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Executive Summary

The Addison County Regional Planning Commission (ACRPC) completed a Phase 1 Geomorphic Assessment of the Little Otter Creek and Mud Creek in the spring and summer of 2006. ACRPC completed the Stream Geomorphic Assessment Tool (SGAT) step previously begun by Dana Allen, a former student at Middlebury College. Post-SGAT steps were completed in the summer of 2006. The Little Otter Creek was divided into 16 reaches and the Mud Creek was divided into 7 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 Little Otter Creek is located in the municipalities of Ferrisburgh, Monkton, Panton, New Haven and Bristol (see Figure 1). The Creek begins west of the Green Mountains in Bristol and flows through primarily agricultural land and wetlands until it reaches North Ferrisburgh where it is bermed and regulated by Lake Champlain. As a result reach M01 was not assessed.

Mud Creek is a tributary of the Little Otter Creek. The headwaters of Mud Creek begin in an agricultural field very near the City of Vergennes in Waltham and continue through the town of New Haven flowing through primarily agricultural lands, residential areas and wetlands until it reaches the Little Otter Creek in the town of Ferrisburgh.

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.

The Little Otter Creek is dominated by reference stream types 'C', 'E' and 'B'. The Mud Creek reaches are type 'C', 'B' and 'E'. (Please see DMS generated report entitled 'Phase 1-Step 2. Preliminary Reference Stream Type' for specific reach typing).

The later steps of the assessment examine watershed influences which may be producing channel adjustments. The most influential potential channel modification affecting the both creeks is straightening. This assumption will be further investigated during a Phase 2 assessment. 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 Little Otter Creek: M02, M05, M10, M12, T2.05 and reach T2.07 on the Mud Creek. All of these reaches have high impact scores and/or are in 'Poor' condition. Reaches M04, M06, M11, M13, M14, T2.02, T2.05 and T2.06 should be assessed due to lack of reach access. The lack of access translated into a lack of complete data sets for Step 7, Windshield Survey. Results from this remote sensing phase indicate that most

reaches are potentially in adjustment and are impacted from surrounding land uses, floodplain modification and to a lesser degree, in-stream modifications. Overall, the impact categories with the greatest total impact scores are Land Use (38.7%) and Floodplain Modification (35.1%).

Project Overview and Background

Study Goals and Objectives

The goal of this assessment is to determine how changes in the Little Otter Creek and Mud Creek'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 field based level of assessment. The Phase 1 data can also inform local planning and restoration measures.

Description of Study Area

The study area for this project is the Little Otter Creek and Mud Creek watersheds (See Figure 1). The Little Otter Creek watershed is 72.5 square miles and Mud Creek's watershed is 9.07 square miles. Reach M01 was not assessed because it is regulated by Lake Champlain due to a channel spanning berm. The watershed for M02 is 58.64 square miles in size. Both surface waters are part of the Otter Creek Basin No. 3. The Little Otter Creek watershed is predominantly agriculture with development centered along highway corridors and the Village of North Ferrisburgh and Bristol. The Mud Creek watershed is similarly dominated by agriculture and transportation infrastructure (Green St.). In both watersheds some 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 15 stream reaches on the Little Otter Creek and 7 reaches on the Mud Creek totaling. See Table 1 for reach mileage and Figure 1 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)
M01	3.67
M02	1.11
M03	.55
M04	1.83
M05	1.78
M06	.32
M07	.84
M08	1.55
M09	.48
M10	1.27
M11	1.93
M12	.85
M13	.79
M14	1.65
M15	1.71
M16	3.22
T2.01	1.08
T2.02	1.51
T2.03	1.63
T2.04	1.46
T2.05	2.23
T2.06	1.97
T2.07	2.21

Table 1: Reach Length

Flood History

The Little Otter Creek has a USGS flow gauge in the town of Ferrisburgh (gauge number 04282650). The Little Otter Creek generally has good access to its floodplain and reaches bank full at least once per year with spring runoff. The gauging records began in 1990. From 1990 to 2001 there are no records of a 25-year or a 50-year discharge. The largest recorded annual peak discharge was in 1996 of 2,200 cfs. The lowest annual peak flow was in 1995 at approximately 500 cfs (USGS website). Three major floods have hit the Otter Creek basin as measured at the Otter Creek gauging station in Middlebury (Gauge number 04282500). 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). Prior to 1990 there are no gauging records of the Little Otter Creek in Ferrisburgh (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 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 5/18/06, Check 2 on 5/25/06 and Check 3 on 7/12/06. 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 with 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. The Little Otter Creek is dominated by reference stream types ‘B’,‘C’ and ‘E’. The Mud Creek reaches are type ‘C’, ‘B’ and ‘E’. (Please see DMS generated report entitled ‘Phase 1-Step 2. Preliminary Reference Stream Type’ for specific reach typing). A ‘B’ type stream reach is generally one within a steeper and more confined valley with a plane-bed or step-pool bed form. 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). An ‘E’ type stream is one which is moderate in slope and is unconfined. It typically has a riffle-pool or dune-riffle bed form. A reach was typed ‘E’ when its sinuosity was great than 1.5 or very close to 1.5. 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 identified an alluvial fan at the reach break between reach T2.01 and T2.02 where there is a significant break in valley slope. The dominant geologic material in the Little Otter Creek and Mud Creek watersheds is Glacial Lake. The dominant soil types in both the Little Otter Creek and the Mud Creek show little to no flooding potential. The exceptions are M12 and T2.06 which have a flooding potential of 'occasional' and 'frequent' respectively. Identification of dams and weirs was a challenge due to the size of the streams. Although ponding was evident in quite a few reaches on both Little Otter Creek and Mud Creek, identifying the cause of ponding was nearly impossible through orthophotos interpretation. There are no dams on the Little Otter Creek according to information provided by Brian Fitzgerald of the Dam Safety program at VTANR. The State of Vermont Dam Inventory records six dams on tributaries to the Little Otter Creek and no dams on Mud Creek or its tributaries. Potential dams or other impounding structures were located through orthophotos interpretation on the following reaches: M03, M07, M11, M13, M16 and T2.07. Lack of access to most of these location precluded verification of dam presence and location. A channel spanning grade control exists on M03 and M07. Reach M03 is a natural grade control which is easily visible from Little Chicago Rd. in North Ferrisburgh. The remnants of a dam are also visible. Reach M07 has a beautiful waterfall which is accessible from Wings Rd.

Falls at Reach M03 on Little Otter Creek, upstream of Little Chicago Rd in Ferrisburgh

Falls at Reach M07, Downstream from wooden bridge

The erodibility factor for Glacial Lake deposits is moderate to high (VTANR Phase One Handbook, 2004). The erodibility factor is determined by the percentage of the reach with erodable soil. On the Little Otter Creek, 7 of the reaches had 'slight' soil erodibility, 3 have 'moderate' erodibility, 4 reaches have 'severe erodibility' and 2 have 'very severe erodibility.' On the Mud Creek, 4 reaches have an erodibility factor of 'slight', 1 reach is 'moderate', 1 is 'severe' and 1 is 'very severe'.

The soils for all of the reaches on the Little Otter Creek and Mud Creek are in 'Hydrologic Group D'. These soils have low infiltration rates and high runoff potential.

The valley side slopes were determined using topographic maps and information in the NRCS soil layer. The valley side slopes are variable on the Little Otter Creek and on Mud Creek.

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 Little Otter Creek is forest. The subdominant watershed land use/land cover is field. The dominant land use/land cover within the river corridors is also summarized in DMS Report 4. For the Little Otter Creek the river corridor dominant and sub-dominant land use varies by reach form crop, forest, field and wetland. Ten reaches have land use of forest or wetland, the remainder crop or field. The Corridor Land Cover Impact is generally 'High' on the Little Otter Creek. The impact is 'Low' for reaches M06, M15 and M16.

In the Mud Creek watershed the dominant watershed land use varies. For most reaches the dominant land use is crop, while T2.06 is forest while T2.07 is field. The subdominant is variable as well (See DMS Report 4 for details). Within the corridor the dominant land use is crop followed by wetland and forest. The subdominant land use for reaches T2.02 and T2.05 is crop. The remaining corridor is either wetland or forest. The Corridor Land Cover Impact is 'High' for all reaches except T2.03 which is 'Low'.

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 les 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 Little Otter Creek except for M06 and M10 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 Mud Creek, the buffer width impact is 'NS' to 'Low', except for T2.05 which is 'High'.

There are abundant groundwater inputs and wetlands throughout the Little Otter Creek and the Mud Creek. The exception is M02 where there are no visible inputs.

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.

Pete Lawson of NRCS reported that there are no withdrawals for agricultural purposes of which he is aware (Lawson, 2006).

Given the corridor land use and points of infrastructure, it is likely that portions of the Little Otter Creek and Mud Creek have been historically armored. There fore, although bank armoring is mostly 'NS' on the Little Otter Creek, much of the river's armoring could not be observed because of high water or inaccessibility to the bank. Fifteen of the 22 reaches assessed have an impact of 'unknown'. 1990's orthophotographs were somewhat helpful in identifying armoring around points of infrastructure.

Mr. Nicholson, the regional VTDEC Stream Alteration Engineer, does not know of any permits permitting straightening or berming in the last twenty years. 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. Fourteen reaches are highly impacted from straightening. The remaining reaches have an impact of 'Low'.

Mr. Nicholson does not know of any dredging activities or gravel extraction for commercial purposes on the Little Otter or Mud Creek in the twenty years he has been working for VTANR (Nicholson, 2006). However, he said that dredging has most likely occurred historically. The headwaters of the Little Otter Creek have alluvial material and there is some visual evidence on the orthophotographs that gravel removal has occurred. This should be further investigated through a Phase 2 assessment.

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, 30 bridges or culverts were identified, including railroad trestles. The impact of these bridges is either 'NS' or 'Low'. Reach M02 is the only reach with a 'High' impact score for bridges and culverts.

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 assesses (Step 6): Berms and Roads, River Corridor Development, Depositional Features, Meander Migration/Channel Avulsion, Meander Width Ration (MWR), and Wavelength Ration (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. There are few roads in either corridor. This is evident from the lack of access to many reaches. Berming is more challenging to evaluate. For this parameter Mr. Nicholson was interviewed for additional information. Mr. Nicholson said that berming has most likely been historically undertaken along the Little Otter Creek and Mud Creek. The impact of berms and roads within the river corridor is 'Unknown' for 13 reaches because little

information is available regarding berming. The remaining reaches lack roads or have very few roads and have an impact of 'Low' to 'NS'. Reaches M02 and T2.07 have the largest impact of all reaches from roads.

River Corridor development is 'Not Significant' throughout the Little Otter Creek and Mud Creek. The reaches with the most development are M02 in Ferrisburgh and T2.07 just outside the Vergennes' city limits along Green Street. These two reaches and reach M16 also have more encroachment from roads than the remaining reaches, although the degree remains low.

Depositional features often are indicative or 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, high water and extensive turbidity. In addition, many reach locations are inaccessible. From what is evident, most of the reaches have 'NS' to 'Low' impacts from depositional features. Reach M13 has 'No Data' because of steep slopes and forest cover made it impossible to see the stream.

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 also helpful in pinpointing potential avulsion locations and old meander scars. Meander migration is evident on both the 1978 and 1995 orthophotos. The degree of change within that time period is low however. Eleven of the reaches on the Little Otter Creek have very apparent meander and avulsion scars and have a meander migration impact of 'High'. Three of the 7 reaches on Mud Creek were also highly impacted based on meander migration. In almost all of these reaches the land use within and in close proximity to the corridor was and/or is currently agriculture.

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, looses 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 Little Otter Creek and Mud Creek's MWR and WLR for most reaches. The specific reach based MWR and WLR data is in the DMS Report Phase 1-Step 6. 'Floodplain Modification and Planform Changes in the Appendices'.

Seven of the reaches on the Little Otter Creek and 4 reaches of the Mud Creek have a MWR impact of 'High'; calculated MWR is < 3. Only two reaches on the Little Otter Creek have a MWR impact of 'Low'. Two reaches on the Mud Creek are considered 'Low' impact. The remaining reaches are either 'NS' or are naturally confined channels and were not evaluated. For 9 reaches on the Little Otter Creek, the WLR is 'High', 2 'Low'. The remaining reaches, M03, M07, M09 and M13 are in naturally confined

valleys and were not evaluated. On Mud Creek the MLR impact is 'High' on T2.01, T2.06 and T2.07. Reach T2.02 was not evaluated and the remaining reaches have a MLR impact of 'NS' to 'Low'.

Bed and Bank Windshield Survey

A windshield survey of the Little Otter Creek and Mud Creek was conducted on the following dates: 5/18/06, 5/23/06, 5/22/06, 5/25/06 and 6/6/06. 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 'NS', 'Low' or 'Not evaluated' for most of the Little Otter Creek and Mud Creek. Reaches M04, M06, M13, T2.02, and T2.06 could not be evaluated because it is surrounded by private property with no public access. For the remaining reaches, only a small portion of the reach was observable due to lack of access. These reaches included M04, M06 M07, M08, M09, M10, M11, M12, T2.05 and T2.06. 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 M16 because of the culvert underneath Plank Rd which was recently replaced after a localized flood. On all other reaches, debris/ice jam potential is 'Unknown', 'NS' or 'Low'.

Data Analysis

Impact Scores

A stream and watershed impact score was developed for each reach on the Little Otter Creek and the Mud Creek. 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 Little Otter Creek are M02, M05 and M10. The remote sensing results indicated that the Mud Creek is in 'Fair' to 'Poor' condition with the highest total impact score of 16 out of 32 on T2.07. (See DMS Report 'Phase 1-Step 8 Summary of Categorical Impact' in the Appendices for more detailed information).

- Step 4, 'Land Use' accounts for 38.7% of the total impact scores in the study area. Land Use encompasses: Watershed land use/land Cover, corridor land cover/land use, riparian buffer width and groundwater and small tributary inputs. Nine of the 15 reaches evaluated on the Little Otter Creek have an impact rating of 5 out of 6 in the 'Land Use' category. M10 has an impact of 6 out of 6. On the Mud Creek, T2.01, T2.04, T2.06, T2.07 have impacts of 5 out of 6. T2.05 has an impact score of 6 and T2.03 has an impact score of 3.

- Step 6, 'Floodplain Modifications' accounts for 35.1% of the total impact scores in the study area. Reach M02 has the highest impact with a score of 8 out of 12. The remaining reaches have a score of 6 or less. 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 on the Mud Creek are 6 out of 12 on reaches T2.01 and T2.07. The remaining reaches have an impact score of between 1 and 5. The lowest being T2.02 with an impact score of 1.

- Step 5, 'Instream Modification' accounts for 21.4% of the total impact scores. This category includes berms and roads, river corridor development, depositional features, meander migration/channel avulsion, meander width ratio and wavelength ratio. (See DMS Report 'Phase 1-Step 8 Summary of Categorical Impact' in the Appendices for more detailed information).

- Step 7, 'Bed and Bank Survey' accounted for 4.8% of the total impact scores. This category includes: dominant bedform, bank erosion and debris and ice jam potential. The categorical impacts would have been more significant if additional reaches and reach points had been accessible to a windshield survey.

Reach ID	**Confinement Type**	**Watershed Area**	**Total Impact Score**	**Reach Condition from Phase 1 DMS**
M01	VB	72.5	Not assessed	
M02	NW	58.64	18	Poor
M03	SC	57.6	9	Fair
M04	VB	57.4	9	Fair
M05	VB	45.01	17	Poor
M06	NC	43.22	13	Fair
M07	SC	39.6	12	Fair
M08	VB	39.44	12	Fair
M09	SC	35.79	7	Fair
M10	VB	35.43	14	Poor
M11	VB	25.47	13	Fair
M12	VB	12.3	13	Fair
M13	NW	11.88	7	Fair
M14	VB	11.56	13	Fair
M15	VB	7.42	11	Fair
M16	BD	4.88	13	Fair
T2.01		9.07	13	Fair
T2.02	SC	8.69	7	Fair
T2.03	VB	8.03	12	Fair
T2.04	NW	6.92	11	Fair
T2.05	BD	3.93	12	Poor
T2.06	VB	2.61	13	Fair
T2.07	VB	1.01	16	Fair

Table 3, Step 9.2 Reach Assessments

Reaches that are in 'Poor' condition on the Little Otter Creek have undergone flood plain modification, agricultural development and impacted buffers. ACRPC suspects that the Little Otter Creek has undergone more extensive berming and straightening than this study reflects. 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). This Phase 1 assessment did not assign any reaches a 'Good' or 'Reference' reach condition.

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 Little Otter Creek is Planform followed by Degradation and Aggradation. On the Mud Creek, Aggradation, Degradation and Planform are the most common adjustment processes. The DMS generated concurrent reach adjustment processes for reaches M04, M05, M06, M07, M13, T2.02, T2.04 and T2.06 (see Table 5). The DMS report in the Appendices entitled, 'Phase 1-Step 9. Adjustment Process and Reach Condition' further details and reveals that there is no clear single adjustment process occurring on these reaches. Further investigation and field work during a Phase 2 assessment can determine the adjustment phase underway that is moving the creeks towards equilibrium.

Reach ID	Current Adjustment Process	Concurrent Adjustment(s)	Reach Sensitivity
M01	Not assessed		
M02	Planform	Aggradation	Moderate
M03	Degradation	Aggradation	High
M04	Planform/Aggradation (same value, 5)	Widening	
M05	Degradation/Aggradation/Planform (same value, 9)		High
M06	Widening/Aggradation(same value, 7)	Degradation	Moderate
M07	Degradation/Aggradation (same value, 7)	Planform	
M08	Planform	Aggradation	
M09	Aggradation	Degradation	
M10	Planform	Aggradation	
M11	Planform	Aggradation	
M12	Planform	Aggradation	
M13	Degradation/Aggradation/Planform (same value 6)		
M14	Planform	Degradation/Aggradation (same value, 6)	High
M15	Planform	Aggradation/Widening (same value, 5)	High
M16	Aggradation	Degradation/Planform (same value, 6)	High
T2.01	Planform	Aggradation	High
T2.02	Degradation/Aggradation (Same Value, 6)	Widening	
T2.03	Planform	Degradation	High
T2.04	Degradation/Aggradation/Planform (same value 7)		High
T2.05	Planform	Degradation/Widening (same value, 7)	
T2.06	Degradation/Aggradation/Planform (same value 7)		
T2.07	Degradation	Aggradation/Planform (same value, 7)	High

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. 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 Little Otter Creek is a river that is potentially adjusting in response to land use changes and floodplain modifications. 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.

On the Little Otter Creek, a Phase 2 assessment should be conducted on the following highly impacted reaches M02, M05, M10, M12, T2.05 and T2.07. Reaches M04, M06, M11, M13, M14, T2.02, T2.05 and T2.06 may also be good Phase 2 candidates because these reaches were not adequately observed during the windshield survey. Additional analysis is needed to determine the amount of impoundments that occurred on the Little Otter Creek. 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.

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.

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Appendix A

Appendix B

Appendix C