Project Proposal and Feasibility Study

Team 01: The Par-fect Stream

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Engr 339/340 Senior Design Project

Calvin College

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Executive Summary

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 process for reducing flooding. The design alternatives consist of a bioswale, stream restoration, and a stream divergent structure.

Currently, the back nine of Indian Trails Golf Course has a 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 a bioswale in at the south end of the portion of Indian creek that runs through Indian trails golf course and stream restoration along the south and east portion of the creek. Team 01 decided against the stream divergent structure due to the budget of the Golf course. Indian Trails received a grant to reduce the flooding.

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

While working on this design project Team 01 has integrated their Christian values by implementing and upholding three design norms. The first is stewardship, Team 01 believes that as humans they are called to take care of this world. By reducing the flooding, they believe they are putting this into practice. The second is transparency, team 01 wants to make sure that they are clear and honest with their design. The final design norm is humility, being students Team 01 realizes they do not know everything. This is important when communicating with advisors and the golf course.

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. In the spring of 2018, Team 01 will develop plans to present to the city for construction to be completed by the winter of 2018. The plans will include HEC-RAS and HEC-HMS models along with a 3-D model of the proposed design. The team will continue collecting data and refining the designs.

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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, and 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. During his time there, he inspected and designed many public construction projects ranging from road resurfacing, water mains, and detention ponds. 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 and holds dual American – Canadian Citizenship. 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 and is interested in hydraulics as well as site development. He plans on joining the workforce after graduation.

1.3 Project Description

1.3.1 Location

The Indian Trails Golf Course is located in Grand Rapids, Michigan on the Northeast corner of Kalamazoo and 28th Street. 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 at the bridge and continue west until it reaches the tree line just north of Hole 11. The proposed bioswale location will be near the southern most point of the creek on the property line for Indian Trails Golf Course shown in figure 2 below.

Figure 2: Site and hole locations

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 978 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 October rain event

1.3.3 Client

The primary client for this project is the City of Grand Rapids. The Indian Trails Golf Course 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, owned by the City of Grand Rapids. 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) 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 the Team's 01 project is concentrated, it is where erosion has been the heaviest. 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 pouring out 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 a bioswale and two locations for 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 plans to gather information concerning the alternative designs: Bioswale, stream restoration, and divergent structure. Team 01 also plans to develop a preliminary design for stream restoration. The months of January and February will consist mostly of designing and refining the preliminary plans.

March is when the team must finish their designs in order to get them into the city to be reviewed. Indian Trails Golf Course plans to start construction in the summer of 2018. Due to this time frame Team 01's schedule has been pushed up. After March, the team will continue to work on different permits and depending on time and comments from the city, may submit revised plans.

In May, Team 01 will be giving a presentation over their final design to friends and family.

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

Plaster Creek Stewards would like to submit plans to the City of Grand Rapids concerning any changes made in the channel by March. This deadline is earlier than the timeline of Calvin's Senior Design course because construction has already been scheduled for this project in the late summer and early fall of 2018. Before construction happens, the plans need to be submitted and approved by the city, and then approved by the Indian Trails Golf course. A city stormwater permit as well as a Land Use Development Services (LUDS) permit must both be granted before then.

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, Team 01 will need as much area as possible for the bioswale design. The Indian Trails Golf course 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 bioswale 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 would include the cost of hiring a consulting firm to come and do additional survey work in case the GPS data already collected is insufficient. 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 Design Approach

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 will be 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.

3. Requirements

For Team 01 to successfully design and complete this project, certain requirements must be met. The combination of the three requirements listed below combine research from the past and data from the present to find a solution for every problem presented by the client.

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, stream restoration, wetlands, and diversion structures. The bioswale 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.

4. Research

4.1 Bioswale

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 7 below.

Figure 7: Bioswale filtration mechanism, Oregon DEQ - Dennis Jurries, PE (2003)

Bioswales are low maintenance and provide pollutant removal naturally (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 will 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 vegetations (Juries, 53). The removal of pollutants is something the team is keeping in mind; Indian creek has high levels of pollutants making the creek a health risk.

4.2 Stream Restoration

Stream restoration is implemented in streams that display signs of high velocity, 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 could use would be a 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 be 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 bioswale for Indian Trails Golf course, the important details to the DEQ are the outlet structure and the size of the overall bioswale. The outlet will be designed within the DEQ requirements for peak discharge since it will be flowing back into Plaster Creek, and the bioswale 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 larger than a 2-year rain event in the model. The sediment leftover after the flood cause 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.

5.1.1 Design Norms

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 help of peers. Humility will play a big role in the design in order 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 Bioswale

The proposed bioswale per Professor Wildschut is to be located west of the drainage culvert along the south side of hole 11. (Figure 8). This bioswale is estimated to provide an additional 11,400 CF of storage during flood events. The exact size and location of the bioswale is still to be determined. As for plant species, the current plan is to collect seeds from an identified Special Concern plant, the hairy fruited sedge. The determination of plant species is out of the scope of Team 01, and is to be officially determined by the Plaster Creek Stewards.

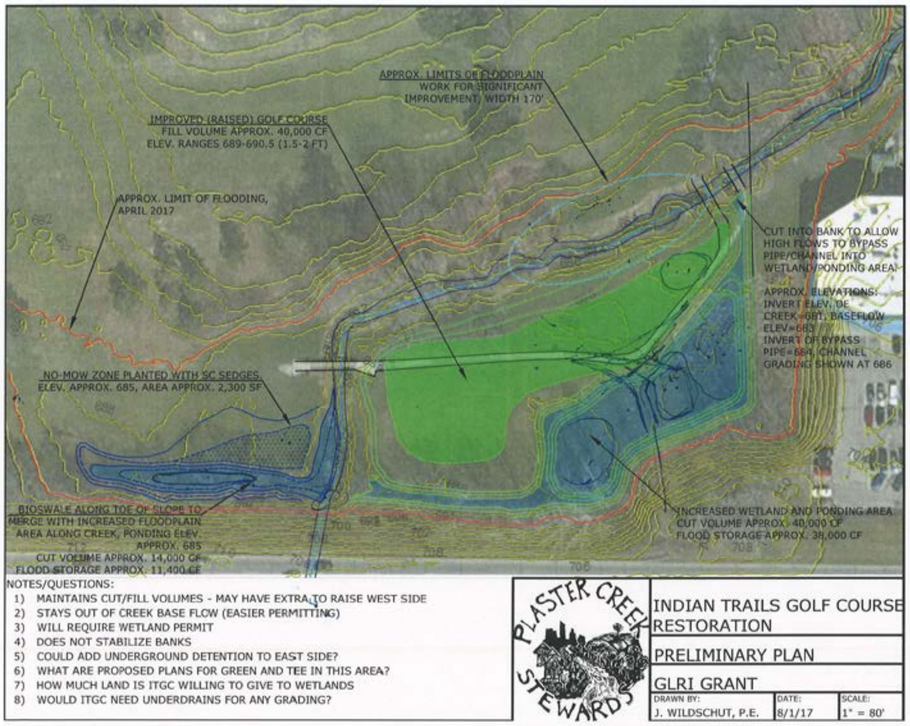

Figure 8: Preliminary plan per professor Julie Wildschut, P.E.

5.2.2 Stream Restoration

One of the options being considered is stream restoration. The design would implement techniques discussed early in this document such as the J-Hook or possibly step pooling. These techniques would lower the chances of erosion during flooding events. The J-Hook would be constructed just after the existing bridge to help reduce erosion to the outside bank of the stream. The step pool technique would be constructed upstream of the existing bridge to help slow down the water 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

The design decisions were determined by Lance Climie due to budget constraints. Currently a combination of stream restoration and the construction of a bioswale is in the budget. The other alternatives are unfeasible at the current time.

6. Testing

6.1 Hydraulic Modeling System

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 will use HEC-HMS to model the watershed of Indian Trails Golf Course. (*Hydrologic)* Figure 9, shows the HEC-HMS model of the creek broken up into the alternative design features.

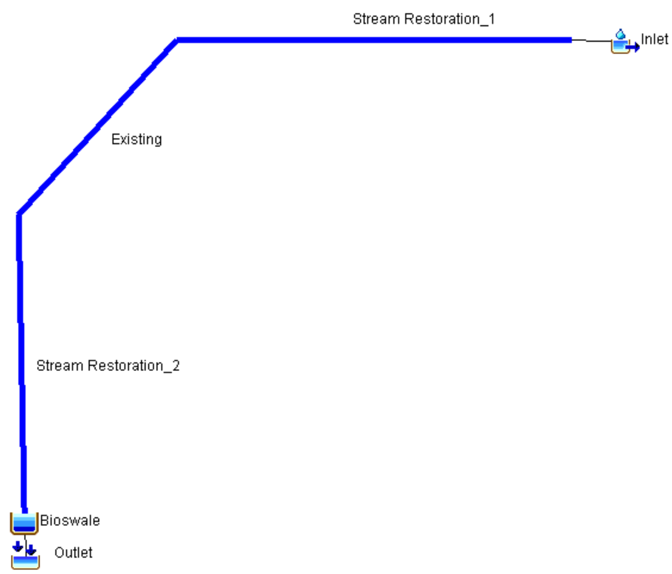

Figure 9: Example of HEC-HMS model layout

6.2 River Analysis System

River Analysis System (HEC-RAS) is a program designed by the US Army Corps of Engineers. This program allows Team 01 to see how Indian Creek water level will rise during a rain event. Team 01 will also be able to see how different manning's n coefficients on the sides off the creek will affect the water level of the stream. Figure 10, shows the layout of the creek with all the different cross sections put in, whereas figure 11 shows how a cross section is modeled. Team 01 will be improving the HEC-RAS model of Indian Creek provided by Plaster Creek Stewards.

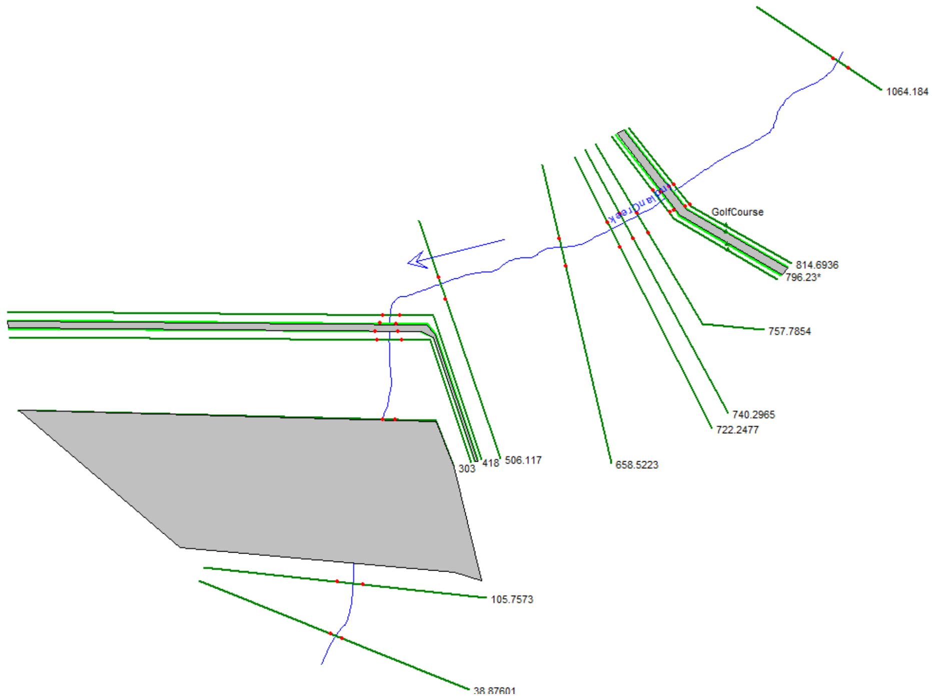

Figure 10: Indian Creek HEC-RAS layout

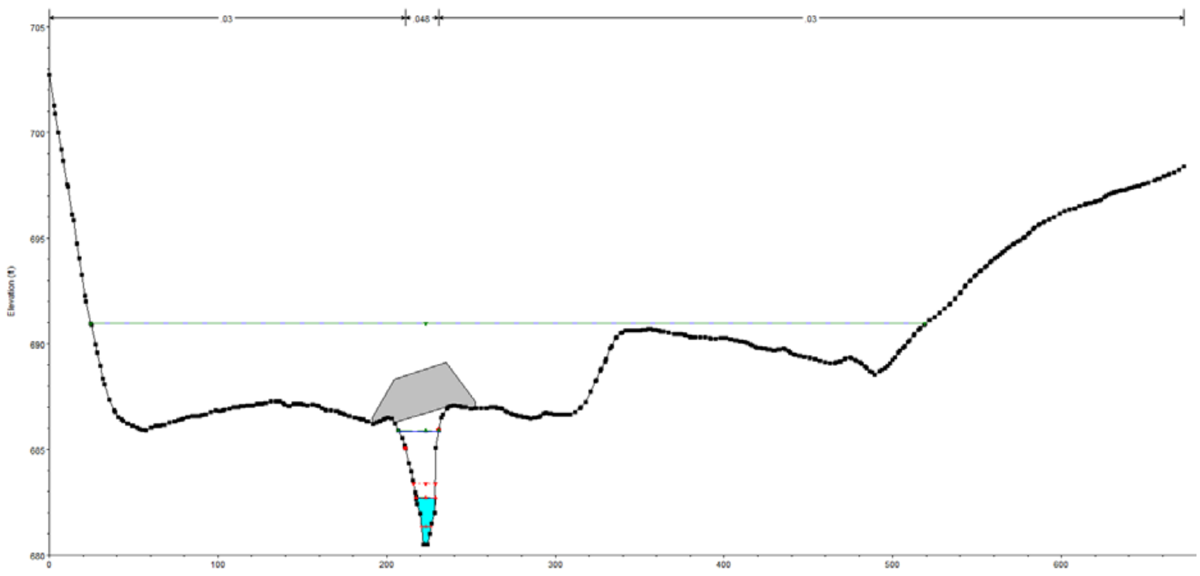

Figure 11: Cross Section of Indian Creek

7. Business Plan

7.1 Cost Estimate

The material and equipment will be the largest cost involved with this project. Stream restoration costs range from $800 to $8000 per mile of affected river. This price includes materials and equipment used for construction. Prices are from the State of Michigan's document titled *Stream Restoration.*

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 bioswale 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 a bioswale 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

Before the end of the semester Team 01 will be giving another presentation in front of their classmates and advisor. In the second semester, Team 01 will work on optimizing the design along with completing the finishing touches on the final report. In April, Team 01 with be giving a presentation for American Society of Civil Engineers (ASCE) West Michigan chapter luncheon. May will consist of the senior design night, where Calvin College puts on an open house for all the senior design teams to show off what they have worked on all year. There is a dinner that follows for family and professors to celebrate making it through Calvin College's engineering program. After the dinner, Team 01 will give a presentation on their project to family and friends.

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 at Indian Trails Golf Course.

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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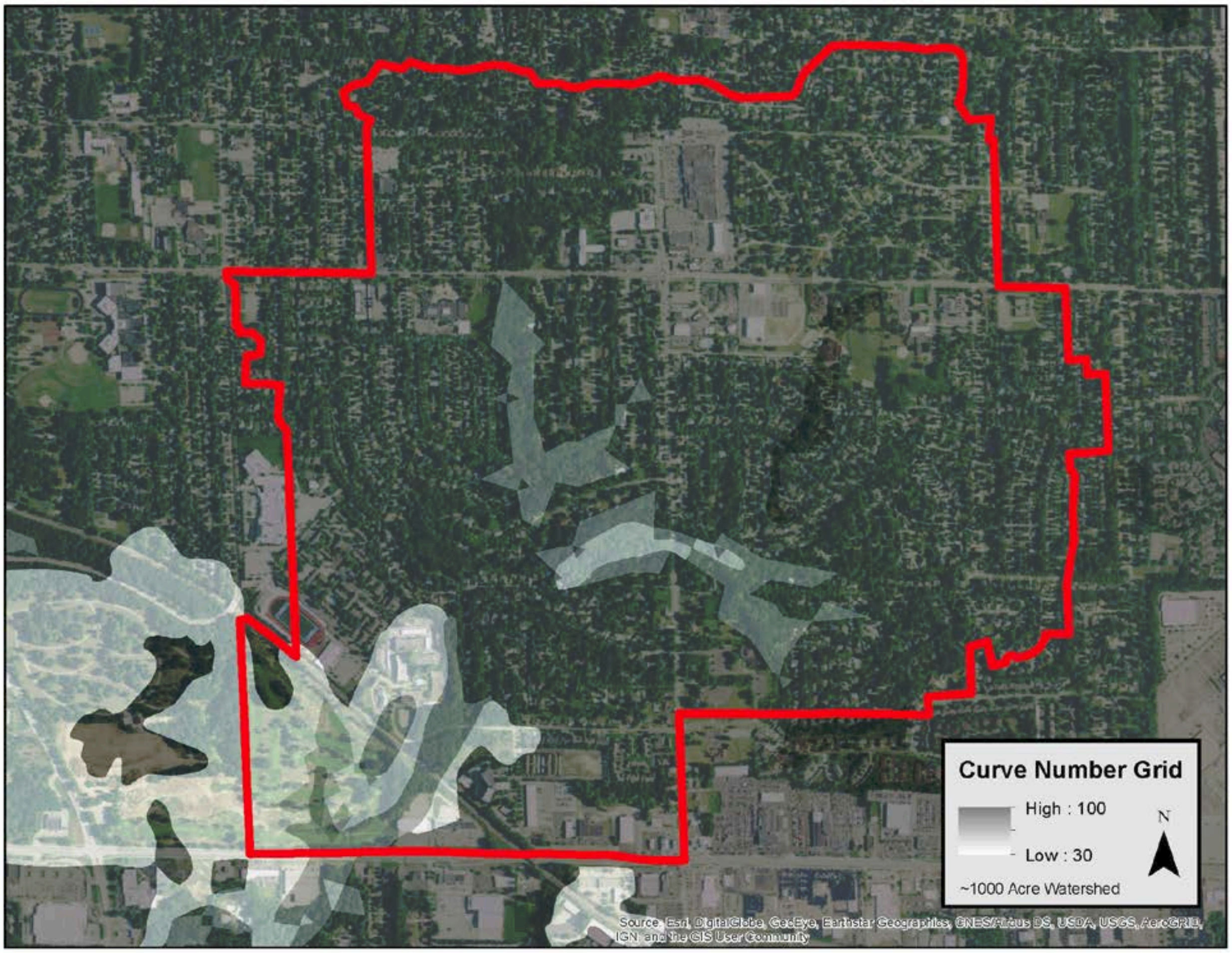
11. Appendices

A. Gantt Chart Task List
B. Curve Number Grid
C. Modeled Flood Map
D. Storm Frequency

A. Gantt Chart Task List

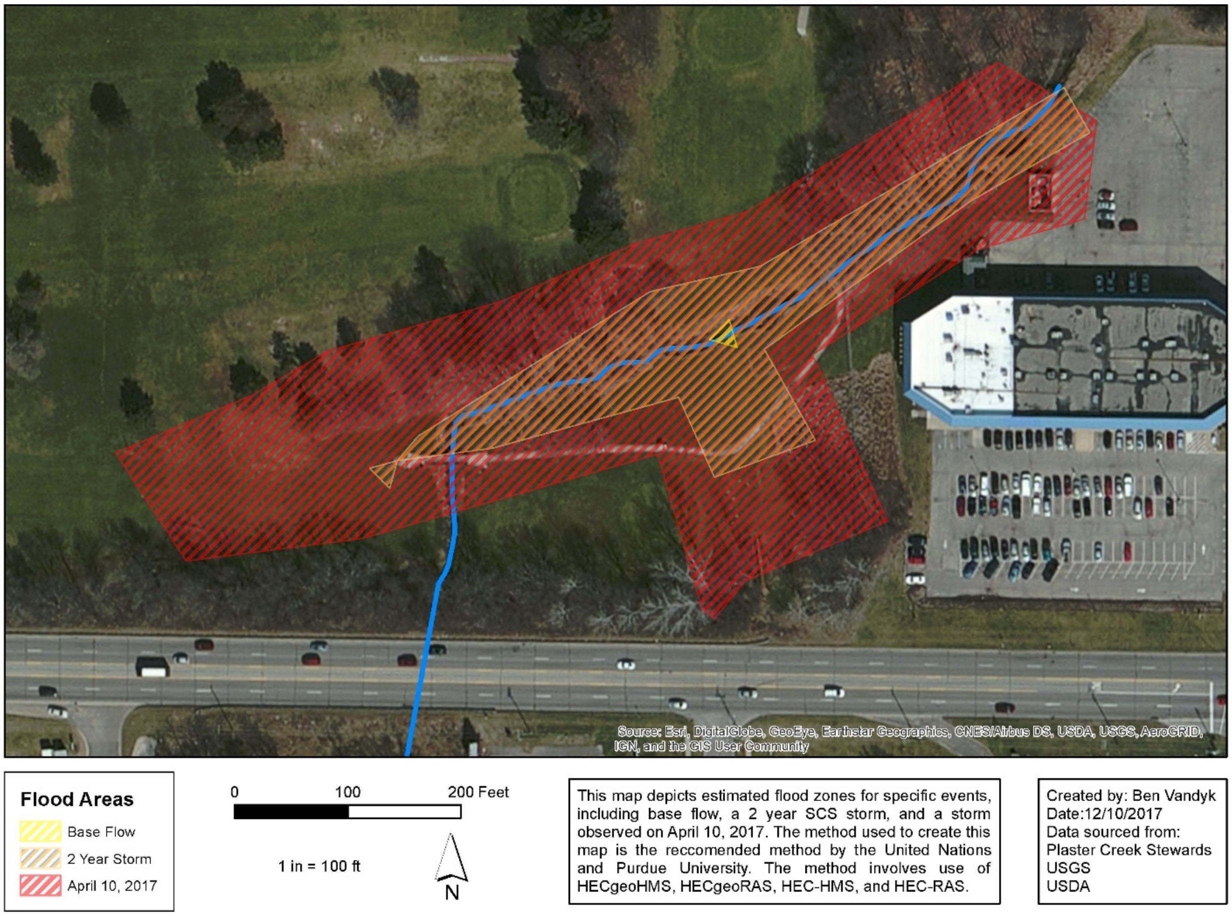
	Task Mode	Task Name	Durati	Start	Finish
1		Refine Scope	5 days	Tue 10/10/17	Mon 10/16/17
2		Collect all existing data	5 days	Tue 10/10/17	Mon 10/16/17
3		Determine missing data	4 days	Fri 10/20/17	Wed 10/25/17
4		Collect missing/needed data	8 days	Fri 10/20/17	Tue 10/31/17
5		Project Brief	5 days	Tue 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

Flood Innudation at Indian Trails Golf Course



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.