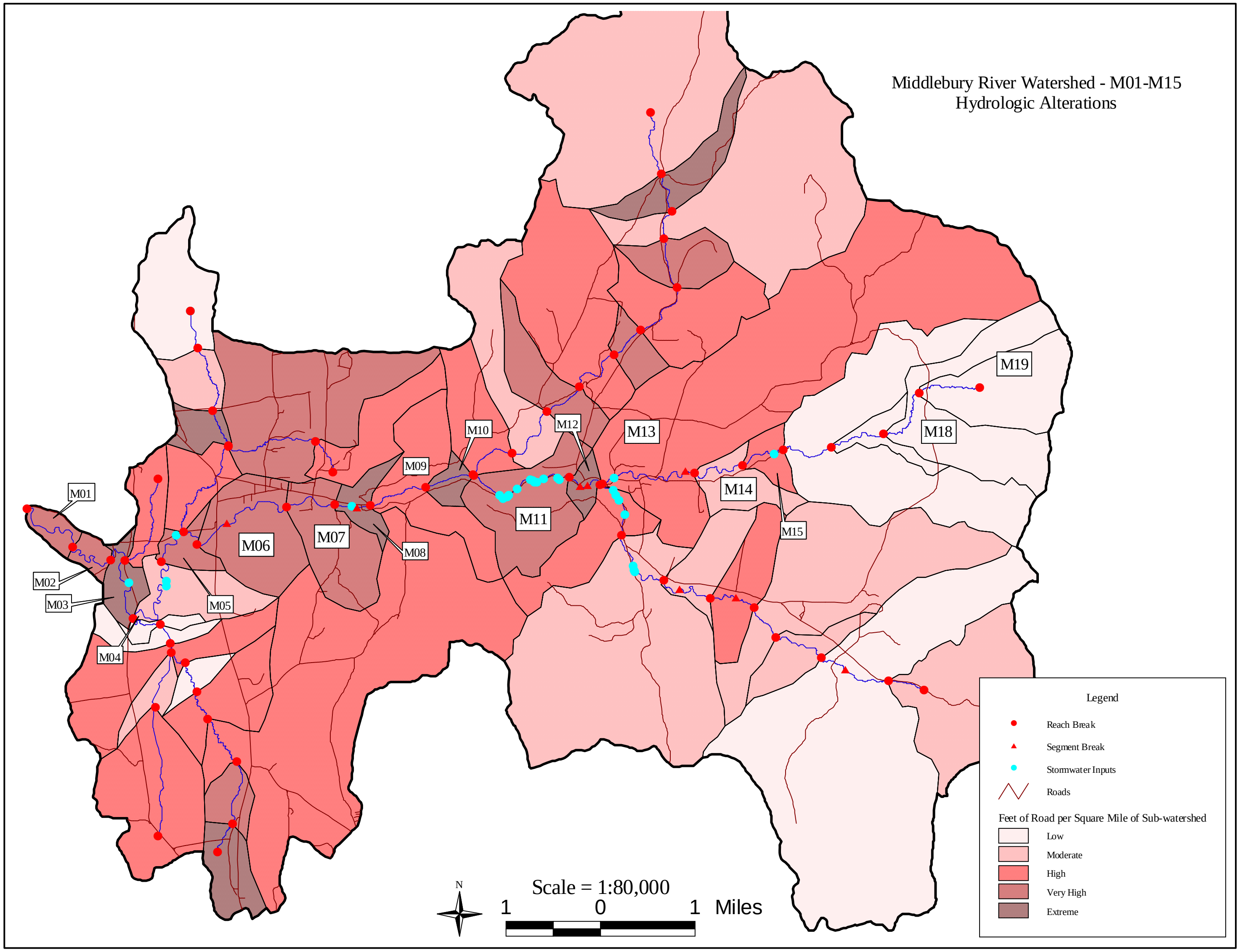


Figure 4. Sediment Load Indicators

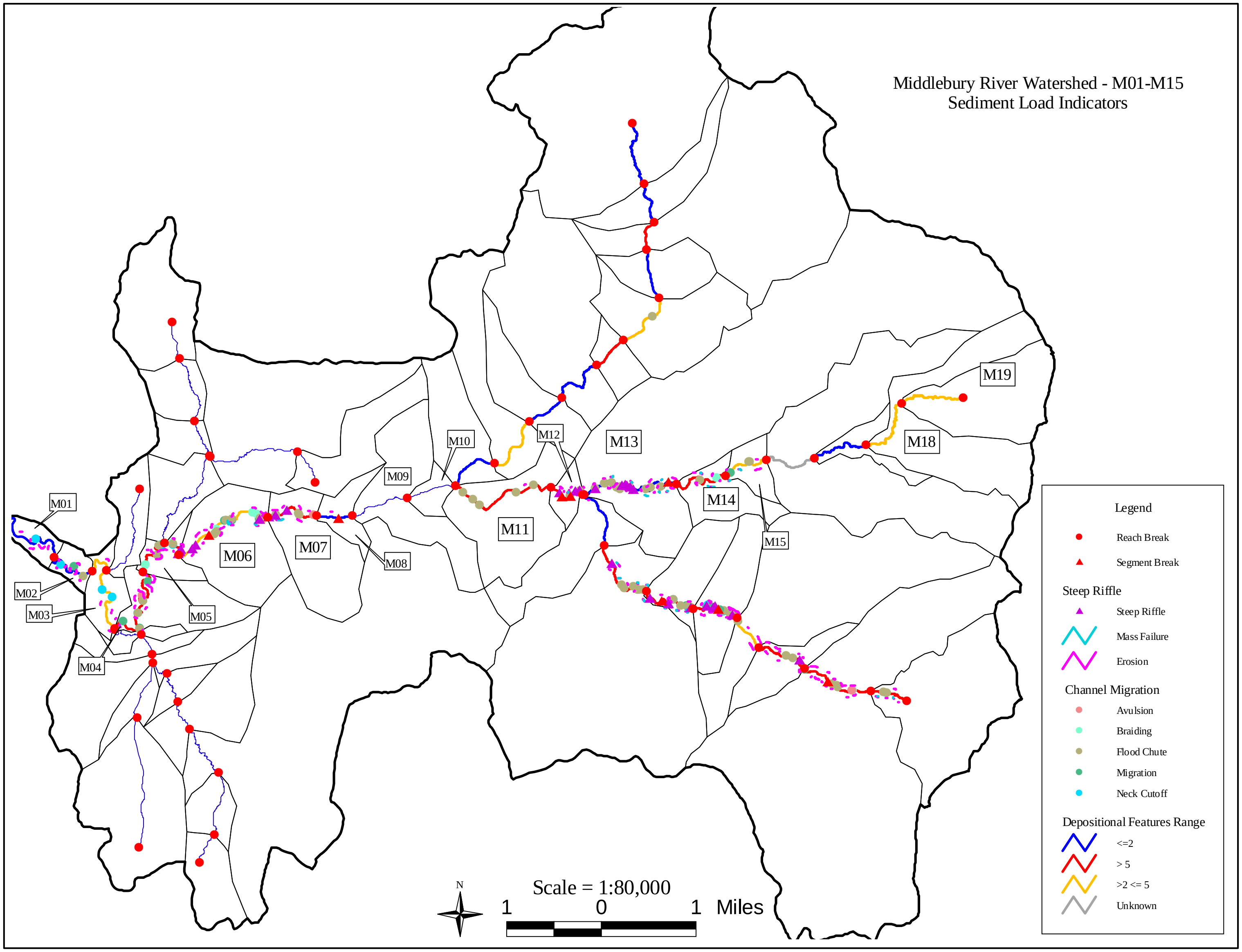


Figure 5. Channel Slope Modifiers

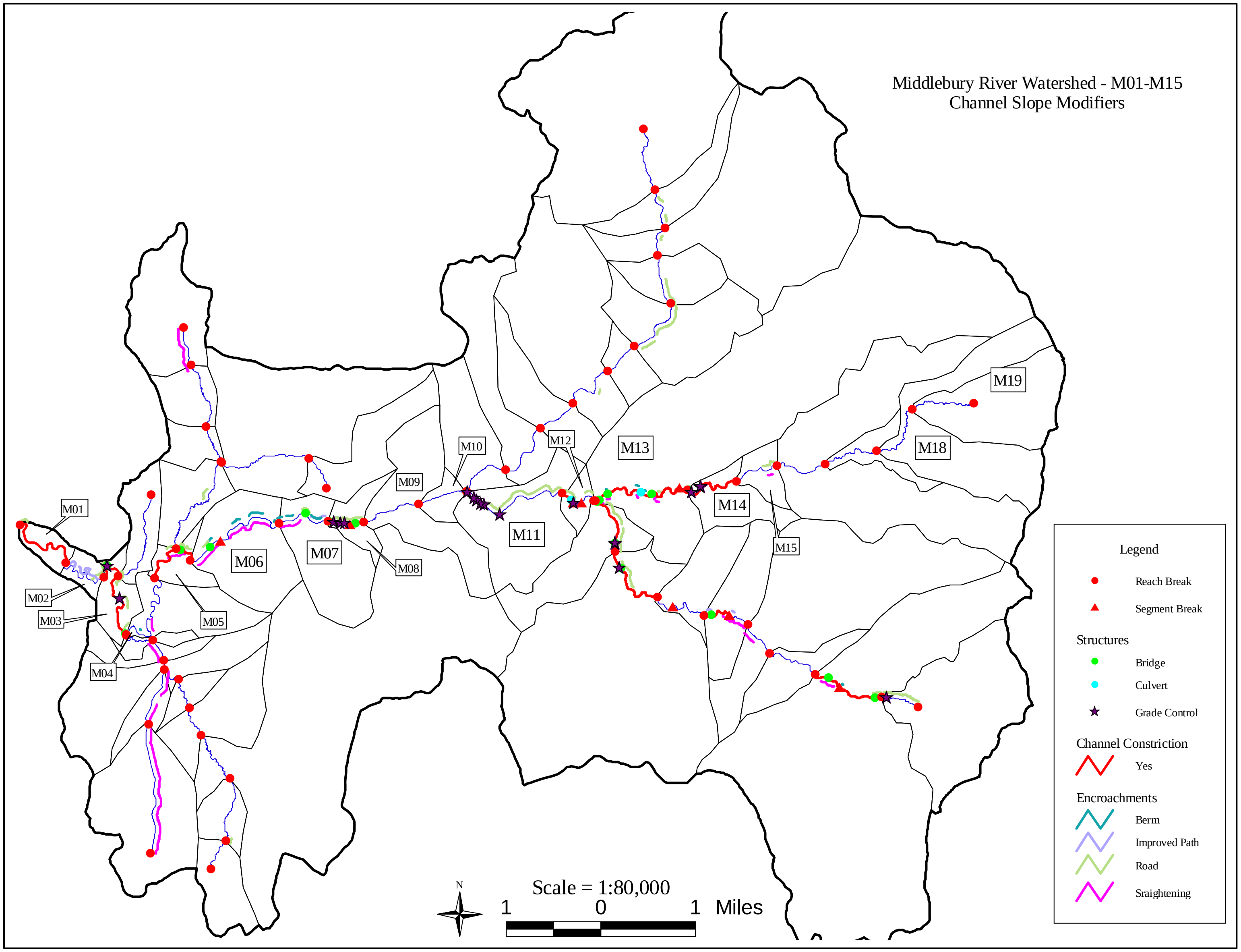


Figure 6. Channel Depth Modifiers

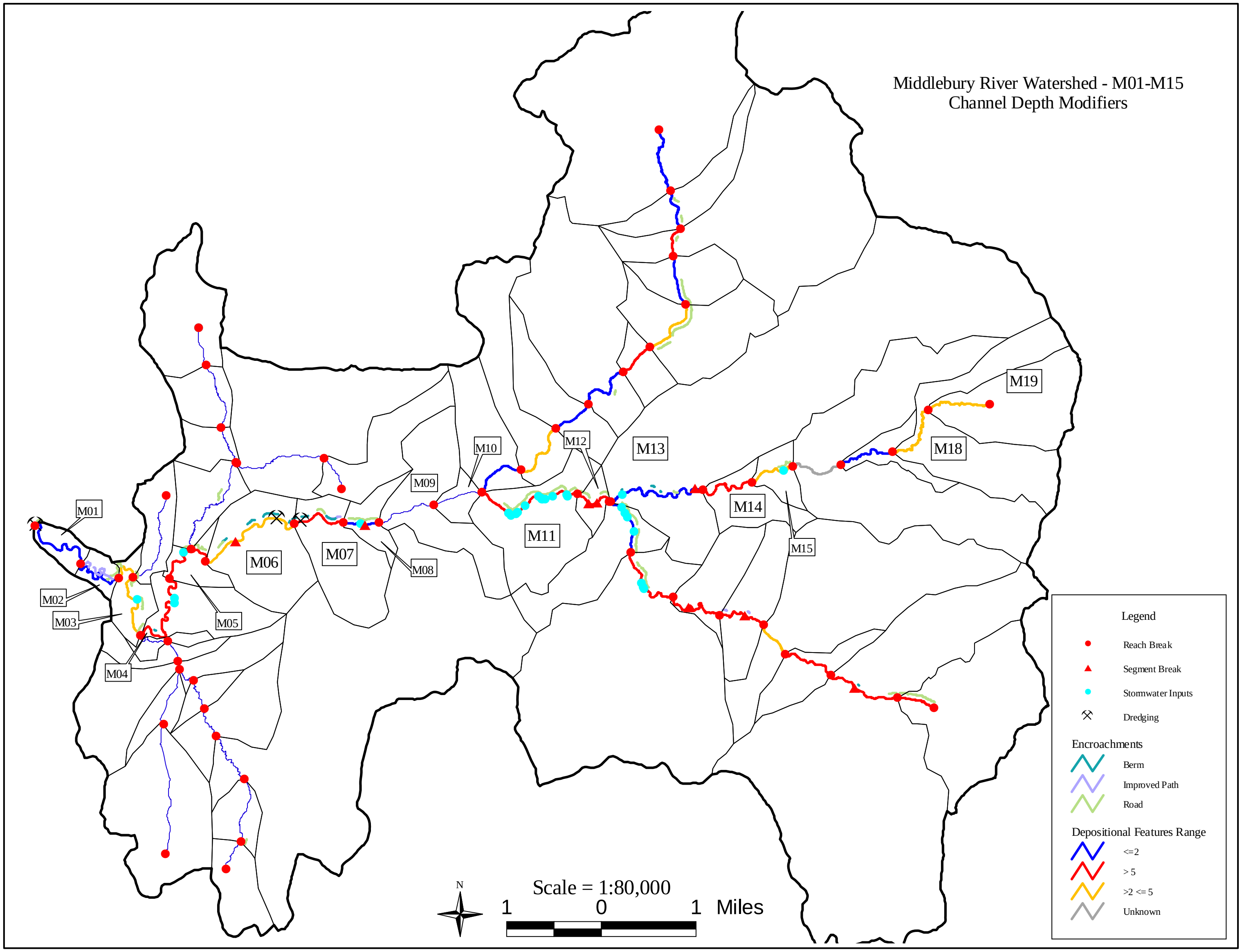


Figure 7. Boundary Condition and Riparian Modifiers – Increased

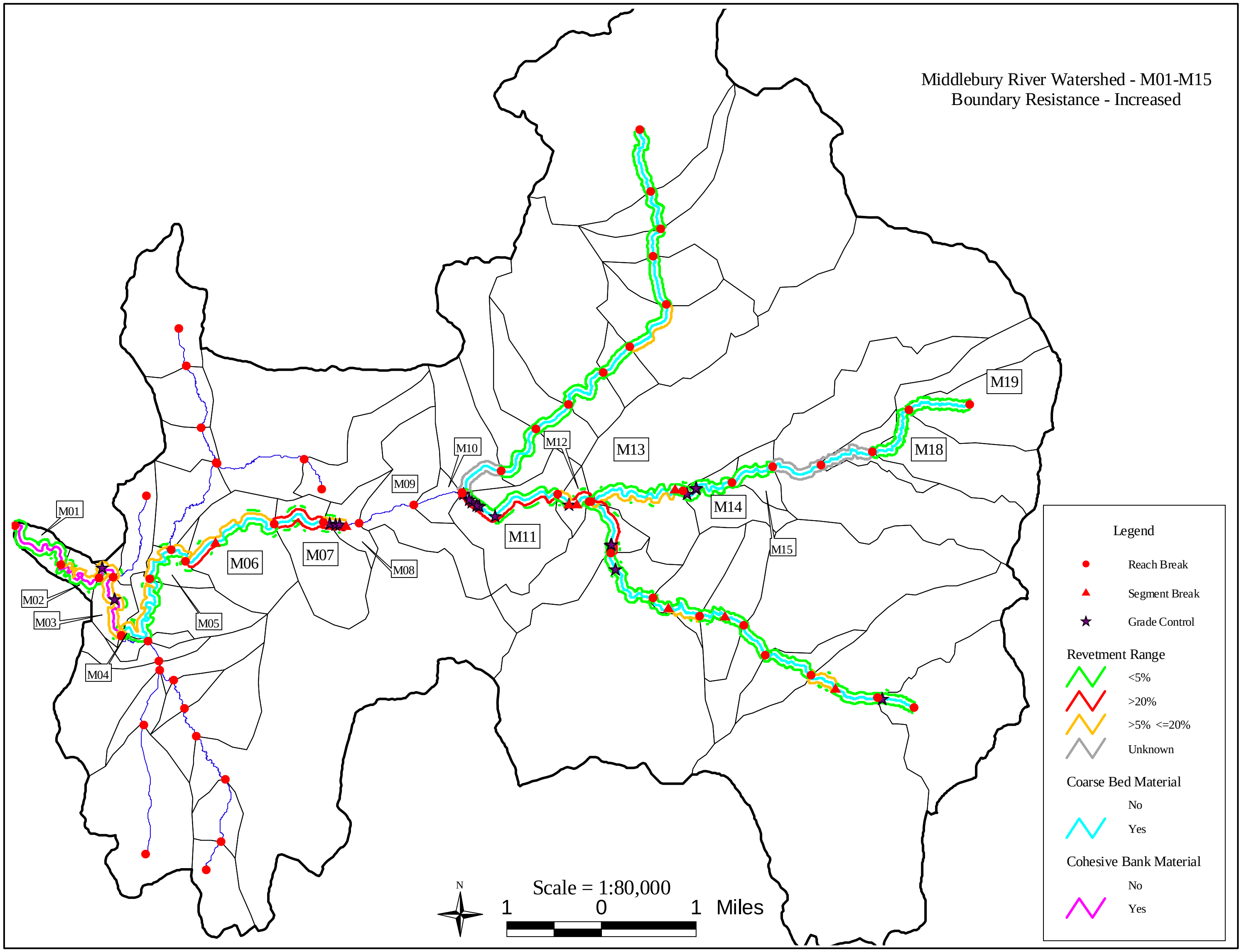


Figure 8. Boundary Condition and Riparian Modifiers – Decreased

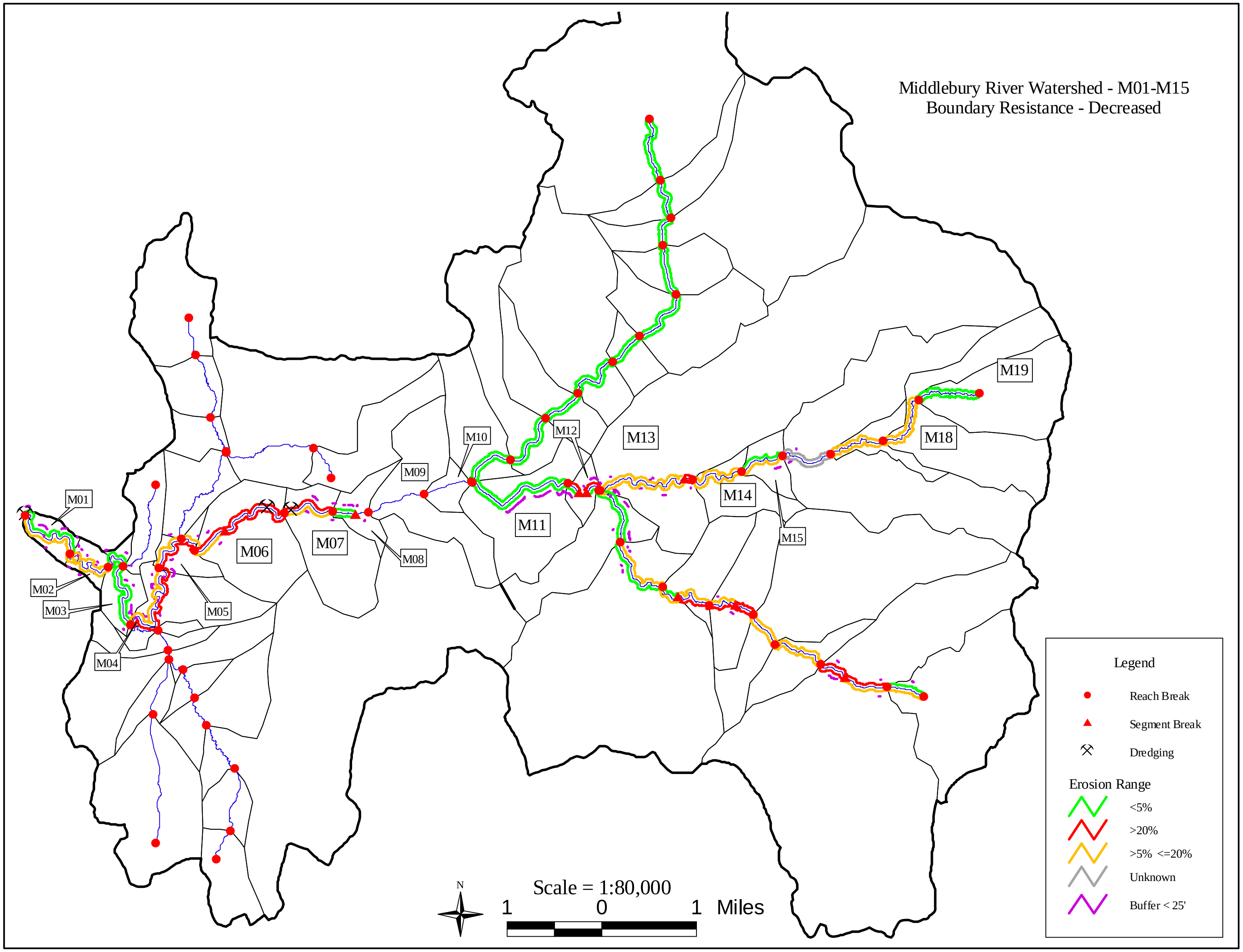


Figure 9. Reference Sediment Regimes

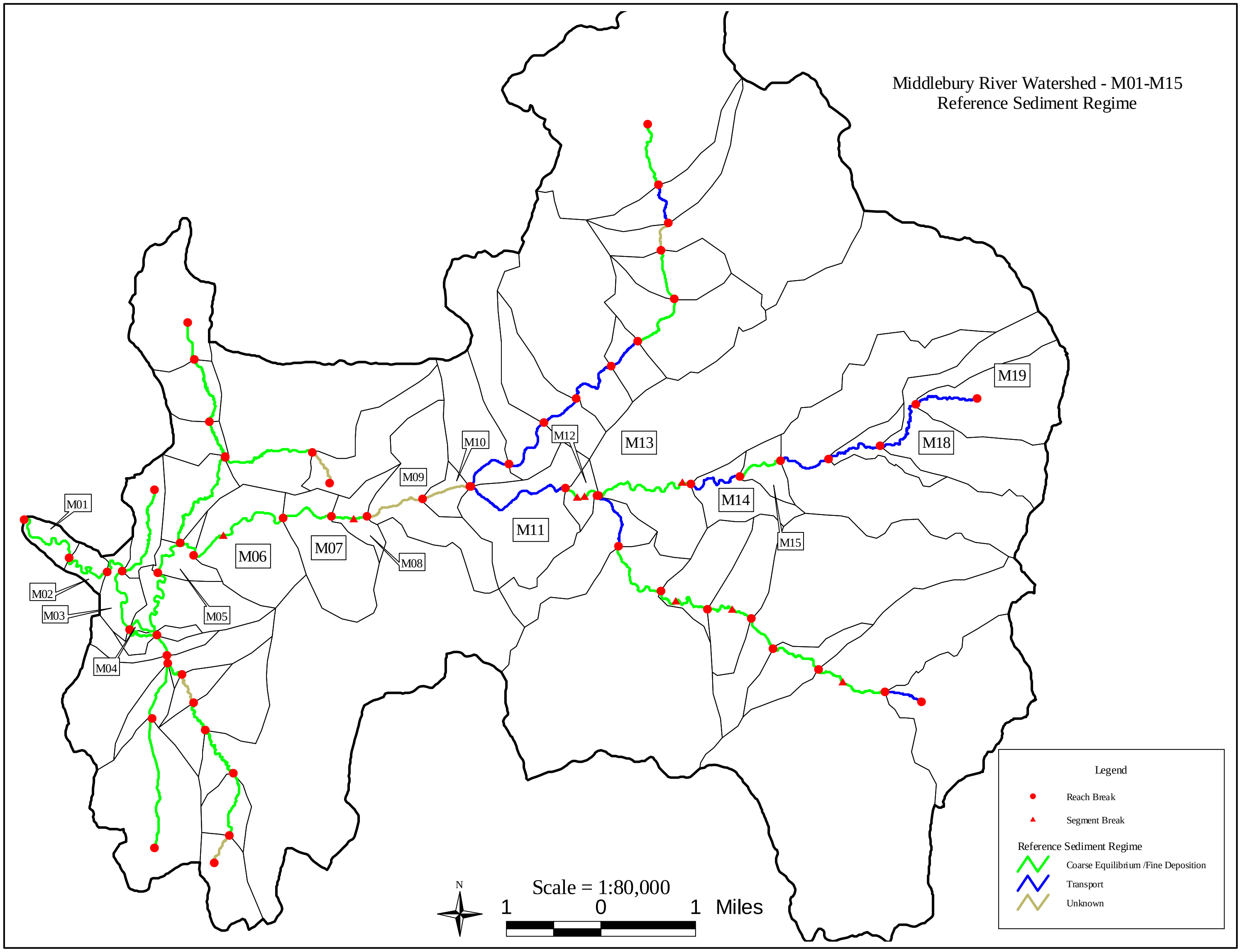


Figure 10. Sediment Regime Departure

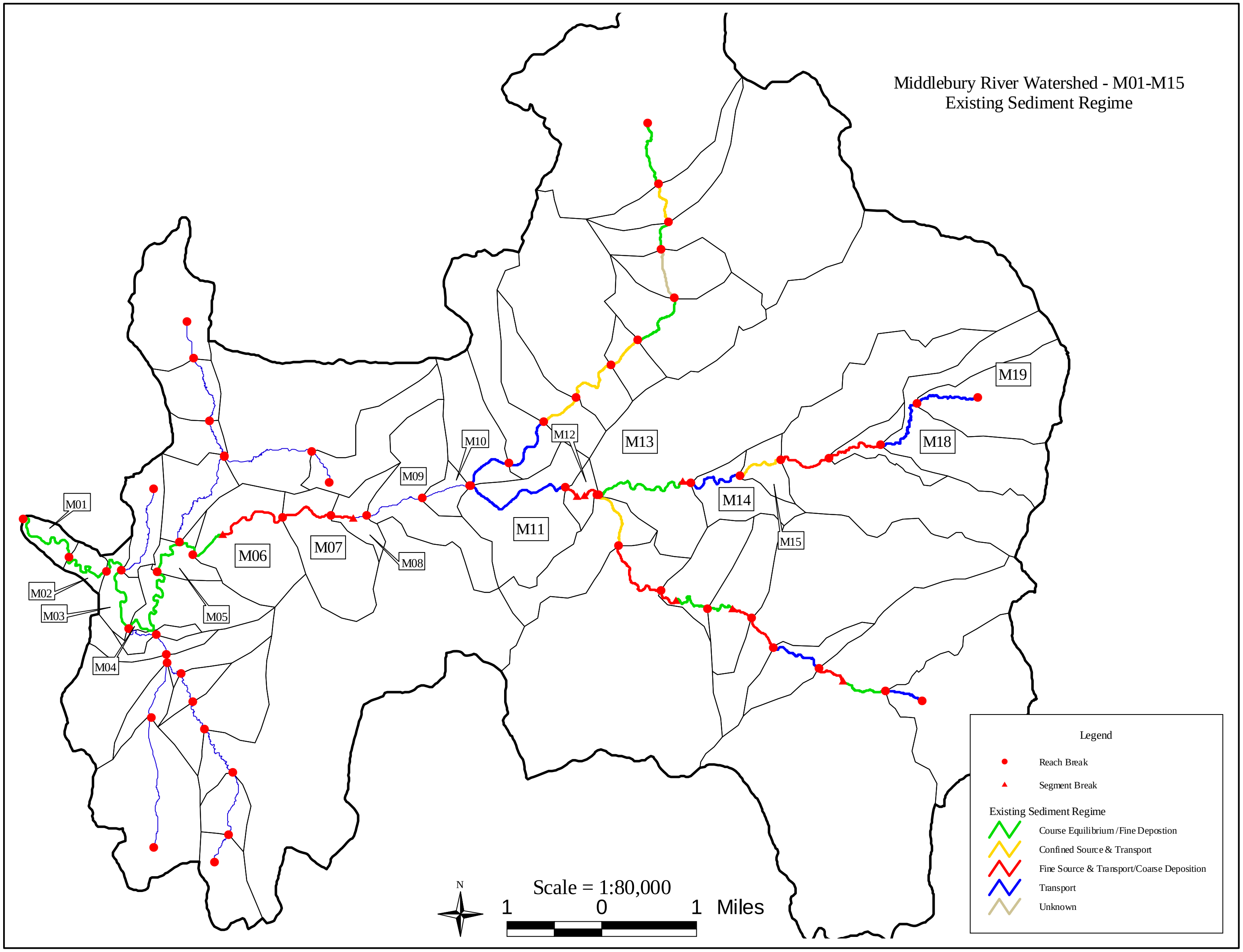
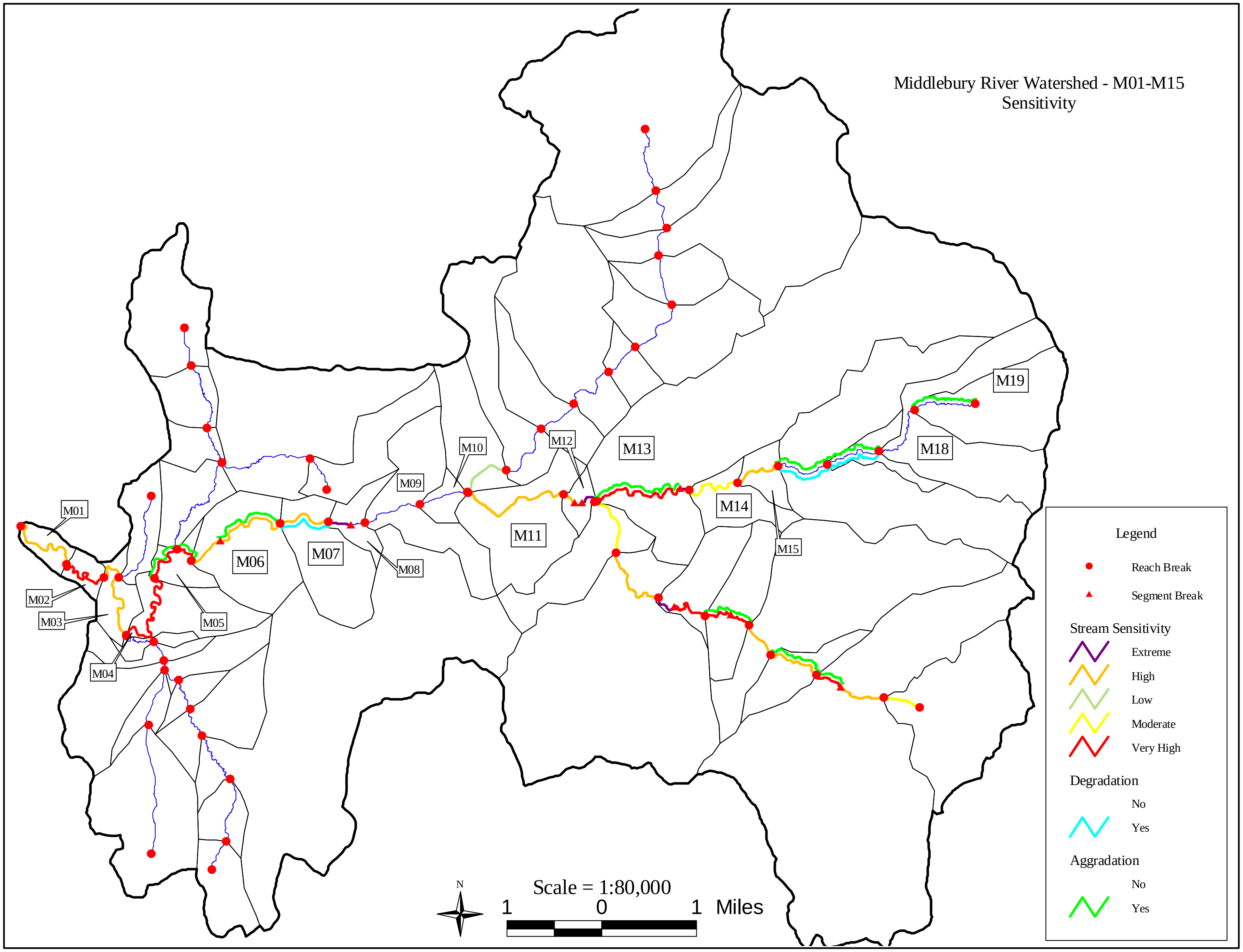


Figure 11. Stream Sensitivity and Current Adjustment



Main Stem & Middle Branch Middlebury River
River Corridor Plan

Appendix B
Tables

Table 1. Hydrologic Stressors

Hydrologic Stressors

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic**	**Sediment Load**	**Stream Power**	**Boundary Resistance**
M01-	Extreme - wetland loss & roads	Increased	None	Decreased - buffers & erosion
M02-	Moderate - roads	Increased	None	Decreased - buffers, erosion & armoring
M03-	High - roads	Increased	None	Increased - armoring
M04-	High - wetland loss	Greatly increased	Decrease - channel slope-deposition	Decreased - buffers & erosion
M05-	High - wetland loss & roads	Greatly increased	Decrease - channel slope-deposition	Decreased - erosion
M06A	High - wetland loss & roads	Increased	Increased - channel slope & depth - straightening, dredging, encroachments	Decreased - erosion
M06B	High - wetland loss & roads	Increased	Increased - channel depth - dredging, encroachments.	Decreased - erosion & dredging
M07-	Moderate - roads	Greatly increased	Increased - channel depth - dredging, encroachments.	Decreased - erosion & dredging
M08A	High - roads	Decreased	Increased - channel slope & depth - straightening*& encroachments	Increased - armoring, coarse bed, ledge
M11-	Extreme - SI & Rds.	Greatly increased	Increase - channel depth - stormwater inputs!	Decreased - buffer; Increased - revetments
M12A	Extreme - roads	Greatly increased	Decrease - channel slope-deposition - constriction; Increased depth - encroachments	Decreased - erosion
M12C	Extreme - roads	Greatly increased	Decrease - channel slope-deposition - constriction; Increased depth - encroachments	Decreased - erosion
M13A	High - wetland loss & roads	Increased	Decrease - numerous undersized structures	Decreased - erosion & buffer
M13B	High - wetland loss & roads	Increased	None	Decreased - erosion
M14-	Moderate - roads	Greatly increased	Decrease - channel slope-deposition - constriction	Decreased - erosion
M15-	Moderate - roads	None	Increased - encroachments	Decreased - erosion & buffer

Table 2. Constraints to Sediment Transport and Attenuation

Departure Analysis

	Constraints		Transport		Attenuation		
River Segment	Vertical	Lateral	Natural	Converted	Natural	Increased	Asset
M01-	None	Old Abutment			X		X
M02-	None	None			X		X
M03-	Ledge	Some road			X		X
M04-	None	None			X		X
M05-	None	None			X	X	X
M06A	None	None			X		X
M06B	None	Some development		X	X	X	X
M07-	None	Some development		X	X		X
M08A	Ledge	Development - one side		X	X		
M11-	Ledge	Road - one side	X				
M12A	Culvert	Road - one side & development		X	X		
M12C	None	Road - one side & development		X	X	X	X
M13A	Culvert	Some development			X	X	X
M13B	None	None			X		
M14-	Ledge	None	X				
M15-	None	Some road		X	X		

Yellow are priorty reaches as sediment and flood attenuation assets.
(c) = culvert for vertical constraint
(o) = old abutment
Vertical: Culverts constricting flow; Ledge
Lateral: Encroachments; hard armoring; berming; development
Transport: Reference transport
Converted: Confined, unconfined & fine source and transport = incised, straighted, armored.
Attenuation: Alluvial Fan/delta bar; Increased = aggradation adj. process; Asset = reference coarse eq. & fine deposition

Table 3. Sensitivity Analysis

Sensitivity Analysis - Middlebury River

River Segment	Sensitivity	Channel Evolution	Dominant Adjusment	Prioritization
M01-	High	I - In regime	Aggradation	Low
M02-	Very high	III - Widening	Widening & Planform	Medium
M03-	High	I - In regime	Widening	Low
M04-	Very high	III - Widening	Planform	Medium
M05-	Very high	IV - Planform	Planform	High
M06A	High	I - In regime	Aggradation (minor)	Low
M06B	High	III - Widening	Planform w/ Widening & Aggradation	Medium
M07-	High	II - Degradation	Planform (moderate)	High
M08A	Extreme	II - Degradation	Aggradation & Widening (minor)	High
M11-	High	I - In regime	Aggradation & Widening (minor)	Medium
M12A	High	II - Degradation	Planform (moderate)	Medium
M12C	Extreme	II - Degradation	Planform & Aggradation (moderate)	High
M13A	Very high	IV - Planform	Planform & Aggradation (moderate)	High
M13B	Very high	II - Degradation	Widening (moderate)	Medium
M14-	Moderate	I - In regime	Planform & Aggradation (moderate)	Low
M15-	High	V - In regime	Planform (minor)	Low

High
Medium — Based on Sensitivity, adjustment
Low — process and threats to infrastructure.

Table 4. Project Identification

Project Identification and Prioritization

River Segment		Project Type	Reach Priority	Watershed Priority	Next Steps & Other Project Notes
M01-	1	Protect river corridor	Low	Low	Entire reach in floodplain; Most of LB has easement.
	2	Plant stream buffer	High	Moderate	
	3	Remove structure	High	Moderate	Old abutment near u/s end
M02-	4	Protect river corridor	Low	Low	Entire reach in floodplain & under agricultural conservation easement.
	5	Plant stream buffer	High	Moderate	Widening is dominant adj. process
M03-	6	Protect river corridor	Low	Moderate	3/4 of reach in floodplain
	7	Plant stream buffer	High	Moderate	
	8	Stabilize stream banks	High	High	
	9	Replace structure	Moderate	Moderate	One bankful constricting bridge w/deposition below.
M04-	10	Protect river corridor	Low	Moderate	>1/2 of reach in floodplain
	11	Plant stream buffer	Very High	Very High	Widening is dominant adj. process; lots of opportunities.
	12	Remove berm	Low	Low	Rest of reach has fp access.
M05-	13	Protect river corridor	High	Very High	Entire reach in floodplain
	14	Plant stream buffer	Low	Low	Only a few spots
M06A	15	Protect river corridor	High	Extremely High	Entire reach in floodplain; minor hx incision - passive restoration possible.
M06B	16	Protect river corridor	High	Extremely High	Much of this area is part of the Sessions-Neil conservation project; continue pursuing conservation.
M07-	17	Protect river corridor	High	Extremely High	2.9 Ac RB u/s of Grist Mill - with berm
	18	Remove berm(s)		Extremely High	RB u/s of Grist Mill Bridge - worth looking at this one.
	19	Restore incised reach	Very High	Very High	Explore utilizing flood chute for stream channel.
M08A	20	Protect river corridor			LB
	21	Replace structure	High	High	40' bridge w/ 60' bankful width - Lower Plains :-)
M11-	22	Protect river corridor	Low	Moderate	Who owns N. side of River?
	23	Manage storm water inputs.	Moderate	Moderate	13 storm water inputs in this segment!
	24	Cost/benefit analysis of maintaining Route 125 in the river corridor.	High	High	
M12A	25	Protect river corridor	Low	Moderate	Who owns N. side of River?
	26	Replace structure	Moderate	Moderate	Check d/s
	27	Restore incised reach		Very High	Explore old mill diversion channel
M12C	28	Protect river corridor	High	Extremely High	Who owns S. side of River?
	29	Restore incised reach			Flood chutes present along LB
M13A	30	Protect river corridor	Moderate	High	To prevent further encroachments though it is in the 100 year floodplain.
	31	Stabilize stream banks	High	Moderate	In areas near roads.
	32	Remove berm		High	Possible u/s of Peddler's Bridge Rd.
	33	Replace structure (s)	High	High	4 permanent structures at least two with deposition above and scour below.
M13B	34	Protect river corridor	Moderate	High	Erosion along both banks high.
M14-	35	Protect river corridor	Moderate	High	In National Forest?
	36	Stabilize stream banks	High	High	
	37	Remove structure	Moderate	Low	Timber bridge collapsing.
M15-	38	Protect river corridor	Moderate	High	Ownership?
	39	Stabilize stream banks	Low	Low	

Table 5. Priority Projects

Middlebury River Corridor Planning		
Project and Strategy Summary Table		
Project Priority	Reach/Segment Condition/Sensitivity	Site Description including Stressors and Constraints
1	M06B Protect river corridor FSTCD/ C3/ High sensitivity	31% bermed, 22% armored, 67% straightened (whole reach), 22% eroding, 13% armored on RB. Numerous flood chutes, sedimented riffles, incised, historic channel migration, dredging, 3 mass failures.
2	M07 Protect river corridor FSTCD/ C3/ High sensitivity	38% bermed, >30% rip rap on both banks, 38% straightened, incised, located on alluvial fan, three hx. Mill diversions, numerous flood chutes and berms w/in the floodplain surrounding the channel, hx.
3	M07 Remove berm FSTCD/ C3/ High sensitivity	See above.
4	M07 Restore incised reach FSTCD/ C3/ High sensitivity	See above.
5	M12C Protect river corridor FSTCD/ Fb2/ Extreme sensitivity	Incised, entrenched, road and development in RB corridor, large MF on RB, FC on LB.
6	M12C Restore incised reach FSTCD/ Fb2/ Extreme sensitivity	See above.
7	M13A Corridor conservation, remove berm; replace structure (Peddler's Bridge Road) CEFD/Cb3/Very high sensitivity	Slightly incised, multiple undersized structures, moderate erosion, multiple mid and point bars, multiple mass failures, and straightening associated with structures.
8	M11 Cost/benefit of maintaining Route 125 along this reach. Transport/Ab3/High sensitivity	11stormwater inputs, 3 sharp bends washed out in 2008, road encroaches on LB for most of reach.
9	M04 Plant stream buffer CEFD/C4/Very high sensitivity	Substantial planform adjustment and erosion due to lack of buffers. Aggrading from in-reach and u/s sources.
10	M06A Protect river corridor CEFD/C4/High sensitivity	Nearly 100% straightened, good riparian buffer.
11	M13B Plant stream buffers FSTCD/Fb4/Extreme sensitivity	Extremely short segement with significant erosion,.
12	M14 Protect river corridor Transport/B3/Moderate sensitivity	Relatively undedeveloped with good riparian buffers.
13	M15 Protect river corridor CST/Cb4/High sensitivity	Relatively undedeveloped with good riparian buffers.