Enhancing Flood Resiliency of Vermont State Lands

30 June 2015 FINAL DRAFT

Prepared under contract to

Vermont Forests, Parks & Recreation
Montpelier, Vermont

Prepared by:

Kristen L. Underwood, PG, MS Geosciences
South Mountain Research & Consulting
Bristol, Vermont

VERMONT FAMILY FORESTS

David Brynn, BS Forestry & MS Natural Resources Planning
Vermont Family Forests
Bristol, Vermont

Table of Contents

Appendices

Acknowledgements

This project was made possible through funding from the Lands and Facilities Trust Fund and the Vermont Housing & Conservation Board. Grant funds were administered by the Vermont Department of Forests, Parks and Recreation. The following Steering Committee members accompanied project personnel on site visits to selected State Lands, attended project meetings and interviews, and reviewed the final report:

Steering Committee

Mike Fraysier	VT Forests, Parks & Recreation *ANR Lands Director*	Montpelier
Shannon Pytlik	VTDEC Watershed Management Division: Rivers Program - *River Scientist*	Rutland
Marie Caduto	VTDEC Watershed Management Division: Monitoring, Assessment & Planning Program - *Watershed Coordinator*	Springfield
Justin Kenney	VTDEC Watershed Management Division: Ecosystem Restoration Program – *Green Infrastructure Coordinator*	Montpelier
Ethan Phelps	VT Forests, Parks & Recreation *Parks Regional Manager*	Springfield
Nate McKeen	VT Forests, Parks & Recreation *Forestry District Manager*	Springfield
Gary Sabourin	VT Forests, Parks & Recreation *Watershed Forester*	Montpelier
Tim Morton	VT Forests, Parks & Recreation *Stewardship Forester*	Springfield
Lisa Thornton	VT Forests, Parks & Recreation *State Lands Stewardship Forester*	Rutland
Robert Zaino	VT Fish & Wildlife Department – *Land Ecologist*	Barre

Executive Summary

Record flooding on Lake Champlain in the spring of 2011 and widespread damages sustained to Vermont's built infrastructure during Tropical Storm Irene in August 2011 motivated the Agency of Natural Resources (ANR) Lands Stewardship Team to request an evaluation of policies, plans and practices on state-owned lands with a goal to enhance flood resiliency. This report has been prepared by a Project Team consisting of Kristen L. Underwood, hydrogeologist (South Mountain Research & Consulting Services), and David Brynn, consulting forester (Vermont Family Forests).

Flood resilience is defined as "a community's capability to anticipate, prepare for, respond to, and recover from floods with minimum damage to social well-being, the economy, and the environment" (NRC, 2010).

State Lands are defined as those lands held on a fee-simple basis or in terms of non-fee interests (e.g., conservation easements) by one of three departments of the ANR that are represented on the State Lands Stewardship Team: Vermont Department of Forests, Parks, & Recreation; Vermont of Fish and Wildlife Department; and the Vermont Department of Environmental Conservation. State Lands management units make up nearly 8% of the Vermont land area and consist of a wide variety of unit types including state parks, state forests, wildlife management areas, boat/fishing access sites, riparian corridors, fish hatcheries, dams, telecommunications facilities, ski areas, working lands and flood control areas.

The majority (90%) of State Lands are located in forested headwater settings, which are particularly susceptible to generating runoff during storm events, given their topography and geologic setting. This inherent vulnerability to overland flow and soil erosion has been exacerbated by a legacy of land use modifications (deforestation, development of road and trail networks) most often pre-dating State acquisition of the lands. Natural vulnerabilities and legacy impacts have combined to create upland forests particularly sensitive to a rapidly changing climate.

In light of increasing storm frequency, intensity, persistence and magnitude, management for enhanced flood resiliency on State Lands will require greater emphasis on forest health and stewardship of forest ecosystem services, including water retention, infiltration and filtering.

Four management units in south-central Vermont were identified by the ANR Lands Stewardship Team for detailed evaluation during this project. These properties were selected by ANR with a goal that they would be generally representative of the range of conditions characterizing state-owned lands. These properties were also impacted by Tropical Storm Irene. Four management units in Rutland and Windsor Counties were identified, including two Wildlife Management Areas (WMAs), one state park and a state forest.

State Lands Management Unit	Acres	Towns
Camp Plymouth State Park	295	Plymouth
Tinmouth Channel WMA	1,261	Tinmouth
Coolidge State Forest	16,000	
- West		Killington, Mendon, Shrewsbury, Plymouth
- East		Woodstock, Bridgewater, Plymouth, Reading
Les Newell WMA	7,988	Barnard, Bridgewater, Killington, Stockbridge

Each of the selected State Lands was visited during the 2014 field season by the Project Team, accompanied by State Lands Stewardship staff. Through interviews and limited site inspections, as well as document review, a suite of plans, policies, and practices has been offered, in an adaptive management framework, to support forest health and enhanced flood resiliency on State Lands.

A basic Geographic Information Systems (GIS) analysis was performed to characterize the varying soil types and topographic settings on selected State Lands and classify these land areas in terms of their vulnerability to flooding and the enhanced generation of runoff and erosion in response to human landscape modifications and climate change. The mapping approach relies on remote-sensing resources available State-wide, and is practical, easily implemented, and consistent with existing Stewardship Team planning approaches. This "hydrologic lens" for long-range planning on State Lands recognizes those landscape settings with a natural vulnerability to generate runoff – namely, those land areas with steep slopes, shallow (or nonexistent) depths to bedrock or other permeability-limiting layer (e.g., hardpan), and soils with limited infiltration capacity. The proposed mapping approach is intended to help inform the designation of existing Long-Range Management Plan land use classifications, and to "red flag" those lands areas that are more sensitive from a hydrologic standpoint.

Camp Plymouth State Park was chosen to illustrate the mapping approach, wherein lands were classified as *Hydrologic Reserve Zones*, *Hydrologic Conservation Zones*, or *Other Lands*. A *River Corridor* layer was then mapped as an overlay to the full area, following existing guidance from ANR. With respect to climate change and flooding, the *Hydrologic Reserve Zone* and the *River Corridor* are composed of land units that have very limited adaptive capacity. *Hydrologic Conservation Zone* lands have low to moderate adaptive capacity, and *Other Lands* have moderate to good adaptive capacity.

Proposed conservation targets were offered for the four hydrologic resource zones with respect to access networks, including truck roads, forwarding paths, skid trails, and log landings. Collectively, these conservation targets represent actions to remove or reduce the degree of hydrologic modification on State Lands and to disconnect sources of concentrated runoff and sediment from the stream network. More stringent standards for access networks are proposed in those land areas that are most sensitive (i.e., *River Corridor* and *Hydrologic Reserve Zone*) due to steepness of slopes, presence of limited soil infiltration capacity, and proximity to the stream network. Performance in meeting these conservation targets should be measured through regular monitoring efforts.

Several of the proposed conservation measures are already being implemented on State Lands. The mapping approach and proposed conservation targets could be further evaluated and refined in a series of pilot tests implemented by Stewardship staff on a subset of State Lands across the state. Pilot testing would provide an opportunity to address concerns raised by the project Steering Committee that selected State Lands may not adequately represent the diversity of soil types, topographic settings and land covers on State Lands as a whole.

Optimal Conservation Practices (OCPs) were proposed for development to enhance both flood resiliency and water quality in forested headwaters. To date, the primary mechanism for ensuring protection of water resources on State Lands has been the *Acceptable Management Practices for Maintaining Water Quality on Logging Jobs* in Vermont (AMPs). AMPs are designed primarily with the objective of maintaining water quality and reducing the likelihood for direct discharges during historic storm conditions. They are not designed to enhance flood resiliency specifically, or to address more extreme storm conditions experienced with greater frequency in recent years and anticipated in coming decades. Through OCPs, greater protection measures would be applied to those land areas most vulnerable to generating runoff.

Priorities were outlined for addressing legacy impacts by hydrologic resource zone, including down-sizing or re-wilding underused road segments in vulnerable settings, and disconnecting road ditches from stream channels using turn-outs, infiltration basins, or settling ponds.

Inventories of built infrastructure should be undertaken or formalized for each State Land management unit to inform hazard planning, capital budgeting, and flood resiliency planning. It is important to know the position and condition of this infrastructure with respect to the hydrologic resource zones to understand the degree that infrastructure may enhance the sensitivity of the landscape to flooding, so that adequate adaptation actions can be undertaken. Similarly, this mapping process can identify infrastructure at risk from flooding, so that appropriate mitigative actions can be prioritized. Identification of structures on a commonly-available GIS platform and database (e.g., Vermont Natural Resources Atlas platform) can increase networking opportunities with private groups and public agencies to leverage additional funding sources for upgrades, retrofitting, or decommissioning. An example inventory was completed for a subset of the road and trail network at Camp Plymouth State Park.

Implementation of flood resiliency measures will be accelerated through collaboration with other stakeholders. Often projects implemented for other purposes can have overlapping benefits for flood resiliency, opening up other avenues for technical and financial resources to accomplish flood resiliency objectives. Our collective investment in plans, policies and practices to enhance flood resiliency on State Lands will realize greater returns in avoided loss of life, reduced flood damages, improved water quality, and improved forest health for future generations.

1.0 Introduction

The Agency of Natural Resources (ANR) Lands Stewardship Team, in partnership with the Vermont Rivers Program, requested an evaluation to improve flood resiliency on state-owned lands. A primary objective of this project was to evaluate current practices and management plans and to make recommendations for improved management with the specific goal of attenuating flood flows, thereby improving water quality and reducing downstream flooding. A second objective was to identify a process and approach that are transferable to other state-owned lands in Vermont.

In this report, flood resilience is defined as "a community's capability to anticipate, prepare for, respond to, and recover from floods with minimum damage to social well-being, the economy, and the environment" (NRC, 2010).

State Lands are defined as those lands held on a fee-simple basis or in terms of non-fee interests (e.g., conservation easements) by one of three departments of the Agency of Natural Resources that make up the State Lands Committee: Vermont Department of Forests, Parks, & Recreation; Vermont of Fish and Wildlife Department; and the Vermont Department of Environmental Conservation. Four State Lands management units were identified by the ANR Lands Stewardship Team for more detailed evaluation during this report. These properties were selected by ANR with a goal that they would be generally representative of the range of conditions characterizing state-owned lands. State Lands are located in a wide variety of geographic, geologic and land use settings, and it was a difficult task to identify a subset of lands that adequately represented this diversity (see Section 3.2 for further discussion).

Practices and activities undertaken to build flood resiliency on State Lands will have attendant benefits to riparian and forest habitats, as well as increased opportunities for sediment and nutrient attenuation leading to improved water quality. Management of State Lands for their ecosystem services related to flood resiliency will serve as a model of exemplary stewardship practices for other publicly- and privately-held lands.

This summary report has been prepared by Kristen L. Underwood, hydrogeologist (South Mountain Research & Consulting Services), and David Brynn, consulting forester (Vermont Family Forests), both located in Bristol, Vermont.

2.0 Project Motivation and Context

Record flooding on Lake Champlain in the spring of 2011 and widespread damages sustained to Vermont's built infrastructure during Tropical Storm Irene in August 2011 were among the motivations for this report. While the majority of State Lands are in forest cover, significant losses were incurred including trail damage, road washouts, culvert and bridge replacements, and impacts to recreational buildings and facilities. The forested headwaters of many of Vermont's State Lands are particularly susceptible to generating runoff during storm events, given their natural topography and geologic setting. This inherent vulnerability to overland flow and soil erosion has been exacerbated by a legacy of land use impacts dating as far back as the late 1700s, most often pre-dating State acquisition of the lands. Natural vulnerabilities and legacy impacts have combined to create upland forests particularly sensitive to a rapidly changing climate.

2.1 Legacy Impacts

There may be a tendency to assume that lands in forest cover are resilient to the effects of flooding simply by virtue of their forested status. However, forest cover does not necessarily equate to forest health and forest flood resilience. Headwater forests of Vermont include a legacy of human modifications that have left certain land areas with a heightened propensity to generate runoff, accelerate soil erosion, and sediment streams. These legacy impacts affect forest lands across the state, not just State Lands.

Widespread deforestation of the Vermont landscape had occurred by the early- to mid-1880s (Thompson & Sorensen, 2000; Albers, 2002; Foster & Aber, 2004) to support subsistence and sheep farming and the lumber industries. Mill dams were established on headwater streams to harness water power in support of various industrial and manufacturing activities including sawmills, grist mills, potasheries, and iron works (Stilwell, 1948; McGrory-Klyza and Trombulak, 1999; Smith, 1886; Beers, 1871). A network of roads and trails was established to access these upland mills and farms and to retrieve harvested timber. These roads and trails crossed the stream network in many locations.

Deforestation and upland development changed the water and sediment routing on previously-forested lands, making these lands more connected to receiving stream channels. Removal of vegetation reduced the amount of water intercepted, evaporated and transpired by plants. Infiltrative capacity of the soils was reduced through compaction of the soils during harvesting. Where road networks intersected the stream network, road-side ditches (and the roads themselves) have effectively served as an extension of the stream network (Wemple *et al*., 1996; King & Tennyson, 1984). The increased density of flowing channels on the land surface led to increased peak flows and velocities, and substantial turbidity in receiving waters. Thus, more water was available for runoff, leading to a shift from gentler pre-settlement flows to flashier, more intense runoff events (“deforested” line in Figure 1).

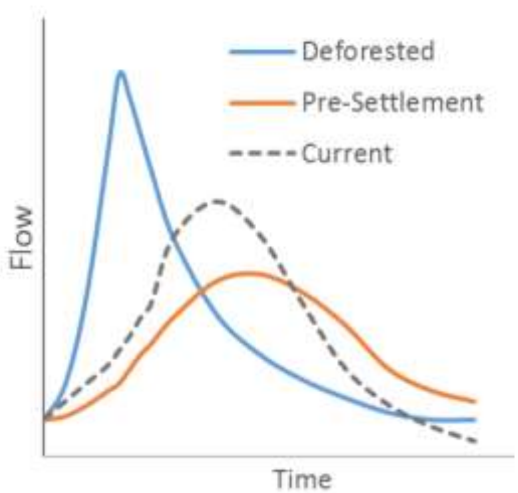


Figure 1. Conceptual diagram of the effects of legacy impacts on watershed hydrology.

Forest cover in the Vermont highlands began to regenerate in the late 1800s and early 1900s, as upland farms and sawmills were abandoned. Forests rebounded to comprise 78% of the landscape by the 1980s, a figure which has remained fairly stable since (NESFA, 2013). However, the quality of those forests is not the same as the pre-Settlement old growth forests. The legacy of early landscape development and a history of channel and floodplain modifications (Kline & Cahoon, 2010) continue to impact water and sediment routing from the land. Landscape modifications have had the effect of increasing the connectedness of land to the river network (Wemple, *et al.,* 1996). It is this enhanced connectivity that needs to be addressed to make our landscape more resilient to flooding and the impacts of a changing climate. Historic access networks of skid trails and forest roads on State Lands were often inherited when the ANR acquired these lands, and are not necessarily representative of current State Lands management practices. Addressing these legacy impacts will require adaptive forest conservation approaches that significantly slow overland flow, increase infiltration, and trap sediment, leading to reduced flood damages.

2.2 Changing Climate

Historic gaging records for Vermont climate stations indicate statistically significant increasing trends in average annual precipitation and temperature over the latter half of the 20^{th} century (Guilbert, *et al.*, 2014). Climate modeling recently performed for the Lake Champlain basin of Vermont projects an increase in mean annual temperature of 4.6°C by late in the 21^{st} century, and a 9.9 % increase in precipitation by late century (Guilbert, *et al.*, 2014).

As average annual rainfall has increased in recent decades, average annual flows in Vermont rivers have also increased. USGS streamflow gages in Vermont show a statistically significant increasing trend in mean annual discharge (Vermont Climate Assessment, 2014; Hodgkins *et al.*, 2010). Based on climate model projections for increased precipitation, we can expect average annual streamflows will continue to increase. High flows are larger in magnitude and are occurring more frequently, often in the winter months associated with earlier thaw dates for snowpack. Records for rivers in New England, including Vermont rivers in particular, indicate a rise in the magnitude of the annual peak discharge over the last several decades (Collins, 2009; Hodgkins & Dudley, 2005; Huntington *et al.*, 2009). A greater fraction of winter precipitation will fall as rain or freezing rain rather than snow, leading to more rain-on-snow events and rain on frozen ground, with associated flooding (Frumhoff, *et al.*, 2007). Up to an 80% increase in the probability of high flows is projected under assumptions of high green-house-gas emissions by the end of the century (Frumhoff *et al.*, 2007; Hayhoe *et al.*, 2007).

Higher magnitude and duration of runoff will generate more flashy flows (Figure 2) and increased stream power leading to increased gullying, and erosion of sediments from the land surface, roads, ditches, landslides and streambanks. It is possible that increased frequency and magnitude of storms in coming decades will rejuvenate erosion processes in headwater regions where hillslopes are closely coupled with stream channels. Such a pattern was evident during TS Irene in the Connecticut River basin (Yellen *et al.*, 2014).

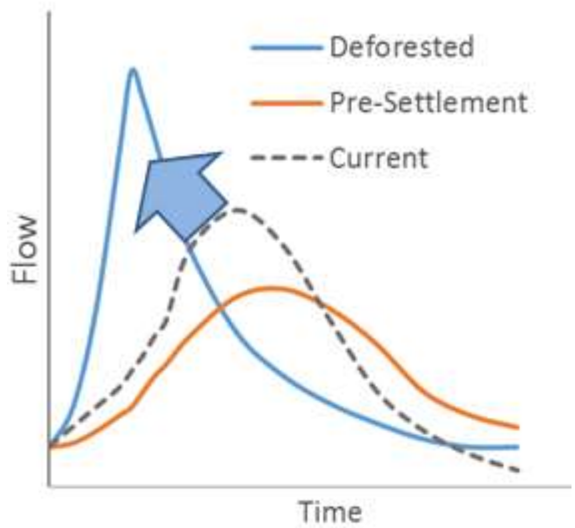


Figure 2. Conceptual diagram depicting expected trend in watershed hydrology with climate change – a return to more flashy flows as noted by the arrow.

3.0 Description of State Lands

As early as 1910, the Vermont State Forester, then Austin F. Hawes, was promoting the importance of acquiring state lands - specifically forest lands - for their role in the protection of water resources (Merrill, 1959). The L.R. Jones State Forest in Plainfield was the first state forest acquired and developed by the State of Vermont in 1909. Since that time, the state has acquired more than 345,000 acres of land and holds conservation easements on more than 44,000 acres of privately-owned lands (Figure 3)[1]. Together these land units comprise nearly 8% of the Vermont land area and consist of a wide variety of unit types including state parks, state forests, wildlife management areas, boat/fishing access sites, riparian corridors, fish hatcheries, dams, telecommunications facilities, ski areas, working lands and flood control areas.

State Lands are managed by three departments of the Vermont Agency of Natural Resources (ANR):

- VT Department of Forests, Parks & Recreation (FPR) "is responsible for the conservation and management of Vermont's forest resources, the operation and maintenance of the state park system, and the promotion and support of outdoor recreation for Vermonters and our visitors"[2]. FPR manages more than 250,000 acres comprising 39 State Forest units and 56 State Parks[1].

- VT Fish and Wildlife Department (VFW) is charged with the conservation of all species of fish, wildlife, and plants and their habitats for the people of Vermont." VFW manages more than 80 Wildlife Management Areas distributed across 109 towns, as well as boat access areas, fish culture stations and pond sites, and river corridor sites in 41 towns.

[1] http://anrmaps.vermont.gov/websites/vgisdata/layers_anr/metadata/CadastralPublands_ANRLANDS.txt
[2] http://www.vtfpr.org/

- VT Department of Environmental Conservation (VDEC) mission is "to preserve, enhance, restore and conserve Vermont's natural resources and protect human health for the benefit of this and future generations".[3] VDEC holdings are limited to lands and infrastructure associated with fourteen flood control dams located in sixteen towns.

State Land management units are distributed in each of the biogeophysical regions of Vermont, although they are somewhat disproportionately representative of the Northern Green Mountains and the Northeastern Highlands (Figure 3). Elevation settings range from 95 feet (e.g., Little Otter Creek WMA adjacent to Lake Champlain) to 4,211 feet above sea level (e.g., flanks of Mount Mansfield).

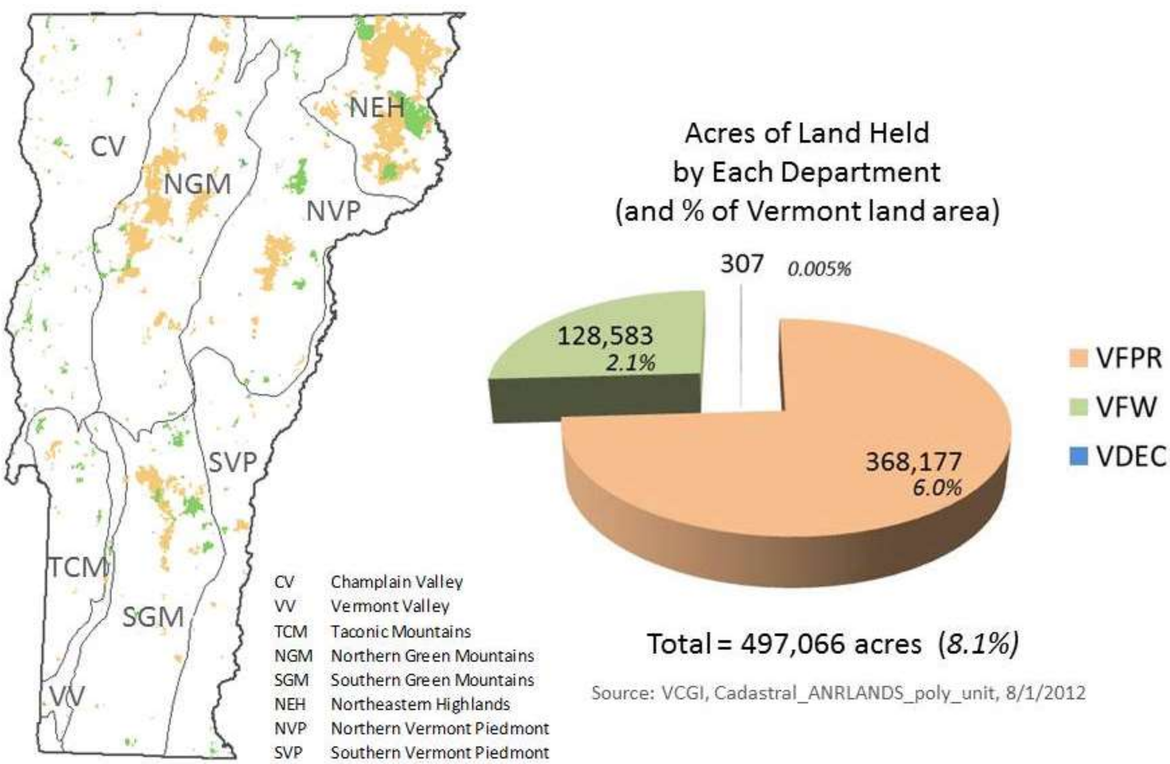


Figure 3. Distribution of State Lands by geographic region and ANR Department .

Land cover and land use on State Lands are dominated by forest cover (Figure 4). State Lands (89.9%) are somewhat more forested than the state as a whole (78%).

[3] http://www.anr.state.vt.us/dec/about.htm

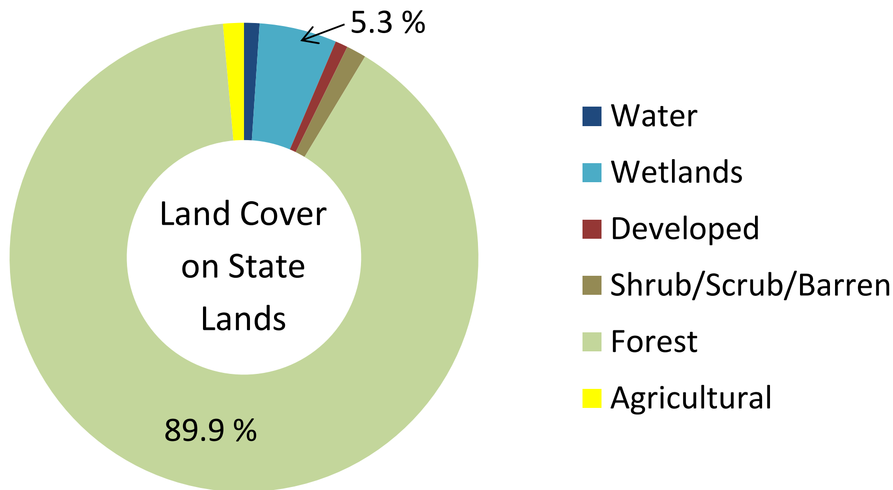


Figure 4. Land cover/ land use distribution for state lands (Source: 2001 NLCD).

Infrastructure on State Lands includes communication towers, camps, state park buildings, parking lots, and associated water and sewer systems. Nearly every State Land management unit includes an access network of roads and trails. In some cases, roads are Class 4 roads owned by the town. In other cases, the relevant department owns a forest access road. Beyond these formal roads, there are informal forest roads, logging access roads and skid trail networks utilized for recreation, hunting, and timber harvest.

Beginning in the early 1940s, seven private ski areas have leased acreage on State Lands for placement of ski lifts, ski trails, and a limited number of buildings (Table 1).

Table 1. Ski areas with lease agreements on State Lands.

Ski Resort	State Lands	Towns	Approx Acreage
Bromley Mountain Resort	Hapgood State Forest	Peru	118
Burke Mountain Resort	Darling State Forest	Burke	1,000
Jay Peak Resort	Jay State Forest	Jay, Westfield	845
Killington Mountain Resort	Calvin Coolidge State Forest	Killington	1,680
Okemo Mountain Resort	Okemo State Forest	Ludlow, Mount Holly	1,223
Smugglers' Notch Resort	Mount Mansfield State Forest	Cambridge, Morristown, Stowe	2,170
Stowe Mountain Resort	Mount Mansfield State Forest	Stowe, Cambridge	1,400

3.1 Forest Resources

Given that the majority of State Lands are in forest cover, the focus of this report has centered on how management of these forests can be modified or adapted to improve flood resiliency. It is informative to review the variety of services and goods provided by our forests, and to evaluate the role of each ANR Department in managing these forest resources.

Forests are composed of a suite of elements, including water, air, wildlife, soil, and vegetation (Figure 5). The recent focus on climate change has directed attention to an additional resource sequestered in the soil and vegetation – i.e., carbon. These forest elements are valued for both their economic (or provisioning) services and their ecosystem (or regulating) services. Ecosystem services include stormwater and floodwater attenuation, water filtering and purification, air filtering, nutrient cycling and habitat provision. Stewardship of these regulating services will support forest health. In the context of flood resiliency, the focus of this report is on water and the flood retention and attenuation roles provided by the forest structure. Provisioning resources provided by our forests include those elements of the forest-based economy, including wood and non-wood products, and the growing importance of forest-based recreation and tourism.

The three departments of VANR are directly involved with these forest resources in two primary ways: Ownership and Trusteeship (Figure 5). FPR and VFW hold the majority of State Lands – either on a fee-simple basis or in non-fee interests (e.g., conservation easements). In administering those state lands, FPR and VFW own and manage those physical public goods including the soil and vegetation, and the carbon stored in each of those elements. FPR and VFW do not own those elements of the commons – including water, air, and wildlife. On the other hand, VFW and VDEC are ***trustees*** of these commonly-held elements.

Protection of ecosystem services promotes forest health while exploitation of the economic services provided by forests connotes forest use. Our forests have the capacity to provide both ecosystem and economic services. However, to promote flood resiliency in the face of a changing climate will require greater emphasis on forest health and stewardship of forest ecosystem services. Forest utilization will need to be optimized to ensure the mutual goals of improved forest health and resiliency to flooding and other impacts of climate change. At the same time, promoting forest health will also ensure the sustainability of our forest-based economy.

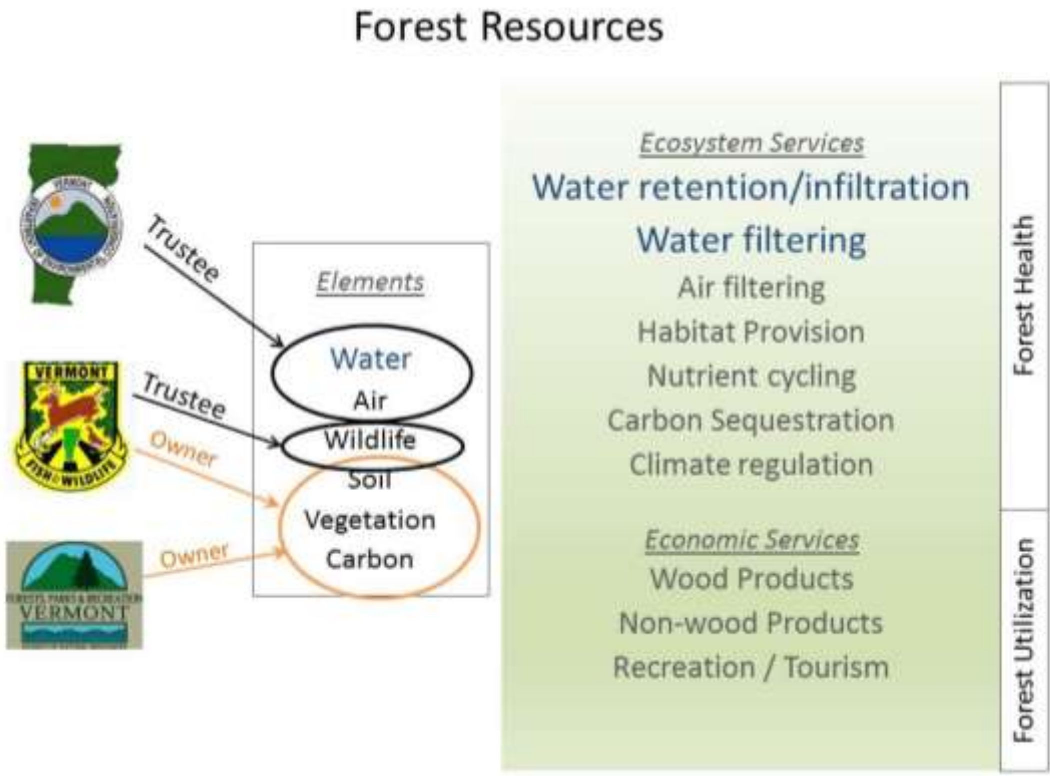


Figure 5. Ecosystem (regulating) services and economic (provisioning) services provided by forest resources and the trustee versus ownership role of VANR Departments over forest elements.

3.2 Selected State Lands

This report focused on a subset of State Lands selected by the ANR Lands Stewardship Team to be representative of the natural settings, land covers and uses of State Lands as a whole (Figure 6) – and yet to be reasonably centralized for easy access by the assessment teams. Four management units in Rutland and Windsor Counties were identified, including two Wildlife Management Areas (WMAs), one state park and a state forest (Table 2).

Table 2. Selected State Lands Management Units

State Lands Management Unit	Acres	Towns
Camp Plymouth State Park	295	Plymouth
Tinmouth Channel WMA	1,261	Tinmouth
Coolidge State Forest	16,000	
- West		Killington, Mendon, Shrewsbury, Plymouth
- East		Woodstock, Bridgewater, Plymouth, Reading
Les Newell WMA	7,988	Barnard, Bridgewater, Killington, Stockbridge

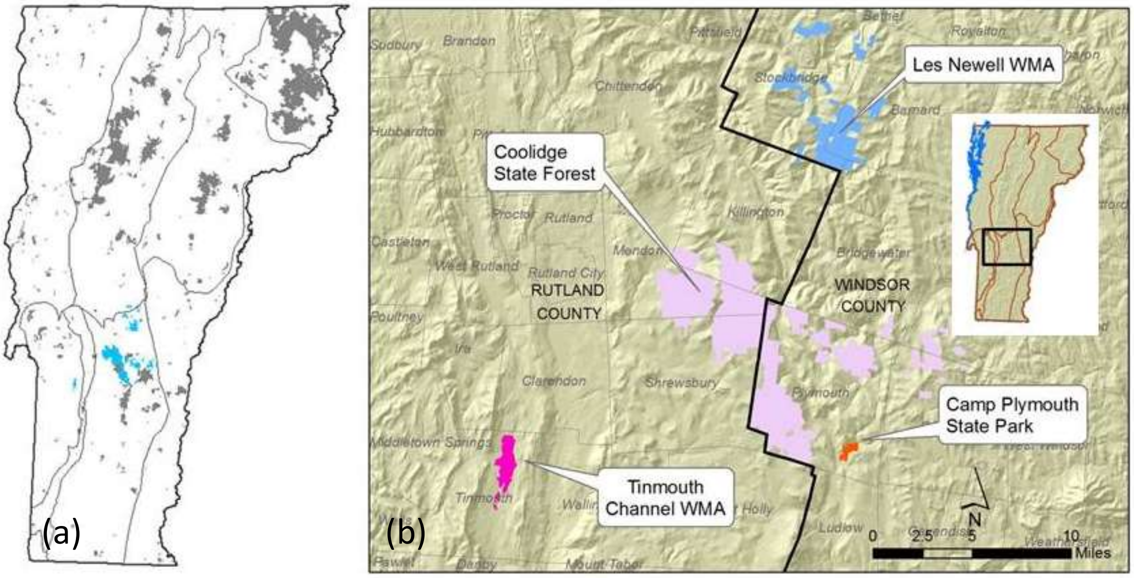
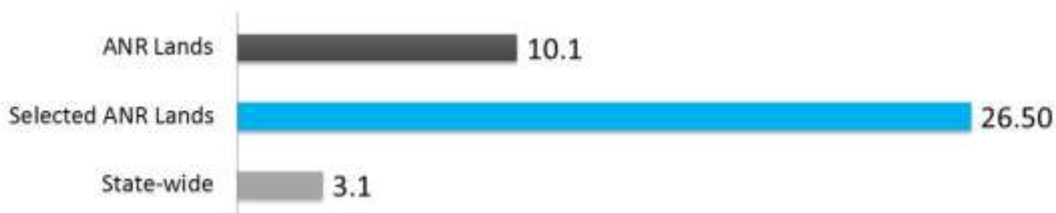


Figure 6. Location of Selected State Lands:
(a) Selected lands (shaded turquoise) vs State Lands as a whole (shaded gray);
(b) detailed view of selected State Lands located in Rutland and Windsor Counties.

Selected lands are 94.3% forested, similar to the 90% forest cover on State Lands as a whole. On the four properties assessed, 26.5% of the land area is above an elevation of 2,500 feet which exceeds and may over-represent high-elevation settings when compared to ANR Lands as a whole (Table 3). Yet, these higher elevation settings are particularly vulnerable to the effects of climate change as they generally receive greater amounts and intensities of precipitation.

Table 3. Percent of land area above 2,500 feet elevation



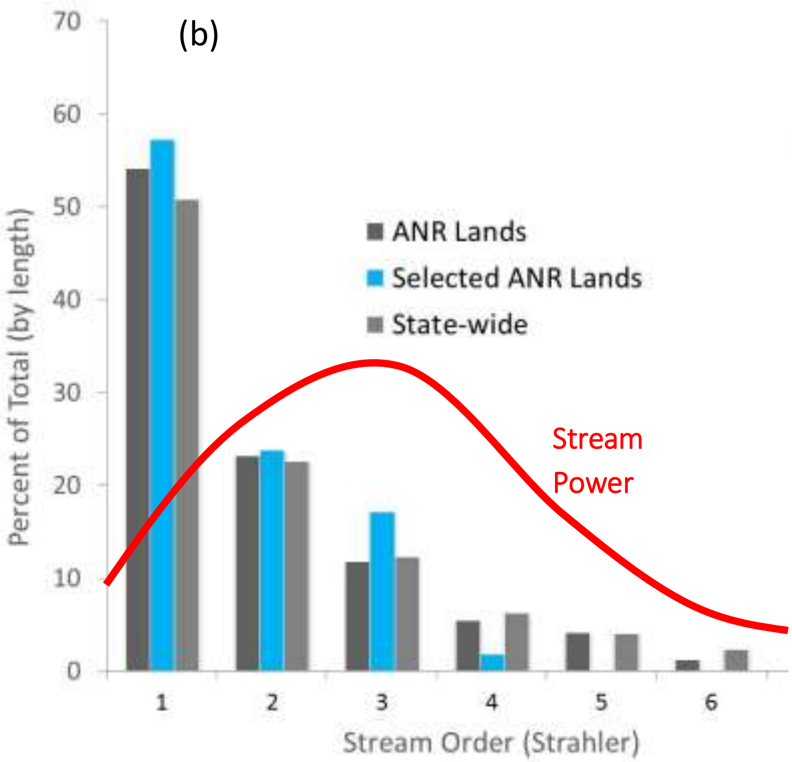
State Lands were evaluated with regard to the stream networks that drain them and the frequency of stream segments of a particular stream order (after Strahler, 1952). First-order streams represent those smallest channels that are generated when runoff or groundwater seepage combines to form concentrated flow in a defined stream channel. First order stream segments are most often located in the headwaters of a catchment. A second-order stream is formed when two first-order streams come together; a third-order stream is formed by two second-order streams, and so on (Figure 7a). Generally speaking, the width and depth of stream channels increases with increasing stream order, as the upstream drainage area grows in size.

Figure 7b shows the distribution of stream segments by Strahler stream order on all State Lands in comparison to the state of Vermont as a whole. Approximately 50.8% of the total length of mapped stream segments in Vermont (VHD_CARTO) are classified as first-order streams. State Lands and the subset of State Lands selected for this report contain somewhat higher percentages of first-order streams (54.1% and 57.3%, respectively). This finding is not unexpected considering that the distribution of State Lands tends to over-represent the mountainous settings of the Northern Green Mountain and Northeastern Highlands biogeophysical provinces (Figure 3).

Thus, in a watershed context (Figure 8), State Lands are generally located in the headwaters and less frequently along middle-order to large-order segments. The maximum order of stream segments represented on the selected State Lands is fourth-order (e.g., Great Roaring Brook, Calvin Coolidge SF in Plymouth; Broad Brook, Coolidge SF East).

Based on a separate study being undertaken by the Vermont Land Trust, stream power has been estimated for mapped stream networks in the state (Fitzgerald, 2013; Schiff, 2014). Stream power refers to the ability of streams to erode sediments and move debris and is primarily a function of water volume and channel slope. At a given stream reach, stream power is greater at high flows than at low flows, due to the larger volume and velocity of water passing through the channel reach. In a watershed context, stream power will generally be greater on steeper reaches than on low-gradient reaches, for a given storm event. Stream power is maximized along those mid-order stream segments (Figure 7b) – usually located near the transition from the headwaters to the transfer zone of a watershed (Figure 8). Here, the volume of water carried in the channel has increased (due to increased drainage area) and channel slopes are generally still steep enough to generate high stream powers sufficient to exceed thresholds for erosion. Notably, many of the damages sustained on selected State Lands during Tropical Storm Irene, were located along these mid-order segments, such as the Buffalo Brook at Camp Plymouth State Park (3rd order; see Appendix A) and the Roaring Brook at Killington Resort in Coolidge SF West (2nd order; Appendix A).

The selected State Lands were chosen by ANR to be generally representative of the range of conditions characterizing state-owned lands. State Lands are located in a wide variety of geographic, geologic and land use settings, and it is a difficult task to identify a subset of lands that adequately represent this diversity. For example, soil types and slope settings of Northeast Highland headwater properties are somewhat different than the soils and slope settings of the headwater lands in the Northern and Southern Green Mountains. Given the location of the selected State Lands in south-central Vermont, these units were more significantly impacted by flooding during Tropical Storm Irene than were State Lands in the northern part of the state. Yet, a focus on how these selected areas fared during TS Irene is informative for all regions of the state, since we can expect more frequent storms with impacts similar to TS Irene in future decades in light of a changing climate.



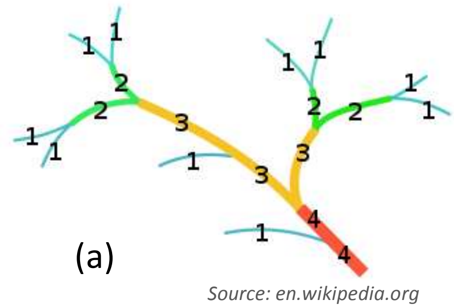
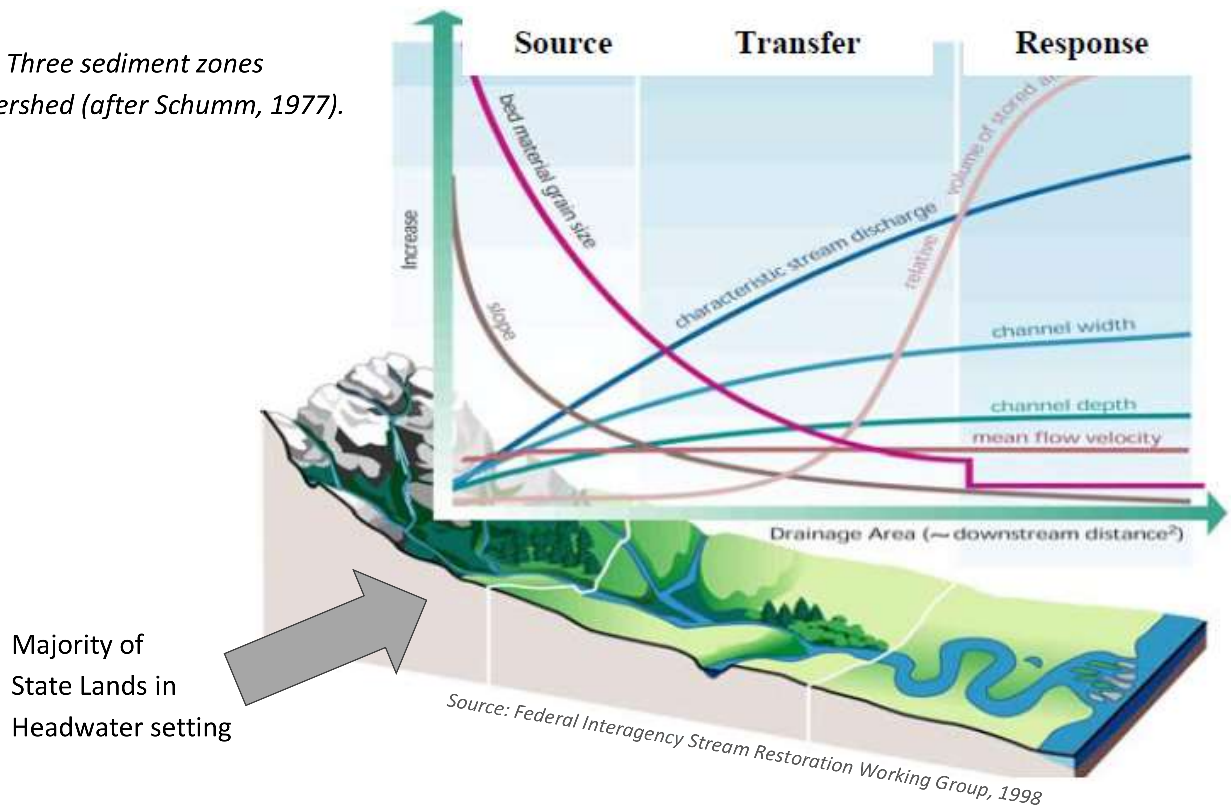


Figure 7. Stream networks on State Lands : (a) stream order graphic *(after Strahler, 1952)*; (b) *distribution of stream segments on State Lands by Strahler stream order. Stream power line conceptualized after findings of Milone & MacBroom, Inc. and Fitzgerald Environmental Associates in a recent study for the Vermont Land Trust (Fitzgerald, 2013; Schiff, 2014).*

Figure 8. Three sediment zones of a watershed (after Schumm, 1977).



4.0 Assessment Methods

The consideration of flood resiliency on State Lands was accomplished through a variety of assessment methods, as outlined in the project proposal.

4.1 Meetings and Presentations

The Project Team attended meetings with Steering Committee members including an initial scoping meeting in Rutland on 3 February 2014 to clarify project goals and expectations and a progress meeting in Rutland on 22 September 2014. A presentation of draft findings was delivered to the State Lands Stewardship Team in Montpelier on 22 January 2015. Proposed GIS mapping methods were delivered to the State Lands Stewardship Team for review during a subsequent meeting on 26 March 2015. A final presentation was made to the 8 April 2015 State Lands Stewardship staff meeting in Waterbury, Vermont. Final comments from the Steering Committee were discussed in a meeting with the State Lands Stewardship Team on 28 May 2015.

4.2 Limited Site Visits and Interviews

Each of the selected State Lands was visited during the 2014 field season by the Project Team, accompanied by various members of the Steering Committee, as summarized in Table 4. Appendix A provides a summary of major findings from these site visits.

Table 4. Field visits to selected State Lands

Camp Plymouth SP	June 5, October 20
Tinmouth Channel WMA	June 18
Coolidge West - Killington	July 31
Coolidge West	September 8
Coolidge East	September 29
Les Newell WMA	December 1

4.3 Review of Documents

A limited review was conducted of select plans relating to management of State Lands, including:

- Long Range Management Plan Documentation
- Long Range Management Plans for the selected State Lands (available for all management units except Les Newell WMA and Coolidge East)
- Water Resources Assessment (no date, internal document)
- Timber/ Vegetative Management Prescriptive Worksheets (select)
- Annual Work Plans (select)
- Vermont State Lands Riparian management Guidelines (March 2015 Draft)
- ANR Policy: Riparian Area Management on ANR Lands (March 2015 Draft)

Several recommendations gleaned from review of these documents are presented in subsequent sections.

4.4 GIS analysis

A basic Geographic Information Systems analysis was performed to characterize the varying soil types and topographic settings on State Lands and classify these land areas in terms of their vulnerability to flooding and the enhanced generation of runoff and erosion in response to human landscape modifications and climate change. The goal of this analysis was to develop a methodology that relies on remote sensing resources available State-wide, and that is practical, easily implemented, and consistent with existing planning approaches for State Lands. Essentially, this mapping approach defines an additional planning "lens" specific to the hydrologic resources of State Lands.

Under this mapping approach (Figure 9), State Lands are mapped into zones including "Hydrologic Reserve" areas, "Hydrologic Conservation" areas and "Other Lands", and a "River Corridor" layer is then mapped as an overlay to the full area.

This "hydrologic lens" for long-range planning on State Lands recognizes those landscape settings with a natural vulnerability to generate runoff – namely, those land areas with steep slopes, shallow (or nonexistent) depths to bedrock or other permeability-limiting layer (e.g., hardpan), and soils with limited infiltration capacity.

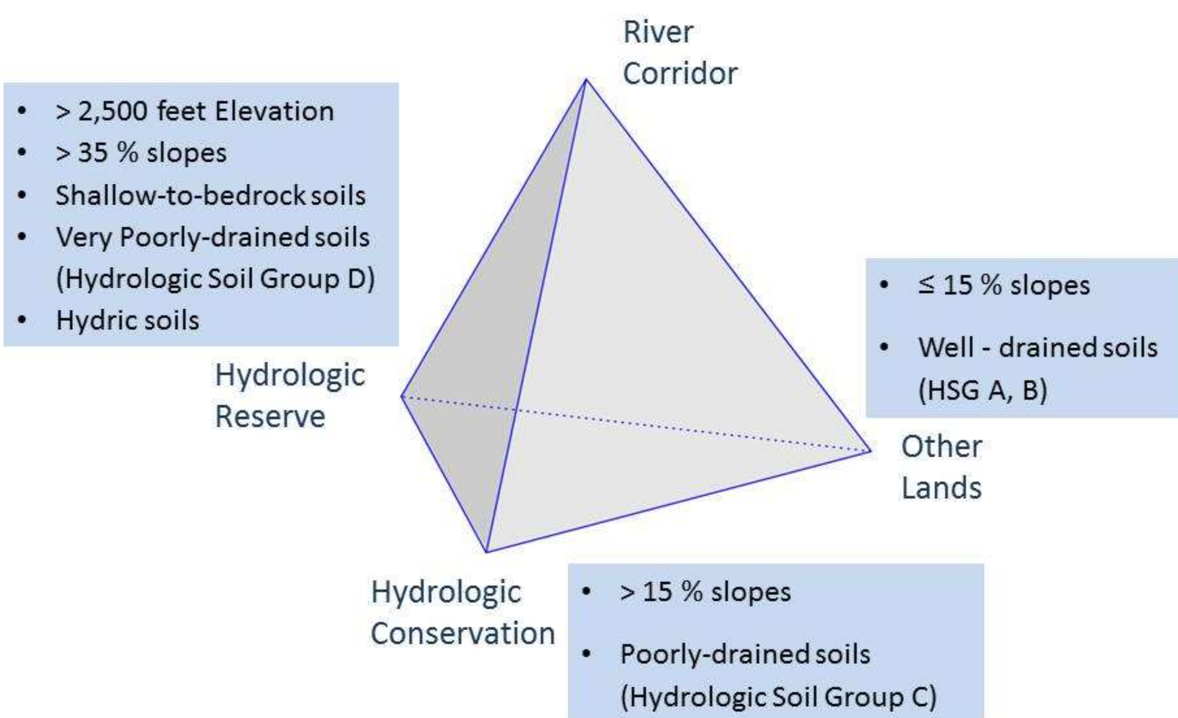


Figure 9. Hydrologic Resource Mapping Approach

A coarse-resolution GIS analysis was completed to classify land areas on select State Lands into the above Hydrologic Resource Zones, so that Steering Committee members could visualize how this hydrologic layer could be incorporated alongside other attributes such as wildlife, natural communities, and recreational and historic resources. This analysis utilized 1:24,000-scale coverage of resource layers readily available through the Vermont Center for Geographic Information in a step-by-step query process carried out in ArcGIS 10.1 with Spatial Analyst extension. The **Hydrologic Reserve Zone** is composed of lands with elevations above 2500 feet; slopes exceeding 35%; shallow-to-bedrock soils; and poor infiltrative capacity identified as Hydrologic Soil Group D and hydric soils using a join of the *Table 20 attributes* from NRCS (Table 5). The **Hydrologic Conservation Zone** is a union of lands with slopes exceeding 15% and soils in Hydrologic Soil Group C (excluding those lands delineated in the Hydrologic Reserve) (Table 5). Remaining areas on State Lands are simply classified in the **Other Lands** category for purposes of delineating the hydrologic resources.

The **River Corridor** overlay follows the stream network, intersecting all three hydrologic mapping zones. The river corridor is delineated by the VDEC based on physical (geomorphic) assessments of Vermont's stream and rivers. A river corridor overlay is a footprint in the landscape, which encompasses the dynamically-adjusting river channel. The corridor varies in width along its length, accounting for the actual width of the river channel at various locations, the size and nature of the watershed draining to that particular reach, the sensitivity of the reach to physical adjustment processes, knowledge of historic migration patterns of the river, and the position of the valley walls adjacent to the channel. For drainage areas greater than two square miles, the river corridor includes a meander belt width component as well as a 50-foot setback as an extension on either side of the meander belt to accommodate a vegetated riparian buffer. For small streams draining an area less than or equal to two square miles, the 50-foot setback from each bank serves both the meander and riparian buffer functions. Further details of the delineation procedure for river corridors are provided in several ANR publications, including the *Flood Hazard Area and River Corridor Protection Procedure* (2014) and *River Corridor Protection Guide* (2008). The updated river corridor layer is accessible via the ANR Natural Resources Altas web page[4] or by contacting VTDEC Rivers Program personnel in the appropriate district.

Where available as GIS files, the **Built Infrastructure** on State Lands was then overlaid on the above mapped elements. Built infrastructure includes the access network of roads, skid trails, parking areas and landings as well as culvert and bridge structures, and buildings and other facilities. In this way, the position of this infrastructure with respect to the natural Hydrologic Resource Zones can be visualized to understand the degree that infrastructure may enhance the sensitivity of the landscape to flooding or be at risk of impacts from flooding.

[4] http://anrmaps.vermont.gov/websites/anra/

Table 5. Hydrologic Resource Mapping Elements

HYDROLOGIC RESERVE ZONE

Variable	Description	GIS Source Layer (vcgi.org)	Data Type	Scale
Elevation	Land areas greater than 2500 feet in elevation	ElevationOther_CON2500	vector	1:24,000
Steepness	Land areas of slope greater than 35%	ElevationSlope_SLOPE24 (generated from USGS 30-m DEM)	raster	1:24,000
Infiltration Capacity	Shallow-to-Bedrock - Soils composed of exposed bedrock or of shallow thickness to bedrock or other permeability-limiting layer	GeologicSoils_SO (NRCS) joined with Table 20 attributes – select ROCKSHALLOW ≤ 20 inches and ROCKDEEP ≤ 20 inches	vector	1:24,000
	Soils of Hydrologic Soil Group D	GeologicSoils_SO (NRCS) joined with Table 20 attributes - select for HSG D soil mapping units	vector	1:24,000
	Hydric Soils	GeologicSoils_SO (NRCS) joined with Table 20 attributes - select for Hydric soil mapping units	vector	1:24,000

HYDROLOGIC CONSERVATION ZONE

Variable	Description	GIS Source Layer (vcgi.org)	Data Type	Scale
Steepness	Land areas of slope greater than 15%	ElevationSlope_SLOPE24 (generated from USGS 30-m DEM)	raster	1:24,000
Infiltration Capacity	Soils of Hydrologic Soil Group C	GeologicSoils_SO (NRCS) joined with Table 20 attributes - select for HSG C soil mapping units	vector	1:24,000

4.4.1 Hydrologic Resource Mapping Elements

The mapping elements which define these Hydrologic Resource Zones relate to the topographic setting and infiltrative capacity of surface sediments.

- **Elevation**

Due to orographic effects, highest elevations of Vermont receive greater amounts of precipitation, and are projected to receive precipitation of increasing magnitude and intensity in future decades (Guilbert, *et al.*, 2014). Available research for Vermont is not conclusive as to a specific threshold elevation above which sensitivity to climate change is enhanced. An elevation of 2500 feet was chosen to be consistent with Vermont Water Quality rules which require greater water quality protections for waters above this elevation (VWMD, 2014).

- **Slope**

All other factors being equal, steeper-gradient hillslopes are likely to yield more runoff at higher velocities than lesser-gradient hillslopes. With greater flow velocities comes greater energy (stream power) to entrain and erode sediments. Where legacy impacts include historic road and skid trail networks established on steep slopes, these former road networks are serving as conduits for concentrated runoff, rill and gully erosion. Often, drainage along these road networks terminates at stream crossings without being adequately disconnected from the stream through turnout structures or infiltration basins. Roads developed on steep slopes disturb wider areas of soil and forest on cut and fill areas adjacent to the road to achieve suitable slopes than do roads traversing lesser-gradient hillslopes (Weist, 1998). Our mapping approach involved a threshold of greater than 35% slopes for Hydrologic Reserve areas and greater than 15% slopes for Hydrologic Conservation areas, consistent with a USDA publication for silvicultural suitability of Vermont soils (USDA, 1991).

- **Shallow-to-Bedrock Soils**

Soils with shallow depths to bedrock or other permeability-limiting layers such as clay or "hardpan" have very limited infiltration capacity. Precipitation and snowmelt will generate a greater amount of runoff from shallow soils as the limited thickness of soils is quickly saturated.

- **Hydrologic Soil Groups D and C**

The Natural Resources Conservation Service (USDA, 1986) classifies soils by their infiltration capacity into four groups (A through D), ranging from a high (A) to very low (D) capacity. Hydrologic Soil Groups D and C have been selected as elements of the Hydrologic Reserve and Hydrologic Conservation Zones, respectively, in the mapping approach recommended for this report:

  - **"Group D** soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material [e.g., bedrock]. These soils have a very low rate of water transmission (0-0.05 in/hr)" (USDA, 1986).

- **"Group C** soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr)". (USDA, 1986).

- **Hydric Soils**

Hydric soils are saturated by water, either on a seasonal or year-round basis and are often associated with wetlands. In headwater settings of Vermont, hydric soils tend to be distributed in isolated pockets associated with vernal pools, or along upper-elevation floodplains, ponds, or wetlands. In lowland settings, hydric soils tend to be more wide-spread. In the Champlain Valley physiographic province, hydric soils are frequently associated with glaciolacustrine deposits of the former Lake Vermont and Champlain Sea. In agricultural and developed areas, hydric soils may be mapped where wetlands were previously converted to other uses through installation of drainage ditching and/or tile drains. This prior-converted status of wetlands is not expected to be a condition representative of the majority of State Lands, which are predominantly forested. Often hydric soils are classified as HSG D soils, though not always.

4.5 Field Application

Camp Plymouth State Park in Plymouth was chosen by the Project Team to serve as a demonstration site for application of recommended measures to enhance flood resiliency on State Lands. For example, limited site assessments were conducted in the Fall of 2014 in the Buffalo Brook watershed upstream of the park to evaluate conformance to AMPs and to visualize the placement of infrastructure and the access network alongside a mapping of hydrologic zones outlined in Section 4.4. This task also leveraged data developed under a separate project by SMRC contracted to the Lake Rescue Association (SMRC, 2014) with funding from a VDEC Ecosystem Restoration Grant. Results of these assessments are summarized in Appendix B.

4.6 Summary Report and Presentations

A presentation of draft findings was delivered to the State Lands Stewardship Team in Montpelier on 22 January 2015. Proposed GIS mapping methods were delivered to the State Land Stewardship Team for review during a subsequent meeting on 26 March 2015. The draft summary report was presented at the 8 April 2015 State Lands Stewardship staff meeting in Waterbury, Vermont, with review comments incorporated in this final summary report.

5.0 Guiding Strategies to Enhance Flood Resilience

Overall strategies to improve flood resilience on State Lands are analogous to those of the EPA and VDEC for treatment of stormwater on developed lands (i.e., Low Impact Development and Green Infrastructure initiatives). Treatment strategies for stormwater involve practices to "slow it, spread it, sink it" (EPA, 2013).

- Slow stormwater runoff
    - increase roughness
    - decrease slopes
    - dissipate energy

- Spread stromwater and disconnect it from stream networks
    - disperse flow paths
    - interrupt flow paths with flow diversion structures (water bars, broad-based dips, turnouts)
    - direct runoff to infiltration or detention ponds

- Store and detain water allowing it to sink into the subsurface
    - Increase infiltration
    - minimize disturbance
    - minimize imperviousness & soil compaction

These strategies should be considered in the development of plans, policies and practices to enhance flood resilience on State Lands. Agency plans and polices should seek to protect river corridors and vulnerable land areas from further modification and encroachments. Implementation of optimal conservation practices will significantly increase infiltration, slow overland flow, trap sediment, and reduce downstream flood damage.

6.0 Findings and Recommendations

In consideration of these overall strategies, a suite of planning, policy and practice recommendations has been compiled to achieve greater flood resiliency on State Lands. Implementation of these recommendations can occur in a phased approach and will demonstrate exemplary practices for adoption by other public and private landowners. Section 7 outlines an implementation plan for these recommendations and addresses cost constraints as well as partnerships that can be leveraged to afford these measures.

Recommendations are organized below within the framework of an adaptive management cycle following *Open Standards for the Practice of Conservation*[5] (CMP, 2013) .

---

[5] http://cmp-openstandards.org/

Figure 10. Adaptive Management Cycle after CMP, 2013.

6.1 Conceptualize

The State Lands Stewardship Team has taken important steps to plan for flood resiliency including commissioning this report. The team is identified and has a strong collaborative history of managing State Lands for various public uses and the protection of natural resources. Previous sections of this report have identified the project context, including critical threats of flooding related to climate change and a legacy of landscape and river network modifications.

To more comprehensively address flood resiliency, additional working sessions could be convened to further align the scope, vision, and conservation and management targets of the three ANR Departments that make up the State Lands Stewardship Team. Proposed conservation targets relevant to flood resiliency are presented in Section 6.2.1 (Table 7).

In keeping with its role as the trustee of Vermont's water resources, the VDEC should take a more active role in the management of State Lands. VDEC should be consistently represented on the district-level Stewardship Teams that meet approximately monthly to identify management priorities and that generate the annual work plans and LRMP for each State Lands management unit. Integration of VDEC staff within the Stewardship Teams has been achieved to varying degrees across the State in recent years. Basin Planners from the VDEC Watershed Management Division have been included in ANR District Stewardship Teams in Springfield, Rutland and Northeast Kingdom districts and have recently co-authored sections of the LRMPs pertaining to water resources. VDEC should take on an expanded role in monitoring land use practices on State Lands with respect to conservation targets and compliance with Vermont Water Quality Standards.

6.2 Plan Actions and Monitoring

In this new day of increased flood magnitude and frequency, the management approach for State Lands should incorporate water resources and water-related forest ecosystem services (i.e., retention, infiltration, filtering) more explicitly in its short-term and long-term planning efforts. Plans and policies should articulate specific targets and objectives for State Lands and Hydrologic Resource Zones in particular to achieve the overall goal of improved flood resiliency.

6.2.1 State-wide application

Update Acceptable Management Practices

To date, the primary mechanism for ensuring protection of water resources on State Lands has been the *Acceptable Management Practices for Maintaining Water Quality on Logging Jobs* in Vermont (adopted in 1987 and last printed in 2011). "The AMPs are the proper method for the control and dispersal of water collecting on logging roads, skid trails and log landings. …The AMPs are intended to prevent discharges" to receiving waters (AMPs, 2011).

With regard to improved flood resiliency, and in light of a changing climate, the Project Team sees significant challenges in relying solely on AMPs. AMPs were designed to address runoff conditions during historic storm conditions, if structures are installed properly and at the recommended density. However, there are no regular practices to quantitatively measure conformance with the AMPs (e.g., appropriate number and spacing of drainage structures on forest access roads or skid trails). State Lands Stewardship Team members report that AMP compliance is more qualitatively measured as the absence of an observed or reported discharge to the waters of the State. This standard for measuring AMP compliance is subjective and contingent upon the conditions at the time of inspection. During spring runoff or intense storms when conditions are such that discharge will be possible, it may be less likely for Stewardship staff or others to be inspecting projects. And yet these are exactly the conditions that contribute most to erosion, downstream flooding and water quality impacts. Improving flood resiliency (and water quality) requires managing for these infrequent, but significant, storm conditions.

Also, in light of increasing storm frequency, intensity, persistence and magnitude, AMPs will not be sufficient for those land areas most vulnerable to generating stormwater runoff (i.e., Hydrologic Reserve Zones and River Corridors). AMPs are designed primarily with the objective of maintaining water quality and reducing the likelihood for direct discharges during historic storm conditions. They are not designed to enhance flood resiliency specifically, or to address more extreme storm conditions experienced with greater frequency in recent years and anticipated in coming decades. Our recommendation is that Optimal Conservation Practices (OCPs) be developed for enhancing both flood resiliency and water quality in forested headwaters (Figure 11). OCPs are outlined in Appendix C. Through OCPs, greater protection measures would be applied to those land areas most vulnerable to generating runoff.

OCPs would apply to all access networks regardless of whether or not they are actively being used for timber harvest . All roads and trails on State Lands have the potential to serve as conduits of stormwater, and flood resiliency is enhanced by ensuring that drainage structures are properly spaced and maintained.

Figure 11. Recommended Optimal Conservation Practices

OCPs should be an element of a proposed *Silvicultural Guide to Understanding, Preserving, and Enhancing the Capacity of Vermont's Headwater Forests to Attenuate Flood Damage and to Produce High Quality Waters in a Rapidly Changing Climate*.

Incorporate Flood Resiliency in Long-range Management Plans

As stated in the ANR Long Range Management Planning Support Document (2001), "the development of the … LRMP for agency lands represents a key step in providing responsible stewardship of these valued public assets. Each LRMP identifies areas where different uses are to be allowed and describes how these uses will be managed to ensure protection of natural resources. The … over-arching management standards further both agency and department missions and are applied to the development of long-range management plans for all ANR lands" . As trustees of water and wildlife, VDEC and VFW, in particular, have a responsibility to oversee land management activities on all State Lands to ensure compliance with State regulations and policies that are designed to protect water quality and reduce flood erosion and inundation hazards.

The management objective of enhanced flood resiliency should be more consistently incorporated within the Long-range Management Plan (LRMP) for each State Lands management unit. Historically, the LRMP has reflected management objectives for those public forest resources that are owned - i.e., timber harvest, habitat provision, wood products, non-wood products, cultural resources and recreational use. There is some discussion and planning for protection of wildlife – particularly rare, endangered, and threatened species – in terms of management of the habitat for those species. However, there is variable treatment of water and those practices and policies that are protective of water quality and which build flood resilience. Those LRMPs which have been updated in more recent years tend to have addressed water resources to a greater degree. The Natural Resource Assessment process should be adapted to more explicitly identify flood resiliency as a management objective. Forest resources should be recognized as part of the stormwater management infrastructure on State Lands, and activities should be managed to further enhance forest health.

The mapping approach outlined in Section 4.4 can be incorporated directly with the Natural Resource Inventory process that is undertaken during the development of the LRMP for each state-owned unit. This mapping approach is intended to help inform the designation of existing LRMP land use classifications, and is not intended as a stand-alone land use classification system. For example, the *Hydrologic Reserve Zone* would be the hydrologic resource component of those lands which are deemed Highly Sensitive Management Areas (Table 6). *Hydrologic Conservation Zones* or *Other Zones* would span those Special Management Areas, General Management Areas, and Intensive Management Areas delineated on the remaining lands. The *River Corridor* overlay would then intersect all planning units. Thus, with respect to climate change and flooding, the *Hydrologic Reserve Zone* and the *River Corridor* are composed of land units that have very limited adaptive capacity. *Hydrologic Conservation Zone* lands have low to moderate adaptive capacity, and *Other Lands* have moderate to good adaptive capacity.

It is clear from interviews with VFPR staff (e.g., Morton, 2014; Thornton, 2014; Lones, 2014) that hydrologically-sensitive areas are being considered during planned activities on State Lands, such as the layout of harvest areas for pending timber sales. However, this has been an informal process to date. Hydrological resources should be explicitly called out and given at least equal weighting among the list of sensitive resources considered in the inventory process.

Table 6. Relationship of Hydrologic Planning Approach to Existing Land Management Classification system used by ANR

Category	Description	Hydrologic Unit
Highly Sensitive Management Areas	"areas with uncommon or outstanding biological, ecological, geological, <<add hydrological >>, scenic cultural or historic significance…"	Hydrologic Reserve Zone
Special Management Areas	areas "where protection and or enhancement of those resources is an important consideration for management…"	Hydrologic Conservation Zone Or Other Lands
General Management Areas	areas where "dominant uses include vegetation management for timber and wildlife habitat, concentrated trail networks, and dispersed recreation…"	
Intensive Management	areas characterized by a "high level of human activity and high intensity development on or adjacent to State land."	

Establish Conservation Targets

Plans and policies should articulate specific targets and objectives for State Lands, and Hydrologic Resource Zones in particular, to achieve the overall goal of enhanced flood resiliency. For example, Table 7 presents proposed conservation targets for the four Hydrologic Resource Zones on State Lands with respect to the access network, including truck roads, forwarding paths, skid trails, and log landings. Road and trail networks are generally "regarded as one of the most hydrologically active areas within a logged forest" (Croke & Hairsine, 2006). A recent study of Vermont stream reaches in forested headwater settings found that proximity between roads and streams and density of stream crossings were the best predictors of geomorphic instability – itself a reflection of increased stormwater and sediment delivery (Pechenick *et al.,* 2014).

Table 7 defines default conditions for each of the hydrologic resource zones, which vary in their propensity to generate stormwater runoff. More stringent standards for access networks are proposed in those land areas that are most sensitive (i.e., River Corridor and Hydrologic Reserve Zones) due to steepness of slopes, presence of limited soil infiltration capacity, and proximity to the stream network. Collectively, these conservation targets represent actions to remove or reduce the degree of hydrologic modification on State Lands and to disconnect sources of concentrated runoff and sediment from the stream network. Performance in meeting these conservation targets should be measured through regular monitoring efforts (see Sections 6.3 and 6.4).

Ideally, the network of road and trail access to a management unit would be laid out such that the most vulnerable land areas are avoided to the greatest extent possible. This may mean longer roads and trails with more switch backs to achieve ideal road gradients (less than 7%). The resulting percentage of land area developed with an access network may, in these cases, exceed conservation targets for percent imperviousness. However, to the degree that stormwater is disconnected from the stream network through adequately constructed and appropriately spaced drainage structures, a higher percentage of imperviousness can be tolerated.

Road gradients of 7% or less are ideal, as they more effectively dissipate stormwater runoff (with the proper density of functioning broad-based dips), cost less to install, and will require less frequent maintenance. At road gradients exceeding 10% the outsloped broad-based dip cannot be effectively used to control drainage. Water bars can be used but are much less effective, and require more frequent maintenance, than when installed on lesser-gradient road segments. The higher density of drainage structures required on steeper road gradients increases installation and maintenance costs.

Conservation targets could be applied, evaluated and refined in a series of pilot tests implemented by Stewardship staff on a subset of State Lands management units across the state. Several of the proposed conservation measures are already being implemented on State Lands, as depicted in Figure 12.

Table 7. Conservation Targets for Enhanced Flood Resiliency by Hydrologic Resource Zone

	River Corridor	Hydrologic Reserve Zone	Hydrologic Conservation Zone	Other Lands
Access Network Targets [1]				
Access Standards	Site-specific design	Site-specific design	OCPs	AMPs
Road density	Site-specific design	Site-specific design	<2 miles/100 acres [4]	-----
Maximum impervious area	5% [2]	0%	5% [2]	10% [3]
Average access segment slope	Site-specific design	Site-specific design	7% [4]	AMPs
Maximum access segment slope/length	Site-specific design	Site-specific design	10%/200 feet	AMPs
Erosion control structures	Site-specific design	Site-specific design	Primarily BBDs	AMPs
Erosion control structure spacing	Site-specific design	Site-specific design	{[100-(6.4*slope)]*3.281} [4] e.g., 118 ft for 10% slope	AMPs
Log landings	None	None	None	AMPs
Construction Season	Site-specific design	Site-specific design	Dry Summer	Dry Summer
Monitoring	VDEC	VDEC	FPR	FPR

[1] Including truck roads, forwarding paths, skid trails, and log landings.
[2] Fitzgerald, 2007 - Recent Vermont-based studies linking percent imperviousness to geomorphic and biologic condition of streams suggests that low-order streams (headwaters tributaries) may experience impacts from stormater runoff at thresholds lower than 5% impervious cover.
[3] Booth, 1991; Center for Watershed Protection, 2003.
[4] Swift, Jr., L.W, 1988. Forest Access Roads: Design, Maintenance, and Soil Loss

Abbreviations: BBDs = Broad-based dips; AMPs = Acceptable Management Practices; OCPs = Optimal Conservation Practices

Figure 12. Exemplary practices implemented at State Lands management units to enhance flood resiliency.

(a) Corduroy stream crossing at Tinmouth Channel WMA reduces sediment erosion and dissipates stormwater runoff along road approaches to the creek.

(b) broad-based dips installed on forest road in Plymsbury WMA off Old Shrewsbury Road.

(c) Road segments have been down-sized, vegetated, and culverts removed in a portion of the access network at Curtis Hollow drainage in Coolidge State Forest East.

Address Legacy Impacts

Often, the state has acquired lands with a legacy of road and trail networks that do not meet the conservation targets recommended in Table 7. Over time, legacy roads and trails located in the most vulnerable land settings should be downsized or decommissioned to reduce the degree to which they may continue to serve as a source of concentrated runoff. Downsizing involves narrowing the road and installing appropriate densities of drainage structures, and would reduce the degree to which stormwaters draining along these networks are directly connected to streams.

Downsizing legacy roads and use of broad-based dips (<10%) or water bars (>10% slopes) at a frequency appropriate to the road grade will still permit recreational and hunting access to State Lands, while discouraging All-Terrain-Vehicle (ATV) access (where ATV access is not allowed). For example, a segment of forest road has recently been downsized and culverts removed in the Coolidge Hollow drainage in Coolidge State Forest East (Figure 12c).

Table 8 identifies priorities for addressing legacy impacts by Hydrologic Resource Zone.

Table 8. Priorities for addressing legacy impacts by Hydrologic Resource Zone

	River Corridor	Hydrologic Reserve	Hydrologic Conservation	Other Lands
Address Legacy Impacts				
Decomission/Replace Road Segments parallel to the Streams	✓✓✓	✓✓✓	✓✓	✓
Rewild Road Segments steeper than…	--	10% ✓✓✓	25% ✓✓✓	25% ✓✓✓
Downsize/optimize access network to meet Conservation targets		✓✓	✓✓	✓
Remove Unused culvert/ bridge crossings	✓✓✓✓	✓✓✓	✓✓	✓
Disconnect roads & trails from stream channels using turn-ups, broad-based dips (active use) or water bars (inactive)	✓✓✓✓	✓✓✓	✓✓	✓
Disconnect road ditches from stream channels using turn-outs, infiltration basins, settling ponds	✓✓✓✓	✓✓✓	✓✓	✓
Buildings, parking areas, lifts/ski trails, recreational structures	Plan for removal or flood-proof	Incorporate Green Infrastructure and LID retrofits		

✓ *Higher number of check marks indicates higher priority*

6.2.2 Unit-specific application

Inventory and Map Hydrologic Resource Zones

At each State Lands management unit, areas most vulnerable to generating runoff should be inventoried and mapped following a procedure such as the mapping approach outlined in Section 4.4. This inventory process is a way to visualize those portions of the management unit more prone to generating stormwater, so that these areas can be avoided to the greatest extent possible when considering new access networks and other built infrastructure. Mapping of these hydrologic resource zones also serves as a way to prioritize restoration and decommissioning activities to address legacy impacts. It may not be practical to apply this inventory and mapping task at all State Lands management units, since not all units will be large enough or have the relevant composition to warrant application of this approach. For those larger management units across the state, however, this can be a useful characterization and prioritization tool.

For example, Figure 13 displays the mapping of Hydrologic Resource Zones at the Buffalo Brook watershed draining to Camp Plymouth State Park. This catchment includes portions of the Arthur Davis Wildlife Management Area in Plymouth and Reading. See Appendix B for an illustration of the individual mapping elements comprising these zones. A majority of the land area in the upstream drainage area to Camp Plymouth State Park is mapped as either Hydrologic Reserve Zone or Hydrologic Conservation Zone, in which proposed conservation targets would include measures somewhat more stringent than AMPs. This finding reflects the mountainous terrain and predominance of infiltration-limiting soils in this watershed. Appendix A illustrates the application of this mapping approach in the other State Lands selected for this project. (Note that a large area of Tinmouth Channel WMA mapped as Hydrologic Reserve Zone was already protected by virtue of its classification as a Class I wetland).

The mapping approach as outlined (Section 4.4), and the related conservation targets for enhanced flood resiliency (Table 7), should be field-truthed. District stewardship teams could select one State Lands management unit in each district to pilot test this inventory and mapping approach. Pilot testing would provide an opportunity to address concerns raised by the project Steering Committee that selected State Lands may not adequately represent the diversity of soil types, topographic settings and land covers on State Lands as a whole. For example, soils in the Northeastern Highlands and Northern Vermont Piedmont can be dominated by Hydrologic Group D soils, but on level or lesser-gradient (<15%) slopes (Bushey, 2015). Given this situation, the mapping approach could be refined such that land areas to be mapped as *Hydrologic Reserve* require both HSG D soils AND steep (>35%) slopes, rather than either HSG D soils OR steep slopes. Further application and testing of the mapping approach could also incorporate variable weighting of mapping elements (Pytlik, 2015).

.

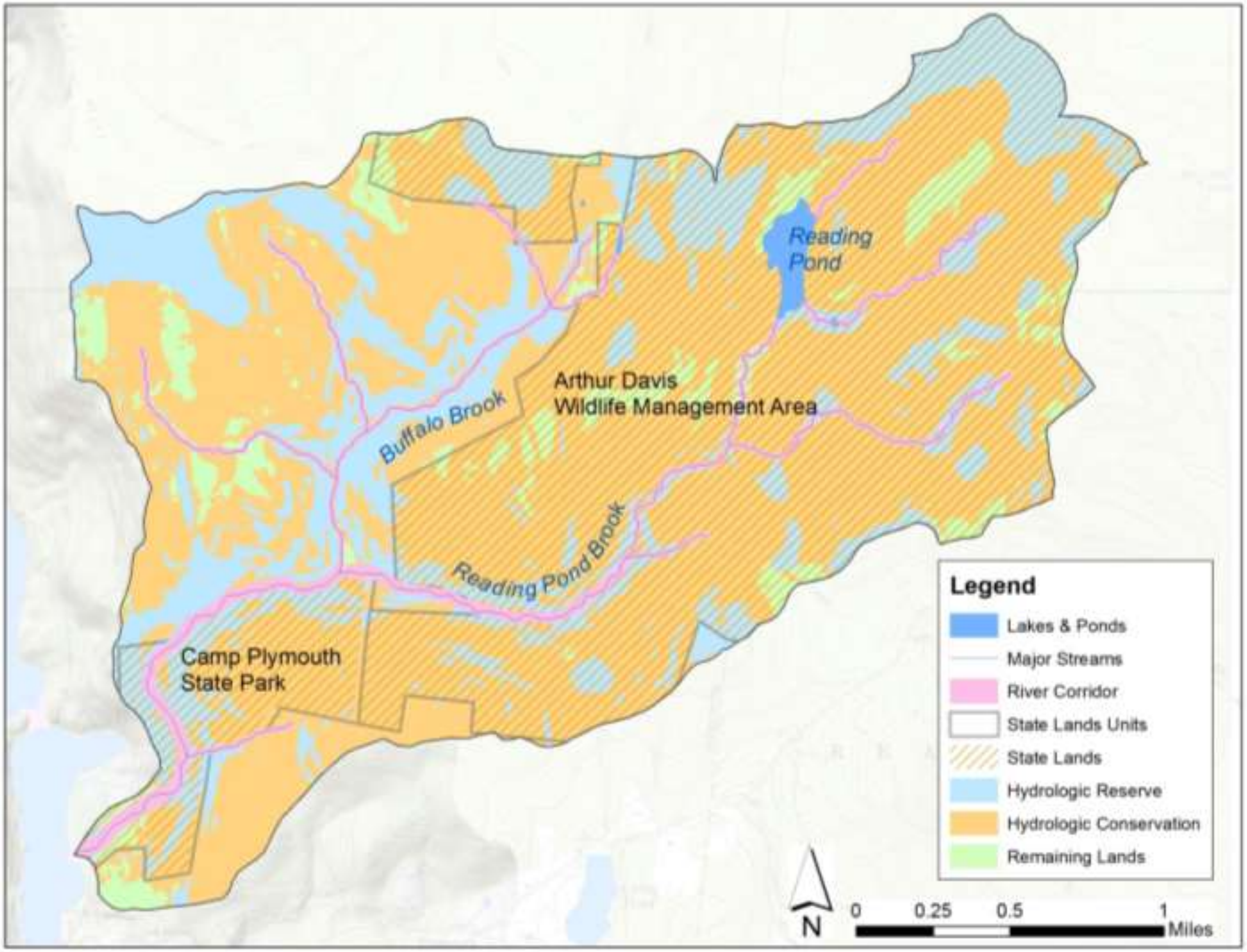


Figure 13. Application of the Hydrologic Resource Mapping Approach to Buffalo Brook watershed draining portions of the Arthur Davis Wildlife Management Area in Plymouth and Reading, joining Echo Lake at Camp Plymouth State Park.

Inventory and Map Built Infrastructure

Inventories of built infrastructure should be undertaken or formalized for each State Land management unit to inform hazard planning, capital budgeting, and flood resiliency planning. It is important to know the position and condition of this infrastructure with respect to the natural Hydrologic Resource Zones to understand the degree that infrastructure may enhance the sensitivity of the landscape to flooding, so that adequate adaptation actions can be undertaken. Similarly, this mapping process can identify infrastructure at risk from flooding, so that appropriate mitigative actions can be prioritized. Identification of structures on a commonly-available GIS platform and database (e.g., Vermont Natural Resources Atlas platform) can increase networking opportunities with private groups and public agencies to leverage additional funding sources for upgrades, retrofitting, or decommissioning.

- Road and Trail Networks - Mapping and assessment of access networks should be conducted, including roads, skid trails, and parking areas and landings. Access networks should be evaluated for conformance with Acceptable Management Practices, and ultimately for conformance with Optimal Conservation Practices. These are rapid assessments, easily implemented using a recreational-grade GPS unit, tape measure and inclinometer in a simple tally system such as the Benchmark Tally published by Vermont Family Forests (Figure 14). Figure 15 and Table 9 provide an example of an assessment performed on trail networks upstream of the Camp Plymouth State Park during this project. Forest logging trails were assessed for gradient and number/ spacing of drainage structures (see Appendix B).

Figure 14. Benchmark tally on skid trail at Camp Plymouth State Park

- Culvert & Bridge Inventories - inventories of culvert and bridge structures located on State Lands, should be conducted, including lands on which timber management rights are owned by private parties. Structure inventories should be evaluated for geomorphic compatibility as well as Aquatic Organism Passage (AOP) in accordance with VTANR Stream Geomorphic Assessment protocols (VTANR, 2009). Unused structures should be identified for removal with appropriate stream restoration. Road ditches should be disconnected from stream networks through turnouts and infiltration and detention basins. Inventory information can be used for capital budget planning and to inform priorities for structure removal, rehabilitation or replacement. Figures 16 and 17 provide examples from the Coolidge State Forest East off Curtis Hollow Road.

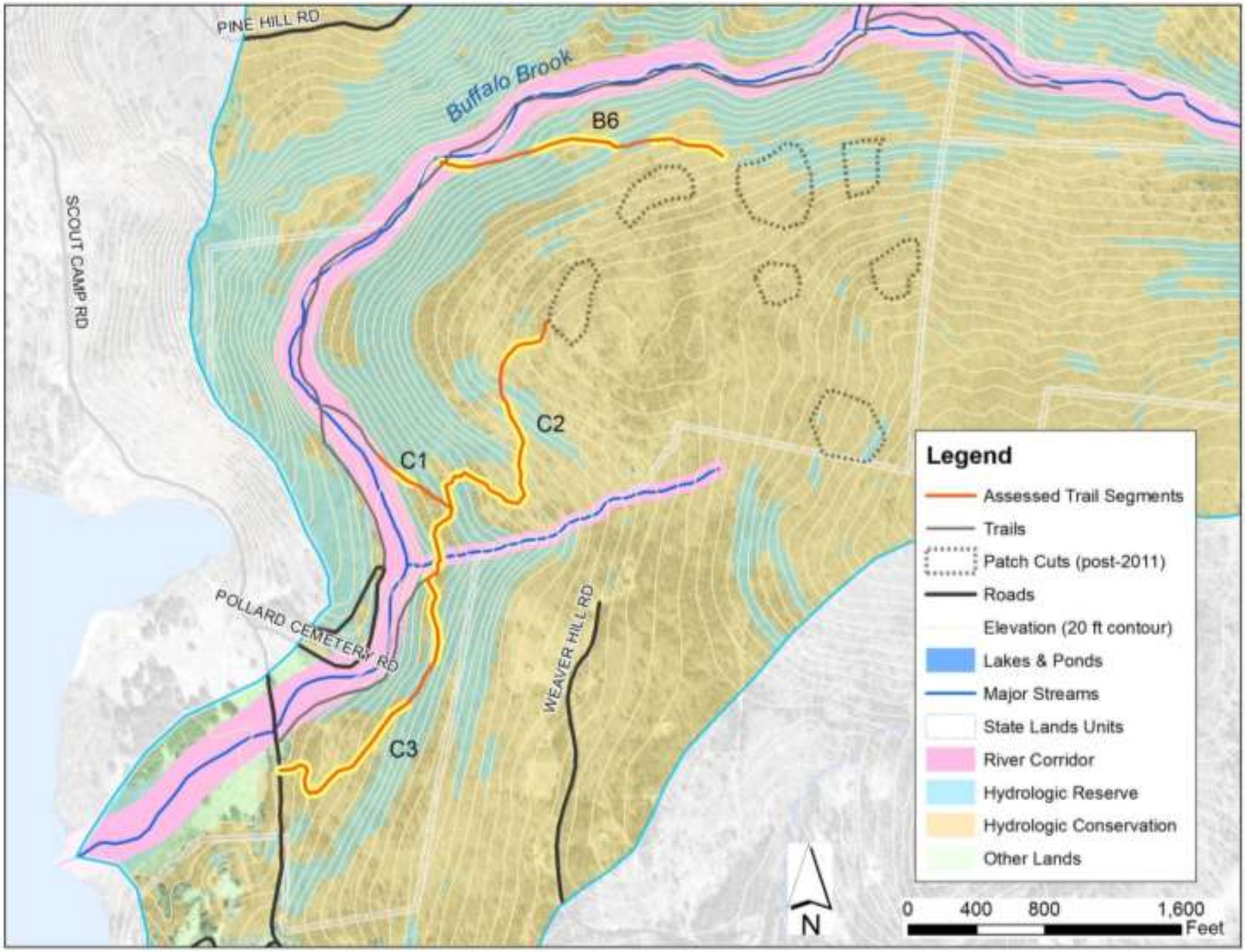


Figure 15. Road Segments Evaluated at Camp Plymouth State Park for Conformance with AMPs. Yellow highlighting indicates road segments exceeding 10% gradient.

Table 9. Evaluation of Forest Road Segments for Conformance to AMPs – Camp Plymouth State Park, Plymouth

Seg-ment	Length Assessed ft	Average slope of segment %	# functional drainage structures in place	# Drainage Structures Recom-mended	Percent Compliant with AMPs %	Percent of Length with Gradient >10% %	Percent of Length with Gradient >15% %
B6	1700	12.8	1	26	4%	59%	29%
C1	500	12.2	5	7.4	68%	40%	20%
C2	1800	16.3	15	32	47%	78%	61%
C3	2244	14.0	26	37.2	70%	85%	36%

Note: Road gradients of 7% or less are ideal, as they cost less to install, require less frequent maintenance, and more effectively dissipate stormwater runoff (with the proper density of fully-functioning broad-based dips). At road gradients exceeding 10% the outsloped broad-based dip cannot be effectively used to control drainage. Water bars can be used but are much less effective than when installed on lesser-gradient road segments, and require frequent maintenance. The higher density of drainage structures required on steeper road gradients increases installation and maintenance costs.

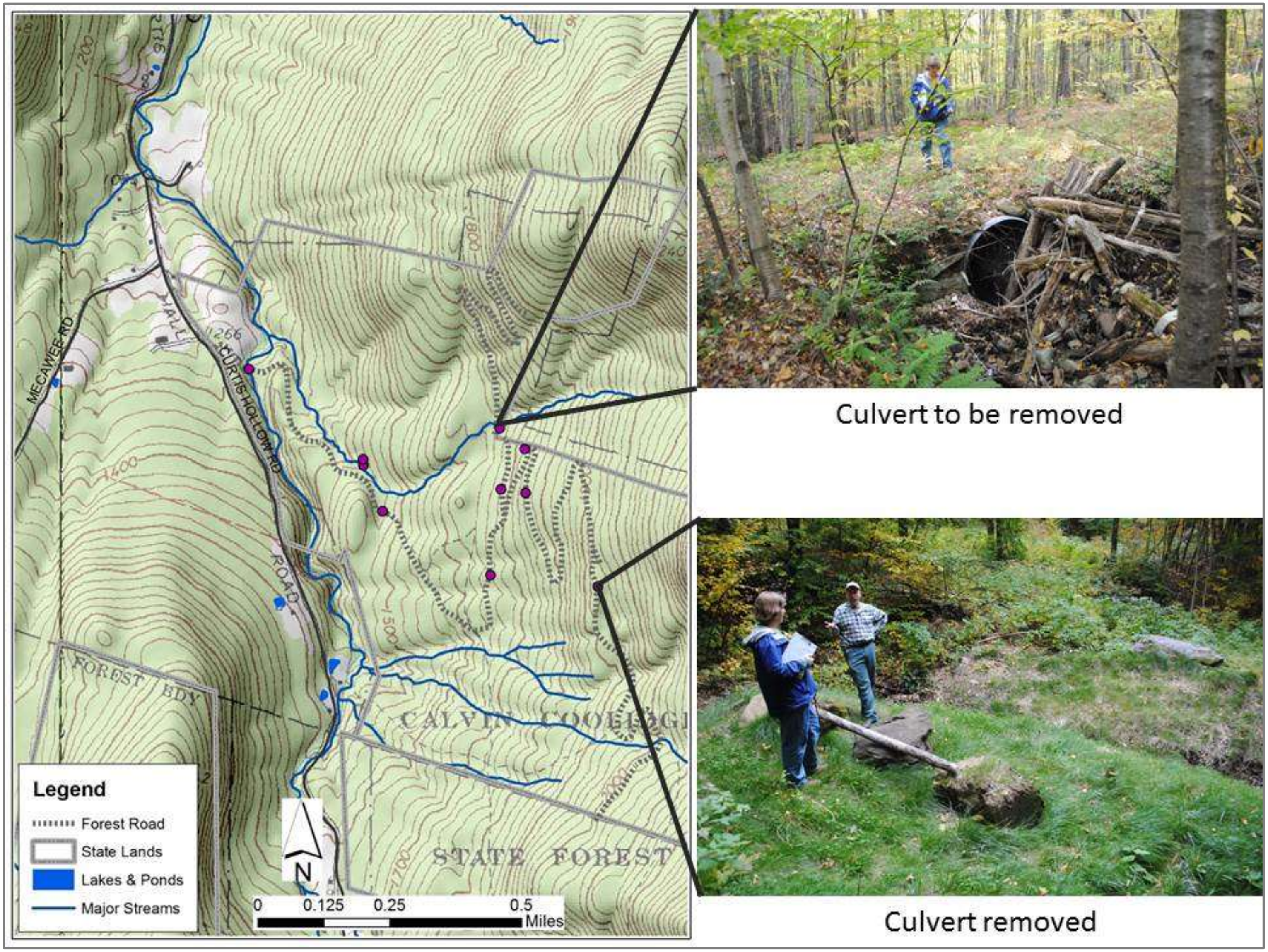
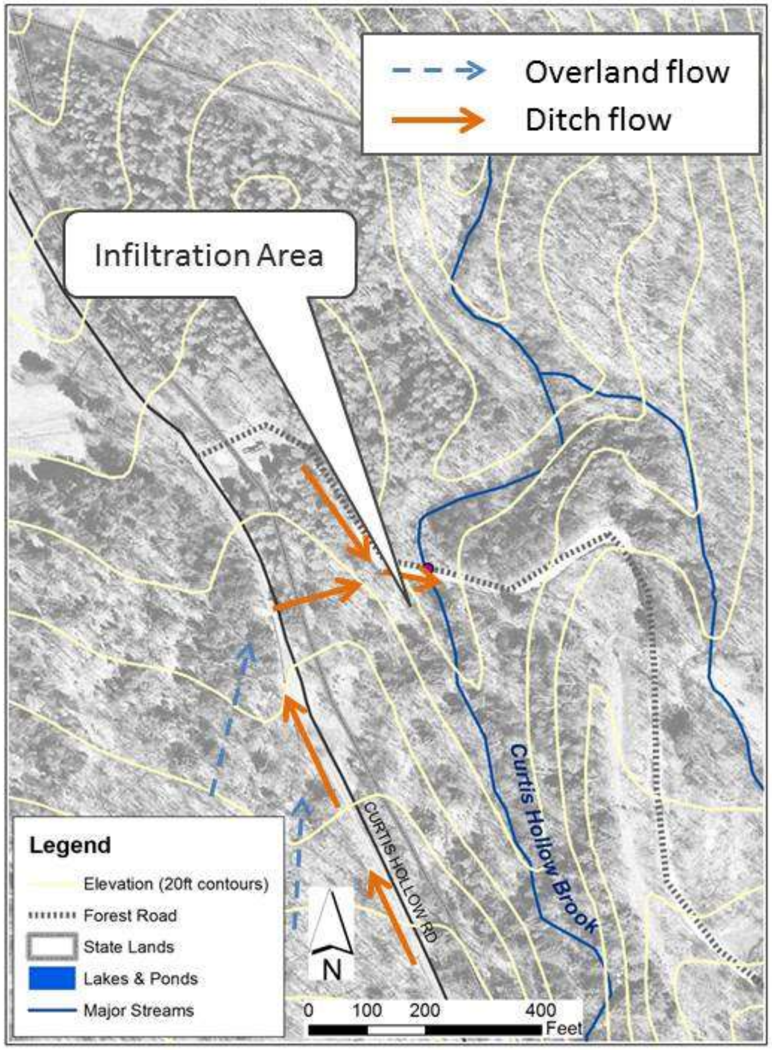


Figure 16. Example of culvert inventories at Calvin Coolidge State Forest – East, off Curtis Hollow Road, Woodstock



Abutment replaced after TS Irene

Opportunity to Disconnect Road Ditch

Figure 17. Example of Opportunity to Disconnect Road Ditch Runoff from Curtis Hollow Brook, Calvin Coolidge SF – East, Woodstock. Ditch network receives stormwater from ditches along Curtis Hollow Road. Opportunity for town collaboration and possible Better Backroads grant – a possible demonstration and training site.

- Buildings / Facilities - inventories should be conducted of buildings and facilities located within mapped river corridors. A record of repeat damages sustained during past flooding events and associated costs should be maintained and included in a life-cycle estimate of building or facility maintenance. Through these inventories, priorities can be assigned to those structures which could be relocated or removed from the corridor, and plans developed for relocation/removal following the next significant flood-damage event, including a cost threshold above which the structure will not be repaired. For those structures which – due to cultural or historical significance or other constraints – cannot be relocated or removed, emergency management plans and possible flood-proofing measures should be developed. Figure 18 depicts several structures at risk from flooding on the alluvial fan of Buffalo Brook at Camp Plymouth State Park.

Develop River Corridor Plans

River corridor plans should be developed for those stream reaches on State Lands draining greater than two square miles in area. Protocols and methods have been published by the VTANR (2009, 2011). Approved data reside in the Stream Geomorphic Assessment Data Management System and are available for viewing on the Vermont Natural Resource Atlas. A subset of these reaches on State Lands has already been assessed. For those unassessed reaches, the State Lands Stewardship Teams could collaborate with towns, Regional Planning Commissions, Conservation Districts and/or local watershed groups to secure funding for technical support services to carry out these assessments.

River corridor plans involve the physical assessment of the stream reach following Stream Geomorphic Assessment protocols. Based on the condition of each reach and the overall sensitivity of adjustment in response to changing water and sediment volumes, various stream and corridor restoration and conservation projects are identified and prioritized.

These existing protocols provide a framework for inventory and evaluation that can be leveraged by ANR on State Lands. Completed river corridor plans should be referenced within the LRMP for the respective management unit. These data will also be incorporated in VDEC Basin Plans as part of the Tactical Basin Planning[6] approach of the VDEC Watershed Management Division. This process opens the door to many more financial and technical resources to implement recommended restoration and conservation projects. An example is the Ecosystem Restoration Grant secured by Lake Rescue Association in Plymouth to accomplish rewilding of forest road segments within the private lands and State Forest lands of Buffalo Brook watershed upstream of Camp Plymouth State Park (to be implemented in 2015).

Stream and river corridor restoration projects could be incorporated in timber harvest contracts on State Lands. For example, directional felling of large woody debris into the stream channel ("chop and drop") can trap sediment and add roughness elements to the channel bed that serve to attenuate flow velocities (Figure 18). Timber sales could incorporate the hydrologic restoration needs of a State Lands unit – a "Hydrologic Restoration Sale" in addition to a "Timber Harvest Sale".

---

[6] http://www.vtwaterquality.org/wqd_mgtplan/swms_ch4.htm

Figure 18. Example of mapping to identify infrastructure at risk of erosion and inundation flooding, Camp Plymouth State Park.

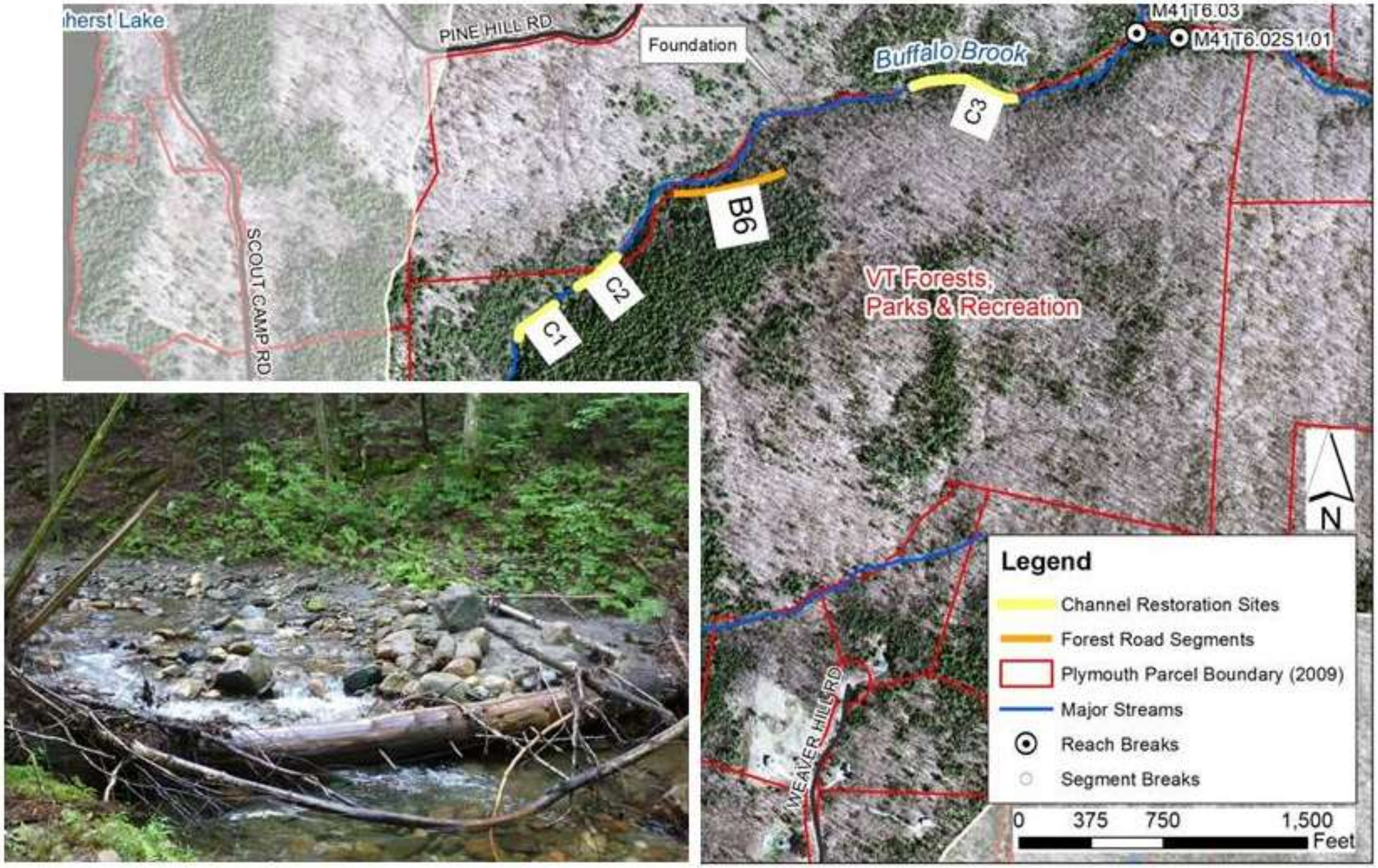


Figure 19. Example of a "chop and drop" stream restoration technique to attenuate flows, trap sediment, and improve aquatic habitats. This strategy was proposed for select segments of the Buffalo Brook upstream of Camp Plymouth State Park as part of a separate project. A similar project could be accomplished on State Lands through a "Hydrologic Restoration Sale".

6.3 Implement Actions and Monitoring

Practices to improve flood resiliency should be incorporated within the existing framework for managing State Lands, including:

- Annual Work Plans
- Lease Agreements (e.g., ski areas)
- Timber Sale Contracts

Forwarders should be used and incentivized where possible on State Lands. In general, they result in less soil compaction and less disturbance than skidders (Figure 20). As a consequence, forwarders are useful in a greater variety of weather conditions and require narrower and fewer access roads.

Skid Path, Camp Plymouth State Park

Forwarding Path, Coolidge East

Figure 20. Comparison of land disturbance from use of skidder versus forwarder to harvest timber.

(Note: Other factors contribute to the difference in site conditions between the skid path site and the forwarding path site, including different years and seasons of logging operations, shaded versus full sun setting, aspect and slope setting) .

6.4 Analyze Data, Use the Results, and Adapt

Inventories and monitoring data should be used to evaluate compliance with conservation targets. Results should be used to update mapping and help to prioritize subsequent project phases. LRMP and annual work plans can be modified and adapted, accordingly.

6.5 Capture and Share Learning

As implementation of flood resiliency measures progresses, State Lands Stewardship Teams should document major findings. Successful projects can serve as demonstration projects for other Districts and for the public. Sharing can also occur in the setting of public outreach meetings convened during development of the Long-Range Management Plans.

Stewardship staff reported a strong interest in training in flood resiliency techniques. Training could be accomplished within the Agency (VFW, VDEC) and with other partners (e.g., US Forest Service, US Fish & Wildlife, Regional Planning Commissions, Ski Areas). For example, the VDEC Rivers Program and VFW have organized training sessions with VTrans and local road crews on how to design, construct and maintain roads and bridges to create greater river stability and more flood resilient transportation infrastructure[7]. A similar model could be employed to train State Lands staff and logging contractors to incorporate conservation practices and various stream and river corridor restoration techniques for improved flood resiliency on State Lands. Projects might include infiltration basins to disconnect ditch drainage from streams, gully stabilization projects utilizing large woody debris harvested during the logging project, or "chop and drop" projects to enhance stream habitats and attenuate sediment. Such projects could involve partnership with other state and federal agencies, utilizing grant funding sources to afford professional design, permitting and construction.

<u>Possible training opportunities</u>

- Use of Planning Tools – VT Natural Resources Atlas, USGS Streamstats, Stream Simulation Design of crossing structures for Aquatic Organism Passage
- Design of flood resiliency techniques/ practices
- Design of access networks to meet conservation targets for flood resiliency
- Measurement techniques for AMPs and OCPs

Citizens should be engaged in basic mapping and monitoring tasks on State Lands, such as GPS mapping of road and trail networks and benchmark tallies to quantify density of drainage structures. This will increase public awareness of the challenges and strategies for addressing flood resiliency. It can be a way to afford necessary monitoring efforts in a context of limited ANR budgets and staffing, and it represents a way to enable the transfer of these techniques to private lands. Citizen science can be coordinated through collaboration with local watershed groups or other non-profits including the Green Mountain Club or local universities and high schools.

7.0 Implementation Plan

This section broadly outlines a plan to implement enhanced flood resiliency on State Lands. It has taken over 225 years to significantly alter the hydrology of Vermont's forests through a legacy of landscape and stream network modifications. Restoring the hydrology will take time, but is not impossible if we support the forest's capacity for self-renewal by minimizing our activities in the most vulnerable settings and by optimally siting our access to the forest for recreational use and wood-product harvest.

[7] http://www.watershedmanagement.vt.gov/rivers/docs/rv_Tier2_Overview.pdf;

Recommended actions should be phased in over time (Table 10). Implementation and refinement of Optimal Conservation Practices and conservation targets for Hydrologic Resource Zones could start small, applying these practices in a pilot project on one management unit in each District or river basin.

Restoration / conservation projects should be implemented according to priorities developed during the LRMP and River Corridor Plans. Greater priority should be placed on projects that disconnect road and trail networks from the stream network. Start with management units that experienced most significant losses in Tropical Storm Irene (in central and southern Vermont) and during the floods of the 1990s (in northern Vermont). Prioritize those areas for river corridor plans and implementation projects.

Table 10. Phased Plan to Implement Recommended Flood Resiliency Measures.

	Year						
	1	2	3	4	5	5 to 10	10 to 20
Align missions and objectives	■						
Update State-wide Plans/Policies to include Flood Resiliency	■						
Refine Conservation Targets for New Projects	■						
Develop Optimal Conservation Practices (OCPs)	■						
Develop Silvicultural Guide for Improved Flood Resiliency	■	■					
Conduct Monitoring and Evaluation - Engage Citizens	■	■	■	■	■	■	■
Conduct Training in Flood Resilience Practices	■	■	■	■	■		
Reach out to Partners to Collaborate on Implementation	■	■					
Implement Restoration / Conservation Projects w/Partners	■	■	■	■	■	■	■
Phase in OCPs			■	■	■	■	■
Address Legacy Impacts		■	■	■	■	■	■

Most importantly, implementation of flood resiliency measures will be accelerated through collaboration with other stakeholders. Often projects implemented for other purposes can have overlapping benefits for flood resiliency, opening up other avenues for technical and financial resources to accomplish flood resiliency objectives. For example:

<u>State and Federal agencies</u>

- US Forest Service - Precedent for USFS technical and/or financial resources to support projects located in the same watershed where USFS holds land.
- US Department of Agriculture, Natural Resources Conservation Service
- US Fish & Wildlife – particularly culvert / bridge crossings for AOP
- FEMA – post-disaster recovery, and hazard mitigation planning (cooperate with towns)
- Department of Homeland Security (e.g., forest road and trail mapping for emergency management purposes)

- VDEC – Ecosystem Restoration Grants, Vermont Watershed Grants (e.g., in collaboration with town or watershed groups)
- Better Backroads grants (improve road networks, collaboration with towns/watershed groups)

Public / private partnerships

- Watershed groups (e.g., citizen science for mapping, monitoring, planting)
- Colleges and Universities (service learning projects including mapping, monitoring)
- Municipalities (towns, conservation districts, RPCs)
- The Nature Conservancy (conservation of forested headwaters and attenuation assets in mid- to low-lands)
- Vermont Land Trust (conservation of forested headwaters)
- Vermont River Conservancy (conservation and restoration of river corridors)
- Private foundations

Given economic constraints, it will be necessary to work collaboratively to accomplish restoration and conservation objectives, relying to a greater extent on private-public partnerships. Our collective investment in plans, policies and practices to enhance flood resiliency on State Lands will realize greater returns in avoided loss of life, reduced flood damages, improved water quality, and improved forest health for future generations.

8.0 Conclusions

State Lands serve as useful demonstration sites to showcase exemplary practices that address the challenges of a changing climate and a legacy of landscape and river network modifications.

A suite of plans, policies, and practices for improved flood resiliency has been offered, in an adaptive management framework, to support forest health and enhanced flood resiliency on State Lands. These public lands are predominantly located in forested headwater settings. This presents an opportunity to address stormwater generation and sediment production at the source, leading to reduced flood damages along downstream reaches.

The recommended approach is not intended to discourage forest utilization for recreational and harvesting purposes, but rather to accommodate these uses through optimally-designed access networks, while supporting and enhancing forest health and structure to slow, spread, and sink stormwater.

References

Albers, J., 2002, *Hands on the land: A history of the Vermont landscape.* The MIT Press.

Beers, F. W., 1871, Atlas of Addison Co., Vermont. New York, NY: F. W. Beers, A. D. Ellis & C.G. Soule.

Booth, D. 1991. Urbanization and the Natural Drainage System-Impacts, Solutions and Prognoses. Northwest Environmental Journal 7(1): 93-118

Center for Watershed Protection, 2003, Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1.

Conservation Measures Partnership, 2013, Open Standards for the Practice of Conservation. Available at: http://cmp-openstandards.org/wp-content/uploads/2014/03/CMP-OS-V3-0-Final.pdf

Croke, J.C., and P.B. Hairsine, 2006, Sediment delivery in managed forests: a review. *Environmental Review*, 14, 59-87.

EPA, 2013, Disaster Recovery and Long-Term Resilience Planning in Vermont: USEPA Smart Growth Implementation Assistance Project, Policy Memo for the Mad River Valley, available at: http://accd.vermont.gov/sites/accd/files/Documents/strongcommunities/cpr/Vermont%20SGIA%20Policy%20Memo%20FINAL.pdf

Fitzgerald, Evan P., 2007, Linking Urbanization to Stream Geomorphology and Biotic Integrity in the Lake Champlain Basin, Vermont. Masters Thesis, University of Vermont, M. Sc. Natural Resources.

Fitzgerald, E., 2013, "Flood Vulnerability Mapping along Vermont Rivers and Road Corridors Using LiDAR Data", July 11, 2013 presentation to Vtrans**.**

Foster, D. R., and J. D. Aber, editors, 2004, Forests in Time: The Environmental Consequences of 1000 Years of Change in New England. Yale University Press, New Haven, CT

Kline, M., & Cahoon, B. (2010). Protecting River Corridors in Vermont. *Journal of the American Water Resources Association, 1*(10). doi: 10.1111/j.1752-1688.2010.00417.x

Lands Administration Division, VT Department of Forests, Parks and Recreation, undated, "Summary of ANR Lands", downloaded January 2015, from http://www.vtfpr.org/lands/landssumm.cfm

Lones, J., 2014, personal communication, VFPR State Lands Forester.

McGrory Klyza, C. and S.C. Trombulak, 1999. The Story of Vermont: A Natural and Cultural History. Hanover, NH: University Press of New England .

Merrill, Perry H., 1959, History of Forestry in Vermont: 1909 – 1959.

Morton, T., 2014, personal communication, VFPR State Lands Stewardship Forester.

Thornton, L., 2014, personal communication, VFPR State Lands Stewardship Forester.

North East State Foresters Association, 2001, The Economic Importance of Vermont's Forests.

North East State Foresters Association, 2004, The Economic Importance of Vermont's Forests.

North East State Foresters Association, 2007, The Economic Importance and Wood Flows from Vermont's Forests.

North East State Foresters Association, 2013, The Economic Importance of Vermont's Forest-Based Economy.

NRC. 2010. Monitoring climate change impacts : metrics at the intersection of the human and Earth systems. Edited by National Research Council Climate, and National Security Topical Panels. Washington, D.C.: National Academies Press

Pechenick, A.M., D.M. Rizzo, L.A. Morrissey, K.M. Garvey, K.L.Underwood and B. Wemple, 2014, A multi-scale statistical approach to assess the effects of connectivity of road and stream networks on geomorphic channel condition. *Earth Surface Processes and Landforms*, 39, 1538-1549.

Schiff, R., 2014, "Vermont River Sensitivity Coarse Screen", November 2014 presentation to Massachusetts Fluvial Geomorphology Task Force Technical Meeting.

Schumm, Stanley A. (1977) The Fluvial System. New York, NY, USA: J. Wiley

Severson, J. P., 1991, Patterns and causes of 19th and 20th century shoreline changes of the Winooski Delta. University of Vermont, Field Naturalist Program, M.S. Thesis.

Smith, H. P., 1886. "History of the Town of Ferrisburgh" in History of Addison County, Vermont. Syracuse, NY: D. Mason & Co., Publishers. Stilwell, Lewis D., 1948, Migration from Vermont

Strahler, A.N., 1952. Hypsometric (Area-Altitude) Analysis of Erosional Topography. *Bulletin of the Geological Society of America*, 63: 1117-1142.

Stilwell, Lewis D., 1948. Migration from Vermont. Montpelier, Vermont: Vermont Historical Society. 246 p.

Thompson, Elizabeth H. and Eric R. Sorenson, 2000. Wetland, Woodland, Wildland: A Guide to the Natural Communities of Vermont. Hanover, NH: University Press of New England.

United States Department of Agriculture, 1986. *Urban hydrology for small watersheds*. Technical Release 55 (TR-55) (Second Edition ed.). Natural Resources Conservation Service, Conservation Engineering Division.

USDA Soil Conservation Service, 1991, Soil Potential Study & Forest Land Value Groups for Vermont Soils.

USDA Natural Resource Conservation Service, 2007, State Data Table Top 20, published by the United States Department of Agriculture, NRCS; available at: ftp://ftp-fc.sc.egov.usda.gov/VT/Soils/top20/

USDA Natural Resource Conservation Service, 2006, Soil Survey Geographic (SSURGO) database, available at: http://www.vcgi.org/dataware/default.cfm?layer=GeologicSoils_SO

VTANR, October 1999, Lands Conservation Plan: A Land Acquisition Strategy for the Agency of Natural Resources

VTANR, August 2001, Long Range Management Planning Support Documentation

Vermont State Auditor, January 2015, "State Land Leases Boost Ski Industry, but Are Dated and Inconsisent": Report to the Vermont Legislature and the Agency of Natural Resources, Non-audit report 15-01, downloaded January 2015, from http://auditor.vermont.gov/reports/other/ski_leases

Vermont Watershed Management Division, 2014. *Vermont Water Quality Standards*. Effective 30 October 2014. Montpelier, VT. http://www.watershedmanagement.vt.gov/rulemaking/docs/wrprules/wsmd_wqs2014.pdf

VT Department of Environmental Conservation, 2014 (Dec 5), Vermont DEC Flood Hazard Area and River Corridor Protection Procedures (available at: http://www.vtwaterquality.org/rivers/docs/FHARCP_12.5.14.pdf

Weist, Richard L. 1998. A Landowner's Guide to Building Forest Access Roads. NA-TP-06-98. Radnor, PA : USDA Forest Service, Northeastern Area State and Private Forestry; 45 p.

Wemple, B. C., J. A. Jones, and G. E. Grant (1996), Channel network extension by logging roads in two basins, Western Cascades, Oregon, Water Resources Bulletin, 32(6), 1195-1207.

*"Health is the capacity of the land for self-renewal.
Conservation is our effort to understand and preserve that capacity." Aldo Leopold*

North American Maple Plot, Coolidge East, October 2014

Appendix A

Site Visit Summaries

30 June 2015 FINAL DRAFT

Table of Contents

Introduction

Each of the selected State Lands was visited during the 2014 field season by the Project Team, accompanied by various members of the Steering Committee and State Lands Stewardship staff, as summarized in Table 1. Interviews with staff were conducted during the site visit; findings are detailed in the following sections, along with site photographs and location maps.

Table 1. Schedule of site visits to selected State Lands, 2014

Management Unit	Town	Date
Camp Plymouth State Park	Plymouth	June 5, October 20
Tinmouth Channel Wildlife Management Area	Tinmouth	June 18
Coolidge State Forest West – *Killington Resort*	Killington	July 31
Coolidge State Forest West - *CCC Rd, Old Plymouth Rd*	Plymouth, Shrewsbury	September 8
Coolidge State Forest East – *Curtis Hollow, Quarry Road*	Woodstock, Plymouth	September 29
Les Newell Wildlife Management Area *Stony Brook Road*	Stockbridge	December 1

Camp Plymouth State Park

Site Visit Date: 5 June 2014

Personnel: Ethan Phelps, VFPR Parks Regional Manager
Tim Morton, VFPR Stewardship Forester
Marie Caduto, VDEC Watershed Management Division
David Brynn, Vermont Family Forests
Kristen Underwood, South Mountain R & CS

Geographic Setting

Camp Plymouth State Park is located in Plymouth, Vermont, on the eastern shore of Echo Lake in the upper Black River watershed. Approximately 45 acres on the west side of Scout Camp Road are improved with parking areas, pavilions, camp buildings, and recreational facilities (Figure 1). The Park also includes 250 acres on the east side of Scout Camp Road, including 4 cabins adjacent to the road, and a road and trail access network on forested lands for recreation and timber harvest [1].

Hydrologic / Geomorphic Setting

Buffalo Brook flows through the State Park crossing under the Scout Camp Road just south of the entrance to the Park. The State Park is located along the lowest reach of Buffalo Brook (M41T6.01). This tributary drains a forested, mountainous catchment approximately 5.7 square miles in area and empties into Echo Lake, the second in a series of four instream lakes on the Black River [2, 3] (Figure 2). The Buffalo Brook watershed spans the towns of Plymouth and Reading; lands are in both public and private ownership. The State of Vermont, Department of Forests, Parks & Recreation (VFPR) owns and manages the Camp Plymouth State Park at the southwest extent of the watershed. The Vermont Fish & Wildlife Department (VFW) owns additional lands in the watershed which are part of the Arthur Davis Wildlife Management Area. A private party (Clifford) holds timber management rights on the lands owned by VFW. Soils of the Tunbridge-Lyman complex and the Berkshire-Tunbridge complex are particularly prevalent in the watershed, reflecting the shallow bedrock and the glacial-till origins of soil parent material [1, 5, 6].

Built Infrastructure

Infrastructure at Camp Plymouth State Park including 4 cabins east of Scout Camp Road, and several buildings including pavilions, camp buildings, lean-tos, parking lots and access roads on the west side of Scout Camp Road (Figure 1). A network of forest access road and trails exists on the east side of the road, providing access to state park and Arthur Davis WMA lands upslope of the park.

Tropical Storm Irene

On 28-29 August 2011, rainfall from Tropical Storm Irene caused widespread flooding in the State of Vermont. Impacts were particularly devastating in central and southern Vermont in areas with significant pre-storm soil moisture levels from rainfall that had fallen in earlier weeks. Between 6.6 and 7.8 inches of rainfall were recorded for the storm at stations maintained by the National Weather Service in Ludlow. Flooding along the upper Black River caused several washouts along Route 100 between Ludlow and Bridgewater Corners. Homes were lost to flooding in Plymouth [6].

Camp Plymouth State Park at the mouth of Buffalo Brook sustained substantial damages during Tropical Storm Irene (Figure 3). More than 35,000 yards of silt, sand and gravel were excavated from the park in the months following the flood [4]. Dredging of silt from the beach area in Echo Lake also occurred following TS Irene.

Echo Lake was highly turbid in the weeks following TS Irene (Figure 4). Water clarity issues persisted for months, in part due to channel activities associated with road and other infrastructure repairs in upstream reaches of the Black River [6].

Major Findings from Site Visit

Areas viewed during the site visit included the State Park facilities on both sides of Scout Camp Road, the flood deposits and delta formed by Buffalo Brook out into Echo Lake, and select trails (C1 and C3) in the lower Buffalo Brook watershed uphill of the Park (Figure 5; see attached Site Photographs).

- The Park sustained significant damages in early floods of 1973, late 1970s, early 1980s, as well as TS Irene (Aug 2011) [7].
- During TS Irene, Echo Lake rose 11 feet, with at least 3 feet of water in the concession stand and water reaching the gate house (photo 1). Septic tanks were submerged and silted in. Silt was later dredged from the beach.
- Trees & debris jammed the Scout Camp Road bridge (photo 5). The bridge span is undersized (46% of the bankfull width) and has a sharp approach angle [5]. Buffalo Brook jumped its banks and breached a 1970s-era berm to flow between cabins and down the camp entry road (photos 3 & 4). Park roads were scoured up to 2 to 3 feet (Figure 3). Grass-turfed areas fared much better and had minimal erosion. The Park incurred approximately $250,000 in damage; some expenses were reimbursed by FEMA, but the majority of expenses were paid for from the capital budget [7].
- Select trails east of Scout Camp Road were accessed on 5 June 2014 (Figure 5). Trail C3 (and C2) represent new skid trails that were installed post-Irene to access patch cut sites further to the northeast on VFPR lands (Figure 5). This new skid trail was installed to avoid using an existing narrower trail that runs close to the Buffalo Brook [8].
- Several segments of the new trail exceed 10% gradient and traverse very steep slopes (photos 6, 8).

The Project Team decided to focus on Camp Plymouth State Park as a demonstration site for application of recommended flood resiliency measures, including monitoring for conformance to the AMPs, and mapping of hydrologic resource zones. An additional site visit was conducted on 20 October 2014 to collect additional field data (see Appendix B).

References:

[1] VTANR, 2004, Camp Plymouth State Park: Long Range Management Plan.

[2] VTANR, 2015, Vermont Natural Resources Atlas, accessed at: http://anrmaps.vermont.gov/websites/anra/

[3] VTANR, 2015, Stream Geomorphic Assessment Data Management System accessed at: https://anrweb.vt.gov/DEC/SGA/projects.aspx

[4] Saylor, Chris, 2012, Vermont State Parks after Irene, 8/22/12, Vermont Public Radio, available at: http://www.vpr.net/episode/54251/slayton-vermont-state-parks-after-irene/

[5] South Mountain Research & Consulting, 2010. Phase 2 Stream Geomorphic Assessment: Black River Watershed, Rutland & Windsor Counties, Vermont - Addendum 1: Patch Brook & Buffalo Brook Tributaries, Towns of Plymouth, Reading, Mount Holly, Ludlow

[6] South Mountain Research & Consulting, 2014. Alternatives Analysis: Buffalo Brook Watershed, Tributary to upper Black River, Plymouth, Windsor County, Vermont. Prepared for Lake Rescue Association.

[7] Phelps, Ethan, 5 June 2014, personal communication.

[8] Morton, Tim, 5 June 2014, personal communication.

Figure 1. Camp Plymouth State Park, located along Scout Camp Road at the eastern shore of Echo Lake, Plymouth, VT.

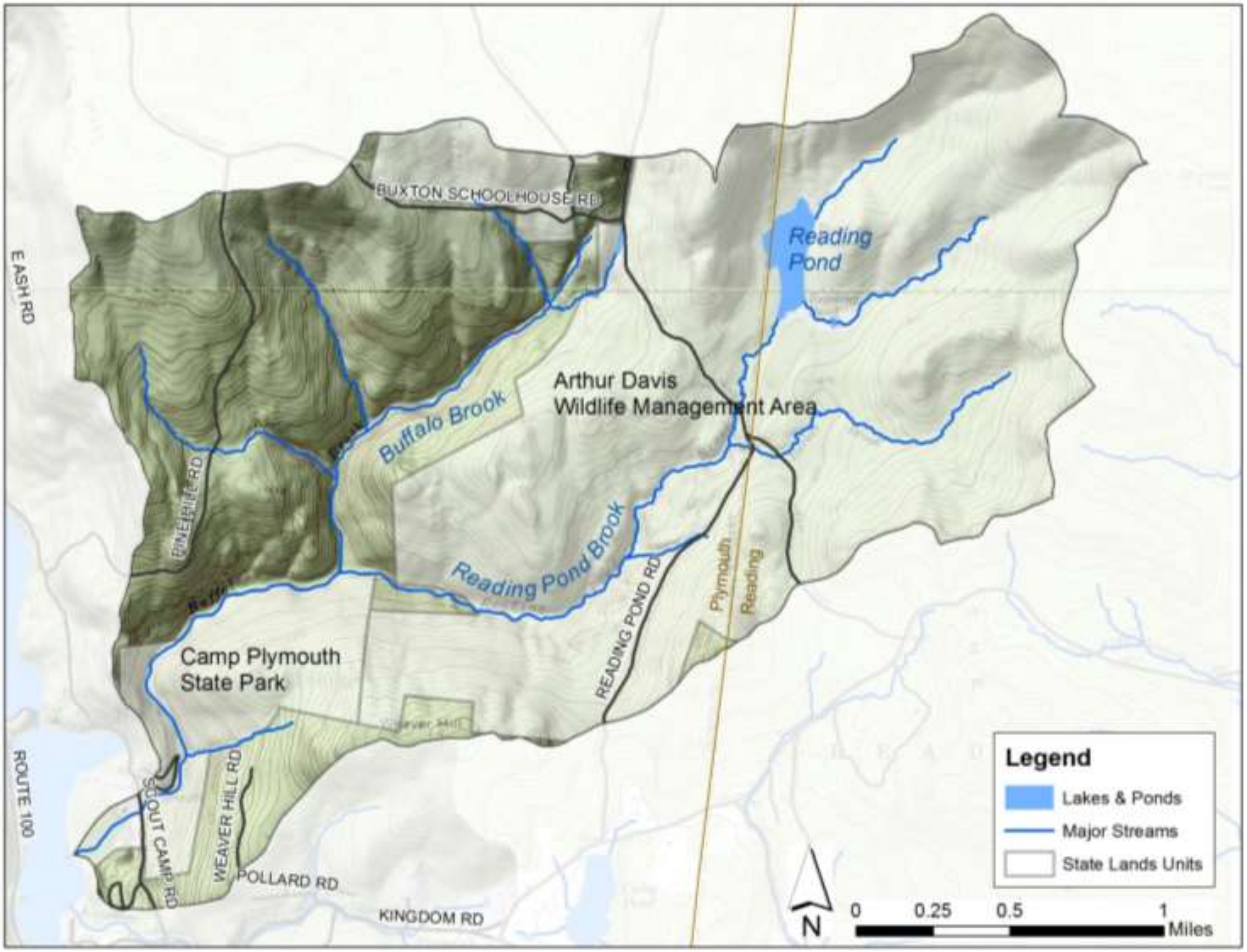


Figure 2. Buffalo Brook watershed draining to Echo Lake at Camp Plymouth State Park.

Figure 3. Camp Plymouth State Park in the hours and days following TS Irene. Photo credits: Chris Saylor. Source: Vermont State Parks after Irene, 8/22/12, Vermont Public Radio http://www.vpr.net/episode/54251/slayton-vermont-state-parks-after-irene/

Washed Away – The Sculpin By Pete Corradino , 9/6/11, Audubon Guides, http://blog.audubonguides.com/tag/hurricane-irene/

Figure 4. Aerial view of Echo Lake just south of Camp Plymouth State Park,
in the vicinity of the Kingdom Brook confluence, view to the southeast, 12 September 2011.
Photo credit: www.mansfieldheliflight.com

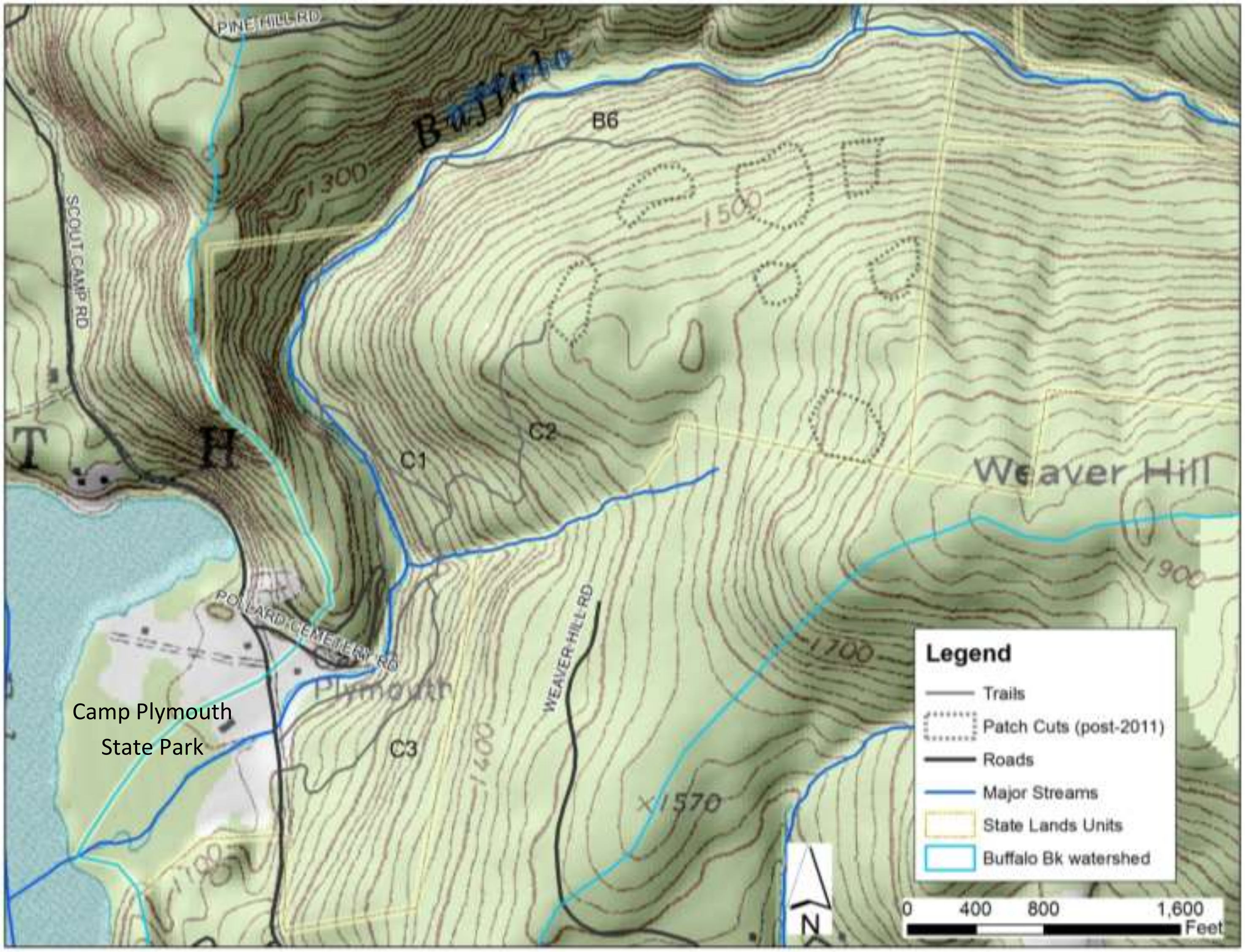


Figure 5. Site visit on 5 June 2014 focused on facilities at the State Park along Scout Camp Road and logging roads, C1 and C3

Camp Plymouth State Park, Buffalo Brook watershed, Plymouth, VT – 6/5/2014

1. View to west from Scout Camp Rd, past Park entrance.

2. View of Buffalo Brook confluence with Echo Lake (delta)

3. View downstream in Buffalo Bk adjacent to Park cabins.

4. View upstream from cabins; post-Irene streambank armor.

Camp Plymouth State Park, Buffalo Brook watershed, Plymouth, VT – 6/5/2014

5. Right-bank abutment of Scout Camp Rd (2009)

6. View uphill from trail junction to C2; 25% road gradient.

7. Incision and widening of stream channel observed downslope from C2 forest road crossing.

8. Forest road installed across >35% slopes, to access patch cuts. Steepness of hillsides and use of skidders necessitated wide road cuts. Steepness of road grade (>10%) required frequent water bars.

Tinmouth Channel Wildlife Management Area -

Site Visit Date: 18 June 2014

Personnel: Lisa Thornton, VFPR Stewardship Forester
John Lones, VFPR Forester
Shannon Pytlik, VDEC Rivers Program
Marie Caduto, VDEC Watershed Management Division
David Brynn, Vermont Family Forests
Kristen Underwood, South Mountain R & CS

Figure 1. View to south into Tinmouth Channel WMA along Clarendon River from North End Rd.

Geographic Setting

Tinmouth Channel Wildlife Management Area (WMA) is located in Tinmouth, Rutland County, Vermont, accessed from VT State Route 140. Three separate lots comprising 1,260 acres are bisected by the Clarendon River (Figure 1) which flows from south to north through a wide valley between Tinmouth Mountains to the west and Clark Mountain to the east (Figure 2) .

The major feature of the WMA is Tinmouth Channel, the channel-contiguous wetland along the Clarendon River. For a brief time in the late 1700s, the area was impounded behind an earthen dam to support operations of an iron forge [1]. Tinmouth Channel is designated as a Class 1 wetland, one of three in the State of Vermont. This designation ensures enhanced protections for wetland ecosystem services including flood attenuation and groundwater and surface water protection.

Hydrologic / Geomorphic Setting

The Tinmouth WMA is drained by the Clarendon River and its tributaries. The three lots of the Tinmouth WMA are bisected by the Clarendon River (reaches R20T1.13 through R20T1.15 [2]). At the North End Road culvert crossing, the Clarendon River has a 16.4 square mile upstream drainage area dominated by forest cover (67%) with lesser percentages of crop (11%) and urban (8%) land uses [3]. The Clarendon River joins the Otter Creek at Center Rutland approximately 12 miles to the north, which drains ultimately to Lake Champlain.

Slopes within the three lots of the Tinmouth WMA are gentle to moderate (less than 15%). Soils are dominated by Hydrologic Soil Group D and hydric soils (Figure 3).

Built Infrastructure

Onsite infrastructure includes parking lots and kiosks off N End Rd and the forest access network (forest roads, skid paths, forwarder paths, and logging landings),. The town of TInmouth maintains roads and stream crossings immediately adjacent to the WMA on North End Rd, Channel Road, and N East Rd. The state of Vermont maintains Route 140 and its crossing of the Clarendon River and its tributaries.

Tropical Storm Irene

On 28-29 August 2011, rainfall from Tropical Storm Irene caused widespread flooding in the State of Vermont. Impacts were particularly devastating in central and southern Vermont in areas with significant pre-storm soil moisture levels from rainfall that had fallen in earlier weeks. Between 5 and 6 inches of rainfall were recorded for the storm at stations maintained by the National Weather Service in neighboring towns. No major losses or damages were reported for Tinmouth WMA by Stewardship staff. It is likely that this wetland served to attenuate flood waters offering protection to downstream communities.

Major Findings from Site Visit

Areas viewed during the site visit included upland forest areas accessed via forest roads from two parking areas along the western and northern boundaries of the largest WMA parcel off N End Rd (see waypoints on Figure 1, and attached Site Photographs).

- Although many of the State Lands management units are located in headwater settings on steep lands, Tinmouth WMA provides an example of a lowland, wetland setting. While slowing and disconnecting runoff is the primary strategy on steeper lands with regard to enhancing flood resilience, support of floodwater attenuation functions is the primary goal in lowland settings such as Tinmouth WMA.
- Primary management goals in the Tinmouth WMA are for wildlife habitat (e.g., support Deer Wintering Areas, create browse) according to the LRMP.
- Private land along the eastern boundary limits access for active timber management.
- Timber sales occurred at this WMA in the winter months of 2013.
- Short segments of the forest access road and logging landing accessed from the western boundary parking area are positioned within required setbacks from a perennial stream (e.g., Photo 4). The group discussed the cost/benefit of moving road segments (and cutting new paths to replace out-of-compliance sections) to comply with AMPs versus maintaining legacy road layouts for short segments that do not meet AMPs.
- Exemplary practices were observed including coarse woody debris corduroy at stream crossings. This site prompted a discussion of the value of river corridors (per VANR guidance) over simple setbacks defined in AMPs.
- Several areas of the WMA are not actively managed (particularly along the eastern boundaries where permission would be required to cross private lands) and therefore function as "ecological reserve" areas.
- Management of hydrologically sensitive areas is accomplished in practice, typically through operational guidelines of a given timber sale or as spelled out in an annual work plan, rather than specifically called out in the Long Range Management Plan.
- Water resource assessments are more commonly being incorporated in the Long Range Management Plan in recent years. Basin planners from VDEC are being included in some of the State Lands Stewardship Teams (but not in all districts) and are involved in Annual Work Plan meetings.
- AMP compliance is typically overseen by VFPR staff. There is no measurement of compliance through monitoring programs. Rather, this is a complaint driven program. A logging contractor is contractually obligated to follow the AMPs. VFPR staff evaluate compliance in a qualitative way through regular inspections of a logging operation and provide guidance through operational requirements specified in the timber sale – (e.g., stream crossing requirements, flag road layout).
- Funding opportunities within VFPR for hydrologic restoration or road decommissioning are significantly limited. In recent years, the Department received approximately $100,000 state-wide to work on roads – the District including Tinmouth WMA received approximately $7,000.

References:

[1] VTANR, 2012, Tinmouth Channel Wildlife Management Area: Long Range Management Plan.

[2] VTANR, 2015, Vermont Natural Resources Atlas, accessed at: http://anrmaps.vermont.gov/websites/anra/

[3] VTANR, 2015, Stream Geomorphic Assessment Data Management System accessed at: https://anrweb.vt.gov/DEC/SGA/projects.aspx

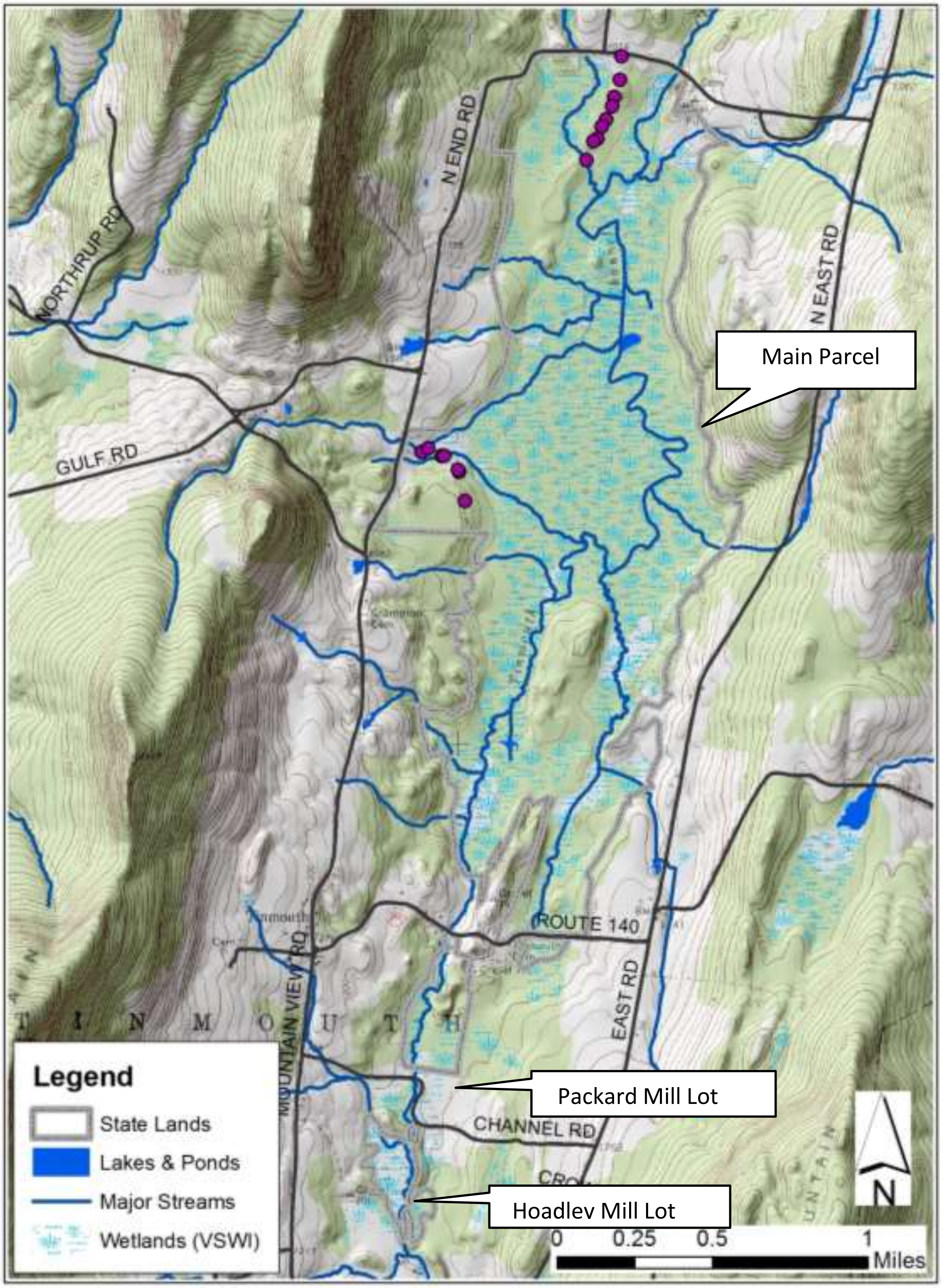


Figure 2. Location map, Tinmouth Channel Wildlife Management Area, Tinmouth, Vermont

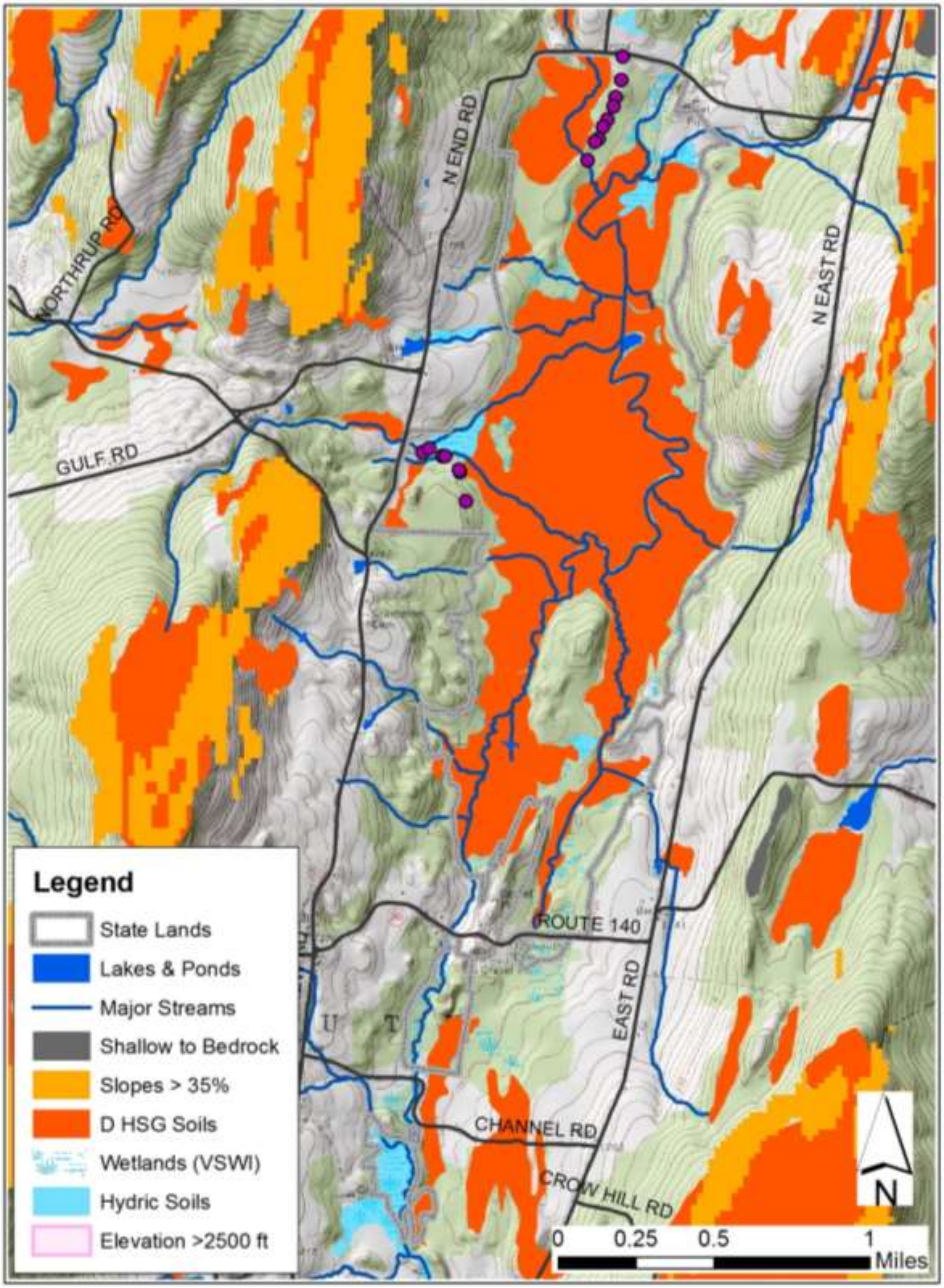


Figure 3. Elements comprising the Hydrologic Reserve zone at Tinmouth Channel WMA.

Tinmouth Channel WMA, Tinmouth, VT – 6/18/2014

1. View to east to log landing last worked in 2013; accessed from western-boundary parking area off N End Rd.

2. Stream crossing stabilized with coarse woody debris.

3. Logging access road through forested uplands used for recreation and hunting.

4. Log landing situated within 30 feet of perennial stream.

Tinmouth Channel WMA, Tinmouth, VT – 6/18/2014

5. Exemplary stream crossing practice.

6. Road approach to stream crossing in photo 5.

7. View to south into former log landing; from northern-boundary parking access off N End Rd.

Coolidge State Forest West -

Killington Resort

Site Visit Date: 31 July 2014

Personnel: Jeff Temple, Director Mountain Operations, Killington Resort
Tait Germon, Patrol Director, Killington Resort
Ethan Phelps, VFPR Parks Regional Manager
Nate McKeen, VFPR Forestry District Manager
Marie Caduto, VDEC Watershed Management Division
Kristen Underwood, South Mountain R & CS

Geographic Setting

Killington Resort leases approximately 1,676 acres of land [1] in the Coolidge State Forest encompassing slopes of Bear Mountain, Killington Peak, Snowden Peak and Rams Head Peak in Killington, Vermont (Figure 1). The resort operates year-round, offering skiing, snowboarding, mountain biking, hiking, golf, and other activities.

Hydrologic / Geomorphic Setting

Leased State Lands of the Killington Resort are positioned on the uppermost reach (T6.08) of the Roaring Brook which drains to the Ottauquechee River [2]. This upper reach has a drainage area of 1.1 square mile and an average slope of 8.3%. The catchment is mostly forested (80%), but contains significant area cleared for ski trails (14.3%) and some development (1.9 %) (Figure 2) [3]. Nearly the entire leased-land area is above 2,500 feet in elevation, and dominated by HSG D and C soils and steep slopes (>35%) (see Figure 3).

Built Infrastructure

Built infrastructure on leased lands within the Killington Resort includes buildings (e.g., Peak Lodge, lift operation buildings), ski lifts and other ancillary structures including a board walk connecting the Peak Lodge to the top of Canyon Quad lift. The area also includes an extensive network of gravel maintenance roads and ski trails, which are utilized year-round.

Tropical Storm Irene

Killington Resort sustained $6.2 Million damage during TS Irene (28-29 August 2011). Insurance covered buildings, but not trail damages [4]. Floodwaters of the Roaring Brook undermined the foundation of the Superstar Pub, an addition to the K-1 Lodge which had been built over the brook (see Photo 1). At this location the Roaring Brook is a second-order stream with an upstream drainage area of only 0.67 square mile. Based on peak flow measured at the nearby Kent Brook gage, the peak flow in Roaring Brook at this location during TS Irene would have been approximately 575 cubic feet per second. At a gradient of 8%, this discharge would have been sufficient to generate bed shear stresses well in excess of 20 pounds per square foot. The pub was rebuilt, but as a separate structure located to the east of the

Brook (photo 3). Further downstream, Roaring Brook caused significant damage in the vicinity of the Route 4 corridor (photo 2).

Major Findings from Site Visit

Areas viewed during the site visit included the K-1 lodge, the Gondola lift and Peak lodge, access roads along the Canyon Quad ski lift, and the board walk connecting the Peak Lodge to the top of the Canyon Quad lift (see attached Site Photographs). The Project Team was accompanied by Tait Germon, Patrol Director. A meeting with Tait and the Director of Operations, Jeff Temple, preceded the field visits.

- VFPR noted there has been great improvement in water quality of Roaring Brook since the 1970s. The resort is undertaking a water quality remediation plan for impaired water segments on the Roaring Brook, including culvert replacements.
- VFPR is a co-applicant on Act 250 permits submitted by the resort for construction or development activities within the boundaries of the Coolidge State Forest. Improved coordination between VDEC Stormwater staff, resort staff and VFPR staff would streamline oversight and ensure greater consistency in methods and guidance.
- Existing trail maintenance guidance could be improved to incorporate flood resiliency planning [5, 6, 7]
- Ski areas on State Lands operate under long-term lease agreements; the current lease agreement for Killington was established in 1960 and extends to 2060 [8]. Killington Resort submits an annual work plan for resort operations/ maintenance to occur on leased State Lands. There is opportunity for State Lands Stewardship Teams to comment on and guide activities to improve flood resiliency.
- There is opportunity to collaborate amongst ski areas which lease State Lands (e.g., Burke Mtn) to implement pilot projects in glade management to improve flood resiliency (e.g., look at alternative harvesting mechanisms and approaches to retain/ detain stormwater runoff in glades; implement improved trail drainage; optimize road network placement; implement signage in high-visibility areas to educate the public re: flood resiliency measures).
- Improved flood resilience on leased State Lands in ski resorts will improve bottom line of resort operations, by reducing or avoided damages sustained during future flood events.

References:

[1] VTANR, 2008, Coolidge State Forest – West of Rt 100: Long Range Management Plan.

[2] VTANR, 2015, Vermont Natural Resources Atlas, accessed at: http://anrmaps.vermont.gov/websites/anra/

[3] VTANR, 2015, Stream Geomorphic Assessment Data Management System accessed at: https://anrweb.vt.gov/DEC/SGA/projects.aspx

[4] Temple, Jeff, 2014, personal interview, Director Mountain Operations, Killington Resort

[5] UVM Agricultural Experiment Station, c.1973, Guide to Vermont Ski Trail Construction and Management, Pamphlet 39.

[6] VDEC, 2000, Guidelines for the Design and Construction of Ski Lifts and Trails in Class A Watersheds in Vermont.

[7] Hastings, Blaine, 2014, hydrologist with VDEC Watershed Management Program, personal communication.

[8] Office of the Vermont State Auditor, 2015, State Land Leases Boost Ski Industry but are Dated and Inconsistent: Report to the Vermont Legislature and the Agency of Natural Resources. Non-audit report 15-01.

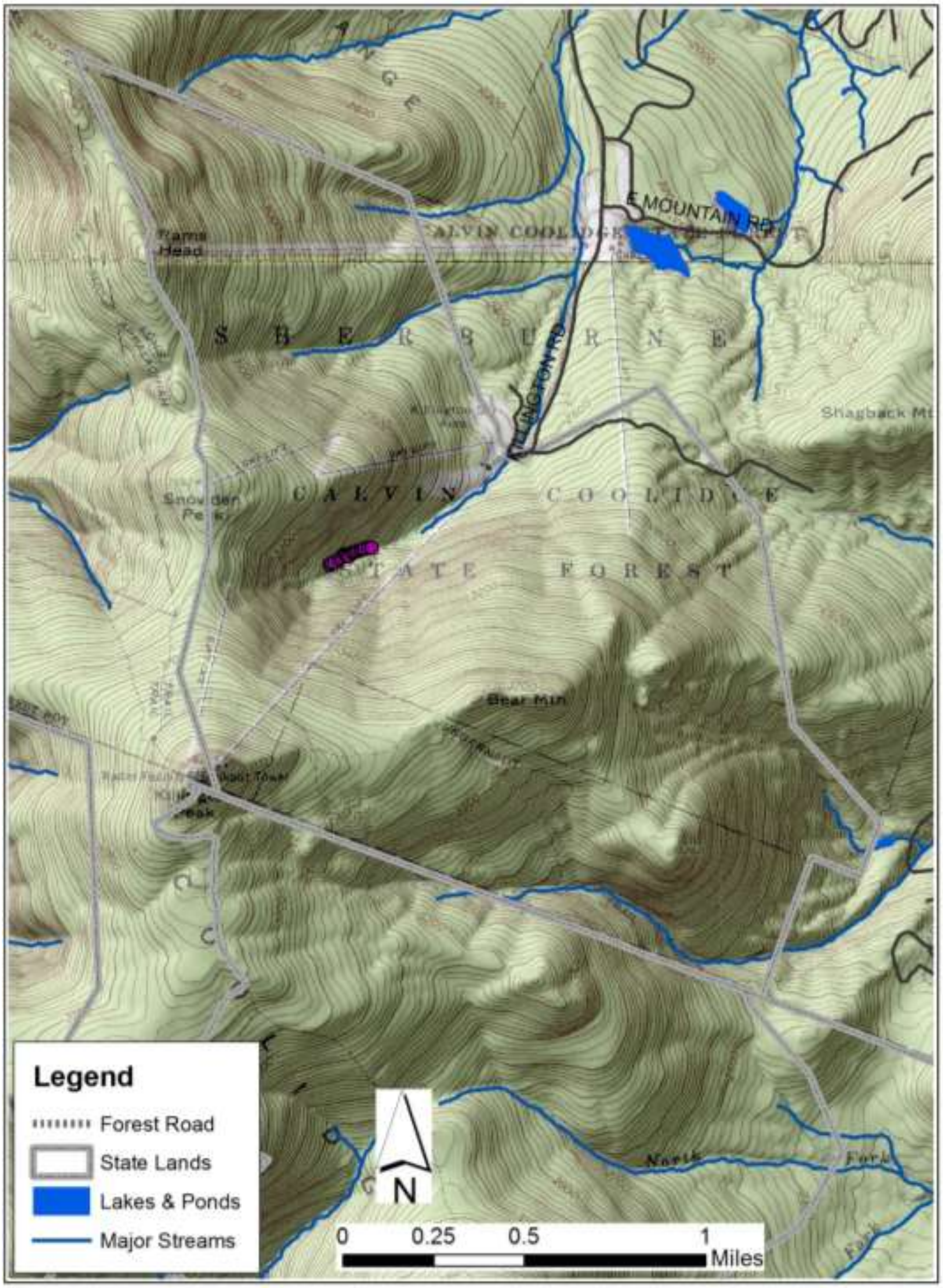


Figure 1. Site Location Map – topographic map,
Killington Resort, Coolidge State Forest West, Killington, VT.

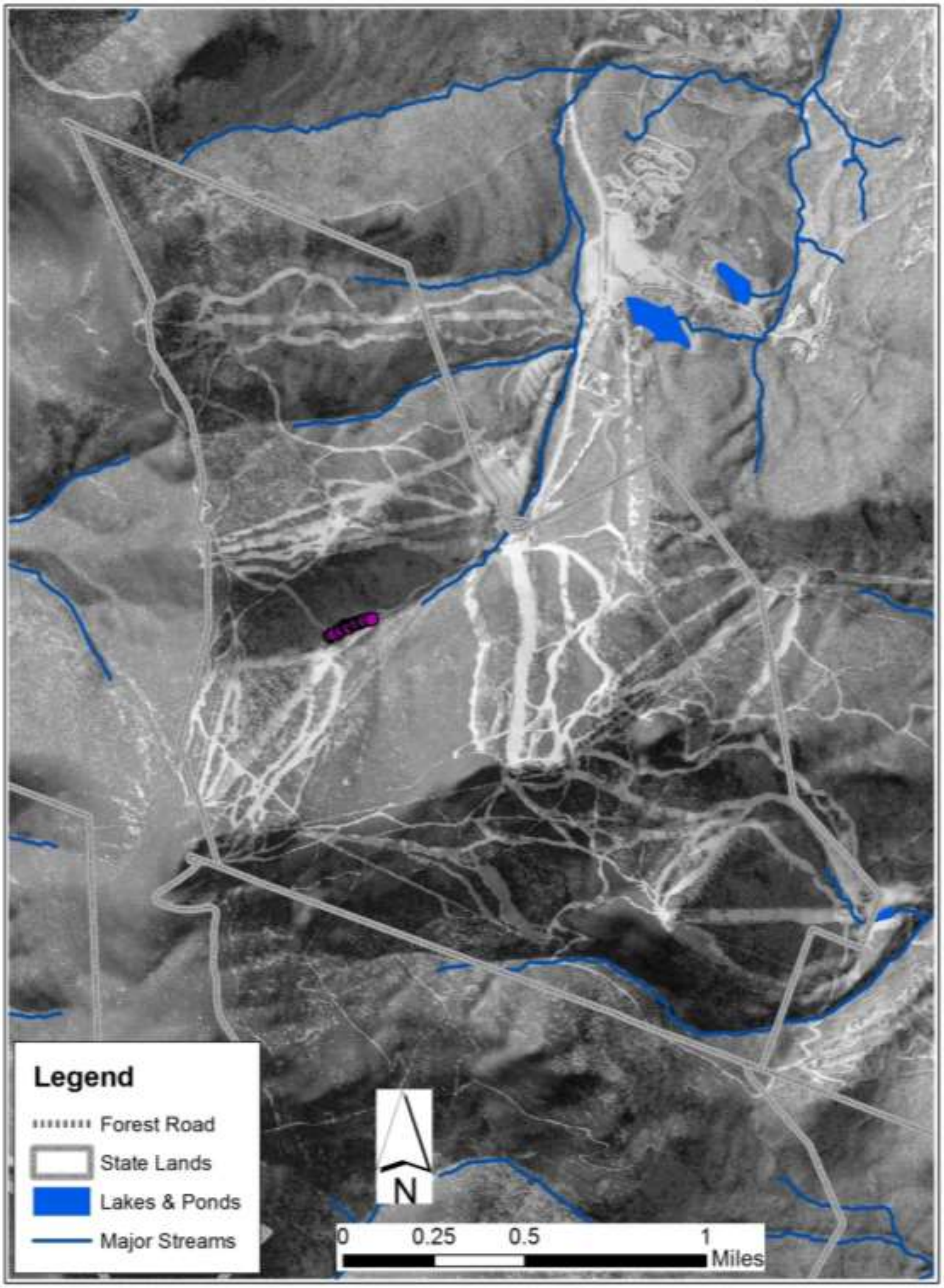


Figure 2. Site Location Map – orthophoto base map,
Killington Resort, Coolidge State Forest West, Killington, VT.

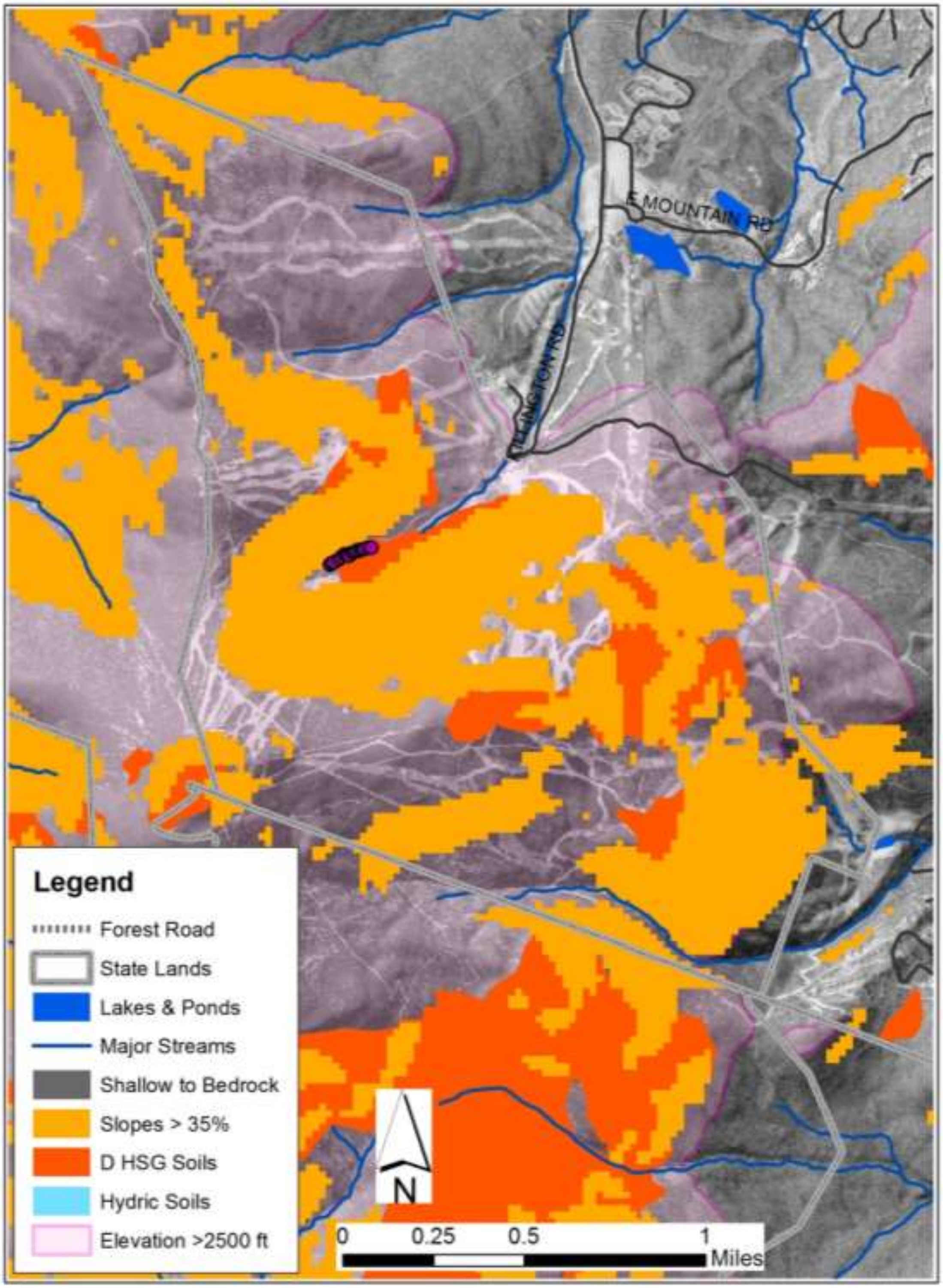


Figure 3. Elements comprising the Hydrologic Reserve zone at Killington Resort, Coolidge State Forest West.

Photo 1. Partial collapse of K-1 base lodge, Superstar Pub addition, at Killington Resort – August 31, 2011. Building foundation and access road undermined by floodwaters from the Roaring Branch. Photo Credit: Lars Gange and Mansfield Heliflight

Photo 2. Damages sustained to the Route 4 corridor further downstream on Roaring Brook during Tropical Storm Irene (August 28, 2011); (photo obtained from draft Town of Killington, Vermont, Local Hazard Mitigation Plan).

Killington Resort, Coolidge State Forest West, Killington, VT – 7/31/2014

2. View downstream in restored reach of Roaring Branch adjacent to pub rebuilt farther to the east.

3. View of Roaring Branch from Gondola lift to Peak Lodge.

4. Boardwalk connecting Peak Lodge to top of Canyon Quad lift. Opportunity for signage/ education/outreach re: glade management.

5. View downstream along maintenance roads to bottom of Canyon Quad lift.

Killington Resort, Coolidge State Forest West, Killington, VT – 7/31/2014

6. View uphill from access road to Canyon Quad lift.

7. One of several water bars on maintenance road, draining to rock-lined detention areas, before discharging to Roaring Brook.

8. View to side slope into Big Dipper glades.

Coolidge State Forest West -

CCC Road, Old Plymouth Rd

Site Visit Date: 8 September 2014

Personnel: Nate McKeen, VFPR Forestry District Manager
Lisa Thornton, State Lands Stewardship Forester
John Lones, VFPR Forester
Shannon Pytlik, VDEC Rivers Program
Marie Caduto, VDEC Watershed Management Division
David Brynn, Vermont Family Forests
Kristen Underwood, South Mountain R & CS

Geographic Setting

Calvin Coolidge State Forest - West is composed of approximately 16,801 acres of forested highlands west of Route 100, exclusive of the abutting Plymsbury Wildlife Management Area (1,859 acres) and the nearby Tiny Pond WMA (739 acres) which are contained in the same management unit as the Coolidge State Forest West [1] (see Figure 1). Coolidge SF West is located in the towns of Killington, Mendon, Shrewsbury and Plymouth.

Two sites were visited with State Lands staff on 8 September 2014: repaired portions of the CCC Road (Shrewsbury Rd SFH) connecting Plymouth to North Shrewsbury (Figures 1 & 2); and two trail heads off the north and south sides of Old Shrewsbury Road near North Shrewsbury providing access to the Plymsbury WMA (Figures 1 & 4). A separate visit was made to leased State Lands on the Killington Resort on 31 July 2014 (see separate entry in this Appendix).

Hydrologic / Geomorphic Setting

CCSF-West is located within the Southern Green Mountain biogeophysical province. The CCC Road and Old Plymouth Road field sites are located in headwaters areas, drained by first-order streams. The small streams crossed by the CCC Road in Plymouth drain toward Woodward Reservoir. On the Old Plymouth Road, the eastern most site providing access to Plymsbury WMA lands south of the road is in the headwaters of Great Roaring Brook (a tributary to the upper Black River). The westernmost site providing access to Plymsbury WMA lands north of the road drains to headwaters of the Cold River, tributary to the Otter Creek [2, 3]. Both the Cold River and Great Roaring Brook were associated with severe flooding during Tropical Storm Irene that resulted in substantial damages to infrastructure.

Portions of the CCSF-West lands near the sites visited are above 2,500 feet in elevation, and underlain by HSG D soils on steep slopes (>35%) (see Figures 3 & 5).

Built Infrastructure

Built infrastructure represented in areas visited on 8 September 2014 consisted primarily of a network of forest access roads and trails that provide access to State Lands for recreation and timber harvest. The CCC Road is owned by VFPR, and is popular with local commuters during non-Winter months as a more direct connection between Plymouth and Shrewsbury.

Tropical Storm Irene

TS Irene resulted in extensive damages to the CCC Road and Old Plymouth Road. Segments of the CCC Road were washed out, timber cribbing was exposed and undermined, and culverts were displaced (see attached photos). The road was closed for 2 years, and reopened in the Spring of 2014. Road repairs were supported by FEMA funds, which reportedly amounted to approximately $250,000.

Major Findings from Site Visit

CCC Road

- The Shrewsbury Road SFH was constructed in the 1930s by Civilian Conservation Corps; hence, it is known locally as the “CCC Road”.
- The switchbacks on the eastern (Plymouth) end of the road traverse hillslopes which are locally up to 55% in gradient. Portions of the CCC Road are 15% grade.
- The road receives approximately 65 cars per week, according to recent estimates.
- The Road is closed and gated during the winter months, and becomes popular for snowmobiles as part of the VAST network of trails.
- In recent years, VFPR receives approximately $100,000 annually, Statewide, for road maintenance activities. The Southwest District manages 30 miles of roads and received $7,000 last year and $11,000 this year for their road budget.
- The cost to repair the CCC Road – approximately $250,000 – is 2.5 times the entire Statewide operating budget for road maintenance. FEMA funding made road repair possible.
- There was discussion about abandoning the road, given the high cost-to-benefit ratio. However, VFPR responded to a vocal sector of the public who exerted pressure to re-open the road for commuting and for recreational access.
- Due to safety concerns, given the steep gradient and limited line of sight, one particular segment was replaced as a single-lane road with appropriate signage.
- The road accesses 12,000 acres of timberland (mostly from Shrewsbury end of the road).
- Alternative routes connect Plymouth and Shrewsbury. The CCC Road is not necessary, and in fact is closed to vehicular traffic for half the year.
- Downsizing the easternmost end of this road to a trail with sufficient broad-based dips would continue to accommodate hiking, birding, hunting, mountain biking, horse riding and other non-motorized recreational uses while significantly decreasing maintenance costs, decreasing flood hazards and water quality impacts. Timber harvest areas could continue to be accessed from the Shrewsbury end of the road.

Old Plymouth Road

- Road access from Fisher Lot was repaired following washouts during Irene.
- Wet areas on forest access from southern parking area were stabilized with log corduroy sourced from the log landing. Small settling pond was used to accept runoff from water bar – disconnecting runoff to stream crossing.
- Timber harvest occurred in winter months three winters ago. Early successional patches were installed for wildlife management (deer, grouse, birds).

General

- During the cost-benefit accounting, the Long Range Management Plans and annual work plans should more explicitly include costs associated with water quality impacts and flooding impacts when considering whether to maintain or decommission road segments. Planning should include options to abandon or downsize road segments in unsuitable settings (e.g. too steep) and identify cost thresholds above which road segments will not be replaced following damages sustained in a future flood event.
- The group discussed the possibility of including deductions in timber harvest contracts to support road maintenance and/or decommissioning. At present, up to 10% of timber revenues may be diverted to upgrade roads/trails to improve AMP compliance.
- The group discussed the importance of assessing road conditions and infrastructure status prior to acquiring new lands. If the true costs associated with decommissioning/ upgrading/ or maintaining infrastructure is tallied before acquisition, there is greater potential for raising adequate endowments to support this work – through increased emphasis on private/public partnerships.
- The group discussed potential means of raising additional revenues to fund road/trail network maintenance/ decommissioning, including:

    - Partnering with towns/ watershed groups to apply for VDEC Ecosystem Restoration Grants (precedent exists, e.g. Lake Rescue Association and road/trail work upstream of Camp Plymouth State Park)
    - Partnering with towns for BetterBack Roads grants
    - Partnering with US Forest Service in watersheds occupied by GMNF – even if project sites on State Lands are located outside the boundaries of the GMNF (precedents exist)
    - Land & Facilities Trust Fund

- More loaner skidder bridges could be made available for logging contractors. Forwarders could be incentivsed in contracts or made available on shared basis – perhaps funded through Working Lands Enterprise.
- Methods for assessing compliance with and enforcement of AMPs were discussed. The State Lands teams do not currently perform quantitative measures of AMP compliance (e.g., tally the number of drainage structures including broad-based dips or water bars per trail segment and

compare to recommendations in the AMPs). The notion of Optimal Conservation Practices for roads, trails, riparian buffers, stream crossings, etc. and protocol for monitoring was discussed in light of climate change.

- There is potential for citizens to be engaged in assessment of post-harvest AMP compliance (precedent exists in Addison County watersheds, funded by ERP grants, involving residents and watershed group members; included instruction in installation of broad-based dips and water bars for technology transfer to private landowners).
- When State Lands staff inspect logging jobs, there is currently no practical recourse for fining smaller infractions of AMPs. Minimum fines are $10,000. Enforcement of AMP compliance could be better enabled if incremental ticketing amounts (e.g., $250 or $1,000) were available.
- Buffer guidance has been somewhat unique to each State Lands district; State Lands Team is working to standardize this guidance statewide and incorporate river corridors rather than default setbacks.

References:

[1] VTANR, 2008, Coolidge State Forest – West of Rt 100: Long Range Management Plan.

[2] VTANR, 2015, Vermont Natural Resources Atlas, accessed at: http://anrmaps.vermont.gov/websites/anra/

[3] VTANR, 2015, Stream Geomorphic Assessment Data Management System accessed at: https://anrweb.vt.gov/DEC/SGA/projects.aspx

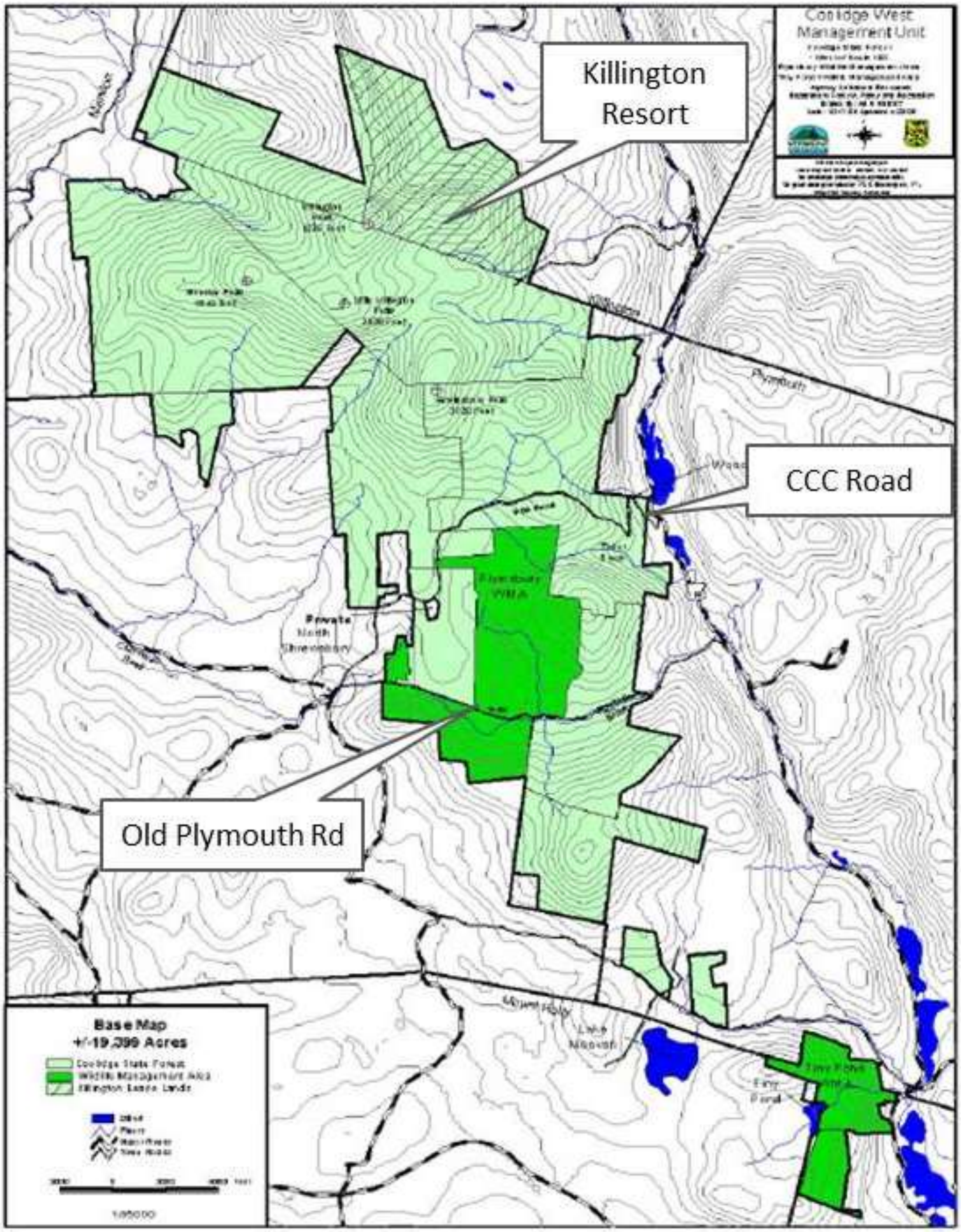


Figure 1. Extent of Calvin Coolidge State Forest – West (excerpted from Long Range Management Plan)

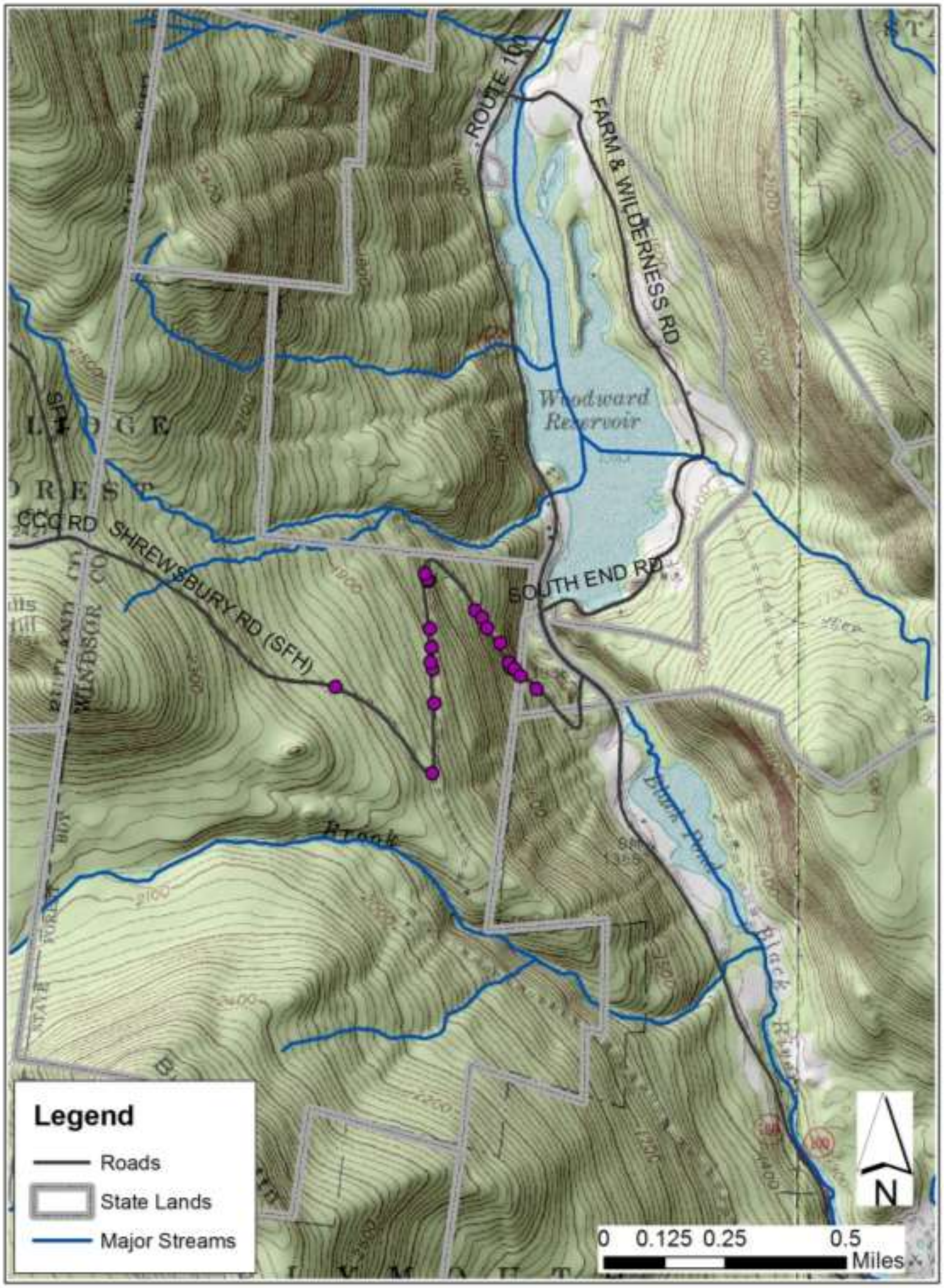


Figure 2. Site Location Map – CCC Road
Calvin Coolidge State Forest – West, Plymouth, Vermont

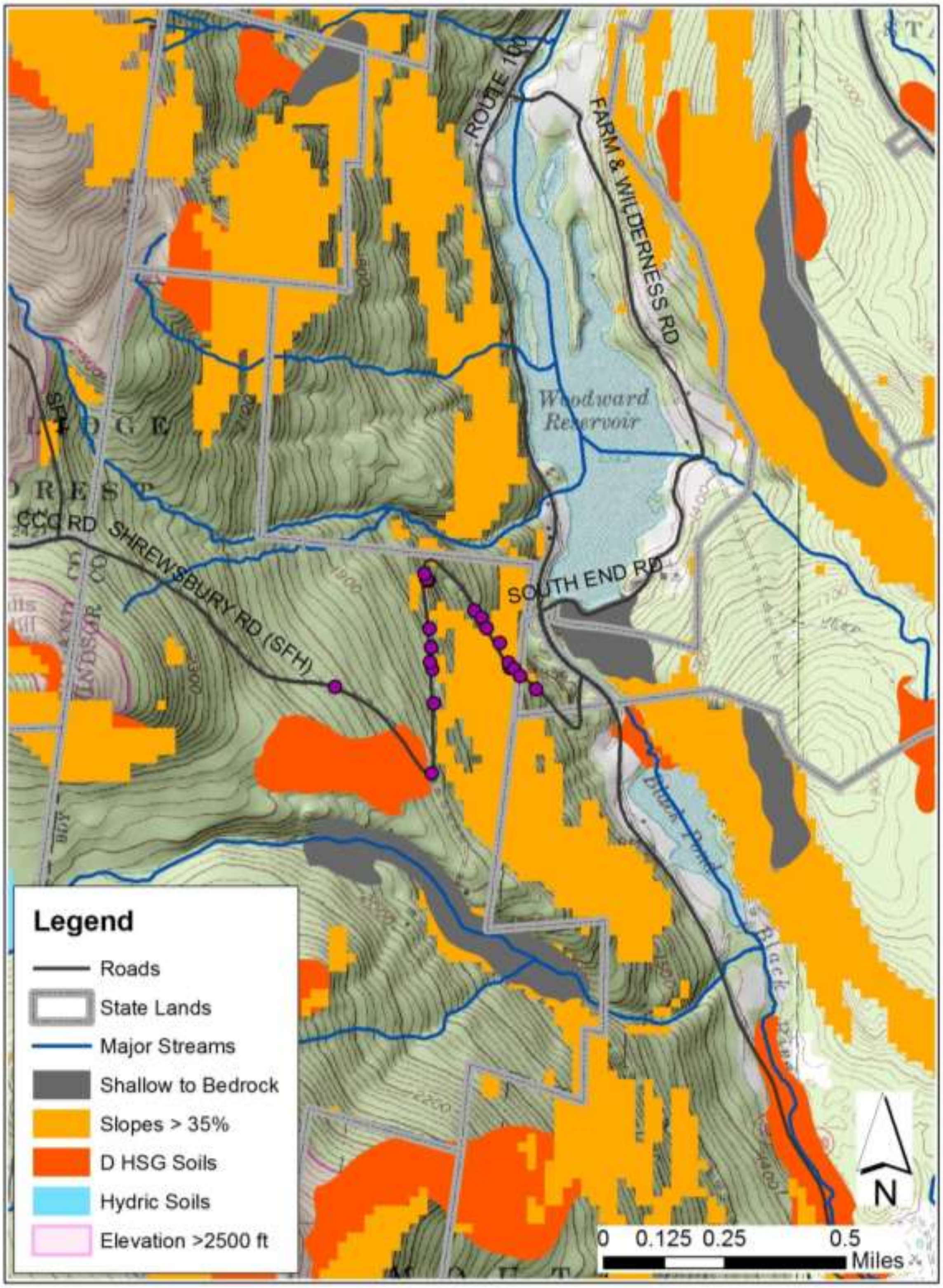


Figure 3. Elements comprising the Hydrologic Reserve zone at the CCC Road site, Calvin Coolidge State Forest – West, Plymouth, Vermont.

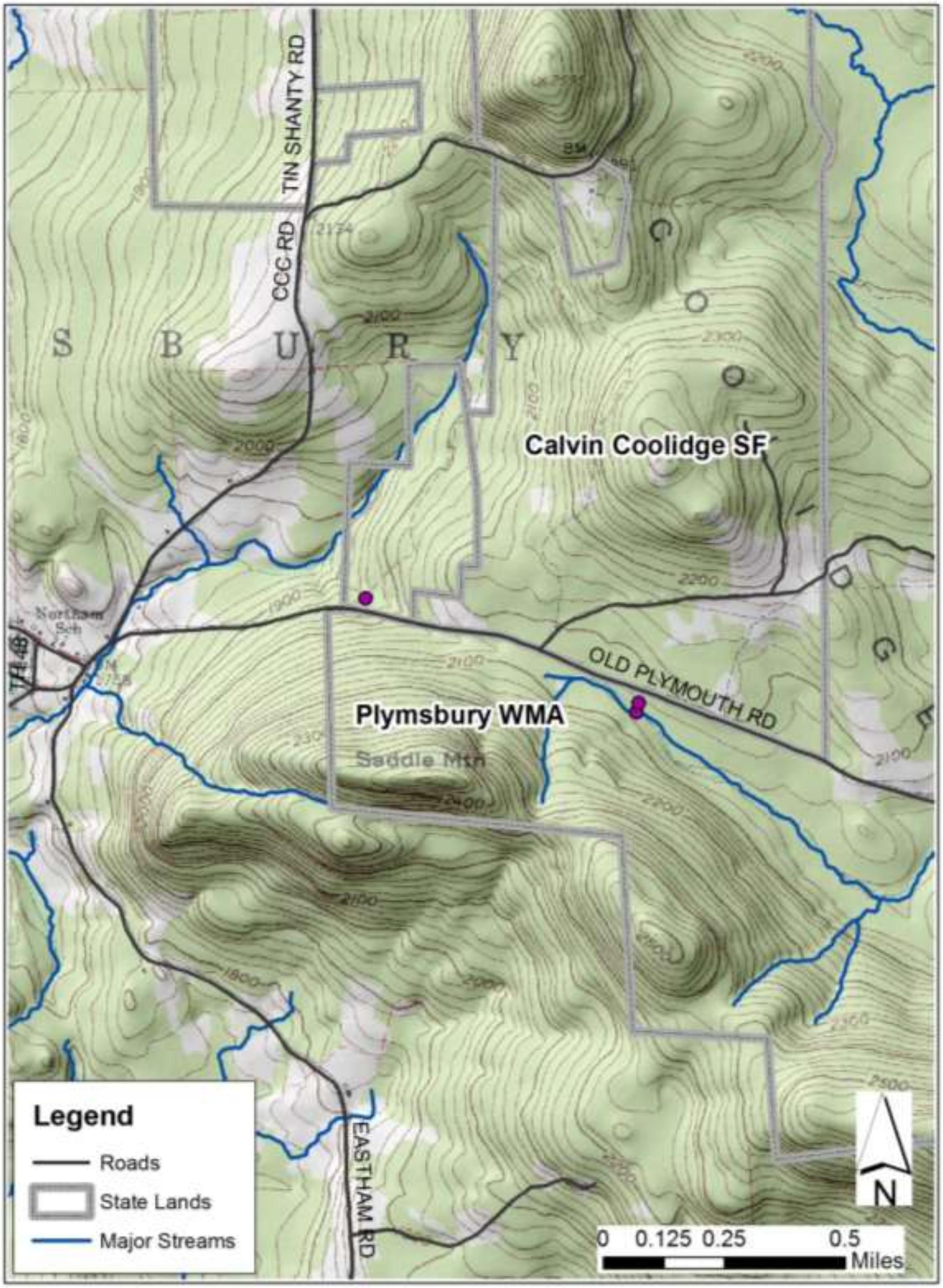


Figure 4. Site Location Map – Old Plymouth Road sites
Calvin Coolidge State Forest – West, Shrewsbury, Vermont.

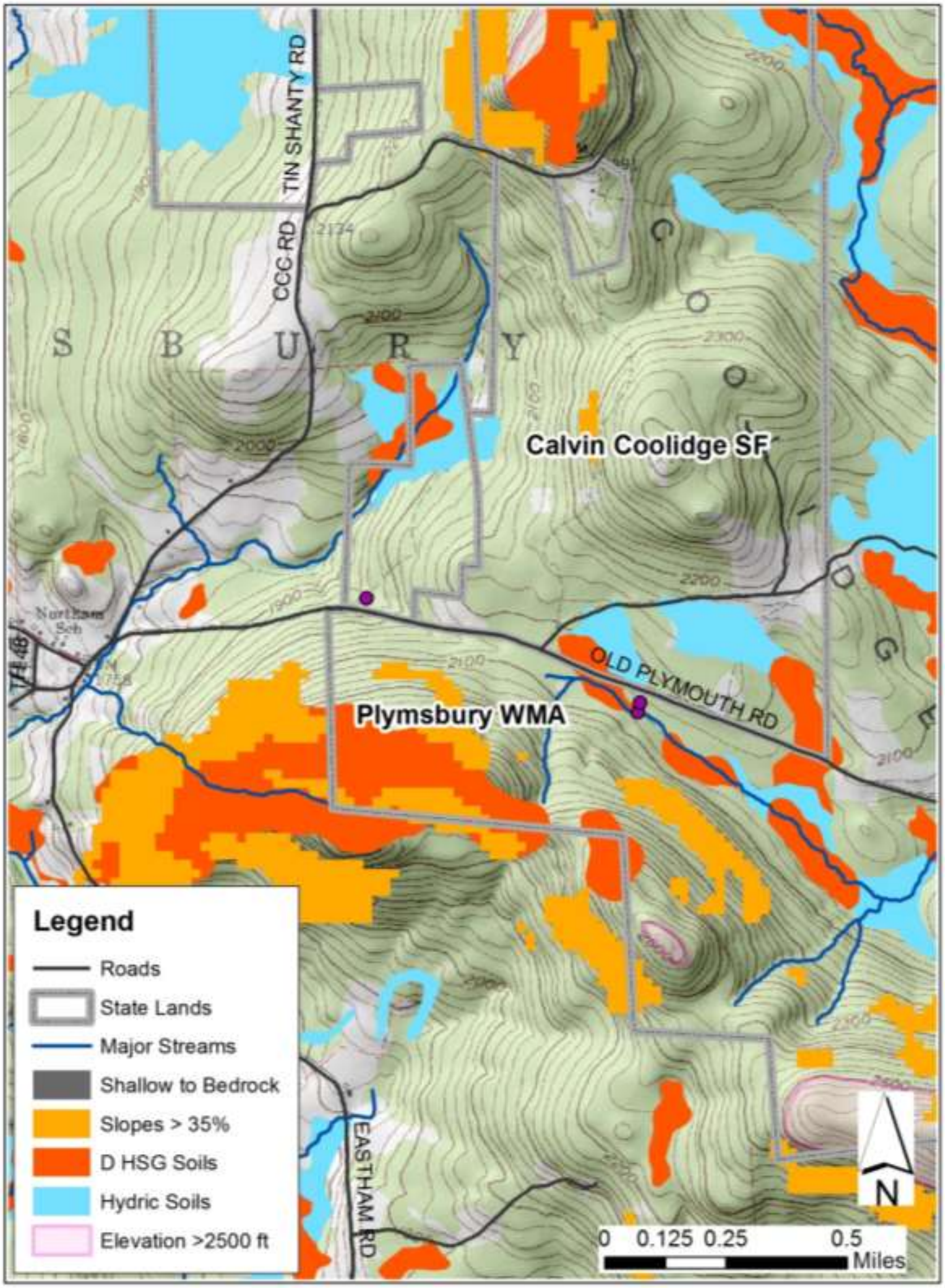


Figure 5. Elements comprising the Hydrologic Reserve zone at the Old Plymouth Road sites, Calvin Coolidge State Forest – West, Shrewsbury, Vermont.

Calvin Coolidge State Forest, West of Rt 100, Plymouth & Shrewsbury, VT – 9/8/2014

1. One-lane segment of CCC Road and stream crossing replaced after TS Irene on >25 % hillslopes through Northern Hardwood Seepage Forest.

2. View downhill, same culvert site as photo 1.

3. Erosion of road sediment from culvert header into tributary draining to Woodward Reservoir; site uphill from photo 1.

Calvin Coolidge State Forest, West of Rt 100, Plymouth & Shrewsbury, VT – 9/8/2014

4. View from south parking area along Old Plymouth Rd into Plymsbury WMA.

5. View into Plymsbury WMA from access area on north side Old Plymouth Road. Repaired following TS Irene.

Damages to CCC Road, Tropical Storm Irene, Plymouth, VT

Source: Town of Shrewsbury

Coolidge State Forest East -

Site Visit Date: 29 September 2014

Personnel: Tim Morton, State Lands Stewardship Forester
David Brynn, Vermont Family Forests
Kristen Underwood, South Mountain R & CS

Geographic Setting

Calvin Coolidge State Forest - East is composed of several thousand acres of forested highlands east of Route 100, in the towns of Woodstock, Bridgewater, Plymouth, and Reading. There is no digitally-accessible Long Range Management Plan for Coolidge State Forest East.

Two sites were visited with State Lands staff on 29 September 2014: (1) a forest road and trail network off Curtis Hollow Road in Woodstock and (2) a box culvert site and recent forest sale on Quarry Road in Plymouth (see Figure 1).

Hydrologic / Geomorphic Setting

CCSF-East is located within the Southern Green Mountain bio-geophysical province. The Curtis Hollow site is drained by Curtis Hollow Brook, a tributary to the Ottauquechee River (Figure 2). The forest access road crosses Curtis Hollow Brook in reach M21S1.02, where the brook is a third-order stream with an upstream drainage are of 1.77 square miles [2, 3]. Lands along the ridge tops at this site are underlain by soils of HSG D on slopes exceeding 35% (Figure 3).

The Quarry Road sites are located in headwaters areas, drained by first-order streams, tributaries to Pinney Hollow Brook which joins Broad Brook and eventually flows to the Ottauquechee River at Bridgewater Corners (Figure 4). Very limited regions of the Quarry Road area on CCSF lands are underlain by soils of HSG D on slopes exceeding 35% (Figure 5).

Built Infrastructure

Built infrastructure represented in areas visited on 29 September 2014 consisted primarily of a network of forest access roads and trails that provide access to State Lands for recreation and timber harvest. At least two year-round residences and four camps on abutting lands are accessed from the Quarry Road.

Tropical Storm Irene

TS Irene caused damage to the forest highway bridge over Curtis Hollow Brook (Figure 5). The left-bank bridge abutment was replaced with design help from VDEC Facilities Engineering and funding from FEMA with local match provided by VFPR capital funds [1].

TS Irene resulted in damages to Quarry Road. Segments of the road were washed out. Debris plugged a box culvert, resulting in a small unnamed tributary overtopping and washing out the road. This stream drains a 250 acre watershed. This stream crossing and the road were constructed during the 1930s by the Civilian Conservation Corps [1].

Major Findings from Site Visit

Curtis Hollow

- Team viewed a recent bridge repair site (Figure 5), examples of culvert in need of removal pending funding, and culverts that have been decommissioned (Figure 4).
- Team viewed a recent patch cut site that was accomplished using forwarders. Saw timber was cut to length, and tops were left in place to some degree. This is a technique that is good for flood resiliency (roughness elements help to detain stormwater flow) but that can invite criticism from hunters using the property.
- Discussed that FOREX system does not include evaluation of road access networks (e.g., for compliance with AMPs, for percent aerial coverage)
- Team viewed the North American Maple Plot – an example of ecological reserve area. This area was last logged in the late 1970s.

Quarry Road / Pinney Hollow

- Team viewed the box culvert crossing of Quarry Road over the unnamed tributary to Pinney Hollow Road (Figure 6, photos 1 & 2). Discussion of possible remedial strategies including raising the stream bed, design to overtop the road in a future major flood, etc.
- Team viewed a recent timber sale off Quarry Road (Figure 8, photos 3 &4). Tight switchbacks on the access road meant that chippers and larger harvesting machinery could not access the site. Patch cuts were accomplished using forwarders. This represents an Optimal Conservation Practice that builds flood resiliency on these State Lands – exemplary practices.

General

- It is helpful to have hydrological restoration and conservation formalized as a management goal.
- There is a recognition that underused roads on unsuitable lands (steep slopes, HSG D soils) should ideally be downsized and decommissioned. However, funding to accomplish this is very limited and insufficient at this time.
- There is a mechanism within timber sale contracts to pay for some property improvements. There could be a deduction in the timber sale contract for stream restoration, for example. However, there is a general rule of thumb not to exceed approximately 10% of the revenues of the sale.
- Training in hydrologic restoration techniques and other practices including disconnecting ditches from streams would be helpful.

References

[1] Morton, Tim, 29 September 2014, personal communication.

[2] VTANR, 2015, Vermont Natural Resources Atlas, accessed at: http://anrmaps.vermont.gov/websites/anra/

[3] VTANR, 2015, Stream Geomorphic Assessment Data Management System accessed at: https://anrweb.vt.gov/DEC/SGA/projects.aspx

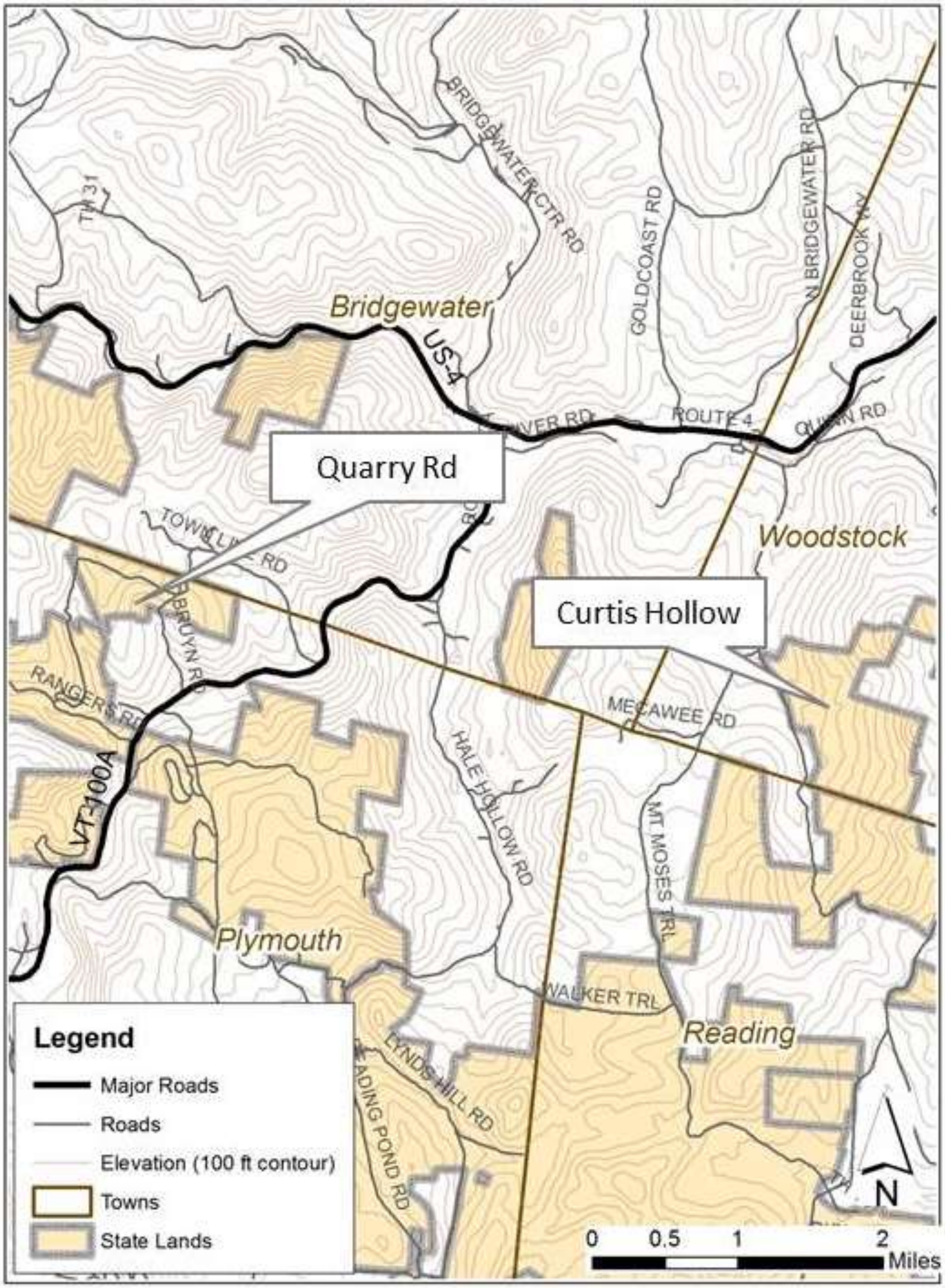


Figure 1. Location of Calvin Coolidge SF – East sites visited on 29 September 2014.

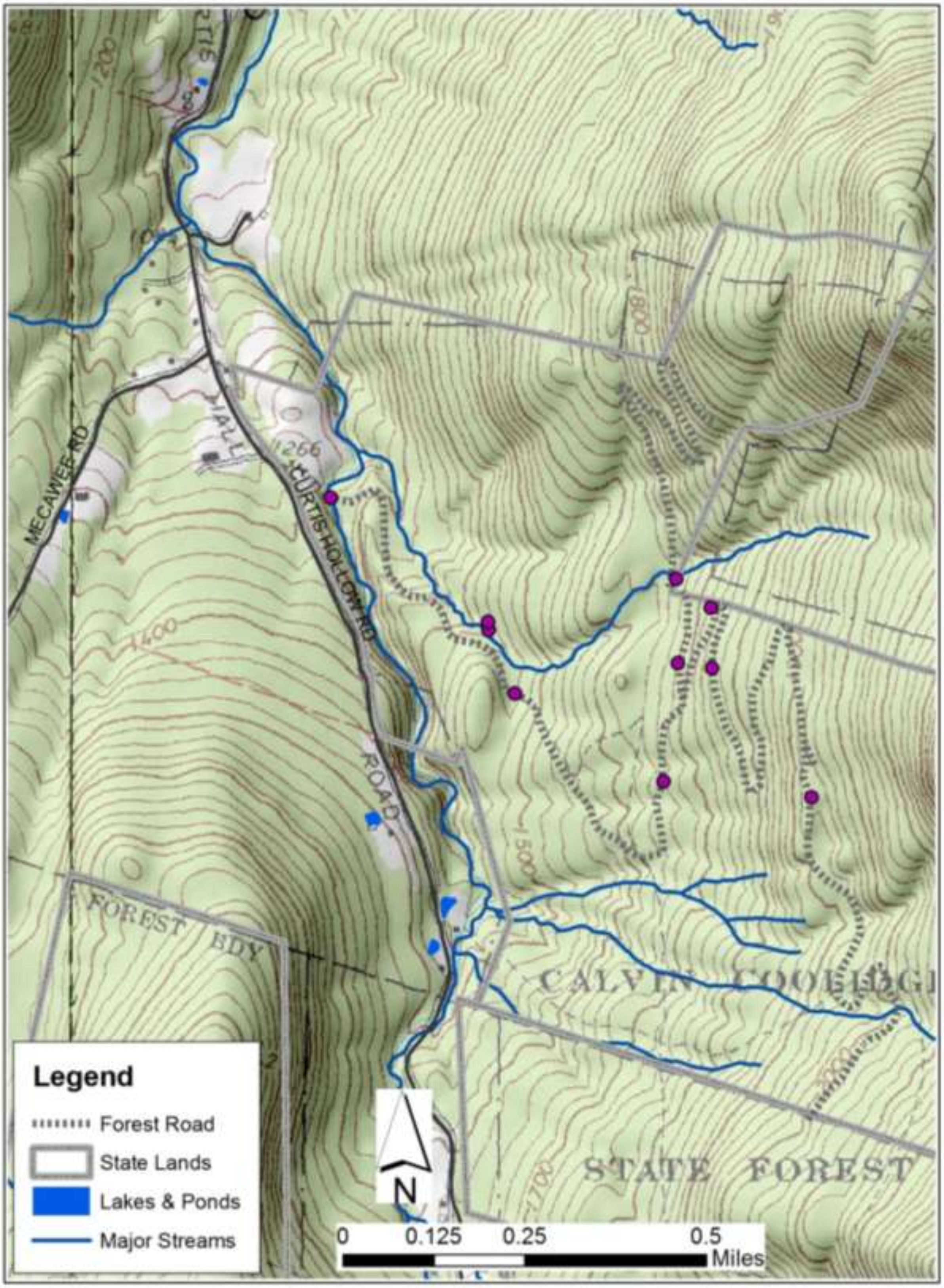


Figure 2. Site Location Map – Curtis Hollow area, Calvin Coolidge SF – East, Woodstock, VT

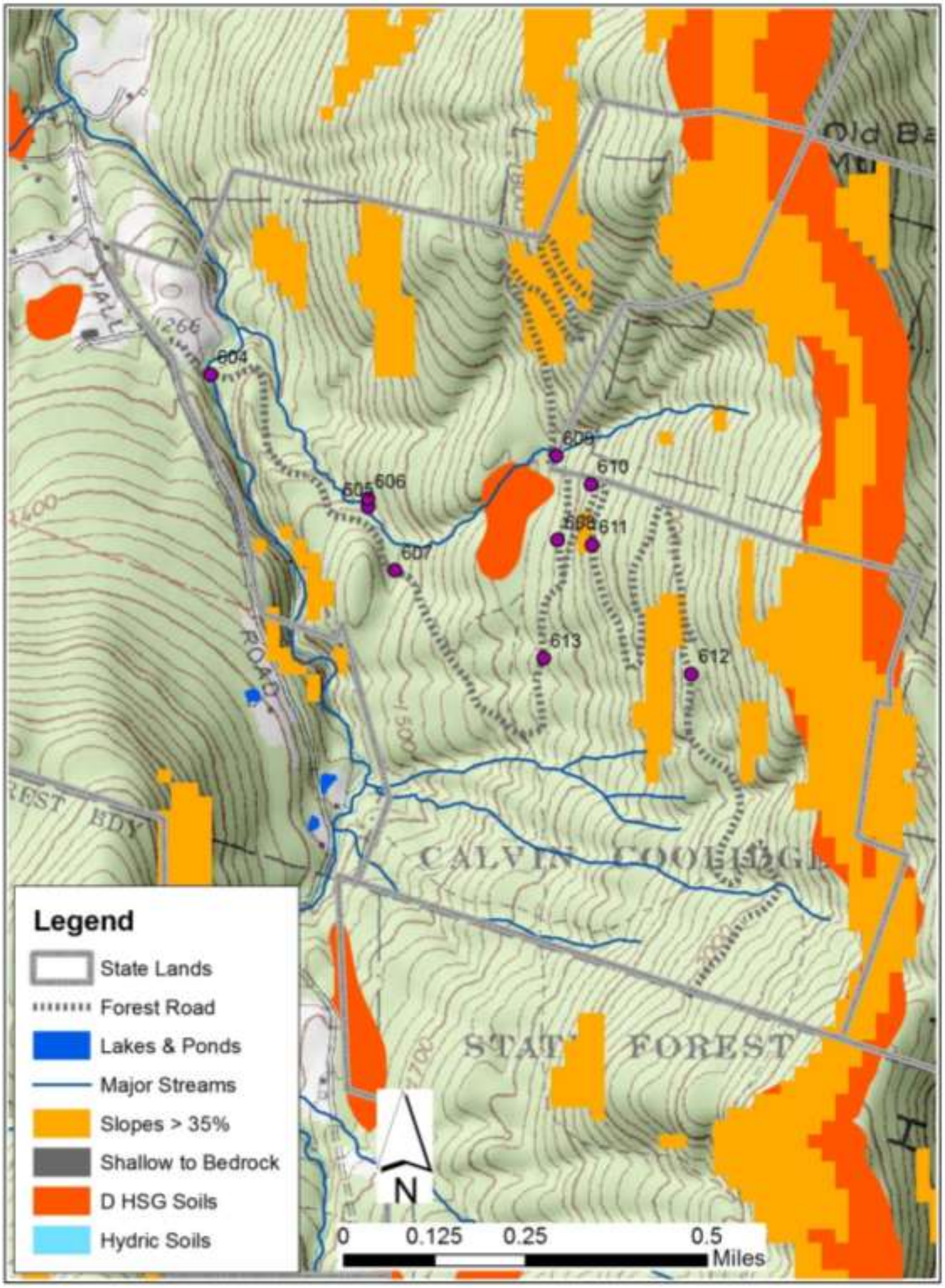


Figure 3. Elements comprising the Hydrologic Reserve zone at the Curtis Hollow site, Calvin Coolidge State Forest – East, Woodstock, Vermont

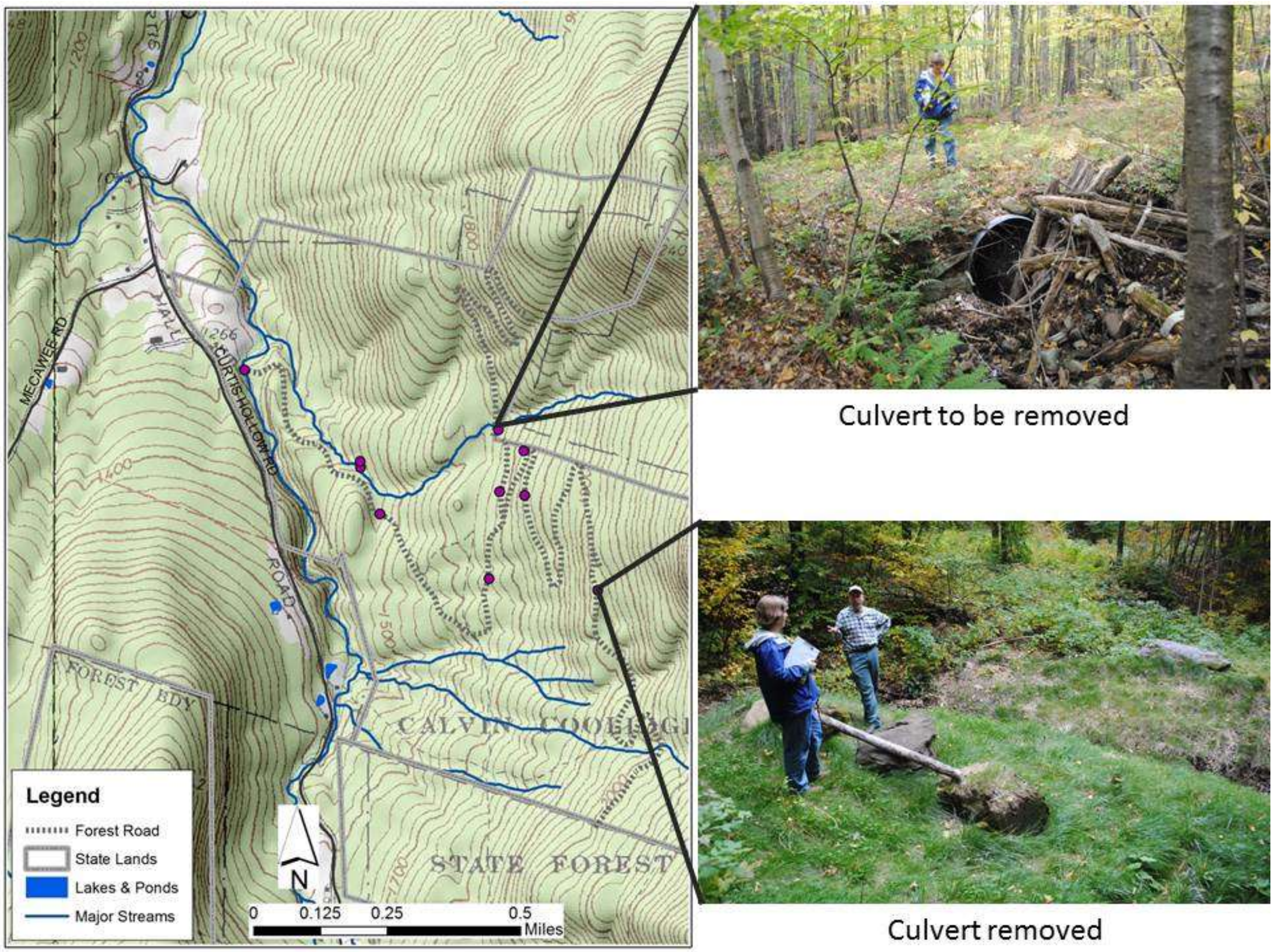
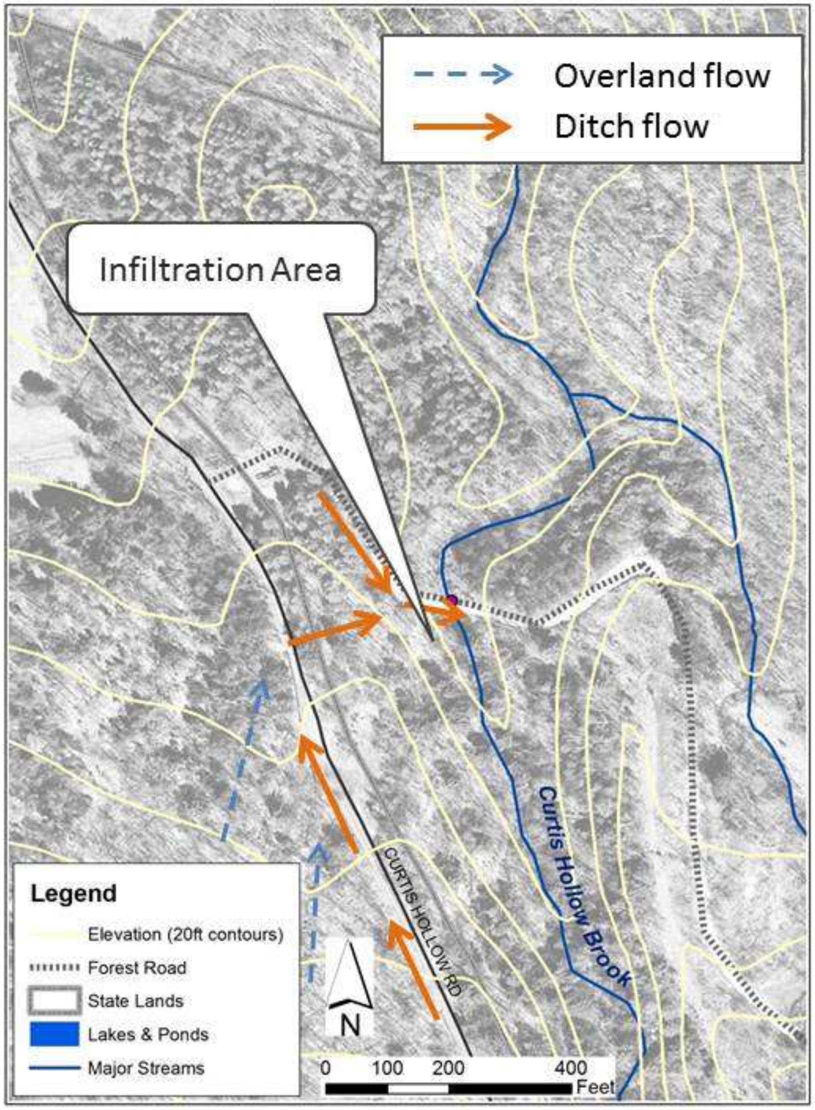


Figure 4. Location of culvert sites, Curtis Hollow area, Calvin Coolidge SF – East.



Abutment replaced after TS Irene

Opportunity to Disconnect Road Ditch

Figure 5. Location of stream crossing of Curtis Hollow Brook, and opportunity to disconnect road ditch drainage.

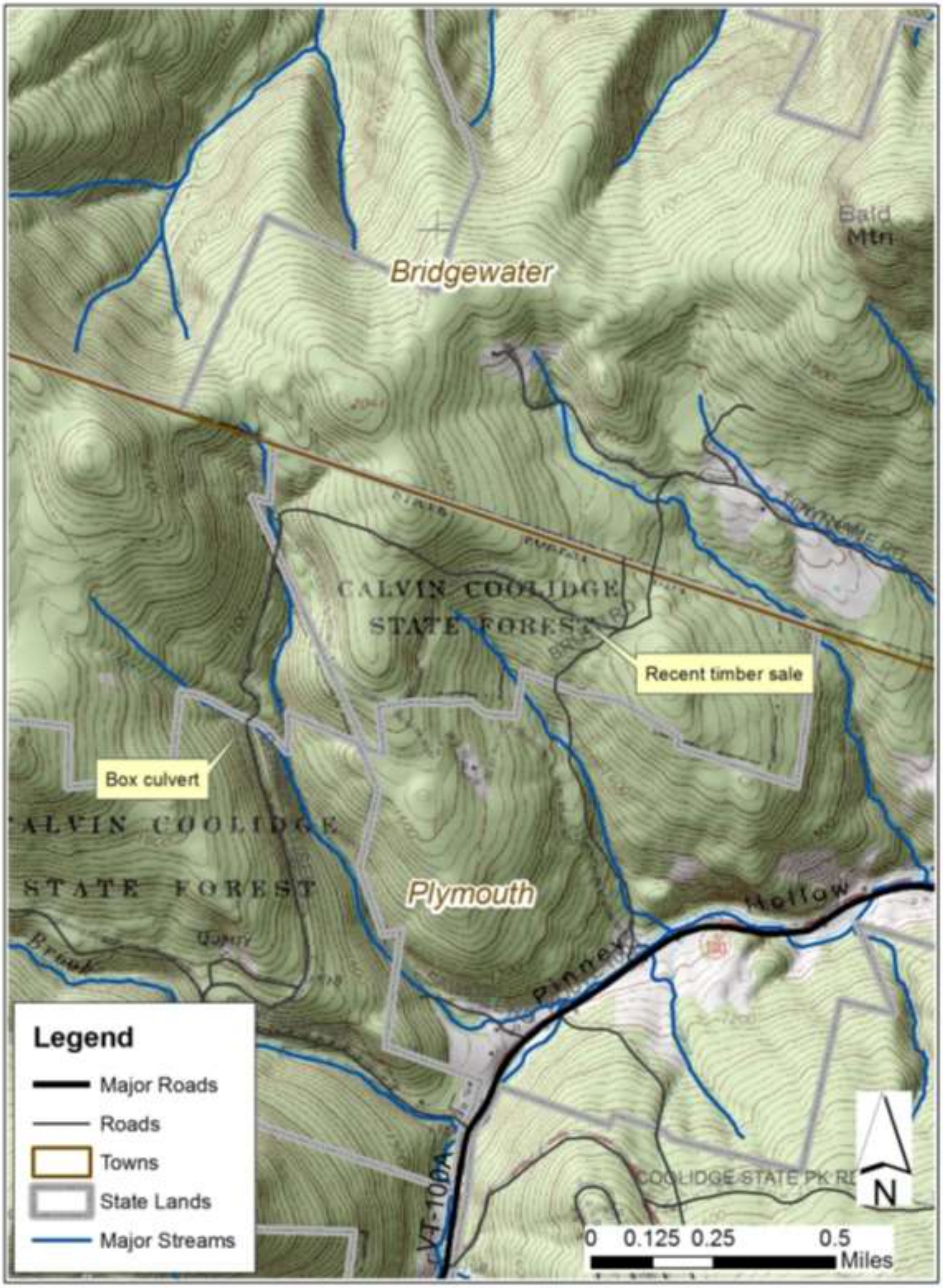


Figure 6. Site Location Map – Quarry Road area, Calvin Coolidge SF – East, Plymouth, VT.

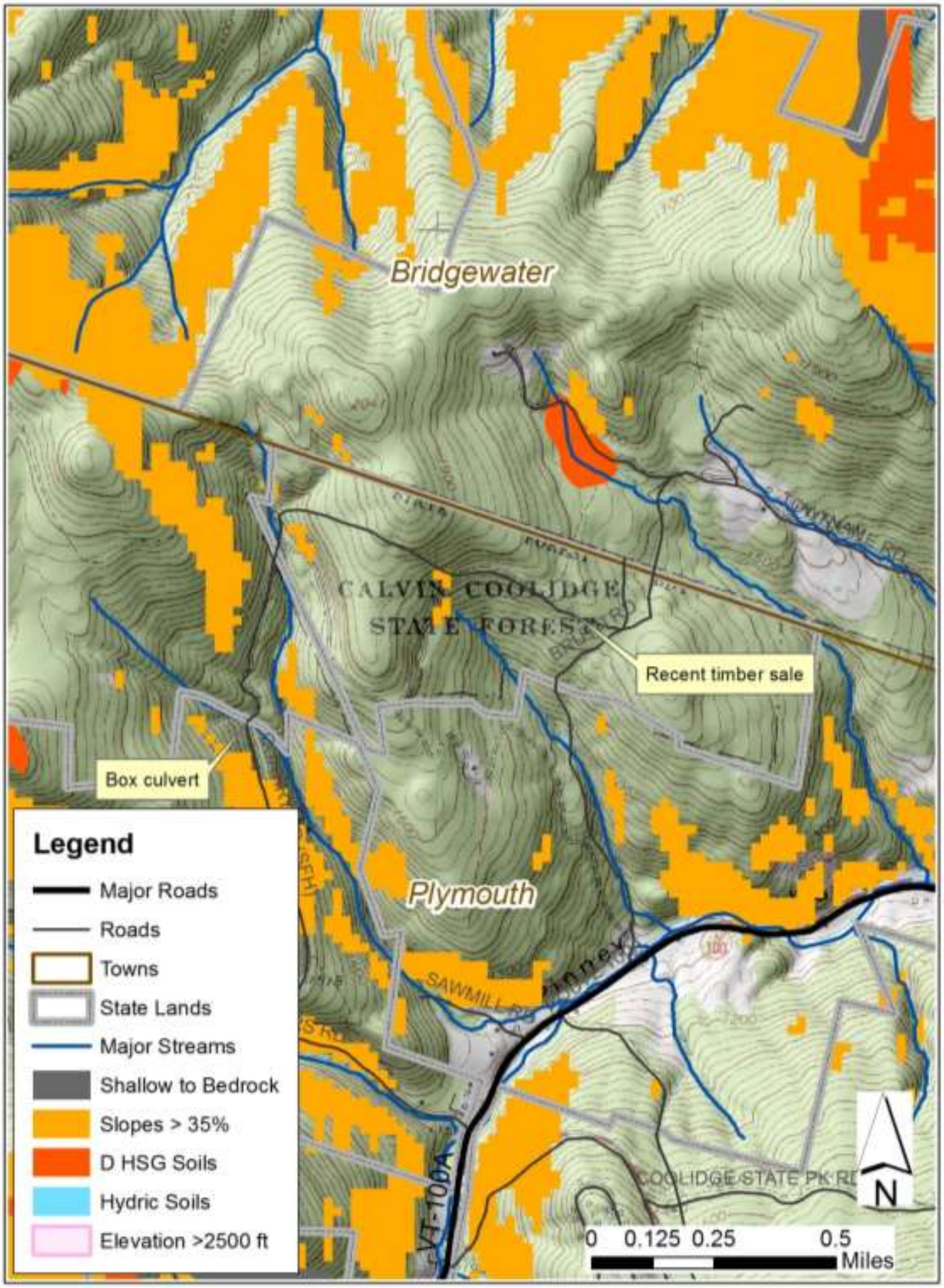


Figure 7. Elements comprising the Hydrologic Reserve zone at the Quarry Road area, Calvin Coolidge State Forest – East, Plymouth, Vermont

Figure 8. Patch cuts implemented using forwarders in 2011 – 2012 at Quarry Road site.

Calvin Coolidge SF – East, Quarry Road / Pinney Hollow area, Plymouth, VT – 9/29/2014

1. View downstream to box culvert crossing of Quarry Road over unnamed tributary to Pinney Hollow Brook.

2. View downstream through box culvert.

Calvin Coolidge SF – East, Quarry Road / Pinney Hollow area, Plymouth, VT – 9/29/2014

3. Forwarding path used to access harvest areas in 2011-2012.

4. Softwood release using forwarder.

Les Newell Wildlife Management Area

Site Visit Date: 1 December 2014

Personnel: David Brynn, Vermont Family Forests
Kristen Underwood, South Mountain R & CS

Geographic Setting

Les Newell Wildlife Management Area is composed of approximately 7,988 acres of forested highlands located in Stockbridge, Barnard, Bridgewater and Killington in the White River watershed (see Figure 1). There is no Long Range Management Plan for Les Newell WMA.

Hydrologic / Geomorphic Setting

Les Newell WMA parcels are located within the Southern and Northern Green Mountain bio-geophysical provinces. The valley along Stony Brook Road is drained by Stony Brook – a 23-square-mile tributary of the White River [1, 2]. Few, sparsely-located pockets of land on Les Newell WMA are underlain by soils of HSG D on slopes exceeding 35%. At the sites visited (Figure 2), the upstream drainage area of Stony Brook is less than 10 square miles and mostly forested.

Built Infrastructure

Built infrastructure represented in areas visited on 1 September 2014 consisted primarily of a network of forest access roads and trails that provide access to State Lands for recreation, hunting, and timber harvest. Bridge and culvert structures are located on Stony Brook and its tributaries.

Tropical Storm Irene

TS Irene caused extensive damages to Stony Brook Road, bridge and culvert crossings and select buildings along the Stony Brook and upstream and downstream segments of the White River in Stockbridge and surrounding communities [3, 4]. Historic and post-Irene channel dredging and management has led to channel instability along the Stony Brook [3].

Major Findings from Site Visit

- Project Team visited a few discrete locations at publically-identified trail heads for the Les Newell WMA. General locations were advised by Tim Morton [4]. State Lands staff members were not able to accompany the Team on these site visits.
- Anecdotally, these areas receive heavy ATV use that results in erosion and impacts to forest roads/trails.
- Legacy trail systems are used for forest harvest access (by A. Johnson Lumber Co. which owns the timber management rights) and for recreational access including hiking, hunting, horse-backriding, mountain biking, and snowmobiling.

- Substantial lengths of these legacy trails are located within 25 feet of streams.
- Insufficient spacing of water bars or broad-based dips has led to stormwater runoff channeled down road beds.
- Road runoff and road-ditch runoff is channeled directly to streams, where room is available to divert this runoff to adjacent side slopes and infiltrate stormwater to subsurface soils.

- It is notable that Les Newell WMA does not have an established Long Range Management Plan. While timber management rights are held by a private party (A. Johnson Lumber Co.), the lands are owned by the State of Vermont. VDEC and VFW are trustees of the water and wildlife resources on these lands. Private operators are responsible to comply with AMPs. VANR has a vested interest to enforce AMPs on lands that it owns and to articulate the management goals for these lands with regard to ecosystem services (flood resiliency, habitat, etc), as well as non-wood products, recreation and tourism.

References:

[1] VTANR, 2015, Vermont Natural Resources Atlas, accessed at: http://anrmaps.vermont.gov/websites/anra/

[2] VTANR, 2015, Stream Geomorphic Assessment Data Management System accessed at: https://anrweb.vt.gov/DEC/SGA/projects.aspx

[3] Ryan, Jim, VDEC Watershed Management Division, email communications.

[4] Morton, Tim, email communications

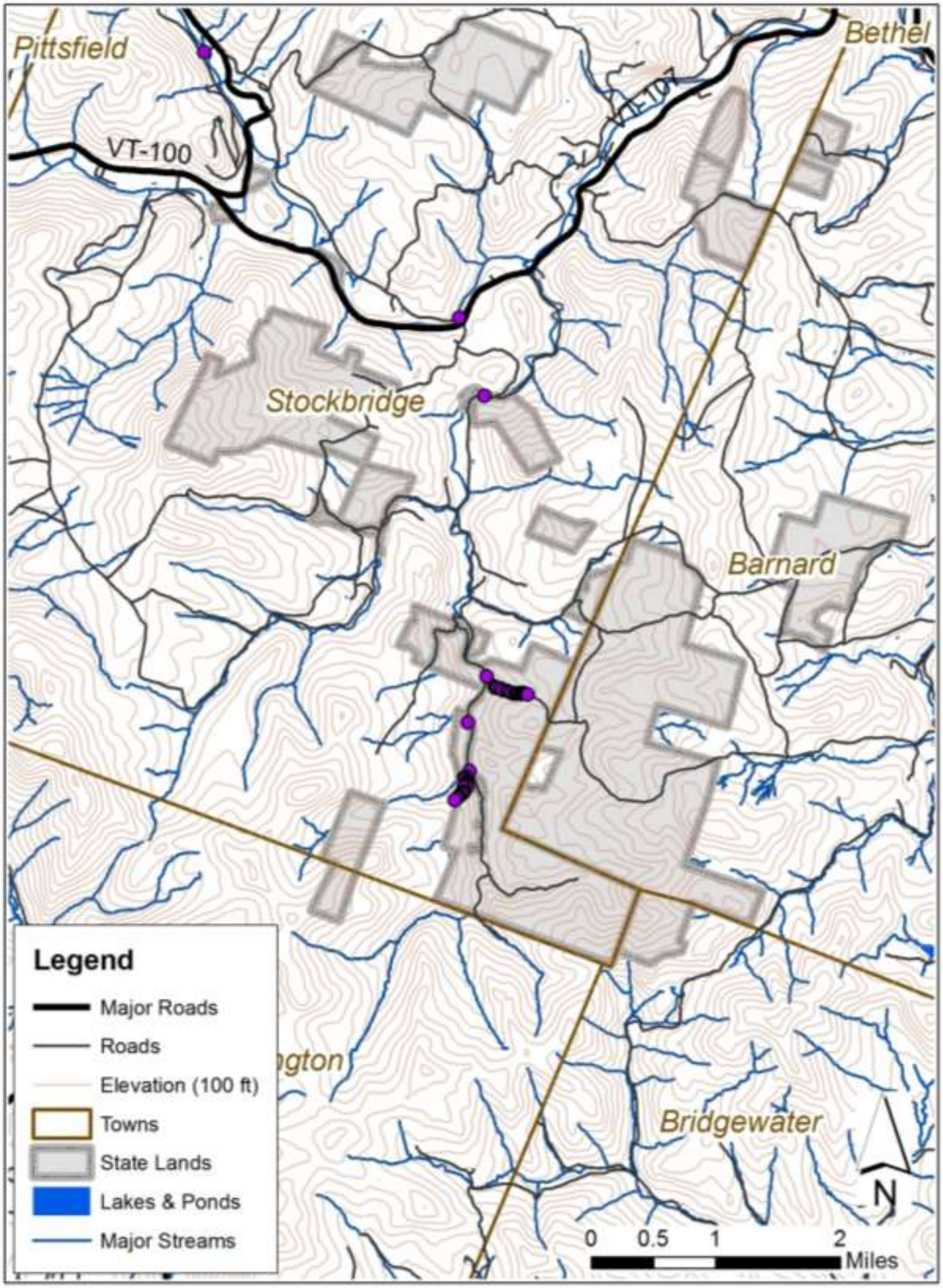


Figure 1. Location map of parcels comprising Les Newell Wildlife Management Area.

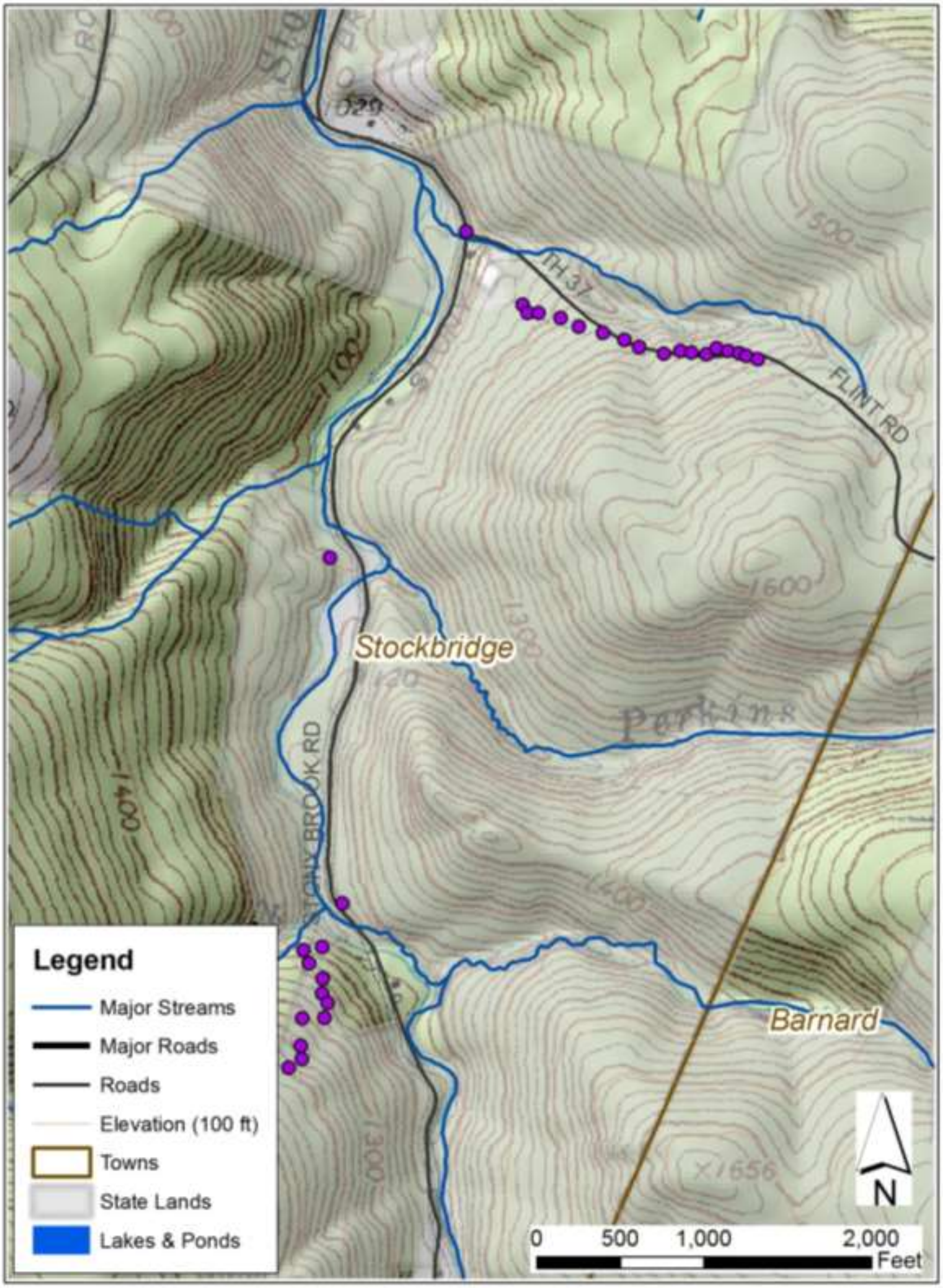


Figure 2. Location Map of sites accessed in Les Newell WMA, 1 December 2014.

Les Newell Wildlife Management Area, White River watershed, Stockbridge, VT – 12/1/2014

1. Southernmost site accessed.

2. Snowmobile trail leading southwest from Stony Brook Rd

3. Steep-gradient road (10 to 40%), with occasional broad-based dips; dugway segment channels water downhill.

4. View upstream in tributary to Stony Brook exhibiting significant widening, incision.

Les Newell Wildlife Management Area, White River watershed, Stockbridge, VT – 12/1/2014

5. Northern trailhead accessed off Stony Bk Rd (see Figure 2).

6. View uphill on narrow forest road that is channeling runoff; dugway banks are 5 ft high in sections.

7. View downhill from photo 6; road drainage runs off to nearby stream

8. Road ditch directs runoff to the stream at the bridge crossing.

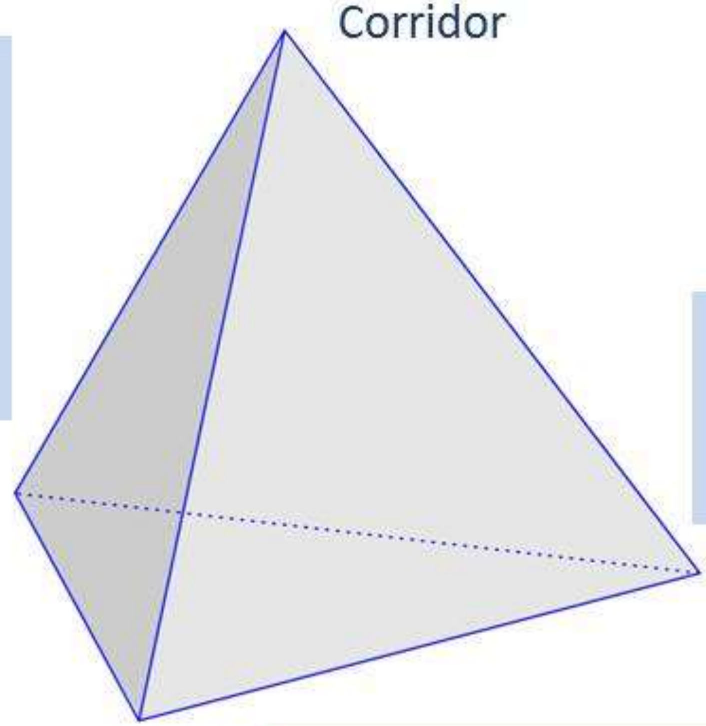
Appendix B

Camp Plymouth State Park - Pilot Study

30 June 2015 FINAL DRAFT

Mapping Approach - Hydrologic Resources

- > 2,500 feet Elevation
- > 35 % slopes
- Shallow-to-bedrock soils
- Very Poorly-drained soils (Hydrologic Soil Group D)
- Hydric soils

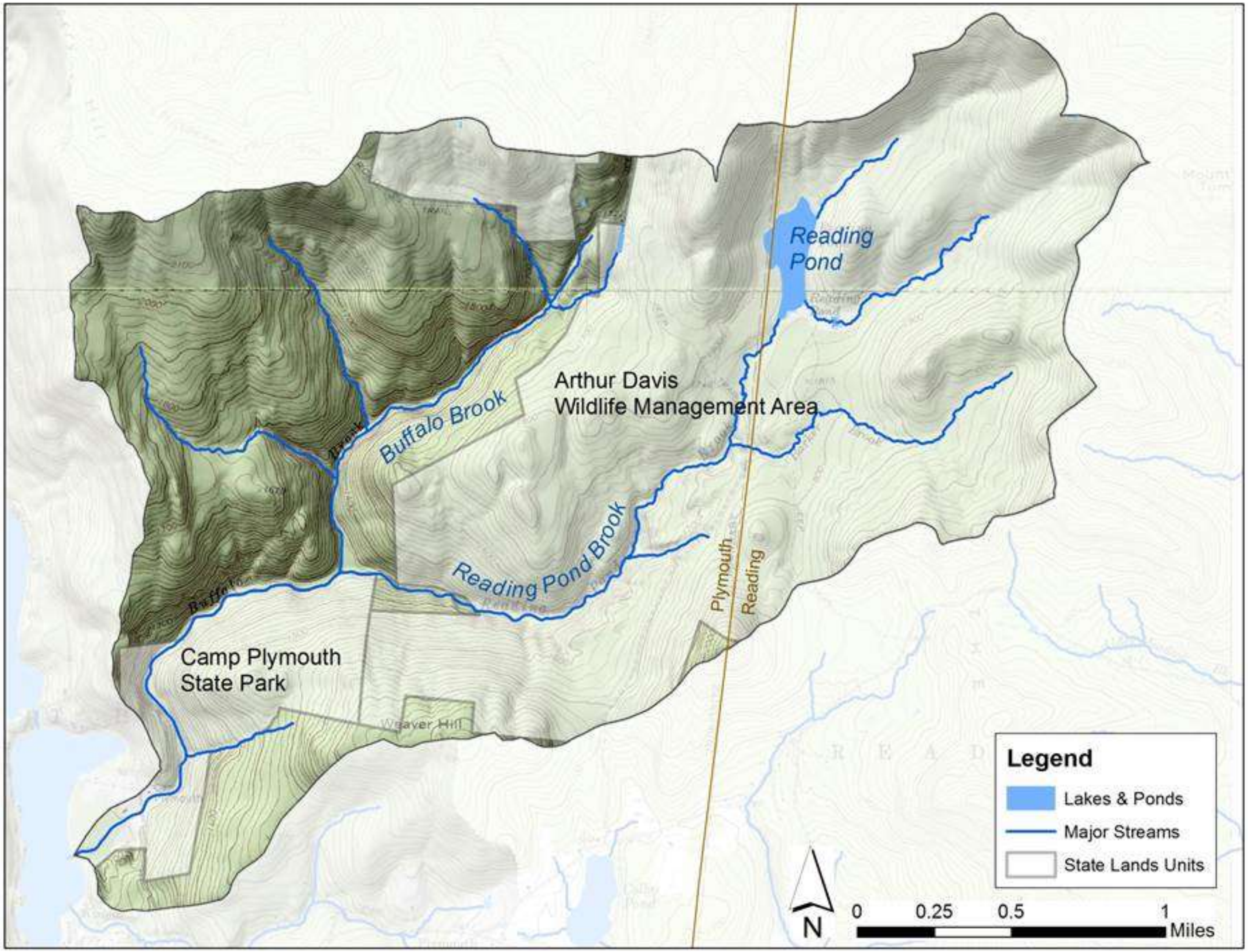


- ≤ 15 % slopes
- Well - drained soils (HSG A, B)

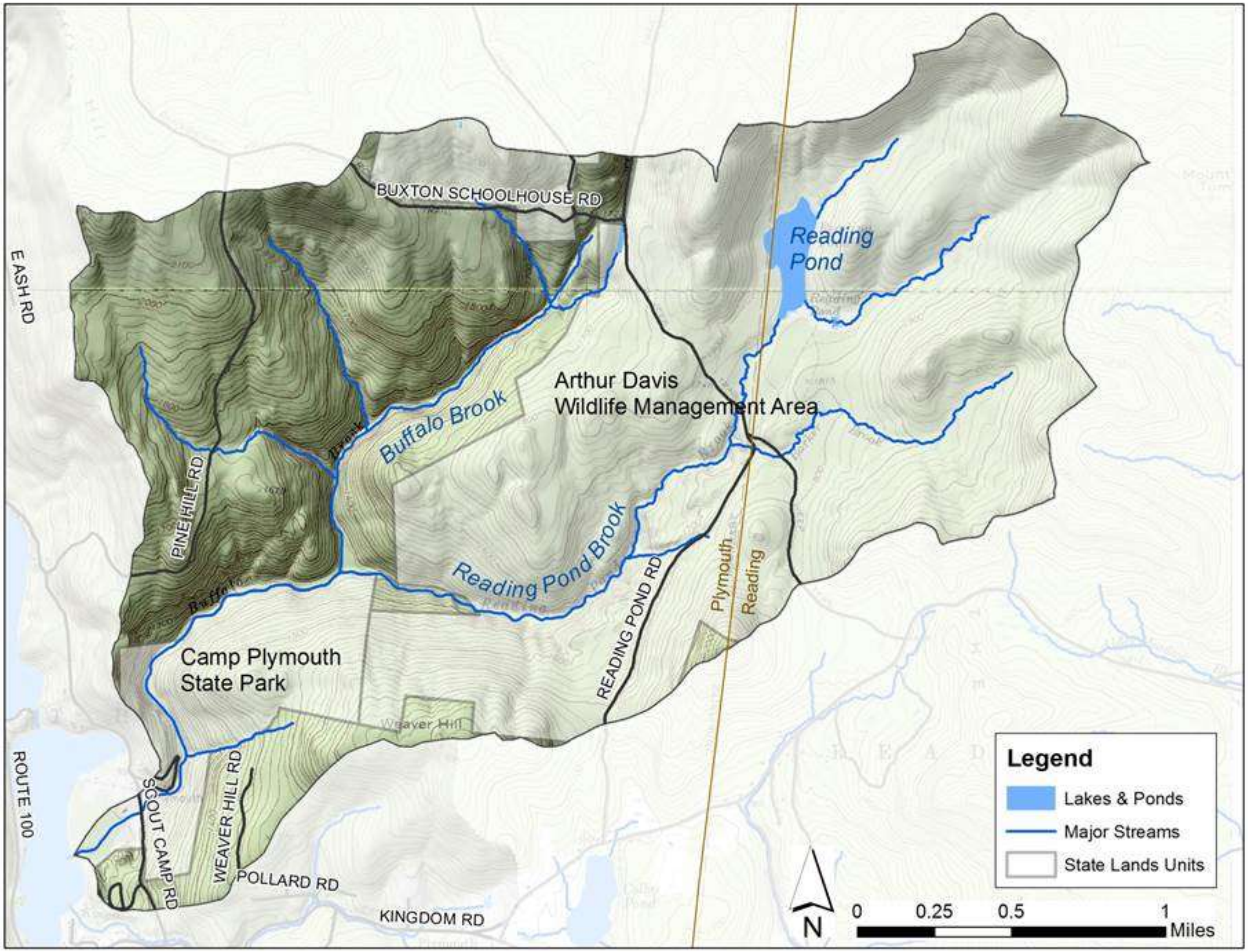
- > 15 % slopes
- Poorly-drained soils (Hydrologic Soil Group C)

Camp Plymouth SP

Buffalo Brook watershed
Plymouth, Vermont



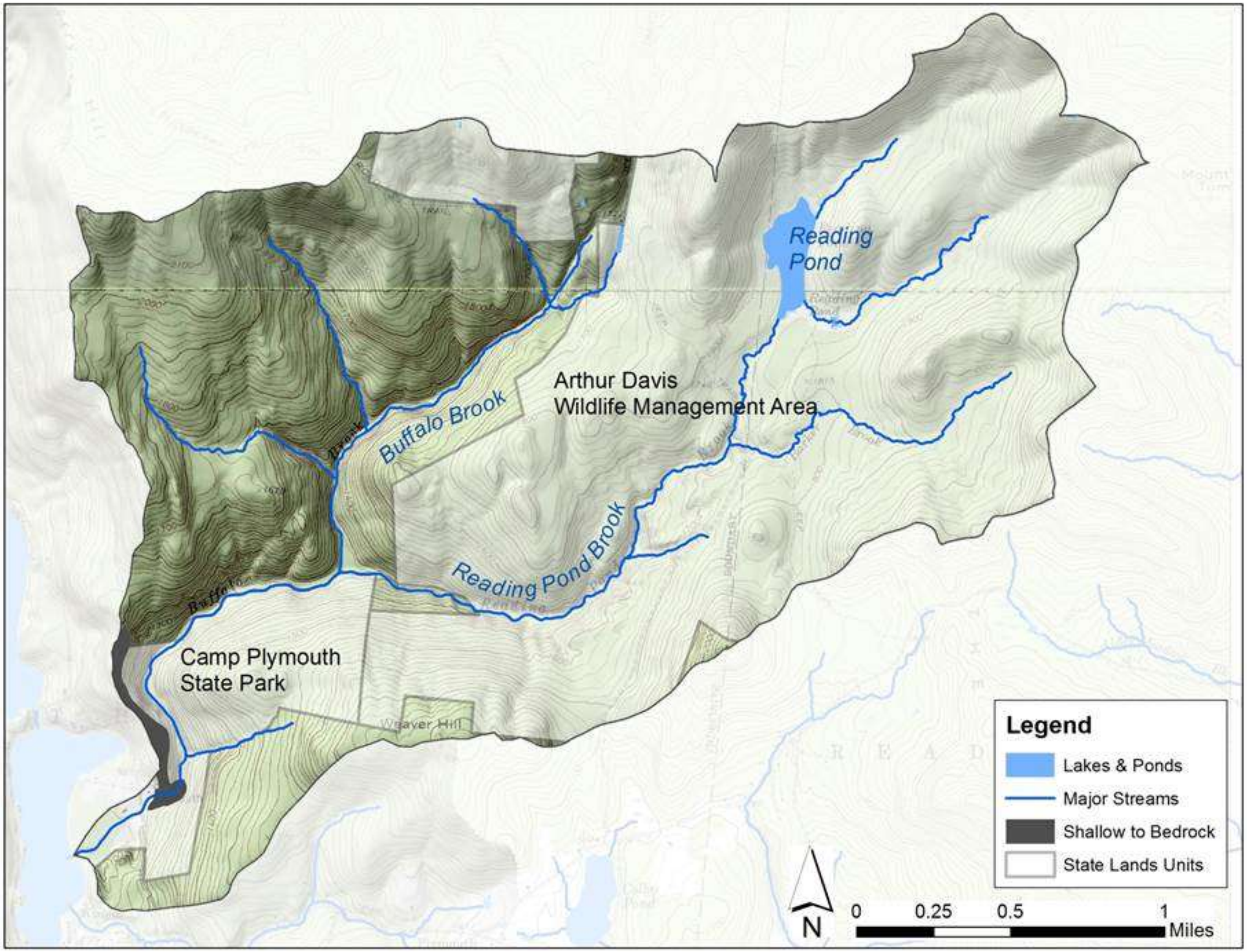
Reading Pond
Arthur Davis
Wildlife Management Area
Buffalo Brook
Reading Pond Brook
Plymouth
Reading
Camp Plymouth
State Park
Weaver Hill
Legend
Lakes & Ponds
Major Streams
State Lands Units
N
0
0.25
0.5
1
Miles



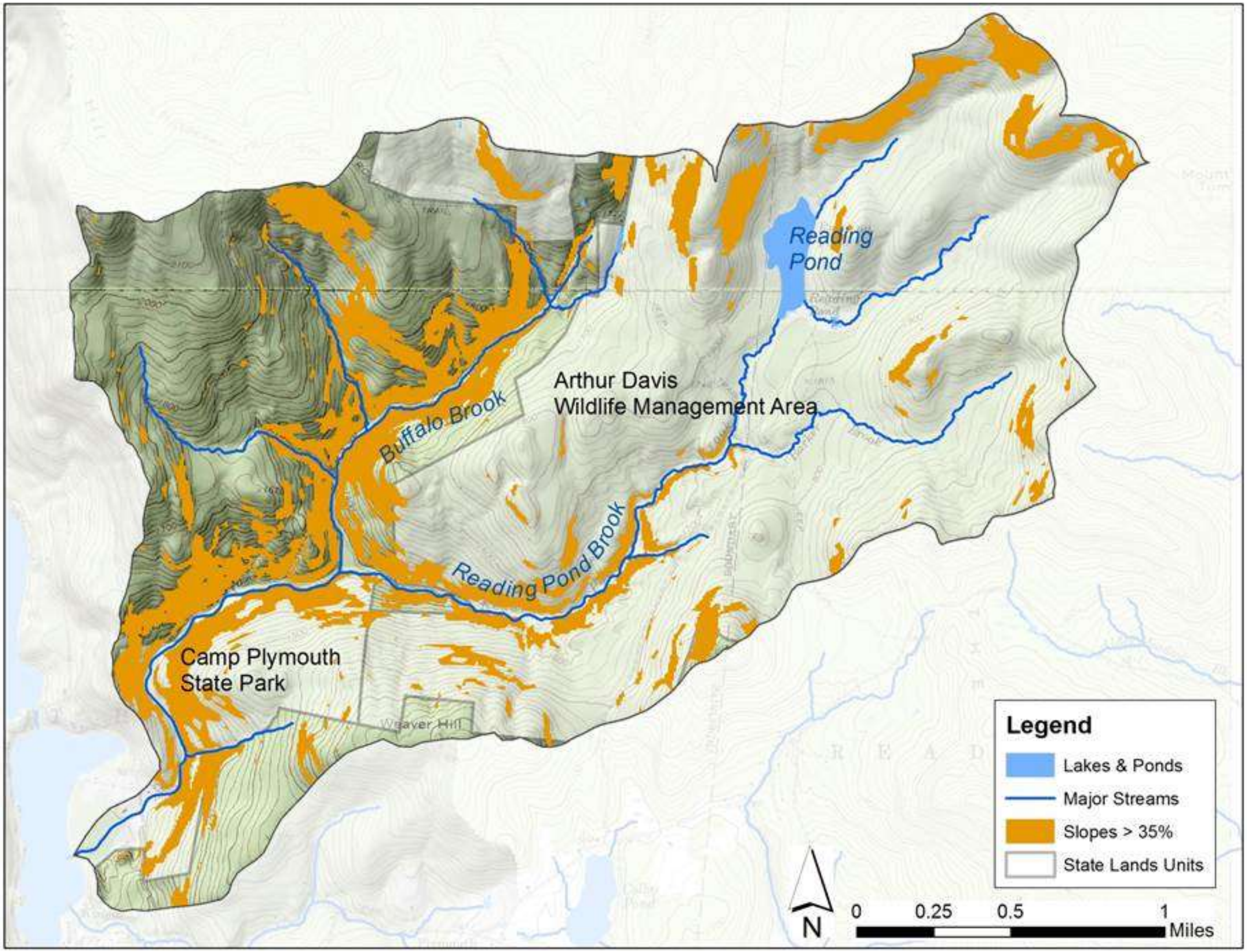
BUXTON SCHOOLHOUSE RD
E ASH RD
Reading Pond
Arthur Davis
Wildlife Management Area
Buffalo Brook
PINE HILL RD
Reading Pond Brook
READING POND RD
Plymouth
Reading
Camp Plymouth
State Park
Weaver Hill
ROUTE 100
SCOUT CAMP RD
WEAVER HILL RD
POLLARD RD
KINGDOM RD
Legend
Lakes & Ponds
Major Streams
State Lands Units
N
0
0.25
0.5
1
Miles

Hydrologic Reserve

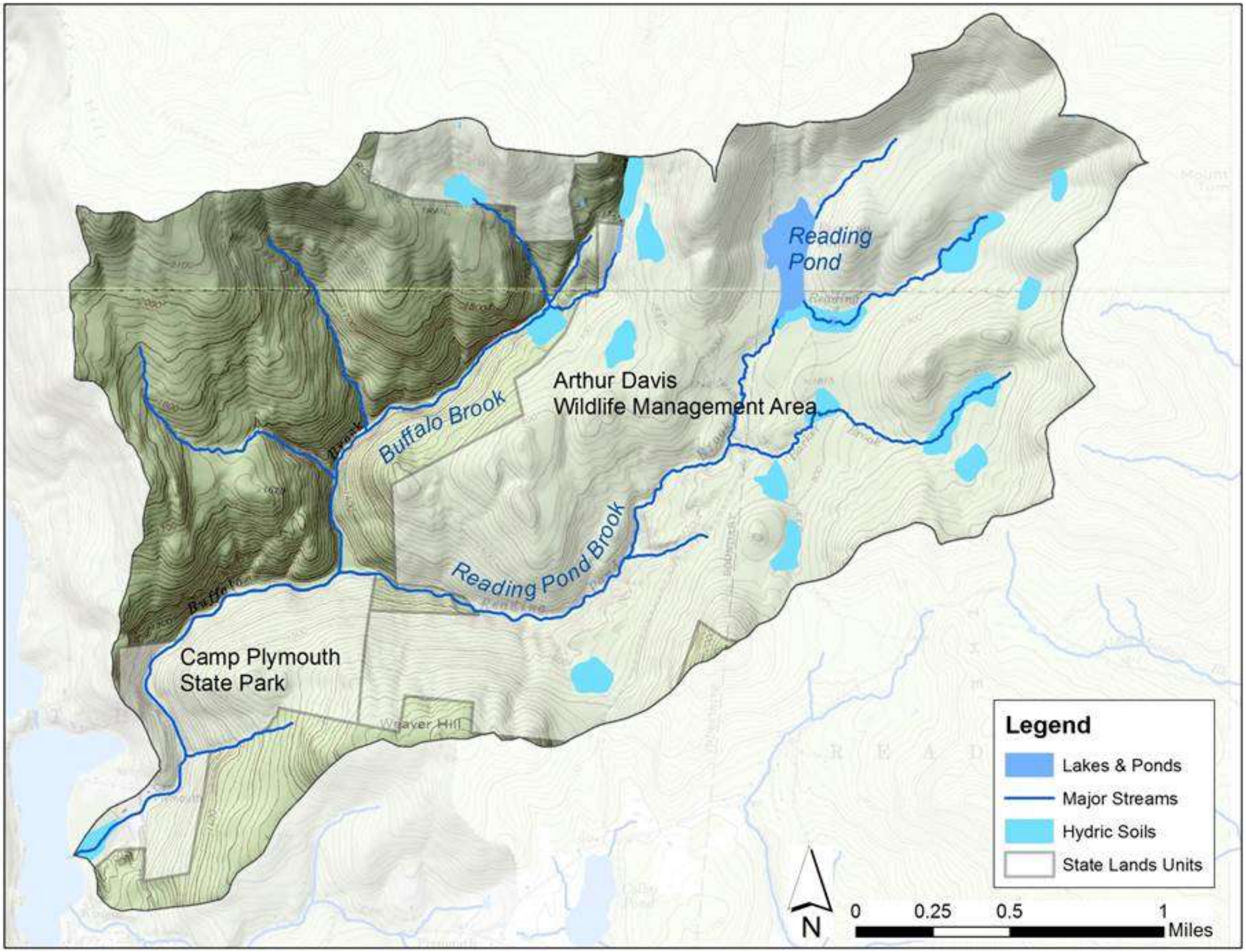
(layers comprising)

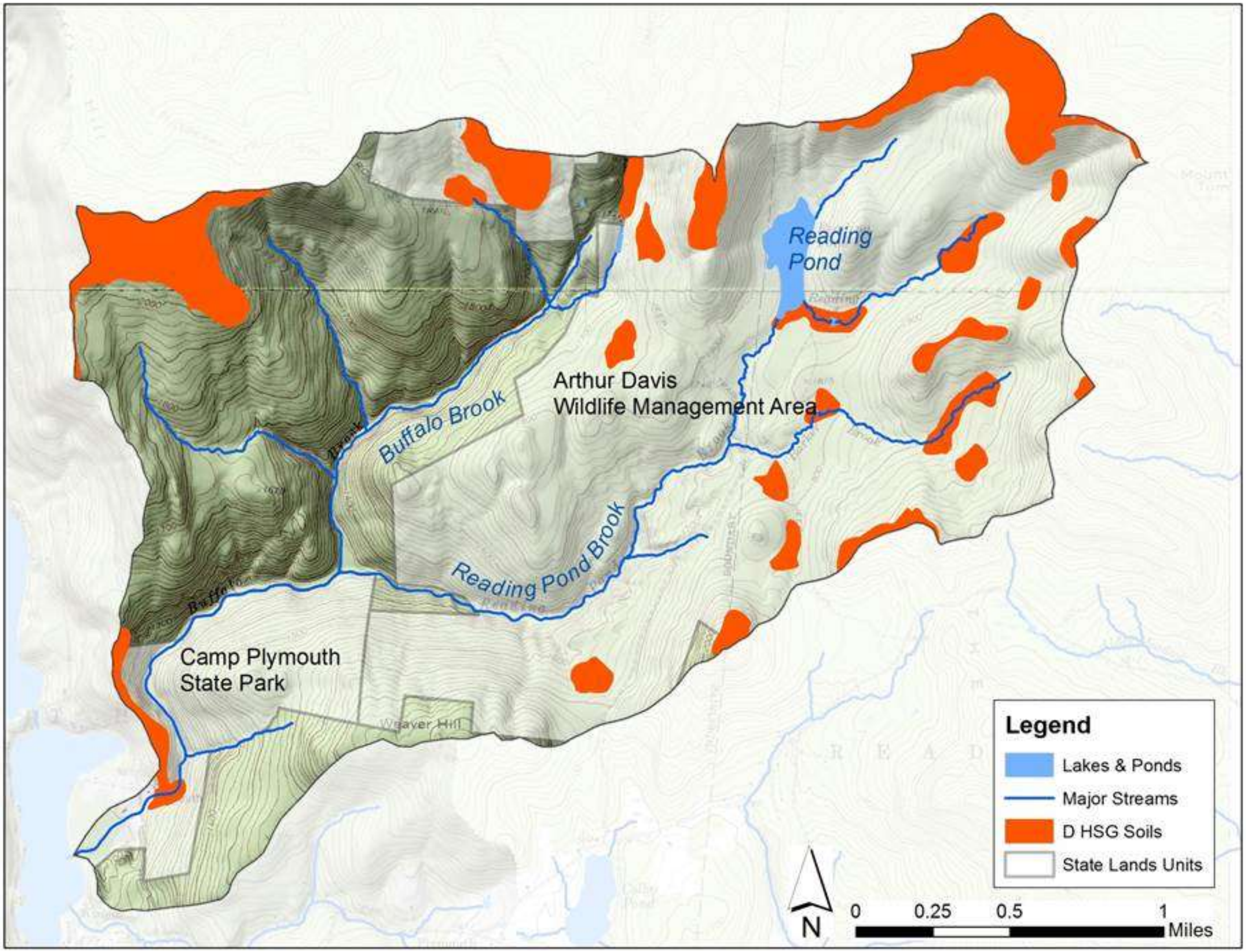


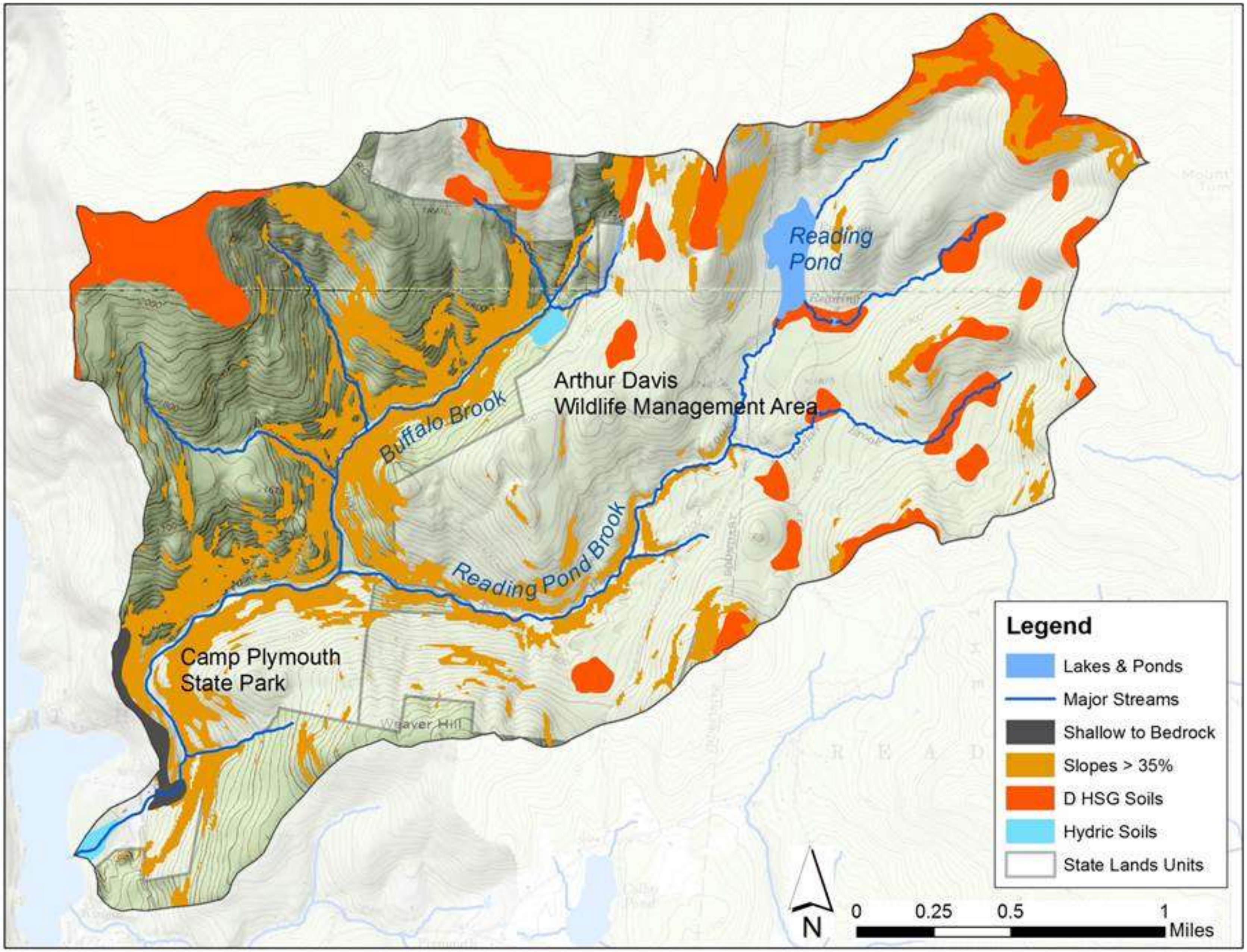
Reading Pond
Arthur Davis
Wildlife Management Area
Buffalo Brook
Reading Pond Brook
Camp Plymouth
State Park
Weaver Hill
Legend
Lakes & Ponds
Major Streams
Shallow to Bedrock
State Lands Units
N
0
0.25
0.5
1
Miles



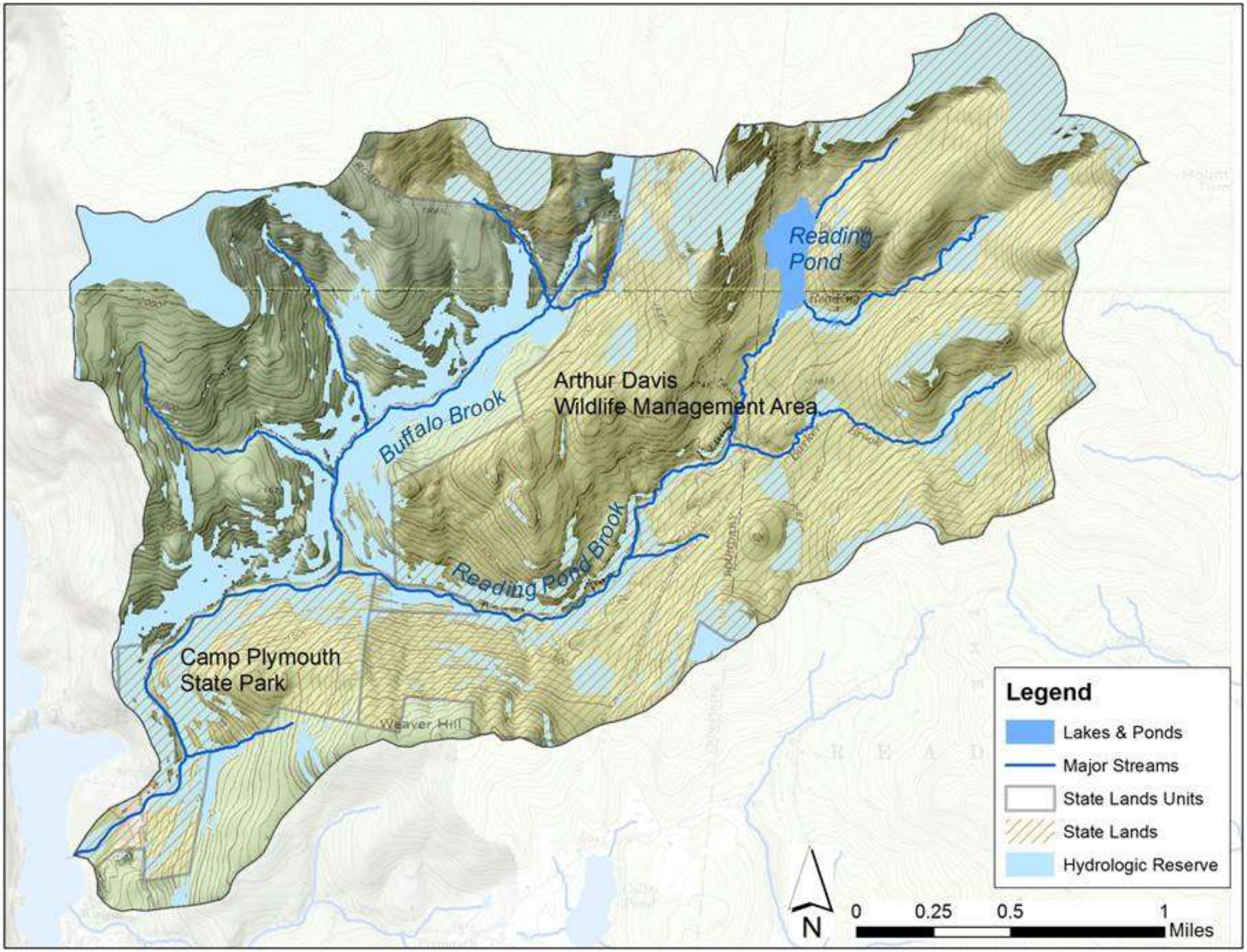
Reading Pond
Arthur Davis
Wildlife Management Area
Buffalo Brook
Reading Pond Brook
Camp Plymouth
State Park
Weaver Hill
Legend
Lakes & Ponds
Major Streams
Slopes > 35%
State Lands Units
N
0
0.25
0.5
1
Miles


Reading Pond
Arthur Davis
Wildlife Management Area
Buffalo Brook
Reading Pond Brook
Camp Plymouth
State Park
Weaver Hill
Legend
Lakes & Ponds
Major Streams
Hydric Soils
State Lands Units
N
0
0.25
0.5
1
Miles


Reading Pond
Arthur Davis
Wildlife Management Area
Buffalo Brook
Reading Pond Brook
Camp Plymouth
State Park
Weaver Hill
Legend
Lakes & Ponds
Major Streams
D HSG Soils
State Lands Units
N
0
0.25
0.5
1
Miles

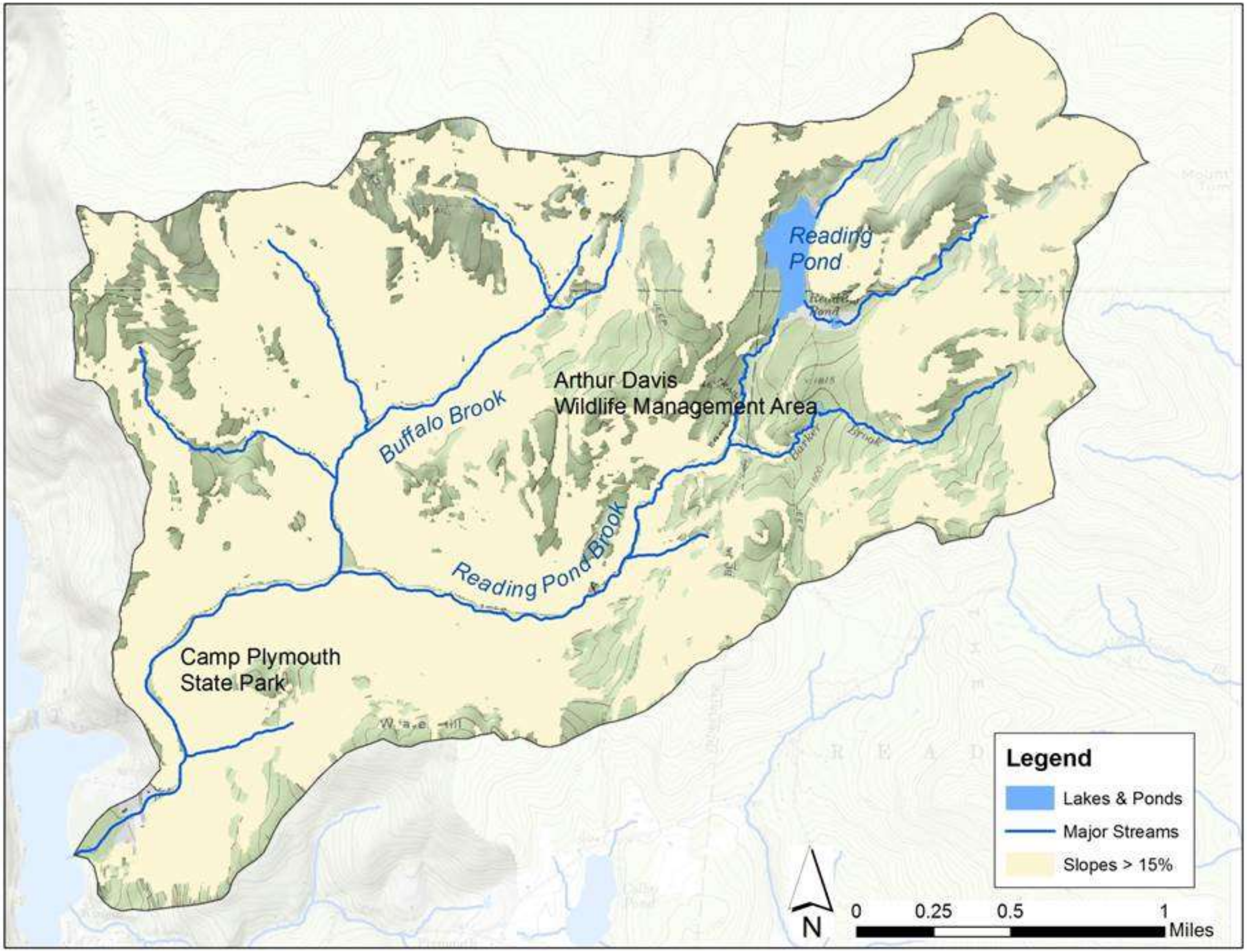


Reading Pond
Arthur Davis
Wildlife Management Area
Buffalo Brook
Reading Pond Brook
Camp Plymouth
State Park
Weaver Hill
Legend
Lakes & Ponds
Major Streams
Shallow to Bedrock
Slopes > 35%
D HSG Soils
Hydric Soils
State Lands Units
N
0
0.25
0.5
1
Miles

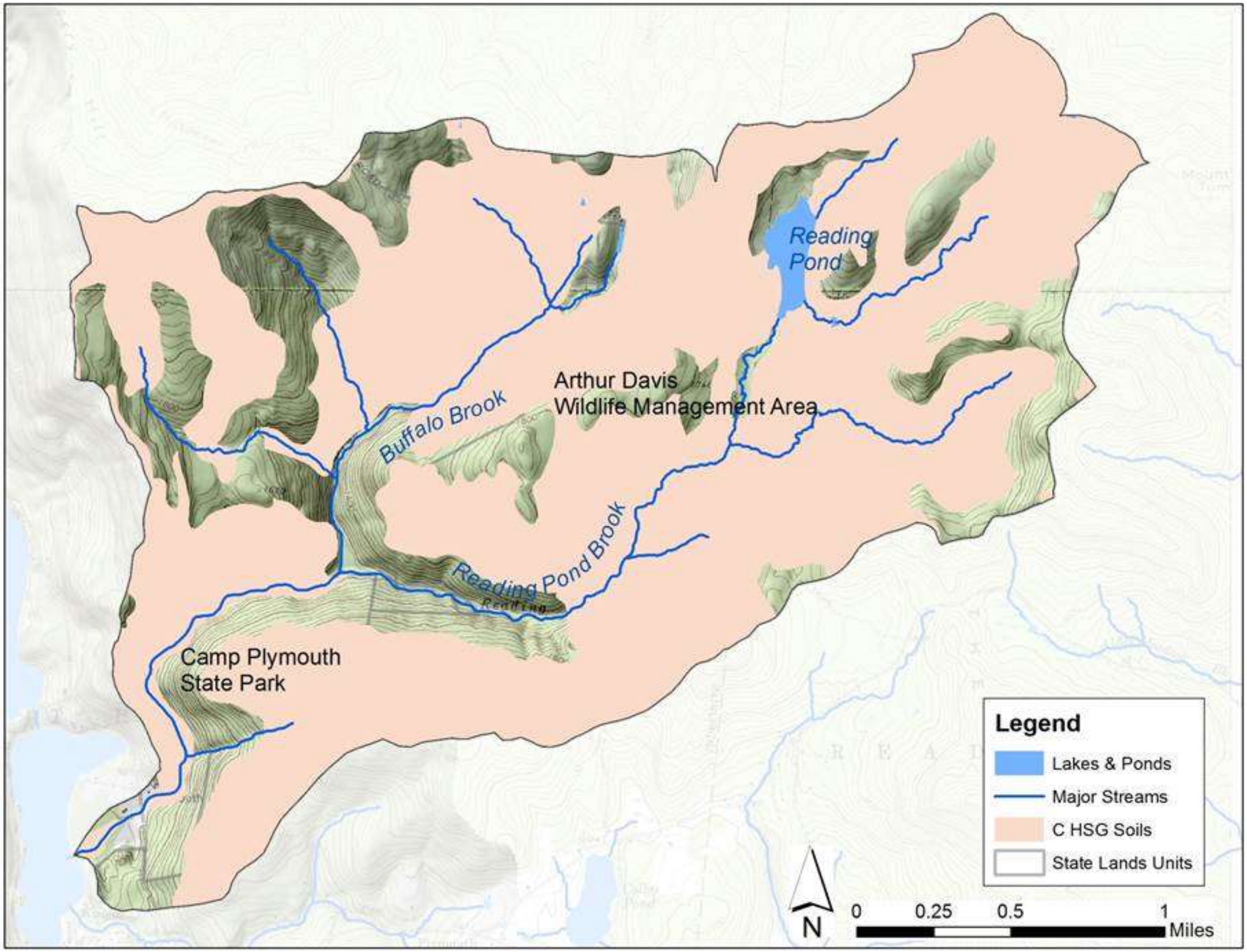

Reading Pond
Arthur Davis
Wildlife Management Area
Buffalo Brook
Reading Pond Brook
Camp Plymouth
State Park
Weaver Hill
Legend
Lakes & Ponds
Major Streams
State Lands Units
State Lands
Hydrologic Reserve
N
0
0.25
0.5
1
Miles

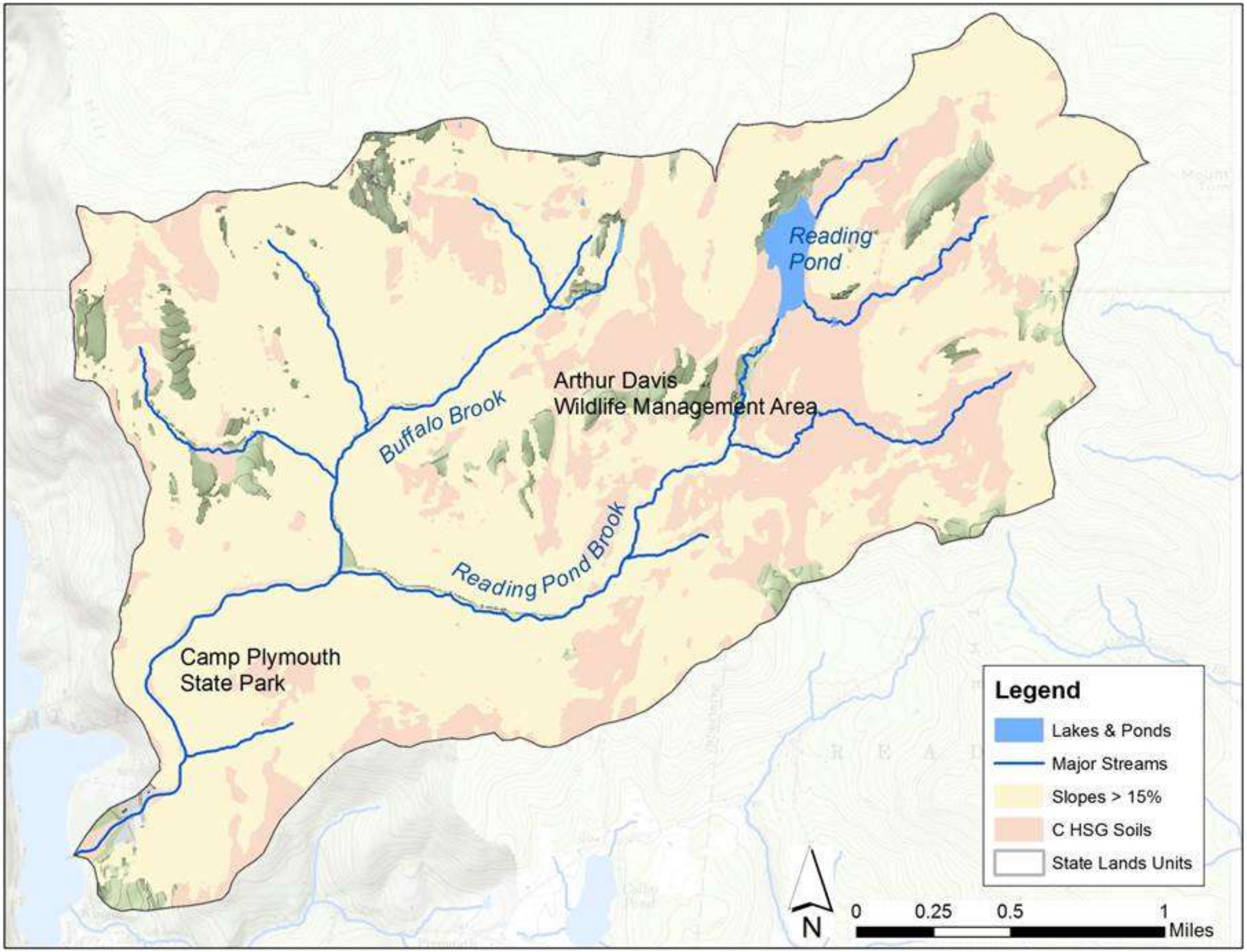
Hydrologic Conservation

(layers comprising)

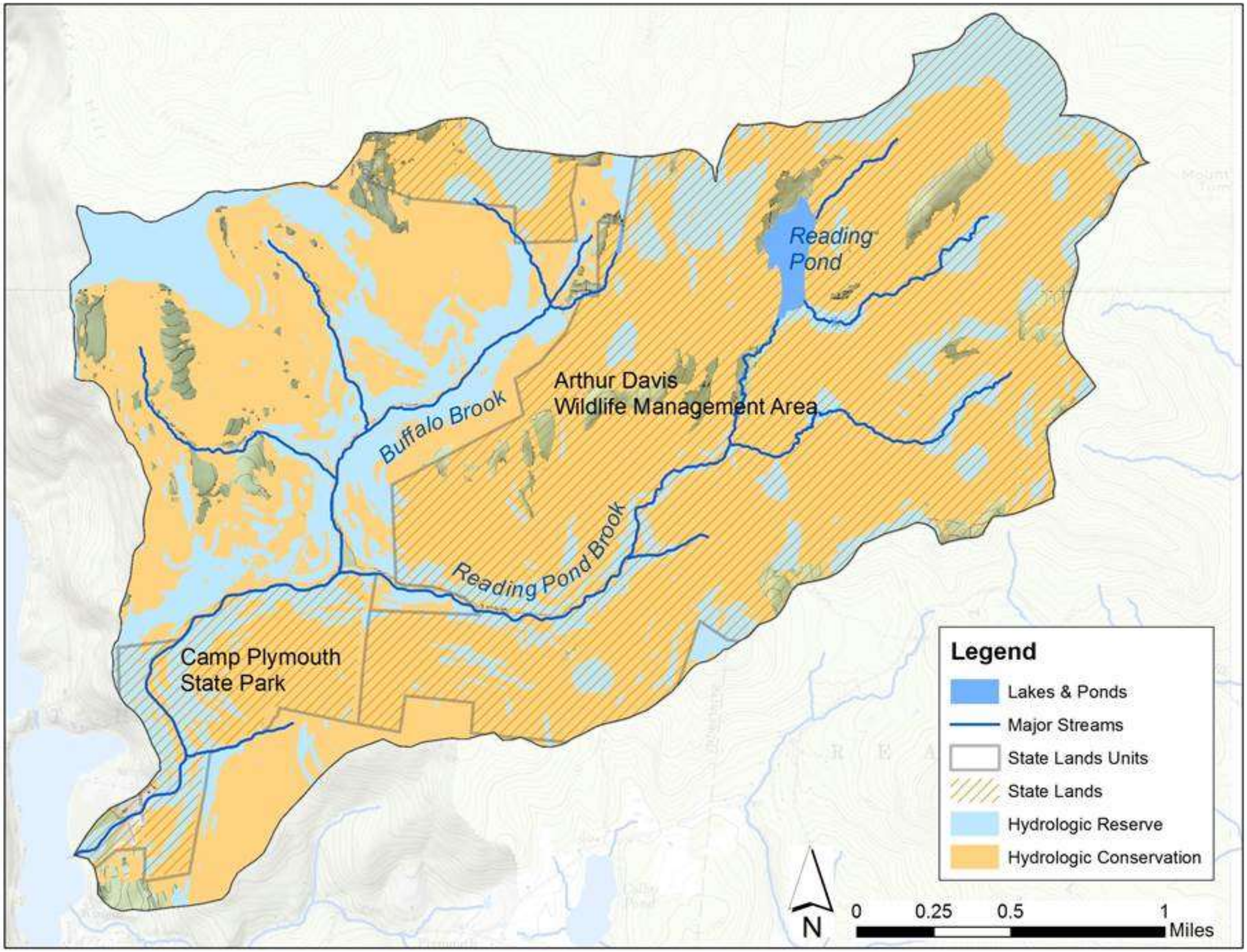


Reading Pond
Buffalo Brook
Arthur Davis
Wildlife Management Area
Reading Pond Brook
Camp Plymouth
State Park
Legend
Lakes & Ponds
Major Streams
Slopes > 15%
N
0
0.25
0.5
1
Miles


Reading Pond
Arthur Davis
Wildlife Management Area
Buffalo Brook
Reading Pond Brook
Camp Plymouth
State Park
Legend
Lakes & Ponds
Major Streams
C HSG Soils
State Lands Units
N
0 0.25 0.5 1
Miles



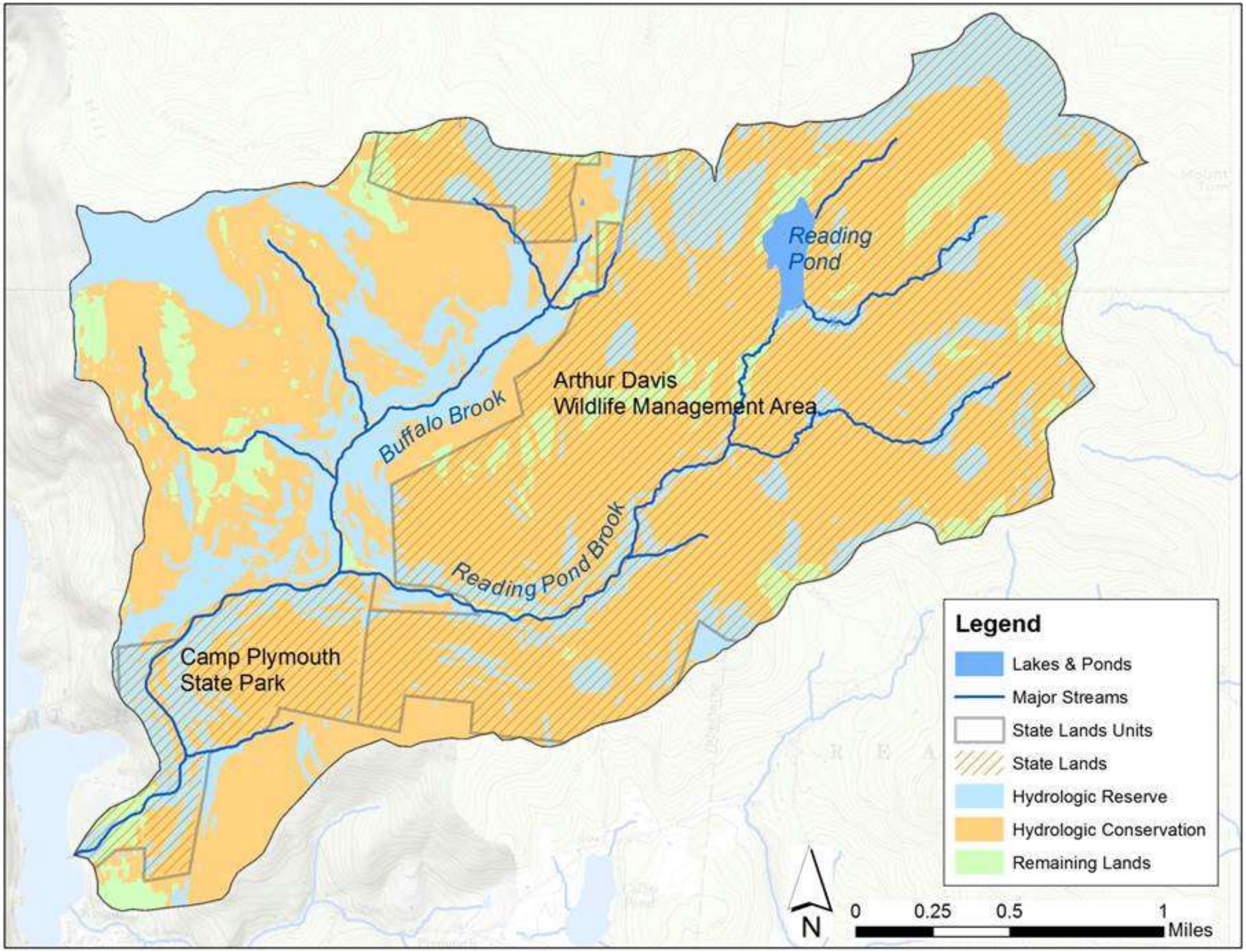
Reading Pond
Buffalo Brook
Arthur Davis
Wildlife Management Area
Reading Pond Brook
Camp Plymouth
State Park
Legend
Lakes & Ponds
Major Streams
Slopes > 15%
C HSG Soils
State Lands Units
N
0
0.25
0.5
1
Miles



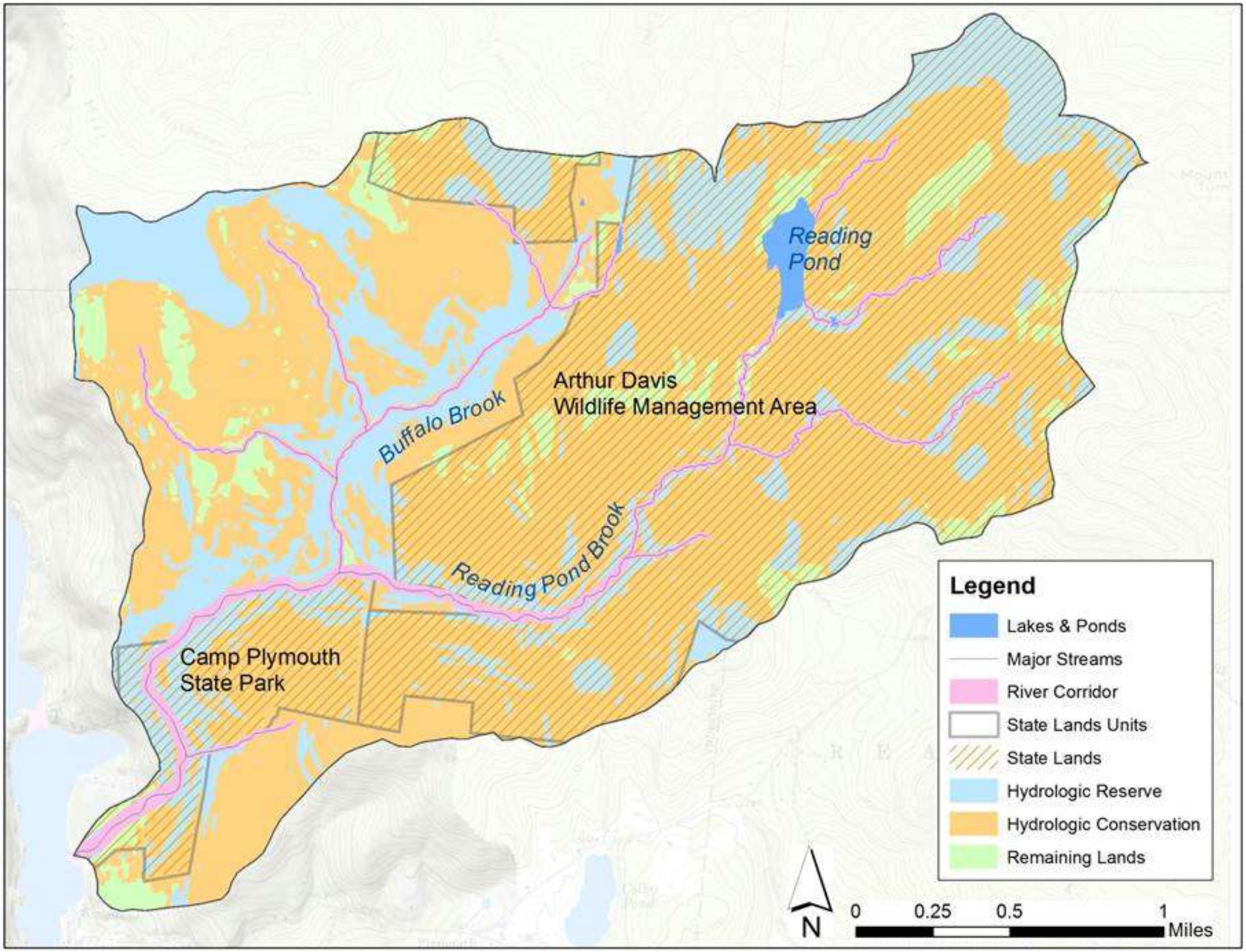
Reading Pond
Arthur Davis Wildlife Management Area
Buffalo Brook
Reading Pond Brook
Camp Plymouth State Park
Legend
Lakes & Ponds
Major Streams
State Lands Units
State Lands
Hydrologic Reserve
Hydrologic Conservation
N
0
0.25
0.5
1
Miles

Full Triad

(plus River Corridor)

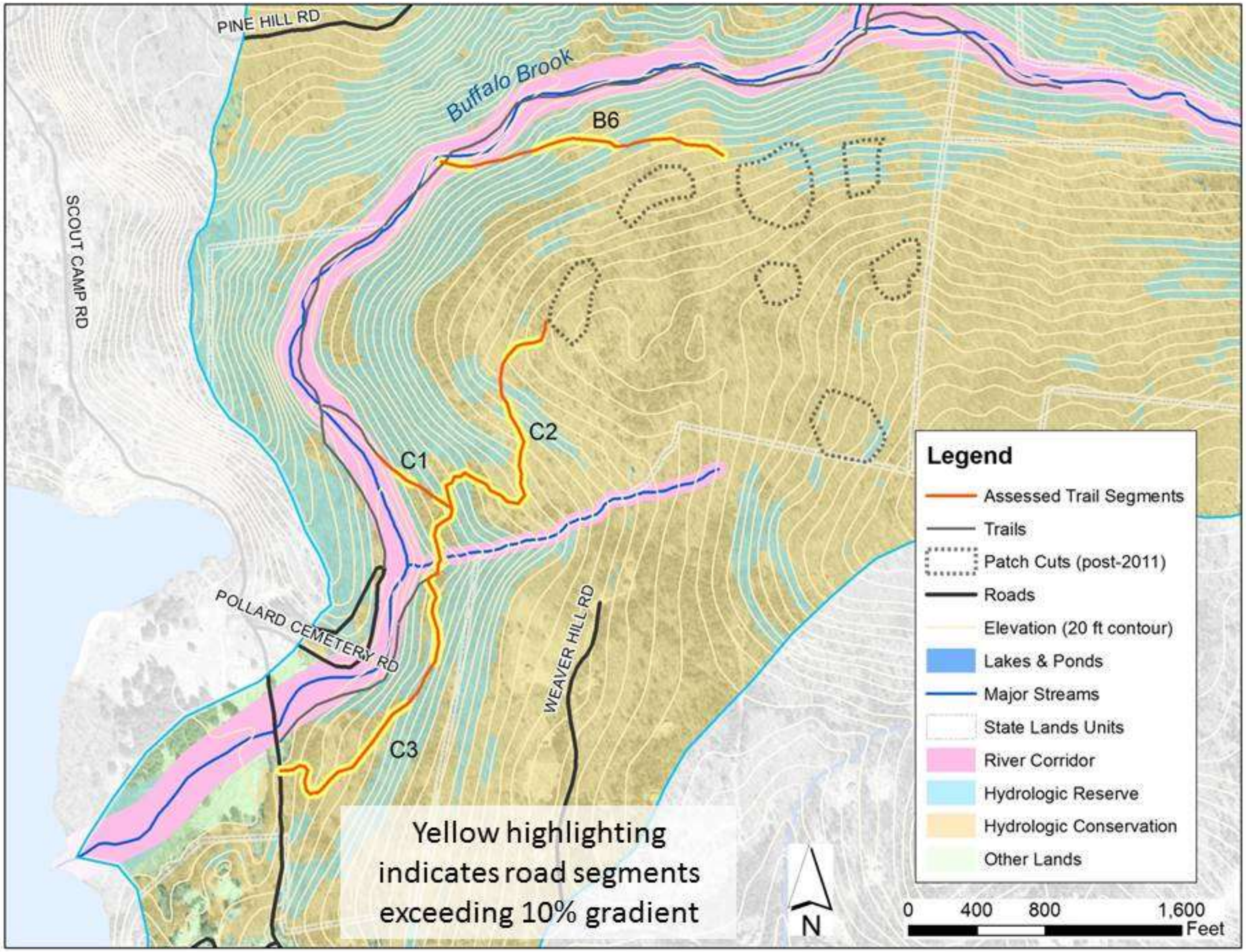


Reading Pond
Buffalo Brook
Arthur Davis Wildlife Management Area
Reading Pond Brook
Camp Plymouth State Park
Legend
Lakes & Ponds
Major Streams
State Lands Units
State Lands
Hydrologic Reserve
Hydrologic Conservation
Remaining Lands
N
0
0.25
0.5
1
Miles


Reading Pond
Arthur Davis
Wildlife Management Area
Buffalo Brook
Reading Pond Brook
Camp Plymouth
State Park
Legend
Lakes & Ponds
Major Streams
River Corridor
State Lands Units
State Lands
Hydrologic Reserve
Hydrologic Conservation
Remaining Lands
N
0
0.25
0.5
1
Miles

Camp Plymouth SP

Measure Conformance with AMPs


PINE HILL RD
Buffalo Brook
B6
SCOUT CAMP RD
C1
C2
C3
POLLARD CEMETERY RD
WEAVER HILL RD
Legend
Assessed Trail Segments
Trails
Patch Cuts (post-2011)
Roads
Elevation (20 ft contour)
Lakes & Ponds
Major Streams
State Lands Units
River Corridor
Hydrologic Reserve
Hydrologic Conservation
Other Lands
Yellow highlighting indicates road segments exceeding 10% gradient
N
0
400
800
1,600
Feet

Evaluation of Conformance to AMPs - Summary

Seg-ment	Length Assessed ft	Average slope of segment %	# functional drainage structures in place	# Drainage Structures Recom-mended	Percent Compliant with AMPs %	Percent of Length with Gradient >10% %	Percent of Length with Gradient >15% %
B6	1700	12.8	1	26	4%	59%	29%
C1	500	12.2	5	7.4	68%	40%	20%
C2	1800	16.3	15	32	47%	78%	61%
C3	2244	14.0	26	37.2	70%	85%	36%

Buffalo Brook watershed, Plymouth/Reading, Vermont 10/20/2014

Benchmark Assessment Tally

** After Town Forest Health Check, Vermont Family Forests, www.familyforests.org*

Forest Road Segment B6

Way-point	Seg-ment	Distance to Next Point Taped (Ft)	Average slope of segment %	# functional drainage structures in place	# Drainage Structures Recom-mended	Meet Bench-mark? Y	N	Notes
623		0						Jct w/ road along Buffalo Bk; downhill end of road segment
623	1	100	20	0	2.1		✓	
	2	100	17	0	1.9		✓	
624	3	100	10	0	1.3		✓	
626	4	100	9	0	1.2		✓	
627	5	100	8	0	1.1		✓	
628	6	100	10	0	1.3		✓	downhill exit of stream flow from road bed
629	7	100	12	0	1.5		✓	uphill entrance of stream flow to road bed
630	8	100	14	0	1.6		✓	
631	9	100	16	0	1.8		✓	
632	10	100	18	0	1.9		✓	
633	11	100	18	0	1.9		✓	
634	12	100	10	0	1.3		✓	
635	13	100	5	1	0.8	✓		wp636 = broad-based dip
637	14	100	15	0	1.7		✓	rill erosion
638	15	100	9	0	1.2		✓	
639	16	100	14	0	1.6		✓	
640	17	100	12	0	1.5		✓	Near post2011 patch cut clearing edge
	18							Uphill end of road segment
	19							
	20							
Total		1700		1	25.7	1	16	4%
Average			12.8					Compliant

Buffalo Brook watershed, Plymouth/Reading, Vermont

10/20/2014

Benchmark Assessment Tally

** After Town Forest Health Check, Vermont Family Forests, www.familyforests.org*

Forest Road Segment C1

Way-point	Seg-ment	Distance to Next Point Taped (Ft)	Average slope of segment %	# functional drainage structures in place	# Drainage Structures Recom-mended	Meet Bench-mark? Y	Meet Bench-mark? N	Notes
654		0						Downhill end assessed segment
655	1	100	10	1	1.3		✓	BBD at wp 655
656	2	100	20	1	2.1		✓	BBD at wp 657
658	3	100	9	1	1.2		✓	BBD at wp 659
660	4	100	10	1	1.3		✓	BBD at wp 661
662	5	100	12	1	1.5		✓	BBD at wp 662
	6							Uphill end segment; Jct w/ New skid road
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16							
	17							
	18							
	19							
	20							
Total		500		5	7.4			68%
Average			12.2					Compliant

Buffalo Brook watershed, Plymouth/Reading, Vermont 10/20/2014

Benchmark Assessment Tally

** After Town Forest Health Check, Vermont Family Forests, www.familyforests.org*

Skid Road Segment C2

Way-point	Seg-ment	Distance to Next Point Taped (Ft)	Average slope of segment %	# functional drainage structures in place	# Drainage Structures Recom-mended	Meet Bench-mark? Y	Meet Bench-mark? N	Notes
		0						Jct btwn old road, new skid road (post 2011)
663	1	100	15	1	1.7		✓	WB conveying stream channel at wp 664
665	2	100	25	1	2.5		✓	WB at wp 665
667	3	100	28	2	2.7		✓	2 WBs at wp 668, 669
670	4	100	25	2	2.5		✓	2 WBs at wp 671, 672
673	5	100	16	1	1.8		✓	WB at wp 674
675	6	100	16	2	1.8		✓	2 WBs at wp 676, 677
678	7	100	16	1	1.8		✓	WB at wp 679
680	8	100	16	1	1.8		✓	WB at wp 681
682	9	100	14	1	1.6		✓	WB at 10 ft uphill from wp 682
684	10	100	24	0	2.4		✓	
686	11	100	24	0	2.4		✓	
688	12	100	13	2	1.5	✓		2 WBs at wp 689, 690
691	13	100	10	0	1.3		✓	
693	14	100	2	0	0.4		✓	
694	15	100	5	1	0.8	✓		WB at wp 695
696	16	100	22	0	2.2		✓	
698	17	100	16	0	1.8		✓	
699	18	100	7	0	1		✓	
700	19							
	20							
Total		1800		15	32			47%
Average			16.3					Compliant

Buffalo Brook watershed, Plymouth/Reading, Vermont 10/20/2014

Benchmark Assessment Tally

** After Town Forest Health Check, Vermont Family Forests, www.familyforests.org*

Skid Road Segment C3 = ~ 16 ft road width

Way-point	Seg-ment	Distance to Next Point Taped (Ft)	Average slope of segment %	# functional drainage structures in place	# Drainage Structures Recom-mended	Meet Bench-mark? Y	N	Notes
663		0						Uphill end segment; Jct old road w/ new skid road (post2011)
663	1	100	15	1	1.7		✓	WB ~10 ft uphill from wp 702
702	2	100	13	1	1.5		✓	WB at wp 703
704	3	100	18	2	1.9	✓		2 WBs at wp 705, 706
706	4	44	18	0	1.9		✓	estimated 2nd order stream crossing; scour, widening,
707	5	100	10	1	1.3		✓	WB at wp 708; Jct of old skid road/trail at wp 709
710	6	100	12	2	1.5	✓		2 WBs at 711, 712
714	7	100	12	1	1.5		✓	WB at 715
716	8	100	14	1	1.6		✓	WB at 717
718	9	100	16	2	1.8	✓		2 WBs at 718, 719
720	10	100	11	1	1.4		✓	WB at 721
722	11	100	7	1	1	✓		WB at 723; river at base of 53% slope below skid road
724	12	100	9	2	1.2	✓		2 WBs at 725, 726
727	13	100	5	2	0.8	✓		2 WBs at wp 728, 729
729	14	100	11	1	1.4		✓	WB at 730
731	15	100	17	1	1.9		✓	WB at 732
733	16	100	16	1	1.8		✓	WB at 734
735	17	100	14	1	1.6		✓	WB at 736
737	18	100	13	2	1.5	✓		WB and perennial stream crossing at 737 +5ft, WB at 738 -5 ft
738	19	100	23	0	2.3		✓	gullied stream crossing at wp 739; drains to gullied old skid road
740	20	100	12	1	1.5		✓	WB at 741
742	21	100	12	1	1.5		✓	WB at 743
744	22	100	17	1	1.9		✓	WB at 745, 746
746	23	100	28	0	2.7		✓	erosional gully (TS Irene) exits to flats along north side trail
	24							
	25							log cribbing stabilizing downslope side road at wp 727
Total		2244		26	37.2			70%
Average			14.0					Compliant

Appendix C

Optimal Conservation Practices - outlined

30 June 2015 FINAL DRAFT

DRAFT

OPTIMAL CONSERVATION PRACTICES (OCPs)

for

Attenuating Flood Damage & Enhancing Water Quality in the Forested Headwaters of Vermont

by David Brynn & Kristen Underwood

March 2, 2015

Introduction

It is predicted that a changing climate in Vermont will result in: earlier spring high flows, ice jams and flooding; a decrease in snowpack and ice; lower, warmer, and less-oxygenated streams and rivers; less habitat for cold-water fish species; increased nutrient inputs; more soil erosion and sedimentation; increased precipitation; and an increase in the number and power of storm events.[1] Although efforts to minimize the negative impacts of global climate change must continue, it is also prudent to identify land conservation practices that will enhance forest resilience in the face of the anticipated gully-washing storm events. The *Optimal Conservation Practices* are intended to help move Vermont's forests away from being the *ditched watersheds* they have become back toward the *spongy catchments* they were at the time of settlement. It is understood that this will require changing our conservation priorities, the ways we access forests and manage the vegetation, adaptive management, multi-disciplinary cooperation, and time. It is also understood that our forests retain the capacity to be active partners in this process.

Optimal Conservation Practices

The Optimal Conservation Practices are designed to slow the rate of water flow, increase the amount of water infiltration, reduce the amount of soil detachment, enhance the capacity of forests to trap sediment, and to maintain water quality even during storm events. In addition they are designed to reduce exposure of streams and rivers to direct solar radiation.

Section I

Practices to be Applied in Hydrologic Reserves

[1] J. Curt Stager and Mary Thill. 2010. Climate Change in the Champlain Basin: What natural resource managers can expect and do. The Nature Conservancy, Montpelier, VT

1. Avoid slopes over 35% - Close and rewild existing legacy access networks, refrain from timber harvesting, and avoid other soil-disrupting activities in areas that are over 35% in slope.

2. Avoid hydric soils - Close and rewild existing legacy access networks, refrain from timber harvesting, and avoid other soil-disrupting activities in areas with hydric soils – including natural communities such as floodplain forests, hardwood swamps, softwood swamps, spring seeps and vernal pools, marshes and sedge meadows, wet shores and shrub swamps

3. Avoid shallow-to-bedrock & D HSD soils -Close and rewild existing legacy access networks, refrain from timber harvesting, and avoid other soil-disrupting activities in areas with shallow-to-bedrock soils and D HSD soils – including natural communities such as upland shores, outcrops & upland meadows, and cliffs and talus slopes and including shallow soils -- should be reserved from timber harvest, access networks, and other soil-disrupting forest management activities.

Section II

Practices to be Applied in Hydrologic Conservation Zones

Access Networks

"Mass soil movement in forested watersheds is a catastrophic event often triggered by road construction." (Brown 1983)

"Although water-quality effects from forest harvesting have been regarded as temporary, effects from improperly constructed or maintained forest roads can pose a major, long-tern problem (Biodiversity on the Forests of Maine page 126 - Kahl 1996).

Access systems – including truck roads, forwarding paths, and recreation trails -- should be planned, designed, constructed, maintained, and monitored: to optimally serve the intended uses of the entire basin; to minimize the width, number, and extent of roads, paths, and trails particularly in or near stream crossings, riparian buffer zones, streams, surface waters and other wet areas, and steep slopes; to attenuate flood damage; and to maintain water quality during significant flood events. (Swift, L.W. page 324)

4. Use Forwarders.

5. All access networks should be constructed with tracked excavators under dry summer conditions.

6. Access networks -- including truck roads, forwarding paths, and log landings --- should only be used when adequately dry or frozen.

7. Post-harvest use of access networks should be restricted as required and monitored in order to prevent erosion, compaction, site disruption, overland flow and stream sedimentation during storm events.

8. Access networks – including truck roads, forwarding paths, and recreation trails -- should be systematically monitored on an annual basis and maintained as required to attenuate storm damage and stream sedimentation.

9. Access networks -- including truck roads, forwarding paths, recreation trails, and log landings --- should occupy less than 5% of the acreage they serve.

10. Access networks – including truck roads and forwarding paths – should have an average grade of 7% or less.

11. Truck roads and forwarding paths should be designed and constructed to be 12 feet wide or narrower, with near vertical cut banks, with few or no inside ditches, and with outsloping surfaces. (Swift, L.W. page 323)

12. Access networks should be designed, constructed, and maintained so that storm waters are removed from the surface of roads, paths, and trails in small amounts and at frequent intervals by turn-ups and durable broad-based dips (when active) and deep waterbars (when closed) at spacing according to Table 1 – Distance Between Waterbars. (Swift, L.W. page 324) (VT FP&R. 2011. AMPs)

13. Log landings should: be located on nearly-level, stable ground; be kept out of stream and other surface waters protective strips; have water diversions installed; and be graded to prevent erosion and sedimentation.

14. All cut and fill slopes should be re-vegetated before September 15. (Swift, L.W. page 323)

15. Brush barriers should be installed at the toe of fills if fills are located within 150 feet of a defined stream channel. (Swift, L.W. page 323)

16. Steep pitches greater than 12% on truck roads and forwarding paths should not exceed 200 feet in length.

17. Unnecessary maintenance of access networks should be avoided.

Riparian Buffer Zones

Riparian buffer zones should be retained adjacent to streams and other surface waters such as beaver meadows, vernal pools, spring seeps, and wetlands in order to attenuate damage and to maintain water quality during significant flood events. Any forest management activities in riparian buffer zones should be conducted under frozen winter conditions only.

18. The width of the forest and shrub riparian buffer strip should be a minimum of 100 feet as measured horizontally and perpendicular to the edge of the historic stream channel or surface water.

19. Optimal condition of retained riparian buffer area. – characterized by little or no soil disturbance, 80%+ tree and shrub canopy closure; and one 16 inch DBH or larger wind-firm legacy trees per 50 linear feet of buffer zone.

20. Areas of exposed soil that occur within the protective strip should be seeded with native species and sources, mulched with material free of invasive exotics, and applied according to Table 3, before September 15.

21. Stream buffer strips should: be kept free of logging vehicles; have little or no tree cutting; and be at least 50 feet wide.

22. Soil disturbance that extends beyond the A soil horizon should be avoided.

23. Down dead wood recruitment and retention.

Stream Crossings

Stream crossing number and location should be optimized so that there are a minimum number of crossings and at the most favorable locations possible in conjunction with a stable and suitable access network capable of withstanding storm events, maintaining water quality, and providing excellent service with minimal maintenance over time.

24. The number of stream crossings should be minimized.

25. Stream Crossings should be located where……

26. Streams should be crossed with bridges or open-arch culverts which are properly sized according to Table 2 and properly installed at right angles to the stream.

27. Fording of streams by motorized vehicles should be avoided.

28. Drainage ditches should not feed directly into streams and other surface waters.

29. Sediment should be prevented from reaching streams by using turn-ups or broad-based dips on access roads, paths and trails prior to stream crossings.

30. Streams and all surface waters shall be kept free of slash and other logging debris unless part of a carefully-designed, dead wood recruitment treatment approved by DEC.

31. Roadbeds that drain into stream channels should be fully graveled to create an erosion-resistant pavement. (Swift, L.W. page 323)

Silviculture in Forested Headwaters: Vegetation Retention & Management

Single tree and small group selection and shelterwood methods should be used for natural forest communities with gap-phase replacement (e.g. northern hardwoods) and the irregular shelterwood method should be used for natural forest communities with stand-replacing disturbance regimes (e.g. spruce-fir). Use forwarders. Log under frozen winter conditions.

32. Practice uneven-aged management by area regulation with 15+ year cutting cycles and long rotation ages.

33. Whole-tree harvesting should be avoided and down dead wood recruitment and retention should be encourage. In general leave as much biomass on the site as possible including all materials that are less than 3 inches in diameter.

34. Promote a vertical stand structure that includes over-story, mid-story, and shrub, and herbaceous vegetation layers.

35. Low-impact logging equipment, including small forwarders, should be used to minimize disruption of the O horizon, soil compaction, and increased overland flow.

36. Logging activities, except for the necessary and proper construction of stream crossing structures and approved ecological restoration shall be kept out of stream channels and meander zones.

37. Soil disturbance including rutting that extends beyond the A soil horizon should be avoided.

38. Legacy tree retention - retain a minimum of three vigorous and wind-firm legacy trees per acres measuring over 19 inches DBH.

39. Manage for at least four downed trees or 16+ feet long logs per acre on average with one exceeding 21 inches DBH and four exceeding 15 inches DBH.

40. Manage for at least four large and secure cavity, snag, and/or decadent, living trees per acre with one exceeding 21 inches DBH and four exceeding 15 inches DBH.