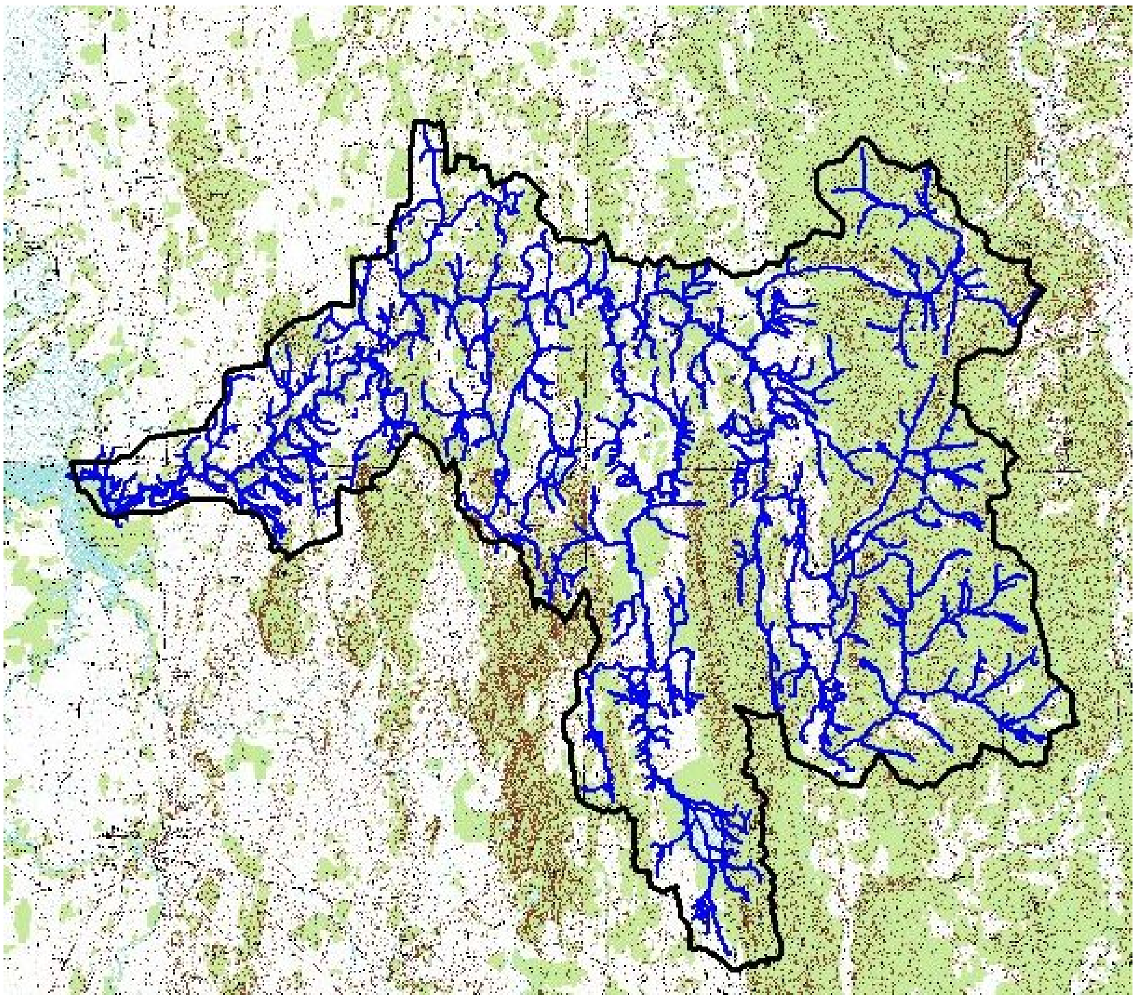
# Stream Geomorphic Assessment of Lewis Creek Pilot Project Report



**Department of Environmental Conservation**

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**Authorship and editing of the Stream Geomorphic Assessment of Lewis Creek, Pilot Project Report was the effort of:**

**Staci Pomeroy** **DEC River Management Program**
**Mike Kline** **DEC River Management Program**

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The Stream Geomorphic Assessment of Lewis Creek may be downloaded from the River Corridor Management, Geomorphic Assessment internet web page at: **www.vtwaterquality.org**

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# Lewis Creek Geomorphic Assessment Pilot Project Report

## Executive Summary

During 2001 and 2002, the DEC River Management Program (RMP) in conjunction with the Lewis Creek Association (LCA) and the Vermont Fish & Wildlife Department conducted geomorphic and habitat assessments of the Lewis Creek watershed. The pilot project was supported, in part, by the Lake Champlain Basin Program (LCBP) to gain a better understanding of ways to protect river corridors, manage stream bank erosion and phosphorus loading to Lake Champlain, and focus on-going river restoration efforts.

Protocols to physically assess rivers at a watershed and reach scale (Phase 1 and Phase 2) were developed and tested as part of the pilot project. A Phase 1 assessment program was developed to gain an understanding of the physical (geomorphic) characteristics of reaches within the watershed and provide a provisional rating of the physical impacts and geomorphic condition of reaches based on evaluations of land use changes, channel modifications, and floodplain modifications. A Phase 2 assessment program was developed to gather field data to verify Phase 1 remote sensing data and support an evaluation of geomorphic and habitat conditions of assessed river reaches. A Phase 3 protocol was also developed, in conjuncture with the pilot project, to collect survey data and characterize channel geometry and sediment transport processes. The protocol series were published and released in April, 2003.

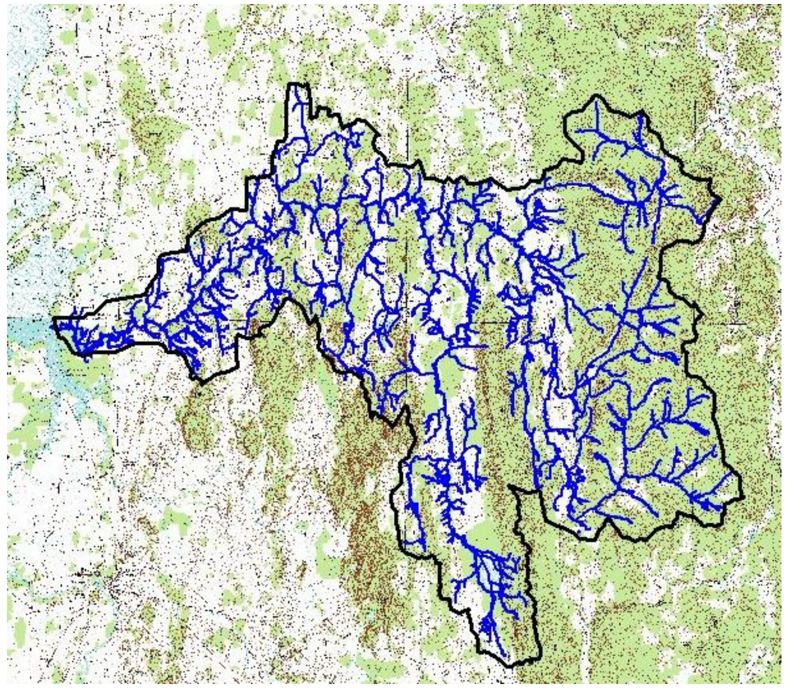
Phase 1 and Phase 2 geomorphic assessments may be used to guide river corridor management and planning decisions made by state and federal agencies, local municipalities, and watershed organizations working with other interest groups, such as landowners, to identify river concerns at a watershed scale. Watershed coordinators can then build community support for considering and using management strategies that resolve immediate site-specific conflicts in the context of broader, problem-solving goals. Upon setting priorities for stream protection, restoration, and management projects following remote sensing and targeted field assessments, more in-depth Phase 3 geomorphic assessments may be required to implement tailored strategies for river corridor protection or restoration.

One cost effective, long-term strategy explored during the pilot project was to place high priority on protecting those reaches that are currently in good condition or have a high recovery potential over those reaches that would require intensive and potentially expensive in-stream management practices. Using a watershed approach rather than the traditional "band-aid" approach to address land use/river conflicts along reaches in fair to poor geomorphic condition may prove to be of long term benefit to both the river and community as a whole. This approach will require coordination at the local, state, and federal level to educate the public and provide incentives to landowners.

At each level of assessment it was very important to have trained individuals collecting data and conducting quality assurance/quality control checks (QAQC) on the data. During the pilot project, trainings were conducted in the "class room" and in the field. Phase 1 trainings were conducted in 5 half day sessions. Volunteers did hands on exercises for each parameter of the assessment to gain an understanding of the parameter and participate in the data collection process. Trainings for Phase 2 were done at the start of each season, and were done over two days. After the initial training, volunteers completed Phase 2 assessments on practice reaches, during which questions could be addressed and additional training provided. Phase 3 assessments were conducted by RMP staff, with volunteers used as "extra hands." It is essential to conduct trainings for those persons collecting data; insuring a full understanding of the parameters assessed and the necessary quality of the data collected.

The value of a QAQC program can not be overemphasized. At each level of assessment QAQC forms were used to document concerns, issues, changes, missing data, etc. For the pilot project, a review of the data was done at the end of each field season. Due to protocol changes and data collected after the pilot project, a full QAQC will be done before the start of the 2004 season. This QAQC check will be conducted by LCA's trained coordinator, with assistance from RMP staff. From the pilot project, and other ongoing projects throughout the state, it has became apparent that lay-person volunteers may not be able to commit the time necessary to acquire the training to collect complete and accurate data without the guidance of a trained professional. During the second year of the project LCA hired a consultant, with a scientific background, to lead the volunteers. The consultant participated in the trainings and was given additional training as needed The consultant became responsible for coordinating the volunteers, conducting the Phase 2 assessments, data entry and data review. This format allowed volunteers to participate, while not being responsible for the full data collection process. By using a consultant the reliability and consistency of the data improved. It is highly recommended that groups starting an assessment determine how data will potentially be used in the future. To insure high quality data, it may be necessary to hire a consultant or other trained person to conduct the assessments.

The “Lewis Creek Geomorphic Assessment Pilot Project Report” is an overview of the first two years of assessment in Lewis Creek. The report attempts to demonstrate how the data collected from geomorphic assessments may be used. A Phase 1 assessment of 80 reaches was used to support decisions on where to complete more time and resource intensive Phase 2 field assessment and to understand the types of major impacts affecting the Creek. Maps demonstrating other uses of Phase 1 data have also been generated (Appendix D). The spatial presentation of data helps agencies and organizations determine where they may want to do different types of corridor protection and restoration work. Maps have also been helpful to the assessment team in learning how to query data and addressing river issues that are systemic in nature. The results of 19 Phase 2 assessments were reviewed in the context of how different management strategies may work within the various reaches given the types and rate of channel adjustments that are underway. Phase 3 assessment results for 6 survey sites were used to verify historic and current channel adjustments and support the management strategy chosen for a given reach.



The geomorphic assessment pilot project conducted on Lewis Creek has been a success. The Lewis Creek project has so far provided a valuable framework for building a partnership between the Agency and the public to begin understanding stream behavior and river corridor management in a watershed context. The data collected will support LCA, LCBP, and State of Vermont objectives, and will be used to help set priorities for future stream and watershed projects. Valuable lessons on how to conduct trainings, improve the quality of data collected, and conduct watershed assessments were gained during this project. Establishing the goals of the project and what the data may be used for, before starting the assessments, has helped to increase data quality and insure that the data can be used for what the group had in mind when taking on the assessment. There are often opportunities to have a variety of people participate in the process. Determining, at the start of the project, the various roles of each participant will help to insure that information is collected in a timely and accurate fashion. Having a professional consultant as the primary data collector, with volunteers as “extra hands” is a good model for many watershed groups looking to conduct assessments. The Vermont Regional Planning Commissions have also become a good resource for helping to conduct all, or part, of the Phase 1 assessments. The River Management Program has become a technical support resource for watershed groups, RPCs and consultants; assisting in training, data review, QA checks, and field evaluations.

The process of a watershed assessment is perhaps a long term project for many groups, spanning many years, with many different people involved. Stream Geomorphic Assessments provide an important context in which to establish baseline information and then build upon that knowledge as further data is collected. The pilot project did not result in a complete assessment of the entire Lewis Creek watershed. Further assessment and a continued local-state-federal partnership will strengthen the work previously done and the work that may continue in the future.

# Lewis Creek Geomorphic Assessment
# Pilot Project Report

## Project Overview

The Lewis Creek pilot project was funded by the Lake Champlain Basin Program and was a collaborative effort between the DEC River Management Section, the Lewis Creek Association, the Vermont Fish and Wildlife Department, the Addison County Regional Planning Commission, and the USDA Natural Resource Conservation Service. The project had two goals; the primary goal was to develop stream geomorphic assessment protocols to conduct assessments at the river site, reach, and watershed-scales. Developing the protocols in a watershed with a well-developed watershed organization, a group that is likely to utilize the assessment results, allowed the VT Agency of Natural Resources (ANR) to test, revise, and format the protocols in a way that insures the data, once collected, is presented in a usable format. The second goal, but no less important, was to substantially start a watershed assessment, collecting both remote sensing and empirical field data, to demonstrate the importance of fluvial geomorphic data to river resource management and planning at the local, state, and federal levels of government.

This report is comprised of three sections. The first section is an overview of the methods, results, and project status of the protocol development and the Lewis Creek assessment components of the Pilot Project. The overview is followed by the presentation and discussion of geomorphic data collected during the two years over which the Pilot Project was conducted (2001 and 2002).

## Protocol Development

### Goals and Objectives

A goal of Vermont's stream and river corridor conservation programs is to resolve or avoid conflicts between human investments and river systems in a manner that is technically sound and both economically and ecologically sustainable. To help reach this goal, the Vermont Agency of Natural Resources has prepared a series of Stream Geomorphic Assessment Protocol Handbooks. The Handbooks are a collaborative effort by the Department of Environmental Conservation, River Management Program; the Department of Fish and Wildlife, Fisheries Division; and the Vermont Geological Survey.

The purpose of the stream geomorphic assessment protocols is to provide a method for gathering scientifically sound information that can be used for watershed planning and detailed characterization of riparian and instream habitat, stream-related erosion, and flood hazards. The handbooks create a standardized methodology to analyze and monitor various parameters that can affect the river system; and will insure the consistency and repeatability of watershed assessments.

The Vermont ANR stream geomorphic assessment protocol brings the best accepted practices of the emerging science of fluvial geomorphology into the practical realm of river management in Vermont. Together with the sciences of engineering, hydrology, and river ecology, Vermont will be in a better position to achieve long-term ecological and economic sustainability of Vermont's river and watershed resources.

At the completion of each phase of assessment, the data that is gathered will assist in making better types of management goals and decisions for a reach of river. Weighing river management alternatives may include the consideration of: the current stream condition as compared to the reference or equilibrium condition; the adjustment processes, or physical changes currently underway in the channel; and the sensitivity of the valley, floodplain, and channel to human and/or natural changes.

Stream geomorphic data has many potential applications. Watershed organizations and agencies can utilize the data to help meet the specific goals and objectives for large or small scale projects; such as revising watershed plans or for site specific remediation projects. Examples of applying collected data are:

- Watershed land use planning and review;
- Flood plain management;
- Riparian habitat protection / restoration;
- Agricultural riparian corridor management and restoration;
- Flood hazard mitigation, flood recovery, and emergency watershed protection; and
- Highway infrastructure design

The assessments provide a way of organizing and using the data that has long been necessary for management decisions and project planning, but has not always been analyzed comprehensively in a format accessible to decision makers. Utilizing the data to complete a variety of objectives will take the cooperative and interrelated efforts of various stakeholders. The DEC River Management Program is currently working on projects with its partners; including Regional Planning Commissions, FEMA, Vermont Emergency Management, Vermont Fish and Wildlife Department, US Fish and Wildlife Service, US Forest Service, the Natural Resource Conservation Service, Vermont Agency of Agriculture, DEC Basin Planning Program, and the Vermont Agency of Transportation to devise specific methodologies for reducing and analyzing stream geomorphic assessment data in a manner that will directly feed into existing river resource and infrastructure management programs. As data is collected and shared in a manner that is accessible to the decision maker, the ability to strategically address specific objectives will become more feasible.

## Methods

The Lewis Creek pilot project was, in part, an opportunity to develop and refine protocols for watershed fluvial geomorphic assessments and reach level assessments. Phase 1 and Phase 2 handbooks were developed to support the remote and field assessment work. A Phase 3 handbook (involving land and river survey techniques) was concurrently developed but not as a part of this pilot project. Two years of field testing were completed in the development of the protocol handbooks. Field testing of the protocols was done by a number of groups and agencies, the LCA, DEC River Management Section, the Vermont Fish and Wildlife Department, and the Vermont Geologic Survey. This collaborative effort insured that there would be consistency between groups that were doing similar work for and within the Agency. After each field season the protocols were reviewed with comments and suggestions from the volunteers, other agency partners, and academia groups. The Lake Champlain Basin Program Technical Advisory Committee also conducted a national peer review of the protocols. Revisions were made to improve the methodology for data collection of various parameters, and to increase the explanations and background information for different parameters. Having various groups and users provide comments and suggestions, insured that the development of the protocols took into consideration the different levels of training and scientific background that a user may have.

To support the data collection work and insure the quality of data collected, a database was developed. The database provides the framework to sort and prioritize the data collected. Queries and reports were created to help with interpretation of data and to provide a consistent set of results for any watershed evaluated.

## Results

The Vermont ANR Stream Geomorphic Assessment Protocols are broken down into three handbooks that offer separate but interrelated approaches for examining a set of physical parameters and evaluating the geomorphic and habitat condition of a stream reach and its watershed. The handbook series was developed because watershed planners and river managers need to understand river forms and processes and have a clear understanding of the spatial and temporal responses associated with certain human activities. While the protocols require technical training for both professionals and interested lay people, the handbooks provide an accessible method for anyone interested in gaining a limited working knowledge of fluvial geomorphology and the physical components of riparian and instream habitat. They are not intended, however, to provide the full compendium of techniques in the emerging applied sciences of fluvial geomorphology or river ecology.

**Phase 1:** The remote sensing phase, involves the collection of data from topographic maps and aerial photographs, from existing studies, and from very limited field studies, called "windshield surveys." Geomorphic reaches and provisional reference stream types are established based on valley land forms and their geology. Predictions of channel condition (departure from reference), adjustment process, and reach sensitivity are based on evaluations of watershed and river corridor land use and channel and floodplain modifications. While stream types and adjustment process predictions are provisional, the Phase 1 remote sensing techniques allow for large watersheds (100-150 square miles) to be assessed within a few months time. Computer and river assessment skills are necessary but there are plenty of tasks that can be completed by someone with limited training.

**Phase 2:** The rapid field assessment phase, involves the collection of field data from measurements and observations at the reach or sub-reach (segment) scale. Existing stream types are established based on channel and floodplain cross-section and stream substrate measurements; supplemented with Phase 1 slope and sinuosity measurements. Stream geomorphic condition, physical habitat condition, adjustment processes, reach sensitivity, and stage of channel evolution are based on a qualitative field evaluation of erosion and depositional processes, changes in channel and floodplain geometry, and riparian land use/land cover.

**Phase 3:** The survey-level field assessment phase, involves the collection of detailed field measurements at the sub-reach or site scale. Existing stream types and adjustment processes are further detailed and confirmed based on quantitative measurements of channel dimension, pattern, profile, and sediments. Phase 3 assessments are completed with field survey and other accurate measuring devices and can take three to four days to survey a stream length of two meander wavelengths.

Phase 1 and Phase 2 geomorphic assessments may be used to guide river corridor management and planning decisions made by state and federal agencies, local municipalities, and watershed organizations working with other interest groups, such as landowners, to identify questions, concerns and issues at a watershed scale. Watershed coordinators can then build community support for considering and using management strategies that resolve immediate site-specific conflicts in the context of broader, problem-solving goals. Upon setting priorities for stream protection, restoration, and management projects following remote sensing and targeted field assessments, more in-depth Phase 3 geomorphic assessments may be required to implement tailored strategies for river corridor protection or restoration.

The Vermont ANR Stream Geomorphic Assessment protocols help river planners and managers take the first steps in applying channel form, adjustment process, and channel evolution data by providing a method for assigning a **geomorphic and physical habitat condition** to stream reaches. The term "departure from reference" is used synonymously with stream geomorphic condition throughout the protocols. The degree of departure is captured by the following three terms:

**In Regime – a stream reach in *reference and good* condition that:**

- Is in dynamic equilibrium which involves localized change to its shape or location while maintaining the fluvial processes and functions of its watershed over time and within the range of natural variability; and
- Provides high quality aquatic and riparian habitat with persistent bed features and channel forms that experience periodic disturbance as a result of erosion, deposition, and woody debris.

**In Adjustment – a stream reach in *fair* condition that:**

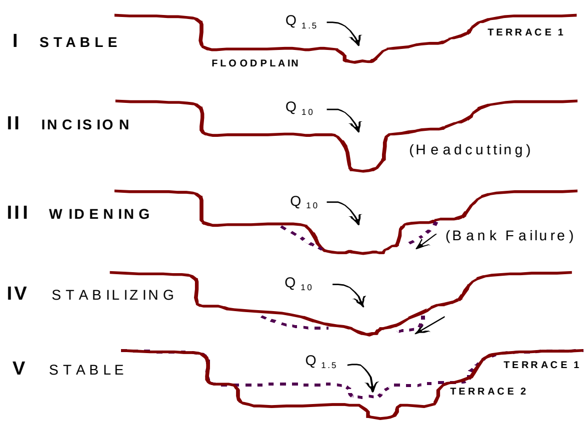
- Has experienced changes in channel form and fluvial processes outside the expected range of natural variability; may be poised for additional adjustment with future flooding or changes in watershed inputs that would change the stream type; and
- Provides aquatic and riparian habitat that may lack certain bed features and channel forms due to increases or decreases in the rate of erosion and deposition-related processes.

**Active Adjustment and Stream Type Departure – a stream reach in *poor* condition that:**

- Is experiencing adjustment outside the expected range of natural variability; is exhibiting a new stream type; is expected to continue to adjust, either evolving back to the historic reference stream type or to a new stream type consistent with watershed inputs; and

- Provides aquatic and riparian habitat that lacks certain bed features and channel forms due to substantial increases or decreases in the rate of erosion and deposition-related processes. Habitat features may be frequently disturbed beyond the range of many species' adaptability.

**Channel Evolution Sequence:** A channel adjustment process occurs due to natural causes or human activity that has or will result in a change to the floodplain and/or channel condition and, in some cases, even the valley characteristics. An analysis of channel adjustment involves determining the departure of the stream's existing conditions from those of a reference stream of the same type, and understanding the physical processes at work in the stream as it comes into balance with the flow and sediment regimes of its watershed. Channel evolution models developed and verified by researchers studying channel adjustment in North America and Europe have been found to be useful in Vermont in understanding why and how streams are responding to various watershed, floodplain, and channel modifications. Depending on when you complete your survey relative to where in the channel evolution stage a channel is, you may come to different conclusions about the adjustment process occurring in the channel.




In regime, reference to good condition, insignificant to minimal adjustment.

Fair to poor condition, major to extreme channel degradation.

Fair to poor condition, major to extreme widening and aggradation.

Fair to good condition, major reducing to minor aggradation, widening, and planform adjustments

In regime, reference to good condition, insignificant to minimal adjustment.

**Figure 1.** Five Stages of Channel Evolution (Schumm, 1977 and 1984), the channel condition and adjustment processes often observed during each stage

**Appendices** have been developed to support all three levels of assessment and include: data sheets, field forms, database instructions, technical information, detailed techniques, and a glossary of terms. Printed copies of the handbooks are distributed with only those appendices that are referenced in a particular phase of assessment.

**Data Management System:** To support the collection and storing of data, and insure the quality of data collected at each phase of assessment, a Microsoft Access® database was developed. The database provides the framework to sort and prioritize the data collected. A Microsoft Excel® workbook has been developed for Phase 3 assessments. Data is reviewed for completeness and accuracy when it is entered into the workbook and then again when transferred into the Access database. To assist in reviewing data for accuracy and consistency, the databases generate standard reports and tables for data at the watershed, reach, segment, and site level. These reports and tables will also help with determining where additional information should be collected and where further phases of assessments may be needed.

**ArcView Tool:** To help speed the process of collecting key measurements, an ArcView® extension was developed to accompany the Phase 1 protocols. The Stream Geomorphic Assessment Tool, SGAT, supports the data collection process for parts of Step 1, Step 2, Step 3, and Step 4. The tool also creates the river corridor described in Appendix E of the protocols. The development of the tool has greatly reduced the amount of time needed to collect measurements previously done by hand with a map-wheel and ruler. The themes generated by SGAT can be used to aid groups with mapping their data; helping them visually display information from all Phases of assessment.

**Quality Assurance Program:** In order to ensure the collection of accurate and consistent data, users of the Vermont ANR Stream Geomorphic Assessment protocols need to establish a quality assurance program for each phase of the assessment. The protocols outline three key components of quality assurance (QA): training, data review, and use of a data management system. Conducting a QA program at all levels of assessment ensures that data is accurate and complete. The protocols call for the establishment of a QA team to support and complete QA requirements. Quality Assurance details for each phase of assessment are described in each handbook.

## Project Status/Recommendation

After two season of field testing, a peer review process, and updates, the Stream Geomorphic Assessment protocols were completed and released state-wide in April of 2003. The protocols provide a scientific method for collecting data at the watershed, reach, and site-scale. With the consistent method of collecting data; watershed organizations, local municipalities, and state and federal agencies are able to share information about their watersheds or a particular river reach within the watershed.

The approach of a watershed assessment lends itself to many possible uses. This approach is effective because it addresses the multiple objectives of various stakeholder groups, and can be understood and applied by such diverse individuals as town planning board members, road foremen, landowners, and local, county, state, and federal resource agencies. This strategy complements more traditional approaches to stream management by creating projects and plans that serve goals of ecosystem restoration in equal measure to human needs of flood risk mitigation, private property protection, water quality improvement and recreational opportunities.


Volunteer field training

Volunteers and watershed groups are a key component of the watershed assessment. These groups and individuals bring not only local knowledge about the area into the assessment, they bring the commitment of protecting a valuable resource into their community. With training and Agency guidance, volunteers and watershed groups are able to do a watershed assessment that is geared towards their goals and current needs. It is also possible for the work to continue on a yearly, monthly, or even daily basis if there are dedicated community groups and individuals involved in the assessment. Doing both the remote sensing work and field work provides valuable knowledge and understanding about the watershed to the lay persons. Watershed groups are better able to focus their resources and goals by doing a watershed assessment. Community planning and resource allocation can also be better guided with more knowledge and understanding of the watershed that is directly affected by those choices.

Currently there are 18 watershed assessments that have been completed or are getting started with different phases of assessment. Groups consisting of a range of knowledge and skills have been established for each assessments. Watershed groups and towns have indicated that the process of collecting and organizing data in the format of the protocols provides them with an easier way to communicate and utilize data. This process will be greatly enhanced as State and Federal agencies complete projects that demonstrate the use of geomorphic data in areas such as habitat restoration, flood hazard mitigation, bridge and culvert replacement, and river corridor protection. Due, in part, to the mix of knowledge and skill that make up assessment groups, many are beginning to rely on the help of RPCs and consultants to complete the bulk of the assessment and data presentation work that needs to be done. The RPCs and consultants often have more of the technical skills and computer equipment needed to complete the data collection in a timely fashion. Volunteers from watershed groups are providing the local knowledge and the extra hands needed to assist the consultant or RPC in the process at all levels.

Training for the Lewis Creek group consisted of workshops and field training for the volunteers. For the second season the LCA chose to hire a consultant to be the primary point person for volunteers to work with in the field. The consultant had more training and time to commit to each reach that was to be evaluated. With a consistent person completing the assessment, the data is more reliable for use in management decisions, and volunteers are able to help in the process, and continue to learn about the river, without being as knowledgeable about the protocols. This model of data collection is being tried in the White River basin and is being suggested to other groups getting started in the Phase 2 process. While groups may not need to hire a consultant to be their point person, it is recommended that a group have at least one person who is willing to be available to help out on all reaches being assessed, has additional training (with exposure to different watershed settings and some background knowledge on river dynamics), and will be with the group throughout the process of collecting field data.

Volunteer field training

At the start of each field season a refresher field training has been conducted for those groups who have already had one season of field experience and a overall training was conducted for groups that were just getting started. Trainings have consisted of two days in the field at reaches used to demonstrate protocols. For those groups where many of the volunteers were not directly involved in the Phase 1 data collection, it would be recommended that the training be more than two days. To help those volunteers who have little knowledge about the data collected in Phase 1, and those who have minimal or no background in river process, an evening meeting should be held before the field training to review what data has already been collected, why the data was collected, and how the data they are going to be collecting will be used. The volunteers that have committed to being trained are often very enthusiastic, but can be overwhelmed with the amount of new information they are asked to learn in two days; the additional training can help to clarify questions about the process and the information that is already known for a reach, reducing the amount of time needed during the field training to go over those types of questions.

A quality assurance program has also been developed for the three phases of assessment. Groups have been asked to establish quality assurance teams to help with review of the data collected and to insure that data used for other projects is complete and as accurate as possible. By following the protocols and using the database and spreadsheets developed for the protocols, groups complete part of their quality assurance program each time they collect and enter data. The quality assurance program allows for groups and users to indicate how comfortable they were in collecting data for a particular parameter and where additional information needs to be collected or reviewed. Completion of the quality assurance program after each phase of assessment will insure that data used to make management decisions, complete protection and restoration projects, or decide on basin planning goals, etc., will be correct and as inclusive as possible.

For all three phases of assessment the establishment of a more extensive, formal training program would be recommended to help with: 1) conducting trainings throughout the state, 2) providing additional training to consultants or volunteers who are the lead persons in their group, and 3) insuring consistency in the level and type of training that accompanies the protocols.

## Lewis Creek Project

### Goals and Objectives

To achieve meaningful cost-effective results in dealing with channel instability at the watershed scale, the Vermont Department of Environmental Conservation (VTDEC) River Management Program in collaboration with academic, agency, and watershed association partners started a pilot project in the Lewis Creek watershed. The project was funded and supported by the Lake Champlain Basin Program to gain a better understanding of ways to manage stream erosion and its impacts on aquatic habitat and phosphorus loads to Lake Champlain. The project was also used to help develop the remote sensing and rapid stream geomorphic assessment methodologies.

The project was done to build more knowledge and understanding about the types and conditions of the river within the watershed community. Increasing the number of people who have a general knowledge about the river's processes and needs may provide for better management decisions at the local and state level. Without the support and understanding of the local residents, whose lives are often directly influenced by the river, the types of river protection and restoration strategies taken on by state and federal agencies would not be possible. Better watershed level planning and problem solving is obtained as the knowledge and interest of the groups involved increases.

When considering LCA's specific priorities for use of this data, a discussion and review of the organization's goals and objectives took place. Current LCA goals include:

1. increase awareness of the natural world and its connection to the economy and community;
2. protect and improve/restore biological diversity;
3. improve water quality;
4. support sustainable rural community;
5. stabilize traditional land uses (agriculture, forestry, fisheries, municipal, residential).

The geomorphic stream assessment process enhances LCA's ability to meet all of these objectives. It can broaden their understanding of water quality trends and patterns, which will in turn help them to understand the present level of in-stream aquatic biodiversity and support future efforts to restore biodiversity. Results of the geomorphic assessment can be used by the member communities to optimally manage roads and other infrastructure in ways which are more cost effective and in concert with natural stream dynamics. Stream geomorphic assessments can also enhance LCA's ability to optimally manage land uses to sustain desired agricultural, fisheries, and forestry land uses while minimizing sedimentation of Lewis Creek, its tributaries, and Lake Champlain.

## Methods

Volunteer Phase 1 training

To successfully have volunteers do a geomorphic assessment of their watershed it was necessary to conduct trainings. For the Lewis Creek project, this training was accomplished through a number of workshops. Workshops were coordinated and put together by the River Management personnel. The Phase 1 geomorphic assessment was introduced to the Lewis Creek project team in 5 half-day workshops. At each workshop two steps of the remote sensing assessment were introduced. For each step, examples had been prepared for the group to review and then the group worked through the step on another part of the watershed. This training method provided an opportunity for the group to have a hands on experience on how the data was collected while helping to contribute to the watershed data set.

For volunteers to understand and accurately evaluate field parameters studied in Phase 2, an on-the-river training was necessary. At the start of each field season, two full-day field workshops were offered for the training of the Lewis Creek project group. The field sites for training were reaches that exhibited different types of conditions and stream types; in the first season the two reaches chosen were ones that the group wanted to do a Phase 2 assessment on. This accomplished not only the training, but also the completion of two reaches for the watershed. Training involved walking the reach and identifying various parameters in the field that would be used to complete the rapid assessment and to correct or complete any Phase 1 data that was necessary. The group decided as a whole, the reach to be evaluated and then completed the assessments in smaller groups. The smaller groups allowed a more focused evaluation of the reach and gave volunteers an opportunity for more personal training. Once both trainings had been completed, the volunteers were broken into teams. Each team was assigned two reaches on which to complete a rapid assessment and field verification.

During the first field season River Management and Fish & Wildlife technicians accompanied the teams on at least one of their reaches to help with any questions, give further field training, and to insure consistency and accuracy of the data. For the second season, the LCA chose to hire a private consultant to be the lead person. The consultant was able to assist all volunteers and visit most reaches during the summer to insure consistency and accuracy with data collected, and continuing the training of volunteers in the use of the protocols. Information from this field season was reviewed and entered into the database by the consultant. Information was also reviewed by a River Management scientist to insure completeness and accuracy. It proved to be very effective to have a full time person to insure that data collected was accurate and consistent.

Using the DEC River Management protocols, 6 reaches (sites) were assessed at the Phase 3 level. Surveys of the longitudinal profile, several cross-sections, pebble counts, and qualitative assessments are completed at the Phase 3 level. The empirical data collected in Phase 3 provides a verification of the geomorphic condition and stability rating of the reach. Volunteers were invited to help with surveying and assessment of the reaches. This allowed them to become familiar with the survey equipment and to have a better understanding of how information is collected for restoration or other management decisions that need more detailed channel data.

## 2001 Results

**Phase 1:** The start of data collection began during the early spring of 2000. The assessment was done in three phases. The first phase of assessment, Phase 1, was largely a remote sensing evaluation of the entire watershed, the main stem of Lewis Creek and five tributaries. Eighty reaches were evaluated in Phase 1. Remote sensing was done by reviewing maps and a 20 year time series of aerial and ortho-photographs. Local information and a windshield survey were also added to the data collected in Phase 1. The results of Phase 1 were a geomorphic typing of all reaches and a provisional rating of the physical impacts and geomorphic condition of each reach based on evaluations of land use changes, channel modifications, and floodplain modifications. Examples of the types of impacts that appear to be having the greatest effect on Lewis Creek are: loss of riparian vegetation, channel straightening, changes in the meander ratios (belt-width and meander wave length), and encroachment within the floodplain. Of the reaches within the Lewis Creek watershed where flood plain function is especially important, almost 27% of the total stream length evaluated had been straightened. Bed degradation and loss of flood plain function that typically follow channel straightening were “red-flagged” as major concerns. Reports from the Phase 1 database, showing stream types, categorical impacts, and adjustment processes are shown in Appendix D. Maps demonstrating how some of the data may be spatially viewed are also in Appendix D. Preliminary results suggest that Lewis Creek is a relatively stable watershed (maximum impact rating score of 14 out of a possible 32). Of the 80 reaches evaluated 92% had impact ratings below 10.

**Phase 2:** The Phase 2 assessments were conducted during the 2001 and 2002 field seasons. The goals of the Phase 2 assessments were to verify Phase 1 data and to collect both qualitative and quantitative data on the geomorphic and habitat condition of the assessed reaches. During the 2001 season the project team selected and evaluated 12 reaches using Phase 2 rapid assessment protocols. Reaches were chosen to allow the project team to field survey the variety of stream types and conditions that exist within their watershed. The reaches observed in 2001 were primarily in good condition for both habitat and geomorphic parameters. Of the 12 reaches evaluated, only 5 received a geomorphic condition score of fair to poor; and only 3 were evaluated as being in fair condition for habitat.

**Phase 3:** In the 2001 field season, three reaches (sites) on the mainstem of the Creek were surveyed in a more detailed Phase 3 assessment. Two reaches were considered reference reaches and the third was considered to be in major adjustment. Data from the reference reaches will be used to support potential protection and restoration projects on reaches that have similar settings and stream type; and to add reference data to the State-wide reference reach database. The reach in adjustment, M19, was surveyed to help confirm the type of adjustment processes seen along the reach and determine how far the reach had departed from a reference condition. The segment of reach M19 that was surveyed appears to be widening and undergoing planform adjustments.

**End of field season review:** At the end of the season reaches were evaluated to determine the type of priority condition they were in. The types of reach condition, and priority associated with that condition, were (in order from highest to lowest priority):

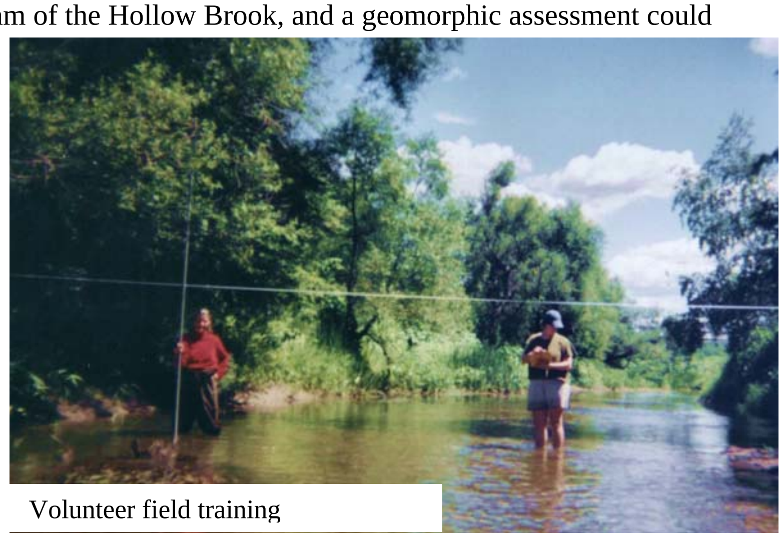
- **Conservation Reaches -** Least disturbed, river structure and vegetation intact.
- **Strategic Sites -** Highly sensitive to disturbance, impacts may trigger off site response.
- **Reaches with High Recovery Potential -** Possible self adjustment with minimal management efforts.
- **Moderate to Highly Degraded Sites -** May require invasive management strategies.

This method of prioritizing reaches is one means of targeting stream protection, restoration, and management projects. It is derived from a protection perspective; acknowledging that there is economic value and cost benefits to protection of reaches in good to reference condition before they become degraded and require management and restoration plans. Reaches with high recovery potential and those that are moderate to highly degraded may also be candidates for protection; however the objective of the conservation effort along those reaches may be to reduce the potential for future conflicts and finding opportunities for the river to reestablish a more stable condition with less intensive management strategies. Other types of prioritization criteria may be more appropriate for other watershed organizational objectives. Of the 12 reaches that were evaluated 7 are good candidates for conservation reaches, 1 is a potential strategic site, 3 are reaches with high recovery potential, and 2 are likely moderately to highly degraded sites.

## 2002 Results

**Phase 1:** Changes in the Phase 1 protocol required a review of information collected using the previous version of the handbook. Phase 1 information for Lewis Creek was updated to reflect changes made to the Phase 1 protocols during the winter of 2001. All reaches were reviewed in the database to be sure that information was accurate and consistent with new protocol requirements; few changes were necessary. The review and updates were made by a River Management technician.

**Phase 2:** In the second field season, 2002, the team decided to focus on a set of reaches on the main stem, M17-M23, and one reach on the Hollow Brook tributary, T4.1. The town of Starksboro owns part of the land on the main stem reach M19. To assist the town of Starksboro with decision regarding this section of Lewis Creek the team choose to look at the reaches upstream and downstream of M19 to see if the adjustments occurring were site specific or caused by adjustments happening off site. LCA also chose to look at reaches surrounding M19 to help support the NRCS with current projects on those reaches. The tributary reach, Hollow Brook T4.1, was looked at for a few reasons; 1) the team was focusing on the Starksboro Valley and this is the major tributary along this portion of the Creek, and may be affecting the main stem both in terms of sediment loading and water quality, 2) State aquatic biologists, found some significant differences (re: diversity) in aquatic habitat colonies upstream and downstream of the Hollow Brook, and a geomorphic assessment could provide helpful insight, and 3) the reach has a similar setting to the headwaters of the main stem (M23, M22) and a comparison could be done.



Volunteer field training

During the 2002 season volunteers took on a greater role in the process of completing the Phase 2 assessment. Teams took on the tasks of completing sketches, doing several basic cross-sections along a reach, completing field forms, and answering the assessment questions with limited guidance from RMP personnel. By taking on more of the tasks and completing the assessment with limited guidance, the LCA was able to learn more about the process and stream types within their watershed, as well as now having the ability to continue the assessment when outside guidance is limited.

Of the seven reaches evaluated during 2002, one reach had habitat in good condition, all others were in fair to poor condition. Two reaches and two segments, within the other 5 reaches, had geomorphic conditions of good, the remaining segments and reaches were in fair to poor condition. The Phase 2 data indicates that the river in the Starksboro valley is very sensitive to watershed changes. Within the Starksboro valley many of the reaches had not experienced as much channel degradation as expected, due to the high level of channel straightening seen in Phase 1. The amount of degradation may have been retarded, in part, by the glacial lacustrine clays that make up part of the boundary conditions of the channel bed. Reaches that are in the response (sediment deposition) part of the watershed, have a high bed load, and were historically straightened are beginning to change and adjust their channel slopes to come back into equilibrium. In areas where historic rip-rap has failed and/or where there was little woody riparian vegetation, the channels are beginning to widen, aggrade, and change planform (thereby reducing slope). Future flood events may cause these reaches to undergo more substantial channel adjustments than reaches with less management history.

**Phase 3:** This season the project team and LCA chose to survey two reaches. To help support LCA's recommendations to the town, a Phase 3 survey was done at the reach near the Starksboro ball field. The volunteers also identified two areas on reach M22 that were under adjustment and were locations for potential remediation projects. On M22 the areas were far enough apart and undergoing potentially different process that two separate surveys were done for the areas of concern. For the surveys, a longitudinal profile was done to determine the slope of the channel and the types of bed features present; cross-sections were done throughout the reach to understand floodplain access, channel dimensions, and the size material being transported. Cross-sections were monumented to assist in future assessments of the reach. Data from Phase 3 helps to identify how far a section of stream has deviated from reference physical conditions. The survey data may be used in deciding what type of river protection or remediation project is appropriate for reach M22 and the types of concerns or issues that may be encountered in those projects. The data for the reach near the town ball field may be used in deciding the types of management activities the town will allow on the town property; and to help monitor the site over time to determine the rate of planform change seen in the area.

**End of field season review:** The process of prioritizing reaches was expanded after the 2002 season to include a discussion on the alternative management strategies that may occur on the reach (discussed in detail in the ANR "Alternatives for River Corridor Management" paper.) For the project, a summary form was created with information from Phase 1 and Phase 2 that would help provide insight as to the types of management stategies that may be consistent with the channel adjustments and equilibrium conditions of the reach. The form provided a means of starting the discussion and reviewing the data that had been collected.

The general types of management stategies that were discussed are:

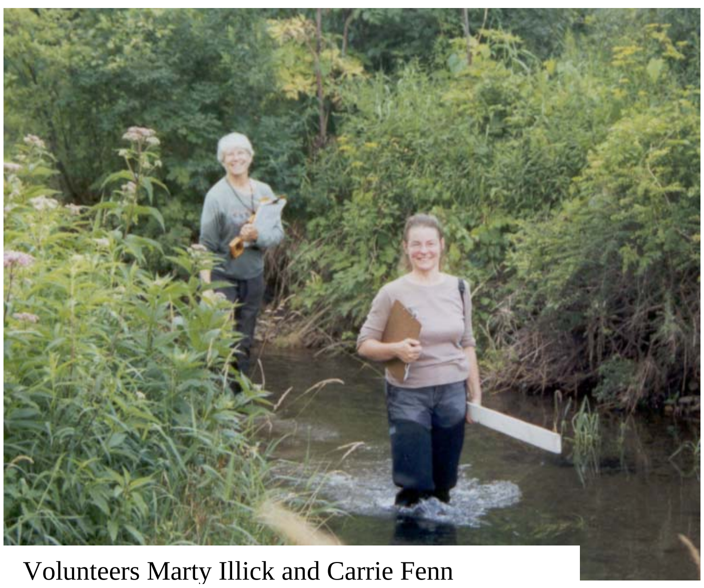
- Short Term Approaches
  - Do Nothing – May be a good option where there is little to no major conflicts.
  - Channelization -Dredging and bank armoring in the context of major conflicts.
- Long Term Approaches
  - Active Geomorphic – Restoring the river and floodplain geometry with human input.
  - Passive Geomorphic – River is able to restore equilibrium (its dimension, pattern, and profile) with minimal human input.
- River Corridor Protection
- Riparian Planting Needs
- Education / Outreach potential or needs

Education and outreach were identified as important strategies for all reaches. Looking for opportunities for riparian planting projects was also identified as a need for most reaches. Most of the reaches have fair habitat conditions. A long term goal of LCA may be to improve habitat conditions in this area. The establishment of buffers and protection of corridors will be essential to the improvement of the habitat and geomorphic conditions in the river. Several reaches were also identified as being strategic sites where the river had lost access to its floodplain at annual and higher events, 10-50 year return frequency floods. LCA decided that the short term approach for these reaches was to do nothing at this time and to not pursue intensive channel restoration projects. LCA will monitor these reaches over the next several seasons to determine the extent of floodplain loss and the potential for other management activities.

## Both Years of Assessment

After two years of assessment on Lewis Creek, a large portion of the watershed has been assessed at some level. Eighty reaches, on the main stem, three major tributaries, and two minor tributaries have been evaluated at the Phase 1 level. There have been 19 reaches assessed at the Phase 2 level; and Phase 3 assessments were conducted at 6 sites on 4 reaches, two reference and two reaches in adjustment. At the completion of each phase of assessment, data was entered into the database, Phase 1 and Phase 2, and the spreadsheets, Phase 3, that were created to support the assessment protocols. To help in spatially locating data from all phases of assessment and to assist with map making an ArcView project was also created with the stream layer, corridor, watershed bounds, soils, and land use/land cover layers. Data from the database can be directly linked to the ArcView project to facilitate in generating the desired product. A preliminary report was completed at the end of each season to review the project, the data collected, and to discuss the potential types of reach priorities and management strategies that were evaluated for the reaches assessed that year.

A notebook was assembled at the completion of Phase 1; containing all of the assessment data, topographic maps, and ortho-photographs for each reach. These notebooks were distributed to the groups directly involved in the project and to agencies that would be working within the Lewis Creek basin, for example the NRCS. The notebooks provide an easy reference for the groups to find and communicate information about a reach or segment of river that they are interested in. For each reach, the field forms, photos, and reach summary reports done in Phase 2 have been assembled into a notebook by LCA. Reach summaries were written for almost every reach (Appendix B). Volunteers and the primary coordinator were responsible for completion of the summaries. These general observations provide more information about a site, will be used to assist in deciding the next step for a reach, and will be of value for future reference. Writing these summaries assisted volunteers in evaluating the data they had collected and in many cases helped the volunteer to understand more of what they had seen by having to describe it in a summary format. Information and copies of the data can be obtained from LCA to assist with discussion on reaches where further study is required or management decision are being made. Phase 3 data is contained in a separate Excel workbook for each reach, and will be available from either the State River Management Program or LCA. Maintaining hard copies and electronic copies of the data is essential in making data available and keeping track of data collected. The creation of notebooks of the hardcopies is one method of organizing the data into a useable format.



Volunteers Marty Illick and Carrie Fenn

A comparison of the preliminary Phase 1 and Phase 2 Lewis Creek data suggests that the remote sensing data is a valid way of evaluating a watershed for information on stream type and potential geomorphic condition; making Phase 1 data very useful for focusing further field studies. The Phase 2 data shows the current stream type and condition of the reach as compared to the expected reference condition and stream type assigned in Phase 1. Phase 2 supports the additional data collection and/or refinement of data that was missing and/or collected during Phase 1; helping to increase the capabilities of utilizing the Phase 1 data for focusing field studies, basin planning, or other management strategies needed within the watershed. New or revised data are tracked within the databases' quality assurance tracking system. Phase 2 data was also used to determine where to do Phase 3 quantitative field surveys. Phase 3 data will be used to support knowledge about the reach gained at the Phase 1 and 2 level and can be used for potential remediation projects.

## Project Status/Recommendations

After two seasons of conducting the assessment programs on Lewis Creek the local level of knowledge has been increased and the data needed to support planning and problem solving is in place for much of the watershed. This data will enable the group to better target their funds and time for conducting field work or other projects, such as land conservation. The information will also help the group with their outreach and education to the local municipalities and towns within the watershed.

The future of assessment in the Lewis Creek watershed will likely be at the Phase 2 level. Conducting a Phase 2 assessment on the remainder of reaches within the watershed will provide the group with more knowledge about their watershed and increase the amount of data used to support various management decisions or projects within the watershed. Updating their database at the end of each field season to capture any changes made to Phase 1 data and incorporating their Phase 2 data will increase the types of queries and questions the group can begin to ask of the data. The establishment of monitoring sites on some of the reaches, to track the various types of conditions and adjustment processes occurring within the watershed, will provide long term data and base line information to compare changes within the watershed over time.

The group plans to continue hiring a consultant to conduct the Phase 2 assessments. However, volunteers will be important to the continuation of the project. The volunteers who have committed time and energy to the process have been a valuable resource for the group and the project; providing the extra hands, different background knowledge about the communities and river in their area, and the interest to see the information collected and utilized within their watershed. The River Management Program will continue to support and train volunteers who are conducting the various levels of assessment.

The Lewis Creek project has been an exciting and rewarding opportunity to work with a dedicated watershed group and other partners who have an interest in the rivers of our state. It has been a model to use for getting other groups started and for helping to work out the kinks in a new type of assessment processes. While the pilot project has come to an end, the project itself will continue to grow and become a key element in the way that the rivers of Vermont are assessed and managed.

Volunteer Everett Larsen

# Lewis Creek Geomorphic Assessment
# 2001 Pilot Project - Data Collection and Analysis

## 2001 Work Plan

During the first year of the project, information and data were gathered in Phase 1, Phase 2, and Phase 3 assessments of the Lewis Creek watershed. The DEC River Management Program, VT Fish & Wildlife Department, Lewis Creek Association (LCA) and community volunteers collaborated to complete the Phase 1 assessment of the watershed and begin the Phase 2 and Phase 3 field evaluation on several reaches within the watershed. Each Phase of assessment, and the results, are presented in the following report. An overview of the geology for the watershed, obtained as part of the assessment, is included to help the reader understand the setting of the Lewis Creek watershed.

### Setting the Stage: Watershed Geology Background

Starksboro valley, looking toward Hinesburg gravel pit

The Lewis Creek watershed has experienced many changes over the course of history. Glaciers, the Champlain Sea, and Lake Vermont have filled the valley and affected the landforms, soils, and characteristics of the stream. The watershed is approximately 81 square miles and spans two major geologic provinces. The headwaters drain the steep, till-blanketed bedrock slopes of the Green Mountains in eastern Starksboro and Hinesburg; while the remainder of the watershed is positioned on the broad Champlain Valley.

Glaciers have left behind various deposits of sediment that the Creek has been working through, on, and around. The headwaters in Starksboro and in the Hollow Brook drainage, are areas where glacial deposits are readily seen. Kame terraces, made up of sands, gravels and cobbles are found along the foot of the Green Mountains near the Starksboro Village and South Hinesburg. These deposits were subsequently re-worked as beach gravels by wave action during the time of Lake Vermont.

It is theorized that the retreating glaciers at one time blocked the Winooski Valley near Burlington, and that the Winooski River detoured to Lake Vermont through the Hollow Brook valley of present-day Lewis Creek watershed. The flow of the Winooski River through the Lewis Creek watershed may help to explain why there are larger valley forms through which the current Lewis Creek is passively meandering. The valley shaped by the larger Winooski River is not readily reformed by the smaller Lewis Creek. The detour of the Winooski River also resulted in delta deposits being overlaid on the kame terrace deposits at the Hinesburg Sand and Gravel quarry in South Hinesburg. The kame terrace and beach deposits of eastern Hinesburg and Starksboro represent a transition zone for the Lewis Creek as it passes from the steeper bedrock slopes of the headwaters to the broader Champlain Valley. These sands and gravel sediments are loose and highly erodible.

The Champlain Sea and Lake Vermont have also left behind various deposits that the Creek is working through. Lake Vermont, at its highest stage, reached to the foot of the Green Mountains near Starksboro Village and South Hinesburg. The Champlain Sea, from approximately 12,800 to 10,200 years before present, inundated the valley from the St. Lawrence Seaway. The brackish waters did not reach perhaps much further east than the North Ferrisburg village. One of the most significant types of deposits left behind in the watershed from these bodies of water are the clays. In the broader Champlain Valley, near South Hinesburg, north of Monkton Ridge and south of Prindles Corner, the landscape is dominated by clay and silt deposits generated during the former occupation of Lake Vermont. Many of the reaches along the main stem, Pond Brook and the Cedar Lake tributary are underlain by clay and silt deposits. These clays and silts are more resistant to downward erosion then many of the glacially deposited sediments, but are susceptible to lateral erosion.

Within the watershed there are also natural bedrock grade controls. Reaches containing bedrock grade controls, confirmed through field-checking, include: M5, M7, M9, M10, M18, M23, and T2.1. The bedrock grade controls provide a limited disconnection between the surrounding reaches and the types of geomorphic adjustments that may work their way through those reaches, such as head-cuts or nick points.

The geology has a direct effect on the type of river seen within a watershed. It is the underlying foundation that the river must work through, on, and around. The type and amount of sediment transported by the river is also influenced by the geology. Runoff rates and ground water discharge, too, are influenced by the geology. With a basic understanding about the geology in the watershed, clues can be gained about the processes the river is currently working through and the potential types of future processes it may go through. A potential role for a trained geologist in the assessment process may be to provide the important context of the geologic setting.

## Assessment and Results

### Phase 1 Assessment

The first part of the Lewis Creek project was a Phase 1 stream geomorphic assessment. By using topographic maps, orthophotos, existing data, and windshield surveys, the Phase 1 utilizes remote sensing techniques to provide information about stream types, valley/geologic setting, factors affecting runoff, channel modifications, floodplain modifications, and a stability rating for each reach within the watershed. The information and data can then be used to assess and prioritize reaches within the watershed based on stream type, valley type, watershed size, and stability rating.

Volunteer Phase 1 training workshop

For the Lewis Creek project, Phase 1 training was accomplished through 5 half-day workshops. Workshops were coordinated and put together by the River Management personnel. Examples of each step had been prepared for the group to review and then work through for another part of the watershed. This training method provided an opportunity for the group to have a hands on experience on how the data was collected while contributing to the watershed assessment.

Volunteer Phase 1 training workshop

Part of the Phase 1 assessment was to do a review of past and current stream stability and the anthropogenic conditions affecting the stream. Orthophotos and aerial photographs were used to assess the changes in the stream planform and the types of anthropogenic impacts that influence the stability and condition of the stream. In order to evaluate the amount of anthropogenic influence on the reach a set of impact rating scores were assigned to each parameter evaluated. Various criteria were used to determine if the influence was high, low, or not significant. A total impact rating score for each reach was then possible.

The total impact scores resulted in a priority ranking for each reach in the watershed. Reaches with high scores have potentially more impacts and warrant further study in the field. Those reaches with low scores were candidates for field assessment to learn more about equilibrium channels and serve as potential reference reaches for unstable or adjusting streams. The impact scores are a way of “red flagging” reaches of concern and candidates for field investigation. After field checking reaches of various impact ratings, a group may adjust their method for identifying high impact reaches. One way of viewing the impacts affecting a river is a longitudinal plot of the impact scores (Figure 2). A longitudinal plot over the length of the stream enables the observer to see the spatial relationship of high and low impact reaches.

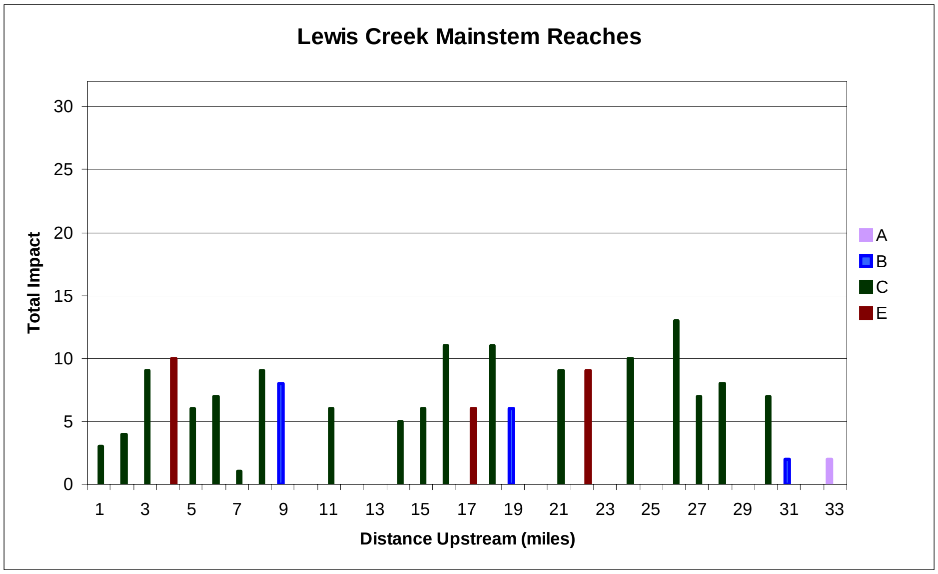



**Figure 2:** Reach stream type and impact score from downstream to upstream

Evaluating the streams' geomorphic condition is another important component of the Phase 1 assessment. The stream geomorphic condition is comprised of three separate, yet interrelated, evaluations of the reaches in the watershed, including adjustment process, condition, and sensitivity. Evaluating geomorphic condition involves looking at the parameters assessed in Phase 1 that may cause channel adjustment (i.e., floodplain modifications or increased sediment load due to land use/land cover changes). A database query was developed to help determine the geomorphic condition for each reach based on the impact ratings and characterizations that were made for 16 of the Phase 1 parameters (Appendix D). A literature review, as well as Vermont field data and observation provided the basis for developing the stream geomorphic condition protocol and database query.

A River Management technician was responsible for the completion of the Phase 1 assessment. The Addison County Regional Planning Commission (ACRPC) was involved in the collection of those Phase 1 data that could be measured using GIS. The ACRPC also built an ArcView map project that contained the reach breaks and compiled data for each reach.

The Phase 1 data and maps for the watershed were compiled into a notebook to help the Lewis Creek Association identify information about each reach in the future. From the completed Phase 1 data, the project group made decisions about where to do Phase 2 rapid assessment work.

## Phase 1 Results

In the Lewis Creek watershed, Phase 1 assessments were completed on 80 reaches. The watershed was broken into six sub-watersheds; mainstem, Cedar Lake tributary, Pond Brook, Hollow Brook, Hogback Brook, and a small headwater tributary, to help with interpretation and to allow a more focused approach for both current and future assessments (See Attachment A for a summary of watershed information).

From the Phase 1 data, the reference stream type of a reach was assigned. Stream type at the Phase 1 level was based on valley confinement, valley slope, and tributary influence. Stream typing gives the general physical characteristics of the channels in the watershed and helps predict the reference or equilibrium condition of the reach. The total number of each stream type in the Lewis Creek watershed is: A (20), B (15), C (38), and E (7) (See Attachment A for watershed distribution of stream types). Although each reach was assigned a specific stream type, some reaches exhibited characteristics of two stream types. For example, one reach had the slope of a C but the valley confinement and sinuosity of a B, so the reach was assigned a stream type of B (see the Phase 1 Handbook for further definition of stream typing). For reaches exhibiting characteristics of two stream types, field verification was needed to determine the specific stream type for the reach.

Reaches were grouped as "like reaches" in Phase 1 based on stream type, impact rating score, and watershed size (Appendix D). Grouping streams by like reaches is useful in selecting a manageable number of reaches on which to conduct the more detailed Phase 2 and Phase 3 assessments. It was decided that for the 2001 field season it would be helpful for at least one reach in each stream type to be looked at using Phase 2 assessment protocols. By assessing at least one reach in each stream type the group could become familiar with the various stream types that are within the watershed and begin to understand the differences between them. The group picked 10 reaches from areas throughout the watershed to represent each of the major tributary watersheds as well as in the mainstem.

Another criteria used in choosing reaches was the total impact ratings. The highest total impact score for Lewis Creek was 14, the lowest was 0. Nine reaches received an impact score of zero. Reach M19 appeared to have the greatest anthropogenic impacts affecting the reach. Some of the parameters affecting M19 were channel straightening, a high percentage of cropland within the corridor, little woody riparian vegetation, extensive bank armoring, and narrow bridges.

The most common type of impacts experienced in the watershed were loss of riparian buffer, channel modification, encroachment (mainly from roads), and imposed changes in the channel planform and slope (as measured with meander width and wavelength ratios). Channel straightening accounted for perhaps the greatest impact to the channel. Of the reaches within the Lewis Creek watershed where flood plain function is important (B, C, and E stream types) almost 27% of the total stream length evaluated had been straightened (Table 1). Bed degradation and loss of floodplain that typically follow channel straightening were "red-flagged" as potential major concerns, due to the series of channel adjustments (channel evolution) and erosion that may be observed following or in lieu of the degradation or incision process. These areas will need examination and confirmation in the field to determine the extent of bed degradation and floodplain loss that may have occurred due to straightening.

Table 1. Amount of stream length channelized by stream types.

| Stream Type | Total Stream Length | Total Length Channelized | Percent Channelized | Total Length Channelized with Low Impact | Percent Low | Total Length Channelized with High Impact | Percent High |
|---|---|---|---|---|---|---|---|
| B | 70,666 | 17,263 | 24.4 | 3,986 | 23.1 | 13,277 | 76.9 |
| C | 21,9238 | 63,414 | 28.9 | 17,526 | 27.6 | 45,888 | 72.4 |
| E | 63,884 | 13,968 | 21.9 | 8,465 | 60.6 | 5,503 | 39.4 |
| **Totals** | **353,788** | **94,645** | **26.8%** | **29,977** | **31.7 %** | **64,668** | **68.3 %** |


Lewis Creek , M17

Finally, valley confinement and watershed size were used for choosing and comparing like reaches. The reaches chosen represent a variety of stream types, watershed sizes, and impacts (Table 2). Reaches were prioritized by stream type, total impact and watershed size. Besides the 10 reaches originally chosen by the group, two additional reaches, M10 and M16, were evaluated during the field season. Reach M10 was added as a reference reach evaluation, and M16 was added through a request by the Natural Resource Conservation Service (NRCS).

Table 2. Stream reaches chosen in the Lewis Creek watershed for Phase 2 assessment.

| *Reach Number | Stream Type | Total Impact (out of 32) | Step 4 Land Use Impact (out of 6) | Step 5 In Stream Modification Impact (out of 10) | Step 6 Floodplain Modification Impact (out of 12) | Step 7 Windshield Observation Impact (out of 4) | Watershed Size | Confinement |
|---|---|---|---|---|---|---|---|---|
| T4.3/S6 | A | 8 | 1 | 2 | 3 | 2 | 0.44 | SC |
| T5.5 | A | 5 | 0 | 2 | 2 | 0 | 0.42 | SC |
| M14 | B | 6 | 1 | 2 | 3 | 0 | 37.87 | SC |
| T2.1 | B | 1 | 1 | 0 | 0 | 0 | 5.20 | NW |
| M7 | C | 1 | 1 | 0 | 0 | 0 | 73.51 | NW |
| M10 | C | 3 | 1 | 0 | 3 | 1 | 69.12 | NW |
| T3.2 | C | 1 | 1 | 0 | 2 | 0 | 16.62 | NW |
| M15 | C | 10 | 0 | 2 | 5 | 1 | 37.51 | VB |
| M19 | C | 14 | 3 | 5 | 4 | 2 | 18.21 | VB |
| M3 | E | 10 | 4 | 2 | 1 | 1 | 78.61 | VB |
| M16 | E | 8 | 2 | 0 | 4 | 2 | 35.41 | VB |
| T3.4 | E | 2 | 1 | 1 | 0 | 0 | 15.48 | VB |

* Reaches were numbered according to their location on the mainstem or major tributary. Mainstem reaches were numbered as M1, M2…etc from downstream to upstream. Each major tributary was assigned a T# as they were crossed moving up the mainstem from downstream to upstream. The T# for each tributary evaluated this season are as follows: Cedar Lake Tributary = T2, Pond Brook = T3, Hollow Brook = T4, Hogback Brook = T5, and the Headwater tributary = T7. Small tributaries that converged with a reach were assigned an S# as they were crossed from downstream to upstream.

## Phase 2 Assessment

Phase 2 involves field verification of data collected in Phase 1, as well as the completion of field forms and rapid habitat and geomorphic assessments. From the data collected, habitat and geomorphic condition, stream type, and valley type are determined for each reach.

Volunteer Phase 2 field training

Two full-day field workshops were offered to train Lewis Creek volunteers and project partners; to help volunteers understand and accurately evaluate field parameters studied in Phase 2. Training involved walking the reach and identifying various parameters in the field that would be used to complete the rapid assessment and to correct or complete any Phase 1 data. The field sites for training were conducted at two of the 10 reaches chosen by the group to do a Phase 2 assessments on. As a whole, the group decided how the reaches would be segmented for evaluation and then completed the assessments in smaller groups. Smaller groups gave volunteers an opportunity for more personal training and allowed a more focused evaluation of reach segments.

The volunteers were split into 3 teams. Two reaches were assigned to each team to complete a rapid assessment and field verification on. To help with any questions and to give further field training, River Management and Fish & Wildlife technicians accompanied the teams on at least one of their reaches.

Volunteer Phase 2 field training

## Phase 2 Results

Each team from the project group assessed two reaches during the 2001 field season. Two reaches, M3 and M15, were assessed during training days. For each reach, a field notes data form and rapid habitat and geomorphic assessments were completed. Measurements on the field notes form helped to determine the existing stream type. Two or more segments were identified on reaches M3 and M15 based on the groups evaluation that there were significant changes along the reach to warrant separate assessments. Reach M19 was also evaluated as two segments to capture the change in reference and existing stream types along the reach. The change in overall reference stream type from a C type in Segment-B to an E type in Segment-A was the reason for segmenting the reach and could provide the basis for creating sub-reaches. The Phase 2 data collected on M19-Segment A, indicated that for at least part of the segment the existing stream type is a C4 riffle-pool; however the overall reference stream type for the segment is an E type (lower width/depth than a C type). Portions of Segment-A have begun to widen and/or become shallower, due in part to beaver activity, and exhibit the characteristics of a C stream. For those reaches with more than one segment evaluated, the segments were labeled from downstream to upstream with a letter value. Stream type was based on entrenchment, width to depth ratio, sinuosity, slope, and dominant sediment size (Table 3).

Table 3. Stream type for Phase 2 reaches, based on field measurements.

| Reach Number | Segment ID | Bankfull width | Flood-prone width | Max depth | Entrench-ment | W/D ratio | Meander pattern (Sinuosity) | Channel slope | Stream type | *Stream type bed material | Stream bed feature type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T4.3/S6 | Reach | 19 | 20 | 2.0 | 1.1 | 19.0 | Low | 7.85% | A | 4 | Step-Pool |
| T5.5 | Reach | 20 | 25 | 2.0 | 1.3 | 10.0 | Low | 5.03% | A | 4 | Step-Pool |
| M14 | Reach | 60 | 150 | 5.0 | 2.5 | 15.0 | Low | 0.16% | C | 3 | Plane-Bed |
| T2.1 | A | 28 | 171 | 2.0 | 6.1 | 28.0 | Low | 2.88% | C | 3 | Riffle-Pool |
| M7 | B | 81 | 264 | 4.6 | 3.3 | 24.5 | Low | 0.70% | C | 3 | Plane Bed |
| M10 | B | 86 | 200 | 6.0 | 2.3 | 21.5 | Low | 0.43% | C | 3 | Riffle-Pool |
| T3.2 | Reach | 38 | 60 | 2.0 | 1.6 | 19.0 | Moderate | 1.04% | B | 4 | Riffle-Pool |
| M15 | A | 58 | 1000 | 5.0 | 17.2 | 19.3 | High | 0.17% | C | 4 | Riffle-Pool |
| M15 | B | 54 | 600 | 4.0 | 11.1 | 18.0 | Oxbows | 0.17% | C | 4 | Riffle-Pool |
| M15 | C | 50 | 500 | 4.0 | 10.0 | 25.0 | Low | 0.17% | C | 4 | Plane Bed |
| M15 | D | 50 | 1000 | 5.0 | 20.0 | 16.7 | Low | 0.17% | C | 4 | Riffle-Pool |
| M19 | A | 40 | 500 | 3.0 | 12.5 | 20.0 | Moderate | 0.40% | C | 4 | Riffle-Pool |
| M19 | B | 69 | 500 | 4.0 | 7.2 | 23.0 | Moderate | 0.40% | C | 4 | Riffle-Pool |
| M3 | A | 57 | 400 | 6.0 | 7.0 | 14.3 | Low | 0.08% | C | 5 | Ripple-Dune |
| M3 | B | 63 | 1500 | 6.0 | 23.8 | 15.8 | High | 0.08% | C | 5 | Ripple-Dune |
| M16 | A | 42 | 300 | 5.0 | 7.1 | 14.0 | High | 0.07% | E | 4 | Plane Bed |
| T3.4 | Reach | unable to measure | 1500 | unable to measure | NA | NA | High | 0.05% | E | 5 | Ripple-Dune |

* Bed material code values are as follows: 3 = cobble, 4 = gravel, 5 = sand or finer.

Field verification at two reaches, T2.1 and T3.2, resulted in changes to the reference stream type chosen during the Phase 1 assessment. The degree of entrenchment at reaches T2.1 and T3.2 was different than that expected from measuring valley width off the topographic map. Reach T2.1 had more floodplain access and was less entrenched than expected, and reach T3.2 had less floodplain and was more entrenched than expected. Redefining the reference stream type to more accurately represent the stream characteristics seen in the field is an important step to ensure a more accurate representation of stream condition or "the departure from reference."

The rapid geomorphic assessments (RGAs) and rapid habitat assessments (RHAs) evaluated geomorphic and habitat conditions in a reach and sensitivity of the reach to changes in the watershed (see Table 4). Major historic and current channel adjustment processes were identified through the RGA as those processes with scores of 10 or less (out of 20). Those reaches that did not receive a geomorphic adjustment process with a score of 10 or less, were considered to be experiencing only a slight or minor adjustment process at this time. The Schumm Channel Evolution Model (as referenced in the Phase 2 Handbook) was used to describe the stage of channel evolution that was ongoing in each reach. The reaches observed during the 2001 season were mainly in good condition for both habitat and geomorphic parameters. Only five reaches out of the 12 assessed received a geomorphic condition score of fair to poor. As for habitat condition, only 3 reaches were evaluated as being in fair condition.

Table 4. Reach condition for the rapid geomorphic and habitat assessment, and the likely channel adjustment processes and sensitivity of the reach.

| Reach Number | Segment ID | RGA Condition | RHA Condition | Channel Adjustment Process | Channel Evolution Stage | *Channel Sensitivity to Disturbance |
|---|---|---|---|---|---|---|
| T4.3/S6 | Reach | Fair | Fair | Unstable – moderate to major Aggradation | Widening III -IV | Extreme |
| T5.5 | Reach | Good | Reference | Stable – slight Planform | Stable 1 | Moderate |
| M14 | Reach | Reference | Good | Stable - slight Aggradation | Stable 1 | Low |
| T2.1 | A | Reference | Reference | Stable - slight Aggradation | Stable 1 | Moderate |
| M7 | B | Reference | Good | Stable –slight Aggradation | Stable 1 | Moderate |
| M10 | B | Reference | Reference | Stable –slight Degradation | Stable 1 | Moderate |
| T3.2 | Reach | Good | Good | Stable – slight to moderate Planform | Stable 1 | Moderate |
| M15 | A | Fair | Good | Unstable – moderate to major Planform | Widening III-IV | Very High |
| M15 | B | Good | Reference | Stable – slight Planform | Stable 1 | High |
| M15 | C | Good | Fair | Unstable – moderate Planform | Widening III | High |
| M15 | D | Good | Good | Stable –slight Planform | Stable 1 | High |
| M19 | A | Poor | Fair | Unstable – major Widening | Widening III-IV | Very High |
| M19 | B | Fair | Fair | Unstable – moderate to major Aggradation | Widening III-IV | Moderate |
| M3 | A | Good | Good | Stable – slight to moderate Widening | Stable 1 | Very High |
| M3 | B | Fair | Fair | Unstable- moderate Widening & Planform | Widening III | Very High |
| M16 | A | Fair | Fair | Unstable – moderate to major Widening | Widening III-IV | Very High |
| T3.4 | Reach | Reference | Reference | Stable - slight Planform | Stable 1 | Very High |

* Sensitivity as defined in Step 7 of the Phase 2 Handbook.

General observations were an important part of the field work done by the Phase 2 field teams. Along with the field note form and rapid assessments, volunteers were asked to write a short summary of their site assessment (Appendix B) . In this way, the volunteers have something to refer back to; they are able to give more general information about the site; and in many cases, by using a summary narrative format, they come to understand more of what they had seen.

### Phase 1 – Phase 2 Comparison

Using the database developed to support the Phase 1 and Phase 2 data collection, it is possible to automate reach evaluations and compare the adjustment processes expected from Phase 1 data to what was seen in the Phase 2 field assessment (Table 5). Scores for each of the four channel adjustment processes and a stream condition (based on a cumulative evaluation of adjustment processes) were determined using the Phase 1, Step 9 protocol. Phase 2 channel adjustment scores and condition were based on the completed RGA.

Most of the reach assessments appear to be comparable between Phase 1 and Phase 2. The condition of some segments varies from the overall condition and adjustment process of the reach as a whole. M15 is an example of a reach with various adjustment processes occurring throughout the reach. Many reaches have a significant score for all four processes. It is typical for a stream that is undergoing one type of adjustment (especially degradation and aggradation) to be undergoing other forms of adjustment as well.

Table 5. Comparison of Phase 1 and Phase 2 channel adjustment processes and geomorphic condition.*

| Reach Number | Total Impact | Phase 1 Degra-dation | Phase 1 Aggra-dation | Phase 1 Widening | Phase 1 Plan-form | Phase 1 Condition | Phase 2 Segment or Reach | Phase 2 Degra-dation | Phase 2 Aggra-dation | Phase 2 Widening | Phase 2 Planform | Phase 2 Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T4.3/S6 | 8 | 6 | 4 | 7 | 6 | Fair | Reach | 14 | 2 | 10 | 17 | Fair |
| T5.5 | 5 | 8 | 8 | 10 | 9 | Reference | Reach | 19 | 14 | 19 | 11 | Good |
| M14 | 6 | 9 | 7 | 10 | 9 | Reference | Reach | 18 | 14 | 18 | 18 | Reference |
| T2.1 | 1 | 10 | 8 | 10 | 10 | Reference | A | 20 | 17 | 19 | 19 | Reference |
| M7 | 1 | 10 | 10 | 10 | 10 | Reference | B | 18 | 15 | 17 | 20 | Reference |
| M10 | 3 | 8 | 8 | 10 | 10 | Reference | B | 19 | 20 | 20 | 20 | Reference |
| T3.2 | 1 | 10 | 8 | 10 | 10 | Reference | Reach | 16 | 13 | 17 | 15 | Good |
| M15 | 10 | 6 | 4 | 5 | 2 | Fair | A | 16 | 10 | 7 | 6 | Fair |
| M15 | | | | | | | B | 20 | 17 | 19 | 10 | Good |
| M15 | | | | | | | C | 19 | 13 | 11 | 16 | Good |
| M15 | | | | | | | D | 19 | 12 | 10 | 14 | Good |
| M19 | 14 | 4 | 1 | 3 | 2 | Poor | A | 8 | 6 | 3 | 10 | Poor |
| M19 | | | | | | | B | 15 | 8 | 10 | 10 | Fair |
| M3 | 10 | 8 | 7 | 10 | 8 | Fair | A | 19 | 13 | 11 | 17 | Good |
| M3 | | | | | | | B | 18 | 8 | 9 | 9 | Fair |
| M16 | 8 | 6 | 2 | 3 | 4 | Poor | Reach | 10 | 10 | 8 | 14 | Fair |
| T3.4 | 2 | 9 | 8 | 10 | 9 | Reference | Reach | 20 | 20 | 20 | 15 | Reference |

*For Lewis Creek Phase 1 scores range from 0-10; with scores over 4 indicating an adjustment process is potentially occurring. Phase 2 scores range from 0-20; with scores of 10 or less indicating a major adjustment process is likely occurring. Note that some reaches have several high (Phase 1) or low (Phase 2) scores, indicating that multiple adjustment process are potentially occurring. (See Phase 1 and Phase 2 handbooks for an explanation of respective adjustment process evaluations).

### Phase 3 Assessment and Results

Using the Phase 3 protocols, 3 reaches were assessed during the 2001 field season. Surveys of the longitudinal profile, cross-sections, pebble counts, and qualitative assessments are completed at the Phase 3 level. The empirical data collected in Phase 3 provides a verification of the geomorphic condition and stability rating of the reach. Volunteers were invited to help with surveying and assessment of the 3 reaches.

Of the three reaches surveyed on the mainstem of Lewis Creek; two reaches, M7 and M10, were considered reference reaches, and one reach, M19, was considered a reach in major adjustment. The reference reaches exhibited good river structure, with the measured values being consistent with the State's hydraulic geometry curves and other published reference regime relationships. Both reaches had intact buffer and corridor vegetation. Although few other reaches in the watershed have a similar valley and stream type as the two reference reaches, the information will be added to the States' reference reach database and the data (Appendix C ) supports the value of the reaches as potential conservation reaches.

The adjusting reach, M19, had the highest Phase 1 impact score in the watershed. The data, (Appendix C ) from the Phase 3 survey of this reach showed that sections of the reach have deviated from the expected channel cross-section width. The expected channel width (for an $18mi^2$ watershed), based on the State hydraulic geometry curves, was 43ft. The range of measured widths was from 44ft to 69ft wide. Much of the reach has extensive rip-rap that is keeping the current straightened planform in place. Those areas that have over widened are areas that do not have, or have lost, previously placed rip-rap and appear to be undergoing planform adjustment.

## Discussion

The data collected in the field, in conjunction with the Phase 1 data, is a source of information to begin prioritizing and evaluating river reaches within a watershed in concert with identified basin planning goals. Watershed basin plans that include an assessment of geomorphic and habitat condition will effectively explain the sensitivity of streams to: land use changes, flood plain encroachments, loss of riparian vegetation and channel management activities. Once completed, these comprehensive plans will help to identify and address the areas of erosion/sediment loading and channel adjustment problems, as well as provide a framework supporting specific corrective/preventive actions that can be prioritized on a watershed by watershed basis. Following remote sensing and targeted field morphology assessments, basin plans should begin to target stream protection, restoration, and management projects. An example of how reaches may be prioritized, is as follows (in order from highest to lowest priority): 1) conservation reaches, 2) strategic sites and incising reaches, 3) reaches with a high recovery potential, and 4) moderate to highly degraded sites.

The Lewis Creek watershed assessment helped to identify examples of reaches with varying sensitivity, experiencing different amounts of anthropogenic influence, and as candidates for further study or action under the above mentioned planning priorities.

### Conservation Reaches

Within the Lewis Creek watershed there are many reaches that have low impact rating scores. Many of these reaches may be potential conservation reaches. The river structure and vegetation associations of these reaches are relatively intact. Of the reaches that were field checked this summer, reaches M7, M10, M14, T2.1, T3.2, T3.4 and T5.5 are examples of potential conservation reaches. Reaches M7, M10, and M14 are examples of reference reaches; in that they are not undergoing adjustment; they have no significant channel or floodplain modifications; and an adjacent forested buffer is present. A completed Phase 3 assessment of M7 and M10, confirmed the assignment of reference condition to each reach. The channel dimension, pattern and/or profile of these two reaches appears to be in balance with the flow and sediment produced in the watershed. The Phase 3 data further supports the value of conserving these reaches in their present condition.

Reaches T2.1, T3.2, T3.4 and T5.5 are reaches on the larger tributaries of the Creek that are in good condition presently and have potential value as conservation reaches. Reach T3.2 currently has a good woody riparian buffer. There is an opportunity to work with landowners to encourage maintenance and potentially enlargement of the woody buffer and corridor. Reach T3.4 is a wetland stream with an intact wetland corridor. This reach has high wildlife value. A beautiful reach, T5.5, provides an example of a reference condition headwater tributary. Reach T2.1 is one of the few reaches on the Cedar Lake tributary that has not been

Phase 3 assessment on M7

straightened and still has an intact riparian buffer and corridor. The reach provides a valuable example of the type of stream and condition that occurs with good riparian buffers and low impact corridor land use. While currently in good condition, reaches T5.5 and T2.1 are highly sensitive to changes in the watershed; new construction or land use changes in their valleys may contribute to changes in the stream condition.

**Strategic Sites and Incising Reaches**

**Reach M3**

An example of a strategic site in the watershed is reach M3. Overall the reach was in good habitat and geomorphic condition. Limited amounts of widening and planform change were occurring in the reach. However, there is the potential for the channel to avulse across the northeast corner of the cornfield. Downstream of the Greenbush Road bridge there is a very sharp meander that has been eroding into the cornfield for a number of years. During high-water events, flood waters spread out over the cornfield and then concentrate in a unvegetated swale/drainage ditch across the upper part of the cornfield. The upstream end of the ditch is near the eroding meander. Just downstream of the eroding meander bend is a large debris jam. During high-water events, water is "dammed" behind the debris jam and more water may be entering the swale than what had previously occurred. On the downstream end, where flood flows re-enter Lewis Creek, a head cut is forming that may significantly deepen the swale. The combination of the sharp eroding meander, concentrated flows in the field, and the deepening swale means that M3 is extremely sensitive to channel avulsion. Figures 3 shows the change in the shape and location of the channel since 1900 and the potential avulsion channel location.

If the avulsion were to occur it would not only disturb the landowner's cornfield, it would greatly change the condition of the reach itself and the condition of the upstream and downstream reaches. The reach would become straighter, shorter, and have an increased slope. The change in channel length, if the avulsion were to occur, would be from 5161ft to about 1500ft, losing approximately 3600ft; this would increase the slope from 0.08% to 0.27%. An increase in slope could lead to incision and head-cuts along the reach. Since there are no grade controls along the reach, any head-cuts that occurred could travel upstream into the adjacent reach (M4). The reach also has some unique and endangered mussels found in the Champlain Valley. An avulsion on the reach would change the habitat for the mussels and other aquatic species.

The reach is highly sensitive to change in the watershed and to changes within the reach. Changes in sediment or flow could increase the avulsion potential or lead to other planform changes along the reach. A pro-active management strategy could help this reach from avulsing and causing substantial changes in the river system. The NRCS is working with the landowner to control the erosion of the meander, and is working towards taking the swale out of corn production and establishing perennial vegetation throughout the ditch. Further surveying and reach evaluation would help to determine the extent and types of appropriate river management practices.

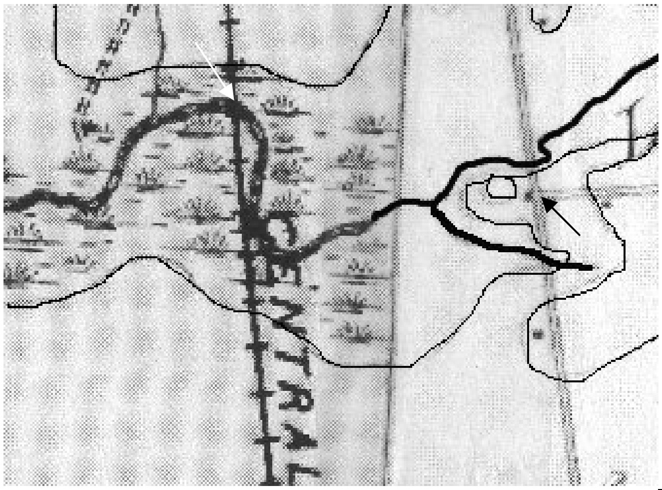


Figure 3a: Topographic map of M3 in1900

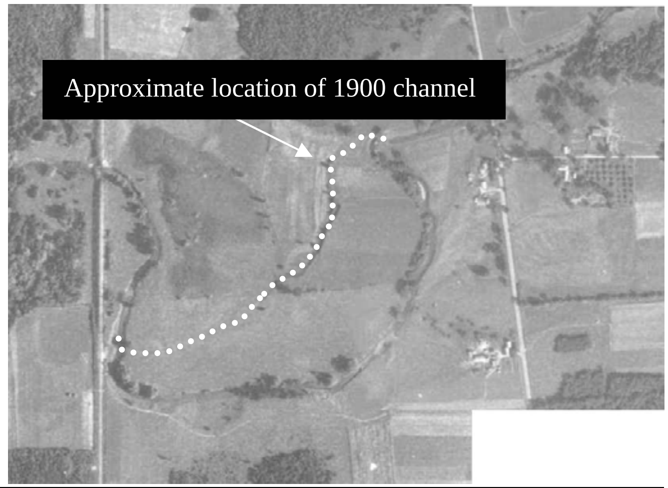



Figure 3b: Orthophoto of M3 in 1942

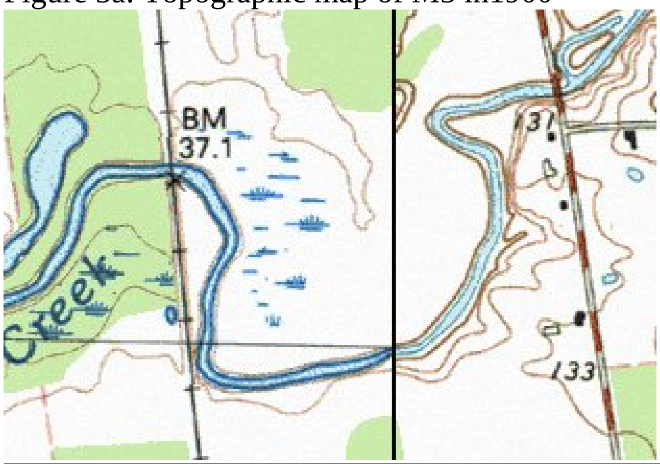



Figure 3c: Topographic map of M3 in2001

Figure 3d: Orthophoto of M3 in 1995

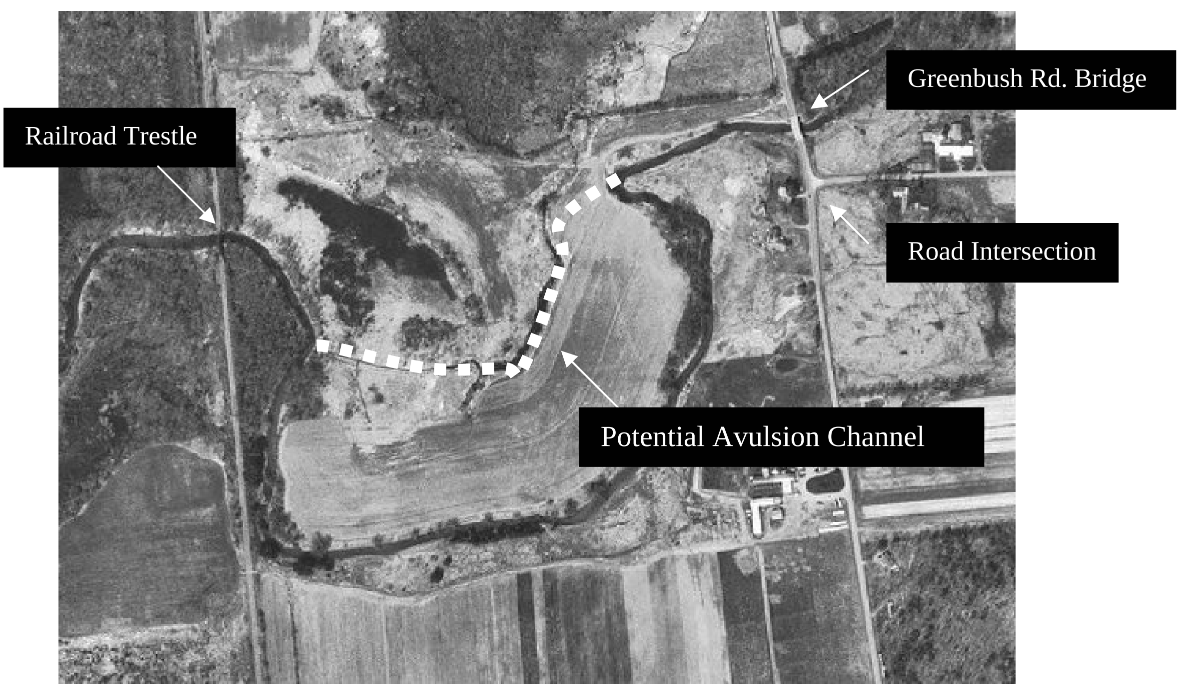



Figure 3e: 1995 orthophoto with overlay of potential avulsion channel

* In all Figures, the railroad trestle, the Greenbush Road Bridge, and the road intersection are common points of reference.

## Reaches with a High Recovery Potential

### Reach M15

Reaches with high recovery potential are those that show signs of returning to equilibrium condition with little or no vertical adjustment (degradation or aggradation), in the manner that fits the present-day setting. Reaches M15 and M16 may be good examples in the Lewis Creek watershed of reaches with high recovery potential. Within the last 10 years, on M15, a large avulsion has occurred on the reach. While the stream is still undergoing minor localized slope adjustment through lateral erosion to accommodate the flow and sediment that pass through the reach; presently, there are no conflicts or adverse affects to human interests with the lateral adjustments of the channel within its corridor. The planform adjustment is moderated by the presence of an intact woody riparian buffer along most of the reach. Corridor development or land-use change along M15 could produce adverse affects not only in the stream channel, but also to the human interests within the corridor.

### Reach M16

Reach M16 is also a location along the Creek that is undergoing planform adjustments. The landowner has been willing to work with the NRCS to take some lands along the reach out of production, to help reduce the conflicts that may arise between the rivers' adjustments and the adjacent agricultural lands. The installation of a 35ft woody riparian buffer and fencing are active management practices that will benefit both the stream and the landowner. Allowing the river to self adjust along this reach will reduce the amount of in-stream channel management needed over time.

## Moderate to Highly Degraded Sites

### Reach M19

Lewis Creek has few moderate to highly degraded sites. Parts of different reaches may exhibit moderate to highly degraded conditions. Of the reaches examined during 2001, sections of M19 are moderately to highly degraded. From the Phase 1 assessment it appeared that much of the reach had been straightened at one time. One parameter that suggested the reach had been straightened was the sinuosity; reach M19 had a much lower sinuosity than expected for a stream in a wide alluvial valley. Channel straightening can lead to changes in the channel slope and stream power; potentially causing more erosion of the bed and banks. Field observations of the reach showed that there was extensive old rip-rap along most of the reach. The downstream area of the reach near the Starksboro baseball field has been experiencing some incision and planform change. Two of the meanders near the field have been rip-rapped this year. These meanders would benefit from tree plantings on the banks. Other areas along the reach have been experiencing over widening. Many of these locations are where old rip-rap has failed. Aggradation, over widening, small chute-cut offs, and high eroding banks are signs that these sites are moderately degraded and undergoing major adjustment. The Phase 3 assessment of reach M19 confirmed the degraded condition and the degree of departure from the reference condition. Only those sections of the reach previously mentioned, exhibited large departures from the expected channel dimension of a similar reference stream type. Many of the adjusting sites are within an area of fallow pasture. There is an opportunity for the river to continue through the adjustments associated with channel evolution without causing adverse affects on human interests. A management plan for the lands along reach M19 that allowed the river to regain a more moderate slope through meandering, would potentially reduce the amount of channel management needed. Land conservation around the downstream portion of this reach has helped to reduce the need to more fully consider the types of active channel management often required for moderate to highly degraded sites where conflicts with adjacent land uses are often extensive and not easily mitigated.

### Reach T4.2S6

Reach T4.2S6 was identified as a reach with high amounts of aggradation occurring. Road maintenance practices, on an adjacent road, have contributed to the amount and type of sediment now entering the stream. Most pools and runs have been filled with fine sediment; reducing habitat and the geomorphic condition of the reach. Without a change in road maintenance practices, the reach is not likely to regain its step-pool characteristics. There is the opportunity for the LCA to work with the local road crew and municipality to help determine the best types of road maintenance that would meet their needs and help reduce the amount of sediment entering the stream.

## Conclusion

The first season of geomorphic assessment provided valuable information about the Lewis Creek watershed; however, conclusions about similar reaches with varying conditions using impact scores are limited. A continuation of the assessment at both the Phase 1 and Phase 2 level will be beneficial. Collecting historical information and documenting local knowledge about the Creek will further enhance the data. Continuing field verification and Phase 2 assessments of additional reaches will enable a better comparison of reaches and conditions. A Phase 3 assessment of one or more of the reaches identified as strategic sites or incising reaches would enhance the understanding of the current and future condition of those reaches. Continued reference reach work would also benefit the LCA and Agency programs.

The first year of the Lewis Creek project provided a valuable context to build a partnership between the Agency and the public to begin understanding stream behavior and river corridor management in a watershed context. Information gained about the watershed has benefited both the LCA and the Agency. Better protocols and training guidelines have been developed through the collaborative efforts of all the partners involved in the project. A continued partnership and further assessment will strengthen previous work and assist watershed groups and government agencies in prioritizing reaches at the watershed scale.

# Lewis Creek Geomorphic Assessment
# 2002 Pilot Project - Data Collection and Analysis

## 2002 Work Plan

The 2002 work plan of the Lewis Creek Pilot Project included additional field studies, a review of the Phase 1 data collected during the first year of the project, and data analysis to support river corridor management decisions being made at the segment, reach, and watershed-scale. Issues such as: erosion and sediment discharge, landowner concerns, wildlife corridors, and habitat loss are being looked at using a watershed approach to address problems identified in river segments where Phase 2 and Phase 3 data were collected. The strong commitment of the Lewis Creek Association (LCA) to continue building their knowledge of the geomorphic processes within the watershed has enabled them to become better advocates for supporting and suggesting various types of management activities within the watershed.

### Data Review and Field Program Development

The ANR Stream Geomorphic Assessment Protocols were revised to reflect comments and needs of groups using the handbooks during the 2001 season. These changes required a review of information collected in the previous version of the handbook. Phase 1 information for Lewis Creek was updated to reflect changes made to the Phase 1 protocols during the winter of 2001. All reaches were reviewed in the database to be sure that information was accurate and consistent with

Volunteer Phase 2 filed training

new protocol requirements; few changes were necessary. The review and updates were made by a River Management technician.

The Phase 2 protocols were also updated during the winter of 2001. A 2 day training was held for the Lewis Creek volunteers to introduce them to the updated protocols. One day of training was done inside to go over material, the second was done on the river. During the summer of 2002, seven reaches were surveyed at the Phase 2 level. LCA volunteers conducted the surveys. The association hired a consultant who had assisted in the assessment work during the first field season. The consultant was able to assist all volunteers and visit most reaches during the summer to insure consistency and accuracy with data collected, and continue the training of volunteers in the use of the protocols. Information from this field season was reviewed and entered into the database by the consultant. Information was also reviewed by a River Management scientist to insure completeness and accuracy. It proved to be very effective to have a full time person to insure that data collected was accurate and consistent. Questions, comments and suggestions about the reaches evaluated during the field season were discussed at a meeting between LCA and RMP in December 2002. Reach summary sheets were completed to assist LCA and included management recommendations that could be to carried out on the reach.

## Assessment and Results

### Phase 1

The project team and LCA decided during the 2002 field season to focus on a set of main stem reaches , M17-M23, and one reach on the Hollow Brook tributary, T4.1 (Table 6). The town of Starksboro owns part of the land on the main stem reach M19. The town currently has investments on the land in the form of baseball fields and soccer fields. There has been some discussion of making a walking path along the river and building a gazebo near the recreational fields. This lower segment of M19 has already had channel management practices done to protect the ball fields and future work maybe needed. To assist the town of Starksboro with decisions regarding this section of Lewis Creek, the LCA choose to look at the reaches upstream and downstream of M19 to see if the adjustments occurring were site specific or caused by channel adjustments happening off site. LCA also choose to look at reaches surrounding M19 to help support the NRCS with current projects on those reaches. Reach M19 was considered a good reach to continue gathering data on by the project team, as there were a variety of potential adjustment processes occurring along the reach to demonstrate the use of the assessment methodology in understanding how past and present management decisions can and do affect the river.

The tributary reach, Hollow Brook T4.1, was assessed this season as: 1) part of LCA’s focus on the Starksboro Valley and a major tributary that may be affecting the main stem both in terms of runoff and sediment loading (in terms of physical and chemical impacts); 2) the DEC has found significant differences (re: diversity) in aquatic insect communities upstream and downstream of the Hollow Brook; and 3) the reach has a similar setting to the main stem headwaters (M23, M22) and LCA thought it would be interesting to compare the two.

Table 6. Stream Reaches chosen in Lewis Creek watershed for 2002 Phase 2 assessment.

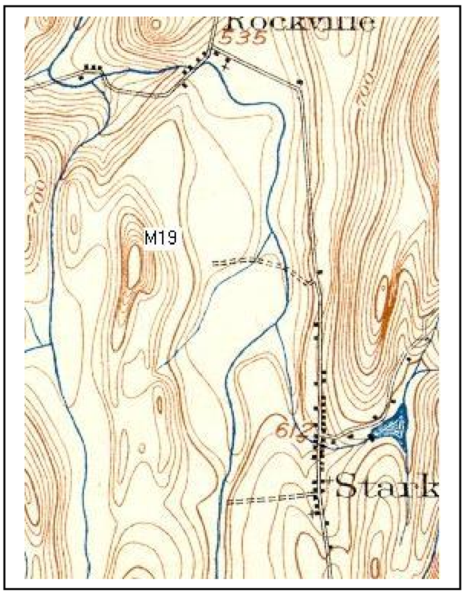
| **Reach Number | Stream Type | Total impact (out of 32) | Step 4 Land Use Impact (out of 6) | Step 5 Instream Modification Impact (out of 10) | Step 6 Floodplain Modification Impact (out of 12) | Step 7 Windshield Survey Impact (out of 4) | Watershed Size | Confinement |
|---|---|---|---|---|---|---|---|---|
| M17 | C | 12 | 2 | 3 | 6 | 1 | 22.7 | 3-VB |
| M18 | A | 0 | 0 | 0 | 0 | 0 | 18.29 | 1-SC |
| *M19 | C | 14 | 3 | 4 | 5 | 2 | 18.21 | 3-VB |
| M20 | C | 5 | 2 | 2 | 0 | 1 | 16.45 | 3-BD |
| M21 | C | 7 | 2 | 1 | 3 | 1 | 10.85 | 3-VB |
| M22 | C | 9 | 4 | 1 | 5 | 0 | 10.44 | 3-VB |
| M23 | B | 2 | 0 | 0 | 1 | 1 | 8.46 | 2-NW |
| T4.1 | C | 9 | 4 | 2 | 3 | 0 | 8.74 | 3-VB |

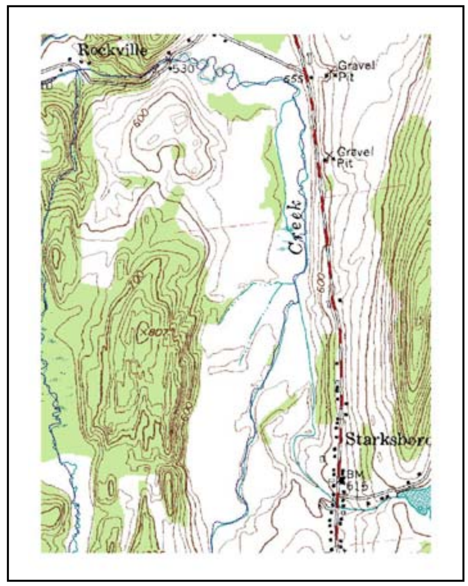
* M19 was evaluated in the 2000-2001 season.
** Reaches were numbered according to their location on the main stem or major tributary. Main stem reaches were numbered as M1, M2…etc from downstream to upstream. Each major tributary was assigned a T# as they were crossed moving up the main stem from downstream to upstream. The T# for each tributary evaluated this season are as follows: Cedar Lake Tributary = T2, Pond Brook = T3, Hollow Brook = T4, Hogback Brook = T5, and the Headwater tributary = T7. Small tributaries that converged with a reach were assigned an S# as they were crossed from downstream to upstream.

Volunteers enjoying a day in the field

## Phase 1 Background to M19, Setting the Stage for Investigation

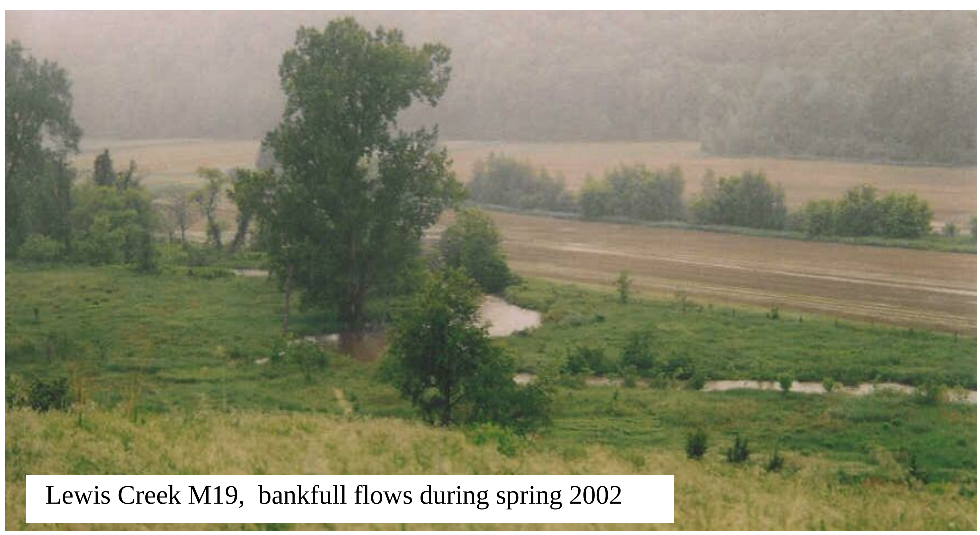
Phase 1 data on reach M19 shows that the reach is 10,032 ft long, is in a broad alluvial valley with a slope of approximately 0.50%. The parent material in the corridor is predominantly alluvial, with small sections of glacial lacustrine and glacial fluvial outwash along its perimeters. The alluvial soils are considered not highly erodible to overland erosion using the NRCS Helclass. The areas of glacial lacustrine and glacial fluvial outwash are either highly erodible or potentially highly erodible (NRCS Helclass). A soil pit, previously done on the Lewis Creek Farm, confirmed the presence of glacial lacustrine clays under the top alluvial layer. Much of the reach experiences occasional to frequent flooding. Local residents have seen the entire valley bottom flooded in recent memory (within the last 50 years). Examples of the soil data, within the corridor, for M19 is in Appendix A.




Topographic maps of Reach M19; 1905 and 1986 respectively.

Agriculture was the primary land use within the corridor observed in the 1942 and 1978 orthophotgraphs. The amount of riparian vegetation has changed over time; with a greater amount of near bank vegetation noted in the 1942 photo than in the 1978 orthophoto. Current land use along the reach is farming and fallow lands. Approximately 4000ft in the downstream section of the reach, from the farm bridge to the State Prison Hollow Rd bridge, has fallow pasture land use within the corridor. There is little near-bank woody riparian vegetation along this section of stream; however, there are trees now growing up within the fallow fields. Row crops are planted within the corridor of the upstream section. There is a riparian woody buffer of 5ft to 25ft wide along much of this section.



Lewis Creek M19, bankfull flows during spring 2002

Much of the reach has been managed in the past, in the form of rip-rap and straightening. Evidence of straightening can be seen in reviewing the historic aerial and current orthophotos. The earliest aerial photograph of the area is from 1942; the latest orthophoto is from 1995 (Figure 4). Rip-rap has been used extensively along the reach for stream bank stabilization. Many of the stream bank stabilization projects were done through NRCS programs to help protect and maintain agricultural lands. The most recent rip-rap to be installed was during the summer of 2001 at the Starksboro ball fields. Rip-rap at the ball fields was done to protect the town's investment in that area. By comparing the 1995 orthophoto and the 1978 orthophoto, it appears that there has been straightening done since the 1978 orthophoto was taken; however, this work was not noted in the NRCS documentation for this reach. Current landowners have commented that previous landowners were known to modify the channel to maintain or "improve" the course of the river. After reviewing the amount of past channel straightening and management there was some concern about the potential for the reach to have lost some access to its floodplain.

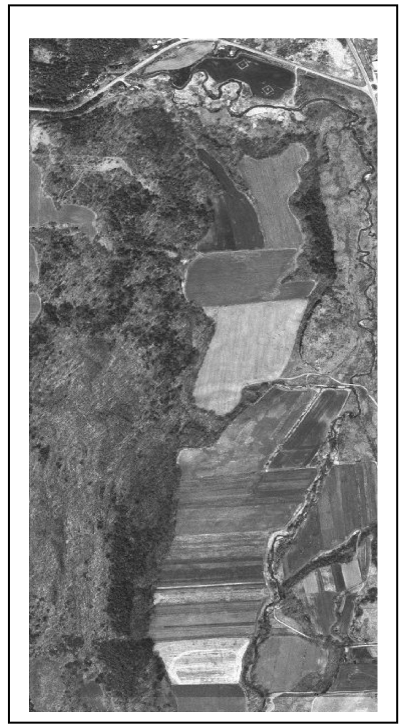


Figure 4: Reach M19, 1942 aerial photograph (left) and 1995 orthophoto (right)

Due to its wide alluvial valley and location within the watershed, reach M19 would be characterized as a response or depositional type of system. Sections of the reach may have become a more effective sediment transport system due, in part, to past channel management practices, such as straightening. Small amounts of meander migration and planform change upstream of the farm bridge were noted by local residents. "Meander scars" were seen on the landscape on a field visit with the Lewis Creek Farm landowner. The landowner also commented on the tendency of the channel to want to change location during high water events; cutting across his farm fields, instead of following the sharp bends of the current channel. The area near the Starksboro ball field is an active area of response. Aerial photos from 1942 show a very sinuous channel in this area. The area continues to show high sinuosity and planform adjustment through the time series of photos; meanders have migrated and changed locations many times due to the relatively high rate of sediment deposition (Figure 5). The bridge and bedrock control at the end of reach M19 have resulted in a channel constriction, backwater conditions during flooding and a flattening of the channel gradient, all of which contribute to the deposition and channel migration that are being observed.

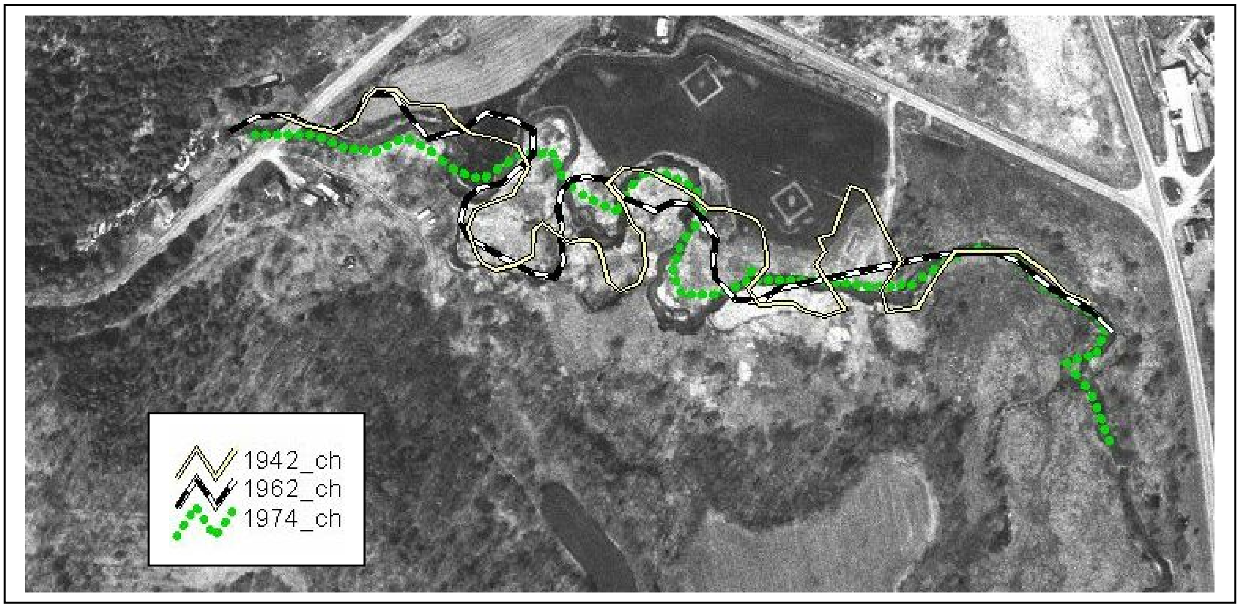



Figure 5: Location of  current and past channels near the Starksboro ball field.

### Phase 2

Understanding the reach from a remote sensing assessment is the first step in deciding what type of work and further investigation is required. The Phase 2 field assessment helps to confirm or refine information observed in Phase 1 and allows for updating information that has changed since the last orthophoto was taken.  Field observation also helps to decide the current geomorphic condition of the reach.

This season volunteers took on a greater role in the process of completing the Phase 2 assessment.  Teams completed sketches, channel cross-sections ,  and field forms with limited guidance from RMP personnel. As a result, the LCA was able to learn more about the process and stream types and conditions within their watershed, as well as now having the ability to continue the assessment when outside guidance is limited.

The seven reaches that were assessed this in 2002 had a range of conditions and stream types. Stream types in Phase 2 are determined using the entrenchment ratio, width to depth ratio, sinuosity, channel slope, sediment size classes, and bed-form.  For those reaches where assessments were completed on two or more segments, the segments are labeled from downstream to upstream with a letter value. (Table 7).

Table 7. Stream type for Phase 2 reaches, based on field measurements

| Reach Number | Segment | Bankfull Width (ft) | Flood-prone Width (ft) | Max Depth (ft) | Low Bank Height (ft) | Entrench-ment | Width /Depth Ratio | Sinuosity | Channel Slope (Phase1) | Incision Ratio | Stream Type | * * Stream Type Bed Material | Stream Bed Feature Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M17 | A | 23.5 | 28.2 | 1.9 | 7.4 | 1.2 | 14.7 | High | 0.31% | 3.9 | F | 4 | Ripple-Dune |
| M17 | B | 23.5 | 33.1 | 2.2 | | 1.4 | 13.5 | Moderate | 0.31% | | F | 5 | Riffle-Pool |
| M17 | C | 30.3 | 78.5 | 2.5 | 4.0 | 2.6 | 13.8 | Moderate | 0.31% | 1.6 | C | 4 | Riffle-Pool |
| M18 | Reach | 50 | 110 | 4.5 | 4.5 | 2.2 | 12.8 | Low | 6.19% | 1.0 | B | 2 | Step-Pool |
| *M19 | A | 40 | 500 | 3.0 | - | 12.5 | 20.0 | Moderate | 0.40% | 1.1 | C | 4 | Riffle-Pool |
| *M19 | B | 69 | 500 | 4.0 | - | 7.2 | 23.0 | Moderate | 0.40% | 1.1 | C | 4 | Riffle-Pool |
| M20 | A | 46 | 186 | 2.8 | 3.3 | 4.0 | 18.4 | Moderate | 0.58% | 1.2 | C | 4 | Riffle-Pool |
| M20 | B | 52 | 66 | 2.5 | 5.2 | 1.3 | 23.6 | Moderate | 0.58% | 2.1 | F | 4 | Riffle-Pool |
| M21 | Reach | 25 | 36 | 2.3 | 5.1 | 1.4 | 11.4 | Low | 0.42% | 2.2 | F | 4 | Riffle-Pool |
| M22 | Reach | 23.5 | 24.5 | 1.3 | 4.0 | 1.0 | 28.7 | Moderate | 0.81% | 3.2 | F | 4 | Riffle-Pool |
| M23 | Reach | 33.6 | 49.1 | 1.5 | | 1.5 | 29.7 | Moderate | 2.79% | | B | 3 | Riffle-Pool |
| T4.1 | A | 24.9 | 360 | 2.2 | 2 | 14.5 | 17.7 | Moderate | 0.97% | 1 | C | 4 | Riffle-Pool |
| T4.1 | B | 30.1 | 88.7 | 2.1 | 1.75 | 2.9 | 18.8 | Moderate | 0.97% | 1 | C | 4 | Riffle-Pool |

* M19 was evaluated in the 2000-2001 season.
** Bed material codes values are as follows: 2 = boulder 3 = cobble, 4 = gravel, 5 = sand or finer

Volunteers completed the rapid geomorphic and habitat assessments of each reach, and/or segment. Both the geomorphic and habitat assessments evaluate the overall condition of the reach. The gemorphic assessment also evaluates the current type of adjustment process and stage of channel evolution occurring on the reach (Schumm, 1969 and 1984). Predominantly the reaches that were evaluated this season were in fair habitat and geomorphic condition. Of the seven reaches evaluated this season only one reach, M18, was assessed as having habitat in good condition, the remainder were in fair-poor condition. From the geomorphic condition, adjustment process and stage of channel evolution a channel sensitivity (VTDEC Phase 3 handbook) have been assigned (Table 8).

Summaries were written for each reach (Appendix B). Volunteers and the primary LCA coordinator were responsible for completion of the summaries. These observations provide more information about a site, will be used to assist in deciding the next management steps for each reach, and will be of value for future reference. Writing these summaries also assisted volunteers in evaluating the data they had collected and in many cases helped the volunteer to understand more of what they had seen by having to describe it in a summary format.

Table 8. Reach condition for rapid geomorphic and habitat assessments.

| Reach Number | Segment | Habitat Condition | Geomorphic Condition | Adjustment Process | Concurrent Adjustment Process | Stage of Channel Evolution | **Channel Sensitivity to Disturbance |
|---|---|---|---|---|---|---|---|
| M17 | A | Fair | Fair | Degradation | Widening | Widening-III | very high to extreme |
| M17 | B | Good | Fair | Degradation | Widening | Widening-III | very high to extreme |
| M17 | C | Fair | Good | Aggradation | Widening | Stabilizing-IV | very high to extreme |
| M18 | Reach | Reference | Reference | None | None | Stable-I | very low to low |
| *M19 | A | Fair | Poor | Widening | Aggradation | Widening –III /IV | very high to extreme |
| *M19 | B | Fair | Fair | Aggradation | Widening | Widening –III /IV | very high to extreme |
| M20 | A | Good | Fair | Aggradation | Widening | Stabilizing-IV | very high to extreme |
| M20 | B | Good | Fair | Aggradation | None | Stable-V | very high to extreme |
| M21 | Reach | Fair | Fair | Aggradation | Planform | Stabilizing-IV | very high to extreme |
| M22 | Reach | Fair | Fair | Degradation | Planform | Incision-II | very high to extreme |
| M23 | Reach | Good | Good | Degradation | | Stable-I | very low to low |
| T4.1 | A | Good | Fair | Aggradation | Planform | Stabilizing-IV | very high to extreme |
| T4.1 | B | Fair | Good | Widening | None | Stable-V | very high to extreme |

*M19 was evaluated in the 2000-2001 season
** Channel sensitivity based on VT DEC Stream Geomorphic Assessment Phase 3 Handbook, Step 6.2

## Phase 2 on M19

The results from Phase 2 surveys will help guide river corridor management decisions on reach M19, as well as the other reaches that were assessed. After the Phase 2 assessment was completed, it was felt that there are at least two segments within the M19 reach. The two segments that have been evaluated to date are; segment A, from the Prison Hollow Rd. bridge to the upstream end of the ball field, and segment B, from the end of segment A to the upstream end of the reach. The geomorphic and habitat condition for both segments were fair to poor (Table 8).

M19-A, Starksboro ball field area

Many areas upstream of the baseball field have been channelized and rip-rapped in place. Along the sections of channel that are straight and rip-rapped the stream appears to be acting more as a transport stream (very little sediment deposition). One piece of evidence to support this is the relative lack of bar development. There are several areas along the reach where old rip-rap has failed, the channel is widening, depositional bars are forming, and the river has begun to create meanders. It appears that the stream may begin to function more naturally as a response system if allowed to more fully develop its historic meanders.

The reach is exhibiting multiple types of adjustment, with aggradation, widening and planform occurring simultaneously and individually throughout the reach. There may have been some minor degradation along the reach in the past, but it does not appear to be actively occurring at this time. The banks are primarily composed of fine alluvial materials. With little to no boundary conditions (e.g. bedrock, cohesive soils, well established vegetative buffers) along the banks of the channel, it is possible that the banks are more easily erodible than the bed, which is comprised of erosion-resistant clays overlain by alluvial sand, gravel, and cobble; this may allow the channel to more readily adjust its slope through a widening and meandering process.

## Phase 1- Phase 2 Comparison

To assist in compiling and maintaining an accurate database and increasing the precision of Phase 1 assessments, a comparison of the Phase 1 and Phase 2 data was completed. For both assessments, stream types and scores for potential adjustment processes are given (Table 9). The Phase 1 adjustment process scores are generated by the database, using the Step 9.1 protocol with the impact scores for Steps 4-7; the condition is determined using the Step 9.2 protocol. Phase 2 adjustment process and condition scores are based on the field-completed rapid geomorphic assessment. Evaluating the current stream type determined in Phase 2, in context of the "reference" stream type assessed in Phase 1 is important in determining future management decisions on a reach.

Table 9. Comparison of Phase1 and Phase 2 stream type, channel adjustment processes and condition.*

| Reach Number | Total Impact | Phase1 Stream Type | Phase1 Degrad. | Phase1 Aggred. | Phase1 Widening | Phase1 Planform | Phase1 Condition | Phase 2 Reach Segment | Phase2 Stream Type | Phase2 Degrad. | Phase2 Aggred. | Phase2 Widening | Phase2 Planform | Phase2 Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M17 | 12 | C | 4 | 6 | 4 | 8 | Poor | A | F 4 Ripple-Dune | 3 | 8 | 8 | 10 | Fair |
| M17 | | | | | | | | B | F 5 Riffle-Pool | 4 | 8 | 6 | 10 | Fair |
| M17 | | | | | | | | C | C 4 Riffle-Pool | 16 | 15 | 15 | 17 | Good |
| M18 | 0 | A | 0 | 0 | 0 | 0 | Reference | Reach | B 2 Step-Pool | 20 | 19 | 20 | 14 | Reference |
| *M19 | 14 | C | 6 | 9 | 7 | 8 | Poor | A | C 4 Riffle-Pool | 8 | 6 | 3 | 10 | Poor |
| *M19 | | | | | | | | B | C 4 Riffle-Pool | 15 | 8 | 10 | 10 | Fair |
| M20 | 5 | C | 2 | 1 | 0 | 2 | Good | A | C 4 Riffle-Pool | 13 | 11 | 11 | 13 | Fair |
| M20 | | | | | | | | B | F 4 Riffle-Pool | 11 | 10 | 12 | 16 | Fair |
| M21 | 7 | C | 3 | 4 | 2 | 3 | Fair | Reach | F 4 Riffle-Pool | 11 | 8 | 10 | 8 | Fair |
| M22 | 9 | C | 2 | 5 | 4 | 4 | Good | Reach | F 4 Riffle-Pool | 3 | 13 | 10 | 5 | Fair |
| M23 | 2 | B | 0 | 0 | 0 | 0 | Reference | Reach | B 3 Riffle-Pool | 12 | 16 | 15 | 13 | Good |
| T4.1 | 9 | C | 2 | 3 | 0 | 2 | Good | A | C 4 Riffle-Pool | 16 | 16 | 8 | 6 | Fair |
| T4.1 | | | | | | | | B | C 4 Riffle-Pool | 18 | 14 | 13 | 18 | Good |

* Lewis Creek Phase1 scores range from 0 to 10; with scores over 4 indicating an adjustment process is potentially occurring. Phase 2 scores range from 0-20; with scores of 10 or less indicating a potential major adjustment process. Note that some reaches have several high (Phase 1) or low (Phase 2) scores that indicate that multiple adjustment processes are potentially occurring (See Phase 1 and Phase 2 handbooks for assigning adjustment processes). M19 was evaluated in the 2000-2001 season.

The current stream type for several of the reaches is different than that expected from the Phase 1 reference stream type (Table 9). For reaches M17, M20, M21, and M22 it appears that the stream has departed from the reference stream type of a C to a current entrenched stream type F. The degradation scores for these reaches seem to indicate that the reaches have undergone either current or past degradation that has caused the stream to lose access to its floodplain at higher flow events. Reach M18 was evaluated as a reference "A" stream type at the Phase 1 level, and as a "B" stream type in Phase 2. The Phase 2 evaluation determined that the majority of the reach had access to floodplain, so the stream type was changed to a less confined stream type of a B. Access to floodplain is not easily seen in the Phase 1 assessment for streams in confined valleys. In the revision of the protocols it was recognized that there will be reaches that have some characteristics of different stream types. To account for the potential of reaches experiencing the slope category of one stream type, but the confinement and characteristics of another, a slope sub-category (consistent with the Rosgen classification) was added to the stream type descriptors. The reference stream type for reach M18 is a "Ba"; that is it has the slope of an A stream, but the entrenchment characteristics of a B stream. The correction of stream type from an A to a Ba has been made in the database to reflect the more accurate stream type.

Several reaches are also experiencing multiple adjustment processes. Sites and segments along a reach may experience different types of adjustment from the overall condition of a reach. This may be due, in part, to the stream reacting differently to past management practices or natural changes along the reach. The different types of adjustment processes also indicate that the reach may have, or is currently, working through different stages of the channel evolution process.

## Phase 3

During the 2002 field season the project team and LCA chose to survey two reaches. The Phase 3 assessment was conducted to help confirm the data collected in Phase 2 and to provide more detailed quantitative data for potential remediation projects. Volunteers assisted River Management Program personnel in collecting Phase 3 data. This allowed them to become familiar with the survey equipment and to have a better understanding of how information is collected for restoration or other management decisions that need more detailed channel data.

To help support LCA's recommendations to the town, a Phase 3 survey was done at the reach near the Starksboro ball field (M19-A). The volunteers also identified two areas on reach M22 that were under adjustment and were locations of potential remediation projects. On M22 the areas were far enough apart and undergoing potentially different process that two separate surveys were done for the areas of concern. The surveys included assessment of the: longitudinal profile to determine the slope of the channel and the types of bed features present; pebble counts and cross-sections throughout the reach to understand floodplain access, channel dimensions, and the size material being transported. Cross-sections were monumented to assist in future assessments of the reach.

### M19, Segment-A

Survey data was collected along M19 Segment-A during the 2002 season, while an upper portion of Segment-B was surveyed during 2001. Five cross-sections and a longitudinal profile were done at Segment-A. The valley slope along this segment is 0.46 % and the channel slope is 0.23%. The data on Segment-A suggests that the channel through this section is predominantly an E (width/depth ≤ 12); with sections that are a C stream type (Table 10). The build up of sediment (aggradation) behind existing beaver dams has increased the width to depth ratio and may be contributing to the change of stream type from an E to a C.

M19-A: Kristen Underwood showing bankfull elevation

Table 10. M19, Segment-A cross-section data

| | Bed Feature | Abkf (sq.ft.) | Wbkf (ft.) | Dmax (ft.) | Bank Ht. (ft.) | FPW (ft.) | Dbkf (ft.) | Entrenchment (+ or – 0.2) | Width / Depth Ratio (+ or – 2) | Q Manning's | D50 (mm) | Stream Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XS-1 | Riffle | 85.20 | 38.03 | 3.45 | 3.90 | 150.00 | 2.24 | 3.95 | 16.97 | 372.26 | 10.66 | C |
| XS-2 | Run | 81.94 | 31.74 | 4.03 | 5.03 | 200.00 | 2.58 | 6.30 | 12.30 | 389.46 | 1.34 | E |
| XS-3 | Run | 71.11 | 27.49 | 3.49 | 5.43 | 300.00 | 2.59 | 10.91 | 10.63 | 335.62 | 0.57 | E |
| XS-4 | Run | 78.60 | 38.00 | 3.60 | 3.52 | 300.00 | 2.07 | 7.89 | 18.37 | 317.71 | 0.25 | C |
| XS-5 | Riffle | 81.04 | 26.28 | 4.25 | 5.38 | 300.00 | 3.08 | 11.42 | 8.52 | 389.44 | 7.10 | E |

As stated earlier, Segment-A is in a high response or depositional zone of the Lewis Creek valley. As is typical of this setting (often seen in meadow-wetland areas), stream equilibrium is achieved through the growth and vegetation of sand and gravel bars that result in an "E" channel that is narrow and deep. The E stream type is typically a hydraulically efficient channel, maintaining a high sediment transport capacity (Rosgen 1996). To determine if the stream is able to transport the sediment supplied to it, a comparison is done between the calculated threshold grain size and the D84. The threshold grain sizes (those sediment sizes the stream has the power to move during bankfull flows) have been calculated for the reach to be in the range from 39.04 mm to 54.88mm, which are very coarse gravels. The larger sediments in the stream bed and banks (D84 size) measured in the range of 17.49mm to 35.32 mm, which are also coarse gravels. Having a higher threshold grain size than the D84 suggests that the channel is transporting all the sediment size classes supplied to it during bankfull and higher events.

The E channel is usually stable unless the stream banks have been disturbed or there is a significant change in the sediment supply and/or stream flow (Rosgen 1996). The channel along Segment-A has changed locations many times over the last 60 years. There has been little woody vegetation along the banks of the channel during that time. With the ability to move all of the sediment supplied to it, the stream may use excess stream power to either degrade its bed or to erode its banks. In this reach the bed material is coarse sands and small gravels, while the banks are fine alluvial material. Both types of materials are susceptible to erosion, however, the underlying glacial lake material in the bed is more resistant to erosion then the alluvial material within the banks. With lateral boundary sediments conducive to erosion, bank erosion and meander migration are likely to continue along this reach.

## M19, Segment–B

Four cross-sections and a longitudinal profile were done along a portion of Segment-B during the 2001 season. The valley slope along this section is 0.46% and the channel slope, partly a result of historic straightening, is currently 0.35%. This portion of the reach is predominantly a C stream type. Along this segment there are several areas where old rip-rap has failed or was not placed. In these areas the stream is eroding its banks and in some locations beginning to create meanders. The Vermont Hydraulic Geometry Curves suggest that this reach would have a width of approximately 42 ft. Cross-sections 2 and 3 are areas where there is no rip-rap or riparian vegetation and the stream is showing signs of over widening (widths listed in Table 11).

Sections of Segment-B are largely transporting the sediment supplied to them from the watershed due in part to the steeper gradient that exists as a consequence of channel straightening and armoring. The range of calculated threshold grain size is 43.77 mm to 55.71mm; while the measured D84 sediment size range is 22.93 mm to 40.69 mm. Where there is no riparian woody vegetation or historic rip-rap and the banks are comprised of fine alluvial materials, the excess stream power is being expressed through bank erosion.

Table 11. M19, Segment –B cross-section data

| Cross-section Number | Bed Feature | Abkf (sq.ft.) | Wbkf (ft.) | Dmax (ft.) | Bank Ht. (ft.) | FPW (ft.) | Dbkf (ft.) | Entrenchment (+ or - 0.2) | Width / Depth Ratio (+ or - 2) | Q Manning's | D50 (mm) | Stream Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XS-1 | Riffle | 85.92 | 45.60 | 2.77 | 4.16 | 600 | 1.88 | 13.16 | 24.20 | 402.28 | 1.9 | C |
| XS-2 | Pool | 95.75 | 62.62 | 3.90 | 5.32 | 600 | 1.53 | 9.58 | 40.95 | 393.76 | 8.12 | C |
| XS-3 | Riffle | 106.26 | 69.20 | 2.59 | 3.43 | 600 | 1.54 | 8.67 | 45.06 | 429.35 | 9.09 | C |
| XS-4 | Run | 81.93 | 44.00 | 4.17 | 4.29 | 300 | 1.86 | 6.82 | 23.63 | 378.63 | 9.68 | C |

## M22, Segment-A

Segment-A on M22 is a small section downstream of the Rte.116 crossing in Starksboro. This area is near a private road that has been eroding. LCA is interested in the survey to help resolve the conflict of the landowners losing their road to erosion by the stream. Two cross-sections (Table 12) and a longitudinal survey were done along this segment. One of the cross-sections was done within the area altered by the landowner; the second cross-section was done in an undisturbed section for comparison and reference data and to assist future remediation.

The valley slope along this segment is 0.71% and the channel slope is 0.61%. Cross-section 1 is within the area that the landowner altered. A channel was created along the back-side of a point bar to redirect flow out of the meander bend. There is a berm along the right bank of the new channel. It appears to be constructed with material bulldozed from the bed and bar to create the new channel. The berm does block access to the original channel along the upper part of the meander bend; however, the height of the berm is not sufficient to eliminate flow from accessing the original channel along the entire length of the new channel. This was evident after a fall rain event generated flows high enough to cut across the berm and the point bar to re-access the original channel at the downstream section of the meander bend.

Cross-section 2 was done at a cross-over riffle along an undisturbed section of the reach. This cross-section exhibits channel dimensions similar to those expected using the VT Hydraulic Geometry Curves. It may provide good reference data for addressing potential channel management practices in the disturbed section of the reach.

At cross-section 1 the berm along the right bank and the dredging of the channel to redirect the flow created a cross-sectional area that is 20% smaller than cross-section 2. Insufficient cross-sectional area will likely lead to a channel widening process which will further threaten the erosion of the constructed berm, leading to the return of stream to its original meander bend. At both cross-sections the stream appears to have the ability to move the D84. The threshold grain size is 102.03 mm at XS-1 and 99.51 mm at XS-2, while the D84 is 74.87 mm and 41.06 mm respectively.

Table 12.M22, Segment-A cross-section data

| Cross-section Number | Bed Feature | Abkf (sq.ft.) | Wbkf (ft.) | Dmax (ft.) | Bank Ht. (ft.) | FPW (ft.) | Dbkf (ft.) | Entrenchment (+ or - 0.2) | Width / Depth Ratio (+ or - 2) | Q Manning's | D50 (mm) | Stream Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XS-1 | Run | 46.32 | 23.85 | 3.77 | 2.92 | 150 | 1.94 | 6.29 | 12.28 | 222.44 | 30.21 | E |
| XS-2 | Riffle | 59.38 | 31.60 | 2.53 | 3.62 | 250 | 1.88 | 7.91 | 16.82 | 280.82 | 41.06 | C |


M22-A: Dave Fenn showing bankfull elevation


M22-A: Staci Pomeroy showing bankfull elevation

## M22, Segment-B

This area, of meander development which has eroded into an adjacent farm field, was surveyed to help LCA determine approximately how much sediment is being delivered to the stream from the eroding stream banks and to potentially assist the farmer with stream bank stabilization. Just upstream of the site the channel had been bermed, straightened and armored in the past. There is a small amount, approximately 20ft, of rip-rap within the surveyed site. Four cross-sections and a longitudinal survey were done along this segment.

The valley slope is 0.99% and the steepened channel slope is 0.87%. Historic channelization of the segment created a more erosive stream that may be still cutting down through its bed. A head cut was identified at cross-section 3. This incision process has continued to the point where the segment is on the verge of being entrenched. The LCA has chosen to identify this segment as an F stream type to red flag it for further investigation and to be conservative on future management decisions that may be needed for this reach. An F stream type, is capable of containing larger discharges; causing the channel to experience greater erosive forces on the bed and banks. In absence of vertical grade controls, these greater erosive forces will cause the bed to down-cut until the bed materials are coarser and/or more resistant to erosion than the bank material. When the bank materials are less resistant to erosion compared to the bed materials the channel will often begin to widen. As the channel continues to adjust it will eventually work towards rebuilding a new floodplain at a lower elevation. The potential for channel adjustment is high in these channels, making them very sensitive to changes in the watershed or channel.

While the higher channel slope and entrenchment has increased erosion and sediment transport in segment-B, the process of floodplain redevelopment appears to have started in the segment. The Vermont Hydraulic Geometry Curves suggest that a stream with a watershed size of 10.44 $mi^2$ would have a width of approximately 32ft. At cross-sections 2 and 3, the channel was observed to be both widening and aggrading sediments (Table 13). These two cross-sections are within the meander that has eroded into the farm field.

Table 13. M22, Segment-B cross-section data

| Cross-section Number | Bed Feature | Abkf (sq.ft.) | Wbkf (ft.) | Dmax (ft.) | Bank Ht. (ft.) | FPW (ft.) | Dbkf (ft.) | Entrenchment (+ or - 0.2) | Width / Depth Ratio (+ or - 2) | Q Manning's | D50 (mm) | Stream Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XS-1 | Riffle | 54.29 | 35.31 | 2.14 | 3.51 | 400 | 1.54 | 11.33 | 22.96 | 234.30 | 34.35 | C |
| XS-2 | Riffle | 59.55 | 44.07 | 2.31 | 3.29 | 500 | 1.35 | 11.35 | 32.61 | 219.53 | 49.43 | C |
| XS-3 | Riffle | 73.46 | 79.69 | 1.97 | 3.37 | 300 | 0.92 | 3.76 | 86.45 | 217.83 | 23.34 | C |
| XS-4 | Riffle | 48.84 | 29.63 | 2.34 | 3.45 | 500 | 1.65 | 16.87 | 17.97 | 233.94 | 20.55 | C |

M22-B: Carrie Fenn working survey rod

M22-B: Area of meander development

## Discussion

During the second year of the Lewis Creek pilot project, the focus of data collection was to demonstrate the use of knowledge concerning river processes at the watershed-scale in resolving erosion, habitat, and river conservation issues for site-specific areas. The focus of the Phase 2 assessment within the Starksboro valley during the 2002 season has helped to define the conditions and processes occurring in the headwaters and upper reaches of Lewis Creek. This information will provide the association, municipalities, and state and federal agencies with data that will support management decisions at those reaches as well as at downstream reaches.

To assist LCA with determining where to go from here with their information, a meeting was held to review the data collected and begin the process of making decisions about each reach. A basic summary sheet was completed (Appendix B) to compile information about the reaches' stream type, geomorphic and habitat conditions, present and past channel management practices, and other concerns. The compilation of this data facilitated an alternatives analysis discussion and documentation of the potential future needs and management strategies that may occur on each reach.

One of the goals for the 2002 season, was to assist the Town of Starksboro with making a decision about the types of land use practice, on the towns property, that would be compatible with the river. The town's property is along the main stem reach M19. A discussion of the assessment results for reaches upstream and downstream of M19 may provide insight into the types of management practices that would be successful along the reach.

Success, in the long term, will primarily be measured by our ability to solve and avoid problems at the watershed and river corridor scale; and secondarily, by how we resolve conflicts at individual erosion sites. From a geomorphic standpoint, this means recognizing that the river transports and deposits sediment; and that the stability and balance in the river system will depend on the river's opportunity to build and access a flood plain and create depositional features such as point bars, steps and riffles to evenly distribute its energy and sediment load in a sustainable manner (ANR DEC Alternatives for River Corridor Restoration, 2002).

**Reaches Upstream of M19**

### Reach M23


Volunteers assessing M23

In terms of sediment, the reaches upstream of M19 start in the source zone of the watershed, work through a transfer zone, and end in the response zone. The two reaches upstream of reach M23, are considered to be in the source zone of the watershed; that is they have a steeper slope, little access to floodplain, store little sediment within the reach, and supply sediment to the system through colluvial and erosional processes. Reach M23 is considered to be more within the transfer zone; less colluvial sediment originates within the reach and, although there is some amount of sediment storage, much of the sediment is moved or transferred through the system. M23 is in good condition for both the habitat and geomorphic functions of the stream. There were no immediate management practices needed along the reach; however, there was discussion about the future potential build out of residential homes along the reach. A need for education and outreach to the community to encourage the maintenance of riparian vegetation and to encourage the development of better zoning for setbacks in this area was identified by LCA. This area may lend itself to conservation of some of the corridor area to protect the intact riparian vegetation and undeveloped land within the corridor. LCA may revisit this reach in a time frame of about 5 years to reevaluate the condition of the reach and to determine if further steps need to be taken along the reach to maintain or improve its current condition.

### Reach M22

Reaches M22, M21, and M20 are in the response zone of the watershed; if in reference condition, they would have a mild to gentle slope, store sediment, have good access to floodplain and move laterally through their valley. Reach M22 was identified as a reach where current and past land practices and management decisions have affected the geomorphic and habitat condition of the stream. The river is in fair condition for both habitat and geomorphic functions along this reach. The volunteers identified the overall stream type for this reach as a deeply entrenched stream, (an F stream type). That the stream has departed from its reference stream type and has become incised in its valley is a cause for concern. The Phase 3 survey data suggests that there are still sections of the reach that have access to the floodplain at the higher events, (10-50 year return frequency floods.)

The presence of a head-cut in Segment-B of the reach may lead to further loss of floodplain access if the head-cut migrates upstream. The river is also trying to create a meander in a portion of Segment-B. This is causing a conflict with the current use of agricultural crop land. Evidence from historic orthophotos show that there were meanders along this section of river at one time. Berming and straightening eliminated the meanders, creating a steeper sloped stream with more power to transport sediment, potentially causing some of the incision and loss of floodplain that was noted in the assessment. A portion of Segment-B becomes a losing stream during part of the summer season. This section of river, approximately 1500 ft, flows over the kame terrace that runs along the eastern edge of the Green Mountains. Much of this material is large cobbles and gravels. The large size and lose compaction of this material may contribute to the groundwater levels lowering during dry seasons. When the ground water level is low enough that it no longer contributes to the discharge of the river, any flow that the river has will tend to flow below the surface and contribute to the ground water. Isolated pools were noted along the dry channel. These pools were providing small areas of refuge for several fish. The pools were a good example of why different types of habitat and bed features are needed along a river in order for there to be a sustainable population of fish and other aquatic species.

After reviewing the assessment data, LCA decided to contact the landowner to determine what types of actions could be taken at those areas of immediate conflict on M22. LCA took the lead to establish a working relationship with the landowner and the NRCS. The eroding bank along segment-B may be eligible for one of the NRCS programs. Although, resolving the conflict of the river meandering into the cornfield may require bank stabilization along the outside of the meander, the channel design should involve an adjustment of channel dimensions to insure success of the project. It could be beneficial to the river and downstream landowners if the meander is maintained as part of the management plan. The creation of a woody riparian buffer would also benefit the long-term stability of the stream bank and habitat in this segment of river.

Segment-A on M22 is also experiencing conflicts between the current land practices, residential and crop, and the river processes occurring on that segment of the reach. Past channelization and armoring of the banks to accommodate the Rte.116 bridge may have contributed to the current planform adjustment and erosion occurring at the upstream section of this segment. Where the channelization and bank armoring ends, a large point bar has developed; it is at this location where the current conflict is happening. The outside of the meander has been eroding into a steep bank where a private road is located. The loss of land and the potential to lose the road, led the landowner to try to relocate the river. Modifications to the channel were made by creating a new channel along the back side of the point bar. The tight radius of the newly created channel and the insufficient berm will not hold during large events, allowing the river to reclaim the meander it created.


M22-A: Volunteers assessing area bulldozed

The conflict along segment-A may require a more active geomorphic approach to resolve the problems. The landowners' constructed channel is not geomorphically compatible with the rivers' processes in this area. It is not clear if this area would be eligible for either NRCS or USFW programs. As the new berm continues to fail, armoring the eroding bank near the private road could reduce the immediate conflict, but it would not be a long term solution to the problem; due, in part, to the river changing in this area from a straightened armored channel to a sharp bendway with steep erodible banks. The Phase 3 survey data may be used to assist in an alternative analysis and project design should the landowner, LCA, and other partners choose to proceed. Since this reach was characterized as undergoing major adjustments, it should be high on the list of areas to revisit in sequential years to monitor the ongoing and/or growing conflict. The monumented cross-sections will be a way for LCA to keep track of the changes occurring over time.

**Reach M21**

The reach immediately downstream, M21, was also typed as a highly entrenched stream (an F stream type); although the volunteer summary also noted that there were locations where the stream accessed the floodplain (C stream type). The river is in fair condition for both the habitat and geomorphic functions. From the orthophotos it appears that channel straightening occurred along this reach in the past; perhaps causing sections of the reach to incise and lose access to the floodplain. There are several locations of channel avulsions and flood chutes, as well as sediment deposits and debris jams. Active planform change and aggradation suggest that this reach may be in the 4th stage of channel evolution, re-establishing a floodplain at a lower elevation. Monitoring of the reach should continue to determine which areas of the reach have fully lost access to the floodplain not only at bankfull events but also at the higher events.

**Reach M20**

Reach M20 was segmented by the volunteers. The two segments showed different riparian buffer widths and overall stream types; which may suggest different management strategies in the future. A review of the orthophotos shows that much of the reach was straightened in the past. The upstream segment of the reach was characterized as entrenched, while the downstream segment had floodplain access. Both segments are in fair condition for geomorphic and habitat values. Past channelization may have contributed to the incision process and loss of floodplain access along sections of this reach. The field notes indicate that there are several types of sediment bar features along the entire reach, and aggradation was considered to be the active adjustment process for both segments. No immediate management activities were decided on for the reach. Continued monitoring to determine the extent of loss to floodplain should be considered for this reach.

**Reach M19**

The data collected on M19 and the surrounding reaches, will support various management activities along the town owned land, which is one of the few areas within the Starksboro valley where the river is not in conflict with the current land use. This section of river is a good candidate for a passive geomorphic approach. Allowing the river to establish meanders and migrate laterally through the valley in this area would help to create a more geomorphically stable river; reducing the long term management activities needed.

The Phase 2 and Phase 3 data show that M19 is undergoing aggradation, widening and planform adjustments throughout the reach. The more resistant glacial lake clays that are part of the boundary conditions of the bed, are helping to prevent the stream from degrading; even though it has been straightened. The data suggests that the reach may have excess stream power to move sediment larger than the current D84. To come into balance with the amount and size of sediment supplied to it, the river may begin to adjust its slope, to be less steep, by creating meanders through erosion of its banks, since it is less able to down-cut through its bed. If a management corridor is established (the Phase 1 corridor is the belt width, total of 6 times channel width, plus two channel widths on either side for woody riparian vegetation; approximately 350 ft to 450ft wide for M19), and the river is allowed to move freely through the valley in this area, it will, over time, reestablish a planform that is able to maintain a balance between the amount of water and the type and amount of sediment supplied to it from the watershed. Five monumented cross-sections were established this season near the Starksboro ball field. Revisiting these cross-sections, on a time line of perhaps every couple years, will assist the town with determining the rate and type of adjustments occurring along the reach in this area. The establishment of additional cross-sections upstream of the ball field would facilitate the gathering of additional information as to the rate and types of adjustment happening along the remainder of the reach.

A few of the banks along the recreation field have been hard armored to protect the investments in that area. Other eroding banks along the reach would not require stabilization techniques to prevent erosion; if the river is given a corridor in which to adjust its planform. The establishment of a woody vegetation within the corridor will ultimately provide for channel stability and the improvement of habitat conditions within the reach. Watching the river develop meanders after it has been locked in place for so long, may not offer short term benefits, over and above the avoidance of ongoing stabilization costs, however, the overall health and equilibrium of the river corridor will accrue several long-term benefits. From a watershed perspective, increasing the sediment deposition along M19, will help to mitigate the conflicts associated with the aggradation, widening, and planform adjustments underway in the lower segments of M17 (downstream). Additionally, the town of Starksboro has a valuable resource that can provide recreational, aesthetic, habitat, educational and open space values.

## Reaches Downstream of M19

### Reach M18

The bedrock along M18, contributes to both the vertical stability of the immediate reach and Lewis Creek in the Starksboro valley. The grade control in M18 will arrest headcuts and incision processes potentially moving upstream through M17 before they reach M19. The bedrock and valley constriction of reach M18 may affect the slope and deposition in M19 immediately upstream of the reach; and the high sediment transport capacity of M18 ensures that any sediment moving through or generated in M19 will rapidly move downstream to reach M17. The habitat and geomorphic condition for M18 are both in reference condition. There is a current flood chute along the right bank of the downstream section of the reach. This area also had a historical flood chute that caused the channel to avulse across the field during the 1937 flood. There is a house near the lower portion of the current flood chute. This is an area to be aware of for potential damage during high flood events. Conservation of the corridor along the reach could provide a connection between the upstream portion of M17 and the downstream segment of M19, which are both town owned land.

### Reach M17

The bedrock grade control created by M18 prevents the channel adjustments along M17 from influencing M19; however, changes along M17 may contribute to channel concerns downstream. Reach M17 is within a broad valley and is within the response area of the watershed. The upstream portion of the reach is fallow fields and the downstream section is pastured heavily. The reach was divided into 3 segments to capture the different land use practices and stream types along the reach. The lower two segments were typed as entrenched streams (F streams). Historical straightening and current pasturing practices may have contributed to the incision of segments within the reach. Information from the landowner indicated that the river does access portions of the floodplain on a regular basis, so there may be a need to reevaluate the reach and adjust the bankfull elevation for portions of the downstream segments. The downstream segments appear to be in the second or third stage of channel evolution; however, widening and planform adjustment were noted by the volunteers, so portions of the segments may be aggrading and moving from the third stage to the fourth stage, stabilization. The geomorphic condition for both downstream segments is fair. The habitat condition for Segment-A is poor, and for Segment-B, fair. The upstream segment was typed as a C stream. Segment-C appears to be in equilibrium and perhaps in the first stage of channel evolution. The segment is in good geomorphic condition and fair habitat condition.

There are three major landowners along M17. Along Segment-C there are few conflicts with the current land use. The Town of Starksboro and LaRue own Segment-B and the land use is currently fallow pasture. The town has asked LCA for input into their management plan for this area. A recommendation may be to allow the river to continue adjusting its slope and building a new floodplain where access has been lost to the historical floodplain. This management strategy would work well with low impact land use such as recreation and wildlife management. Development of a woody riparian buffer and corridor will establish boundary conditions for the long term stability of the river. Management strategies appropriate for Segment-A include education and outreach, as well as the implementation of agricultural BMPs. There may be opportunities for the landowner to qualify for NRCS programs and for volunteer tree planting projects along some sections of the segment. NRCS has had contact with this landowner, facilitated by LCA. To date, the landowner has signed up for the WHIP program (Wildlife Habitat Incentives Program). Due to the high sensitivity of an entrenched stream, this area should be red flagged for future monitoring and to take actions, where opportunity allows, for creating woody riparian corridor conditions.

## Reaches Surrounding M19

The data from the reaches surrounding M19 suggest that the river in the Starksboro valley is very sensitive to change and will likely continue to undergo adjustments as it works to come back into balance, with its sediment and discharge, from changes in the watershed and past and present management practices. Those reaches that were found to be entrenched (F stream types) are areas where major adjustment may occur during flood events or from traditional channel management activities. While the incision process may have taken place historically for many of these reaches, there is some evidence to suggest that the incision process is currently ongoing in some locations. There are no grade controls in the three reaches immediately upstream of M19 or in reach M17. Any headcuts or nick points that occur within these reaches will be able to migrate upstream. Monitoring of these locations will help to determine the rate of incision, head-cut migration rates, and the sensitivity of that area to changes in the watershed or future floods. A review of the bankfull indicators and floodprone widths should also be done to confirm the current amount of incision and loss of floodplain access.

Several of the reaches were noted to have undersized bridges that would restrict bankfull or higher events. Further investigation of the bridges may facilitate actions to upgrade, where feasible, the bridges to accommodate bankfull and higher events. Undersized bridges should be highlighted as areas where conflict or damage may occur during flood events.

Along segments of several reaches there are proposed projects for bank stabilization. LCA is helping to provide data and explanation of river adjustment process to the landowners and agencies undertaking those projects. Review of the stream condition, adjustment, and sensitivity (expressed as current stage of channel evolution) will insure that the projects are consistent with long term solutions to the conflicts and the physical imperatives of the river system. There may be opportunities, where none were noted before, to work with landowners to allow the river to begin adjusting its planform and slope through deposition and erosion processes. Table 14 shows the width land that may encompass the lateral extent of meanders (calculated belt widths) should the adjustment process continue, and Lewis Creek were to reach equilibrium conditions in the Starksboro Valley.

Table 14. Calculated belt widths for Lewis Creek reaches in the Starksboro valley.*

| Starksboro Reaches | Channelization Impact Rating | **Range of Existing Belt Width | Reference Channel Width | Calculated Belt Width |
|---|---|---|---|---|
| M17 | High | 48.5-187 | 48.5 | 291 |
| M18 | NA | NA | NA | NA |
| M19A | NA | 302 | 44 | NA |
| M19B | High | 44-145 | 44 | 264 |
| M20 | High | 41-301 | 41 | 246 |
| M21 | High | 33.5-123 | 33.5 | 201 |
| M22 | High | 33-140 | 33 | 198 |

* See Appendix H in the VT ANR Stream Geomorphic Assessment Handbook for a more detailed discussion and references on belt width calculations.

** The range of existing belt width shows two things: 1) Where there was extensive straightening the channel width is used as the lower end of the range of existing belt width, and 2) where there was some planform along the reach, belt widths were measured and the average of two or more belt widths is used as the upper range of existing belt width. For M19-A the calculated belt width is NA due to stream type.

As the river begins to approach a more gentle slope through greater sinuosity and has banks held together with woody vegetation, the erosion and erosion-related conflicts would be expected to diminish significantly. This would break the cycle of chasing the erosion in straightened reaches with increasingly expensive bank armoring projects. In those segments identified as entrenched, where dramatic erosion and adjustment may occur during large flooding events, it may be especially important for the stream to be able to come back into balance with the sediment and discharge inputs from the watershed.

## Hollow Brook, T4.1

The other area of interest for LCA during the 2002 season was the Hollow Brook tributary. The Hollow Brook tributary may be a large contributor of sediment to Lewis Creek. LCA looked at the most downstream reach on the brook, T4.1. The reach was evaluated in two segments. Segment-A is in the response area of the watershed and contains the confluence of Hollow Brook with Lewis Creek. There were several beaver dams and areas of beaver activity in the downstream portion of Segment-A. Within the upstream portion of Segment-A recent instream channel activities by the landowner were noted. There is a current conflict with the location of the channel's proximity to the landowner's home. To address this concern the landowner constructed a channel block to redirect the flow to an area where the channel may have been historically. It does not appear that this solution will be a long term fix to the landowners issues with the river. Segment-A is a highly depositional C type stream, with sections of E within the most downstream portion of the segment. Beaver activity may be affecting the stream type along this portion of the reach. The overall habitat and geomorphic condition in the segment is fair.

The upstream segment, Segment-B, is more within the transitional zone of the watershed. A long section, approximately 800 ft, becomes a losing stream for much of the season. This section flows over the kame terrace along the edge of the valley, similar to the losing stream section on M22. A few isolated pools with fish were observed in this section. Two areas of mass failure were noted as likely contributors of sediment to the stream. Segment-B is considered a C stream, and is in good geomorphic condition and fair habitat condition.

The areas of Segment-A near the confluence and just upstream may be good candidates for river corridor conservation. High beaver activity and good wetland connection within this portion of the reach would provide good wildlife habitat. Conservation of this area would also provide an area where the natural high levels of sediment deposition and planform adjustment could continue with minimal conflict with surrounding landowners. Management strategies for Segment-B should include education and outreach, as well as working with the towns to insure that good zoning regulations are in place to minimize the increase of river-related conflicts in the future.

Hollow Brook Trib – T4.1: Volunteers conducting Phase 2 assessment

LCA's objective of comparing reach T4.1 with reaches M22 and M23 shows that there are some similarities between parts of those reaches. Reach T4.1 and M22 both have sections that flow over the kame terrace and become losing streams during part of the season. The loss of stream flow contributes to the fair habitat condition on both reaches. Any type of habitat improvement strategies that are considered for one reach may also provide similar benefits within the similar section of the other reach. Reach T4.1 appears to share few similarities with M23; except perhaps in the most upstream section of T4.1 and the most downstream section of M23, where the stream is transitioning out of the more confined mountain valley to the broader valley floor. No clear evidence was noted in the assessment to verify similarities in these sections of the reaches. Reach M23 may share more similarities with reach T4.2 on Hollow Brook, as they are both B streams and in similar valley setting. Reaches T4.1, M22, and M23 would all benefit from similar management strategies that protect current riparian vegetations and long-term protection of the corridor.

LCA also looked at T4.1 to try and provide data to the DEC Biomonitoring and Aquatic Studies Section on related habitat issues on the main stem reaches upstream and downstream of the confluence. The contribution of sediment to the main stem from Hollow Brook is perhaps one reason for the difference seen in habitat communities surrounding the confluence. A review of the habitat and geomorphic conditions of the reach may provide biologists with more knowledge about the area and insight into the types of aquatic communities likely to be found in the vicinity of the confluence.

## Conclusion

The project team and volunteers of LCA collected valuable data during the 2002 season. Completed assessments show a majority of Lewis Creek in Starksboro may be highly sensitive to erosion during large floods or that may result from modifications to stormwater and/or sediment runoff. This is due largely to the physical processes at work where the river, during floods, attempts to undo the practice of channel straightening and incision by redeveloping its floodplain and eroding and depositing until a more sinuous channel is achieved. This knowledge may be put directly to use in river corridor decisions and in town plans for the surrounding area. Landowners, towns, and resource agencies have traditionally sought, with increasing expense, to resolve conflicts by maintaining old channel works because "that is where the river has always been." Through education and outreach, other river corridor management strategies may now be more fully considered. If land use and infrastructure investments are minimized on those lands where the river will regain the sinuosity, slope, and floodplain necessary to achieve equilibrium conditions, landowners and towns may begin to enjoy significantly reduced flood-related losses. The corridor lands owned by Starksboro and the working relationships that have been established with other landowners create an opportunity for a more holistic watershed based approach to the management of erosion that will protect agricultural land and human infrastructure while simultaneously improving river and riparian habitat.

For those conflict areas where river corridor protection and allowing the river to "evolve" to a more naturally stable condition are not viable options, short-term solutions should consider the river's geomorphic condition to the greatest extent possible. To do otherwise will significantly increase the risk of greater river management costs into the future. Projects that have been planned with an understanding of the river processes occurring at that site, and upstream and downstream of the site, may ultimately cost less, require less maintenance, and create fewer off site impacts.

The Lewis Creek pilot project has enhanced the working relationship between landowners, municipalities, and state and federal agencies working to minimize conflicts and insure the long term stability of the river. Lewis Creek Association's commitment to continue with the assessments in future years will further those relationships and help to bridge the gaps between groups with different interests in the river and its watershed.

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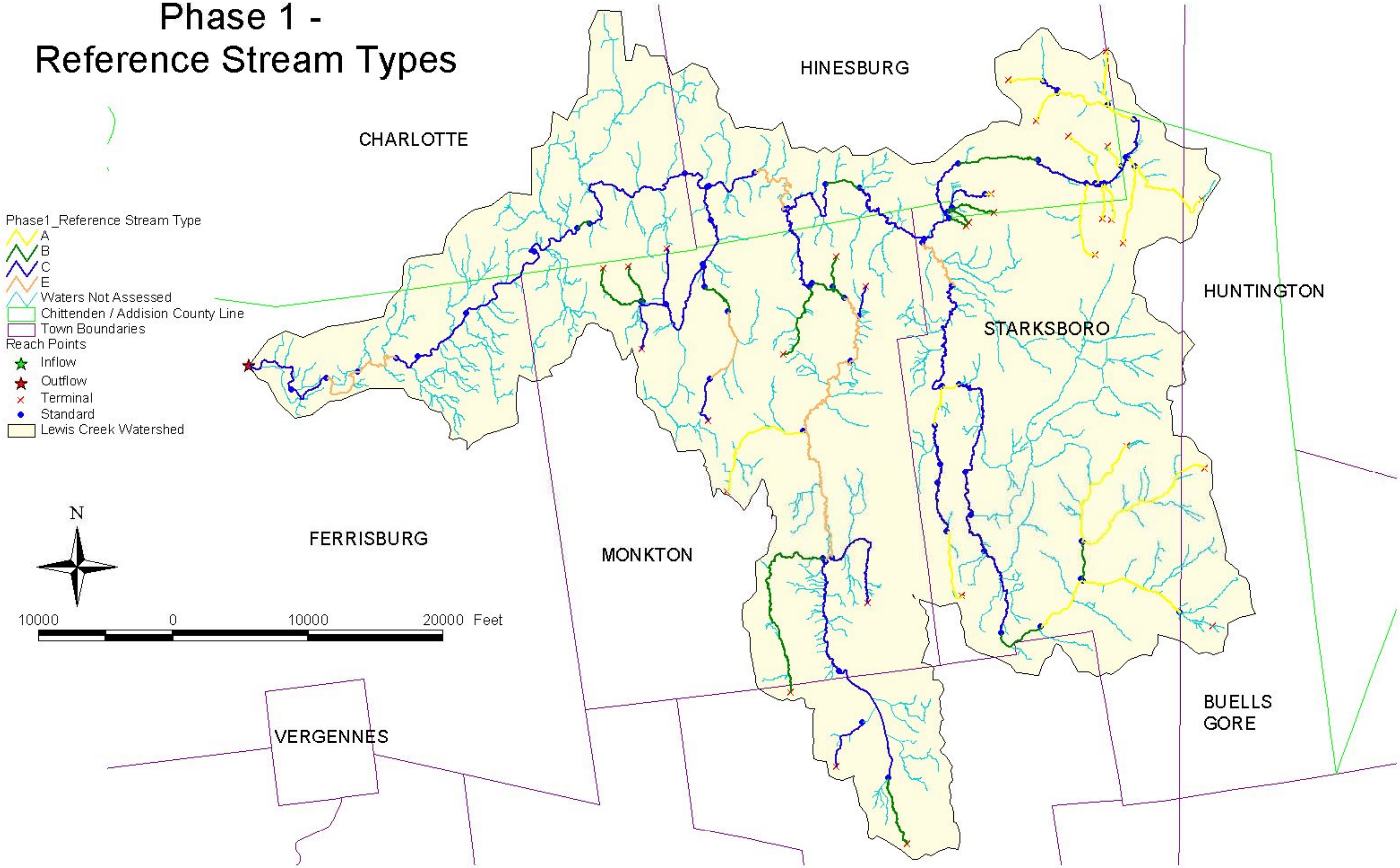
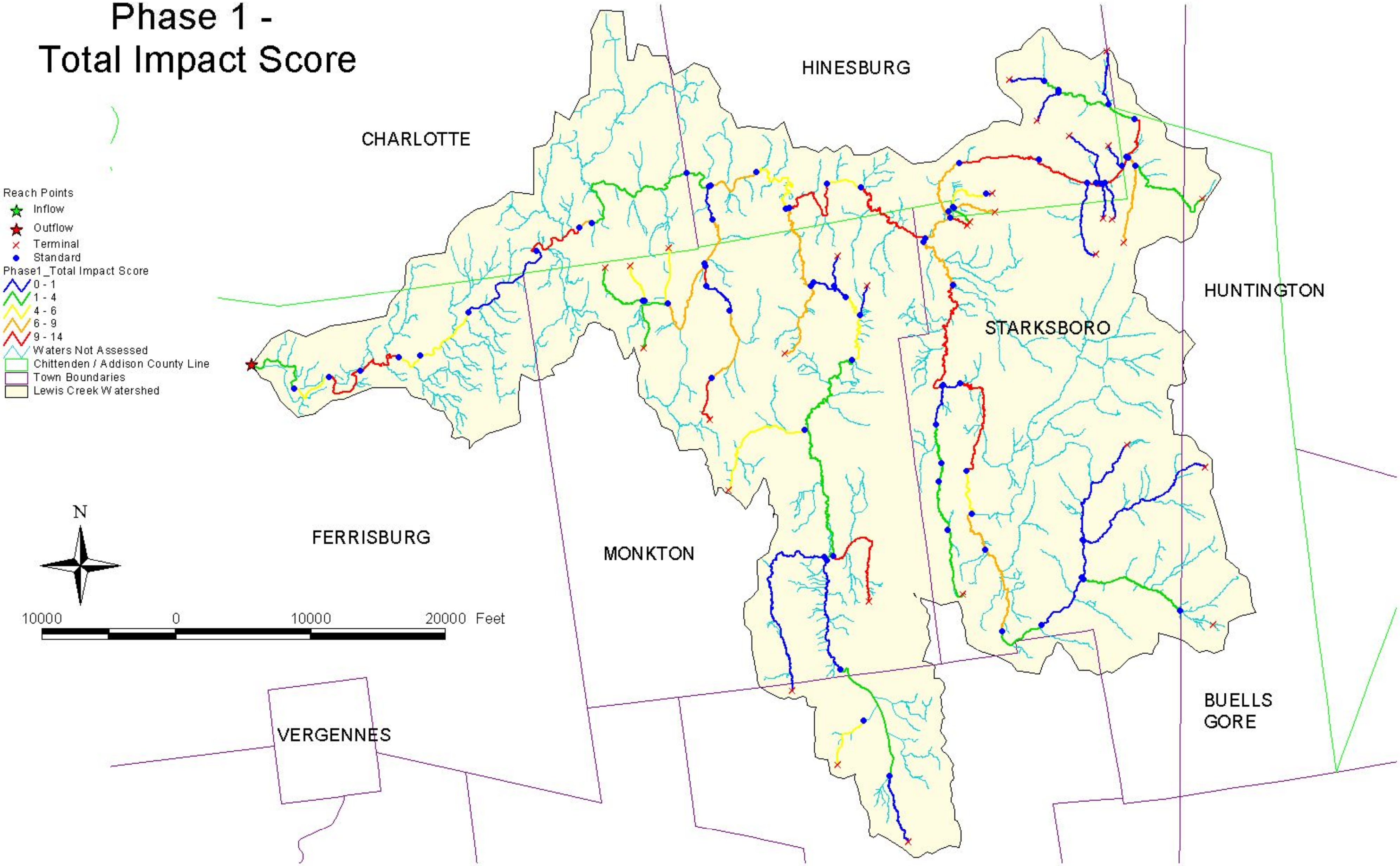
# Phase 1 - Reference Stream Types



# Phase 1 - Total Impact Score



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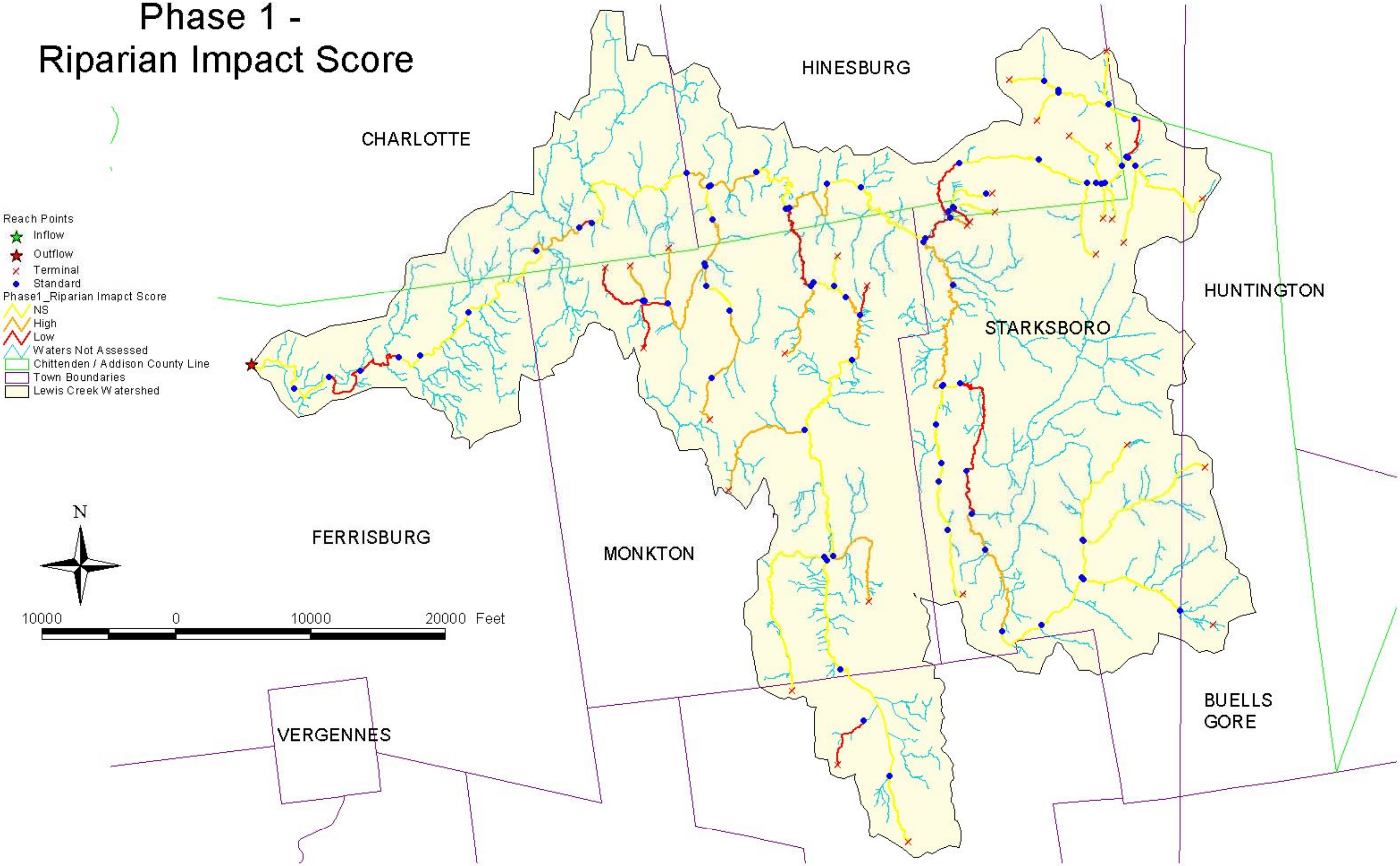

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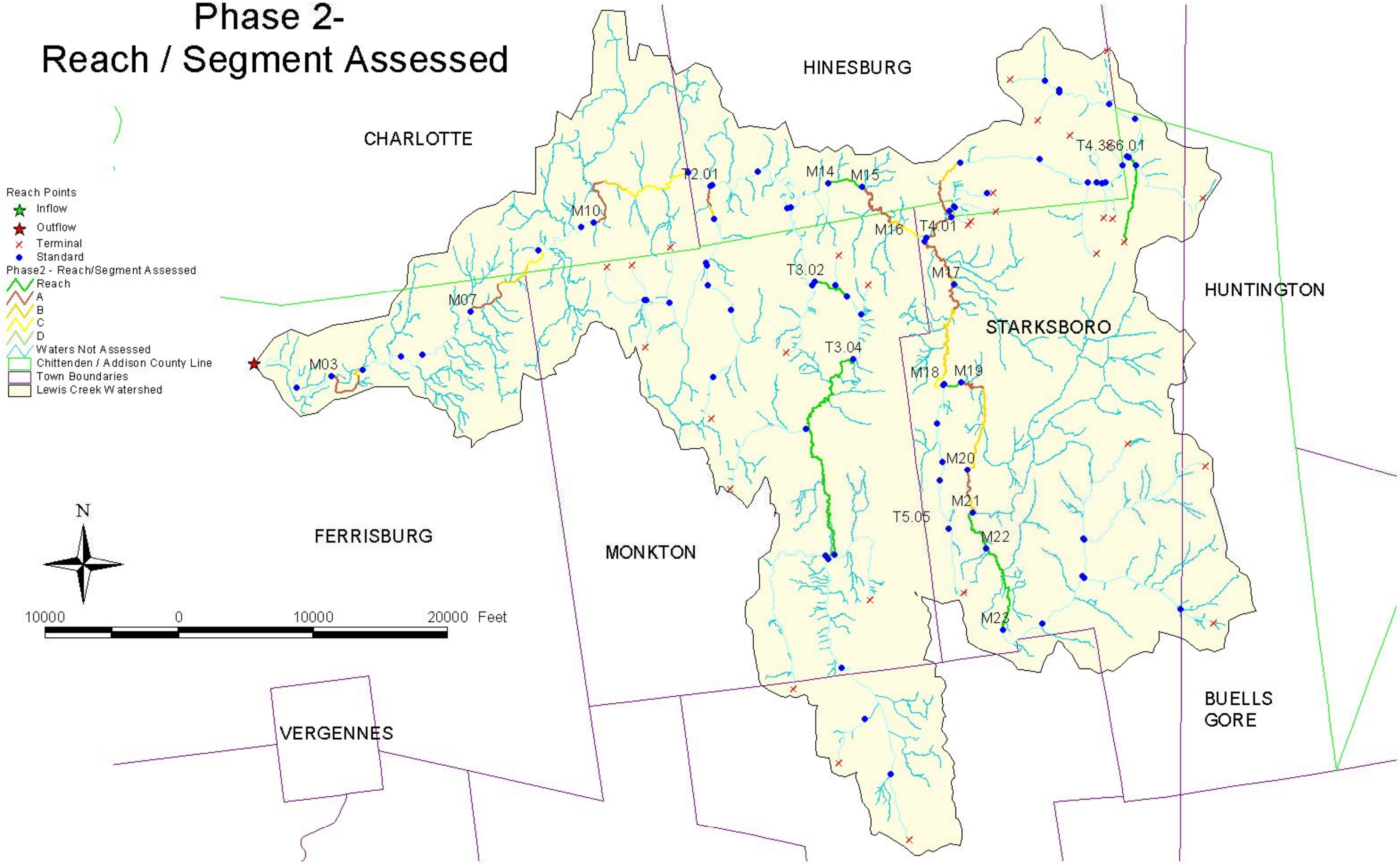
# Reach / Segment Assessed



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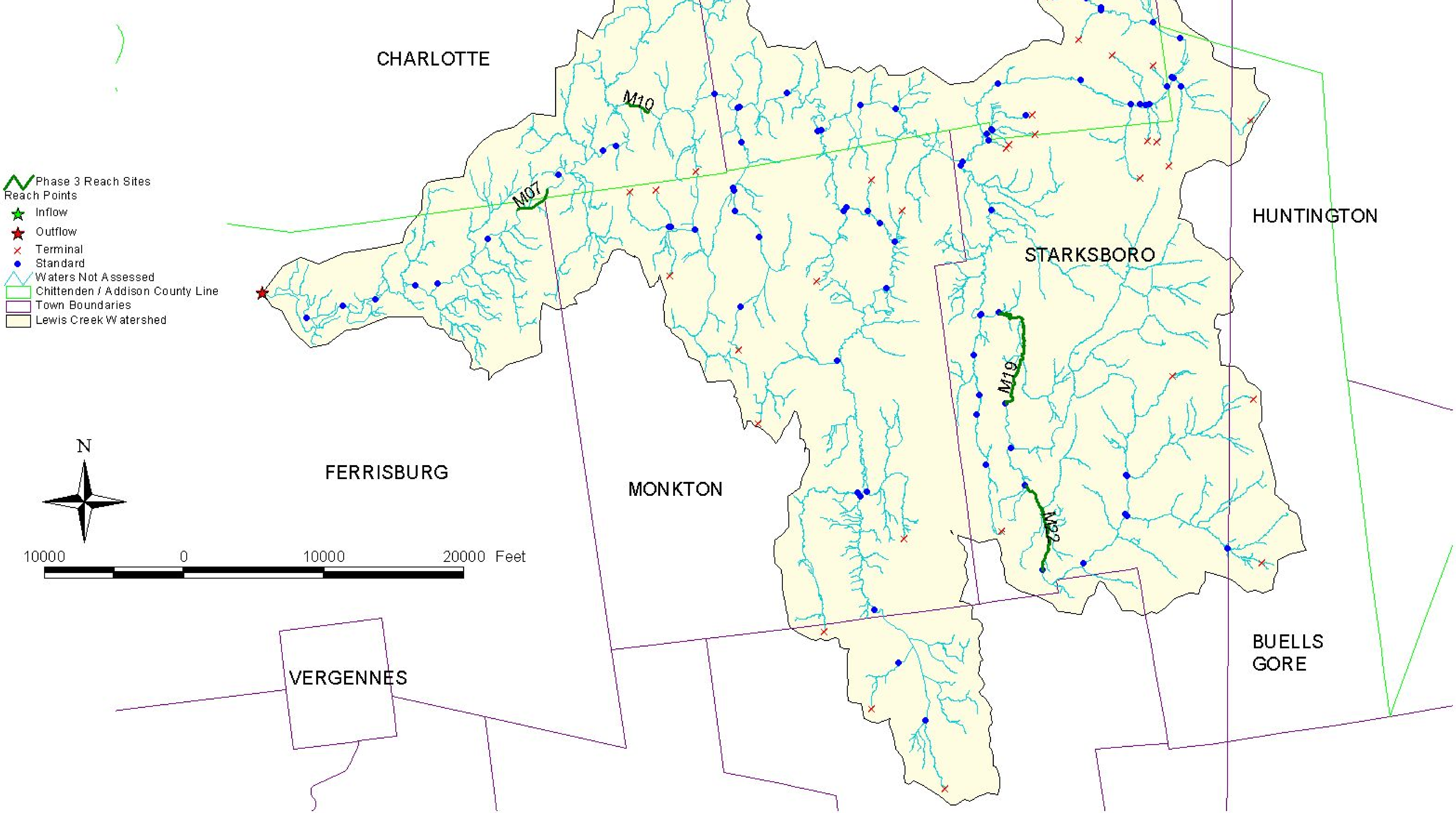
# Reach / Segments Assessed



# Appendix A

# Appendix B

# Appendix C

# Appendix D