Final Design Report

Team 01: The Par-fect Stream

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Engr 340 Senior Design Project

Calvin College

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Abstract

Calvin College's engineering program requires seniors to work on a design project for their capstone. Team 01 chose to work on reducing the flooding problem in Indian Trails Golf Course, a project presented by Professor Julie Wildschut. The following report examines the feasibility of the design of alternative processes for reducing flooding. The design alternatives consist of a series of rain gardens, stream restoration, a stream divergent structure, and expanded wetlands.

Currently, the back nine of Indian Trails Golf Course has regular flooding on hole 11 and 12. The flooding leaves sediment on the course requiring higher maintenance and reduces the quality of the holes. Erosion on the banks of the creek is another effect of the flooding, reducing the useable land for golfing. Part of the problem is the backup at the culvert leading into the golf course that increases the water level. There was recent reconstruction of the golf course, they put in a new bridge and left the remains of an old bridge. This creates an obstacle for the flow of water, creating unnecessary damage to the banks.

The design plan that Team 01 has decided to go with is three rain gardens, with the biggest rain garden being located at the south end of the portion of Indian creek that runs through Indian Trails Golf Course. Stream restoration will also be conducted, along the North and East portion of the creek. Team 01 decided against the stream divergent structure and expanded wetlands due to the budget of the project. The project is receiving all funding through the EPA's Great Lakes Restoration Initiative Grant.

Team 01 is working closely with Plaster Creek Stewards at Calvin College, under the guidance of Professor Julie Wildschut and Professor Leonard De Rooy.

Team 01's end goal is to provide a plan that will prevent further erosion and flooding on the back nine of Indian Trails Golf Course. Team 01 will do this by developing plans to be kept on file by the city for when they are ready to begin construction. The plans will include HEC-RAS and HEC-HMS models along with a 3-D model of the proposed design.

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1. Introduction

1.1 Calvin College Engineering Program Senior Design Capstone Course

Calvin College is a Liberal Arts college located in Grand Rapids, MI. Calvin offers a 4-year engineering degree that is accredited by the Accreditation Board of Engineering and Technology (ABET). A graduate would receive a Bachelor's of Science in Engineering (BSE) degree with a concentration in one of the four disciplines: chemical engineering, civil and environmental engineering, electrical and computer engineering, or mechanical engineering.

Senior Design is the capstone class taken in the final year in the BES program. The class combines the engineering design process with a Christian reformed worldview into a project, to teach Christian professionalism.

1.2 Team members

Team 01 is the Par-fect stream. They are comprised of four Calvin College civil and environmental engineering students. A picture of Team 01 is shown below in Figure 1.

Figure 1: Team 01, The Par-fect Stream: (L to R) Heidi Boeve, Ben VanDyk, Joe Jackson, and Kyle VanDeWeert

1.2.1 Heidi Boeve

Heidi is an engineering major with a civil and environmental concentration from Wyoming, Michigan. She has interned at Exxel Engineering, Inc. for the past two years. At Calvin, she is involved with the Society of Women Engineers, Calvin's Women Rugby Club, American Society of Civil Engineers, and the Snow Sports Club. She will be graduating in May 2018 and is looking for a job where she can utilize her skills, preferably in site development and planning.

1.2.2 Joe Jackson

Joe Jackson is a Senior Civil/Environmental major from Eugene, Oregon. He likes spending his free time in the outdoors with friends or playing tennis. Joe spent his last summer interning with Prein & Newhof here in Grand Rapids. This internship gave him experience working with the survey crew, the smoke testing crew, and different on-site inspectors. After graduation, he is looking to work for an engineering firm that values sustainability and serving the city it resides in.

1.2.3 Kyle Van De Weert

Kyle Van De Weert is a senior Civil and Environmental Engineering major from Wyoming, Michigan. He was a part of Calvin College's soccer program during his freshman year and enjoys being outdoors. During the summers of 2016 and 2017, Kyle interned for the City of Wyoming's Engineering Department where he inspected and designed many public construction projects ranging from road resurfacing, water mains replacement, and detention ponds improvements. Kyle is interested in pursuing a career in project management or site development.

1.2.4 Ben VanDyk

Ben VanDyk is a Senior Civil and Environmental Engineering major. He is from Chilliwack, British Columbia. Ben likes to spend his time outdoors, playing soccer, skiing, and hiking. Ben has been an intern at Vriesman and Korhorn Civil Engineering in Byron Center, MI since May 2016. He will be working for Atkins Global in Atlanta, GA following graduation.

1.3 Project Description

1.3.1 Location

The Indian Trails Golf Course (ITGC) is located in Grand Rapids, Michigan on the Northeast corner of Kalamazoo and 28th Street (Figure 2). Team 01's focus is on Indian Creek, a tributary to Plaster Creek. Indian Creek runs through the golf course between holes 11 and 12 in the Southeast corner. Stream restoration will start after the East bridge and continue west until it reaches the tree line just north of Hole 11. The proposed rain garden locations will vary based on soil map and hole locations, blending seamlessly into the existing greenery.

Figure 2: Site location relative to Calvin College (Google Maps)

1.3.2 Current Conditions

Indian Trails Golf Course is experiencing flooding and erosion. Flooding occurs during moderate to heavy rainfall due to excessive amounts of stormwater runoff from neighboring watersheds. The watershed that flows through Indian Creek is roughly 1000 acres of mostly residential neighborhoods. High and fast waters are the main cause of erosion between the two tree lines. The flooding also causes large amounts of debris to make its way onto the green, which drastically increases the amount of maintenance the course needs. The worst-case scenario that has been documented for flooding is during the end of the winter season during snow melt. Figure 3 shows water puddling after a rain event in October.

Figure 3: Hole 11 after an October rain event

1.3.3 Client

The primary client for this project is the City of Grand Rapids. The Indian Trails Golf Course (Figure 4) is on city land, and the final design will be reviewed by the city. The secondary client for this project is the Indian Trails Golf Course. Lance Climie is our primary contact at the golf course. Mr. Climie is the general manager of the golf course and is very familiar with the flooding that has been occurring for the past couple of years.

Figure 4: Indian Trails Golf Course Logo

1.3.4 Partners

Plaster Creek Stewards (PCS, Figure 5) is a collaboration of Calvin College faculty, staff, and students. Professor Julie Wildschut is the project engineer for PCS, and is working with Team 01. Their mission is to restore the health and beauty of the Plaster Creek watershed. PCS has been able to provide valuable research and data from the creek. They have done similar projects in the Plaster Creek watershed, such as a bioswale project at Calvin College's nature preserve. PCS handles most of the direct contact with the client.

Figure 5: Plaster Creek Stewards Logo

1.3.5 Project Scope

This design project is focused on controlling water flow through Indian Creek. After a rain event, the amount of stormwater is significantly higher than the stream is designed to handle. The area of the stream between holes 11 and 12 is where Team 01's project is concentrated, where erosion has been the most severe. When first taking a tour of the golf course, Professor Wildschut pointed out on the stretch flowing East to West that the bank has eroded back an entire foot on each side since last year. Along with flooding and erosion, the stream has large amounts of debris, which greatly contributed to the extra water flooding onto the cart path. This large amount of debris that finds its way into the stream is a product of the gradual erosion which Team 01's stream restoration is aimed at fixing. The design will comprise of three rain gardens and stream restoration. With the resources provided by Julie Wildschut, the team will also record the depth of the stream during the design. The main concerns that Mr. Climie (client) expressed was the budget for the project and what parts of the green he was willing to use to help remedy the erosion. Due to this constraint, the flow divergent structure and expanded wetlands alternative has been eliminated from the scope of this project.

2. Project Overview

2.1 Team Organizations

2.1.1 Roles of Team Members

To manage time appropriately the team has designated roles to certain aspects of the project. The time keeper keeps track of the meeting minutes. The manager keeps track of due dates and organizes meeting times. The webmaster maintains and updates the project website. The designer is in charge of the HEC-RAS and HEC- HMS modeling. The advisor is a resource to the team and helps maintain the deadlines and timeframe of the project. The mentor is another resource to the team who is more involved in the project, and who the team consults with on the project details. A chart of the assignment of roles is shown below in Table 1.

Table 1: Assignment of Roles

Role	Assigned to
Time keeper	Joe Jackson
Manager	Heidi Boeve
Webmaster	Ben VanDyk
Designer	Kyle Van De Weert
Advisor	Leonard De Rooy
Mentor	Julie Wildschut

Team meetings are set by the manager during class times or through instant messaging. Most communication between the four team members is done through these methods. Team meetings are held on a weekly basis on Wednesdays from 3:30PM to 6:00PM in the Calvin Engineering Building. Additional meetings times are created depending on deadlines and is discussed in more detail below. Meetings first start with the purpose of the meeting, then roles are assigned to the required tasks for that meeting, and work is then started on these tasks. If necessary, meetings end with any additional assignment of tasks, discussion of the timeframe of deadlines, and the planning of later meeting times.

Project documents are kept in two locations. On a shared OneDrive folder and in the Calvin Engineering Shared folder (S:\Engineering\Teams\Team01). Working documents with multiple users, such as reports, are stored in the teams shared online OneDrive folder. These files will be moved to the Calvin Engineering Shared folder upon completion. All other files are located in the Shared Team 01 folder.

2.1.2. Meeting Minutes

Meeting Minutes are kept at each meeting using the template shown in Figure 6.

[Organization Name]

Meeting Minutes

November 9, 2017

Present:	Ben, Heidi, Joe, and Kyle
Next meeting:	11/12/17, 6:30, Engineering Building

4. **Announcements**

   [List all announcements made at the meeting. For example, new members, change of event, and so forth.]

5. **Discussion**

   [Summarize the discussion for each issue, state the outcome, and assign any action items.]

6. **Roundtable**

   [Summarize the status of each area/department.]

Figure 6: Meeting Minute Template

2.2. Schedule

Senior Design is broken into two semesters. In the first semester, Team 01 gathered information concerning the alternative designs: rain gardens, stream restoration, divergent structure, and expanded wetlands. Team 01 then used rain data and watershed modeling to find how much stormwater their design would need to remove. Next, the team developed a preliminary design for stream restoration in HEC-RAS, and a preliminary design for rain gardens in HEC-HMS. January and February were spent designing and refining the preliminary plans resulting in final models that could be tested.

Most of the work in March was done in AutoCAD Civil3D, manipulating locations and contours to meet our design criteria. By the end of March, the team had finished their designs, and began creating construction plans for the three rain gardens and for stream restoration.

2.2.1. Schedule Overview

An overview of the scheduling timeline can be shown in the Gantt chart found in Appendix A.

2.2.2. Conflicts

The Plaster Creek Stewards informed Team 01 at the beginning of March that ITGC has postponed their project indefinitely. Unfortunately, Team 01 had no say in this decision. Due to this, the Plaster Creek Stewards will keep construction plans on file for submittal to the City of Grand Rapids when the project gets approved. Once the plans are submitted and approved by the city and the golf course, a city stormwater permit as well as a Land Use Development Services (LUDS) permit must both be granted before construction is permitted.

Team 01 has also encountered difficulty in collecting data through the level logger installed at the North end of the culvert. The level logger has been washed out before, and must be physically taken out of the creek to transfer the data it collects to a computer. Debris is constantly building up around this area and requires regular maintenance in order to keep the level logger accessible. Another conflict affecting the project's design is the amount of land available. To meet the goal of reducing 1.25 million gallons of stormwater runoff per year (overall GLRI grant), Team 01 will need as much area as possible for the rain garden design. ITGC wants to maintain all 18 holes, so it can only offer to shorten Hole 11 by giving up a small portion of the green.

The final conflict that initially slowed the progress of the design process is the software used. Plaster Creek Stewards provided all of their past information collected around the site in HEC-RAS, HEC-HMS, and GIS. These three software programs are still new to Team 01, and has required extra time to learn how to properly use and sort through the data given. Significant time has been spent sorting through what information is beneficial for the project since it was presented in various formats.

2.3 Budget

The budget will dictate which parts of the design get implemented. Lance Climie will make the final decision on which design alternatives suggested in Team 01's solution fit the golf course's needs, after the plans are approved by the City of Grand Rapids.

2.3.1 Calvin Budget

The budget for this project will be for $0. Team 01 does not expect to spend any money during the process.

2.3.2 Client Budget

The budgeting for this project is part of the Great Lakes Restoration Initiative (GLRI) Action Plan II which awarded $178,837 to Plaster Creek Stewards. The Indian Trails Golf Course location was allocated $45,000 for constructions costs, $12,000 for engineering costs, and $12,000 for plants. Team 01's project is anticipating lots of plants being used as part of the stream restoration as well as being an integral part of the rain garden design. The $12,000 for engineering costs acts as a safety net for things beyond the in-house ability between Team 01 and the Plaster Creek Stewards. This included the additional cost of obtaining a survey of the site by Spicer Engineering. The money will also be used in running the bid process and any other final design plans that lay outside of the scope of the class design project.

2.4 Method of Approach

2.4.1 Research & Communication Methods

Team 01 used the Hekman library database to access textbooks on water resource engineering to aid in their research of design alternatives. The Plaster Creek Stewards provided helpful links to County data, a web soil survey, and the Low Impact Development Manual for Michigan. Most of the cost estimates were made using data from the National Resources Conservation Service which had costs for similar projects in West Michigan.

Communication between the team members was mainly over Facebook messenger and in weekly meetings. Communicating with the client was all handled through Plaster Creek Stewards. Team 01's main contact at PCS was Professor Julie Wildschut, who emailed the Team back and forth answering any questions and concerns throughout the design process. Team 01 would also meet in person with Professor Wildschut every other week to stay updated on the changing requirements for the project and keep her updated.

2.4.2 Design Methods

The design methods used in this project are intended to follow that of normal industry. HEC-HMS and HEC-RAS models of the existing stream from Professor Wildschut were modified and updated to better reflect the existing conditions of the stream. Then design solutions will be modeled using the existing stream models in these programs. Finally, with the hydraulics in place, the site layout will be created in AutoCAD. An overview of the process can be seen below in Figure 7.

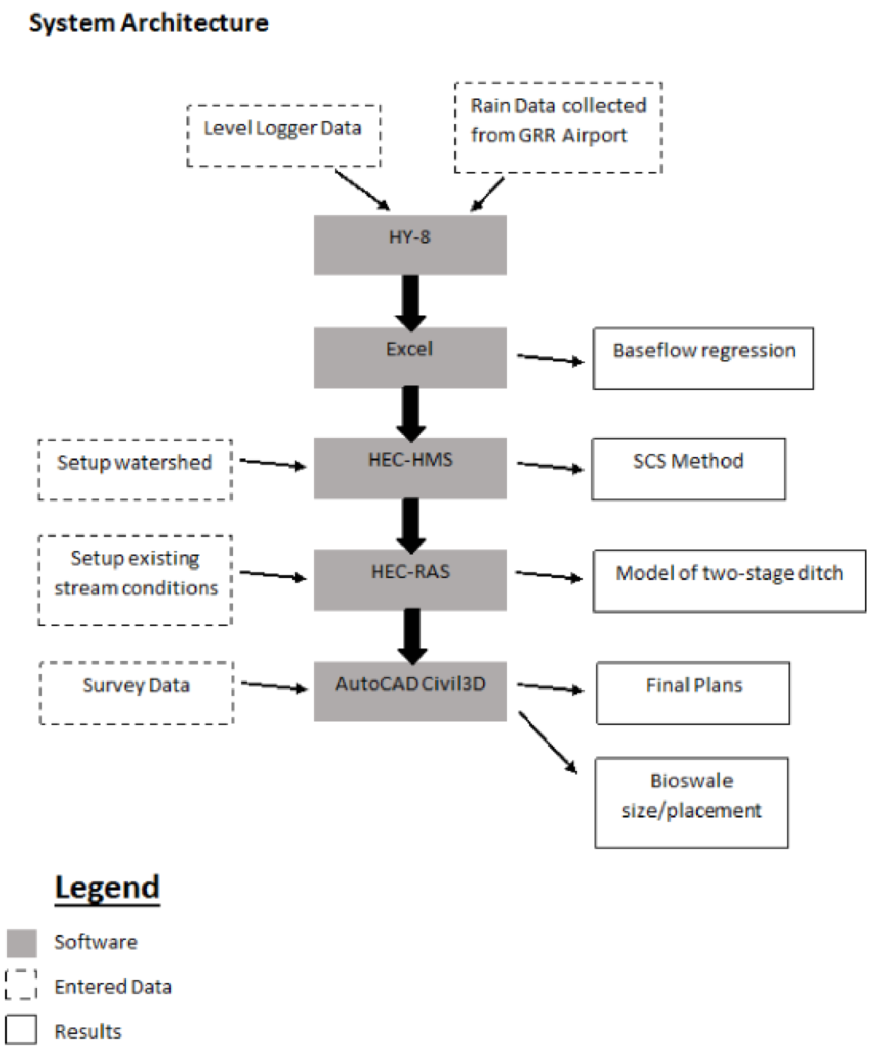

Figure 7: Design Process

3. Requirements

For Team 01 to successfully design and complete this project, certain requirements must be followed. These requirements were given to team 01 by either the client, the GLRI grant, or Calvin College senior design. With the combination of requirements listed below and data collected, team 01 has solved the problems presented to them from the varies sources.

3.1 Plaster Creek Stewards Recorded Data

The stream through Indian Trails Golf Course has been studied previously and various data has been recorded by members of the Plaster Creek Stewards. By partnering with Professor Wildschut, Team 01 has access to this information to aid in the design process. The files received include: a culvert analysis for the culverts in the project area, stream cross sections, a partial HEC-HMS model of the stream, a partial HEC-RAS model of the stream, and an ArcGIS shapefile of the contributing watershed.

3.2 Research/Data Analysis

In addition to the data provided by Plaster Creek Stewards, Team 01 has also conducted in depth research on design solutions and alternatives using the Hekman Library's resources. This research has included text on bioswales, rain gardens, stream restoration, wetlands, and diversion structures. The rain garden was made priority, since Professor Wildschut as well as the Indian Trails Golf Course have agreed that it will be an essential part of the flooding solution.

3.3 Open Communication

Since the design project was a concern of the Plaster Creek Stewards before Team 01 took it upon themselves to design the solution, continual email conversations and meetings have been key. Professor Wildschut has been the main contact for Team 01 and handles all communication with Lance Climie.

3.4 Great Lakes Restoration Initiative Grant

The Great Lakes Restoration Initiative Grant (GLRI) is a grant provided by the EPA working inside of the Indian Creek and Plaster Creek Watersheds. The outlined goals in the GLRI grant for the Indian Trails Golf Course site was to reduce stormwater runoff from the golf course, restore native vegetation habitats, and create a stable flood bench for Indian Creek. Team 01 made these outlined goals of the grant constraints and requirements for their project.

3.5 Class Based Requirements

Team 01 had to comply with requirements presented to them by the Calvin College Senior Design Class. PPFS, Final Report, design notebooks, team website. Some of these requirements included designing and implementing a major project, understanding budgeting of a major project, applying engineering sciences to their project, and having an ability to communicate truthfully and effectively the results of their project. Some examples of required material were the PPFS, Final Report, and team website.

4. Research

4.1 Bioswale/Rain Gardens

A bioswale is a swale with vegetation that acts as an infiltration basin and detention pond during storm events. Along with these water management features, the bioswale will act as a bio-filter to improve water quality as shown in Figure 8 below.

Figure 8: Bioswale filtration mechanism, Oregon DEQ - Dennis Jurries, PE (2003))

Bioswales are also low maintenance and provide a natural approach to pollutant removal (Jurries, 51). The bioswale preforms differently depending on the shape, soil, intended retention time, and type of vegetation. It has been suggested that a trapezoidal cross section is the most effective shape, which Team 01 has implement into their design. The most effective bioswales have longer retention times and higher infiltration rates. To reduce the velocity of the water it is recommended to use dormant vegetation (Juries, 53). Indian creek has high levels of pollutants making the creek a health risk so the removal of pollutants was something that team 01 implemented into their design.

Rain gardens are similar to bioswales since they are both heavily vegetated areas that act as detention ponds that temporarily hold and infiltrate stormwater runoff. However, the primary difference between the two is what made Team 01 choose rain gardens for their design. Rain gardens infiltrate the stormwater runoff, keeping it all on site which meets the Team's goal. Bioswales slowly release the water back into the creek once the flooding has subsided.

4.2 Stream Restoration

Stream restoration is implemented in streams that display signs of high velocity flows, flooding issues, and/or erosion. The National Oceanic and Atmospheric Administration (NOAA) places requirements on stream restoration such that any activity in the streams shouldn't put physical barriers that prevent or impede fish from passing. NAOO has many suggested techniques for stream restoration and erosion control. The first potential technique that Team 01 researched was the technique called Cross Veining. This is a technique that places stones across the stream in a "C" or "V" shape to direct the water towards the center of the stream and away from the stream bank in order to reduce erosion. A second technique that could have been implemented would be a technique called "J-Hook". This technique places rocks in a "J" shape on the bank where the hook protrudes out into the stream. This would channel the flow of water away from the eroding stream banks and into the center of the stream. A third technique would be to use step pools. This technique is a series of pools with rocks that mimic staircase to slow down stream flow.

4.3 Michigan Department of Environmental Quality

The DEQ regulates all construction within the 100-year floodplain. When designing a rain garden for Indian Trails Golf course, the important details to the DEQ are the outlet structure and the size of the overall rain garden. The outlet will be designed within the DEQ requirements for peak discharge since it will be flowing back into Indian Creek, and the rain garden itself will need to be under the maximum size allowance set by the DEQ. Many of the permits required to go through with the design implementation would be acquired through the DEQ, however the Plaster Creek Stewards have agreed to handle the permitting process.

4.4 Indian Trails Past Data

Indian Creek flooded the Indian Trails Golf Course on April 10, 2017. The water level raised to the elevation of 690, this is 7.25 feet above normal water level. The flooding due to the storm resembled less than a 2-year rain event in the HEC-HMS model. The sediment leftover after the flood caused more maintenance on holes 11 and 12. The money spent on the maintenance could have gone to other areas if the creek was designed for the contributing watershed.

5. Preliminary Design

5.1 Design Criteria

While understanding the requirements put in place by Calvin College Engineering, Team 01 has also determined three design norms that will be used to help shape the project. These design norms were chosen to incorporate Team 01's faith as well as being ethical in the design. A decision matrix was also made to help team 01 determine the best alternative for the project. Table 2 shows the decision matrix with explanatory text following.

Table 2: Decision Matrix of Alternatives

Factors	Cost		Effectiveness		Land Usage		Aesthetics		
Weights	5		9		8		7		
	Score	Total	Score	Total	Score	Total	Score	Total	Total Score
Rain Gardens	8	40	6	54	9	72	8	56	222
Divergent Structure	3	15	7	63	7	56	3	21	155
Expanded Wetlands	2	10	7	63	2	16	4	28	117
Two-Stage Ditch	6	30	7	63	9	72	6	42	207
Stream Restoration	7	35	6	54	9	72	8	56	217

Cost: The cost involved with design and construction of the alternative

Effectiveness: How effective the alternative is at removing stormwater and meeting goals

Land Usage: The amount of land needed to implement the alternative

Aesthetics: The physical appeal of the alternative after construction and restoration

5.1.1 Design Norms

Team 01 understands that their Christian faith plays a crucial role in their design and testing. The team has chosen the appropriate design norms that best glorify God through their project which were stewardship, transparency, and humility as the building blocks for the design.

Stewardship: To incorporate Team 01's faith into their design, they chose stewardship as their first design norm. In many sections of The Bible God tells His people to be care takers of the earth. Team 01 will incorporate stewardship into their design through the materials chosen and the integrity of the design.

Transparency: The design team understands that the golf course is on public property which means they must be transparent on what they are doing with the property. This transparency will include communication with the golf course as well as communication with all parties involved in the design.

Humility: Team 01 understands that they don’t have all the answers and that there will be questions that can’t be answered without the help of peers. Humility will play a big role in the design to create proposed solutions to the problems at hand. Through humility, Team 01 will be able to understand the problem presented better and have better design solutions.

5.2 Design Alternatives

5.2.1 Rain Gardens

Team 01 will use rain gardens to help reduce stormwater runoff. The main use of rain gardens is to hold runoff and allow for longer infiltration times which will lower the flooding elevation of the stream. The rain gardens would be constructed throughout the golf course in the natural drainage paths to better control the runoff.

5.2.2 Stream Restoration

Team 01 has also designed stream restoration techniques. This design implements techniques discussed early in this document such as the cedar log vanes and a two-stage ditch. These techniques would lower the chances of erosion during flooding events. The log vane would be located on the bottoms of the banks downstream of the new bridge and help control erosion. The two-stage ditch technique would be constructed downstream of the existing bridge to help lower the velocity of the water and add storage volume before it reaches the main bend in the stream located just after the bridge.

5.2.3 Flow Divergent Structure to Existing Wetlands

A flow divergent structure was proposed to be constructed upstream of the existing bridge. The flow divergent structure would divert part of the flow from the main channel to a secondary channel that would lead to the existing wetlands. This would reduce the amount and velocity of water flowing through the stream during rain events and in turn reduce the erosional properties of the stream.

5.3 Design Decisions

Team 01 constructed to the decision matrix based off the constraints determined from the client and the GLRI Grant. The decision matrix was then used to help determine which design options were most feasible. Team 01 determined that a score of 200 or more would mean that the design option would be feasible for their project. A divergent structure and expanding the wetlands was not feasible due to the high construction costs and lack of available land. From the design matrix, it was determined that rain gardens in conjunction with stream restoration and a two-stage ditch would be the best approach for solving the problem while still conforming to the constraints of the project.

6. Design Approach

6.1 LGROW and Excel

The Lower Grand River Organization of Watersheds (LGROW) is an organization that handles the watersheds of the lower portion of the Grand River that drains into Lake Michigan. There are many sub-watersheds within this area, including team 01's project watershed. Team 01 received an excel sheet created by Professor Hoeksema and Fishbeck Thompson Carr & Huber (FTCH) that calculates pre and post development storage volumes required for watersheds in the LGROW areas. Team 01 entered values into the excel sheet that were specific for their project location. These values included the hydrologic soil group, SCS curve number, area, and land use for existing and proposed conditions. The excel sheet then calculated the 2-year, 24-hour runoff volume for pre-development(existing) conditions. After designing a rain garden into the post-development conditions and entering in the associated values which included area of the rain garden, available water storage volume, and design infiltration rate. The excel sheet calculated the total volume of stormwater runoff removed for the post-development conditions. Team 01 compared the pre and post-development volumes to validate the proposed design.

The Soil Conservation Service (SCS) developed the SCS Runoff Curve Number method to estimate rainfall excess of a specified rain event. Team 01 used the SCS method to determine the amount of runoff that would occur during a 2-year 24-hour storm. The team entered in the values for rainfall, potential maximum retention, initial abstraction, and runoff curve number specific for their site location to calculate the total runoff. Once the total runoff was calculated, Team 01 could use it to validate the time of concentration in their HEC-HMS computer model.

6.2 HY-8

HY-8 is a culvert modeling program designed by the Federal Highway Administration. Team 01 created a model of the 28th street culvert in HY-8. Then running the program with hypothetical flow rates, the program determined their corresponding headwater elevations. These values where then exported to Microsoft Excel.

6.3 HEC-HMS

Hydrologic Modeling System (HEC-HMS) is a program designed by the US Army Corps of Engineers. This program allows hydrologic processes of dendritic watersheds systems to be modeled and tested. Team 01 decided to use this software as it was familiar, and an existing model was already created. Using the existing model given to Team 01 from PCS as a start, Team 01 modified and changed multiple parameters to better represent the watershed. Data for these geometric inputs were processed from ArcGIS and Microsoft Excel. Ponding factors at two nearby culverts were considered from data sourced from HY-8 and the Kent County Drain Commission (KCDC). The initial HEC-HMS model can be seen in Figure 9 below.

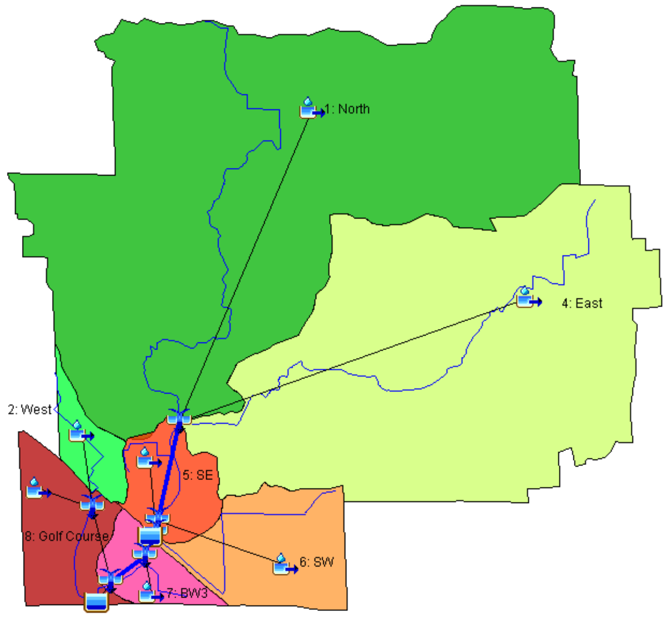

Figure 9: Initial HEC-HMS model

6.3.1 Model Validation and Optimization

PCS have placed stream level loggers throughout the watershed. These level loggers record the water pressure every 5 minutes. Team 01 replaced one of these loggers early October in 2018. The level logger for the ITGC site is located approximately a foot in front of the 4'x4' box culvert under 28th street. Through data processing using an Excel script written by Professor Hoeksema for the PCS flow rates were determined from the level logger. The hypothetical flow rates through the culvert and their corresponding headwater elevations from HY-8 were related to and interpolated with the water surface elevations determined from the level logger pressures. This flow rate was then used to calibrate the HEC-HMS model. Team 01 chose a rain event on April 10, 2017 to calibrate their model which was the closest to 2-year 24-hour storm event for the area.

The flow rates from the level logger where then combined with the corresponding rain data from the Grand Rapids airport and inputted into HEC-HMS. From there, using the HEC-HMS optimization feature, the model was optimized to best match what was observed on April 10, 2018. The parameters that varied were: time of concentration, initial abstraction, and the runoff curve number for each subbasin. After calibrating, the 2-year 24-hour storm was run, and the peak flow rate was determined. Calibrating the model before computing these peak flows allows for a more accurate depiction of the watershed. The peak flow rate was then used as an input into

HEC-RAS to model the corresponding water surface elevation to determine flood levels. The observed and modeled hydrographs can be seen in Figure 10 below.

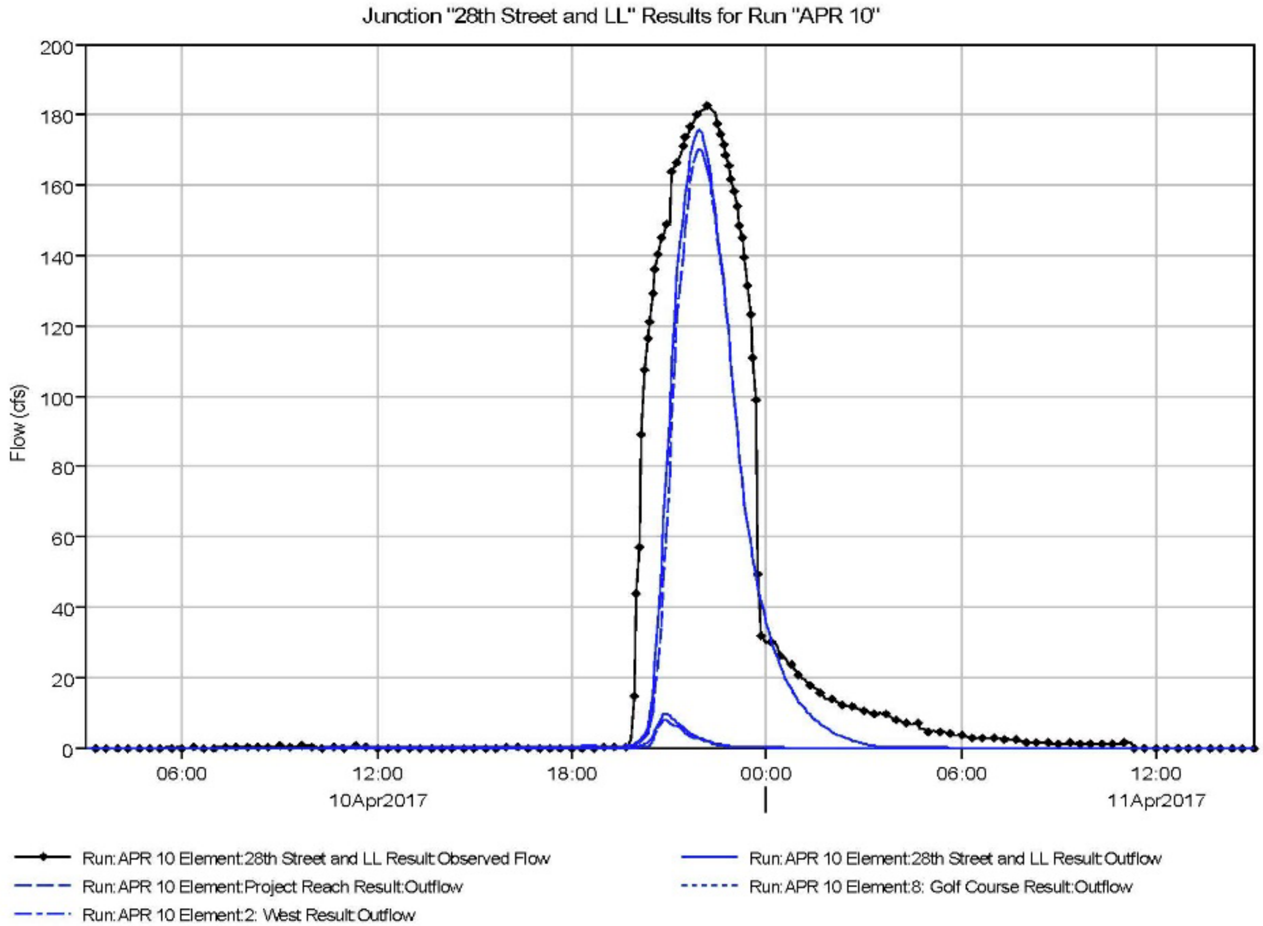

Figure 10: Observed and Modeled Hydrograph for storm event on April 10, 2017.

6.3.2 Rain Garden Model

Using the calibrated model as a base, a new model was created with the addition of 3 rain gardens. These rain gardens were modeled as reservoir features with spillway outlets. The size of these rain gardens were determined using AutoCAD and inputted into HMS using an area-elevation table. Similarly, this model was run and the resulting peak flow was determined, and inputted into HEC-RAS. This model can be seen below in Figure 11.

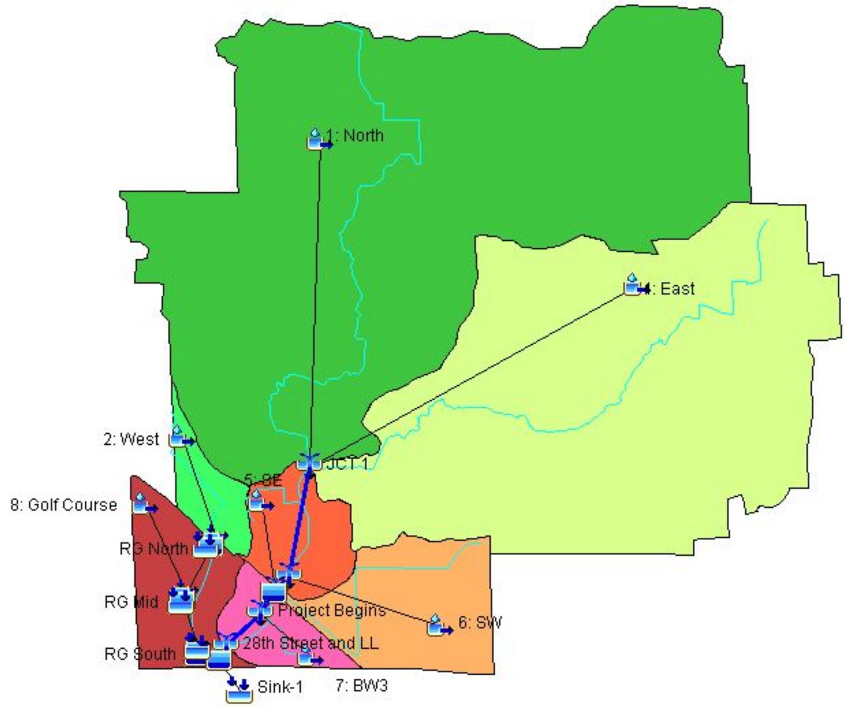

Figure 11: Watershed model with Rain Gardens

6.4 HEC-RAS

HEC-RAS is a program that models the hydraulics of the water flow through natural rivers. The program was created by the U.S. Army Corps of Engineers and is open for the public to use. Team 01 used HEC-RAS to model in 1D, Indian Creek that runs through the southeast part of the golf course. HEC-RAS allows Team 01 to see the water surface elevation during a rain event. HEC-RAS was also used by team 01 to model their proposed two stage ditch design in Indian Creek and view corresponding water surface elevations during specific rain events. Figure 12 below shows a profile view of the stream and the different water surface elevations based on their corresponding rain events shown in Table 3.

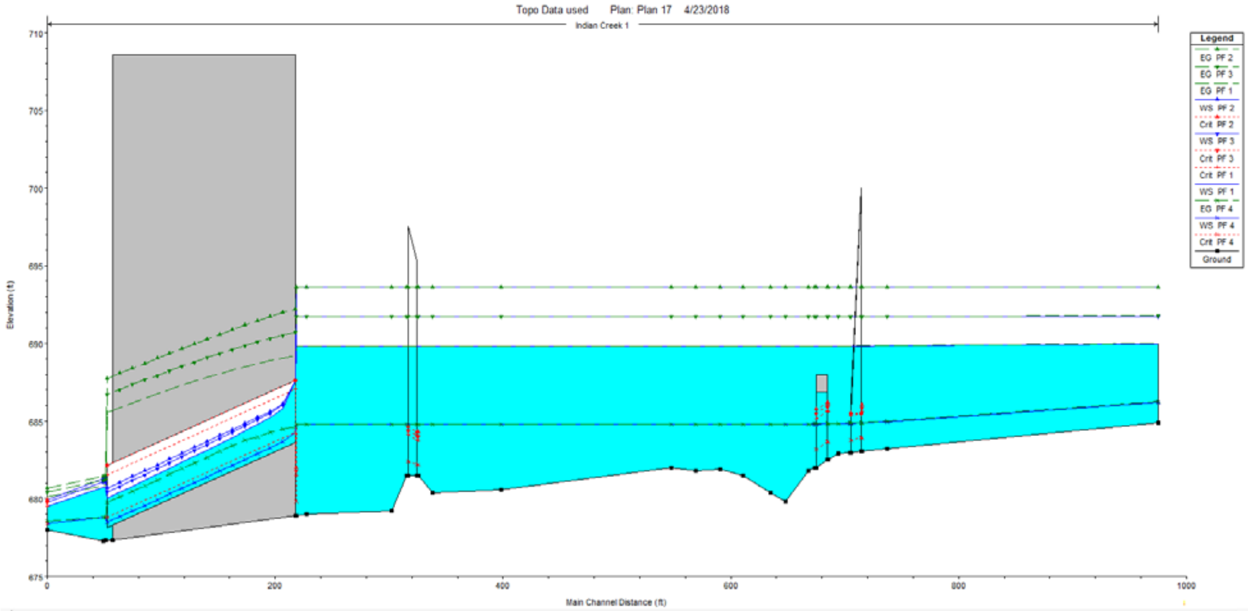

Figure 12: HEC-RAS Model of Different Water Elevations

Table 3: Water Profiles and their Corresponding Flow Rates

Profile Name	Flow Rates (cfs)	Rain Event
PF1	143.7	April 10
PF2	215.8	2-yr, 24-hour Existing Conditions
PF3	183.5	2-yr, 24-hour Proposed Conditions
PF4	12.25	baseflow

HEC-RAS allows Team 01 to model the existing and the proposed cross sections on the river for certain rain events. The proposed conditions include the teams two-stage ditch design. In Figure 13 below, the different water surface levels can be seen at Cross-section 595 for the 2-yr, 24-hour existing conditions rain event

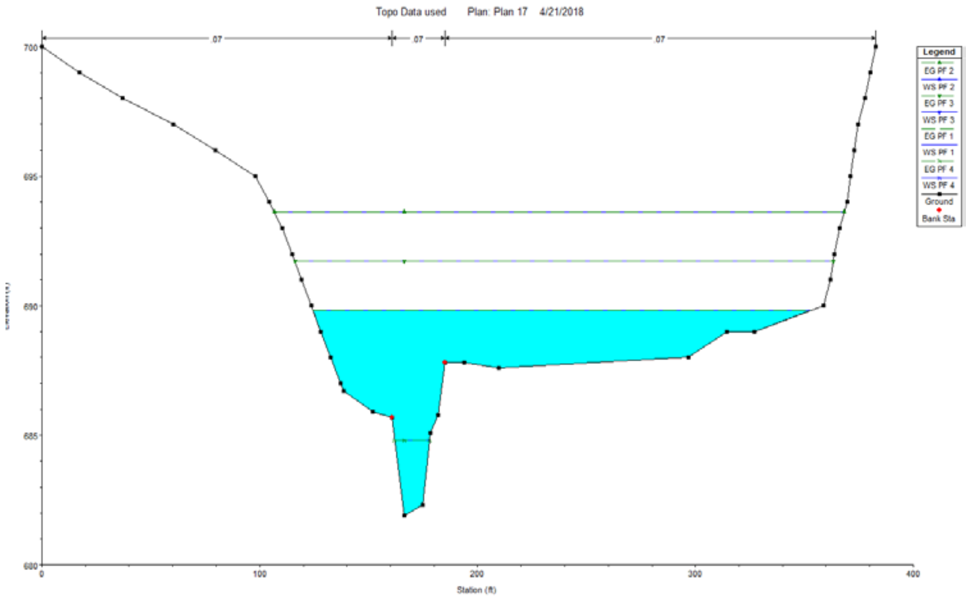

Figure 13: Water Surface Elevations for Existing Conditions

Team 01 then simulated a 2-year, 24-hour proposed condition rain event and compared the results (Figure 14). The results showed there was a reduction in the flood elevation level from the existing to proposed conditions which validates that the team 01's design helps to reduce stormwater runoff.

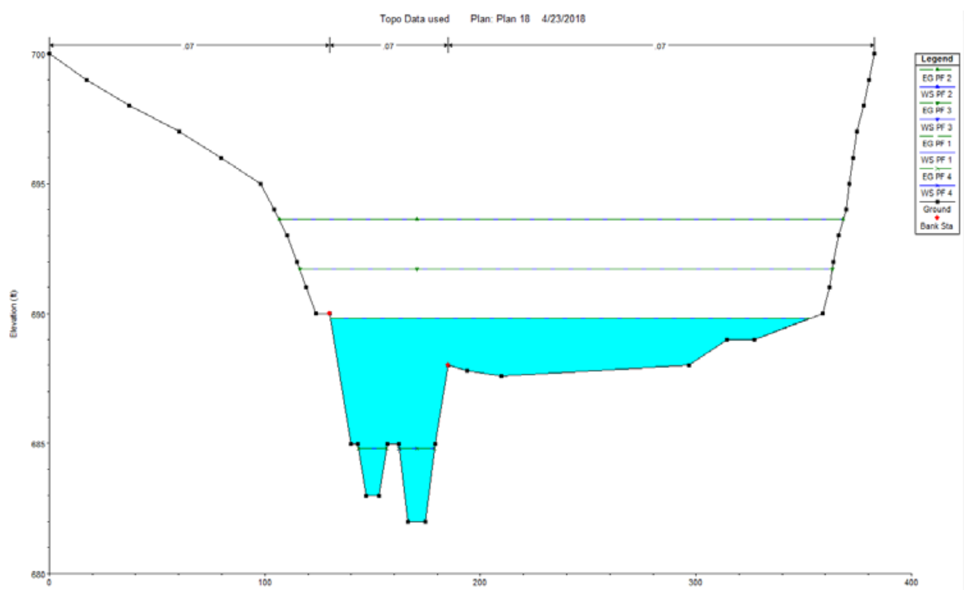

Figure 13: Water Surface Elevations for Proposed Conditions

Team 01 included a comparison of the proposed and existing cross sections to show the added 1500 CF of storage volume that the two-stage ditch will provide doing storm events (Figure 15).

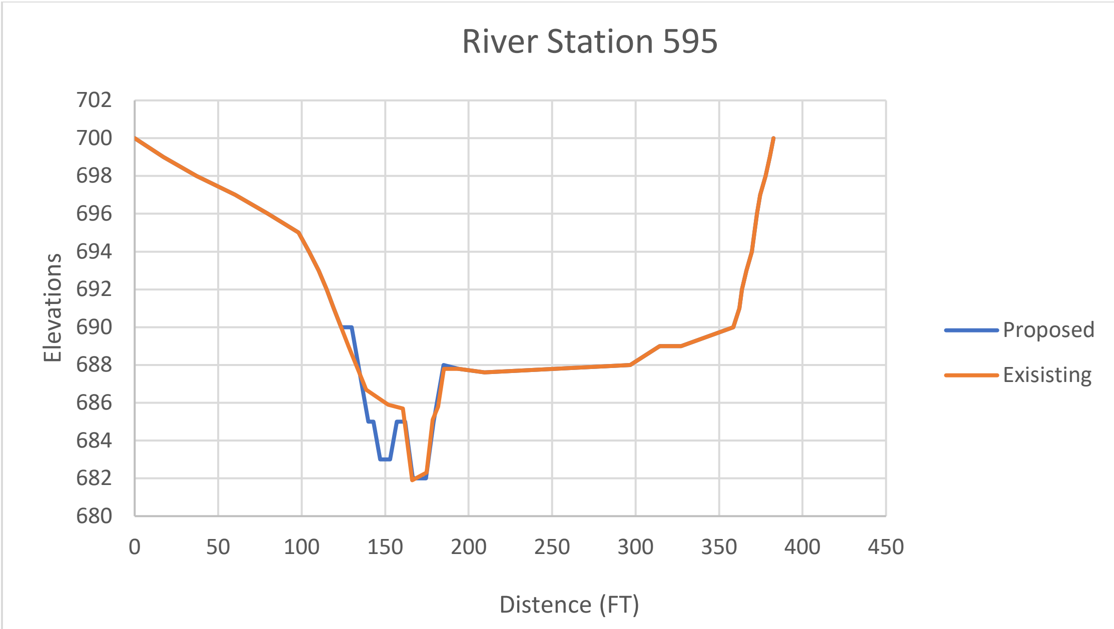

Figure 14: Proposed and Existing Cross Sections

Team 01 conducted research and calculations when designing the stream restoration so as to insure they were in compliance with local regulations. Using the Adjusted Curve Regional Bankfull width, depth, and area curves for the Southern Lower Michigan Ecoregion, Team 01 could calculate the corresponding required values. Table 4 shows the bankfull calculated values.

Table 4: Bank Full Requirements

	Calculated	**Proposed**	**Explanation**
Area (ft^2)	11.7	57	= 0.5*(9*3) + (10*3) + 0.5*(9*3)
Width (ft)	9.6	22	The existing creek bottom width is 8 ft. Team 01 decided to widen it by 2 ft creating a 10 ft bottom for decreased velocities. The side slopes are 3:1 due to the presents of Loamy sands on the bank.
Depth (ft)	2.8	3	Normal water depth is 2.8 ft and so the proposed bankfull depth needs to be at least that deep.

Normally, a two-stage ditch has two grass benches at the bankfull height. Team 01's design alters this design due to existing utilities located on the south side of the stream. On the north side of the stream, Team 01 has proposed to place the designed two-stage ditch. The ditch is designed to divert water out of the main stream during rain events to help reduce erosive velocities. This design will also add storage volume to help lower the flood elevation level.

To help reduce the erosive properties of the stream,Tteam 01 designed the banks at a 3:1 slope. This slope is specific to the loamy sands found on the golf course. However, Team 01 still recommends reinforcing the bank walls where there is constant water flowing with a fiber blanket and cedar logs. Vegetation will be planted along the banks of the stream because the roots of the plants will help stabilize the banks and combat the erosion.

6.5 AutoCAD Civil3D

Auto-CAD Civil 3D is a program for civil engineers to aid them in designing 3D surfaces. Team 01 is using Civil 3D to design the proposed rain gardens, stream restoration, and construction plans.

The team decided to design three rain gardens. The North rain garden is 1.5 feet deep with a storage volume of 7000 CF. This rain garden will be collecting the runoff from the culvert that leads from the local high school. 200 CY of cut will need to be removed and relocated to a different location on the golf course. Figure 16 shows the layout of the north rain garden.

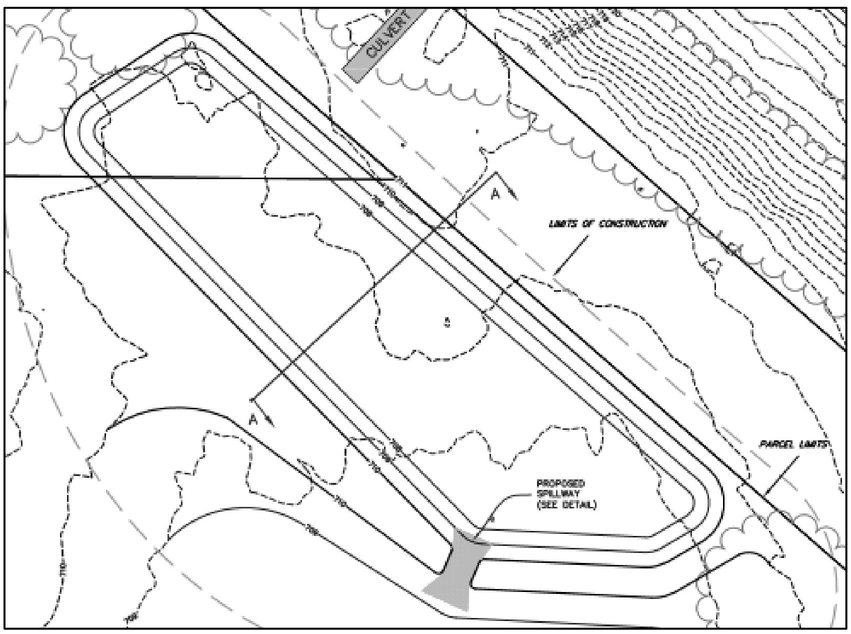

Figure 15: Plan View of the North Rain Garden

The middle rain garden is located between hole 4 and 13. The purpose for this rain garden is to collect the runoff that overflows the north rain garden and the additional runoff from the west and north sections of the golf course. The location of the rain garden is in a natural flow path. This rain garden has the storage volume of 17000 CF with a depth of 1.5 feet. Figure 17 shows the layout of the rain garden. The shape of the rain garden was constrained by the tree line and the natural contours of the area.

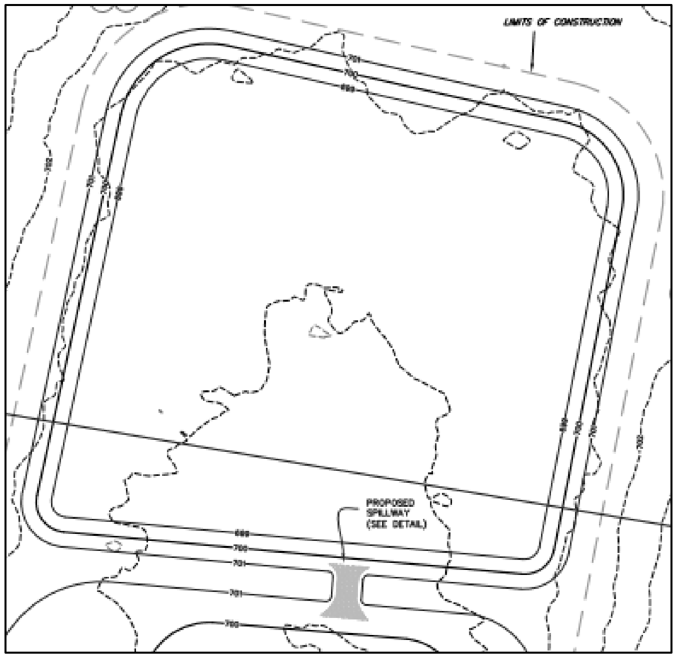

Figure 16: Plan View of the Middle Rain Garden

The third rain garden is located just north of 28th street and west of Indian Creek. The rain garden is 1.5 feet deep with a storage volume of 4500 CF. The purpose of this rain garden is to capture the remaining runoff from golf course and create a vegetative bench for restoring native vegetative habitat. Figure 18 shows the layout of the south rain garden. The shape of the rain garden was constrained by how much fairway the golf course was willing to give up and the existing contours.

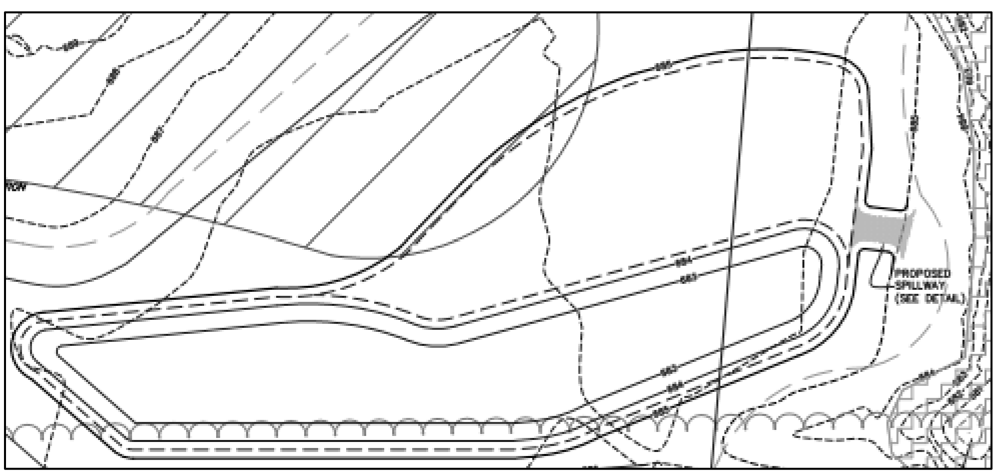

Figure 17: Plan View of the Middle Rain Garden

Civil 3D has also aided in the design of the stream restoration. Team 01 used the topographical survey of the steam and a digital elevation model to create a realistic existing surface. This was useful in creating the cross sections of the existing stream. Figure 19 shows the different cross-sections created to model the stream in HEC-RAS.

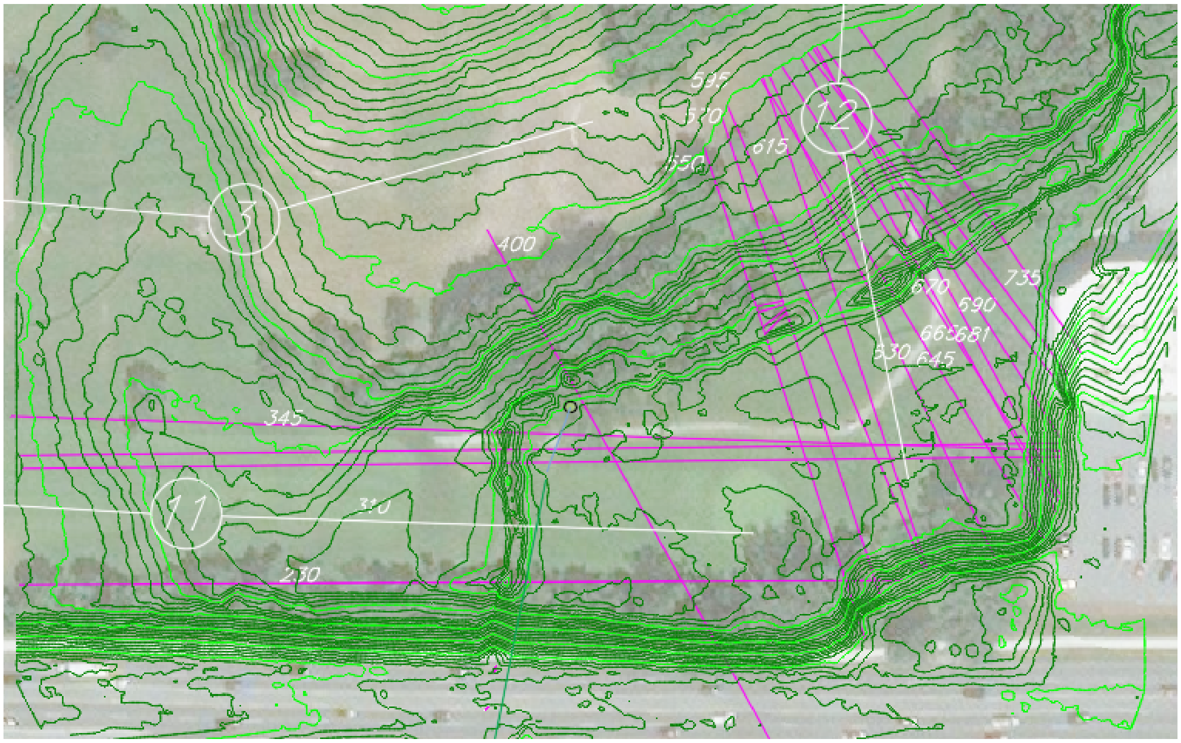

Figure 18: Topo and Contour Data with Created Cross Sections

Figure 20 shows the proposed layout design of the two-stage ditch created in AutoCAD. This was useful in showing how Team 01's design will be incorporated into the existing contours.

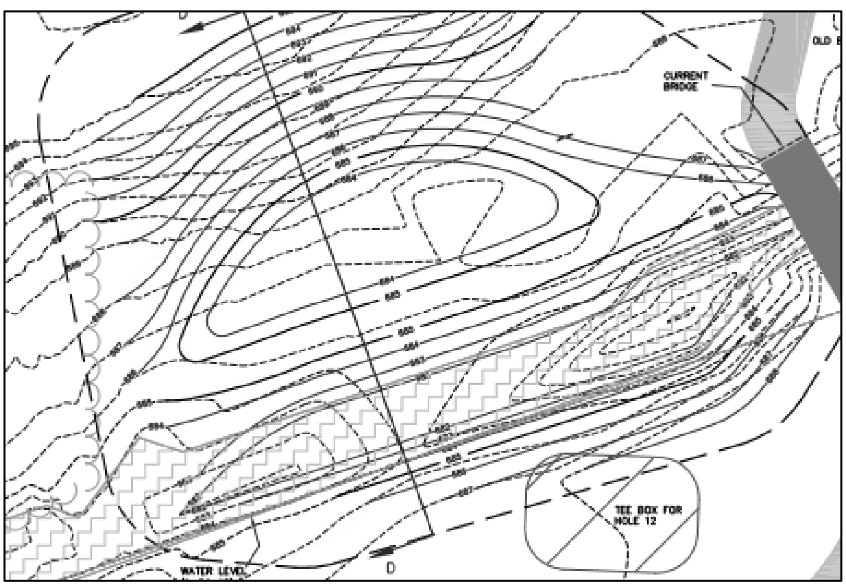

Figure 19: Two-Stage Ditch Layout

Team 01 also created construction plans through AutoCAD 3D. The construction plans show the existing conditions of the site, post conditions, and proposed rain gardens/two-stage ditch details. Construction plans were created based on industry standards and they can be seen in Appendix F.

7. Business Plan

7.1 Cost Estimate

Table 5 shows the items and associated costs to complete team 01's project.

Table 5: Cost Estimate of Project

Item	Units	Quantity	Cost/Unit	Total Cost
Excavation and grading	cyd	650	$36.00	$23,400.00
Vegetative Planting	lft	675	$9.00	$6,075.00
Two-Stage Ditch	lft	120	$12.00	$1,440.00
Slope Stabilization	lft	120	$137.00	$16,440.00
Underdrain	lft	50	$60.16	$3,008.00
			Total	$50,363.00

A more detailed cost analysis can be seen in Appendix E. These rates were found using web services and incorporated a 20% contingency for a better real-world estimate. The Excavation and grading item includes the cost of construction for the three rain gardens. The vegetative planting item includes the cost of planting the plants needed for the rain gardens and two-stage ditch. Slope Stabilization includes the cost of grading and preventative erosion measures. The Two-Stage Ditch item includes only construction. The underdrain item includes the materials needed for construction of the south rain garden's outlet structure.

7.2 Benefits

7.2.1 Aesthetic Appeal

The Indian Trails Golf Course has put a lot of effort into making their course look professional and at a high standard. Team 01's design must not only be a solution to their flooding problem but be aesthetically appealing to golfers. This will be done by adding vegetation to the surrounding area and matching the stones that will make up the sides of the rain gardens and stream restoration. The goal is to make the design match the rest of the course, creating a seamless integration.

7.2.2 Water Quality

The addition of stream restoration, will provide more friction and slow down the velocity of the water. Additionally, with some stabilization of the banks, soil erosion will be mitigated due to slower flows and stronger banks. The addition of three rain gardens will provide chances for suspended solids to drop out and be filtered by the present plant species.

8. Conclusion

8.1 Key Lessons Learned

Team 01 has learned and is continuing to learn how to work as a team on a project with no set guidelines. The team has learned the importance of assigning roles, such as webmaster, time keeper, or manager. With such a large timeframe for the project, budgeting time and creating team deadlines is also something that was learned and is continuing to be learned.

8.2 Future Work

In addition to the main design project, Team 01 has three recommendations outside the scope of their project for the golf course to consider. The first recommendation is to remove the old bridge. As observed from Team 01, debris gets caught behind the beams of the bridge which leads to higher flooding elevations and increased velocities. The second recommendation is to install a trash grate at the culvert passing underneath 28th street. This grate would allow debris to be lifted and water to flow underneath during storm events leading to lower flooding elevations. Additionally, this grate would make the removal of debris easier. The third recommendation is to modify the chain linked fence upstream of the old bridge. Debris gets caught on this fence during storm events which also leads to higher flooding elevations.

9. Acknowledgments

Team 01 would like to show their appreciation and thanks to the following people for the guidance and support:

Professor De Rooy of Calvin College Engineering Department for being the team's adviser and keeping us accountable on the schedule.

Professor Julie Wildschut of Calvin College Engineering Department and Plaster Creek Stewards for allowing us to use one of Plaster Creek Stewards project as Team 01's Senior Design project. Along with answering our many questions on the project and being Team 01's representative between the Indian Trails Golf Course.

Professor Hoeksema of Calvin College Engineering Department for providing the Excel spreadsheets that Team 01 used.

Indian Trails Golf Course for trusting and allowing Team 01 to work on their course.

Lastly Team 01 would like to thank their friends and family for their continually support and prayers. They are much appreciated.

10. References

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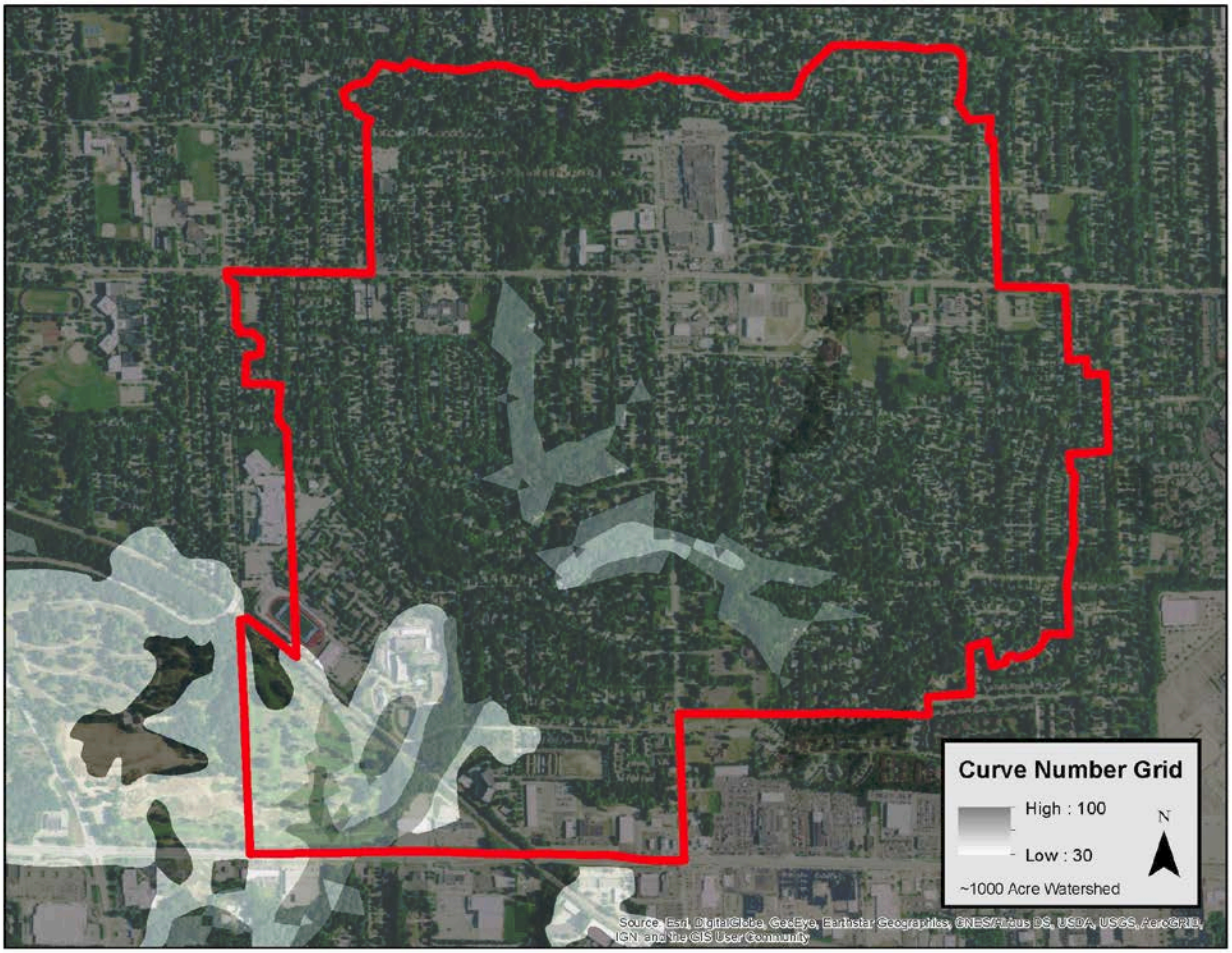
11. Appendices

A. Gantt Chart Task List
B. Curve Number Grid
C. Modeled Flood Map
D. Storm Frequency
E. Cost Analysis
F. Construction Plans
G. HY-8 Culvert Rating Curves
H. 28th Street Culvert Dimensions
I. Indian Creek Watershed Map
J. Existing and Proposed Site Hydrograph

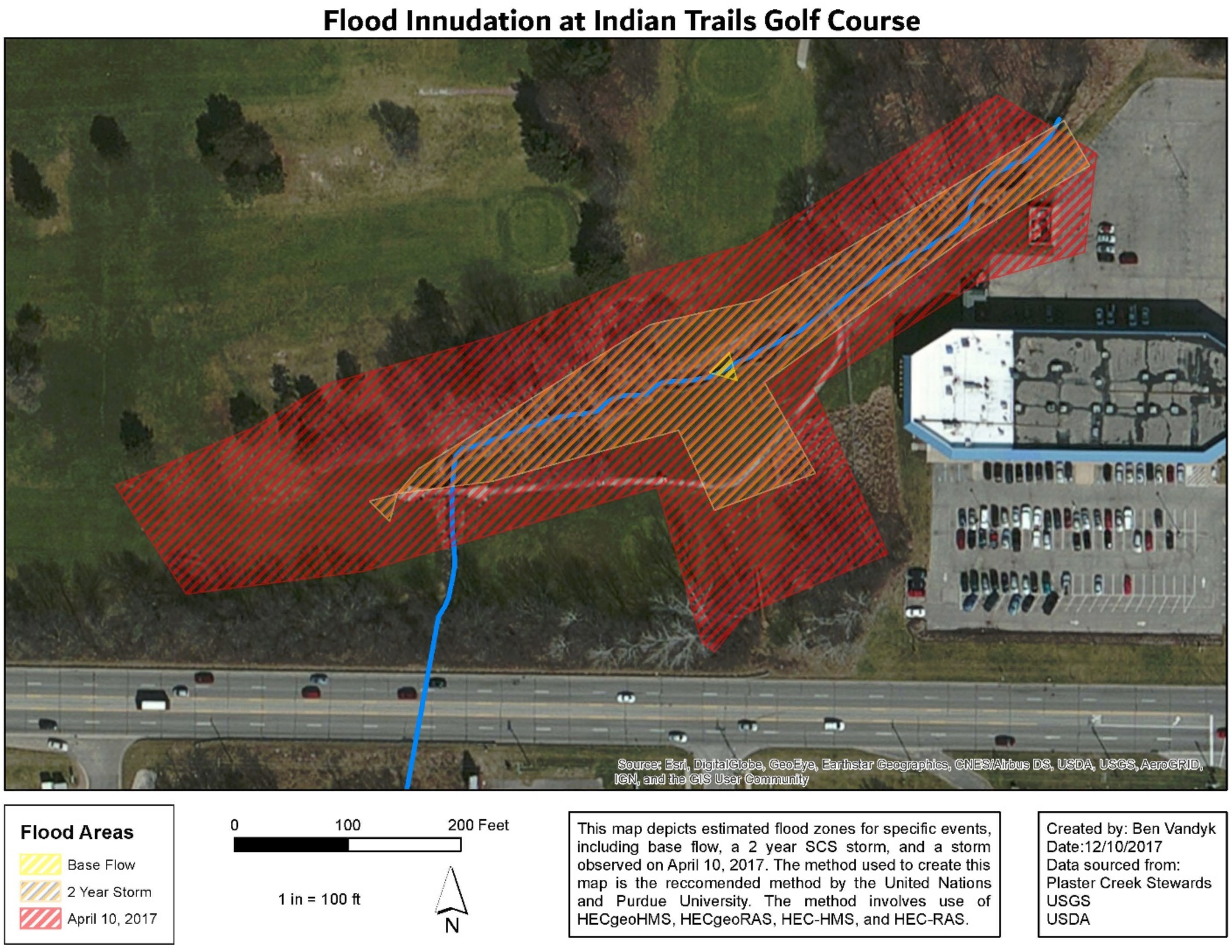
A. Gantt Chart Task List

	ℹ	Task Mode	Task Name	Durati	Start	Finish
1			Refine Scope	5 days	Tue 10/10/17	Mon 10/16/17
2			Collect all existing data	5 days	Tue 10/10/17	Mon 10/16/17
3			Determine missing data	4 days	Fri 10/20/17	Wed 10/25/17
4			Collect missing/needed data	8 days	Fri 10/20/17	Tue 10/31/17
5			Project Brief	5 days	Tue 10/10/17	Mon 10/16/17
6			Select team webmaster	6 days	Mon 10/16/17	Mon 10/23/17
7			Post poject website	1 day	Mon 10/16/17	Mon 10/16/17
8			Update Project poster at station	6 days	Fri 10/27/17	Fri 11/3/17
9			PPFS Outline (to advisor)	6 days	Mon 10/30/17	Mon 11/6/17
10			PPFS Draft (to advisor)	6 days	Mon 11/6/17	Mon 11/13/17
11			Final PPFS (to advisor & post on webpage as pdf)	34 days	Wed 10/25/17	Mon 12/11/17
12			Plan bioswale tasks	16 days	Fri 10/6/17	Fri 10/27/17
13			Plan stream restoration tasks	1 day	Fri 10/27/17	Fri 10/27/17
14			Team Photos	1 day	Mon 10/30/17	Mon 10/30/17
15			Model the surface	6 days	Tue 10/31/17	Tue 11/7/17
16			Design Norms determined	10 days	Sat 10/21/17	Thu 11/2/17
17			Research a "good stream"	8 days	Tue 10/10/17	Thu 10/19/17
18			Find Constraints of Bioswales	8 days	Tue 10/10/17	Thu 10/19/17
19			Design Bioswales	6 days	Fri 11/3/17	Fri 11/10/17
20			Write Bioswale Section	25 days	Tue 10/10/17	Mon 11/13/17
21			Calculations/Design Restoration	12 days	Mon 11/13/17	Tue 11/28/17
22			model Restoration	5 days	Tue 11/28/17	Mon 12/4/17
23			Fix Projection/ Coord System in GIS	5 days	Thu 10/12/17	Wed 10/18/17
24			Find Existing Flooding Photos	17 days	Tue 10/10/17	Wed 11/1/17
25			Cost Estimate	13 days	Thu 11/23/17	Mon 12/11/17
26			Write Restoration Section	9 days	Wed 11/29/17	Mon 12/11/17

B. Curve Number Grid



C. Modeled Flood Map



D. Storm Frequency

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.298** (0.258-0.347)	**0.350** (0.302-0.409)	**0.441** (0.379-0.516)	**0.520** (0.444-0.612)	**0.637** (0.521-0.787)	**0.733** (0.579-0.919)	**0.834** (0.627-1.08)	**0.941** (0.668-1.25)	**1.09** (0.734-1.50)	**1.21** (0.784-1.69)
10-min	**0.436** (0.377-0.509)	**0.513** (0.443-0.598)	**0.645** (0.554-0.755)	**0.762** (0.650-0.897)	**0.933** (0.762-1.15)	**1.07** (0.848-1.35)	**1.22** (0.919-1.58)	**1.38** (0.978-1.84)	**1.60** (1.07-2.20)	**1.77** (1.15-2.47)
15-min	**0.532** (0.460-0.620)	**0.625** (0.540-0.730)	**0.787** (0.676-0.921)	**0.929** (0.792-1.09)	**1.14** (0.930-1.41)	**1.31** (1.03-1.64)	**1.49** (1.12-1.92)	**1.68** (1.19-2.24)	**1.95** (1.31-2.68)	**2.16** (1.40-3.02)
30-min	**0.797** (0.689-0.928)	**0.934** (0.807-1.09)	**1.17** (1.01-1.37)	**1.38** (1.18-1.63)	**1.69** (1.38-2.09)	**1.94** (1.53-2.43)	**2.20** (1.66-2.84)	**2.48** (1.76-3.31)	**2.87** (1.93-3.96)	**3.18** (2.06-4.45)
60-min	**1.05** (0.910-1.23)	**1.23** (1.06-1.43)	**1.54** (1.32-1.80)	**1.81** (1.55-2.13)	**2.22** (1.82-2.75)	**2.56** (2.02-3.21)	**2.91** (2.19-3.77)	**3.29** (2.34-4.40)	**3.83** (2.58-5.28)	**4.26** (2.76-5.95)
2-hr	**1.31** (1.14-1.51)	**1.52** (1.32-1.77)	**1.90** (1.64-2.21)	**2.24** (1.92-2.62)	**2.75** (2.27-3.38)	**3.17** (2.53-3.96)	**3.62** (2.75-4.66)	**4.11** (2.94-5.45)	**4.79** (3.26-6.56)	**5.33** (3.49-7.40)
3-hr	**1.45** (1.26-1.67)	**1.68** (1.47-1.94)	**2.10** (1.82-2.43)	**2.48** (2.13-2.89)	**3.05** (2.53-3.75)	**3.53** (2.83-4.40)	**4.05** (3.09-5.19)	**4.60** (3.32-6.09)	**5.39** (3.69-7.36)	**6.03** (3.97-8.33)
6-hr	**1.70** (1.49-1.94)	**1.97** (1.72-2.25)	**2.45** (2.14-2.82)	**2.91** (2.51-3.36)	**3.59** (3.00-4.39)	**4.18** (3.37-5.18)	**4.81** (3.70-6.13)	**5.50** (4.00-7.23)	**6.48** (4.48-8.80)	**7.28** (4.84-9.98)
12-hr	**1.95** (1.72-2.22)	**2.26** (1.99-2.57)	**2.83** (2.48-3.23)	**3.36** (2.92-3.85)	**4.17** (3.51-5.07)	**4.86** (3.95-5.99)	**5.61** (4.35-7.11)	**6.44** (4.72-8.41)	**7.61** (5.31-10.3)	**8.57** (5.76-11.7)
24-hr	**2.23** (1.97-2.51)	**2.57** (2.27-2.90)	**3.20** (2.82-3.63)	**3.79** (3.31-4.32)	**4.71** (3.99-5.69)	**5.49** (4.50-6.72)	**6.35** (4.97-7.99)	**7.30** (5.40-9.47)	**8.65** (6.10-11.6)	**9.76** (6.62-13.2)
2-day	**2.56** (2.28-2.87)	**2.91** (2.59-3.27)	**3.57** (3.16-4.02)	**4.20** (3.69-4.76)	**5.18** (4.42-6.22)	**6.03** (4.97-7.33)	**6.96** (5.49-8.70)	**7.99** (5.97-10.3)	**9.47** (6.74-12.6)	**10.7** (7.32-14.3)
3-day	**2.83** (2.53-3.16)	**3.19** (2.85-3.57)	**3.87** (3.44-4.34)	**4.51** (3.98-5.09)	**5.52** (4.72-6.58)	**6.38** (5.28-7.71)	**7.33** (5.81-9.11)	**8.37** (6.29-10.7)	**9.88** (7.07-13.1)	**11.1** (7.66-14.8)
4-day	**3.05** (2.73-3.40)	**3.43** (3.07-3.82)	**4.13** (3.68-4.62)	**4.79** (4.23-5.38)	**5.80** (4.98-6.89)	**6.68** (5.54-8.03)	**7.63** (6.06-9.44)	**8.67** (6.54-11.1)	**10.2** (7.31-13.4)	**11.4** (7.89-15.2)
7-day	**3.60** (3.24-3.99)	**4.02** (3.61-4.46)	**4.79** (4.28-5.32)	**5.48** (4.87-6.12)	**6.54** (5.62-7.67)	**7.43** (6.19-8.84)	**8.38** (6.69-10.3)	**9.42** (7.14-11.9)	**10.9** (7.88-14.2)	**12.1** (8.44-16.0)
10-day	**4.10** (3.69-4.52)	**4.57** (4.11-5.04)	**5.39** (4.83-5.97)	**6.13** (5.46-6.82)	**7.22** (6.22-8.41)	**8.13** (6.79-9.62)	**9.10** (7.28-11.1)	**10.1** (7.71-12.7)	**11.6** (8.42-15.0)	**12.8** (8.95-16.8)
20-day	**5.59** (5.06-6.12)	**6.20** (5.61-6.79)	**7.22** (6.51-7.94)	**8.09** (7.25-8.94)	**9.33** (8.05-10.7)	**10.3** (8.65-12.0)	**11.3** (9.11-13.6)	**12.4** (9.47-15.3)	**13.8** (10.1-17.7)	**14.9** (10.6-19.4)
30-day	**6.88** (6.25-7.50)	**7.61** (6.91-8.30)	**8.80** (7.96-9.63)	**9.79** (8.79-10.8)	**11.1** (9.62-12.7)	**12.2** (10.2-14.1)	**13.2** (10.7-15.8)	**14.3** (11.0-17.6)	**15.7** (11.5-19.9)	**16.7** (11.9-21.7)
45-day	**8.55** (7.80-9.28)	**9.43** (8.59-10.2)	**10.8** (9.83-11.8)	**12.0** (10.8-13.1)	**13.5** (11.6-15.2)	**14.6** (12.3-16.7)	**15.6** (12.7-18.5)	**16.7** (12.9-20.4)	**18.0** (13.3-22.7)	**18.9** (13.6-24.5)
60-day	**10.00** (9.14-10.8)	**11.0** (10.1-11.9)	**12.6** (11.4-13.7)	**13.8** (12.5-15.1)	**15.4** (13.4-17.3)	**16.6** (14.0-18.9)	**17.7** (14.3-20.8)	**18.7** (14.5-22.7)	**19.9** (14.8-25.0)	**20.8** (15.0-26.8)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

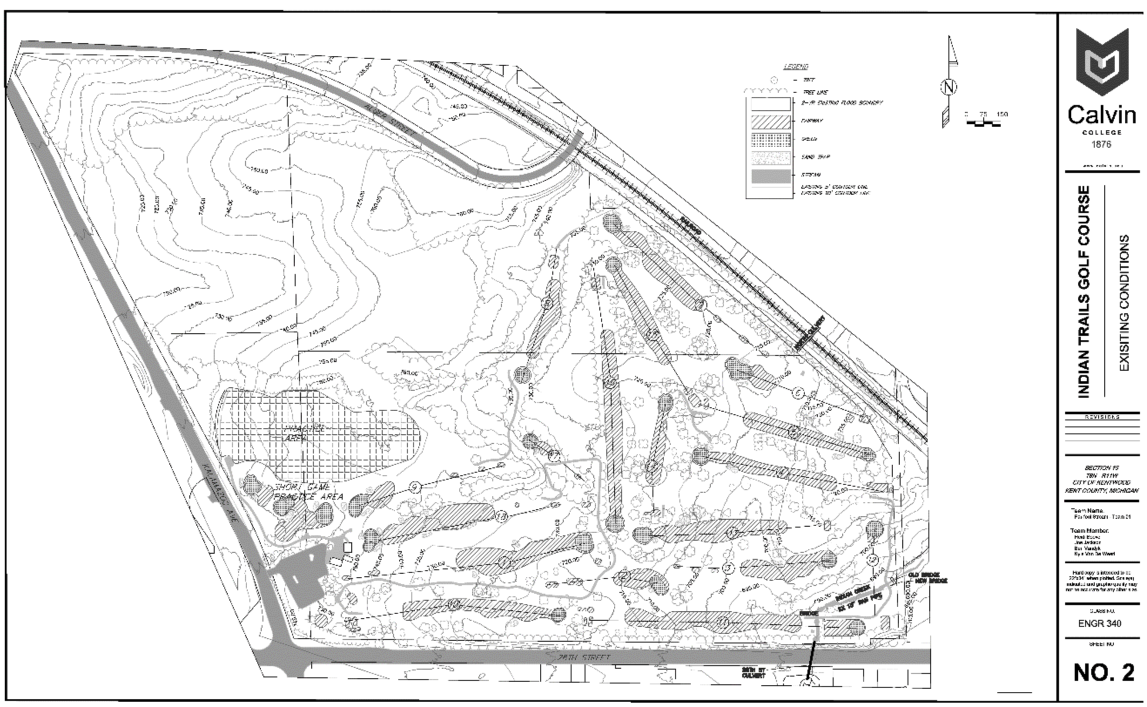
Please refer to NOAA Atlas 14 document for more information.

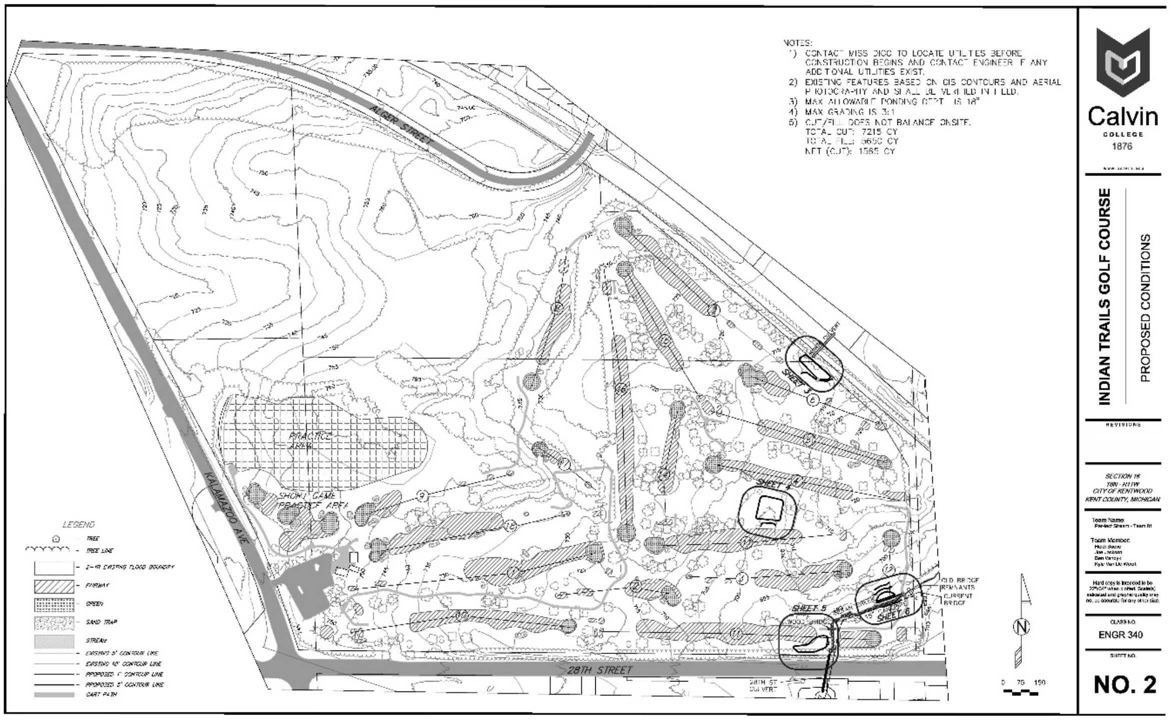
E. Cost Analysis

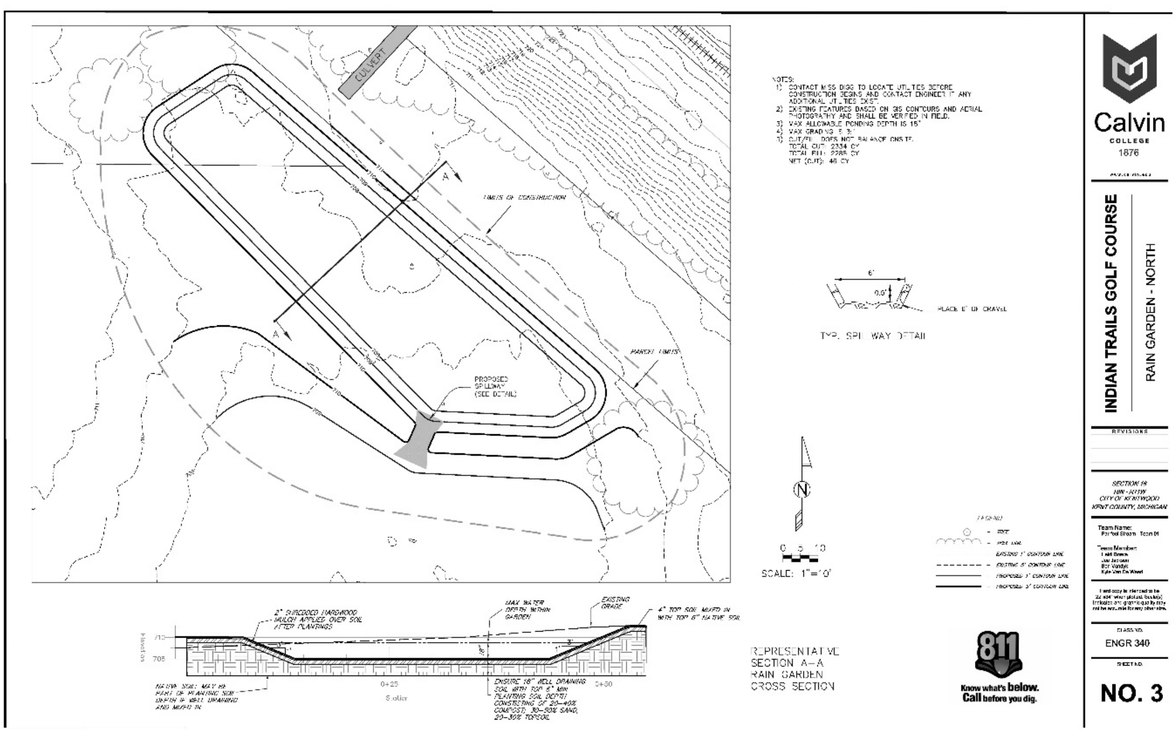
Item	Units	Quantity	Cost/Unit	Total Cost	Source
					20% contingency applied to all items
Excavation and grading	cyd	650	$36.00	$23,400.00	
Vegetative Planting	lft	675	$9.00	$6,075.00	
Two-Stage Ditch	lft	120	$12.00	$1,440.00	
Slope Stabilization	lft	120	$137.00	$16,440.00	
Excavation and grading	cyd	350	$36.00	$12,600.00	
Cedar log vanes	lft	120	$19.50	$2,340.00	http://www.ozarkloghomesupply.com/cedar-log-11-12.html
Coconut fiber erosion blanket (8 ft x 113 ft)	lft	1500	$1.00	$1,500.00	https://www.amleo.com/coconut-erosion-control-blanket-8ft-x-113ft-roll/p/C4000/
Underdrain	lft	50	$60.16	$3,008.00	
6 inch corrugated plastic tubing	lft	50	$2.00	$100.00	https://www.zoro.com/advanced-drainage-systems-corrugated-drainage-pipe-10-ftl-6india
6 inch corrugated plastic 90-degree elbow	each	1	$10.00	$10.00	
6 inch round catch basin	each	1	$18.00	$18.00	https://www.dripdepot.com/item/6-inch-round-catch-basin-outlets-one
Rip Rap	cyd	40	$72.00	$2,880.00	https://www.michigan.gov/documents/MDOT_MS4_App_91743_7_.09_B_Drainage_Manual.pdf
			Total	$50,363.00	

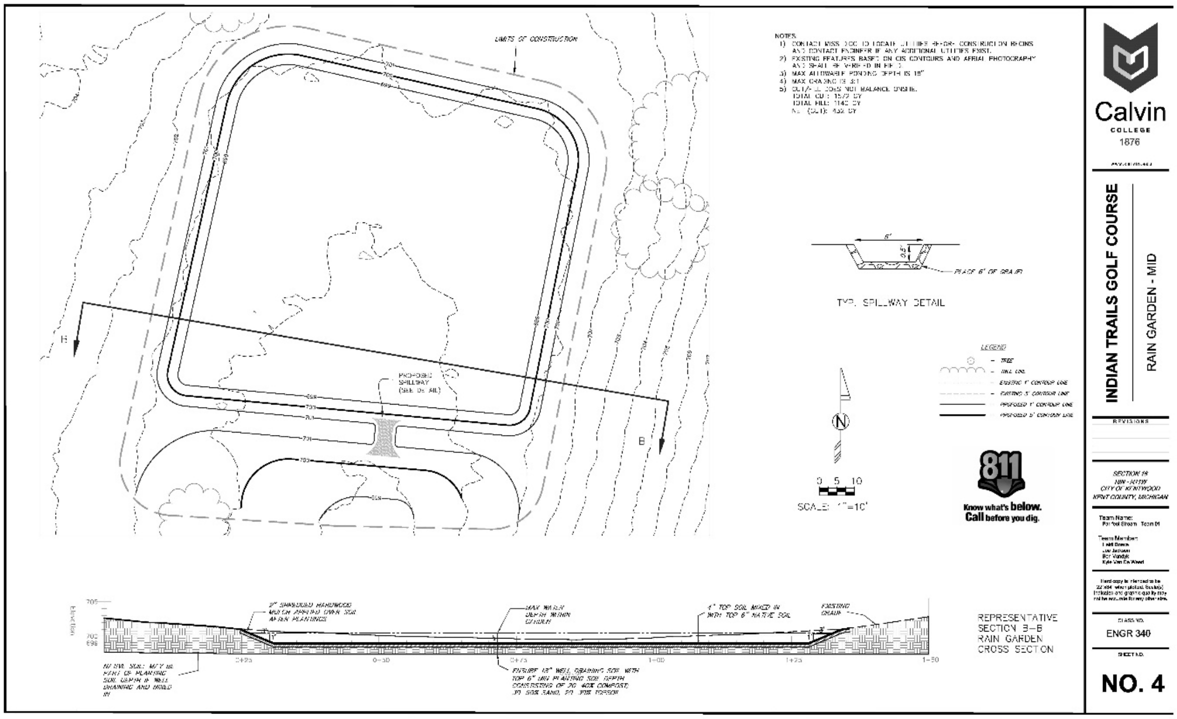
F. Construction Plans

The following construction plans are not for construction.

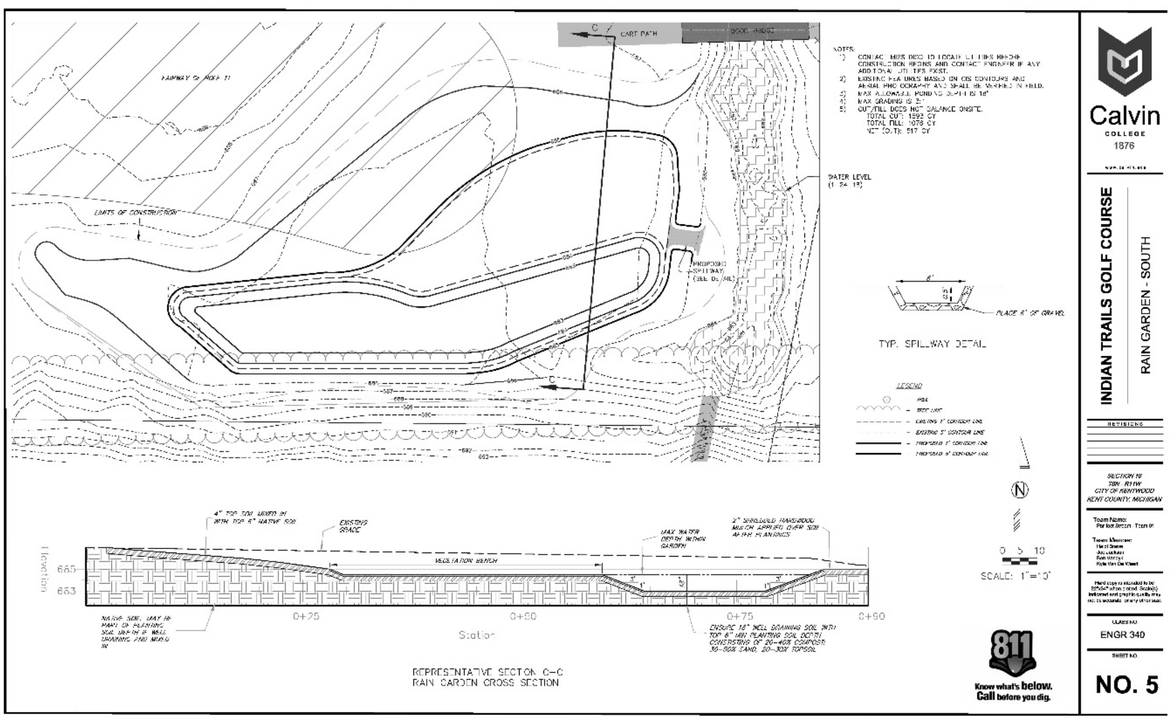



NOTES:
1) CONTACT MISS DIGG TO LOCATE UTILITIES BEFORE CONSTRUCTION BEGINS AND CONTACT ENGINEER IF ANY ADDITIONAL UTILITIES EXIST.
2) EXISTING FEATURES BASED ON GIS CONTOURS AND AERIAL PHOTOGRAPHY AND SHALL BE VERIFIED IN FIELD.
3) MAX ALLOWABLE PONDING DEPTH IS 18"
4) MAX GRADING IS 3:1
5) CUT/FILL DOES NOT BALANCE ONSITE.
TOTAL CUT: 7215 CY
TOTAL FILL: 5650 CY
NET (CUT): 1565 CY
AUGER STREET
PRACTICE AREA
SHORT GAME PRACTICE AREA
KALAMAZOO AVE
28TH STREET
SHEET 4
SHEET 5
SHEET 6
SHEET 7
LEGEND
Calvin
COLLEGE
1876
INDIAN TRAILS GOLF COURSE
PROPOSED CONDITIONS
ENGR 340
NO. 2

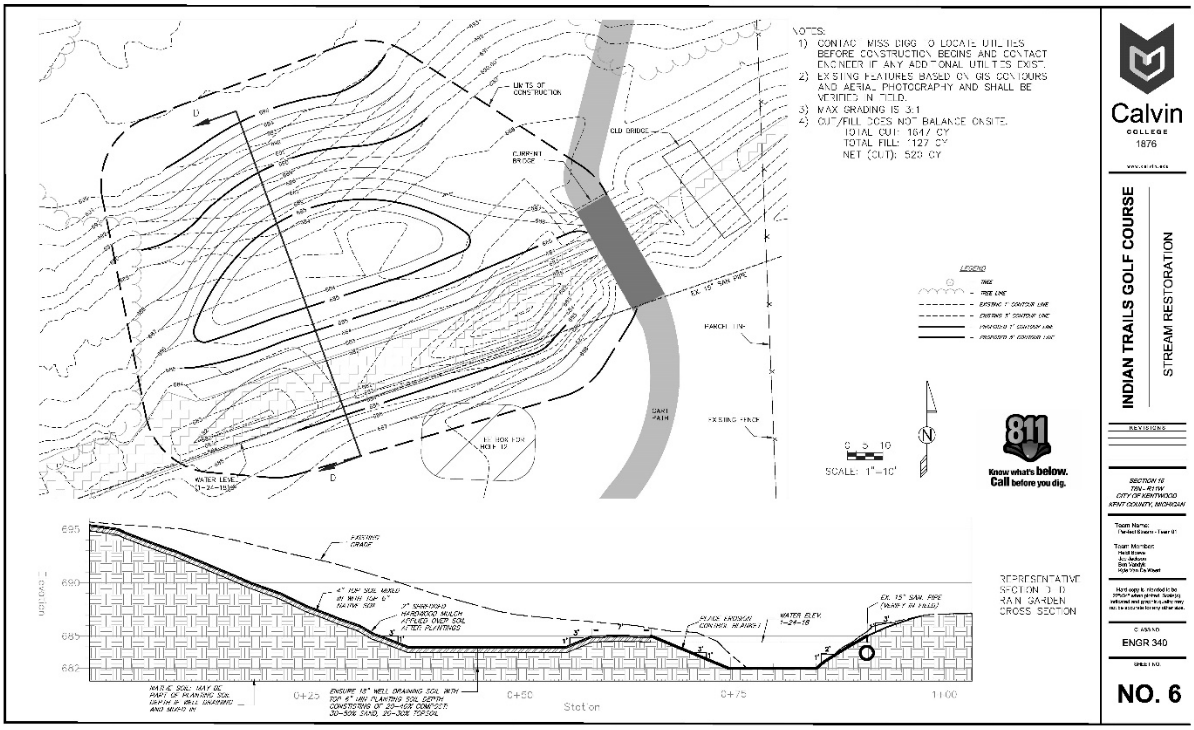

NOTES:
1) CONTACT MISS DIGG TO LOCATE UTILITIES BEFORE CONSTRUCTION BEGINS AND CONTACT ENGINEER IF ANY ADDITIONAL UTILITIES EXIST.
2) EXISTING FEATURES BASED ON GIS CONTOURS AND AERIAL PHOTOGRAPHY AND SHALL BE VERIFIED IN FIELD.
3) MAX ALLOWABLE PONDING DEPTH IS 15"
4) MAX GRADING IS 3:1
5) CUT/FILL DOES NOT BALANCE ONSITE.
TOTAL CUT: 2334 CY
TOTAL FILL: 2288 CY
NET (CUT): 46 CY
CULVERT
LIMITS OF CONSTRUCTION
PROPOSED SPILLWAY (SEE DETAIL)
PLACE 6" OF GRAVEL
TYP. SPILLWAY DETAIL
SCALE: 1"=10'
REPRESENTATIVE SECTION A-A RAIN GARDEN CROSS SECTION
Know what's below. Call before you dig.
Calvin
COLLEGE
1876
INDIAN TRAILS GOLF COURSE
RAIN GARDEN - NORTH
ENGR 340
NO. 3



LIMITS OF CONSTRUCTION
NOTES:
1) CONTACT MISS DIG TO LOCATE UTILITIES BEFORE CONSTRUCTION BEGINS AND CONTACT ENGINEER IF ANY ADDITIONAL UTILITIES EXIST.
2) EXISTING FEATURES BASED ON GIS CONTOURS AND AERIAL PHOTOGRAPHY AND SHALL BE VERIFIED IN FIELD.
3) MAX ALLOWABLE PONDING DEPTH IS 18"
4) MAX GRADING IS 3:1
5) CUT/FILL DOES NOT BALANCE ONSITE.
TOTAL CUT: 1572 CY
TOTAL FILL: 1140 CY
NET (CUT): 432 CY
TYP. SPILLWAY DETAIL
PROPOSED SPILLWAY
LEGEND
SCALE: 1"=10'
Know what's below. Call before you dig.
REPRESENTATIVE SECTION B–B RAIN GARDEN CROSS SECTION
Calvin COLLEGE 1876
INDIAN TRAILS GOLF COURSE
RAIN GARDEN - MID
REVISIONS
CLASS NO.
ENGR 340
SHEET NO.
NO. 4

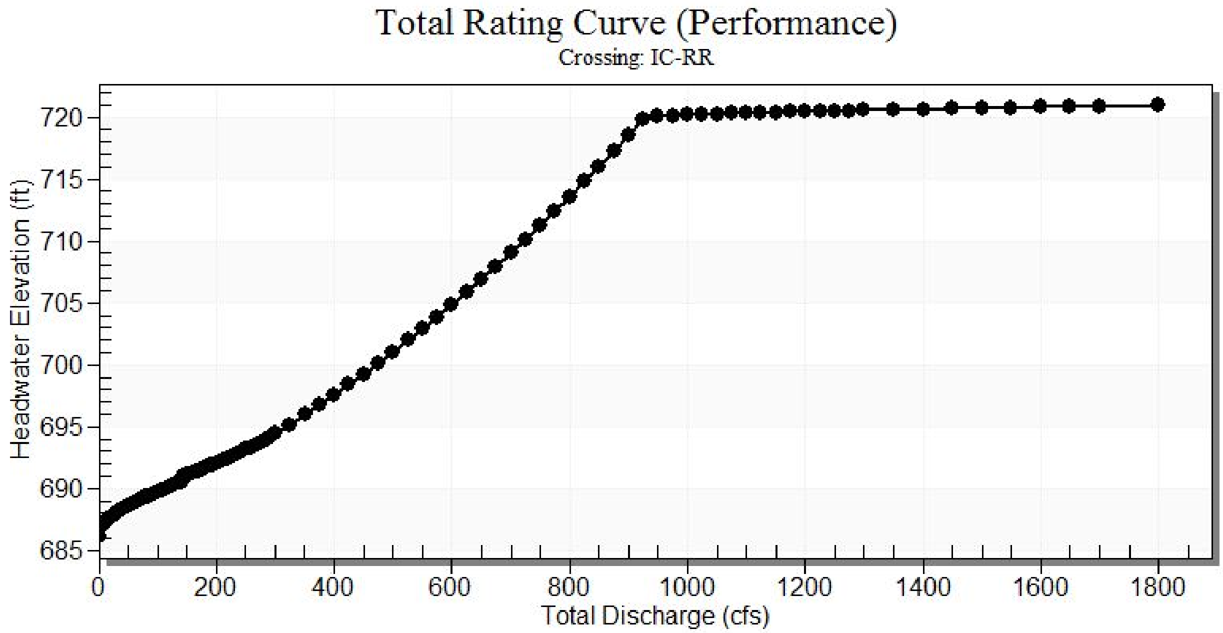


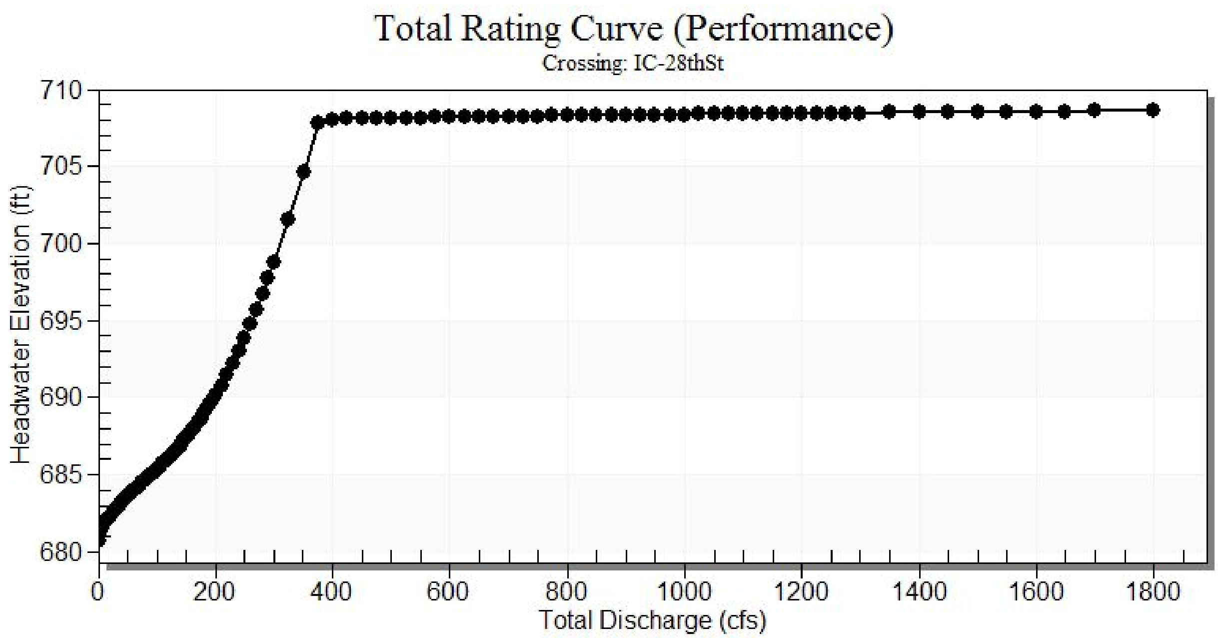
CART PATH
LIMITS OF CONSTRUCTION
NOTES:
1) CONTACT MISS DIG TO LOCATE UTILITIES BEFORE CONSTRUCTION BEGINS AND CONTACT ENGINEER IF ANY ADDITIONAL UTILITIES EXIST.
2) EXISTING FEATURES BASED ON GIS CONTOURS AND AERIAL PHOTOGRAPHY AND SHALL BE VERIFIED IN FIELD.
3) MAX ALLOWABLE PONDING DEPTH IS 18"
4) MAX GRADING IS 3:1
5) CUT/FILL DOES NOT BALANCE ONSITE.
TOTAL CUT: 1593 CY
TOTAL FILL: 1076 CY
NET (CUT): 517 CY
WATER LEVEL
PROPOSED SPILLWAY
TYP. SPILLWAY DETAIL
PLACE 6" OF GRAVEL
LEGEND
SCALE: 1"=10'
Elevation
Station
REPRESENTATIVE SECTION C–C RAIN GARDEN CROSS SECTION
Know what's below. Call before you dig.
Calvin COLLEGE 1876
INDIAN TRAILS GOLF COURSE
RAIN GARDEN - SOUTH
REVISIONS
CLASS NO.
ENGR 340
SHEET NO.
NO. 5



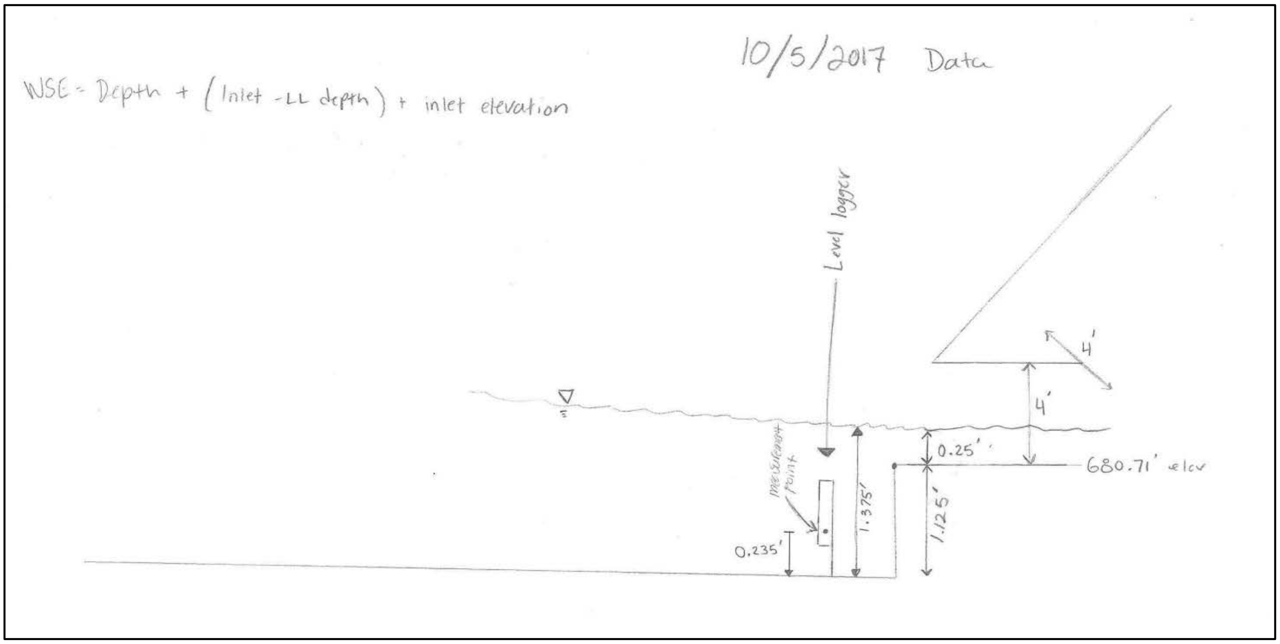
NOTES:
1) CONTACT MISS DIGG TO LOCATE UTILITIES BEFORE CONSTRUCTION BEGINS AND CONTACT ENGINEER IF ANY ADDITIONAL UTILITIES EXIST.
2) EXISTING FEATURES BASED ON GIS CONTOURS AND AERIAL PHOTOGRAPHY AND SHALL BE VERIFIED IN FIELD.
3) MAX GRADING IS 3:1
4) CUT/FILL DOES NOT BALANCE ONSITE.
TOTAL CUT: 1647 CY
TOTAL FILL: 1127 CY
NET (CUT): 520 CY
LIMITS OF CONSTRUCTION
OLD BRIDGE
CURRENT BRIDGE
EX. 15" SAN PIPE
CART PATH
EXISTING FENCE
TEE BOX FOR HOLE 12
LEGEND
SCALE: 1"=10'
Know what's below. Call before you dig.
REPRESENTATIVE SECTION D-D RAIN GARDEN CROSS SECTION
EXISTING GRADE
WATER ELEV. 1-24-18
EX. 15" SAN. PIPE (VERIFY IN FIELD)
Station
Calvin COLLEGE 1876
INDIAN TRAILS GOLF COURSE
STREAM RESTORATION
REVISIONS
SECTION 18 T6N - R11W CITY OF KENTWOOD KENT COUNTY, MICHIGAN
ENGR 340
NO. 6

G. HY-8 Culvert Rating Curves

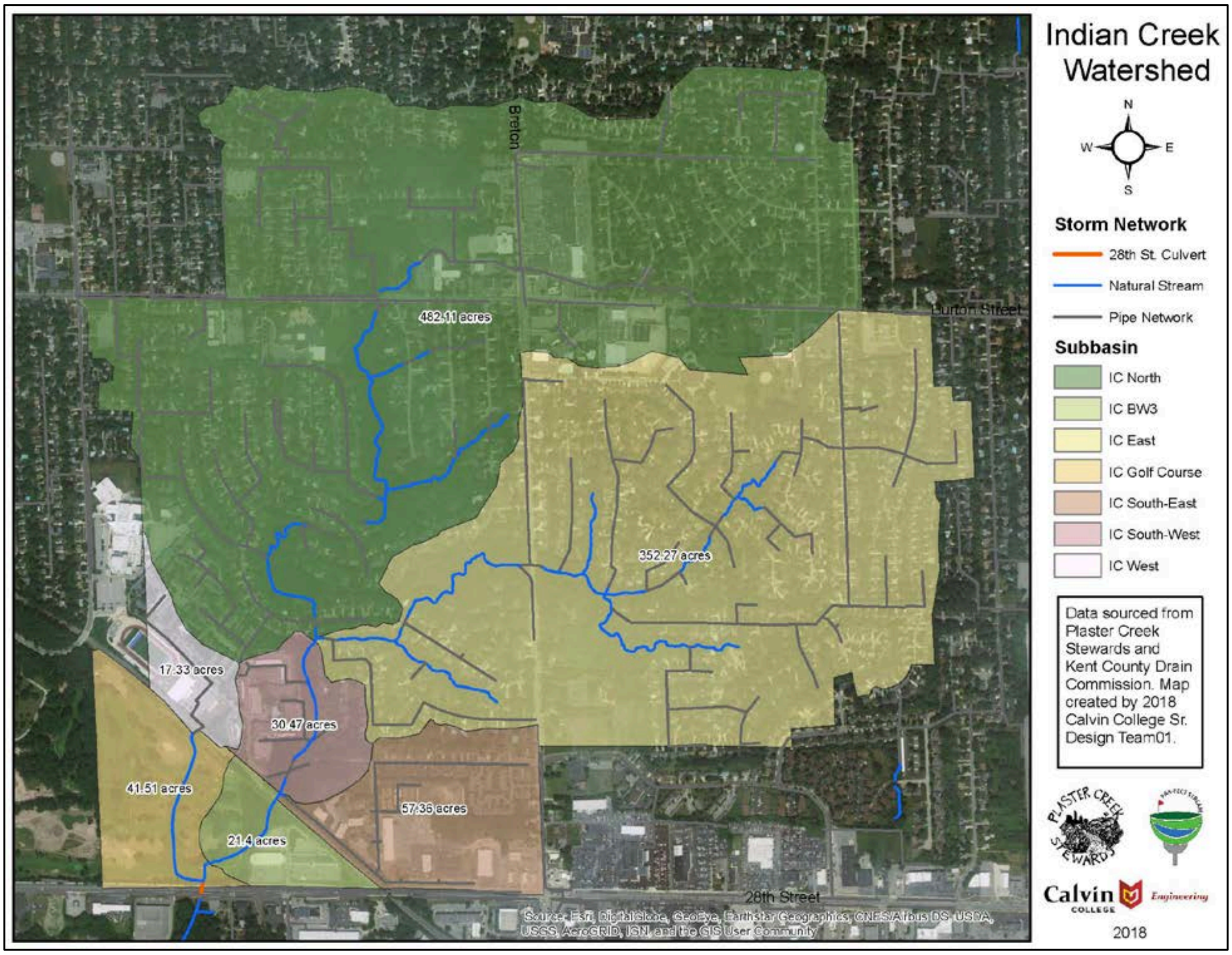




H. 28th Street Culvert Dimensions



I. Indian Creek Watershed Map



J. Existing and Proposed Site Hydrograph