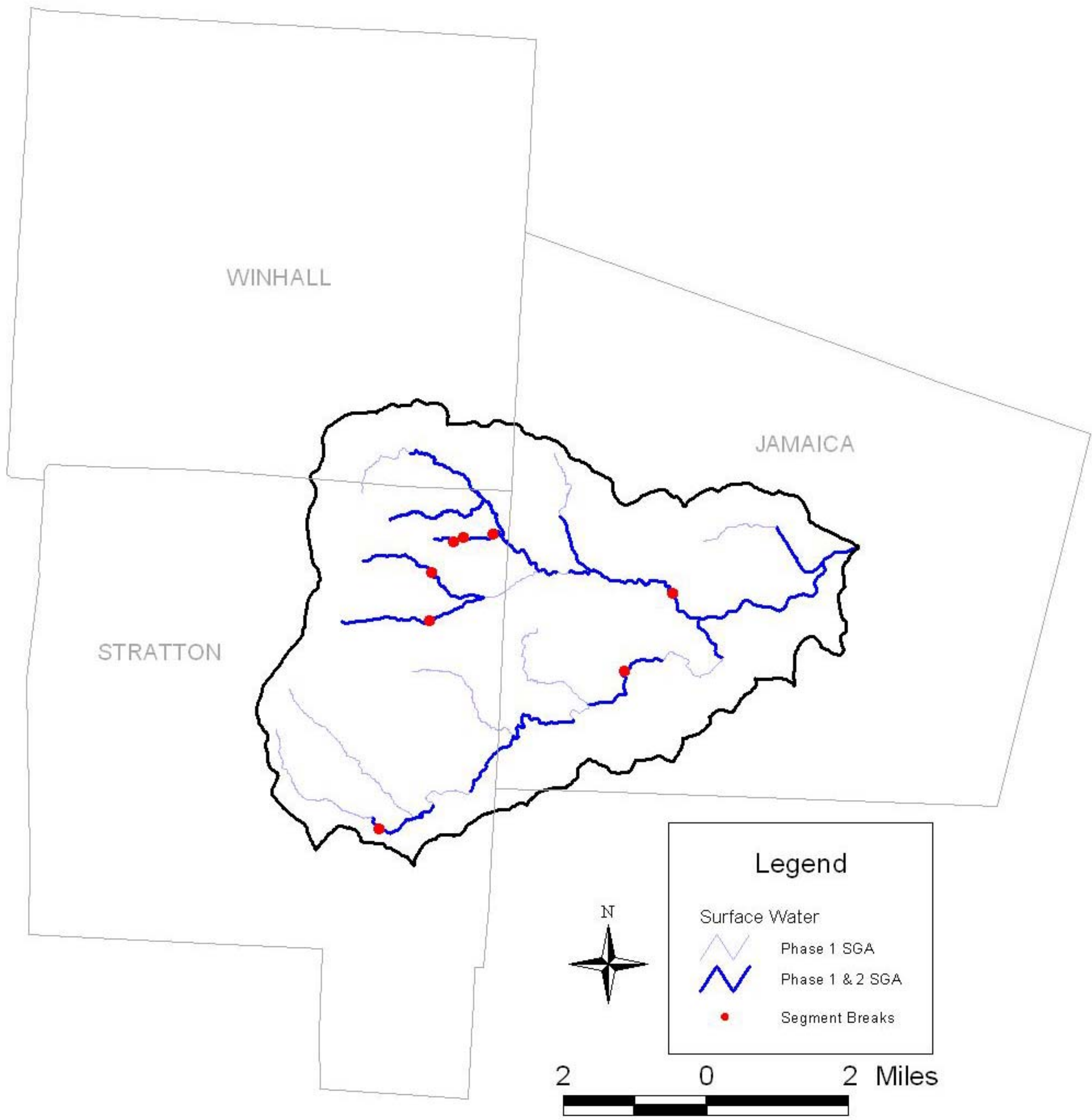
Ball Mountain Brook Watershed
River Corridor Conservation Plan
Phase 2 Report
May, 2007



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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 Ball Mountain Brook Watershed. In the past, almost complete deforestation at the end of the 19th century combined with 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. Presently, these past management practices, combined with development in the upper reaches of the North Branch 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 and otherwise increasing the capacity for water and sediment movement) will gain force, and impacts to downstream areas will increase.

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 large storm events (managing toward equilibrium). Other benefits that come from looking at the "big picture" include a reduction in the amount of sediment and nutrients entering the stream system from human land uses and improved aquatic habitat.

Managing for equilibrium watershed wide will allow the river to regain a new, relatively stable planform that provides for changes to the water and sediment flows that are a result of human activity. This plan has identified a list of critical restoration activities which, if implemented, will move the stream system toward a more even distribution of energy throughout the watershed, reducing impacts to downstream reaches, specifically, in the Village of Jamaica.

Opportunities exist today throughout the watershed to move the Ball Mountain Brook toward an equilibrium condition. Individual property owners, towns, agencies and organizations all have a role in making this happen. River corridor conservation is one of the most economical and effective strategies for watershed wide restoration. This is an entirely voluntary opportunity for people who own areas of the river that are important for flood and sediment storage to sell "river right of way" easements. These corridor conservation areas provide an insurance policy for downstream property owners. The Ball Mountain Brook Corridor Plan makes working with these landowners the highest priority restoration activity.

As river corridor development increases, however, conservation opportunities are lost for the foreseeable future. Another concurrent strategy that towns can use is to establish a "Fluvial Erosion Hazard Zone". This zone is identified by using information gathered through Stream Geomorphic Assessments to determine the width of river corridor necessary for re-establishing channel equilibrium. When implemented by towns, it prevents development from occurring in those areas that are most likely to erode over time, reducing future, costly conflicts between private and municipal property owners and the river.

2.0 Project Overview

2.1 Introduction

Watershed scale restoration planning is in its infancy in Vermont and the Ball Mountain Brook Corridor Conservation Plan is one of the first plans of its kind. The project was completed in seven months and it is the beginning of a dialogue about restoring Ball Mountain Brook. It provides a list of prioritized potential restoration projects that are selected to address the multiple goals of river management: reduction of flood and erosion hazards; reduction of sediment and nutrients running into the stream and; improvement of aquatic habitat. It has been arranged with appendices so that interested parties who want to assist with its implementation can do so without amending the plan itself. It is our hope that the plan will inspire many partners to engage in "re-establishing equilibrium" on Ball Mountain Brook!

2.2 Project Partners

The Windham County Natural Resource Conservation District (WCNRCD), 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: Jolene Hamilton, District Manager for WCNRCD, Shannon Pytlik, River Scientist with DEC River Management Section, Marie Caduto, Basin Planner with DEC, John Bennett, Senior Planner with Windham Regional Commission (WRC) and Amy Sheldon, President of Landslide, Inc.

2.3 Background

Concern about managing sediment in the Ball Mountain Brook Watershed has been growing. The upper reaches of the North Branch of the Ball Mountain Brook and several smaller tributaries are on the State of Vermont's 1998 303(d) list of impaired streams. Stratton Mountain Corporation is addressing these impacts as part of its water quality remediation plan. In 1998 the WRC completed the "West River Tributaries Non-Point Source Pollution Stream Assessment Report" which identified 14 significant erosion sites along the Ball Mountain Brook. More recently, Phase 1 and 2 Stream Geomorphic Assessments (SGA) were completed in 2004 and 2005 by staff from the WCNRCD and professional consultants. The results of these studies were published in December, 2005 as the "Ball Mountain Brook Watershed Stream Geomorphic Assessment Phase 1 and Phase 2 Report" and provide the basis for this Corridor Plan.

Throughout this document reference will be made to stream "reaches" and "segments". The Phase 1 SGA defined 40 sub-watersheds that comprise the Ball Mountain Brook watershed (a watershed is an area of land that all drains into the same body of water). These sub-watersheds define 40 distinct reaches of the stream. Twenty-six reaches were assessed for the Phase 2 SGA. During that assessment, reaches were further sub-divided into 32 segments. Figure 1 in Appendix A is a map of assessed reaches with segment breaks shown.

2.4 Goals and Objectives of the Project

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 major 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 Ball Mountain Brook and in improving aquatic and terrestrial habitat within the watershed.

2.5 Geomorphic Setting

The Ball Mountain Brook is a tributary of the West River, which is located in the Connecticut River Valley of Vermont. It drains an area of 34 square miles or 21,500 acres and its headwaters are on the east side of the Green Mountains draining the Stratton Mountain massif. The watershed is typified by higher gradients and relatively narrow valleys. The headwaters of the largest tributary, the North Branch, are extremely developed compared to other watersheds in Vermont.

Vermont has experienced three major statewide flood events in the past: 1927, 1938 and 1973. After all three of these events, especially 1973, extensive straightening and berming occurred on the Ball Mountain Brook. This has 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 Ball Mountain Brook watershed where the channel is kept straightened and even high flows remain in the channel, not having access to the floodplain.

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 Ball Mountain Brook and its tributaries provide an inventory of the human induced stressors that are causing dis- equilibrium. 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 Ball Mountain Brook 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 run-of-the-river dam on the assessed reaches of the North Branch of the Ball Mountain Brook, on T08.04-S1.12. Run of the river dams do not alter the amount of water in the stream, but they do reduce the amount of sediment entering downstream reaches and can result in downstream bed degradation. The downstream reach, T08.04-S1.11 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 Ball Mountain Brook Watershed is primarily associated with roads and residential development and is relatively minor compared to other watersheds in Vermont.

Urban development in the upper reaches of the North Branch is the most significant alteration of the natural hydrologic cycle in the Ball Mountain Brook Watershed. It 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. Due to the narrow valleys that dominate the Ball Mountain Brook Watershed, many roads have been built along the streams. 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. Five of the 40 reaches assessed in the Phase 1 SGA have greater than 10% developed land and 12 have between 5 and 10%. All but two of these are on the North Branch and none of them are on the main stem of Ball Mountain Brook. On the North Branch, urban development in sub-watersheds ranges from a high of 31% to a low of 6%. Overall development for the whole watershed is 5.8%, which is quite high when compared to other watersheds in the State. (See Figures 8 and 9 in Appendix A.)

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 the upper portion of T08.04-S1.10-S1.01 (Styles Brook). (See Figure 2 in Appendix A.)

In this analysis, hydrologic alterations were considered “Extreme” if development was the primary land use on both sides of the river corridor or if urban development within the sub-watershed was greater than 10%. Four segments were found to have extreme alterations to the hydrologic regime: T08.04-S1.09-S1.01A, B, & C (Brazer’s Brook) and T08.04-S1.11 (North Branch). Hydrologic impacts were considered “High” if corridor development was the primary land use on both sides of the river corridor or if urban development within the sub-watershed was between 5 and 10%. Five segments were found to have high hydrologic alterations: T08.04-S1.08, T08.04-S1.10, T08.04-S1.10-S1.01, T08.01 and T08.02. Hydrologic impacts were considered “Moderate” if 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%. Nine segments had moderate alterations to the hydrologic regime. A “low” impact was assessed to segments with neither side of the corridor having development as the primary use and less than 5% urban lands in the watershed. (See Table 1 in Appendix A.)

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.

In this analysis, sediment load impact was rated none, low, moderate or high 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.
Two segments had no impact, 13 had low impact, 9 had moderate impact and 5 had high impact. (See Table 1 in Appendix B.) Watershed wide, approximately 6% of both the right bank and left banks are eroding, or 1.3 miles of each bank. (See Figure 4 in Appendix A for a map of Sediment Load Indicators.)

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 Ball Mountain Brook Watershed was found to be increased on 21 of the 32 assessed segments; ten segments were found to have neither an increase nor a decrease in transport capacity and; one segment was found to have a decrease in stream power/transport capacity due to a beaver dam. (See Table 1 in Appendix B.)

A total of 1.8 miles or 9% of the assessed channel length on 9 segments were found to be straightened. (See Figures 2 and 5 in Appendix A.) 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. Development on one or both banks occurred in 27% of the channel corridor length. Roads occur along 60% of one or both sides of the channel corridor. Development within the corridor increases the volume of water flowing into the stream, causing bed degradation and an increase in slope. Thirteen of the 26 assessed reaches have channel constrictions, which can increase channel slope down stream by concentrating flows and reducing the amount of sediment available to the stream.

Stream power was reduced on one reach, T08.04-S1.11 due to the presence of three beaver dams.

3.2.2 Boundary Condition and Riparian Modifiers

Channel bed and bank resistance may be increased or decreased by human alterations. Stressors that decrease bed resistance are: snagging, dredging, and windrowing. Removal of bank vegetation reduces stream bank resistance. Grade control and bed armoring will increase bed resistance to erosion and bank armoring decreases the streams ability to move laterally. (See Figure 7 in Appendix A and Table 1 in Appendix B.)

Seven segments were found to have increased bank resistance due to hard armoring (rip-rap) and 11 were found to have increased bed resistance due to the presence of natural grade control. One segment (T08.01) had both increased bed and bank resistance due to hard armoring as well as natural grade control. Two reaches had a decrease in bank resistance due to a loss of riparian vegetation (T08.04-S1.10 and T08.03). T08.02 and T08.07B had a decrease in bed resistance due to dredging and windrowing. Ten reaches had no increase or decrease in bed and bank boundary resistance.

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 Ball Mountain Brook main stem and North 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. Twenty of the 32 assessed segments are Coarse Equilibrium/Fine Deposition in reference condition and 12 are steeper transport streams by reference. Currently, only 5 segments are in Coarse Equilibrium/Fine Deposition regime and only 3 of the Transport segments are in regime. This means that 15 formerly Coarse Equilibrium/Fine Deposition type streams have been converted to Transport type streams. Streams that have been converted from Coarse Equilibrium/Fine Deposition to Transport reduce sediment and flood attenuation capacity on that reach as well as 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 3 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 or horizontally) given its current geomorphic condition. The rating scale is low, moderate, high, very high, and extreme. See Figure 10 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 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 Ball Mountain Brook 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 un-sustainable. Managing a stream toward long-term geomorphic equilibrium can be accomplished when attenuation of up-stream 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, 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 Ball Mountain Brook watershed. The Ball Mountain Brook and more specifically, its tributary, the North Branch, have experienced dramatic urban development, widespread historic channel straightening, many corridor encroachments, and consequently, numerous segments have been converted from Coarse Equilibrium to Transport streams. Because much of the watershed has been converted to transport type streams and there is significant urban development in the upstream reaches of the North Branch in particular, those reaches that are providing flood and sediment attenuation are extremely critical to restoring equilibrium throughout the watershed.

Segments that are in or close to equilibrium will provide “release valves” for the rest of the watershed, making corridor conservation along these segments the highest priority. Conservation and restoration of the reaches upstream and downstream of the delta bar that exists at the confluence of the North Branch and Ball Mountain Brook is also a highest priority, given that the reaches downstream from it have limited potential for flood plain access, particularly as the stream enters Jamaica village.

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 Ball Mountain Brook and its tributaries are either currently forested or adjacent to roads, opportunities for tree planting are limited to the first three reaches starting in

Jamaica Village, and these projects are in localized areas. Engaging the community in tree planting projects can be an effective means of educating citizens about watershed based restoration efforts, which raises the priority of the few stream planting projects identified.

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. Although there is significant erosion occurring on T08.04-S1.10-S1.01 (Style's Brook) and T08.04-S1.04-S1.01 (Dalewood Brook) it is related to increased flows directly related to rapid development of these watersheds. The most effective way to manage this erosion is to implement Best Management Practices for storm water management within these neighborhoods. T08.07 A and B and T08.09 are both have a lot of erosion, but it is due to planform adjustment that is a response to past straightening. T08.09 is in regime and recommended for corridor conservation. Over time, it will re-gain a stable planform and the erosion will subside. T08.07A and B are both incised and entrenched and will be discussed under "Restore Incised Reaches" below.

4.4 Arrest Head Cuts

Head cuts can result in the rapid degradation of the stream bed, removing floodplain access and transporting significant amounts of sediment to downstream reaches. There are possible head cuts noted on T08.03 and T08.05, though neither of them has been confirmed. This restoration plan calls for the identification and monitoring of both of these potential head cuts to determine if they are a threat to establishing equilibrium. (See Figure 4 in Appendix A.)

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, as seen throughout the Ball Mountain Brook Watershed. 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. Berm removal has been recommended on two reaches: T08.04-S1.10-S1.01 (Styles) and T08.07B. A more thorough inventory of berm location will be completed this field season, documenting three levels: those that are currently protecting a house; those protecting a road and; those protecting nothing.

4.6 Remove/Replace Structures

Bridges and culverts with openings that are narrower than the bankfull channel width 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 Ball Mountain Brook 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 actually 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.

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. Much of the Ball Mountain Brook is incised and entrenched and many reaches have a plane bed form with large particles dominating. 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 progress. 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.

Many reaches along the Ball Mountain Brook have been converted to transport type streams, which results 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.

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 4). Spot fixes in the village of Jamaica, for example, 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. Attenuation of sediment and flow before it gets to the village will increase the likelihood of success on downstream projects.

5.0 Technical and Social Feasibility of Project Implementation

The restoration activities identified in this plan have been prioritized based exclusively on their ability to move the stream toward equilibrium conditions. The Steering Committee began the process of analyzing social feasibility when they selected the first reaches to focus restoration efforts on. Because Stratton Mountain Corporation is working with the State on a water quality plan to reduce sediment discharge into the stream, the Steering Committee decided to focus efforts on conservation of existing flood and sediment attenuation assets. Two reaches were selected, T08.09 and T08.04-S1.09. Preliminary landowner response has been positive on T08.09 where we have started work on a corridor conservation project. T08.04-S1.09 is a Class 2 Wetland that is protected by state statute with a 50' buffer. Landowners along this reach were contacted to tell them about the important functions occurring along their portion of the stream.

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. Inclusion of these interested citizens will assist with further restoration prioritization.

The towns of Stratton and Jamaica can do a lot to assist with the effort to restore the Ball Mountain Brook to equilibrium by establishing a Fluvial Erosion Hazard zone. 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

Past and present alternations to the natural hydrologic and sediment regimes on the Ball Mountain Brook have led to a frequently incised and entrenched channel with limited access to floodplain. The restoration of channel equilibrium depends on the even distribution of flow energy throughout the system that is currently disrupted by increased flows from significant urban development, bank armoring, channel straightening and berming. As the Stratton Mountain development continues to expand, impacts to downstream reaches, specifically in the village of Jamaica, will increase with the potential for costly remediation measures increasing commensurately. Increased development pressure within the river corridor between the ski area and the village makes pursuit of corridor conservation measures the highest priority.

The conservation of attenuation assets will result in a more even distribution of flow and sediment throughout the watershed where sediment can be stored and flow energy dissipated, reducing sediment loading and erosion hazards downstream. Presently, there is relatively little development within the river corridor and many opportunities still exist in the watershed for creating attenuation areas. If development continues in these areas, many of the highest priority restoration sites in the watershed could be permanently lost.

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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Ball Mountain Brook
River Corridor Plan

Appendix A Maps

Figure 1. Phase 2 Reaches

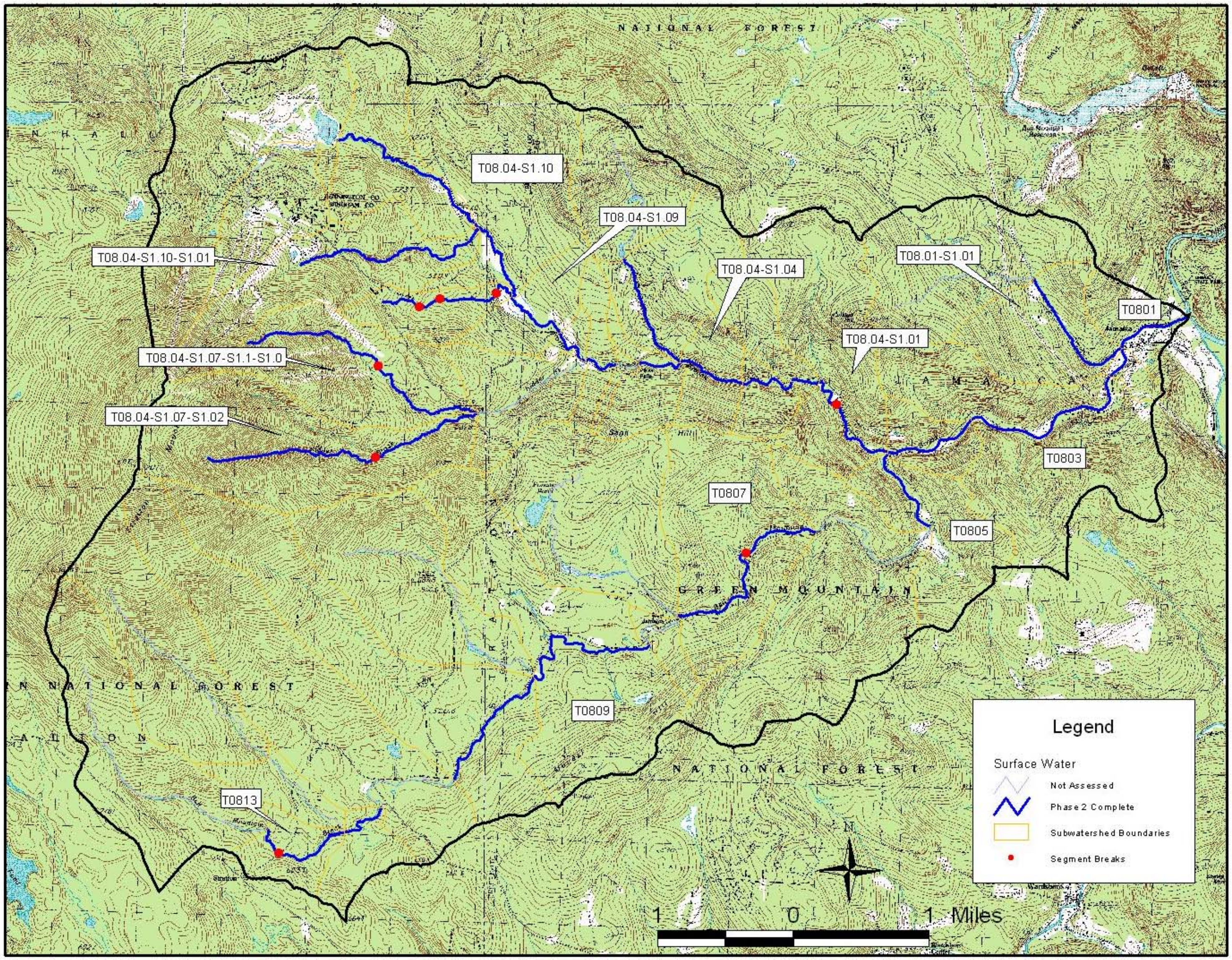
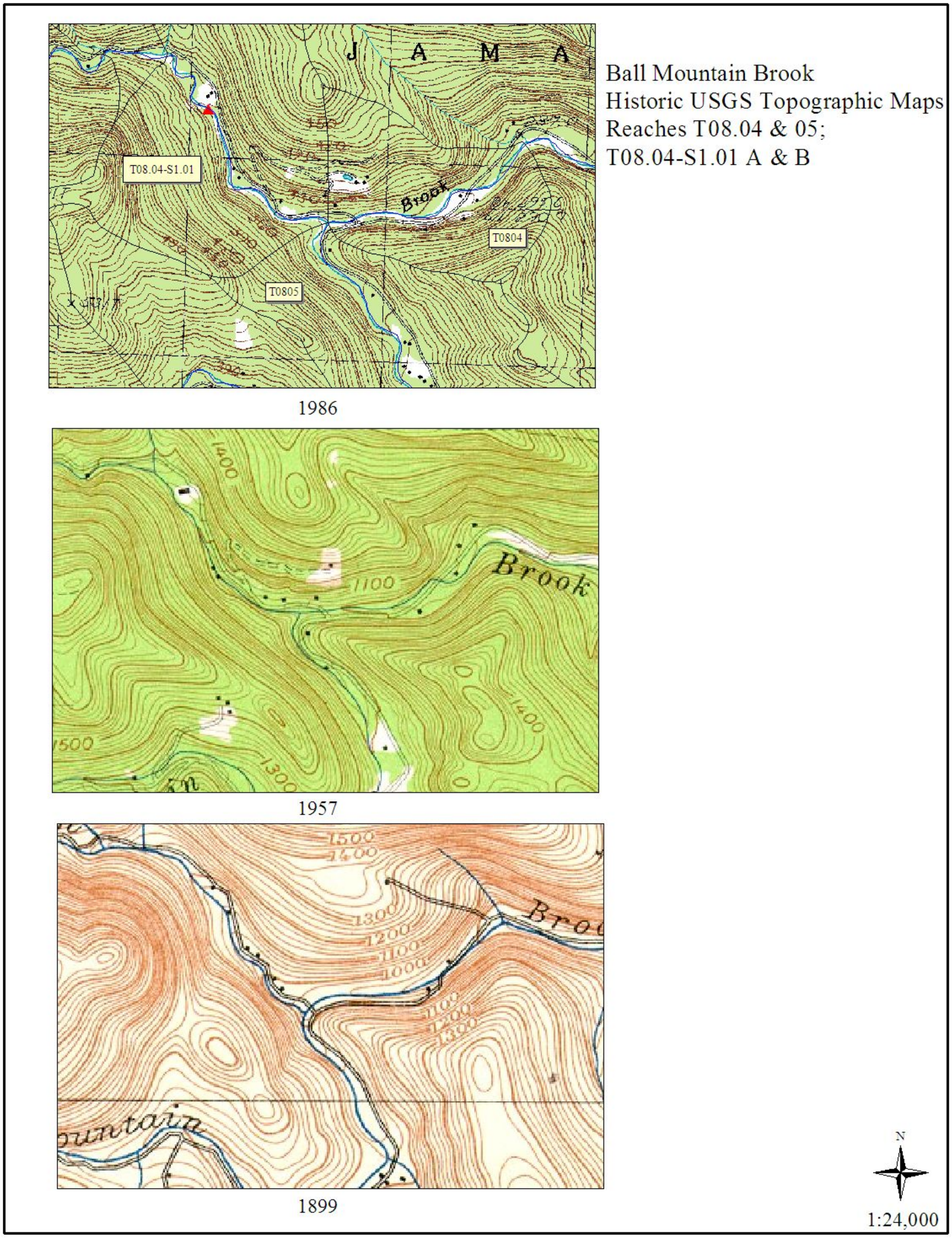
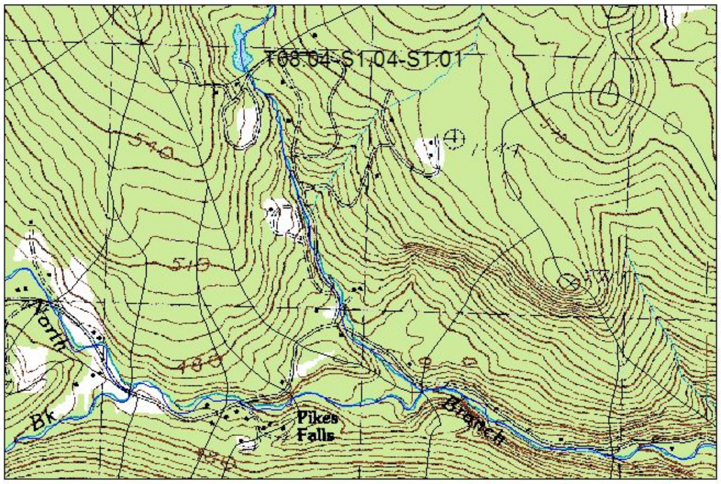


Figure 2. Historic Topographic Maps



Ball Mountain Brook
Historic USGS Topographic Maps
Reach T08.04-S1.04-S1.01
Dalewood Brook



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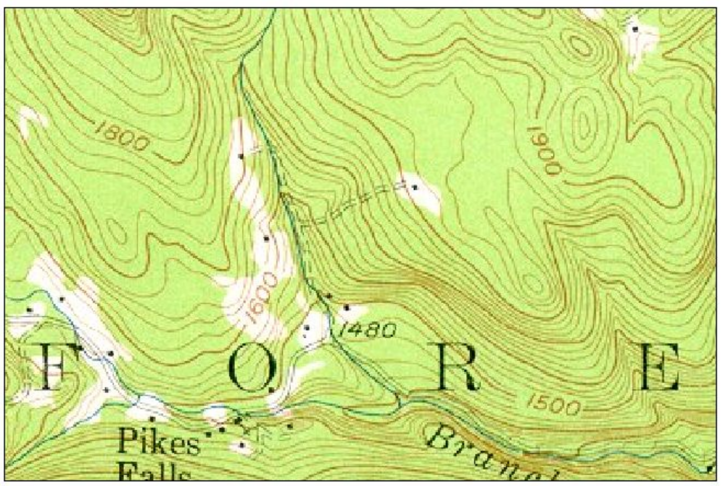

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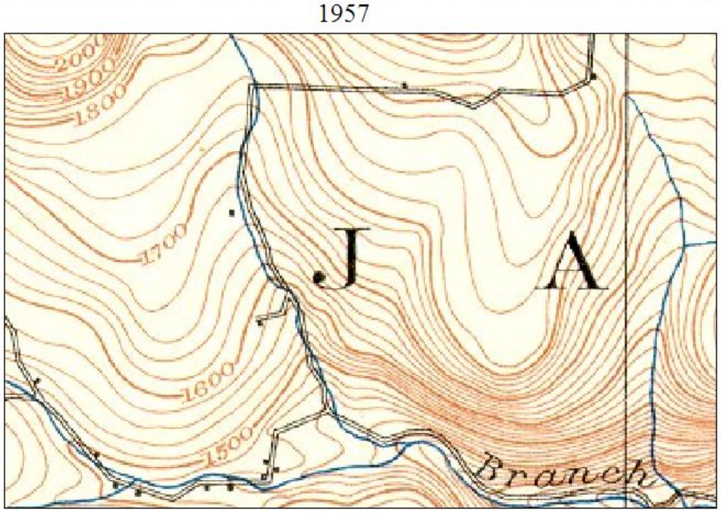

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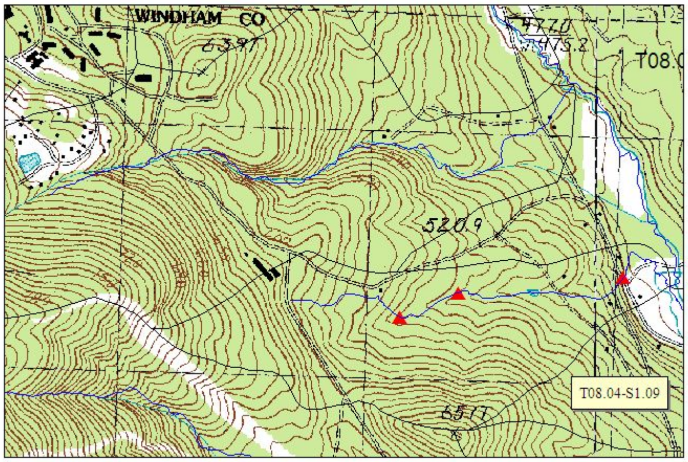
Ball Mountain Brook
Historic USGS Topographic Maps
Brazer's and Styles Brooks



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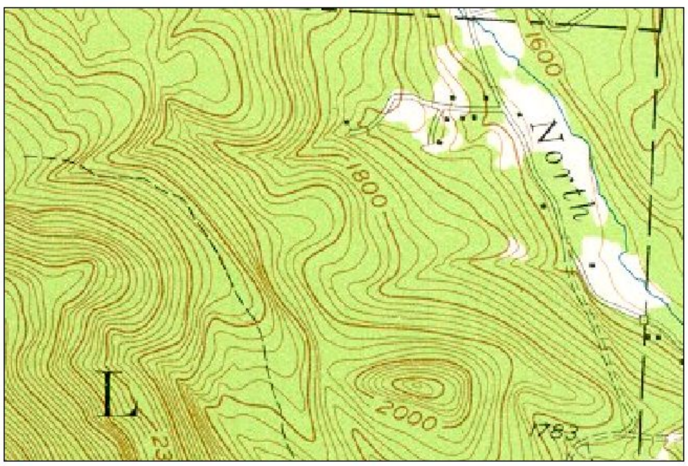

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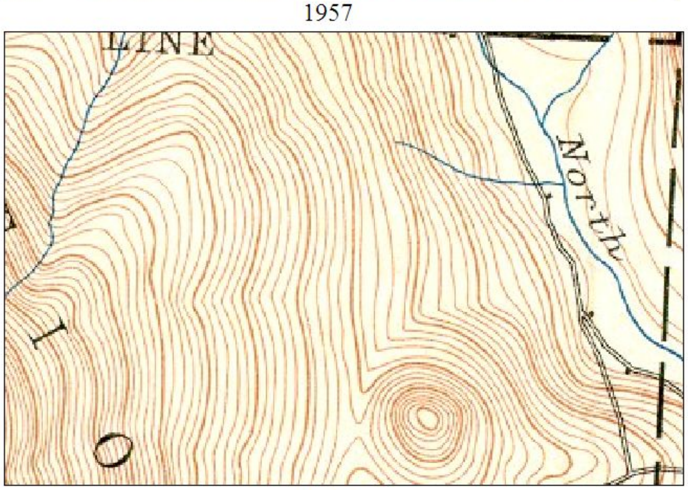

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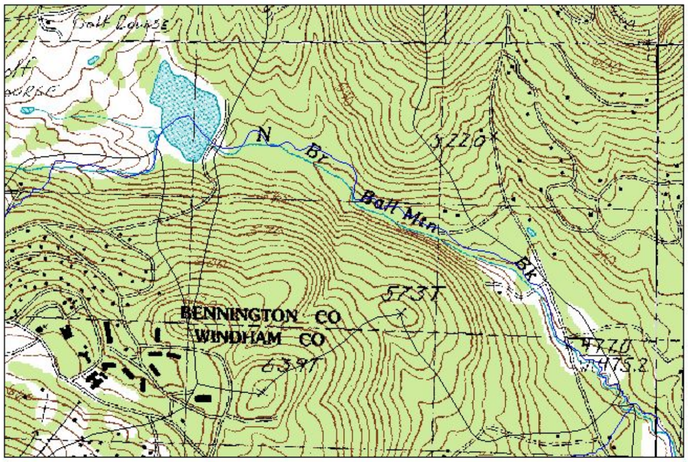
Ball Mountain Brook
Historic USGS Topographic Maps
T08.04-S1.11



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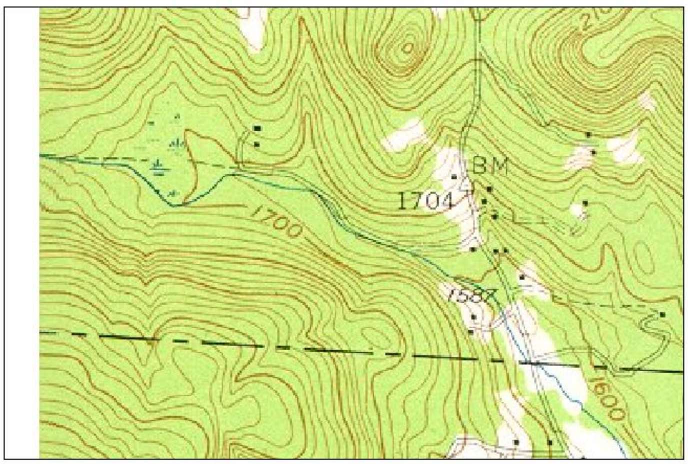

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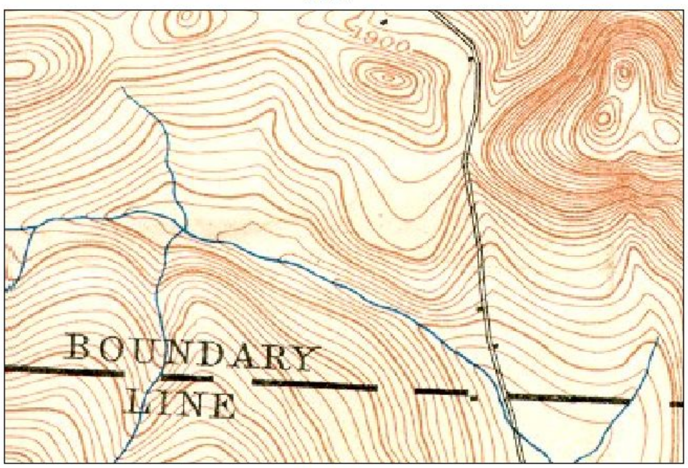

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Figure 3. Hydrologic Alterations

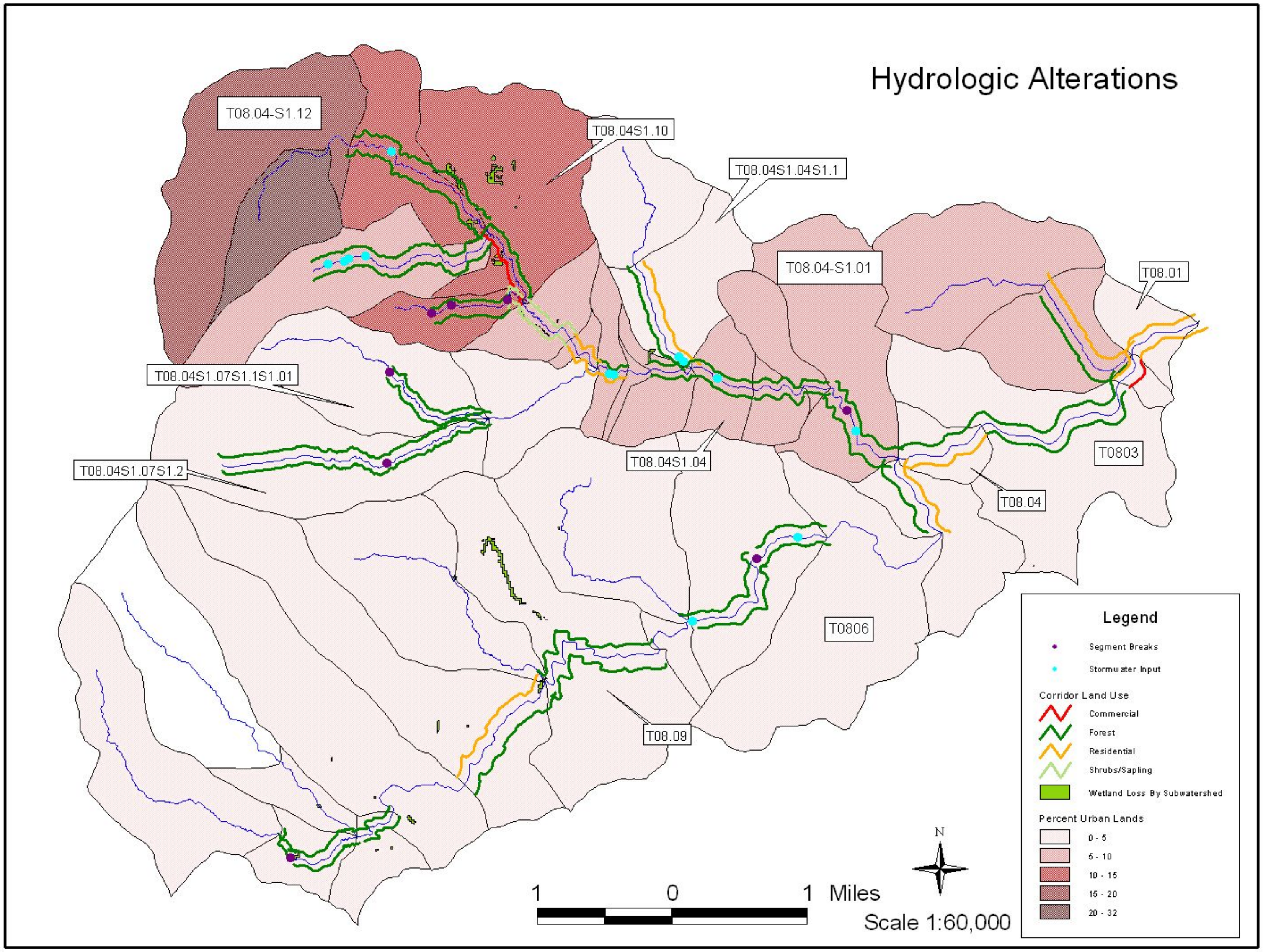


Figure 4. Sediment Load Indicators

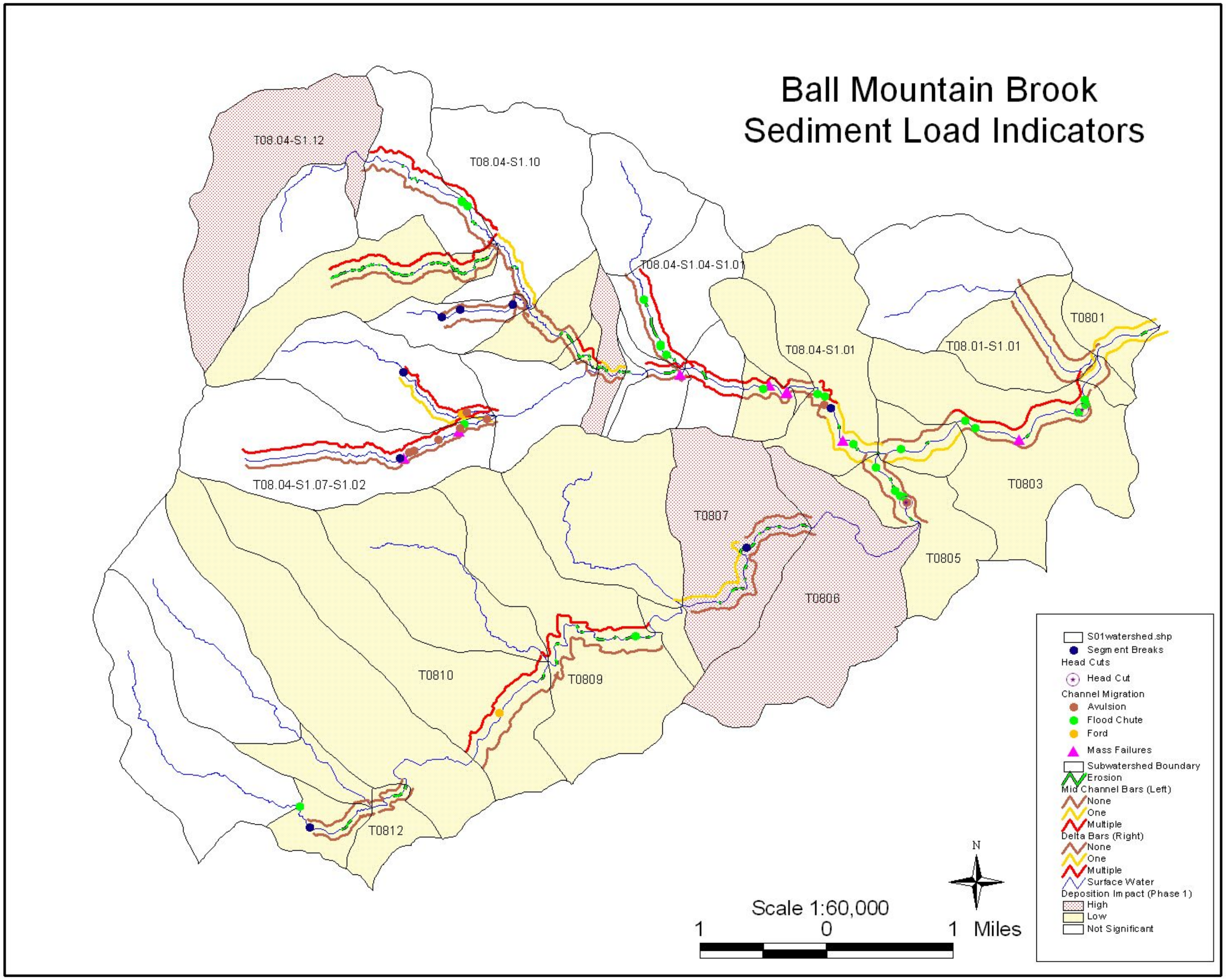


Figure 5. Channel Slope Modifiers

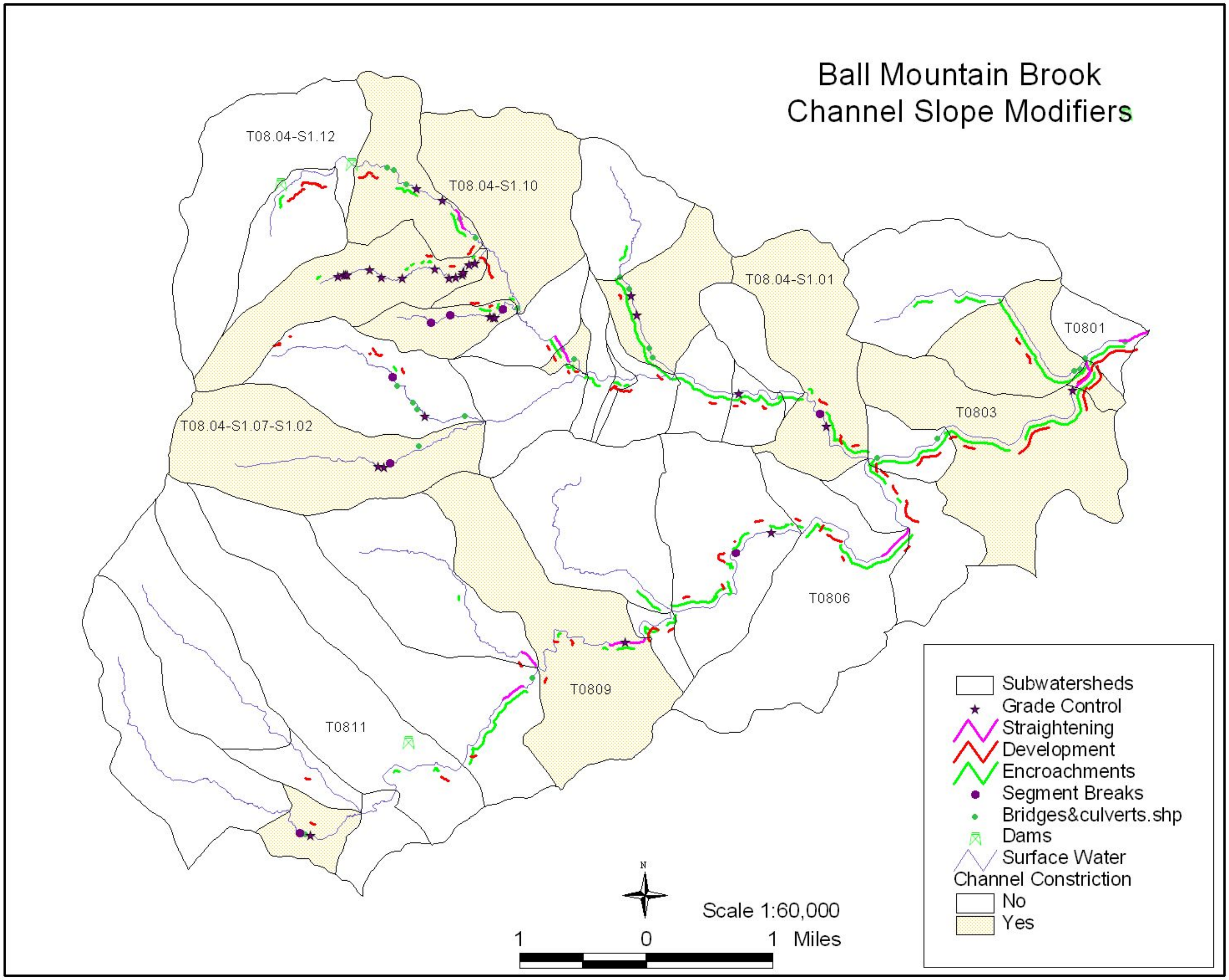


Figure 6. Channel Depth Modifiers

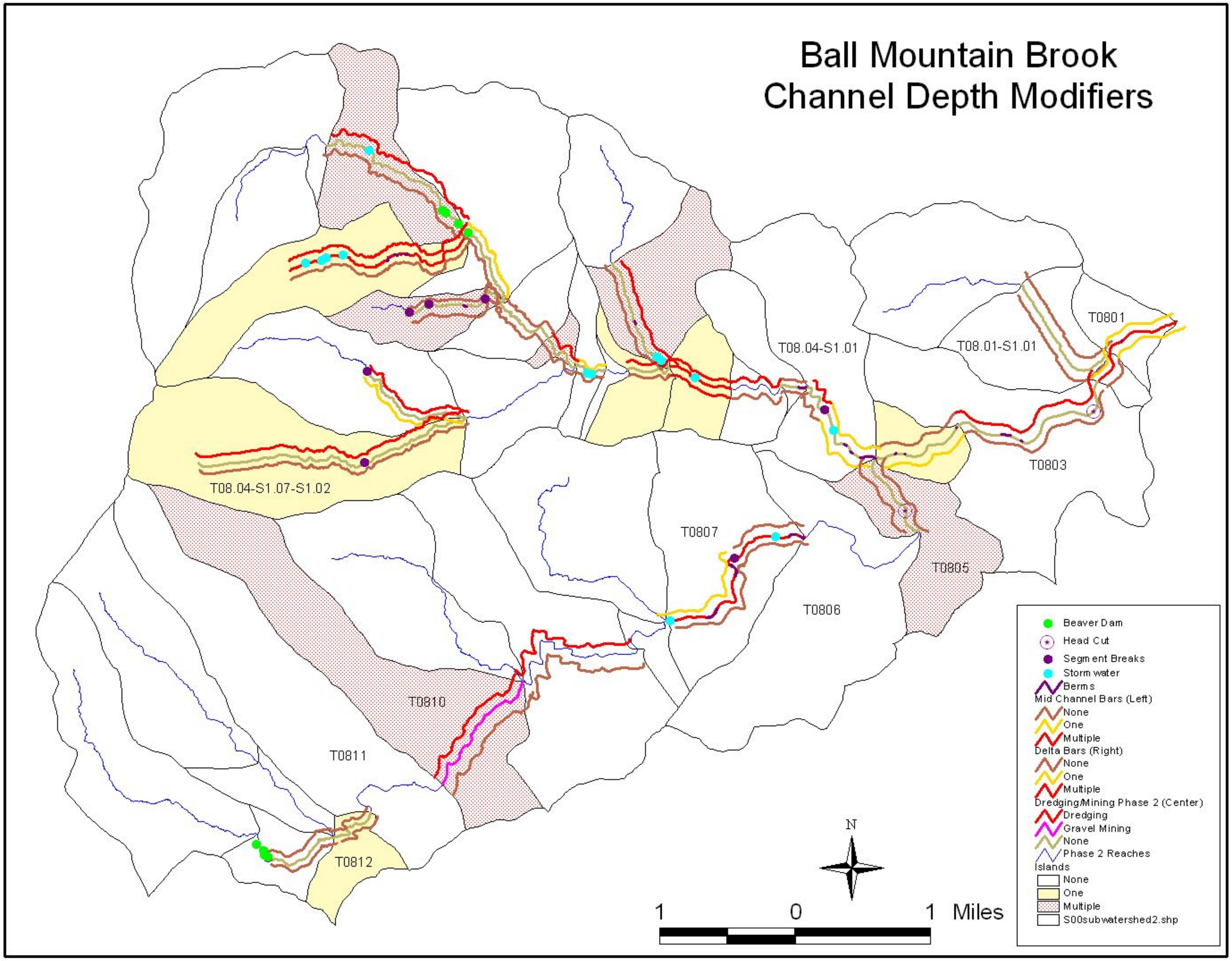


Figure 7. Boundary Condition and Riparian Modifiers

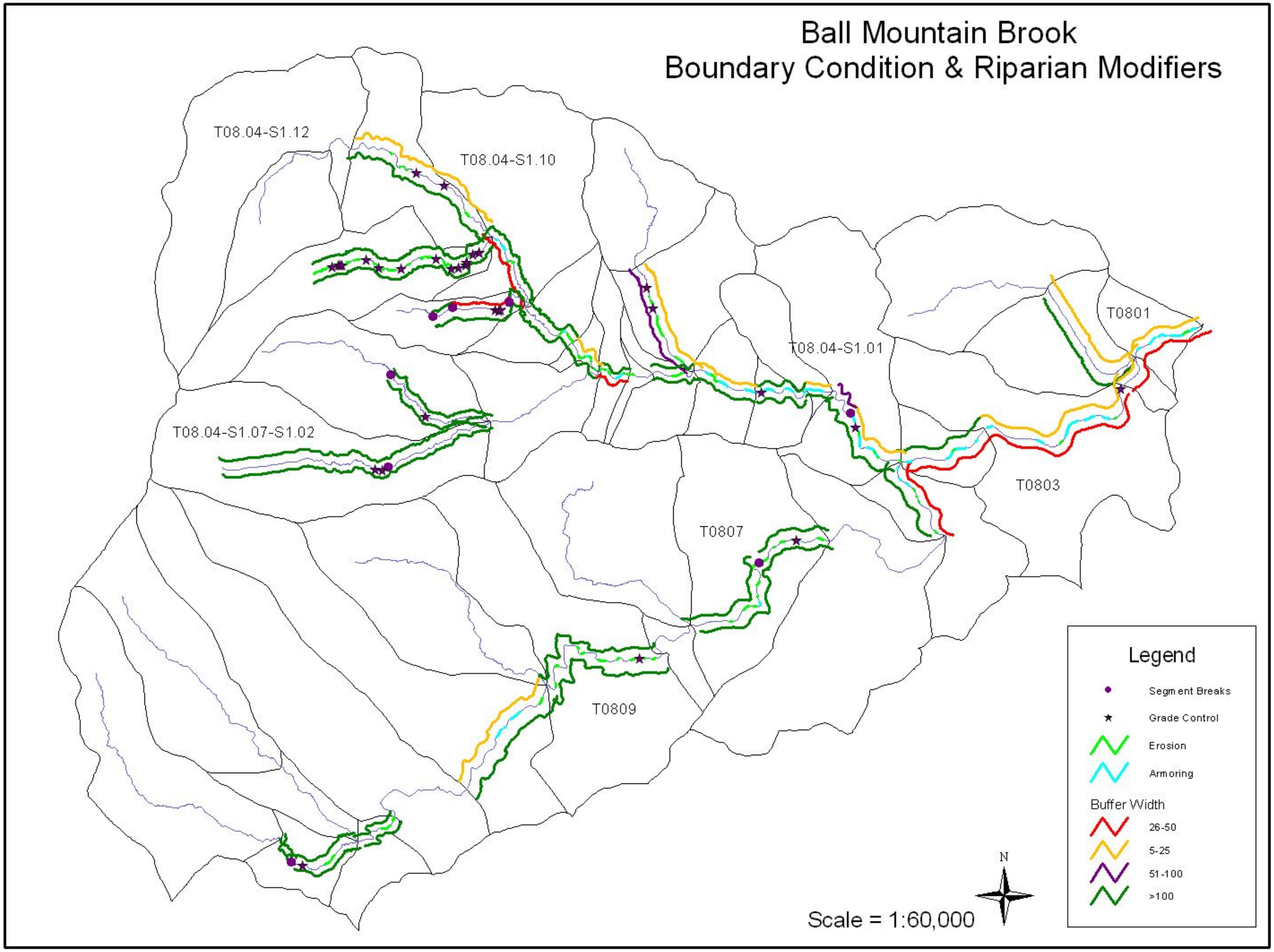


Figure 8. Reference Sediment Regimes

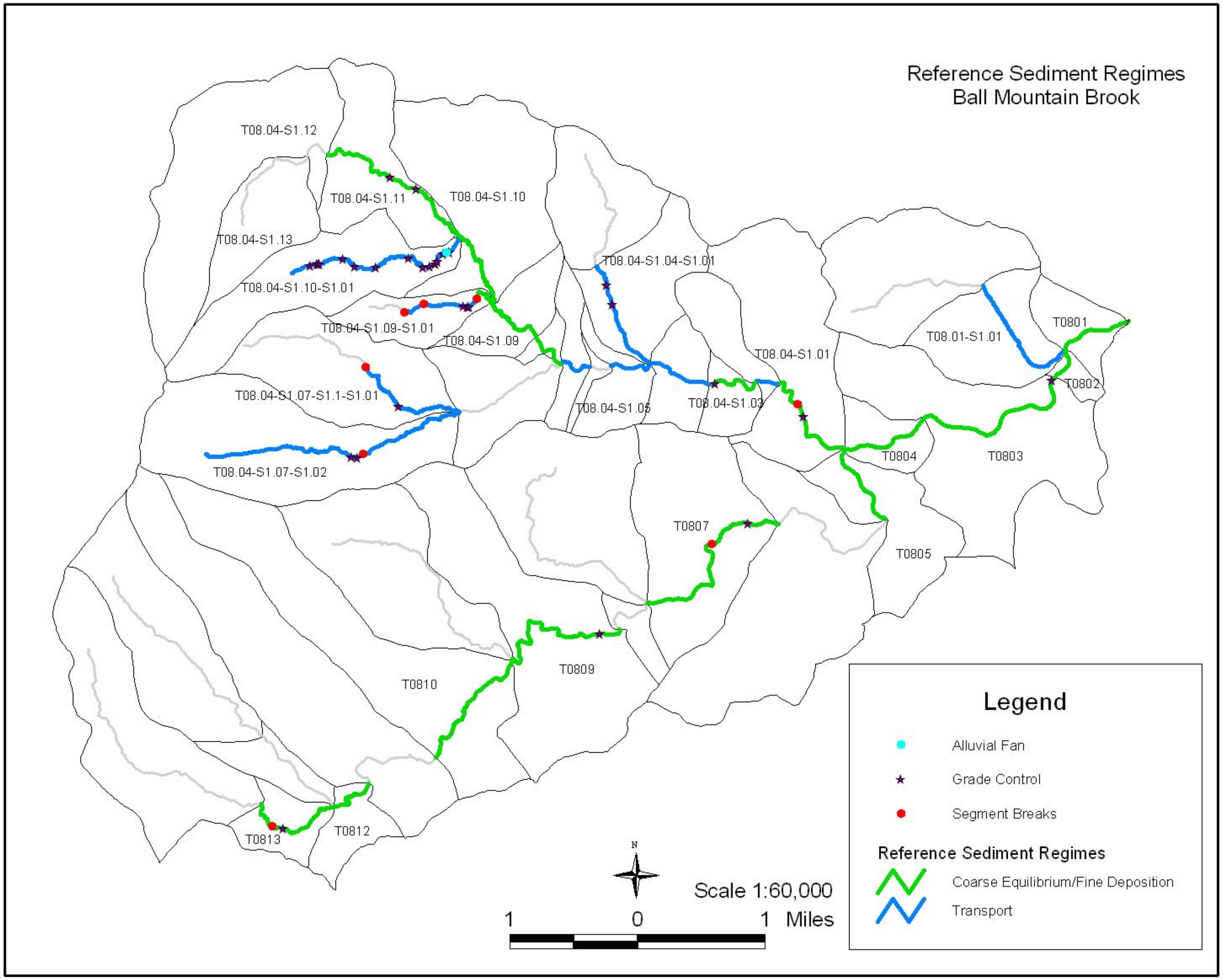


Figure 9. Sediment Regime Departure

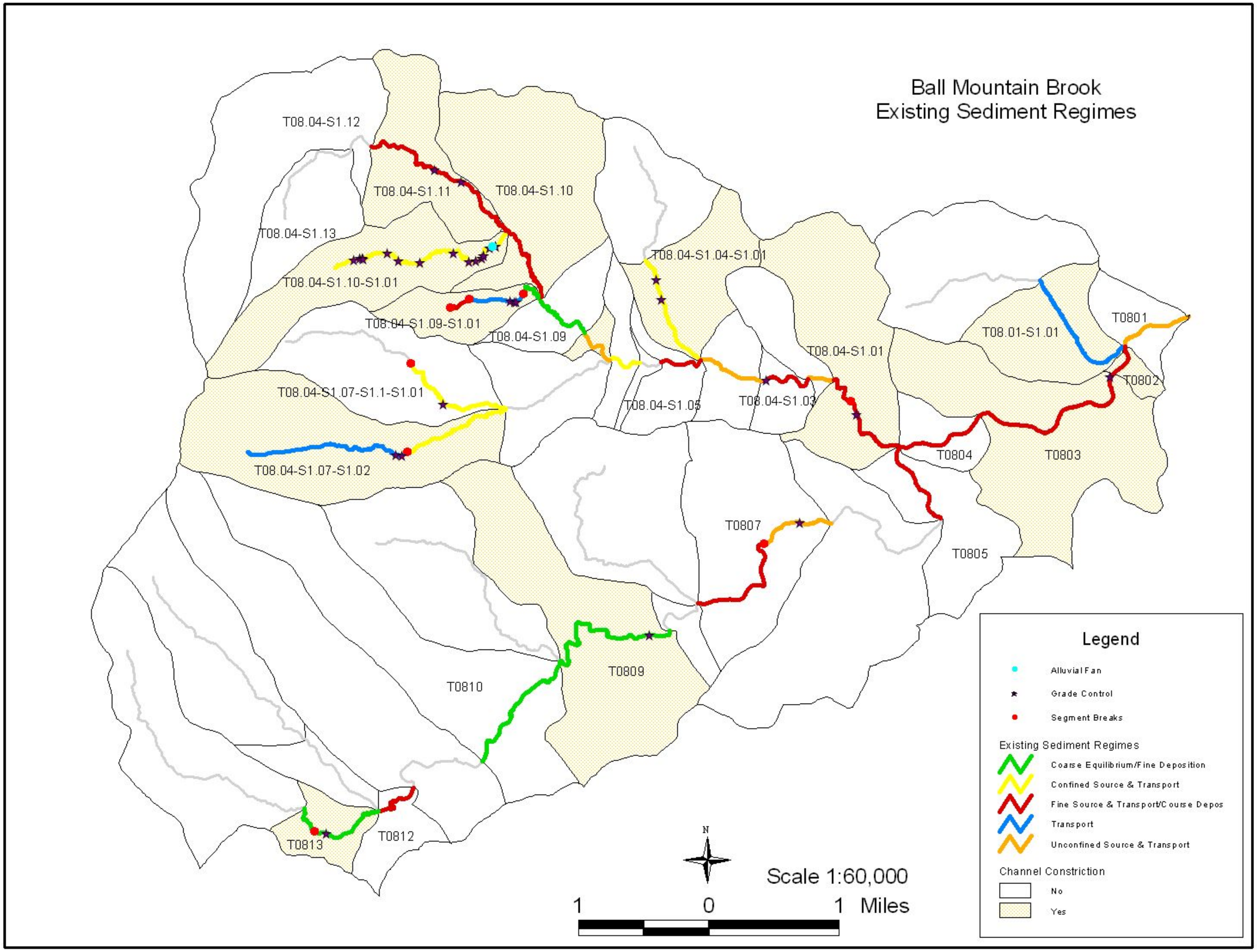
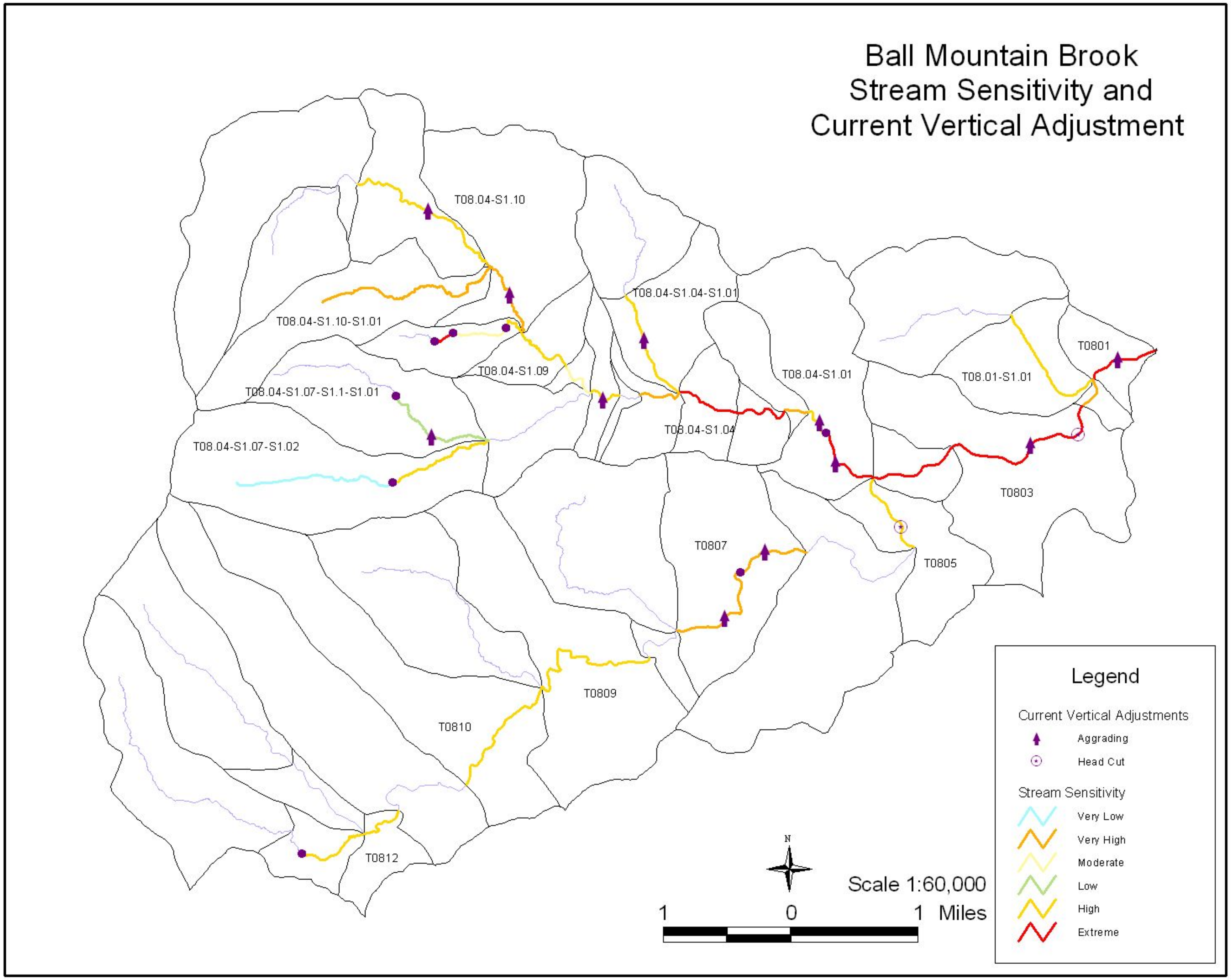


Figure 10. Stream Sensitivity and Current Adjustment



Ball Mountain Brook
River Corridor Plan

Appendix B
Tables

Table 1. Hydrologic Stressors

	Watershed Input Stressors		Reach Modification Stressors	
River Segment	**Hydrologic**	**Sediment Load**	**Stream Power**	**Boundary Resistance**
T08.01-S1.01-	Moderate	None	Increase - slope	Increase - bank armoring
T08.04-S1.01A	Low	Low	Increase - slope	Increase - bank armoring*a lot
T08.04-S1.01B	Low	Low	Increase - depth	None
T08.04-S1.02-	Low	None	Increase - slope & depth	Increase - bank armoring*a lot
T08.04-S1.03-	Low	Moderate	Increase - slope	Increase - bank armoring
T08.04-S1.04-	Low	Moderate	Increase - slope	Increase - bank armoring
T08.04-S1.04-S1.01-	Moderate	Moderate	Increase - slope	None
T08.04-S1.05-	Low	Moderate	None	Increase - u/s GC
T08.04-S1.07-	Moderate	Low	Increase - slope	Increase - bank armoring
T08.04-S1.07-S1.02A	Low	Moderate	None	None
T08.04-S1.07-S1.02B	Low	Low	None	Increase - GC
T08.04-S1.07-S1.1-S1.01A	Moderate	High	None	Increase - GC
T08.04-S1.08-	High	Low	Increased - slope	Increase - Bed - GC
T08.04-S1.09-	Moderate	Low*	None	None
T08.04-S1.09-S1.01A	Extreme	No data	None	Increase - Bed - GC
T08.04-S1.09-S1.01B	Extreme	No data	None	Increase - Bed - GC
T08.04-S1.09-S1.01C	Extreme	High	None	Increase - depth
T08.04-S1.10-	High	Low	Increase - slope	Decrease - riparian
T08.04-S1.10-S1.01-	High	High	Increase - slope & depth	Increase - GC
T08.04-S1.11-	Extreme	Moderate	Decrease - slope (Beaver Dam)	Increase - GC
T0801-	High	Low	Increase - slope & depth	Increase - GC, bank armoring
T0802-	High	Low	Increase - slope & depth	Decrease - dredging
T0803-	Moderate	High	Increase - slope	Decrease - riparian
T0804-	Moderate	Low	Increase - slope & depth	Increase - bank armoring
T0805-	Moderate	Moderate	None	None
T0807A	Low	Moderate	Increase - depth	None
T0807B	Low	High	Increase - slope	Decrease - Bed (windrowing)
T0809-	Low	Moderate	Increase - slope	None
T0810-	Moderate	Low	Increase - slope	Increase - bank armoring
T0812-	Low	Low	Increase - depth	None
T0813A	Low	Low	Increase - depth	None
T0813B	Low	None	None	None

Table 2. Constraints to Sediment Transport and Attenuation

	Constraints		Transport		Attenuation		
River Segment	Vertical	Lateral	Natural	Converted	Natural	Increased	Asset
T08.01-S1.01-	None	Human	X			X	
T08.04-S1.01A	Natural	Human		X	X	X	X
T08.04-S1.01B	None	Human (o)		X	X	X	
T08.04-S1.02-	None	Human	X				
T08.04-S1.03-	Natural	Human		X			
T08.04-S1.04-	None	Human		X		X	X
T08.04-S1.04-S1.01-	Both (t)	Human(o)	X			X	
T08.04-S1.05-	None	None	X			X	
T08.04-S1.07-	None	Human	X			X	
T08.04-S1.07-S1.02A	Human (t)	None	X			X	
T08.04-S1.07-S1.02B	Natural	Natural	X				
T08.04-S1.07-S1.1-S1.01A	Both (t)	None	X			X	X
T08.04-S1.08-	Human (t)	Human		X	X	X	
T08.04-S1.09-	None	None			X		X
T08.04-S1.09-S1.01A	None	Human			X		X
T08.04-S1.09-S1.01B	Natural	Human	X				
T08.04-S1.09-S1.01C	None	None				X	
T08.04-S1.10-	Human (t)	Human		X	X		
T08.04-S1.10-S1.01-	Both (t)	None	X				X
T08.04-S1.11-	Both (t)	None		X	X	X	
T0801-	Both	Human		X	X		X
T0802-	None	Human		X	X		
T0803-	Natural	Human		X	X		
T0804-	None	Human		X	X	X	X
T0805-	None	Human		X	X		
T0807A	None	Human		X	X		
T0807B	Natural	Human		X	X		
T0809-	None	Human(o)			X		X
T0810-	None	Human			X		
T0812-	None	None		X	X		
T0813A	Human (t)	None		X	X		
T0813B	Human (t)	None			X		X

(t) = 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

Ball Mountain Brook Corridor Planning -- Sensitivity Analysis				
River Segment	**Sensitivity**	**Channel Evolution**	**Dominant Adjusment**	**Prioritization**
T08.01-S1.01-	High		Aggradation	High
T08.04-S1.01A	Extreme	III	Widening	High
T08.04-S1.01B	High	IIc	Widening	Medium
T08.04-S1.02-	Very High	II	Widening	High
T08.04-S1.03-	Extreme	IV	Planform	Medium
T08.04-S1.04-	Extreme	III	Planform	Medium
T08.04-S1.04-S1.01-	High	IIb	Aggradation	High
T08.04-S1.05-	Very High	III	Widening	Medium
T08.04-S1.07-	High	III	Aggradation	High
T08.04-S1.07-S1.02A	High		Planform	Low
T08.04-S1.07-S1.02B	Very Low		Planform	Low
T08.04-S1.07-S1.1-S1.01A	Low	IIb	Widening	Medium
T08.04-S1.08-	Moderate	IIc	Aggradation	Medium
T08.04-S1.09-	High		Planform	Medium
T08.04-S1.09-S1.01A	High	I	None	Medium
T08.04-S1.09-S1.01B	Moderate	V	Widening	Medium
T08.04-S1.09-S1.01C	Extreme	IId	Planform	High
T08.04-S1.10-	Very High	IIc	Aggradation	High
T08.04-S1.10-S1.01-	Very High	III	Degradation	High
T08.04-S1.11-	High	IIc	Aggradation	High
T0801-	Extreme	II	Widening	High
T0802-	Very High	IV	Incision	High
T0803-	Extreme	III	Widening	High
T0804-	Extreme	III	Planform	High
T0805-	High	IIc	Planform	High
T0807A	Very High	II	Aggradation	High
T0807B	Very High	IV	Widening	High
T0809-	High		Planform	Medium
T0810-	High	IIc	Planform	Medium
T0812-	High	IV	Planform	Medium
T0813A	High	IIc	Planform	Medium
T0813B			Planform	Low

Transport
Confined Source & Transport
Unconfined Source & Transport
Unconfined Fine Source & Transport/Course Deposition
Course Equilibrium/Fine Deposition

Table 4. Identification and Prioritization

River Segment	Project Type	Reach Priority (based on Sensitivity Analysis)	Watershed Priority	Independent of Reach Restoration	Next Steps
T08.01-S1.01-	Reduce sediment input; restore habitat	High	Low	Yes	Work with Town & State to reduc sediment; work with landowners on habitat improvements.
T08.04-S1.01A	Restore Incised Reach	High	Highest	No	Contact landowners.
T08.04-S1.01B	Protect River Corridor	Medium	Highest	Yes	Contact landowners.
	Remove Old Abutment (Hx)	High	Highest	Yes	Explore historic value of structure; contact landowner.
T08.04-S1.02-	Manage as transport	Medium	Medium	Yes	
T08.04-S1.03-	Manage as transport	Medium	Medium	Yes	
T08.04-S1.04-	Manage as transport	Medium	Medium	Yes	
T08.04-S1.04-S1.01-	Remove Old Abutments (Hx)	High	Highest	Yes	Explore historic value of structure; contact landowner.
Dalewood Brook	Reduce sediment input		Highest	Yes	Work with developer & neighborhood to implement BMP on site.
	Restore Incised Reach		Highest	Yes	Contact landowners.
T08.04-S1.05-	Protect River Corridor	Medium	Medium	Yes	Contact landowners.
T08.04-S1.07-	Protect River Corridor	High	Medium	Yes	Contact landowners.
T08.04-S1.07-S1.02A	Conservation Easement in place.	Low	N/A		
	Replace Structure (1 Culvert)		Medium	Yes	Work with Town.
T08.04-S1.07-S1.02B	Conservation Easement in place.	Low	N/A		
T08.04-S1.07-S1.1-S1.01A	Conservation Easement in place.	Medium	Highest		
Sun Bowl Brook	Replace Structures (1)		Highest	Yes	Work with Stratton Mountain Corp.
	Reduce u/s input of sediment & runoff		Highest	Yes	Work with Stratton Mountain Corp.
T08.04-S1.08-	Replace Structures (2)	Medium	High	Yes	Contact landowners.
	Restore Incised Reach (u/s)		High	No	Contact landowners.
T08.04-S1.09-	Protect River Corridor;	Medium	Highest	Yes	Contact landowners.
	Stabilize stream banks on d/s end.		Highest	Yes	Contact landowners.
	Restore Incised Reach (d/s)		Highest	No	Contact landowners.
T08.04-S1.09-S1.01A	Protect River Corridor	Medium	High	Yes	Contact landowners.
Brazer's Brook	Replace Structure		High	Yes	Contact landowners.

River Segment	Project Type	Reach Priority (based on Sensitivity Analysis)	Watershed Priority	Independent of Reach Restoration	Next Steps
T08.04-S1.09-S1.01B Brazer's Brook	Protect River Corridor	Medium	High	Yes	Contact landowners.
	Replace Structure		High	Yes	Contact landowners.
T08.04-S1.09-S1.01C	Protect River Corridor	High	Highest	Yes	Contact landowners.
Brazer's Brook	Reduce sediment & flow inputs		Highest	Yes	Contact landowners.
T08.04-S1.10-	Protect River Corridor	High	High	Yes	Contact landowners.
	Plant Stream Buffers		High	Yes	Contact landowners.
	Replace Structure		High	Yes	Contact landowners.
T08.04-S1.10-S1.01- Style's Brook	Remove Berms	High	Highest	Yes	Contact landowners.
	Replace Structures (4)		Highest	Yes	Contact landowners.
T08.04-S1.11-	Protect River Corridor	High	Medium	Yes	Contact landowners.
	Replace Structures (4)				Contact landowners.
	Address sediment & flow inputs		Highest	Yes	Work with Stratton Mountain Corp.
	Restore Incised Reach (d/s)			No	Contact landowners.
T0801-	Plant Buffers to improve Habitat.	High	Low	Yes	Inventory potential planting areas; contact landowners.
T0802-	Plant Buffers to improve Habitat.	High	Low	Yes	Inventory potential planting areas; contact landowners.
T0803-	Plant buffers to increase habitat and protect banks.	High	Medium	Yes	Inventory potential planting areas; contact landowners.
	Monitor steep riffle/possible head cut.		High	Yes	Establish permanent cross section & longitudianl survey.
	Restore Incised Reach		Medium	No	Contact landowners.
T0804-	Restore Incised Reach	High	Highest	No	Contact landowners; assess options for restoration.
T0805-	Protect River Corridor	High	Highest	Yes	Contact landowners.
	Monitor head cut.		Highest	Yes	Establish permanent cross section & longitudinal survey.

River Segment	Project Type	Priority (based on Sensitivity	Watershed Priority	Independent of Reach Restoration	Next Steps
T0807A	Protect River Corridor (IV)	High	High	Yes	Contact landowners
	Restore Incised Reach		High	No	
T0807B	Protect River Corridor (IV)	High	High	Yes	Contact landonwers
	Remove Berms		High	Yes	
	Restore Incised Reach		High	No	
T0809-	Protect River Corridor	Medium	Highest	Yes	Contact landowners
	Remove Structure (Hx)		Highest	Yes	
T0810-	Protect River Corridor (RB)	Medium	Low	Yes	Contact landowners
T0812-	Protect River Corridor (IV)	Medium	Medium	Yes	Contact landonwers
T0813A	Protect River Corridor	Medium	Medium	Yes	Contact landowners
	Replace Structure (1 culvert)		Medium		
T0813B	Protect River Corridor	Low	Medium	Yes	Contact landonwers

carried over to Project

Protect River Corridor: In regime or reference stream type & low corridor development; some still have undersized structu

Hx = Old abutments

Table 5. Project Summary Identification and Prioritization

Ball Mountain Brook Corridor Planning			
Project and Strategy Summary Table			
Project #	Reach/Segment Condition/Sensitivity	Site Description including Stressors and Constraints	Project or Strategy Description
1	T08.04-S1.01A - North Branch Fine Source & Transport Extreme	Confined by road & berms; >60% armored; STD C to F; entrenched & incised; aggradation & widening; 1 mass failure; extreme sensitivity; at confluence with Rock River.	Restore delta bar at confluence with Rock; stabilize bank erosion; improve habitat.
2	T08.04-S1.01B - North Branch Unconfined Source & Transport High	Still has access to floodplain; C Riffle Pool; widening & planform; 1 avulsion & some braiding; aggradation; old abutment & berming.	Protect corridor; remove berms and consider removing old abutments.
3	T08.04-S1.04-S1.01 - Dalewood Confined Source & Transport High	Confined by road; erosion; multiple flood chutes, mid-channel & side bars; fine sediment deposition; aggradation; 4 constricting culverts; development.	Work with Dalewood community to reduce sediment inputs; explore history & consider restoration to old channel beds.
4	T08.04-S1.07-S1.1-S1.01A - Sun Bowl Confined Source & Transport Medium	Multiple flood chutes, islands, mid-channel and side bars; moderately incised; widening and aggradation; some erosion; two culverts constricting the channel.	Assess segment B to determine source of sediments and determine reason for moving the channel at Mountain Road.
5	T08.04-S1.09 - North Branch Coarse Equilibrium/Fine Deposition High	E-dune ripple; part of wetland complex; some erosion & deposition of fine sediments; coarse sand deposition possibly from roads.	Protect corridor.
6	T08.04-S1.09-S1.01C - Brazen's (er's?) Transport (But not) Extreme	D stream type; extreme aggradation & major widening; attenuation asset.	Address increased sediment & flow from the watershed.
7	T08.04-S1.10-S1.01 - Styles Confined Source & Transport Very High	15 grade controls; erosion!; 4 stormwater inputs; major widening & planform.	Examine opportunities to reduce sediment load and flow inputs upstream.
8	T08.04-S1.11- North Branch Fine Source & Transport High	C-riffle pool; ROR dam upstream of reach traps sediment; 4 constrictions, 2 grade controls, multiple islands & mid-channel bars.	Investigate sediment & flow inputs; protect corridor.

Project #	Reach/Segment Condition/Sensitivity	Site Description including Stressors and Constraints	Project or Strategy Description
9	T08.04 - Rock River Unconfined Source & Transport Extreme	buffers 5-25 on both banks, one grade control, one constriction, two thirds developed, berming high, extremem sensitivity.	Plant buffers, monitor head cut.
10	T0804- Rock River Fine Source & Transport Extreme	33% armored; berming prevalent; std C to F; old erosion; aggradation & planform; 2 constrictions; at confluence with Rock.	Opportunities exist for creation of floodplain and increased sinuosity.
11	T0805- Rock River Unconfined Source & Transport High	Several islands, flood chutes and abandoned channels; C-riffle-pool; planform with minor aggradation; at confluence with North Branch.	Arrest head cut; protect corridor.
12	T0809- Rock River Coarse Equilibrium/Fine Deposition High	21% straightened; >30% eroding banks; critical attenuation asset.	Protect river corridor; remove historic abutments