

Table of Contents

Executive Summary	1
Project Overview and Background	4
Study Goals and Objectives	4
Description of Study Area	4
Reach Locations.....	4
Flood History	5
Phase 1 Stream Geomorphic Assessment.....	5
Methodology- Phase 1 Parameters	5
Results.....	6
Reference Stream Types	6
Basin Geology and Soils.....	6
Land Cover/Reach Hydrology	7
Historic Channel Modifications.....	8
Bridge and Culvert Assessment.....	9
Floodplain Modifications and Planform Changes	10
Bed and Bank Windshield Survey	11
Data Analysis.....	12
Impact Scores.....	12
Adjustment Process.....	15
Reach Sensitivity	16
Recommendations.....	17
References.....	18
Figure1-Study Area.....	18
Figure 2-Reach Locations.....	19
Figure 3- Flow Modifications.....	20
Figure 4- Berms, Roads, Armoring and Straightening.....	21
Figure 5- Meander Widths & Length Locations.....	22
Figure 6-Adjustmnet Locations and Potential Locations.....	23

Appendices

- A. Reach based orthophotographs
- B. Phase 1 Data
- C. Data CD

Executive Summary

The Addison County Regional Planning Commission completed a Phase 1 Geomorphic Assessment of the Lower Otter Creek and the Leicester River in the spring of 2005 and the winter of 2006. For the purpose of this study, the Lower Otter Creek watershed was defined by the county boundary separating Addison County from Rutland County. The Lower Otter Creek was divided into 12 reaches and the Leicester River was divided into 4 reaches. This study was funded by the Vermont Department of Environmental Conservation (VTDEC). The assessment followed the latest Phase 1 Fluvial Geomorphic Assessment Protocols developed by the Vermont Agency of Natural Resources (VTANR).

The Lower Otter Creek is located in the municipalities of Ferrisburgh, Vergennes, Panton, Weybridge, Waltham, Addison, New Haven, Middlebury, Cornwall, Whiting, Leicester and Salisbury (see Figure 1). The Otter Creek is the only river in Vermont which flows north. The Otter Creek served as a major trade route for Native Americans and early colonialists. It was often referred to as the 'Indian Road' because the Iroquois and Abanokies used it as a highway (Patterson, 1995). The Creek begins in the mountains of East Dorset and enters Addison County in Leicester. From its confluence with the Leicester River it flows through approximately 20 miles of wetlands (VTDEC, 1998). From there it moves through acres of farmland and additional wetlands to the Upper Middlebury Falls in downtown Middlebury. From the falls downstream, the Creek is controlled by a series of dams, the last being in the City of Vergennes. Otter Creek then flows lazily through residential areas, forests and farms until it enters Lake Champlain at Fort Cassin Point.

The Phase 1 Geomorphic Assessment is designed to understand a river's basic physical features and its associated watershed. The assessment relies heavily on analysis of map-based data, existing data and windshield survey data. Steps 1-4 of the protocol documents baseline physical features such as valley and channel characteristics, slope, and watershed size. These characteristics predict the reach's reference stream type. All reaches on the Lower Otter Creek are reference stream type 'C'. All reaches on the Leicester River are type 'C' except for one type 'B' reach.

The later steps of the assessment examine watershed influences which may be producing channel adjustments. The most influential potential channel modifications affecting the Otter Creek are dams. This assumption will be further investigated during a Phase 2 assessment. On the Leicester, the impacts identified are less severe, although one dam and an impoundment is of concern. The final products of the assessment are the condition of each reach, the channel adjustment process that may be underway, and the sensitivity of the reach to change from anthropogenic and/or natural sources.

This report recommends that a Phase 2 assessment be conducted on the following reaches on the Lower Otter Creek: R03, R04, R06, R07, R08, R09, R10, R11 and R12. Reaches R03 and R08 on the Lower Otter Creek should be assessed because not all information was available and an inadequate windshield survey was conducted on these reaches.

Results from this remote sensing phase indicate that the remaining reaches may potentially be in adjustment and may be highly impacted from flood-plain modification, in-stream modifications and surrounding land uses. Overall, the impact category with the greatest total score is Floodplain Modification (39.6%).

A Phase 2 assessment should be completed on all four reaches on the Leicester River. Reaches R12T1.03 and R12T1.04 should be assessed because not all information was available and an inadequate windshield survey was conducted on these reaches. Reach R12T1.01 is an impacted reach that may benefit from a proactive restoration. Reach T12T1.02 is a reference reach that needs further evaluation for purposes of reach comparison and conservation.

Project Overview and Background

Study Goals and Objectives

The goal of this assessment is to determine how changes in the Lower Otter Creek and the Leicester River's watersheds have manifested themselves through the channel adjustment process or have lead to stream-instability. The secondary purpose of the study is to determine which reaches should under go a Phase 2 Assessment. A Phase 2 assessment is an additional and finer and field based level of assessment. The Phase 1 data can also inform local planning and restoration measures.

Description of Study Area

The Otter Creek Basin, Basin 3 is 936 square miles. The study area for this project is the Lower Otter Creek Basin which begins at the Rutland/Addison County line. This is roughly where the Otter Creek begins to develop a less confined valley dominated by agricultural land use. The Rutland County Regional Planning Commission on cooperation with the Poultney Mettowee Natural Resources Conservation District recently conducted a Phase 1 assessment of the Upper Otter Creek Watershed.

The Lower Otter Creek study area is located in the municipalities of Ferrisburgh, Vergennes, Panton, Weybridge, Waltham, Addison, New Haven, Middlebury, Cornwall, Whiting, Leicester, Salisbury and a portion of Brandon and Sudbury in Rutland County. Most of the major tributaries, except for Dead Creek and the Leicester River have been the subject of, at a minimum, a Phase 1 assessment. The study area for this project is the direct drainage of the Lower Otter Creek and the Leicester River watershed beginning at Lake Dunmore's outlet (See Figure 1). The Leicester River study area is 38 square miles (SGAT generated). The Lower Otter Creek watershed is predominantly agriculture with development centered along highway corridors and the City of Vergennes and Town of Middlebury. The Leicester River watershed is sparsely populated in comparison and is predominately forested. In both watersheds land is being converted from agriculture and forest to residential land use. Perhaps the most dramatic change in both watersheds was the large scale deforestation which occurred after colonization and throughout the 19th century. This conversion had a profound influence on the morphology of Vermont rivers (VTDEC, 2003).

Reach Locations

This study assessed 12 stream reaches totaling approximately 43 stream miles on the Otter Creek and 4 reaches on the Leicester River totaling approximately 6.7 stream miles. See Table 1 for reach mileage and Figure 2 for reach locations. Step 1 of the Protocols produces the reach description, town and latitude and longitude locations and can be found in the VTDEC Data Management System (DMS) Report located in the Appendices.

Reach ID	Reach Length (miles)
R01	4.11
R02	1.74
R03	2.14
R04	7.07
R05	1.59
R06	3.67
R07	2.71
R08	2.14
R09	1.79
R10	3.80
R11	10.62
R12	1.70
R12T1.01	2.07
R12T1.02	2.27
R12T1.03	1.45
R12T1.04	0.90

Table 1: Reach Length

Flood History

The Otter Creek has a USGS flow gauge in the town of Middlebury (gauge number 04282500) which has a drainage area of 628 square miles (USGS website). The Lower Otter Creek generally has good access to its floodplain and reaches bank full at least once per year with spring runoff. In 1913, 1927, 1936 water levels at the gauge topped the 50 year discharge of 10,000 cfs. The 1927 flood was recorded at almost 13,600 cfs in Middlebury (Vermont ANR, 2004, VSGA app L, Flood History of Vermont Rivers). A 25 year event was recorded in 1960 and a 10 year event in 1986. Prior to 1904 there are no gauging records of the Otter Creek in Middlebury (USGS website).

Phase 1 Stream Geomorphic Assessment

Methodology- Phase 1 Parameters

The methodology used for this study was developed by the Vermont Agency of Natural Resources River Management Section (VTANR RMS). It represents the first phase of a three phase protocol to determine stream type classification and channel evolution prediction to inform river management decisions. The first phase is largely provisional and uses map-based techniques along with windshield surveys to establish stream geomorphic reaches and reference stream types based on geology and landform. A Phase 1 also analyzes the river corridor land use and modification to channel and floodplain to inform channel condition, adjustment process, and reach sensitivity (VTANR, 2003 position paper). This study used the Stream Geomorphic Assessment Tool Version 3 (SGAT) which automates much of the data calculations. The steps taken to assign a provisional impact rating to each reach (Step 8.1) can be found in the Step 8 DMS (Data

Management System). All data generated after running SGAT were entered into the DMS (see Appendices for data sheets and DMS generated reports).

A Phase 2 geomorphic assessment is a rapid stream assessment based on field observations and measurements that verifies data collected during a Phase 1 assessment. It is also completed for reaches defined as priority reached during a Phase 1 assessment. Phase 2 assessments are completed on both disturbed and undisturbed reaches to determine the departure from reference conditions and potential management alternatives. A Phase 2 assessment recommends specific sites which could benefit from active management projects.

Phase 1 Quality Assurance Review

Following Phase 1 protocols, ACRPC and VTDEC conducted quality assurance reviews throughout the term of this project. Shannon Hill of VTDEC River Management Section conducted quality assurance Check 1 on 6/9/2005, Check 2 on 1/31/2006 and Check 3 on 3/28/06. Throughout the SGAT process, ACRPC staff shared results to ensure data were consistent and correct prior to beginning the next SGAT step. A similar process was followed on post-SGAT steps. ACRPC manually checked data entered into the DMS against field notes and data sheets.

Results

Reference Stream Types

The Phase 1 protocol uses the Rosgen Stream Channel Classification System and the Montgomery-Buffington System to determine the provisional reference stream type of each reach. All 12 reaches on the Lower Otter Creek are reference stream type 'C'. On the Leicester River, 3 reaches are type 'C' and one reach is reference stream type 'B'. A 'C' type stream is one which is generally unconfined, has floodplain access, is moderate to gentle in slope and has a Riffle-Pool or Dune-Ripple bed form (VTANR Phase One Handbook, 2004). Streams in steeper and more confined valleys with a plane-bed or step-pool bed form are generally considered 'B' type streams. A stream type of 'C' was chosen instead of 'E' in three reaches where sinuosity values were greater than 1.5. Other parameters such as windshield survey did not support nor reject this classification. Much of the Lower Otter Creek has undergone channel modification. It is possible that prior to straightening and damming, many of the reaches were type 'E'. A Phase 2 assessment will check if the provisional reference stream type is correct.

Basin Geology and Soils

DMS Report Number 3 details the basin characteristics of geologic material, grade control, valley side slopes and soil properties. This study failed to identify any alluvial fans. The dominant geologic material in the Lower Otter Creek is Glacial Lake or Alluvium. The dominant geology of the first two reaches of the Leicester River is 'Other' and the last two are Till. The dominant soil types in both the Lower Otter Creek and the

Leicester River show little to no flooding potential. The multitude of grade control structures also influences the low probability of flooding. There are six dams and one bedrock gorge on the Lower Otter Creek. On the Leicester River there are three grade controls, two dams and one channel spanning ledge.

The erodibility factor for Glacial Lake deposits and Glacial Till are moderate to high. The erodibility of Alluvium (river sediments) is high (VTANR Phase One Handbook, 2004). The erodibility factor is determined by the percentage of the reach with erodable soil. On the Lower Otter Creek three of the reaches had 'slight' soil erodibility, four have 'moderate' erodibility, two reaches have 'severe erodibility' and three have 'very severe erodibility.' On the Leicester River, the first reach's erodibility factor could not be determined, although interviews with NRCS staff concluded that this reach is prone to erosion and flooding (Collins & Hartline, 2006). Reach R12T1.02 has slight erodibility and an intact riparian buffer. The last two reaches have 'very severe' erodibility.

The soils for all but two of the reaches on the Lower Otter Creek are in 'Hydrologic Group D'. These soils have low infiltration rates and high runoff potential. On the Leicester River, the first two reaches are in 'Hydrologic Group D' and the last two reaches are in 'Hydrologic Group B'.

The valley side slopes were determined using topographic maps and information in the NRCS soil layer. The valley side slopes are variable on the Lower Otter Creek. Except for R01 and R07/R08 which are flat and very steep respectively, all the other reaches are hilly or steep. The Leicester River's valley side slopes are also quite variable, but overall are either hilly or steep.

Land Cover/Reach Hydrology

The land use within a watershed has a direct influence on the hydrology and physical characteristics of the receiving water. Generally, intensive land use leads to negative impacts on receiving waters. Land use and land cover is a watershed factor that can be manipulated to achieve a desired management objective. Increased stream flow volume and higher peak flows are hallmarks of a watershed that has been converted from forest to higher intensity land uses like farming or residential development (Brooks, 1997).

The dominant watershed land cover/land use (See DMS Report 4) in the Lower Otter Creek is forest. The subdominant watershed land use/land cover is field except in R12, R12T1.03 and R12T1.04 which is urban. The watershed impact rating from R01 to R05 is 'High'. The remaining Lower Otter Creek reaches and the entire Leicester River watershed has an impact rating of 'Low'. The dominant land use/land cover within the river corridors is also summarized in DMS Report 4. The corridor impact rating is 'High' from R01-R10, R12, and R12T1.03. It is 'Low' or 'NS' for the remaining reaches. A 'High' impact rating is generated when 10% or more of the land cover/land use in the stream corridor is crop and/or urban. It is 'Low' when land cover/land use is between 2 and 10% crop and/or urban and 'NS' if it is less than 2% crop and/or urban (VTANR Phase One Protocol Handbook, 2004).

Intact and healthy riparian buffers are vital in maintaining a high quality stream ecosystem. Riparian buffers improve bank stability and reduce erosion potential, maintain cooler water temperatures and contribute large woody debris benefiting aquatic life. Riparian buffers provide wildlife corridors and protect and enhance water quality.

The buffer width impact is 'NS' or 'Low' for most of the Lower Otter Creek except for R12 which is 'High'. However, on quite a few reaches there are large areas that have very little buffer on one side or the other. The buffer width should be reassessed during a Phase 2 survey because additional field work and review of aerial photographs may reveal less riparian buffer. For the Leicester River, the buffer width impact is 'NS' to 'Low'. In general, the Leicester River has a well vegetated buffer. This assumption will be further examined during a Phase 2 assessment.

There are abundant groundwater inputs and wetlands throughout the Lower Otter Creek and the Leicester River. On reach R11, drainage ditches are being plugged for the purpose of restoring wetlands.

Historic Channel Modifications

Modification of the stream channel may lead to changes in a stream's sediment regime and hydrology. The Phase 1 protocol attempts to quantify this impact by assessing the frequency of dams, bridges and culverts, length and type of bank armoring and channel straightening and dredging.

The number of dams on the Lower Otter Creek was determined through examination of topographical maps, field observations, orthophotographs and a phone interview with Brian Fitzgerald of the VTANR, Dam Safety Section. All of the operating dams on the Lower Otter Creek and the Leicester River have an impact rating of 'High' according to Brian Fitzgerald.

The Vergennes Dam (R03) is operated by Green Mountain Power (GMP) and is impounded with a 75 foot bypass. The dam is 17 feet high. The Weybridge Dam (R06) is operated by Central Vermont Public Service (CVPS) and is impounded with a bypass and a dam height of 43 feet. The Huntington Falls Dam (R07) is operated by OMYA and is impounded with a bypass and a dam height of 36 feet. The Beldens Dam (R08) is also operated by OMYA, is impounded with a bypass and a dam height of 27 feet. There is a gorge in the middle of R08 which was not observed due lack of access to private property. This gorge is most likely channel spanning ledge which is a grade control. Middlebury Lower (R09) is operated by CVPS, the bypass is 400 feet with a 1 mile impound. The dam height is 15 feet. Middlebury Upper (R09) is non-operational, with no impoundment or bypass. It is bedrock controlled and does not have a significant impact. Middlebury Upper is the last dam on the Lower Otter Creek (Fitzgerald, 2006).

The Salisbury Dam (beginning of R12T1.04) is operated by CVPS and has an impoundment 100 ft upstream. The power station is 1,750 feet downstream after a large

channel spanning ledge (R12T1.03) which is functioning as a grade control. The last dam (R12T1.04) controls the height of Lake Dunmore which provides storage capacity to the dam downstream (Fitzgerald, 2006).

According to Dennis Neelan of the VTANR Water Supply Division there are no permitted water withdrawals from the Lower Otter Creek or the Leicester River (Neelan, 2006). Bob Collins and Keith Hartline of NRCS both reported that there are two water withdrawals for agricultural irrigation on R04. These withdrawals are minimal, do not have a significant impact and do not require a permit (Collins and Hartline, 2006).

Bank armoring is prevalent throughout the Lower Otter Creek and portions of the Leicester River. Although bank armoring is mostly 'Low' or 'NS' on the Lower Otter Creek, much of the river's armoring could not be observed because of snow or inaccessibility to the bank. Besides a windshield survey and use of current orthophotographs, the sole source of data for the armoring parameters was from Mr. Collins, Mr. Hartline and Mr. Nicholson, the regional VTDEC Stream Alteration Engineer. Each source can recall only what has been armored in approximately the last twenty years. The reaches which received a 'High' impact score are R07, R09 and R10. These reaches are dominated by infrastructure near the river which is armored.

The professionals interviewed do not know of any permits permitting straightening in the last twenty years. Mr. Nicholson did believe there was extensive straightening after the 1973 and 1976 floods, but did not know the locations. When evaluating orthophotographs and topographical maps from different time periods, very few alterations are evident. It is obvious when examining these sources that certain sections were straightened because of sharp angles and lack of meander patterns. Reaches R04, R10-R12 are highly impacted from straightening. R12T1.01 received an impact rating of 'Low' while the 11 other reaches assessed received of an impact of 'Unknown' or 'Not Evaluated' because of lack of data. There were certain stretches of river like R01, R03, R06 and R07 which have most probably been straightened. These reaches should be further assessed to determine if this is true.

According to Mr. Nicholson, dredging has a large impact behind hydroelectric dams because thousands of cubic feet of material are typically removed. This is considered 'routine maintenance' under FERC licenses. Mr. Nicholson does not know of any gravel extraction for commercial purposes in the twenty years he has been working for VTANR (Nicholson, 2006).

Bridge and Culvert Assessment

ACRPC did not conduct a detailed assessment of bridges and culverts using Appendix G, Bridge and Culvert Assessment and Survey Protocols, 2004. Using topographic maps, orthophotographs and personal observation, 12 bridges were identified, including railroad trestles. The impact of these bridges is either 'NS' or 'Unknown'.

Floodplain Modifications and Planform Changes

To determine the degree of floodplain modification which affects floodplain access and can lead to vertical and lateral confinement at high flows, the following parameters were assessed (Step 6): Berms and Roads, River Corridor Development, Depositional Features, Meander Migration/Channel Avulsion, Meander Width Ratio (MWR), and Wavelength Ratio (WLR). DMS Report 6 in the Appendices contains the Phase 1 information for floodplain and planform changes.

Berms and Roads were evaluated to determine if the river is laterally constricted at certain locations, which can lead to vertical adjustments in the corridor (VTANR Phase 1 Handbook, 2004). The roads are apparent on orthophotographs and topographical maps. Berming is more challenging to evaluate. For this parameter Mr. Nicholson, Mr. Hartline and Mr. Collins were interviewed for additional information. Mr. Nicholson pointed out that berming is illegal, but has been historically undertaken all along the Lower Otter Creek and where the Leicester River meets the Otter Creek. Mr. Collins explained that from the mouth of the Otter Creek until the Vergennes Dam, the entire right bank is bermed. Historically this 'trail' was used by horses to transport barges upstream to the mill at the dam (Collins, 2006). The impact of berms and roads within the river corridor is 'High' throughout most of the reaches. It is 'Low' in R04 which is primarily agriculture and has little infrastructure. The impact is also 'Low' for R11 which is largely wetland or farmland. Reach R12T1.03 is mostly forested with one pocket of infrastructure and roads and berms have a 'Low' impact within the reach. The remaining Leicester River reaches are 'Unknown' because little information is available on berming and very few roads are apparent.

River Corridor development is 'High' throughout the Lower Otter Creek with the exceptions of reaches R11 and R12. These two reaches are predominately wetland or farmland. The first two reaches on the Leicester River have an insignificant amount of development. The two last reaches have a 'High' impact due to the Village of Salisbury and camps around Lake Dunmore. Development can decrease the lateral extent to which the outside of a meander bend can migrate away from the upstream meander. The closer the meanders are from one another, the increased potential for bed degradation because the river can less effectively adjust to changes in channel slope. If a river has this process occurring, it is more likely that during a large event an avulsion can occur or another type of change that is indicative of a channel evolution process (VTANR Handbook Protocols, 2004).

Depositional features often are indicative of a river which is either aggrading or undergoing lateral migration. The increased sediment loads create point or mid-channel bars and deltas. When assessing depositional features, ACRPC found it difficult to identify mid-channel bars because of sun reflection, extensive flooding when the orthophotographs were taken and extensive turbidity. In addition, many reach locations are inaccessible. The point bars and deltas are generally easier to identify. From what is evident, most of the reaches have 'NS' to 'Low' impacts from depositional features. The

exceptions are R04, R06-R09. Meander migration is 'Low' to 'NS' for most reaches except for an impact rating of 'High' for R06 and R07.

Historic topographical maps available from the University of New Hampshire and current topographical maps were compared to assess meander migration; avulsion and bifurcation (see CD for those events and Figure 6). The side-by-side comparison of 1978 orthophotos to 1995 orthophotos is helpful in pinpointing potential avulsion locations and old meander scars. In general, meander migration is 'Low' or 'NS' on both the Lower Otter Creek and the Leicester River. The exceptions are reaches R06 and R07 show a high degree of migration and bifurcation.

The Meander Width Ratio (MWR) and the Wavelength Ratio (WLR) can reveal if the channel is undergoing adjustment. When a channel aggrades it is in the process of becoming more sinuous. There is typically a decrease in channel slope and lateral migration from an increase in fine sediments. The process of degradation is when the channel becomes steeper and straighter, loses access to its floodplain and degrades its bed (VTANR Handbook Protocols, 2004). ACRPC used the 1990 series of orthophotographs along with current topographic maps to determine the Lower Otter Creek and Leicester River's MWR and WLR for most reaches.

Two of the reaches on the Lower Otter Creek and one reach of the Leicester River have a MWR impact of 'High'; calculated MWR is < 3 . One reach on the Leicester River is considered 'Low' impact. The remaining 7 reaches were either a 'B' type (R12T1.03) or the MWR is 'Unknown'. For the 'Unknown' reaches, ACRPC was unable to identify any fully developed meander bends. ACRPC was able to identify more representative meanders to calculate the WLR. For three reaches on the Lower Otter Creek the WLR is 'Unknown' because this was not the case.

Bed and Bank Windshield Survey

A windshield survey of the Lower Otter Creek and the Leicester River was conducted on February 27, 2006. Unfortunately, snow had covered most of the banks the night before. Shannon Hill of VTDEC RCM accompanied ACRPC staff. The results from the survey are summarized in the DMS Report 7 in the Appendices. The parameters assessed are the dominant bed form, dominant bank material, bank erosion/bank height, and debris/ ice jam potential. Many pictures were taken and are documented on the accompanying CD entitled 'Phase One Photographs'. The dominant bedform and bank material is discussed in the Geology and Soils section of this report. Additional information can be found in DMS Report 7 in the Appendices. The dominant bed and bank material was only recorded when it was readily observable from the bank. Bank erosion and bank height were observed at specific reach locations. In general the bank height and erosion lead to a bank erosion impact rating of 'High' for most of the Lower Otter Creek. The first two reaches of the Lower Otter Creek have an impact rating of 'Low' because of bank armoring on the right bank and access to flood plain on the left. Reach R08 and R12T1.03 could not be evaluated because it is surrounded by private property with no public access. Every reach location observed has some degree of erosion. As a result, a

‘Bank Erosion’ event was not produced because without floating the river, a complete picture of the degree of bank erosion cannot be determined.

The ice and debris jam potential is ‘High’ on Gooseneck Bend (R06) because of the abrupt and severe bend. Most of the bridges especially the Pulp Mill Bridge and Cedar Swamp Bridge have potential for jamming. Pulp Mill is not channel spanning, has a middle abutment and little clearance. The approach and departure have undergone straightened. Cedar Swamp Bridge is also very low, is supported by a middle abutment and the river upstream and downstream is straightened. The first reach on the Leicester River has a large ‘S’ curve before its outlet and is constricted because of the road and bridge.

Data Analysis

Impact Scores

A stream and watershed impact score was developed for each reach on the Lower Otter Creek and the Leicester River. The following parameters were each given an impact score.

Step Number	Parameter
4.1	Watershed Land Cover/Land Use
4.2	Corridor Land Cover/Land Use
4.3	Riparian Buffer Width
4.4	Groundwater and Small Tributary Inputs
5.1	Flow Regulations and Water Withdrawals
5.2	Bridges and Culverts
5.3	Bank Armoring or Revetments
5.4	Channel Straightening
5.5	Dredging and Gravel Mining History
6.1	Berms and Roads
6.2	River Corridor Development
6.3	Depositional Features
6.4	Meander Migration / Channel Avulsion
6.5	Meander Width Ratio
6.6	Wavelength Ratio
7.1	Dominant Bedform / Material
7.2	Bank Erosion – Relative Magnitude
7.3	Debris and Ice Jam Potential

Table 2: Parameters included in impact scores.

Impact scores are assigned to each reach and each parameter above to gauge the possible channel adjustment process occurring. The total impact score also permits reaches to be compared against each other and ranked as a priority for attention. These impact scores are provisional until a more detailed field based analysis can be completed on the ‘Fair’ and ‘Poor’ reaches. Impacts are measured and then rated according to the following: NS, Low Impact, High Impact or No Information. A zero is scored for options NS, No Data or Note Evaluated, a 1 for Low Impact and a 2

for High Impact. See the DMS Report entitled ‘Stream and Watershed Impact Ratings’ in the Appendices for more detailed information.

According to the Phase 1 Data, the most impacted reaches on the Lower Otter Creek are R03, R04, R06, R07, R09, R10 and R12. The remote sensing results indicated that the Leicester River is relatively non-impacted with total impact scores less than 16 out of 32 (See DMS Report ‘Summary of Categorical Impact’ in the Appendices for more detailed information).

- Step 4, ‘Land Use’ accounts for 24.8% of the total impact scores in the watershed. Land Use encompasses: Watershed land use/land Cover, corridor land cover/land use, riparian buffer width and groundwater and small tributary inputs. The majority of the reaches on the Lower Otter Creek have 4 out of 6 impacts. R04, R05 and R12 have an impact of 5. R08 and R11 have an impact of 3. On the Leicester River, R12T1.01 and R12T1.04 have impacts of 2 out of 6. R12T1.03 has an impact score of 3 and R12T1.02 has an impact score of 1.
- Step 5, ‘In stream Modifications’ accounts for 20.4% of the total impact scores in the watersheds. The majority of the reaches on the Lower Otter Creek have an impact rating of between 4 and 6 out of the highest possible total impact score of 10. This category includes flow regulations and water withdrawals, bridges and culverts, bank armoring or revetments, channel straightening and dredging and gravel mining history. The highest impact scores are R07 and R09. On the Leicester River, all of the reaches have an impact score of between 0 and 3. The highest being the first reach with an impact score of 3.
- Step 6, ‘Flood Plain Modification’ accounts for 39.6% of the total impact scores, the largest impact of the four possible. This category includes berms and roads, river corridor development, depositional features, meander migration/channel avulsion, meander width ratio and wavelength ratio. Reach R07 is the most impacted reach with an impact score of 10 out of 12. Reaches which have a score of 6 or more are R01, R03-R10 and R12T1.03
- Step 7, ‘Bed and Bank Survey’ accounted for 15.2% of the total impact scores. This category includes: dominant bedform, bank erosion and debris and ice jam potential. The highest score for this category is 4 out of 4 on R06, R09, R11 and R12 and R12T1.04.

Reach ID	Confinement Type	Watershed Area	Total Impact Score	Reach Condition from Phase 1 DMS	Reach Condition from Professional Judgment
R01	VB	944.02	12	Fair	Fair
R02	VB	877.98	11	Fair	Good
R03	VB	876.71	19	Poor	Unknown
R04	BD	873.47	16	Fair	Fair
R05	BD	857	14	Fair	Poor
R06	BD	758.1	21	Poor	Poor
R07	NW	755.66	22	Poor	Poor
R08	NW	752.21	13	Fair	Not Observed
R09	NW	748.81	21	Poor	Poor
R10	VB	746.24	16	Fair	Poor
R11	VB	560.12	14	Fair	Poor
R12	VB	489.24	18	Poor	Poor
R12T1.01	VB	38.44	10	Fair	Good
R12T1.02	VB	29.04	3	Reference	Reference
R12T1.03	NW	22.47	12	Good	Good
R12T1.04	NW	21.16	8	Fair	Unknown

Table 3, Step 9.2 Reach Assessments for Unconfined Channels

Reaches that are in ‘Poor’ condition are located on the Lower Otter Creek. These reaches have undergone flood plain modification, urban and agricultural development, impacted buffers and flow regulation. As a result of these changes, there is a lack of representative and predictable meander bends. ACRPC suspects that the Lower Otter Creek has undergone more extensive straightening than this study reflects. However, documentation of this was not found and professionals interviewed only identified areas they know were historically straightened. In addition, topographical maps from the late 1800s were very similar to current topographical maps. The sheer number of dams and impoundments has significantly impacted the sediment regime and flows leading to a stream that seems to be no longer in equilibrium.

The reaches which are in ‘Fair’ condition are in adjustment and may have lost connection to floodplain. There may also be moderate to major changes in planform (VTANR Protocols Handbook, 2004).

Those reaches in ‘Good’ condition are generally in equilibrium. There may be changes occurring in the watershed that could cause river instability. These are reaches are sensitive to watershed alterations.

Reaches in ‘Reference’ condition are in equilibrium and have access to floodplain and little change in land cover or channel modification. Reach R12T1.02 appears to be in reference condition and is functioning as it may have centuries ago. This reach is primarily forested or forested wetland with little development.

Adjustment Process

The following table details the type of adjustment processes that can occur in a river corridor.

Degrading	Downward erosion of stream bed via a head-cutting process
Aggrading	Excessive sediment build up on streambed and bars
Widening	Erosion of both banks leading to an over-widened streambed
Planform	Rapid and/or irregular meander movement and pattern
None	No significant adjustment process indicated
Multiple	Multiple adjustments indicated

Table 4, Step 9.1, Adjustment Process Options

The Phase 1 assessment generates the Provisional Geomorphic Condition Evaluation by evaluating three parameters; adjustment process, reach sensitivity and reach condition (VTANR Protocol Handbook, 2004). The Phase 1 assessment evaluates causal factors that can lead to channel adjustment and is a hypothesis based on best available data. This data may have changed or the river itself may have already completed its next logical adjustment process. The actual affects of these parameters like floodplain modification are measured through Phase 2 and 3 assessments. These assessments are field based and directly measure the signs of impacts and channel adjustment (VT ANR Handbook Protocols, 2004).

According to the Phase 1 algorithm, the most common primary adjustment process on the Lower Otter Creek is Degradation followed by Aggradation and Planform. On the Leicester River, Aggradation and Planform are the most common adjustment processes. R12T1.02 does not have any significant adjustment process occurring.

Reach ID	Total Impact	Current Adjustment Process	Concurrent Adjustment(s)	Reach Sensitivity
R01	12	Degradation	Aggradation/Planform (same value, 6)	High
R02	11	Degradation	Aggradation/Planform (same value, 6)	High
R03	19	Degradation	Aggradation	High
R04	16	Degradation	Aggradation/Widening (same value, 9)	High
R05	14	Degradation	Aggradation	
R06	21	Degradation (12)	Aggradation/Planform (same value of 12)	
R07	22	Degradation (14)	Planform (14)	
R08	13	Degradation (10)	Planform (10)	Moderate
R09	21	Degradation (10)	Aggradation/Planform (same value, 12)	
R10	16	Degradation	Planform	
R11	14	Degradation	Aggradation	
R12	18	Aggradation	Degradation	
R12T1.01	10	Planform	Aggradation	High
R12T1.02	3	None	None	
R12T1.03	12	Aggradation	Degradation/Planform (same value, 5)	Moderate
R12T1.04	8	Planform	Degradation/Aggradation (same value, 6)	Moderate

Table 5: Step 9.1 and 9.3 Channel Adjustment Process and Reach Sensitivity

Reach Sensitivity

Sensitivity Rating is the degree to which the river will respond to a local disturbance or a larger, watershed-scale disturbance. Rivers that are aggrading or degrading can be particularly sensitive to changes in the watershed (VTANR Phase 2 Protocols Handbook, 2004). A Phase 1 assessment does not take into account the degree of departure from reference conditions. Rather the sensitivity impact score is based on the reference stream type which in all cases, but one (R12T1.03) are unconfined, 'C' type streams. These reference type streams receive a sensitivity rating of 'Moderate' to 'High'. In addition, when the substrate is sand or gravels the sensitivity is 'High'. When the substrate is cobble the sensitivity rating is 'Moderate'. There are reaches where no reach sensitivity rating is assigned because the reach substrate is 'Unknown' or 'Not Evaluated'.

Recommendations

Phase 1 data can identify reaches which are good candidates for a Phase 2 assessment. The Lower Otter Creek is largely a regulated river due to the high frequency of dams and impoundments. This is affecting the rivers ability to transport sediment and water input from its tributaries and associated watersheds. The result is a river that is potentially adjusting in response to in-stream and floodplain modifications and land use changes. However, for most reaches it is unclear exactly how much adjustment and what stage in the evolutionary process is underway. Phase 2 assessments on these reaches will help determine if active adjustment is underway. In addition, a Phase 2 could inform the dam management to mitigate some of their affects on the river's equilibrium.

On the Lower Otter Creek, Phase 2 assessments should be conducted on the following reaches R03, R04, R06, R07, R09, R10, R11 and R12. These reaches are highly impacted by in-stream modifications and floodplain modifications. Reach R03 and R08 were not adequately observed during the windshield survey and should also be included in any further assessment. Additional analysis is needed to determine the amount of straightening that has actually occurred on the Lower Otter Creek. The MWR and MLR left many of the reaches with a lower impact score than they probably should. Additional work should be conducted to determine buffer widths and buffer quality on a few of the reaches for which this parameter was difficult to assess (R04, R10, R11 and R12). The reaches which are most impacted by all parameters are R06, R07 and R09. Reach R06 has the potential for a significant avulsion and is very unstable. This is evident by meander scars and active bank erosion. Reach R07 above the Weybridge Dam has an active mass failure that has undermined Field Days Rd. closing it indefinitely. Reach R09 is largely impacted by the town of Middlebury, dams, erosion and channelization.

The Leicester River is potentially more stable despite an impoundment and dams. The village of Salisbury on reach R12T1.03 could benefit from a Phase 2 assessment due to the flooding and erosion potential upstream and downstream of the village. The entirety of R12T1.03 and R12T1.04 were not adequately observed during the windshield survey and should also be included in any further assessment. Reach R12T1.02 should undergo a Phase 2 because it is reference condition.

ACRPC encourages municipalities to examine this assessment. Towns can apply for funding to complete a Phase 2 assessment on those reaches identified as candidates. Findings from a Phase 2 assessment inform local zoning and subdivision regulations. A Phase 2 assessment can also identify erosion hazards and if locally supported, lead to zoning that restricts development in areas where high erosion potential exists. Although Clean and Clear funds cannot be used for property protection, infrastructure and farmland can be identified that is at risk and measures can be taken to protect these areas if appropriate.

References

- Brooks, et al. Hydrology and the Management of Watersheds. Iowa State University Press/Ames, Iowa. Second Edition 1997.
- C.L. Davis Consulting Associates for Vermont Agency of Natural Resources. Stream Geomorphic Assessment SGAT User Guide, Stream Geomorphic Assessment Tools, Version 4: An ArcView Extension. October, 2005.
- Collins, Robert. Natural Resource Conservation Service, Addison County Retired District Conservationist, Interview, February 16, 2006.
- Fitzgerald, Brain. Vermont Department of Environmental Conservation. Water Quality Division, Dam Safety. Phone Interview, February 9, 2006 and April 29, 2006.
- Hartline, Keith. Natural Resource Conservation Service, Addison County District Conservationist. Interview, February 16, 2006.
- Nicholson, Fred. Vermont Department of Environmental Conservation, Water Quality Division. Phone Interview, February 9, 2006.
- Paterson, James E. Otter Creek Indian Road. Salisbury, Vermont: Dunmore House, 1995.
- Vermont Agency of Natural Resources. Vermont Stream Geomorphic Assessment Phase 1 Handbook – Watershed Assessment Using Maps, Existing Data, and Windshield Surveys. April, 2005.
- Vermont Agency of Natural Resources. Vermont Stream Geomorphic Assessment Phase 2 Handbook – Rapid Stream Assessment Field Protocols. April, 2005.
- Vermont Agency of Natural Resources. ‘Alternatives for River Corridor Management, Vermont DEC River Management Program Position Paper’. April 18, 2003.
- Vermont Agency of Natural Resources, Vermont Stream Geomorphic Assessment, Appendix L Flood History of Vermont, 2004.
http://www.anr.state.vt.us/dec/waterq/rivers/docs/assessmenthandbooks/rv_apxlloodhistory.pdf

Appendix A

Appendix B

Appendix C