The Perfect Stormwater

Team 07

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Executive Summary

The Perfect Stormwater Team will provide preliminary design plans for Calvin's Physical Plant on daylighting a storm sewer underneath the Covenant Fine Arts Center parking lot. The team is proposing to daylight the storm sewers that currently contain Whiskey Creek. This creek starts on Calvin's campus in the Nature Preserve and flows into 30" to 36" storm sewers, eventually discharging into the Seminary Pond. The team has decided to improve the water quality of the storm water runoff entering the Seminary Pond via Whiskey Creek. The team is also looking to improve storm water detention for the Whiskey Creek Watershed per Kent County Drain Commission request. The Team has provided alternatives for all design areas, and will decide on a final design based on client preferences and regulations of governing bodies. A plan has been developed to focus efforts on how the team will proceed.

The team is also entered in the United States Environmental Protection Agency's Campus RainWorks Challenge. This is a contest among colleges and universities across the country. The purpose of this contest is to challenge students to redesign their campus's storm water systems to include innovative storm water management techniques to improve the quality of the storm water runoff.

In the spring, the team will develop a preliminary design for the chosen design alternative. In addition to the preliminary design a 3D model of the bridges will be constructed over the daylighted stream.

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Abbreviations:

AutoCAD	Autodesk's Computer-Aided Design
CFAC	Covenant Fine Arts Center (Calvin College Building)
CFS	Cubic Feet per Second
EPA	United States Environmental Protection Agency
EPA SWMM	Environmental Protection Agency Storm Water Management Model
KCDC	Kent County Drain Commission
HEC-HMS	Hydraulic Engineering Center – Hydraulic Modeling System (U.S. Army Corps of Engineers Program – Free Download)
USGS	United States Geological Survey
WSS	Web Soil Survey

1. Introduction:

Calvin College is a private liberal arts college located in Grand Rapids, Michigan. This project is a part of the Engineering Senior Design class that all engineering students at Calvin College must take during their senior year. The project aims to daylight Whiskey Creek from a storm sewer underneath campus with the intention to improve both the storm water runoff quality and the water detention upstream of the Seminary Pond. This report will discuss the feasibility of this project for the Senior Design class.

1.1 Team Members

The Team consists of four Civil and Environmental engineering seniors at Calvin College. Members of the Team are pictured in Figure 1. From left to right is: Ryan Roggie, Ha Ram Kang, Travis Hanko, and Anna Camilleri.

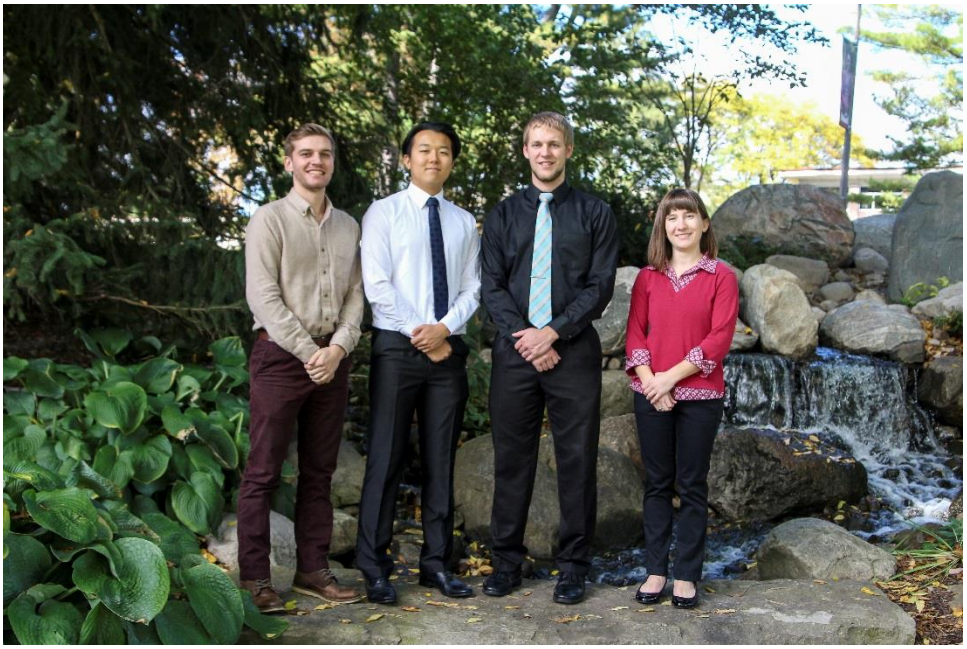

Figure 1. Team Photograph

Ryan Roggie

Ryan Roggie is from Erie, Pennsylvania and graduated from North East High School. He enjoys spending time outdoors doing activities such as, hiking, skiing, snowmobiling, and soccer. Ryan is majoring in Civil and Environmental Engineering and has developed interest in water resources engineering as well as road design. He plans to pursue a job in the Midwest where he can utilize his skills, preferably in storm water and wastewater management or as a traffic engineer.

Ha Ram Kang (David)

Ha Ram Kang is from South Korea, and he also goes by the name David Kang. David did not grow up in South Korea. He has lived in many different parts of Asia. David can speak and write in three languages: English, Korean, and Chinese. Currently, David is majoring in Civil and Environmental Engineering at Calvin College. He is interested in all of the focuses in the field of Civil and Environmental Engineering, as long as

the projects are related to sustainability. David plans to pursue an entry-level job in Michigan where he can utilize his engineering skills.

Travis Hanko

Travis Hanko is from Grand Rapids, Michigan and graduated from Covenant Christian High School. He has always lived in West Michigan, but enjoys adventure and travelling, especially to the Rocky Mountains and the West Coast. During his free time, he likes to play soccer, hockey, and board games. Travis is majoring in Civil and Environmental Engineering. During his time at Calvin College, Travis has developed an interest for storm water management as well as traffic engineering. After graduating Travis plans to pursue a civil engineering job where he can pursue his interests.

Anna Camilleri

Anna Camilleri is from Grandville, Michigan and graduated from Grandville High School. She loves Michigan and the Great Lakes, and in her spare time she enjoys camping and hiking. Anna is majoring in Civil and Environmental Engineering and has an interest in water quality and water resources engineering. After graduation she plans to pursue a job that can utilize her skills, preferably in storm water and wastewater management.

1.2 EPA Campus RainWorks Challenge:

The EPA is hosting its 5th annual Campus RainWorks Challenge [1]. This challenge is a competition for colleges and universities. The EPA competition challenges students to redesign their campus's storm water sewer systems to incorporate storm water management and treatment techniques that would improve the quality of storm water runoff.

There are two possible categories to enter the project in within the competition. The first category, the Demonstration Project Category, requires proof that the proposed design will work and could be implemented into the Team's campus. Submissions for this category should be very detailed in the design and prove to be feasible to the campus facilities planning department. The second category, the Master Plan Category, requires a report on the conceptual design. This concept should involve a discussion of how green infrastructure can be implemented into a broad area of the Team's college campus. The conceptual design should also enhance the sustainability of campus and fit into the college's master plan. The deadline to submit the project design is December 16, 2016. The winners of the competition will not be announced until April 2017.

The Team has decided to enter this project under the Master Plan Category. This project is intended to be completed during a semester-long senior design course. By entering the project into this category, there will be more detailed design work to be completed in the spring semester. The Team also considered the limited time window available for work on the project this semester and came to the conclusion that a conceptual design would be a more achievable goal.

2. Project Overview:

Whiskey Creek currently flows through 30" to 36" storm pipes under the campus of Calvin College. The storm water runoff collected by these storm sewers brings a variety of pollutants from the impervious

surfaces into the sewers containing Whiskey Creek. The goal of this project is to daylight Whiskey Creek in order to improve the water quality of the water discharged into the Seminary Pond. A map with the location of the proposed project area can be seen in Figure 2.

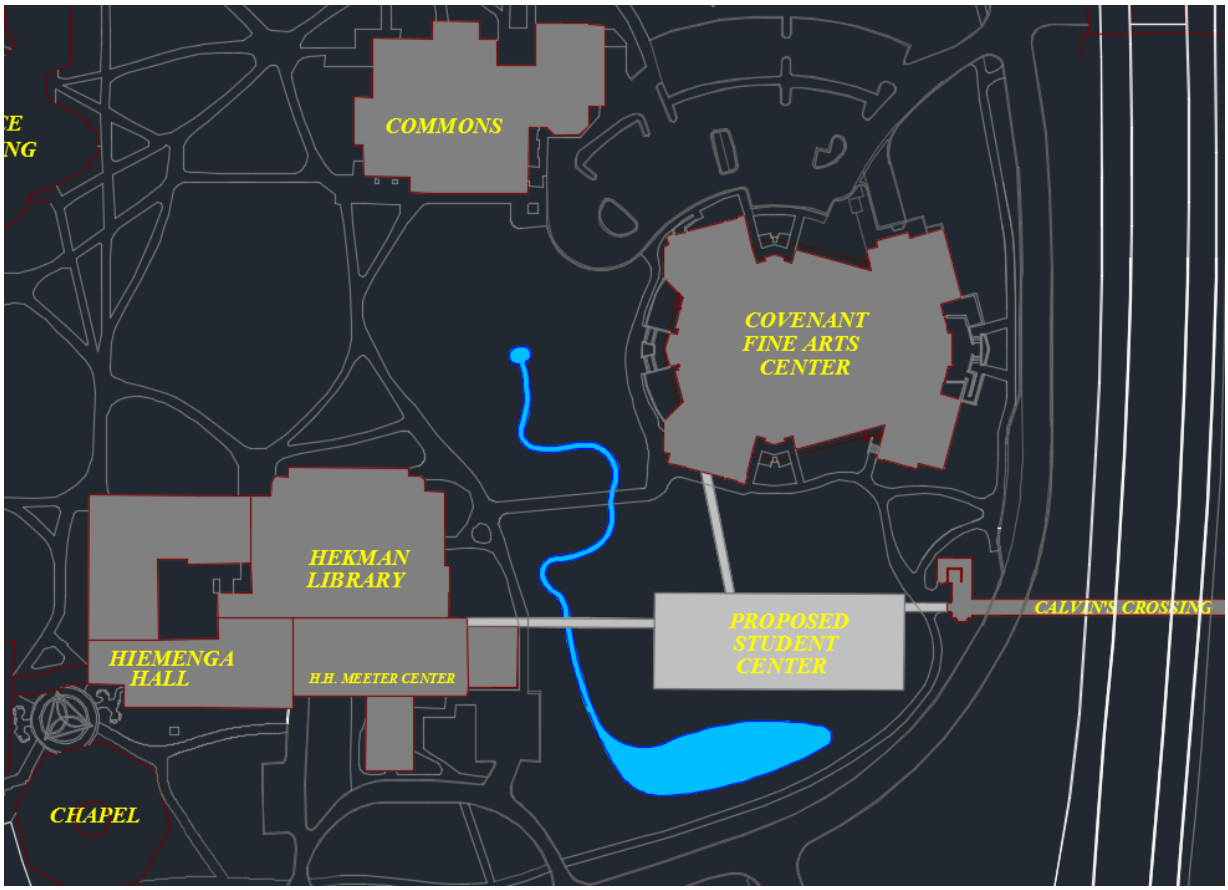

Figure 2. Preliminary Depiction of Proposed Improvements

An additional goal of this project is to add additional storm water detention on Calvin's Campus, either by simply adding a detention pond somewhere, or by implementing detention within the Team's daylighted creek design. This goal was suggested to the Team by William Byl who is the commissioner of the KCDC. The KCDC is currently looking into ways of achieving more detention within the Whiskey Creek Drain district due to flooding issues with the large pond just North of Centerpointe Mall, which would be flooded if a 100-year storm event would occur this year. The Whiskey Creek Drainage District can be seen below in relation to Calvin's Campus (as shown in red) in Figure 3. The drainage area considered for the Team’s project can also be seen in Figure 4Figure 4. Contributing Drainage Area

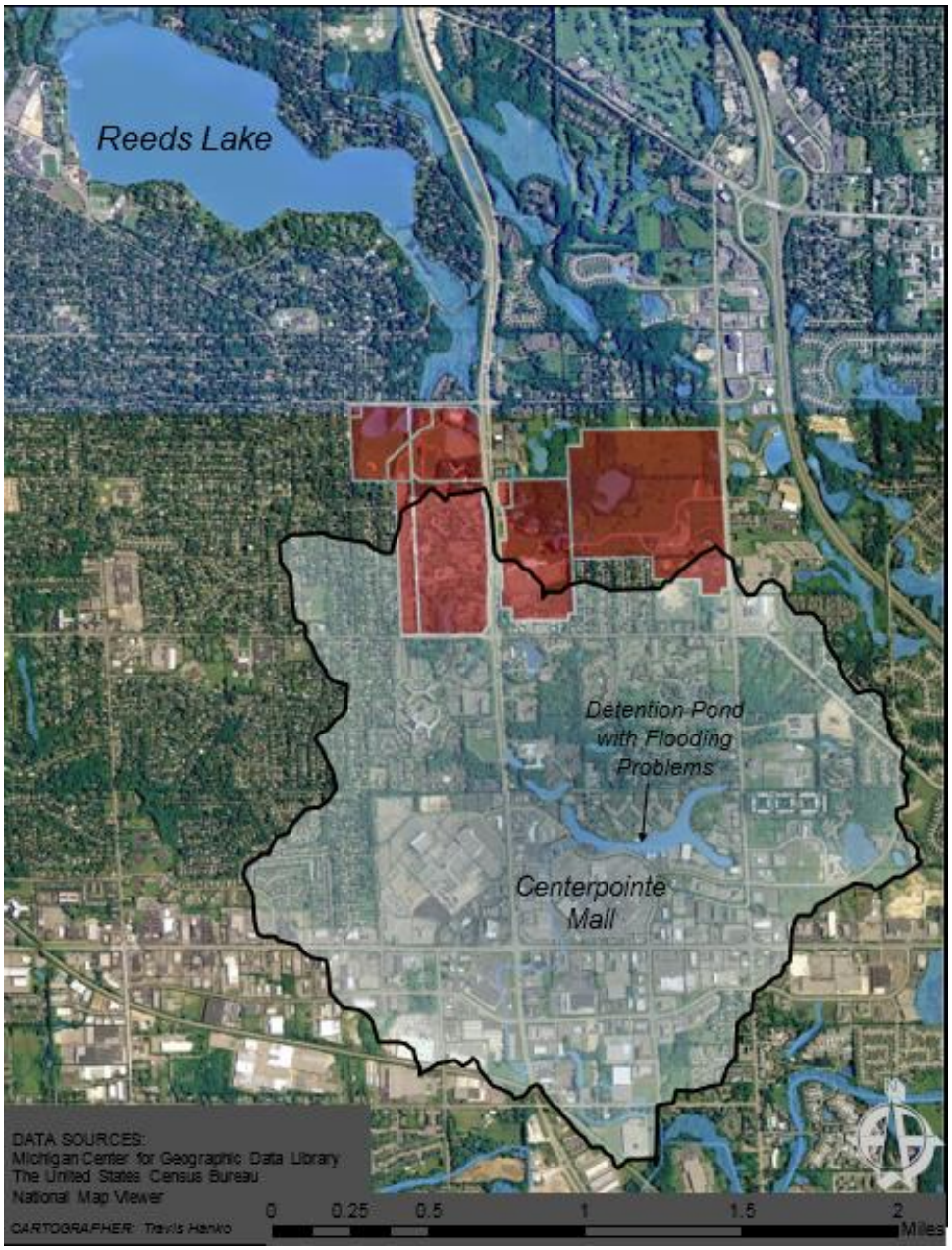

Figure 3. Map of the Whiskey Creek Watershed (as shown in the white overlay)

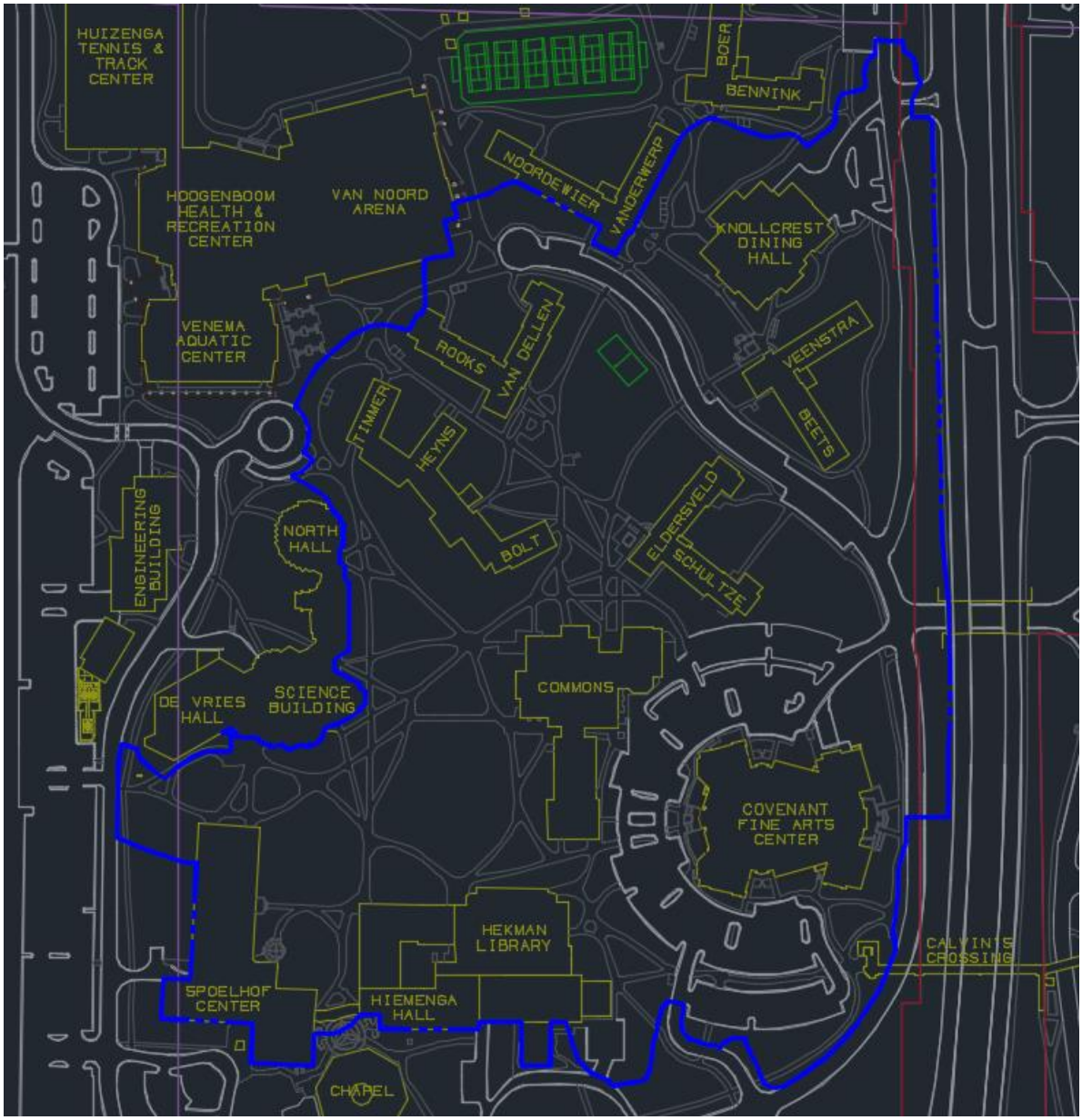

Figure 4. Contributing Drainage Area (Outlined in Blue)

2.1 Project Management

2.1.1 Team Organization:

The Team consists of four members. The project tasks were split up as evenly as possible between all the members. Additionally, each one of the members specialized in different tasks and took charge of their respective areas of responsibility. Ryan Roggie is the Team's website master, keeping track of everything that is posted on said website and regularly updating it. Anna Camilleri is the Team's designated public contact and researcher, researching the project and dealing with all the important emails and communications with the Team's advisor as well as local municipalities and businesses. Additionally, Anna was also in charge of the hydraulic modelling. Travis Hanko is the Team's technician,

operating the surveying equipment used as well as creating the CAD files used for this report. Ha Ram Kang is the Team's coordinator and 3D modelling expert, planning and organizing the Team's project outline in details as well as creating 3D models and cross sections of the site.

Meetings were held informally after most Senior Design classes every Monday, Wednesday, and Fridays. During these meetings, the project status was discussed and the Team decided what needed to get done next. Once every one or two weeks, the Team would meet in a more formal fashion and would discuss what was finished and what has yet to be done. The time frame was also discussed. Minutes were kept for these meetings.

Table 1 shows the notable mentors involved with this project.

Table 1. Senior Design Contacts

Course Instructors	Mentor	Team Advisor
Leonard De Rooy Mark Michmerhuizen Ned Nielsen Ren Tubergen Jeremy VanAntwerp	Professor Leonard De Rooy	Professor Leonard De Rooy

2.1.2 Schedule:

A team schedule was created and kept using Microsoft Project Professional. An initial schedule was created with broad tasks that usually spanned time periods of several weeks. After this was created and agreed upon, the upcoming tasks (one to two weeks out) were then put into more detail with sub-tasks. Sometimes, even these sub-tasks were given their own sub-tasks if needed. Whenever a task was not completed within the specified time frame, the Team met and discussed why the task went over schedule, and also readjusted the overall schedule to meet the new time requirements. Whenever the project schedule was adjusted, the whole Team was present to approve said adjustments to reduce confusion and miscommunications. Each team member worked approximately 5 hours a week on the project, majority of the work took place in the last half of the semester.

2.1.3 Budget:

There were no real budgeting concerns for the Team’s budget of this project as most of the work is computer modelling. The Team was given a budget of 500 dollars for the two semesters and the Team estimates a total spending of less than 150 dollars for competition fees, flow meters, as-built plans, and other such paper resources. Any new expense was first talked about with the whole team and was agreed upon beforehand. This reduced the amount of senseless spending. Additionally, the Team’s expenses were logged in an Excel spreadsheet and shared amongst the Team. However, the total projected cost for the Team’s proposed design has been taken into consideration to be within the Team’s client’s budget.

2.1.4 Method of Approach:

First and foremost, the Team worked together and approached their problems with a Christian perspective. Nobody was left out of important decisions and everybody was given a chance to voice their own opinions. As for the methodology of the Team's design, a general process was used. This process started with stating a problem the Team faced, after which a number of ideas, both good and bad, were discussed. These ideas were then evaluated based on feasibility, cost-effectiveness, and the seven design norms (Cultural Appropriateness, Trust, Integrity, Transparency, Stewardship, Caring, Justice). After evaluating each idea, the Team selected the optimal idea and developed it further. Problems arose within this developmental stage and were dealt with. Alterations were made to the idea as a result. Finally, after much reviewing and editing the final design alternatives were chosen.

2.2 Project Requirements:

The purpose of the Team's project is to reduce the runoff contaminants flowing from the surface runoff into the storm sewer system containing Whiskey Creek. This would improve the water quality flowing into the Seminary Pond. Additionally, the Team is registered in the National Campus Rainworks Challenge that is held by EPA of United States. The requirements of the challenge will also be included within the scope of the Team's project. The competition will evaluate the innovation and resiliency of the design as well as the likelihood of the design being implemented. There are seven areas that will be judged for the master plan category. The criteria for judging are paraphrased as follows: [1]

Documentation (10 points)

This section will be based on the presentation of the project. The judges will focus mainly on whether the documents are well-formatted and if they effectively present the project.

Performance (20 points)

The reality of the project's effectiveness will be evaluated in this section. The design must show its ability to improve the storm water runoff quality. It must also address multiple water resource goals (e.g. Flood mitigation, groundwater recharge). Finally, the design must be supported by appropriate modeling and calculations.

Resiliency (20 points)

This section evaluates the Team's current and long-term impacts of climate change on their campus. The project should also show how it can be resilient against the effects of climate change while effectively improving the storm water quality.

Innovation and Value to Campus (15 points)

The judges will be focusing on the project's ability to protect and improve the ecosystem while integrating into the college's campus life. The design should show how its integration will benefit the campus community.

Interdisciplinary Collaboration (15 points)

A demonstration of collaboration with different disciplines should be shown. The project should also communicate its value from both an engineering and design perspective.

Likelihood of Implementation (15 points)

The project should show how the design will fit into the campus master plan. There should also be evidence of the Team communicating with the campus facilities department when planning the design.

Community Engagement (5 points)

The judges will evaluate the community involvement (city, county, state, or other organizations) and their support of the project. The project should also consider public education of the problem and solution.

Additionally, the Team met with William Byl (Drain Commissioner up until 2016) and Brad Boomstra (Senior Engineer) at the KCDC to talk about an ongoing project in the area of Calvin College's campus. This project involves increasing the storm water detention upstream of the large detention pond just North of Centerpointe Mall (Figure 3). This detention pond was first designed many years ago when the standards for storm water detention were much smaller. In fact, when this pond was designed, the 100-year storm runoff volume was half of what the current volume is. In the time since construction, the Grand Rapids area has experienced larger storms, increasing the rainfall depth for all storms in the area. Additionally, the areas draining into this pond have seen a large increase in impervious area. Originally, this area was mostly undeveloped forest land, but has now been developed into subdivisions, apartment complexes, and industrial parks. Due to this increase in runoff volume and average rainfall depth over the years, the existing detention pond is very undersized for current conditions. As estimated by William Byl, a 100-year storm would flood the Centerpointe Mall just to the South and would cause millions of dollars in property damages. Due to this concerning prediction, the KCDC has decided to reduce this hazard by increasing the upstream detention within the Whiskey Creek Drainage District (Figure 3.) Calvin College's campus resides within this drainage district and includes a considerable amount of the districts contributing runoff volume due to the large amount of impervious area on campus. Therefore, the Team has decided to look into improving the storm water detention on campus. This further challenge will be approached in the spring semester.

2.3 Project Specifications and Schedule:

The project was broken down into three major phases: research, data gathering and brainstorming, and initial design. The research consisted of gathering a lot of documents on the topics of daylighting streams, contaminant removals in open channel flow, and municipality standards on storm water management techniques. The data gathering and brainstorming portion consisted of meeting with the Calvin's Physical Plant a number of times as well as the KCDC. During this phase, as-built data was collected, campus improvement CAD files were acquired, surveys were conducted, and Whiskey creek contaminant data was gathered. The final phase consisted of analyzing the research and collected data and putting together preliminary designs for a daylighted creek.

Phase one (research) was subdivided into different research topics: stream daylighting, storm water management regulations, and water quality. All gathered research information was placed on the Team's Dropbox folder so all members could access the researched information.

Phase two (data gathering and brainstorming) was subdivided into two major tasks. The first task was gathering data on utility placement and sizes in the proposed area, and the second task was brainstorming initial alternatives to look into during the design stage. Data on storm sewers has been gathered through a survey completed using surveying equipment provided by Feenstra and Associates: Civil Engineers and Surveyors, Inc. Information on the other existing utilities such as water mains, sanitary sewers, and gas mains were acquired from as-built plans the team received from the Physical Plant and

Professor De Rooy. Elevation data has also been acquired from a previous design team, The Calvin Drain Trust, along with contaminant data for Whiskey Creek. The Team used the USGS WSS web application to find soils data. The Team is still working on gathering historical flow data on Whiskey Creek as well as collecting their own flow data. This flow data would be gathered using flow meters borrowed from Professor Deanna VanDijk of Geology, Geography, and Environmental Studies department at Calvin. The Team has concluded that the flow data is not necessary for the feasibility study due to the use of hydraulic modelling of the entire drainage area on Calvin's campus.

Phase three (initial design) was also subdivided into several tasks: preliminary flow calculations, proposed stream location, initial modelling (AutoCAD, EPA SWMM, and HEC-HMS), visual 3D models (plan view and cross-sectional,) optimal vegetation to plant within the excavated area, initial bridge design, and a very preliminary cost estimate. Anna was given the task of working on the preliminary flow calculations. Travis and Ryan worked on determining the proposed stream location, Travis did the drafting of the CAD model and Ryan came up with preliminary bridge designs and determined the vegetation to be used in the riparian zone of the proposed stream. David was given the task of doing the 3D modelling for both the stream plan view and cross section.

2.4 Design Criteria/Approach

The Team's first task will be to determine the feasibility of the project. The final design will incorporate a daylighted stream, one or more bridges, and a pond to increase storm water detention on Calvin's campus. There will be some design aspects that the KCDC and MDEQ will have control over. The Team has received requirements from KCDC to improve storm water detention and water quality coming from Calvin's campus. This requirement is due to Calvin being in the same watershed as Centerpointe Mall. Modeling for the entire watershed has been done by Prein & Newhof, who determined that the detention pond directly behind Centerpointe Mall will overflow in all directions during a 100-year storm event. William Byl stated that there could be sheet flow through the mall's parking lot for such a storm as well as water entering into the mall itself.

The Team has received water quality and drainage models from Professor Muyskens and The Calvin Drain Trust. The Calvin Drain Trust is a previous Calvin design team who got their data from the Plaster Creek Stewards. The Team has also received as-builts for the majority of Calvin's campus. No data has been gathered on the location of the proposed Student Center Building seen in Calvin's Master plan. This is due to the exact location of the proposed building not being specified yet. This gives some flexibility to the Team's proposed creek location. Since no official plans have been made for the proposed building as of yet, the Team can determine the location of said building to a certain extent. The Team will be mindful that there are plans to place a building in the daylighting area and will not over constrain the location for future development.

There are several requirements that need to be met concerning the walkway bridges, stream bank erosion control, and channel design. All of regulations are known, and the Team has the as-builts, therefore the Team is moving forward with the preliminary design of the alternatives. However, no flow data for the storm sewers has been collected. Due to waiting for this data, not all of the final design alternatives could be fully developed at this time and their preliminary cost estimates. Once the flow data is collected for the existing storm sewers, the team will further develop the design alternatives. When the

final design alternatives are chosen, the Team will begin sketching, analyzing, and preparing preliminary cost estimates for the potential designs. Then the Team, KCDC, and Calvin's Physical Plant will collaborate to determine which alternative is the most economical, feasible, sustainable, and aesthetically pleasing. When this alternative is chosen, the Team during spring semester will work on preliminary plans for the proposed design.

2.5 Standards and Regulations

The MDEQ has a large amount of standards for water crossings provided in a document [2]. This document includes standards for culverts, bridges, and other types of crossings. Only the standards for bridges were considered for this report due to a lack of use for the other types of crossings.

The KCDC also has various standards for detention basins, and these standards can be found in a report [3]. As for detention ponds, volume standards are to meet 25-year flow capacities. Additionally, the first flush, the first 1" of a rainfall event, are to be infiltrated within 12 to 24 hours. Emergency floodways must be able to withstand a 10-year storm flow and must not compromise the berm structure. Floodplains for the channels are to be designed for a 100-year storm capacity.

The City of Grand Rapids also has various standards for sanitary and storm sewers in their standard construction specifications document [4]. Due to the site being on private land, the Team's design should meet the standards of the MDEQ and the KCDC. However, the Team believed that also following the standards for the City of Grand Rapids would be valuable. These standards that would be followed are for the sanitary and storm sewers. The various standards for sanitary and storm sewers include being 1.5 feet away from existing utilities, piping material, soil erosion control, minimum slope, minimum and maximum sewer velocities, and many more.

If this project were to be constructed, the contractor would also be required to adhere to current design standards at the time of construction for KCDC, MDEQ, and other associated municipalities.

3. Preliminary Design Alternatives

3.1 Proposed Stream

Several designs have been thought of for daylighting Whiskey Creek. They include implementing a bioswale design (this has already been done on Calvin's campus), a grassed waterway design, which could potentially remove most or even all of the sediment loads, or an innovative elongated detention basin design, which would have a continual flow of water and could greatly reduce the streams contaminants. All of these BMPs could include a series of check dams, which could help remove a larger percentage of the current sediments. All of the design alternatives have the ability to greatly improve the aesthetics of the site. The Team's soils data in Figure 5 shows that the soil types covering the daylighting area are mainly soil types 78 (Urban Land) or 82B, also known as Urban Land-Perrinton Complex with zero to eight percent slopes. This soil type consists of 40 to 80% urban land (impervious surfaces) and Perrinton Soils. Perrinton soils typically have a surface layer of dark brown friable (easily crumbled) loam and a sub-surface layer of pale brown friable loam. This soil type has moderately slow permeability characteristics,

meaning slow infiltration of surface water. Additionally, the main concern for this type of soil is erosion, which the Team will have to consider in each of their daylighting designs [5].

Figure 5 Soils Map of Calvin's Campus [6]

3.1.1 Bioswale

One of the options the Team is considering for the stream is a bioswale. A bioswale is a treatment technique that reduces storm water runoff, filters sediment, and has the ability to absorb chemicals. Calvin College currently utilizes a bioswale located on the east side of campus near the nature preserve. The only difference is the client desires continuous flow through the daylighted stream, so the Team will implement this change. The sizing of the swale is predicted to be of similar size to the nature preserve bioswale based on it already being a part of the Whiskey Creek drainage system on Calvin's Campus.

Figure 6. Bioswale next to Nature Preserve on Calvin's Campus [7]

The Team is also considering to incorporate an underdrain to collect the runoff that isn't absorbed through infiltration. The channel walls will have deep rooted native plants for nutrient absorption. An overbank flooding zone will be utilized to prevent flooding. A drawback is these can be large in size, depending on the designed infiltration volume and rainfall amount. Bioswales also are not normally designed to have a continuous flow through them, which is a requirement of the client. The Team would be challenged to come up with an innovative idea to implement with this design alternative.

3.1.2 Storm Water Conveyance Channel/ Grassed Waterway

Storm water conveyance channels or grassed waterways are used to convey storm water runoff. They also transport runoff without causing flooding or erosion and reduce or even eliminate sediment loads. Their limitation is in their ability to remove pollutants. The channel's wall is normally lined with native vegetation or riprap. The design of the channel depends on soil type, topography, volume, and velocity of flow. The Team's initial design idea for the channel is to have deep rooted native vegetation lining the channel wall for nutrient absorption. The determination of whether to use riprap will depend on the velocity of flow through the channel. MDEQ recommends using vegetation for flowrates under 6 cfs and riprap for over 6 cfs. This channel will also incorporate a floodplain to prevent flooding to the surrounding campus.

3.1.3 Check Dams

This BMP will be considered in both waterway systems. Check dams will allow the Team to better control the runoff velocity through the channel, preventing erosion, and protecting the vegetation lining the channel. It can be implemented to improve the amount of suspended solids settling by acting as a small settling basin. This could be used with about 80% removal efficiency while also having a small footprint. Some drawbacks of check dam designs are they may clog with leaves or larger debris, thus

requiring added maintenance. The materials used in the design will meet the standards set by the City of Grand Rapids. The relative cost of check dams depends on the material used.

Figure 7. Check Dams in a Grassed Waterway Channel [14]

3.1.4 Extended Detention Basin

An extended detention basin will be considered due to the possibility of the daylighted stream not being able to convey storm water long enough to meet the KCDC's new storm water detention requirement for the Whiskey Creek Watershed. A detention basin reduces the peak discharge rate, thus reducing downstream flooding. Additional functions are removing sediments, non-soluble metals, and nutrients through settling. A drawback of detention basins is their settling ability is heavily affected by the soil's infiltration rate, which was determined to be moderately slow. The Team's design idea of the detention basin is to retain water from the first flush, or the first 1" of rainfall, for 48 hours. The flow rate and emergency spillway out of the elongated detention pond will be controlled by an outflow structure based on a modelled water level in the pond for a given rain event (typically 100-year storm.) To improve the aesthetics of the detention basin the team is considering adding a fountain to the design. This fountain will also prevent stagnation of water and algal blooming, which would ruin the aesthetics of the area.

3.2 Bridge Design

There are two basic bridge designs, which are movable and fixed. In this project, the fixed bridge design will be most feasible and cost efficient. However, bridges are considered to have more than just two types, but the team considered these two types to reduce complexity. Four main factors are used in describing a bridge: span, material, placement of the travel surface in relation to the structure, and form. There are three types of span bridges: simple, continuous, and cantilever. There are also many different kinds of materials that bridges can be made out of. Another consideration for bridge design is the placement of the travel surface in relation to the structure, which would pertain to the deck, pony, and

through. The last and most important design consideration is the form, which could be a beam, arch, truss, etc. The figure below shows the design of the vehicular and pedestrian bridge the team had in mind.

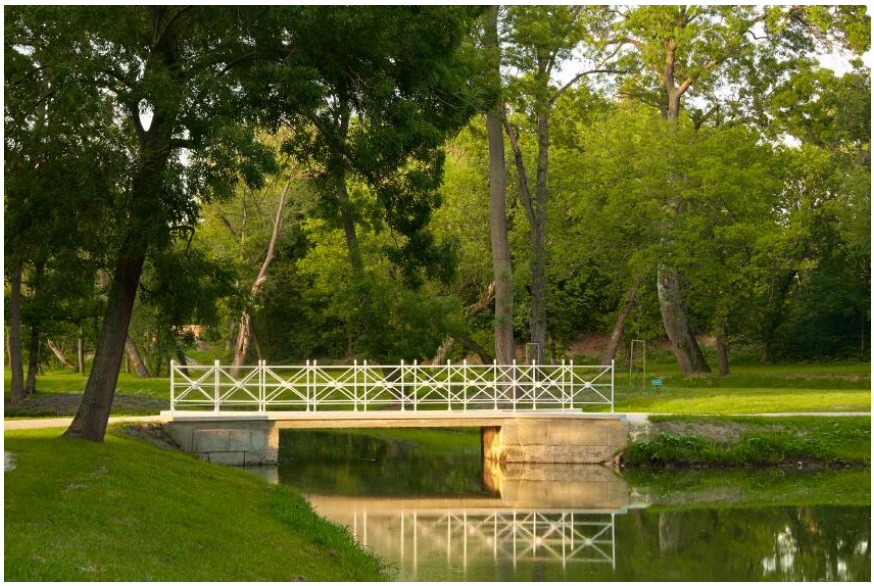

Figure 8. Example of a possible pedestrian bridge [15]

3.3 Plant Alternatives

The final decision on which plants to use and their location is dependent on which stream alternative is chosen and the velocity of flow through the stream. However, the Team was able to put together a list of plants native to Michigan as well as their respective possible planting locations that will be considered in the channel design. The plants are ones that thrive in areas of periodic flooding, such as flood plain perennials, trees, shrubs, and some wild flowers.

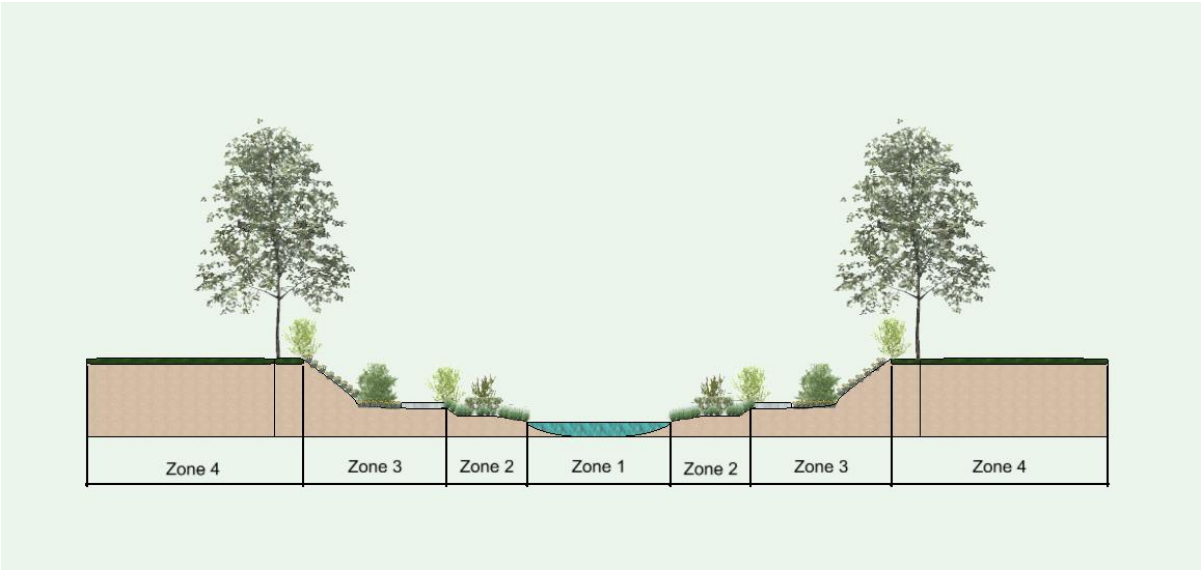

Figure 9. Proposed Channel Cross Section Planting Zones

The cross section of the day lighted stream is split up into zones based on type of plants in the zone as well as the conditions the plants will face. Zone 1 of the channel is the submergent zone, which will primarily feature no plants, because there will be consistent water flowing in this zone. Zone 2 is the wet meadow zone where there will normally be some moist to wet conditions. Zone 3 is the floodplain. This zone is only flooded during snowmelt conditions and large storms. It will also incorporate a sidewalk or walking path so students, faculty, and visitors can walk alongside the daylighted creek and enjoy its full beauty. The last zone is outside of the daylighted stream excavation area and this will be primarily medium sized trees. The table below shows the different native plants that will be considered to be planted in each zone.

Table 2. Michigan Native Plants Considered for Design Alternatives [8]

Zone 2: Wet Meadow Zone	**Zone 3: Floodplain Zone**		**Zone 4: Upland Zone**
Wildflowers:	**Wildflowers:**	**Shrubs:**	**Trees:**
Canada anemone	Smooth aster	Downy arrow-wood	River birch
Hairy Beard-tongue	Butterflyweed	Maple leaf viburnum	Hackleberry
Golden alexanders	Black eyed susan	Cokecherry	Green Ash
Great blue lobelia	Prairie smoke	Gray Dogwood	Basswood
Marsh marigold	Blue-eyed grass	New Jersey Tea	Black willow
Blue flag iris	Columbine	Serviceberry	Sycamore
Jack in the pulpit	Spiderwort	Fragrant sumac	Yellow birch
Marsh blazing star	Lupine		Blackgum
Obedient plant	Bee balm		Northern White Cedar
Pink turtlehead	Purple coneflower		Eastern hemlock
	Giant hyssop		Black maple
Grasses and Sedges:	Bergamot		Musclewood
Fox grass	Blue False indigo		Pawpaw
Cotton grass	Beebalm		Redbud
Rushes			Tulip Tree
Satin Grass	**Grasses and Sedges:**		Shingle oak
Sedges	Little bluestem		Swamp white oak
	Pennsylvania sedge		Flowering Dogwood
	June grass		Trembling Aspen
	Purple love grass		Blue Ash
	Big bluestem		White Ash
	Bottlebrush grass		Red oak
	Wool grass		Eastern red cedar
	Switch grass		White Oak
	Canada wild rye		Black cherry

The team has not decided which plants will be used in each zone, this will be done during second semester when the design alternatives are chosen. When choosing the type of plants, the team will consider root length, looks, containment removal ability, and the amount of people allergic to the plant.

4. Design Decisions

Decisions for this project have been and will be made using decision matrices. Not very many decisions have been made with regards to this project as of yet. The Team has focused on more of the research, data gathering, and developing alternatives side of this project for this semester. Additionally, the Team has not acquired sufficient data to calculate the velocities of the proposed stream. A large portion of the decisions to be made in the future depends on this data, including decisions on vegetative selection for the riparian and floodplain zones and the overall design alternative.

4.1 Overall Daylighted Stream Design

Several alternatives for the overall design of the daylighted stream have been looked into: bioswale, elongated detention pond, check dam design, and a grassed waterway. This matrix can be seen in Appendix A below in Table A-1. The most important design criterion is listed as effective contaminant removal due to the fact that this is the ultimate goal of the entire project. Following this are the two criteria of feasibility and campus value and aesthetics. These are highly ranked because more feasible projects are easier to implement and the overall aesthetics of Calvin's campus core is very important to the Team. This is also a large factor that plays a part in the 10-year Master Plan. With improved aesthetics, students, teachers, and visitors alike will be able to more fully enjoy the bright and cheerful atmosphere exhibited in the campus core. This area of campus could potentially become a major selling point for prospective students and would become a peaceful gathering place for everybody to enjoy. The next criterion listed is increased infiltration. Ground water infiltration will further increase Calvin's environmental sustainability as well as reducing the peak discharge from storm events. Finally, cost effectiveness and resiliency are also considered in the design process. Resiliency is considered because the Team desires to design a beautiful piece of campus that will make Calvin College greener and more environmentally friendly that will also last generations. Another factor that has not been considered within this decision matrix is the average velocity of the water flow. The overall design has yet to selected due to lack of modelling data for the final design decision.

4.2 Sanitary Sewer Interference

Currently, an 8" sanitary sewer services the CFAC. This pipe resides directly in the way of our proposed daylighted stream. To make matters worse, the sanitary sewer is located at a higher elevation than the storm sewer. This makes it impossible to simply have the stream flow over the still buried sanitary sewer as an easy solution. This sewer will need to be moved or worked around in some other way. The location of this sewer interference can be seen in Figure 10.

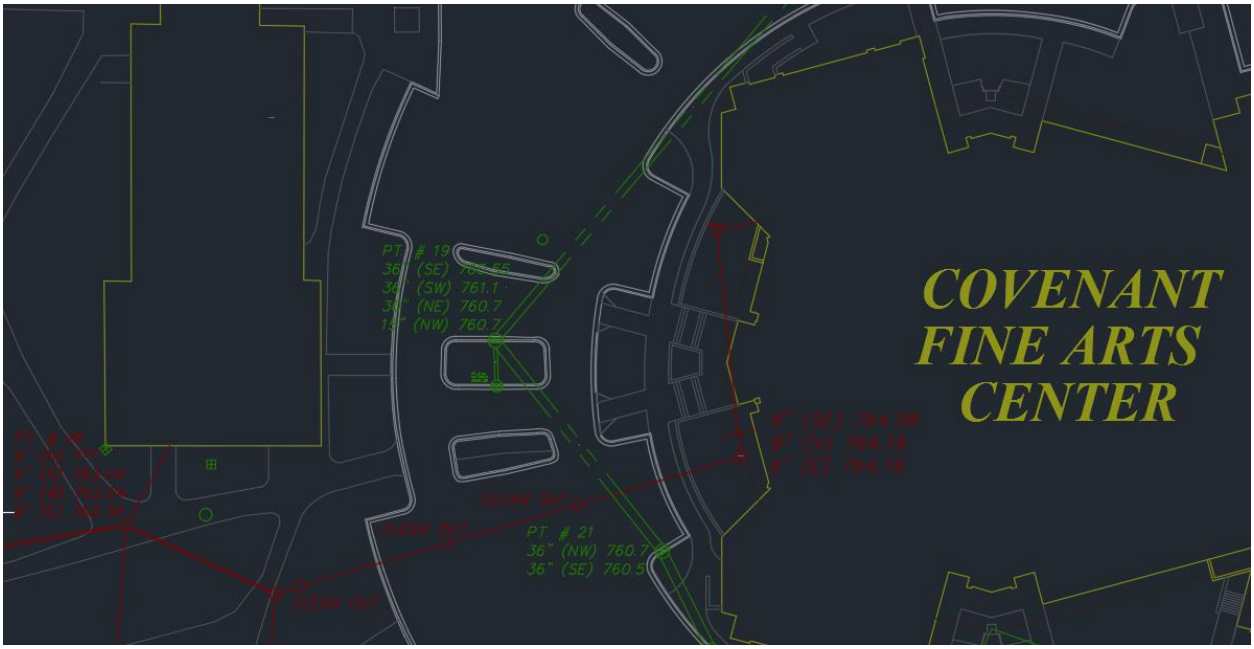

Figure 10. Existing Layout of Sanitary and Storm Sewers

The Team analyzed a few alternatives to overcome this problem. The first option was to simply have the daylighted stream begin after the sanitary sewer has been crossed by the storm sewer. This option would be the most cost effective, but it would greatly reduce the area available to daylight Whiskey Creek. The second option was to implement an inverted siphon. This design would replace the two sanitary sewer manholes on either side of the crossing with deeper manholes and simply run a new sanitary sewer below the proposed daylighted stream. This option would require accessing a manhole directly in front of the CFAC and excavating a very deep trench within 20 feet of the existing foundations. Additionally, this would mean that the new sanitary sewer running beneath the stream would constantly be filled with sewage and would require extra maintenance to reduce the risk of blockage. The third and final option considered was to re-route the sanitary sewer upstream of the proposed daylighted stream. This would be more expensive than the other options, but would not constrict the location of the beginning of the stream and would not require a permanently filled sanitary sewer line. The team used the decision matrix found in Table A-2Table A-2 of Appendix A and determined that the best alternative to implement was the third option: re-routing the existing sanitary sewer as seen in Figure 11. Here the proposed sewers and subsequent text take on a lighter red color. The proposed invert that outlets back into the existing sewer system is 0.15 feet above the current invert. The proposed pipes are both 8” pipes at 0.40% slopes, meeting the required standards for sanitary sewers.

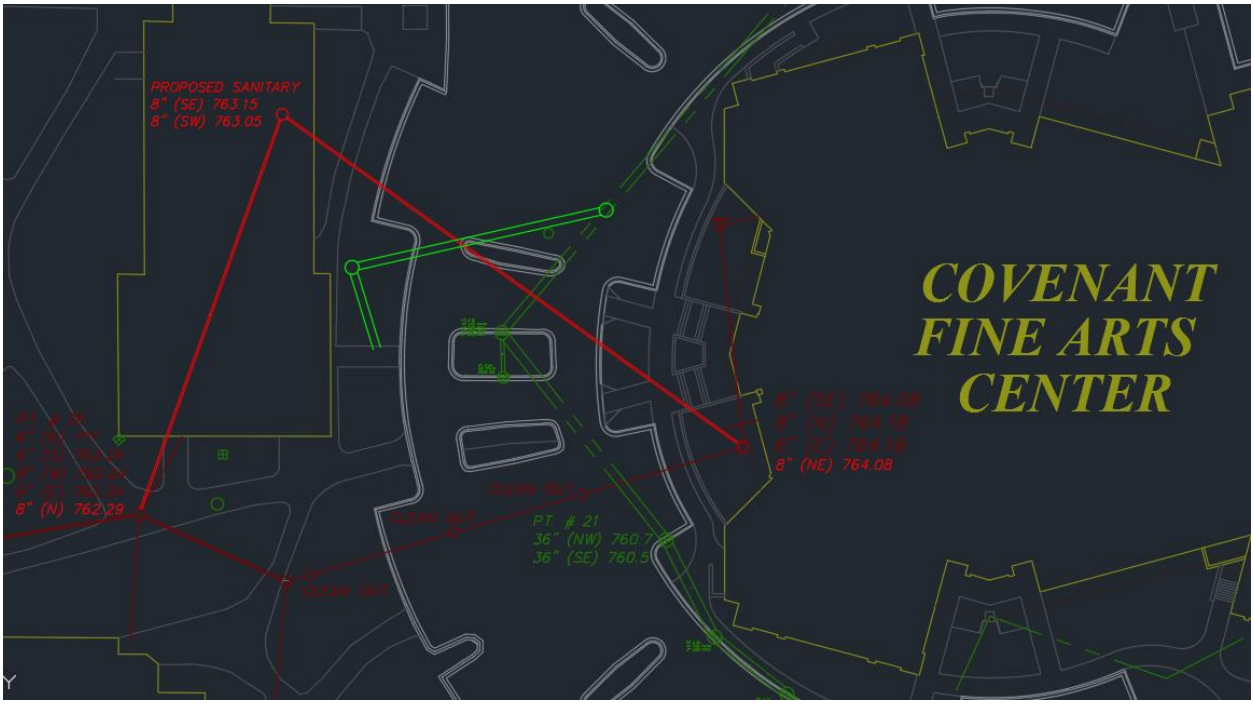

Figure 11. Proposed Locations of Storm and Sanitary Sewers

4.3 Bridge Design

The team has not narrowed down the bridge design for almost all the categories described previously, but plan on having one or two bridge crossings over the day lighted stream. One of the crossing would be a bridge where Calvin vehicles could cross over and mainly would be used as a pedestrian bridge. The second is only a pedestrian bridge. The team has also narrowed down the materials to be used for the bridge design: stone, metal, concrete, and timber.

4.4 Business Plan

Materials and equipment used will account for the largest portion of the costs of this project. The largest items of the costs will be the excavation of earth as well as grading of the channel. Other items that will be considered in the cost (among many others) will be bridge materials, topsoil and hydro-mulch, cost to re-route local utilities, and selected vegetation.

Table 3. Cost of Estimate of Items of Project

	Cost	Units
Excavation Earth	$10.00	CYD
Riprap	$70.00	SYD
Topsoil, 4 inch	$5.00	SYD

Unit prices are from the Michigan Department of Transportation 2016 weighted average item price report [9]. These unit prices are averages of the all contractor's bidding price based on the quantity and region of the project. The pricing for all design alternatives are unavailable due to no completed designs. These cost estimates will be developed in the future.

The Team met with KCDC who stated that the City of Kentwood as well as the City of Grand Rapids would possibly fund the full cost of the project if enough storm water detention is added to Calvin's campus. This goal of KCDC is to reduce the effect of a 100-year flood event in the Whiskey Creek watershed, and thus reducing the possibility of flooding in the Centerpointe Mall from a 100-year flood event. This would be funded by these municipalities because it is the responsibility and mission of the Kent County Drain Commission to "improve and maintain storm water drainage for the public health, safety, convenience, and welfare of the citizens of Kent County" [10]. Since there would be possibly millions of dollars lost if Centerpointe Mall is flooded, it is their responsibility to increase storm water detention in the area to reduce the risk of flooding and damages within the next few years. The Team has not been given exact numbers on the amount of detention needed to meet their goal, so the Team will try to add as much detention as possible to comply with KCDC's overall goal. If outside funding is not available or feasible, Calvin could then add in these improvements to their current Master plan and reduce a portion of the overall cost by implementing the Team's daylighted stream design at the same time as the proposed Student Center building.

5. Conclusion

This project is very feasible for Calvin College to implement. The Team believes that the project will fit in with the 20-year master plan for Calvin's campus in addition to adding aesthetic beauty and an innovative attraction to Calvin's campus core for current students, faculty, and staff, as well as prospective students and alumni. Furthermore, the downstream water quality of Whiskey Creek and the Seminary Pond could also be positively impacted as a result of implementation. Most of the cost of this project will be due to the excavation and vegetation of the daylighted creek. However, there is the potential for Calvin College to not pay for the development of this project, so long as the storm water detention is increased to the expectations of the KCDC. If this were to happen, KCDC would work with the City of Grand Rapids and the City of Kentwood to pay for the storm water detention improvements.

Future work for this project includes estimating the water quality improvement and detention provided by each design alternative. The cost estimates for the design alternatives will be further defined as each alternative is designed with greater detail. The team will also continue to collect more flow data for Whiskey Creek to create a more accurate model of the proposed daylighted stream.

Acknowledgements

The Team would like to thank everyone that has provided help with the project. There were many areas in the planning and designing stage that required guidance and assistance. A special thanks goes out to the following:

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David Hanko, Feenstra & Associates Civil Engineers and Surveyors
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Chalie Huizinga, Physical Plant, Calvin College
Beulah Kruis, Graphic Design Major, Calvin College
Professor Mark Muyskens, Chemistry, Calvin College
Ben Spoelhof, Team Photographer, Calvin College
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Professor Deanna VanDijk, Geography, Calvin College
Professor Julie Wildschut, Plaster Creek Stewards, Calvin College
Professor David Wunder, Engineering, Calvin College
Calvin Drain Trust, Senior Design Team (2015-16), Calvin College

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Appendix

Appendix A: Decision Matrices

Table A-1. Decision Matrix for Selecting Daylighted Stream Design

	Cost Effective *(6)*	Increased Infiltration *(7)*	Effective Contaminant Removal *(10)*	Campus Value & Aesthetics *(9)*	Resiliency *(6)*	Improved Detention *(8)*	**Totals**
Bioswale	7	6	7	7	9	5	318
Elongated Detention Pond	5	8	7	10	7	10	368
Check Dams	8	5	8	10	8	7	357
Grassed Waterway	8	6	6	7	9	5	307

Definition of Terms:

Cost Effective:

-Measure of the cost of implementation

-Scale of 1 being very expensive to 10 being very inexpensive.

Increased Infiltration:

-Measure of the increased ground water infiltration due to implementation

-Scale of 1 being no increase to 10 being a large increase.

Effective Contaminant Removal:

-Measure of the amount of contamination removed

-Scale of 1 being none removed to 10 being all contaminants removed

Campus Value & Aesthetics:

-Measure of the increased value to campus and the overall aesthetic improvement

-Scale of 1 being no increased value or aesthetics to 10 being a large increase of both

Resiliency:

-Measure of the predicted life-span of the design alternative

-Scale of 1 being less than 5 years with lots of maintenance to 10 being no maintenance and lasting more than 30 years

Improved Detention:

-Measure of the amount of detention gained from the alternative

-Scale of 1 being no added detention to 10 being large amounts of added detention

Table A-2. Decision Matrix for Sanitary Sewer Alternatives

	Cost Effective ***(10)***	Depth of Sewers ***(6)***	Proximity to Stream ***(8)***	Decrease to Proposed Aesthetics ***(9)***	**Totals**
Re-route Around Stream	6	8	10	9	269
Lower Sewer Under Stream	5	4	2	8	152
Begin Steam After Sewer	10	10	8	1	233

Definition of Terms:

Cost effective:

-Measure of the cost of implementation

-Scale of 1 being very expensive to 10 being very inexpensive

Depth of Sewer:

-Measure of how deep the proposed sanitary and storm sewers will be

-Scale of 1 being very deep (over 15 feet) to 10 being no deeper or shallower than existing conditions

Proximity to Stream:

-Measure of how close the proposed sanitary sewer will come to the proposed stream

-Scale of 1 being within 3 feet to 10 being more than 50 feet

Decrease to Proposed Aesthetics:

-Measure of the loss of the proposed aesthetic improvement (assuming a maximum length for the daylighted stream and no manholes restricting channel width or depth) associated with each alternative

-Scale of 1 being no decrease to aesthetics to 10 being a large decrease

Appendix B: Important Meetings Overviews

September 19, 2016

Calvin Physical Plant: 3:30-4:30 pm

Attendees:

ALL Members of Team 7

Charles Huizenga (Calvin Physical Plant)

Phil Beezhold (Calvin Physical Plant)

Subject: Meeting about Senior Design Ideas with the Physical Plant

The team had a meeting scheduled with Charlie Huizenga and Phil Beezhold in the Physical Plant to go over some of the senior design project ideas that the team had. In the meeting we discussed the Vos House, drainage improvements for fields, soccer stadium design with turf fields, daylighting Whiskey Creek, and Calvin crossing building. During the meeting we discussed our interest in doing storm water projects and they steered us in the direction of pursuing daylighting Whiskey Creek. The team decided that we would like to do our senior design project for daylighting Whiskey creek on campus.

As the meeting ended Phil Beezhold gave us permission to use the masterplan and utilities AutoCAD drawing which we receive later in an email.

October 17, 2016

Professor Hoeksema's Office 12:30 – 1:30pm

Attendees:

ALL Members of Team 7

Professor Hoeksema (Civil & Environmental Engineering Professor at Calvin)

Subject: Overview of Daylighting Whiskey Creek, Ideas, and Guidance for design

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In the meeting with Professor Hoeksema we describe the scope and plan for the senior design project. He told us a couple of his concerns: daylighting a stream doesn't reduce sedimentation, flood event issues, and surcharging upstream manholes. He stated that in order to reduce sedimentation there needs to be infiltration somewhere in the daylighted stream design. The Team was also informed which modeling systems work the best for storm water management practices. EPA's SWMM is good for storm sewers but is merely okay with modeling open channels, whereas HEC-RAS is best at modeling stream and open channel flow. He also described that we are going to need to do a survey and get as-builts for the existing storm sewer. The team also learned methods to find the peak discharge for the storm sewer systems.

October 18, 2016

Professor Wunder's Office 2:30 – 3:30pm

Attendees:

ALL Members of Team 7

David Wunder (Civil & Environmental Engineering Professor at Calvin)

Subject: Guidance on Infiltration Techniques

In the meeting with Professor Wunder the team asked for guidance on where the team should be heading with regards to the next steps. The team would need the as-builts, water quality data, and flow data in order to begin the analysis of the storm sewer. The team was also informed that reducing sedimentation by BMP's would depend heavily on the soil type, route of stream, and detention ability of the BMP. We also asked him about the water quality, and he pointed us in the direction of Professor Muyskens, who takes containment data around Calvin. He then stated that the Seminary Pond water quality is most likely due to fertilizers in the water as well as the clay soil underneath of the pond.

October 25, 2016

Kent County Drain Commission Office 1:00 – 2:00pm

Attendees:

Anna & Travis (Members of Team 7)

William Byl (Drain Commissioner, KCDC)

Brad Boomstra (Senior Engineer, KCDC)

Subject: Project Introduction, Guidance on Standards, Design Requests

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Members of the team discussed the scope of the project with the KCDC. They discussed their project in the Whiskey Creek watershed, in which Calvin College's campus is located in and how CenterPointe mall is located in the 100-year floodplain. They told us if we improved the storm water detention on Calvin's campus with this project they could possibly make the cities of Kentwood as well as Grand Rapids fund the project instead of Calvin College. We discussed our possible stream designs and they stated that having flood plain storage for the stream channel would be the optimal design for the daylighted stream. The team also asked if they had any flow data for whiskey creek as well as contaminant data, which they did not. Instead, they told us to talk to Prein & Newhof about the flow data as well as possibly using their EPA SWMM Model. We ended up getting in contact with the engineering staff at Prein & Newhof and they did not have any of the items we requested.

October 29, 2016

Calvin's Campus: 8:45 – 1:00pm

Attendees:

All Members of Team 7

Subject: Surveying Site

With the permission of Campus Safety and the Physical Plant, the team surveyed all the storm manholes, catch basins, and inverts for the Whiskey Creek storm sewer system. The Team was able to borrow equipment from Feenstra & Associates Civil Engineers and Surveyors through a team member's connection.

November 18, 2016

Calvin's Campus: 3:30 – 4pm

Attendees:

All Members of Team 7

Charles Huizenga and Phil Beezhold (Calvin Physical Plant)

Subject: Update of the status of the Project, Clarification on as-builts

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The team met with Phil Beezhold and Charles Huizenga of the Physical Plant to give them a status update on the project and also for the team to be further clarified on different aspects of the project. One of the items that became clarified was where the team could get the as-builts from for the site, and was pointed in the direction of GMB architecture. They also told us to talk with Julie Wildschut about the weir design in Buster's Hollow. The team also received clarification that there will not be any surprises for utilities that are underneath the CFAC parking lot.