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2020-2021

Designing affordable housing for Egg Harbor

Preliminary engineering report

UniverCity Alliance
UNIVERSITY OF WISCONSIN–MADISON

Ex Nihilo Engineering Consultants
1227 Engineering Hall
1415 Engineering Drive
Madison, WI 53706

April 6, 2021

Jan Kucher, PE, Adjunct Professor
2346 Engineering Hall
1415 Engineering Drive
Madison, WI 54706

RE: 100% Preliminary Engineering Report for the Egg Harbor Affordable Housing Project

Dear Mr. Jan Kucher, PE,

Enclosed please ind the 100% preliminary engineering design report for the Egg Harbor Affordable Housing project.

Ex Nihilo Engineering Consultants has spent the last nine weeks studying the project needs and constraints and has identi ied four design alternatives that would provide Egg Harbor with housing needs for seasonal or long-term residents. Each design alternative includes an analysis of the geotechnical, hydrological, and structural conditions on site, along with a construction analysis of the four design options.

Through careful consideration of the cost, schedule, and constraints of each design, a decision matrix is provided that supports Ex Nihilo's design recommendation, to proceed with the hybrid design alternative which consists of two duplexes and a dormitory and 16 bedrooms.

Ex Nihilo is excited to work with the village of Egg Harbor to meet the affordable housing needs and looks forward to discussing questions or comments in regards to the preliminary engineering design report. Please contact the project manager, Molly Nemcek, at mknemcek@wisc.edu or at (262) 422-5610 with further questions.

Sincerely,

Engineering Student
Project Manager
Ex Nihilo Engineering Consultants

100% PRELIMINARY ENGINEERING REPORT FOR THE CONSTRUCTION OF AFFORDABLE HOUSING IN THE VILLAGE OF EGG

Prepared For:

Village of Egg Harbor Wisconsin

Prepared By:

- Ex Nihilo -
Engineering Consultants
Dedicated to Building a Better Tomorrow

Disclaimer

The content of this preliminary engineering design report is provided by students in the Department of Civil and Environmental Engineering at the University of Wisconsin - Madison, and does not represent the work of a licensed professional engineer. The concepts, drawings, and written material are prepared for the course Civ Engr 578 - Senior Capstone Design, and should not be used for construction purposes.

0.0 Executive Summary

0.1 Project Description

The Village of Egg Harbor is located on Lake Michigan and has a permanent population of about 250 residents. Approximatly 40% of the population is above the age of 60 and in retirement.

Because of its location on lakeside property, Egg Harbor sees a dramatic increase in population during the summer months due to tourism. Many businesses provide recreational summer activities such as boating, kayaking, gol ing, and many other activities. Seasonal employees lock to the village to provide services to the tourists during the summer months, but leave as soon as the tourism season ends.

Because the demographics of the village consists of an older and retired population, the cost of living is quite high. The seasonal employees hired by these businesses are often a younger and less inancially robust population; therefore, they are unable to afford the typical housing units available for rent in Egg Harbor and many of the employees only need housing for a few months. During the summer season, the need for affordable housing units increases. Businesses in the area have expressed interest in partnering with the affordable housing unit owners to provide for their employees.

The Village of Egg Harbor has provided a 1.4 acre plot of land on Harbor School Rd. to build affordable housing units as shown in **Figure 1** below. They have provided a budget of $1,000,000 for the design and construction of the units along with necessary additions such as wells, stormwater retention basins, and grading of the site.

Figure 1: Aerial view of the proposed building site

This preliminary engineering design report explores four designs for affordable housing and identi ies a geotechnical, hydrological, structural, and construction analysis of each alternative as well as a recommendation for the most feasible design option.

0.2 Design Alternatives

Four designs have been selected for consideration within this preliminary design report. Each option provides 16 bedrooms for seasonal employees along with parking and shared patio space.

The irst design option considered is dormitory style housing. This design consideration includes two buildings each with eight bedrooms. One shared kitchen and living space is to be provided in each building and each building has one bathroom for each two rooms. This design does not require a sprinkler system as it is governed by the Universal Building Code (UBC).

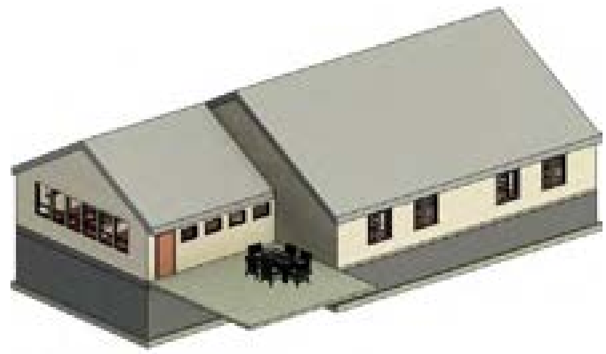

Figure 2: Eight bedroom dormitory unit

The second design consideration is the apartment style building which also consists of two separate buildings with four units each. Each unit is to have two bedrooms, a kitchen and living area, and one bathroom. There are two large apartment units and two small units per building. This design requires a sprinkler system per the International Building Code (IBC).

Figure 3: Apartment style unit

The third design alternative is four duplex units each with two separate units per building. Each unit consists of two bedrooms, a living and kitchen area, and one bathroom. Because each duplex consists of two units, a sprinkler system is not required per the UBC.

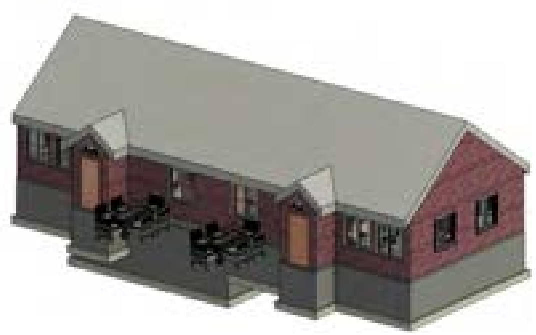

Figure 4: Two bedroom duplex unit

The fourth design alternative is a hybrid consisting of the eight bedroom dormitory style units and the two bedroom duplex units. One dormitory style building and two duplex units is to be built on site to maintain the 16 bedroom availability provided by the other alternatives. The dormitory style building has one kitchen and living area for its residents and one bathroom per two bedrooms. The duplex units include one bathroom, kitchen, and living area per unit. Since both designs fall under jurisdiction of the UBC, no sprinkler system is to be installed.

0.3 Project Constraints

This project had a variety of constraints that dictated the direction of design alternatives. These included economic, social, geotechnical and site conditions, functionality, political, and health and safety constraints. For economic constraints, developing affordable housing with a budget of one million dollars heavily impacted what type of structures were designed. The design team aimed to reduce perimeter length and design square footage in order to make the project costs lower. Rent was constrained to a level deemed affordable, through village estimates and team research, and is constrained to $400 to $500 per month depending on the unit. The main social constraint concerned the community preference for design solutions matching the aesthetic of the existing structures in the village. As for geotechnical and site conditions, the main concern was the bedrock which sat anywhere from two to four inches below grade. The functionality constraint focused on the design's ability to ef iciently temporarily house individuals from non-family units. This also addresses the challenge of illing vacancies during off season months and looked into designing an effective ratio of beds-bathrooms-kitchens. As for Political constraints, designs took into consideration the fact that funding for the project comes from the village taxes and business owners' investment. As a result, public opinion was a large concern. Finally, for the health and safety constraint, designs and alternatives were required to comply with the International Building Code and the Universal Building Code.

0.4 Probable Cost Estimates

Ex Nihilo has given an initial cost estimate for each of the design alternatives for the affordable housing project. Because each design is in the preliminary phase, estimates are subject to change going further with the design option. The cost estimate included the construction costs, administrative costs, engineering costs, and a contingency cost (only to be used if unforeseen situations arise). The dorm style was estimated to be $1,225,000, the apartment style was estimated to be $1,620,000, the duplex style was estimated to be $1,331,000, and the hybrid style was estimated to be $1,268,000.

0.5 Evaluation of Alternatives and Recommendation

Each alternative design solution was analyzed based on a set of 3 criteria groups. These include Economic Factors, Construction Factors, and Social Factors. Subcategories for each criteria group were also assigned, as seen in the decision matrix featured in **Table 1**. Each design criteria was assigned a weighted value to better display that item's importance in comparison to other subcriteria. An unweighted score ranging from 1-5 was assigned to each alternative design based on their ability to meet the expectations of the established criteria.

Table 1: Decision matrix for the four alternative design solutions

Decision Matrix - Egg Harbor Affordable Housing Ranked (1-5)									
		Two Bedroom Duplex Units		Eight Bedroom Dorm Style Housing		Apartment Complex		Hybrid design	
Criteria Group	Weights	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
Economic Factors									
Construction Cost	0.4	3	1.2	5	2	3	1.2	4	1.6
Life Cycle Cost	0.05	4	1.6	5	2	4	1.6	4	1.6
Construction Factors									
Space Limitations and Accessibility	0.05	4	1.6	5	2	3.5	1.4	5	2
Structural Efficiency	0.05	5	2	4	1.6	5	2	5	2
Geotechnical Limitations	0.025	3.5	1.4	5	2	5	2	4	1.6
Scalability	0.05	5	2	4.5	1.8	3	1.2	4	1.6
Sustainability	0.1	5	2	4	1.6	4	1.6	4.5	1.8
Social Factors									
Aesthetic and Community Approval	0.2	5	2	4	1.6	4	1.6	4.5	1.8
Amenities for Young Professionals	0.05	3.5	1.4	4	1.6	4	1.6	4	1.6
COVID-19 Benefits	0.025	5	2	3	1.2	5	2	4.5	1.8
Total	1	43	17.2	43.5	17.4	40.5	16.2	43.5	17.4

0.6 Project Schedule

The project duration including design phases, bidding periods, and construction, is one year in length. The project start date as seen in the schedule in **Appendix B** begins with design on January 26, 2021 and ends with project completion and turn over on January 25, 2022.

The project has been split up into ive phases as seen below:

Phase 1 - Proposal Preparation

Phase 1 is entirely inished and has therefore been collapsed in the current project schedule. This phase included scope review and proposal preparation.

Phase 2 - Preliminary Engineering Design

This is the current project phase. This phase included the submission of the

75 percent geotechnical report as well as the submission of the 90 percent project design report. This phase also includes this submission of the 100 percent preliminary design report and the 100 percent geotechnical report.

Phase 3 - Final Design

Phase 3 includes the submission of the 90 percent technical speci ication and the 90 percent drawings. Documents are to be submitted during this phase.

Phase 4 - Project Bid

The project bid phase is to begin following the submission of the documents. During this phase, there is to be a regulatory agency review and the release of the bid documents. Contractors are to be given the opportunity to construct and submit their bids. Bid evaluation then begins. Finally, the contract is to be awarded and contract execution and permitting ensues.

Phase 5 - Construction

The construction phase has been split into sub divisions. These include site work and foundation, framing and enclosing the building, exterior siding, paving, and landscaping. It also includes interior framing, MEP work, and inishes. The last step in the construction process is the closeout process which includes punch list, walkthrough, and cleaning.

0.7 Design Recommendation

Based on the decision matrix, either the Dorm Style or Hybrid Style could be feasible alternatives to a solution to the village's problem. However, when drawing comparisons between these designs and their ability to meet the long term needs of the client, it was found that the Hybrid Design was ideal. Ex Nihilo believes that although the Hybrid Design has a higher capital cost than the Dorm Design, it provides business owners with more options for purchasing and investing in housing for seasonal employees. Based on the need and inancial capabilities of business owners in the village, they are to be able to determine whether they would like to purchase individual bed spaces as is available in the dorm, or if they would prefer to purchase entire units as can be done with the duplex design.

To reiterate, after much analysis and comparison of alternative designs, Ex Nihilo Engineering Consultants would recommend proceeding with the Hybrid Design for the remainder of the project.

0.8 Implementing the Design

Establishing effective project implementation strategies is an ongoing effort and requires collaboration between a variety of parties. The Village of Egg Harbor Affordable Housing project is to be managed by a developer that would invest in the project. This developer serves as the owner while the project is being built. The property is then likely to be sold off to individual investors and business owners. The developer would have dominion over property management including lawn care, utilities, well maintenance and other general maintenance of the property.

One main concern for the economic sustainability of this project is obtaining the investment of local businesses early in the project. Interested businesses are to be given the opportunity to purchase property from the developer for use as housing for their seasonal employees. Ownership by businesses could be both singular or shared among multiple entities, depending on need and inancial feasibility. In Egg Harbor, there are currently four business owners who have established seasonal workforce housing in the village. The Village administration has indicated that interest has been shown by others as well. As a inancial investment, this has historically been a losing proposition for businesses on its own; however, it is a net positive as they are then able to secure seasonal staff. As a result of this inancial loss, some amount of state or federal tax incentives would need to be included to make the project viable. One potential incentive program that would increase project viability is the Wisconsin Housing and Economic Development Authority (WHEDA) pilot program in which Door County is involved.

Prior to getting a developer involved in the project, there would need to be prospective businesses prepared in advance. Equitable project investment opportunities would be given to Egg Harbor businesses, but priority would be given to establishments on a irst come, irst serve basis. In the event that there is more interest than available development space, the design solutions detailed in this Preliminary Design Report could be replicated on the back half of the designated plot of land.

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1.0 Introduction - Project Needs and Scope

Ex Nihilo Engineering Consultants is pleased to have been given the opportunity to work in collaboration with the Village of Egg Harbor to develop an affordable housing design that serves the needs of the community.

The Village of Egg Harbor, located in Door County, Wisconsin, was irst established in 1861. Upon visiting the village, one of the irst things a person might notice is its quaint architecture and historic sites. This village's charm as well as the plethora of summer activities they offer, are the main draws that bring tourists locking towards Egg Harbor year after year. Whether it be for the water sports and activities, the beautiful park space, opportunities to get out on the golf greens, or the array of performing arts, galleries, and eateries that are always available to explore, tourists continue to travel up the coast of Wisconsin for some summer fun. As a result of the in lux of visitors during the summer months, the tourism industry makes up 35% of the village's workforce.

Figure 5: Egg Harbor, Wisconsin geographical location

Local businesses are often required to hire seasonal employees to help manage the increased workload during the tourism season. The challenge that then arises, is to ind housing for these temporary residents. With very few options available to house seasonal workers affordably, this is where Ex Nihilo Engineering Consultants comes in.

The following report analyzes four different alternative solutions to the affordable housing shortage in Egg Harbor. These solutions include a two bedroom duplex unit, an eight bedroom dorm style housing unit, an apartment complex, and a hybrid design that utilizes both the duplex and the dorm style. Each of these solutions has been developed based on a combination of client needs and project constraints. Additionally, technical analyses were performed on each alternative solution in order to better understand the feasibility of each design and assist in determining a solution. These analyses can be found in the following sections and consist of a geotechnical, construction, structural and design, and hydraulic and hydrology analysis.

2.0 History of The Problem

The Village of Egg Harbor has long struggled with housing seasonal employees affordably, due to its position as a tourism location on the lake. Because such a large percentage of its economy is dependent on seasonal tourism, the in lux of workers on a seasonal basis by some estimates increases the population from around 200 to upwards of 2,000 during the busy months. The problem is so impactful on the local economy that in 2016, after over a decade of discussion, village administrator Ryan Heise initiated a project to build a one story dormitory with 20 rooms to house 40 seasonal workers. Modeled similarly to the Hiawatha Residence Hall in the Wisconsin Dells, the project was eventually canceled due to lack of available funding. Hiawatha Residence Halls were constructed to solve the same problem of seasonal worker in lux that Egg Harbor experiences, however on a larger scale.

Large scale housing projects such as Hiawatha Residence Hall have been feasible in tourism towns and resort locations around the country, but the failure of the 20 room dorm project in Egg Harbor indicates that the lack of available capital investment is a serious limiting factor. Larger businesses in the area have cleared the capital barrier to entry and built their own dorm style housing, such as Birch Creek Music Center and the Landmark Resort, but these large businesses are not typical of downtown Egg Harbor. However, with investment from local small businesses, and tax breaks from the local and state government, a smaller scale housing project is still feasible.

3.0 Forecasting Clients Needs

Our client, the Village of Egg Harbor, detailed their needs in the request for proposal. As aforementioned, the village has affordable housing needs for their seasonal workers. The Village would like a design for 10-16 beds and 600 to 800 SF per bedroom in the unit, allowing for 1 parking spot per 2 sleeping spaces, providing patio space, and utilizing either a hip, gable, or green roof.

According to the Egg Harbor 2020-2040 Comprehensive Plan, the population and industry of the Village is not expected to change signi icantly over the next 20 years, however the designs aimed for the high end of their goals in order to accommodate potential growth. Additionally, the current designs only take up approximately 50-60% of the provided lot; with this extra space, the recommended design could be duplicated on the back half of the lot with entrance on the Ridgewood Bluff Drive should the Village ind the project a success and need more housing in the future. The probable cost of the expansion could be approximated by taking the project costs layed out in this report and adjusting using a time factor to accommodate for the date of new construction.

Additionally, it is understood the Village is attempting to put in place more restrictive stormwater regulations, because of this, the stormwater management is to be designed to meet these potential future standards.

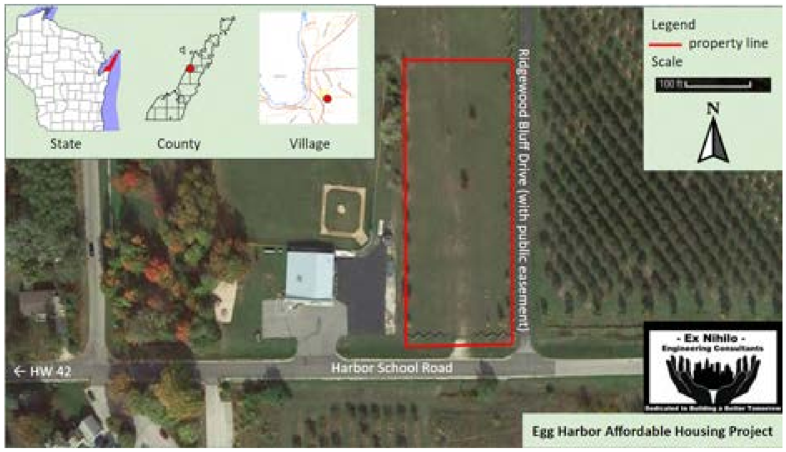

Figure 1: Aerial view of the proposed project site

4.0 Project Constraints

The main project constraints that Ex Nihilo Engineering adhered to throughout the preliminary design process were as follows:

Economical

Due to the project being classi ied as affordable housing, budgetary constraints were a signi icant concern from the very beginning. With a budget of one million dollars, there were many design avenues that had to be curtailed early on when investigating potential solutions. For example, due to the added expense of blasting rock as a part of excavating, the designs for the retention pond had to be adjusted. Additionally, as a result of this high excavation cost, basements were removed from initial design alternatives. Additionally, designs such as larger apartment complexes were eliminated, as they required the installation of expensive high capacity wells to service the sprinkler systems that would be needed for that type of design. Another economic design constraint can be seen in the development of project inancing. These housing units are intended to serve as affordable housing for less af luent individuals. As a result, the rent per unit was set at $400 for dorm bedrooms and $500 for apartment and duplex bedrooms. Additionally, conversations about project funding were deeply ingrained in project decision making.

Social - Aesthetics

The village of Egg Harbor is well known for its quaint architecture and consistent aesthetic design. According to a poll conducted by and on the community, over 75% of the public would like more attention paid to maintaining the quaintness of the village. In an effort to better serve the community, Ex Nihilo has made an effort to consider the preferences of the community when developing architectural design. This can be seen in items such as the roof selection and exterior design.

Environmental - Geological, Site Conditions, & Stormwater

Although the plot of land selected for construction is geotechnically acceptable for development, a variety of characteristics constrain the project. For example, a 10 percent grade exists in the east-west direction that impacts construction costs and building orientation on the site. Additionally, with a limestone bedrock depth ranging from 2 to 4 feet below grade, many design factors had to be considered and adjusted. Much of the site sits on bedrock around 2 feet below grade. Due to large capital costs of excavation and blasting, basements were not considered. Furthermore, the stormwater retention pond is designed to be 4 ft deep which also requires removal of bedrock. Rock removal subsequently constitutes an increase in construction costs which was a large constraining factor in the design.

The village is exempt from Wisconsin's NR216 stormwater management regulations and does not have speci ic regulations on stormwater management. In the comprehensive plan they express the need to develop stormwater plans, and note one plan to develop a fee system for properties that contribute to runoff. With this in mind, stormwater management is to be developed to reduce runoff and avoid these future penalties.

Manufacturability

There are few manufacturability constraints on the designs, simply that the design passes structural analysis for safety and uses common materials and methods to lower costs.

Functionality

When designing alternative solutions, Ex Nihilo had to analyze factors beyond the design and construction phase and look further into the building's life cycle. A large consideration was whether businesses would prefer renting out individual dwelling units or if they would be interested in purchasing entire complexes for their employees. This question was very signi icant when designing solutions. Additionally, outside of serving the needs of seasonal employees, designs were analyzed by their ability to handle the challenge of off season vacancies. Solutions to this could include renting to vacationers in the winter, or selling the property to full time residence. The issue of determining an effective ratio of beds-bathrooms-kitchen and living space was also considered through a functionality lens during the design process.

Health and Safety

In order to preserve the health and safety of residents and the general public, the designs comply with applicable codes and standards as discussed in the codes and standards section as well as engineered based on the engineering code of ethics.

Political

The project site is within a special development district (§152.025), developed by the village to "preserve the small town character of the village and yet promote development." the conditions of this zone include consistency with the Village comprehensive plan and architectural consistency. With this, there is no need to rezone the alternatives. Additionally, this project is to be funded by village tax dollars, business owner investment, and WHEDA subsidese (Wisconsin Housing and Economic Development Authorities). As a result, the alternative designs were developed in order to reduce costs. As much of the funding is provided through tax dollars, public opinion was a top consideration.

Sustainability

The village listed a green roof, as well as rain gardens and native plantings in the request for proposal, and thus Ex Nihilo takes sustainable building practices and the local landscape into consideration in building and site design.

5.0 Codes and Standards

Designs must comply with the International Building Code or Universal Building Code to establish acceptable design and construction. The International Building Code (IBC) and the Universal Building Code (UBC) are similar in nature, but are used for different types of buildings, and the UBC is generally less restrictive. The UBC is applicable to residential buildings with 2 or less dwelling units, while the IBC is applicable to residential buildings with 3 or more. Because of this the duplex and dorm styles are classi ied under the UBC, as they have only 2 and 1 dwelling unit respectively per building, while the apartment style is governed by the IBC.

The Village of Egg Harbor is exempt from Wisconsin's NR216 stormwater management regulation for in iltration purposes within the hydrologic design, but must follow Door County's requirements for total suspended solid removal within the stormwater retention pond. It is required that 80% of total suspended solids is removed from the stormwater before it lows into the retention pond. Additionally, stormwater retention pond regulations require a 6 to 8 feet depth with 2.5:1 side slopes for lightly maintained stormwater ponds.

As a long standing irm, Ex Nihilo follows the NSPE code of ethics in practice. Ex Nihilio follows the six fundamental canons of this code, as well as the rules of practice and professional obligations.

6.0 Design Tools

A variety of modern computer softwares were utilized to develop the designs for each discipline. For structural and design analysis Revit was primarily used to develop the models and drawings. For stormwater analysis Civil 3D, Hydra low, and RECARGA bioretention sizing, were used to develop hydrographs and determine adequacy of stormwater systems. For construction analysis, WinEst was used to develop construction costs for the project. Finally, computer aids including bluebeam and excel were utilized throughout design for each of the four disciplines.

7.0 Decision Matrix

Table 1: Decision matrix for the four alternative design solutions

Decision Matrix - Egg Harbor Affordable Housing
Ranked (1-5)

Criteria Group	Weights	Two Bedroom Duplex Units		Eight Bedroom Dorm Style Housing		Apartment Complex		Hybrid design	
		Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
Economic Factors									
Construction Cost	0.4	3	1.2	5	2	3	1.2	4	1.6
Life Cycle Cost	0.05	4	1.6	5	2	4	1.6	4	1.6
Construction Factors									
Space Limitations and Accessibility	0.05	4	1.6	5	2	3.5	1.4	5	2
Structural Efficiency	0.05	5	2	4	1.6	5	2	5	2
Geotechnical Limitations	0.025	3.5	1.4	5	2	5	2	4	1.6
Scalability	0.05	5	2	4.5	1.8	3	1.2	4	1.6
Sustainability	0.1	5	2	4	1.6	4	1.6	4.5	1.8
Social Factors									
Aesthetic and Community Approval	0.2	5	2	4	1.6	4	1.6	4.5	1.8
Amenities for Young Professionals	0.05	3.5	1.4	4	1.6	4	1.6	4	1.6
COVID-19 Benefits	0.025	5	2	3	1.2	5	2	4.5	1.8
Total	1	43	17.2	43.5	17.4	40.5	16.2	43.5	17.4

The above decision matrix displayed in **Table 1** was used to analyze the four alternative solutions and select the solution to be moved forward with through the duration of the project. When analyzing the values found for each solution as well as the individually assigned values for each criteria group, please note that high scores equate more desirable solutions. Although the four outcomes were very similar, the eight bedroom dorm style housing design as well as the hybrid design are the two top contending alternatives to be selected from as the recommended solution. Due to the small degree of variation between the alternative scores, the alternative's ability to meet the long term needs of the community was analyzed with increased weight, and a recommended alternative solution was then selected. Discussions with the client also took place, which contributed to the inal decision. Please see the **Recommendation** section for decisions.

As can be seen in **Table 1**, each alternative solution was analyzed based on a set of three overarching criteria groups. These groups include economic factors, construction factors, and social factors. Each criteria group was then broken up into subgroups. These groups were given weighted values, summing to one, that signi ied their importance in comparison to the other listed criteria. The weights were determined by the project team according to what they understood to represent the needs of the project. Additionally, after weights were assigned, each design alternative was given a score ranging from one to ive, with one being undesirable and ive being desirable, based on their ability to meet the expectations of the speci ied criterion. After each item was assigned a score, the cumulative score of each alternative was tallied and compared, with higher scores being ideal.

Descriptions of the criteria subgroups can be seen broken out below:

Economic Factors

<u>Construction cost</u>: Each design alternative was analyzed based on the anticipated probable costs which were developed by Ex Nihilo's construction management analyst. With an initially presented project budget of 1 million dollars, minimizing project costs was a top priority, and therefore was given a weighted value of 0.4.

<u>Life cycle cost</u>: Life cycle costs were also considered in the decision matrix. These include the cost of maintenance, yearly air conditioning, gas, and electric, and other accumulated costs through the working life of the building. The hybrid design and the apartment design were assigned smaller scores due to the larger prevalence of kitchen and living space in the appartements that would require maintenance and the nonuniformity of design for the hybrid solution.

Construction factors

Space Limitations and accessibility: Each alternative solution was scored based on their ef iciency of space usage. For example, the dorm was scored with a ive because it has a more ef icient ratio of kitchen-bedroom-bathroom space. The apartment in comparison was scored lower as it does not show uniformity in unit layout. It also takes up a large square footage and is not the most ef icient design in terms of building layout.

Structural Ef iciency: Structural ef iciency was scored for each alternative, however there was not much difference in structural requirements between building designs as they are each one story concrete and wood framed constructions. The dorm design, however, did require a bearing wall to help support the wider roof truss span. As a result, the dorm model received a slightly lower evaluation.

Geotechnical limitations: Geotechnical limitations were evaluated, however this category was given a lower weight, as it was assumed that much of the con lict caused by blasting bedrock would be captured by the construction cost criteria category. Each alternative was given a score based on the number of excavation holes that would need to be blasted, and the area being removed.

Scalability: Alternatives were analyzed based on their ability to be reduced in size to meet the project budget. As seen in the decision matrix, the duplex was awarded the highest score of a ive because it would be very easy to simply remove one of the units from the site plan. Additionally, this same thing could be done for the hybrid design. For the dorm, the building footprint could be reduced in depth by removing the two end bedrooms. The apartment complex is much more dif icult to scale down. As a result it was evaluated with the lowest score.

Sustainability: When analyzing for sustainability the perspective taken was of inancial sustainability rather than environmental. This is analyzing the ability for the buildings to be easily managed and maintained over a long period of time. The duplex design was awarded the highest score, because it is the most feasible for a business owner to purchase an entire unit for their employees. In comparison, shared housing such as what is seen in the dorm, would need to be managed under shared ownership. This is because many individual entities would be renting out or owning bed spaces for their seasonal workers. This type of ownership is much less sustainable and stable than individual ownership.

Social Factors

Aesthetic and Community Approval: It was stated clearly in the RFP and related documents that the community in Egg Harbor values the quaint aesthetic of the village. As a result, Ex Nihilo assigned a relatively high weight to this category. Each alternative solution was analyzed based on how well the design it the existing architecture in the village. As a whole, each of these designs ranked very highly in this category.

Amenities for Young Professionals: This criteria group analyzes the design's ability to serve the demographics that are predicted to reside in the buildings. This likely includes young adults who may still be in school while working their summer jobs. Therefore, this category compares the design's capacity for private space while simultaneously analyzing its capacity for socialization and collaborative spaces. The duplex was assigned the lowest score, for while it does feature private rooms like the other designs, it is not as well set up for socialization.

Covid-19 Bene its: Given the unforeseen circumstances within the past year, Covid-19 has become a prominent part of everyday life. As a result, it was taken into consideration when designing alternative solutions. Designs were analyzed based on their ability to mitigate the spread of Covid-19 in the case that a resident becomes infected. Designs such as the duplex and the apartment scored well in this category, for there are only two residents per bathroom, kitchen, and living area. The dorm design in comparison scored much lower as there is a shared kitchen and living room among eight residents.

8.0 Summary of Existing Conditions

8.1 Transportation

Transportation in and out of the Village of Egg Harbor is facilitated largely through State Highway 42, which is a two lane country highway traveling in North and South directions. The existing speed limit for State Highway 42 is 55 miles per hour and has an annual average daily traf ic count of 6,400 passenger car equivalents just north of the proposed project site location off Harbor School Road. This rural highway provides a straight route from Sturgeon Bay to the South-West, and further access to Green Bay as it converges with State Highway 57 in Sturgeon Bay. Current geometry of State Highway 42 is an undivided two-lane road with unpaved shoulders.

Access to the proposed project site is provided by Harbor School Road, a residential road in the East and West directions beginning at State Highway 42 just south of the Village of Egg Harbor, and continuing until a dead end at a rural farm 2.6 miles from its beginning. The geometry of Harbor School Road is an undivided two-lane highway with an unpaved and minimal shoulder. The speed limit is unmarked at its inception, but transitions to 45 miles per hour in the Eastbound direction roughly 150 feet prior to the proposed project site. West bound traf ic is posted at 35 miles per hour. No weight limits are posted or presented in the ordinances provided by the Village of Egg Harbor.

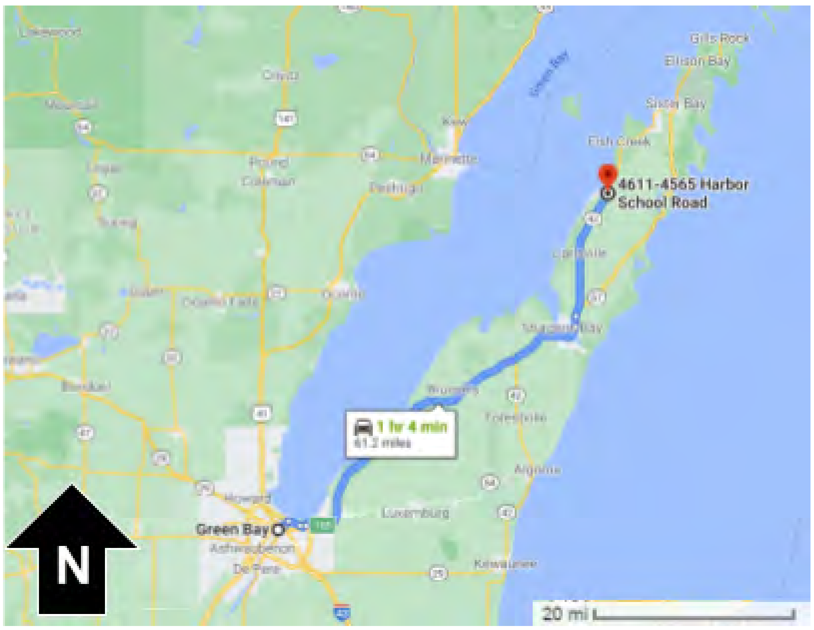

Figure 6: Highways 57 and 42 showing the route from Green Bay to Egg Harbor

8.2 Geotechnical Site Investigation

Detailed geotechnical analysis beyond the following excerpts can be found in the geotechnical report.

The proposed 1.4 acre site is located on Harbor School Road, on the southeast side of downtown Egg Harbor. The parcel is currently zoned as a Special Development district under statute §152.026 of the Village of Egg Harbor zoning code. The topography is relatively lat, and the parcel is constrained to the south and east by two lane roads.

This proposed site is currently lightly vegetated, sparsely populated with shrubs and grass. Currently an entrance drive is present on the south side of the parcel as it faces Harbor School Road, and should be considered for use as a construction entrance. The land historically has been vacant, though it has been maintained and would require relatively minimal site preparation prior to construction. Site topography is provided in **Appendix B**. The site has a steep grade throughout, 10% in some places.

The subsurface conditions on site can be generally characterized as gravelly sands and silts extending down until bedrock, typically encountered between 2 and 4 feet. Sands are dark and greyish brown, moist, and contain traces of silt and gravel. No cohesive soils were encountered in the soil borings, therefore no in depth soil testing was required. Surface soils encountered in the soil borings indicated an average of 3" of topsoil, and subsequently a gravelly sand until reaching bedrock. The NRCS soil survey indicates that the topsoil present at the project site is primarily Namur Loam (NaB), but also present is Longrie Loam (LoB). The soils on site are extremely adequate to provide bearing capacity to a structure, and are seen in relative uniformity throughout the entire proposed site. A detailed soil map is included below in **Figure 7.**

Figure 7: An NRCS soil map of the proposed site

8.3 Construction Requirements

The site requires preparation prior to the commencement of construction activities. Prior to excavation, utilities must be located. The topsoil requires removal so that no organic material is present, and the removal of trees is necessary. A construction entrance should be constructed of clear stone so that no mud is tracked onto village roads. Additionally, a water truck should be present onsite during the construction activities to keep dust to a minimum.

While some grading and excavation is required to prepare the site for the buildings, design consideration is to be given to creating buildings in a North-South direction, in order to reduce the cross slope across the building.

8.4 Utilities

Door County is known regionally for its minimal available municipal utilities due to its relative remoteness, lower population, and the shallow bedrock. The Village of Egg Harbor has a sanitary sewer system, but does not have potable water. This need for potable water needs to be addressed in each design alternative in order for the design to be considered acceptable. Ex Nihilo is to provide designs for water, sewer, and electrical supply to each building, while electrical and plumbing design within the building is to be performed by a consultant.

The site currently does not have a lateral pipe for sanitary water. The pipe connects the sanitary pipes from the complex to the sanitary main found below the road on the South side of the project along Harbor School Road. The calculation to determine the size of the lateral pipe can be found in the **Appendix C**. It was determined that a 4" lateral is adequate to serve the needs of the facility.

9.0 Alternative Solutions

9.1 Two Bedroom Duplex

Structural and Design Analysis

This design is the most basic structurally, the long exterior walls bear most of the weight of the roof, which is supported by relatively short trusses. The estimated roof weight in its worst case condition, under an extreme snow load, is approximately 185,100 lbs. The weight of the walls is approximately 76,000 lbs and the weight of the main loor is approximately 94800 lbs. The structural analysis concluded that the current design of the building was able to support the weight of the various loads impacting the structure. Detailed calculations can be found in **Appendix C**.

Figure 4: Two bedroom duplex unit

Construction Management

Current site conditions show shallow bedrock. Blasting is only required if unexpected site conditions are discovered in which bedrock is deeper than 4 feet below grade. Additionally, the current site has a grade of about 10%. Ex Nihilo proposes that the new grade of the site be 4%. After completing an earthwork analysis, it was determined that about 320 CY of ill is needed to achieve this 4% grade.

To the sediment eroding in the neighboring properties, Ex Nihilo plans to place a silt fence in the west and south limits of the property line for 375 lf. Additionally, water is to be used on the site to reduce the dust and debris in the air during construction. A cost estimate found the estimated capital costs to be $1,331,000 for this option.

Geotechnical

See the **Preliminary Design Criteria and Layouts** section under **Geotechnical Analysis** for a summary of the geotechnical analysis of the site and design alternatives. See the submitted geotechnical report dated 04/06/21 for detailed geotechnical analysis.

Hydraulics/Hydrology

Stormwater analysis was conducted on the 1.4 acre plot of land using Hydra low Hydrographs and TR-55 in Civil 3D. Precipitation values in inches for a 24-hour storm event for a 2-year, 10-year, and 100-year recurrence interval found on Door County's website were imported into Hydra low. The peak runoff for the existing, undisturbed site was calculated to be 1.975 cfs, 4.290 cfs, and 7.029 cfs for a 2, 10, and 100-year, 24-hour storm event, respectively. The existing conditions produce a runoff volume of 3,449 cf, 7,498 cf, and 12,516 cf, for a 2, 10, and 100-year recurrence interval, respectively. Next, the peak runoff for the proposed site was calculated using the impermeable area on site after construction which includes the building footprints, walkways, patios, parking lot, and water well. For the duplex units, the impermeable area on site after construction is 0.31 acres which produces a curve number of 82. Because this design produces the same curve number as the dormitory and hybrid style units, the peak runoff volume and lows are the same for the dormitory and hybrid units even after stormwater routing. The new peak runoff for the post-construction site is 2.534 cfs, 5.012 cfs, and 7.877 cfs for a 2, 10, and 100-year 24-hour storm events, respectively. The post-construction site produces a runoff volume of 4,408 cf, 8,888 cf, and 14,244 cf, for a 2, 10, and 100-year recurrence interval, respectively. Calculations for this were done through Hydra low Hydrographs; therefore, the information presented in this section is provided as tables in **Appendix C**.

In order to reduce the peak runoff low and volume on the constructed site to match the existing site runoff volume, a 40 foot top diameter lined retention pond is to be constructed at the southwest corner of the lot. A contoured retention pond was drawn in Civil 3D following the design standards for a lined retention pond. The pond has a bottom elevation of 671 feet and is to be 4 feet in depth with a 2.5:1 slope per retention pond standards. The pond is to include a 10-inch discharge pipe should the water in the pond exceed the volume of the pond. The water would then drain into the drainage ditch along Harbor School Road. Additionally, a weir for stormwater over low would be placed at the southwest portion of the pond as the site is graded lowest in this section. These retention pond parameters were entered into Hydra low Hydrographs and the stormwater runoff for the proposed site was routed to the retention pond to ind the new peak runoff values for the constructed site with the lined retention pond.

The new peak runoff values calculated by Hydra low for the proposed duplex site with a 40 foot top diameter lined retention pond are 2.004 cfs, 3.432 cfs, and 5.585 cfs for a 2, 10, and 100-year, 24-hour storm event, respectively. The proposed retention pond is adequate for stormwater management as the new peak runoff values on the proposed constructed site are less than or insigni icantly larger than the original runoff on the undisturbed site.

Door County's stormwater ordinance requires 80% total suspended solid (TSS) removal from water in a retention pond. After entering site and soil types and conditions into RECARGA, a bioretention sizing program, a bioretention device was sized to allow for 80% TSS removal. This design includes a 1000 sf bioretention device with 2 feet of engineered soil which would be installed at the northeast portion of the pond at the highest elevation. A 4 inch diameter perforated pipe 2 feet below grade at the bottom of the engineered soil would allow the iltered stormwater to low from the bioretention device to the retention pond after achieving 80% TSS removal.

Detailed design information can be found under the Hydrological Analysis subsection of the Preliminary Design Criteria and Layouts section.

9.2 Eight Bedroom Dorm Style

Structural and Design Analysis

This design is structurally complicated by the length of the trusses spanning the bedroom wing of the dorm. Because of this added length, both to reduce the potential cost of a long span truss and to reduce the forces on the exterior walls, a load bearing wall

Figure 2: Eight bedroom dormitory unit

was added to one side of the hallway, and a footing wall and footer beneath that wall. The estimated roof weight in its worst case condition, under an extreme snow load, is approximately 324,100 lbs. The weight of the walls is approximately 78,500 lbs, and the weight of the main loor is approximately 233,300 lbs. The structural analysis concluded that the current design of the building was able to support the weight of the various loads impacting the structure. Detailed calculations can be found in **Appendix C**.

Construction Management

Current site conditions show shallow bedrock. Blasting is only required if unexpected site conditions are discovered in which bedrock is deeper than 4 feet below grade. Additionally, the current site has a grade of about 10%. Ex Nihilo proposes that the new grade of the site be 4%. After completing an earthwork analysis, it was determined that about 320 CY of ill is needed to achieve this 4% grade.

To reduce the sediment eroding in the neighboring properties, Ex Nihilo plans to place a silt fence in the west and south limits of the property line for 375 lf. Additionally, water is to be used on the site to reduce the dust and debris in the air during construction. A cost estimate found the estimated capital costs to be $1,225,000 for this option.

Geotechnical

See the **Preliminary Design Criteria and Layouts** section under **Geotechnical Analysis** for a summary of the geotechnical analysis of the site and design alternatives. See the submitted geotechnical report dated 04/06/21 for detailed geotechnical analysis.

Hydraulics/Hydrology

Stormwater analysis was conducted on the 1.4 acre plot of land using Hydra low Hydrographs and TR-55 in Civil 3D. Precipitation values in inches for a 24-hour storm event for a 2-year, 10-year, and 100-year recurrence interval found on Door County's website were imported into Hydra low. The peak runoff for the existing, undisturbed site was calculated to be 1.975 cfs, 4.290 cfs, and 7.029 cfs for a 2, 10, and 100-year, 24-hour storm event, respectively. The existing conditions produce a runoff volume of 3,449 cf, 7,498 cf, and 12,516 cf, for a 2, 10, and 100-year recurrence interval, respectively. Next, the peak runoff for the proposed site was calculated using the impermeable area on site after construction which includes the building footprints, walkways, patios, parking lot, and water well. For the dormitory style units, the impermeable area on site after construction is 0.25 acres which produces a curve number of 82. Because this design produces the same curve number as the duplex and hybrid style units, the peak runoff volume and lows are the same for the duplex and hybrid units even after stormwater routing. The new peak runoff for the post-construction site is 2.534 cfs, 5.012 cfs, and 7.877 cfs for a 2, 10, and 100-year 24-hour storm events, respectively. The post-construction site produces a runoff volume of 4,408 cf, 8,888 cf, and 14,244 cf, for a 2, 10, and 100-year recurrence interval, respectively. Calculations for this were done through Hydra low Hydrographs; therefore, the information presented in this section is provided as tables in **Appendix C**.

In order to reduce the peak runoff low and volume on the constructed site to match the existing site runoff volume, a 40 foot diameter lined retention pond is to be constructed at the southwest corner of the lot. A contoured retention pond was drawn in Civil 3D following the design standards for a lined retention pond. The pond has a bottom elevation of 671 feet and is to be 4 feet in depth with a 2.5:1 slope per retention pond standards. The pond is to include a 10-inch discharge pipe should the water in the pond exceed the volume of the pond. The water would then drain into the drainage ditch along Harbor School Road. Additionally, a weir for stormwater over low would be placed at the southwest portion of the pond as the site is graded lowest in this section. These retention pond parameters were entered into Hydra low Hydrographs and the stormwater runoff for the proposed site was routed to the retention pond to ind the new peak runoff values for the constructed site with the lined retention pond.

The new peak runoff values calculated by Hydra low for the proposed dormitory site with a 40' diameter lined retention pond are 2.004 cfs, 3.432 cfs, and 5.585 cfs for a 2, 10, and 100-year, 24-hour storm event, respectively. The proposed retention pond is adequate for stormwater management as the new peak runoff values on the proposed constructed site are less than or insigni icantly larger than the original runoff on the undisturbed site.

Door County's stormwater ordinance requires 80% total suspended solid (TSS) removal from water in a retention pond. After entering site and soil types and conditions into RECARGA, a bioretention sizing program, a bioretention device was sized to allow for 80% TSS removal. This design includes a 1000 sf bioretention device with 2 feet of engineered soil which would be installed at the northeast portion of the pond at the highest elevation. A 4 inch diameter perforated pipe 2 feet below grade at the bottom of the engineered soil would allow the iltered stormwater to low from the bioretention device to the retention pond after achieving 80% TSS removal.

Detailed design information can be found under the Hydrological Analysis subsection of the Preliminary Design Criteria and Layouts section.

9.3 Apartment Complex

Structural and Design Analysis

This design is structurally complicated by the L-shaped corners, which requires specialty built up sections in addition to the regular trusses on the straight lengths. The estimated roof weight in its worst case condition, under an extreme snow load, is approximately 395,300 lbs. The weight of the walls is approximately 107,900 lbs, and the weight of the main loor is approximately 291,300 lbs. The structural analysis concluded that the current design of the building was able to support the weight of the various loads impacting the structure. Detailed calculations can be found in **Appendix C**.

Figure 3: Apartment style unit

Construction Management

Current site conditions show shallow bedrock. Blasting is only required if unexpected site conditions are discovered in which bedrock is deeper than 4 feet below grade. Additionally, the current site has a current grade of about 10%. Ex Nihilo proposes that the new grade of the site be 4%. After completing an earthwork analysis, it was determined that about 320 CY of ill is needed to achieve this 4% grade.

To reduce the sediment eroding in the neighboring properties, Ex Nihilo plans to place a silt fence in the west and south limits of the property line for 375 lf. Additionally, water is to be used on the site to reduce the dust and debris in the air during construction. A cost estimate found the estimated capital costs to be $1,620,000 for this option.

Geotechnical

See the **Preliminary Design Criteria and Layouts** section under **Geotechnical Analysis** for a summary of the geotechnical analysis of the site and design alternatives. See the submitted geotechnical report dated 04/06/21 for detailed geotechnical analysis.

Hydraulics/Hydrology

Stormwater analysis was conducted on the 1.4 acre plot of land using Hydra low Hydrographs and TR-55 in Civil 3D. Precipitation values in inches for a 24-hour storm event for a 2-year, 10-year, and 100-year recurrence interval found on Door County's website were imported into Hydra low. The peak runoff for the existing, undisturbed site was calculated to be 1.975 cfs, 4.290 cfs, and 7.029 cfs for a 2, 10, and 100-year, 24-hour storm event, respectively. The existing conditions produce a runoff volume of 3,449 cf, 7,498 cf, and 12,516 cf, for a 2, 10, and 100-year recurrence interval, respectively. Next, the peak runoff for the proposed site was calculated using the impermeable area on site after construction which includes the building footprints, walkways, patios, parking lot, and water well. For the apartment units, the impermeable area on site after construction is 0.37 acres which produces a curve number of 83. The new peak runoff for the post-construction site is 2.683 cfs, 5.194 cfs, and 8.085 cfs for a 2, 10, and 100-year 24-hour storm events, respectively. The post-construction site produces a runoff volume of 4,674 cf, 9,257 cf, and 14,692 cf, for a 2, 10, and 100-year recurrence interval, respectively. Calculations for this were done through Hydra low Hydrographs; therefore, the information presented in this section is provided as tables in **Appendix C**.

In order to reduce the peak runoff low and volume on the constructed site to match the existing site runoff volume, a 40 foot diameter lined retention pond is to be constructed at the southwest corner of the lot. A contoured retention pond was drawn in Civil 3D following the design standards for a lined retention pond. The pond has a bottom elevation of 671 feet and is to be 4 feet in depth with a 2.5:1 slope per retention pond standards. The pond is to include a 10-inch discharge pipe should the water in the pond exceed the volume of the pond. The water would then drain into the drainage ditch along Harbor School Road. Additionally, a weir for stormwater over low would be placed at the southwest portion of the pond as the site is graded lowest in this section. These retention pond parameters were entered into Hydra low Hydrographs and the stormwater runoff for the proposed site was routed to the retention pond to ind the new peak runoff values for the constructed site with the lined retention pond.

The new peak runoff values calculated by Hydra low for the proposed apartment site with a 40' diameter lined retention pond are 2.104 cfs, 3.507 cfs, and 5.989 cfs for a 2, 10, and 100-year, 24-hour storm event, respectively. The proposed retention pond is adequate for stormwater management as the new peak runoff values on the proposed constructed site are less than or insigni icantly larger than the original runoff on the undisturbed site.

Door County's stormwater ordinance requires 80% total suspended solid (TSS) removal from water in a retention pond. After entering site and soil types and conditions into RECARGA, a bioretention sizing program, a bioretention device was sized to allow for 80% TSS removal. This design includes a 1000 sf bioretention device with 2 feet of engineered soil which would be installed at the northeast portion of the pond at the highest elevation.

A 4 inch diameter perforated pipe 2 feet below grade at the bottom of the engineered soil would allow the iltered stormwater to low from the bioretention device to the retention pond after achieving 80% TSS removal.

Detailed design information can be found under the Hydrological Analysis subsection of the Preliminary Design Criteria and Layouts section.

9.4 Hybrid Design

Structural and Design Analysis

There were no structural calculations for this design as it is a simple combination of two of the other designs and has no impact on the structure of the building.

Construction Management

Current site conditions show shallow bedrock. Blasting is only required if unexpected site conditions are discovered in which bedrock is deeper than 4 feet below grade. Additionally, the current site has a current grade of about 10%. Ex Nihilo proposes that the new grade of the site be 4%. After completing an earthwork analysis, it was determined that about 320 CY of ill is needed to achieve this 4% grade.

To reduce the sediment eroding in the neighboring properties, Ex Nihilo plans to place a silt fence in the west and south limits of the property line for 375 lnft. Additionally, water is to be used on the site to reduce the dust and debris in the air during construction. A cost estimate found the estimated capital costs to be $1,268,000 for this option.

Geotechnical

See the **Preliminary Design Criteria and Layouts** section under **Geotechnical Analysis** for a summary of the geotechnical analysis of the site and design alternatives. See the submitted geotechnical report dated 04/06/21 for detailed geotechnical analysis.

Hydraulics/Hydrology

Stormwater analysis was conducted on the 1.4 acre plot of land using Hydra low Hydrographs and TR-55 in Civil 3D. Precipitation values in inches for a 24-hour storm event for a 2-year, 10-year, and 100-year recurrence interval found on Door County's website were imported into Hydra low. The peak runoff for the existing, undisturbed site was calculated to be 1.975 cfs, 4.290 cfs, and 7.029 cfs for a 2, 10, and 100-year, 24-hour storm event, respectively. The existing conditions produce a runoff volume of 3,449 cf, 7,498 cf, and 12,516 cf, for a 2, 10, and 100-year recurrence interval, respectively. Next, the peak runoff for the proposed site was calculated using the impermeable area on site after construction which includes the building footprints, walkways, patios, parking lot, and water well. For the hybrid style units, the impermeable area on site after construction is 0.28 acres which produces a curve number of 82. Because this design produces the same curve number as the duplex and dormitory style units, the peak runoff volume and lows are the same for the duplex and dormitory units even after stormwater routing. The new peak runoff for the post-construction site is 2.534 cfs, 5.012 cfs, and 7.877 cfs for a 2, 10, and 100-year 24-hour storm events, respectively. The post-construction site produces a runoff volume of 4,408 cf, 8,888 cf, and 14,244 cf, for a 2, 10, and 100-year recurrence interval, respectively. Calculations for this were done through Hydra low Hydrographs; therefore, the information presented in this section is provided as tables in **Appendix C**.

In order to reduce the peak runoff low and volume on the constructed site to match the existing site runoff volume, a 40 foot diameter lined retention pond is to be constructed at the southwest corner of the lot. A contoured retention pond was drawn in Civil 3D following the design standards for a lined retention pond. The pond has a bottom elevation of 671 feet and is to be 4 feet in depth with a 2.5:1 slope per retention pond standards. The pond is to include a 10-inch discharge pipe should the water in the pond exceed the volume of the pond. The water would then drain into the drainage ditch along Harbor School Road. Additionally, a weir for stormwater over low would be placed at the southwest portion of the pond as the site is graded lowest in this section. These retention pond parameters were entered into Hydra low Hydrographs and the stormwater runoff for the proposed site was routed to the retention pond to ind the new peak runoff values for the constructed site with the lined retention pond.

The new peak runoff values calculated by Hydra low for the proposed hybrid site with a 40' diameter lined retention pond are 2.004 cfs, 3.432 cfs, and 5.585 cfs for a 2, 10, and 100-year, 24-hour storm event, respectively. The proposed retention pond is adequate for stormwater management as the new peak runoff values on the proposed constructed site are less than or insigni icantly larger than the original runoff on the undisturbed site.

Door County's stormwater ordinance requires 80% total suspended solid (TSS) removal from water in a retention pond. After entering site and soil types and conditions into RECARGA, a bioretention sizing program, a bioretention device was sized to allow for 80% TSS removal. This design includes a 1000 sf bioretention device with 2 feet of engineered soil which would be installed at the northeast portion of the pond at the highest elevation. A 4 inch diameter perforated pipe 2 feet below grade at the bottom of the engineered soil would allow the iltered stormwater to low from the bioretention device to the retention pond after achieving 80% TSS removal.

Detailed design information can be found under the Hydrological Analysis subsection of the Preliminary Design Criteria and Layouts section.

10.0 Site Logistics & Staging Plan

Ex Nihilo estimates that the project is to be divided into three stages. The irst stage of the project is grading the land to the proposed 4% grade. The second stage includes excavating for the foundations for each building and retention pond, installing the well, and pouring the foundations for the building. The third stage is constructing the remainder of the buildings, pouring the asphalt parking lot, pouring the concrete sidewalks, and other miscellaneous details that are needed to inish the project. Materials and equipment is to be stored in the northern portion of the lot throughout the construction process.

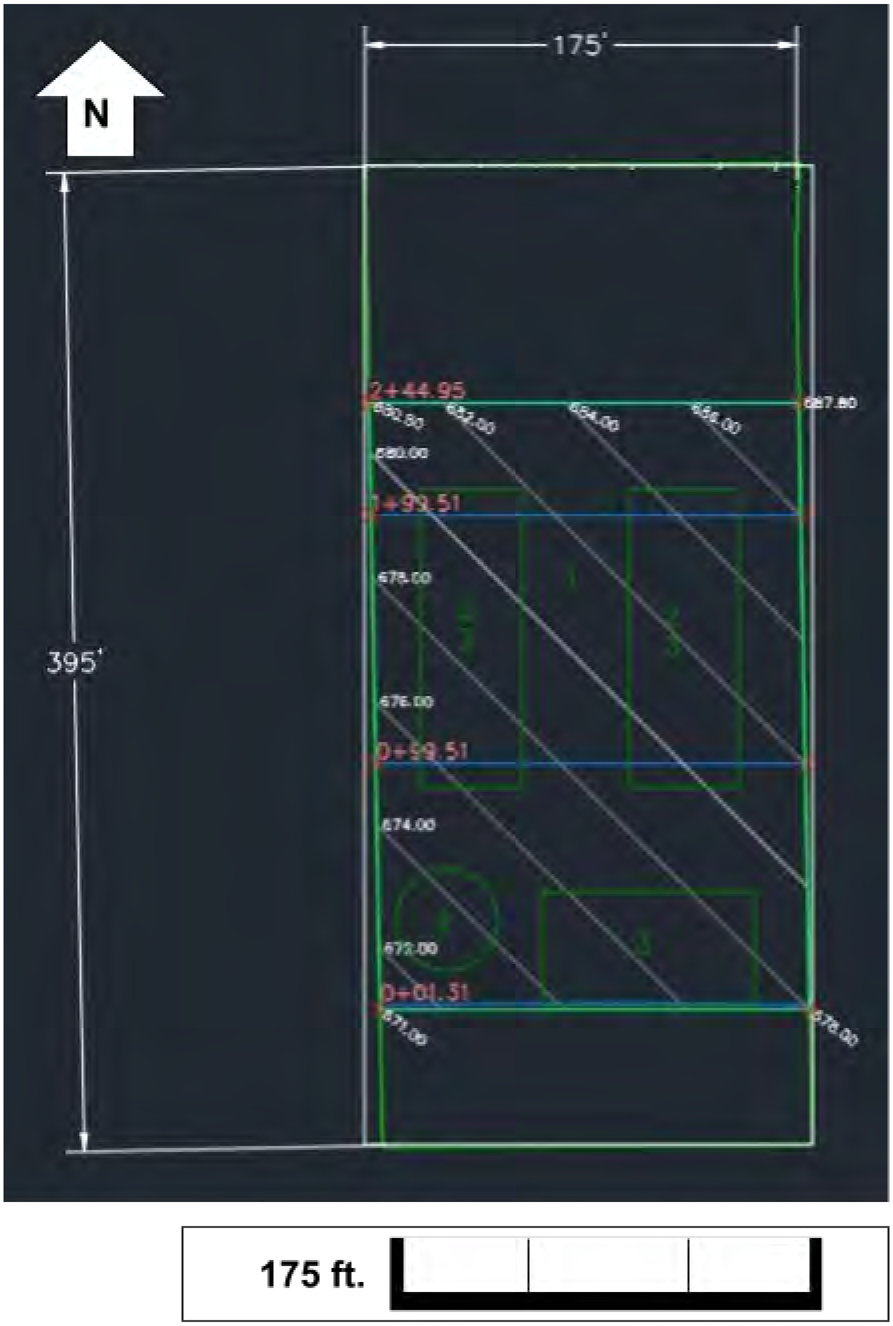

Figure 8: Proposed site grading plan excluding retention pond design

11.0 Opinion of Probable Cost

11.1 Capital costs

Capital costs were calculated for the project as seen in **Table 2** below. These costs are valid as of 1st quarter 2021, and expected to remain steady if the project moves forward as anticipated in the project schedule; should the project construction be delayed these costs may increase.

Table 2: Summary of capital costs for each design alternative

Alternative	**Dorm**	**Apartment**	**Duplex**	**Hybrid**
Site Improvements	$36,100	$190,400	$44,400	$33,200
Structure	$820,600	$965,400	$892,500	$856,600
Administrative Costs	$132,800	$179,100	$145,200	$137,900
Design	$93,900	$93,900	$93,900	$93,900
Contingency	$141,400	$190,700	$154,578	$146,800
Combined Costs	$1,224,800	$1,619,600	$1,330,600	$1,268,400

This table summarizes the results of a more detailed cost estimate that can be found in **Appendix C**. These costs were calculated using RS Means, WISDOT bid history, and US average cost data. Graphical representations of this data are presented in **Figures 9, 10, 11, 12** below. These costs can be split up as follows;

- Site Improvements: grading, curb and gutter, HMA pavement, concrete sidewalk, and water supply.
- Structure: excavation, substructure, superstructure
- Administrative costs: Owner admin costs, mobilization

Note that land costs are omitted from capital costs as the Village of Egg Harbor is providing the land at no cost.

11.2 Operations and Maintenance

Operating costs were determined by inding the average costs of the following utilities: air conditioning, heating, gas, electricity, and internet. After each utility cost was obtained, the amount was multiplied by the number of units for each design option and then multiplied by 12 months. These results are shown below in **Table 3.**

Maintenance costs were estimated as 1% of the capital costs of the project. These costs are assumed to reoccur each year. The results for each of the designs are shown below in **Table 3**.

Table 3: Summary of Operating and Maintenance costs for each design alternative.

Alternative	**Dorm**	**Apartment**	**Duplex**	**Hybrid**
Operating Cost	$11,800	$23,500	$23,500	$17,600
Maintenance Cost	$12,200	$16,200	$13,300	$12,700
Total	$24,000	$39,700	$36,800	$30,300

A more detailed analysis of the operating costs can be found in **Appendix C**.

11.3 Salvage Value

The salvage value is the estimated value of the building and materials at the end of its life cycle. The average depreciation of a building was found to be 3.6% per year. The average life expectancy of a building was found to be 100 years. Below, in **Table 4**, is the breakdown of the salvage values for each building alternative.

Table 4: Summary of salvage cost for each design alternative

Alternative	**Dorm**	**Apartment**	**Duplex**	**Hybrid**
Initial Capital Cost	-$1,224,800	-$1,619,600	-$1,330,600	-$1,268,400
Depreciation % per year	3.6	3.6	3.6	3.6
Average Life Expectancy [yr]	100	100	100	100
Salvage Value	$31,300	$41,400	$34,000	$32,400

Equation (1) used to ind each salvage value can be found in **Appendix C**. Note that this value only uses the capital costs of the alternative designs and does not include the property value.

11.4 Life Cycle Cost

The life cycle cost analysis was performed by annualizing the costs and values of the capital cost, operating and maintenance costs, and the salvage values. Ex Nihilo assumed that the interest rate for these values would be the same as the depreciation of the building, about 4%. Below in **Table 5**, the results of this analysis are shown.

Table 5: Summary of Life Cycle Cost for each design alternative

Alternative	**Dorm**	**Apartment**	**Duplex**	**Hybrid**
Annualized Capital Cost	-$49,700	-$65,00	-$54,000	-$51,500
Annualized O&M Costs	-$24,000	-$39,700	-$36,800	-$30,300
Annualized Salvage Value	$25	$33	$27	$26
Combined Annualized Costs	-$73,700	-$105,400	-$90,800	-$81,800
Annualized Rent Revenue	$38,400	$48,000	$48,000	$43,200
Combined Present Value	-$841,000	-$1,375,000	-$1,023,000	-$920,000

A more detailed analysis of how each of these values were obtained can be found in **Appendix C**.

11.5 Project Financing

This project is to be partially funded by local government taxes. As such, public opinion was a high priority when designing the project alternatives. Along with being funded by tax dollars, there are other possible avenues to reduce the cost of the project. One such example of this is the Housing Tax Credit. Through this tax credit, the federal income tax owed by owners or investors can be reduced for projects with certain quali ications. This includes projects with tenants whose incomes are below 60 percent of the county median income. Another mode of inancing this project is to be through local business investment. Business owners are to be encouraged to purchase either individual bed spaces or entire units for use by their seasonal workers. This business involvement early on in the project could help inance construction. Finally, Door County, and in turn the village of Egg Harbor, has been chosen as a pilot community for an affordable workforce housing initiative. Through this initiative, the WHEDA (Wisconsin Housing and Economic Development Authority's), provides supplemental funding tools that are provided through WHEDA operations rather than state taxes. The Egg Harbor Affordable Housing Project is to be inanced through a combination of the above avenues.

12.0 Proposed Project Schedule

The project schedule is a 5 phase approach to design and construction.

Phase 1, the proposal preparation phase
Phase 2, the preliminary engineering and design phase
Phase 3, the inal design phase
Phase 4, the project bid phase
Phase 5, the construction phase

The entire project schedule, including dates and durations can be seen listed in **Appendix B.**

13.0 Preliminary Design Analyses

Plan sets of alternative designs are presented in the **Appendix A**.

13.1 Structural and Design Analysis

Decision Matrix Weight
Structural Ef iciency was assigned a weight of 0.05 in the decision matrix. It was assigned this value due to the somewhat simple nature of the structural elements of the designs, but also the fact that structurally the buildings are quite similar and thus not as valuable to the decision matrix.

Design and Materials
The project was initially designed by the structural team to attempt to encompass the needs outlined in the RFP and ideas discussed by the project team. The designs were modeled using revit and typical residential construction materials and methods. These conventional materials and methods included:

- Foundation walls at least 4' below grade or to the bedrock
- 8" thick foundation walls
- 4" thick concrete slabs
- 2x6 studded exterior and separating walls
- 2x4 studded interior walls
- Stairs a minimum 3ft wide, with a maximum 8" riser and minimum 10" tread with 3ft landings at the top and bottom.

These common practices were incorporated into the design and analysis for structural suf iciency.

Design Con iguration and Rework
In order to cut costs, maintain consistency with client desires as outlined by the RFP, and continue to develop the design, the project underwent several interactions and revisions. These revisions took input from the mentors and project team. Major changes and updates included reducing square footage and perimeter length, adding speci ic design details, ensuring code requirements are met, etc. This rework resulted in more polished designs meeting up to the standards of Ex Nihilo and better representing the needs of the client.

Structural Analysis Calculations
After designing the buildings, calculations had to be done to establish the safety and functionality of the structure. Structural calculations are based on guidance from the *Residential Structure Design Guide* provided by the U.S. Department of Housing and Urban

Development published in October 2017. Design values are from both the Residential Structure Design Guide and the *2018 National Design Speciic ation Supplement* published in October of 2017 and provided by the American Wood Council.

The three building types were analyzed using a LRFD design with the following loads in mind. Vertical Loads included dead, live, snow, and wind. Horizontal Loads included wind and soil. Omitted calculations included seismic, lood, tornado, and tsunami loads. These calculations were omitted due to the project site being in a location of minimal lood, seismic, tornado, and tsunami hazards.

The following LRFD Load combinations (1-6) were used to determine structural reliability.

- Headers, girders, joists, interior load bearing walls and columns, footings (gravity loads)
  - $1.2D + 1.6L + 0.5(L_r \text{ or } S)$ (1)
  - $1.2D + 1.6(L_r \text{ or } S) + L$ (2)
- Exterior load-bearing walls and columns (gravity and transverse lateral load)
  - Same as immediately above, plus
  - $1.2D + 1.0W$ (3)
  - $1.2D + 1.0E + L + 0.2S$ (4)
- Roof rafters, trusses, and beams; roof and wall sheathing (gravity and wind loads)
  - $1.2D + 1.6(L_r \text{ or } S)$ (5)
  - $0.9D + 1.0W_u$ (6)
  - $1.2D + 1.0W$ (3)

Where D = dead weight, E = earthquake load, H = soil lateral pressure, L = loor live load, L_r = maximum roof live load from construction, maintenance, S = design roof snow load, W = design wind load, W_u = wind uplift load on roof

The following loads were used in these calculations as listed in the Residential Structural Design Guide.

- Dead Loads
  - Roof construction: 15psf
  - Floor construction: 10psf w/ carpet
  - Wall construction:
    - Exterior walls: 8psf for vinyl siding w/ 2x6 walls
    - Interior walls: 6psf
  - Foundation construction: 100psf for concrete walls
- Live loads
  - Roof: 15psf uniform load
  - Attic: 10psf uniform

- Floors
    - Bedroom areas: 30psf uniform
    - Other areas: 40psf uniform
- Wind loads
  - Design wind speed of 115mph, velocity pressure of 16psf (with a K_z of .57)
  - Lateral wind pressure coef icients
    - Roof (projected) = .85 for a 9:12 slope
    - Wall (projected) = 1.1
- Snow loads
  - 50 psf

After calculating worst case loads for the superstructure, materials were evaluated for suf iciency and applicable loads were compared to those used in foundation recommendations from the geotechnical report. In each case the geotechnical recommendation had marginally overestimated structural loads, which established the suf iciency of foundations in supporting the structure. Calculations for each alternative are listed in **Appendix C** with the results of the analysis listed in the description of each alternative.

13.2 Geotechnical Analysis

Decision Matrix Weight

The geotechnical conditions at the proposed site are of extreme pertinence to the design and feasibility of construction. The soil quality, soil properties, depth to bedrock, and water table can have monumental impacts on the cost of the project if ill is needed, or blasting is involved. Stormwater mitigation methods are also dependent on the properties of the surrounding soils. Because of the presence of the very shallow bedrock, the hydraulic conductivity of the surrounding soils, there is to be little geotechnical limitations beyond the cost of the rock blasting. Geotechnical limitations were thus given a weight of 0.025, to represent the relative lack of limitations found onsite.

Subsurface Conditions

Based on the geotechnical exploration and analysis performed by Ex Nihilo Consulting Engineers, the proposed site of the Village of Egg Harbor affordable housing project is geotechnically adequate for construction. The Namur Loam (NoB) that makes up the majority of the topsoil at the project site is classi ied as an excessively drained soil, consistent with it's very shallow nature. Longrie Loam (LoB), making up the lesser portion of the project site, is similarly hydraulically conductive and well drained. Due to the potential for organic material to be found present in the loams, removal is necessary in areas where construction is occurring. Soils encountered between the loam topsoil and the dolomite bedrock are generally a ine sand with gravel (SW), and are considered to have very high stability as well as a potential for high load bearing capacity. This soil has very high compaction and drainage characteristics, making it acceptable for use as either a bearing material or engineered back ill. This sand was the weakest bearing material found onsite, and therefore the analysis was conducted for a 5' sand pocket, representing the worst case bearing material scenario. It was found that even in this worst case scenario, the lateral earth pressures, bearing capacity, and settlement were acceptable to support each design alternative. Overall, the bearing material is expected to be bedrock, and therefore the conservative analysis of the sand allows for a con ident design even with unknown variations in the subsurface conditions. Lateral earth pressures remain the same between the designs, so these calculations were omitted from this Preliminary Design Report as it has no bearing on the decision making process between alternatives. The lateral earth pressure of the three designs was found to be, at maximum, 244.02 lbs/ft. Additionally, settlement is calculated on a square foot basis, so settlement between each alternative was found to be the same at 0.184 in. Detailed calculations and further geotechnical analysis can be found in the **Geotechnical Report** submitted by Ex Nihilo Engineering Consultants previously.

It is the opinion of Ex Nihilo that due to the shallow bedrock present at the site, the substructure is adequate and capable of holding the weight of each of the proposed structures. The only geotechnical problem found during the geotechnical investigation was the possibility of increased costs due to the necessity of rock blasting to accomodate a foundation design. Although the bedrock provides an extreme amount of support on the site, and is one of the key bene icial features in the area, it is expensive to construct in the subsurface. Because of this high cost of removal and construction, both the dorm style and the apartment style buildings received the highest scores of 5 due to the lower number of overall buildings proposed, and therefore requiring less bedrock removal.

Groundwater Conditions

No groundwater was encountered in the subsurface exploration. The dolomite bedrock serves as the primary aquifer in the area, though the lack of groundwater encountered by the soil borings indicates that the bedrock is continuous, without vertical joints or discontinuities. Because of this, groundwater is not expected to be found throughout the duration of the construction phase, though groundwater levels luctuate seasonally.

Encountering groundwater during the construction phase would create the potential for destabilizing engineered back ill around the foundation. It is necessary to install adequate drainage measures around the base of the foundation to prevent the collection of water against the foundation. In addition to the bedrock serving as an aquifer in the area, it also has a much lower hydraulic conductivity than the surrounding sands, which contains the potential for restricting in iltration from rainfall, allowing for pooling of water around the foundation. Perforated pipe should be installed along the perimeter of the foundation and covered in clear stone or washed gravel, then covered with a geotextile to protect against sand interference with the system.

The proposed site is also located within a half mile to Lake Michigan. Due to the isolated nature of the aquifer, however, it is unlikely that the lake has a signi icant impact on the groundwater. According to the Door County GIS, groundwater is estimated to be approximately 75 to 85 feet below the project site. Groundwater low contours found in the Door County GIS are provided in the **Geotechnical Report**.

13.3 Construction Analysis

Design Matrix Weight

Ex Nihilo determined that the construction cost of the project would have the greatest impact on the decision to move forward with the alternative. With a small budget, Ex Nihilo carried out each design with caution regarding how it would affect the budget. With knowing that each additional item added to the design has a larger impact on the budget, it has been decided that a 0.4 weight on the construction cost would emphasize that the cost is important.

Cost Estimation

Not many projects were let recently in Egg Harbor, so Ex Nihilo found other means of estimate databases to provide cost estimates for items pertaining to this project. RSMeans, previous WisDOT bid history, and national averages were used to carry out the cost estimate process.

Project Payoff

Ex Nihilo performed an analysis to determine if one of these solutions would be viable. Looking at the Life Cycle Costs in **Table 6**, Ex Nihilo compared these to the tentative rates that each design alternative would generate. It was determined that residents in the dorm alternative would have a rent of $400/month, and residents in the apartment or duplex alternative would have a rent of $500/month. Below in **Table 6**, it compares the rent sum to the estimated yearly costs for each of the design alternatives.

Table 6: Compares the monthly Life Cycle Costs to the monthly rent sum

Alternative	**Dorm** $400/room	**Apartment** $500/room	**Duplex** $400/room	**Hybrid** $400-$500/room
Life Cycle Cost	-$73,700	-$105,500	-$90,800	-$81,800
Entire Capacity (year round)	$76,000	$96,000	$96,000	$86,400
Entire Capacity (6 months)	**$38,400**	**$48,000**	**$48,000**	**$43,200**
Half Capacity (year round)	$38,400	$48,000	$48,000	$43,200
Half Capacity (6 months)	$19,200	$24,000	$24,000	$21,600

As seen above, for all but the apartment, if the building is full to capacity year round, the project will be pro itable. However, due to the seasonality of the economy in Egg Harbor and to be conservative in the estimate, entire capacity for six months of the year was chosen as the likely scenario. This scenario was used to calculate the present value of the project in Table 5. In addition, Ex Nihilo believes that this project would be eligible for some grants or subsidies. If able to receive these, these solutions would become more viable.

13.4 Hydrological Analysis

Weight on Decision Matrix

As the site hydrology is consistent on site and does not change between the four alternatives, the stormwater management system designed is the same for each design alternative. The costs, environmental considerations, design, and construction associated with the stormwater management system is consistent throughout each design; therefore, the stormwater management system does not have a large weighting on the decision matrix.

Initial Hydrology Screening

According to the United States Department of Agriculture, USDA, the main soil type found on the 1.4 acre plot of land is Longrie Loam (LoB) and Namur Loam (NaB) respectively. Properties and qualities of the LoB soil type is that the drainage class is "well drained" and the runoff class is "medium". One restrictive feature of this site is the shallow lithic bedrock.

As for the NaB, the drainage class is also well drained. However, the lithic bedrock may reduce drainage capacities in some areas. The area's ability to transmit water ranges from very low to very high with a transmission rate ranging from 0 in/hr to 1.98 in/hr.

The hydraulic soil group listed for NaB is soil group D and the hydraulic soil group listed for LoB is soil group C.

The site is currently an empty, exposed ield, but is to be converted to residential space upon construction.

There are no known endangered species nor historical sites that are expected to be disturbed within the construction area. Documentation of this is provided by the Village of Egg Harbor and can be found in **Appendix D**.

Site Erosion Mitigation

In order to manage the and mitigate the risks associated with soil erosion during the construction phase of the project, a silt fence is to be constructed on the West and South limits of the site. This is to constitute approximately 375 linear feet of silt fence. Additionally, one of the irst construction phases is to be reducing the site grade's 10% incline to an incline of 4%. In order to do this, the site is to be cut and illed such that minimal outside material needs to be supplied. Additionally, the site is to be rough graded such that the runoff low paths lead to the constructed retention pond. Inlet protection is to be applied as required on the site. Please reference **Appendix B** for erosion mitigation cut sheets.

Discharge Locations

According to Door County's stormwater policy, a 24-hour 2-year, 10-year, and 100-year storm event produces precipitation of 2.4 inches, 3.6 inches, and 4.9 inches, respectively. This precipitation data was entered into the Hydra low Hydrographs extension in Civil 3D to calculate the peak runoff rates for the existing, undisturbed site and for each alternative proposed site. Unit Hydrographs for each design alternative and 2-yr, 10-yr, and 100-yr storm recurrence interval can be found in **Appendix B** which are an intermediate step to providing the inal Hydra low Hydrograph retention pond sizing. Provided in **Table x** below is a summary of the peak runoff lows for each design alternative and the undisturbed site for each recurrence interval. More detailed Hydra low tables can be found in **Appendix C.**

Table 7: Summary of the peak runoff lows for each design alternative and the undisturbed site for each recurrence interval

	Peak Runoff Flow [cfs] (2-Year)	Peak Runoff Flow [cfs] (10-Year)	Peak Runoff Flow [cfs] (100-Year)
Existing Site	1.975	4.290	7.029
Apartment Site	2.682	5.194	8.085
Dormitory Site	2.534	5.012	7.877
Duplex Site	2.534	5.012	7.877
Hybrid Site	2.534	5.012	7.877

As seen in **Table 7** above, each proposed design alternative site produces a peak runoff low higher than the undisturbed site conditions. This is due to impermeable areas such as walkways, patios, parking lots, and the building footprints. It is desired that the peak runoff rate is similar to that of the existing site conditions; therefore, a stormwater retention pond was sized in Hydra low to reduce the runoff from the proposed sites to a value less than or insigni icantly larger than the peak runoff low calculated for the undisturbed site. **Table 8** below shows the peak runoff values for each site and storm event after the installation of a 40' diameter lined retention pond. Design standards for this retention pond are discussed in further detail in the section following **Table 8**.

Table 8: Peak runoff values for each site and storm event after the installation of a 40' diameter lined retention pond.

	Peak Runoff Flow [cfs] (2-Year)	Peak Runoff Flow [cfs] (10-Year)	Peak Runoff Flow [cfs] (100-Year)
Apartment Site	2.104	3.507	5.989
Dormitory Site	2.004	3.432	5.585
Duplex Site	2.004	3.432	5.585
Hybrid Site	2.004	3.432	5.585

Site is to be graded to establish water runoff lows towards the water retention ponds at the southwest corner of the site. This retention pond is to be circular and has a footprint of

1256.64 square feet. The depth of the retention pond is to be four feet to match the industry average.

Per Door County's stormwater management ordinance, 80% of total suspended solids must be removed from the stormwater lowing into the retention pond. A bioretention device is to be placed at the northwest portion of the retention pond at the pond's highest elevation so stormwater can be iltered through engineered soil. Further detail regarding the bioretention device is discussed in the **Design Standards** section below.

Design Standards

In order to maintain the aesthetics and geotechnical integrity of the site, stormwater runoff is to be managed away from the site and into a stormwater retention pond.

When building an in iltration retention pond in which stormwater can low and be iltered and then in iltrated into the soil, there must be at least six feet of soil below the bottom liner of the retention pond. Because the construction site sits on shallow bedrock between two and four feet below grade, a typical retention pond could not be considered for use and management of stormwater runoff due to the lack of soil and inability for in iltration to occur.

As an alternative, a lined retention pond with a mechanical release valve for large storm events is to be installed at the southeast corner of the site in which the soil borings show a bedrock depth of four feet. As Egg Harbor is exempt from Wisconsin's NR216 stormwater ordinance in terms of in iltration, this lined option is viable. The lined retention pond retains water after storm events and slows the water release. The pond is to be lined with a PVC liner in order to reduce transportation costs of clay. A 10-inch pipe is to be included to allow water to be released to a drainage ditch along Harbor School Road in the event of an extreme precipitation event so that the pond does not over low onto the site.

After site grading, the pond begins at an elevation of 675 feet and is to be excavated four feet for a bottom elevation of 671 feet. A broad crested weir is to be built around the southwest portion of the lined retention pond to direct water over low to the southwest most corner of the pond to avoid site erosion around the retention pond.

Design standards allow an unmowed 2.5:1 slope at the pond edges for safety purposes; therefore, the bottom of the pond has a 20 foot diameter for a bottom area of 314 sf, creating a conical shaped pond. Native vegetation such as Bottlebrush Sedge, June Grass, and Canada Wild Rye is to be planted along the banks of the pond and on the unmowed side slopes to promote the aesthetic appeal of the pond and act as a ilter for the stormwater runoff in the case that it is released to Harbor School Road and in iltrated off site to avoid ground pollution nearby the site. The vegetation also acts as a barrier to unwanted fauna in the pond and helps maintain the integrity of the soil around the retention pond.

After performing the hydrologic analysis of a 24-hour 2-year, 10-year, and 100-year rain event in Hydra low in Civil 3D, it was determined that a lined retention pond with a top diameter of forty feet and a depth of four feet with 2.5:1 sloping sides modeled in **Figure 9** below would have the capacity to hold and slow the low of stormwater runoff from the impervious surfaces on site such as the roofs, parking lots, walkways, and patios.

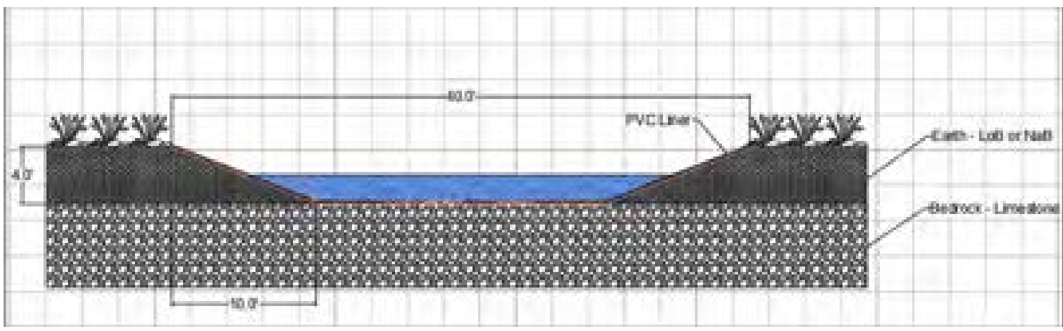

Figure 9: Lined stormwater retention pond

Discussed in the previous section, Door County requires at least 80% total suspended solid (TSS) removal from the stormwater lowing into the retention pond. An annual stay-on value of 17 inches is needed to achieve 80% or higher TSS removal.

Using RECARGA, a bioretention sizing program, site area and soil depth and type values were entered to calculate the necessary sizing for the bioretention device needed on site.

RECARGA calculated that a 1000 sf bioretention device with a 2 feet depth of engineered soil would be adequate in achieving 80% TSS removal. At the bottom of the bioretention device, a 4 inch perforated pipe is to low from the device into the retention pond. Calculations for the bioretention device sizing were done through RECARGA; therefore, a screenshot of the model and selected values can be found in **Appendix C** for further detail**.**

A drawing of the proposed lined stormwater retention pond along with the proposed weir, bioretention device, and discharge pipes can be found in **Appendix B.**

Maintenance

Maintenance of a lined stormwater retention pond must be performed consistently after the completion of construction. In order to reduce the money and time spent repairing a damaged retention pond, the following considerations should be made when maintaining a lined retention pond.

Routine maintenance should be performed once or twice a month depending on the volume of precipitation that occurred within the month. Vegetation management (mowing), debris and litter removal, mechanical component maintenance, and general inspections are to be performed under the routine maintenance requirements. Mowing of vegetation up to 5 feet from the shoreline helps to manage the water that lows into the pond. Leaving 5 feet of shoreline unmowed with vegetation at 24 to 30 inches promotes deeper root growth and soil stability at the pond edge even with a lined retention pond with no in iltration. Additionally, the vegetation ilters runoff from surrounding areas reducing nutrients and other pollutants in the pond in the case that water needs to be released into stormwater gutters rather than evaporating, the water is to not pollute surrounding areas. Vegetation also deters use of the facility by unwanted fauna. When considering debris within the ponds, a retro itted catchment can be built in the retention pond and should be cleaned once a month. General inspections of the mechanical systems within the basin should also be performed monthly or after large storm events to make sure the basin is able to perform under high volumes of water.

Many other inspections and maintenance should be performed at longer intervals. Semi-annual erosion inspections should be performed at the banks of the retention pond. Inspection of the liner should be done to make sure there are no tears and holes so the water is being held in the pond and not in iltrating into the bedrock. Annually, sediment accumulation should be noted and inlet and outlet devices on the pond should be cleared of debris or litter. Seeding and sod around the perimeter of the pond should also be repaired annually. Sediment from the forebay should be removed once each 5 to 7 years. Additionally, stabilization of the site should be performed during the 5 to 7 year maintenance inspection.

Grading Plan

The current site conditions are shown in **Figure 10** found in the **Appendix B**. Ex Nihilo determined that the proposed grade should be 4%. To reduce costs, instead of grading the entire plot of land, Ex Nihilo only plans to grade the southern 245 feet of land where construction is to be performed. **Figure 8** found in **Appendix B** is the intended grading plan.

14.0 Project Sustainability

14.1 Economic Sustainability

Economic sustainability was of foremost priority when selecting a design for the affordable housing units so that design and construction would follow the $1,000,000 budget provided by the Village of Egg Harbor.

Affordable housing requires consideration for economic sustainability in the aspects of design and construction. When selecting the several design alternatives, Ex Nihilo prioritized the reduction of square footage and building permienter to reduce construction costs. In the hybrid design, which includes an eight bedroom dormitory building and a two bedroom duplex unit, the layout of each unit was carefully considered to reduce costs associated with necessary systems. According to the Universal Building Code (UBC) sprinkler systems are required in residential buildings with greater than two units. To bypass this requirement and bring construction costs down, the selection of duplexes with two units and dormitory style housing reduces construction costs greatly.

14.2 Environmental Sustainability

Environmental considerations to reduce negative environmental impacts were made throughout the construction and design process.

Before construction began, a historical and wildlife site analysis was conducted to con irm no endangered species of lora or fauna would be affected by the construction of affordable housing units in egg harbor. This documentation can be found in **Appendix D.**

To promote environmental sustainability during construction, site material is to be recycled. Foundation walls would be constructed to the depth of the berock, or to a minimum depth of four feet. Boring samples indicate that bedrock typically begins around 2 feet below grade. This requires the excavation of sand for the irst two feet below grade. The sand is to be preserved and used for back ill throughout the project to reduce the need to truck in material for back ill.

Environmental sustainability was also considered in the design of the stormwater management system. Since the site sits on shallow bedrock, stormwater from impermeable surfaces is unable to in iltrate through the soil easily, therefore a lined retention pond is to be built to store water until it evaporates. To reduce the amount of pollutants in the water, native plants are to be planted along the perimeter of the retention pond to act as natural iltration for the stormwater runoff. This is important in the case that the water from the pond needs to be released to stormwater ditches off site and is then to be in iltrated into the ground elsewhere,

Ex Nihilo strives to reduce the environmental footprint made during construction of the affordable housing units in Egg Harbor, Wisconsin.

14.3 Social Sustainability

The Village of Egg Harbor is primarily a community of residents above the age of 65. During the summer months, the Village's population increases rapidly due to tourism. Because the Village is located in close proximity to Lake Michigan and is home to many small businesses that provide several seasonal activities, the Village is likely to maintain its tourism industry for years to come. Since the Village's long-term residents are an older, retired population, the current residences available are higher cost to match the economic class of the Village's residents. During the summer months, these residences are used as vacation homes and AirBnBs, so they have many amenities which drives the renting and buying price quite high. Since tourism in Egg Harbor continues to thrive each summer, the need for affordable housing for the short-term seasonal employees is to be a constant need each in lux season.

Egg Harbor has a twenty year comprehensive plan detailing the Village's needs and desires while also discussing how new developments can maintain the quaint essence of the Village. The residents of Egg Harbor pride their Village in quaintness and aesthetic architecture; therefore, when designing the affordable housing units, architectural designs of surrounding dwellings were considered to make sure that the buildings would add to the culture and maintain the timeless design of the Village. Conserving the Village's aesthetic is of utmost importance as to maintain the appeal of the Village to tourists and to residents that provide funding for future projects.

The consideration of necessary amenities and housing styles for seasonal employees was discussed and captured within each design alternative presented within the preliminary design report. Apartment and duplex units allow for more privacy among residents and the dormitory style units provide the cheapest option for the most affordable housing. The hybrid which includes the eight bedroom dormitory and two bedroom duplex design allows for more inclusivity amongst the residents in need of affordable housing as it gives options for more private style housing or shared housing. This is an important consideration especially in the wake of the Covid pandemic. The residents of Egg Harbor, no matter their economic status, should be provided with the option to select their desired level of comfort, safety, and privacy.

Ex Nihilo understands the importance of social sustainability within the design to make sure that the Village of Egg Harbor's affordable housing needs are met and are able to sustain generations of seasonal employees during the tourism season. The design provided is aesthetically and structurally congruent with other residences in the village to make sure little enhancements are required in the future.

15.0 Uncertainties

As the design of affordable housing units in Egg Harbor is in the preliminary design phase, there are several uncertainties associated with the project that must be considered in the current stage. These can be split into two areas, knowledge based and data-based.

15.1 Data Based

After performing a preliminary geotechnical analysis and report of the project site, the soil borings taken show the majority of the below grade surface to be made up of limestone bedrock. Because the soil borings were not taken from the site, but rather on the road near the site, the site conditions are based on assumptions. These assumptions were used when calculating costs for excavations of the foundations. It is currently assumed that the foundations rests upon the shallow bedrock. If the situation occurs in which bedrock is found to be deeper than 4 feet below grade, foundation walls must be constructed to extend below the frost line. This is a data based issue resulting in a lack of valid information.

Another geotechnical and hydrologic uncertainty lies in the location of the water table below grade. The geotechnical analysis found the water table to sit approximately 7.5 feet below grade. If the water table is to luctuate up or down excavation costs for foundations and wells would be affected. If the water table is deeper below grade, the cost of excavation for the wells needed to provide potable water on site would increase greatly. In contrast, with a shallow water table, the cost of excavations for building foundations would increase as the water would need to be drained and managed to maintain the structural integrity of the soil on site. This is a data based issue resulting from a lack of valid information.

Hydrologic uncertainties also arise in stormwater management and runoff. Although the peak runoff rate calculated for this report is based on a 24-hour, 100 year storm event using historical rainfall data, these numbers cannot predict future storms in Egg Harbor. This consideration was accounted for by creating a retention pond with the capacity to store a runoff capacity of 3350.9 cubic feet of water which is, at the least, 1141.97 cubic feet larger than the runoff volume calculated from the four different design alternatives. Additionally, because the retention pond serves to store the water until it evaporates, a release valve is built in the design in the case that the retention pond is in danger of over lowing. This is a data based issue resulting from a lack of weather predictability.

15.2 Knowledge Based

Construction materials and labor availability are also major uncertainties within the affordable housing project. Egg Harbor is a relatively small community with an older, retired population so labor must be found from surrounding communities. The location of available construction laborers signi icantly affects the costs needed to compensate workers for travel and transportation. Construction materials such as lumber and concrete can luctuate signi icantly depending on the time of year and current availability of materials. This is a knowledge based issue resulting from a lack of knowledge of labor and materials in the area.

15.3 Effect on Safety and Performance

Fortunately, the uncertainties on the project are expected to have a minimal effect on safety and performance. The construction and labor uncertainty is only a cost uncertainty and has no effect on safety. For the geotechnical and hydrological uncertainties, the designs were engineered to take these into account. The footings are designed to be below the frost line, and the stormwater retention pond is approximately 50% higher than required based on the maximum runoff calculation.

16.0 Recommendation

Over the course of the past seven weeks, Ex Nihilo Engineering Consultants has dedicated their time to investigating, developing, and analyzing four alternative solutions for affordable housing in the Village of Egg Harbor. The designs developed and discussed in this report included the Two Bedroom duplex Units, the Eight Bedroom Dorm Style Housing, the Apartment Complex, and inally the Hybrid Design. Each of these alternatives were analyzed under the scope of geotechnical analysis, construction management analysis, structural and design analysis, and hydraulic and hydrology analysis. After the completion of these procedures, a decision matrix was constructed featuring a set of three main criteria groups that the alternatives were analyzed against. Subsequently, the results of this decision matrix as well as Ex Nihilo's understanding of client needs, were used to select the recommendation to be proceeded with. It can be seen in the decision matrix that the Eight Bedroom Dorm Style Housing and the Hybrid Design came out with the same scores of 17.4. As these scores were the same, either alternative could reasonably be selected to proceed with. However, when drawing comparisons between these designs and their ability to meet the long term needs of the client, it was found that the Hybrid Design was ideal. Ex Nihilo believes that although the Hybrid Design has a higher capital cost than the Dorm Design, it provides business owners with more options for purchasing and investing in housing for seasonal employees. Based on the need and inancial capabilities of business owners in the village, they are to be able to determine whether they would like to purchase individual bed spaces as is available in the dorm, or if they would prefer to purchase entire units as can be done with the duplex design.

To reiterate, after much analysis and comparison of alternative designs, Ex Nihilo Engineering Consultants would recommend proceeding with the Hybrid Design for the remainder of the project.

Appendix A: Design Drawings

Design drawings for alternatives

1 (3D)

www.autodesk.com/revit

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1415 Engineering Drive
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Design Team:
Molly Nemcek
Calob Limberg
Jasmine Shah
Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of egg Harbor

Affordable Housing

3D View - Duplex

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-100

Scale

3/29/2021 7:02:21 PM

1 South
3/8" = 1'-0"

- Ex Nihilo -
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Dedicated to Building a Better Tomorrow

www.autodesk.com/revit

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(262) 422-5160

Design Team:
Molly Nemcek
Calob Limberg
Jasmine Shah
Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of egg Harbor

Affordable Housing

Elevation View - Duplex

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-101

Scale	3/8" = 1'-0"

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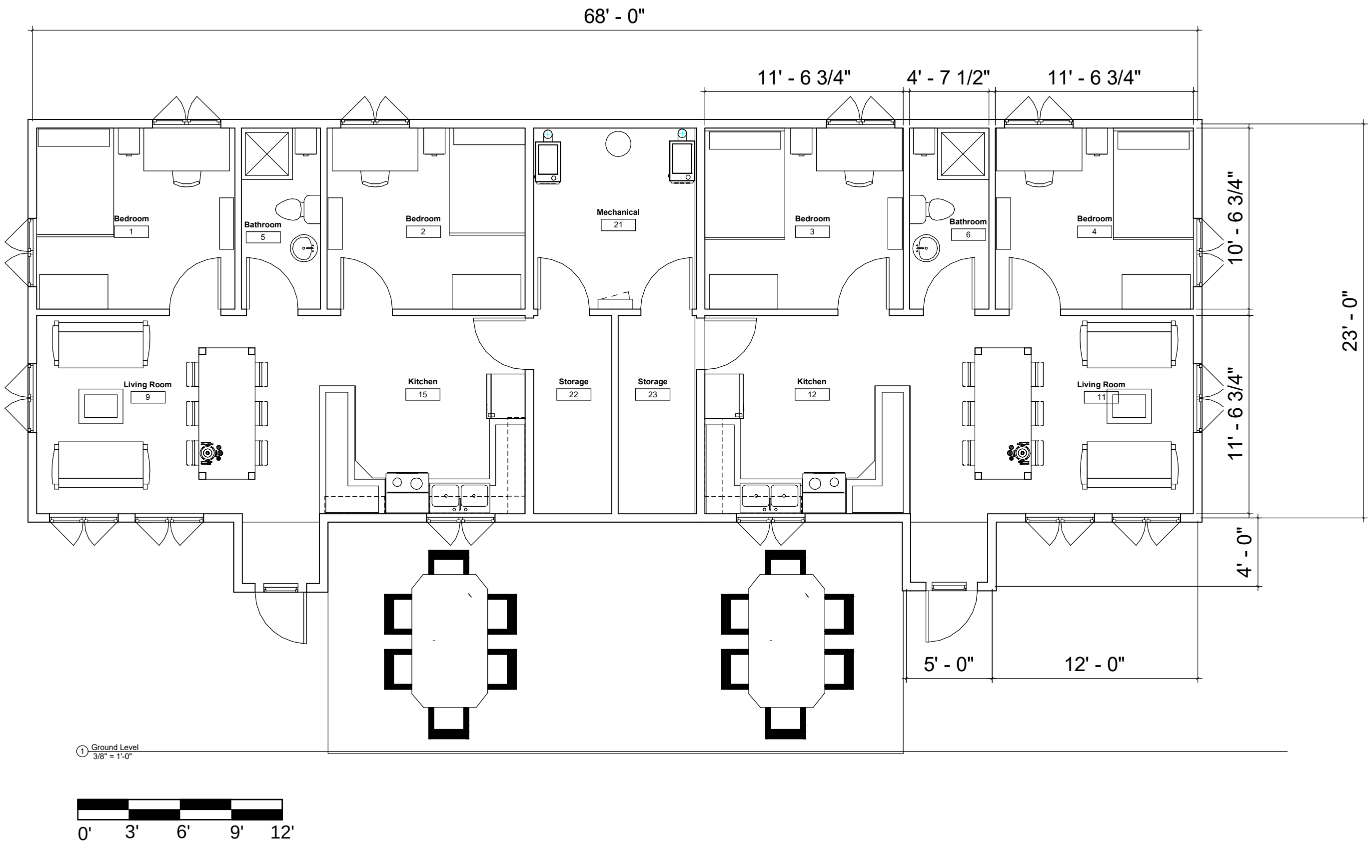

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Design Team:
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Calob Limberg
Jasmine Shah
Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of egg Harbor

Affordable Housing

Ground Level - Duplex

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-102

Scale	3/8" = 1'-0"

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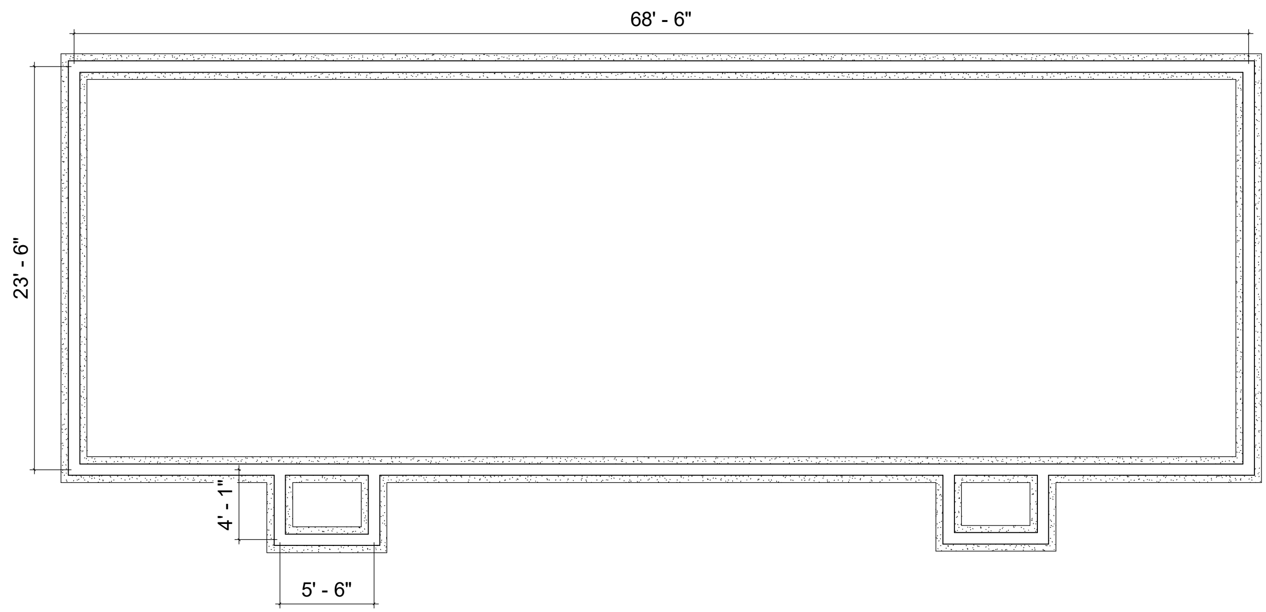

1 Footings
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Brett Hielsberg

No.	Description	Date

Village of egg Harbor

Affordable Housing

Footings - Duplex

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-103

Scale	3/8" = 1'-0"

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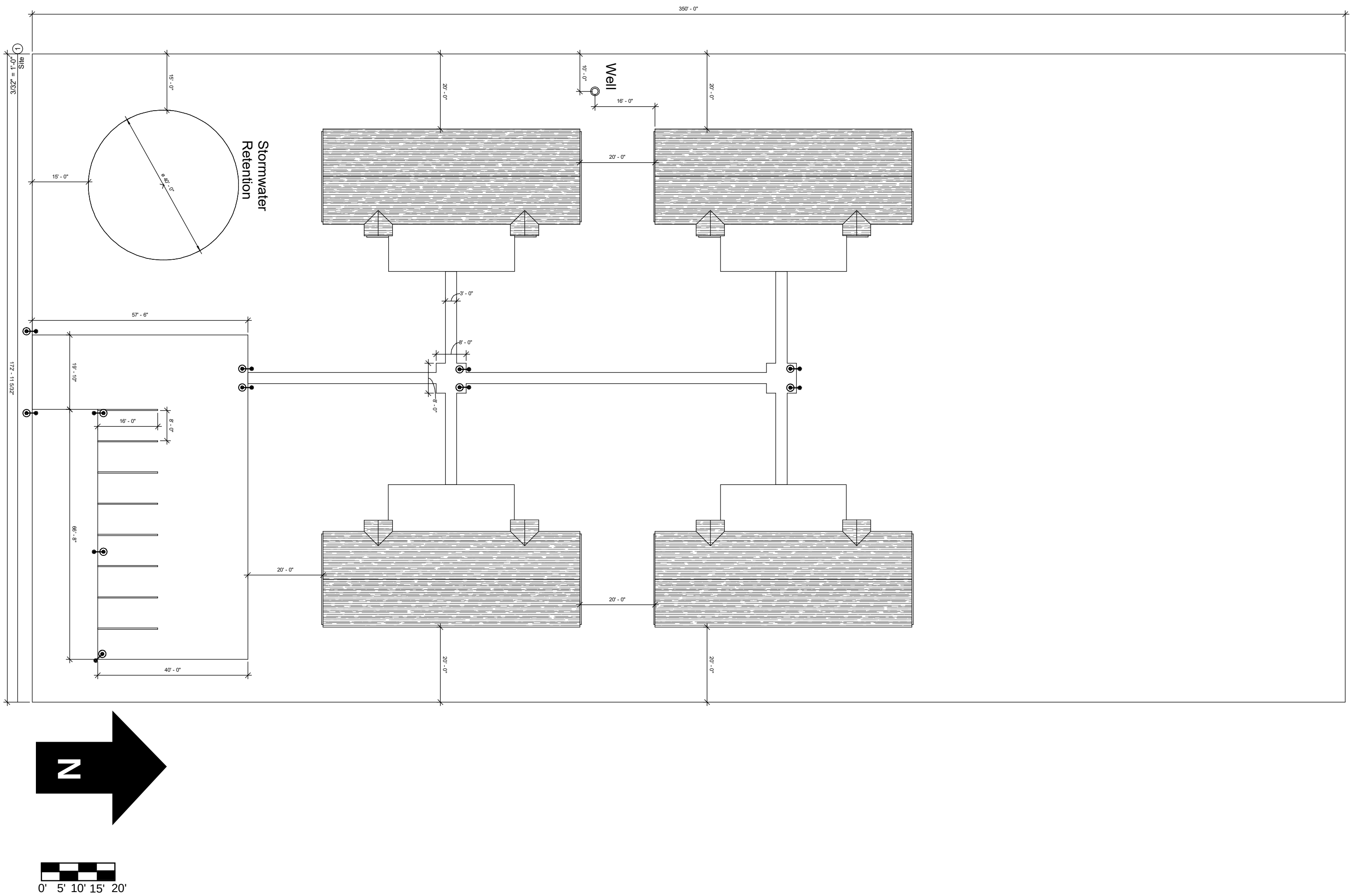

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No.	Description	Date

Village of Egg Harbor

Affordable Housing

Duplex Site Plan

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-104

Scale	3/32" = 1'-0"

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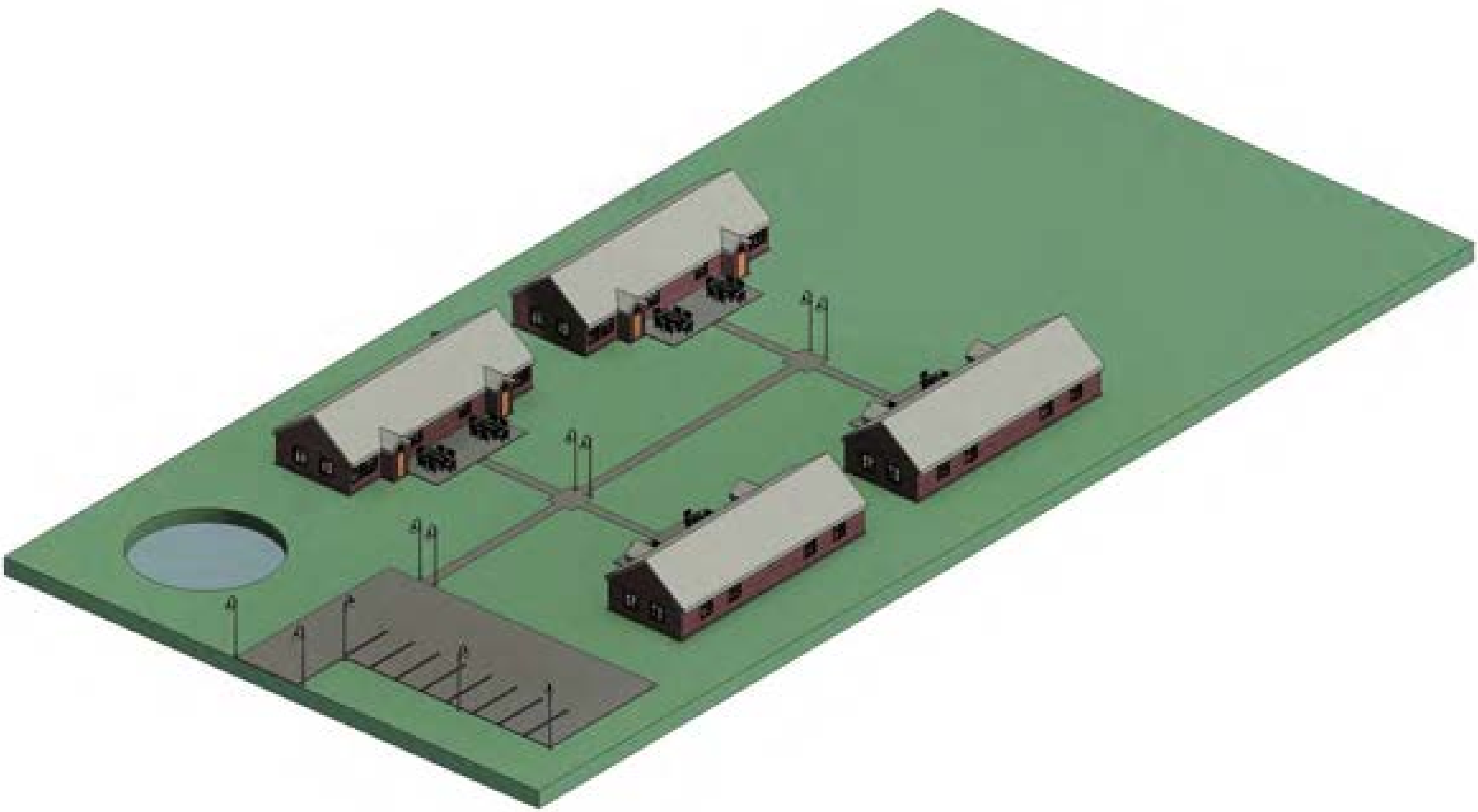

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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Duplex Site 3D View

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-105

Scale

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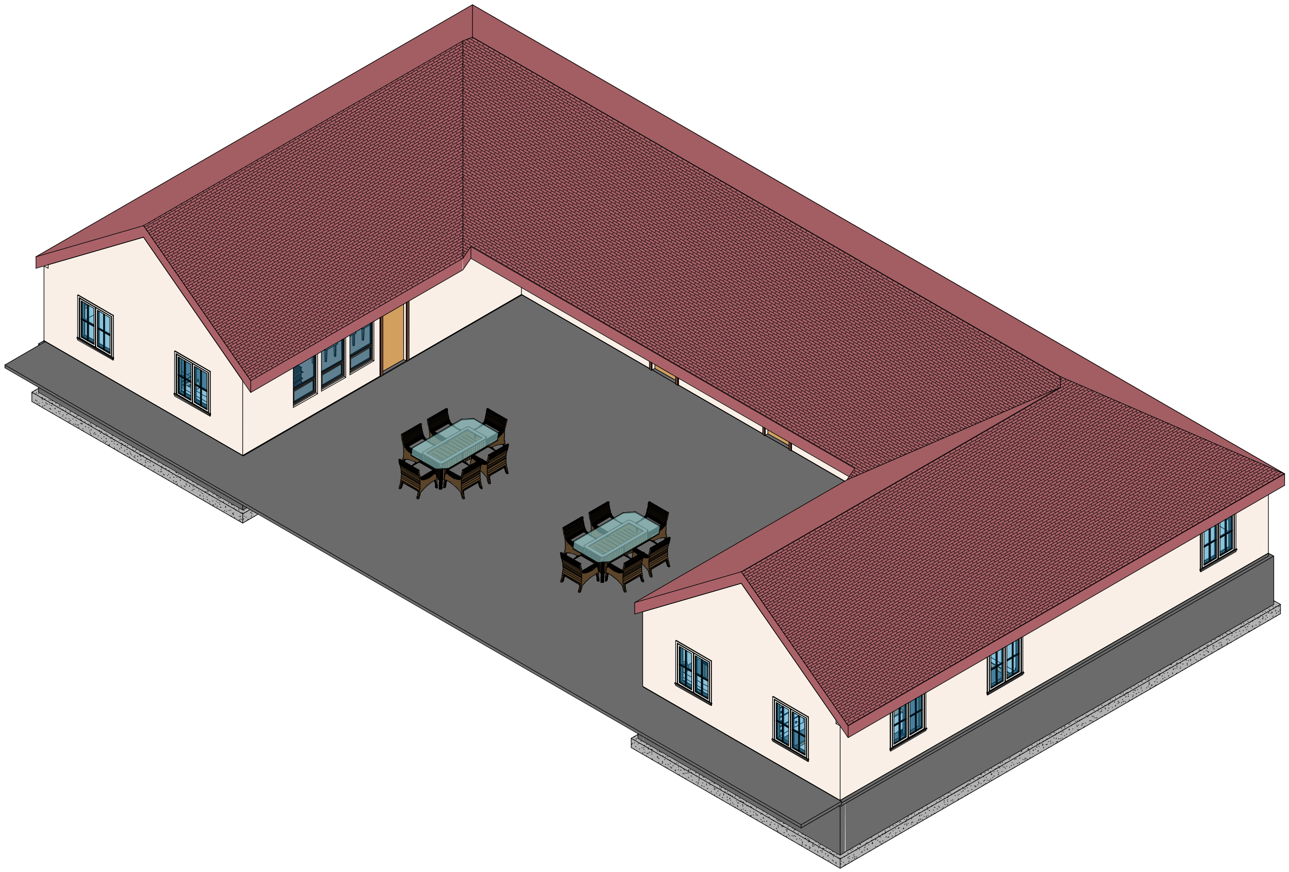

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Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

3D View - Apartment

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-200

Scale

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1 South
1/4" = 1'-0"

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Jasmine Shah
Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Elevation View - Apartment

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-201

Scale	1/4" = 1'-0"

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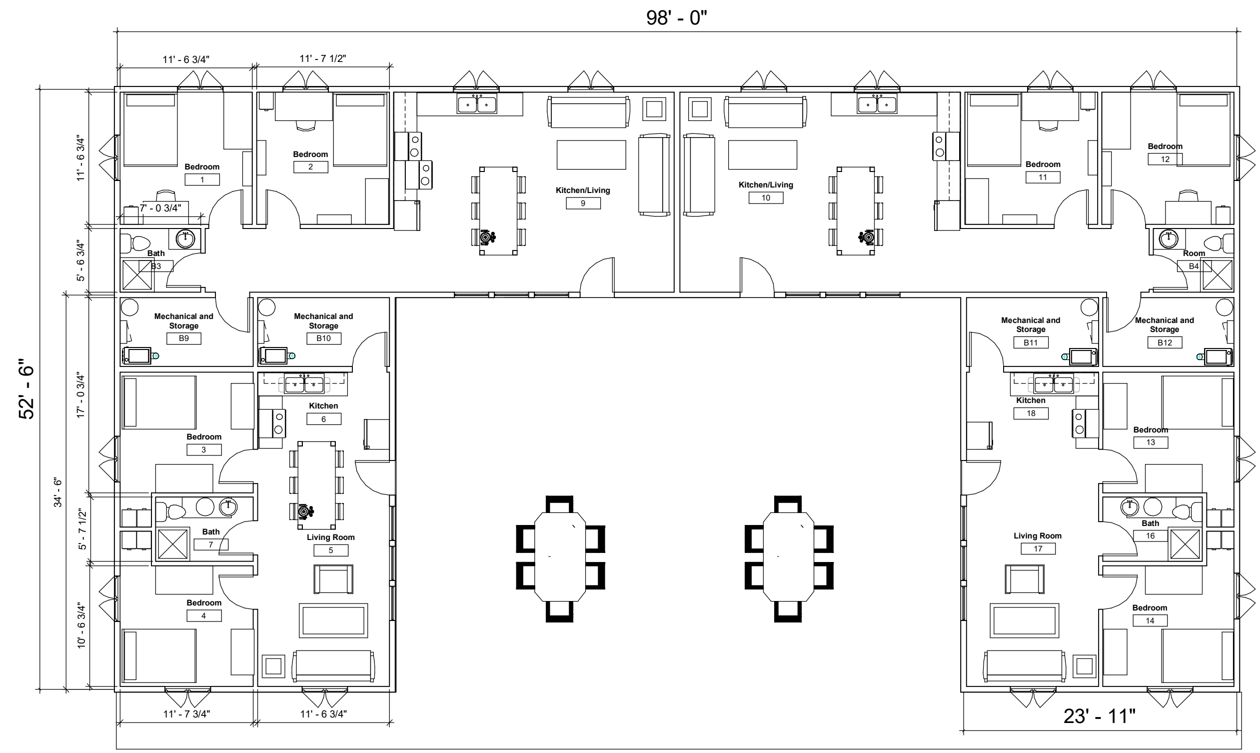

1 Ground Level
1/4" = 1'-0"

0' 3' 6' 9' 12'

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Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Ground Level - Apartment

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-202

Scale	1/4" = 1'-0"

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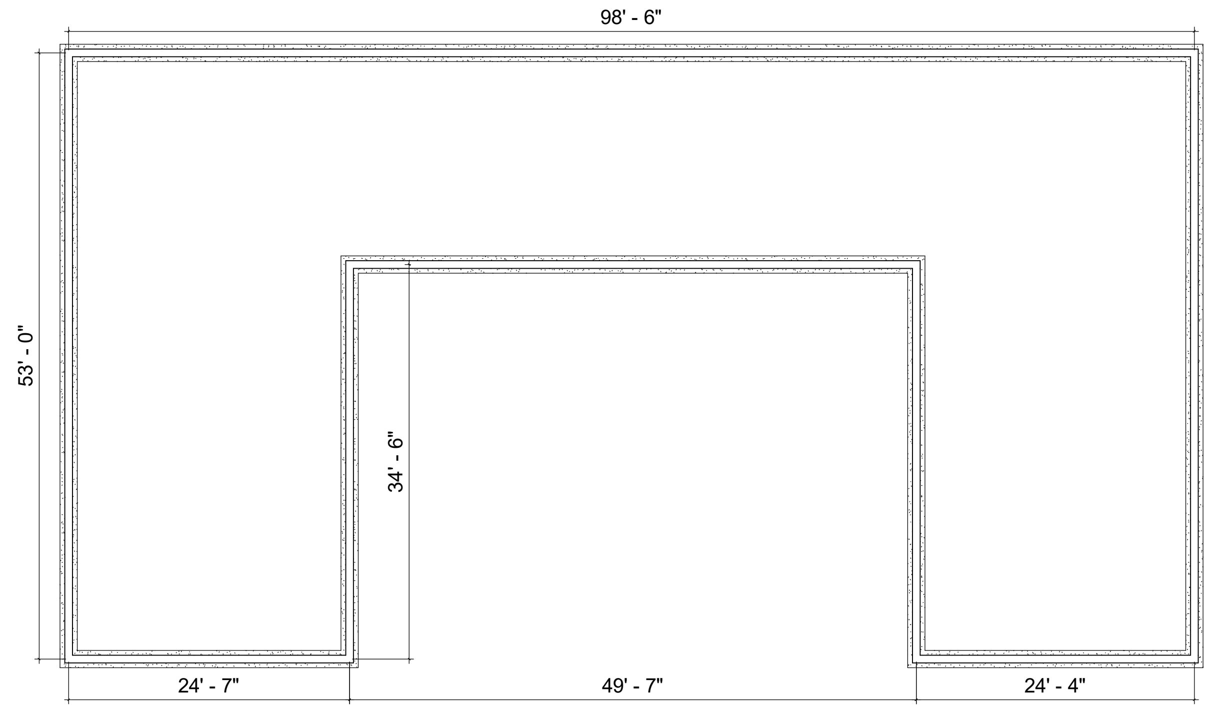

1 Footings
1/4" = 1'-0"

0' 3' 6' 9' 12'

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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Footings - Apartment

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-203

Scale 1/4" = 1'-0"

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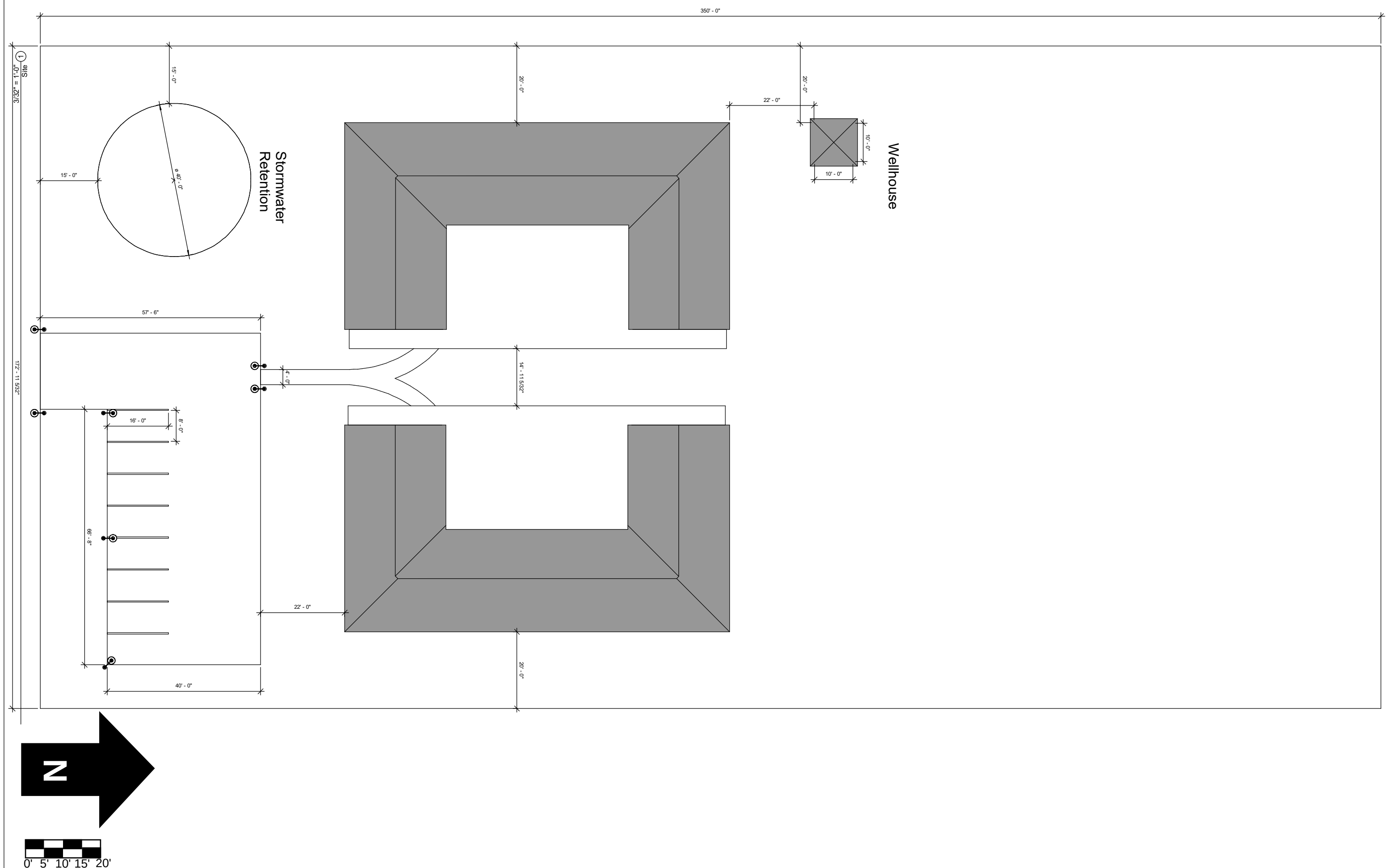

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Jasmine Shah
Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Apartment Site Plan

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-204

Scale 3/32" = 1'-0"

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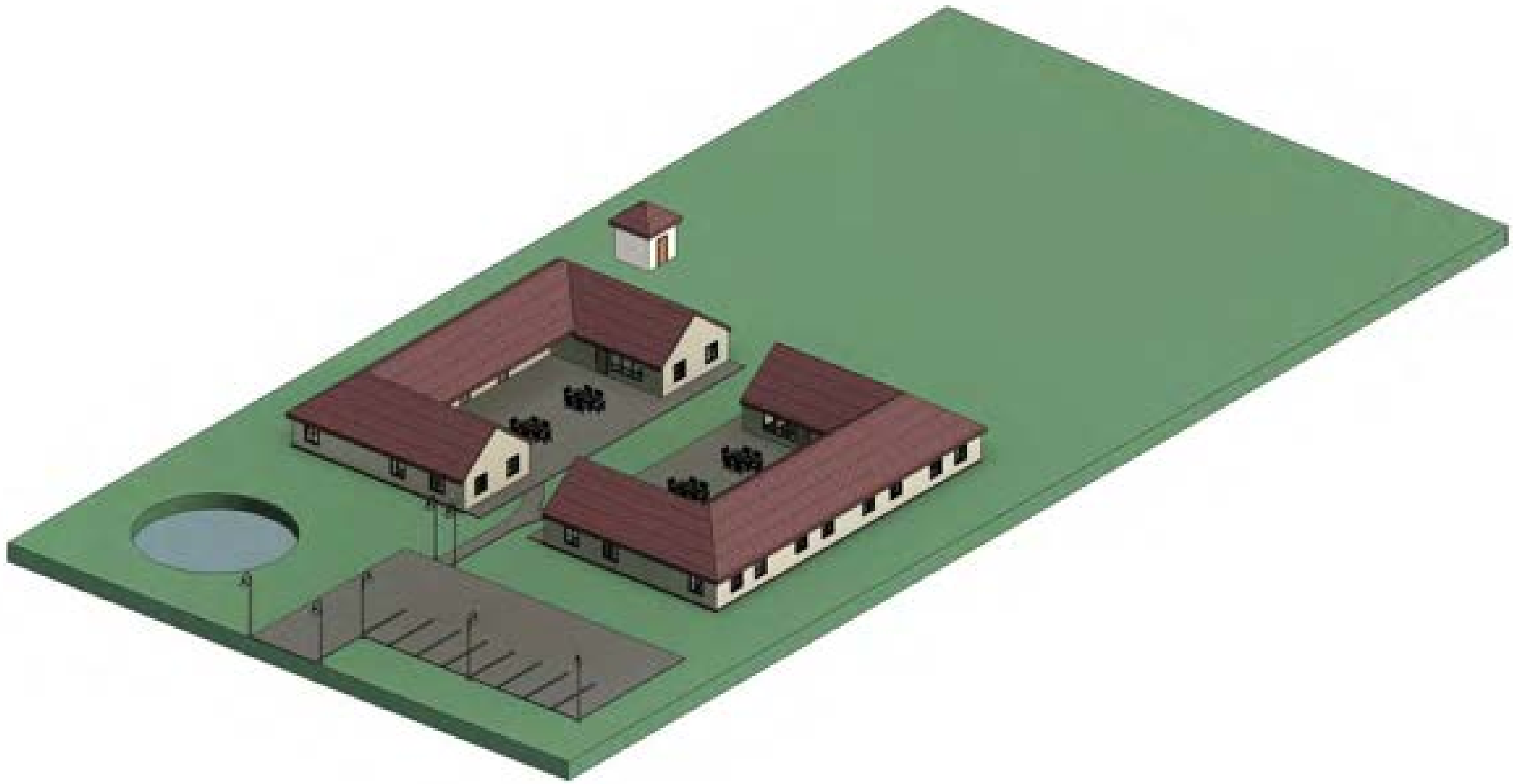

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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Apartment Site 3D View

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-205

Scale

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Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

3D - View Dorm

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-300

Scale

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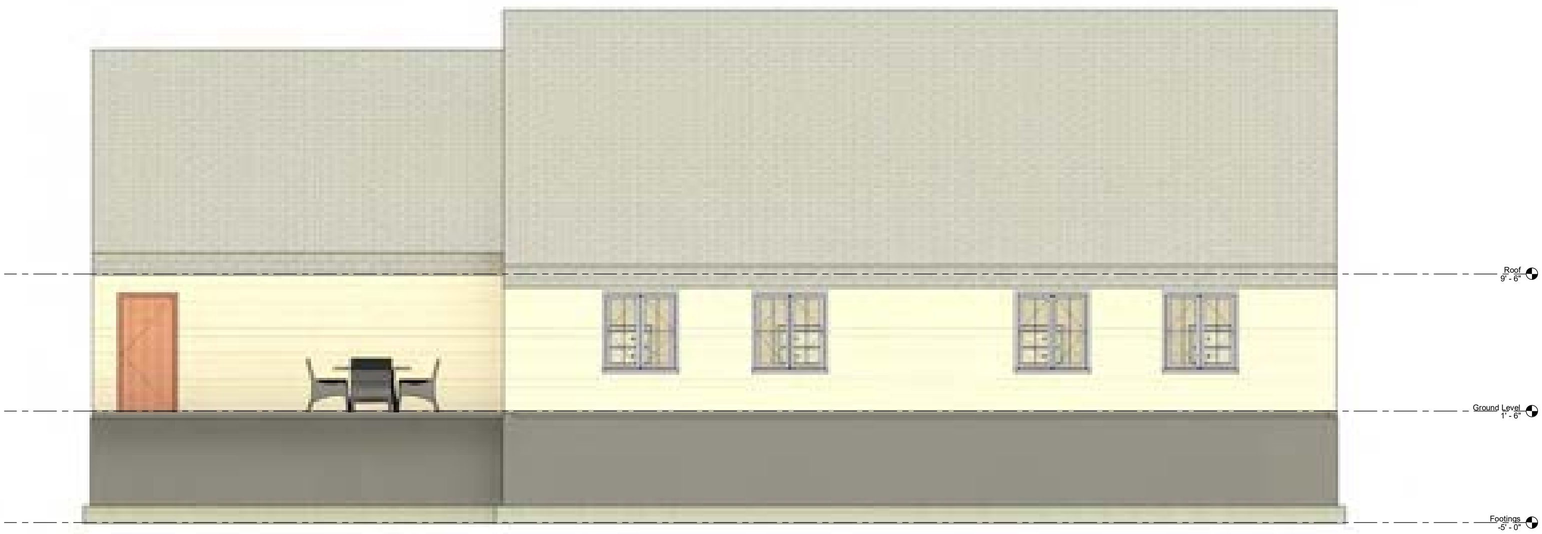

1 South
3/8" = 1'-0"

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Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Elevation View - Dorm

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-301

Scale	3/8" = 1'-0"

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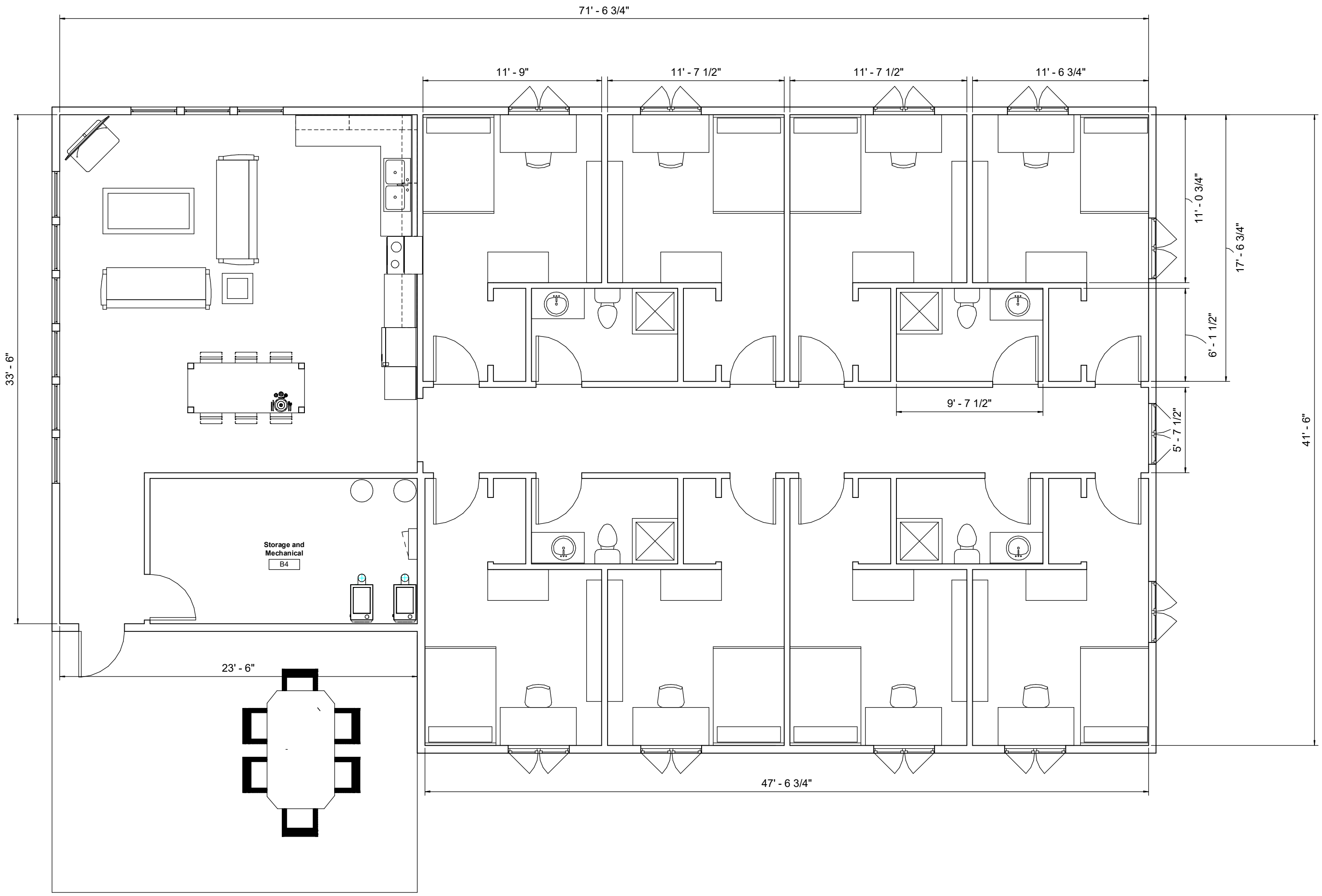

1 Ground Level
3/8" = 1'-0"

0' 3' 6' 9' 12'

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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

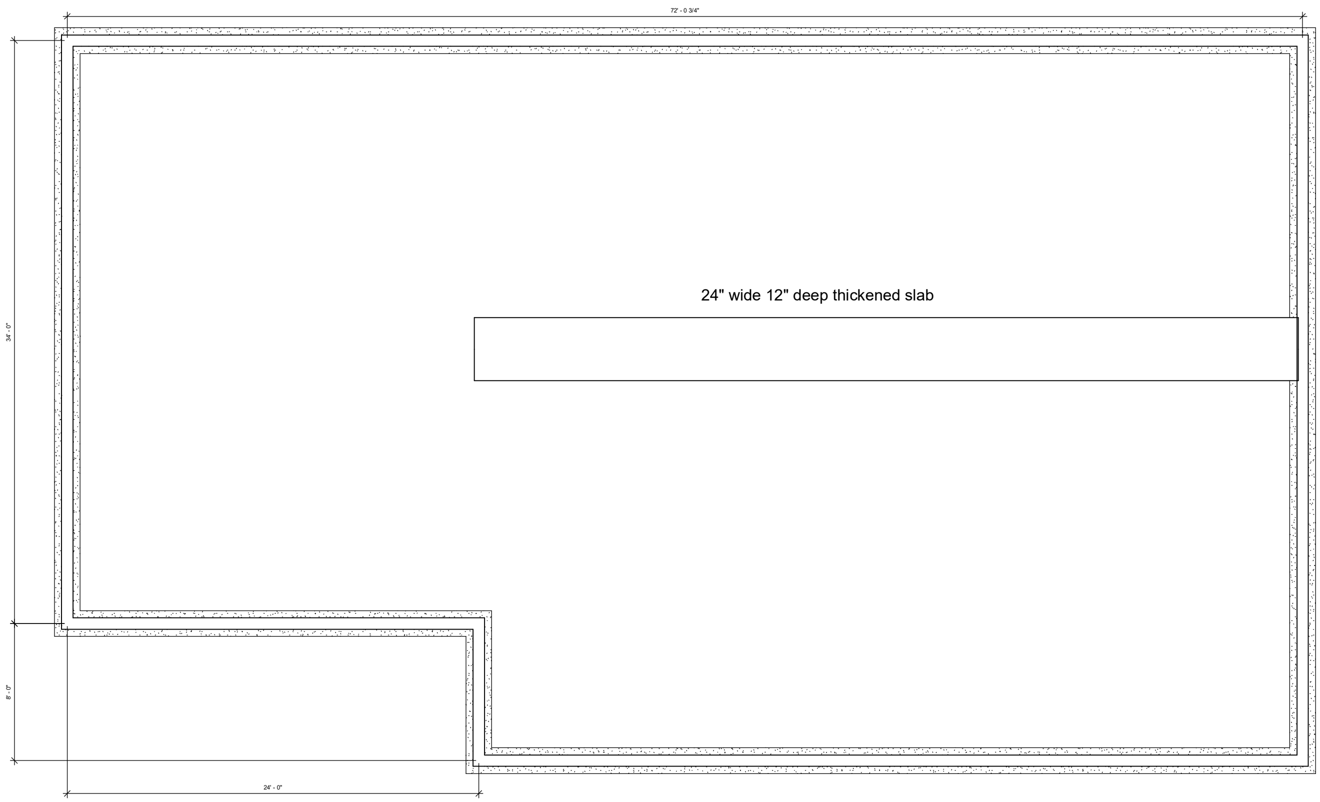
Ground Floor - Dorm

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-302

Scale	3/8" = 1'-0"

3/29/2021 7:15:23 PM



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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Footings - Dorm

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-303

Scale	3/8" = 1'-0"

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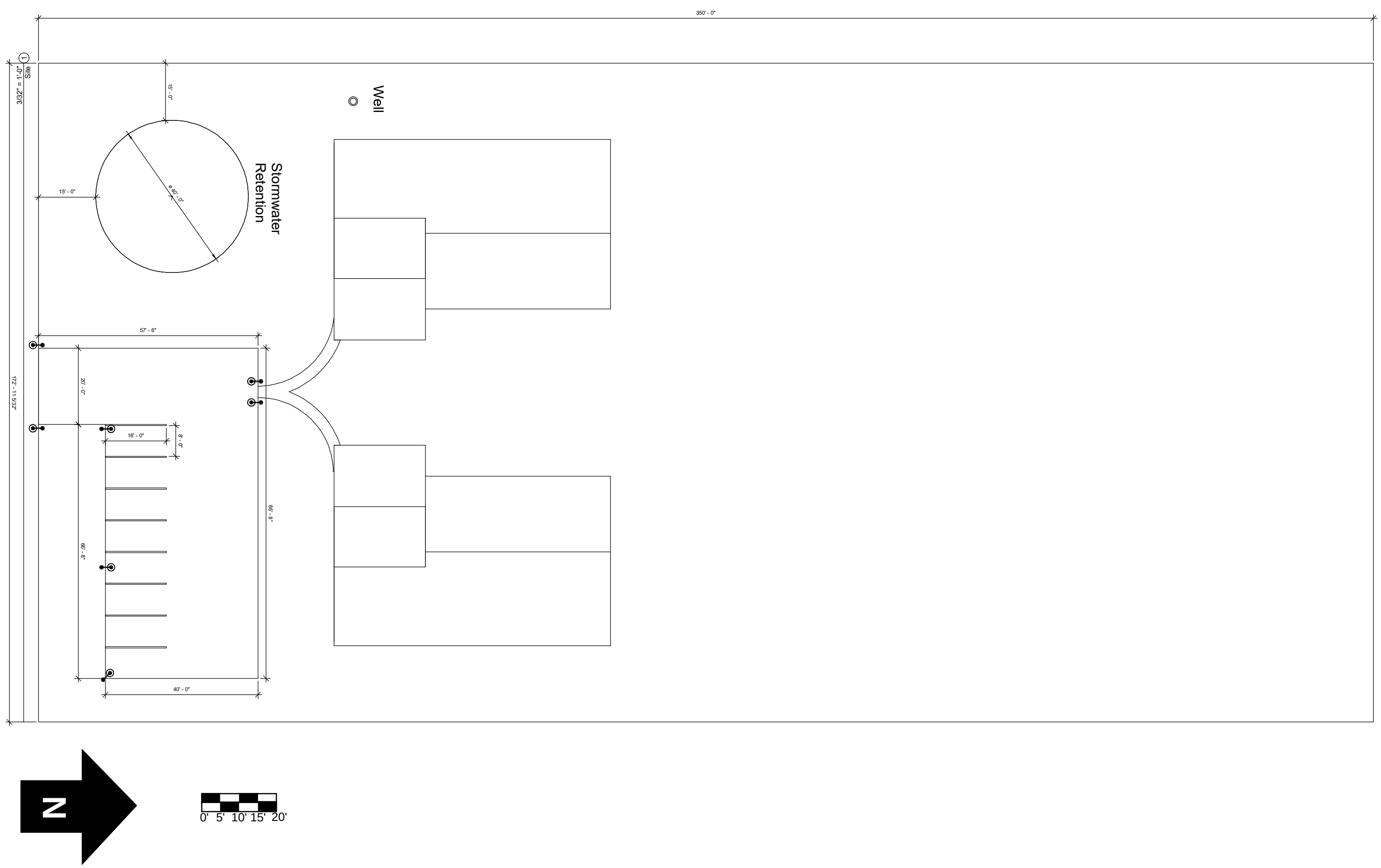

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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Dorm Site Plan

Project Number	191848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-304

Scale 3/32" = 1'-0"

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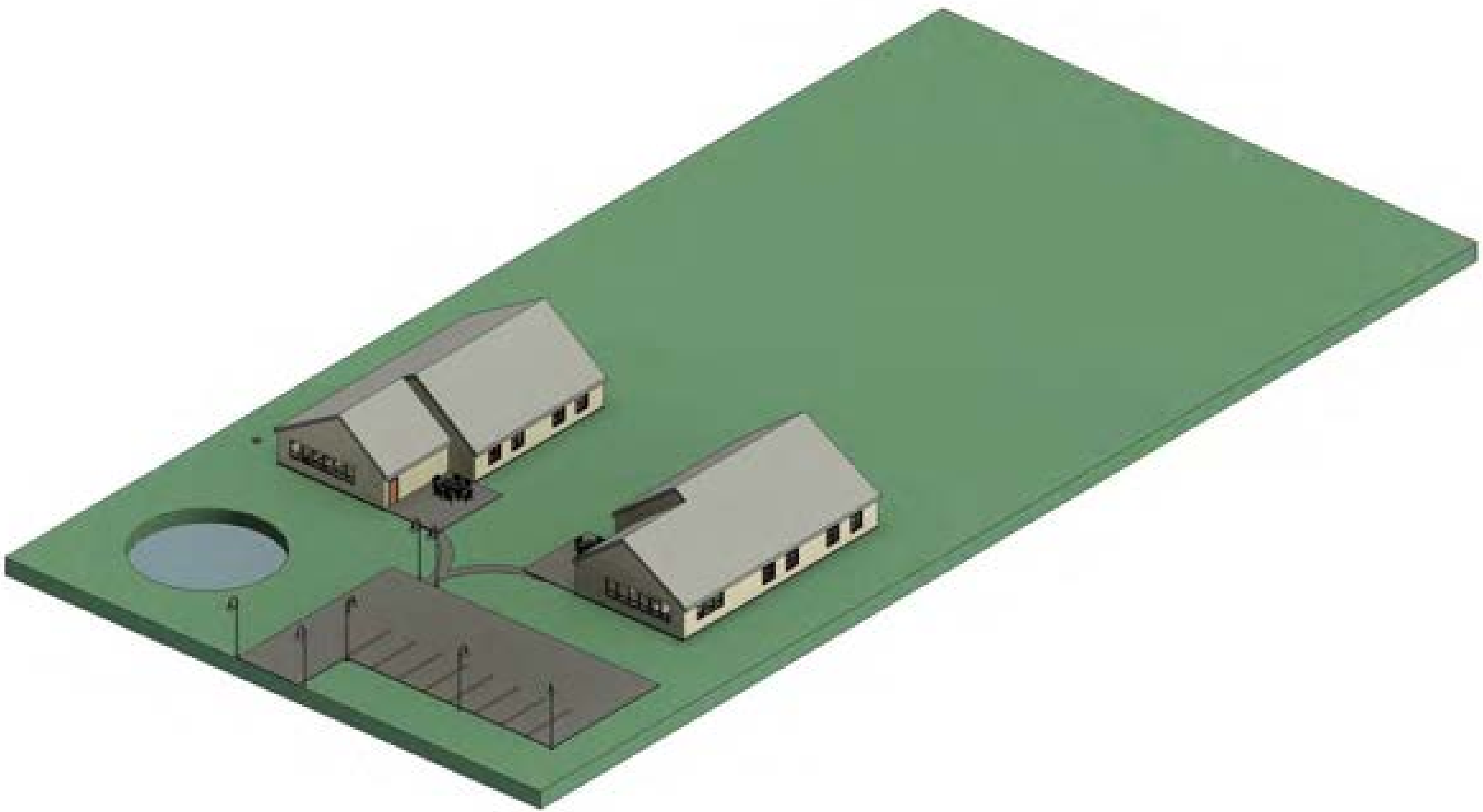

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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Dorm Site 3D View

Project Number	191848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-305

Scale

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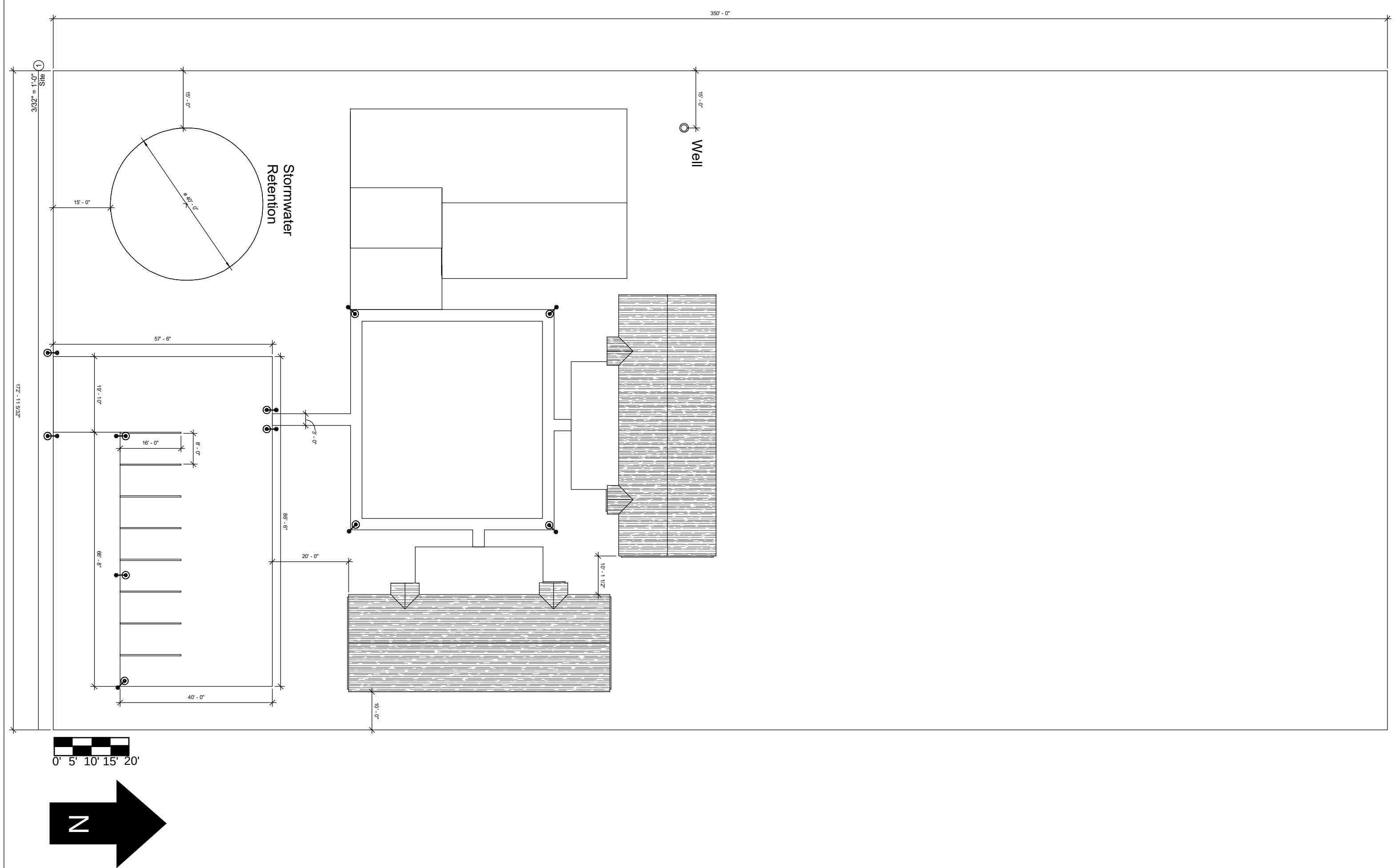

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Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

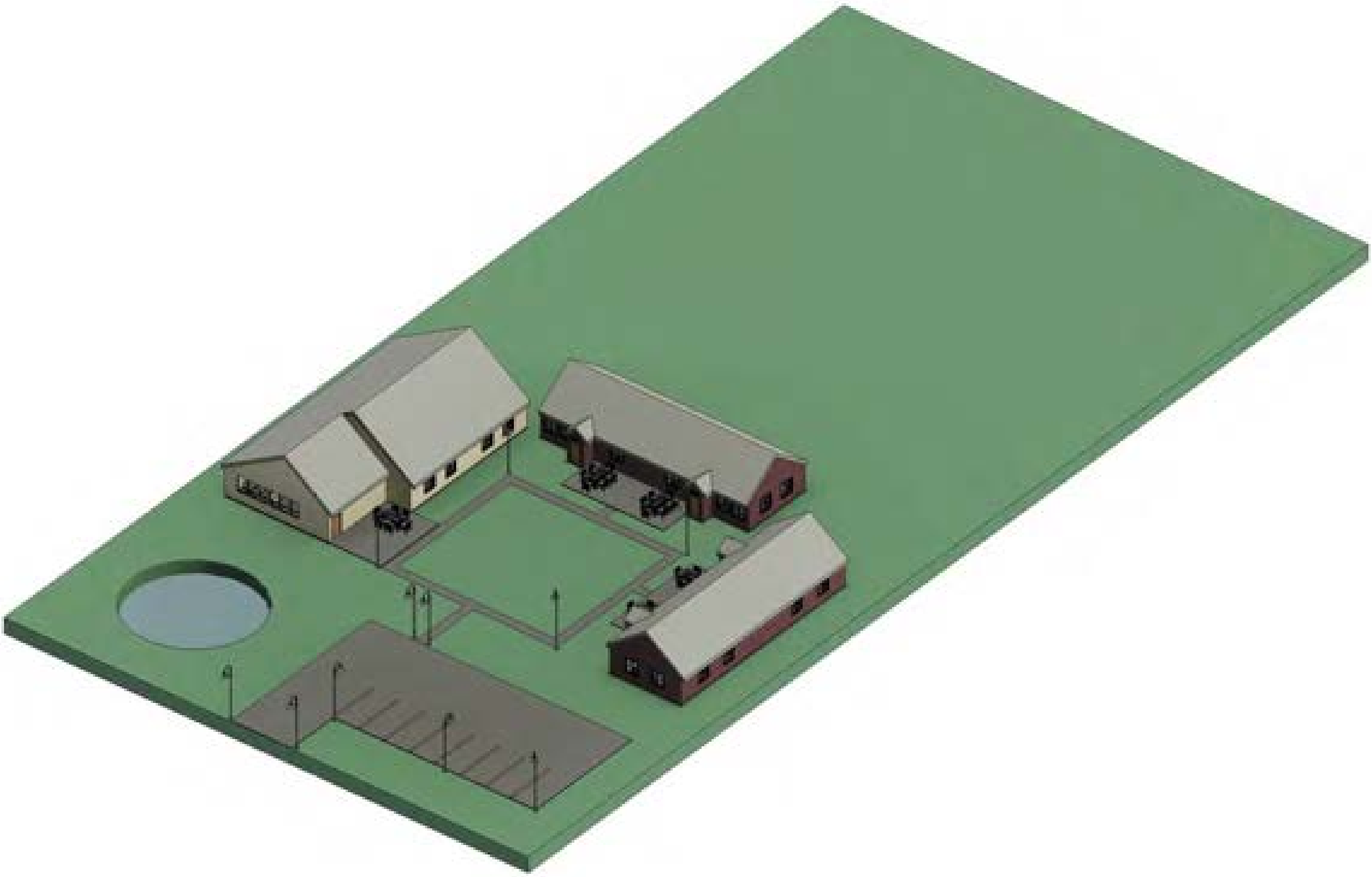
Hybrid Site Plan

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-404

Scale	3/32" = 1'-0"

3/29/2021 7:33:07 PM



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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Hybrid Site 3D View

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-405

Scale

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Appendix B: Site Schematics

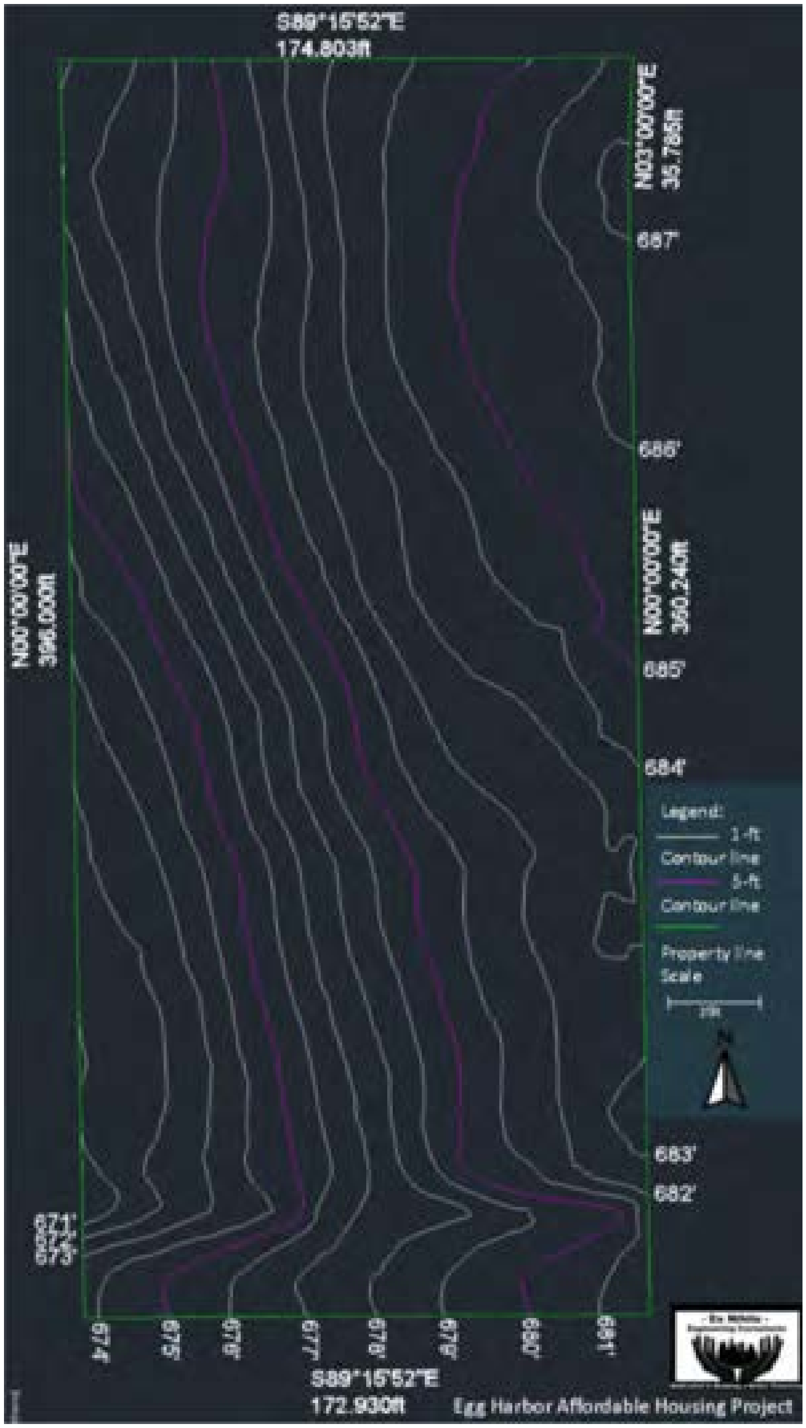


Figure 10: Existing project site grade

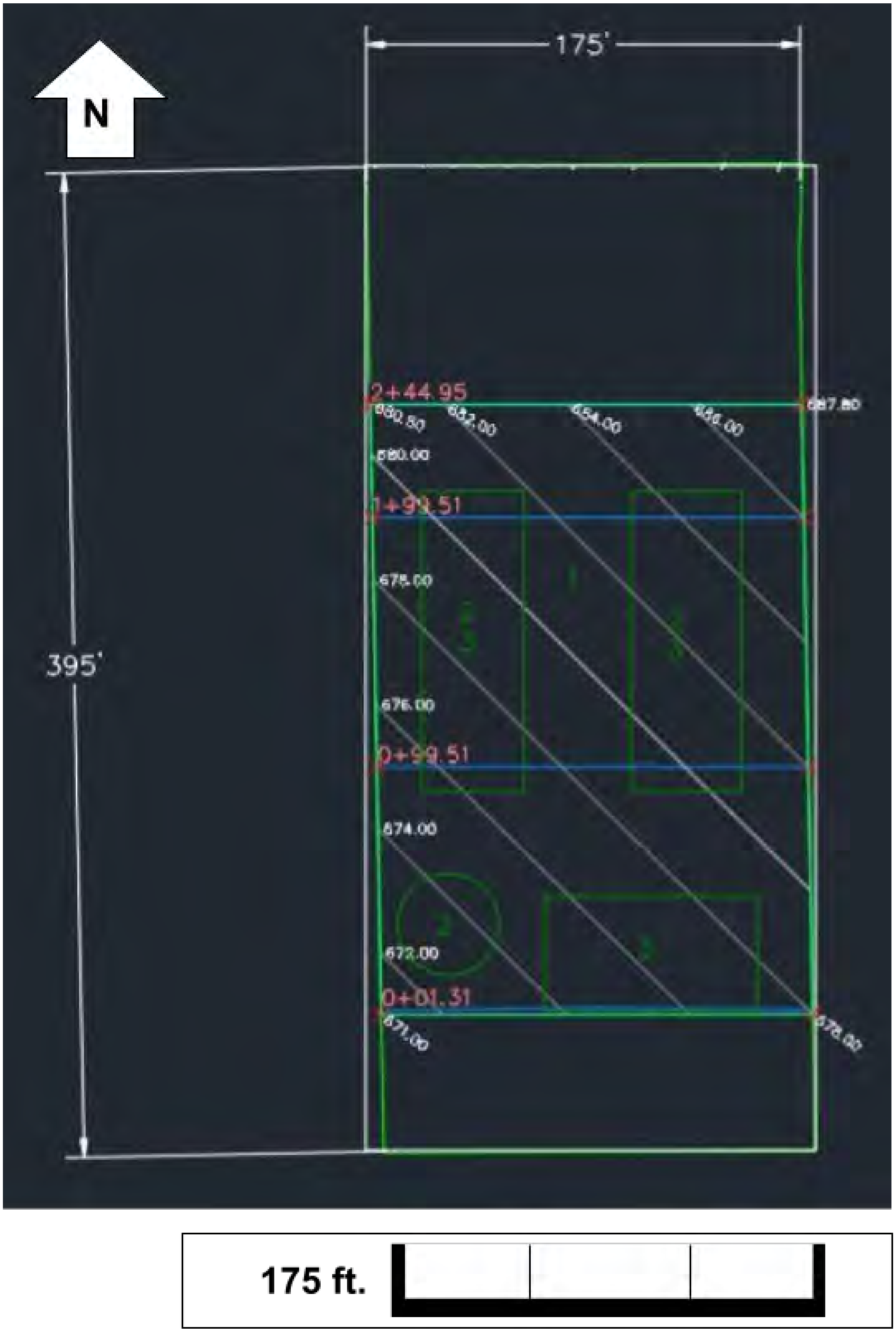


Figure 8: Proposed site grading plan excluding retention pond design

Figure 11 below shows the stormwater retention pond (green concentric circles) at the southwest corner of the lot. A broad crested weir denoted in yellow sits at the southwest portion of the pond. The bioretention device is denoted as the light pink gamma reversed L-shaped area with a dark pink perforated pipe that leads to the retention pond. At the southeast portion of the pond, a 10-inch release valve from the retention pond to Harbor School Road is denoted in purple.

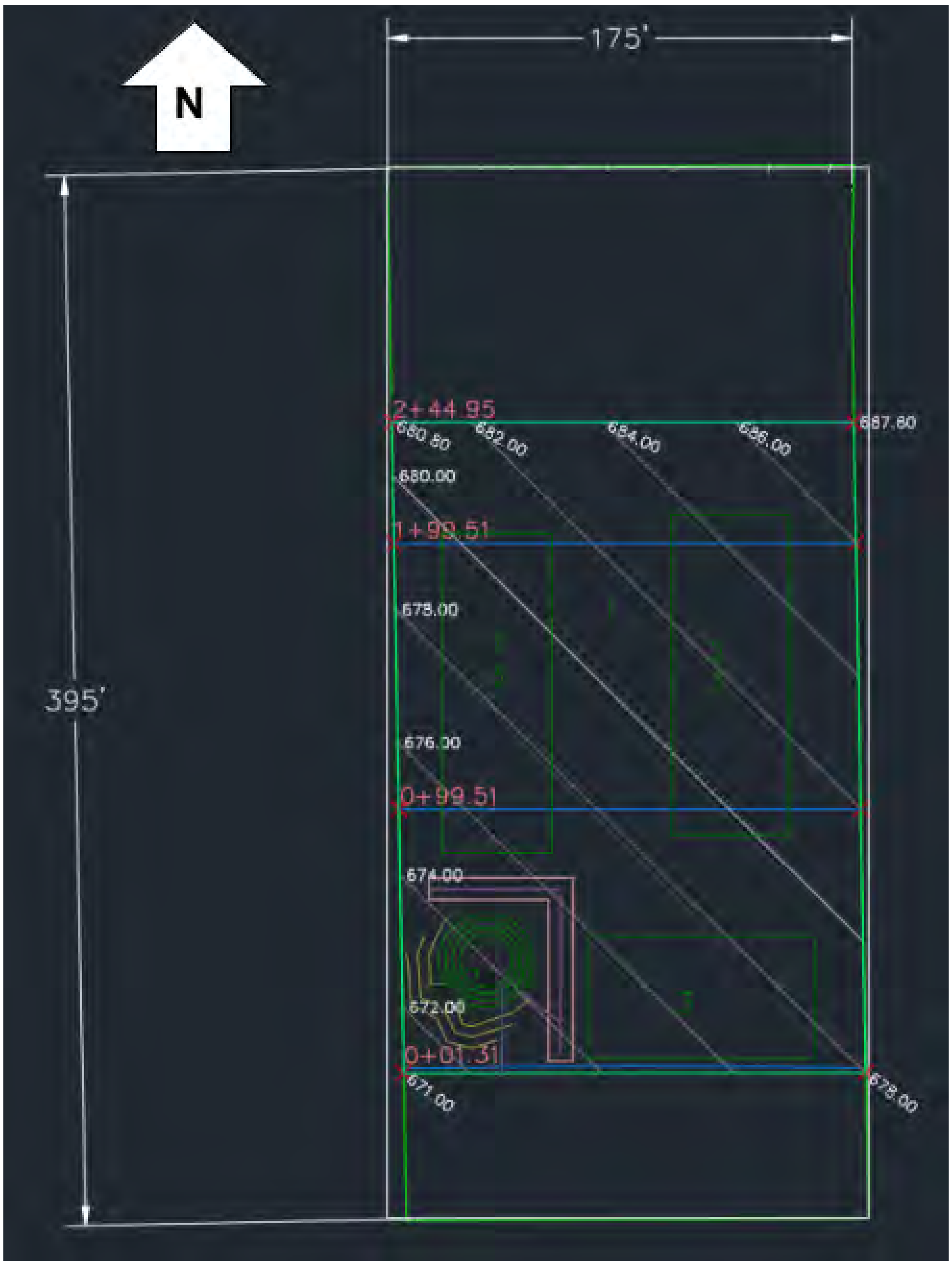


Figure 11: Proposed lined retention pond, broad crested weir, and bioretention device

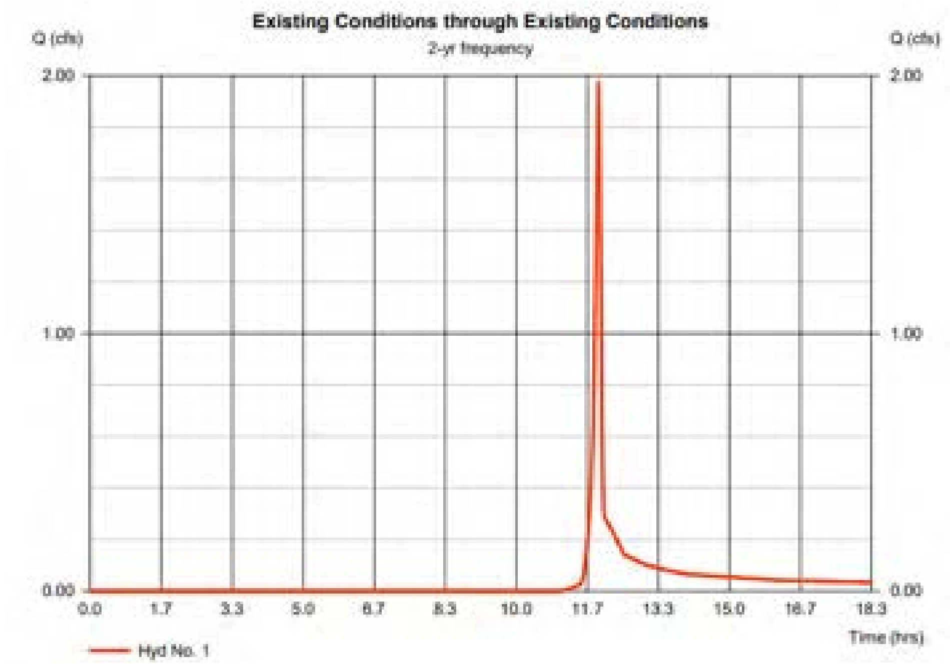


Figure 12: Hydrograph for 24-hour, 2-yr storm event on undisturbed site

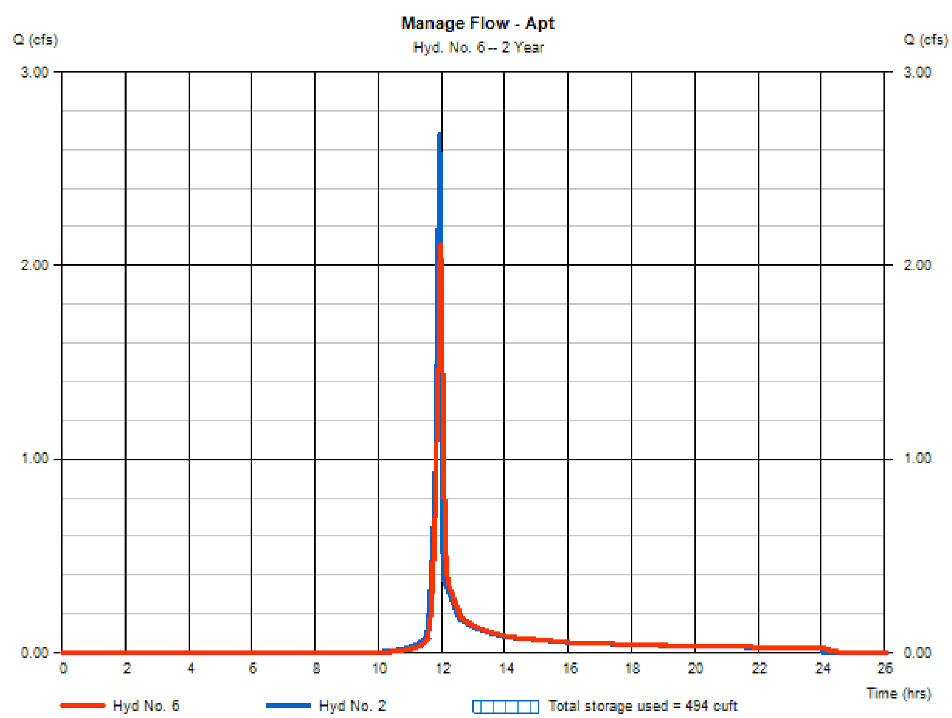


Figure 13: hydrograph for 24-hour, 2-yr storm event on apartment site with (red line) and without (blue line) retention pond

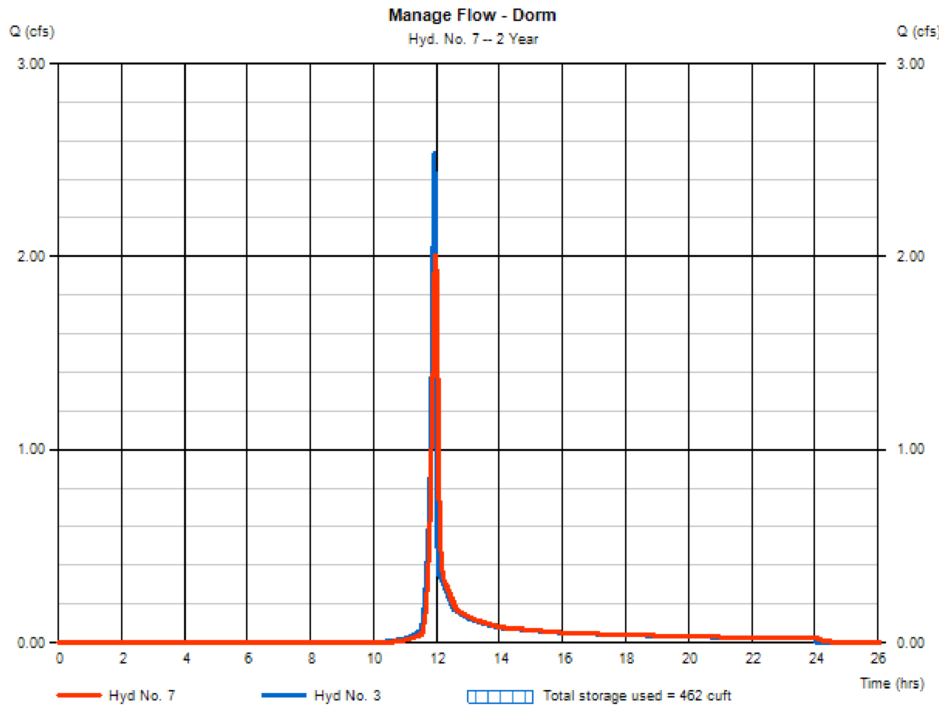


Figure 14: Hydrograph for 24-hour, 2-yr storm event on dormitory site with (red line) and without (blue line) retention pond

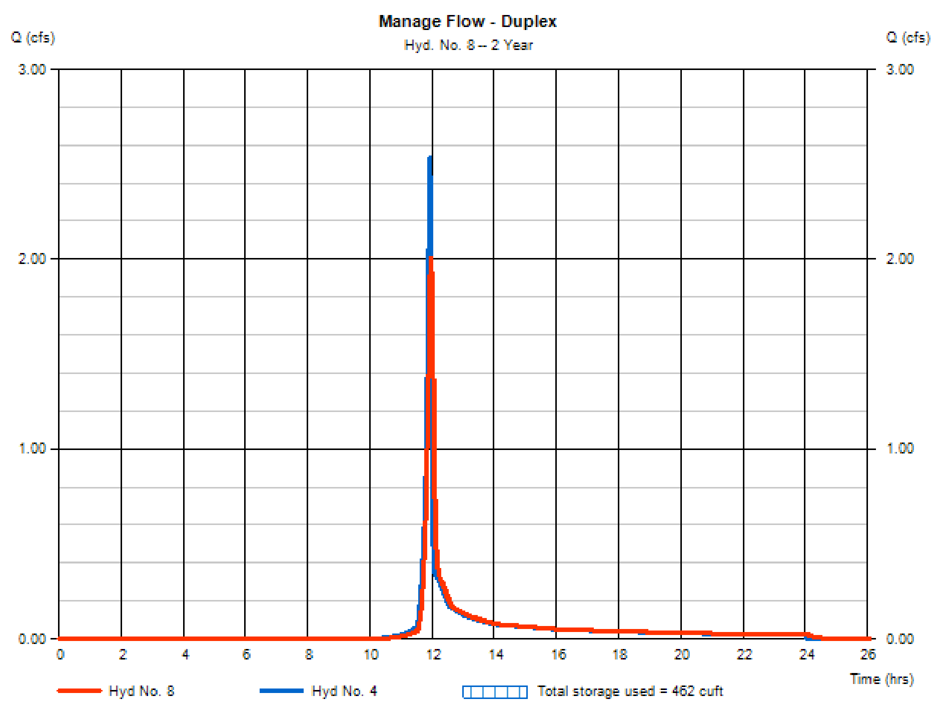


Figure 15: Hydrograph for 24-hour, 2-yr storm event on duplex site with (red line) and without (blue line) retention pond

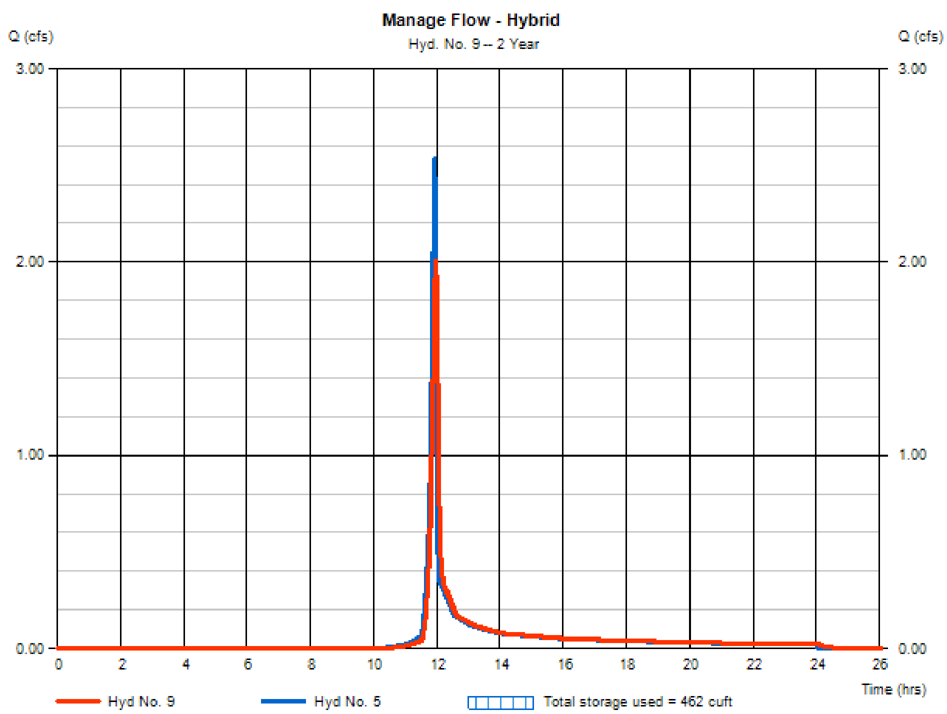


Figure 16: Hydrograph for 24-hour, 2-yr storm event on hybrid site with (red line) and without (blue line) retention pond

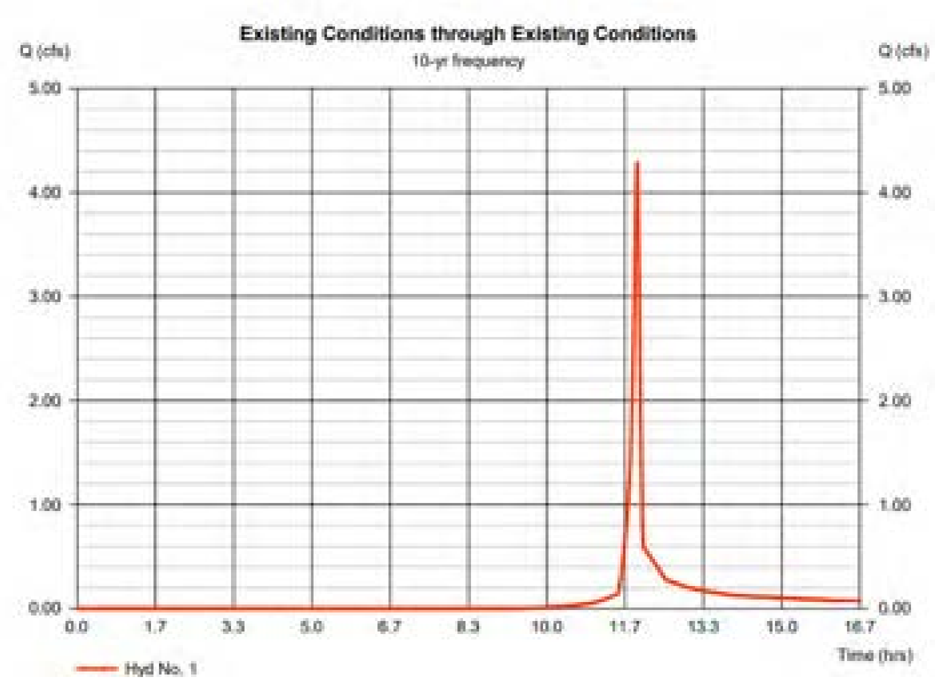


Figure 17: Hydrograph for 24-hour, 10-yr storm event on undisturbed site

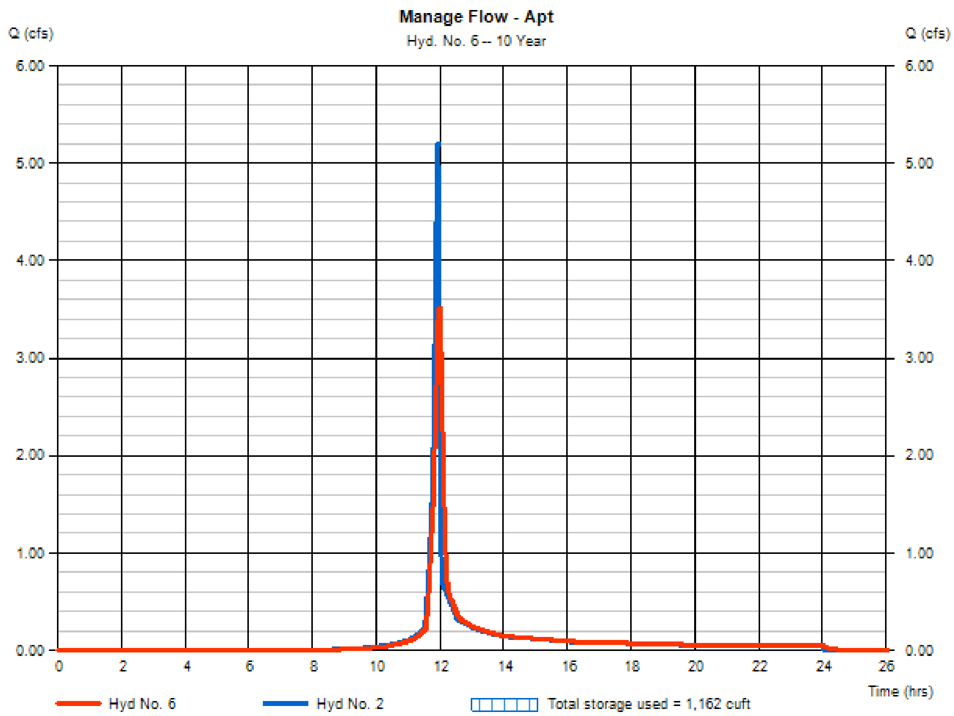


Figure 18: Hydrograph for 24-hour, 10-yr storm event on apartment site with (red line) and without (blue line) retention pond

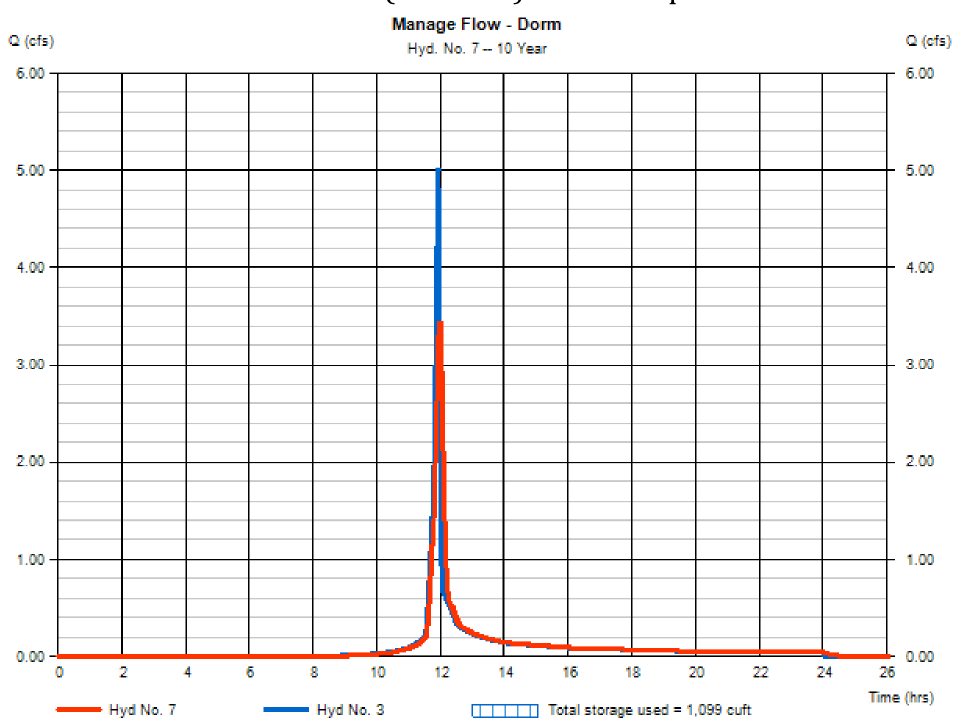


Figure 19: Hydrograph for 24-hour, 10-yr storm event on dormitory site with (red line) and without (blue line) retention pond

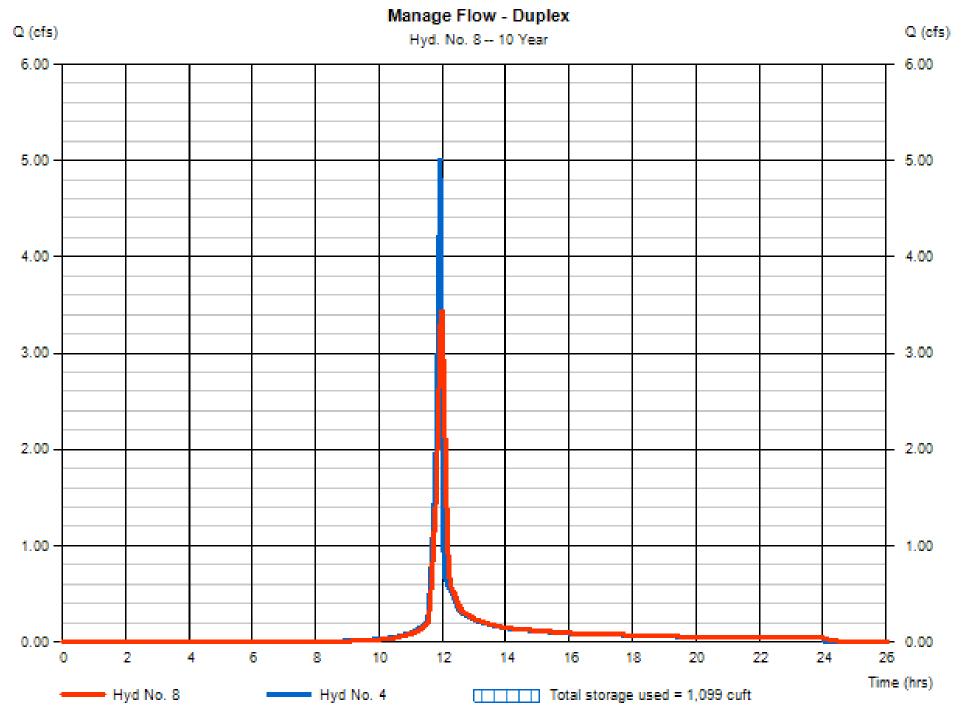


Figure 20: Hydrograph for 24-hour, 10-yr storm event on duplex site with (red line) and without (blue line) retention pond

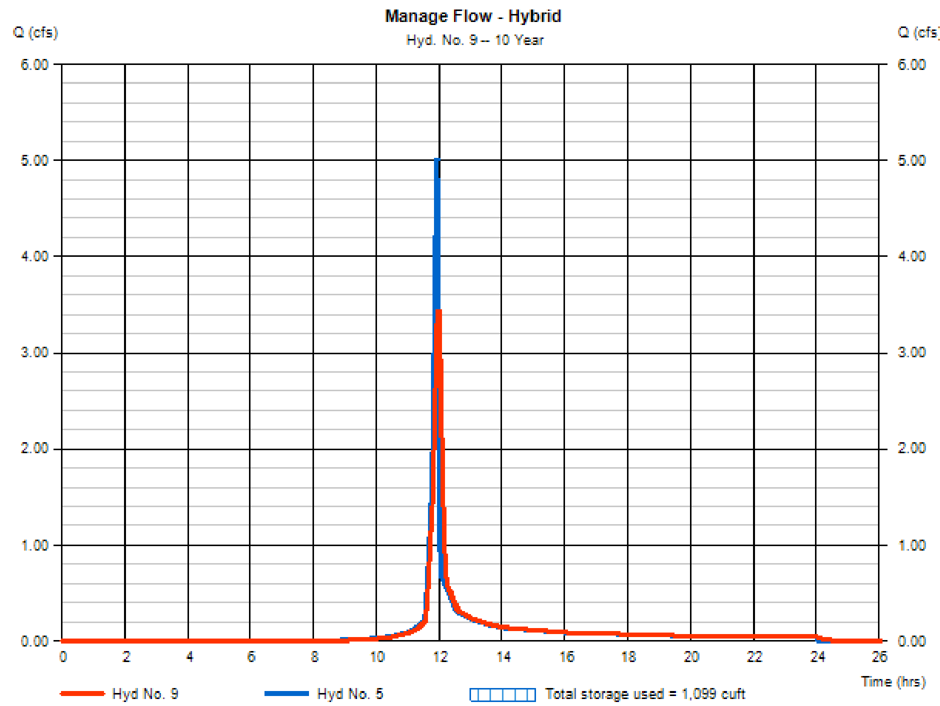


Figure 21: Hydrograph for 24-hour, 10-yr storm event on hybrid site with (red line) and without (blue line) retention pond

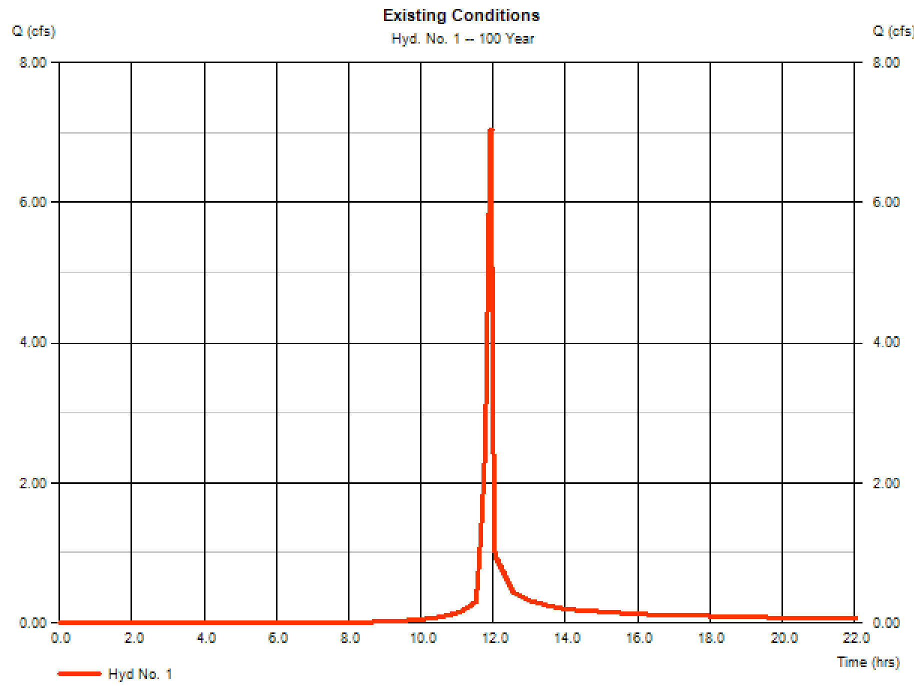


Figure 22: Hydrograph for 24-hour, 100-yr storm event on undisturbed site

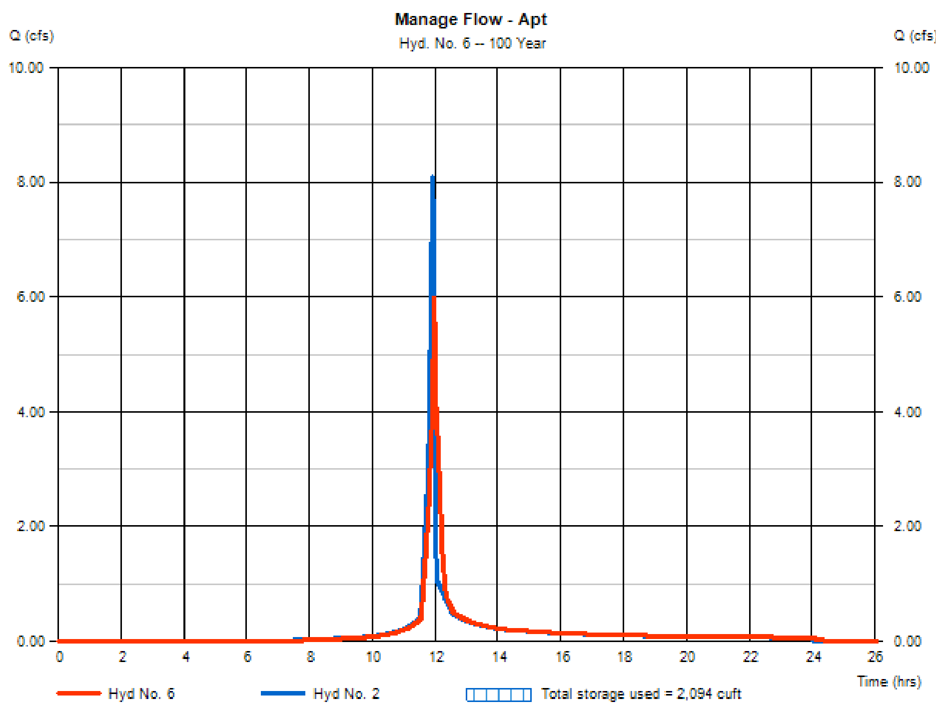


Figure 23: Hydrograph for 24-hour, 100-yr storm event on apartment site with (red line) and without (blue line) retention pond

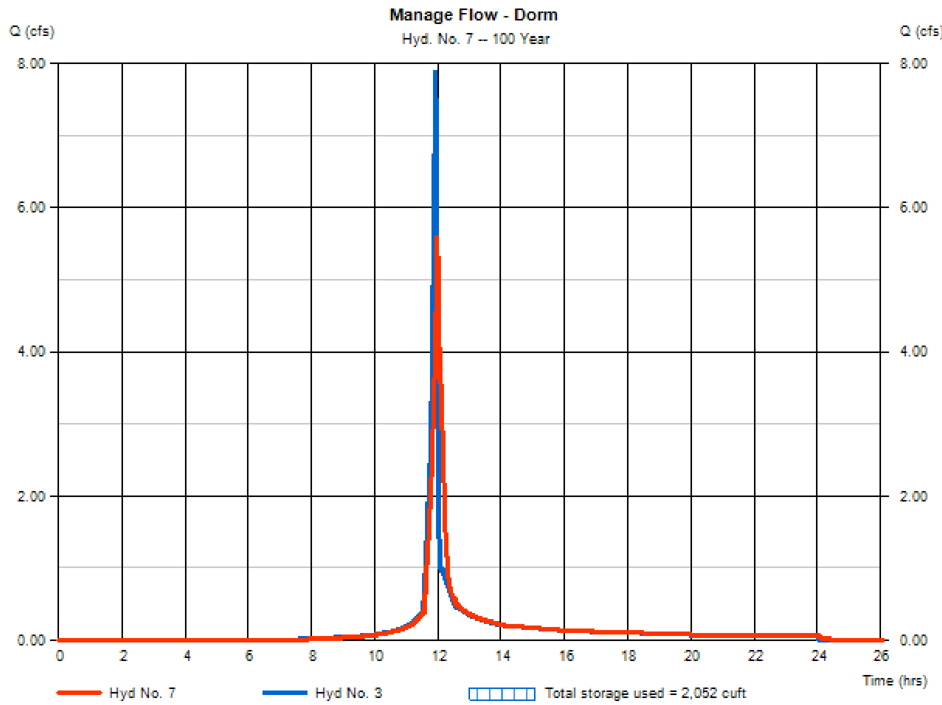


Figure 24: Hydrograph for 24-hour, 100-yr storm event on dormitory site with (red line) and without (blue line) retention pond

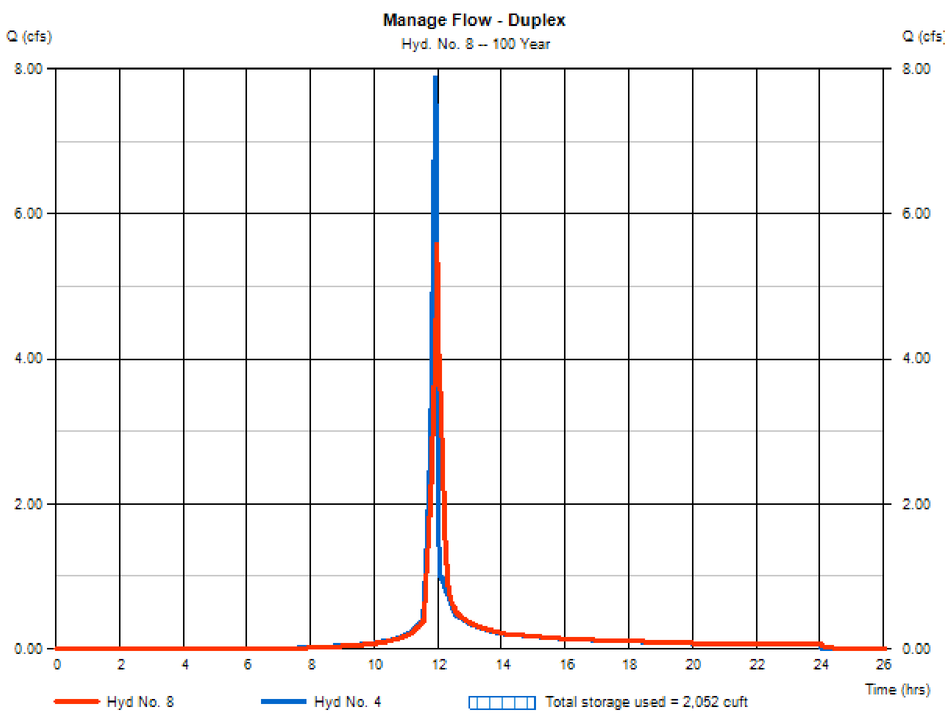


Figure 25: Hydrograph for 24-hour, 100-yr storm event on duplex site with (red line) and without (blue line) retention pond

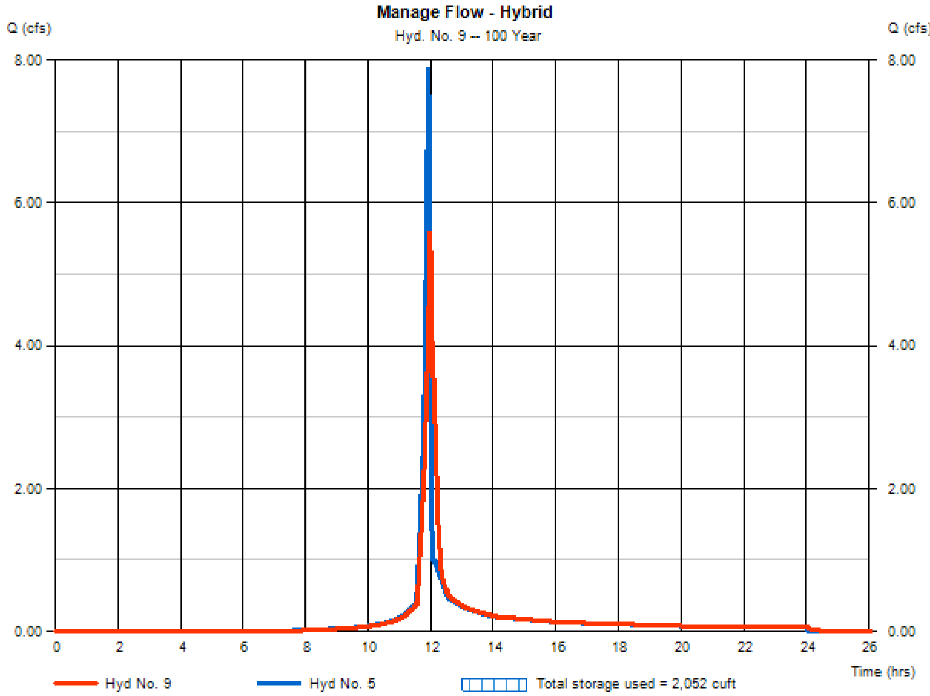
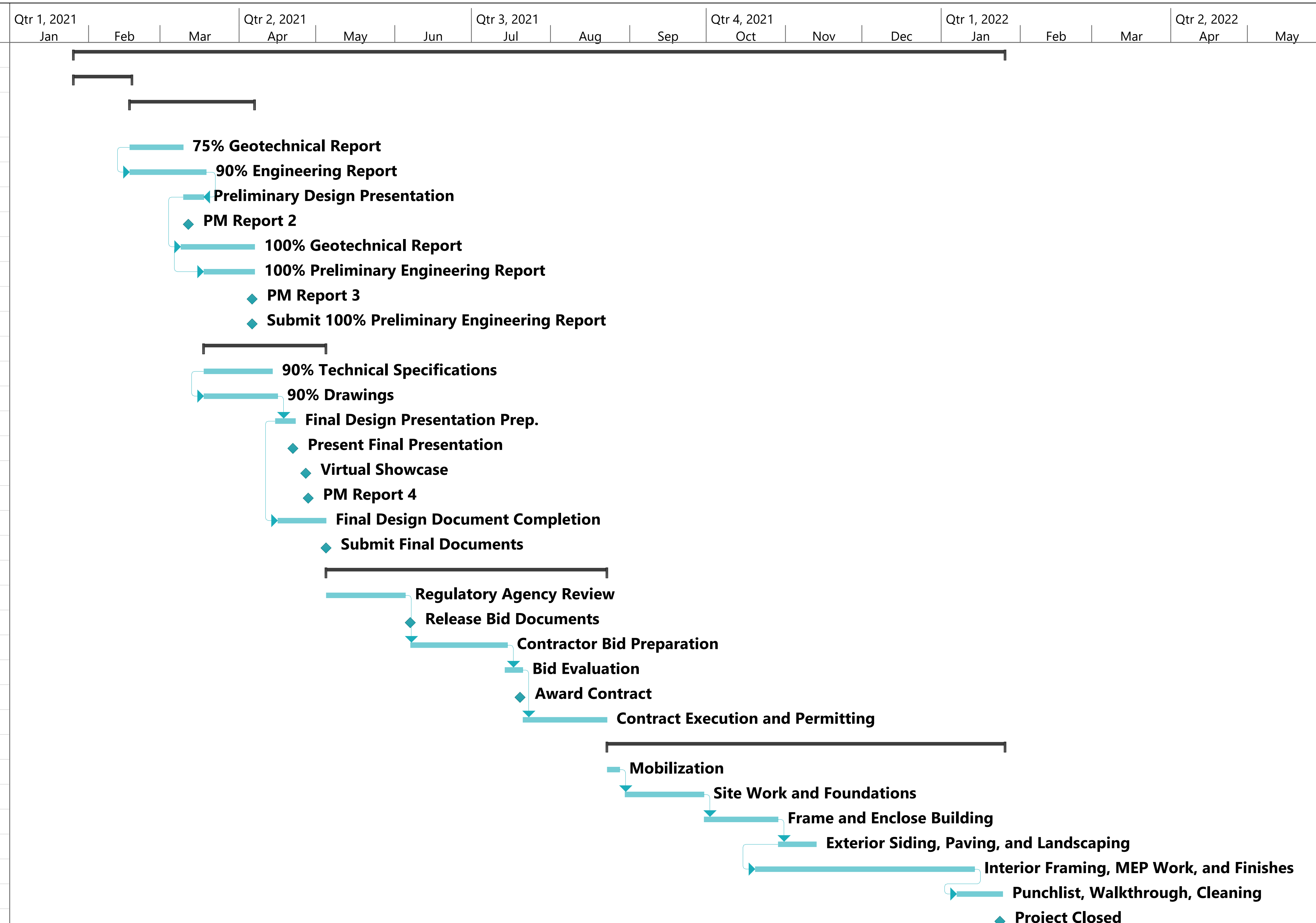


Figure 26: Hydrograph for 24-hour, 100-yr storm event on hybrid site with (red line) and without (blue line) retention pond

Egg Harbor Affordable Housing Design-Bid-Build Schedule 04/06/21

ID	Task Name	Start	Finish
1	**Egg Harbor Affordable Housing Projec**	**1/26/21**	**1/25/22**
2	**Phase 1: Proposal Preparation**	**1/26/21**	**2/17/21**
9	**Phase 2: Preliminary Engineering and Design**	**2/17/21**	**4/6/21**
10	75% Geotechnical Report	2/17/21	3/9/21
11	90% Engineering Report	2/17/21	3/18/21
12	Preliminary Design Presentation	3/10/21	3/17/21
13	PM Report 2	3/12/21	3/12/21
14	100% Geotechnical Report	3/9/21	4/6/21
15	100% Preliminary Engineering Rep	3/18/21	4/6/21
16	PM Report 3	4/6/21	4/6/21
17	Submit 100% Preliminary Enginee	4/6/21	4/6/21
18	**Phase 3: Final Design**	**3/18/21**	**5/4/21**
19	90% Technical Specifications	3/18/21	4/13/21
20	90% Drawings	3/18/21	4/15/21
21	Final Design Presentation Prep.	4/15/21	4/22/21
22	Present Final Presentation	4/21/21	4/21/21
23	Virtual Showcase	4/27/21	4/27/21
24	PM Report 4	4/27/21	4/27/21
25	Final Design Document Completio	4/16/21	5/4/21
26	Submit Final Documents	5/4/21	5/4/21
27	**Phase 4: Project Bid**	**5/5/21**	**8/22/21**
28	Regulatory Agency Review	5/5/21	6/4/21
29	Release Bid Documents	6/7/21	6/7/21
30	Contractor Bid Preparation	6/7/21	7/14/21
31	Bid Evaluation	7/14/21	7/20/21
32	Award Contract	7/20/21	7/20/21
33	Contract Execution and Permitting	7/21/21	8/22/21
34	**Phase 5: Construction**	**8/23/21**	**1/25/22**
35	Mobilization	8/23/21	8/27/21
36	Site Work and Foundations	8/30/21	9/29/21
37	Frame and Enclose Building	9/30/21	10/28/21
38	Exterior Siding, Paving, and Lands	10/29/21	11/12/21
39	Interior Framing, MEP Work, and I	10/20/21	1/13/22
40	Punchlist, Walkthrough, Cleaning	1/7/22	1/24/22
41	Project Closed	1/24/22	1/24/22



Manual Task | Manual Milestone | Summary | Manual Summary

Appendix C: Calculations

Construction

Table 9: Two bedroom duplex capital costs

Item	**Unit**	**Quantity**	**Estimated Cost**	**Estimated Total**	**Reference**
Mobilization	EACH	1	$93,684	$93,684	10% of budget
Erosion Mitigation	LF	425	$3	$1,275	RS Means
Excavation	CY	327	$55	$12,870	WisDOT Bid Tabs
Grading	CY	320	$13	$4,165	RS Means
Retention Pond	CY	186	$55	$10,230	RS Means
Water Well	EACH	1	$10,000	$10,000	National Average
Super Structure	SF	5864	$150	$879,600	RS Means
Curb and Gutter	LF	269	$8	$2,152	RS Means
HMA Pavement	TON	18	$70	$1,260	RS Means
Concrete Sidewalk	SF	3056.9	$5	$15,285	RS Means
Subtotal				**$1,030,520**	
Contingency		15% of capital costs		$154,578	
Administrative Costs		5% of capital costs		$51,526	
Design Fee				$93,940	
Final Total				**$1,330,564**	

Table 10: Eight bedroom dorm style capital costs

Item	**Unit**	**Quantity**	**Estimated Cost**	**Estimated Total**	**Reference**
Mobilization	EACH	1	$94,745	$94,745	10% of budget
Erosion Mitigation	LF	425	$3	$1,275	RS Means
Excavation	CY	203	$55	$6,985	WisDOT Bid Tabs
Grading	CY	320	$13	$4,165	RS Means
Retention Pond	CY	186	$55	$10,230	RS Means
Water Well	EACH	1	$10,000	$10,000	National Average
Super Structure	SF	5424	$150	$813,600	RS Means
Curb and Gutter	LF	269	$8	$2,152	RS Means
HMA Pavement	TON	18	$70	$1,260	RS Means
Concrete Sidewalk	SF	1412	$5	$7,060	RS Means
Subtotal				**$942,399**	
Contingency		15% of capital costs		$141,360	
Administrative Costs		5% of capital costs		$47,120	
Design Fee				$93,940	
Final Total				**$1,224,819**	

Table 11: Apartment style capital costs

Item	**Unit**	**Quantity**	**Estimated Cost**	**Estimated Total**	**Reference**
Mobilization	EACH	1	$126,781	$115,580	10% of budget
Erosion Mitigation	LF	425	$3	$1,275	RS Means
Excavation	CY	256	$55	$11,385	WisDOT Bid Tabs
Grading	CY	320	$13	$4,165	RS Means
Retention Pond	CY	186	$55	$10,230	RS Means
High Capacity Water Well	EACH	1	$150,000	$150,000	National Average
Super Structure	SF	6360	$150	$954,000	RS Means
Curb and Gutter	LF	269	$8	$2,152	RS Means
HMA Pavement	TON	18	$70	$1,260	RS Means
Concrete Sidewalk	SF	4267	$5	$21,335	RS Means
Subtotal				**$1,271,382**	
Contingency		15% of capital costs		$190,707	
Administrative Costs		5% of capital costs		$63,569	
Design Fee				$93,940	
Final Total				**$1,619,598**	

Table 12: Hybrid style capital costs

Item	**Unit**	**Quantity**	**Estimated Cost**	**Estimated Total**	**Reference**
Mobilization	EACH	1	$88,798	$88,798	10% of budget
Erosion Mitigation	LF	425	$3	$1,275	RS Means
Excavation	CY	265	$55	$9,955	WisDOT Bid Tabs
Grading	CY	320	$13	$4,165	RS Means
Retention Pond	CY	186	$55	$10,230	RS Means
Water Well	EACH	1	$10,000	$10,000	National Average
Super Structure	SF	5644	$150	$846,600	RS Means
Curb and Gutter	LF	269	$8	$2,152	RS Means
HMA Pavement	TON	18	$70	$1,260	RS Means
Concrete Sidewalk	SF	828	$5	$4,140	RS Means
Subtotal				**$978,754**	
Contingency		15% of capital costs		$146,813	
Administrative Costs		5% of capital costs		$48,938	
Design Fee				$93,940	
Final Total				**$1,268,445**	

Table 13: Yearly operating costs

Utility	Price per Unit	Dorm	Duplex	Apartment	Hybrid
Air Conditioning	$60	$2,880	$5,760	$5,760	$4,320
Heating	$60	$2,880	$5,760	$5,760	$4,320
Gas	$40	$1,920	$3,840	$3,840	$2,880
Electric	$40	$1,920	$3,840	$3,840	$2,880
Internet	$45	$2,160	$4,320	$4,320	$3,240
Total		$11,760	$23,520	$23,520	$17,640

Salvage Value

The salvage value, as seen in Equation 1 below, can be obtained by the use of the following formula:

Salvage Value = Capital Cost x (1 - depreciation rate) ^ life expectancy (7)

Salvage Value = $1,397,000 x (1 - 0.036) ^ 100 = $35,719 ~ $36,000

Annualizing Costs

Given Compound Interest Tables, values for annualized costs can be found given future and present costs. With the given conditions of a 4% interest rate and the project's life expectancy to be 100 years, values can be obtained for the annualized costs. **Table 12** below is used to ind the values used to calculate the annual costs for the analysis. Highlighted are the values used.

Table 14: Compound interest table

4%	Single Payment		Uniform Series				Arithmetic Gradient Series	4%
	Compound Amount Factor (CAF)	Present Worth Factor (PWF)	Present Worth Factor (PWF)	Capital Recovery Factor (CRF)	Compound Amount Factor (CAF)	Sinking Fund Factor (SFF)	Present Worth Factor (PWF)	
n	F/P	P/F	P/A	A/P	F/A	A/F	P/G	n
36	4.103 933	0.243 669	18.908 282	0.052 887	77.598 314	0.012 887	253.405 199	36
37	4.268 090	0.234 297	19.142 579	0.052 240	81.702 246	0.012 240	261.839 886	37
38	4.438 813	0.225 285	19.367 864	0.051 632	85.970 336	0.011 632	270.175 447	38
39	4.616 366	0.216 621	19.584 485	0.051 061	90.409 150	0.011 061	278.407 030	39
40	4.801 021	0.208 289	19.792 774	0.050 523	95.025 516	0.010 523	286.530 302	40
41	4.993 061	0.200 278	19.993 052	0.050 017	99.826 536	0.010 017	294.541 420	41
42	5.192 784	0.192 575	20.185 627	0.049 540	104.819 598	0.009 540	302.436 992	42
43	5.400 495	0.185 168	20.370 795	0.049 090	110.012 382	0.009 090	310.254 056	43
44	5.616 515	0.178 046	20.548 841	0.048 665	115.412 877	0.008 665	317.870 049	44
45	5.841 176	0.171 198	20.720 040	0.048 262	121.029 392	0.008 262	325.402 779	45
46	6.074 823	0.164 614	20.884 654	0.047 882	126.870 568	0.007 882	332.810 403	46
47	6.317 816	0.158 283	21.042 936	0.047 522	132.945 390	0.007 522	340.091 406	47
48	6.570 528	0.152 195	21.195 131	0.047 181	139.263 206	0.007 181	347.244 554	48
49	6.833 349	0.146 341	21.341 472	0.046 857	145.833 734	0.006 857	354.268 929	49
50	7.106 683	0.140 713	21.482 185	0.046 550	152.667 084	0.006 550	361.163 846	50
60	10.519 627	0.095 060	22.623 490	0.044 202	237.990 685	0.004 202	422.996 648	60
70	15.571 618	0.064 219	23.394 515	0.042 745	364.290 459	0.002 745	472.478 923	70
72	16.842 262	0.059 374	23.515 639	0.042 525	396.056 560	0.002 525	481.016 968	72
80	23.049 799	0.043 384	23.915 392	0.041 814	551.244 977	0.001 814	511.116 144	80
84	26.965 005	0.037 085	24.072 872	0.041 541	649.125 119	0.001 541	523.943 092	84
90	34.119 333	0.029 309	24.267 278	0.041 208	827.983 334	0.001 208	540.736 923	90
96	43.171 841	0.023 163	24.420 919	0.040 949	1 054.296 034	0.000 949	554.931 180	96
100	50.504 948	0.019 800	24.504 999	0.040 808	1 237.623 705	0.000 808	563.124 875	100
108	69.119 509	0.014 468	24.638 308	0.040 587	1 702.987 724	0.000 587	576.894 913	108
120	110.662 561	0.009 036	24.774 088	0.040 365	2 741.564 020	0.000 365	592.242 761	120
240	12 246.202 364	0.000 082	24.997 959	0.040 003	306 130.059 094	0.000 003	624.459 016	240
∞	∞	0	25.000 000	0.040 000	∞	0	625.000 000	∞

Geotechnical

The geotechnical calculations are contained within a separate document. Refer to the previously submitted **Geotechnical Report** for detailed geotechnical calculations.

Hydraulics

Provided in **Table 15** below in lines 1 - 5 labelled 'SCS Runoff' is Hydra low Hydrograph data for the peak runoff low and volumes for the existing, pre-construction site and the post-constructed sites for each design alternative for a 24-hour, 2-year storm event. Lines 6-9 labelled 'Reservoir' provide the peak runoff low for each alternative constructed site after the stormwater runoff is routed to a 40' diameter PVC lined retention pond for a

24-hour, 2-year storm event. Lines 6-9 also show the predicted water elevations in the retention pond for each design alternative.

Table 15: Hydra low Hydrograph data for a 24-hour, 2-year storm event

Model | Hydrographs | Ponds

1-Yr | 2-Yr | 3-Yr | 5-Yr | 10-Yr | 25-Yr | 50-Yr | 100-Yr

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time of conc. Tc (min)	Time to peak (min)	Volume (cuft)	Inflow hyd(s)	Maximum Elevation (ft)	Maximum Storage (cuft)	Hydrograph description
1	SCS Runoff	1.975	1	2.00	716.00	3.449				Existing Conditions
2	SCS Runoff	2.682	1	2.00	716.00	4.874				Apt
3	SCS Runoff	2.534	1	2.00	716.00	4.408				Dorm
4	SCS Runoff	2.534	1	2.00	716.00	4.408				Duplex
5	SCS Runoff	2.534	1	2.00	716.00	4.408				Hybrid
6	Reservoir	2.104	1		718.00	4.873	2	672.16	494	Manage Flow - Apt
7	Reservoir	2.004	1		718.00	4.407	3	672.10	462	Manage Flow - Dorm
8	Reservoir	2.004	1		718.00	4.407	4	672.10	462	Manage Flow - Duplex
9	Reservoir	2.004	1		718.00	4.407	5	672.10	462	Manage Flow - Hybrid

Provided in **Table 16** below in lines 1 - 5 labelled 'SCS Runoff' is Hydra low Hydrograph data for the peak runoff low and volumes for the existing, pre-construction site and the post-constructed sites for each design alternative for a 24-hour, 10-year storm event.

Lines 6-9 labelled 'Reservoir' provide the peak runoff low for each alternative constructed site after the stormwater runoff is routed to a 40' diameter PVC lined retention pond for a 24-hour, 10-year storm event. Lines 6-9 also show the predicted water elevations in the retention pond for each design alternative.

Table 16: Hydra low Hydrograph data for a 24-hour, 10-year storm event

Model | Hydrographs | Ponds

1-Yr | 2-Yr | 3-Yr | 5-Yr | 10-Yr (selected) | 25-Yr | 50-Yr | 100-Yr

Hyd. No.	Hydrograph type	Peak flow	Time interval	Time of conc. Tc	Time to peak	Volume	Inflow hyd(s)	Maximum Elevation	Maximum Storage	Hydrograph description
	(origin)	(cfs)	(min)	(min)	(min)	(cuft)		(ft)	(cuft)	
1	SCS Runoff	4.290	1	2.00	716.00	7,498				Existing Conditions
2	SCS Runoff	5.194	1	2.00	716.00	9,257				Apt
3	SCS Runoff	5.012	1	2.00	716.00	8,888				Dorm
4	SCS Runoff	5.012	1	2.00	716.00	8,888				Duplex
5	SCS Runoff	5.012	1	2.00	716.00	8,888				Hybrid
6	Reservoir	3.507	1		718.00	9,256	2	673.20	1,152	Manage Flow - Apt
7	Reservoir	3.432	1		718.00	8,887	3	673.13	1,099	Manage Flow - Dorm
8	Reservoir	3.432	1		718.00	8,887	4	673.13	1,099	Manage Flow - Duplex
9	Reservoir	3.432	1		718.00	8,887	5	673.13	1,099	Manage Flow - Hybrid

Provided in **Table 17** below in lines 1 - 5 labelled 'SCS Runoff' is Hydra low Hydrograph data for the peak runoff low and volumes for the existing, pre-construction site and the post-constructed sites for each design alternative for a 24-hour, 100-year storm event.

Lines 6-9 labelled 'Reservoir' provide the peak runoff low for each alternative constructed site after the stormwater runoff is routed to a 40' diameter PVC lined retention pond for a 24-hour, 100-year storm event. Lines 6-9 also show the predicted water elevations in the retention pond for each design alternative.

Table 17: Hydra low Hydrograph data for a 24-hour, 100-year storm event

Model | Hydrographs | Ponds

1-Yr | 2-Yr | 3-Yr | 5-Yr | 10-Yr | 25-Yr | 50-Yr | 100-Yr (selected)

Hyd. No.	Hydrograph type	Peak flow	Time interval	Time of conc. Tc	Time to peak	Volume	Inflow hyd(s)	Maximum Elevation	Maximum Storage	Hydrograph description
	(origin)	(cfs)	(min)	(min)	(min)	(cuft)		(ft)	(cuft)	
1	SCS Runoff	7.029	1	2.00	716.00	12,616				Existing Conditions
2	SCS Runoff	8.085	1	2.00	715.00	14,692				Apt
3	SCS Runoff	7.877	1	2.00	716.00	14,244				Dorm
4	SCS Runoff	7.877	1	2.00	715.00	14,244				Duplex
5	SCS Runoff	7.877	1	2.00	715.00	14,244				Hybrid
6	Reservoir	5.989	1		718.00	14,691	2	674.24	2,094	Manage Flow - Apt
7	Reservoir	5.686	1		718.00	14,243	3	674.20	2,062	Manage Flow - Dorm
8	Reservoir	5.686	1		718.00	14,243	4	674.20	2,062	Manage Flow - Duplex
9	Reservoir	5.686	1		718.00	14,243	5	674.20	2,062	Manage Flow - Hybrid

Figure 27 below shows the data used to size the bioretention device around the lined stormwater retention pond to achieve 80% total suspended solid removal.

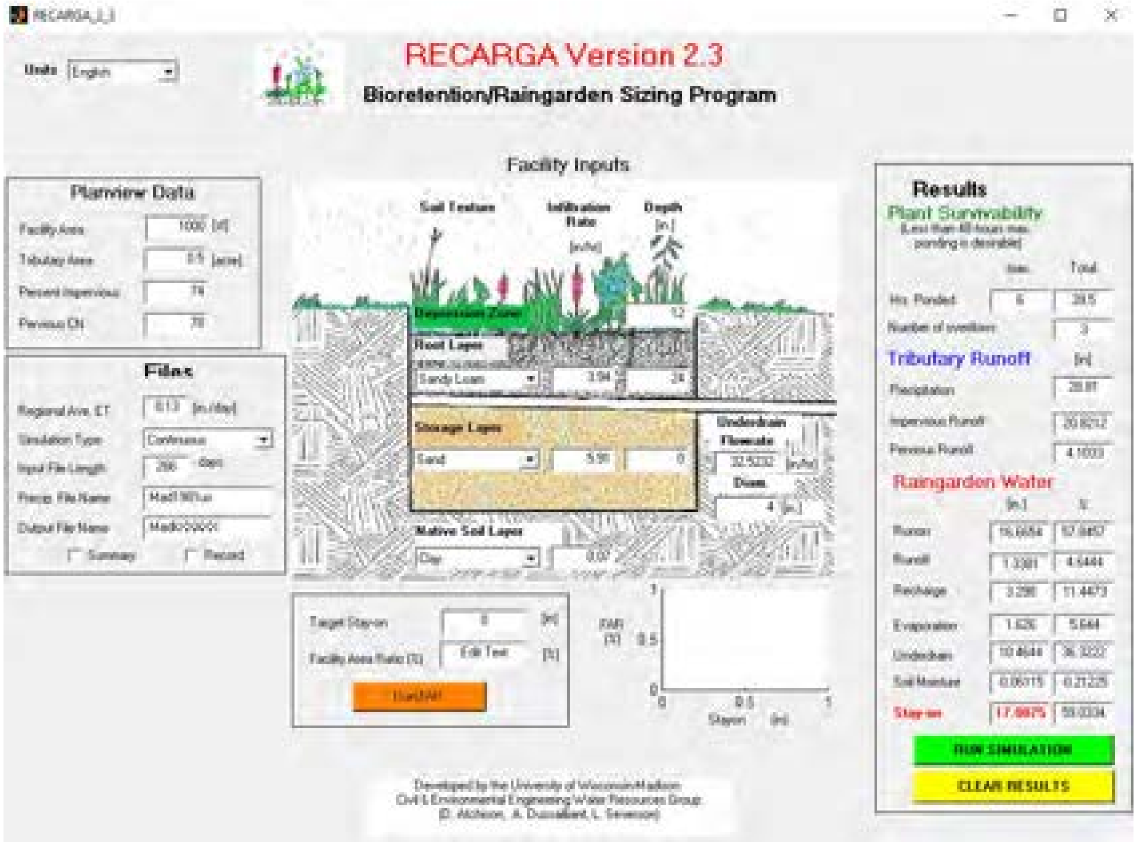


Figure 27: RECARGA bioretention device sizing program data and calculations

Structural

Sample Structural Calculations

Purpose: The purpose of structural analysis calculations is to determine the adequacy of structural building materials in supporting the loads on the structure. While most interior loads are transferred to the soil through the slab on grade, the weight of the roof and exterior walls are transferred to the foundations and thus this weight is used for bearing capacity calculations.

Methodology: Structural calculations are carried out in accordance with the *Residential Structure Design Guide* provided by the U.S. Department of Housing and Urban Development with design values from both the design guide and the *2018 National Design*

Speciic ation published in October 2017. Estimated loads are calculated using LRFD load combinations.

The following LRFD Load combinations were used to determine structural reliability.

- Headers, girders, joists, interior load bearing walls and columns, footings (gravity loads)
    - $1.2D + 1.6L + 0.5(L_r \text{ or } S)$ (1)
    - $1.2D + 1.6(L_r \text{ or } S) + L$ (2)
- Exterior load-bearing walls and columns (gravity and transverse lateral load)
    - Same as immediately above, plus
    - $1.2D + 1.0W$ (3)
    - $1.2D + 1.0E + L + 0.2S$ (4)
- Roof rafters, trusses, and beams; roof and wall sheathing (gravity and wind loads)
    - $1.2D + 1.6(L_r \text{ or } S)$ (5)
    - $0.9D + 1.0W_u$ (6)
    - $1.2D + 1.0W$ (3)

Where D = dead weight, E = earthquake load, H = soil lateral pressure, L = loor live load, L_r = maximum roof live load from construction, maintenance, S = design roof snow load, W = design wind load, W_u = wind uplift load on roof

Assumptions: The following loads were used in the equations above.

- Dead Loads
    - Roof construction: 15psf
    - Floor construction: 10psf w/ carpet
    - Wall construction:
        - Exterior walls: 8psf for vinyl siding w/ 2x6 walls
        - Interior walls: 6psf
    - Foundation construction: 100psf for concrete walls
- Live loads
    - Roof: 15psf uniform load
    - Attic: 10psf uniform
    - Floors
        - Bedroom areas: 30psf uniform
        - Other areas: 40psf uniform
- Wind loads
    - Design wind speed of 115mph, velocity pressure of 16psf (with a K_z of .57)
    - Lateral wind pressure coef icients
        - Roof (projected) = .85 for a 9:12 slope

        - Wall (projected) = 1.1
- Snow loads
    - 50 psf

Results: Example calculations are provided for 1 option, and values are reported for each option.

The roof is supported by a truss system, 23ft long, a slope of 9:12, and with a 1ft overhang on each end.

Dead load = 68'*25'*15psf = 25500lbs
Live load (roof+attic) = 68'*25'*15psf + 68'*25'*10psf = 42500lbs
Snow load = 68'*25'*50psf = 85000lbs
Wind uplift = 68'*25'*-.8*16psf = -21760 lbs
Lateral wind load = 68'*25'*(9/12)*.85*16psf = 17340lbs

LRFD load combinations

$1.2D + 1.6(L_r \text{ or } S)$ (5)

$0.9D+1.0W_u^5$ (6)

$1.2D+1.0W$ (3)

1.2 * 25500lbs + 1.6 * 42500lbs = 98600lbs
1.2 * 25500lbs + 1.6 * 85000lbs = 166600lbs
.9 * 25500lbs + 1*(-21760lbs) = 1190lbs
1.2 * 25500lbs + 1 * 17340lbs = 47940lbs

Therefore the largest load combination is 166,600lbs; With a resistance factor of .9, this can be assumed to be 185,111.11lbs.

The span of the trusses is relatively small and truss selection to support this load should not be an issue.

The tributary area of the walls is approximated as below.

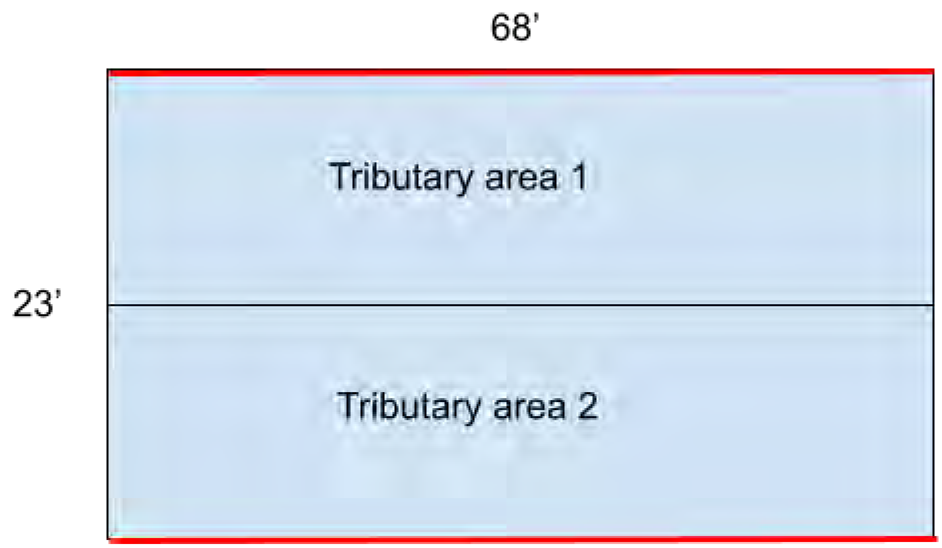


Figure 28: Tributary area of walls for duplex units

185,111.11lbs / 136ft = 1361.11lb/ft.

Given this tributary area, the approximate lb/lf on the wall length is 1361.11lb/ft..

The design compression parallel to the grain for 2x6's is 925psi. Assuming studs are placed 16" apart and 2x6's are used on exterior walls, the exterior walls support this weight.

2in*6in*925psi = 11,100lbs/stud * 1 stud/1.33ft = 8,345.86 lbs/ft

Wall Calculations

Exterior load-bearing walls
Note: there are no interior load bearing walls for this alternative.

Assuming the worst case load from the roof is to transfer down through the walls, the LRFD load combination worst case scenario must be calculated for the walls.

Long wall dead load = 9ft*(68ft*2)*8psf = 9792lbs
Long wall wind load = 9ft*(68ft*2)*1.1*16psf = 21542.4lbs
Short wall dead load = 13.3ft*(23ft*2)*8psf = 4,894lbs
Short wall wind load = 13.3ft*(23ft*2)*1.1*16psf = 10,768lbs
LRFD Load Combinations

$1.2D + 1.6L + 0.5(L_r \text{ or } S)$ - no loor above and L_r and S accounted for in roof load (1)

$1.2D + 1.6(L_r \text{ or } S) + L$ - no loor above and L_r and S accounted for in roof load (2)

$1.2D + 1.0W$ (3)

$1.2D + 1.0E + L + 0.2S$ - no loor above or earthquake calculations, S accounted for in roof load (4)

1.2 * (9792lbs + 21542.4lbs) + 1 * (19958.4lbs + 10768lbs) = 68327.68lbs

With a resistance factor of .9 this can be assumed to be 75919.64lbs

This weight is to be spread throughout the exterior walls, thus

75919.64lbs / 182ft = 417.14lbs/ft

The load on the 68' walls is 1361.11lb/ft + 417.14lb/ft = 2048.25lb/ft

The load on the 23' walls is 417.14lb/ft

Ground Floor Calculations

Slab on grade loads transfer down into the soil and can thus be ignored, while the loads supported by the joists route down through the footing walls.

Dead load on LRFD Load Combinations

$1.2D + 1.6L + 0.5(L_r \text{ or } S)$ (1)

$1.2D + 1.6(L_r \text{ or } S) + L$ (2)

In both combinations there is only one story and the snow and roof live loads are already accounted for in earlier calculations.

Dead loads
Bedroom: 528SF*10psf = 5280lbs
Other Area: 1036SF*10psf = 10360lbs
Wall: 170lf*9ft*6psf = 9180lbs
Dead loads = 24820lbs

Live loads
Bedroom: 528SF*30psf = 15840lbs

Other Area: 1036SF*40psf = 41440lbs
Live loads = 57280lbs

1.2 * 15840lbs + 1.6 * 41440lbs = 85312lbs

Given a resistance factor of .9, this can be assumed to be 94791.11lbs

Weight on foundation

The weight on the foundation walls is 261030.75 lbs. Over a foundation wall length of 198lf, weight per lf of foundation wall is 261,030.5lbs/198lf = 1318.34lb/lf.

Building weight

The weight of the building is 318,172lbs.

Conclusion: The structural analysis for each design option is fairly simple; Due to the slab on grade supporting the ground loor, the foundation is only supporting the exterior walls and roof load. In each option, the building design was determined to be structurally adequate to support the most extreme loads as determined by code requirements.

Summary Across Options

In order to determine bearing capacity of the footings weight per lf of exterior wall for each option is summarized below.

Table 18: Summary table of weight per exterior wall

Design Option	**Weight per lf exterior wall**
Duplex	1318.34 lb/lf
Apartment	1359.92 lb/ft
Dorm	2096.72 lb/ft

Table 19: Flow of Sanitary Water

Water Supply Fixture Units (WSFU)

Fixture	Count
Toilet	8
Sink	13

Cold each	Cold Total	Hot each	Hot Total	Total Each
6.5	52	0	0	52
0.5	6.5	0.5	0.25	6.75
				59

GPM Total
54
21
75

INFORMATION REQUIRED TO CALCULATE WATER SERVICE SIZE

1. Demand of building in gallons per minute. WSFU's 59 = (GPM) 75
2. Difference in elevation from main or external pressure tank to building control valve. (feet) 0
3. Size of the water meter. (When applicable) 5/8" __ 3/4" __ 1" __ 1-1/2" X 2" __ 3" __ 4" __ 6" __.
4. Developed length from main or external pressure tank to building control valve. (feet) 100
5. Low pressure at main in street or external pressure tank. (psig) 40

CALCULATE WATER SERVICE PRESSURE LOSS

6. Low pressure at main in street or external pressure tank. (value of # 5 above) 40
7. Water service diameter is 2". Material is Copper. Pressure loss per 100 ft = 2.4 psi. X 1.0 (decimal equivalent of service length, i.e.: 65ft = .65) 2.4

(Subtract line 7. from line 6.) **subtotal** 37.6

8. Determine pressure **gain or loss** due to elevation. (multiply the value of # 2 above by .434) value of "8" 0
9. Available pressure after the bldg. control valve. (Subtract or add line 8. Enter in "B".) **subtotal** 37.6

CALCULATE THE PRESSURE AVAILABLE FOR UNIFORM LOSS (VALUE OF "A")

B. Available pressure after the bldg. control valve. (from "9" above) Value of "B" 37.6

C. Pressure loss of water meter (when meter is required or installed) Value of "C" 6.5

(Subtract line C. from line B.) **subtotal** 31.1

D. Pressure at controlling fixture. (Controlling fixture is Toilet) Value of "D" 25

(Subtract the value of D.) **subtotal** 6.1

E. Difference in elevation between the building control valve and the controlling fixture in feet 0 X .434 psi/ft. Value of "E" 0

(Subtract the value of E.) **subtotal** 6.1

F. Pressure loss due to water treatment devices, instantaneous water heaters and backflow preventers which serve the controlling fixture. (Pressure loss due to Water Softener) Value of "F" 6

(Subtract the value of F.) **subtotal** 0.1

G. Developed length from building control valve to controlling fixture in feet 40 X 1.5 Value of "G" 60

(Water distribution piping material is Type L Copper) (Divide by the value of G.) **subtotal** 0.00167

Multiply by 100

A. Pressure available for uniform loss "A" = 0.167

Figure 29: Pressure Available for Uniform Loss

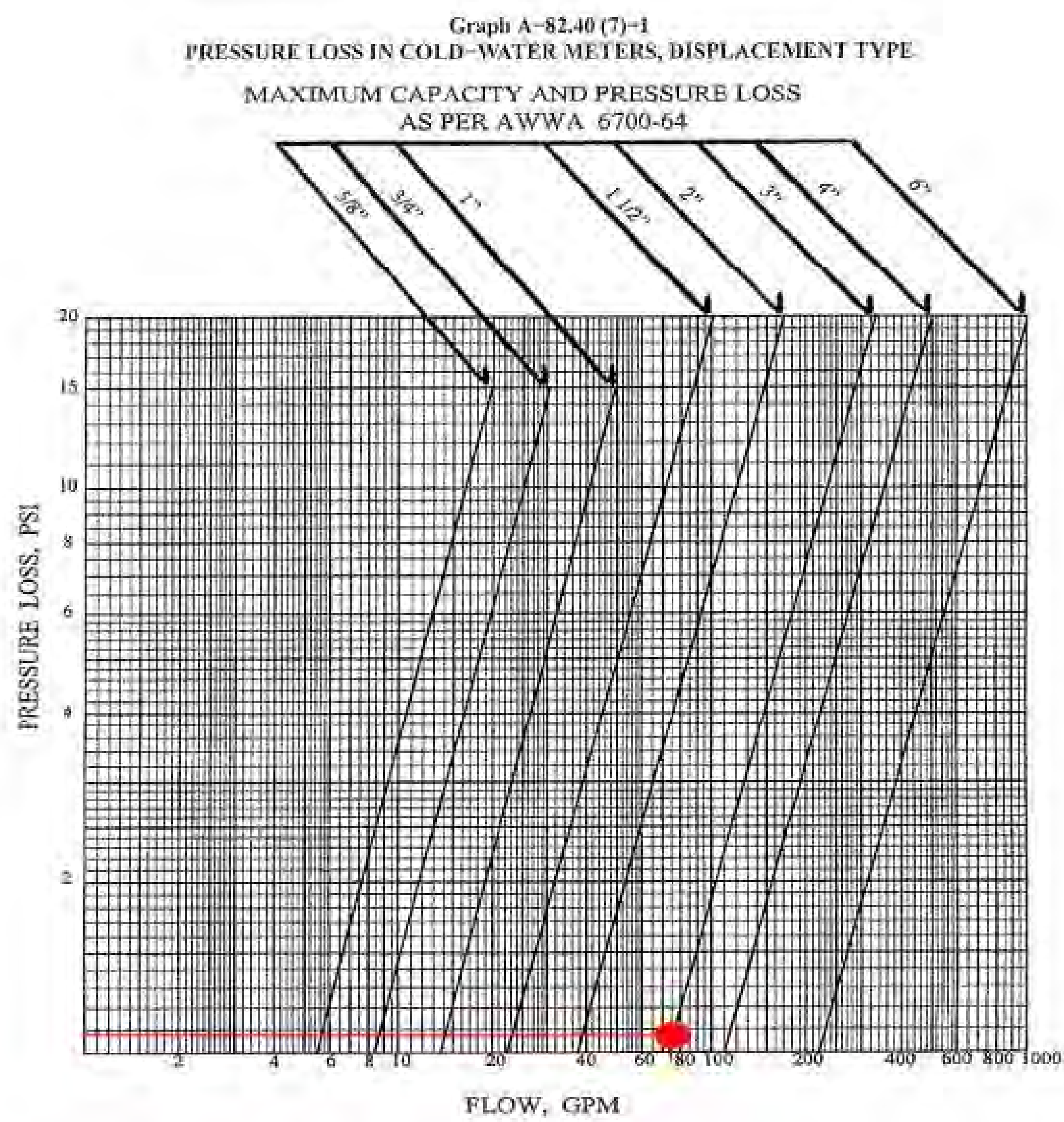


Figure 30: Lateral Pipe Size

Appendix D: Historical Site and Endangered Species Protection Documentation

Village of Egg Harbor
7860 State Hwy 42
PO Box 175
Egg Harbor, WI 54209

Egg Harbor Wisconsin

March 18, 2021

Ex Nihilo Engineering Consultants
1227 Engineering Hall
1415 Engineering Drive
Madison, WI 53706

The Village of Egg Harbor and the Wisconsin Department of Natural Resources has performed a historical importance analysis on various land parcels within the community.

The 1.4 acre land parcel provided for the design and construction of affordable housing units has no historical significance. Additionally, there are no buildings near the site limits with historical importance that require protection and preservation; therefore, excavation and construction of the land can proceed without extra consideration.

The Village of Egg Harbor has also performed an analysis of the flora and fauna wildlife in the area.

The flora found on the land parcel considered for this project is native to Egg Harbor, Wisconsin and does not require special protection.

The fauna in the area include squirrels, rabbits, and native, well-populated aves. There are no endangered species found in Egg Harbor that would be affected by the construction of affordable housing units.

Disclaimer: This is a fictional historical site analysis created solely for the purpose of the senior capstone design class - CEE 578 at the University of Wisconsin - Madison. Please do not take this to be a legal document. This document is not to be used in practice outside of the scope of CEE 578.

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Ex Nihilo Engineering Consultants
1227 Engineering Hall
1415 Engineering Drive
Madison, WI 53706

April 6, 2021

Jan Kucher, PE, Adjunct Professor
2346 Engineering Hall
1415 Engineering Drive
Madison, WI 54706

RE: 100% Geotechnical Report for the Village of Egg Harbor Affordable Housing Project

Dear Mr. Jan Kucher, PE,

Ex Nihilo Engineering Consultants has put together the following geotechnical report for use on the Egg Harbor Affordable Housing Project. Within this document, you can find information on the surface and subsurface investigations that were performed by our geotechnical team. This document also holds discussion and design recommendations for the floor slab, foundation, and subgrade walls.

The recommendations are based on the findings of the four boring samples performed on the site. Additionally, settlement, bearing capacity, and lateral earth pressure calculations were performed to support the findings and recommendations.

Please take note that this report represents the complete geotechnical report. Information stated in this report takes precedent over the previous 75% geotechnical report that you received.

Please contact the project manager, Molly Nemcek, at mknemcek@wisc.edu or at (608) 867-5309 with further questions related to this report.

Sincerely,

Adam Gorski
Adam Gorski
Geotechnical Engineer
Ex Nihilo Engineering Consultants

Molly Nemcek
Molly Nemcek
Project Manager
Ex Nihilo Engineering Consultants

100% GEOTECHNICAL REPORT FOR THE CONSTRUCTION OF AFFORDABLE HOUSING IN THE VILLAGE OF EGG HARBOR

PREPARED FOR:

Village of Egg Harbor Wisconsin

PREPARED BY:

- Ex Nihilo -
Engineering Consultants
Dedicated to Building a Better Tomorrow

DISCLAIMER

The content of this geotechnical report is provided by students in the Department of Civil/Environmental Engineering at the University of Wisconsin - Madison as an activity in the course Civ Engr578 - Senior Capstone Design. It does not represent the work of a licensed professional engineer. The provided recommendations, boring logs, descriptions, and other exhibits in this report are ictitious or obtained from another site. This boring log has been prepared for a UW Capstone Engineering class for educational use ONLY. It does NOT represent actual conditions and should NOT be used for other purposes.

Introduction

Ex Nihilo Engineering Consultants has performed the geotechnical investigation and report for the Village of Egg Harbor affordable housing project. Included in this report are the existing soil and geological conditions at the proposed project site, along with recommendations and calculations as it relates to the design and construction of the affordable housing project.

Project Description

The Village of Egg Harbor has expressed the need for affordable seasonal and year round housing. Seasonal housing is identi ied by the village as the need of highest importance to the community, because the local economy relies in large part on seasonal tourism. As such, the need to lodge seasonal employees is of paramount importance in order to provide the highest bene it to the community. The village has also expressed an interest in establishing itself as a year round, active community. Because between 90% and 95% of the housing in the area is considered seasonal, there is a need for an affordable year round option to create more accessibility to the community in off season months. The village has provided a 1.4 acre parcel free of cost for development to accommodate this affordable housing project. Currently there are no buildings, and there is no indication that the site has ever been built on.

Because of budget restraints, the village has limited the scope of design to a one story, wood framed building, to keep costs low and meet the needs of the community with minimal capital investment. The site is relatively lat and exhibits no signi icant topographical contrast. The designed building includes a parking lot with one spot per two sleeping spaces and a small road is expected to be built leading to the parking lot. A patio and rain gardens are also expected to contribute to the quaint charm of the surrounding community.

Scope of Work

The scope of services included in this geotechnical report are a geotechnical investigation and associated interpretation and recommendations. The geotechnical investigation includes a soil boring plan, as well as boring services to analyze the existing subsurface conditions at the site. Following the completion of the borings, the soils that were collected via split spoon sampling are to be classi ied by a staff geotechnical engineer to determine the depth, extent, and thickness of the soil stratum as well as an analysis of the engineering properties of these classi ied soils. Also included in this report is a discussion of the local geology, groundwater conditions, recommended bearing capacities, recommended foundation design, discussion of anticipated environmental issues, and recommended pavement parameters.

Four soil borings were performed by Dirt and Sons Drilling Company, a subsidiary company of Ex Nihilo, at the proposed project location to determine the subsurface conditions present. Drilling was started and completed on May 21st, 2020. Borings were done using a truck-mounted rotary drilling rig utilizing continuous light augers to advance the boreholes, which continued until refusal, which was between 2 and 10.5 feet. Representative soil samples were obtained by the Standard Penetration Test (SPT) method in general accordance with ASTM D-1586 procedures at 2.5-foot intervals to 10 feet, and then at 5-foot intervals thereafter to the end of the borings. A detailed boring location map can be found below in **Figure 1**, as well as an expanded view in the **Appendix**. Locations were chosen to provide the most representative sample of the subsurface conditions as it relates to the constructability of the proposed housing project. This included drilling within the proposed building pad, as well as the location of the proposed parking lot and the surrounding area.

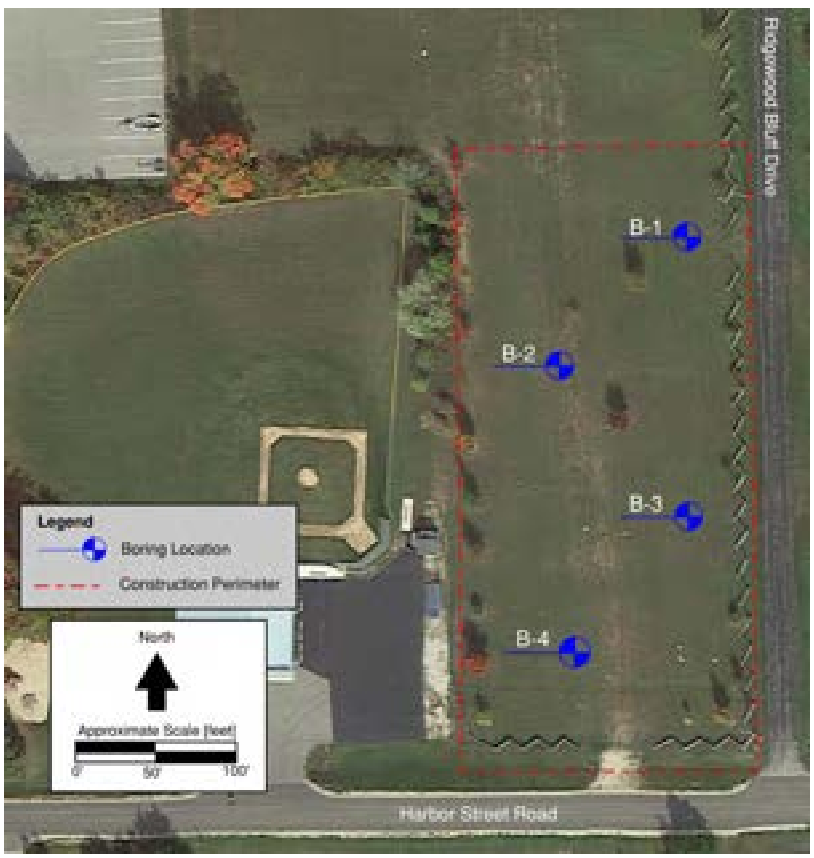


Figure 1: A detailed site plan showing boring locations.

Site Description and Investigation

Site Description

The proposed 1.4 acre site is located on Harbor School Road, on the southeast side of downtown Egg Harbor. The parcel is currently zoned as a Special Development district under statute §152.026 of the Village of Egg Harbor zoning code. The topography is relatively lat, and the parcel is constrained to the south and east by two lane roads.

Field and Laboratory Testing

The standard penetration value (N) was found in the ield by measuring the number of blows required for a 140-pound hammer traveling 30 inches to advance the split spoon sampler one foot. The sampler is subsequently lowered to the bottom of the drill hole and the number of blows is recorded for each of the three successive 6 inch increments. The N value is calculated in the ield by summing the second and third incremental blow counts. The SPT test provides an accurate approximation of the relative density of granular soils as they exist in-situ, which allows an estimation of the relative strength and compressibility characteristics of the soils.

Soil samples collected from the split spoon sampler were visually classi ied by the driller onsite, and once more in the laboratory. These soils are classi ied using the Uni ied Soil Classi ication System (ASTM D2487-00). Once in the laboratory the soils are subjected to moisture content testing (ASTM D2216), and selected cohesive soils were additionally tested in uncon ined compression with a calibrated pocket penetrometer (ASTM WK27337).

Subsurface Conditions

Regional Geology

The Village of Egg Harbor is located in Door County, Wisconsin, which was formed on the Wisconsin Arch of the Michigan Basin and consisted primarily of Niagaran Series Dolomite bedrock. This Niagaran bedrock also forms the Niagara escarpment, which extends the length of the peninsula and forms the characteristic caves that helped popularise the area. Included within these Niagran series bedrocks include those from the St. Peter Sandstone, Prairie du Chien group, Trempealeau formation, and the Tunnel City group. The average depth to bedrock in the county is 24 inches.

Much of the topography in the county was created through Pleistocene glaciation. Silurian dolomite forms the upper bedrock unit throughout most of the county, and additionally serves as the most important aquifer in the region. Due to the active glacial history of the area, this silurian dolomite bedrock is exposed in many areas north of Sturgeon Bay. This region is classi ied by its rocky soils, and glacial till as a result of glacial erosion and deposition from the late Wisconsin Woodfordian glaciation. Soil is thin, discontinuous, and unconsolidated on top of the dolomitic bedrock. The predominant soil in the area according to the NRCS is longrie loam, additionally summerville, namur, and omena sandy loams are also present.

According to the Wisconsin Geological and Natural History Survey, quaternary geology of the egg harbor area includes:

- Ltsk: Thin till cover on streamlined topography. Low-relief land surface with drumlins and/or lutes on bedrock. Bedrock typically within 5ft of the ground surface.
- Ltrk: Thin till cover on rolling topography with very low relief. Bedrock typically within 5 ft of the ground surface. Sediment is primarily liberty grove till.
- B: Beach and nearshore sediments including beach ridges, gravel, sand, and ine sand deposits. Possibly including wave-washed till. Sediment cover is more than 5 ft.
- Exposed bedrock: Bedrock exposure along steep slopes with discontinuous patches of till.

Project site is located within the ltrk region, as is consistent with soil borings. See **Appendix** for Quaternary Geology of Door County, Wisconsin map.

Surface Characteristics

This proposed site is currently lightly vegetated, sparsely populated with shrubs and grass. Currently an entrance drive is present on the south side of the parcel as it faces Harbor School Road, and should be considered for use as a construction entrance. The land historically has been vacant, though it has been maintained and would require relatively minimal site preparation prior to construction. Site topography is provided in the **Appendix**; The site has a steep grade throughout, 10% in some places.

Subsurface Characteristics

The subsurface conditions on site can be generally characterized as gravelly sands and silts extending down until bedrock, typically encountered between 2 and 4 feet. Sands are dark and greyish brown, moist, and contain traces of silt and gravel. No cohesive soils were encountered in the soil borings, therefore no in depth soil testing was required. Surface soils encountered in the soil borings all indicated an average of 3" of topsoil, and subsequently a gravelly sand until reaching bedrock. All topsoil encountered was a longrie loam. Soils are extremely adequate to provide bearing capacity to a structure, and are seen in relative uniformity throughout the entire proposed site. Included below in **Figure 2** is a generalized soil pro ile created from the data collected in the soil borings.

Soil Cross Section	
0-1'	Gray/Brown Gravelly Sand, Moist MC: 3-5% N: 22
1.25-1.875'	Brown/Gray Fine Sand, with Gravel and Trace Silt MC: 6-20% N: 23
0'-1.875'	Grayish Brown Silty, Fine Sand, with gravelMoist MC: 9-15% N: 68/11"
	Bedrock

Figure 2: A generalized soil pro ile created from the four soil borings performed during subsurface exploration.

Significant Test Results

Moisture contents observed were typically between 4 and 9%. Most signi icant of the test results was the extremely high blow counts encountered during the soil borings, particularly in boring B-4, where the blow counts averaged 61. This represents an extremely high ability to support an engineered load, and demonstrates that the proposed site contains all necessary soil conditions to be adequate for construction.

Groundwater Conditions

Groundwater was not encountered in the four soil borings performed on the proposed site. According to the Door County GIS, the depth to groundwater is estimated to be approximately 75 to 85 feet below the project site. Groundwater low contours found in the Door County GIS are provided in the **Appendix**, but are not anticipated to have an effect on construction.

It is not anticipated that groundwater will be encountered during construction of the design alternatives. However, encountering groundwater during the construction phase would create the potential for destabilizing engineered back ill around the foundation. It is necessary to install adequate drainage measures around the base of the foundation to prevent the collection of water against the foundation. In addition to the bedrock serving as an aquifer in the area, it also has a much lower hydraulic conductivity than the surrounding sands, which contains the potential for restricting in iltration from rainfall, allowing for pooling of water around the foundation. Perforated pipe should be installed along the perimeter of the foundation and covered in clear stone or washed gravel, then covered with a geotextile to protect against sand interference with the system.

The proposed site is also located within a half mile to Green Bay. Due to the isolated nature of the aquifer, however, it is unlikely that the lake has a signi icant impact on the groundwater.

Environmental Issues

Existing Contamination Sources: Because of the historically vacant land, placement in a primarily residential area, and distance from industrial facilities, it is unlikely there is any existing contamination onsite. One potential source of contamination is from the village's wastewater treatment plant approximately 1,500 ft away; but again, contamination is unlikely.

Liquid Emissions and Discharge: Large construction equipment such as bulldozers, rollers, and excavation equipment are to be used to construct the affordable housing project. These diesel powered machines contain the potential to spill fuel and oil on the ground's surface during construction, possibly contaminating the groundwater below the site.

Air Quality: Diesel powered construction equipment emit exhaust fumes that contain the potential for environmental degradation and lowered air quality during the construction period.

Discussion and Recommendations

Introduction

Based on the geotechnical exploration and analysis performed by Ex Nihilo Consulting Engineers, the proposed site of the Village of Egg Harbor affordable housing project is geotechnically adequate for construction. It is the opinion of Ex Nihilo that due to the shallow bedrock present at the site, the substructure is feasible and capable of holding the weight of the proposed structure. The main geotechnical problem found during the geotechnical investigation was the possibility of increased costs due to the necessity of rock blasting to accommodate foundation design. Although the bedrock provides a large amount of support on the site, and is one of the key bene icial features in the area, it is expensive to construct in the subsurface.

Sand with gravel was found in abundance onsite above the bedrock in pockets up to 5 feet deep. In order to provide a conservative estimate of geotechnical adequacy for construction, all foundation calculations were carried out assuming the sand to be the bearing material of the foundation. Although it is expected that the bearing material will be the bedrock, the positive results of this worst case scenario allows for a larger factor of safety.

Site Preparation Routine measures

The site requires preparation prior to the commencement of construction activities. Prior to excavation, utilities must be located. The topsoil requires removal so that no organic material is present, and the removal of trees is necessary. A construction entrance should be constructed of clear stone so that no mud is tracked onto village roads. Additionally, a water truck should be present onsite during the construction activities to keep dust to a minimum.

While some grading and excavation is required to prepare the site for the buildings, design consideration is to be given to creating buildings in a North-South direction, in order to reduce the cross slope across the building.

In terms of hydrology, the soil on site is highly moisture sensitive and can create instability when wet, therefore, silt fences and proper site grading during construction should be performed before excavation begins. Because of the shallow bedrock, in iltration within the soil for stormwater cannot occur. Due to this, a lined stormwater retention pond is to be built on site to manage stormwater runoff for the housing units. This retention pond should be excavated before other construction occurs to allow for runoff to low away from site and foundational excavations and into the pond to avoid soil instability. The site should be graded so that stormwater runoff lows towards the southwest corner of the site into the retention pond.

Additionally, the geography of Egg Harbor exposes the site to frost conditions during winter months. Moisture and water should be drained to avoid frost build up during construction.

Foundation Recommendations

Bearing Capacity

Due to the shallow nature of the bedrock, bearing capacity is not expected to be a concern. Typically bearing capacity on bedrock is simply negated, however, for thoroughness we chose to use recommended bearing capacity values from the NAVFAC Design Manual 7.2 to provide a better understanding of the subsurface conditions. According to the geotechnical report from Egg Harbor, the site's bearing material is coarse to medium sand with gravel (SW) in a loose state. From **Table 2** in the **Appendix**, the recommended withstandable foundation stress is 6,000 psf. The foundation stresses calculated for the apartment building is 1423.28 psf and the dormitory building is 1914.48 psf which are well below the recommended foundation stress, the site can withstand the structure of each building design. Detailed calculations can be found in the **Appendix**.

Settlement

Settlement is considered negligible for bedrock, however, settlement in this case was calculated considering the worst case scenario of a 5 foot pocket of sand identi ied in the soil borings. This provides the Ex Nihilo geotechnical team with a better understanding of the subsurface conditions under many scenarios. When completing the settlement calculations for this worst case scenario, it was found that the settlement of each alternative would not exceed 0.184 inches. Based on a maximum allowed total settlement on a granular soil of 1 inch (Terzaghi et al., 1996), we can conclude that the settlement is acceptable, and the bearing material contains the appropriate engineering properties to support the designed foundations.

Shallow Foundation Design

Due to the bearing material being a shallow bedrock, a conventional and shallow foundation design would be adequate for the proposed structure. Strip footings must have a minimum width of 18 inches. To accommodate for frost expected in Zone 3, footings should be placed no less than 48 inches from the ground surface, in accordance with the Wisconsin Administrative Code, Subchapter IV, Comm 21.16. Additionally, footings and walls should be placed no closer than 12 inches to the edge of the excavation to allow adequate spacing for drainage and structural back ill.

An example footing detail can be seen below in **Figure 3.**

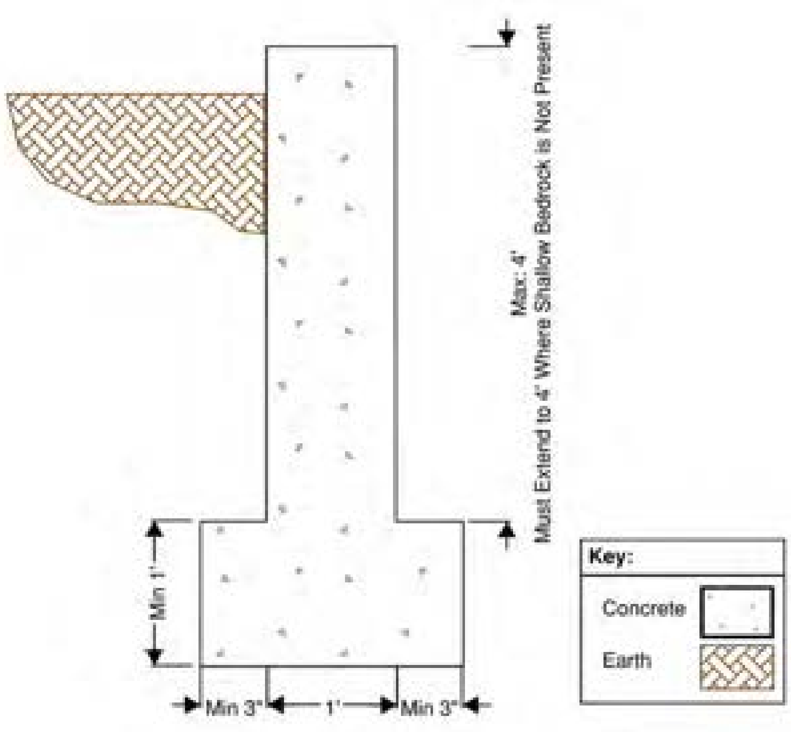


Figure 3: Footing Detail

The footings should be placed on an engineered ill with a 4 inch minimum thickness. This engineered ill should be compacted to create a subgrade and a surface more conducive to the forming and casting of concrete footings. No footings should be poured directly on bedrock.

Because no rock cores for RDQ or core recovery were taken, it is the opinion of Ex Nihilo that the allowable bearing pressure design be made conservatively to represent the weakest soil identi ied, the sand with gravel. In accordance with the NAVFAC Design Manual 7.2, a conservative value of 6,000 should be used to allow room for safety in regards to any geotechnical uncertainties. This value allows for a signi icant factor of safety and still provides more than adequate support for the proposed building.

Floor Slab Recommendations

Based on the soil borings, we expect the soil and shallow bedrock to provide support to the proposed building. Because of the shallow nature of the bedrock, it is expected that the foundation load be transferred to the bedrock following a brief layer of sand. As a result, problem soils are not expected. Slabs should be constructed separately from the foundations, construction joints should be made and reinforced to manage cracking.

Below-Grade Walls

The lateral earth calculations were performed under the assumption that the native sandy soils can be re-used as structural back ill. This was chosen as the preferred course of action because it can cut down on the trucking costs, as well as the cost of importing ill, and can help to keep the project within the tight budget constraints. Based upon Ex Nihilo's geotechnical analysis, the expected lateral earth pressure of the structural ill was found to be, at maximum, 244.02 lb/ft. Designed ill parameters are shown below in **Table 1**.

Table 1: A summary of lateral earth pressure calculations

Soil type	Dry/saturated Unit Weight [lb/ft^3]	Friction Angle [Degrees]	Cohesion [lb/ft^2]	Earth Pressure Coef icient			Lateral Earth Pressure [lb/ft]
SW	109/130	37	0	K0= 0.398	Ka= 0.249	Kp= 4.023	244.02

The foundations should be supported by an approved structural back ill. Additional geotechnical testing is required to determine an approved low cost back ill, but approved back ills can be determined by the project engineer on a case by case basis. A modi ied proctor test (ASTM D1557) is needed before placement, and compaction of 90% the maximum achieved dry density is recommended. Existing soils are expected to be stockpiled and used as back ill, contingent on meeting gradation requirements set forth by the Wisconsin DOT Standard Speci ications in section 210.2.2.

Pavements

One parking spot per two sleeping spaces should be provided, in accordance with the request for proposal submitted by the Village of Egg Harbor. The road and parking lot area must be prepared prior to construction by removing the topsoil, and illing to grade with spoils from the retention pond construction. These spoils must be compacted and proof rolled prior to the placement of asphalt. The pavement construction must meet the requirements of Wisconsin DOT Standard Speci ications for Road Construction. Pavement design parameters must be in accordance with the AASHTO 1972 Asphalt Pavement Design Equation.

Construction Complications and Considerations

In order to keep within the budget, it is recommended that the spoils resulting from the excavation of both the foundation and the retention pond be stockpiled onsite for use as structural ill. This ill can be used for placement under the roadway and parking lot, and well graded sands can be used for back ill against foundation walls. In order for use in this capacity, additional soils testing is necessary and performed on an as needed basis should the source material change during excavation. A modi ied proctor test (ASTM D1557) is needed before placement, and compaction of 90% the maximum achieved dry density is recommended.

Due to the shallow bedrock, it is expected that rock blasting may be required for the construction of the foundation. The depth to bedrock varies across the site, and may present itself at a shallower depth than anticipated in areas of the building footprint. Should bedrock be encountered in depths that vary signi icantly than those found in the soil borings, the project geotechnical engineer should be consulted prior to removal. Additionally, contingencies in the project budget may be adjusted if unforeseen blasting and earth removal beyond the scope of the project is required. In order to maintain the safety of the community, traf ic on both School Harbor Road and Ridgewood Bluff Drive should be stopped during active blasting. As an additional precaution, spoils from excavation should be stockpiled on the southwest side of the lot to provide protection to the parking lot and existing structure at the baseball diamond. Should the bedrock prove to be more cost prohibitive than expected, an alternative design may be considered, such as the raising of grades around the building to limit the depth of blasting required.

No groundwater was encountered in the subsurface exploration, groundwater in iltration in excavations is not expected. However, if groundwater presents itself, water must be pumped away from the foundation walls. It is recommended that drain pipe be installed around the perimeter of the foundation, so that in iltration can be drawn away from the foundation.

Per OSHA standards, excavations must be sloped if they are deeper than ive feet.

Closing Statement

This geotechnical report and the recommendations were written based upon the geotechnical investigation performed on May 21, 2020, and are consistent with the indings at that time. Conditions in the ield may present themselves differently, and may have impacts unforeseen on the construction and constructability of the project. In such a case, Ex Nihilo is prepared to provide additional consulting services beyond the scope de ined in the project proposal agreed upon on February 17th, 2021. We look forward to providing continued support throughout the duration of this project. Should questions arise from information presented in this report, please contact us at our of ice number (608) 867-5309.

Appendix

Site Map

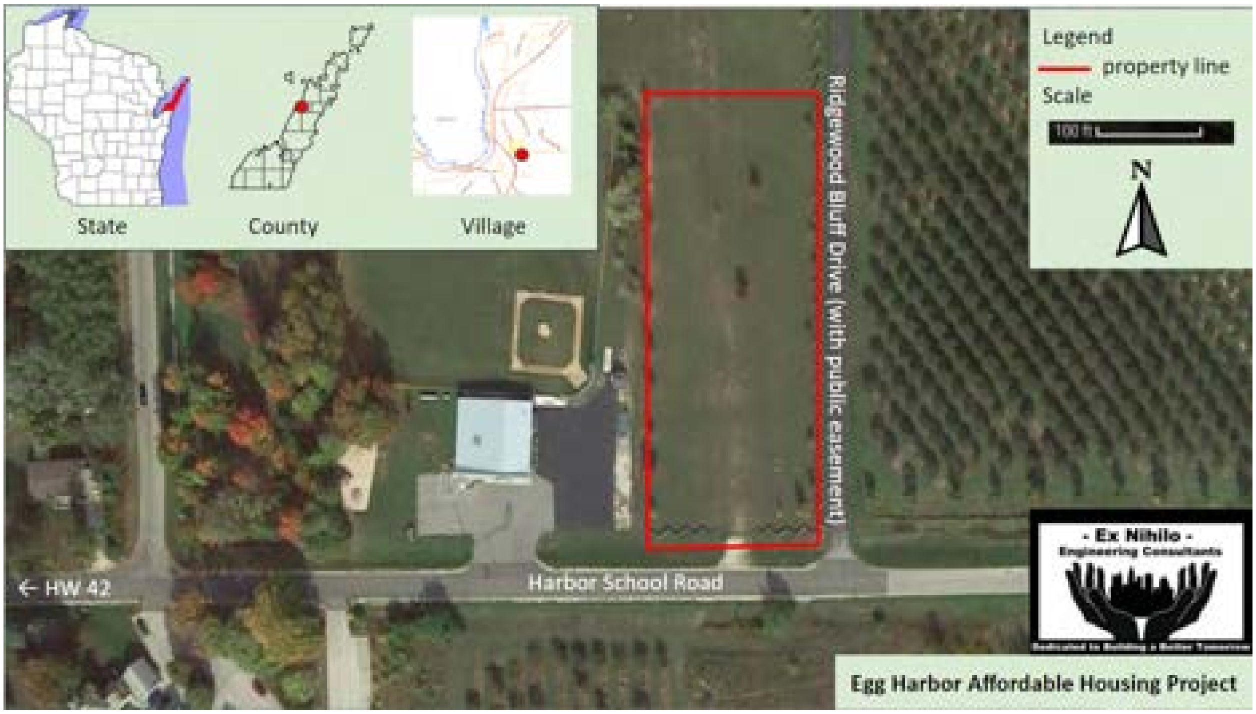


Figure 4: Site map with location, property lines, & geographic features.

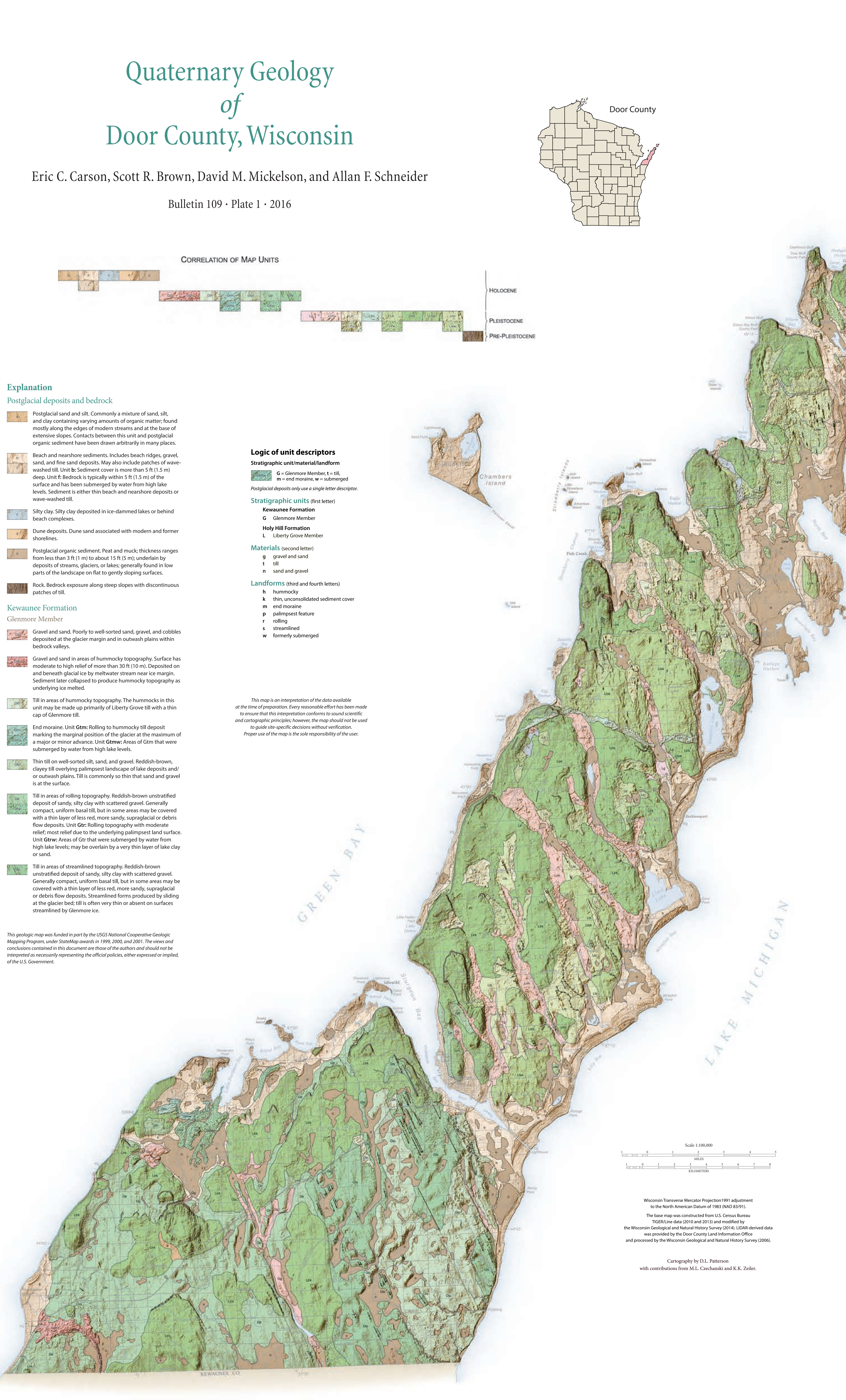
Regional Geology

Quaternary Geology of Door County Map included on the following page.

Quaternary Geology *of* Door County, Wisconsin

Eric C. Carson, Scott R. Brown, David M. Mickelson, and Allan F. Schneider

Bulletin 109 · Plate 1 · 2016



Explanation

Postglacial deposits and bedrock

Postglacial sand and silt. Commonly a mixture of sand, silt, and clay containing varying amounts of organic matter; found mostly along the edges of modern streams and at the base of extensive slopes. Contacts between this unit and postglacial organic sediment have been drawn arbitrarily in many places.

Beach and nearshore sediments. Includes beach ridges, gravel, sand, and fine sand deposits. May also include patches of wave-washed till. Unit **b:** Sediment cover is more than 5 ft (1.5 m) deep. Unit **f:** Bedrock is typically within 5 ft (1.5 m) of the surface and has been submerged by water from high lake levels. Sediment is either thin beach and nearshore deposits or wave-washed till.

Silty clay. Silty clay deposited in ice-dammed lakes or behind beach complexes.

Dune deposits. Dune sand associated with modern and former shorelines.

Postglacial organic sediment. Peat and muck; thickness ranges from less than 3 ft (1 m) to about 15 ft (5 m); underlain by deposits of streams, glaciers, or lakes; generally found in low parts of the landscape on flat to gently sloping surfaces.

Rock. Bedrock exposure along steep slopes with discontinuous patches of till.

Kewaunee Formation

Glenmore Member

Gravel and sand. Poorly to well-sorted sand, gravel, and cobbles deposited at the glacier margin and in outwash plains within bedrock valleys.

Gravel and sand in areas of hummocky topography. Surface has moderate to high relief of more than 30 ft (10 m). Deposited on and beneath glacial ice by meltwater stream near ice margin. Sediment later collapsed to produce hummocky topography as underlying ice melted.

Till in areas of hummocky topography. The hummocks in this unit may be made up primarily of Liberty Grove till with a thin cap of Glenmore till.

End moraine. Unit **Gtm:** Rolling to hummocky till deposit marking the marginal position of the glacier at the maximum of a major or minor advance. Unit **Gtmw:** Areas of Gtm that were submerged by water from high lake levels.

Thin till on well-sorted silt, sand, and gravel. Reddish-brown, clayey till overlying palimpsest landscape of lake deposits and/or outwash plains. Till is commonly so thin that sand and gravel is at the surface.

Till in areas of rolling topography. Reddish-brown unstratified deposit of sandy, silty clay with scattered gravel. Generally compact, uniform basal till, but in some areas may be covered with a thin layer of less red, more sandy, supraglacial or debris flow deposits. Unit **Gtr:** Rolling topography with moderate relief; most relief due to the underlying palimpsest land surface. Unit **Gtrw:** Areas of Gtr that were submerged by water from high lake levels; may be overlain by a very thin layer of lake clay or sand.

Till in areas of streamlined topography. Reddish-brown unstratified deposit of sandy, silty clay with scattered gravel. Generally compact, uniform basal till, but in some areas may be covered with a thin layer of less red, more sandy, supraglacial or debris flow deposits. Streamlined forms produced by sliding at the glacier bed; till is often very thin or absent on surfaces streamlined by Glenmore ice.

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program, under StateMap awards in 1999, 2000, and 2001. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

Logic of unit descriptors

Stratigraphic unit/material/landform

G = Glenmore Member, **t** = till, **m** = end moraine, **w** = submerged

Postglacial deposits only use a single letter descriptor.

Stratigraphic units (first letter)

Kewaunee Formation
- **G** Glenmore Member

Holy Hill Formation
- **L** Liberty Grove Member

Materials (second letter)
- **g** gravel and sand
- **t** till
- **n** sand and gravel

Landforms (third and fourth letters)
- **h** hummocky
- **k** thin, unconsolidated sediment cover
- **m** end moraine
- **p** palimpsest feature
- **r** rolling
- **s** streamlined
- **w** formerly submerged

This map is an interpretation of the data available at the time of preparation. Every reasonable effort has been made to ensure that this interpretation conforms to sound scientific and cartographic principles; however, the map should not be used to guide site-specific decisions without verification. Proper use of the map is the sole responsibility of the user.

Symbols

Geologic contact
Position shown on map is judged to be generally within 0.2 km of actual position.

Beach ridge
Wave deposited gravel and cobbles marking former shoreline positions. Symbol marks the crest of the ridge.

Drumlin
Length of arrow on symbol proportional to length of drumlin axes; arrow points in the direction of ice flow; cross-line on symbol proportional to drumlin width.

Esker
V points in direction of meltwater stream.

Meltwater stream

Niagara Escarpment

Holy Hill Formation

Liberty Grove Member

Gravel and sand. Poorly to well-sorted sediment deposited at the glacier margin and in outwash plains.

Sand, gravel, and till in patchy hummocky topography. Well-sorted to poorly sorted sediment deposited by meltwater and as debris flows from melting ice. Patchy hummocks and discontinuous fluvial channels were produced by melting blocks of ice and subsequent debris flows.

Till in areas of hummocky topography. Unit **Lth:** Brown to light yellowish-brown, crudely stratified or unstratified gravelly, clayey, silty sand; generally compact, uniform basal till, except in upper 10 ft (3 m), where sand lenses and other discontinuities may be found in mudflow sediments. Surface has moderate relief (less than 30 ft; 9 m), hummocky topography. Unit **Lthw:** Areas of Lth that were submerged by water from high lake levels.

End moraine. Rolling to hummocky till deposit marking the marginal position of the glacier at the maximum of a major or minor advance.

Till in areas of rolling topography. Light yellowish-brown, crudely stratified or unstratified, gravelly, silty sand, with little clay; generally compact, uniform basal till. Unit **Ltr:** Rolling topography with moderate relief. Unit **Ltrw:** Areas of Ltr that were submerged by water from high lake levels; may be overlain by a very thin layer of lake clay or sand.

Areas of thin till cover on rolling topography with very low relief. Bedrock typically within 5 ft (1.5 m) of the ground surface; sediment is Liberty Grove till, but in the southern part of the county may be covered with scattered patches of Glenmore till. In many places sediment has been completely altered by soil-forming processes making identification of parent material difficult.

Areas of thin till cover on streamlined topography. Low-relief land surface with drumlins and/or flutes on bedrock. Bedrock typically within 5 ft (1.5 m) of the ground surface. In many places sediment has been completely altered by soil-forming processes making identification of parent material difficult.

Till in areas of streamlined topography. Light yellowish-brown, crudely stratified or unstratified, gravelly, silty sand, with little clay; generally compact, uniform basal till. Unit **Lts:** Streamlined forms produced by sliding at the glacier bed; in areas with thin till cover, streamlined forms are composed entirely of till, but essentially lie directly on bedrock. Unit **Ltsw:** Areas of Lts that were submerged by water from high lake levels; may be overlain by a very thin layer of lake clay or sand.

Scale 1:100,000

1 0 1 2 3 4 5
MILES

1 0 1 2 3 4 5 6 7 8
KILOMETERS

Wisconsin Transverse Mercator Projection1991 adjustment to the North American Datum of 1983 (NAD 83/91).

The base map was constructed from U.S. Census Bureau TIGER/Line data (2010 and 2013) and modified by the Wisconsin Geological and Natural History Survey (2014). LIDAR-derived data was provided by the Door County Land Information Office and processed by the Wisconsin Geological and Natural History Survey (2006).

Cartography by D.L. Patterson
with contributions from M.L. Czechanski and K.K. Zeiler.

Wisconsin Geological and Natural History Survey

3817 Mineral Point Road • Madison, Wisconsin 53705-5100 • 608/263.7389
Kenneth R. Bradbury, *Director and State Geologist*
wisconsingeologicalsurvey.org

Topography

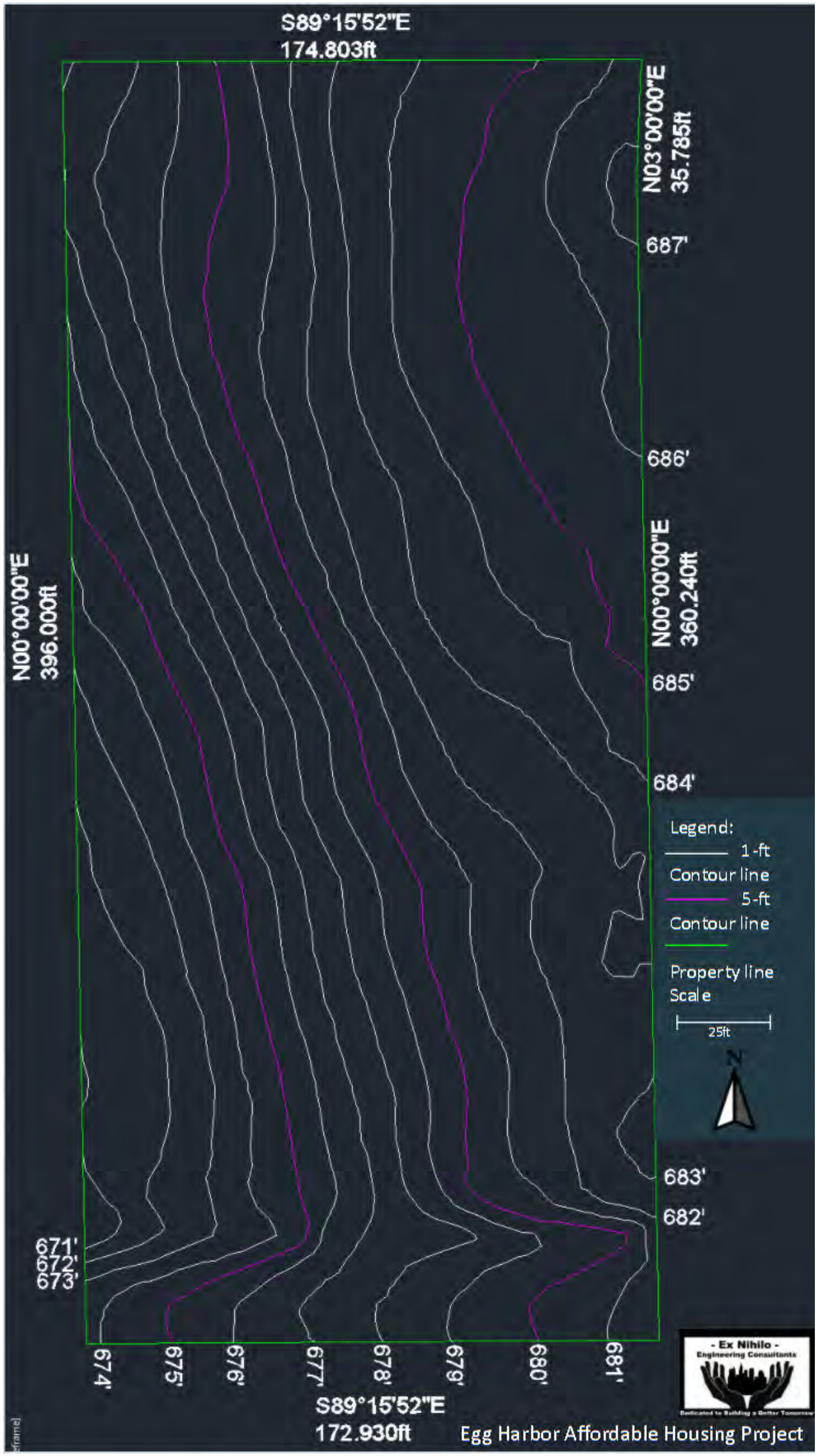


Figure 5: A detailed topographic map of the proposed site.

Boring Location Plan

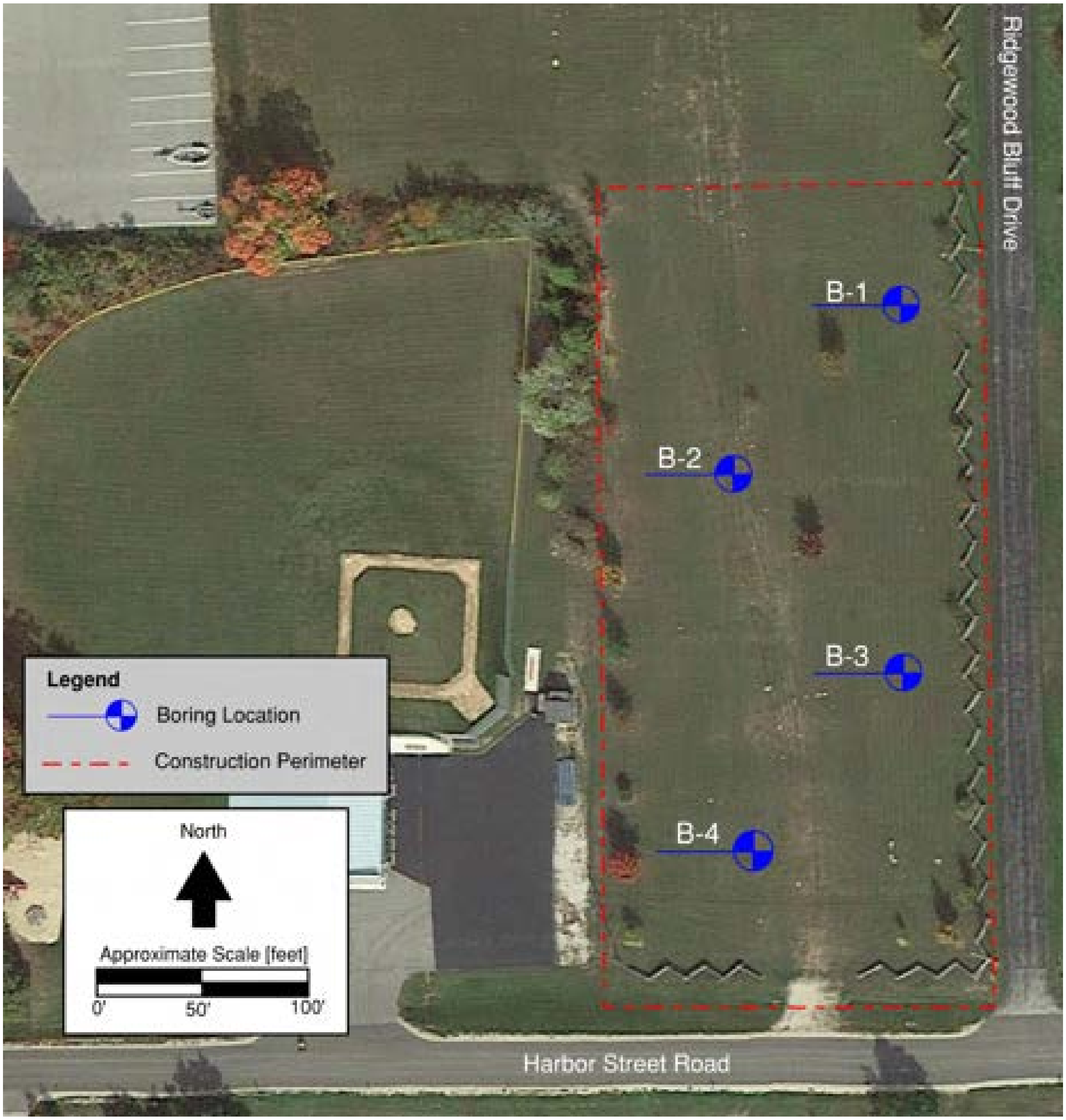
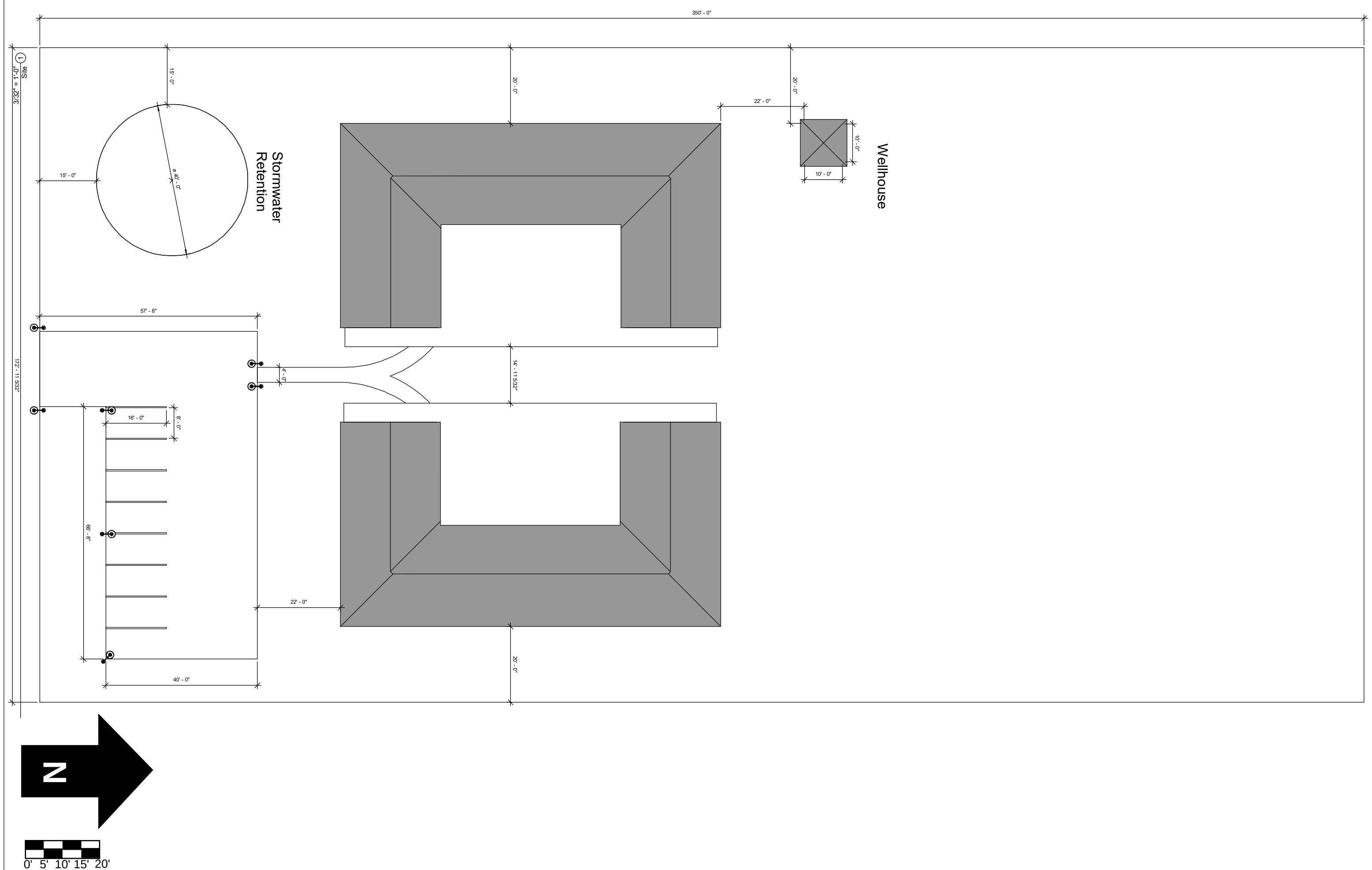


Figure 1: A detailed site boring plan.

Conceptual Design

Conceptual designs including floor plans, elevation plans, and site layouts included in the following pages.



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Ex Nihilo Engineering Consultants
1227 Engineering Hall
1415 Engineering Drive
Madison, WI 53706
(262) 422-5160

Design Team:
Molly Nemcek
Calob Limberg
Jasmine Shah
Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

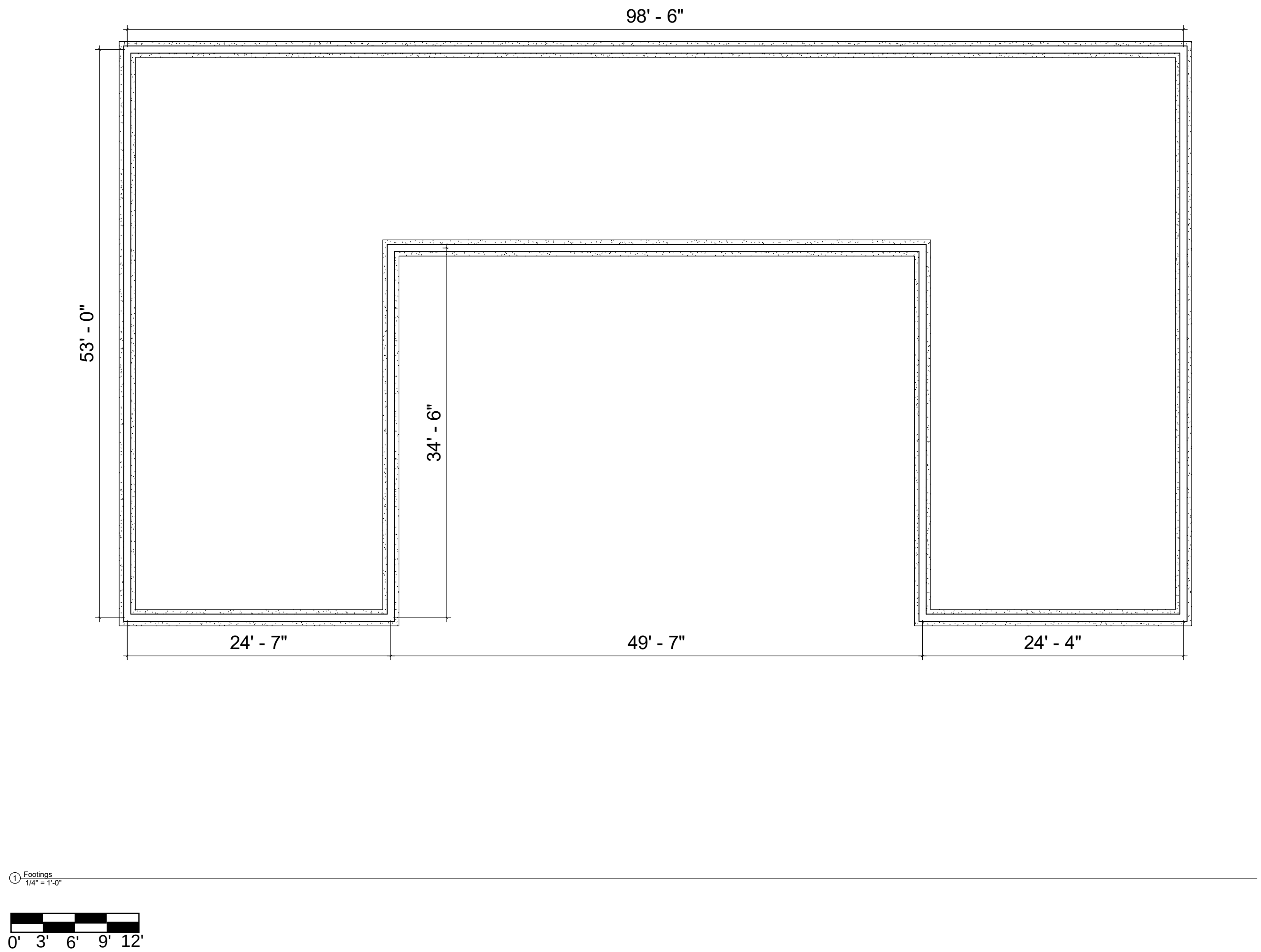
Apartment Site Plan

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-204

Scale	3/32" = 1'-0"

3/29/2021 7:27:43 PM



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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Footings - Apartment

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-203

Scale	1/4" = 1'-0"

3/29/2021 7:20:02 PM

1 South
1/4" = 1'-0"

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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Elevation View - Apartment

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-201

Scale	1/4" = 1'-0"

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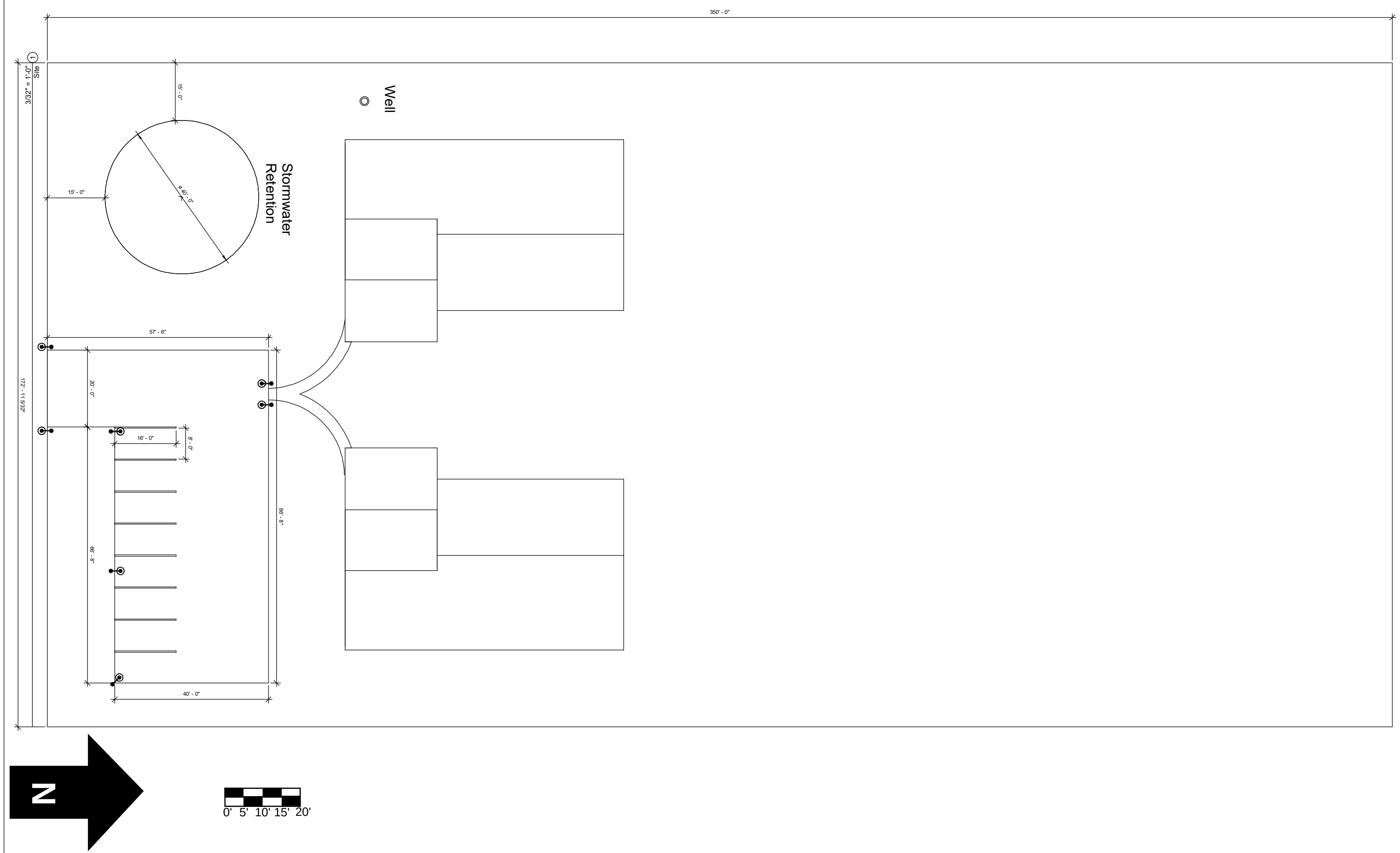

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No.	Description	Date

Village of Egg Harbor

Affordable Housing

Dorm Site Plan

Project Number	191848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-304

Scale	3/32" = 1'-0"

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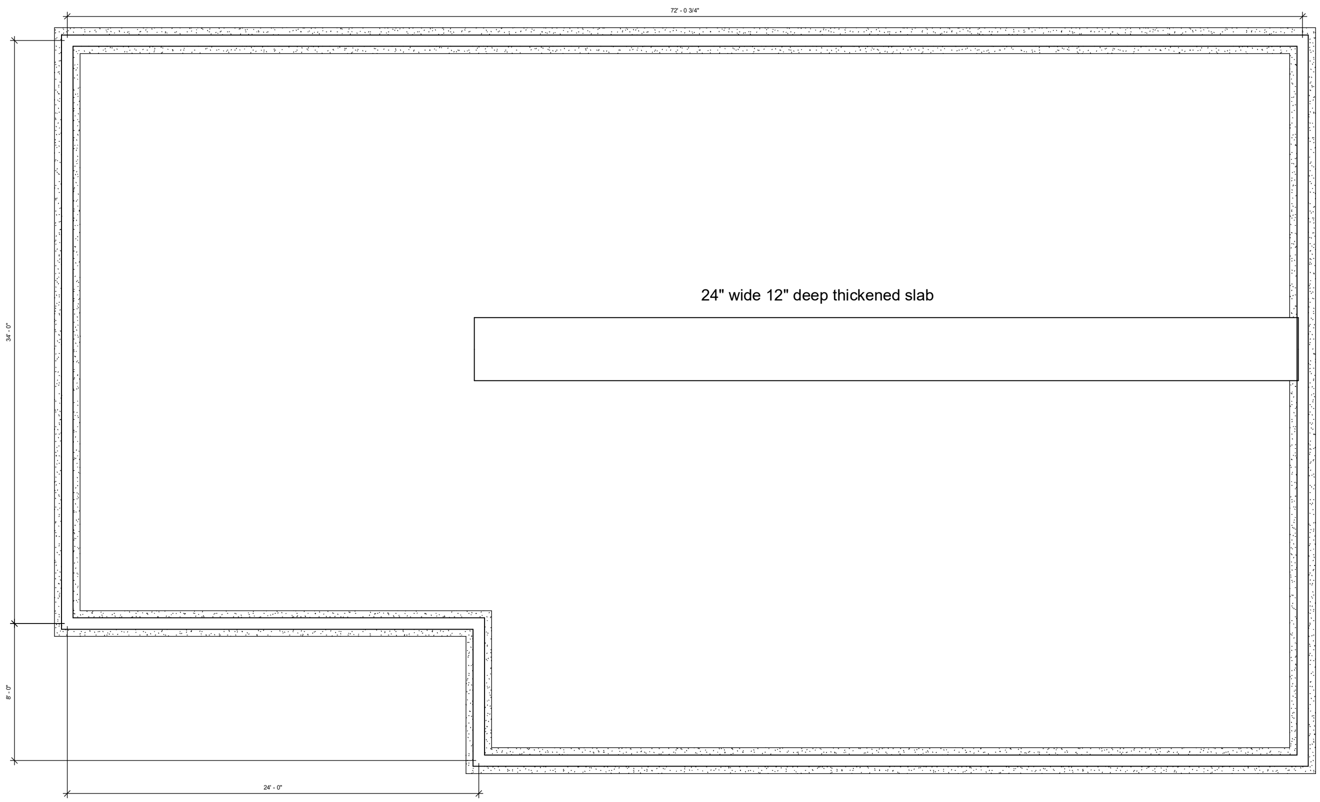

1 Footings
3/8" = 1'-0"

0' 3' 6' 9' 12'

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No.	Description	Date

Village of Egg Harbor

Affordable Housing

Footings - Dorm

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-303

Scale 3/8" = 1'-0"

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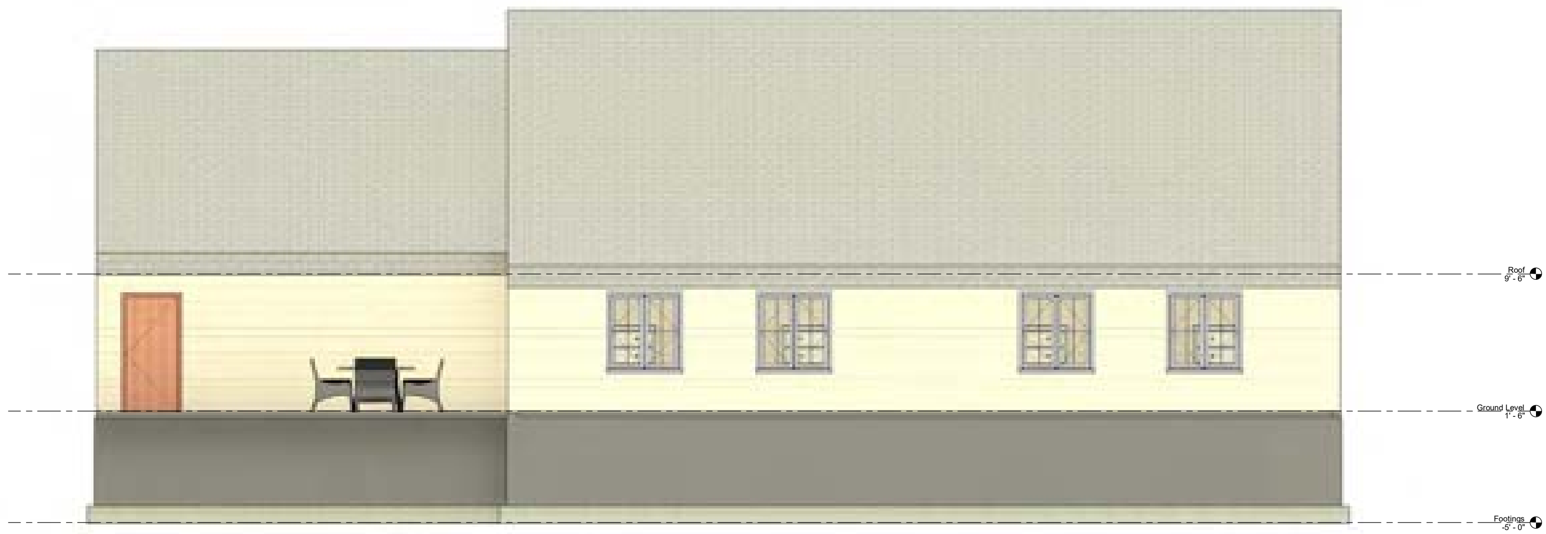

1 South
3/8" = 1'-0"

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Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Elevation View - Dorm

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-301

Scale	3/8" = 1'-0"

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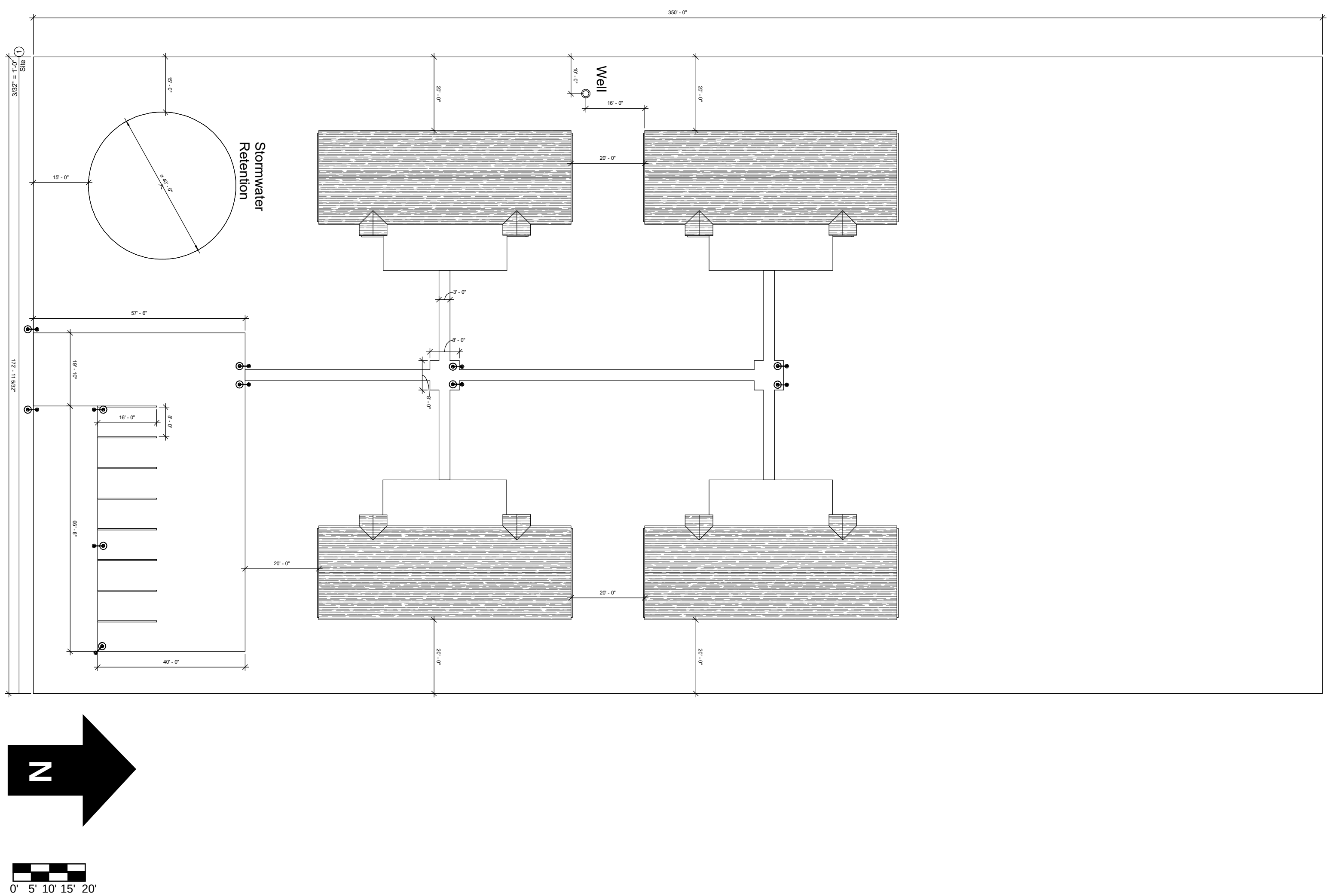

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Brett Hielsberg

No.	Description	Date

Village of Egg Harbor

Affordable Housing

Duplex Site Plan

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-104

Scale	3/32" = 1'-0"

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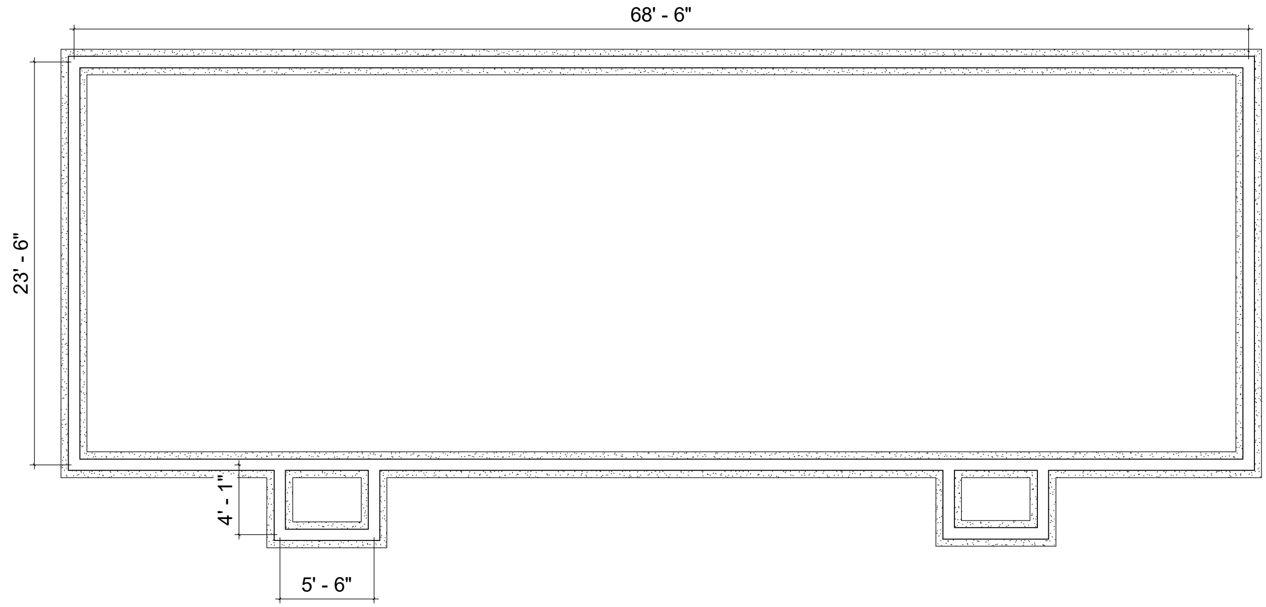
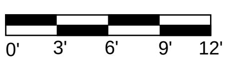


1 Footings
3/8" = 1'-0"



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Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of egg Harbor

Affordable Housing

Footings - Duplex

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-103

Scale	3/8" = 1'-0"

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1 South
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Design Team:
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Calob Limberg
Jasmine Shah
Adam Gorski
Brett Hielsberg

No.	Description	Date

Village of egg Harbor

Affordable Housing

Elevation View - Duplex

Project Number	091848
Date	3/29/2021
Drawn By	Calob Limberg
Checked By	Molly Nemcek

A-101

Scale	3/8" = 1'-0"

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Groundwater Flow Map

Figure 6: Ten Foot Groundwater Contours Map

Detailed Boring Logs and Laboratory Testing Results

Boring logs and laboratory testing results are attached on the following pages.

SOIL BORING LOG: B - 1

Project: Egg Harbor Affordable Housing
Project No.: 8675309

Location: Northeast corner of lot
Drill Date: May 21, 2020
Drilled By: KD/MD

DEPTH (feet)	EL.	VISUAL SOIL CLASSIFICATION (GROUND SURFACE ELEVATION: 686.0)	SAMPLE NO.	N (bpf)	Qp (tsf)	Qu (tsf)	MC (%)	REMARKS
		0-3": TOPSOIL	1-AU	-	- / -	- / -	- / 4	
		3-8": Gray Gravelly SAND, moist						
	690							
		Dark brown Silty Fine SAND, with gravel and light brown seams, moist						
1	689.5							
	689.0		2-SS	22	-	-	13	
2	688.5							⊥
	688.0		3-SS**	50/S2"	-	-	-	
		AUGER REFUSAL ON POSSIBLE COBBLES, BOULDERS, OR BEDROCK @ 2.5± FEET **END OF BORING @ 2.5± FEET**						
3	687.5							
	687.0							
4	686.5							
	686.0							
5	685.5							
	685.0							
6	684.5							

This boring log has been prepared for a UW Capstone Engineering class for educational use ONLY. It does NOT represent actual conditions and should NOT be used for any other purpose.

FIELD OBSERVATIONS:

Water Level during drilling: Not Encountered ⊻
Water Level upon completion: Not Present ▼
Caved at upon completion: 2± feet below ground surface (EL. 688.5±) ⊥
Delay Time: N/A
Water Level delayed: N/A ¥
Caved at delayed: N/A

ADDITIONAL COMMENTS:

**** No sample recovery.**

Note: Lines of stratification represent an approximate boundary between soil types. Variations may occur between sampling intervals and/or boring locations. Transitions may also be gradual.

SOIL BORING LOG: B - 2

Project: Egg Harbor Affordable Housing | **Project No.:** 8675309

Location: 100' S and 100'W of B-1 | **Drill Date:** May 21, 2020

Drilled By: KD/MD

DEPTH (feet)	EL.	VISUAL SOIL CLASSIFICATION (GROUND SURFACE ELEVATION: 678.0)	SAMPLE NO.	N (bpf)	Qp (tsf)	Qu (tsf)	MC (%)	REMARKS
		0-3": TOPSOIL	1-AU	-	-	-	-	
	679.5	3-9": Dark brown Gravelly SAND, moist			-	-	5	
1	679.0	Light brown Fine SAND, with gravel and trace silt, moist	2-SS	24	-	-	9	
	678.5							
2	678.0	Gray GRAVEL, with sand, moist	3-SS*	50/S2"	-	-	2	
		AUGER REFUSAL ON POSSIBLE COBBLES, BOULDERS, OR BEDROCK @ 2± FEET						
		END OF BORING @ 2± FEET						
	677.5							
3	677.0							
	676.5							
4	676.0							
	675.5							
5	675.0							
	674.5							
6	674.0							

FIELD OBSERVATIONS:

- Water Level during drilling: Not Encountered
- Water Level upon completion: Not Present
- Caved at upon completion: N/A
- Delay Time: N/A
- Water Level delayed: N/A
- Caved at delayed: N/A

ADDITIONAL COMMENTS:

*** Poor sample recovery.**

Note: Lines of stratification represent an approximate boundary between soil types. Variations may occur between sampling intervals and/or boring locations. Transitions may also be gradual.

SOIL BORING LOG: B - 3

Project: Egg Harbor Affordable Housing
Project No.: 8675309

Location: 200' N of Harbor School Road, east edge of lot
Drill Date: May 21, 2020
Drilled By: KD/MD

DEPTH (feet)	EL.	VISUAL SOIL CLASSIFICATION — GROUND SURFACE ELEVATION: 683.0	SAMPLE NO.	N (bpf)	Qp (tsf)	Qu (tsf)	MC (%)	REMARKS
		0-3": TOPSOIL	1-AU	-	-	-	-	
		3-8": Dark brown SAND, with gravel, moist			-	-	5	
	670.5	Dark brown SILT, with fine sand and gravel, and reddish brown seams, moist (BURIED TOPSOIL or POSSIBLE TOPSOIL FILL)	2-SS	50/5"	-	-	8	
1	670.0							
	669.5							
2	669.0		3-SS**	50/S2"	-	-	-	
		AUGER REFUSAL ON POSSIBLE COBBLES, BOULDERS, OR BEDROCK @ 2± FEET END OF BORING @ 2± FEET						
	668.5							
3	668.0							
	667.5							
4	667.0							
	666.5							
5	666.0							
	665.5							
6	665.0							

FIELD OBSERVATIONS:

Water Level during drilling: Not Encountered
Water Level upon completion: Not Present
Caved at upon completion: N/A
Delay Time: N/A
Water Level delayed: N/A
Caved at delayed: N/A

ADDITIONAL COMMENTS:

**** No sample recovery**

Note: Lines of stratification represent an approximate boundary between soil types. Variations may occur between sampling intervals and/or boring locations. Transitions may also be gradual.

SOIL BORING LOG: B - 4

Project: Egg Harbor Affordable Housing | **Project No.:** 8675309

Location: South end of lot, 100'N of Harbor School Road | **Drill Date:** May 21, 2020

Drilled By: KD/MD

DEPTH/EL. (feet)		VISUAL SOIL CLASSIFICATION GROUND SURFACE ELEVATION: 675.0	SAMPLE NO.	N (bpf)	Qp (tsf)	Qu (tsf)	MC (%)	REMARKS
		0-3": TOPSOIL	1-AU	-	-	-	-	
	659	3-8": Dark brown SAND, with gravel, moist			-	-	4	
1	658.5	Grayish brown Silty Fine SAND, with gravel, moist	2-SS	65/9"	-	-	8	
	658.0							
2	657.5							
	657.0	Brown Gravelly SAND, with trace silt, moist	3-SS	68/11"	-	-	9	
3	656.5							
	656.0							
4	655.5	Gray GRAVEL, moist	4-SS*	50/S1"	-	-	-	
		AUGER REFUSAL ON POSSIBLE COBBLES, BOULDERS, OR BEDROCK @ 4± FEET **END OF BORING @ 4± FEET**						
	655.0							
5	654.5							
	654.0							
6	653.5							

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FIELD OBSERVATIONS:

Water Level during drilling: Not Encountered

Water Level upon completion: Not Present

Caved at upon completion: N/A

Delay Time: N/A

Water Level delayed: N/A

Caved at delayed: N/A

ADDITIONAL COMMENTS:

*** Poor sample recovery.**

Note: Lines of stratification represent an approximate boundary between soil types. Variations may occur between sampling intervals and/or boring locations. Transitions may also be gradual.

<u>Site Photos</u>

Figure 7: An aerial view of the proposed site. (Credit: Google Earth)

FigurÍ ï : North facing site photo of proposed site, taken 03/04/21

FigurÍ ī : South facing site photo of proposed site, taken 03/04/21

FigurÍ ģġg West facing site photo of proposed site, taken 03/04/21

FigurÍ ģġg North-East facing site photo of proposed site, taken 03/04/21

Calculations

BÍ ĢĻĪĴ Ĩ CĢĹĢĦĪĻÒCĢĮĦŃĮĢĪĶĴ

Purpose: To determine the soil’s ability to carry the load created by the addition of a building. This calculation allows us to determine if the subsurface conditions are adequate to support the designed structure.

Methodology: Bearing capacity calculations are performed using the information provided by the Village of Egg Harbor geotechnical borings from an adjacent road project. Because the information is somewhat limited and assumptions will be required, our team has chosen to compare the calculated bearing capacities with recommended values present in the NAVFAC Design Manual 7.2 in order to determine their appropriateness relative to a standard design value.

Assumptions: Since each building sits on building footings around the perimeter of the building and no basement is included, it is assumed that the unit weight of concrete is 150 psf. The values for area of footing wall which is 775 lbs/lf, area of the footing which is 1.5 sf, and weight per lf of exterior building walls which are 1359.92 lb/ft for the apartment and 2096.72 lb/ft for the dormitory style are calculated in **Appendix C** in the **Preliminary EĴ Ĩ ĪĴ Í Í ĻĪĴ Ĩ DÍŁĪĨ Ĵ Report.**

Results: When calculating the bearing capacity range of the affordable housing units, the bearing capacity of the smallest and largest design options were considered. This considers the design of the dormitory style building with an area of 2891.9 sf per building and the apartment style building with a square footage of 3518.5 sf per building. Both designs sit on footings along the perimeter of the building.

The calculation for the weight per lf of the exterior walls of each building style were done in the **Structural and Design Calculations** in **Appendix C** of the **Preliminary Engineering Design Report**. The weight per lf of the footing wall (1) was calculated and added to the weight per lf of the exterior wall to then be used to find the foundation stress (2) of the apartment building and dormitory style building. Since each building is one floor and sits on foundation walls that cover the perimeter of the building, the calculated foundation stress (2) of the apartment building is 1423.28 psf and the dormitory style building is 1914.48 psf.

$h = * h$

(1)

Weight per lf footing wall = 5.17 sf * 150 sf = 775 lbs/lf

$$= \frac{h \qquad + \quad h}{\qquad}$$

(2)

Foundation Stress of apartment = (1359.92 lbs/lf + 775 lbs/lf) / 1.5 sf = 1423.28 psf
Foundation Stress of dormitory = (2096.72 lbs/lf + 775 lbs/lf) / 1.5 sf = 1914.48 psf

Once the foundation stress of each design was calculated, the value was compared to **Table 2** from the NAVFAC Design Manual 7.2 shown below. Because the bearing material in this case is a sand with gravel, (SW), in a loose state the recommended bearing capacity is 6,000 psf. Based on our calculated value of 1914.48 psf, we can conclude the bearing material is adequate with a factor of safety of 3.

TǤĤĮÍ ĥgNAVFAC Design Manual 7.2

NAVFAC Design Manual 7.2 (1982)			
Bearing Material	**In Place Consistency**	q_{all} (ksf) Recommended	Range
Massive crystalline igneous and metamorphic rock	hard sound rock	160	120 – 200
Sedimentary rock	medium hard sound rock	70	60 – 80
Weathered or broken bed rock	soft rock	20	30 – 50
Well-graded glacial till, hardpan (GW-GC, GC, SC)	very compact	20	16 – 24
Gravel, gravel-sand mixtures (SW,SP, SW, SP)	very compact	14	12 – 20
	medium to compact	10	8 – 14
	loose	6	4 – 12
Coarse to medium sand (SW, SP)	very compact	8	8 – 12
	medium to compact	6	4 – 8
	loose	3	2 – 6
Fine to medium sand, silty to clayey medium to coarse sand (SW, SM, SC)	very compact	6	6 – 10
	medium to compact	5	4 – 8
	loose	3	2 – 4
Homogeneous inorganic clay, sandy or silty clay (CL, CH)	very stiff to hard	8	6 – 12
	medium to stiff	4	2 – 6
	soft	1	1 – 2
Inorganic silt, sandy or clayey silt, varved silt-clay-fine sand	very stiff to hard	6	4 – 8
	medium to stiff	3	2 – 6
	soft	1	1 – 2

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Purpose: The purpose of the settlement calculation is to determine the adequacy of the subsurface conditions to support the designed structure without deflecting downward and causing damage to the structure.

Methodology: Hough's method was used in this instance to determine the total settlement of the subsurface. The Hough's Equation is shown below in Equation 3.

$$= \frac{}{\,'\,} \times \quad (\frac{\sigma_0 + \Delta}{\sigma_0}) \qquad (3)$$

Where,
δ = Total settlement of the layer in feet
H = Height of the soil layer in feet
C' = Bearing capacity index
σ_0 = Initial stress of the layer in psf (height of the layer * relative density of the layer)
ΔP = Applied load, the change in stress felt by the layer in psf

Assumptions:

- The relative density of the fine sand with gravel was determined to be the average value for sand with gravel of 122.5 lb/ft^3 in the NAVFAC 7.01.
- The sand is consistent in its engineering properties throughout the entire project site.
- The building load is uniformly distributed over the entire foundation.
- The maximum allowable settlement is 1".
- The weight per area of the buildings is 200 psf.
- The bearing capacity index, C' was approximated as a function of the corrected SPT value from the soil borings, a value of 135.
- Settlement occurs only in the sand layer.

Results: Because all Hough's settlement calculations are carried out and on a per unit area basis, our foundation stress assumption of 200 psf applies equally in each design option, leaving only one settlement calculation for all of our design alternatives. This 200 psf is then the only change in load the soil will experience in any given design scenario. Thus, the square footage is superfluous in this calculation. The below correlation shown in **Figure 12**, was used to find the C' value from the given corrected SPT values on the soil borings. Relative density in accordance with the soil boring logs was found in **TĢĤĮÍ ħ**.

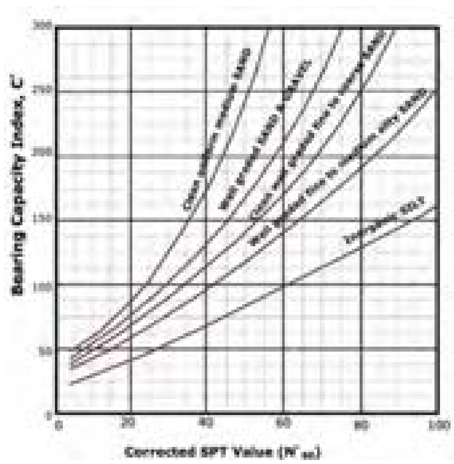

Figure 12: N’60 and C’ correlation used to complete the Hough’s calculation.

Table 3: Typical design relative density values from the NAVFAC 7.01.

Typical Values of Soil Index Properties (from *NAVFAC 7.01*)

Soil Type	γ (lb/ft^3)	γ_{sub} (lb/ft^3)
Sand; clean, uniform, fine or medium	84 - 130	52 - 73
Silt; uniform, inorganic	81 - 130	51 - 73
Silty Sand	88 - 142	54 - 79
Sand: Well-graded	86 - 148	53 - 86
Silty Sand and Gravel	90 - 155	56 - 92
Sandy or Silty Clay	100 - 147	38 - 85
Silty Clay with Gravel; uniform	115 - 151	53 - 89
Well-graded Gravel, Sand, Silt and Clay	125 - 156	62 - 94
Clay	94 - 133	31 - 71
Colloidal Clay	71 - 128	8 - 86
Organic Silt	87 - 131	25 - 69
Organic Clay	81 - 125	18 - 62

Using the C’ and γ values obtained in **Figure 12** and **Table 3**, they were inserted into the Hough’s equation to find the overall settlement of the 5’ sand layer. All variables are shown below in **Table 4**. Initial stress (σ_0) was found by multiplying the height of the layer (H) by the relative density (γ).

Table 4: Table of Settlement Variables and Results

Soil Description	N’60 [-]	Bearing Capacity Index [-]	Height of Soil Layer [ft]	Relative Density [psf]	Initial Stress [psf]	Applied Load [psf]	Settlement [in]
Fine Sand with Gravel	40	135	5	122.5	612.5	200	**0.184**

$$= \frac{}{'} \times \quad (\frac{\sigma_0 + \Delta}{\sigma_0})$$

$$= \frac{5}{135} \times \quad (\frac{612.5 + 200}{612.5}) = 0.0153 \text{ ft} \qquad (3)$$

0.0153 ft * 12 in/ft = 0.184 inches

Given that the maximum allowable settlement for a structure is 1 inch, the calculated settlement of 0.184 inches is deemed acceptable, and settlement is not expected to be an issue even in the worst case scenario where this sand is present. Settlement in the bedrock is negligible due to its stability.

Lateral Earth Pressure Calculations

Purpose: Lateral earth pressure is a calculated force on the below grade foundation walls, used to determine the adequacy of a designed foundation system and eliminate any overturn or wall movement.

Methodology: The Rankine method was used to determine the total active earth pressure force acting on the wall as a result of the presence of engineered backfill. The Equations 4-6 below outline the process of finding the coefficient of lateral earth pressures to be used in the final lateral earth pressure equation (7). The active coefficient is used in the final lateral earth pressure calculation.

Coefficient of lateral earth pressure at rest $(K_0) = 1 - \sin(Ø)$ (4)

Coefficient of active lateral earth pressure $(K_A) = (1 - \sin(Ø)) / (1 + \sin(Ø))$ (5)

Coefficient of passive lateral earth pressure $(K_P) = (1 + \sin(Ø)) / (1 - \sin(Ø))$ (6)

Lateral Earth Pressure $= ½ \times K_A \times \gamma \times z^2$ (7)

Where,
γ = *Relative density of the soil*
Ø = Internal friction angle of the soil
Z = Depth of the soil layer

Assumptions:

- The relative density (γ) of the fine sand with gravel was determined to be the average value for sand with gravel of 122.5 lb/ft^3 in the NAVFAC 7.01.
- The sand is consistent in its engineering properties throughout the entire project site.
- The internal friction angle (*Ø*) of the fine sand with gravel was assumed to be 37°.

Results: To calculate the lateral earth pressure, the depth of fill (z) next to the foundation is required. In each of the design options, there would be a maximum of 4 feet of fill next to the foundation walls. Additionally, lateral earth pressure coefficients are needed to be calculated to solve for the lateral earth pressure. Calculations for the rest (4), active (5), and passive states (6), respectively:

Coefficient of lateral earth pressure at rest $(K_0) = 1 - \sin(37) = 0.398$

Coefficient of active lateral earth pressure (K_A) = (1 - sin(37)) / (1 + sin(37)) = 0.249

Coefficient of passive lateral earth pressure (K_P) = (1 + sin(37)) / (1 - sin(37)) = 4.023

After these coefficients are determined, the active coefficient is used to calculate the lateral earth pressure with the following Equation 7:

Lateral Earth Pressure = ½ x 0.249 x 122.5 x 4^2 = 244.02 [lb/ft]

Limitations of Geotechnical Report

No rock coring or analysis of the bedrock was conducted in this geotechnical investigation, so the quality of the bedrock was not analyzed.

Groundwater conditions are known to vary seasonally and may differ from the conditions presented in this report.

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UniverCity Year is a three-phase partnership between UW-Madison and communities in Wisconsin. The concept is simple. The community partner identifies projects that would benefit from UW-Madison expertise. Faculty from across the university incorporate these projects into their courses, and UniverCity Year staff provide administrative support to ensure the collaboration's success. The results are powerful. Partners receive big ideas and feasible recommendations that spark momentum towards a more sustainable, livable, and resilient future. Join us as we create better places together.

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