VT State LiDAR Plan

Version 2.0

Introduction

The 2011 flooding and destruction from Tropical Storm Irene emphasized the impact of having an inadequate statewide digital elevation model in Vermont. Following TS Irene FEMA recommended Vermont to acquire a high-resolution elevation model in order to support future hazard mitigation efforts. The emergency and public safety community and a broad range of other critical state interests have identified significant needs for a statewide high resolution digital elevation model (DEM).

Airborne Light Detection and Ranging (LiDAR) technology is currently the recommended method for acquiring high accuracy elevation data sufficient for those purposes. Other states have routinely collected LiDAR with several already having statewide coverage (VA, PA, MD, IA, LA and NC) while others such as OR, NH, TN, KY, OH and FL have funded acquisition plans. All 50 states have some LiDAR data coverage in their state although it is mostly limited to local regions.

Vermont currently has 63% state LiDAR coverage to support high resolution elevation data needs with 9.25-18.5cm vertical accuracy and surface contours of 1 – 2ft. These accuracy levels reflect quality levels “QL2” and “QL3” as defined by the National Digital Elevation Program (NDEP). All future data development efforts should be at the “QL2” accuracy threshold.

Objective

The objective of this plan is to establish an approach and determine actions for acquiring statewide LiDAR data and derivative products that are of sufficient design, accuracy, consistency, coverage and resolution to meet the business needs of the broadest possible user community in the state.

Cost

The cost to acquire “no data” areas, store and distribute LiDAR and derivative products for the state according to the specifications that would be most useful to the community is estimated to be **approximately** $732,000 under current conditions. A three year phased approach, as outlined in ***Attachment B: Current Extent of Available LiDAR*** affords contributing entities the ability to budget in advance and ensures a broader coalition. Coverage priorities were assigned by weighting the need and size of population served for lake shore protection, flood plain mapping and emergency management and public safety efforts.

Table 1: Remaining Statewide LiDAR Acquisition Cost Estimate - 1 year				
Description[1]	**Area_SqMi**	**Cost_SqMi**	**Total Cost**	**Minimum Required State Match (50%)**[2]
Data Acquisition (No Data Areas)	2,186	$335	$732,310	$366,155
Data Acquisition (Out of Date Areas)	672	$335	$225,120	$112,560
Total	2,858		$957,430	$478,715

[1] See map below for options

[2] 50% is minimum match required for the USGS Broad Agency Announcement Funding Grant Opportunity.

Table 2: Remaining Statewide LiDAR Acquisition Cost Estimate - 3 Years				
Description	**Area_ SqMi**	**Cost_ SqMi**	**Total Cost**	**Minimum Required State Match (50%)**
Proposed Coverage 2016 Acquisition (Option 1)	1025	$335	$343,375	$171,687
Proposed Coverage 2017 Acquisition (Option 2)	1161	$335	$388,935	$194,468
Proposed Coverage 2017 Acquisition (Option 3)	672	$335	$225,120	$112,640
Total	2,858		$957,430	$478,715

The cost of statewide LiDAR is primarily dependent upon the product specifications (i.e. accuracy, post spacing), the types of derivative products that are requested (i.e. contours, hydro-enforced DEM), and the size of the project. Cost and accuracy are further determined in Vermont by the terrain and tree cover of the collection area. Utilizing the NDEP "QL2" product specification on all future projects will ensure alignment and consistency with current projects at a horizontal point spacing of 0.7m and vertical accuracy of 9.25cm.

The "raw" LiDAR elevation point data consists of millions (possibly billions) of points and is of relatively limited use to the community without the derivative products that are created from that data. The vast majority of agencies, towns, organizations and businesses that need LiDAR data require the derivative products to do the work they want to do.

Historically, there have been partnerships of funding organizations that have come together to provide the necessary funding for regional LiDAR acquisition projects in the state. Past funding sources for regional LiDAR projects have been FEMA, USGS, USDA, VTrans, ANR, LCBP, CCRPC and MPO, This model of partnership funding will almost certainly continue. However, none of the partners listed has the funding to be the primary contributor to a project of this size. If a primary funding contributor can be established, history has shown other partners will come forward to provide additional funding.

<u>LiDAR Description</u> (excerpted from USGS)

Light Detection and Ranging (LIDAR) is a technology similar to RADAR that can be used to create high-resolution digital elevation models (DEMs) with vertical accuracy as good as 9 cm. LIDAR equipment, which includes a laser scanner, a Global Positioning System (GPS), and an Inertial Navigation System (INS), is generally mounted on a small aircraft. The laser scanner transmits brief laser pulses to the ground surface, from which they are reflected or scattered back to the laser scanner. Detecting the returning pulses, the equipment records the time that it took for them to go from the laser scanner to the ground and back. The distance between the laser scanner and the ground is then calculated based on the speed of light. While flying, the airplane's position is determined using GPS, and the direction of the laser pulses are determined using the INS. Because one laser pulse may reflect back from multiple surfaces, such as the top of a tree, a house, and the ground surface, there are multiple returns from each pulse that can be used to map such things as the top of the tree canopy, buildings, and the ground. Post-processing is used to differentiate between these multiple returns to determine the bare-earth surface. Using the combined information from the laser scanner, the GPS, and the INS, a very accurate DEM can be made from closely spaced (typically 1-2 per square meter) X, Y, Z coordinates.

LiDAR Use Cases

As high resolution digital elevation data has become available, critical uses for that information have grown significantly. A small sample of the potential uses of high resolution elevation data in the state are listed below.

- **Flood plain Mapping**
  - Update FIRM to DFIRM from LiDAR
  - Flow Analysis
  - Storm water analysis
- **Transportation Infrastructure**
  - Design
  - Construction
  - Repair
- **Archeology & Historic Preservation**
- **Solar and Wind Energy Suitability**
- **Dam Management**
- **Town Planning**
- **Soils Mapping**
- **Emergency Planning**
- **Line of Sight and Viewshed Analysis**
- **Forestry, Biomass, & Vegetation Management**
- **Habitat Analysis**
- **Shoreline Erosion**
- **Ice Jam Potential**
- **Timber Volume**
- **Energy/Communications Planning**
- **Fire Fuel Models**
- **Evacuation Planning**
- **Hazardous Spill Analysis**
- **Agriculture**
  - Storm Water Flow Mapping On Crop Land
  - Erosion Assessment and Mitigation
  - Gully Detection

- Riparian Buffer Mapping and Protection
- **Land Cover Mapping**
  - Landslide Potential
- **Farm-to-Plate Initiative**

A more extensive listing of use cases and their specific requirements is provided as Attachment A: VT Statewide LiDAR Use Cases

Specifications and Derivative Products

In order to be most useful to the widest community, while still remaining cost reasonable, statewide LiDAR should be collected to the same specifications as applied to the 2013 Rutland County/Otter Creek Subbasin LiDAR acquisition to provide as uniform and consistent a statewide coverage as possible. The final specifications as well as the number and types of derivative products will be determined by the needs of the community, available funding and the final acquisition plan. It is suggested that the following deliverables be included in the final product;

- Control and Reference Point Survey Report
- Processing Report
- Flight Plan with actual aircraft trajectories included.
- Intensity images.
- FGDC Compliant Metadata
- Final Tested Accuracy Report (Delineated by area for significant changes due to terrain and canopy)

- Raw LiDAR Point Data in latest LAS format (currently version 1.2) and the following NDEP Quality Level 2 (QL 2) specifications;
  - 0.7m Grid with an accuracy of 9.25 cm RMSE
  - An All Return Unclassified Point Cloud
  - An All Return Classified Point Cloud
    - Code 1 – Processed, but unclassified
    - Code 2 – Bare-earth ground
    - Code 7 – Noise (low or high, manually identified, if needed)
    - Code 9 – Water
    - Code 10 – Ignored Ground (Break line Proximity)
    - Code 13 - Hydro Enforced Ground Points (removed during hydro enforcement process
    - Code 17 – Overlap Default
    - Code 18 – Overlap Ground
    - Code 25 – Overlap Water

- Delivered Derivative Products are to include the following:

- Bare Earth DEM
- Hydro Enforced DEM with Breaklines (suitable for use in Hydraulic and Hydrologic (H&H) modeling).
- Hydro "flattened" DEM (removes "tinning" in water for cartographic and aesthetic purposes only)
- LiDAR generated 2ft. contours in both moderate and heavy relief

- Optional Derivative Products may include the following:
  - DEM with full breaklines (removes "tinning" on other surfaces, e.g., buildings)

Project Management

The LiDAR data and derivative product acquisition contract should be managed by a single state entity. However, the project support team composed of individuals from interested agencies and organizations created as a subcommittee of the state's Enterprise Geospatial Consortium should be maintained. This subcommittee will provide support and guidance as well as resolve any contracting questions. Any agency or entity that provides funding should provide a representative to the project team.

Data Storage and Delivery

The infrastructure necessary to support storage and data access requirements for statewide LiDAR and derivative products on the statewide scale is substantial and cannot be assumed without financial support. When the final product specifications and derivative products are determined there must be funding consideration adequate to meet the cost of establishing a long term LiDAR data storage and delivery capacity. In reading other state "after reports" one of the most prevalent lessons learned is not allocating enough time and resources to data storage and distribution. LiDAR and the derivative products represent Terabytes of data. The final delivered derivative products should be made available for download through VCGI's public data access portal in keeping with VCGI's statutory responsibilities to make geospatial data available.

Table 1. VCGI LiDAR Data Delivery Services						
Access Options	**Datasets***					**Description**
	DEM	***DSM***	***Contours***	***Source LAS files***	***Other Derivatives****	
External Drive Product	✓	✓	✓	✓	✓	All source and derived data. Future option w/NOAA to host LAS files online
Direct Download	✓	✓	✓		✓	Data for download
Map Services	✓***	✓	✓			1) DEM Hillshade; 2) Contours and Hillshade; 3) Contours. All cached.
Image Services	✓	✓			✓	Image services afford access to raster cell values/geo- processing. None cached.
VT Interactive Map Viewer	✓	✓	✓		✓	
* Where available; coverage is not currently statewide						
** Derivatives: Aspect, Normalized DSM (nDSM) and Slope rasters						
*** As Hillshade derived from DEM						
Note: Map and Image Services detailed in "Proposed Suite of LiDAR-based Web Services Created and Hosted by VCGI".						

Existing LiDAR coverage in the State

Existing LiDAR coverage exists within Vermont in Addison, Bennington, Essex and Rutland Counties, most of the Missisquoi subbasin and all of the Little River and Mad River watersheds. Refer to **Attachment B: Current Extent of Available LiDAR**. The data in those areas should be evaluated for acceptability and inclusion in the statewide elevation dataset. If these areas are found to meet the needs of the community, they may be eliminated from the acquisition request area, thereby providing a cost reduction to the project. Final project coverage area plans would ideally be delineated by watershed with consideration given to both stakeholder priorities and the most effective field data collection approach.

Recommendations

- This plan was collectively created by many of the interested agencies, organizations and academic entities in the state and should be used as the foundation for consideration of future funding for the statewide LiDAR collection in VT.
- The LiDAR sub-committee of the state Enterprise Geospatial Consortium (EGC) should be continued in order to provide leadership for this effort. The sub-committee should include non-EGC members from any other interested state or federal partner organization. The EGC sub-committee should focus on the following tasks;
    - Maintain and update this contracting plan as new details, technologies and cost drivers become available.
    - Maintain a final set of specific LiDAR specifications and derivative products to support funding estimate discussions
    - Maintain an accurate cost estimate recognizing new LiDAR data acquisitions in the state as they occur.
    - Maintain the Statement of Work that will support the acquisition of statewide LiDAR and derivative products from the recommendations above.
    - Provide advocacy materials and support for stakeholders in their efforts to raise LiDAR awareness and achieve funding support within their own organization.
    - Create recommended language for including the funding request in the state FY 2014 Capital Bill (or other recommended alternative funding means) and a strategy for acceptance and adoption of that language.

Acknowledgements

Contributions to the development of this plan came from representatives of the following agencies and organizations, all of whom would be willing to provide a more extensive explanation of how important LiDAR data is to their organization.

Vermont Center for Geographic Information
VT Agency of Transportation
Vermont Emergency Management
VT Agency of Natural Resources
VT Agency of Agriculture
VT Dept. of Public Service
VT Agency of Commerce and Community Development
University of VT – Spatial Analysis Laboratory
Lake Champlain Basin Program
VT Electric Power Company (VELCO)
VT Association of Planning and Development Agencies
VT Sustainable Jobs Fund
US Dept. of Agriculture
US Geological Survey
Federal Emergency Management Agency
US Environmental Protection Agency

Attachment A

VT Statewide LiDAR Use Cases	
Category	**Use Case**
Agriculture	Precision agriculture
Agriculture	Storm Water Flow Mapping on Crop Land
Agriculture	Erosion Assessment and Mitigation
Agriculture	Gully Detection
Agriculture	Riparian Buffer Mapping and Protection
Archeology	Archeological site identification
Cadastral	Height Modeling
Climate	Carbon Estimates
Communications	Cell phone tower placement analysis
Conservation	Erosion Studies
Conservation	Geomorphology
Conservation	Groundwater Resource Availability, Mgmt, Protection
Conservation	Invasive Species
Conservation	Land Conservation
Conservation	Riparian Buffers
Conservation	Impervious Surfaces & Storm Water analysis
Conservation	Shoreline Erosion
Conservation	Wetland Inventory\Analysis
Conservation	Wildlife Habitat Management and Protection
Emergency Management	Dam Failure Site Analysis and Planning
Emergency Management	Evacuation Planning
Emergency Management	FEMA applications
Emergency Management	Fire Prevention and Management, e.g., Fire Fuel Models
Emergency Management	Flood Prevention and Management Floodplain Mapping; update FIRM to DFIRM
Emergency Management	Hazardous Spill analysis, control and remediation
Emergency Management	Ice jam studies
Emergency Management	Landslide prone areas mapped
Emergency Management	Landslides
Emergency Management	Lake Champlain Shoreline Flooding
Emergency Management	Plume Modeling (VY)
Emergency Management	Slope Stability
Energy	Biomass/Woody Biomass fuel estimates
Energy	Energy/Communications Planning
Energy	Infrastructure Planning and Management
Energy	Solar Energy Site Suitability
Energy	Wind Energy Site Suitability
Geology	Bedrock Geology

Geology	Soil modeling
Geology	Geologic fault mapping
Geology	Surficial Geology
Geospatial Data	Improved ortho-rectification accuracy of aerial photos
Hydrology	Ditch/Depression, Improved Network Connectivity
Hydrology	Snow Pack and Water Runoff Modeling
Hydrology	Sub-watershed and Catchment Delineation
Municipal	Property valuation
Natural Resource Mngmnt	Enhanced Soil Surveys
Natural Resource Mngmnt	Enhanced/Updated Hydrography
Natural Resource Mngmnt	Forestry Uses & Management, e.g., biomass, timber volume, invasive species
Natural Resource Mngmnt	Habitat - Wildlife
Natural Resource Mngmnt	Headwater Stream Mapping
Natural Resource Mngmnt	Land Cover Mapping
Natural Resource Mngmnt	Timber Volume
Natural Resource Mngmnt	Water Quality Monitoring
Planning	3D Visualization: building extraction, change detection, building footprints
Planning	Building Footprints
Planning	Impervious Surfaces
Planning	Resort Planning - Viewsheds
Planning	Trail planning and design, maintenance
Planning	Urban Planning/Mapping
Planning - Land Use	Forest Type and Density
Planning - Land Use	Forest/Farmland Fragmentation
Planning - Land Use	Forest/Tree Canopy Analysis
Pollution Mitigation	Non-point source pollution analysis
Pollution Mitigation	Plume Modeling
Pollution Mitigation	Point source Pollution analysis
Renewable Energy	Assessment, Infrastructure & Siting
Security	Security Management, line-of-sight
Transportation	Bridge Scour Assessment
Transportation	Highway Design
Transportation	Identify old road alignments
Transportation	Transportation Planning
Utilities	Broadband Services: line-of-sight & viewshed analysis
Utilities	Electrical Transmission Reliability & Planning
Utilities	Federal Safety Compliance Verification
Utilities	Vegetation Management

Attachment B: Current Extent of Available LiDAR