RECREATIONAL TRAIL DESIGN

IN FULTONVILLE, NEW YORK

A Major Qualifying Project Report:

Submitted to Faculty of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

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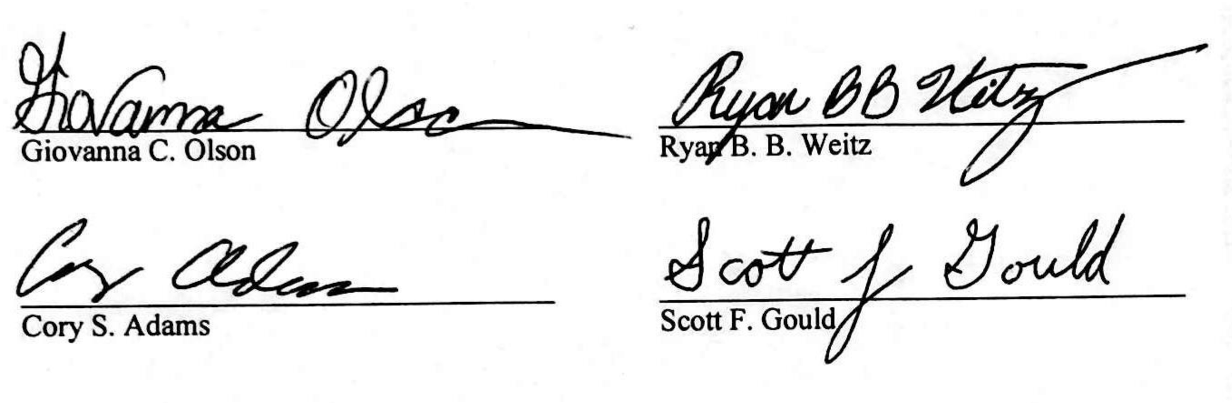
Abstract

This MQP examined sustainable alternatives in the design of a recreational trail in Fultonville, New York. Design components included trail surfacing, stormwater management, and slope retention in areas of concern along the proposed trail. Topographic surveying and a hydrologic analysis were conducted in order to investigate a number of alternatives for each design component. The options were evaluated based on holistic criteria and presented to the sponsor as final design recommendations for the proposed trail.

Authorship

The majority of this project was equally divided between the two members. The majority of the site work was conducted by both members in addition to Cory Adams, a member of the complementary team designing pedestrian bridge options for the trail. Olson took a leading role in the environmental aspects of this project while Weitz took a leading role in the planning and structural aspects. The writing, editing, and formatting of this report was shared evenly. Olson and Weitz drafted the Executive Summary accompanied by both Adams and Scott Gould of the bridge team.



Acknowledgements

The project team would like to recognize and thank a few individuals for their help throughout the process of completing this project. First and foremost, we would like to thank our project advisors Professor Suzanne LePage and Professor Leonard Albano for their insight, guidance, and willingness to help. Professor Paul Mathisen greatly aided in our understanding of hydrologic analysis and stormwater management. Professor John Hall was generous enough to work with us to understand the use of surveying equipment that was used in the field. Lastly, a special thanks to Cory Adams and Scott Gould for their mutual dedication in working on this project's complementary MQP.

Executive Summary

Two Major Qualifying Projects (MQP) involved the design of a site development plan for a recreational trail in Fultonville, New York on lands currently used as a cemetery and natural burial ground. The site offers scenic vistas and is located adjacent to a statewide trail system. A number of issues have limited the construction of a trail including the lack of a bridge crossing, stormwater management, and steep slopes. Recreational Trail Design in Fultonville, New York investigated trail, stormwater management, and slope retention design. Pedestrian Bridge Design in Fultonville, New York investigated bridge design. The designs were approached with sustainability in mind to be congruent with the natural setting of the site. This executive summary outlines the methods used to design alternatives and present recommended designs to be implemented in the construction of a recreational trail in the Fultonville Cemetery & Natural Burial Ground.

Trail Design

The design of the trail as a whole was comprised of the determination of a route, a use characteristic, construction specifications, and a surfacing material. Data was gathered through Geographic Information Systems (GIS) databases as well as informal community input. A number of alternatives were investigated for each part of this design. The trail is suggested to roughly follow the perimeter of the parcel utilizing mostly existing roadbeds. One section of the trail will require new construction. It is recommended that all motorized vehicles be prohibited on the trail, but that any pedestrian uses be acceptable. A trail width of 10 feet is recommended with a clearing width of 14 feet and clearing height of 12 feet. Out of three surfacing materials investigated, it is recommended that gravel be used to surface the trail due to its durability, while remaining permeable. Five hundred cubic yards of gravel will be required to surface the trail,

costing approximately $5,300 from Cushing Stone Company in Amsterdam, New York. The next steps in the implementation of this component require clearing the recommended path of all vegetation, grading said path, and surfacing the same.

Bridge Design

Currently there is a ravine with existing stone abutments that interrupts the trail. It was clear that a new bridge needed to be designed to continue the trail. Four bridge designs were considered in order to connect the trail – a Whipple Truss design, a Flatcar Bridge design, an aluminum Pratt Truss design, and a simple girder design. Each of the bridge options needed to fit the purpose of the trail and accommodate pedestrian traffic. Since the trail will need to maintained, each bridge design must also accommodate small utility vehicles such as John Deere Gators. Each option was evaluated on cost, constructability, aesthetics, and environmental impact. After evaluating each of the four designs, it was found that the Whipple Truss Bridge would be best suited for the site. The next step for this element of the design will require the review and approval by a licensed engineer.

Stormwater Management Design

One portion of the trail, in particular, experiences issues due to stormwater runoff. The trail remains muddy much of the time with standing water sometimes present. A hydrologic analysis was conducted for the area to determine peak runoff rates for 2-, 25-, and 100-year design storms. This information was used in designing three alternatives to alleviate the stormwater runoff concerns. It is recommended that a 60-foot long portion of the trail in this area be paved with a permeable paver known as Turfstone by Belgard. This product aids in the retention and stabilization of soils exposed to erosive conditions. Six hundred square feet of pavers will be required to pave this area, costing approximately $1,900 from Cranesville Block Company in

Amsterdam, New York. The next step in the implementation of this component is the installation of the product.

Slope Retention Design

Very steep slopes abut many areas along the trail. One area, along the entrance trail, has exhibited signs of failure due to the lack of any means of retention. A topographic survey was conducted to gather information related to the existing slopes. Three design alternatives were generated to stabilize the slope and prevent future failure. It is recommended that a two-foot tall timber wall be constructed along the base of the slope to aid in retention while the hillside itself be planted with a combination of Black Chokeberry and Red Oak to stabilize the soil. The construction of an 84-foot long timber wall and the installation of two-dozen Black Chokeberry bushes and Red Oak trees will cost approximately $1,200 from Tree Nursery Company online and Lowe’s Home Improvement. The next steps in the implementation of this component will require clearing the slope of any debris, planting said slope with the aforementioned vegetation, and constructing the timber wall. Once these steps are carried out, the trail in the area will be able to be cleared to the required 10-foot width.

Next Steps

The next step in the development of the proposed recreational trail will require the approval of this project by the Fultonville Board of Cemetery Commissioners and the Village Board of Trustees. Following their approval, funding must be located to move this project forward. Many aspects can be advanced at this point. Others, however, such as the construction of a bridge, will require professional consultation to finalize designs. For these costs, grant funding may be sought.

Capstone Design

This trail design project team held itself to certain design and method standards. We ensured our designs constituted the utmost integrity in the following aspects: economic, environmental, sustainability, constructability, ethical, health and safety, and social and political. Each of these areas was carefully thought out while each design decision was made.

Economic

Economics is a key factor that governs the implementation of all projects. A balance must be maintained between cost and effectiveness in all design. For this project, cost estimates were obtained for all design alternatives to aid in the final recommendation. The two main concerns were construction and lifetime costs. These concerns were incorporated into an evaluation matrix that was used in recommending design alternatives.

Environmental

This project included many designs with varying degrees of impact on the natural setting. Design alternatives were initially chosen to limit their environmental impact. The team chose to place emphasis on erosion control and encouraging stormwater recharge through the use of permeable materials whenever possible. Alternatives were evaluated, in part, on the extent of the environmental impact each would have.

Sustainability

Sustainable practices were incorporated into this project to ensure its viability in the community. Proposed designs were generated with an impetus to create alternatives that encourage both environmental and economic sustainability for years to come. The project team analyzed each alternative's maintenance requirements during their lifetime.

Constructability

The constructability of design alternatives in this project varied greatly. This aspect was weighted heavily in the team's evaluation of each design. Alternatives that could be implemented easily using volunteer labor when possible were favored opposed to those requiring specialized labor.

Ethical

This project was conducted in accordance with the American Society of Civil Engineers Code of Ethics. This project aimed to provide the best possible solutions for each party affected. The design does not convey any falsified information or violate any regulations of a governing body. The first Fundamental Canon of Engineers is: Hold paramount the safety, health, and welfare of the public (*National Society of Professional Engineers*, 2013). Safety of the public comes first.

Health and Safety

Health and safety are a paramount concern to any project. The design alternatives were chosen and evaluated to ensure the safety of all trail users.

Social and Political

To minimize environmental impacts that construction may have on surrounding areas, various procedures during the construction process were evaluated. For example, setting the appropriate time for construction activities as to not disturb the community. The overall success of this project depends on the community's acceptance and use of the trail. To accomplish this, public input was informally garnered through discussions with property abutters as to their wants and concerns with the proposed trail development. Additionally, the success of this project requires the acceptance by the Board of Cemetery Commissioners and Village Board of Trustees. Incorporating these social and political aspects ensures the final success of this project.

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1 Introduction

Recreational trails can be a very beneficial element to a community. Trails provide a variety of activities for residents such as hiking, bicycling, and horseback riding. Recreational trails can be of use to joggers, couples, families, and many other community demographics. Importantly, these community assets frequently cause little to no harm to the environment.

The Village of Fultonville, New York is interested in constructing a recreational trail utilizing land in the Fultonville Cemetery and Natural Burial Ground. The land in question is owned by the Village and presently serves local burial needs. However, due to its proximity to the New York State Erie Canalway Trail and the scenic features contained within the property, the local government and residents would like to utilize an abandoned road system to enhance the recreational offerings of the Village. The Fultonville Board of Cemetery Commissioners (hereinafter "Cemetery Commissioners") sought out a project group at Worcester Polytechnic Institute to create a site plan for the property.

The objective of this Major Qualifying Project (MQP) was to investigate multiple solutions to a handful of problems that limited the constructability of a recreational trail in the Fultonville Cemetery and Natural Burial Ground. These solutions focused on delineating a trail loop, establishing a use policy that dictates trail surfacing and clearance, and implementing erosion control methods. A separate MQP, *Pedestrian Bridge Design in Fultonville, New York* (Gould, Adams, 2014), investigated the problem of bridging a creek that crosses a predefined section of the trail.

Data collection centered on property research, a series of site visits, and discussions with the Cemetery Commissioners. A preliminary site visit established the key issues and constraints that would drive the design process. A second visit consisted of surveying two previously identified problem areas that were representative of issues the trail design faced.

Design recommendations were planned to meet the requirements of the Cemetery Commissioners, the Fultonville Board of Trustees (hereinafter “Village Trustees”), and trail standards outlined by organizations such as the USDA Forest Service, NYS Office of Parks, Recreation, and Historic Preservation, as well as other non-profit groups. Hydrologic calculations were performed utilizing rainfall data from Cornell’s *Extreme Precipitation in New York & New England: Interactive Web Tool for Extreme Precipitation Analysis*. ESRI’s ArcMAP was used as the primary means of organizing all geospatial data collected and created throughout this project. Further, Autodesk’s AutoCAD Civil 3D was utilized to plot topographic survey data the project team gathered in the field. This information was used to define a trail use and construction specifications. Additionally, three alternative designs for managing stormwater in an area that consistently experiences washing out and retaining steep slopes along the trail were prepared. These designs were independently evaluated based on cost, constructability, safety, environmental impact, aesthetic appeal, and accessibility. The evaluations were used to recommend final designs to the Cemetery Commissioners.

2 Background

Located along the south bank of New York's Mohawk River, the village of Fultonville is a small, rural community built upon agriculture. Figure 1 shows the location of Fultonville in New York State. Established as a canal town in 1823, Fultonville grew to become a widely known stop on the Erie Canal until its removal to the Mohawk River in the early twentieth century. The surrounding Mohawk Valley is rich in history and has placed an amplified value upon its heritage in recent years.

Figure 1: Fultonville is located less than 40 miles west of the state capital at Albany

2.1 History of the Fultonville Cemetery and Natural Burial Ground

Two burial grounds serve the residents of Fultonville, New York. The older of the grounds, shown in Figure 2, dates to 1844 when the minister, elders, and deacons of the Reformed Protestant Dutch Church of Fultonville purchased an acre of land in the northwest corner of Garret Yates' upper field for use as a burying ground (Deed Liber, Montgomery County). The parcel was laid out into large, square lots and sold at auction (*History of Montgomery and Fulton*

Counties, F. W. Beers & Co.). Shortly after the incorporation of Fultonville as a village in 1848, the Church turned the burying ground over to the municipality. Additional land was purchased from Yates in 1860 that more than doubled the size of the cemetery (Deed Liber, Montgomery County). In 1861, a right of way to "construct, use, and maintain a road" to access the cemetery was granted to the village by Samuel Donaldson. Construction of a bridge was required to cross a ravine at a "point called the falls." A dozen years later, a deed registered that Lewis J. Bennett, a former Fultonville merchant now of Buffalo, for the consideration of one dollar and interest in a "family lot," conveyed to the village "the iron super structure of the bridge now erected over the stream running past the Fultonville Cemetery, and in the road leading to said Cemetery."(Deed Liber, Montgomery County) There are no other known accounts referencing the cemetery bridge.

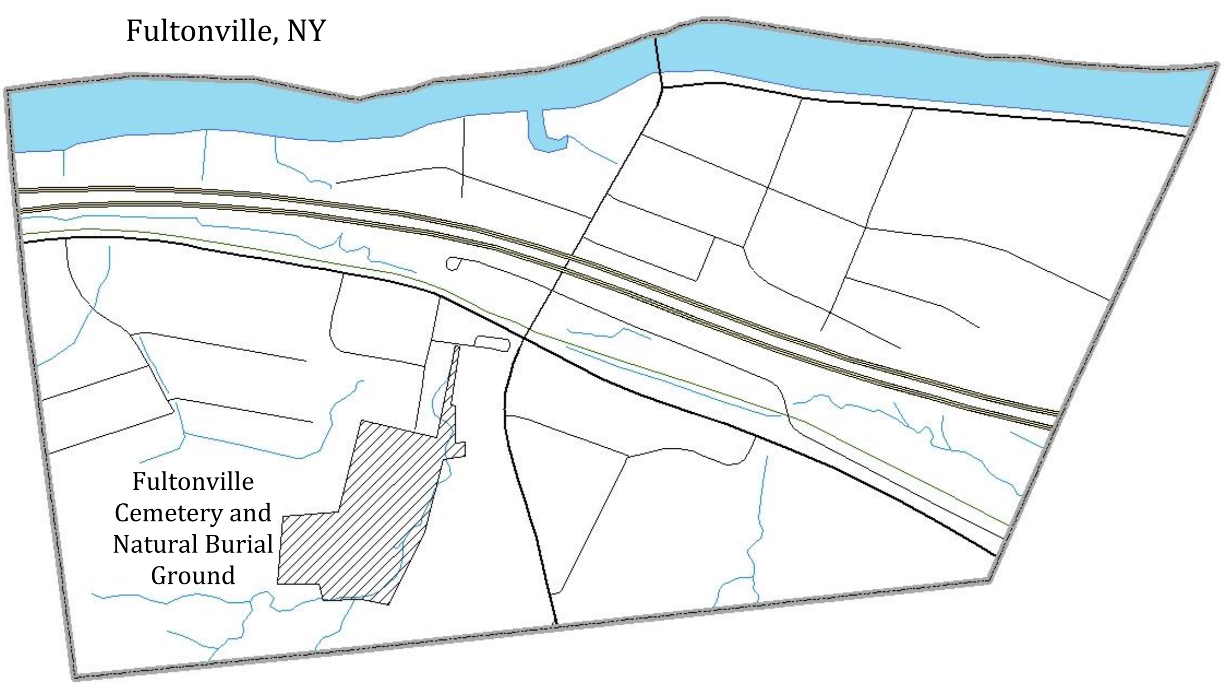

Figure 2: The Fultonville Cemetery and Natural Burial Ground encompasses nearly 10 acres in the southwestern portion of the village

Two large additions were made by donation in 1875 and 1890 by Hon. John H. Starin as shown in Figure 3. Starin, who grew up in Fultonville, founded a shipping empire in New York City prior to the Civil War. At one time, it is said that his shipping fleet was the largest in the world. He served two terms in Congress representing Fultonville from 1877 to 1881. His time in New York City and Washington, D.C. made him many influential and memorable friends including Presidents Grant and Arthur as well as Lewis Comfort Tiffany. The acreage he purchased adjacent to the Fultonville Cemetery was "[laid] out beautifully" most likely by one of his close friends (*History of Montgomery and Fulton Counties*, F. W. Beers & Co.). He erected a large mausoleum for his family in the addition and donated the remainder to the village. The mausoleum, which included windows designed by Tiffany, eventually fell into disrepair and was demolished in the 1970s. Its absence leaves a large, open space in the cemetery.

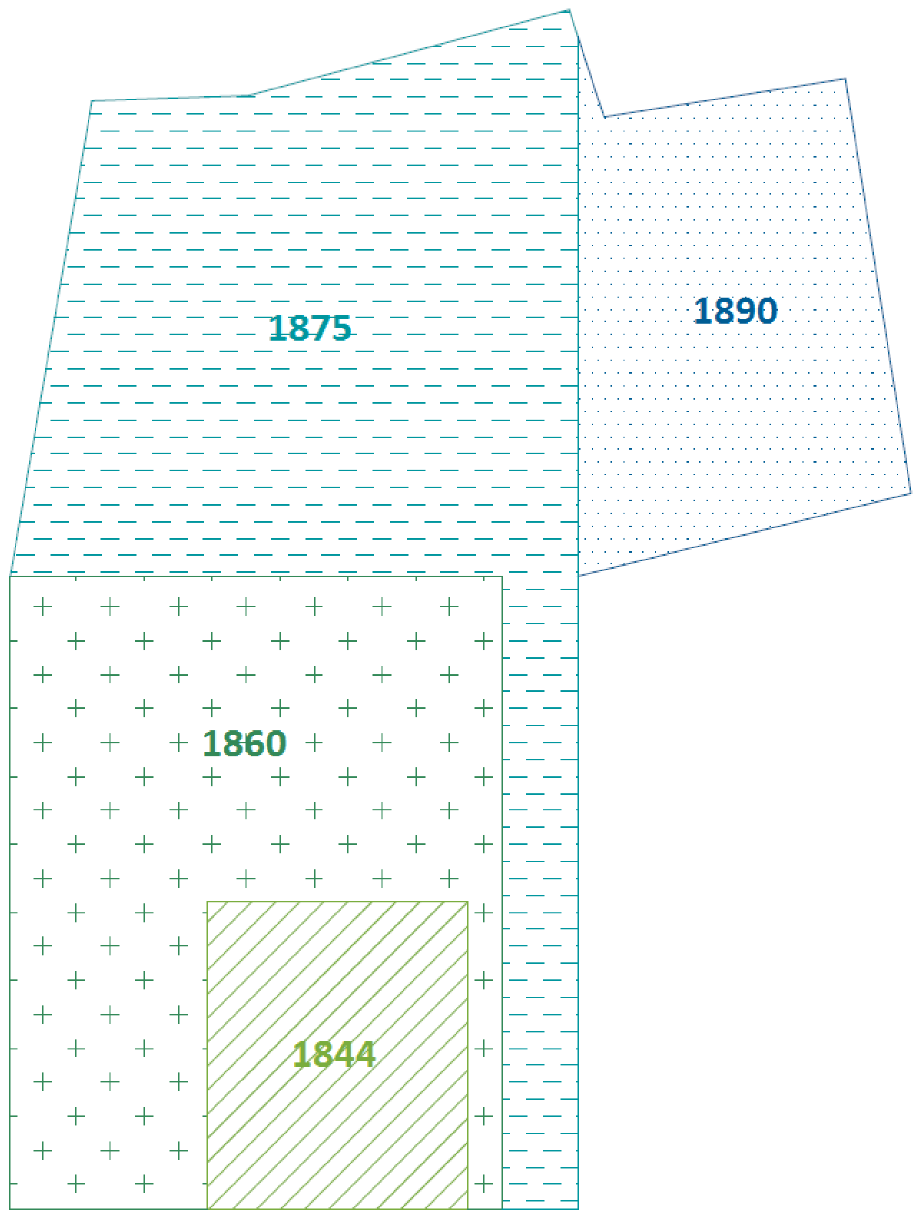

Figure 3: The Cemetery is made up of four parcels purchased between 1844 and 1890

Beginning in 2007, a large revitalization effort began in the cemetery. Decades of neglect allowed many areas to become overgrown that have since been cleared. Dozens of grave markers have been restored. Part of the ongoing work included drafting and adopting regulations for the proper functioning of the cemetery. These regulations were adopted by the Fultonville Board of Trustees in 2009 and created a Board of Cemetery Commissioners. The Cemetery

Commissioners then investigated the prospect of creating a "natural burial" section. The alternative burial method, which has grown in popularity nationally in recent years, is a commonsense, traditional, and affordable alternative to what is most commonly practiced today. Deceased persons are not chemically preserved and are interred only in biodegradable containers. In June 2013, the Trustees adopted regulations to establish a natural burial ground in a wooded area in the southwest corner of the cemetery. This area, used for natural burial, will be forever preserved as woodland. The low-impact, conservation-minded ethos at the core of natural burial has been espoused to the Fultonville Cemetery and Natural Burial Ground.

2.2 Project Description

The Cemetery Commissioners desire to develop underutilized land into a recreational trail through the Fultonville Cemetery. Many residents stroll the grounds, and the Commissioners believe that a recreational trail would greatly benefit the community. While the Cemetery has only been used as such, a local master plan from the mid-twentieth century suggested creating a park utilizing portions of the Cemetery now recommended for use as a recreational trail.

The design work required for this project was divided into three main sections: the trail itself, stormwater management, and slope retention. The following sections describe the existing conditions for each section. Background knowledge implemented for each area of design is also explained.

2.2.1 Trail

The Cemetery Commissioners wish to incorporate existing roadways, as displayed in Figure 4, for portions of the proposed trail. A majority of the roads, however, have become overgrown and are completely unusable in their current form. The Cemetery Commissioners' design request is for a ten-foot wide trail (topography permitting) that, in part, follows the ravine along the eastern property line. They also require that the trailhead be located along West Church Street to allow for easy access from the Erie Canalway Trail and a municipal parking lot. Within this predefined section of the trail, a ravine bisects the path necessitating the erection of a bridge where one formerly stood. A second project group designed a number of bridge alternatives. These designs may be found in *Pedestrian Bridge Design in Fultonville, New York* (Gould, Adams, 2014). The second half of the trail is not defined by existing roads, tasking the project group with determining a route.

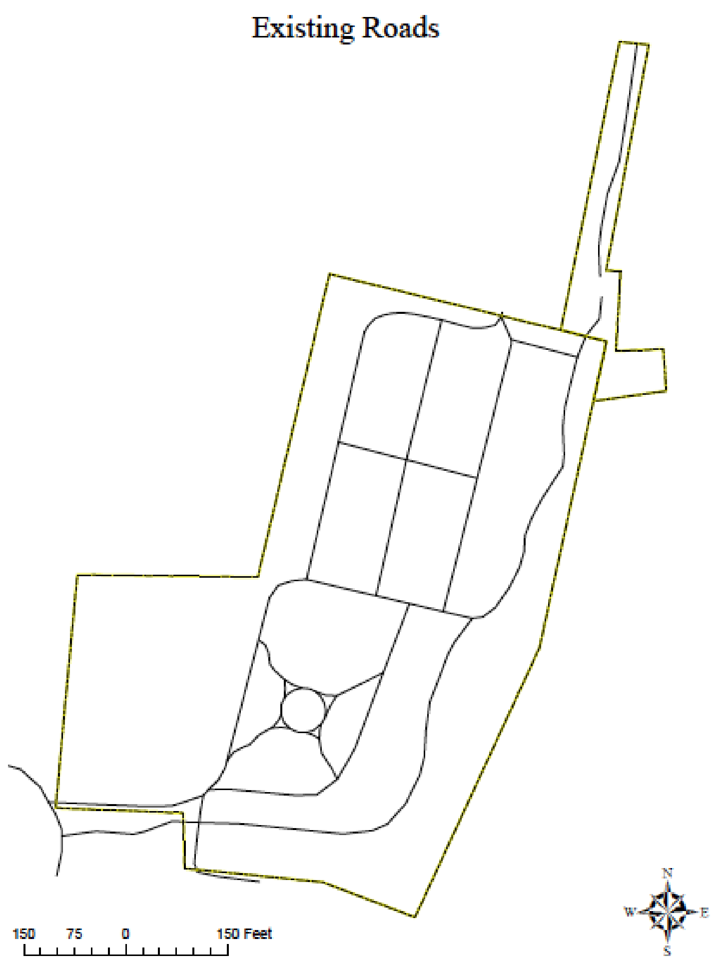

Figure 4: Numerous existing roads traverse the cemetery grounds

Expected use was not explicitly defined; however, the Cemetery Commissioners asked the project group to keep the setting in mind (i.e. a cemetery located in a residential area). They also informed the group of previous noise and safety concerns stemming from snowmobile use within village limits. Since the construction of the Erie Canalway Trail through the village, there has been a persistent issue with snowmobilers using village sidewalks leading to safety concerns and noise complaints. Lastly, the Cemetery Commissioners requested a recommendation of surfacing material fitting to the trail use.

2.2.2 Stormwater Management

Stormwater poses a concern to the proposed trail in a handful of areas. One, in particular, pictured in Figure 5, frequently becomes a rivulet following precipitation events. With the exception of prolonged dry periods, the area remains wet due to the topography. Resultantly, the existing roadway is eroded. The Cemetery Commissioners wish to alleviate this problem while minimizing the impact to the environment.

Figure 5: A portion of the proposed ravine trail that experiences frequent drainage issues

Engineers address stormwater management first and foremost through methods of hydrologic analysis. Generally speaking, a hydrologic analysis predicts the amount and frequency of rainfall and runoff in an area. These predictions can then be assessed for methods of managing the stormwater in a safe way. One hydrologic analysis method commonly used is the Rational Method. This method is a calculation model used to approximate stormwater runoff quantities for small watersheds during design storms. A design storm is a precipitation event of stated magnitude that is likely to occur within a time interval. Colloquially, these events are referred to as "x-year storms," however they represent a probability of occurrence. For example, a two-year storm has a 50% chance of occurring in any given year whereas a one hundred-year storm has a 1% chance of occurring. These design storms are determined using historic rainfall data. The Rational Method, as shown in Equation 1, determines the peak flow in relation to a runoff coefficient (C), the average rainfall intensity (i), and the area of the watershed in acres (A).

Equation 1: Peak Flow Equation (Rational Method)

$$Q_p = CiA$$

where

$$\begin{aligned} Q_p &= Peak\ Runoff\ Rate\ (cfs) \\ C &= Runoff\ Coefficeint\ (unitless) \\ i &= Average\ Rainfall\ Intensity\ \left({}^{in}/_{hr}\right) \\ A &= Watershed\ Area\ (acres) \end{aligned}$$

Values for the runoff coefficient are dependent upon the terrain of the watershed. Table 1 lists common C values used in Rational Method calculations.

Table 1: Typical Runoff Coefficients

Watershed Description	Runoff Coefficient
Downtown Business Area	0.70-0.95
Apartment Dwelling Area	0.50-.070
Single-Family Residential	0.30-0.40
Playgrounds	0.20-0.35
Lawns with Sandy Soil and 2-7% Slopes	0.10-0.15
Lawns with Sandy Soil and Steep Slopes	0.15-0.20
Lawns with Heavy Soil and 2-7% Slopes	0.18-0.22

(Bedient et. al, 2013)

The Rational Method utilizes a graphical representation of the intensity and duration of rainfall, called intensity duration frequency (IDF) curves, which can be modeled in different ways depending on the design storm to be analyzed.

The peak flow, determined through the Rational Method, is used to determine the best method to manage stormwater for a particular watershed. There are many options, often referred to as best management practices, or BMPs, that address stormwater management through different methods. A sampling of these BMPs can be seen in Table 2. One of the main considerations is whether to retain or divert runoff. This is primarily dependent on the volume of water that accumulates during a precipitation event and the watershed area. These alternatives are designed based upon the peak flow determined by the Rational Method and volumes calculated using the peak flow and arbitrary storm durations and chosen dependent upon site constraints (*Stormwater Management Best Practices*, 2012; Bloomberg, Strickland, 2012; *New Jersey Stormwater Best Management Practices Manual*, 2004; Lake, 2005; *New York Standards and Specifications for Erosion and Sediment Controls (August, 2005),* 2005; *Plant Selection Guide,* 2014; Ryan, 2014).

2.2.3 Slope Retention

As the pre-defined portion of the trail follows a ravine, there are many areas that are surrounded by very steep slopes – the worst of which exhibits significant slumping. The Cemetery Commissioners asked the project group to investigate a variety of options to retain the steepest slopes. Within the engineering field, slope retention concerns are typically addressed through a number of BMPs, as shown in Table 3, that revolve around stabilization and slope reduction. Stabilization solutions focus on creating a three-dimensional structure within the slope to retain the earth and prevent failure. Slope reduction methods typically utilize structural solutions to minimize the change in elevation over a given distance.

2.3 Overview of Committees

The site development of the Fultonville Cemetery and Natural Burial Ground falls under two main public entities. The land is owned by the Village of Fultonville, of which the responsible parties are an elected Board of Trustees and Mayor. The Village Trustees and Mayor appoint a Board of Cemetery Commissioners biannually. The Cemetery Commissioners oversee all cemetery business. Their actions are only binding if approved by the Village Trustees. The Cemetery Commissioners acted as the primary source for project information.

The final design for the site development will be presented to the Cemetery Commissioners. Upon their acceptance, the Village Trustees must then approve the plan.

Table 2: Common Stormwater Management BMPs

BMP	Description	Benefits	Drawbacks	Design
Culvert	Conduit designed to direct stormwater under an obstruction and to another channel	Can use a wide variety of materials and designs	Could disrupt wildlife passage if not designed to accommodate	Peak Flow Headwater
Detention Basin	Artificial basin designed to hold water temporarily, controlling the outflow through a low-level outlet	Reduces downstream erosion and flooding	Requires much construction and materials	Design Storm Volume
Retention Basin	Artificial basin designed to collect and retain stormwater, allowing it infiltrate on site	Encourages groundwater recharge, reduces risk of downstream erosion and flooding	Does not work well with high volumes of stormwater	Soil Composition, Design Storm Volume
Infiltration Basin Bioretention Cell	Depressed area with vegetated surface atop porous soils	Encourages groundwater recharge and pollutant removal	Requires significant changes to natural setting	Soil Composition, Design Storm Volume
Permeable Pavement	Pavement that allows stormwater to drain through into a stone reservoir	Encourages groundwater recharge	Does not work well with high volumes of stormwater	Design Storm Volume
Permeable Pavers	Pavers containing voids that allow for stormwater to infiltrate the subsurface	Has a minimal impact to natural hydrography and ecosystem, encourages groundwater recharge	Does not remove pollutants	Soil Composition, Design Storm Volume
Soil Amendment	Additions to natural soils increasing permeability and retention properties	Has minimal agitation to ecosystem	Does not work well with high volumes of stormwater	Soil Composition, Design Storm Volume

Table 3: Common Slope Stabilization BMPs

BMP	Description	Benefits	Drawbacks
Retaining Wall	Structure designed to retain soil and reduce natural grade	Can retain very steep slopes, may be built of wide variety of materials	Large construction cost and greatly alters topography
Riprap	A layer of stone designed to protect and stabilize areas subject to erosion	Can be used on steeper slopes without altering topography	Frequent maintenance required
Matting	Stabilizing slopes with synthetic mats	Does not require altering topography	Short life span, aesthetically displeasing
Vegetation	Utilizing a variety of plants to retain soils	Does not require altering topography	Cannot be used on very steep slopes

3 Methodology

This project's designs were divided into three main components: trail design, stormwater management design, and slope retention design. Through a series of methods outlined in the following sections, the project group was able to refine design constraints. Two site visits, discussions with the client, and data collection enabled the group to provide accurate and detailed results.

3.1 Preliminary Site Visit

The project group elected to visit the project site to better familiarize ourselves with it as well as collect preliminary data. An initial survey of the existing roads within the cemetery grounds was conducted using *Runmeter*, a mobile application on the iPhone, and is displayed in Figure 6 (*Runmeter*, Abivo, 2014). The exported data was supplemented with orthographic images and digital elevation models to create a map of the existing road network. More on these methods can be found in §3.3.1 on trail design data collection.

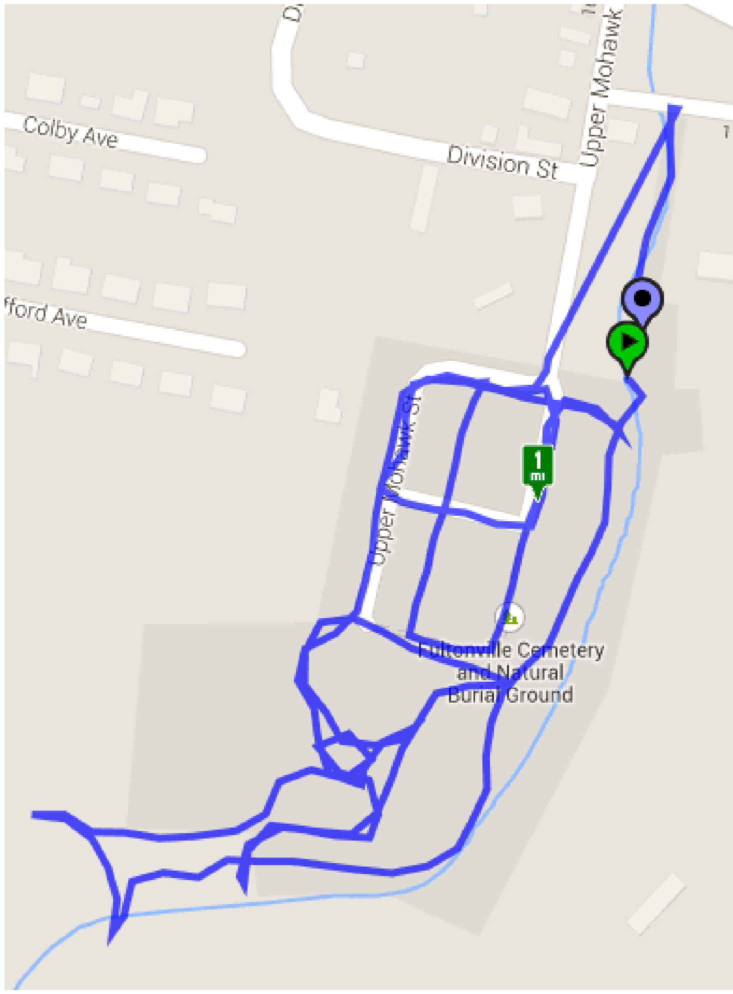

Figure 6: *Runmeter* GPS data of trail route

3.2 Site Survey and Plotting

After furthering our background knowledge on the methods and data required for the design process, the project group conducted a second site visit. Using a Trimble TS105 total station we collected topographic survey data for the stormwater management and slope retention areas of concern for the project as well as the existing bridge abutments. The readings obtained were in a cylindrical-coordinate format (i.e. a radial (ρ), angular (ϕ), and z-coordinate). This data is displayed in tabular format in Appendix C.

In order to plot the survey data using AutoCAD's Civil3D software, the data, in cylindrical coordinates, first had to be converted into Cartesian coordinates (i.e. x-, y-, and z-coordinates). This was done using Microsoft Excel and basic trigonometric principles as shown Equation 2.

Equation 2: Cylindrical-coordinate Conversion Equations

$$x = -\rho\cos(\phi)$$
$$y = \rho\sin(\phi)$$
$$z = z$$

The converted data was imported into Civil 3D where a TIN surface was created from the points. These surfaces were then displayed as topographic maps that can be seen in Figures 10 and 12 on pages 37 and 44, respectively.

3.3 Trail Design

A significant, yet broad and introductory portion of this project was to determine the general trail design. That is to say: the trail route, user guidelines, construction specifications, and surfacing material. Much of this design was constrained by the existing physical characteristics of the site in addition to the input of the Cemetery Commissioners. By collecting accurate survey data route delineation was mapped. Lastly, with research on the community and potential use of the trail, a variety of surfacing options were reviewed.

3.3.1 Data Collection

The Cemetery Commissioners provided the project team a majority of the background relating to the site. Other geospatial data was obtained from a variety of depositories and organized using ESRI's ArcMAP. The Montgomery County, New York Real Property Tax Service provided a tax map layer that was used to approximate parcel boundaries. It is important to note that this data layer is used for real property assessment and does not necessarily reflect accurate property boundary surveys. With this in mind, other data sets and observations in the field were used to adjust the property lines within reason. A number of data sets were obtained from the New York State GIS Clearinghouse including orthographic images, hydrology, and a digital elevation model. Soil data was obtained from the U.S. Natural Resources Conservation Service's Web Soil Survey (*Archived Soil Surveys*, 2014).

These data layers were overlaid in ArcMAP and edited based upon data gathered in the field. Two examples of these alterations came from locating property markers and the *Runmeter* data discussed in §3.1.

3.3.2 Route Delineation

Approximately half of the trail route, as shown in Figure 7, was specified in the initial discussions with the Cemetery Commissioners. They required that the trailhead be located along West Church Street in Fultonville on a former right-of-way that was used to access the Cemetery in the past. This location is extremely beneficial as it is located adjacent to a municipal parking lot and is approximately two hundred feet south of the Erie Canalway Trail. Beginning here, the trail follows existing roadbeds along a ravine and creek known as Cemetery Creek. After reaching the southern property line, this path ceases. The project group was tasked with determining a route to return to the trailhead. This was accomplished by utilizing the GIS database and discussions with the project sponsor. Informally, a handful of options were discussed with the sponsor and one was decided upon given their input.

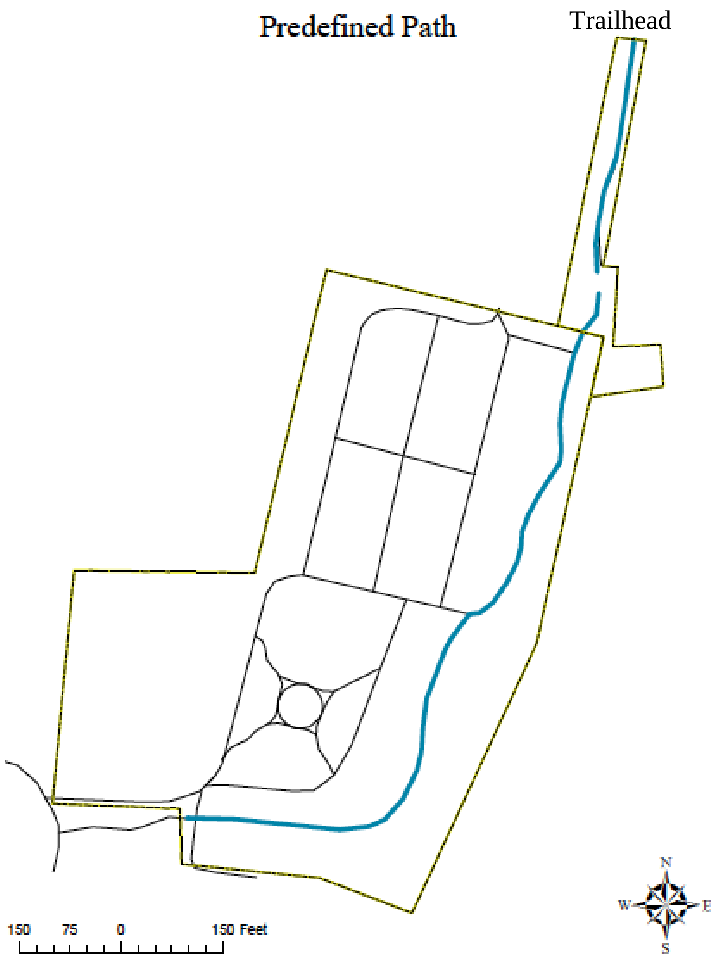

Figure 7: The predefined portion of the trail is highlighted in blue

3.3.3 Trail Use and Specifications

As outlined in the project description, the Cemetery Commissioners asked the project group to determine trail use characteristics given background information about the site and community. The use was further refined through many informal discussions with community members. A final use statement was determined using this information as well as the categories outlined in a number of trail manuals. Many of these manuals are tabulated in Table 4.

Table 4: Trail Design Guides

Authority	Guide	Type of Agency
USDA Forest Service	*Trail Construction and Maintenance Notebook* (2007)	Government
USDA Forest Service	*Trail Fundamentals and Trail Management Objectives* (2011)	Government
NYS Office of Parks, Recreation, and Historic Preservation	*New York Statewide Trails Plan* (2010)	Government
Appalachian Mountain Club	*Complete Guide to Trail Building & Maintenance* (2008)	Non-Profit Organization
Parks & Trail New York	*A Guide to Planning Trails in New York State* (2004)	Non-Profit Organization
University of Minnesota Extension	*Woodland Stewardship: Recreational Trail Design* (2009)	Educational Institution

Construction specifications were highly dependent upon the determined use. The guides listed above were used in creating a trail design standard from a combination of specifications tabulated in §4.1.2. The specifications outlined in this standard include trail width, clearing width, and clearing height. These specifications were determined by finding a consensus between guides and acceptable trail uses.

3.3.4 Surfacing

The trail surface was largely dependent on use characteristics. After determining the latter, a number of typical surfacing materials were discussed. The options were first refined to permeable materials to minimize impacts on the natural hydrography of the area as dictated by the Cemetery Commissioners. Consideration was also given to historically relevant surfacing materials. In the end, three materials were evaluated based upon an analysis as outlined in §3.6.

3.4 Stormwater Management Design

An evaluation of stormwater management is standard for any site development. To accomplish the goals outlined in the project description, this team conducted a hydrologic analysis for a particular sub basin within the site that posed runoff issues. Site characteristics and knowledge of stormwater engineering BMPs were implemented in brainstorming possible solutions to the trail's runoff concerns. A number of possible solutions were initially eliminated from consideration in a preliminary research phase due to their environmental impact. The methods used to conduct the stormwater management analysis are outlined in the following subsections.

3.4.1 Precipitation Data and Calculations

The first step in the hydrologic analysis was to determine the peak flow during precipitation events. The Rational Method was used to analyze the stormwater runoff. This method calculates the peak runoff rate in a watershed as shown in Equation 1.

Equation 1: Peak Flow Equation

$$Q_p = CiA$$

where

$$\begin{aligned} Q_p &= Peak\ Runoff\ Rate\ (cfs) \\ C &= Runoff\ Coefficeint\ (unitless) \\ i &= Average\ Rainfall\ Intensity\ ({}^{in}/_{hr}) \\ A &= Watershed\ Area\ (acres) \end{aligned}$$

A runoff coefficient was determined using tables similar to that presented in Table 1 in the Background. A value was chosen based on the topography, soil, and vegetative coverage of the site.

Rainfall data was obtained from Cornell's *Extreme Precipitation in New York & New England: Interactive Web Tool for Extreme Precipitation Analysis*. This database enabled us to generate an intensity duration frequency (IDF) curve for the site area. The IDF curve relates rainfall intensity to duration for specific design storms. For this project the team analyzed 2-, 25-, and 100-year design storms of different durations.

Using these IDF curves, the rainfall intensity was found for a given duration. This duration was determined by calculating the time of concentration, meaning the time required for stormwater to flow from the furthest point in the watershed to the outlet of the watershed. Due to the small size of the watershed in this project, the team used the Kerby-Kirpich method, as shown in Equation 3, to determine the time of concentration (*Hydraulic Design Manual: Time of Concentration*, 2011; Bedient et. al, 2013).

Equation 3: Time of Concentration Equation

$$t_c = t_{ov} + t_{ch}$$

where

$$\begin{aligned} t_c &= Time\ of\ Concentration \\ t_{ov} &= K(LN)^{0.467} S^{-0.235} = Overland\ Flow\ Time \\ K &= 0.828 = Units\ Conversion\ Factor \\ L &= Overland\ Flow\ Length\ (ft) \\ N &= Retardance\ Coefficient\ (unitless) \\ S &= Slope\ of\ Watershed\ (unitless) \\ t_{ch} &= Channel\ Flow\ Time \end{aligned}$$

Due to the lack of channel flow in the watershed in this project, the factor t_{ch} was taken to be zero. The overland flow length and slope of the watershed was determined from data gathered in the field as outlined in §3.4.2. A retardance coefficient was selected from a table of coefficients used in the Kerby equation as displayed in Table 5 (*Hydraulic Design Manual: Time of Concentration*).

Table 5: Retardance Coefficients

Watershed Description	**Retardance Coefficient**
Pavement	0.02
Smooth, bare, packed soil	0.10
Poor grass, cultivated row crops, or moderately rough packed surfaces	0.20
Pasture, average grass	0.40
Deciduous forest	0.60
Dense grass, coniferous forest, or deciduous forest with deep litter	0.80

The last factor in the peak flow equation, that being the area of the watershed, was at first approximated and then determined by a survey using a total station. This process is described in further detail in §3.4.2.

These values were used to calculate the peak flow during three different design storms as indicated earlier in this subsection.

3.4.2 Data Collection

Frequently, engineering judgment can be utilized by viewing any trends in topography or soil depressions. By predicting where each raindrop would flow after a rainfall, an engineer can determine the extents of watersheds. The data collection process for the stormwater management portion of this project involved a combination of observation, engineering judgment, and technical data processing. Upon the project group's first site visit, the general characteristics of the watershed were determined. A rough estimate of the area was made as well as the area of a lowland region that collected water from the watershed. This lowland area was noted to frequently have standing water.

During the second site visit, more accurate data was collected using a total station. Data was collected for the entire surrounding area to more accurately determine the watershed and lowland area as well as the slopes in the sub basin. These survey points were plotted using AutoCAD.

3.4.3 Design Alternatives

Building off of Table 2 of stormwater management BMPs, the project team briefly and informally evaluated each alternative based upon social and environmental constraints. Some of the BMPs were eliminated due to their large impact on the environment, while others were judged as not practical for the site. A natural-bottom box culvert, retention basin, and permeable paver system were chosen as three alternatives to be investigated further. These alternatives were chosen, in part, because they represent a spectrum of structural solutions. The methods used to design each of the alternative systems are outlined below.

3.4.3.1 Natural-Bottom Box Culvert

Culverts are a common stormwater management design that constrict and divert stormwater flow. For this project a culvert would direct stormwater underneath the trail. As the project sponsor indicated a desire to minimize any environmental impacts, the team investigated a natural-bottom box culvert due to the ability to maintain a natural stream bottom throughout the conduit. Further, this design eases constructability and mitigates environmental concerns stemming from man-made surfaces.

To design a natural-bottom box culvert for stormwater management, preliminary calculations were first carried out based on assumptions made by the project team. It was assumed that the limiting factor in the culvert design was the inflow due to the unrestricted nature of the outflow. Working within this assumption, the orifice flow equation, shown in Equation 4 (Mohtar, 2014) was used to calculate the maximum outflow given the culvert geometry and available storage preceding the culvert. An iterative approach was taken when testing various size culverts' ability to handle certain flows.

Equation 4: Orifice Flow Equation

$$Q = C_d A_c \sqrt{2gHW}$$

where

$$\begin{aligned}
Q &= Flow\ Rate\ (cfs) \\
C_d &= \frac{1}{\sqrt{1+k_e}} = Coefficient\ of\ Discharge\ (unitless) \\
k_e &= Entrance\ Loss\ Coefficient \\
A_c &= Cross\ Sectional\ Area\ of\ Orifice\ (ft^3) \\
g &= Acceleration\ due\ to\ Gravity\ ({}^{ft}/_{s^2}) \\
HW &= Head\ Water\ (ft)
\end{aligned}$$

The flow calculated using the orifice flow equation is required to be greater than or equal to the peak flow calculated for a given design storm as outlined in §3.4.1. The team chose to analyze the culvert for adequacy during a 100-year storm to accommodate 99% of precipitation events.

An initial estimate was made as to the geometry of the culvert and these dimensions were tested to analyze the adequacy of the geometry to handle the peak flow. This process was repeated until an optimized geometry was determined based upon the ability to handle certain flows while not being too obstructive to flow. While the cross-sectional area was directly dependent upon the geometry, the headwater value was indirectly dependent. Headwater is the depth of water at the culvert's point of inflow. For this design it was assumed that the headwater would be equal to the height of the culvert plus the width of the culvert top, and six inches of earth to allow for adequate cover. This value was reduced by a factor to ensure that the trail would never be overtopped by stormwater flow. This calculation is displayed in Equation 5.

Equation 5: Headwater Equation

$$HW = h_c + t_c + d - s$$

where

$$\begin{aligned} HW &= Head\ Water\ (ft) \\ h_c &= Culvert\ Height\ (ft) \\ t_c &= Culvert\ Thickness\ (ft) \\ d &= Depth\ of\ Soil\ Cover\ (ft) \\ s &= Safety\ Factor\ (ft) \end{aligned}$$

Once the size of the culvert was established, the team selected a construction material typically used in recreational trail design for small box culverts. The material should be able to withstand dead loads from trail surfacing and any live loads from trail users, which may include maintenance vehicles. The materials required were calculated based upon the sidewalls of the culvert extending one-third of its length into the earth to eliminate the chance of failure from erosion. The top of the culvert was assumed to sit flush on the sidewalls. The length of the culvert was solely dependent upon the trail width.

3.4.3.2 Retention Basin

Retention basins function by holding stormwater runoff in an artificially made pond to encourage on-site infiltration. When designing a retention basin the critical factor is the required storage. During our first site visit, we approximated the available lowland area to be about 500 square feet. With this approximation, we were able to calculate the necessary depth of the basin to retain the volume of rainfall during a specific design storm by a simple volumetric calculation as shown in Equation 6.

Equation 6: Storage Capacity Equation

$$V = dA$$

where

$$\begin{aligned} V &= Storage\ Volume\ (ft^3) \\ d &= Retention\ Basin\ Depth\ (ft) \\ A &= Retention\ Basin\ Surface\ Area\ (ft^2) \end{aligned}$$

The project team decided to use a 100-year storm with duration of one hour to design the retention basin, to be consistent with the culvert design. These criteria were chosen to have a degree of certainty that the retention basin would adequately handle runoff from less intense storms.

During our second site visit we were able to use the total station to gather accurate topographic data. After these data points were plotted in Civil3D, it was determined that the lowland area capable of retention is 460 square feet. This value was used to solidify the necessary depth of the retention basin.

To promote in constructability and limit environmental impact, it was determined that the best way to construct a retention basin was to elevate the trail, in effect creating a depressed area to retain runoff. The necessary fill level for the trail was calculated using topographic information gathered during the site survey and the required depth of the basin. For the ease of calculation, the topography of the trail was assumed to be a straight line from the lowest point to the high points as dictated by the required basin depth.

3.4.3.3 Permeable Paver System

Permeable pavers are a relatively new option for stormwater management. Their main objective is to stabilize soils while allowing for stormwater infiltration. Many pre-made products are available from a variety of suppliers. The project team investigated a handful and chose to present a design using Belgard's "Turfstone."

Belgard describes the product as allowing “rainwater to be gradually filtered back into the soil naturally, resulting in the control and stabilization of soil erosion.” In doing so, the paver system “reduces run-off and allows greenery to grow right through it, creating a highly unique hardscape design that works in harmony with nature” (*Turfstone: Transitional Collection*, 2014)

To estimate the required quantity of the product, the team chose an elevation at which all points below, in the given section of the trail, should be paved. This decision was based upon evidence of soil erosion that was witnessed in the field.

3.5 Slope Retention Design

Steep slopes surround many areas along the proposed trail. A very steep slope along the eastern side of the predetermined entrance trail is one such area. This particular area has exhibited slumping due to the lack of any means of retention. This project team followed the succeeding methods in designing a number of slope retention alternatives.

3.5.1 Data Collection

After assessing the general need for slope retention, the team surveyed the trail entrance area to quantify the existing slopes. Data was collected along both sides of the existing roadbed as well as along the ridgeline to the east of the trail and the edge of the creek on the west side. Four rows of data points were collected to measure the area of the trail that needs to be addressed for slope retention. This data was input into AutoCAD’s Civil3D. The map was used to calculate the slopes along the trail as well as the existing trail width.

3.5.2 Design Alternatives

Three design alternatives were chosen from the set of slope retention BMPs in Table 3 based upon a holistic and sustainable view of the site. The team investigated a vendor-designed gravity retaining wall, a terrace system using timber walls, and vegetation.

3.5.2.1 Gravity Wall

With such a small space between the entrance trail and the property line, the team investigated retaining wall systems that allowed for a minimum setback. One product that quickly became apparent as an ideal option for this product was Redi-Rock's Gravity Wall system (*Gravity Retaining Walls*, 2014). Redi-Rock's gravity wall relies on the mass of each precast block to retain earth. No additional reinforcement is required. This allows for a smaller setback as well as reduced costs and construction times.

After the team became familiar with the product and the general engineering assumptions built into the block system, a design was created to estimate the necessary length and height of the wall. Using the survey data, the team determined the length of the entrance trail that experienced slumping and identified all slopes that were greater than 50%. It was decided to attempt to minimize all slopes to no greater than 50% as this value is generally accepted as naturally stable (*Sediment and Erosion Control*, 2014). This information was entered into AutoCAD where a wall layout was designed given the Redi-Rock block specifications. Vendor engineering design charts, available on Redi-Rock's website, were utilized in verifying the adequacy of the design. While many aspects of the design were addressed in the analysis, it is pertinent to note that the global stability, or the stability of the slope after alteration, was not incorporated and should be addressed if this alternative is recommended by the team.

3.5.2.2 Timber Terraces

Implementing a series of timber terraces along the slope in question would aid in reducing the overall slope of the hillside. While this is a commonly implemented technique along recreational trails and in landscaping, there are very few specific rules on the design of terraces. The few rules that do exist are only applicable if the area between two terraces has a zero-percent slope, which is not the case in this project. When the area separating two terrace walls is sloped, the walls become structurally dependent upon one another. For this site, several short terrace walls would be required creating a complex interaction of forces. With these factors in mind, the project team approached the design of terraces using recommendations within published trail guides, as listed in Table 4.

3.5.2.3 Vegetation

Vegetating a slope is one of the most direct ways to prevent erosion and slope failure. The introduction of a variety of native species to the hillside promotes the development of a vast sub-surface web of root systems that stabilize the slope. The project team looked to present a planting recommendation that would accomplish three main objectives (Liley and Pleninger, 2008).

First, the combination of species should be able to not only adapt and mature quickly, but also endure long into the future. Second, the recommendation should require minimal maintenance due to the steepness of the slope in question. And third, the recommendation should include a combination of groundcovers and trees to maximize the root system.

In order to accomplish these goals, the team researched species native to upstate New York using published material from universities and municipalities and prepared a list of suggested species to be planted along the bank.

3.6 Evaluation Criteria

In an effort to analyze design alternatives for trail, stormwater management, and slope retention design, the project team created an evaluation protocol based upon six different criteria. These criteria were created based upon a holistic view of the site development and assigned values from one to five, with five being the best. The criteria, and a general description of how each was judged can be seen in Table 6. Weight factors were incorporated to place emphasis on certain criteria deemed more important due to economic and environmental strains. The summation of multiplying each criteria score by the respective weight factor results in a total score. Each alternative's total score was ranked in relation to each other in the process of recommending an alternative.

Table 6: Evaluation Criteria and Description

Criteria	Weight Factor	Description
Construction Cost	2	The financial costs, both material and labor, associated with the design
Lifetime Cost	1	The financial, environmental, and maintenance costs associated with the design over its lifespan
Constructability	2	The ease of construction of the design
Safety	2	How safe the design is for users
Environmental Impact	2	The extent of the impact to the existing natural setting
Aesthetic Appeal	1	The aesthetic appeal of the design to users and how well it fits with the landscape

The scores generated for each alternative are presented in §5 of this report in each respective section.

4 Results

Throughout the following section, design results for all areas of this project are outlined. These designs were established through the aforementioned methods. The topics include: trail, stormwater management, and slope retention design. Each option design is supplied with final drawings, figures, and calculations as well as cost estimates.

4.1 Trail Design

The following section presents the details of the feasible trail design options. The trail designs are in compliance with New York State standards and regulations as cited in Table 4. Further, the options were designed to best fit the project sponsors requests.

4.1.1 Trail Layout

Several trail layout options were informally discussed within the project group with the input of the sponsor. This information went into generating a final trail layout that is presented in §5.1.1.

4.1.2 Trail Use and Construction Specifications

After a thorough analysis of the constraints limiting trail use, it was determined that given the characteristics of the site, all motorized traffic be strictly prohibited. Many pedestrian uses were investigated in terms of the suggested trail construction specifications. These values are tabulated in Table 7. The final specification recommendations, found in §5.1.2, were formed using a combination of the following values as discussed in §3.3.3.

Table 7: Trail Construction Specifications

Trail Use	Trail Width	Clearing Width	Clearing Height
Trail Fundamentals and Trail Management Objectives			
Hiker/Pedestrian	2-6'	4-6'	8-10'
Bicycle	2-7'	6-8'	8-9'
Cross-Country Ski	8-16'	8-14'	8-10' above snow
Snowshoe	3-8'	6-8'	8-10' above snow
New York Statewide Trails Plan			
Hiking	4-6'	4-8'	8-10'
Mountain Bike	1-3'	1.5-6'	8-10'
Trailbike	1-4'	4-8'	8'
Cross-Country Ski	4-10'	8-12'	8-10' above snow
Snowshoe	4-10'	8-12'	8-10' above snow
Woodland Stewardship: Recreational Trail Design			
Hiking	2-6'	4-10'	8'
Mountain Bike	2-3'	6-8'	8-10'
Touring Bike	3-10'	8-14'	8-10'
Cross-Country Ski	5-10'	8-14'	8' above snow

4.1.3 Trail Surface

The length of the recommended trail layout presented in §5.1.1 is approximately 0.75 miles long. At a width of 10 feet, as requested by the sponsor, the approximate surface area of the trail was calculated to be 40,000 square feet. A standard surface thickness of four inches was selected as is standard in many trail systems. Multiplying the surface area by the thickness yielded a value of 493.85 cubic yards of surfacing material required. For cost estimation purposes, 500 cubic yards was used.

Three design alternatives were investigated: gravel, crushed oyster shells, and wood chips. Gravel is a relatively inexpensive and commonly used surfacing material for trails similar to the one on this project site. When combined with stone dust, gravel hardens into a durable, yet permeable, surface. Crushed oyster shells were considered due to the historical significance as well as the fact that it is a recycled material. Wood chips, likewise, can be a recycled material and are highly permeable. Unlike the other two surfacing alternatives, wood chips naturally biodegrade decreasing the overall life of the surface significantly.

4.1.4 Required Work

The required work associated with general trail design includes clearing the chosen route of vegetative growth within the recommended construction specifications, and laying the selected surface material. It is highly likely that this work could be primarily conducted by volunteer labor. The Village of Fultonville Department of Public Works indicated a willingness to transport local materials to the site at no charge. This significantly reduces the construction costs associated with using gravel and wood chips. As there is no local supplier of crushed oyster shells, that particular product would require shipping to the site.

A short portion of the trail will require new construction. Similar to the parts of the trail that utilize existing roadbeds, clearing the trail can be conducted by volunteer labor. It is highly likely, however, that this new portion of trail will require grading using heavy equipment. Due to the relatively small size of the project it is possible that a local contractor may donate his or her time to conduct this grading before application of the surfacing material.

4.1.5 Cost Estimate

The following table displays cost estimates for the three surfacing alternatives. These prices were gathered from local suppliers when possible

Table 8: Trail Surface Cost Estimates

Alternative	Unit Price	Material Cost	Freight	Total Cost
Gravel	$10.59/yd^3	$5,300	N/A	$5,300
Oyster Shells	$353.76/yd^3	$177,900	$115,500	$293,400
Wood Chips	$15.00/yd^3	$7,500	N/A	$7,500

4.2 Stormwater Management Design

The proposed trail route identified by the project sponsors contains an area of concern dealing with stormwater management. The following section presents the results from a hydrologic analysis conducted on the particular watershed as well as three alternative designs suggested for the management of the stormwater.

4.2.1 Hydrologic Analysis Results

The rational method for calculating the peak flow rate due to a particular precipitation event in a watershed relies on three factors: a runoff coefficient, the average rainfall intensity for the event, and the area of the watershed. For the watershed in question, a runoff coefficient of 0.15 was used which is typical for cemeteries, parks, and other similar areas that contain a mix of slopes and vegetative cover (*Hydraulic Design Manual: Rational Method*, 2014).

The average rainfall intensity is determined using intensity duration frequency curves. The curves the team generated for this analysis were based on data associated with the Fultonville Cemetery and Natural Burial Ground from Cornell University's online tool *Extreme Precipitation in New York & New England.* These curves, shown in Figures 8 and 9, were created for 2-, 25-, and 100-year precipitation events.

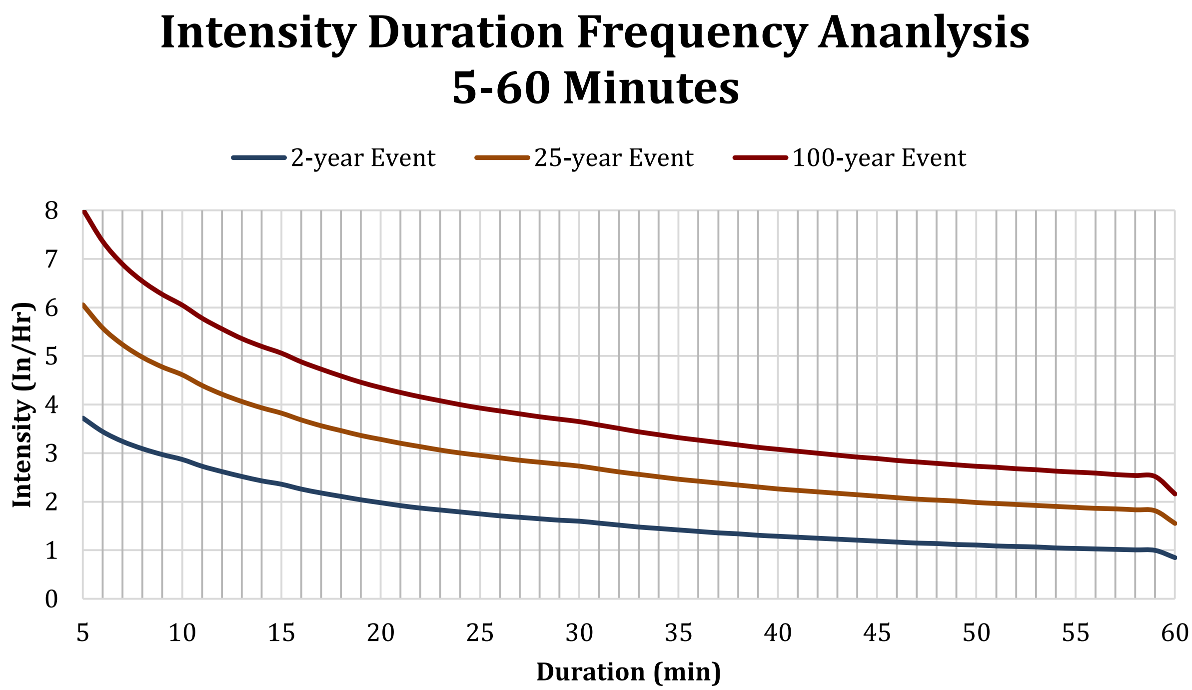

Figure 8: IDF Curve, 5 to 60 Minute

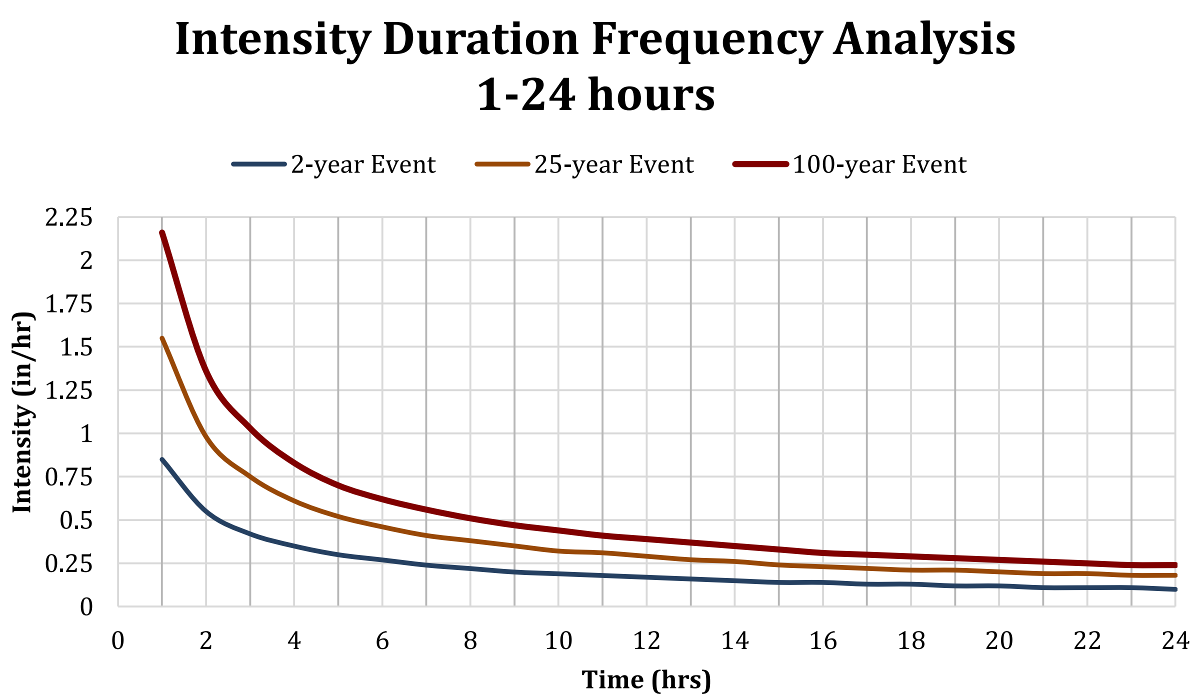

Figure 9: IDF Curve, 1 to 24 Hour

The duration that is used to determine the intensity from the IDF curves is referred to as the time of concentration. In calculating the time of concentration the team determined both the channel flow time and the overland flow time of the watershed as outlined by the Kerby-Kirpich method. Due to the lack of any significant channels, the channel flow time was assumed to be zero. In the calculation of the overland flow time, the team was required to calculate many other values. The length of the overland flow distance was determined to be 200 feet using a topographic map created from survey data the team gathered. This map is shown in Figure 10.

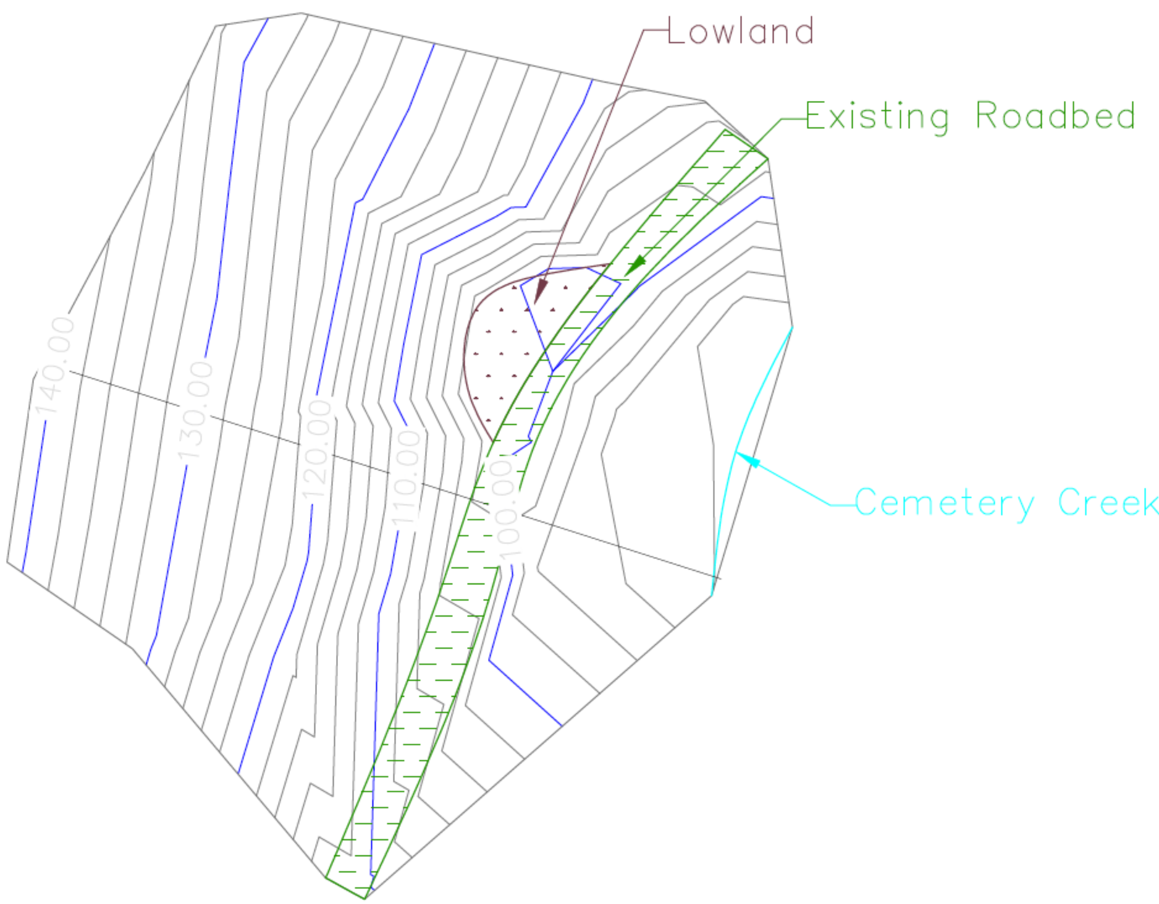

Figure 10: Topographic Map used in Stormwater Management Design

A retardance coefficient of 0.60 that is typically used in deciduous forests was used in our calculations. The average slope of the area was determined to be 0.50 using the aforementioned topographic map. With these factors as well as a conversion factor of 0.828, the time of concentration was calculated to be 9.115 minutes of 0.17 hours as shown below (*Hydraulic Design Manual: Time of Concentration*, 2011).

$$t_c = t_{ov} + t_{ch} = K(LN)^{0.467}S^{-0.235} + t_{ch} = 0.828(200' * 0.60)^{0.467}0.50^{-0.235} + 0$$
$$= 9.115\, min$$

The last factor used in the Rational Method is the area of the watershed found to be 0.5 acres. This was determined using survey data gathered by the team.

The peak flows calculated using the Rational Method are shown in Table 9 for the three design storms investigated. A sample calculation is shown below.

$$Q_{p,2-year} = CiA = 0.15 * 2.87\frac{in}{hr} * 0.5acres = 0.21585cfs$$

Anticipated stormwater volumes were calculated using the peak flows and three arbitrary storm durations. These values are displayed in Table 10. A sample calculation is shown below.

$$V_{2-year,30\,min} = Q_pD = 0.21585\frac{ft^3}{s} * 30\text{ min}\left[\frac{60s}{min}\right] = 387ft^3$$

Table 9: Peak Flow Results

	Peak Flow (cfs)
2-year Storm	0.22
25-year Storm	0.35
100-year Storm	0.45

Table 10: Storm Volume Results

Volume (ft^3)	**Storm Duration**		
	30 min.	**1 hour**	**5 hours**
2-year Storm	387	775	3,875
25-year Storm	622	1,245	6,224
100-year Storm	817	1,634	8,168

4.2.2 Natural-Bottom Box Culvert Results

One alternative method investigated by the team for stormwater management was a natural-bottom box culvert. This type of culvert is both easy to construct and allows for a natural-bottom that does not interrupt any natural characteristics of the overland flow. Through an iterative approach, the team calculated the required size of the culvert using the orifice flow equation. This equation calculates the allowable flow for an orifice, in this case a culvert, based primarily on its cross-sectional area. A coefficient of discharge, based upon an entrance loss coefficient of 0.5 for sharp entrances, was calculated to be 0.8165. Both the cross-sectional area and headwater values used in the equation are dependent upon the tested geometry. A one-foot-square cross-section was tested as a starting point. With this geometry, the cross-sectional area was calculated to be 1 square foot. The headwater was determined to be 1.5 feet using Equation 5, illustrated in §3.4.3.1 given that the height of the culvert tested was 1 foot, the culvert thickness was 2 inches, the depth of soil cover was 6 inches, and the safety factor was 2 inches. Using these values, the allowable flow in a one-foot-square culvert was calculated to be 8.025 cubic feet per second, as shown below. This value, upon comparison to the peak flow of a 100-year design storm, was found to be satisfactory. To ease in the constructability of the culvert, no smaller sizes were tested.

$$Q = C_d A_c \sqrt{2gHW} = \frac{1}{\sqrt{1+k_e}} A_c \sqrt{2g(h_c + t_c + d - s)}$$

$$= \frac{1}{\sqrt{1+k_e}} (1' * 1') \sqrt{2 * 32.2 \frac{ft}{s^2} \left(1' + \frac{1'}{6} + \frac{1'}{2} - \frac{1'}{6}\right)} = 8.025 cfs$$

The materials required for construction were a function of geometry. While the bottom of the culvert remained natural, the sidewalls and the top were designed to be constructed with two-inch thick bluestone. Given a one-foot-square culvert, 16 inch wide pieces were required for both the sides and the top as shown in Figure 11.

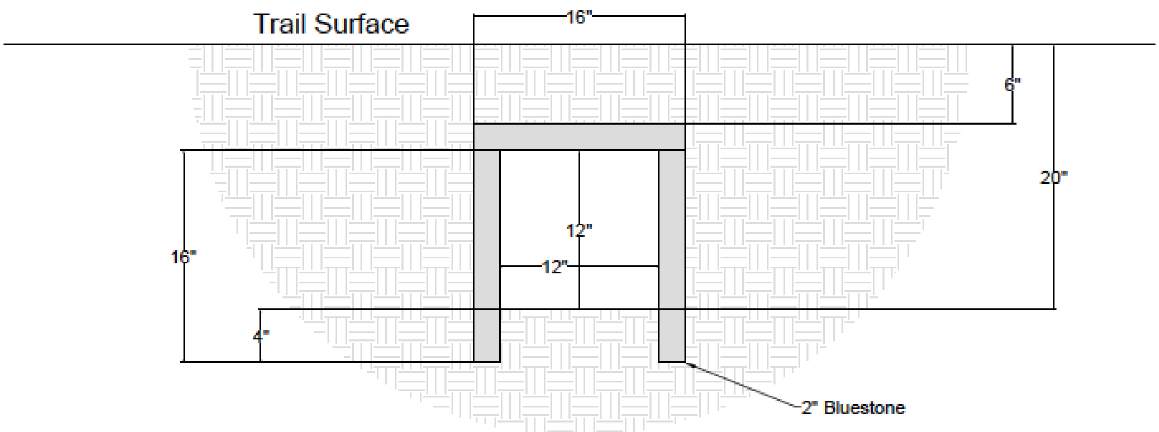

Figure 11: A cross-sectional view of the designed culvert

The last factor in the culvert design was to determine the length of the culvert. This value was calculated to be 2 feet wider than the required trail width to allow for a one-foot shoulder on each side, yielding a total length of 12 feet.

4.2.3 Retention Basin Results

A retention basin was designed for the site based upon the relatively small stormwater volumes calculated in the hydrologic analysis. The volume for a 100-year storm lasting 1 hour was used as a guiding value in the retention basin calculations. Using a topographic map, shown in Figure 10, generated from survey data, the area of the existing lowland area to be used as a basin was found to be 460 square feet. Given the required storage capacity of 1,634 cubic feet, a required basin depth of 3.6 feet was calculated.

To ease in construction, it was suggested that the trail be raised to create the required depth through the area. Again, using the topographic map above, it was determined that the trail surface must be raised to a relative elevation of no less than 104 feet, given that the lowest point of the trail in this area is 100 feet in elevation, to accommodate the retention basin. The retention basin created through raising the trail to this elevation would have a total capacity of over 1,800 cubic feet. The required fill for the trail to create this minimum elevation was calculated using topographic data and geometric principles. Approximately 150 cubic yards of fill would be required in creating the retention basin.

4.2.4 Permeable Paver System Results

A permeable paver system presents a feasible option for managing runoff in this area. Utilizing such a system would have a minimal impact on the existing landscape while preventing erosion of the trail through soil stabilization. Using the topographic map shown in Figure 10, the team determined that all trail elevations less than 101 feet in relative elevation required pavement with pavers to maintain a trail that was dry and would not erode due to stormwater runoff. The trail length requiring pavers was found to be 60 feet, requiring 600 square feet of pavers. A local supplier of Belgard products, the manufacturer of the Turfstone paver, determined that for such an area, 240 pavers would be required.

4.2.5 Cost Estimate

The following table displays cost estimates for the three stormwater management alternatives. These prices were gathered from local suppliers when possible.

Table 11: Stormwater Management Cost Estimates

Alternative	Unit Cost	Quantity	Material Cost
Stone Culvert	$25/ft^2$	$48ft^2$	$1,200
Retention Basin	$25/yd^3$	$150yd^3$	$3,800
Belgard Turfstone	$7.90/pc.	240pcs.	$1,900

4.3 Slope Retention Design

While many areas in the Fultonville Cemetery and Natural Burial ground exhibit steep slopes, one area along the proposed trail has experienced slumping due to a lack of slope retention. The team has done extensive research and site analysis to determine the best methods for retaining the area of concern. The options analyzed were a vendor-designed gravity retaining wall, timber terraces, and vegetation. The following section outlines how these practices could be put in effect on the site.

4.3.1 Gravity Wall Results

In the design of a gravity retaining wall, the team chose to investigate a vendor-designed modular block system by Redi-Rock. While the engineering analysis of specific walls is publicly available on Redi-Rock's website, the team first had to determine a wall layout that consisted of a height and length as well as the load conditions and soil type.

The wall layout was generated with two main factors – creating a trail width of 10 feet throughout the area and minimizing the slope to 50% or less. These factors were investigated using a topographic map, shown in Figure 12, created from survey data the team collected in the field. In the figure a yellow line indicates a 10-foot trail width, while the green-hatched region shows the existing roadbed. It can be seen that there is a length of the trail in this area that is less than 10 feet in width. This length, approximately 80 feet, was used to begin the gravity wall layout. The height of the required wall was determined given existing slope conditions calculated from the topographic survey. In order to minimize all slopes in the area to 50% or less, a wall height of 5 feet is required.

Using the dimensions of Redi-Rock's Gravity Wall blocks, a layout was created as can be seen in Figure 13. A cross-section of the wall is shown in Figure 14 (*Gravity Retaining Walls,* 2014). The wall dimensions were calculated to be 82.4 feet long by 6 feet tall with 1 foot below grade to meet vendor standards. As the grade changes throughout the length the height of 5 feet is maintained for approximately two-thirds the length of the wall until tapering to ground level. This layout requires the following Redi-Rock blocks:

(25) 60" Bottom Block
(40) 41" Middle Block
(6) 41" Half Middle Block
(18) 28" Top Block
(6) 28" Half Top Block

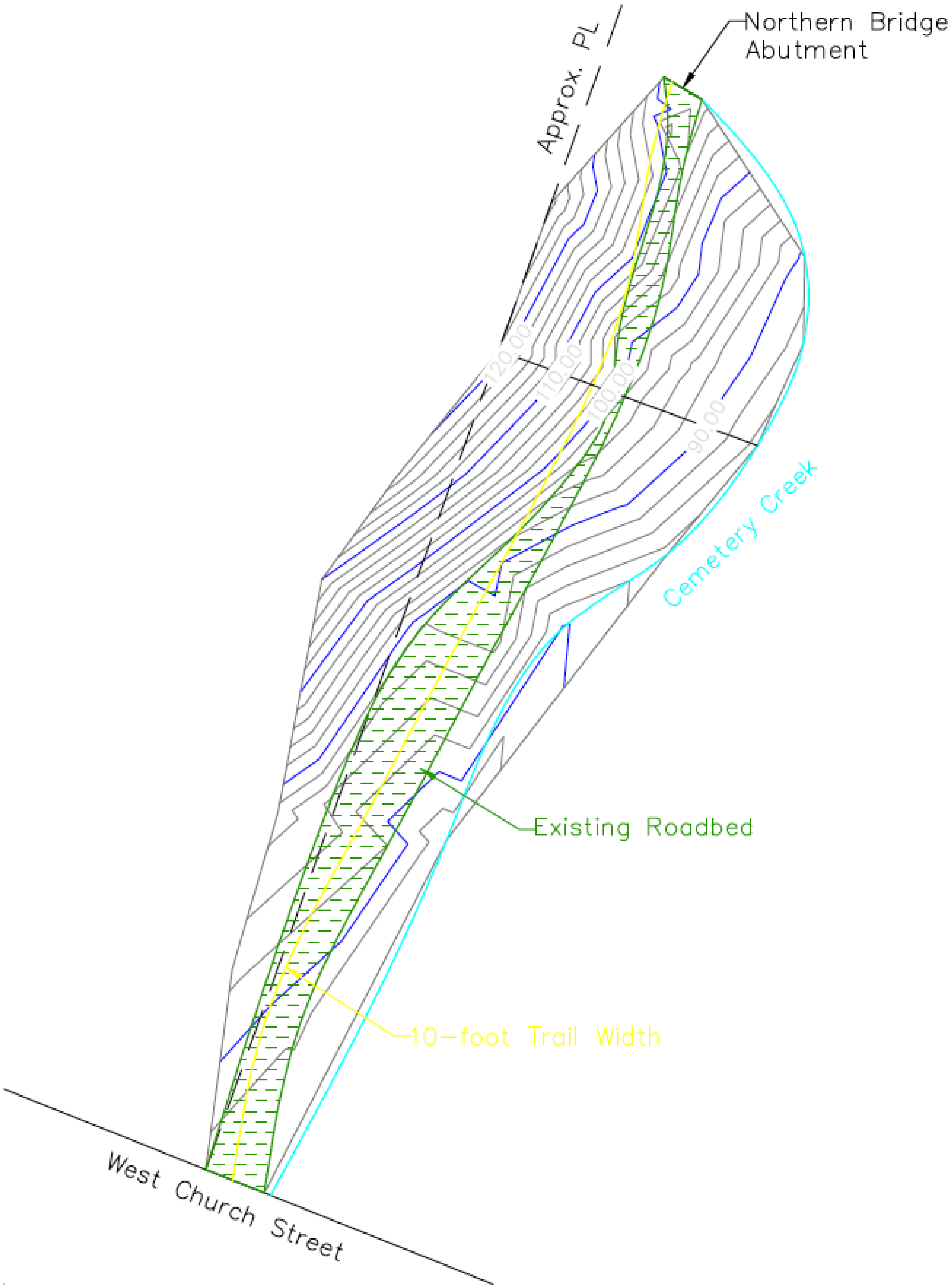

Figure 12: Topographic map of Trail Entrance Area used in Slope Retention Design

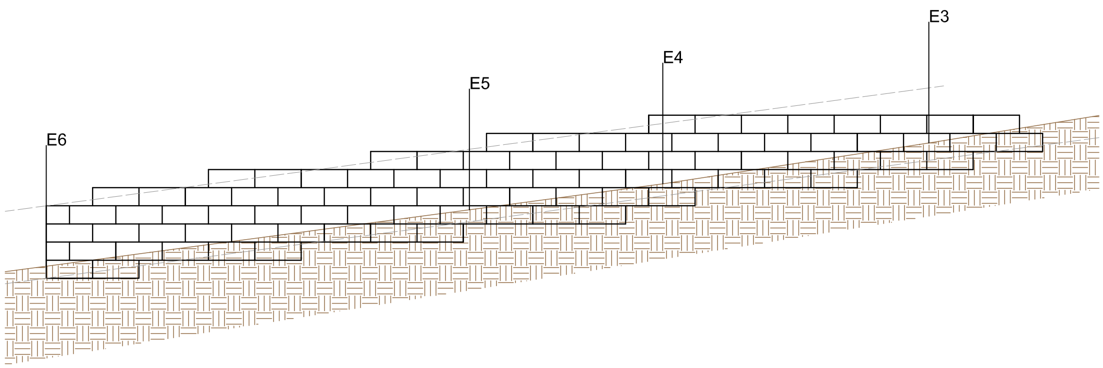

Figure 13: Gravity Wall Layout

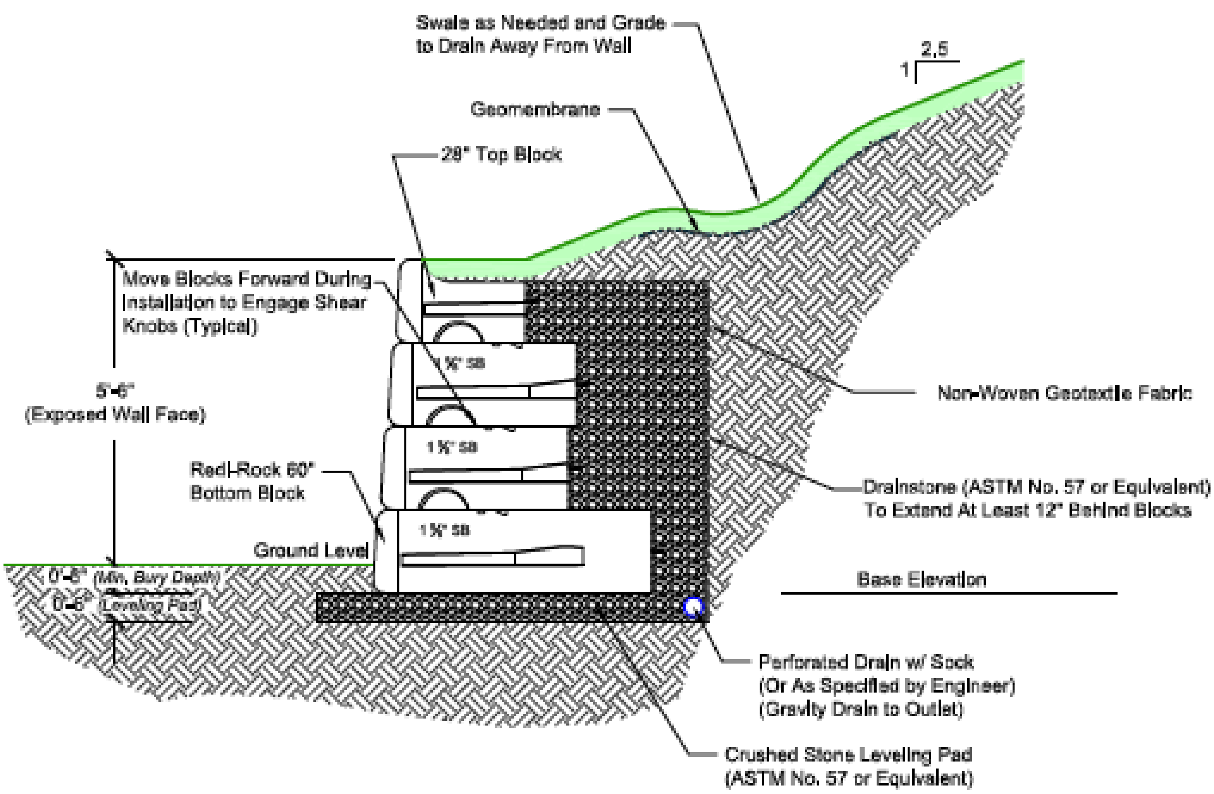

Figure 14: Gravity Wall Cross-Section

The vendor-based engineering analysis related to this wall is available to the public online and can be found in Appendix D of this report.

4.3.2 Timber Terraces Results

A second alternative to slope retention is the use of a series of timber retaining walls in creating terraces along a slope. This practice is commonly implemented along recreational trails; however, very few standards exist. Two typical construction methods for timber walls are shown in Figures 15 and 16 ("Woodland Stewardship", 2011; Ryan, 2014). The method shown in Figure 15 utilizes a structural element referred to as a "Deadman" to secure the wall while the method in Figure 16 requires a more substantial footing for the vertical wall elements. Other differences can be observed in the images.

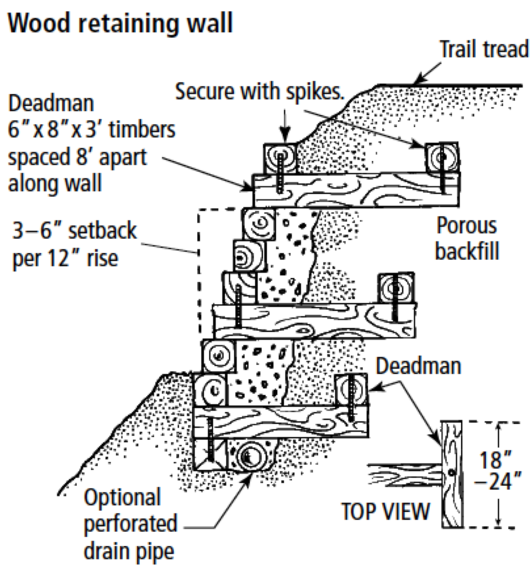

Figure 15: Typical Timber Wall Cross-Section

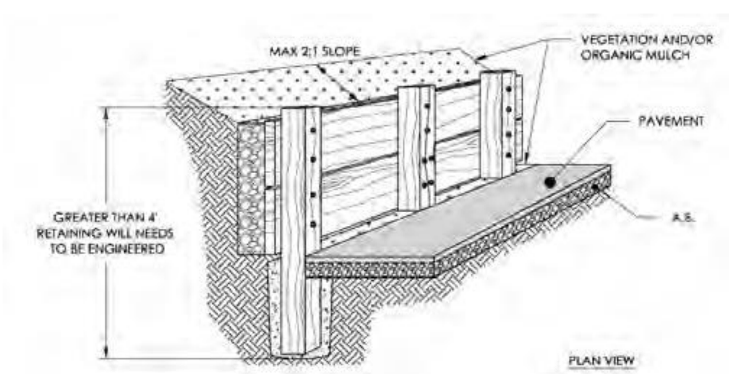

Figure 16: Typical Timber Wall Cross-Section

One guiding principle in the implementation of timber walls, such as the one shown in Figure 16, along recreational trails is that the complete structural height of the wall, that being from the bottom of the footing to the top of the wall, should not exceed 4 feet (Ryan, 2014). If a wall should exceed this height, an in-depth engineering analysis should be conducted. As a rule of thumb, the footing should be equal to the wall height, thus limiting the wall height to no more than two feet (Ryan, 2014). A significant drawback to timber walls is the lack of resilience compared to a masonry or concrete wall (*Concrete Retaining Wall vs. Timber Retaining Wall,* 2014). The costs associated with construction, however, are much less due to lower material costs and the ability for the wall to be constructed using volunteer labor.

With this information at hand, the team designed a primary 2-foot tall timber wall following the eastern trail edge throughout the section experiencing slumping. This length was determined to be 84 feet by using the topographic survey data referred to above. Two additional walls were designed at equal horizontal distances into the slope at a height of 1 foot. With the combined four-foot height of these three walls in place, the slope will be both lessened in severity and stabilized.

4.3.3 Vegetation Results

In a report conducted in Irondequoit, New York on several large-scale slope failures that had occurred where vegetation had been recently removed, researchers found that the "reestablishment of native vegetation on slopes that have failed or are in partial failure is a clear recommendation." (Luley and Pleninger, 2008). There are a number of types of vegetation that vary from inches tall to over 100 feet tall. Typically, plant species are separated into two main categories: ground covers and trees.

Ground covers tend to remain low to the ground and form a dense layer of vegetation that prevent the growth of other unwanted species. Ground covers are also very helpful in retaining soils along slopes where grass cannot be grown or maintained. When selecting native ground covers to place on a slope one important consideration for the northeast is its winter hardiness. A plant that is winter-hardy means that it will be able to tolerate the cold of winter without losing any important landscape characteristics. Table 12 displays hardy ground covers for central New York State (Lieberman & Mower, 1974).

Table 12: Ground Covers Hardy to Central New York

Species Height	Species
1-6 Inches	Bulge Plant, Moss Sandwort, , Wintergreen, Trailing Arbutus, Patridgeberry, Moss Pink, Creeping Thyme, Myrtle, Baby Wintercreeper, Wintercreeper, Siebold Sedum
6-12 Inches	Golden Tuft, Creeping Hollygrape, Bearberry, Creeping Juniper, Lowbush Blueberry, Plumbargo, Barrenwort, Hardy Candytuft, Chamaedrys Germander, English Ivy, Shore Juniper, Hall's Honeysuckle, Japanese Spurge, Memorial Rose
3-5 Feet	Black Chokeberry, Tamarisciflora, Drooping Leucothoe, Coralberry, Rockspray, Fragrant Sumac, Spreading English Yew
5-10 Feet	Fiveleaf Aralia, Gray Dogwood, Pfitzer's Juniper, Rose Acacia, Japanese Yew, Arrowwood, Drooping Forsythia, Bayberry

Trees are typically divided into two groups: conifers that produce cones and are typically evergreen and deciduous hardwoods that lose their foliage seasonally. Within both of these groups, species mature height, longevity, and growth rate can vary greatly. Disease resistance is also a significant concern when choosing a particular tree. Many species in America have undergone massive epidemics such as the Elm and Chestnut. Table 13 displays a sampling of tree species that are hardy to central New York (*2014 Annual Conservation Tree & Shrub Sale*, 2014).

Table 13: Trees Hardy to Central New York

Species	Mature Height	Growth Rate
Conifers		
Red Pine	50-80’	Fast
Black Hills Spruce	30-60’	Slow
Balsam Fir	45-75’	Slow
Douglas Fir	40-70’	Moderate
White Pine	50-80’	Fast
Colorado Blue Spruce	50-75’	Slow to Moderate
Norway Spruce	40-60’	Moderate to Fast
Fraser Fir	30-60’	Moderate
White Cedar	20-30’	Slow to Moderate
Deciduous Hardwoods		
Red Oak	50-75’	Fast
White Oak	40-50’	Slow to Moderate
Red Maple	40-60’	Moderate to Fast
Sugar Maple	50-75’	Slow
Sargent Crabapple	6-12’	Slow
Black Walnut	50-75’	Fast
Native Birch	50-70’	Fast

A combination of groundcovers and trees can successfully retain any slope. Out of the options tabulated above a combination of Black Chokeberry, *Aronia melancarpa,* and Red Oak, *Quercus rubra*, would successfully retain the slope. Black Chokeberry is native to the eastern United States and is hardy in upstate New York. It remains low to the ground, typically 3 to 5 feet, and spreads to form large groupings. Black Chokeberry is very adaptable and can thrive in sun and shade. It is a great species for slope stabilization (*Aronia Melanocarpa*,2014). Likewise, the Red Oak is native and hardy to the area. It is a relatively fast growing tree and can reach heights of 75 feet. It has a very long life span (*Quercus Rubra*, 2014). The combination of these two species will accomplish the three goals the team established for vegetative retention. First, the combination will both mature quickly and have a long lifespan. Second, the combination will cover the hillside and require minimal to no maintenance. And third, the combination contains both a groundcover and a tree species. The species should be planted along the slope in a manner that is aesthetically pleasing.

4.3.4 Cost Estimate

The following table displays the cost estimates for the three slope retention options. The data was collected from a variety of suppliers.

Table 14: Slope Retention Cost Estimates

Alternative	Material Cost	Professional Services	Total Cost
Redi-Rock Gravity Wall	$11,900	$3,600	$15,500
Timber Terraces	$1,900	N/A	$1,900
Vegetation	$250	N/A	$250

5 Recommendations and Conclusions

The following section outlines the final recommendations for the Fultonville Cemetery & Natural Burial Ground recreational trail design. Each decision was made utilizing the evaluation matrix described in §3.6. The final trail, stormwater management, and slope retention design are presented. Final drawings and deliverables are provided. Lastly, the next steps in ensuring the trail's existence and success is discussed.

5.1 Trail Design Recommendation

Trail design recommendations include the final layout, trail use, surfacing, and construction specifications.

5.1.1 Trail Layout

The recommended trail layout is shown in blue in Figure 17. This route roughly follows the perimeter of the parcel providing access to the entire Fultonville Cemetery and Natural Burial Ground as well as a variety of scenic vistas. The trail length is three-quarters of a mile.

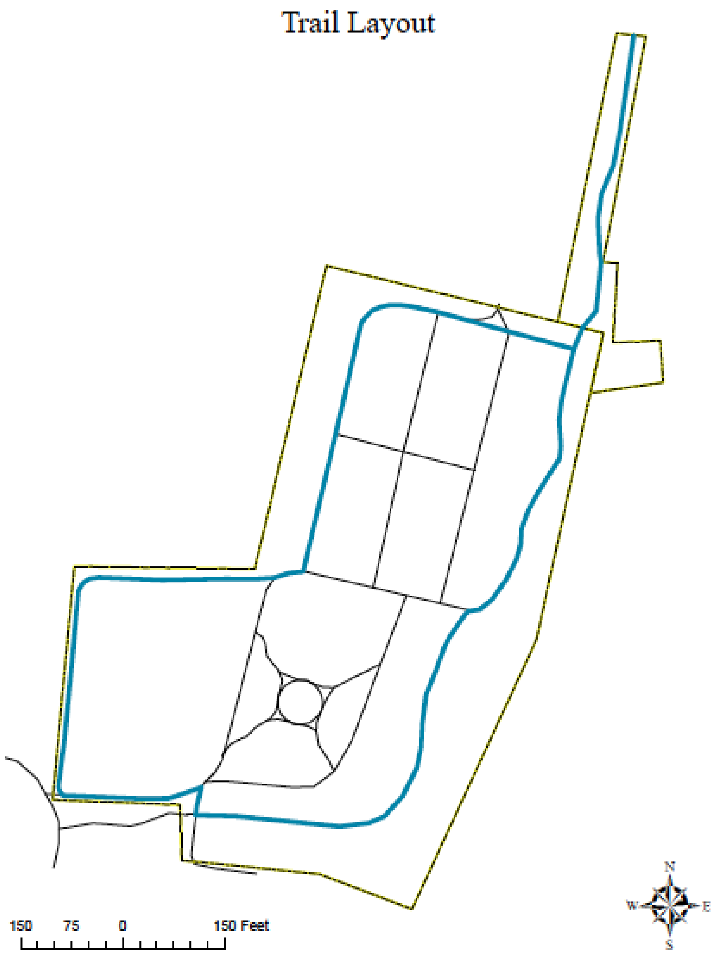

Figure 17: Recommended Trail Layout

5.1.2 Trail Use and Construction Specifications

It is the recommendation of this project team that all motorized vehicle use be prohibited on the trail. In accordance with the vision of our sponsor, this will promote pedestrian enjoyment of the trail and ensure the protection of fragile environments. Further, minimal disturbance to the trail surface itself will ensure less maintenance needed for the site.

Trail construction specifications are recommended based upon an analysis of many trail design guides. The specifications are shown in Table 15, while a typical trail cross-section is shown in Figure 18.

Table 15: Trail Design Specifications

Tread Width	Clearing Width	Clearing Height
10’	14’	12’

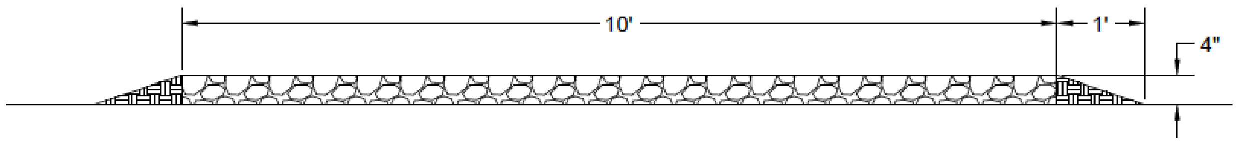

Figure 18: Typical Trail Cross-Section

5.1.3 Trail Surface

The trail surfacing materials were analyzed using the evaluation matrix. Gravel scored the highest mainly due to its environmental sustainability, prolonged lifetime, and lower cost. Oyster shells ranked the lowest mainly due to its price. Table 16, found below, lists the final scores for each of the trail surfacing options. The full results from the evaluation matrix for trail surfacing can be found in Appendix E.

Table 16: Trail Surface Evaluation Results

Alternative	Overall Score
Gravel	*41/50*
Oyster Shells	35/50
Wood Chips	39/50

5.2 Stormwater Management Recommendation

The stormwater management design alternatives were analyzed and the application of Belgard Turfstone was ranked the highest on the evaluation matrix compared to a stone culvert and retention basin. This is mainly due to the ease of constructability and low maintenance required of the Belgard Turfstone and its environmental sustainability. Table 17, found below, lists the final scores for each of the stormwater management options. The full results from the evaluation matrix for the stormwater management alternatives can be found in Appendix E.

Table 17: Stormwater Management Evaluation Results

Alternative	Overall Score
Stone Culvert	37/50
Retention Basin	33/50
Belgard Turfstone	*48/50*

5.3 Slope Retention Recommendation

The slope retention design alternatives were analyzed using the evaluation matrix, and vegetation ranked the highest compared to the gravity wall and timber terraces as shown in Table 18. This is primarily due to the significantly lower construction cost of the option. However, it is the recommendation of the team that in addition to the slope being populated with Black Chokeberry and Red Oak, a two-foot timber wall be constructed along the base of the slope on the eastern side of the trail. This solution is recommended to remediate the slumping that has already occurred.

Table 18: Slope Retention Evaluation Results

Alternative	Overall Score
Gravity Wall	30/50
Timber Terraces	33/50
Vegetation	*44/50*

5.4 Total Cost Estimate

Given the above stated design recommendations, an approximate total project cost estimate of $8,400 is shown in Table 19. These costs are based solely on material and professional fees. It is assumed that the majority of the labor required will be volunteered. The price for the trail surfacing material was obtained from Cushing Stone Company in Amsterdam, New York. The price for the stormwater management recommendation was obtained from Cranesville Block Company in Amsterdam, New York. The price for the slope retention recommendation is a combination of vegetation costs obtained from Tree Nursery Company online and Lowe's Home Improvement.

Table 19: Project Cost Estimate

Design Element	Recommendation	Cost
Trail Surface	Gravel	$5,300
Stormwater Management	Belgard Turfstone	$1,900
Slope Retention	Vegetation & Timber Wall	$1,200
	Total Cost:	**$8,400**

5.5 Next Steps

The next step in the development of the Fultonville Cemetery & Natural Burial Ground recreational trail is to receive approval from the Board of Cemetery Commissioners and the Village Board of Trustees to implement the recommendations. Following their approval, a funding source must be located. Due to the relatively low cost of this project, it is likely that the Village and Cemetery Commissioners may carry out the majority of the tasks through local fundraising. However, due to the necessity of building a bridge along the entrance trail as stated in the Background of this report and investigated in the complementary MQP, *Pedestrian Bridge Design in Fultonville, New York*, it is recommended that the Village and Cemetery Commissioners pursue grant funding for the entirety of this project. While a funding source is located, preliminary work on clearing the trail of vegetation and other debris may commence.

Additionally, there are a number of things that could be investigated for further development and consideration. A complete topographic survey of the site is one task that could not be completed by this team due to time constraints but would aid in a more detailed design. The addition of wayward signage along the trail would add an educational component to the site. Signs could discuss local history and ecology among other pertinent topics. These two tasks would further enhance the site for community use.

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Appendices

Appendix A – Project Proposal

FULTONVILLE TRAIL DESIGN

A Proposal for a Major Qualifying Project Report:

Submitted to Faculty of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

Cory S. Adams

Scott F. Gould

Giovanna C. Olson

Ryan B. B. Weitz

Date:

Approved:

Professor Suzanne LePage, Advisor

Professor Leonard D. Albano, Advisor

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LIST OF TABLES AND FIGURES

Capstone Design

This project team will hold itself to certain design and method standards. We will ensure the design constitutes the utmost integrity in the following aspects: economic, environmental, sustainability, constructability, ethical, health and safety, and social and political. Each of these areas will be carefully thought out while each design decision made.

Economic

Economics is a key factor that governs the design of all engineering projects. The project must be determined to be economically feasible before a project can get past the design stage. There has to be a balance between a project that is too expensive and one that is too low-cost to fulfill other design criteria. A cost analysis will be performed for both the trail design and the bridge design. The main concerns are material, maintenance, and construction costs.

Environmental

This project will include various designs for erosion control. All hydrological designs will comply with *New York Standards and Specifications for Erosion and Sediment Controls.* The design will be sized for a 100-year storm as to minimize erosion impact on the surrounding environment from water runoff. To minimize environmental impacts that construction may have on surrounding areas, various procedures during the construction process must be evaluated. For example, setting the appropriate time for construction activities as to not disturb the community. Further, environmental protection methods should be put in place as to not disturb the natural state of the ecosystem.

Sustainability

Sustainability is very important on this project to ensure that this trail could be enjoyed for years to come. All parts of the project should be as easy and inexpensive as possible to maintain. This means designing the bridge, trail surface, and culverts to last as long as possible. Maintenance costs will have to be factored into the overall cost of the project to show a better representation of the project's economic feasibility. It is also crucial that the environmental sustainability of the bridge design is minimized by assessing the lifecycle of materials and manufacturing necessary for the bridge development. Recycled bridges and bridge materials may be used.

Constructability

Located in the woods on a dirt trail, the bridge components would have to be transported over rough terrain. Depending on the final bridge design chosen, pre-fabricated or to-be-constructed on site, the parts would have to be maneuvered through the woods. Construction vehicles would be needed to place the bridge in its final location. The bridge design will be heavily influenced by its location. The environmental impact made by the construction of the bridge and trail is a top priority when going through the planning and designing stages.

Ethical

This project will be conducted in accordance with the American Society of Civil Engineers Code of Ethics. This project will aim to provide the best possible solutions for each party affected by the design. The design will not convey any falsified information of violate any regulations of a governing body. The first Fundamental Canon of Engineers is: Hold paramount the safety, health, and welfare of the public (National Society of Professional Engineers, 2013). Safety of the public comes first.

Health and Safety

Safety and health regulations have already been put in place by the *Americans with Disabilities Act*, and *New York State Building Code.* These regulations will be closely followed to ensure the safety of the public since this trail is in the woods and may pose more danger to pedestrians and users. Culvert designs will comply with *New York Standards and Specifications for Erosion and Sediment Controls.* This ensures the wellbeing of the environment which pedestrians will be utilizing.

Social and Political

The overall success of this project depends on the community's acceptance and use of the trail. To accomplish this, public input will be sought to determine a handful of design constraints including trail use and bridge design. Additionally, we must work with the Board of Cemetery Commissioners and Board of Trustees to ensure the adoption of the final plan. Incorporating these social and political aspects will aid in the overall success.

1 Problem Statement

The village of Fultonville is interested in constructing a recreational trail utilizing land in the Fultonville Cemetery and Natural Burial Ground. Due to its proximity to the New York State Erie Canalway Trail, the proposed project would serve as an additional point of interest. The proposed trail project requires identifying a preferred route, developing erosion control methods, and designing a bridge.

2 Objective

The objective of this project is to complete a site development plan for a recreational trail in the Fultonville Cemetery and Natural Burial Ground. Multiple design options for the trail route, erosion controls, and bridge will be prepared. Factors governing the designs include cost, environmental impact, sustainability, constructability, ethical practices, health and safety standards, and social and political facets.

3 Scope of Work

This Major Qualifying Project will be divided into two segments. The first segment entails identification of a preferred trail route and design, including hydrological analysis and drainage considerations. The second segment entails designing a bridge to span a ravine. Both segments will be divided into four main phases: site visits and data collection, analysis, design, evaluation of alternatives and preparation of a final proposal.

Throughout the data collection period a series of site visits and discussions with The Fultonville Board of Cemetery Commissioners and Board of Trustees will determine the vision for the recreational trail. Field data will be collected and analyzed to design multiple trail routes. Additionally, trail surfacing options and erosion control methods will be created. The different options will be evaluated with consideration towards cost, environmental impact, sustainability, constructability, ethical practices, health and safety standards, and social and political facets.

Due to given constraints by The Fultonville Board of Cemetery Commissioners and Board of Trustees, the trail is required to cross a ravine. Existing limestone bridge abutments will be visually inspected to assess their ability to be reused. The design is dependent upon trail use. Multiple bridge designs will be prepared with various construction materials and aesthetics. All of the bridge designs will be evaluated with consideration towards the aforementioned factors. These designs will be outlined to supply the village with multiple possibilities. Finally, a completed design package will be presented.

4 BACKGROUND

Located along the south bank of New York's Mohawk River, the village of Fultonville is a small, rural community surrounded by agriculture. Established as a canal town in 1823, Fultonville grew to become a widely known stop on the Erie Canal until its removal to the Mohawk River in the early twentieth century. The surrounding Mohawk Valley is rich in history and has placed an amplified value upon its heritage in recent years.

Figure 1: Fultonville is located less than 40 miles west of the state capital at Albany.

4.1 History of the Fultonville Cemetery and Natural Burial Ground

In 1844, the minister, elders, and deacons of the Reformed Protestant Dutch Church of Fultonville purchased an acre of land in the northwest corner of Garret Yates' upper field for use as a burying ground (Deed Liber, Montgomery County). The parcel was laid out into large, square lots and sold at auction (*History of Montomery and Fulton Counties,* F. W. Beers & Co.). Shortly after the incorporation of Fultonville as a village in 1848, the Church turned the burying ground over to the municipality. Additional land was purchased from Yates in 1860 that more than doubled the size of the cemetery (Deed Liber, Montgomery County*)*. In 1861, a right of way to "construct, use, and maintain a road" to access the cemetery was granted to the village by Samuel Donaldson. Construction of a bridge was required to cross a ravine at a "point called the falls." A dozen years later, a deed registered that Lewis J. Bennett, a former Fultonville merchant now of Buffalo, for the consideration of one dollar and interest in a "family lot," conveyed to the village "the iron super structure of the bridge now erected over the stream running past the Fultonville Cemetery, and in the road leading to said Cemetery."(Deed Liber, Montgomery County) There are no other known accounts referencing the cemetery bridge.

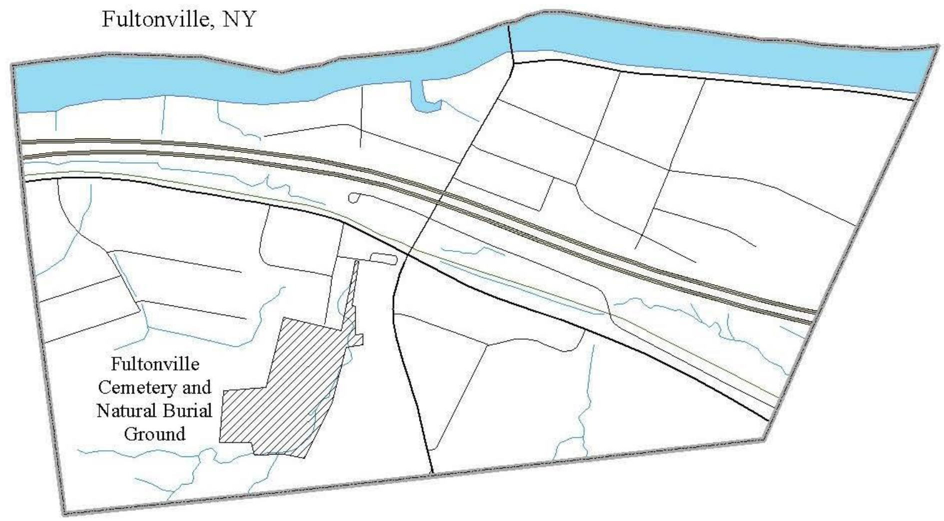

Figure 2: The Fultonville Cemetery and Natural Burial Ground encompasses nearly 10 acres in the southwestern portion of the village.

Two large additions were made by donation in 1875 and 1890 by Hon. John H. Starin. Starin, who grew up in Fultonville, founded a shipping empire in New York City prior to the Civil War. At one time, it is said that his shipping fleet was the largest in the world. He served two terms in Congress representing Fultonville from 1877 to 1881. His time in New York City and Washington, D.C. made him many influential and memorable friends including Presidents Grant and Arthur as well as Lewis Comfort Tiffany. The acreage he purchased adjacent to the Fultonville Cemetery was "[laid] out beautifully" most likely by one of his close friends (*History of Montomery and Fulton Counties,* F. W. Beers & Co.). He erected a large mausoleum for his family in the addition and donated the remainder to the village. The mausoleum, which included windows designed by Tiffany, eventually fell into disrepair and was demolished in the 1970s. Its absence leaves a large, open space in the cemetery.

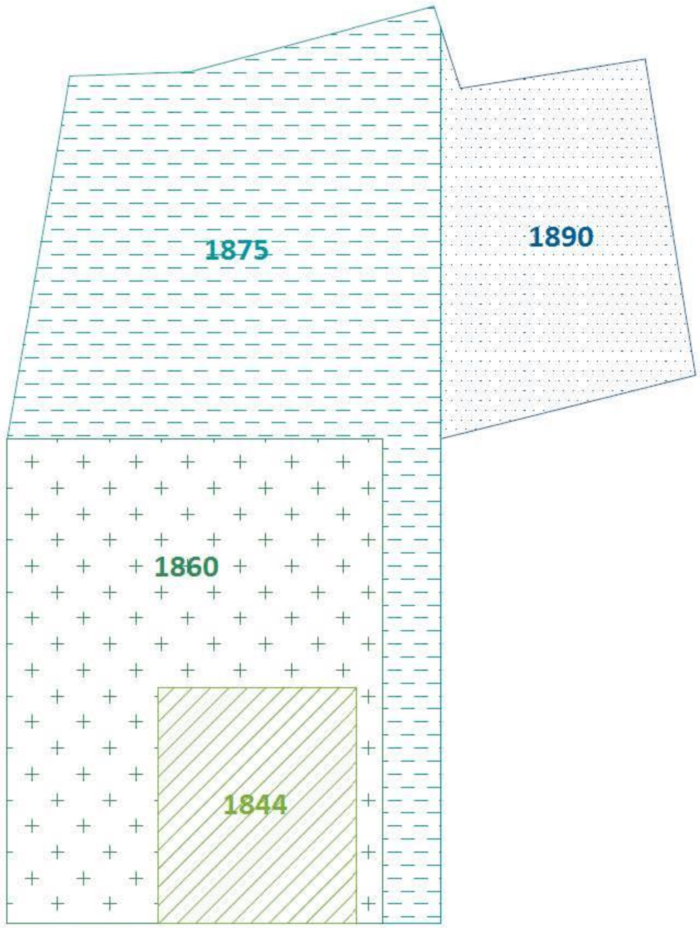

Figure 3: The cemetery is made up of four additions, spanning from 1844-1890.

Beginning in 2007, a large revitalization effort began in the cemetery. Decades of neglect allowed many areas to become overgrown that have since been cleared. Dozens of grave markers have been restored. Part of the ongoing work included drafting and adopting regulations for the proper functioning of the cemetery. These regulations were adopted by the Fultonville Board of Trustees in 2009 and created a Board of Cemetery Commissioners. The Commissioners then investigated the prospect of creating a "natural burial" section. The

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alternative burial method, which has grown in popularity nationally in recent years, is a commonsense, traditional, and affordable alternative to what is most commonly practiced today. Deceased persons are not chemically preserved and are interred only in biodegradable containers. In June 2013, the Trustees adopted regulations to establish a natural burial ground in a wooded area in the south west corner of the cemetery. This area, used for natural burial, will be forever preserved as woodland. The low-impact, conservation-minded ethos at the core of natural burial has been espoused to the Fultonville Cemetery and Natural Burial Ground.

4.2 Trail Background

The proposed trail to be constructed throughout cemetery grounds will utilize existing roads. A majority of the roads, however, have become overgrown and are completely unusable in their current form. The Commissioners' design request is for a ten-foot wide trail (topography permitting) that, in part, follows the ravine along the eastern property line. They also require that the trailhead be located along West Church Street to allow for easy access from the Erie Canalway Trail and a municipal parking lot. With these constraints in mind, the trail requires the crossing of the ravine where a bridge formerly stood. The remaining length of the trail shall be decided based on environmental constraints and aesthetic factors. Trail use and surfacing have not been strictly defined, yet the Commissioners wish to minimize environmental impacts in the final design.

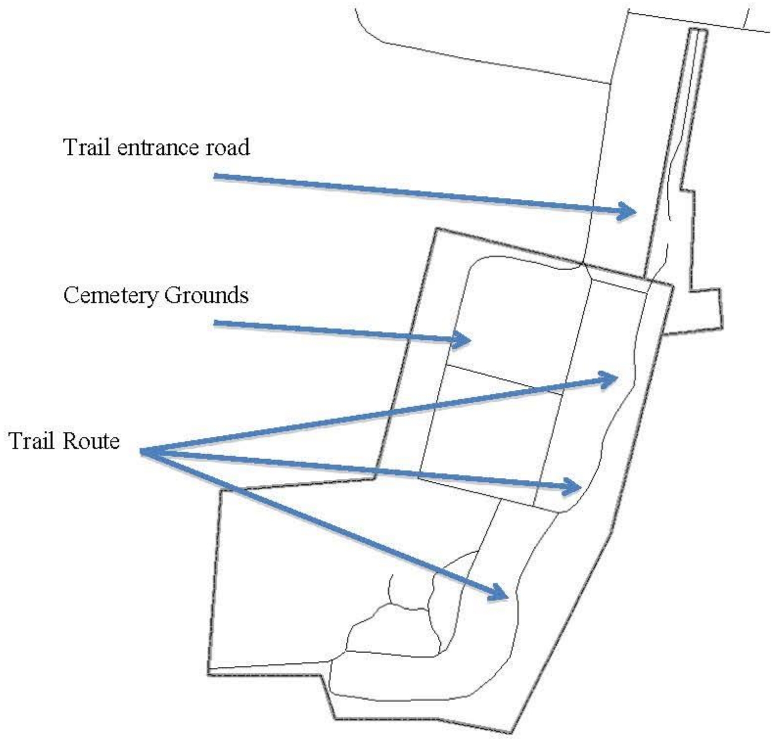

Figure 4: Numerous existing roads transverse the cemetery grounds.

4.3 Erosion Control Background

Portions of the requested ravine trail experience varying degrees of erosion. As the trail in this section follows along a very steep ravine, there are a handful of areas that will need to be visually assessed for stability. If there are any areas that are of concern, further investigation will have to be conducted. Runoff also poses a concern in some areas. One of which, pictured in Figure 5, frequently becomes a rivulet following precipitation events. This area, in particular, will require a focused hydrological assessment. Using available weather data and approximating a catchment area will aid in developing an adequate solution that aligns with the minimalist tone taken on by the Commissioners.

Figure 5: A portion of the proposed ravine trail that experiences frequent drainage issues.

4.4 Bridge Background

4.4.1 Intro

The proposed trailhead determined by the sponsor requires that the trail pass over a ravine. There are many different factors that determine the design of the bridge. These range from local and state laws that have to be upheld all the way to something as simple as being aesthetically pleasing and fitting in with the atmosphere of the surrounding area.

4.4.2 ADA Requirements

One of the more important regulations that will be influencing this design is the American Disabilities Act (ADA) which guarantees a project is safe and accessible to all people regardless of disabilities (Department of Justice, 2010). These requirements include clauses regulating design and construction. Design specifics include the slope of the bridge, handrail width, handrail height from the finish floor, and handrail geometry and design loads. Most importantly, there are clauses that directly apply to pedestrians. The following table illustrates some of the requirements:

Table 1: ADA specific requirements

Handrails	Walking Surface
Space between wall and rail: 1 ½"	Slope Grade: 1:20 or 5%
Installation height: between 33" and 36"	Slope perpendicular to travel: Grade: 1:48 or 2%
Diameter: 0.95" minimum and 1.55" maximum	36" minimum distance between handrails
Must hold horizontal and vertical force of 250lbs	Planks cannot be more than ½" apart in direction perpendicular to travel

4.4.3 New York Building Code

The village of Fultonville uses New York State's Building Code as its own. The Building Code of New York State was modeled after The International Code Council's building codes. These codes are written for adoption by state or local governments by reference only and guide the design of projects to help ensure public safety (New York State Department of State, 2010).

Structures of all kinds must be designed to account for dead and live loads, as well as wind, snow, and seismic loads that depend on location. The dead load is the force acting upon the members due to their own weight as well as the weight of any permanent attachments. Live loads can be defined as variable loads that account for all possible loading combinations in the life of the structure. These need to be incorporated in the design in order to ensure the safety of the public. New York State Building Code, for walkways and elevated platform, specifies the maximum live load capacity at 60 pounds per square foot (psf).

The bridge is going to be designed to accommodate small maintenance vehicles. To account for these forces, the New York State Building Code states that the concentrated wheel load shall be applied on an area of twenty square inches. This requirement addresses local stresses in the deck due to the wheels on the vehicle.

In order to determine the size and position of the members, accurate computations must be made in order to withstand maximum forces acting upon the bridge. New York State Building Code states that all calculations made with sizes of members must be done with actual sizes rather than their nominal dimensions.

4.4.4 Bridge Designs

Several different bridge designs will be designed and analyzed in this project. A wooden pedestrian bridge and a Whipple truss bridge will be designed and assessed and they will be compared with a reused flatcar and another prefabricated design. Each type of bridge has unique characteristics that lend to different strengths and weaknesses in terms of the capstone design requirements.

4.4.4.1 Flatcar Bridge

Flatcar bridges are made from either retired or unused flatbed railway cars. These flatcars do not have any structural problem which may have forced them into retirement (Rick Franklin Corporation, 2012). These cars are made from top grade steel and require little maintenance, making them ideal for hard to reach locations such as farmland cut off by streams. Flatcar bridges are constructed off-site to eliminate the downtime of a site. The cars are pre-cut before being shipped to the site with a desired span, and then fastened to the abutments at the site when they are being installed. Flatcar bridges made by Rick Franklin Corporation provide a HS-25 load capacity (Rick Franklin Corporation, 2012). This rating comes from the American

Association and Highway Transportation Officials, or AASHTO. The rating means that two-axial trucks are given an "H" rating. The "HS" loading comes from a truck with a semi-trailer as seen in the figure below:

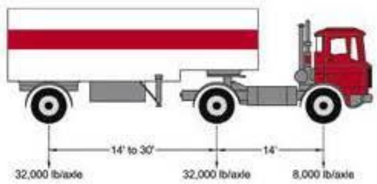

Figure 6: An HS-20 Loading

This loading system allows the load of a truck to be distributed to certain points along the bridge it is traveling on. Since flatcar bridges have a high HS rating and are able to hold up to an 180,000lb load, they are ideal for reaching all corners of any property and easily accommodate a variety of pedestrian applications

4.4.4.2 Whipple Truss Bridge

In 1841 Squire Whipple patented a bridge truss called The Whipple Arch Truss (site attachment from Mr. Fonzi). The first Whipple Truss Bridge was made from cast iron for compression members and wrought iron for tension members. Squire Whipple's design was so well thought of by the community, that New York State later adopted the design as their official standard. The first Whipple Truss Arch was built in Buffalo, New York, spanned Buffalo's Commercial Slip. The 100 foot Commercial Slip Whipple Truss had three arches, each with nine panels. The arches separated two lanes of traffic, and two outward pedestrian walkways. The image below shows the original Commercial Slip Whipple Truss, taken around 1870:

Figure 7: Whipple Truss Bridge circa1870

4.4.4.3 Prefabricated Bridge

Prefabrication has been practiced throughout history. Prefabricated structures can be anything that is assembled or partially assembled before being brought to the work site. Prefabricated structures can be shipped in sections and connected at the site. This applies to bridges as well as buildings. Some houses have been built and shipped in this same way. In this project a separate prefabricated bridge designed by a company will be evaluated and compared with other bridge designs. These bridges will be designed and built by a third party so much of the engineering aspect of them will be already taken care of by their respective company.

4.4.4.4 Wooden Pedestrian Bridge

The first bridges dating back to ancient times consisted of laying trees across a river to cross. The ancient Romans constructed wooden bridges that were up to 20 feet wide. Wooden bridges can be constructed with numerous species of trees and can be designed to resist heavy loading combinations. They are still used today primarily for pedestrian bridges.

4.5 Overview of Committees and Approval Process

The site development of the Fultonville Cemetery and Natural Burial Ground falls under two main public entities. The land is owned by the Village of Fultonville, of which the responsible parties are an elected Board of Trustees and Mayor. The Trustees and Mayor appoint a Board of Cemetery Commissioners biannually. The Commissioners oversee all cemetery business. Their actions are only binding if approved by the Trustees and Mayor. The final design for the site development will be presented to the Board of Cemetery Commissioners. Upon their acceptance, the plan must be then approved by the Board of Trustees and Village Mayor.

4.6 Summary

An economic, sustainable, and safe option exists to create a recreational trail and bridge through the Fultonville cemetery grounds. Through extensive research and data collection, an achievable option will be presented to the Board of Cemetery Directors.

5 Preliminary Results

5.1 Bridge Abutments

An initial site assessment was used to determine the needed dimensions of the bridge. Measurements of the existing abutments were recorded, as well as measurements over the stream from side to side. A visual assessment was also conducted to see if existing stone abutments would be able to hold the desired dead and live loads. The image below shows an example of measurements taken on site from a bird's eye view.

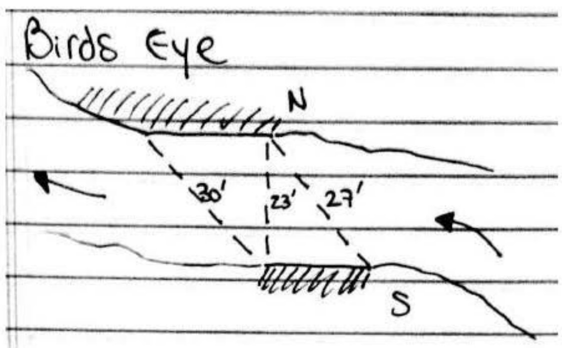

Figure 8: Bird's eye view of bridge site with measurements

Figure 9: Existing stone abutment

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From the image below one can see that the existing stone is still in place, but has been cracked and eroded away over time.

Figure 10: Existing abutment worn over time by cracks and erosion

The weathering of these stones makes the use of these abutments a judgment call based on safety.

5.2 Trail Assessment

An initial survey was conducted using *Runmeter*, a mobile application on the iPhone. The exported data did not meet the accuracy standards required for the project. This finding has necessitated a second site survey utilizing professional grade equipment.

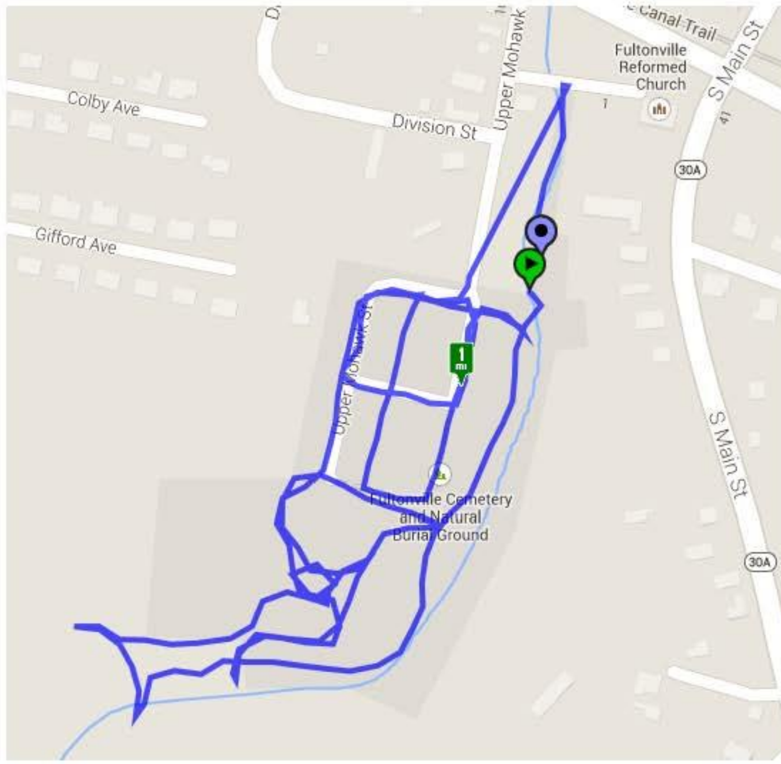

Figure 11: *Runmeter* GPS data of trail route

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6 METHODOLOGY

This section will outline how exactly we plan on coming up with our designs. Certain elements of this project will require site analysis and site-specific research, where other areas such as bridge design will require more outside data collection for applicable feasibility. We were able to utilize the data collected on our initial site assessment to analyze what else we needed to complete the design successfully.

6.1 Trail Design

In order to ensure the most accurate design for the trail, detailed site data must be collected. To collect more accurate data than was found from the initial site assessment, a second site visit will be done. During the second visit, we will use GPS and total station surveying equipment to gather the most accurate data we can. The data collected will be used in the selection of a trail route, including ingress, egress, and grading; and a hydrological analysis to determine necessary erosion control methods.

A finalized trail route will be determined primarily upon sponsor constraints. Unless determined to be necessary, the trail will follow previously established roadways, many of which have been completely reclaimed by nature. These roadways will be the focus of the site survey. Additionally, the sponsor has requested a trail width of approximately ten feet. Coupled with elevation data and trail use preference, this constraint will be used to determine a finalized grading plan including the selection of a trail surface. These determinations will be heavily based upon aesthetic appeal, consistency with the natural setting, and cost.

Utilizing rainfall data collected at a nearby weather station, hydrological flow calculations will be based on analysis of a 100-year design storm. These calculated flows will be employed in the designs of the erosion control plan.

6.2 Geographic Information Systems (GIS)

ESRI's ArcMAP will be used as the primary means of organizing all geospatial data collected and created throughout this project. Utilizing information available from the New York State GIS Clearinghouse and the Montgomery County, New York Real Property Tax Service, base maps will be constructed to include orthoimagery, hydrology, elevation, and approximate parcel outlines. Data collected in the field will increase the accuracy of the aforementioned features while also providing site-specific data that is not available at any repository.

6.3 Bridge Design

6.3.1 Intro

Several bridges will be designed using the Load and Resistance Factor Design (LRFD) method. The LRFD approach is less conservative than the Allowable Stress Design (ASD) method when the live loads are low. Pedestrian bridges have very low live loads so the more conservative ASD design would be less economical and not necessary for these designs.

6.3.2 Load Combinations

The bridge design will start with finding all possible loads associated with the bridge. These values can be used with the LRFD load combination equations to determine the total factored load. These calculations will be used in all of the bridge designs. The LRFD load combination equations from ASCE 7 are:

$1.4D$

$1.2D+1.6L+.5(Lr \text{ or } S \text{ or } R)$

$1.2D+1.6(Lr \text{ or } S \text{ or } R)+(.5L \text{ or } .8W)$

$1.2D+1.6W+.5L+.5(Lr \text{ or } S \text{ or } R)$

$1.2\pm1.0E+.5L+.2S$

$.9D\pm(1.6W \text{ or } 1.0E)$

D= Dead Load

L= Live Load

Lr= Roof Live Load

S= Snow Load

R= Rain Load

W= Wind Load

E= Earthquake Load

6.3.3 Abutments

The existing abutments must be analyzed to assess their current structural condition and to determine their capability for reuse. Since the tools and technologies needed to scientifically test the abutments are not readily available to our group, we visually investigated the structures.

Since safety is a top priority, our group has decided to use an alternative bridge support design to hold the bridge in place. The next step is to decide whether to use new concrete abutments in place of the old ones, or to use wooden posts of a prefabricated bridge. Deciding whether cast-in-place concrete or wooden posts are to be used is the next step. This depends on the type of bridge chosen, wooden prefabricated or a bridge that can be fastened to concrete abutments. Lastly, we will need to make sure the option chosen will be sustainable in the environment in which it will stand.

6.3.4 Wooden pedestrian

The first step in designing any bridge is determining the maximum load combination using the equations shown above. This is the loading that will be used to design every aspect of the bridge. The load will start at the deck of the bridge and be distributed through the entire bridge and down to the abutments.

The next step involves designing the members of the bridge. First the decking material is determined. Then the beam size will be chosen and a spacing will be determined. Then the girders will be designed. After that, connections to the girders will be designed based on the loading on each connection. Finally, the abutments will be designed that will support the entire bridge.

Figure 12: Example of a typical wooden pedestrian bridge

6.3.5 Prefab 1

Several companies will be considered to determine a possible prefabricated bridge design to test. We will have to compare requirements such as cost and aesthetics to determine which bridge will be used in the project. With these designs bridge abutments would be designed and then the chosen bridge would arrive at the site preassembled and dropped into place. Several possible companies are Pioneer Bridges, York Bridge Concepts, and Big R Bridge. These different companies use a variety of designs and materials such as wood and steel. Another possibility here would be to adapt one of the other design options for prefabrication. The wooden pedestrian bridge could be designed for this. However, a separate prefabricated bridge will still be evaluated to give more alternative designs.

Figure 13: Prefabricated bridge by Pioneer Bridges as it is shipped to the construction site

6.3.6 Flatcar Bridge

Flatcar railway cars are being used to create bridges. These flatcars can be designed to custom lengths to fit the desired span. Flatcars installed properly will provide a HS-25 load capacity rating. Custom concrete abutments can be installed as well. The image below shows a flatcar being used as a bridge:

Figure 14: Flatcar Bridge

The first step to determining if this would be a feasible option would be to determine the site specific loading conditions. Snow, wind, live, and seismic loads all apply to this site. The next step would be to determine the length of the flatcar we would need to have a bridge span from abutment to abutment. The following step is to design the connection between the flatcar and the abutments. Lastly, we will need to design, or order, handrails that are ADA compliant and factor them into the design. The figure below shows a flatcar with handrails and concrete abutments:

Figure 15: Flatcar pedestrian bridge

6.3.7 Whipple Truss Bridge Design

Our group will obtain the design plans from the Civil Engineers who worked on a Whipple Truss replica bridge in Buffalo, New York. We will modify the design to fit the new conditions, including loading, length, and size. The next step is to design the connection between the bridge and the abutments to ensure maximum safety. The last step will be to decide if the Whipple Truss Bridge will be prefabricated and brought in, or if it will be built on site.

6.4 Schedule

Table 2: Proposed Work Schedule for A Term, B Term and C Term

Task				A						B					C						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Proposal																					
Problem, Objective, Scope																					
Background																					
Capstone																					
Methodology																					
Final Proposal							10/15														
Site Visits																					
Preliminary Assessment																					
Survey																					
Analysis																					
Data organization																					
Bridge Design Analysis																					
Trail Data Analysis																					
Application of Evaluation																					
Final Report																					
Background																					
Methodology																					
Establish Designs																					
Determine Preferred Design/Recommendations																					
Final MQP Report																					2/26

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Appendix B – Precipitation Data

5-60 Minutes

2-year Event		25-year Event		100-year Event	
Time (min)	Intensity (in/hr)	Time (min)	Intensity (in/hr)	Time (min)	Intensity (in/hr)
5	3.72	5	6.05	5	8.02
6	3.44	6	5.57	6	7.36
7	3.24	7	5.23	7	6.89
8	3.09	8	4.97	8	6.54
9	2.97	9	4.77	9	6.27
10	2.87	10	4.61	10	6.05
11	2.73	11	4.39	11	5.78
12	2.62	12	4.21	12	5.56
13	2.52	13	4.06	13	5.36
14	2.43	14	3.93	14	5.2
15	2.36	15	3.82	15	5.06
16	2.26	16	3.68	16	4.88
17	2.18	17	3.56	17	4.73
18	2.11	18	3.46	18	4.59
19	2.04	19	3.36	19	4.46
20	1.98	20	3.28	20	4.35
21	1.92	21	3.2	21	4.25
22	1.87	22	3.13	22	4.16
23	1.83	23	3.06	23	4.08
24	1.79	24	3	24	4
25	1.75	25	2.95	25	3.93
26	1.71	26	2.9	26	3.87
27	1.68	27	2.85	27	3.81
28	1.65	28	2.81	28	3.75
29	1.62	29	2.77	29	3.7
30	1.6	30	2.73	30	3.65
31	1.56	31	2.67	31	3.58
32	1.52	32	2.61	32	3.51
33	1.48	33	2.56	33	3.44
34	1.45	34	2.51	34	3.38
35	1.42	35	2.46	35	3.32
36	1.39	36	2.42	36	3.27
37	1.36	37	2.38	37	3.22
38	1.34	38	2.34	38	3.17
39	1.31	39	2.3	39	3.12
40	1.29	40	2.26	40	3.08
41	1.27	41	2.23	41	3.04
42	1.25	42	2.2	42	3
43	1.23	43	2.17	43	2.96
44	1.21	44	2.14	44	2.92

45	1.19	45	2.11	45	2.89
46	1.17	46	2.08	46	2.85
47	1.15	47	2.05	47	2.82
48	1.14	48	2.03	48	2.79
49	1.12	49	2.01	49	2.76
50	1.11	50	1.98	50	2.73
51	1.09	51	1.96	51	2.71
52	1.08	52	1.94	52	2.68
53	1.07	53	1.92	53	2.66
54	1.05	54	1.9	54	2.63
55	1.04	55	1.88	55	2.61
56	1.03	56	1.86	56	2.59
57	1.02	57	1.85	57	2.56
58	1.01	58	1.83	58	2.54
59	1	59	1.81	59	2.52
60	0.99	60	1.8	60	2.5

1-48 Hours

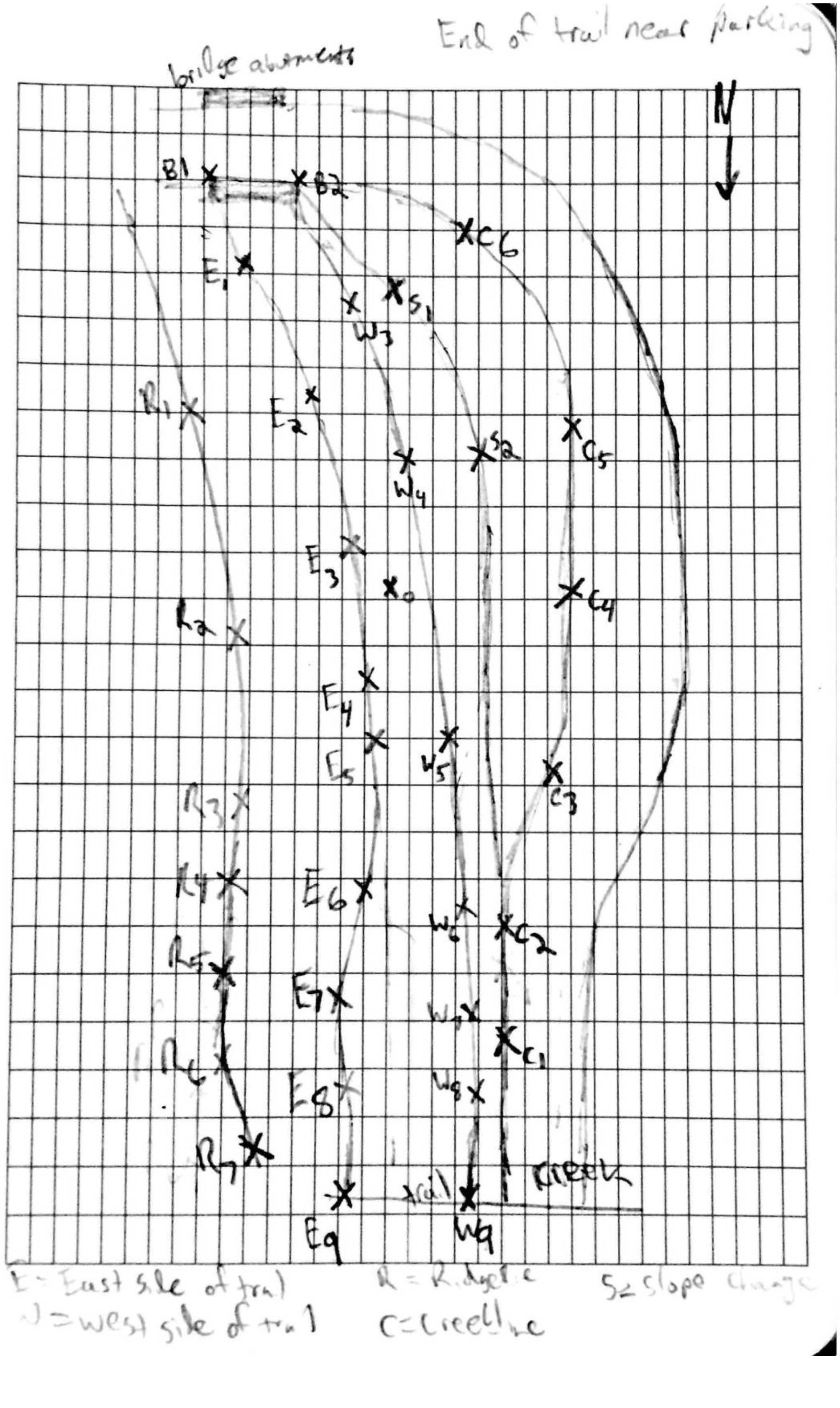
2-year Event		25-year Event		100-year Event	
Time (hrs)	Intensity (in/hr)	Time (hrs)	Intensity (in/hr)	Time (hrs)	Intensity (in/hr)
1	0.85	1	1.55	1	2.16
2	0.55	2	0.98	2	1.36
3	0.42	3	0.75	3	1.03
4	0.35	4	0.61	4	0.83
5	0.3	5	0.52	5	0.7
6	0.27	6	0.46	6	0.62
7	0.24	7	0.41	7	0.56
8	0.22	8	0.38	8	0.51
9	0.2	9	0.35	9	0.47
10	0.19	10	0.32	10	0.44
11	0.18	11	0.31	11	0.41
12	0.17	12	0.29	12	0.39
13	0.16	13	0.27	13	0.37
14	0.15	14	0.26	14	0.35
15	0.14	15	0.24	15	0.33
16	0.14	16	0.23	16	0.31
17	0.13	17	0.22	17	0.3
18	0.13	18	0.21	18	0.29
19	0.12	19	0.21	19	0.28
20	0.12	20	0.2	20	0.27
21	0.11	21	0.19	21	0.26
22	0.11	22	0.19	22	0.25
23	0.11	23	0.18	23	0.24
24	0.1	24	0.18	24	0.24
25	0.1	25	0.17	25	0.23
26	0.1	26	0.17	26	0.22
27	0.09	27	0.16	27	0.21
28	0.09	28	0.16	28	0.21
29	0.09	29	0.15	29	0.2
30	0.09	30	0.15	30	0.2
31	0.08	31	0.14	31	0.19
32	0.08	32	0.14	32	0.19
33	0.08	33	0.14	33	0.18
34	0.08	34	0.13	34	0.18
35	0.08	35	0.13	35	0.17
36	0.07	36	0.13	36	0.17
37	0.07	37	0.12	37	0.17
38	0.07	38	0.12	38	0.16
39	0.07	39	0.12	39	0.16
40	0.07	40	0.12	40	0.16

41	0.07	41	0.11	41	0.16
42	0.07	42	0.11	42	0.15
43	0.06	43	0.11	43	0.15
44	0.06	44	0.11	44	0.15
45	0.06	45	0.11	45	0.14
46	0.06	46	0.11	46	0.14
47	0.06	47	0.1	47	0.14
48	0.06	48	0.1	48	0.14

Appendix C – Survey Notes

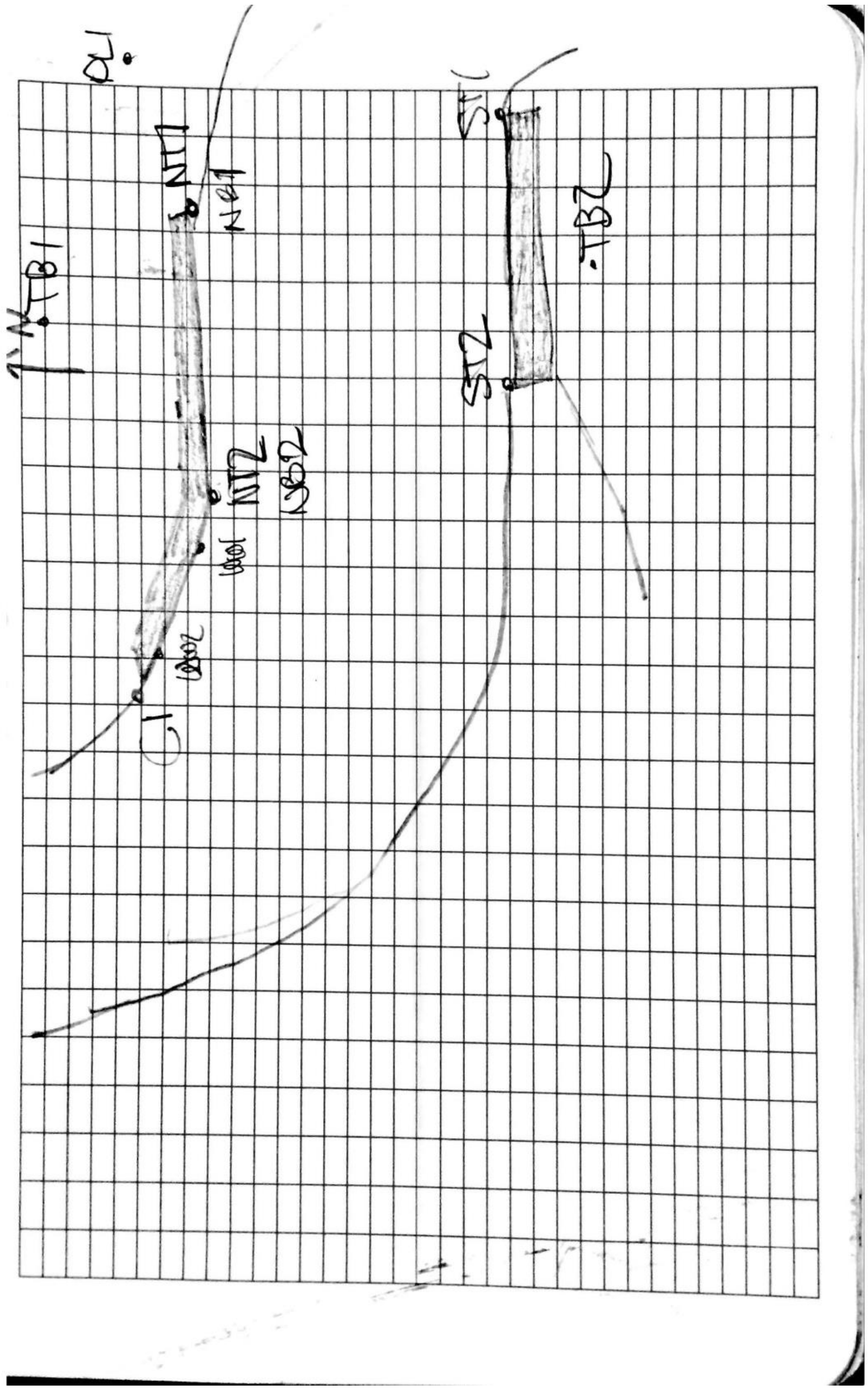
Setup 1 – Slope Retention

Pt.	Hz	Hz (Rad)	HD	h	x	y	z	Notes
TBM				0.000	0	0	100.000	
B1	97.35166667	1.699107116	87.149	9.355	11.15149898	86.43258802	109.355	
B2	105.6541667	1.844013077	82.940	9.180	22.37972188	79.86358149	109.180	
E1	95.775	1.671589091	75.582	10.503	7.605226287	75.1983993	110.503	
E2	99.66111111	1.739414525	72.582	5.541	12.1807334	71.55261322	105.541	
E3	76.14638889	1.3290052	9.898	1.423	-2.369997253	9.610073726	101.423	
E4	293.7316667	5.126584701	15.239	-1.970	-6.132993315	-13.95039476	98.030	
E5	297.3616667	5.189940153	32.042	-4.124	-14.72668569	-28.45723972	95.876	
E6	305.5258333	5.332431742	67.086	-8.791	-38.9816595	-54.59818329	91.209	
E7	308.4302778	5.38312386	96.759	-12.167	-60.14170149	-75.79762413	87.833	
E8	304.42	5.313131309	154.944	-16.374	-87.58286885	-127.8158215	83.626	
E9	297.7619444	5.196926318	266.581	-23.076	-124.1731641	-235.8950081	76.924	
W9	293.7658333	5.127181022	265.274	-23.198	-106.9053199	-242.778804	76.802	
W8	296.47	5.174377633	217.449	-21.830	-96.92336129	-194.6533576	78.170	
W7	296.6836111	5.178105851	157.116	-18.019	-70.55505147	-140.3831264	81.981	
W6	295.5266667	5.157913361	89.292	-11.410	-38.47870268	-80.57574514	88.590	
W5	289.6288889	5.05497772	29.337	-4.359	-9.855076268	-27.63217401	95.641	
W4	112.6441667	1.966011591	28.836	3.439	11.10205806	26.61313967	103.439	
W3	105.7041667	1.844885741	61.914	7.645	16.7582905	59.60287825	107.645	Last West
R1	65.88861111	1.149973203	54.149	26.633	-22.12051085	49.42466187	126.633	PL?
R2	8.602222222	0.150137101	38.008	21.652	-37.58043207	5.684996898	121.652	PL?
R3	334.8977778	5.84506888	75.419	19.100	-68.29585236	-31.99534515	119.100	
R4	325.5316667	5.681599403	109.014	10.018	-89.87540497	-61.69654592	110.018	
R5	315.7058333	5.510106259	134.174	0.424	-96.03689697	-93.69939539	100.424	
R6	308.2258333	5.379555631	166.300	-13.093	-102.9002299	-130.6416193	86.907	
R7	303.36	5.294630819	211.636	-17.364	-116.3781649	-176.7651527	82.636	
C1	290.9469444	5.077982129	148.452	-23.707	-53.07208079	-138.6410853	76.293	
C2	283.7394444	4.952187523	78.288	-20.211	-18.59394322	-76.0478548	79.789	
C3	257.2575	4.4899904	55.519	-16.722	12.24581257	-54.15163373	83.278	
C4	209.8502778	3.662578283	44.657	-14.642	38.73231197	-22.22736283	85.358	
C5	171.4194444	2.991833707	52.909	-13.008	52.31679336	7.894011213	86.992	
C6	147.6752778	2.577419821	62.407	-10.607	52.73586147	33.37008486	89.393	
S1	123.8144444	2.160969717	52.960	-2.138	29.47250965	44.00150878	97.862	
S2	178.3061111	3.112028715	23.241	-7.395	23.23084412	0.686995404	92.605	


End of trail near parking
bridge abutments
N
B1
B2
C6
E1
S1
W3
R1
E2
W4
S2
C5
E3
X0
C4
R2
E4
E5
W5
C3
R3
R4
E6
W6
C2
R5
E7
W7
C1
R6
E8
W8
R7
trail
creek
E9
W9
E = East side of trail
W = west side of trail
R = Ridgeline
C = Creekline
S = slope change

Setup 2 – Bridge Abutments

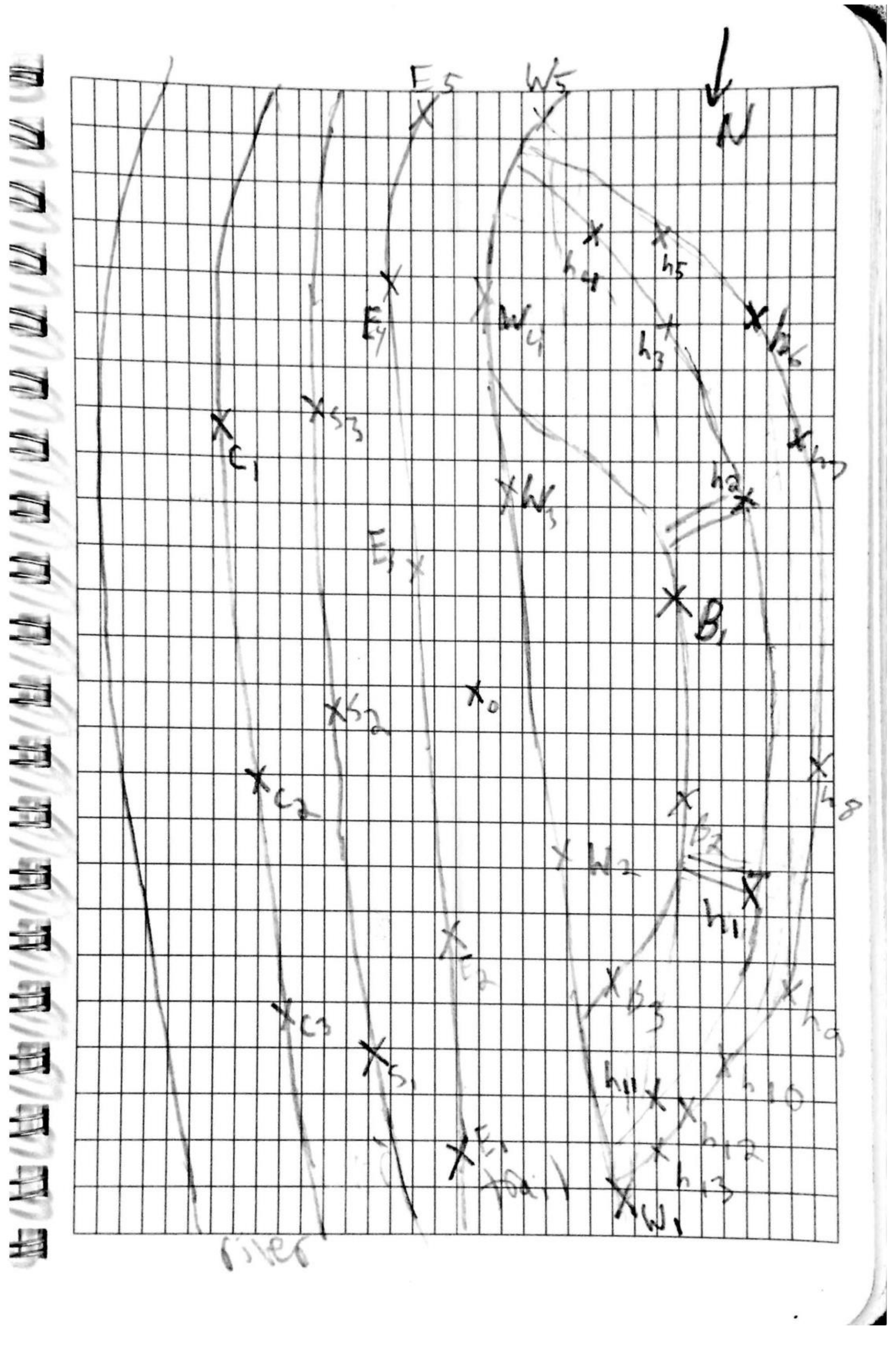
Pt.	Hz	HD	h	Abs. h	Notes
TBM			0.000	100.000	
NT1	30-16-47	35.534	-6.609	93.391	
NT2	12-01-57	41.410	-6.787	93.213	
WW1	7-14-56	43.364	-8.569	91.431	
WW2	358-46-46	56.307	-17.859	82.141	
C1	356-47-28	55.134	-22.030	77.970	
NB2	4-46-17	43.234	-20.077	79.923	
NB1	32-24-50	34.380	-15.827	84.173	
ST1	69-24-17	10.906	-3.502	96.498	
ST2	10-40-15	10.976	-2.925	97.075	



TB1
NT1
NT2
C1
ST1
ST2
TB2

Setup 3 – Stormwater Management

Pt.	Hz	Hz (Rad)	HD	h	x	y	z	Notes
TBM				0.000	0	0	100.000	
E1	135.3513889	2.362327383	58.997	3.037	41.97223962	41.46054884	103.037	
W1	125.4797222	2.190034297	57.963	3.062	33.64258262	47.20048733	103.062	
E2	134.6594444	2.350250674	23.342	0.170	16.40689113	16.60309873	100.170	
W2	118.2011111	2.062998568	23.837	0.511	11.26459997	21.00741194	100.511	
E3	283.5869444	4.949525896	14.184	-0.085	-3.332114267	-13.78705445	99.915	
W3	309.9363889	5.409410458	18.124	0.739	-11.63446135	-13.8967149	100.739	
E4	285.5775	4.984267645	42.036	3.075	-11.2884133	-40.49193773	103.075	
W4	297.4975	5.192310891	46.313	3.701	-21.38317105	-41.08106577	103.701	
E5	289.6236111	5.054885605	109.413	10.534	-36.74523514	-103.0581984	110.534	
W5	294.1516667	5.133915084	108.378	10.473	-44.34323213	-98.89119601	110.473	
B1	345.5747222	6.031416714	16.922	0.670	-16.38850602	-4.215560969	100.670	
B2	44.54777778	0.777505397	19.417	0.919	-13.83783043	13.621099	100.919	
B3	89.04555556	1.554138129	19.137	-0.735	-0.318773193	19.13434485	99.265	
H1	40.36583333	0.704516697	51.659	20.602	-39.36026599	33.45776057	120.602	
H2	351.1688889	6.129053342	53.630	24.135	-52.99422524	-8.233407017	124.135	
H3	323.7719444	5.650886456	62.204	21.330	-50.17816403	-36.76260969	121.330	
H4	312.5180556	5.454469041	75.888	18.664	-51.28681875	-55.93434336	118.664	
H5	326.5958333	5.700172615	98.323	31.495	-82.08081017	-54.13088704	131.495	
H6	340.7294444	5.946850664	112.868	41.182	-106.5440826	-37.24975013	141.182	
H7	359.1144444	6.267729447	101.412	41.249	-101.3998874	-1.567347286	141.249	
H8	26.10638889	0.455642442	88.659	36.526	-79.61387706	39.01344462	136.526	
H9	45.68416667	0.797339124	94.192	32.490	-65.80375909	67.39434809	132.490	
H10	54.92138889	0.958559066	85.385	28.423	-49.07074168	69.87603692	128.423	
H11	73.90138889	1.289822558	36.762	12.811	-10.1937851	35.32041038	112.811	
H12	99.95166667	1.744485676	57.375	9.302	9.9153958	56.51172932	109.302	
H13	119.3213889	2.082551104	60.497	6.187	29.62586287	52.74651892	106.187	
S1	160.9927619	2.809853767	38.994	-8.773	36.86794728	12.69986219	91.227	
S2	210.7963889	3.679091037	16.197	-6.716	13.91309613	-8.292681415	93.284	
S3	275.0027778	4.799703924	39.132	-3.933	-3.412468475	-38.98292553	96.067	
S4	234.7130556	4.096515617	53.659	-7.956	30.99728265	-43.8001912	92.044	Creek
S5	203.7769444	3.55657862	39.005	-8.320	35.69433277	-15.72592232	91.680	Creek
S6	169.5730556	2.959608142	47.539	-9.871	46.75396327	8.603687549	90.129	Creek


E5
W5
N
h4
h5
E4
W4
h3
h6
C1
S3
h7
h2
W3
E3
B1
S2
h8
C2
W2
h1
E2
C3
S1
h11
h10
E1
h12
h13
W1
tail
river

Appendix D – Redi-Rock Gravity Wall Vendor Analysis

Analysis of Redi Rock wall

Input data

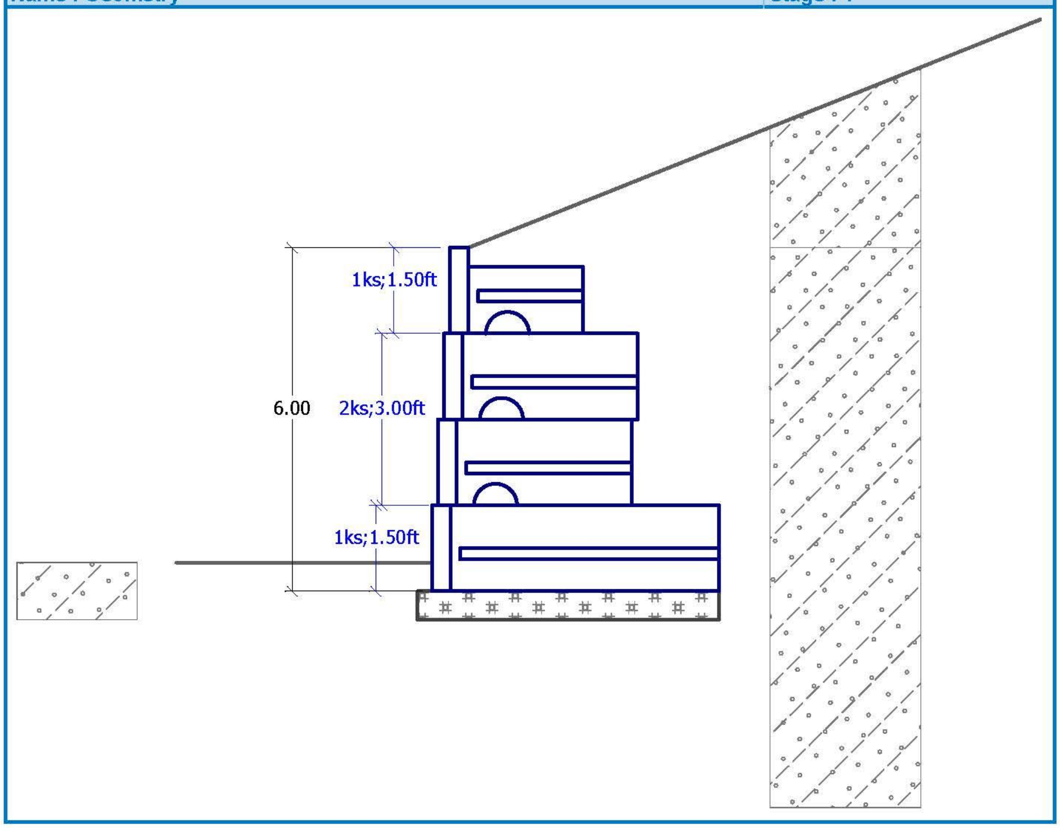
Project

Task : Redi-Rock Wall - Preliminary Calculation
Descript. : H=6.0, LL=0 psf, BS= 2.5H:1V
Author : JWB
Customer : RRI - Preliminary Design Charts
Date : 9/27/2008

Geometry

No. group	Description	Count	Setback s [in]
1	Block 60	1	1.25
2	Block 41	2	1.25
3	Block 28	1	1.25

Name : Geometry	Stage : 1



Base

Geometry

Upper setback a_1 = 0.25 ft
Lower setback a_2 = 0.25 ft

Height h = 0.50 ft
Width b = 5.25 ft

Material
Soil creating foundation - Crushed Stone #57
Soil bearing capacity R_d = 15000.0 psf

Soil parameters

Silty Sand

Unit weight :	γ =	120.0 pcf
Stress-state :	effective	
Angle of internal friction :	φ_{ef} =	28.00 °
Cohesion of soil :	c_{ef} =	0.0 psf
Angle of friction struc.-soil :	δ =	18.30 °
Saturated unit weight :	γ_{sat} =	130.0 pcf

Crushed Stone #57

Unit weight :	γ =	130.0 pcf
Stress-state :	effective	
Angle of internal friction :	φ_{ef} =	40.00 °
Cohesion of soil :	c_{ef} =	0.0 psf
Angle of friction struc.-soil :	δ =	26.00 °
Saturated unit weight :	γ_{sat} =	140.0 pcf

Geological profile and assigned soils

No.	Layer [ft]	Assigned soil	Pattern
1	-	Silty Sand	

Terrain profile

Terrain behind construction has the slope 1: 2.50 (slope angle is 21.80 °).

Water influence

Ground water table is located below the structure.

Resistance on front face of the structure

Resistance on front face of the structure: at rest
Soil on front face of the structure - Silty Sand
Soil thickness in front of structure h = 1.00 ft
Terrain in front of structure is flat.

Analysis settings

Active earth pressure calculation - Coulomb (CSN 730037)
Passive earth pressure calculation - Caqout-Kerisel (CSN 730037)
Analysis carried out according to classical theory (safety factor)

Safety factor for slip = 1.50
Safety factor for overturning = 1.50
Factor of safety for bearing capacity = 2.00

Hinge Height Concept is not considered in analysis.
MRF (block - soil found.) μ = 0.70
Masonry friction reduction factor base-soil μ = 1.00

Verification No. 1

Forces acting on construction

Name	F_{hor} [lbf/ft]	App.Pt. Z [ft]	F_{vert} [lbf/ft]	App.Pt. X [ft]	Design coefficient
Weight - wall	0.0	-2.76	3083.4	2.31	1.000
FF resistance	-31.8	-0.33	0.1	0.12	1.000
Weight - earth wedge	0.0	-5.01	897.4	3.57	1.000
Active pressure	1798.1	-2.68	1261.4	4.82	1.000

Verification of complete wall

Check for overturning stability
Resisting moment M_{res} = 16395.1 lbfft/ft
Overturning moment M_{ovr} = 4803.2 lbfft/ft

Safety factor = 3.41 > 1.50
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force H_{res} = 2787.4 lbf/ft
Active horizontal force H_{act} = 1766.3 lbf/ft

Safety factor = 1.58 > 1.50
Wall for slip is SATISFACTORY

Forces acting at the centre of footing bottom
Overall moment M = 2169.1 lbfft/ft
Normal force N = 5242.3 lbf/ft
Shear force Q = 1766.3 lbf/ft

Overall check - WALL is SATISFACTORY

Bearing capacity of foundation soil

Forces acting at the centre of the footing bottom

Numbe	Moment [lbfft/ft]	Norm. force [lbf/ft]	Shear Force [lbf/ft]	Eccentricity [ft]	Stress [psf]
1	2169.1	5242.3	1766.3	0.41	1185.4

Spread footing verification

Input data

Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [psf]	γ [pcf]	γ_{su} [pcf]	δ [°]
1	Silty Sand		28.00	0.0	120.0	67.5	18.30
2	Crushed Stone #57		40.00	0.0	130.0	77.5	26.00

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

Silty Sand

Unit weight : γ = 120.0 pcf
Angle of internal friction : φ_{ef} = 28.00 °
Cohesion of soil : c_{ef} = 0.0 psf
Saturated unit weight : γ_{sat} = 130.0 pcf

Crushed Stone #57

Unit weight : γ = 130.0 pcf
Angle of internal friction : φ_{ef} = 40.00 °
Cohesion of soil : c_{ef} = 0.0 psf
Saturated unit weight : γ_{sat} = 140.0 pcf

Foundation

Foundation type: strip footing

Depth from ground surface h_z = 6.50 ft
Depth of footing bottom d = 1.00 ft
Foundation thickness t = 0.50 ft
Incl. of finished grade s_1 = 0.00 °
Incl. of footing bottom s_2 = 0.00 °

Unit weight of soil above foundation = 120.0 pcf

Geometry of structure

Foundation type: strip footing

Overall strip footing length = 10.00 ft
Strip footing width (x) = 5.25 ft
Column width in the direction of x = 0.33 ft
Volume of strip footing = 2.63 ft^3/ft

Inserted loading is considered per unit length of continuous footing span.

Material of structure

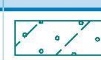
Unit weight γ = 130.0 pcf
Analysis of concrete structures carried out according to the standard ACI 31802.

Concrete : Concrete ACI
Compressive strength f_c = 3000.0 psi
Tensile strength f_r = 410.8 psi
Elastic modulus E_c = 3122.0 ksi

Longitudinal steel : A615/40
Tensile strength f_y = 40000.0 psi
Elastic modulus E_s = 29000.0 ksi

Transverse steel: A615/40

Geological profile and assigned soils

No.	Layer [ft]	Assigned soil	Pattern
1	-	Silty Sand	

Load

No.	Load new	Load change	Name	Type	N [lbf/ft]	M_y [lbfft/ft]	H_x [lbf/ft]
1	YES		LC 1	Service	4586.0	1285.9	-1766.3
2	YES		LC 2	Design	4586.0	1285.9	-1766.3

Analysis settings

Type of analysis - Analysis for drained conditions
Analysis of vertical bearing capacity - NCMA
Analysis of settlement - Do not calculate
Bounding of influence zone - by percentage of Sigma,Or
Coeff. of bounding of influence zone = 10.00 %
Analysis carried out according to classical theory (safety factor)

Factor of safety - vertical bearing capacity = 2.00
Factor of safety - horizontal bearing capacity = 1.50

Masonry friction reduction factor μ = 1.00

Verification No. 1

Analysis carried out with automatic selection of the most unfavourable load cases.
Computed self weight of strip foundation G = 341.3 lbf/ft
Computed weight of overburden Z = 295.3 lbf/ft

Vertical bearing capacity check

Shape of contact stress : rectangle
Parameters of slip surface below foundation:
Depth of slip surface z_{sp} = 7.78 ft
Length of slip surface l_{sp} = 22.76 ft

Design bearing capacity of found.soil R_d = 6199.9 psf
Extreme contact pressure σ = 1181.8 psf

Factor of safety = 5.25 > 2.00
Bearing capacity in the vertical direction is SATISFACTORY

Horizontal bearing capacity check

Earth resistance: not considered
Friction angle foundation-footing bottom ψ = 28.00 °
Cohesion foundation-footing bottom a = 0.0 psf

Horizontal bearing capacity R_{dh} = 2776.9 lbf
Extreme horizontal force H = 1766.3 lbf

Factor of safety = 1.57 > 1.50
Bearing capacity in the horizontal direction is SATISFACTORY

Bearing capacity of foundation is SATISFACTORY

Dimensioning No. 1

Forces acting on construction

Name	F_{hor} [lbf/ft]	App.Pt. Z [ft]	F_{vert} [lbf/ft]	App.Pt. X [ft]	Design coefficient
Weight - wall	0.0	-2.57	2742.2	2.02	1.000
FF resistance	-8.0	-0.17	0.0	0.00	1.000

Name	F_{hor} [lbf/ft]	App.Pt. Z [ft]	F_{vert} [lbf/ft]	App.Pt. X [ft]	Design coefficient
Weight - earth wedge	0.0	-4.51	897.4	3.32	1.000
Active pressure	1593.7	-2.49	1193.7	4.55	1.000

Table of utilization of individual rows of blocks

Numbe of block	Height [ft]	Overturning [%]	Slip [%]
1	0.00	42.68	83.78
2	1.50	47.43	13.70
3	3.00	28.48	8.42
4	4.50	17.71	4.93

Block with max. utilization No. 1

Check for overturning stability:

Resisting moment M_{res} = 13936.0 lbfft/ft
Overturning moment M_{ovr} = 3965.1 lbfft/ft

Safety factor = 3.51 > 1.50

Joint for overturning stability is SATISFACTORY

Check for slip:

Resisting horizontal force H_{res} = 2838.9 lbf/ft
Active horiz. force H_{act} = 1585.7 lbf/ft

Safety factor = 1.79 > 1.50

Joint for verification is SATISFACTORY

Verification of bearing capacity of soil:

Maximum stress σ = 1171.5 psf
Bearing capacity of footing material R_d = 15000.0 psf

Safety factor = 12.80 > 2.00

Footing bearing capacity is SATISFACTORY

Slope stabilty analysis

Results (Stage of construction 1)

Analysis 1

Circular slip surface

Slip surface parameters							
Center :	x =	-1.39	[ft]	Angles :	α_1 =	-23.61	[°]
	z =	13.87	[ft]		α_2 =	72.48	[°]
Radius :	R =	21.14	[ft]				
The slip surface after optimization.							

Slope stability verification (Bishop)

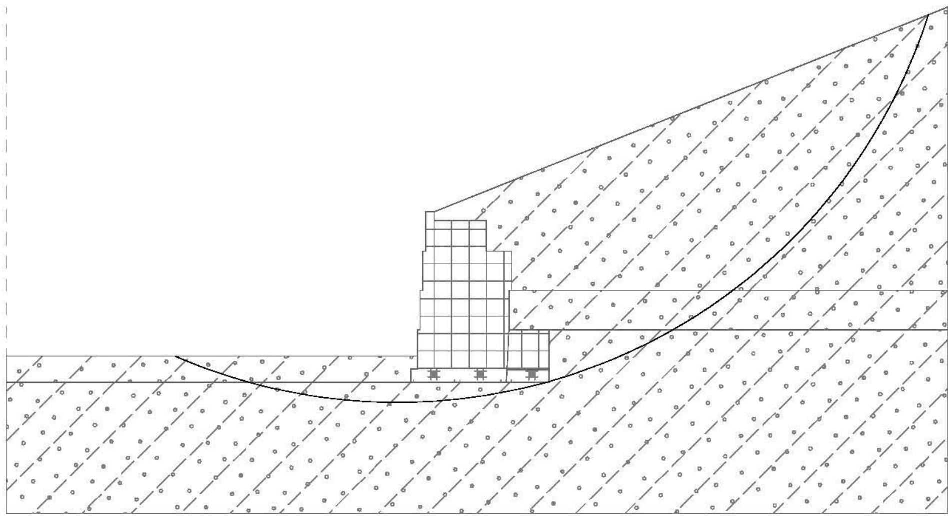
Sum of active forces : F_a = 6789.2 lbf/ft
Sum of passive forces : F_p = 9061.6 lbf/ft

Sliding moment : M_a = 143540.1 lbfft/ft
Resisting moment : M_p = 191584.9 lbfft/ft

Factor of safety = 1.33 > 1.30

Slope stability SATISFACTORY

Name : Analysis	Stage - analysis : 1 - 1



Appendix E – Evaluation Analysis Results

Surfacing Material – Gravel

Criteria	Weight Factor	Score					Weighted Score
		1	**2**	**3**	**4**	**5**	
Construction Cost High-Low	2					5	10
Lifetime Cost High-Low	1				4		4
Constructability Low-High	2				4		8
Safety Low-High	2					5	10
Environmental Impact High-Low	2			3			6
Aesthetic Appeal Low-High	1			3			3
					Total Score		**41**

Surfacing Material – Oyster Shells

Criteria	Weight Factor	Score					Weighted Score
		1	**2**	**3**	**4**	**5**	
Construction Cost High-Low	2	1					2
Lifetime Cost High-Low	1				4		4
Constructability Low-High	2				4		8
Safety Low-High	2					5	10
Environmental Impact High-Low	2			3			6
Aesthetic Appeal Low-High	1					5	5
					Total Score		**35**

Surfacing Material – Wood Chips

Criteria	Weight Factor	Score					Weighted Score
		1	**2**	**3**	**4**	**5**	
Construction Cost High-Low	2				4		8
Lifetime Cost High-Low	1			3			3
Constructability Low-High	2				4		8
Safety Low-High	2				4		8
Environmental Impact High-Low	2				4		8
Aesthetic Appeal Low-High	1				4		4

Total Score	**39**

Stormwater Management – Stone Culvert

Criteria	Weight Factor	Score					Weighted Score
		1	**2**	**3**	**4**	**5**	
Construction Cost High-Low	2				4		8
Lifetime Cost High-Low	1			3			3
Constructability Low-High	2			3			6
Safety Low-High	2				4		8
Environmental Impact High-Low	2				4		8
Aesthetic Appeal Low-High	1				4		4

Total Score	**37**

Stormwater Management – Retention Basin

Criteria	Weight Factor	Score 1	2	3	4	5	Weighted Score
Construction Cost High-Low	2		2				4
Lifetime Cost High-Low	1				4		4
Constructability Low-High	2				4		8
Safety Low-High	2					5	10
Environmental Impact High-Low	2			3			6
Aesthetic Appeal Low-High	1	1					1
					Total Score		**33**

Stormwater Management – Belgard Turfstone

Criteria	Weight Factor	Score 1	2	3	4	5	Weighted Score
Construction Cost High-Low	2				4		8
Lifetime Cost High-Low	1					5	5
Constructability Low-High	2					5	10
Safety Low-High	2					5	10
Environmental Impact High-Low	2					5	10
Aesthetic Appeal Low-High	1					5	5
					Total Score		**48**

Slope Retention – Gravity Wall

Criteria	Weight Factor	Score					Weighted Score
		1	2	3	4	5	
Construction Cost High-Low	2		2				4
Lifetime Cost High-Low	1				4		4
Constructability Low-High	2		2				4
Safety Low-High	2				4		8
Environmental Impact High-Low	2			3			6
Aesthetic Appeal Low-High	1				4		4
					Total Score		**30**

Slope Retention – Timber Terraces

Criteria	Weight Factor	Score					Weighted Score
		1	2	3	4	5	
Construction Cost High-Low	2			3			6
Lifetime Cost High-Low	1			3			3
Constructability Low-High	2			3			6
Safety Low-High	2			3			6
Environmental Impact High-Low	2				4		8
Aesthetic Appeal Low-High	1				4		4
					Total Score		**33**

Slope Retention – Vegetation

Criteria	Weight Factor	Score					Weighted Score
		1	**2**	**3**	**4**	**5**	
Construction Cost High-Low	2				4		8
Lifetime Cost High-Low	1					5	5
Constructability Low-High	2					5	10
Safety Low-High	2			3			6
Environmental Impact High-Low	2					5	10
Aesthetic Appeal Low-High	1					5	5
					Total Score		**44**