A Conservation Blueprint for Lewis Creek, VT using the Active River Area conservation framework

Paul Marangelo

Dan Farrell

The Nature Conservancy, Vermont Chapter

November 30, 2010

The Nature Conservancy
Protecting nature. Preserving life.™

Executive Summary

The Vermont Chapter of The Nature Conservancy (TNC) worked with conservation partners in the Lewis Creek watershed in Addison and Chittenden Counties, Vermont, to develop a 'blueprint' to address the most pressing conservation needs for river conservation using the *Active River Area* framework. This framework defines river system components that are collectively responsible for forming and maintaining aquatic habitat and allowing natural disturbance-driven river processes to take place. This analysis was conducted in a data-rich environment, as detailed conservation assessments and plans already exist for Lewis Creek. Accordingly, we oriented our ARA analysis on Lewis Creek to partner input on conservation needs and the capabilities of ARA GIS modeling tools developed by TNC. The result was a synthesis of new ARA-based analyses with existing information on Lewis Creek. We characterized of landcover and quantified riparian wetlands within the floodplain component of the ARA assessment framework. We also developed ARA-derived measures for floodplains associated on floodwater attenuation potential, ranked river reaches based on this measure, and with existing assessment data, characterized our analysis results in terms of functionality of floodplain connectivity, geomorphic condition, and geomorphic sensitivity to disturbance. This information was synthesized to produce conservation priorities for the river. While limitations were encountered due to analysis scale and data accuracy, the ARA framework and associated GIS-based assessment work provided a unique lens through which to prioritize conservation in Lewis Creek.

Table of Contents

Introduction

Towards meeting the challenge of developing conservation plans that take into account a river's key physical processes and ecological attributes, the Vermont Chapter of The Nature Conservancy worked to develop a 'blueprint' for river conservation in the Lewis Creek watershed using the *Active River Area* framework. The Active River Area (ARA) framework (Smith et al 2008) is based on geomorphology and fluvial dynamics, and consists of five river system components: (1) headwaters and other material contribution areas, (2) the channel and meander belt, (3) floodplains (4) riparian wetlands, and (5) terraces. These river system components are collectively responsible for forming and maintaining aquatic habitat and allowing natural disturbance-driven river processes to take place. As such, this blueprint seeks to address river system conservation from an aquatic biodiversity perspective.

This collaborative project was organized by the Vermont Chapter of The Nature Conservancy, and involved a number of partners that are interested or engaged in Lewis Creek conservation work, including the Lewis Creek Association, The Vermont Agency of Natural Resources, Vermont Rivers Conservancy, and the U. S. Fish and Wildlife Service. Project collaboration was organized via a series of 3 meetings, where the information needs for conservation were gathered by TNC from the project partners. Partners also assisted with interpretation of Active River Area analysis results, helped TNC understand the most pressing conservation needs, and provided feedback on the identification of priorities for conservation.

The project was initiated by describing the ARA framework to partners, and then reaching consensus among the partnership on the conservation needs for each of the Active River Area components. We oriented our ARA analysis activities in accordance to feedback from partners, within the capabilities of the available ARA GIS assessment tools. The result was a synthesis of new ARA-based analyses with existing information and conservation plans for the river, most notably, the River Corridor Conservation Plan based on a Stream Geomorphic Analysis of Lewis Creek (South Mountain Research and Consulting 2010), and to a lesser degree, a wetland restoration plan for the Lake Champlain Basin (Pioneer Environmental Associates 2007). The analysis focused on the ARA components that were most valuable in terms of filling information gaps in existing Lewis Creek conservaton plans and were able to be adequately characterized with existing GIS assessment tools: the floodplain and riparian wetland component.

Lewis Creek

Lewis Creek is a medium sized to small river in Vermont in the Lake Champlain basin, straddling Addison and Chittenden Counties in Vermont. The creek drains 81 square mile basin that includes 7 Vermont townships, and two major geologic provinces (Figure 1). In terms of hydrological and geological attributes, approximately 30% of the watershed occupies the till-blanketed bedrock slopes of the Northern Green Mountain province, mostly in headwater areas of the watershed. The remaining 70% of the watershed is in the Champlain Valley, with soils of lacustrine clays and silts, and some areas of post-glacial fluvial deposits (South Mountain Research and Consulting 2010). Mean daily discharge ranges

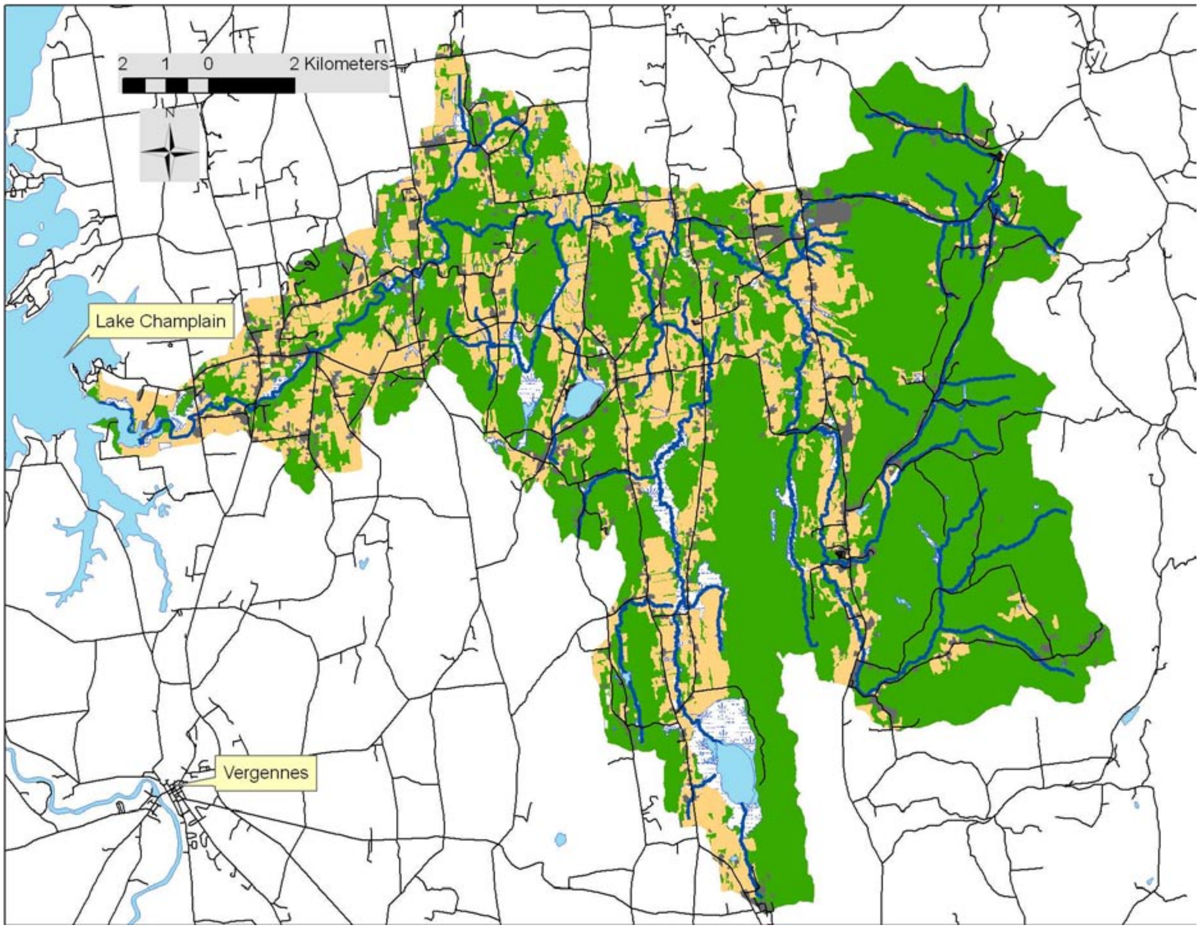


Figure 1: Lewis Creek and its watershed in Addison/Chittenden Counties, Vermont.

from 22 CFS (early September) to 288 CFS (early April) at the USGS gauge in the lower portion of the watershed in North Ferrisburg. There are no hydropower dams on Lewis Creek that impact flow via hydroelectric generation. A detailed summary of the geological and hydrological setting of Lewis Creek, and a comprehensive summary of Lewis Creek water quality and habitat threats can be found in the River Corridor Conservation Plan (South Mountain Research and Consulting 2010).

The lower portion of the river is connected directly to Lake Champlain, so the lower reaches of the river below the first major falls (below North Ferrisburg) supports a number of rare and state-endangered species of fish and mussels. Also, the lower reaches of Pond Brook, a major tributary of Lewis Creek supports one of the few viable wood turtle populations left in the state of Vermont.

The Lewis Creek Active River Area project was conducted in a data-rich environment. Lewis Creek was a pilot site for the development of Vermont Department of Environmental Conservation River

Management Program (VTDEC RMP) geomorphic assessment protocols (VT Agency of Natural Resources, 2007), and as such, it has been the subject of an exceptionally comprehensive and detailed stream geomorphic assessment (South Mountain Research and Consulting 2010), conducted from 2001 through 2009 for 42.6 river miles of the Lewis Creek main stem and major tributaries. Based on this assessment work, project partners have identified and ranked hydrologic and sediment regime stressors, and have developed short-term and long-term conservation objectives, strategies, and projects following Vermont Agency of Natural Resources (VT ANR) guidance (VT ANR, 2007). These have been identified and ranked for implementation at a variety of levels and scales to address the most pressing ecological threats to Lewis Creek. Notably, this assessment included detailed field-based assessments of geomorphic features such as valley walls, effectively providing a field-based demarcation of a physical feature that ARA GIS modeling tools seek to estimate – the floodzone. Moreover, VTDEC River Management Program Reach Habitat Assessment protocols (RHA) were also developed on Lewis Creek (Shiff et al 2009). This involved an intensive field data collection effort of data on channel attributes that indicate/maintain biological integrity.

In addition to the detailed assessment work done in the basin, this project relied on a number of other data sources: 1) detailed LIDAR-derived digital elevation data for a portion of the northeastern Lewis Creek watershed. This fine-resolution[1] data set is supremely well suited as an input for the GIS tools developed by TNC to characterize two of the five major ARA components (riparian wetlands and floodplains); 2) A wetland restoration plan that identifies wetland restoration priorities in the Lake Champlain Basin in Vermont (Pioneer Environmental et al 2007); 3) A detailed land-cover data set created by the University of Vermont (UVM Spatial Analysis Lab, 2006) by digitizing orthophotos. This data set is superior to existing National Landcover Dataset (NLCD 2001) information that is more typically used for land-cover analyses, and has a resolution for land cover classes down to 0.01 acres; 4) Vermont Significant Wetland Inventory database (VTDEC 2010).

The Corridor Plan (South Mountain Research and Consulting 2010) also includes a detailed assessment of culverts, dams, and other channel constraining or fragmenting features that impairs habitat and geomorphic function, along with a prioritization ranking for dam and structure removal and culvert replacement. While it is recognized that these features impact the hydrology and biodiversity of Lewis Creek, we did not make an effort to replicate this information in this project.

Due to the abundance of conservation-oriented data on Lewis Creek, conservation partners already had a detailed understanding of the existing physical and biological processes, location of rare fauna, existing threats, and have developed a set of river corridor conservation priorities based on this understanding. Since the essence of our charge for this project was conservation planning within a specific river assessment framework, our analysis was oriented towards testing for corroboration between ARA based results and existing river assessment efforts and related conservation priorities on Lewis Creek. Also, we made decisions at the outset on which ARA framework components to focus our analyses. Criteria for

[1] LIDAR data produces digital elevation models with a resolution of 3.2 square meters

deciding on framework components to focus on were 1) components that would help define characteristics and metrics that fill gaps within the current body of understanding about Lewis Creek; and 2) components with specially designed GIS modeling tools that were likely to yield results that were useful, informative, and/or novel.

Accordingly, our work only directly encompassed a subset of the full suite of ARA components: the floodplain and riparian wetlands. ARA asessment tools were also able to indirectly encompass the meander belt component. We were unable to adequately characterize the terrace ARA component, for reasons desribed later. For the headwater streams/material contribution area component, headwater streams were perceived to have outstanding landscape context and were heavily vegetated, so limited resources for assessment analysis effort were focused elsewhere. Finally, modeling tools for the material contribution areas component (GIS buffer functions) was judged to be less likely to produce analysis that would provide partners with novel perspectives on river conservation.

By targeting our efforts at a subset of components, we were able to develop a unique ARA framework-based lens to assess the overall systemic health of Lewis Creek that was tailored to the existing data/information environment on Lewis Creek.

The process for this project was as follows:

1. A kickoff meeting was held in April 2009 with project partners to solicit input on which components of the ARA framework would be the most valuable.
2. Conduct analysis focused on these components.
3. Use existing spatial and geomorphic data from the watershed to assess/validate the results of ARA analysis.
4. Generate spatial information on Lewis Creek through new TNC-developed GIS analysis tools that characterize the components of the Active River Area framework that would be most likely to add new perspectives to existing conservation priorities within the watershed.
5. Describe conservation priorities through the lens of the ARA based analysis and framework.

Methods

We defined a “floodzone” for the river by deciding on cost-surface (see Appendix 1) derived “thresholds” to demarcate the floodzone. Decisions on the threshold were made by comparing the spatial distribution of cost surface values away from the river channel with the location of field-derived valley wall designations (South Mountain Research and Consulting, 2010) (Figures 2a and 2b) and supplemental field data collected from three reaches (M4, M17, and M15). Once a threshold was decided upon that best approximated the location of RMP valley walls, the threshold was used to spatially define ARA floodzones along Lewis Creek and major tributaries. The floodzone was then longitudinally divided along the river valley according to the location of RMP geomorphic reaches, resulting in a GIS layer of discrete *floodzone reaches*, consisting of a series of polygons bounded by floodzone lines and RMP reach breaks (Figure 3). The resulting floodzone reaches represent sub-divisions of the ARA floodzone that possess specific fluvial geomorphic attributes and functions.

These polygons together formed the analysis units that were used to "clip" land cover data, deriving land-cover metrics for each floodzone reach. Land-cover data was generalized into the following categories: "natural cover", wetlands, forested, and developed (Table 1), and used to quantitatively characterize each floodzone reach. Where alternative datasets were available, we compared the different data sources against each other and against our knowledge of field conditions, and selected what we thought to be the most accurate source to use for floodzone reach-based analyses (Table 2).

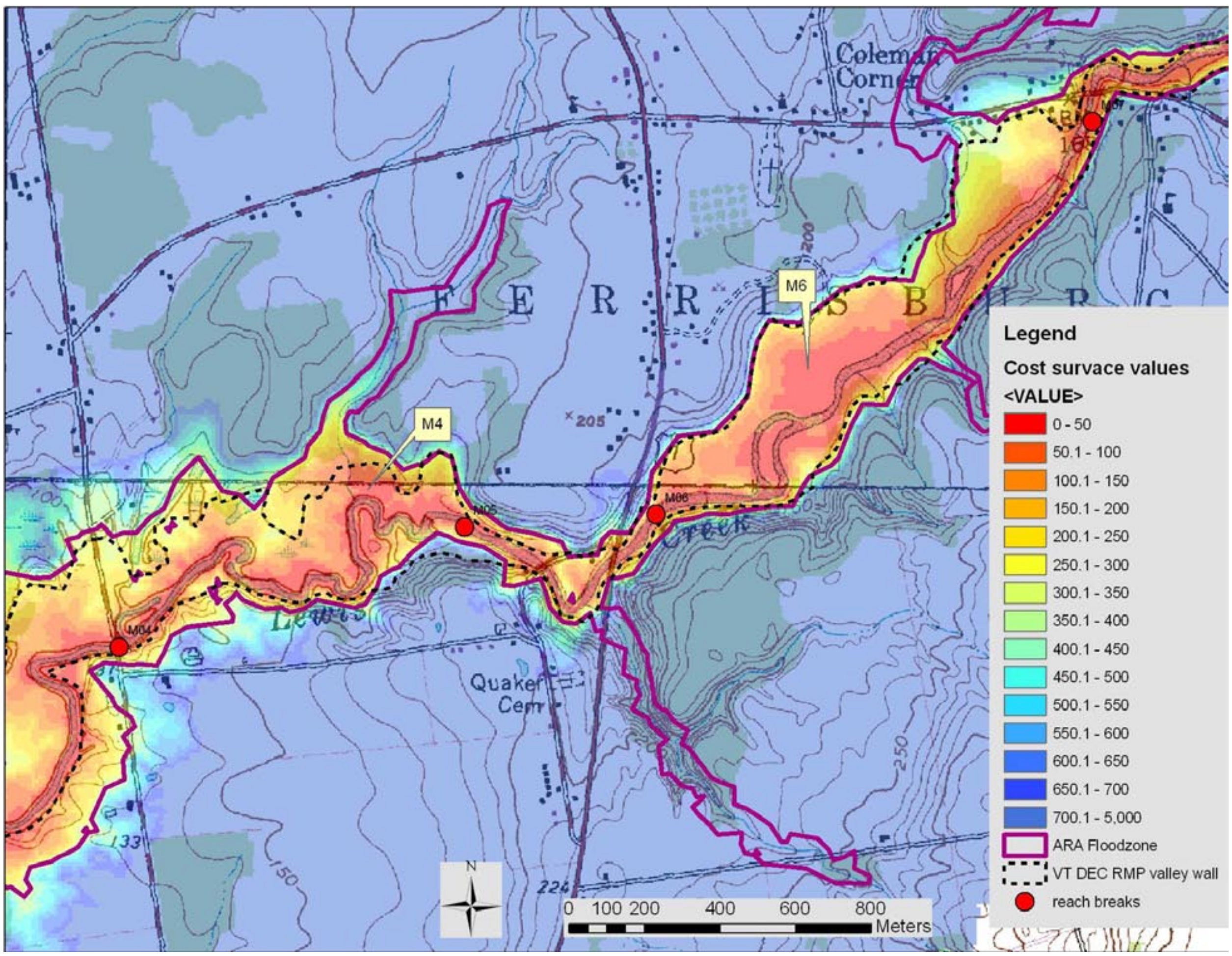


Figure 2a: Comparison of Floodzone cost surface values, VTDEC RMP valley wall designation, and chosen cost surface threshold used to define ARA floodzones on Lewis Creek Reaches M4 – M6.

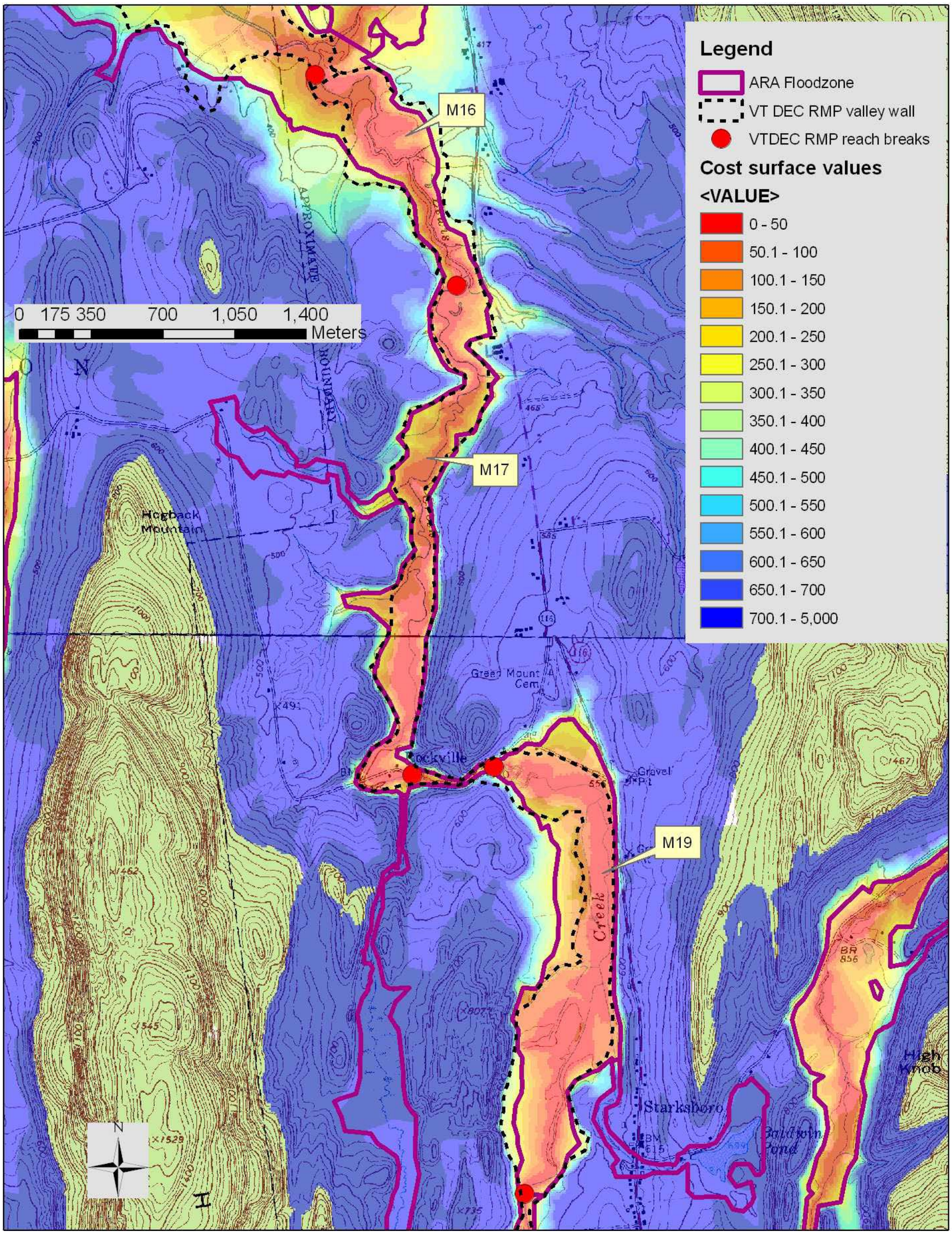


Figure 2b: Comparison of Floodzone cost surface values, VTDEC RMP valley wall designation, and chosen cost surface threshold used to define ARA floodzones on Lewis Creek Reaches M17 – M19.

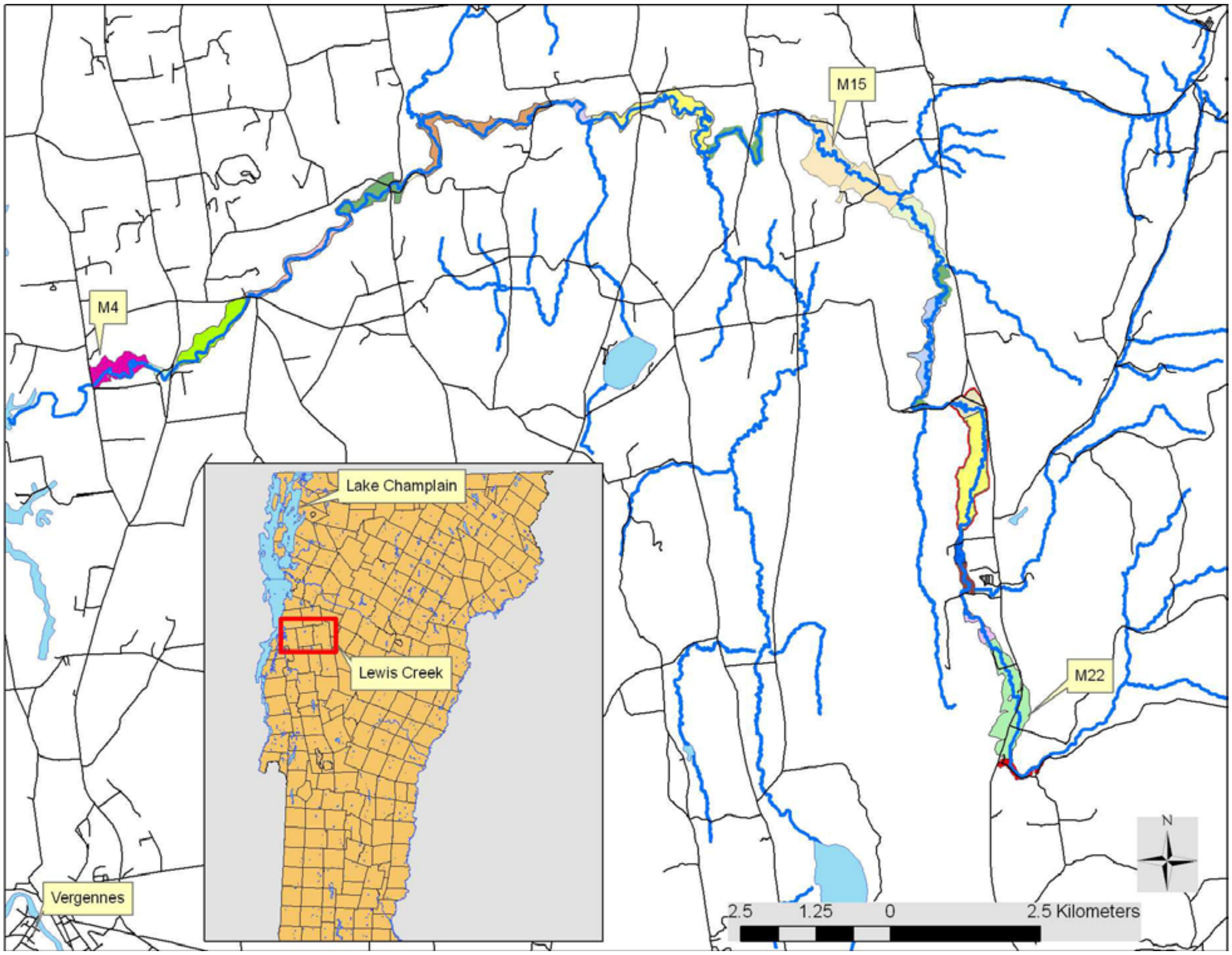


Figure 3. Map of all floodzone reaches along mainstem and select tributaries used for the analysis.

Table 1. The composition of land cover categories used for analysis with ARA GIS tools.

Landcover classification (UVM Spatial Analysis Lab 2006)	Land cover categories			
	developed	natural cover	forested	wetland
Shrub/brush		■		
deciduous forest		■	■	
mixed forest		■	■	
coniferous forest		■	■	
forested wetland		■	■	■
emergent wetland		■		■
scrub/shrub wetland		■		■
emergent wetland		■		
developed	■			
field/pasture				
row crops				
orchard				
water				

Table 2. Data used for analysis with ARA GIS tools, and alternative data sources not selected for analysis.

Land use category	Source data	Alternative data not used
Natural Cover	UVM Spatial Analysis Lab, 2006	NLCD (2001)
Wetland	UVM Spatial Analysis Lab, 2006:	VSWI wetland data, “wet flat” ARA data, NWI data
Forested	UVM Spatial Analysis Lab, 2006:	NLCD (2001)

Floodzone reaches were developed for all reaches along the entire mainstem and select tributaries based on underlying 10m digital elevation data upstream of Reach M4. Floodzone reaches were named according to VTDEC River Management Program (RMP) reach-naming conventions. Below M4, the backwaters of Lake Champlain influences fluvial dynamics, making demarcation of landscape features that predictably corresponds with fluvial processes such as flooding problematic, so reaches M1 – M3 were excluded from our analysis.

As a point of comparison to floodzone reaches based on 10m digital elevation model (DEM) data, floodzone reaches were also developed with a LIDAR derived DEM for river reaches where this data was available (M11 – M16, T4.01) (Figure 4). Both the shape of LIDAR based floodzones and select metrics from floodzones were compared to 10m DEM based floodzones, RMP valley walls, and information from field verification to assess the precision of the GIS tools derived from the more widely available but coarser DEM dataset.

Also, the relative ability of major tributaries to store floodwaters was assessed by compiling the ratio of floodzone area to individual tributary watershed area, and in turn comparing to the overall storage capacity of the floodzone within the entire basin.

Results and discussion

The floodzone reaches derived from ARA floodzones and RMP river reaches are depicted in Figure 3**.** When compared to the RMP valley wall designations, the floodzone demarcation lines were generally consistent with RMP valley walls (Figures 2a and 2b). However, some deviations from RMP valley wall locations were observed. This deviation was especially pronounced in some reaches compared to others, and there appeared to be few consistent patterns – in some cases the floodzone extended well beyond the valley wall and in other cases, the converse was true. For example, in the downstream southern portion of reach M4 on the south bank (Figure 2a), the floodzone area encompassed areas located on up steep slopes that are likely never flooded. This area features an abrupt topographic rise in close proximity to the river channel in the southern bank within the floodzone. This was not consistently observed in comparison to other areas, however. For example, near the upstream end of reach M4 on the south bank, the floodzone is more constricted than the RMP Valley Wall Designation. We specifically calibrated the cost surface threshold in reach M4 so that the oxbow lake on the north side of the floodzone was within the floodzone boundary, a judgement that we justified via a field investigation at this location.

While the reasons for the discrepancies between the ARA floodzone and RMP Valley Wall Designation are not completely clear, the coarseness of the underlying 10M DEM data compared to the spatial scale of this analysis might result in some of these inconsistencies. Another possible explanation is that the distance component in the underlying alogarithm used to calculate the cost surface might produce lower cost surface values on higher eleveations that are closer to the river channel, while field-demarcated valley walls would be free from such bias.

In contrast to reach M4, in reaches M19 and M15, floodzone boundaries extended well beyond the RMP valley wall designation (Figure 2b). Both these reaches feature low, indistinct relief features that occur over wide river valleys, where imprecision in the 10m DEM data are likely to have the largest potential distorting influence over floodzone demarcation.

We were able to further assess floodzone demarcation precision issues by comparing LIDAR derived floodzones, 10m DEM derived floodzones, and RMP valley wall designations. Results from reach M15 illustrates an improvement in precision from LIDAR derived floodzones compared to the more commonly available 10m DEM (Figure 4). Reach M15 features a low relief feature in the floodzone south of the channel not captured on USGS topo map that was used to demarcate the RMP valley wall, which was interpreted as a point of differentiation between active floodplain and a terrace. This feature was not picked up by the 10m DEM cost surface, and accordingly, the 10m DEM floodzone was substantially overestimated when compared to the valley wall designation. The LIDAR floodzone, however, was able to pick up on this low relief feature, and closely corresponded to the field-based

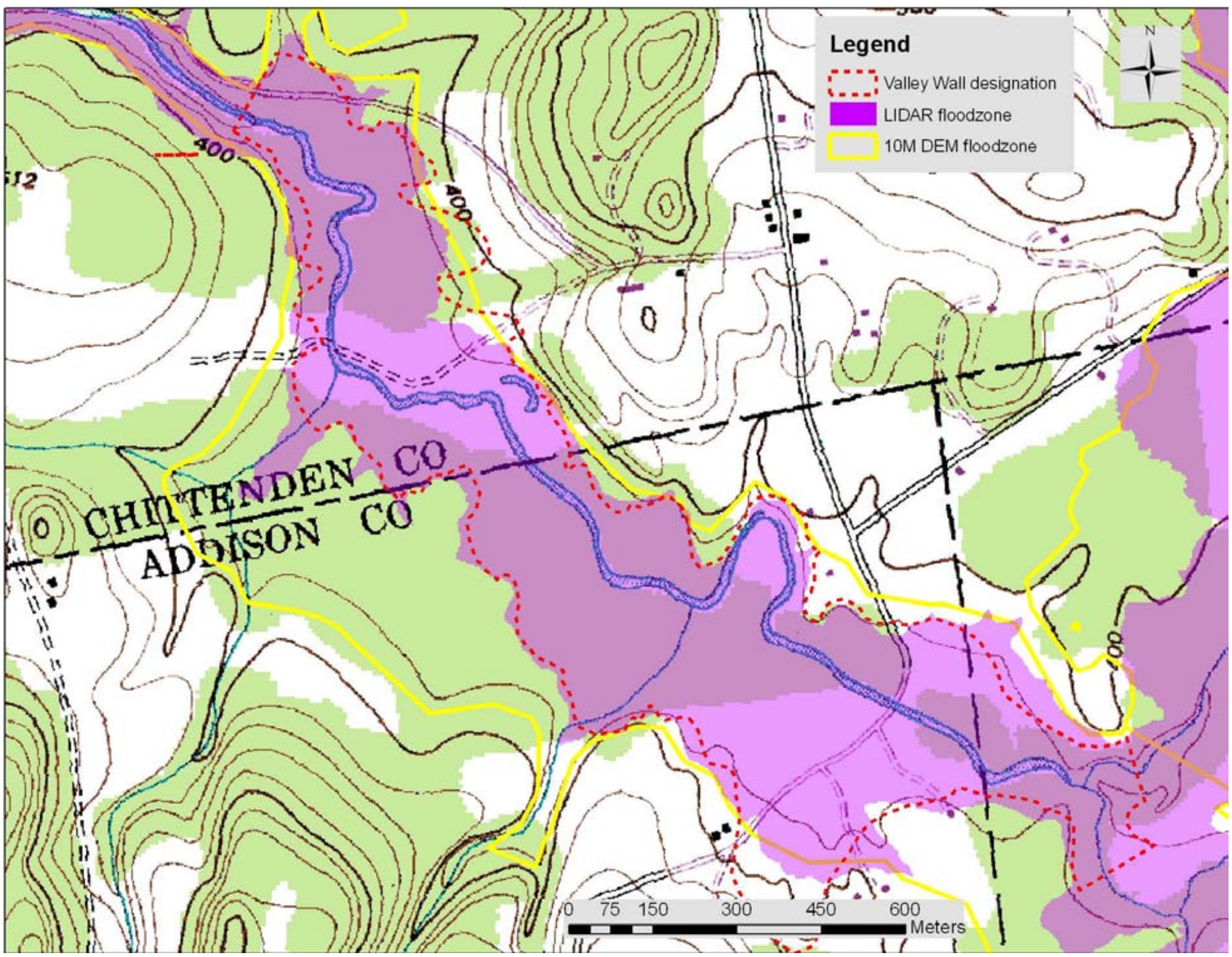


Figure 4: Comparison of LIDAR derived floodzone, 10m DEM floodzone, and VTDEC RMP valley wall designation on reach M15. Note that the LIDAR derived floodzone closely corresponds to the RMP valley wall designation.

valley wall demarcation. This comparison suggests the limitations of 10m DEM data, especially for the fine scale-analysis needed for a small river such as Lewis Creek. Morevover, it called into question our ability to adequately characterize the terrace ARA component with the floodzone analysis tool. Also, it suggests that LIDAR data may enable accurate and precise designations of valley walls with remotely sensed data. In general, the largest discrepancies between LIDAR derived floodzone reaches and the 10m DEM floodzone reaches were in reaches with broad floodzones with gradual topographic transitions between riparian zones and uplands (M15a, M15b, T4.01; Figure 5). LIDAR and 10m DEM-based floodzones among more confined reaches had greater degrees of corroboration (M14, M13, M16, M12; Figure 5). It should be noted that riparian areas in reaches with broader floodzones are likely more ecologically important, and also more important to demarcate accurately from a conservation planning and fluvial erosion hazard assessment perspectives, suggesting that LIDAR based analyses are vastly superior in situations where increased data confidence is more important.

In general, we assumed that the floodzone is a landscape feature defined by its relationship to the river channel elevation, and is defined by physical elevation features that defines a “river valley”, as shaped by floodwaters of an unknown but consistent recurrence interval that are based on flow duration curves from the current geological period. Areas within the floodzone are assumed to be subject to inundation from floodwaters, and areas outside of the floodzone are assumed to be largely free from flooding

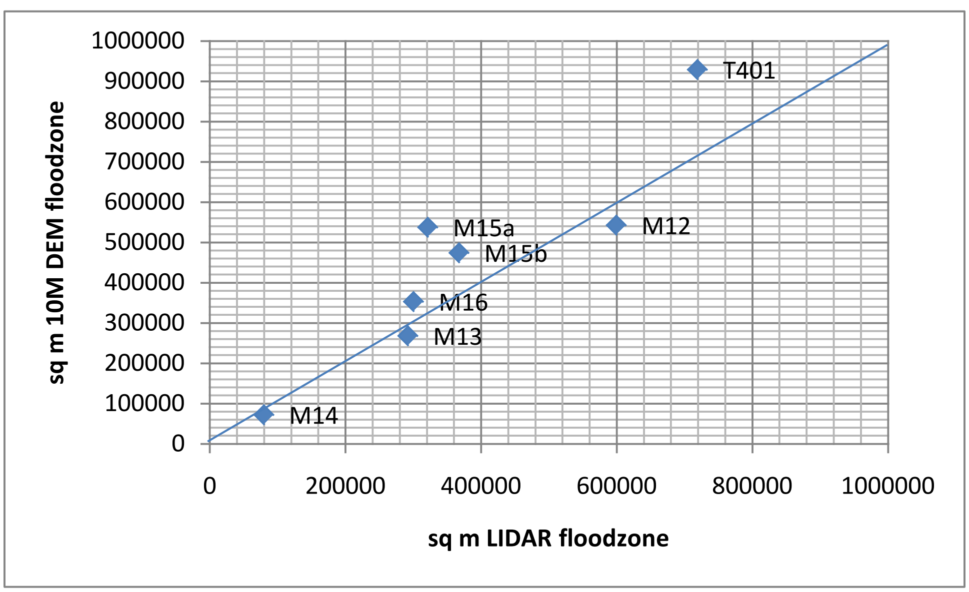


Figure 5: Scatter plot of the estimates of the area of floodzone reaches of LIDAR derived floodzones vs. 10m DEM floodzones. The line represents a 1 to 1 relationship, so the greater the distance from the line, the greater divergence of the 10m DEM floodzone reach area compared to the LIDAR floodzone reach.

inundation. Implicit in this working definition with respect to the ARA components are that floodplains are defined by the floodzone, and terraces that no longer flood are not.

Floodzone area analysis (Floodplain ARA component):

We ranked floodzones according to the ratio of floodzone reach area/valley length, which serves as a measure of the breadth a floodzone relative to the length of the reaches valley (Figure 6). This ratio can serve as coarse metric for the *floodwater attenuation potential* (FAP) of floodzone reaches by providing an indicator of floodwater accommodation capacity, assuming capacity equity among channels within geomorphic reaches to convey floodwaters. Figure 6 illustrates that the 10 highest ranked reaches in terms of this ratio are M15b, M22, M4, M19b, M19a, M15a, M16, M12, M17a, and M17b. Actual floodwater attenuation however, is also influenced by a number of other factors. One such factor is the storage capacity of the river channel itself. *Incision ratios (IR)*[2] offer a basis to compare this capacity between reaches, and these measures ranged from 1.0 to 3.95 in Lewis Creek (South Mountain Research and Consulting, 2010). When incision ratios were plotted against the FAP for each reach (Figure 7), we gained additional insights into how well connected floodzones are to the river channel in floodzone reaches with high FAP. The IR in reaches with the highest FAP ranged from 1.0 to 1.7, and among the reaches ranked highest for FAP, reaches M12, M22, and M15b appear to have the most impaired floodwater attenuation potential.

A potential for error in ranking reaches based on our measures of floodwater attenuation potential stems from the coarseness of the 10m DEM floodzone analysis. The comparison of results between LIDAR and 10m DEM derived floodzones illustrates the limitations of estimates derived from 10m DEM-derived floodzones. Accordingly, it is reasonable to suspect that some features within the 10m DEM-derived floodzone may be free from floodwater inundation.

Landcover metrics (floodplain and riparian wetland ARA components)

Landcover metrics derived from landcover and wetland data enabled the characterization of floodzone reaches in terms of area, landuse and land cover. Since LIDAR data was only available for a portion of the Lewis Creek watershed (reaches M11-M15), the floodzone derived from the 10m DEM was used (in conjunction with the RMP reach breaks) to develop the spatial analysis units used to derive these floodzone landcover metrics.

Overall, 15 of 25 reaches have a high degree (>60%) of "natural cover" (Figure 8), which includes 6 of the 10 floodzone reaches with the largest FAP. 8 of 25 floodzone reaches have a high degree (> 20% cover) of wetlands, including 5 of the 10 floodzones with the largest FAP (Figure 9). In terms of wetlands within floodzone reaches, M15a, M15b, M12, M6, M19a, and M17b had the largest areas of wetlands within the floodzone.

With these metrics, we can start to prioritize floodzone reaches for conservation based on comparative assessments of both landcover characteristics, FAP, and floodplain functionality (Figure 7) by classifying

[2] "low bank" height/bankfull height, where the "low bank" represents a terrace on the floodplain.

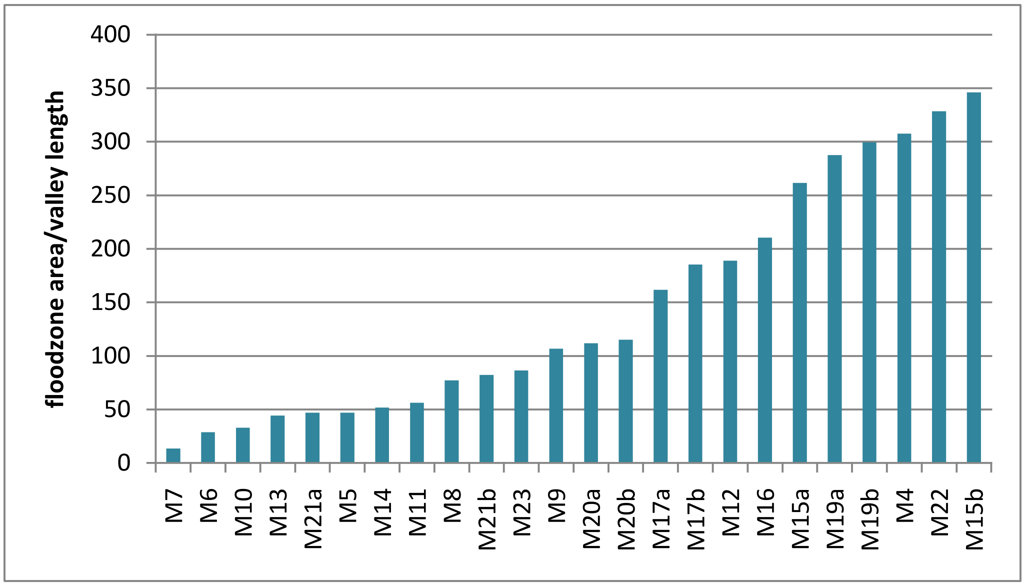


Figure 6. Comparison of the ration of floodzone area/reach valley length among mainstem reaches in the watershed (floodwater attenuation potential, or FAP). Reaches with the highest ratios (>150) were considered to have the highest rank in terms of the value of the floodzone for FAP per unit of river valley length.

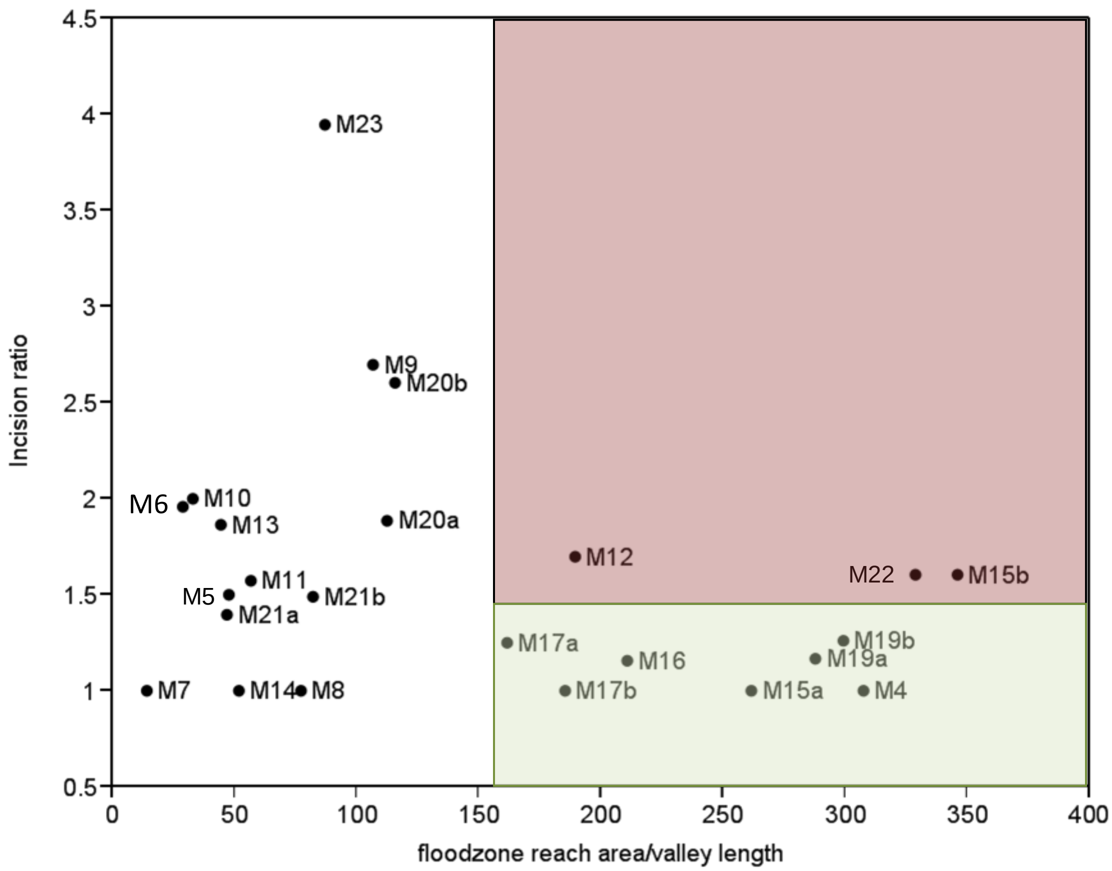


Figure 7. Channel incision ratios for each reach plotted against the ratio of floodzone reach area/valley length (floodwater attenuation potential, or *FAP*). Reaches with the highest FAP and highest incision ratios (red box) represent the most valuable reaches for floodwater attenuation where the FAP is impaired by geomorphic incision. Reaches with lower incision ratios and high FAP (green box) have more intact geomorphic function and likely have the largest actualized floodwater attenuation functionality.

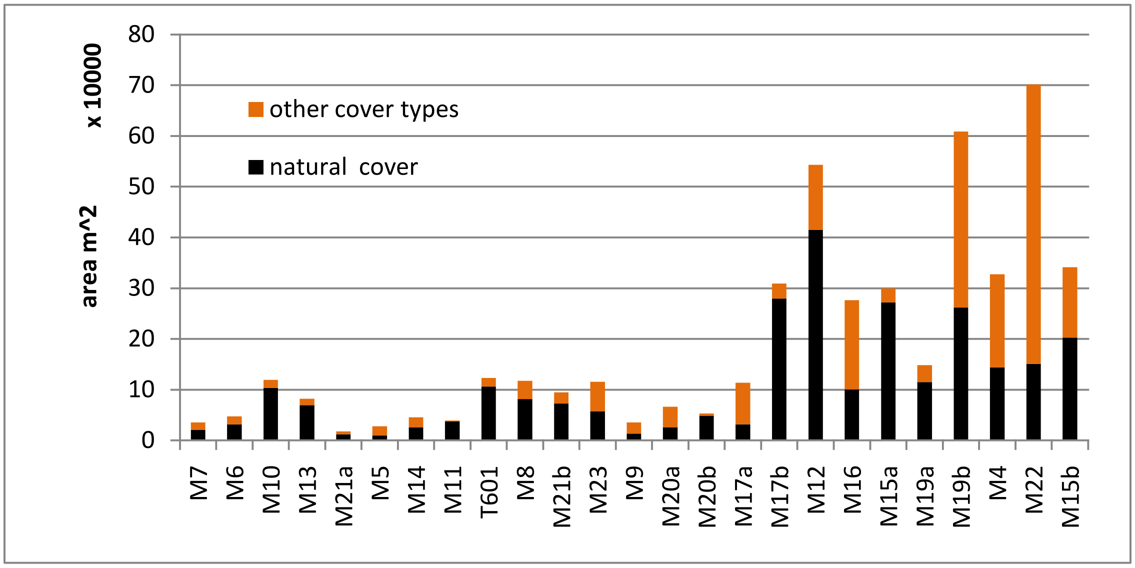


Figure 8: Natural cover (UVM Spatial Analysis Lab 2006) in floodzone reaches of Lewis Creek, sorted by the FAP (floodzone reach area/valley length ratio).

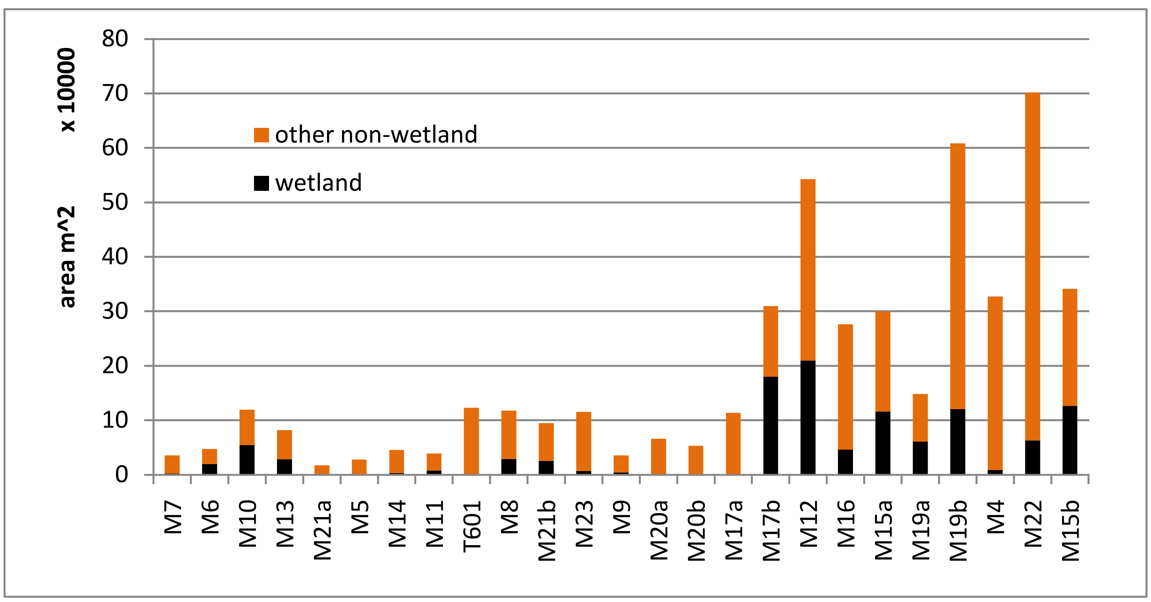


Figure 9: Wetland landcover (UVM Spatial Analysis Lab 2006) in floodzone reaches of Lewis Creek, sorted (low to high) by the FAP (floodzone reach area/valley length ratio).

floodzones on the basis of all these factors.

Table 3 illustrates this analysis by incorporating the classification of floodzone reaches by FAP, natural cover, and floodplain functionality. This classification scheme allows us to coarsely characterize conservation needs of individual floodzone reaches in terms of restoration or protection, and rank reaches in terms of the importance of its potential floodwater attenuation value. This classification starts by ranking reaches based on FAP (Figure 6), with the highest 10 ranking reaches placed into a higher priority category . The landcover composition and floodplain functionality of these reaches is then used to provide characterizations in terms of the most pressing conservation needs: protection (easements, fee acquisition, etc) or restoration (eg. Floodplain re-forestation, riparian buffer planting, wetland restoration, channel geomorphic restoration). For example, reaches M15a and M15b have relatively large FAP, and also feature a high percentage of natural cover and wetland (Figures 8 and 9). Moreover, these reaches consist of a mosaic of wetlands and forest within the floodzone that are for the most part continuous near the river channel. As such, these reaches should be considered outstanding examples of intact vegetation, and accordingly should be considered protection priorities. Reach 15b however, is also a priority for geomorphic channel restoration, on account of its impaired floodplain functionality (per the reach's higher Incision Ratio; Table 3). From the perspective offered by existing fluvial geomorphic assessment information (South Mountain Research and Consulting 2010), reach 15A has a geomorphic assessment rating of fair, while its geomorphic sensitivity is extreme, and has moderate planform adjustment. Given the sensitivity of the reach to geomorphic stressors, the intact condition of the landcover within the floodzone might have somewhat of an ameliorative value to existing stressors.

Conversely, reaches such as M22 and M19b have high FAP, low proportions of natural cover, and (especially M22) lower proportions of wetlands within the floodzone (Table 3). These reaches fall into the high priority restoration category in terms of natural cover in the floodzone. M22 has the additional priority need of gemorphic channel restoration. In such reaches, opportunities to restore natural cover, especially within river meander belts or floodzone wetlands should be pursued whenever possible. Active or passive geomorphic restoration approaches should be used where those are prioritized in the river corridor management plan (South Mountain Research and Consulting, 2010). Floodzone reaches in the restoration category often have a high proportion of agricultural land use, so conservation initiatives obviously need to be mindful of the agricultural values that these lands provide. Fortunately, emerging river conservation strategies in Vermont are making advances in striking a balance between protecting conservation and agricultural values in terms of models for conservation easement language for use in river corridor land protection efforts.

Both these reaches in this example (M22 and M19b) have fair geomorphic condition and are undergoing moderate planform adjustment, with some channel aggradation (South Mountain Research and Consulting, 2010). M22 in particular is noted to have a lack of forest buffers and erodible channel margins, so reforestation or wetland restoration in the meander belt will help restore river processes. This reach in particular has an important potential attenuation function for flows originating from higher gradient, more constrained channels in the headwaters. However, corridor restoration in this reach will

Table 3: Prioritization table for floodzone reaches classified by proportion of natural cover and floodwater attenuation potential. Underlined reaches are higher priorities for approaches to restore incised channels (see Figure 7).

	High proportion natural cover	**Low proportion natural cover**
Largest floodwater attenuation potential High priority	M15a M15b M17b M12 M19a	M22 M4 M16 M19b M17a
Smaller floodwater attenuation potential: Lower priority	M23 M6.01 M21a M20b M7 M13 M20a M14 M10 M6 M8	M21b M17c M11 M9 M5

be needed in order to realize this attenuation potential, given the incised nature of the channel in M22 (Table 3, Figure 7).

Contribution of major tributaries to floodwater storage/flood attenuation:

Responding to partner inquiries about possibly using ARA modeling tools to provide insights into the value of reaches for which there is less geomorphic assessment data, we estimated the relative FAP of major tributaries by comparing the ratios of the floodzone area of each tributary to watershed area, and comparing this ratio to the ratio for the entire watershed. Tributaries with a ratio higher than the entire watershed were considered to have a disproportionate water storage potential relative to their size, and thus have a disproportionately large floodwater storage/attenuation potential. This estimate is an initial attempt to use ARA GIS modeling tools in streams with less geomorphic data on valley wall locations. As such, this estimate is coarse, with, as being noted earlier, overall size being one of just a variety of factors that ultimately determine the water storage capacity of floodzones. Based on this estimate, floodzones in these tributaries T1, T2, and T3 (Figure 10) could be considered higher priorities for floodzone protection effort that involve conservation easements, wetland restoration in the floodzone, and natural cover restoration.

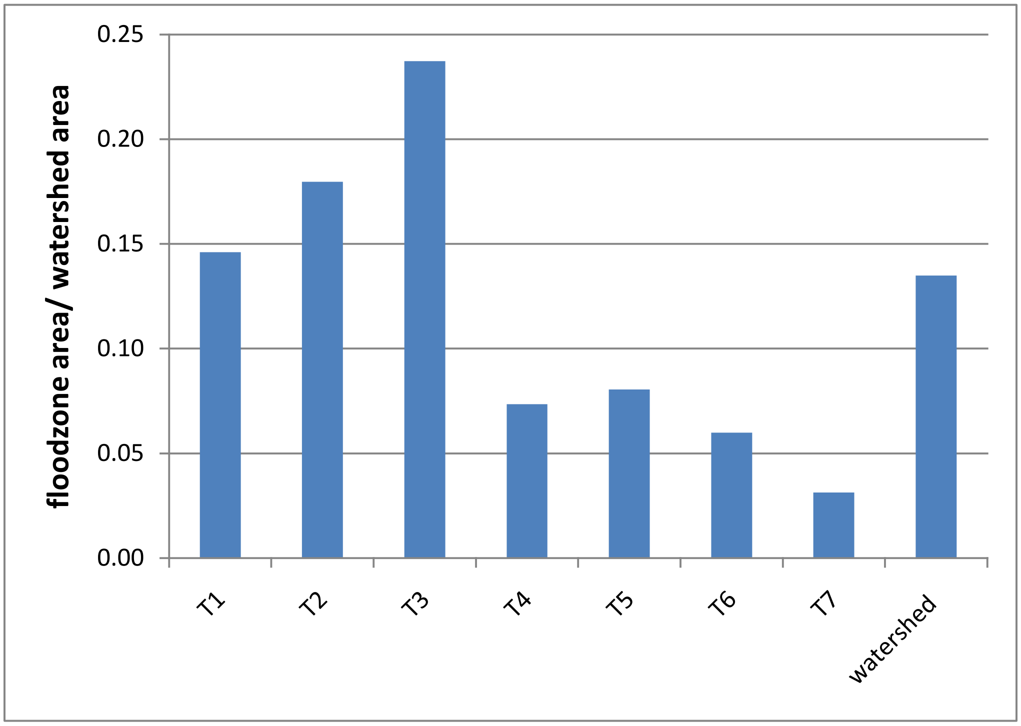


Figure 10. Proportion of floodzone area to watershed area for major tributaries in Lewis Creek and the entire watershed. T1, T2 and T3 have greater ratios than the ratio for the entire watershed, suggesting that these reaches may have a disproportionately larger contribution to floodwater storage/attenuation processes.

Riparian Wetland Analysis (Riparain Wetland ARA Component):

The wetflat tool delineated predicted water accumulation areas (or "wetflats") on the landscape according to the underlying DEM. We compared the wetflat areas to existing information on wetland occurrence in floodzone areas to assess whether this tool was a good predictor of either extant or historical (drained or otherwise altered) wetlands. Initial visual comparison between 10m DEM wetflat tool outputs to existing spatial information on wetlands (VSWI data and UVM Spatial Analysis Lab 2006 data; Figure 11) suggested very little corroboration between the wet flat data and other wetland data sets throughout the floodzone on the mainstem. This non-corroboration was sufficiently obvious to preclude investing the time to quantify wetflats within the floodzone, as it appeared that such a metric would have little interpretive value. Accordingly, we concluded that the wetflat tool was not the best way to quantify and derive metrics on wetlands and potential wetlands within the ARA floodzone. The tool did however appear to be able to capture flow channels, either extant or historic, to a greater degree than UGSG or hydrology datasets, and this has some interpretive benefit in reaches to identify historic river channels.

Though we hoped that the use of LIDAR data for the cost surface would improve the predictive ability of the wet flat tool, the results also did not corroborate whatsoever with wetland data. Furthermore, the

LIDAR results differed from existing wetland data in ways that were not easily explainable. In Figure 12 there is some corroboration between existing wetland data and LIDAR wet flat results, but only in a small portion of the reach examined (M15). On account of these differences, we did not incorporate the results of the wet flat analysis into our interpretation of landcover metrics within floodzone reaches.

We instead chose to use existing spatial information on the occurrence of wetlands in the watershed in order to characterize the floodplain wetlands component of the Active River Area. However, additional difficulties with the data quality of wetland spatial information were encountered. In general, The UVM data (UVM Spatial Analysis Lab, 2006) depicted more wetland coverage in floodzone reaches than Vermont Significant Wetland Inventory data (Figure 13). And while not quantitatively compared, VSWI wetland data in turn appeared to be greater than National Wetland Inventory wetland coverage within floodzone reaches. For this analysis, we chose to use data extracted from UVM Spatial Analysis Lab 2006 to characterize wetland coverage within floodzones, because it was not subject to the minimum size thresholds that limits the comprehensiveness of the VSWI data set (which does not document wetlands < 3 acres in size). Of the 25 floodzone reaches examined, 8 had wetland coverages above 20% (Figure 9).

It is likely that many of the floodzone reaches have had substaintial amount of historical wetland drainage or filling. The Lewis Creek corridor plan (South Mountain Research and Consulting 2010) provides a rough estimate of wetland conversion/loss in the basin by comparing coverage of hydric soils with VSWI and NWI wetland coverage. This exercise suggested that 64% of historic wetlands were converted in the watershed. Data inaccuracies and limitations of the resolution of these data sets made this comparison coarse at best, but nevertheless suggest that wetland loss in floodzones was likely considerable. Considering the relatively small size of individual floodzone reaches and resolution issues with these data sets (wetlands data not recording class III wetlands, hydric soils limited to patches >3 acres in size), a similar analysis for this project was not conducted.

Wetland restoration projects within the floodzone would undoubtedly increase the floodwater storage capacity of the floodzone and thereby facilitate passive geomorphic restoration by ameliorating flood dynamics by increasing the flow and sediment attenuation role of the floodzones surrounding the channel. Towards this end, South Mountain Research and Consulting (2010) and the Lake Champlain Basin Wetland Restoration Plan have identified several potential wetland restoration projects. South Mountain Research and Consulting cites two locations where the restoration of channel-contiguous restoration is possible (M17b and T3.01b). Moreover, the Lake Champlain Wetland Restoration Plan used a modeling process to identify 19 additional potential wetland restoration sites in the Lewis Creek mainstem floodzone. This process was designed to prioritize restoration sites on the basis of phosphorous removal potential. Most of the potential restoration sites within floodzone reaches were located on tributaries T1 and T3, although some sites were identified along the mainstem in reaches M4, M15, M19, and M22 (see Appendix 2).

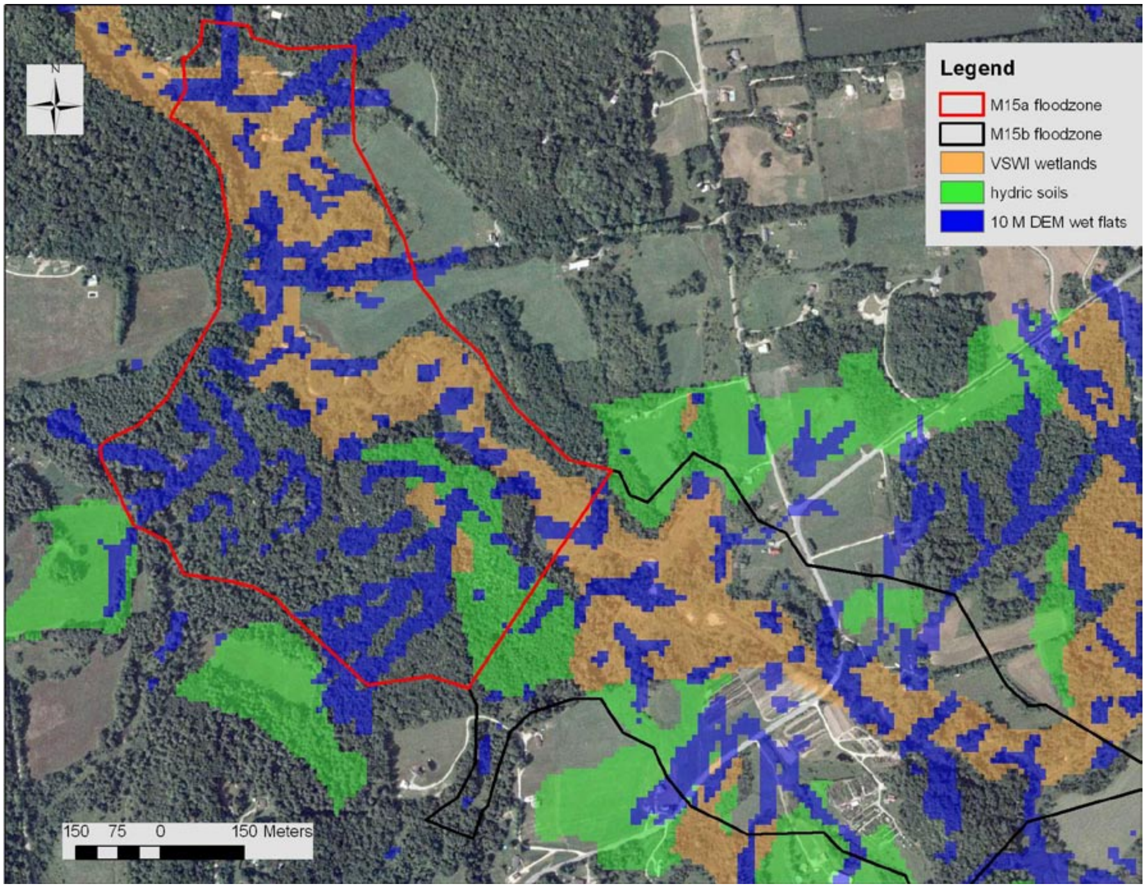


Figure 11: Comparison of modeled “wet flat” water accumulation areas within the floodzone of M15, along with mapped VSWI wetlands and hydric soils. The lack of correspondence between data layers led us to not use this tool for deriving wet flat metrices for each floodzone reaches. The tool however does appear to capture small drainage channels and parts of some historic river channels.

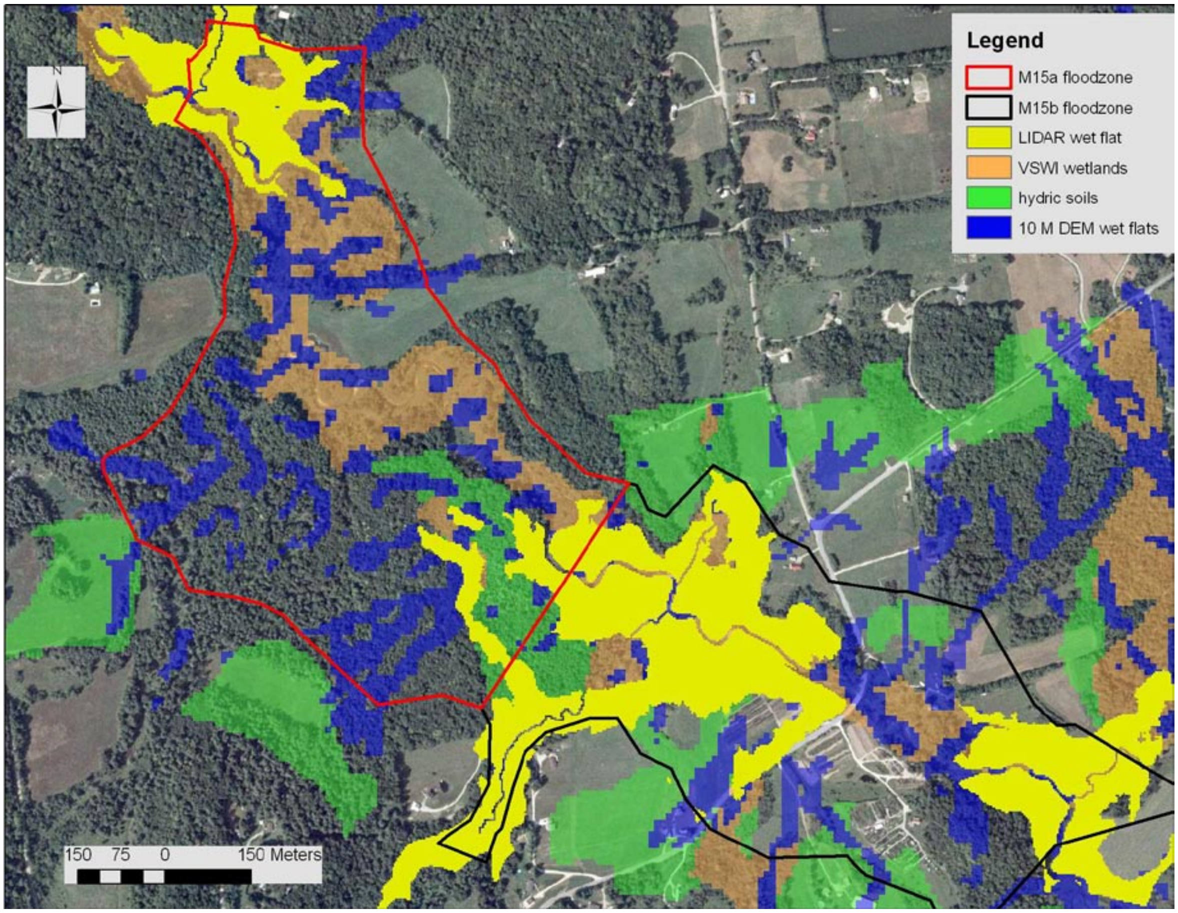


Figure 12. Comparison of LIDAR and 10mDEM wet flats with VSWI wetlands for reach M15. Lack of correspondence between data layers prompted us to reject the use of the wet flat modeling tools for this analysis.

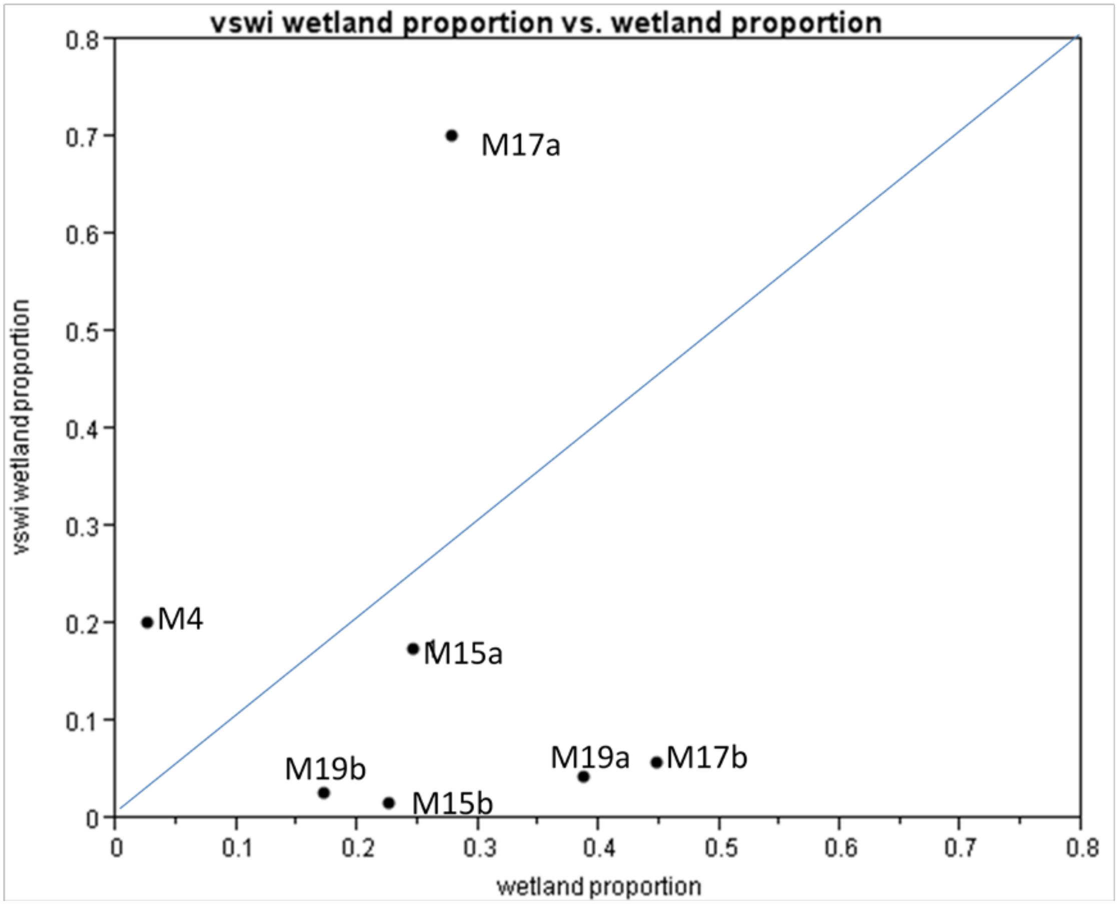


Figure 13. Comparison of VSWI Proportion of wetlands within floodzone reaches vs. UVM Spatial Data Analysis Lab (2006) data. There is substantial scatter around the 1 to 1 relationship line, and UVM data depicts a much greater area of wetlands compared to VSWI data, with the exception of some outliers. Reaches chosen for this analysis all have broad floodzones in relatively unconfined valleys.

Other ARA Components

One of the objectives of the VTDEC RMP is to explicitly identify meander belts along rivers for the purposes of accommodating the meanders and slope of a balanced or equilibrium river channel. Meander belt designations serve as guides for fluvial erosion hazard assessment for land use planning, and also habitat management. VT ANR stream geomorphic assessments have in essence institutionalized the meander belt ARA component (VT ANR 2004), thereby encompassing additional ARA framework components (meander belt and river channel) into the existing body of information on Lewis Creek. Given that we did not have ARA related GIS assessment tools able to explicitly define and characterize meander belts, we did not make any effort to incorporate this component into this report.

In regards to the terraces ARA component, the coarseness of the 10M DEM floodzone analysis appeared to lack the resolution to be able to capture floodplain terraces with any confidence and differntiate between terraces and active floodplains. This was clearly illustrated in the comparison of 10M DEM floodzone vs. LIDAR derived floodzone for reach M15, as noted earlier. The 10M DEM floodzone incorporates what is likely a terrace that is seldom if ever flooded, while the LIDAR analysis is able to differentiate between terrace and active floodplain in this reach. Therefore, the terrace component will need to be more clearly demarcated if/when LIDAR data becomes available for the entire reach.

Prioritization of conservation in Lewis Creek: Integrating geomorphic assessment and ARA metrics.

ARA analysis tools enabled the characterization of landcover and quantification of riparian wetlands within the floodplain component of the ARA assessment framework. Accordingly, this analysis provides a perspective that supplements other conservation planning effort for Lewis Creek. Our riparian wetland analysis starts to fill a gap in existing conservation planning work by explicitly characterizing the quantity and distribution of wetlands within the floodplain, thereby providing insights into the habitat and potential floodwater storage/attenuation values they provide. Unfortunately, inaccuracies in wetlands data limits the confidence terms of any conclusions we can reach. Nevertheless, this analysis provides a unique conservation perspective, and should be revisited whenever improvements in wetland datasets become available.

We cross referenced results from ARA GIS tools with geomorphic condition metrics from the Corridor Management Plan (South Mountain Research and Consulting 2010): Reach Geomorphic Assessment rating, reach geomorphic Sensitivity rating, and reach geomorphic departure analysis for reaches with the highest FAP (Figure 14). Results identified reaches that featured both the most compromised geomorphic conditions, reaches most sensitive to geomorphic disturbance, and reaches featuring low metrics for attributes such as floodzone natural cover. This analysis serves as an additional prioritization lens for conservation planning, as reaches that have lower ranking landcover metrics from the present analysis and impaired ratings from the Corridor Plan (South Mountain Research and Consulting, 2010) can be given higher priority. Restoration work on the reaches identified here can achieve multiple objectives: maximizing the value of natural habitats in the floodzone for both biodiversity conservation and the attainment of geomorphic equilibrium conditions in terms of geomorphic processes. For example, reaches having low proportions of natural cover and/or wetlands, along with impaired geomorphic assessment conditions and high sensitivity would rank as the highest priorities for restoration work. Reaches M4 and M23 had the highest ratings for sensitivity and impaired geomorphic condition, and the lowest ratings for natural vegetation cover in the floodzone (Figure 14). Restoration of forested buffer within the meander belts in ARA floodzones and/or forests in the floodzone and wetlands would be the highest conservation priorities in these reaches. Results from this analysis complement results from Table 3, which illustrates priorities for river corridor protection: floodzone reaches that have the highest floodwater attenuation potential, high proportions of natural cover/wetlands, and relatively intact floodplain processes (Figure 7).

Figure 14: Comparison of the proportion of natural cover in select floodzone reaches with geomorphic assessment results (South Mountain Research and Consulting, 2010).

Results from Figure 14 do need, however, additional information in order to be properly interpreted. For example, the results for M21a were somewhat puzzling. M21a had a relatively high incidence of natural cover, a low sensitivity rating, yet scored only a “fair” rating in terms of geomorphic condition. Compared to other floodzone reaches, M21a is a short river segment in a confined setting, with a very narrow floodzone. The River Corridor Plan (South Mountain Research and Consulting, 2010) suspects some degree of historic channel straightening in this reach, suggesting a possible source of geomorphic condition impairment that is independent of ARA derived indices. Moreover, the high degree of the proportion of natural cover is misleading in this particular reach, because the floodzone is very small (11.3 hectares, or 23 acres), and the shape of the floodzone is biased by a “flair” that was caused by the broadening of the valley at the transition between M21a and M20b. This “flair” consists of predominantly forested landcover, and thereby upwardly biases the proportion of in-floodzone natural cover. The occurrence of the “flair” can be attributed to the necessity of having to arbitrarily draw lines of demarcation between reach segments in order to define floodzone reaches (Figure 15). Moreover, this reach is very small – the width of the floodzone is no more than 80m outside of the

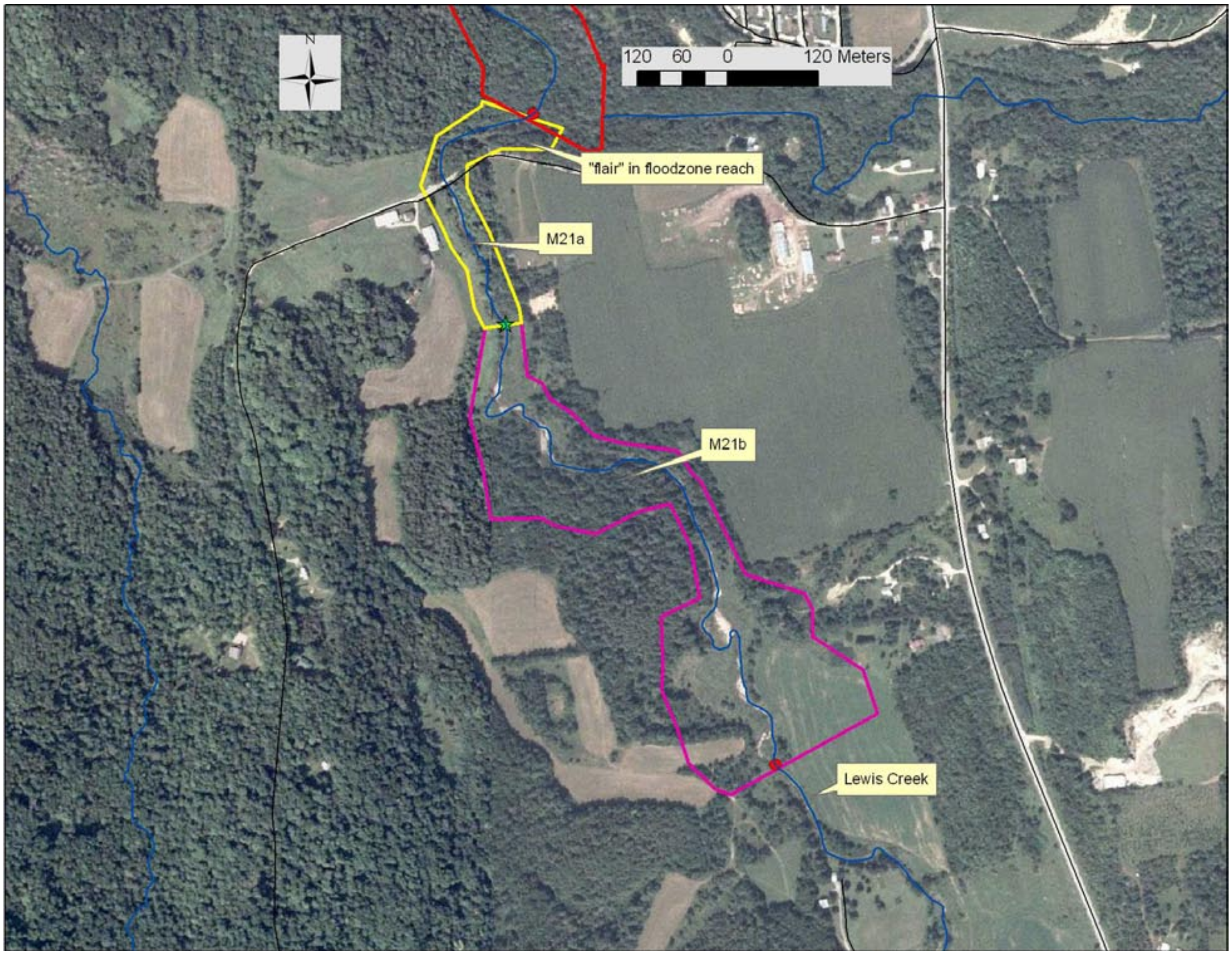


Figure 15: The shape of the polygon that defines the floodzone reach for M21a is "flared" at the downstream end, which increases its ratio of natural cover in Figure 14.

"flair", so floodzone reach landcover metrics in this case are especially susceptible to bias from idiosyncrasies that arise out of the construction of floodzone reach boundaries.

Overall, relating ARA landcover and floodzone metrics to geomorphic assessment data provides a useful perspective, but is also limited in that the dynamic processes governing fluvial geomorphic equilibrium on a reach basis are much more complex and multifaceted than can be captured by an analysis of landcover and wetlands within floodzones. Nor, obviously, would floodzone reach landcover metrics be even an indirect reflection of predominant geomorphic processes and adjustments. But we are able to use ARA floodzone metrics as an additional layer on top of geomorphic assessment data to provide a more complete reach-based characterization that combines ARA floodplain modeling, landcover, wetlands, and geomorphic assessment data.

The interpretation of results from reach M21a is a good example of the scale limitations of the analysis of the GIS ARA tools. Our results suggest that the finer the scale of the analyses, given current data limitations, the more GIS tool analyses are prone to misleading biases and distortions. In the case of Lewis Creek, existing geomorphic assessment data on Lewis Creek has provided a remarkably detailed picture on geomorphic processes and perturbations in the watershed that is invaluable for identifying the scale based limitations of the ARA analysis. Lacking geomorphic assessment data on Lewis Creek, much of the interpretation of this analysis would be difficult given the small size of the river relative to the resolution of the underlying DEM data.

Conclusions

Despite the limitations of scale and data accuracy noted earlier, the ARA framework and associated GIS assessment provide a unique lens through which to assess and prioritize conservation in Lewis Creek. By deriving landcover metrics from units defined by floodzone reaches and incorporating data from existing geomorphic assessment work, we generated conservation priorities from a perspective informed by landcover metrics and geomorphic condition data among floodzone-based analysis units that are geomorphically distinct. This information alone is highly complementary to existing conservation assessments on Lewis Creek. With this analysis, we were able to identify restoration and protection priorities for Lewis Creek that was informed by the framework provided by the Active River Area. Significant refinements can be made by repeating this analysis with a LIDAR derived DEM for the entire watershed.

This project also illustrates the value and limitations of GIS-based analysis with ARA-oriented spatial assessment tools for characterizing and prioritizing for conservation components of rivers which for which there is less geomorphic, wetlands, and aquatic habitat assessment data. Analysis with the GIS tools demonstrated here can provide an intitial prioritization scheme, particularly when paired with other spatial analysis exercises such as the VTDEC Phase 1 SGA, which defines the geomorphcially unique river reaches that provided one of the foundations of floodzone reach definition. Analysis with ARA GIS assessment tools increases in value to the extent that LIDAR data is available for development of floodzone cost surfaces, and may be especially useful in smaller tributaries and streams, where the lack of resolution in 10M DEM data becomes increasingly problematic. In general, this project complements the existing Phase 1 SGA protocols, and ARA-based spatial analysis as demonstrated here can be streamlined and standardized to make this a cost effective approach for river assessment in less-data rich envrionments.

References:

1/3-Arc Second National Elevation Dataset (2009); National Elevation Data (NED). United States Geological Survey.

Active River Area (ARA) Three-Stream Class (3SC) Toolbox Documentation (2010). The Nature Conservancy.

Lewis Creek Watershed Association (2010); Lewis Creek Watershed: River Corridor Conservation & Management Plan, prepared by South Mountain Research and Consulting. 118 pages, appendices

Milone & MacBroom, Inc., February 2009, Stream Habitat Assessment: Lewis Creek Watershed, Addison & Chittenden Counties, Vermont.

Northeastern Aquatic Habitat Classification System Flowlines (2008). U.S. Environmental Protection Agency (USEPA), the U.S. Geological Survey (USGS), and The Nature Conservancy (TNC) Eastern Conservation Science.

Pioneer Environmental Associates, Arrowood Environmental, Stone Environmental, and Donald Meals (2007). Lake Champlain Basin Wetland Restoration Plan, prepared for Vermont Agency of Natural Resources. 119 pages, appendices

Smith, Mark, Roy Schiff, and Jeff Opperman (2008). Riparian Zones: They Aren't Just For Buffers Any More. *Water Resources Impact* 10(3)

The Vermont Hydrography Dataset RF 5,000 scale (2008); VT Center for Geographic Information.

University of Vermont Spatial Analysis Lab (2006), Stream Corridor Land Use / Land Cover, Lewis Creek

Vermont Agency of Natural Resources (2004). Stream Geomorphic Assessment Protocol Handbook. www.vtwaterquality.org/rivers/htm

Vermont Department of Environmental Conservation, (2010) Vermont Significant Wetlands Inventory http://www.vcgi.org/dataware/

VT Agency of Natural Resources, 2007 (11 July draft). *River Corridor Planning Guide to Identify and Develop River Corridor Protection and Restoration Projects*. Available at: http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_rivercorridorguide.pdf

APPENDIX 1: GIS analysis methods

We used The Active River Area (ARA) Three-Stream Class Toolbox, a tool for ArcGIS created by TNC (TNC 2010), to create a raster data set that contains representations of most of the elements of the six components of the active river area. Input data for the tool included the 1/3-Arc Second National Elevation Dataset DEM (USGS 2009) with a horizontal resolution of 10m and a DEM derived from Bare Earth LiDAR for Chittenden County, Vermont (UVM 2008) with a horizontal resolution of 3.2m as representations of topography and the Vermont Hydrography Dataset (VCGI 2008) for representations of streams and lakes.

The Vermont Hydrography Dataset (VHD) is based primarily on the Vermont Mapping Program (VMP) digital orthophotos and is the most detailed stream data available for Vermont. We used a combination of stream size classes from the Northeastern Aquatic Habitat Classification System (EPA, USGS, TNC 2008) and stream orders from VHD to assign the stream and lake shapes to 4 different size classes. As the shapes in the Northeastern Aquatic Habitat Classification System (NAHCS) are extracted from a spatially coarser dataset, some stream segments in VHD are not represented in NAHCS. VHD streams with stream orders of 1 and 2 that are not represented in NAHCS make up the smallest stream class (size 0). VHD streams with stream orders of 3 and 4 that are represented in NAHCS and have watershed areas of 0 to 3.861 mi^2 make up the small stream class (size 1). Medium and large streams (size 2 and 3) have watershed areas of 3.861 to 38.61 mi^2 and 38.61 to 200 mi^2, respectively. VHD lakes that intersect with VHD streams were assigned a size class equivalent to the size class of the stream that it drains into. All of the components of the ARA, except the headwater watershed material contribution zone and the upper terraces, were created for stream sizes 1, 2, and 3. Only the riparian material contribution zone was created for stream size 0.

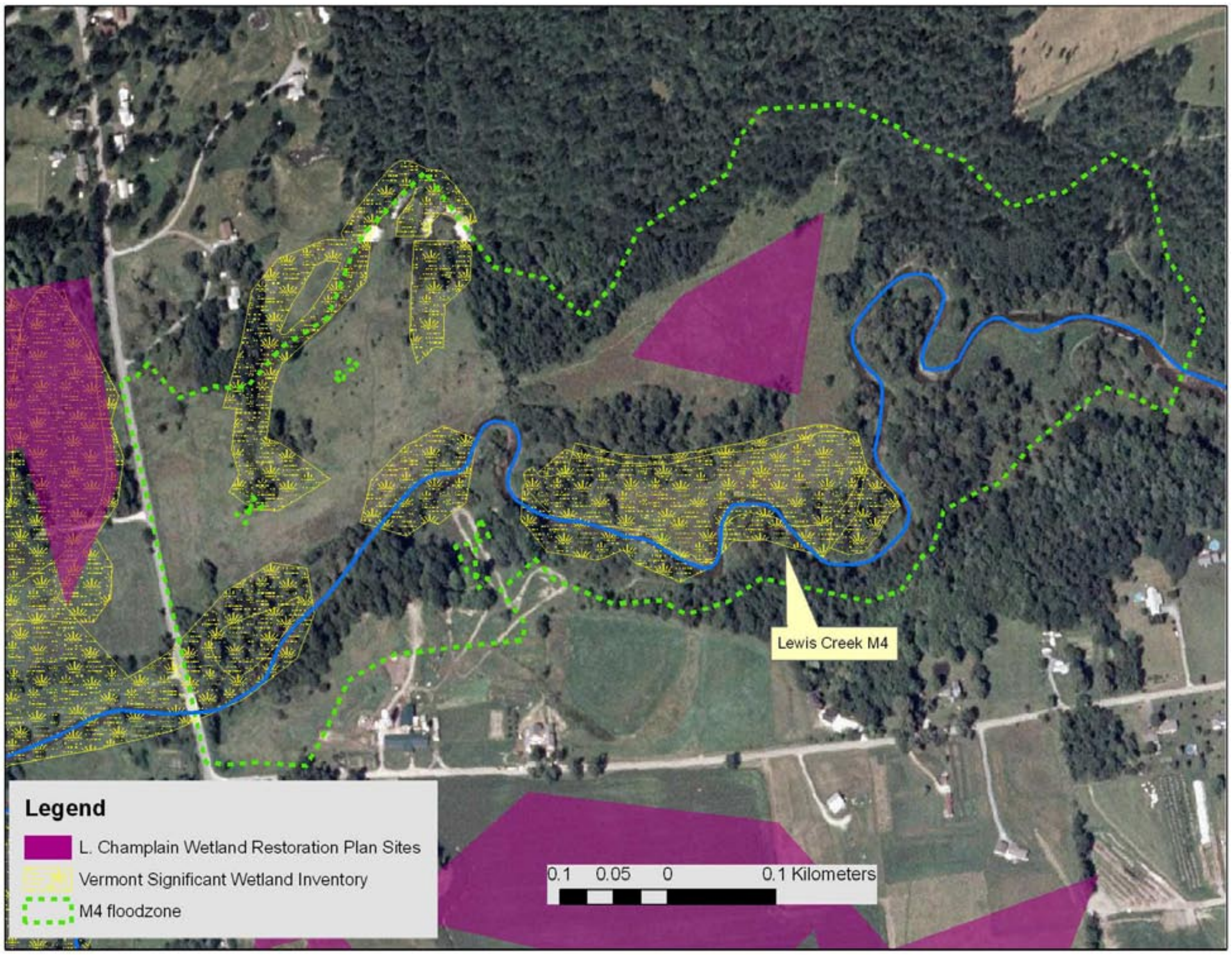
We used the ARA toolbox to create a cost distance grid from the DEM and the classified stream input data. The cost distance grid is calculated from intermediate grids that are derived from the DEM: a slope grid, a flow direction grid, and a flow accumulation grid. The value of each cell in the cost distance grid is the cost distance for that location, when cost distance is defined as the relative cost of water to travel upslope out and away from the stream/river. The cost takes into account both the slope due to elevation change and the distance from the channel, with higher costs for greater slopes and distances from the stream/river (TNC 2010).

We identified areas in which wet areas adjacent to the streams would be included in the riparian wetland component of the ARA. These “wet flat grab zones” are areas defined by the doubled cost-distance thresholds for stream sizes 1, 2, and 3.

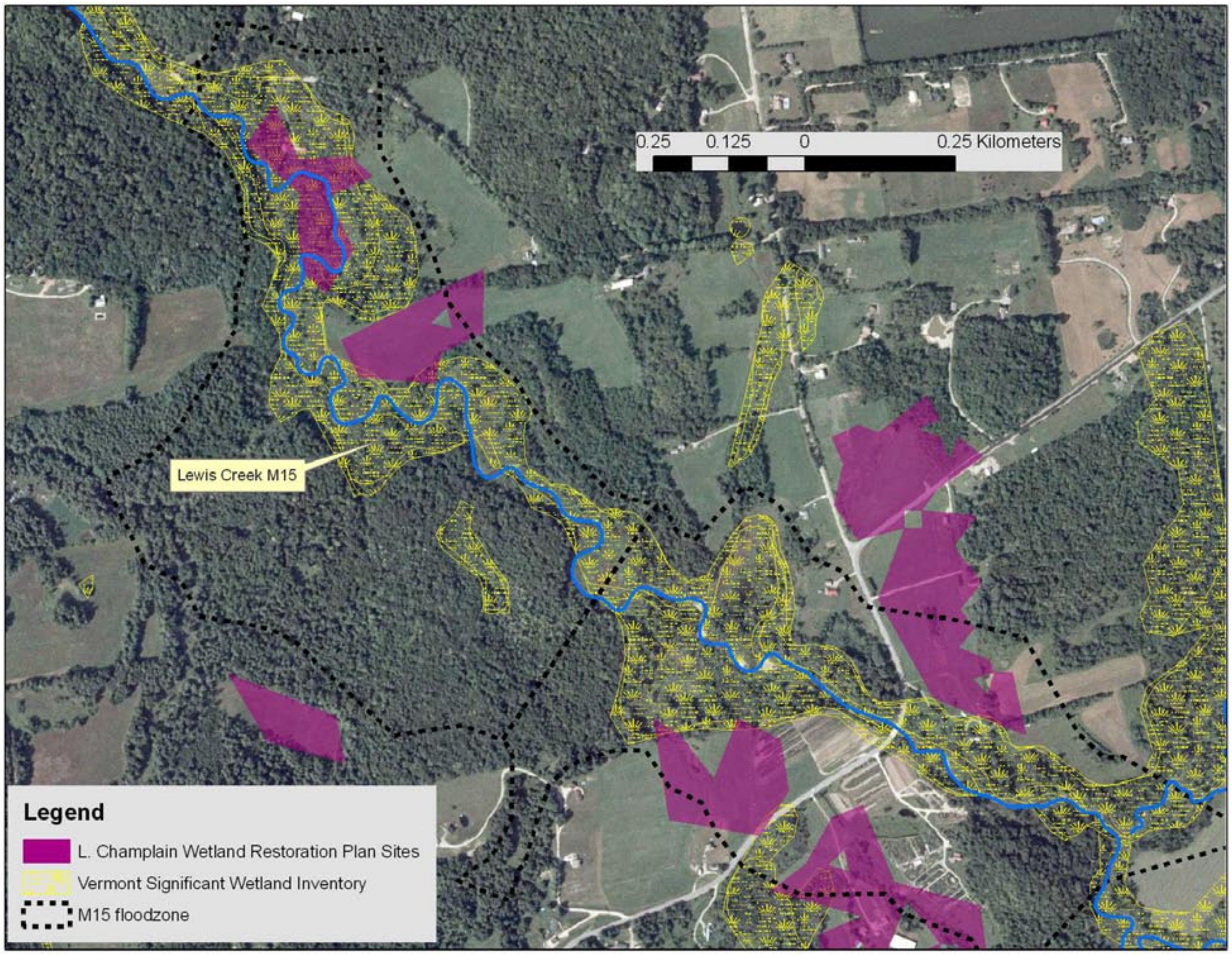
Wet flats “are areas that are likely to be wet as a result of high groundwater and overland runoff from adjacent uplands” (TNC 2010). We used the ARA toolbox to create a wet flat grid from the DEM.

Our first step in creating the wet flat grid was to create a moisture index grid derived from the slope grid and flow direction grid that were created in the process of calculating the cost distance grid. The resulting moisture index grid was then compared to wetland data, hydric soils, and topographic information in the wet flat grab zone in order to select values of the index that most consistently correspond to current and historical wet areas and areas likely to be wet based on topography. A wet flat grid was created by selecting cells in the moisture index grid that had values that were less than the chosen index value (wet flat threshold).

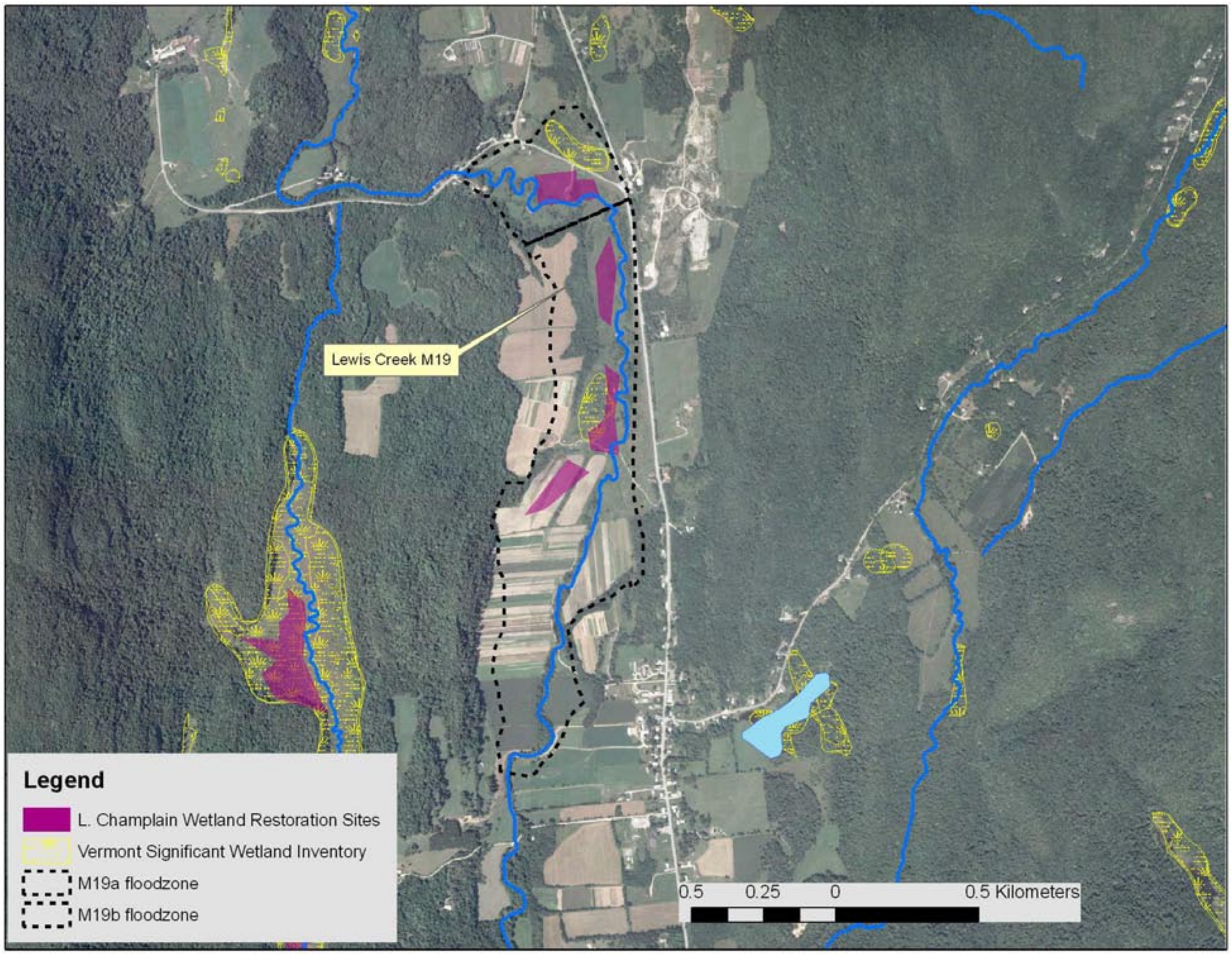
APPENDIX 2: Wetland Restoration Sites in Lewis Creek in the Lake Champlain Wetland Restoration Plan



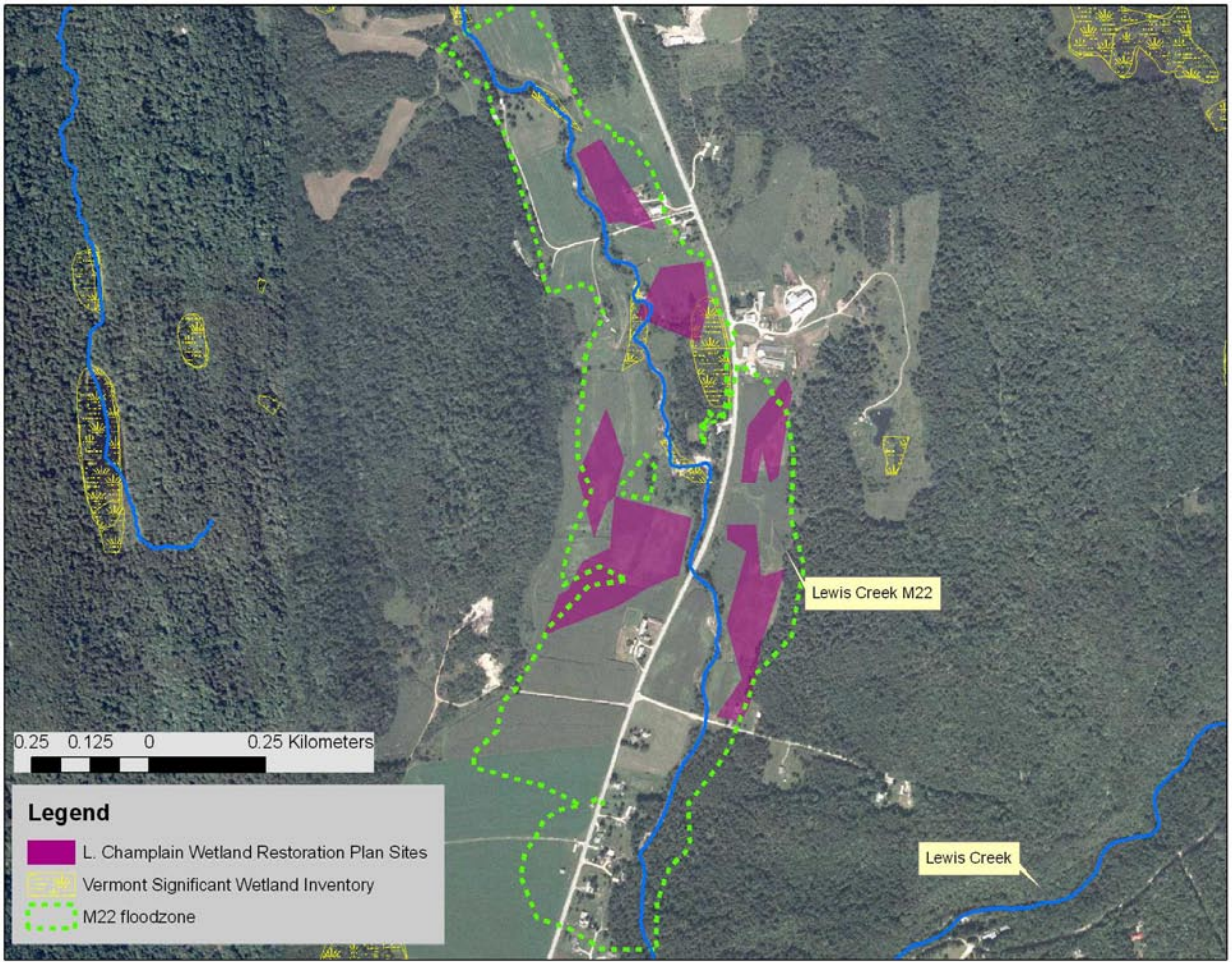
Lake Champlain Wetland Restoration Plan Sites and mapped VSWI wetlands in floodzone reach M4.



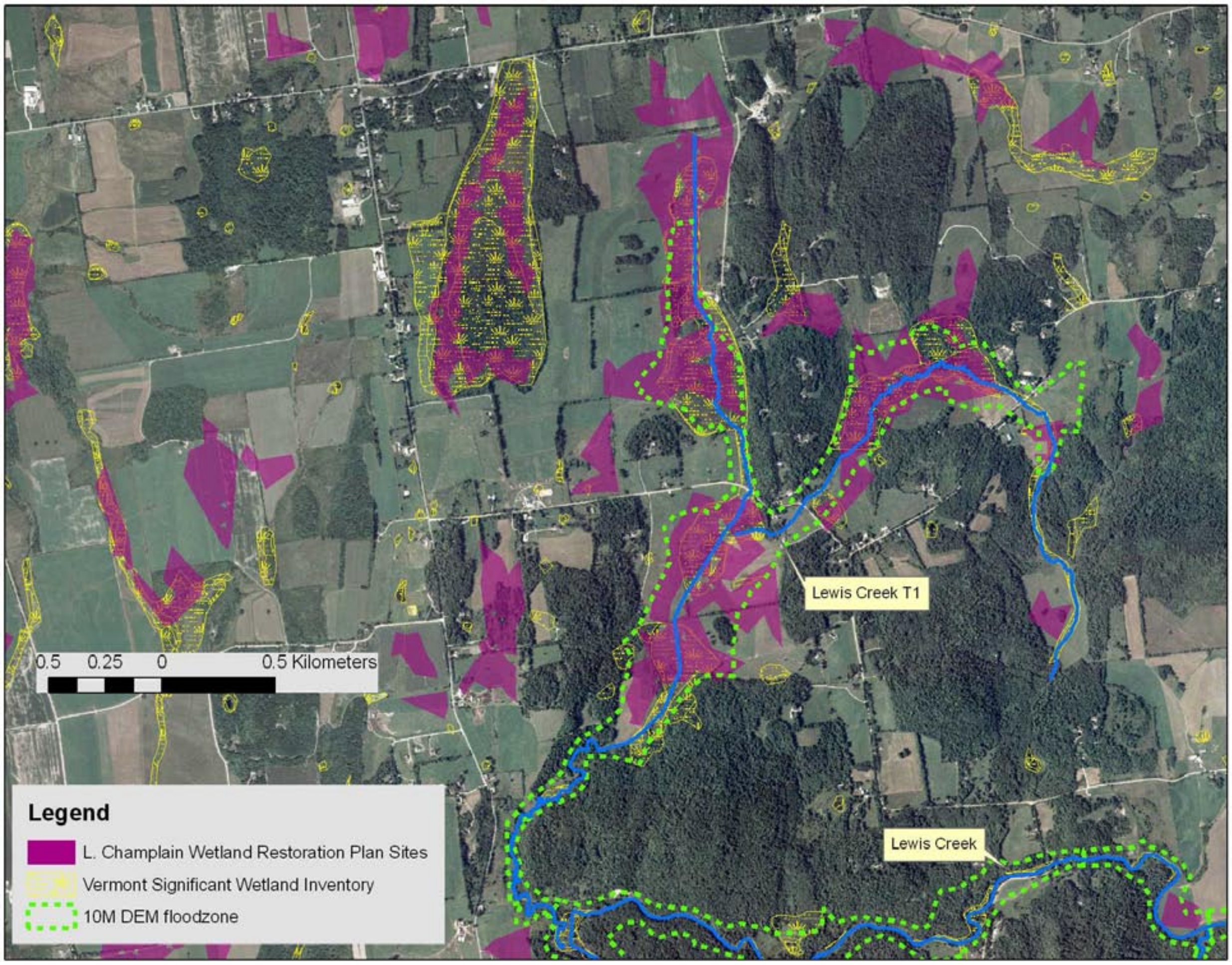
Lake Champlain Wetland Restoration Plan Sites and mapped VSWI wetlands in floodzone reach M15 a and b.



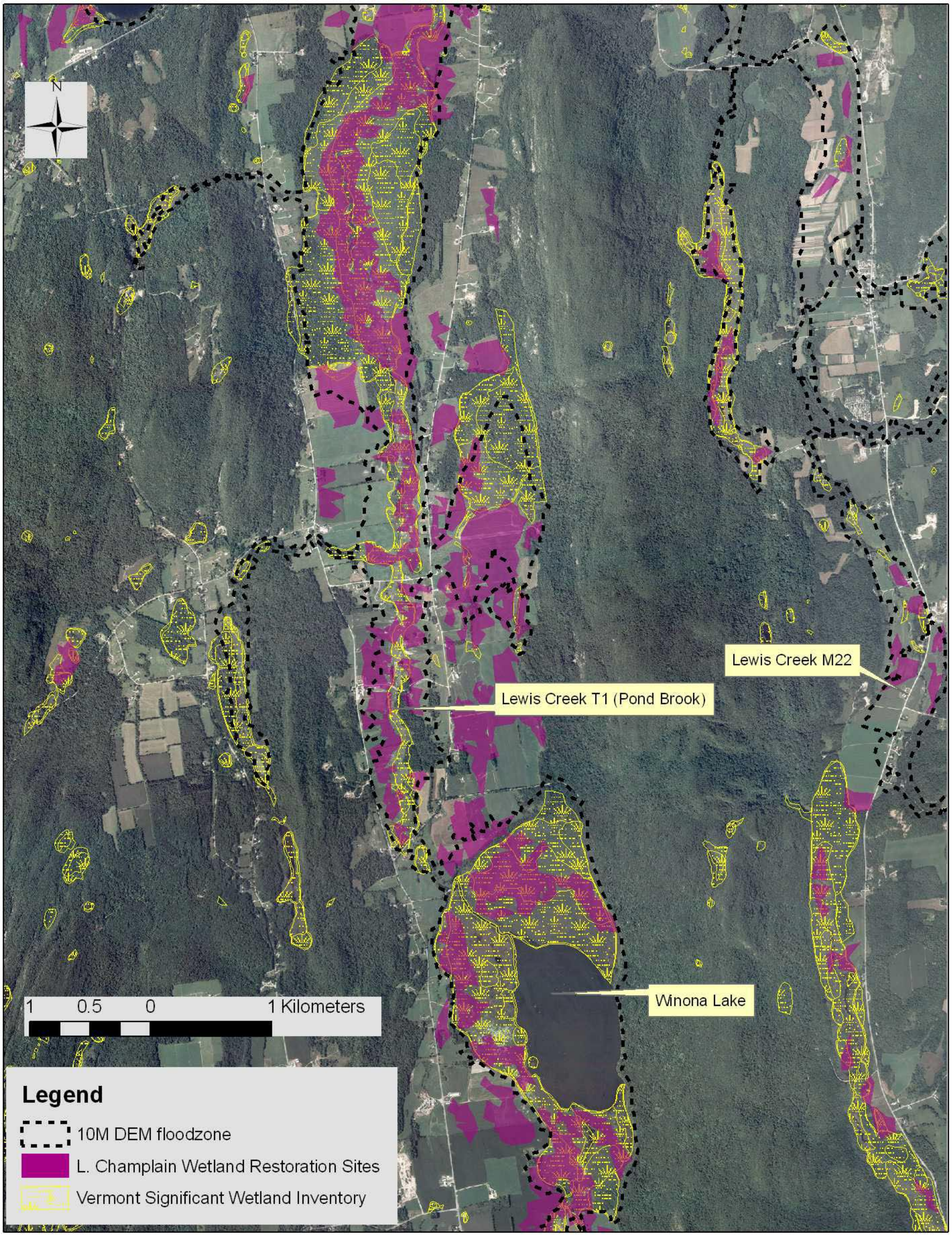
Lake Champlain Wetland Restoration Plan Sites and mapped VSWI wetlands in floodzone reach M19.



Lake Champlain Wetland Restoration Plan Sites and mapped VSWI wetlands in floodzone reach M22.



Lake Champlain Wetland Restoration Plan Sites and mapped VSWI wetlands in the floodzone in T1 (unnamed tributary)



Lake Champlain Wetland Restoration Plan Sites and mapped VSWI wetlands in the floodzone of T3 (Pond Brook).