FINAL REPORT

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Prepared By:	Allaire Diamond
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NUTRIENT QUANTIFICATION AND PHASE I RESTORATION DESIGN OF MILL BROOK FLOODPLAIN IN THE WINOOSKI RIVER WATERSHED

CONTACT INFORMATION

Vermont Land Trust

8 Bailey Ave, Montpelier, VT 05602

802-879-6672 – allaire@vlt.org

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EXECUTIVE SUMMARY

Nutrient Quantification and Phase 1 Restoration Design of Mill Brook Floodplain is the critical research component of a multi-part restoration strategy for the confluence of Mill Brook and the Winooski River in Jericho, Vermont. The confluence occurs on farmland owned by Jericho Settlers Farm that was conserved with a Vermont Land Trust easement in 2014. Mill Brook has been moving dramatically since that time, eroding acres of farmland and coming closer to VT Rt 117, a busy state highway. Vermont Land Trust worked with the farmer landowners to retire the land from agriculture with a floodplain overlay easement in 2021, and has engaged volunteers to plant trees in the floodplain area and implement process-based restoration in a nearby small stream.

This project aimed to elucidate hydrologic and hydraulic dynamics in the Mill Brook floodplain, quantify phosphorus and sediment being lost from the site, and develop a robust restoration plan that would stabilize the road interface while also promoting ecological values and floodplain function in the former farmland. By showing the concerningly high erosion rates and phosphorus migration out of the site as the brook moves closer to the road, the project underscored the need for thoughtful restoration that enhances floodplain function. The preferred alternative emerging from the field work and analysis here involves removing two historic areas of rock armor – one on Mill Brook and one on the Winooski – and constructing a flood bench and a ballasted engineered log jam in the reach of Mill Brook closest to the road. Vermont Land Trust and its partners are currently seeking funding to implement this plan.

CONTENTS

1. PROJECT SYNOPSIS

The recent movement of Mill Brook near its confluence with the Winooski River, eroding conserved farmland along VT Rt. 117, is a dramatic example of channel readjustment and floodplain formation easily visible to thousands of passersby each day. Historic channel straightening and land use influence these processes. After extensive scoping with partners, Vermont Land Trust (VLT) is undertaking ecological restoration here to enhance ecological function in the floodplain, while promoting stability of the nearby road and avoiding emergency or ongoing riprap placement. In 2021, we permanently protected the floodplain area with an easement overlay, which ceased agricultural production here. In this project, VLT completed Phase 1 of active restoration. Working with hydrology consultants at SLR International Corporation who gathered baseline nutrient, hydraulic, and geomorphic data, we evaluated alternative designs and commissioned preliminary plans for streambank and instream structures for the lowest reach of Mill Brook, from Rt. 117 to the Winooski mouth. The site data and plans, our outputs, inform the outcomes, a comprehensive restoration plan integrating ecological function with infrastructure protection, and the phosphorus data necessary to justify implementation funding from partners. Partners including the farmer landowners, the Vermont Agency of Transportation, the town of Jericho, and river scientists from the Vermont Department of Environmental Conservation engaged throughout the process, which has led to a present search for implementation funding.

2. TASKS COMPLETED

Task 1: *Seek bids for design, modeling, and QAPP work.* This task's objective was to identify a qualified firm for modeling and design work through a competitive process. We developed an RFP and sent it to three hydrology and environmental consulting firms, and received two proposals as well as an initial intent to submit but ultimately regrets from the third firm that did not submit a proposal. There are very few firms in Vermont that can perform this kind of specialized work to VLT's standards. We selected SLR Consulting to receive the contract after consulting with the Lake Champlain Basin Program.

Task 2: *Develop a QAPP.* SLR Consulting developed the QAPP for this project.

Task 3: *Perform sediment and water quality analysis, topographic and geomorphic survey, geomorphic assessment, GIS and CAD data, model hydrological and hydraulic processes, and develop an alternatives analysis.* SLR Consulting completed the field work in summer and fall 2021 and provided their interim project report in winter 2022. They found significant phosphorus leaving the site and modeled a range of restoration alternatives. SLR presented their results to VLT and partners, including Vermont Agency of Transportation, and refined the report based on feedback. A selection of figures and excerpts from the report follows.

Figure 1 Project Site Map (Imagery from FluidState Consulting)

The geomorphic setting has led to active erosion on lower Mill Brook downstream of VT Route 117 for the past few decades. From 1999 to 2018 the channel has eroded through approximately 350 feet of floodplain (range of 120 feet to 490 feet) (Figure 14). The volume of eroded material based on the average bank height is over 76,000 cubic yards! The rate of erosion during this period was 4,030 cubic yards per year.

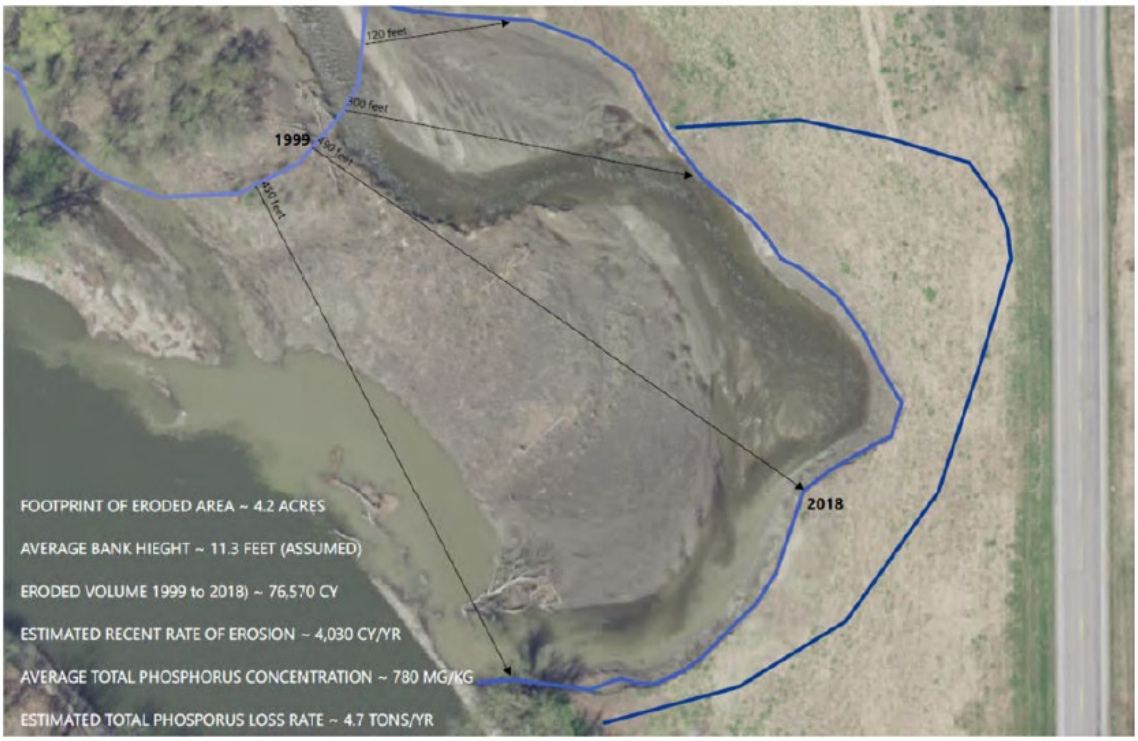


Figure 14 Bank Erosion 1999 to 2018

Bank erosion continued between 2018 and 2021 where the bank moved an average of 85 feet (range of 30 feet to 150 feet) (Figure 15). The volume of eroded material based on the average bank height is 23,654 cubic yards. The most recent estimate of the rate of erosion is 7,885 cubic yards per year.

Bank erosion and the accompanying loss of sediment continues today. The active erosion is both threatening VT Route 117 and impacting water quality.

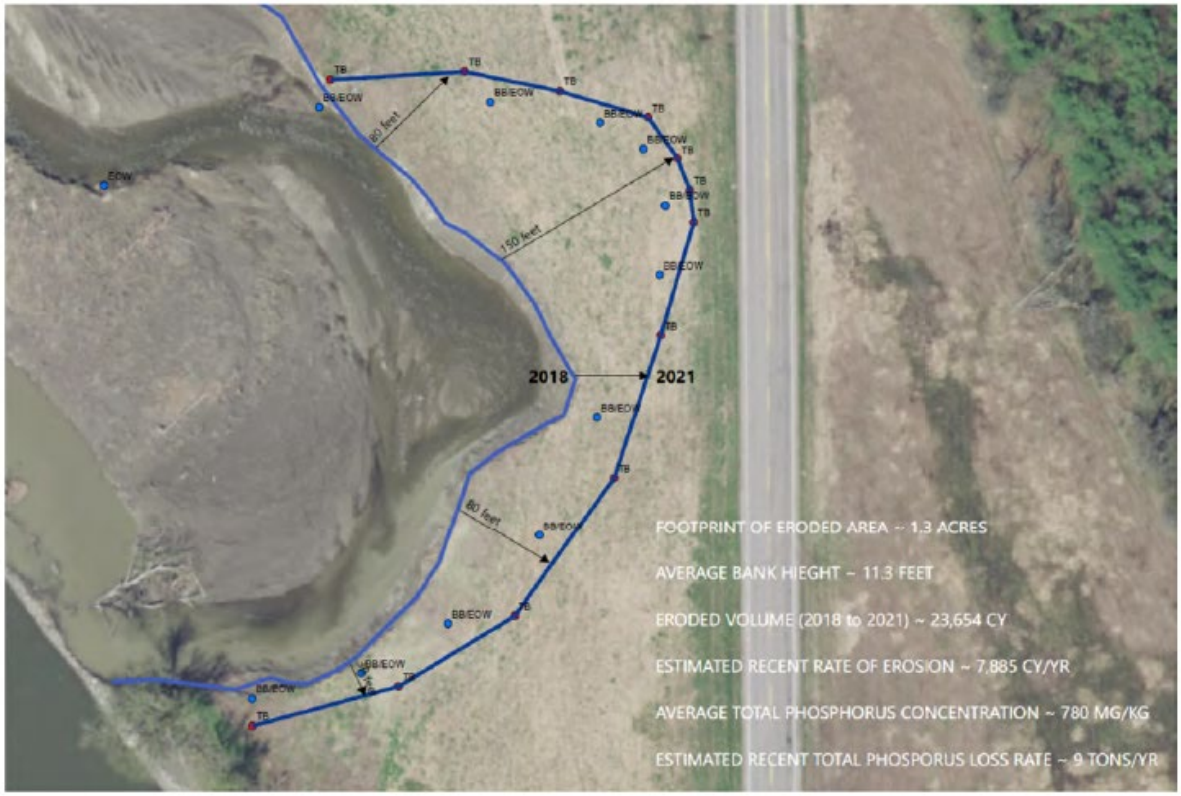


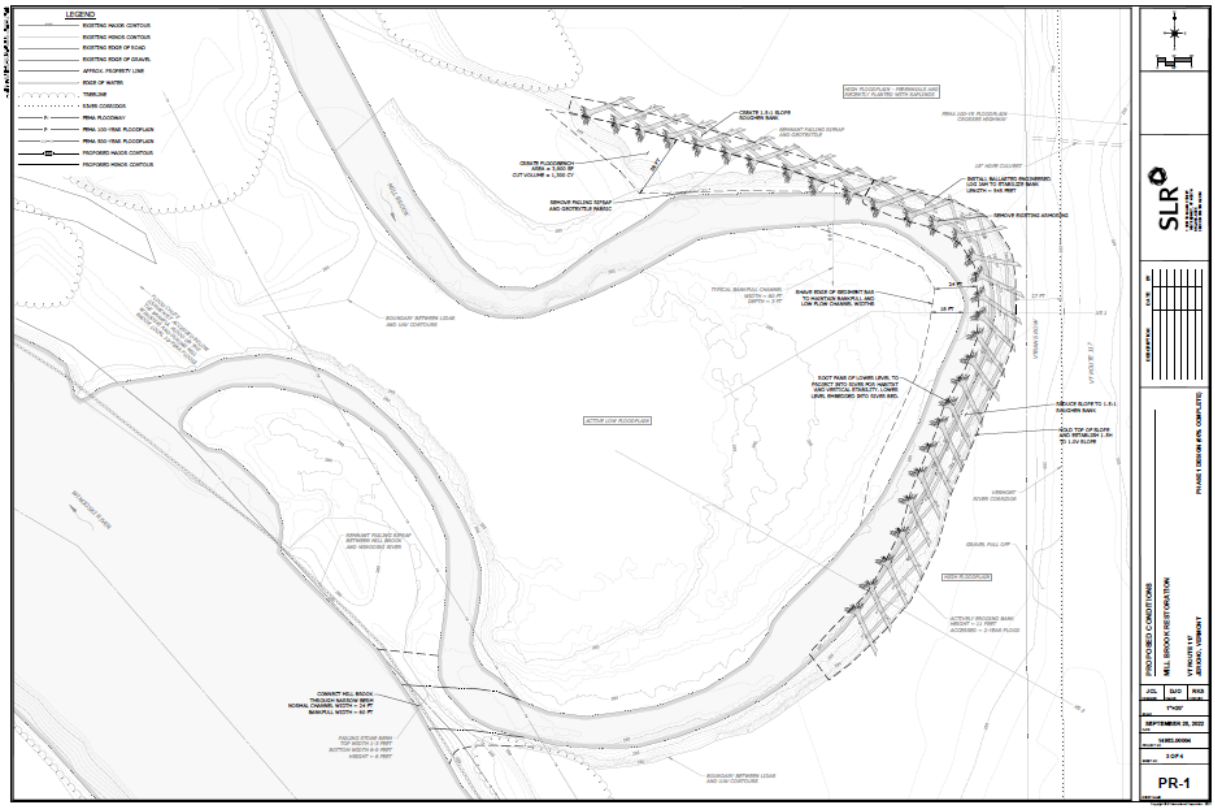
Figure 15 Bank Erosion 2018 to 2021

Figure 28 Flood Depth and Inundation Area for the Modeled 10-Year Flood

Figure 41 **The Preferred Alternative**

Task 4. *Develop Phase 1 channel restoration plan.* SLR developed this plan, which includes a ballasted engineered log jam and removal of old armoring along Mill Brook, and removal of a stone berm along the Winooski River, based on feedback from VLT and partners. SLR also

included an engineer's cost estimate to guide the search for implementation funding, which is presently underway. An image from the proposed plan follows.



Task 5. *Quarterly Progress Reports.* Quarterly progress reports to update funders and partners have been submitted for this project.

Task 6. *Final Report.* This final report summarizes the project.

3. METHODOLOGY

This section will summarize the methodology for Task 4, which is described in detail in the Engineering Report for this project completed by SLR.

SLR evaluated recent history of the site and a range of maps including historic and recent topographic and orthophoto maps, FEMA maps and flood profiles, and current aerial imagery and LiDAR data provided by FluidState Consulting, who were contracted to obtain UAS imagery for this project. SLR reviewed existing geomorphic assessments and performed additional field work, including surveying, to update and refine stream geomorphic and bank erosion conditions. They installed a stream gauge to monitor Mill Brook's flow and evaluated wildlife habitat including fish passage, and natural communities at the site. They sampled floodplain soil to estimate phosphorus export associated with erosion, by collecting six samples 18-24" deep and sending them for analysis at a local lab using EPA method 6010C. After quantifying soil phosphorus concentrations, they could estimate the amount of soil lost at the site since 1999, using approximate methods for determining sediment yield.

Hydrologic analysis estimated peak flows using USGS StreamStats and the New England steep streams regression equations. The stream gauge was installed in July 2021 and used to develop an initial three-point rating curve and synthetic flood hydrographs. Flood water surface elevations for normal conditions, 2-year floods, and 10-year floods were developed using FEMA flood profiles and nearby USGS gauge flows. These were used to set up a hydraulic model, made with HEC-RAS and RAS Mapper, that would represent water depth, velocity, elevation, and extent for Mill Brook and the Winooski River in a range of flood conditions including high and low flows in both stream systems and how they would impact this confluence area. Survey and LiDAR-generated elevation surfaces were used in the model. The model showed how several restoration alternatives would alter flow conditions in the area near Rt. 117 and the confluence site.

SLR proposed and evaluated ten restoration alternatives using this model and ended up with a preferred alternative that involved:

- Stabilize the Mill Brook bank along Rt. 117 with a gentler side slope, stone-ballasted Engineered Log Jam (ELJ), and revegetation
- Remove the failing armor constraining Mill Brook upstream of the eroding bank
- Create a flood bench upstream of the eroding bank closest to Rt. 117 on Mill Brook
- Remove the narrow-armored berm along the Winooski River at the Mill Brook confluence

VLT chose to move forward with this preferred alternative as the Phase 1 (60%) design, which formed the basis of Task 5. In Task 5, SLR generated detailed planview and design details for the site and the construction of the Engineered Log Jam using CAD.

4. QUALITY ASSURANCE TASKS COMPLETED

All quality control tasks required by our approved QAPP were completed. Our project was in compliance with the QAPP.

5. DELIVERABLES COMPLETED

Deliverables include the QAPP, Engineering Report, and Phase 1 Design. The QAPP was approved on June 17, 2021. Working versions of the Engineering Report and Phase 1 Design were completed in spring 2022 and refined in September 2022 to reflect final proposed configuration. These are currently being used to seek implementation funding through the FEMA Hazard Mitigation Grant Program. No problems were encountered.

Quarterly reports submitted on 4/7/21, 7/9/21, 10/9/21, 12/23/21, 4/6/22, and 7/4/22 are on file with the Lake Champlain Basin Program and NEIWPPC.

6. CONCLUSIONS

Through this project, Vermont Land Trust and its partners have developed a much clearer understanding of the complex hydrologic and ecological dynamics of the Mill Brook-Winooski River confluence area, and possible restoration alternatives. SLR's hydrologic analysis showed the variable influence of flooding in both the Mill Brook and the Winooski watersheds, and the importance of modeling both when determining the best restoration alternative. Soils and

sediment analysis show that the highest rates of erosion occur after inundation, when saturated streambank soils break off in chunks or collapse in mass failures. Huge amounts of phosphorus bound in sediment, approaching nine tons per year in some years, are being lost from the site and migrating downstream, causing water quality concerns in the lower Winooski River and Lake Champlain.

The lack of woody vegetation and structural roughness due to a legacy of agriculture are facilitating Mill Brook's excessive erosion. The dramatic channel changes are also partially due to historic riverbank armoring in Mill Brook (installed around 2014) and along the Winooski (installed around the 1940s) and may have been exacerbated by heavy storms in the Mill Brook watershed in 2013. The armoring impacts stream power and prevents both streams from naturally migrating across their active river areas, distributing floodborne sediment and debris laterally rather than washing it downstream and accessing their floodplains.

Mill Brook's changes are resulting in new floodplain formation and the area is beginning to stabilize from a channel evolution perspective. The area has been retired from agriculture with a Vermont Land Trust floodplain overlay easement, and was planted with trees in spring 2021. But these ecologically positive steps are challenged by the continuing movement of Mill Brook toward Rt. 117, and this project showed, through hydrologic modeling, how that movement will likely continue if no action is taken.

SLR's preferred alternative of a stone-ballasted engineered log jam along the stretch of Mill Brook adjacent to the road will stabilize the road while also introducing essential woody structure to the floodplain and providing a complex structural network to trap floodborne sediment and debris, slow flood waters, provide habitat for aquatic and terrestrial species, and support the continued development of this area into a highly functional confluence floodplain. The use of logs with root wads to create this type of feature has been used in similar places where road stabilization and floodplain function are both priorities. Emergency response to stabilize the road right of way with rock is likely inevitable, but the proposed restoration design can incorporate any stone used.

The preferred alternative restoration design also removes the armoring along Mill Brook and the Winooski River – actions supported by the project models.

Vermont Land Trust and landowners Jericho Settlers Farm would like to move forward with implementing the preferred alternative. Due to the large amount of tree root wads needed, the project is expensive, and we are working to secure funding for implementation. Vermont Land Trust is currently working with a set of partners including Vermont Emergency Management, Vermont Agency of Transportation, Jericho Settlers Farm, and the Town of Jericho to apply for FEMA's Hazard Mitigation Grant Program funds. A challenge with this is timing – while Mill Brook creeps closer to the road right of way after every rainstorm, funds will likely not be available before emergency riprap is placed. The shape of the floodplain will be different by the time funding is secured, so we are postponing final design until we are closer to implementation so that it can be based on current conditions.

7. REFERENCES

Schiff, R., Louisos, J. and A. Diamond. Quality Assurance Project Plan for *Nutrient Quantification and Phase 1 Restoration Design of Mill Brook Floodplain*. June 2021.

SLR International Corporation. Engineering Report for *Nutrient Quantification and Phase 1 Restoration Design of Mill Brook Floodplain*. September 2022.

SLR International Corporation. Mill Brook Restoration Phase 1 Design (60% Complete). September 2022.

8. APPENDICES

Appended Documents:

1. Quality Assurance Project Plan for *Nutrient Quantification and Phase I Restoration Design of Mill Brook Floodplain*, June 17, 2021
2. Engineering Report for *Nutrient Quantification and Phase I Restoration Design of Mill Brook Floodplain*, September 28, 2022
3. Phase I Design for Mill Brook Restoration, September 28, 2022
4. This project was discussed in a press release from February 28, 2022: *Farmers' efforts improve water health and flood resilience.* https://vlt.org/newsroom/clean-water-and-climate/

SUBRECIPIENT FINAL CERTIFICATION

Subrecipient: Vermont Land Trust

Project Title: Nutrient Quantification and Phase 1 Restoration Design of Mill Brook Floodplain

Project Completion Date: 9/30/22 Project Code: LS-2021-001 CFDA: 66.481

By the signature below, SUBRECIPIENT certifies it has met all REQUIREMENTS AND RESPONSIBILITIES of this subaward as outlined in its agreement with NEIWPCC, including all additional obligations for Subawards, and has complied with all Environmental Protection Agency terms and regulations as referenced in http://www2.epa.gov/grants/grant-terms-and-conditions#General%20Terms%20and%20Conditions" and http://www2.epa.gov/grants/cybersecurity-grant-condition-other-recipients-including-intertribal-consortia.

AUTHORIZED SIGNATURE

Signature: _____ Date: 10/20/22

Typed Name/Title: Allaire Diamond, Ecologist

Email Address: allaire@vlt.org

Phone: 802-879-6672 Fax: _____

NEIWPCC
650 Suffolk Street, Suite 410, Lowell, MA 01854
Tel: (978) 323-7929 Fax: (978) 323-7919