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April 22, 2024

Nancy G. Love, Ph.D, P.E., BCEE
Salem Meadows Development
2350 Hayward St. 2020 GG Brown,
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(734) 763-9664

Re: Schematic Design Report for the Salem Meadows Development Project

Dear Dr. Love:

CEEquilibrium Engineers (CE^3) is pleased to share our report covering our Schematic design for the Site-Wide Services needing to be implemented onto the planned Salem Meadows Development (SMD). In this report, we will present our proposed systems and the estimated total cost created by our three subject area teams: Environmental Engineering, Stormwater, and Transportation Services.

The intended focus of the SMD is delivering an integrated residential, office, and retail development. Incorporating sustainable features onto the site will attract high-rent tenants who value and demand sustainable services, as well as generate long-term returns for investors and the Owner. For this reason, the design must uphold the Owner's values in creating sustainable systems and incorporate the vision for civil infrastructure articulated by the UM-CEE department.

The main systems CE^3 is designing are solar arrays, rain gardens, stormwater conveyance, stormwater storage system, stormwater reuse, accessible roads, and mixed-use pathways between buildings on-site. These systems and their proposed designs will be explained in detail within our report.

Our firm, CEEquilibrium Engineers, has the technical knowledge and experience to design and analyze solutions to achieve the goals of the Owner. We appreciate the opportunity to collaborate with you on creating sustainable systems and solutions for the SMD. Please contact me if you have any questions or concerns regarding the information in the following report.

Sincerely,
Julien Nyberg
Project Manager, CEEquilibrium Engineers
jnyberg@umich.edu | (231) 742-6597

Salem Meadows Development:
Site-Wide Services Schematic Design Report

Project start date and duration: February 2024 - October 2025

Prepared for

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April 22, 2024

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Executive Summary

We are excited to present our designs to meet the demand for a mixed-use residential, office, and retail development near the city of Ann Arbor targeted at young and mid-career professionals. In addition to the mixed-use building development, sustainable services will be incorporated into the design. These include stormwater processes, transportation systems, and environmental features. The goal of the Owner is to attract tenants who demand sustainable services, producing long-term returns for investors and the Owner.

Since there are currently no on-site services in place at the Salem Meadows Development, our team at CE^3 is needed to provide these services. Our team has designed multiple attractive features for the site. These systems and their design elements are listed in Table 1 below. An overall site map showing all incorporated systems is shown in Figures 1 and 9.

Table 1. List of site-wide systems and their design elements

Subteam	Systems	Design Elements
Environmental	Solar Arrays	• Combined rooftop and carport
	Rain Gardens	• Location - Roadside swales • Plant type - Deep-rooted plants
Stormwater	Conveyance	• Vegetated swales • Subsurface reinforced concrete pipe (RCP) • Rain gardens • Pumping station
	Storage	• Wet detention ponds
	Reuse	• Stormwater cisterns
Transportation	Site Layout	• Two access points, including direct expressway accessibility • Mixed-use (cycling and pedestrian) pathways
	Intersection Design	• Roundabouts
	Sustainable Design Features	• EV charging stations • Land preservation • Diverse mixed-use transportation facilities

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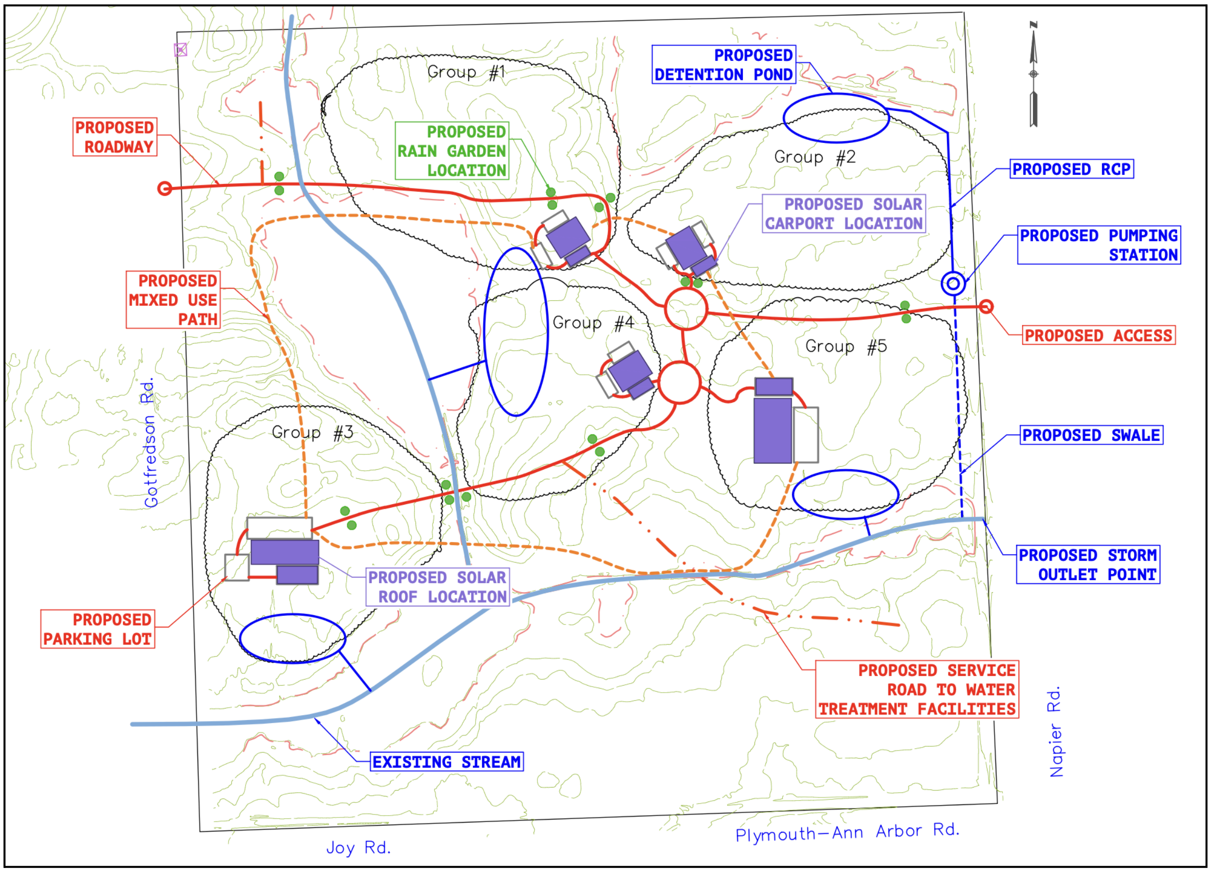

Figure 1. Schematic site map of combined systems

We expect to have the initial signature building complete and ready for occupancy by October 2025. Services we provide must be incorporated into the building by this same deadline. Phasing of the other four buildings will ensue over the next eight to ten years to accommodate the market demand. Although the Owner has not specified a budget, it is important that our design decisions will balance costs with services while prioritizing sustainability. The estimated total cost across our systems is currently ranging from $23.51 - $38.22 million.

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1. Introduction

The Owner of Salem Meadows, an undeveloped site, distributed an RFP requesting Site-Wide services to aid in its development. As shown in Figure 2 below, Salem Meadows is a 400-acre undeveloped parcel of land located northeast of Ann Arbor. The site contains two existing buildings, one road access point, and existing gas and electrical lines. Once developed, the site will contain a mixture of residential, office, and retail buildings.

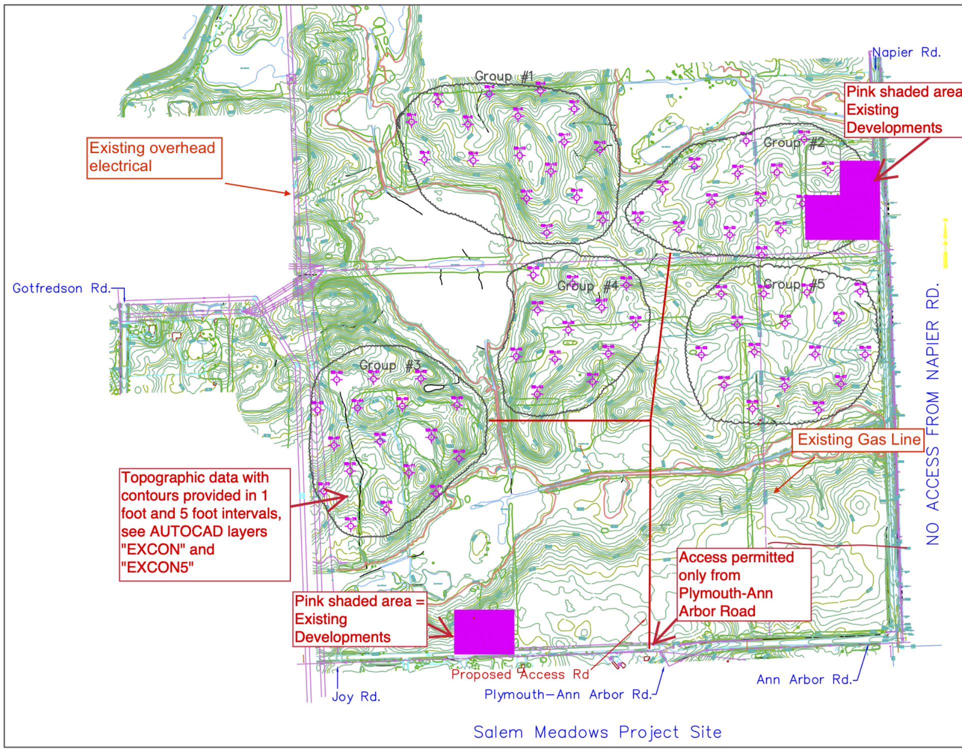

Figure 2: Existing site layout with five proposed development sites

Salem Meadows has no site utilities, so a site-wide engineering team is required to implement them. As the Site-Wide services team, we have planned transportation infrastructure, stormwater management, and the implementation of environmentally friendly features.

An overall site map of all our systems is shown in Figure 1. The team is composed of engineers with different technical backgrounds, namely hydrology and hydraulics, environmental and resource recovery design, and transportation logistics. For a wholesome integration of teams, CE^3 has collaborated with Building Services and Water Services throughout the project.

This is the third and final design report we will deliver to the Owner. The purpose of this document is to inform the Owner of our team's schematic design for the Salem Meadows site. Since our second report—the concept design of the Salem Meadows Development Project—CE^3 has performed alternative assessments based on system specific criteria to determine an ideal design. These are discussed in detail within this report and in the appended Subject Area Technical Reports.

2. Project Understanding

The Owner has indicated there is a demand for an integrated residential, office, and retail development around the city of Ann Arbor targeted at young and mid-career professionals. Within the township of Salem, there is undeveloped land that is viable for site development. This site currently has no water or environmental services. The Owner plans to incorporate sustainable services in addition to the development of the mixed-use initial signature building. These services include stormwater processes, transportation systems, and environmental features, to create an attractive site to bring in tenants that value sustainable services, thus producing long-term returns for investors and the Owner. The Owner desires the first initial signature building and site-wide services to be ready for occupancy by October 2025, with the phasing of the other four buildings over the next eight to ten years to accommodate the market demand.

The Owner desires to retain a firm to design and deliver these site-wide services. This involves designing the site's technical systems and planning the construction for the initial building and the subsequent four buildings in phases. CE^3 is a firm composed of engineers who specialize in hydrology and hydraulics, transportation logistics, and environmental and resource design. Our team has experience designing innovative solutions incorporating sustainability into environmental service designs. For this design, we will focus on attracting tenants by promoting sustainability throughout the development of our design. Although the Owner has not specified a budget, it is important that our design decisions will balance costs with services while prioritizing sustainability. We will present and justify the necessary services incorporated in our design that will provide the Owner with long-term returns on investments.

Key outcomes to achieve the Owner's goals of attracting high-rent tenants who demand sustainable services and in turn, earn long-term returns on investments include: 1) providing a design that provides a sustainable solution while balancing costs, 2) communicating with the Building Services team to provide cost-effective solutions and obtain LEED gold certification of the initial signature and subsequent buildings, and 3) upholding the values of the Owner and incorporating the vision for civil infrastructure articulated by the UM-CEE department. Our team has conducted research and collected data for our design alternatives presented in this report. Each of our sub-teams will perform specified calculations as necessary once the preferred alternative has been chosen. At this time, modeling will be completed for the stormwater and transportation systems. We will hold service-specific and Project Manager meetings between each service team to sustain effective communication and collaboration between disciplines. Our current recommended designs include solar arrays, rain gardens, stormwater conveyance, detention ponds, multi-access roads, and mixed-use paths. We are confident that our proposed systems will result in the delivery of sustainable site-wide services to the SMD.

3. Task and Coordination Summary

Each subteam has made a list of tasks to follow throughout the design process. Here we describe the coordination needed with other services teams to achieve said tasks. More details for each task and coordination details can be found within the Subject Area Technical Reports and Memorandums to file.

3.1 Environmental Task and Coordination Summary

The following provides a short outline of the tasks to be completed in regards to the Solar Panel Project and Rain Garden Projects, and the collaboration with other teams that will be utilized to maintain a cohesive project. Further information regarding these tasks and subtasks is documented in the attached Subject Area Technical Report in Appendix A (pg. A-5).

Solar Panel Tasks:

1. Assess the solar area and energy demand of the site
    - Work with the Transportation Team and Building Services Team to identify available locations for solar panels
2. Complete an assessment of the manufacturers available for solar panel installation
3. Analyze the business case and carry out extensive calculations to determine the best option
4. Analyze the end-of-life protocols and costs for the solar arrays
5. Complete the LEED Certification
    - Provide our data to the Building Services Team regarding energy savings

Rain Garden Tasks:

1. Determine the most suitable location(s)
    -Work with the Transportation Team and Building Services Team to assess available locations
2. Determine size and soil composition
    - Share rain garden location data with the Transportation Team and Building Services Team in order to clear up any overlap in design
    - Share soil data with Stormwater Team as they will also be utilizing this information
3. Complete plant selection and pollinator garden considerations
4. Research of proper garden maintenance techniques
5. Determine the runoff detention quality and make design choice
    - Provide data to Stormwater Team regarding runoff detention so they can consider the data in their runoff control strategies
6. Analyze economic feasibility

The team plans to further expand and develop these tasks as the project progresses. These subsequent reports will be updated during the design process.

3.2 Stormwater Task, and Coordination Summary

The following provides a short outline of the tasks to be completed for stormwater conveyance, storage, and reuse design, as well as collaboration points with other teams. Further information regarding these tasks and subtasks is documented in the attached Stormwater Subject Area Technical Report in Appendix B (pg. B-4).

1. Determine design criteria and constraints
    - Work with Transportation, Building Services, and Environmental teams to establish feasible locations for new infrastructure
2. Collect pre-development hydrology data
3. Calculate pre-development hydrology with EPA's Stormwater Management Model (SWMM)
4. Collect post-development hydrology data
    - Obtain data from Transportation, Building Services, and Environmental teams to determine pervious surface area
5. Calculate post-development hydrology with EPA SWMM
6. Design conveyance, storage, and stormwater reuse systems meeting hydraulic standards
    - Collaborate with the Environmental team to include rain garden as a part of stormwater management design
7. Validate that site-wide stormwater design meets Washtenaw County Water Resources Commission (WCWRC) requirements

3.3 Transportation Task and Coordination Summary

The following list provides a summary of the tasks to be completed by the Transportation team over the entire project. These tasks define how our team serves the needs of the site, while best providing value to the Owner. The Transportation team collaborates with the Building Services, Stormwater, and Site-Wide Environmental teams to streamline a cohesive final system-wide design. Specific tasks and subtasks for the schematic design phase are documented in the Transportation Subject Area Technical report in Appendix C (pg. C-7).

1. Gather and review existing data about development site
2. Coordinate with other engineering teams at CE^3
    - Share and receive information with Building Services, Stormwater, and Site-Wide Environmental teams
3. Develop a master plan
4. Develop a transportation system design
5. Budgeting and finalization

4. Preliminary Assessment of the Project

Our team has considered the following points of interest regarding the project scope. These points determine the challenges and points of ease for designing and constructing our solutions. Each subteam has made a list of challenges and points of ease for their specific disciplinary project.

4.1 Preliminary Environmental Assessment (Solar arrays and rain gardens)

The implementation of solar power at the site will facilitate energy production and management for the Owner. The environmental team is proposing an investment on renewable energy to obtain a reasonable payback period, as the average lifespan of solar arrays is 30 years. Solar arrays also have low operation and maintenance costs. Therefore, the ongoing costs will be minimal. Additionally, the renewable solar arrays will aid in achieving a LEED Gold Certification for the building. Figure 3 below shows a potential design layout for a rooftop solar array.

Figure 3. Rooftop Solar Array Concept. (Zeoluff)

The challenges associated with the implementation of solar arrays include the availability of space, limitations of array type, realistic payback period, end-of-life costs, and the site's distance from the closest substation. The availability of space on the site limits the feasibility of certain arrays. While the ground mount is generally less expensive than rooftop or carport solar arrays, the ground space needed for an array this size is likely unavailable. The Owner emphasized that the payback period is of utmost importance, so the cost of certain arrays versus their energy production may limit the panel and power inverter model options. Figure 4 below demonstrates a potential solar carport design.

Figure 4. Potential solar carport design. (Meissa Reeve)

The installation of rain gardens throughout the site will help improve three key qualities of the site. Figure 5 shows a diagram of the typical rain garden. This is not our design; however, it can be useful in understanding the design aspects of a rain garden.

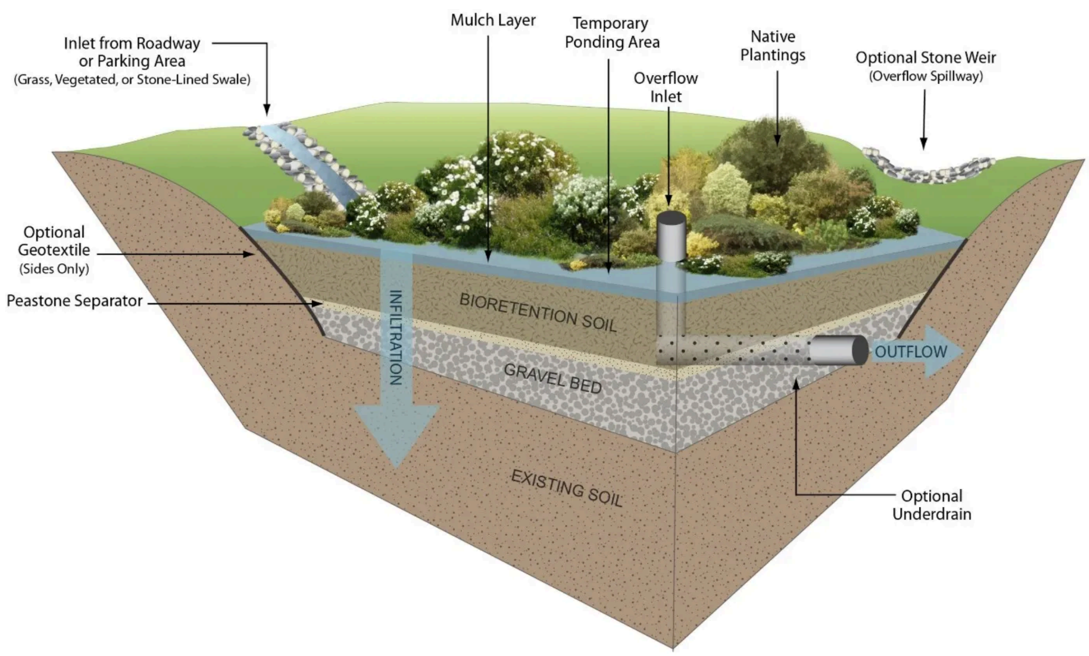

Figure 5. Typical rain garden outline with components (Brownlee, 2020)

Firstly, rain gardens provide a natural, sustainable way to control runoff and treat pollutants. Rain gardens are effective systems at controlling stormwater runoff, limiting peak runoff by retaining runoff until it can infiltrate into the watershed over time, thus reducing the load upon the stormwater conveyance system and detention pond system. The water that is retained by the gardens infiltrates through rooted soil, resulting in natural pollutant and contaminant filtration of the water. The installation of rain gardens reduces the runoff load of the site, and helps purify the water of harmful contaminants. Thus,

Secondly, rain gardens boost the aesthetics of surrounding areas. It is imperative that if rain gardens are to be installed, they be designed with an aesthetically pleasing location, plant selection, and arrangement. CE^3 's rain garden designs will be filled with flowering and otherwise vibrant plants that bolster the aesthetic appeal of the site.

Thirdly, when filled with a diverse set of native plants, rain gardens can provide health benefits to the local ecosystem. CE^3's rain gardens will promote the health and resilience of the site's ecosystem. With an effective selection of native, high pollen producing plants, the rain gardens promote the natural balance to what the local ecosystem needs to thrive.

Capital investment is required for both rain garden installations and maintenance. CE^3 is deeply committed to the Owner's goals of site sustainability, quality, and cost efficiency. We intend to design high quality, aesthetically pleasing, native rain gardens with effective runoff control, and we intend to do so in a cost effective manner.

Possible challenges associated with implementing a rain garden include the soil type and availability of space. Certain soil types hold less water than others due to the varying compositions, so choosing the appropriate soil type can pose a challenge to successful rain garden implementation. Availability of space will also pose challenges, as rain gardens need to be at least 10 feet away from buildings in order to prevent the hydrostatic pressure from pushing groundwater into the foundation and damaging it. (Bryan 2022). An example of a rain garden in an urban setting is shown in the figure below.

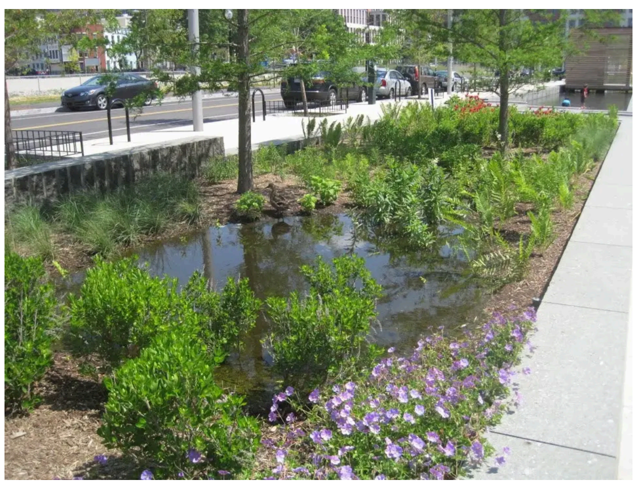

Figure 6. Potential rain garden design within a developed site. (Saha, 2020)

4.2 Preliminary Stormwater Assessment

An effective stormwater management system includes storage and conveyance structures that are able to mitigate negative impacts of post-development runoff at this site. A schematic design is provided that utilizes existing drainage systems to provide an efficient and sustainable solution for managing stormwater runoff. In addition, a rainwater harvesting and reuse system is incorporated into the design to meet the Owner's expectations on sustainability. Sustainable features, such as vegetated swales and wet detention ponds, were implemented to provide the opportunity to incorporate walking paths and a fountain, that improve the aesthetics of the site.

The design for a cost-effective and sustainable stormwater storage, conveyance and rainwater reuse system are outlined in Section 5.3.

Designing a stormwater management system presents significant challenges that require multidisciplinary coordination and adaptability. The complexity arises in part from the need to integrate the stormwater conveyance system with existing infrastructure, avoid conflicts with utilities such as drinking water pipes, and collaborate with building services and transportation teams to account for impervious surfaces that increase runoff. The locations of the stormwater detention ponds must be maximized by utilizing existing drainage paths (see Figure 7 below) to reduce additional costs, such as additional excavation or pumps. The detention pond outlet and conveyance pipe sizes must be sized according to the calculated runoff volumes and minimum flow rates outlined by the Washtenaw County Water Resources Commission (WCWRC) and Michigan's Department of Transportation (MDOT).

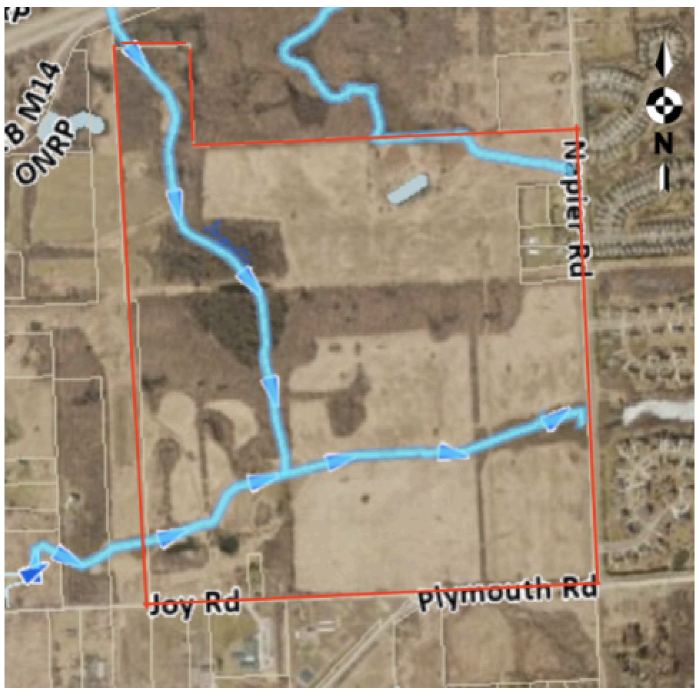

Figure 7. Existing drainage routes trisect the site, running south and east

Additionally, the stormwater storage system and conveyance system must not only serve current needs, but also remain flexible for future expansion. With multiple building sites under consideration for development within the next decade, the conveyance and storage system must be scalable.

While developing a stormwater management system has challenges, there are different resources and existing data that aid in the design process. Pre-existing drain locations and elevation data can readily be extracted from CAD files, and the WCWRC offers a comprehensive stormwater system design manual with clear guidelines and assumptions. These resources simplify certain tasks, allowing the team to focus on the more complex dimensions of the stormwater management system design.

4.3 Preliminary Transportation Assessment

There are two key factors of the SMD site that make it simpler and more attractive to design a transportation system around: the land is relatively flat in potential construction zones, and it is located near M-14, a major expressway in the surrounding region. Flatter geography will reduce the overall cost of the project as less excavation will be required during road construction. Additionally, by locating an access point on the border of the site near M-14, our proposed transportation design can provide the development with direct connection to the surrounding regional network.

The challenge associated with the site is that there is currently no infrastructure in place for functional transportation facilities, so a Traffic Impact Study (TIS) was needed to serve as the baseline for both the master plan and the system-wide transportation design. This TIS was used to estimate the volume of traffic that the new development will add to the existing transportation network. The current lack of site assets and given layout certainly makes it more difficult to adequately connect the transportation system to the surrounding regional network, but potential solutions such as mixed-use paths and biking facilities will be implemented to integrate these systems. Since the Owner emphasized the wellbeing of future residents, there is also a need to have sufficient traffic control to reduce the speed that cars travel through the development. To best address this challenge, our proposed speed limits have been adjusted to match slower residential limits and encourage alternative modes of transit. Figure 8 provides a visual representation of how reduced driving speeds positively impacts pedestrian safety.

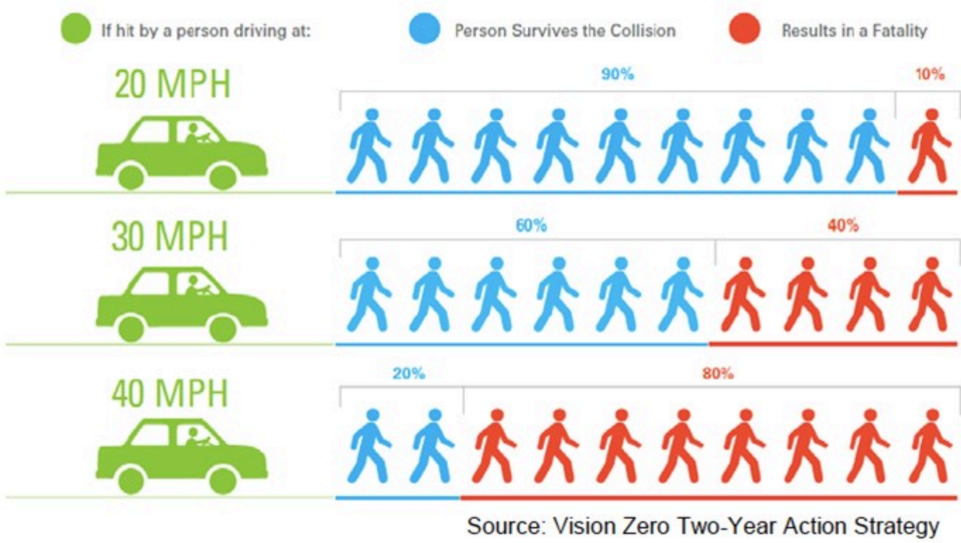

Figure 8. Impact of reduced driving speeds on pedestrian safety

An additional challenge to consider is that the Owner's vision for the development requires sustainable integration of the various services within the development. The transportation network will have to construct roadways, intersections, and walkable pathways to comply with this design guideline. In particular, the roads have been designed to accommodate the rain gardens proposed by the Environmental team and they will be located to best optimize water drainage within the overall site. Due to the natural limitations of the development, it could prove challenging to balance all of these design parameters without compromising the longevity of the sustainable infrastructure. However, through coordination with the other site-wide engineering teams and focusing on a mixed-used design framework, an optimized site-wide system has been produced.

5. Specific Systems

CE[3] has developed multiple systems in order to make the Salem Meadows Development sustainable. Figure 9 below shows the overall site map with all systems included on it. This helped with communication between each team to make sure all our systems can be integrated together. Each system will be presented in detail along with its final chosen solution picked from the alternatives presented in our previous report, the concept design.

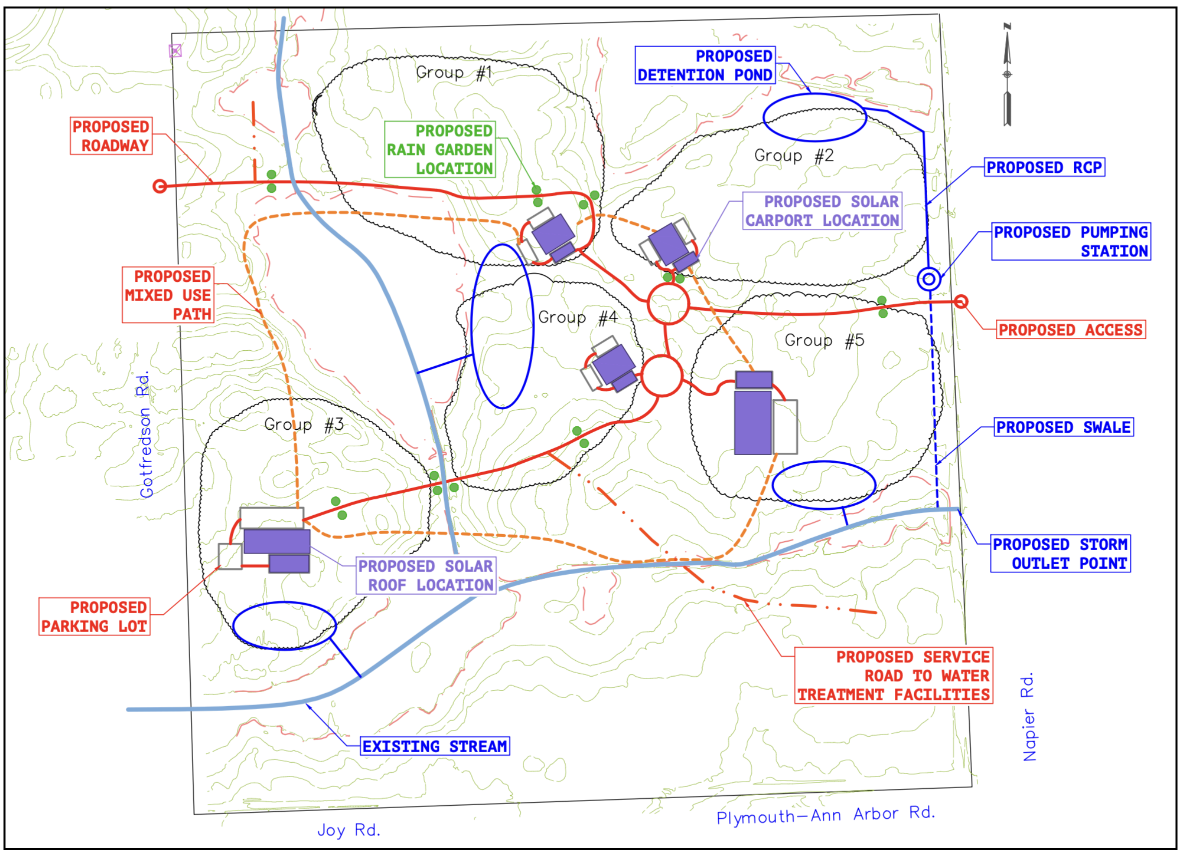

Figure 9. Schematic design of proposed site-wide systems in Salem Meadows

Our team performed assessments of each system alternative based on specific criteria to determine the proposed design of the systems seen above. To keep uniformity across systems, we created a criteria scoring system seen in Figure 10 below.

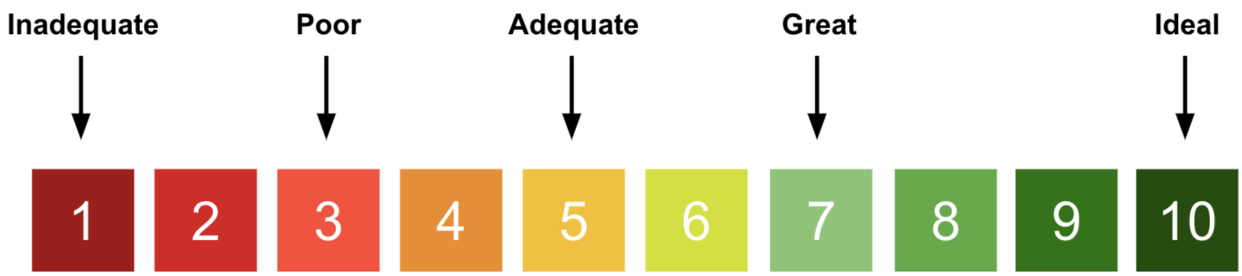

Figure 10. Criteria scoring system ranked from 1 - 10, with 1 being inadequate and 10 being ideal

5.1 Environmental - Solar Panels

The installation of rooftop and carport solar will occupy unutilized space for energy production. The majority of solar panels are ground-mounted and installed in natural spaces such as deserts, cropland, and grasslands; only 2.5% of new solar panel installations are located in urban areas. Urban spaces, like rooftops and parking lots, have a very low albedo, so they absorb a significant amount of solar energy due to their dark colors and hard surfaces, and can lead to the creation of urban heat islands. Utilizing these spaces to produce green energy through the installation of solar panels maintains more of the natural space of the site as opposed to implementing ground-mounted solar panels (Coniff, 2021). Implementing these solar panels will also reduce the urban heat island effect by reducing heat that reaches the roof by about 38%. This can help keep the building cool in the summer and help keep warm air inside in the winter (Penfolds). A diagram showing the locations of the solar installations can be seen below in Figure 11.

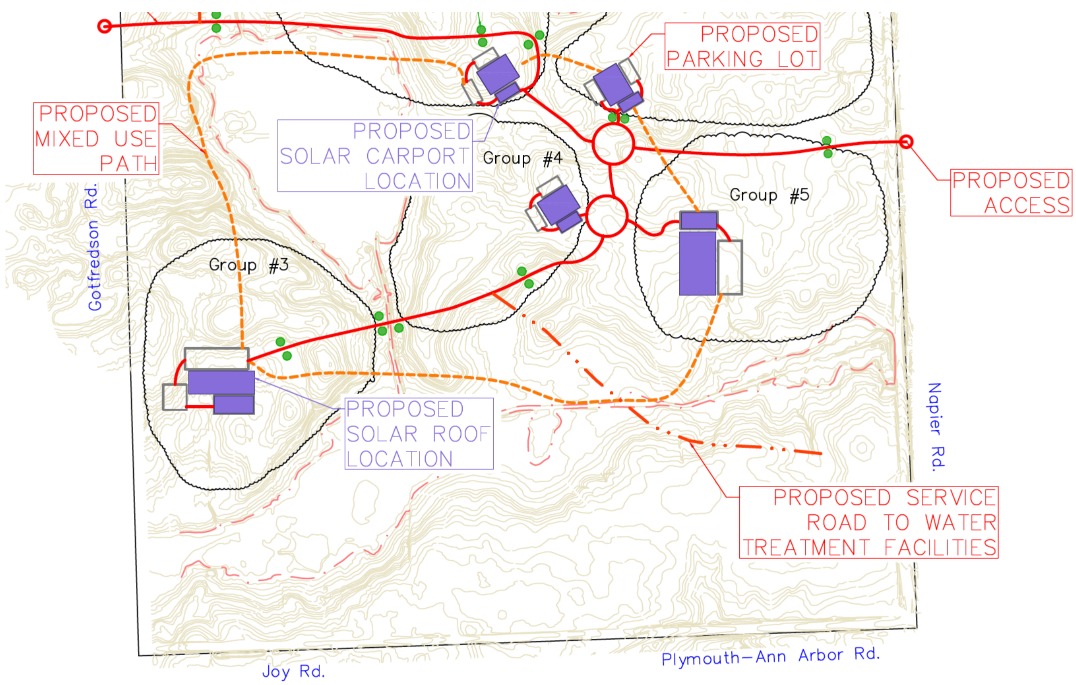

Figure 11. The first building will include rooftop solar panels and carport solar panels in the residential parking lot

Despite the steep capital cost of solar installations, the installation of solar arrays provides long-term financial benefits. In addition to producing a significant portion of the site's energy demand and reducing the cost of electricity over time, many existing federal tax incentives minimize the installation costs to encourage businesses to invest in solar. The Investment Tax Credit offers a 30% tax credit for new commercial solar builds. Additionally, domestic production adds an additional 10% tax credit, significantly reducing the capital costs of the solar panels.

In order to determine the optimal implementation of solar panels, the team evaluated three different alternatives for solar panel design and placement. The team considered the effectiveness of building:

- Rooftop solar arrays
- Carport solar arrays
- Rooftop and carport solar arrays

The installation of rooftop solar will reduce the cost of electricity over time, increase the site's sustainability score, and utilize otherwise unused roof space, as the roof serves as a platform for the solar arrays. By generating local power, the site reduces reliance on utility companies, leading to long-term savings on energy bills. Over time, these savings surpass the initial costs of installation and maintenance, resulting in a profitable investment for the Owner. This shift from fossil fuels to solar power decreases the site's carbon footprint, showcasing a commitment to sustainability at Salem Meadows, attracting like-minded tenants.

Solar arrays will be placed horizontally along the entirety of the uppermost roof, facing south, rated at 313 kW DC and consisting of 569 modules. The cost of this system after the tax credit is approximately $535,523, costing $17.93 per square foot. The dimensions of the overall system are shown in Figure 12 below:

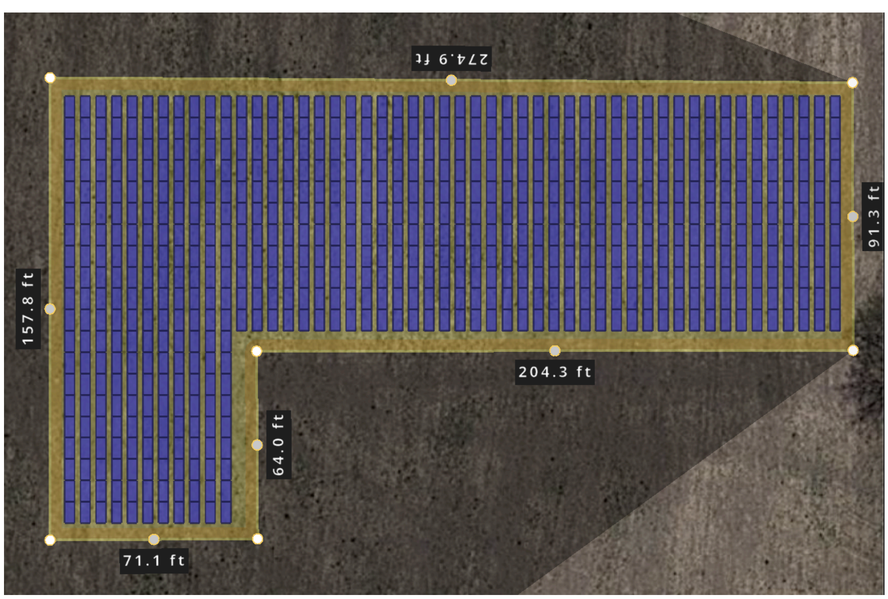

Figure 12. Proposed Rooftop Design and Dimension

In addition to rooftop solar panels, we considered the installation of carport solar arrays overtop the residential lot. The company that we chose for this consideration is Harvest Solar because they are a local company, they produce domestically, and they offer flexibility and comprehensive guides to the systems. The carport solar system would offset additional energy from the grid, increase the energy independence of the site, utilize the overhead space of the parking lot, and offer benefits to residents, such as added shade in the summer and snow protection in the winter.

Solar carports can be placed overtop the entire lot, or a preferred portion. A 3-dimensional mockup of the fully solar carport design can be seen in Figure 13 below. Alternatively, it would cost half the price and produce half the amount of energy to only cover half of the parking lot, whether that be only the outer carports or only the inner carports.

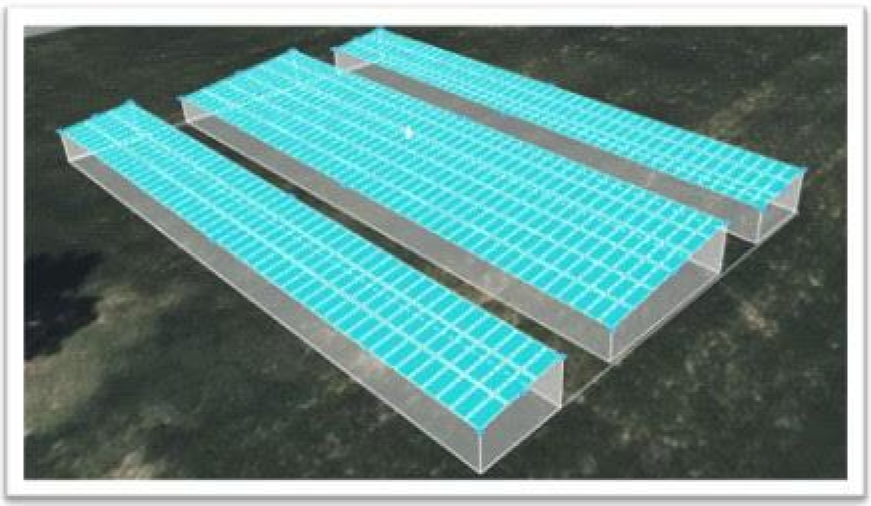

Figure 13. Solar carports above the parking lot will produce around 350 MWh annually (Harvest Solar)

This design of this 300 kW DC system will utilize otherwise wasted space into a hub for green energy. The installation would cost approximately $1.3 million dollars, with few to no additional costs required during its lifetime. Such a system typically lasts around 25-30 years, but has the potential to last up to 50 years. It will produce approximately 350 MWh annually, helping to move more of the energy demand of the site towards renewable sources. More details regarding this installation can be found in Appendix A in the Environmental Subject Area Technical Report.

We evaluated our solar array designs using a decision matrix, that can be seen in Appendix A, including the following criteria:

- Sustainability
- Cost
- Quality
- Aesthetics
- Residential benefits

After evaluating the three alternatives based on the above criteria, we determined that installing the carport system in tandem with the rooftop system will allow more energy generation while maintaining a low payback period. The installation of both rooftop and carport will offset double the amount of energy as installing only one system, while maintaining a payback period of 9.74 years, including the cost of operation and maintenance. The levelized cost of electricity, which is the cost of electricity over the assumed lifetime of both systems, is 8.1 cents per kWh, only 41% of the average cost of electricity in Salem Township. Based on these analyses, we recommend the implementation of both the rooftop and carport solar systems.

5.2 Environmental - Rain Gardens

CEEquilibrium's environmental team has a completed schematic design of the system. Figure 14 shows the current proposed locations of 16 gardens within our 33-garden system. More information about the benefit of rain gardens and the design decisions made, as well as a schematic design is found later in this section of the Schematic Design Report. More detailed information is found in Appendix A of this report.

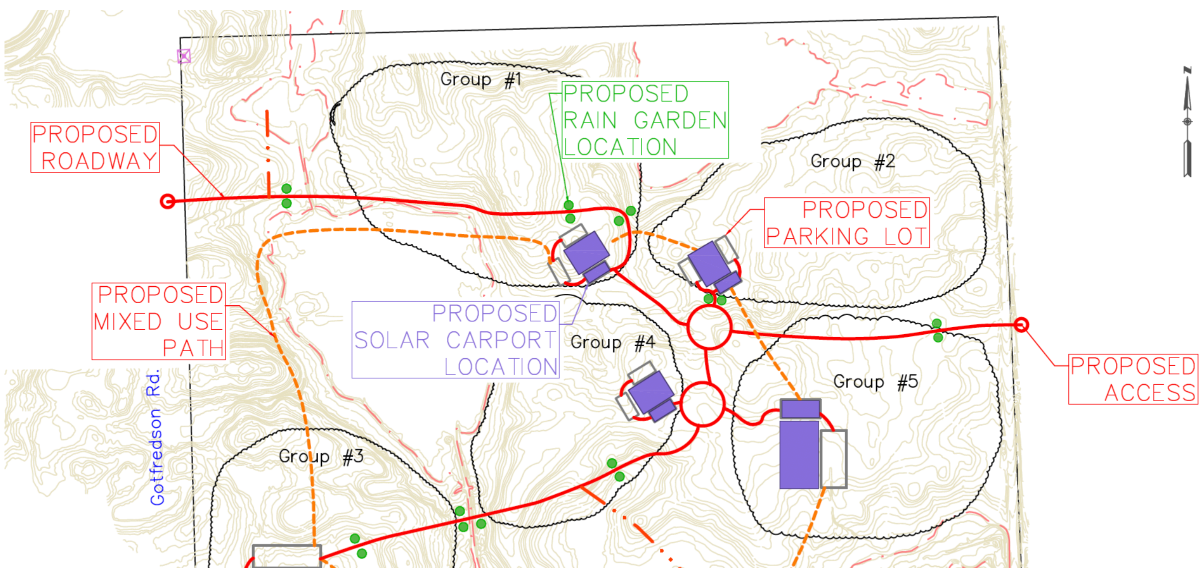

Figure 14. Proposed rain garden site locations

Throughout our design process for the rain gardens, we assessed 2 key sets of alternatives:

Location/sizing

- Roundabout
- Swale

Plant selection:

- Deep rooted
- Mixed root length

We have evaluated our rain garden designs using a decision matrix that includes the following criteria:

- Installation cost
- Flexibility
- Road First Flush Treatment
- Runoff Treatment
- Aesthetics
- Ease of construction
- O&M Cost
- Biodiversity Support

An in-depth description and discussion of our recommended rain garden system design can be found in Appendix A of this report; however, the design itself is found in this section of the report. First we detail the runoff control capabilities of our system. We next detail the recommended locations of our garden system before describing the dimensions, plant selection, and material makeup. Lastly, we detail both the preliminary and long-term maintenance strategies for the garden.

The rain garden system will be designed to completely detain the road first flush during a precipitation event. The first flush is described as the first inch of rainfall during a precipitation event, and the total paved roadway area is estimated to be 91,465 ft^2. Therefore the rain garden system must be designed to detain and treat 7,622 ft^3 of stormwater. Each garden can detain 236 ft^3 of runoff, thus the system will be composed of 33 gardens.

The rain gardens in our system will be placed within the roadside swales of the site. Figure 15 shows how the swale will expand into the garden system through a plan view of an individual garden. 17 of the 33 gardens are recommended in potential swale ponding and runoff outlet locations. These recommended locations can be seen as the green dots on our overall site map (Figure 14). The remaining 16 gardens can be placed almost anywhere along the swale system providing aesthetic benefits to the location. Instead of guessing where these gardens should be placed, we recommend that the Owner meets with us in a workshop to discuss their preferences as to where these rain gardens should be. With this method, we can verify the rain garden placements agree with the Owner's vision of the site and give more aesthetic decision-making power to the Owner.

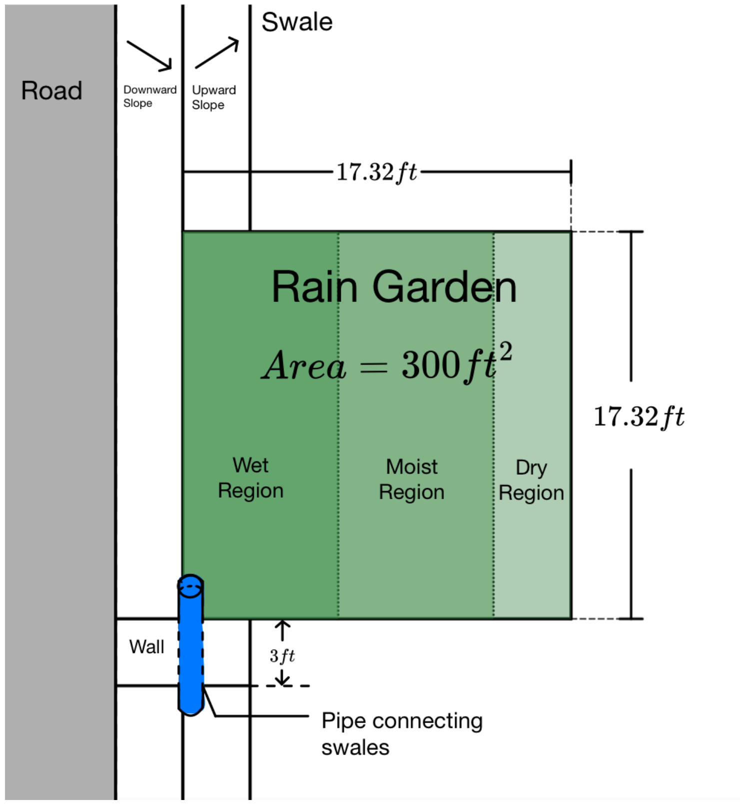

Figure 15. Plan view of combined rain garden/swale schematic design

The rain garden system will be made up of 33 identical square rain gardens placed within the swales. As seen in Figure 15**,** each rain garden will be 300 ft^2, with side lengths of 17.32 ft. Figure 16 shows the cross-section of the garden design. The garden will begin once the swale meets its maximum depth of 1 ft and remain at that depth for 6.93 ft. The garden will then slope upwards by 5.5° until it reaches ground level (depth of 0). This cross section remains constant throughout the design.

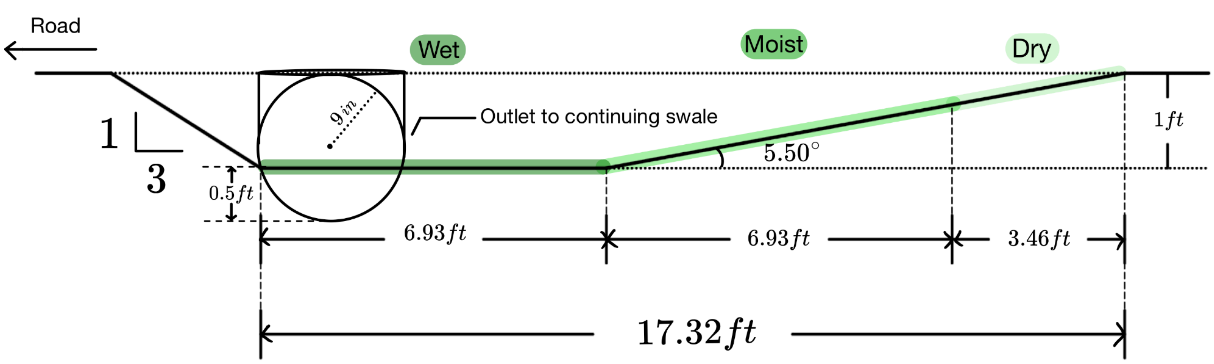

Figure 16. Elevation profile of a combined rain garden/swale schematic design from an into/out view

Due to the clay soil makeup of the site, a bio-mix of sandy loam and compost will be installed as the soil for our gardens. The gardens will be excavated 2.5 ft below the bottom of the garden. The garden is designed to have a 6-inch layer of gravel laid underneath 2 ft of bio-mix underneath a final 3-inch layer of mulch.

An 18-inch concrete pipe will be installed vertically as seen in Figures 15 and 16 with an open vertically facing inlet. The pipe will flow downwards 18 inches before turning 90° towards the soil wall. 6 inches above the bottom of the pipe (level with the bottom depth of the garden), there will be a small water intake hole with a 0.1 inch diameter. This intake hole will drain the full gardens in approximately 48 hours, thus ensuring the plants do not drown. The pipe will continue through the wall and release the runoff further along the swale system.

Our garden will be planted with a diverse set of native plants that both enhance the health of the site's ecosystem as well as the roadside aesthetics. Tables of these plants are found in Tables A-11 and A-12 in Appendix A. Due to the changing depth of the gardens, each garden will be split into 3 planting zones with differing plant selections: the wet region, the moist region, and the dry region. These zones are demonstrated in the plan view and cross-section of the gardens as well as in the below plant layout diagram (Figure 17).

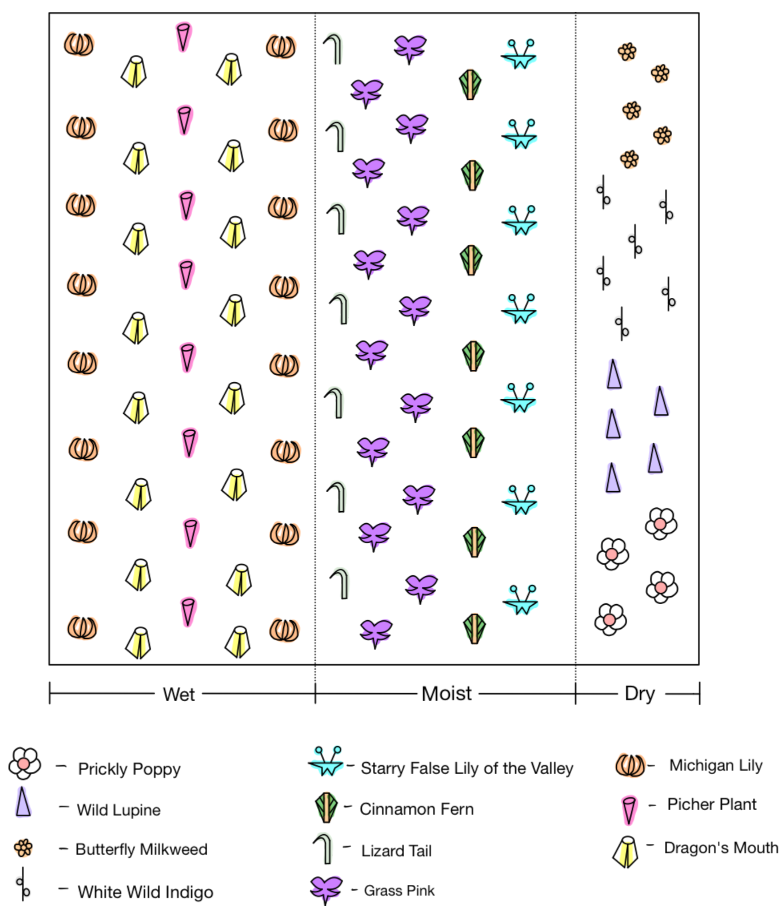

Figure 17. Rain garden plant layout

3.4 Tasks

The tasks for the stormwater system design include analyzing pre-development and post-development hydrology, designing conveyance and storage systems, and meeting relevant regulatory requirements.

TASK 1. DETERMINE DESIGN CRITERIA AND CONSTRAINTS
- Task 1A. Identify existing drainage systems

TASK 2. COLLECT PRE-DEVELOPMENT DATA
- Task 2A. Determine precipitation for storms of interest
- Task 2B. Collect SWMM parameters (subcatchment area, average slope, width)

TASK 3. CALCULATING PRE-DEVELOPMENT HYDROLOGY
- Task 3A. SWMM calibration
- Task 3B. Pre-development watershed analysis (SWMM)

TASK 4. COLLECT POST-DEVELOPMENT DATA
- Task 4A. Determine precipitation for storms of interest
- Task 4B. Collect SWMM parameters (requires coordination with transportation and building services team)
  - i. subcatchment area, average slope, impervious areas, width

TASK 5. CALCULATING POST-DEVELOPMENT HYDROLOGY
- Task 5A. SWMM calibration (post-development)
- Task 5B. Post-development watershed analysis (SWMM)
- Task 5C. Post-development runoff analysis

TASK 6. DESIGN CONVEYANCE, STORAGE, AND REUSE SYSTEM MEETING HYDRAULIC STANDARDS
- Task 6A. Design storage system
- Task 6B. Design conveyance system
- Task 6C. Design stormwater reuse system

TASK 7. VALIDATE THAT SITE-WIDE STORMWATER DESIGN MEETS WCWRC REQUIREMENTS
- Task 7A. Determine WCWRC requirements needed

3.5 Schedule

Figure B2, below, outlines a general timeline for our stormwater projects. In this stage, we are providing the main stages of our development, including design, construction process, and major deadlines.

Key Updates in Schedule:

- Detention pond pump installation was added to the construction schedule
- More time was allotted for the construction of the conveyance system (to align with road construction)

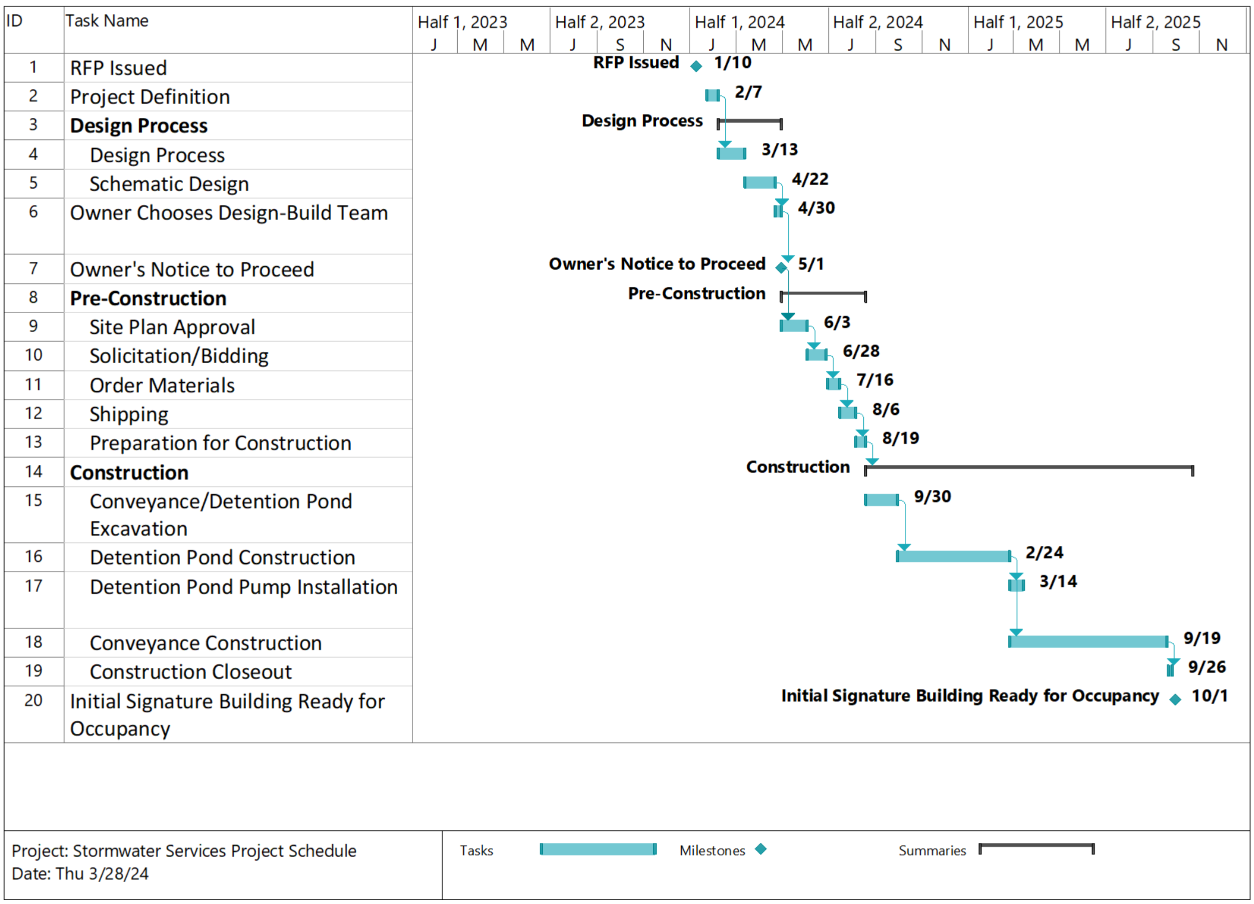

Figure B2. Preliminary Gantt chart schedule providing main design and construction processes for the Stormwater Services.

Each building will require its respective wet detention pond and conveyance. With each group, the wet detention pond should be built first, before the building and transportation infrastructure. The conveyance should be constructed starting at the outlet and continuing upstream until the future impervious surfaces within the group are reached. The only noticeable outlier is the construction of buildings 1 and 4. These two buildings share a wet-detention pond that must be built to accommodate both buildings, even if one will not be built in the near future. Once the detention ponds are built, only the conveyance for the remaining building (either building 1 or 4) will have to be built.

3.7 Regulations and Codes

The Washtenaw County Water Resources Commission (WCWRC) promulgates guidelines and regulations for proper stormwater management practices, and our design fully complies with WCWRC regulations. The specific codes and standards will be discussed in our conveyance and storage recommended solution in detail. In Table B6, a list of primary design criteria are described.

Table B6. WCWRC stormwater system design criteria summary

Design requirement	WCWRC regulation	Summary
Bankfull volume	Sec. 4, Part A	The management methods must also account for a 2-year recurrence interval/24-hour storm event as determined by the Natural Resources Conservation Service (NRCS) Method.
Release rate	Sec. 4, Part A	The allowable release rate from a facility designed for the flood control storage volume should not exceed 0.15 cfs per acre of the drained property.
Storage capacity	Sec. 4 Part B	The amount of runoff (V_d) that must be managed via detention basins or through additional BMPs is expressed as the 100-year recurrence interval volume (V_{100})
Conveyance capacity	Sec. 4 Part F	Streams, drains and other open channels will be expected to withstand all events (capacity and stability) up to the 10-year flow without increased erosion or deposition.

3.8 LEED Points

Upon reviewing the *LEED v4.1 for Building Design + Construction* scorecard, the Site-Wide Stormwater team will be able to earn four points in the Sustainable Sites category. These four points are derived from Site Assessment and Rainwater Management categories as shown in Table B7 below. In order to fulfill the requirements in the Site Assessment category, we completed a site survey focused on hydrology. The site survey included Flood Hazard Areas, delineated natural water bodies, rainwater collection and reuse opportunities, and impervious and pervious surfaces within the site boundary. Additionally, the site is fulfilling the Rainwater Management LEED requirement by retaining the 90th percentile of on-site runoff. According to the State of Michigan Department of Environmental Quality, the 90-percent annual non-exceedance storm event is .90in for Zone 10. Our stormwater system is designed to retain water for the 10-year 24-hour rainfall event (3.26 inches) as a minimum.

Table B7. LEED point breakdown-sustainable sites

Category	Points
Sustainable sites	
Construction activity pollution prevention	0/1
Site Assessment	1/1
Protect or Restore Habitat	0/2
Open Spaces	0/1
Rainwater Management	3/3
Heat Island Reduction	0/2
Light Pollution Reduction	0/1
Total	**4/10**

4.0 SPECIFIC SYSTEMS

This section outlines the specific systems the stormwater team is analyzing with a brief discussion of the functional objectives, design criteria, alternatives and a recommended solution for each system.

4.1.1 Functional Objectives

The functional objectives of a flood management storage system are mitigation of extreme and frequent storms, sediment and pollutant control, and public safety.

According to WCWRC standards, the storage facility should accommodate the total runoff volume from the 100-year storm. This aims to manage extreme and frequent events to mitigate stream erosion and prevent flooding. The post-development total volume of stormwater runoff for each group during the 100-year storm is shown below in Table B8.

Table B8. Pre and post-development data for the 100-year storm

	Area (ac)	Parameter	Pre-development value	Post-development value
Group 1 + 4	60.65	Total volume [ft^3]	345,000	759,000
		Peak flow [cfs]	216	883
Group 2	27.81	Total volume [ft^3]	130,000	336,000
		Peak flow [cfs]	42	260
Group 3	28.52	Total volume [ft^3]	123,000	341,000
		Peak flow [cfs]	50	341,000

In addition to accommodating total runoff from the design storm, storage facilities should include components to reduce the velocity of incoming stormwater and trap sediments, such as a sediment forebay. They should also incorporate features to protect injury in and around the facilities. These include gradual side-slopes, protective plantings, and safety shelves.

4.1.2 Alternative Evaluation Criteria

We have identified several feasible alternatives for the stormwater storage system at Salem Meadows. We will use the following criteria to evaluate and select an alternative or combination of alternatives for stormwater storage.

- **Sustainability** - We will select options that minimize disturbances to the environment, have a lower carbon footprint, conserve existing resources, and promote biodiversity.
- **Aesthetics** - We will select options that are visually appealing and attractive to potential tenants.
- **Capital cost** - We will select options that minimize the total upfront cost of materials and installation.
- **Life cycle cost** - We will select options that minimize operations and maintenance costs, as well as the cost of labor for maintenance.
- **Construction risk** - We will select options that minimize the risk of the project going over budget and off schedule.
- **Implementability risk** - We will select options that will be acceptable to future tenants and the surrounding public, utilize land availability, and are feasible for county standards.
- **Impact to water quality** - We will select options that remove at least the minimum of necessary pollutants (TSS) according to Washtenaw County standards.

4.1.3 Alternatives Evaluated

The alternatives considered for the storage system include a wet detention pond, bioretention basin, and rain gardens. Each storage option will collect and hold stormwater runoff from the conveyance system. The stormwater will be discharged from the storage system and conveyed to the outlet.

I. Wet Detention Pond

A wet detention pond would store the water from WCWRC design storm events and mitigate flooding on the site. A wet detention pond will hold a permanent water depth and will begin to drain once the water surface level reaches a specific height. An example of a wet detention pond can be seen in Figure B3 below. In comparison to the other storage alternatives wet detention ponds have the highest capital costs due to the large amount of excavation necessary. Additionally, the excavation associated with the wet detention ponds increases the risk with construction and decreases the land available on the site. However, wet detention ponds throughout their design life have minimal operation and maintenance (O&M) costs in comparison to the storage alternatives. Wet detention ponds are the most aesthetic option for storage and can accommodate a fountain, promoting recreational use for tenants of Salem Meadows. The ponds also have a low environmental impact and will promote ecological health within the site.

II. Bioretention Basin

Bioretention basins are shallow, vegetated basins used to store and treat on-site stormwater runoff. An example of a bioretention basin can be seen in Figure B3. Bioretention basins are just as effective at storing and treating stormwater as wet detention ponds and rain gardens. The basins also have a low environmental impact and will promote ecological health within the site. Additionally, the capital and O&M costs will be less than a wet detention pond but still more expensive than rain gardens due to the additional excavation required. However, because there is less excavation compared to wet detention ponds, the construction and feasibility risk is less. Due to the grassy vegetation used in bioretention basins, the year-round aesthetics of the basins were ranked poorly in our evaluation as the plants will not have the intended aesthetic look during the winter months.

III. Rain Gardens

Rain gardens are small basins filled with native plants used to slow and treat stormwater before being released to the outlet. An example of a rain garden can be seen in Figure B3 below. Due to the minimal excavation needed to construct a rain garden, the capital cost, construction risk, and implementability risk are minimal. However, due to the large amount of seasonal maintenance rain gardens require there is a higher O&M cost associated with this option. Rain gardens have a lower environmental impact and will promote more ecological health within the site compared to the two other storage options. Finally, rain gardens have an added aesthetic benefit to the site, but lack the added recreational component that wet detention basins provide.

Figure B3. Examples of wet detention ponds, bioretention basins, and rain gardens. (Professional Waterfront Cleanup, Dragonfly Pond Works, Pratt.)

Based on our design criteria, we chose the first alternative, the wet detention pond as our preferred alternative. A breakdown of our criteria evaluation can be seen below in Table B9. We gave each alternative a weight based on importance, making sure to account for the owner's request in the RFP.

Table B9. Evaluation of criteria for storage system

		ALT 1: Wet detention pond		ALT 2: Bioretention basin		ALT 3: Rain gardens	
Criteria	**Weight**	Rank	Weighted	Rank	Weighted	Rank	Weighted
Sustainability	0.2	8	1.6	8	1.6	9	1.8
Aesthetics	0.2	10	2	3	0.6	7	1.4
Capital cost	0.1	4	0.4	5	0.5	6	0.6
Life cycle cost	0.1	7	0.7	5	0.5	4	0.4
Construction risk	0.1	6	0.6	7	0.7	8	0.8
Implementability risk	0.1	6	0.6	6	0.6	7	0.7
Impact to water quality	0.2	9	1.8	9	1.8	9	1.8
Sum	1		**7.7**		**6.3**		**7.5**

4.1.4 Recommended Solution in Detail

Our stormwater storage system consists of three wet detention ponds, with a fourth proposed for future development. We selected locations for each of our wet detention ponds by determining flow paths through each building group. In order to maximize efficiency and minimize the use of conveyance systems to transport runoff to the storage system, detention ponds should be placed at lower elevations with respect to the buildings. Based on site topography and existing flow paths, we have selected four locations for the detention ponds. Groups 2, 3, and 5, each have their own wet detention pond. Groups 1 and 4 will share a detention pond located between the two groups. Proposed wet detention ponds to scale can be seen highlighted in blue, in Figure B4**,** below.

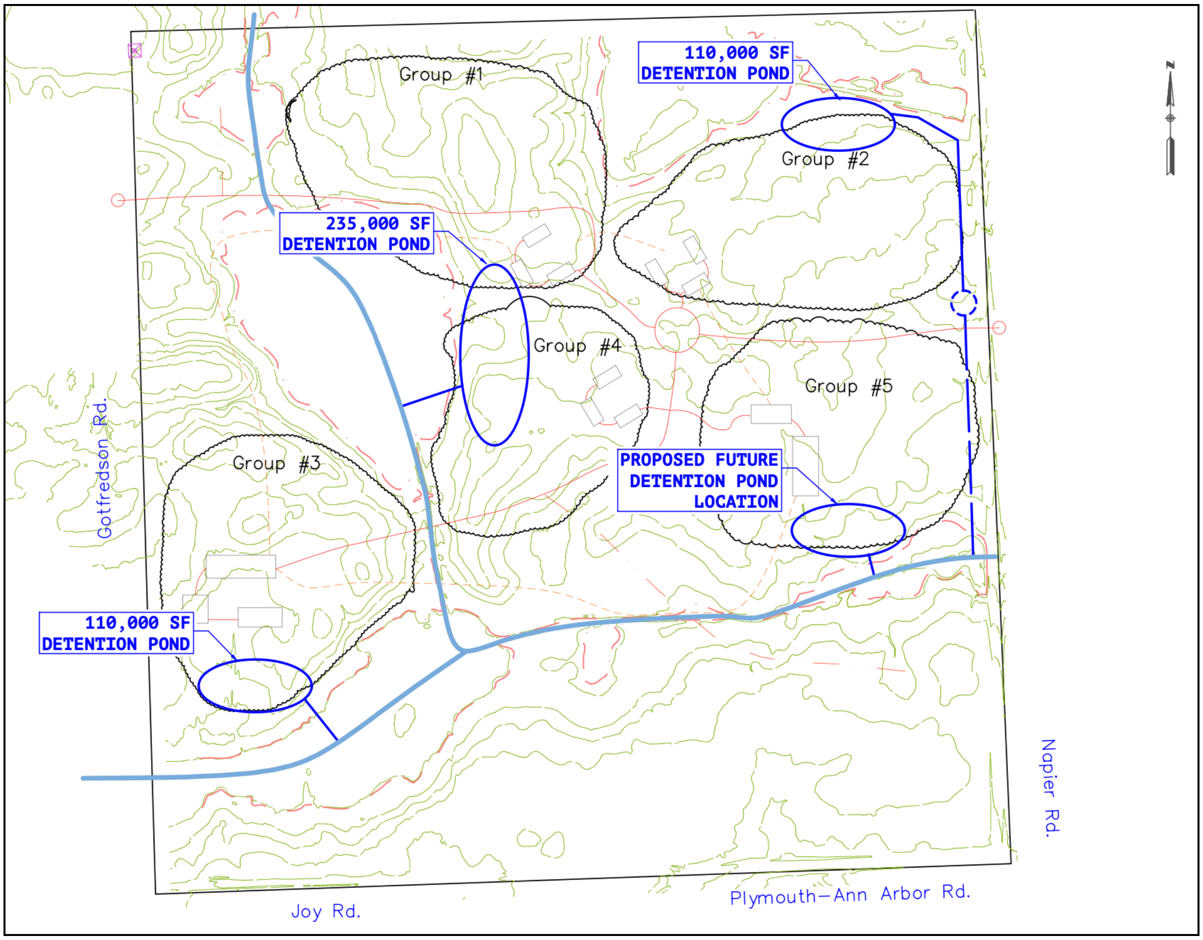

Figure B4. Proposed detention ponds are located near each group

We plan to develop a stormwater management system that will service Salem Meadows through the first phase of development, and that can expand to service a growing site as development continues in the coming years. The Salem Meadows site contains five building groups, three of which have current designs for development. Building services teams are currently developing plans for signature buildings in Groups 1, 2, and 3. The development of Groups 4 and 5 will be designed and implemented over the next 8-10 years. Because of this, we have created detailed plans for three of the four wet detention ponds. We can provide general guidance on the sizing and location of the final pond, to serve Group 5, but this pond's specific design and construction should be phased alongside building services for Group 5. Table B10, below, outlines the wet detention ponds serving each group, and the status of their design.

Table B10. Detention pond design and construction will be phased alongside building services

Group	Pond	Status
1	Pond 1+4	Current design
2	Pond 2	Current design
3	Pond 3	Current design
4	Pond 1+4	Current design
5	Pond 5	To be designed and phased with the development of Group 5

We designed wet detention ponds to have a suitable shape and volume to carry runoff from the 100-year rainfall event. Each pond will have an oval-shaped surface, with a length approximately three times as long as its width. This creates a longer flow path for runoff and increases removal of sediments. Additionally, each detention pond will have a permanent depth of water of four feet, increasing the aesthetics of our storage facilities. A sample cross section for one of our detention ponds is shown below in Figure B5.

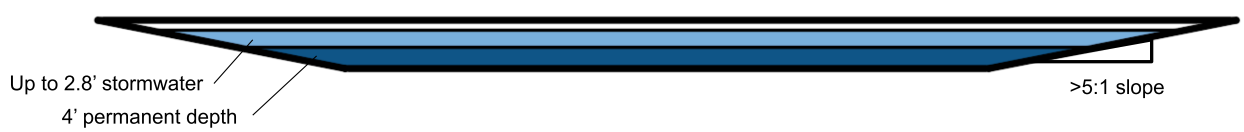

Figure B5. Detention pond cross section

We used EPA-SWMM software to perform a hydrological analysis of the site and to create a hydraulic model of our stormwater system. Based on site topography, we divided the building groups of interest into subcatchments. A subcatchment is an area with a relatively uniform slope in which all water drains to a single outlet. We used topographic maps to draw drainage paths and calculate slopes. From this analysis, we selected seven subcatchments. Figure B6, below, shows the subcatchments. We divided each group, G, into two subcatchments, A and B, based on the topography. This excludes Group 4, which shares a pond with Group 1, and Group 5, which will be phased into the development in the future.

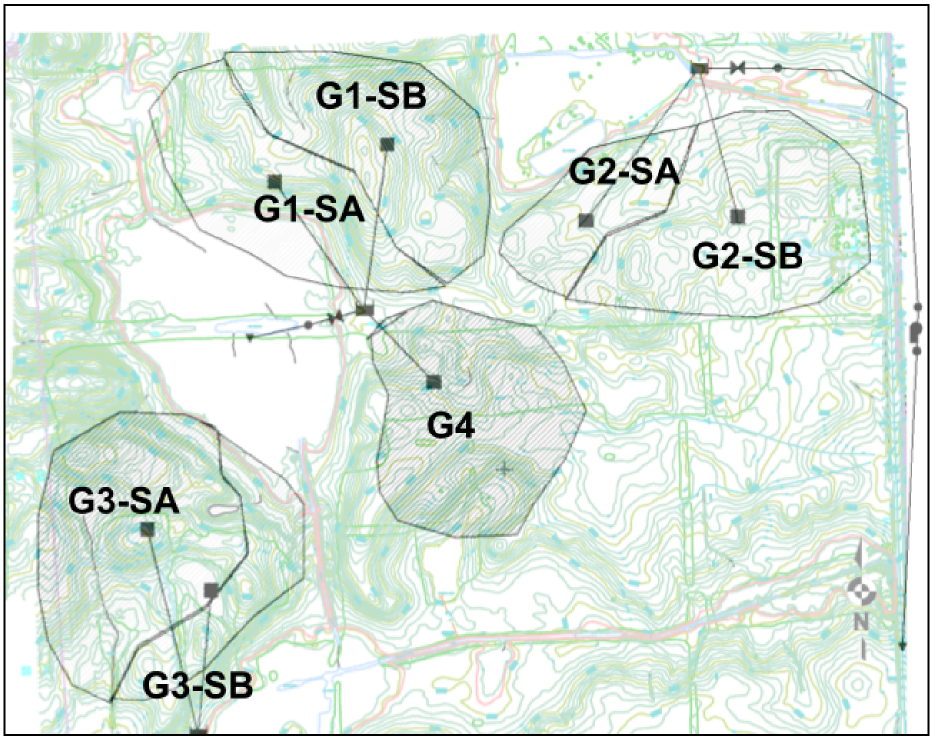

Figure B6. Seven subcatchments reflect the topography and drainage of the site

To properly size our detention ponds, we ran a simulation of the 100-year 24-hour storm event in SWMM. To account for uncertainty in the development of building services in Group 4, we have artificially increased runoff volume in SWMM for this subcatchment by a factor or 1.5. The dimensions and storage capacity of our three detention ponds are shown below in Table B11. We recommend that the eventual detention pond for Group 5 be designed with similar dimensions to Pond 2 and Pond 3.

Table B11. Detention ponds are sized to store designed storm runoff

	Pond 1+4	**Pond 2**	**Pond 3**
Available Volume [ft^3]	1,467,500	600,000	600,000
Maximum volume (100-year storm) [ft^3]	1,237,000	484,000	483,000
Permanent depth [ft]	4	4	4
Maximum depth (100-year storm) [ft]	6.7	6.8	6.8
Surface area [ft^2]	235,000	110,000	110,000

In addition to storing the required runoff volume, each detention pond complies with all relevant WCWRC standards for storage facilities. Table B12, below, outlines the relevant guidelines and how our design follows them.

Table B12. Detention ponds fully comply with regulatory requirements

Regulation	Requirement	Component	WCWRC limit	Design value
WCWRC Section V. Part A (3)	"The allowable release rate from a facility designed for the flood control storage volume should not exceed 0.15 cfs per acre of the drained property."	Pond 1+4	$Q_{peak} \le 9.51$ cfs	$Q_{peak} = 9.42$ cfs
		Pond 2	$Q_{peak} \le 4.28$ cfs	$Q_{peak} = 3.65$ cfs
		Pond 3	$Q_{peak} \le 4.18$ cfs	$Q_{peak} = 4.13$ cfs
WCWRC Section V. Part C (4e)	"Where a pipe outlet or orifice plate is to be used to control discharge, it will have a minimum diameter of 4 inches"	Pond 1+4	D ≥ 4"	D = 15"
		Pond 2	D ≥ 4"	D = 9"
		Pond 3	D ≥ 4"	D = 12"
WCWRC Section V. Part C (5)	"For safety purposes and to minimize erosion, basin side slopes will not be steeper than one-foot vertical to five feet horizontal (5:1). "	Pond 1+4	S ≥ 5/1 (h/v)	S = 6.5/1
		Pond 2	S ≥ 5/1 (h/v)	S = 6.1/1
		Pond 3	S ≥ 5/1 (h/v)	S = 6.1/1
WCWRC Section V. Part C (5)	"A minimum of one foot of freeboard will be required above the 100-year recurrence interval stormwater elevation on all detention/retention facilities."	Pond 1+4	$Z_{FB} \ge 1'$	$Z_{FB} = 1.3'$
		Pond 2	$Z_{FB} \ge 1'$	$Z_{FB} = 1.2'$
		Pond 3	$Z_{FB} \ge 1'$	$Z_{FB} = 1.2'$
WCWRC Section V. Part C (5)	"At a minimum, the volume of the permanent pool should be at least 2.5 times the first flush volume for the area managed."	Pond 1+4	$V_{perm} \ge 2.5\ V_{FF}$	$V_{perm} = 2.80V_{FF}$
		Pond 2	$V_{perm} \ge 2.5\ V_{FF}$	$V_{perm} = 2.97V_{FF}$
		Pond 3	$V_{perm} \ge 2.5\ V_{FF}$	$V_{perm} = 2.90V_{FF}$
WCWRC Section V. Part C (5)	"In general, depths of the permanent pool must be varied and average a minimum of three (3) feet."	Pond 1+4	$Z_{perm} \ge 3'$	$Z_{perm} = 4'$
		Pond 2	$Z_{perm} \ge 3'$	$Z_{perm} = 4'$
		Pond 3	$Z_{perm} \ge 3'$	$Z_{perm} = 4'$
WCWRC Section V. Part C (5)	"A minimum length to width ratio of 3:1 is preferred unless structural measures are used to extend the flow path."	Pond 1+4	l/w ≥ 3	l/w = 3.01
		Pond 2	l/w ≥ 3	l/w = 3.01
		Pond 3	l/w ≥ 3	l/w = 3.02

The WCWRC also sets regulations for how long the volume from specific storms should take to drain from the detention pond. Our compliance with these regulations is outlined below in Table B13.

Table B13. Detention ponds drain in acceptable time

Regulation	Requirement	Component	WCWRC limit	Design value
WCWRC Section V. Part C (4g)	"The minimum detention time for the first flush volume is 24 hours."	Pond 1+4	T ≥ 24 hrs	T = 90 hrs
		Pond 2	T ≥ 24 hrs	T = 80 hrs
		Pond 3	T ≥ 24 hrs	T = 80 hrs
WCWRC Section V. Part C (4h)	"The bankfull volume must be detained for a minimum of 36 hours and a maximum of 48 hours"	Pond 1+4	100% drained	>95% drained*
		Pond 2	100% drained	>95% drained*
		Pond 3	100% drained	>95% drained*
WCWRC Section V. Part C (4i)	"The maximum detention time for the 100-year storm volume is 72 hours."	Pond 1+4	100% drained	>97% drained*
		Pond 2	100% drained	>97% drained*
		Pond 3	100% drained	>97% drained*

For the bankfull volume, and 100-year storm, our detention ponds take slightly longer than the maximum detention time to drain. These are marked in Table B13 with an asterisk. To meet the detention time, we could increase the size of the detention pond orifice. However, the discharge from each pond would then exceed the allowable release rate. As advised by our senior consultant, we chose to prioritize complying with maximum discharge rate, to protect existing streams and channels. Additionally, for the bankfull and 100-year volume, all ponds are more than 95% drained after the allotted detention time. Therefore, all ponds would be capable of storing a subsequent 100 year storm.

4.2. CONVEYANCE SYSTEM

4.2.1 Functional Objectives

A stormwater conveyance system is used to manage stormwater in urban and rural areas after storm events. The functional objective of our conveyance system will be to transport runoff from the development to defined outlet points. The design will consist of a mixture of natural streams and channels, vegetated swales, and pipe systems as defined in the WCWRC Rules and Guidelines (Pratt).

Each component has unique applications for stormwater management and its own set of design requirements. Natural channels are existing channels, and need to be preserved on site. Vegetated swales are useful to maintain the site's natural drainage paths and remove pollutants, such as TSS, from runoff. Enclosed drainage systems are helpful for conveying large quantities of runoff, particularly where topography impedes the use of open drainage systems. These components will work together to prevent flooding, control erosion, and manage water quality on site.

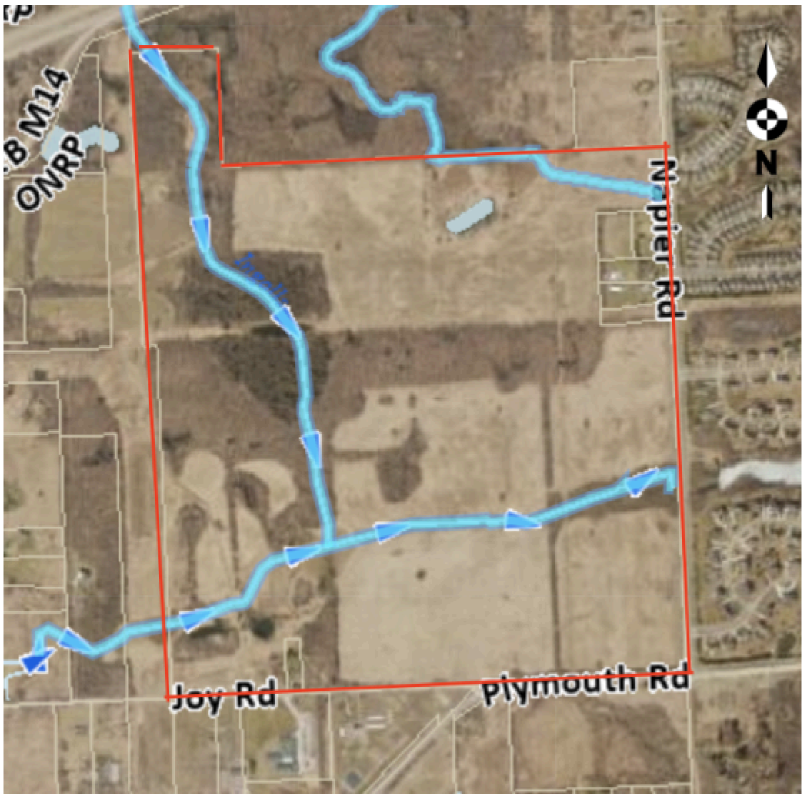

Figure B7. Existing drainage routes trisect the site, running south and east.

To design the most effective and efficient conveyance system, we analyzed the topography of the site and the existing drainage pathways (see Figure B7) to determine where runoff may need to be conveyed with pipes, where it can be conveyed with vegetated swales, and where the runoff can discharge into existing streams. Some critical factors to consider in this process include determining an outlet point for runoff to be discharged, avoiding the floodplain and wetlands around the site for post-development conveyance, and preserving existing streams.

Runoff volumes and peak flows from the 10-year storm event will be used to inform the conveyance system design. We collected key hydrological data for the 10-year storm event, including peak flow and runoff volume. These pre- and post-development data are summarized below in Table B14.

Table B14. Pre and post-development data for the 10-year storm

	Area (ac)	Parameter	Pre-development value	Post-development value
Group 1 + 4	60.65	Total volume [ft^3]	152,000	458,000
		Peak flow [cfs]	51.4	75.5
Group 2	27.81	Total volume [ft^3]	48,000	199,000
		Peak flow [cfs]	13.5	34.7
Group 3	28.52	Total volume [ft^3]	46,000	204,000
		Peak flow [cfs]	13.8	32.0

4.2.2 Alternative Evaluation Criteria

We have identified several feasible alternatives for the stormwater conveyance system at Salem Meadows. We will use the following criteria to evaluate and select an alternative for stormwater transport.

- **Sustainability** - We will select options that minimize disturbances to the environment, have a lower carbon footprint, conserve existing resources, and promote biodiversity.
- **Aesthetics** - We will select options that are visually appealing and attractive to potential tenants.
- **Capital cost** - We will select options that minimize the total upfront cost of materials and installation.
- **Life cycle cost** - We will select options that minimize operations and maintenance costs, as well as the cost of labor for maintenance.
- **Construction risk** - We will select options that minimize the risk of the project going over budget and off schedule.
- **Implementability risk -** We will select options that will be acceptable to future tenants and the surrounding public, utilize land availability, and are feasible for county standards.
- **Impact to water quality -** We will select options that remove necessary runoff pollutants (TSS) according to Washtenaw County standards.

4.2.3 Alternative Evaluation Criteria

After eliminating conveyance options that did not meet the minimum legal requirements for WCWRC standards, the remaining alternatives for the stormwater conveyance system include a combination of reinforced concrete pipe (RCP) with either concrete channels, vegetated swales, or bioswales. These options pertain particularly to Group 2, which does not have any natural conveyance to Ingalls Drain. Due to the topography across Salem Meadows, concrete pipes will be required for subsurface conveyance for all groups. Each combination includes a surface conveyance method that will be used for transporting runoff from roadways, parking lots, and building pads. Examples of concrete channels, vegetated swales, and bioswales are in Figure B8.

I. Concrete channels and subsurface RCP
Concrete channels are a surface conveyance method that utilizes a gradually sloped concrete canal to transport stormwater, similar to a gutter. The lack of natural infiltration associated with concrete channels indicates that this alternative is not acceptable for appropriate stormwater quality treatment per Washtenaw County guidelines. Additionally, the capital costs of concrete channels are by far the greatest out of all three alternatives. Concrete channels would also reduce the aesthetics on the property, as opposed to vegetated swales or bioswales that would contribute to the aesthetics.

II. Vegetated swales and subsurface RCP
Vegetated swales are ditches lined with grass that convey runoff. This form of surface conveyance is able to transport runoff and treat pollutants through natural infiltration. Vegetated swales are often used in standard practice alongside roadways and parking lots because of their minimal landscaping and maintenance costs. Additionally, the capital cost of vegetated swales is the cheapest out of the three alternatives being considered. The aesthetics of vegetated swales can be improved with native plantings, and can provide green areas around buildings. Vegetated swales offer similar benefits to bioswales in terms of water quality, aesthetics, and sustainability but do not cost as much to maintain or install.

III. Bioswales and subsurface RCP
Bioswales are vegetated swales that also include a subsurface bioretention element and an underdrain. They are retrofitted with native plants and highly permeable soil or media for infiltration, making them extremely effective in removing runoff pollutants. Bioswales are the most visually pleasing alternative, but their additional excavation and long-term maintenance costs do not justify the initial investment within the project's budget constraints.

Figure B8. Examples of concrete channels, vegetated swales, and bioswales from left to right. (Penrith City Council, Brock University, Chapel Valley Landscape Company).

Based on our design criteria, we chose the second alternative, a combination of vegetated swales and subsurface RCP, as our preferred alternative. A breakdown of our criteria evaluation can be seen below in Table B15.

Table B15. Evaluation of criteria for conveyance alternatives

		ALT 1: Concrete channels		ALT 2: Vegetated swales		ALT 3: Bioswales	
Criteria	**Weight**	Rank	Weighted	Rank	Weighted	Rank	Weighted
Sustainability	0.2	1	0.2	9	1.8	10	2
Aesthetics	0.1	1	0.1	9	0.9	10	1
Capital cost	0.1	1	0.1	8	0.8	4	0.4
Life cycle cost	0.15	6	0.9	5	0.75	4	0.6
Construction risk	0.15	5	0.75	8	1.2	7	1.05
Implementability risk	0.1	4	0.4	8	0.8	8	0.8
Impact to water quality	0.2	1	0.2	8	1.6	9	1.8
Sum	1		**2.65**		**7.85**		**7.65**

4.2.4 Recommended Solution in Detail

Our conveyance system will transport stormwater runoff from buildings and parking lots to wet detention ponds to treat sediments and pollutants, then to the existing streams that ultimately discharge to Ingalls Drain. Vegetated swales will run alongside roadways. Subsurface RCP will be used at the outlets of each wet detention pond, sized according to the volume of each pond to mitigate erosion in the floodplain. Subsurface RCP will also be used for discharging stormwater from the Group 2 wet detention pond, but will be followed by a pumping station in order to transport runoff across the topography of the site. Roadway runoff will be conveyed using vegetated swales to the existing floodplain. Figure B9, below, shows an overview of proposed conveyance routes from each wet detention pond to the existing stream and floodplain, as well as pipe diameters for each pond outlet.

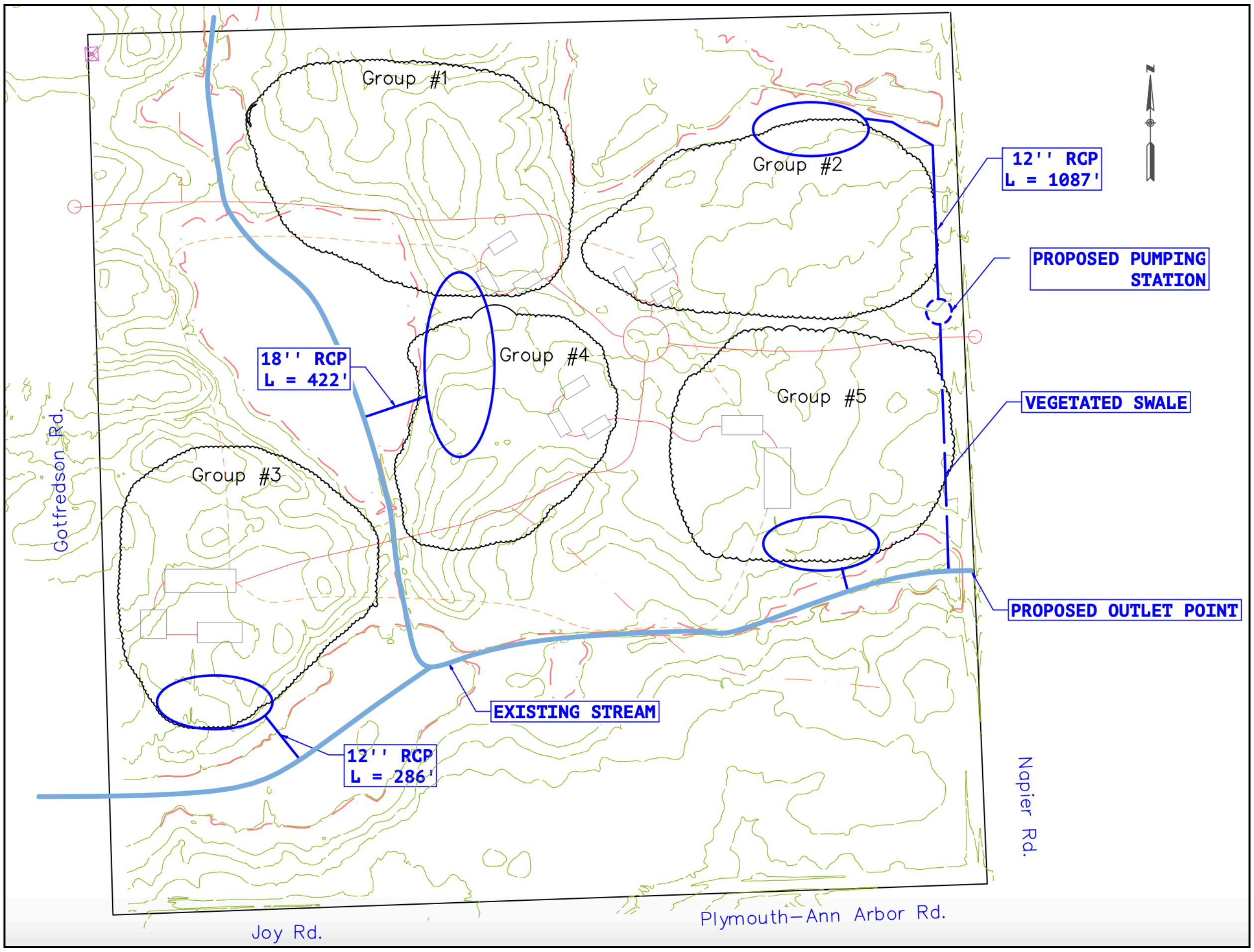

Figure B9. Conveyance transports stormwater runoff from building sites to outlet

We prioritized compliance with WCWRC regulations and made it our design baseline. The WCWRC states that drainage sites should follow natural streams and drains. So, we prioritized using existing streams and creeks for our conveyance system. However, we considered vegetated swales and subsurface conveyance when existing streams were unavailable.

Conveyance Design Priorities:

I. Existing drainage paths in Salem Meadows: We prioritized using existing drainage paths due to their low impact on the site's natural hydrology. In addition, our stormwater management successfully mitigates and lowers peak runoff from sites from design storms (10-yr and 100-year storms), and minimizes erosion to the existing banks.

II. Vegetated Swales: From Section 4.1.3, the subteam selected vegetated swales for surface conveyance. Surface conveyance is preferred over subsurface conveyance due to cost, ease of maintenance, and ease of access. However, vegetated swales have unique topographic limitations, and their use is not appropriate for all scenarios, including large volumes of runoff and flatter areas.

III. Subsurface conveyance (RCP): The subteam will use RCP to convey runoff that cannot be conveyed through surface conveyance, ensuring pipe diameters, self-cleaning slopes, and discharge all fall within WCWRC and the Michigan Department of Transportation (MDOT) standards.

4.2.4.1 Group 1 + 4 Conveyance

Conveyance from Groups 1 and 4 contains the most runoff due to the large area it serves. This group will have an underground RCP system that will outlet to an existing stream that will leave the site at Ingalls Drain. Figure B10, below depicts the peak flow for its design storm.

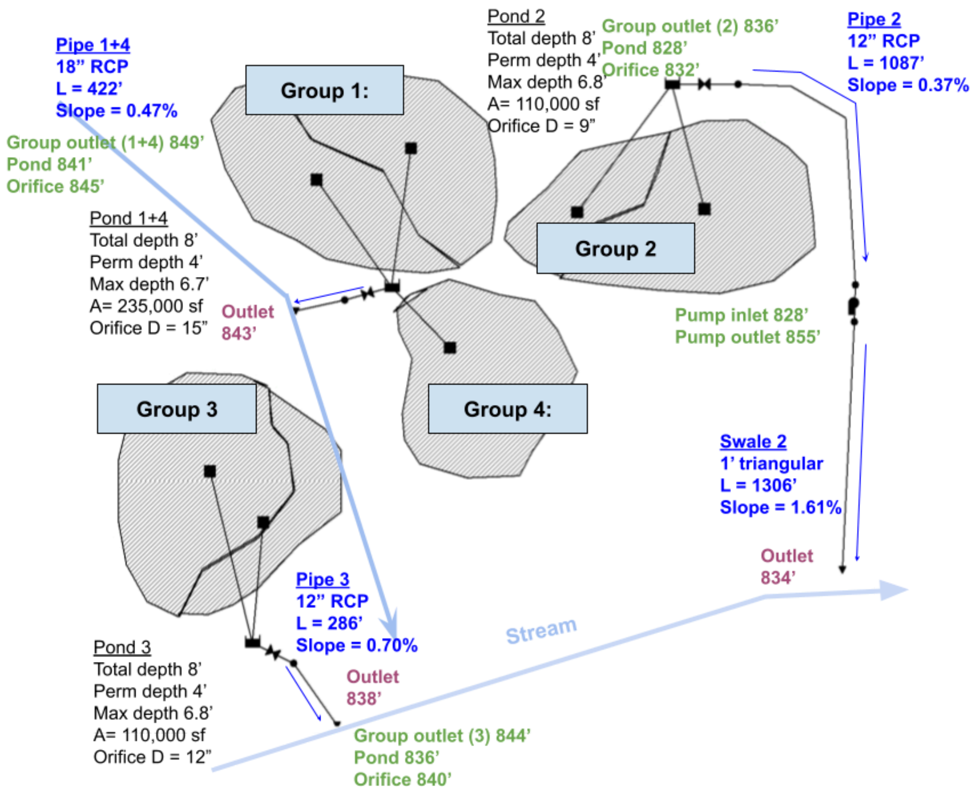

Figure B10. Stormwater's subteam schematic design plans

We have divided our conveyance system to serve a group on the site, leading to a more effective phasing during construction without impacting the project's overall cost. The only outlier is the conveyance from groups 1 + 4, which share a wet-detention pond due to the topography of Salem Meadows. Combining these two ponds makes it possible to convey runoff without the need for additional underground RCP or pumps.

Figure B11, outlines the required dimensions for the RCP pipe required to outlet to the existing drain in Ignalls Drain and depicts the peak flow conditions during the 10-yr storm.

Group 1+4 conveyance specifications	
Underground RCP	
Length	422 ft
Diameter	18"
Slope	0.47%

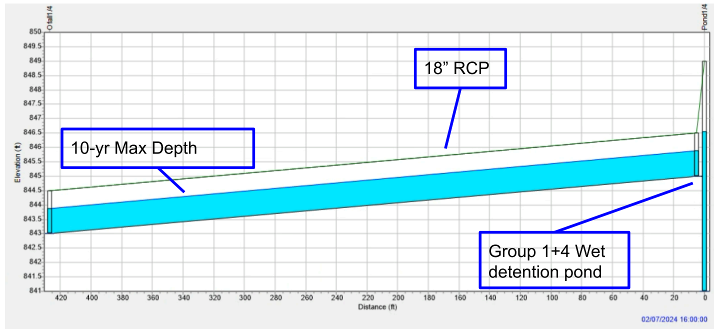

Figure B11: Dimensions of RCP and peak flow hydraulic grade line for Group 1+4

4.2.4.2 Group 2 Conveyance

Group 2 lacks existing streams nearby; therefore, we chose to combine vegetated swales and RCP for its entire conveyance. See Section 4.1.3 for all alternatives evaluated. In addition to the lack of an existing watershed, group 2 also has a complex topography, highlighted in Figure B12 and the overall site layout in figure B9. This site’s topography requires a pumping system to meet all gradient, flow, and depth requirements set by the WCWRC. Though pumps are not ideal due to their high maintenance, they are necessary to avoid flooding and erosion from stormwater runoff exiting Group 2.

Group 2 Conveyance Specification	
Underground RCP	
Length	1087 ft
Diameter	15"
Slope	0.37%
Pump	
Capacity	1,852 gal/min
Vegetated Swale	
Length	1306 ft
Slope	0.0161
Shape	Triangular
Depth	1 ft
Side Slope	3:1 (W:H)
Top Width	6ft

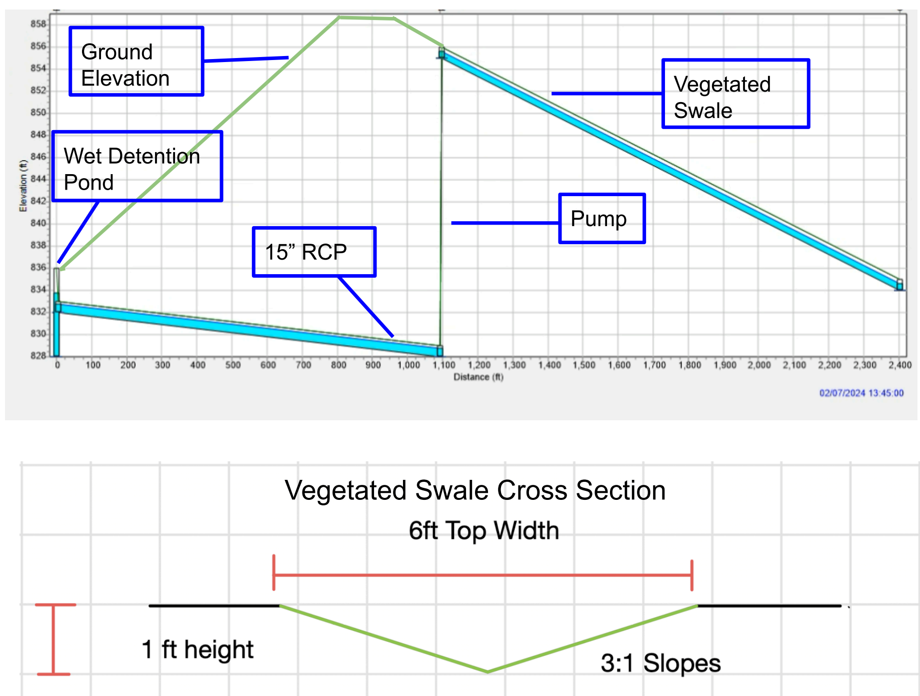

Figure B12. Dimensions of conveyance system, Peak Flow Hydraulic Grade line and vegetated swale schematic for Group 2.

4.2.4.3 Group 3 Conveyance

Group 3's conveyance is similar to Groups 1 and 4. It consists of an underground RCP system that outlets to the nearby stream. However, since conveyance for Group 3 serves a lower peak flow, smaller pipes can be implemented. Smaller pipes also reduce the cost of the overall project. Swales cannot be implemented due to small slopes, so RCP is recommended. Figure B13 shows peak flow Hydraulic Grade Line in addition to specifications of the conveyance system for Group 3.

Group 3 Conveyance Specification	
Underground RCP	
Length	286ft
Diameter	12"
Slope	0.70%

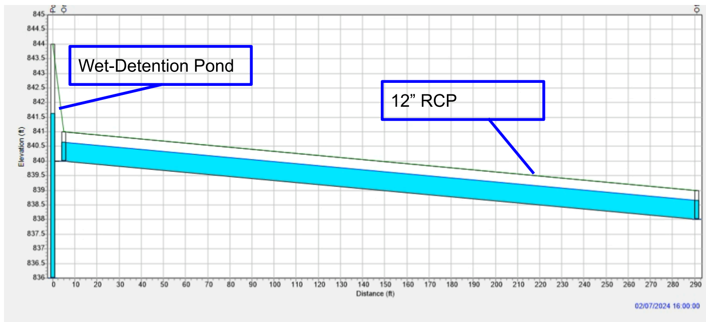

Figure B13. Dimensions of conveyance system and Peak Flow Hydraulic Grade line for Group 3

We have made sure to follow both WCWRC regulations, consultant guidance, MDOT regulations, and RFP requirements to provide the best conveyance system for Salem Meadows. We have included some of the technical compliance information from the WCWRC guidelines in Table B16.

Table B16. Conveyance system fully complies with WCWRC standards

Regulation	Requirement	Component	WCWRC limit	Design flow
WCWRC Section V. Part P (2.C)	"Streams and channels will be explored to withstand all events up to the 100-year storm without increased erosion. " WCWRC Limit equals pre-development peak runoff in the 100-year	Stream 1+4	Q ≤ 118 cfs	Q = 9.4 cfs
		Stream 2	Q ≤ 33 cfs	Q = 3.7 cfs
		Stream 3	Q ≤ 29 cfs	Q = 4.1 cfs
Section V Part A (1b)	Open swales (cross lot drainage): minimum of 30 feet total width.	Swale (Group 2)	L > 30'	L > 30'
WCWRC Section V. Part P (3.C)	"Open ditch flow velocities will be neither siltative nor erosive. The minimum acceptable velocity will be 2.0 ft/sec., and the maximum acceptable velocity will be 6.0 ft./sec"	Swale (Group 2)	2 ≤ V ≤ 6 ft/s	V = 2.4 ft/s
WCWRC Section V. Part P (3.D)	"The minimum acceptable slope is 1.5%, unless other techniques such as infiltration devices are implemented"		S ≤ 1.5%	S = 2.67%
WCWRC Section V. Part P (3.E)	"Side slopes of ditches shall be no steeper than 3:1. Soil conditions, vegetative cover and maintenance ability will be the governing factors for determining side slope requirements."		S ≥ 3/1 (h/v)	S = 3/1 (h/v)
WCWRC Section V. Part P (4.B.iv)	"For smaller enclosed pipes, 12 to 24 inches in diameter"	Underground Conveyance (Group 1 + 4)	12" ≤ D ≤ 24"	D = 18"
		Underground Conveyance (Group 2)	12" ≤ D ≤ 24"	D = 15"
		Underground Conveyance (Group 3)	12" ≤ D ≤ 24"	D = 12"
WCWRC Section V. Part P (4.E)	" In order to avoid accumulation of sediment in the drain, the pipe will be designed to have a minimum velocity of 3 ft/sec."	Underground Conveyance (Group 1 + 4)	3 ≤ V ≤ 10 ft/s	V = 6.1 ft/s

	“The maximum allowable velocity flowing full will be 10 ft/sec”	Underground Conveyance (Group 2)	3 ≤ V ≤ 10 ft/s	V = 4.1 ft/s
		Underground Conveyance (Group 3)	3 ≤ V ≤ 10 ft/s	V = 5.6 ft/s
WCWRC Section IV. Part A (3)	“The allowable release rate from a facility designed for the flood control storage volume will not exceed 0.15 cfs per acre of the property being drained.”	Group 1+4 Outlet	Q ≤ 0.15 cfs/ac	Q = 0.15 cfs/ac
		Group 2	Q ≤ 0.15 cfs/ac	Q = 0.13 cfs/ac
		Group 3	Q ≤ 0.15 cfs/ac	Q = 0.14 cfs/ac
Section IV Part F (4a)	“Enclosed storm drains and piping systems will be sized to accommodate the 10-year flow, with the hydraulic gradient maintained below the top of the” pipe.	Underground Conveyance (Group 1 + 4)	Z_w ≤ 18”	Z_w = 11.1”
		Underground Conveyance (Group 2)	Z_w ≤ 15”	Z_w = 9.5”
		Underground Conveyance (Group 3)	Z_w ≤ 12”	Z_w = 8”

While most of our conveyance system will be above ground, the transition to underground conveyance through pipe flow is recommended in locations of high flow and at the wet detention pond inlet. In addition to WCWRC guidelines, we have implemented MDOT sewer requirements from Chapter 7 to have self-cleaning pipes shown below in Table B17.

Table B17. Self-cleaning pipe design specifications

Group	Pipe size	Minimum self cleaning slope	Designed slope
Underground Group 1 + 4	18”	0.28%	0.47%
Underground Group 2	15”	0.36%	0.37%
Underground Group 3	12”	0.48%	0.70%

4.2.4.4 Roadside Swales

Vegetated swales should be located along roadways and parking lot perimeters to capture runoff (USDOT). In collaboration with the Environmental Services subteam, rain gardens, and filter strips incrementally placed in the swales will remove pollutants from the road's initial runoff. Figure B14, below, shows a typical cross-section of a vegetated swale.

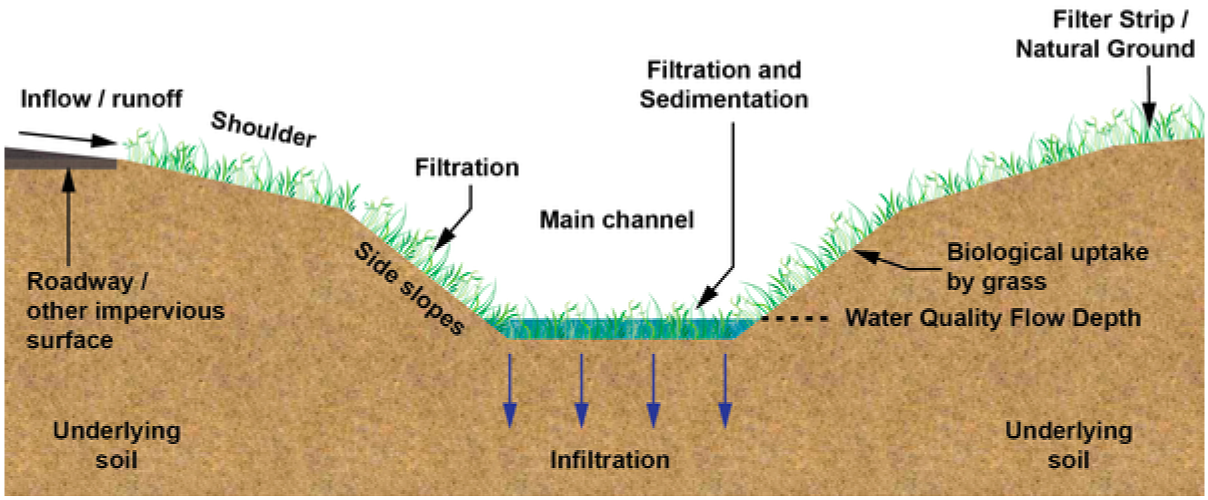

Figure B14. Vegetated swale and its infiltration properties relevant to capture and filter roadway runoff (Ekka, 2020).

In conjunction with the transportation and environmental subteams, our solution for road runoff includes two small swales on either side of the road to capture and convey storm runoff. The environmental Site-wide subteam has all the specifications for regulations regarding TSS management. Figure B15 shows the left side of the two-way road alongside its respective swale.

Roadside Conveyance	
Vegetated Swale	
Length	17,240 ft
Slope	0.01
Shape	Triangular
Depth	1 ft
Side Slope	3:1 (W:H)
Top Width	6 ft

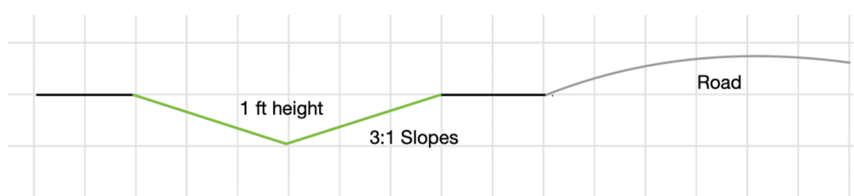

Figure B15. Roadside conveyance specifications and vegetated swale cross-section

Since roadside swales are part of the conveyance system, they must meet all WCWRC requirements for swale volume and velocity runoff. Table B18 summarizes the specifications for the roadside swale.

Our design complies with all the WCWRC regulations at face value, except for WCWRC Section V. Part P (3.D). Our design does not have a 1.5% slope minimum required for vegetated swales. To mediate the low incline of our swales, we have worked with the environmental subteam, which has implemented rain gardens within vegetated swales. Rain gardens will be implemented as an infiltration system, for more details on rain gardens, see Environmental Subteam's Technical report.

Table B18. WCWRC roadside swale compliance

Regulation	Description	Component	WCWRC Limit	Design value
Section V Part A (1b)	Open swales (cross lot drainage): minimum of 30 feet total width.	Roadside Swales	L > 30'	L > 30'
WCWRC Section V. Part P (3.C)	"Open ditch flow velocities will be neither siltative nor erosive. The minimum acceptable velocity will be 2.0 ft/sec., and the maximum acceptable velocity will be 6.0 ft./sec"	Roadside Swales	$2 \leq V \leq 6$ ft/s	V = 5.6 ft/s
WCWRC Section V. Part P (3.D)	"The minimum acceptable slope is 1.5%, unless other techniques such as infiltration devices are implemented"		$S \geq 1.5\%$ OR Infiltration devices implemented	S = 1% with infiltration devices (rain gardens) implemented within swales
WCWRC Section V. Part P (3.E)	"The side slopes of ditches shall be no steeper than 3:1. Soil conditions, vegetative cover, and maintenance ability will be the governing factors for determining side slope requirements."	Roadside Swales	$S \geq 3/1$ (h/v)	S = 3/1 (h/v)