Forest Land Analysis to Support Implementation of Lake Champlain and Lake Memphremagog Restoration Plan

FINAL REPORT FOR TRACK A - TASKS 1 AND 2
SEPTEMBER 1, 2021

Watershed Consulting Associates | University of Vermont

INTRODUCTION

Phosphorus pollution in Lake Champlain and Lake Memphremagog is attributable to a variety of anthropogenic land uses, including residential and commercial development, agriculture, and forest management. Of these possible sources, least is known about the role of skid paths, tote roads, log landings, and other infrastructure associated with actively managed forest tracts. The University of Vermont Spatial Analysis Laboratory (UVM SAL) recently developed a modeling workflow for mapping forest roads and identifying potentially-erosive sections of these features, testing it on pilot sites in the Champlain Valley (MacFaden et al. 2017). In this follow-up project, conducted in conjunction with the Vermont Department of Environmental Conservation (VT DEC), Watershed Consulting Associates (WCA) and the UVM SAL applied these methods to the entirety of the Champlain and Memphremagog Basins. Task 1 focused on acquisition and processing of high-resolution LiDAR, a remote-sensing data type that is essential to fine-scale analysis of topographic features. Task 2 included development and refinement of a modeling rule set that identified potentially-erosive features in forested settings, providing a starting point for subsequent pollution analysis, field investigation, and mitigation. This report summarizes the individual steps in both tasks and the resulting modeling output.

TASK 1 – KICKOFF MEETING, DATA ACQUISITION, AND DATA PREPARATION

Task 1.1 – Project Kickoff Meeting

The project kickoff meeting was held remotely on August 5, 2020. Attendees included Ethan Swift, Phillip Jones, and Katie Bockwoldt (VT DEC); David Wilcox and Keith Thompson (Vermont Department of Forest, Parks & Recreation); Andres Torizzo, Kerrie Garvey, and Tommy Ott (WCA); and Jarlath O'Neil-Dunne, Nina Safavi, and Sean MacFaden (UVM SAL).

Task 1.2 – Acquire Data

The Vermont Center for Geographic Information (VCGI) coordinates acquisition and distribution of LiDAR in Vermont, and all data are freely available for download and use (https://vcgi.vermont.gov/data-and-programs/lidar-program). The UVM SAL obtained the most recent LiDAR collections covering the state, acquired in 9 sections during the period 2013-2017 (Figure 1), and used the original 0.7-m post-spacing point clouds to derive digital elevation

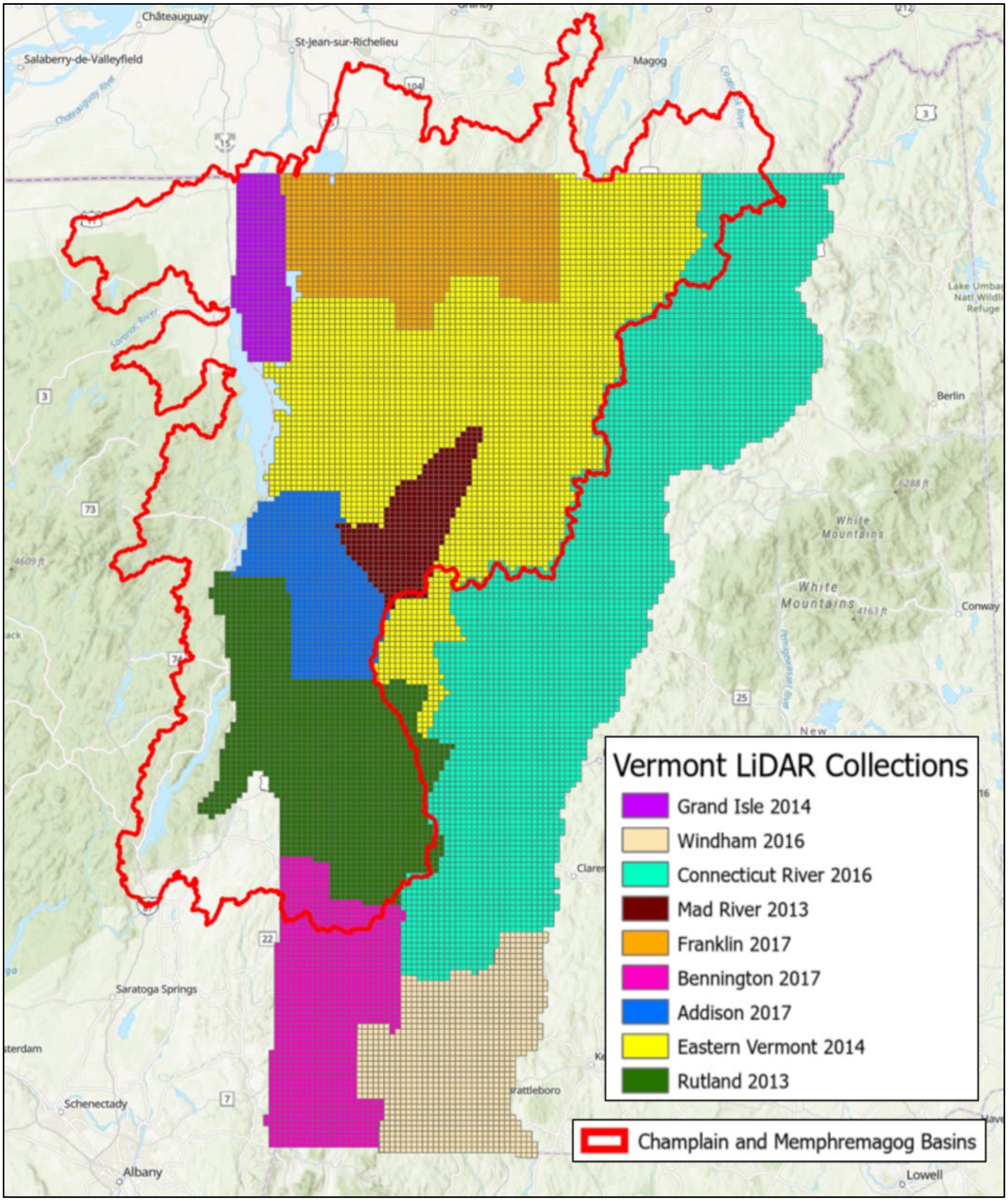

Figure 1. LiDAR collections for the State of Vermont. The most-recent databases were acquired during the period 2013-2017 with a nominal post spacing of 0.7 m.

Table 1. LiDAR derivatives developed for mapping and evaluating potential erosive features in forested setting.

LiDAR Derivative	Processing Method
Digital Elevation Model (DEM) - Original	First LiDAR returns filtered in LASTools and exported as raster surface model
Digital Elevation Model (DEM) - Filled	Original DEM modified by identifying (SCALGO Topology 1.5 – Depression Identification) and filling depressions (SCALGO Topology 1.5 – Depression Filling) that would interrupt stream modeling
Flow Accumulation	Filled DEM used to calculate flow directions (SCALGO Hydrology 1.4 – Flow Directions) and then flow directions used to calculate flow accumulation (SCALGO Hydrology 1.4 – Flow Accumulation).
Dissection	Unfilled DEM used to evaluate surface texture, identifying breaks in otherwise continuous topography (ArcGIS 10.6.1 – Geomorphometry and Gradient Metrics Toolbox 2.0 – Surface Detection – Dissection). Calculations based on 5x5 rectangular analysis window.
Landform	Unfilled DEM used to evaluate surface texture, identifying landscape concavities and convexities (ArcGIS 10.6.1 – Geomorphometry and Gradient Metrics Toolbox 2.0 – Surface Detection – Landform). Calculations based on 5x5 rectangular analysis window.
Modeled Streams	Flow directions calculated from filled DEM used to model streams (SCALGO Hydrology 1.4 – Stream Segmentation). Calculations based on a threshold of 5,000.

models (DEMs) that finely characterize the earth's surface (Table 1). To provide an optimal balance of detail and processing efficiency in subsequent modeling, all DEMs were produced with 1-m resolution.

The DEM for each LiDAR collection was then used to develop a series of derivative layers useful to mapping potential erosive features, including flow models, surface textures, and modeled streams (Table 1). These layers help visualize complex topographies and the stream networks that cross them. In particular, the dissection and landform layers show breaks in landscape texture that could be forest roads or other anthropogenic alterations (Figure 2). During

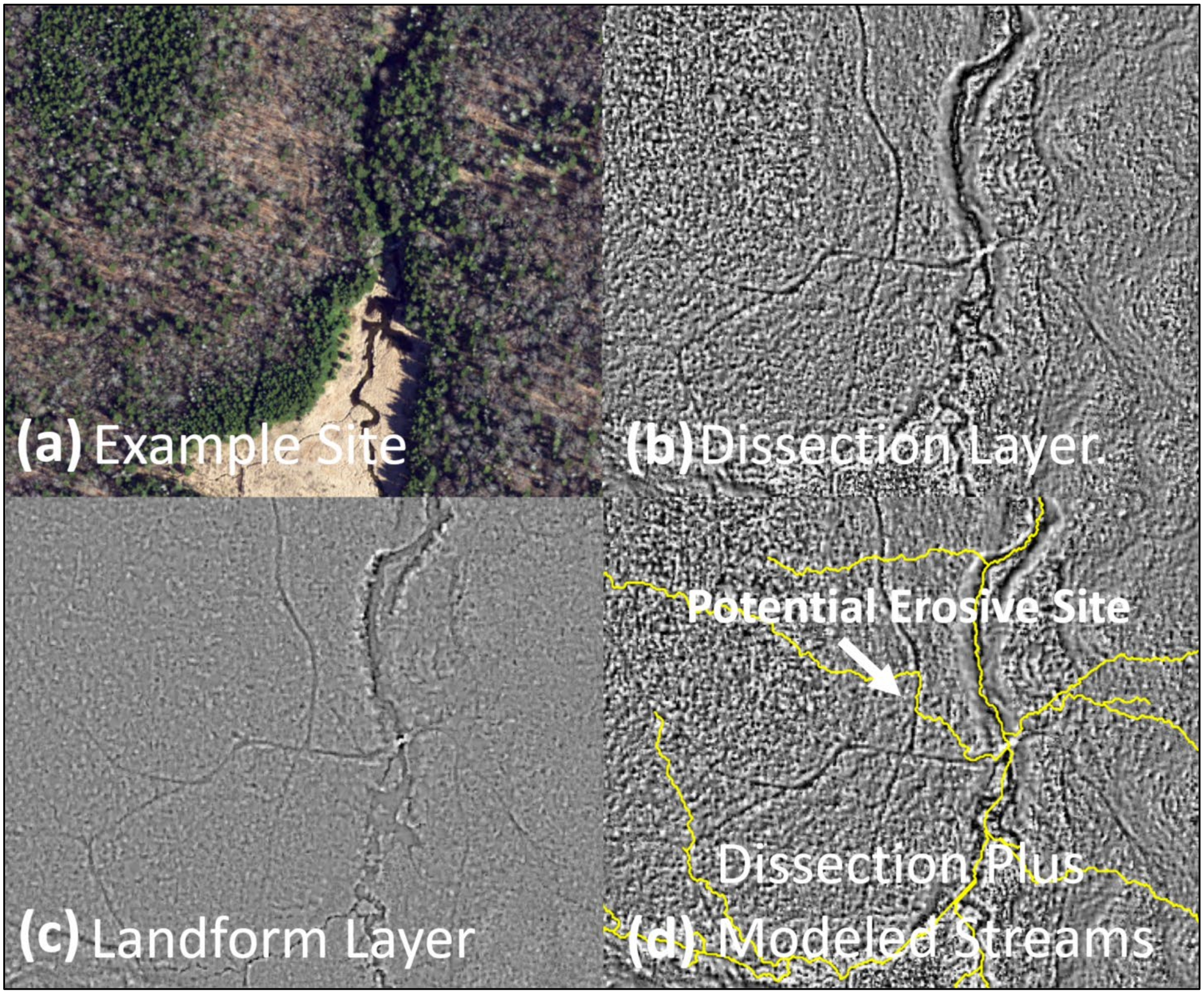

Figure 2. Visualization of LiDAR-derived surface textures that facilitate forest-roads mapping. At a mostly-forested site with a mix of deciduous and coniferous cover (a), the dissection (b) and landform (c) layers highlight old forest roads or paths not visible in aerial imagery. Subsequent modeling steps will focus on identification of roads that coincide with high-volume streams that could facilitate erosion.

the subsequent modeling phase of this project, a primary goal was to identify and evaluate sites where these breaks coincide with potentially erosive stream flows. Other datasets useful to landscape characterization were also obtained during this stage, including the 2016 Statewide Vermont Land Cover Dataset previously developed by the UVM SAL (https://vcgi.vermont.gov/data-release/statewide-high-resolution-vermont-land-cover-data-nowavailable) and leaf-off orthoimagery (https://vcgi.vermont.gov/data-and-programs/imagery-program).

Task 1.3 – Request Information from Key Experts

After reviewing the statewide LiDAR coverage and the mapping workflow previously developed by MacFaden et al. (2017), the UVM SAL determined that all input datasets and modeling parameters were available for the Champlain and Memphremagog Basins. No additional information was necessary for data processing or subsequent modeling.

Task 1.4 – Review Data for Accuracy, Completeness, Data Gaps Analysis

No data gaps were identified during final review of the LiDAR-derived topographic layers and stream models. Complete coverage exists for not only the Champlain and Memphremagog Basins but also for the entire state of Vermont. All DEMs and derivative products listed in Table 1 were submitted to Phillip Jones of VT DEC in July 2021, via external hard drive.

TASK 2 – IDENTIFICATION OF POTENTIALLY-EROSIVE FEATURES

Task 2.1 – Additional Data Preparation

In consultation with WCA and VT DEC, the UVM SAL also produced a "Distance to Water" raster that could later be used to provide each modeled, potentially-erosive feature with an attribute describing its proximity to surface waters. This layer was created by using the 10-m USGS National Elevation Dataset (NED) in combination with water features from the Vermont Hydrography Dataset (VHD) and the 2016 Statewide Vermont Land Cover Dataset to estimate, anywhere in the state of Vermont, the distance to the nearest stream, river, or open water body. The final Distance to Water raster was submitted to VT DEC on the same external hard drive containing the LiDAR derivatives. For completeness, also submitted were publicly-available statewide datasets used either in data preparation or modeling: Vermont Land Cover Dataset (2016); Vermont Impervious Surfaces (2016); Vermont Soil Survey Geographic Database (SSURGO); Vermont Hydrography Dataset (VHD).

Task 2.2 – Erosion Risk Mapping

The UVM SAL adapted the existing modeling approach (MacFaden et al. 2017) for use with the Lake Champlain and Memphremagog Basins, developing draft output for the 8 LiDAR collections covering the study area during September and October 2020. The compiled output was then submitted to WCA for use in field verification.

Task 2.3 – Mapping Accuracy Assessment via Field Verification

With the assistance of the Vermont Youth Conservation Corps, Watershed Consulting Associates conducted targeted site visits during period October-December 2020. At each of the 21 sites, the features highlighted by the draft erosion map were examined for signs of erosion, active water flow, and best management practices. This information was compiled into site-specific data sheets with accompanying photographs.

Task 2.4 – Refinement of Methodology

After receiving the completed field data in January 2021, the UVM SAL evaluated the degree of correspondence between the modeled features and their actual site characteristics. Overall, the field data compared favorably to the modeled sites, with 18 of 21 locations showing similar perceived erosion risk. No obvious causes were apparent for the discrepancies observed with the remaining 3 locations; the UVM SAL concluded that random variability in the modeled risk parameter (a combination of Stream Power Index, Area, Gully Depth, and soils survey-derived Soil Erodibility) was the likely reason for the lack of correspondence at these sites. In subsequent model refinements, the UVM SAL eliminated errors caused by overlapping LiDAR sections and improved discrimination of features in suburban and urban areas, avoiding inclusion of features outside of predominantly-forested settings. New routines to eliminate spurious features (e.g., drainage ditches) adjacent to engineered roads were also included.

Task 2.5 – Field Analysis of Confidence of Mapping

Watershed Consulting Associates performed a second round of field visits in April 2021, visiting 14 sites. As with the earlier set of sites, the field data generally corresponded well to the draft modeling with observed discrepancies mostly a function of random variability in the estimated risk parameter.

Task 2.6 – Prioritization of Areas for AMPs

For the final data deliverable, the refined modeling workflow was reapplied to the entirety of the Lake Champlain and Memphremagog Basins, producing a revised set of potentially-erosive features. To avoid the issues of interpretability observed previously with the modeled risk parameter, no risk labels (e.g., High, Moderate, Low) were assigned to the final set. Instead, each feature was exported with an expanded set of estimated physical characteristics that will facilitate subsequent analysis by stakeholders: Area (m^2), Depth (m); Volume (m^3), Mean Slope (percent), Mean Flow Accumulation (number of upstream pixels draining to individual pixels), Mean Stream Power Index (SPI), Soil Erodibility (K Factor, as derived from SSURGO soils survey), and Distance to Water (m). In addition, the Mean SPI at each site was evaluated at the basin and sub-basin scales, noting all features that fall within in the 50, 75, 95, and 99th percentiles (Figure 3). The final dataset with full attribution and metadata was delivered to VT DEC on June 30, 2021.

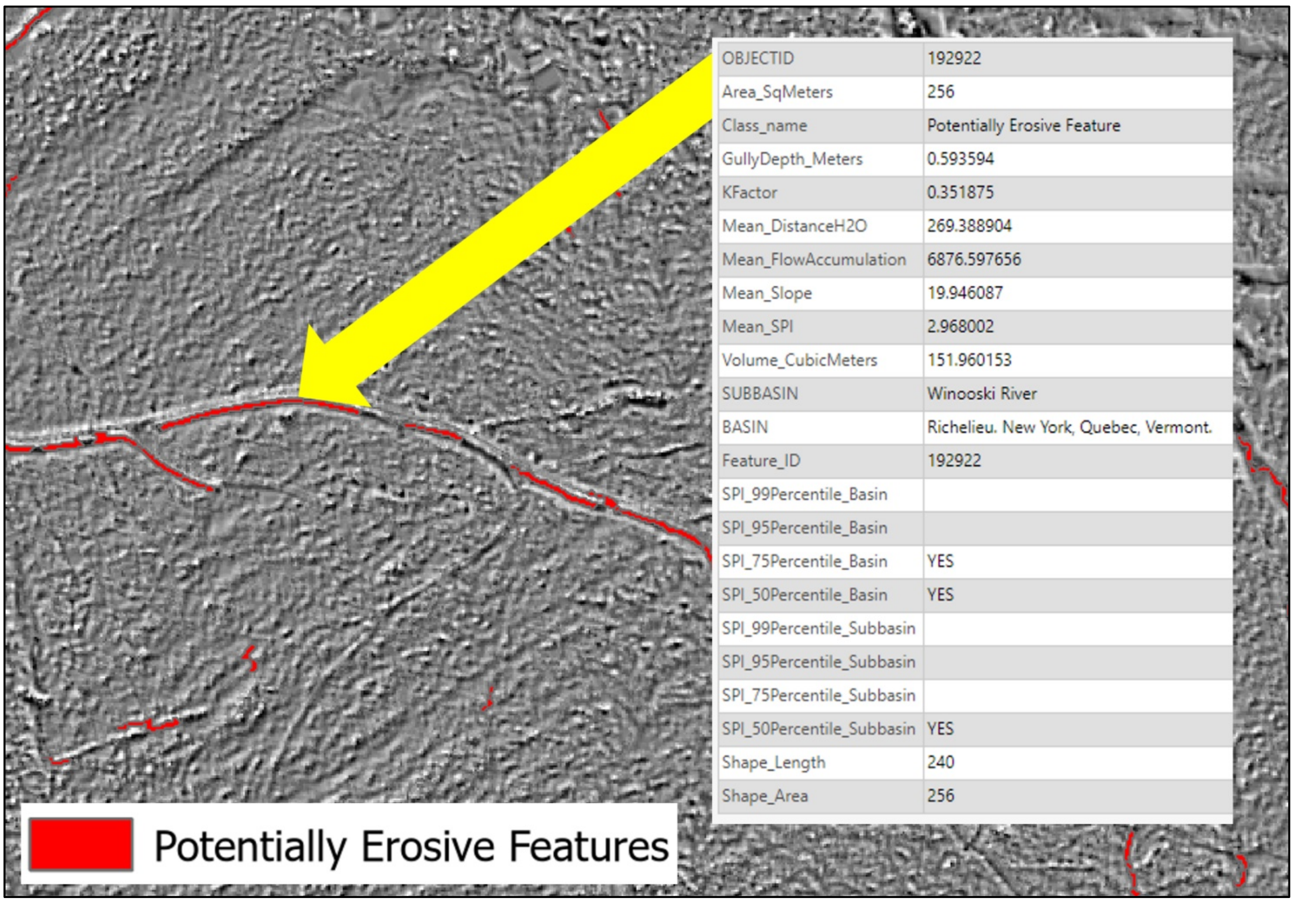

Figure 3. An example of a potentially-erosive feature identified by LiDAR-based modeling. In the final modeled dataset, each site was attributed with a suite of physical characteristics (e.g., estimated depth, slope) plus percentile labels calculated for Mean Stream Power Index (SPI) at the basin and sub-basin scales.

CONCLUSIONS

This LiDAR-based modeling effort produced a comprehensive dataset of potentially-erosive features across the Champlain and Memphremagog basins. In total, more than 450,000 features were identified, with 4,524 falling in the 99th percentile for SPI at the basin scale and 22,617 in the 95th percentile. Undoubtedly, this number contains some proportion of false positives, features that are gullies, swales, or other landform breaks with adequate flow potential but whose ground cover is vegetated or otherwise non-erosive. Some of these false positives may be anthropogenic in origin that were not created by forest-management activities, such as old roads, trails, or agricultural ditches in areas that have reverted to forest. Others may be the legacy of decades-old forest management: remnant skid paths, tote roads, or log landings. Still others may be naturally-occurring features that are difficult to discriminate from anthropogenic features, such as intermittent drainages and actual stream courses. The modeling workflow used for this project included routines for differentiating anthropogenic, potentially-erosive sites from natural features but in some instances their topographic profiles were too similar to provide effective discrimination. Indeed, some eroded sites become streams during significant runoff events, making them indistinguishable from natural water courses. Nonetheless, the sites identified by the methods described here provide an important framework for landscape-level analysis of eroded features in forested settings, as well as a starting point for field-based verification and potential mitigation. The high spatial resolution of the data combined with their rich site-specific attribution will permit end-users to query and display features as individual goals dictate, and the data can also be used in conjunction with other GIS datasets (e.g., forest stands, management zones, recreational trails) to filter the full collection of sites into meaningful subsets of interest. Future modeling work should focus on identification of additional LiDAR-derived topographic variables that refine feature discrimination and importance ranking.

REFERENCES

MacFaden, S., A. Marcucci, J. O'Neil-Dunne, and M. Nealon. 2017. Pilot project using existing LiDAR to identify and map forest roads, trails, and log landings on private forests in Vermont: Final report submitted to the Natural Resources Conservation Service.

APPENDIX A – Metadata Accompanying Final GIS Dataset of Potentially Erosive Sites

ITEM DESCRIPTION

Title: Potentially Erosive Sites in Predominantly Forested Settings, Identified by LiDAR-based Modeling, Champlain and Memphremagog Basins, Vermont, Final Dataset, June 30, 2021
Abstract: Runoff from logging roads, skid paths, and other features associated with forest management can contribute to phosphorus pollution in downstream water bodies. In Vermont, however, the magnitude of this problem is unknown. This dataset helps address the existing information gap by identifying potentially erosive sites in predominantly forested settings. It is based on a pilot project conducted by MacFaden et al. (2017) for parts of Addison County, which used high-resolution LiDAR to examine landscape features with topographic characteristics suggestive of erosive gullies (i.e., linear concavities with sufficient flow potential). The methodology for Addison County was extended to the full Vermont extent of the Champlain and Memphremagog Basins and modified to better discriminate actual forestland features from urban\suburban gullies or roadside ditches. A total of 452,306 features were identified across the two basins. Unlike the pilot project, no attempt was made to categorize risk in the new, larger dataset; instead, sites with Stream Power Index (SPI) values in the 50, 75, 95, and 99th percentiles were identified at the basin and sub-basin scales. Also, a suite of variables estimated for each site (SPI, Gully Depth, Area, Volume, Soil K Factor, Flow Accumulation, Slope, and Distance to Water) was exported with the polygon data, permitting subsequent, focused analysis of features by project stakeholders. Part or all of 8 LiDAR datasets, acquired during the period 2013-2017, were used in this modeling effort. References: MacFaden, S., A. Marcucci, J. O'Neil-Dunne, and M. Nealon. 2017. Pilot project using existing LiDAR to identify and map forest roads, trails, and log lands on private forests in Vermont: Final report submitted to the Natural Resources Conservation Service.

Purpose: This dataset is intended to help identify and address potentially erosive sites in forested settings that could contribute to phosphorus pollution in the Lake Champlain and Lake Memphremagog Basins, Vermont.

Progress: Complete

Update: None planned

TOPICS & KEYWORDS

Theme Keywords: erosion, forest management, LiDAR, topographic modeling, environment

Place Keywords: Champlain Basin, Memphremagog Basin, Vermont

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Data Credit: University of Vermont Spatial Analysis Laboratory

LINEAGE

Lineage Statement: Using the 8 most-recent LiDAR collections encompassing the Vermont portion of the Champlain and Memphremagog Basins, potentially erosive sites in predominantly forested areas were identified using topographic modeling. In a series of preliminary steps, the original LiDAR point clouds were used to create high-resolution digital elevation models (DEMs). These DEMs were in turn used to create two surface-texture models useful in terrain analysis: Dissection (breaks in otherwise continuous topography) and Landform (concavities and convexities). For use in flow modeling, the original DEMs were also filled to avoid "holes" that would interrupt stream mapping. The filled DEMs in turn were used to calculate flow accumulation and to model stream locations.

Following data preparation, all modeling was performed in eCognition using object-based image analysis techniques. First, existing land-cover data for Vermont were used to identify predominantly forested areas where timber management is being practiced or was practiced in the past. Potentially-eroded sections of skid paths, tote roads, and other anthropogenic features were then extracted from the Dissolution and Landform layers to create an initial set of candidate features. This set was refined by eliminating non-linear features unlikely to be related to forest management (e.g., natural depressions), and sites more likely to be permanent streams rather than anthropogenic features were also eliminated. All modeling was performed at a resolution of 1 meter. Prior to export, a suite of variables describing physical characteristics, soil erodibility, and flow potential was calculated and assigned to each identified site.

Following export from eCognition, the output was compiled in ArcPro 2.8. Rather than perform an approximate risk assessment, sites with the highest Stream Power Index (SPI) values were grouped into 50, 75, 95, and 99th percentiles at the basin and sub-basin scales.

Process Step 1 (2020-09-18): Data Preparation. During a series of preparatory steps, the original LiDAR point clouds were used to create high-resolution digital elevation models (DEMs). These DEMs were in turn used to create two surface-texture models useful in terrain analysis: Dissection (breaks in otherwise continuous topography) and Landform (concavities and convexities). For use in flow modeling, the original DEMs were also filled to avoid "holes" that would interrupt stream mapping. The filled DEMs in turn were used to calculate flow accumulation and to model stream locations.

Process Step 2 (2021-06-15): Erosive Site Modeling, Part 1 (Preliminary Steps). In eCognition, predominantly forested areas were identified using the 2016 Statewide Vermont Land Cover Dataset. Also, urban and suburban areas were removed from consideration.

Process Step 3 (2021-06-15): Erosive Site Modeling, Part 2 (Feature Identification and Refinement). In eCognition, candidate features were identified by examining breaks in continuous topography (Dissection layer) and also landscape concavities (Landform layer). The initial candidate set was then refined by removing features that significantly overlapped with modeled streams, suggesting that the modeled sections were actually streambeds rather than anthropogenic features. Features with very low flow potential, indicating a correspondingly low erosion potential, were also removed.

Process Step 4 (2021-06-15): Erosive Site Modeling, Part 3 (Feature Attribution). In eCognition, the final set of potentially-erosive features were attributed with variables that will assist further evaluation: Area, Depth, Volume, Stream Power Index (SPI), Flow Accumulation, Slope, Soil Erodibility (SSURGO K Factor), and Distance to Water.

Process Step 5 (2021-06-29): Post-processing. All modeling in eCognition was performed on 1,400x1,400-pixel tiles. After these tiles were exported as individual vector tiles (shapefiles), they were merged in ArcPro 2.8 to create a single, comprehensive dataset in geodatabase format. A spatial join was then performed to add basin and sub-basin identifiers, from the Vermont Watershed and Subwatershed Hydrologic Unit Boundaries, to each feature. To facilitate subsequent evaluation, Stream Power Index (SPI) values at the 50, 75, 95, and 99th percentiles were calculated, in Excel, by basin and sub-basin and this information was then joined with the original features to create binary attribute fields for the percentiles (i.e., "YES" indicates that a feature's SPI value is within the 50, 75, 95, or 95th percentiles; a blank entry indicates the SPI value is outside of the percentile thresholds).

DATA SOURCES

Data Source 1: LiDAR Point Clouds, 2013-2017, 0.7-m Resolution. These point-cloud datasets were collection in 8 sections: Addison (2017); Bennington (2017); Connecticut River (2017); Eastern Vermont (2014); Franklin (2017); Grand Isle (2014); Mad River (2013); and Rutland (2013). Source: Vermont Center for Geographic Information (VCGI).

Data Source 2: Digital Elevation Models (DEMs), Original, 2013-2017, 0.7-m Resolution. For each of the 8 LiDAR point clouds necessary to cover the Champlain and Memphremagog Basin, DEMs were created by filtering first returns in LASTools and exported as a raster surface. Source: University of Vermont Spatial Analysis Laboratory.
Data Source 3: Digital Elevation Models (DEMs), Filled, 2013-2017, 0.7-m Resolution. The original DEMs were modified by identifying (SCALGO Topology 1.5 - Depression Identification) and filling depressions (SCALGO Topology 1.5 - Depression Filling) that would interrupt stream modeling. Source: University of Vermont Spatial Analysis Laboratory.

Data Source 4: Flow Accumulation Models. The filled DEMs for each LiDAR collection were used to calculate flow directions (SCALGO Hydrology 1.4 – Flow Directions) and in turn flow directions were used to calculate flow accumulation (SCALGO Hydrology 1.4 – Flow Accumulation). Source: University of Vermont Spatial Analysis Laboratory.

Data Source 5: Dissection Models. Unfilled DEMs were used to evaluate surface texture, identifying breaks in otherwise continuous topography (ArcGIS 10.6.1 – Geomorphometry and

Gradient Metrics Toolbox 2.0 – Surface Detection – Dissection). These calculations based on a 5x5 rectangular analysis window. Source: University of Vermont Spatial Analysis Laboratory.

Data Source 6: Landform Models. Unfilled DEMs were used to evaluate surface texture, identifying landscape concavities and convexities (ArcGIS 10.6.1 – Geomorphometry and Gradient Metrics Toolbox 2.0 – Surface Detection – Landform). These calculations based on a 5x5 rectangular analysis window. Source: University of Vermont Spatial Analysis Laboratory.

Data Source 7: Modeled Streams. Flow directions calculated from the filled DEMs were used to model streams (SCALGO Hydrology 1.4 – Stream Segmentation). These calculations were based on a threshold of 5,000. Source: University of Vermont Spatial Analysis Laboratory.

Data Source 8: Statewide High-resolution Vermont Land Cover Data, 1-m Resolution. Source: Vermont Center for Geographic Information.

Data Source 9: Vermont Soil Survey Geographic Database (SSURGO). Digital soil map for Vermont. Source: USDA Natural Resources Conservation Service.

Data Source 10: Distance to Water Model, 10-m Resolution. This dataset was created by using the 10-m USGS National Elevation Dataset (NED) in combination with water features from the Vermont Hydrography Dataset (VHD) and the 2016 Statewide Vermont Land Cover Dataset to estimate, anywhere in the state of Vermont, the distance to the nearest stream, river, or open water body. Source: University of Vermont Spatial Analysis Laboratory.

Data Source 11: Vermont Watershed and Subwatershed Hydrologic Unit Boundaries. Source: USDA Natural Resources Conservation Service.

COORDINATE REFERENCE SYSTEM

Coordinate Reference System: NAD 1983 State Plane Meters Vermont FIPS 4400

FIELDS

Field 1: OBJECTID. Internal feature number. Esri Sequential unique whole numbers that are automatically generated.

Field 2: Shape. Feature geometry. Esri. Coordinates defining the features.

Field 3: Area_SqMeters. Feature area in square meters. University of Vermont Spatial Analysis Laboratory.

Field 4: Class_name. Descriptive label for identified features. After all low-potential features were removed, all remaining features were labeled "Potentially Erosive Feature." University of Vermont Spatial Analysis Laboratory.

Field 5: GullyDepth_Meters. Feature depth in meters. University of Vermont Spatial Analysis Laboratory.

Field 6: KFactor. Soil erodibility factor as derived from the Vermont SSURGO dataset. University of Vermont Spatial Analysis Laboratory.

Field 7: Mean_DistanceH2O. Mean distance to water in meters, as derived from 30-meter statewide Distance to Water layer. University of Vermont Spatial Analysis Laboratory.

Field 8: Mean_FlowAccumulation. Mean flow accumulation, as calculated from DEM-derived Flow Accumulation layer. For each pixel, this value indicates the number of upstream pixels that contribute flow to it. University of Vermont Spatial Analysis Laboratory.

Field 9: Mean_Slope. Mean percent slope, calculated in eCognition from the filled DEM. University of Vermont Spatial Analysis Laboratory.

Field 10: Mean_SPI. Mean Stream Power Index (SPI). This index was calculated in eCognition using the formula: ln((Flow Accumulation+0.001)*((Slope From Filled DEM/100)+0.001)). Index values indicate erosion potential (low to high). University of Vermont Spatial Analysis Laboratory.

Field 11: Volume_CubicMeters. Feature volume in cubic meters. University of Vermont Spatial Analysis Laboratory.

Field 12: SUBBASIN. The watershed in which a feature occurs, at the sub-basin level (HUC8), as derived from the USDA NRCS Vermont Watershed and Subwatershed Hydrologic Unit Boundaries. University of Vermont Spatial Analysis Laboratory.

Field 13: BASIN. The watershed in which a feature occurs, at the basin level (HUC6), as derived from the USDA NRCS Vermont Watershed and Subwatershed Hydrologic Unit Boundaries. University of Vermont Spatial Analysis Laboratory.

Field 14: Feature_ID. Unique numeric identifier assigned to each feature. University of Vermont Spatial Analysis Laboratory.

Field 15: SPI_99Percentile_Basin. Label indicating whether a feature's mean Stream Power Index (SPI) value occurs within the 99th percentile, at the basin level (HUC6). "YES" indicates the SPI value is in the 99th percentile; a blank entry indicates the value is below the 99th percentile. In combination with the BASIN field, this field can be used to identify the features in each basin that have the highest comparative SPI values. University of Vermont Spatial Analysis Laboratory.

Field 16: SPI_95Percentile_Basin. Label indicating whether a feature's mean Stream Power Index (SPI) value occurs within the 95th percentile, at the basin level (HUC6). "YES" indicates the SPI value is in the 95th percentile; a blank entry indicates the value is below the 95th percentile. In combination with the BASIN field, this field can be used to identify the features in each basin that have the highest comparative SPI values. University of Vermont Spatial Analysis Laboratory.

Field 17: SPI_75Percentile_Basin. Label indicating whether a feature's mean Stream Power Index (SPI) value occurs within the 75th percentile, at the basin level (HUC6). "YES" indicates the SPI value is in the 75th percentile; a blank entry indicates the value is below the 75th percentile. In combination with the BASIN field, this field can be used to identify the features in each basin that have the highest comparative SPI values. University of Vermont Spatial Analysis Laboratory.

Field 18: SPI_50Percentile_Basin. Label indicating whether a feature's mean Stream Power Index (SPI) value occurs within the 50th percentile, at the basin level (HUC6). "YES" indicates the SPI value is in the 50th percentile; a blank entry indicates the value is below the 50th percentile. In combination with the BASIN field, this field can be used to identify the features in each basin that have the highest comparative SPI values. University of Vermont Spatial Analysis Laboratory.

Field 19: SPI_99Percentile_Subbasin. Label indicating whether a feature's mean Stream Power Index (SPI) value occurs within the 99th percentile, at the sub-basin level (HUC8). "YES" indicates the SPI value is in the 99th percentile; a blank entry indicates the value is below the 99th percentile. In combination with the SUBBASIN field, this field can be used to identify the features in each sub-basin that have the highest comparative SPI values. University of Vermont Spatial Analysis Laboratory.

Field 20: SPI_95Percentile_Subbasin. Label indicating whether a feature's mean Stream Power Index (SPI) value occurs within the 95th percentile, at the sub-basin level (HUC8). "YES" indicates the SPI value is in the 95th percentile; a blank entry indicates the value is below the 95th percentile. In combination with the SUBBASIN field, this field can be used to identify the features in each sub-basin that have the highest comparative SPI values. University of Vermont Spatial Analysis Laboratory.

Field 21: SPI_75Percentile_Subbasin. Label indicating whether a feature's mean Stream Power Index (SPI) value occurs within the 75th percentile, at the sub-basin level (HUC8). "YES" indicates the SPI value is in the 75th percentile; a blank entry indicates the value is below the 75th percentile. In combination with the SUBBASIN field, this field can be used to identify the features in each sub-basin that have the highest comparative SPI values. University of Vermont Spatial Analysis Laboratory.

Field 22: SPI_50Percentile_Subbasin. Label indicating whether a feature's mean Stream Power Index (SPI) value occurs within the 50th percentile, at the sub-basin level (HUC8). "YES" indicates the SPI value is in the 50th percentile; a blank entry indicates the value is below the 50th percentile. In combination with the SUBBASIN field, this field can be used to identify the features in each sub-basin that have the highest comparative SPI values. University of Vermont Spatial Analysis Laboratory.

Field 23: Shape_Length. Length of feature in internal units. Esri. Positive real numbers that are automatically generated.

Field 24: Shape_Area. Area of feature in internal units squared. Esri. Positive real numbers that are automatically generated.

METADATA

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FGDC Content Standard for Digital Geospatial Metadata
FGDC-STD-001-1998