Chesterfield Fire Station and Parks and Recreation

A Technical Report submitted to the Department of Civil and Environmental Engineering

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Design Problem Statement

Chesterfield county, located south of Richmond in Virginia with approximately 380,000 people, has been steadily increasing in population, especially given the proximity to the state's capital. The growing population has led to an increased demand for essential services, particularly emergency services and recreational opportunities. The lack of proper emergency services can pose a significant threat to the residents in the surrounding area, such as putting property or lives at risk, as they provide responses across the area. In addition to the fire station, there is a need for a parks and recreation facility. These facilities will create opportunities for community members to engage in various physical and social events. A collection of parcels in Chester, Virginia have been combined for the project to be developed in order to address such issues. The ultimate goal of this project is to design a fire station and parks and recreation facility on this plot of land to ensure public safety and provide the community with a way for interactions, all while meeting the necessary jurisdictional requirements.

Design Objectives

By April 2025, we will submit an approximately 8-page plan set, which will include at least one of each of the following: existing conditions, demolition plan, grading plan, utility plan, site plan, stormwater management plan, and erosion and sediment control plan. In addition to that, we will also submit a brief report summarizing the process and end results of this capstone project.

For the design to be accepted, our project needs to be submitted on time and meet industry standards for site design. Deliverables need to be compliant with local, county, state, and federal regulations for buildings, parks, and especially the fire station design. This includes federal regulations such as ADA compliance for the parks and recreation area or local zoning ordinance compliance. Additional regulations exist such as specific rules for fire houses because of the nature of the activities conducted within. These include the need for a safe roadway for fire trucks to drive through, a truck fuel area, and many more. All these requirements need to be met for the design to be accepted. Additionally, work needs to be clear, complete, and on time to be accepted as a proper design plan.

The constraints for our design project are detailed in the project requirements. This design project constrains us to the 15,500 sq. ft area of the fire station footprint, as well as the layout of the footprint itself, such that we are limited to where this building can be placed while still adhering to all of the other requirements including ADA, the setbacks defined under the Chesterfield zoning code for the O-2 district (and all other county policies and regulations), and all constraints defined by the Virginia DEQ. Additionally, the parks and recreation portion of this project has its own set of design requirements that constrain the area we may work in, such as avoiding as much disturbance as possible to the wetlands located on the parcel, while adhering to all the other similar requirements as stated before in addition to VDOT access management requirements.

Throughout the duration of our design project, we are assuming that all work will proceed according to the established schedule, meaning that everything must stay on schedule. This is important for managing risks and making sure that we meet our project deadlines without unexpected delays. We are also relying on a stable supply chain that will allow access to all the necessary materials, as would be expected in a professional setting. Furthermore, we assume that the software required for the project will remain properly licensed and accessible throughout the entire duration of the project, allowing us to complete the design work without any interruptions. Another assumption that we've made was that the overall goals and objectives of the project will remain stable, with stakeholders adhering to the original vision and refraining from making any changes that could alter the project's scope or impact the direction of our work.

There are several risks that could be presented as we progress with our project, and it is essential to be aware and prepared to tackle such risks. Time is a factor that is very sensitive and must be planned very meticulously as there are several aspects to the project and deadlines that we have set for ourselves. Variability in the team members' schedules is another factor that can significantly impact time because it requires coordination and communication. Further, communication in general is another risk as there are several moving parts in this project, including the team members, industry partners, and advisors. As each member brings different experiences and backgrounds in the collaboration, the individual skill and knowledge may vary, which can pose challenges. However, this can also be extremely beneficial as it can be an opportunity to learn from one another. Additionally, it is crucial that the team does not get carried away in the work and focuses on the project scope.

Design Constraints

Regulatory

The county of Chesterfield, in which the project site is located, presents several regulations and guidelines that engineers must follow. These constraints are implemented to ensure safety, protect the natural environment, and ensure ethical strategies. The Virginia Department of Environmental Quality provides projects with an Erosion and Sediment Control Handbook that outlines several standards that are intended to protect individuals on site as well as the site itself. An example of the safety regulation is a safety fence that wraps around the site perimeter to block people out who are not permitted to be on site. The constraints may present additional steps to the construction process, such as testing, certification, and selection of materials. However, it is crucial for engineers to consider these regulatory constraints in order to construct a properly functional design and meet all the requirements of developers.

Environmental

The wetlands on the site present an environmental constraint for the design process. Wetlands are protected by the Virginia Department of Environmental Quality and there are a few extra considerations for designs that are done on wetlands. Because of this, the design of the fire station and parks and recreation need to either avoid the wetland portion of the site or obey stricter standards. Because of other constraints which restrict the buildings to specific areas closer to the road, most of the design naturally avoids the wetlands. The trail through the back of the site must avoid disturbing the wetlands as well, and is therefore restricted to a small area which can be used.

Material Constraints

The site contains mostly soils of hydrologic soil group D and B with some group A soils, which affects a few of the design considerations for the redevelopment. We should consider those soil groups primarily when making decisions regarding cut/fill operations, grading, and stormwater management BMP (Best Management Practices) choice and design. Although we are not technically constrained by a budget, we have attempted to design with a reasonable budget in mind as a means to appeal to typical material constraints. Possibly the biggest restraint when it came to material was in pavement and roadway design. We aimed to minimize the amount of pavement used to generate less runoff and to appeal to budgetary constraints which would typically be present in this type of project. Otherwise, we are relatively unconstrained in the materials department due to this project being primarily land development based.

Site Limitations

The site for the proposed Fire Station and Parks and Recreation facility at 4700 West Hundred Road, Chester, VA, presents several limitations that must be considered during the design process. These include the need to rezone and combine parcels to meet the O-2 designation, adherence to specific fire station footprint and layout requirements, including multiple bays, parking, and utility connections, and compliance with access constraints outlined by VDOT, such as driveway width and turning radii. The maximum allowable grade for slopes is limited to 3:1, which may accommodate stormwater management facilities, ADA-compliant sidewalks and marking, and utility infrastructure. For the Parks and Recreation component, the inclusion of a muti-use path, shelters, and parking also requires thoughtful spatial planning within the undeveloped parcel. These constraints shape the available buildable area and demand a well-coordinated layout to adhere to both functional and buildable area as well as regulatory needs. Both the parks and recreation and fire station have set entrances that the designs must be connected to.

Design

To begin this project, the team determined the legal requirements and constraints put into place by the Americans with Disabilities Act (ADA) and the Virginia Department of Transportation (VDOT) to ensure that the design for the entrances, exits, and parking lots met the requirements put forth by these entities and those put forth by Dewberry (our industry partner). The specific requirements are listed in Appendix C. The team also determined the buildable area on the parcel prior to creating changes on the plot.

The property assigned to this project will have a 50’ setback from adjacent properties (zoned R-7, C-2, and C-3) except with the boundary with the road which will have a 10’ setback following [chapter 19.1 of the Chesterfield County, VA Planning Department Code Portal.] Additionally, The wetlands area may be developed with the proper permissions and precautions but should generally be avoided.

From there, the team worked on a demolition plan and a site plan. The first goal of the site plan was to place the fire station building footprint in a way that allowed emergency vehicles to exit quickly and easily return to their bays. Ease of fueling and maneuvering around the building was also considered. Once the approximate location of the building was determined, a large apron was designed on either side of the bays. A fueling station and dumpster were put on the back apron (further from the main road) in order to allow refueling to occur as trucks returned from calls, preventing congestion of bay exits on the front apron.

Then the team placed the fire station parking lot, focusing on keeping it close to the building without impeding the exits from the bays or the required buffer zone at the edge of the property. Once the parking lot was in place, a road could be designed to connect it and the aprons on the truck bays to the main road. Here the required minimum turn radius was used to ensure that trucks can pull in and out without reversing. The road and entrance were designed according to VDOT standards.

In conjunction with the design of the fire station section of this project, the team also worked on the recreational aspect. The first task was to determine ADA and VDOT requirements (similar to those for the fire station area, see Appendix C for more information). Then the parking lot was placed, this time close to the main road to minimize connection road length. A trail connecting to the Fall Line trail was mapped from the parking lot to the far edge of the parcel. Restroom facilities were placed near the parking lot to increase accessibility and decrease disturbance from construction on the site. Three shelters were placed along the trail at various intervals, one being right next to the parking lot for increased accessibility.

There were many iterations of the site plan before the above described version was selected. The one selected best met the requirements for minimal land disturbance, accessibility for people and emergency vehicles, and feasibility. With the site plan finalized, the team moved on to more detailed plans for various parts of the project: grading, erosion and sediment control, and stormwater management.

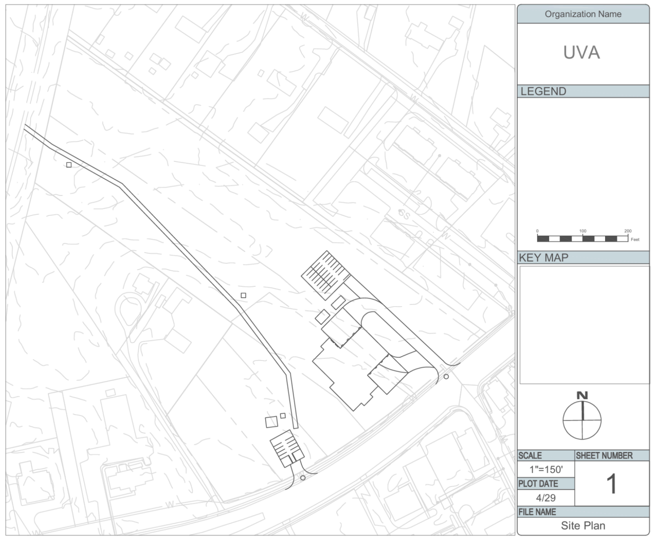

Figure 1: Site Plan

Once the site layout was finalized, grading was made according to project requirements and comply with ADA and VDOT standards. Grading for the Fire Station, Parks and Recreation, and Trail areas was designed in accordance with ADA and VDOT standards. Per ADA requirements, parking lots must maintain a maximum running slope of 1:20, a cross slope of 1:48, and a minimum width of 36 inches. VDOT standards require a maximum slope of 3:1 for roads, a minimum turning radius of 26 feet, and a drive aisle width between 24 to 30 feet. The trail through the site must follow a slope of 8% according to Dewberry, but maintains a reduced width of 10 feet. These requirements ensure safe, accessible, and efficient circulation throughout the site. To meet the standards and improve grading clarity, several adjustments were made during the design process. The simplified grading design for all three sites was kept, making the plans easier to read and revise. For the Fire Station Area (Figure D4), grading around the area still existed for the water to flow away from structures and pavement, reducing the risk of water accumulation or damage. Some adjustments to the feature lines were made to further enhance the contour lines. The grading for the Parks and Recreation Area (Figure D5) was adjusted to add slope onto the parking lot so that water would not accumulate on the parking lot. In the Trail area (Figure D6), was left as it was because it has already met ADA requirements. In the future, adjustments to the feature lines of the Fire Station will be revised even more. Some feature lines still produce inconsistent slope, especially along roads and near the Fire Station building. Adding cross-connecting feature lines will help you control cross slopes and improve surface transitions. The parking lot and the road zones next to it may also need slope adjustments. If one area is a dumpster pad, it must be leveled, and a retaining wall may be required where slopes exceed 3:1. These updates will enhance drainage, usability, and compliance.

The erosion and sediment control sheet of a plan set outlines the necessary methods of erosion control on the construction site. Such practices can be found in the Virginia Erosion and Sediment Control Handbook (VESCH) written by the Virginia Department of Environmental

Quality. The handbook functions to establish minimum design and implementation standards for these measures to control sedimentation from land-disturbing activities. Although there is a certain amount of erosion that occurs naturally, major problems can occur when excessive amounts of sediment enter waterways. The VESCH aids in properly managing any damage that happens, specifically with construction sites as the primary sediment pollution source.

The methods used for this project were a safety fence, super silt fence, construction entrance, temporary seeding, and permanent seeding. The safety fence acts as a protective barrier to prevent unwanted access to the site, while the super silt fence acts as a temporary sediment barrier to detain small amounts of sediment. A construction entrance is a stone pad with filter fabric that reduces the amount of mud transported onto public roads from the site. The seeding refers to a vegetative cover on disturbed areas, which helps reduce damage from sediment and runoff downstream. There are temporary and permanent seeding, where temporary seeding is implemented on areas that will not be brought to the final grade for more than 14 days and permanent seeding on areas left dormant for a period of more than a year.

For stormwater, the team attempted to model pre-existing conditions in ArcGIS Pro, however this was abandoned. This was done to determine the area of each land use accounted for in VRRM (forest, mixed open, managed turf, and impervious cover) crossed with underlying soil HSG (hydrologic soil group). HSG and land use greatly affect runoff volume, thus having the area of each land use combined with each HSG allows for the most effective stormwater management plan to be made. ArcGIS was used due to the team having experience with it on other projects, however it did not function with the CAD files from Civil 3D and the conversion to geodatabase files resulted in problems. The team shifted to learning how to use Civil 3D to combine the land use and HSG data. Once this was done the area of each land use and HSG combination was used to determine a composite curve number that can be used in a Stormwater Management Model (SWMM) model to model runoff for various storm events.

Using the models above, the team selected BMPs that meet the stormwater management needs of the site, reduce phosphorus and runoff, and seamlessly blend into natural and managed landscaping of the design. The chosen BMPs were bioretention and infiltration trenching.

The stormwater management portion of the design consists of a SWMM model that depicts the change in peak flow and total runoff volume for 24 hour 1, 10, and 100 year storms between the current developed area and the proposed redevelopment for the parcel. Additionally, the Virginia Runoff Reduction Method (VRRM) was used to determine the total phosphorus reduction that is needed to satisfy our design and existing government standards. Once these numbers were finalized, the VRRM spreadsheet was updated and gave the required phosphorus and runoff reductions. From here, the team selected the best BMPs, based on criteria in the Virginia Stormwater Management Handbook, and began determining their placement in the design. SWMM modeling supported the selection process and provided information on runoff within the parcel.

The SWMM and VRRM models were used in tandem to make decisions regarding the design of the best management practices (BMP) to be implemented to meet volume and pollutant reduction goals. The post development SWMM model was then updated with the chosen BMP specifications as added LIDs and an updated composite curve number to make appropriate comparisons. VRRM showed that the chosen BMP designs met all reduction requirements and exceeded the reduction requirements for phosphorus. SWMM showed a 0.79 inch reduction in total runoff from the site after the addition of bioretention and infiltration trenching to the post-development model for a 10 year design storm. Using VRRM, we had found that a 1.38lb/yr in total phosphorus and a 4535 ft^3 in volume were required for reduction to meet 80% reduction goals for pollutants and runoff volume reduction.

Using numbers gathered from SWMM and VRRM BMP selection was done such that the site meets 80% pollutant and volume reduction goals. The selected BMPs for this project include a level 1 bioretention system and an infiltration trenching system (following the design guidelines of "conventional infiltration") and designed in accordance with the virginia stormwater management handbook (see appendices D7 and D8 for details of the design). The bioretention system was chosen primarily to treat runoff from the fire station as well as the nearby roads and truck aprons due to its compactness and ability to function well in a relatively tight area (blue area, 31,000sq ft, see appendix D7). The infiltration trenching system was chosen as a means to treat the remainder of the stormwater for the site, including the rest of the roadway,, the parking lot, and nearby surrounding turfed area (green area, 77,000sq ft) see appendix D7). Additionally, the infiltration trench was designed with a pre-treatment course of grassy channeling (which would work alongside the grading done for this project) in mind serving as a way to direct runoff to the BMP. Both BMPs utilize infiltration as a means of volume control, so both had been sited atop HSG B soils such that their infiltration rates fall within the .3-.5 in/hr range which are required for the use of these practices.

Conclusion and Discussion

For this project our group worked to design a fire station and parks and recreation area in Chesterfield, Virginia. The result is a nine page plan set covering the buildable area, demolition plan, site plan, erosion and sediment control plan, grading, stormwater management, and utilities. The plan sheets show the final design choices for each of these categories, the design processes for which are explained above in the design section.

Further work on the design should focus on the details in the plan sheets. Profiles should be designed for both the BMPs and utilities, along with further specifications for both sheets. The design also requires the addition of electric connections, which have not been designed yet. Each plan sheet is a basic layout of the plan for that design aspect, but they could all benefit from more detailed designs which address the plan in a more granular manner. The SWMM modeling for the BMPs added to the stormwater design could also have benefited from further detailed design. Some assumptions were made to complete the modelling that could be replaced with more accurate values with a more thorough design process.

Transportation and access to the parcel was not heavily considered in this design project. Focus was given to the sheets that were produced, so further design work on the parcel could focus on understanding the transportation option to and from the parcel and ensuring that the roads and entryways are designed properly.

Given further time and the proper resources we would have wanted to be able to conduct a study of public opinion to factor into the design of the parcel. The fire station is defined by regulation and is necessary for the county, but the parks and recreation portion of the parcel design is flexible in what could be built. Discussions with the community would allow the design of the park to better meet the needs of the community it would serve, but this report did not complete that analysis.

While all of the sheets are successful in conveying a basic layout, several could be improved by considering the conclusions reached in the others. The stormwater design and grading were done at the same time, and relied on each other in some aspects. Stormwater design depends on the grading to understand slopes and paths of flow to model the movement of water on the site. Grading needs to be done around the BMPs to make sure that they are successfully implemented and meet the design standards for that specific BMP. We worked on grading and stormwater simultaneously, and the final designs would have benefitted from additional work together, as some decisions were made that were not able to be considered in the final versions of other design aspects. Additionally, the total phosphorus reduction goals had been exceeded; going forward we would likely rethink BMP design choices or resize them in a way that cuts back on pollutant reduction as a means of appealing to the increased cost that comes with the overengineering of BMPs.

Appendices

Appendix A - Detailed Schedule

The schedule for this project is split into four main sections based on the final deliverables we plan to complete – demolition; site plan; erosion, sediment and stormwater; and grading and utility. Each of these four sections is then divided into subsections that represent phases towards their completion. In general these subsections are a research phase, evaluation with existing conditions in mind, a concept rough draft, iterations of the design, and the final draft of the design, in the form of a plan sheet (or set of sheets). Each subsection is tasked to a team member or a group of two to three team members. Demolition (including mapping existing conditions) is headed by Esther and Jeremiah; site plan by Emma, Jeremiah, and Greg (though everyone was involved in selecting concepts to present to our industry partner and the final draft); erosion, sediment, and stormwater by Scout, Greg, and Emma; and grading and utilities headed by Greg and Esther. All group members will fill in as needed under each section.

Beyond the division of deliverable components, we have split tasks around scheduling meetings, communicating with our advisor and industry partners, and amongst group members. Scout was in charge of submitting our scheduling, scoping, and complexity assignments on time, including ensuring everyone had completed their parts. All group members contributed to writing and creating these assignments.

Appendix B - Design Evolution

Our design has gone through several iterations. One of the primary areas of evolution being the orientation of the roadway and fire station house; we had long debated how the fire station should be oriented to maximize fire station efficiency while minimizing the amount of road we must build in order to accommodate each orientation, until we finally landed on the final iteration for the overall design as can be seen in Figure D3.

We have also gone through a change in strategy for our approach to the stormwater design for this project. Initially, we were going to develop a set of SWMM models using ArcGIS Pro first to map out runoff in the pre and post developed scenarios. However, we then decided to first develop the VRRM model and determine what BMPs we will make use of and to get an idea of the runoff conditions we will be dealing with. Then we developed the SWMM models to help understand and meet runoff reduction goals.

For further information about design selections and progress see the Design section of the main report above.

Appendix C - Engineering Standards

The ADA handbook was consulted for the associated requirements that are applicable to the site's parking lots and trail access. The site contains 2 parking lots, both which must adhere to the sloping requirements of a 1:20 maximum running slope, 1:48 crossing slope, and width of 36” minimum. The international symbol for accessibility is included into each accessible space as requested by ADA standard. Each parking space has a width of at least 96” and includes an access aisle of desirable width. The parking spaces were orientated such that they are as close as possible to the entrance to the firehouse and the trailhead for ease of access. Each parking lot has a capacity of less than 25 spaces, so both lots were given one 132” wide accessible van parking space. The shelters along the path were designed to meet the requirements set by ADA; they each supply 10’ by 10’ of floor space, with a restroom and shelter supplied at the trailhead for accessibility.

The Virginia Department of Transportation has several guidelines that were used to design parking lots for both the parks and recreation area and the fire station. Entrance and exit requirements include a 26’ minimum inside turn radii and maximum entrance grade for trucks is 8%. This turning radius was used for the design of the parking lots and adequate apron space was included for trucks to turn completely without reversing. The entrance grade was also followed in grading efforts. VDOT also requires that a two way road must be at least 24’ wide. Connecting roadways from the entrance and exit of the site are two-way and follow this requirement.

The Virginia Erosion and Sediment Control Handbook was used to identify standards for erosion and sediment control on the site. The guidelines for several options are established in the handbook and four options were chosen to be implemented. A silt fence and a safety fence were designed on the property lines as well as construction entrances at the two locations where the site connects to existing road and seeding is planned in several areas depending on predicted disturbance and proximity to construction.

The Virginia Stormwater Management Handbook was used to collect many of the values used in the SWMM models. Appendix A of the handbook contains information about Manning’s numbers, storage coefficients, and curve number values that can be used for different land uses and soil types. These standard values from the handbook were used for modeling stormwater flow and runoff to match state standards. The industry standard design storms of 1, 10, and 100 years were used to estimate runoff values and runoff reductions due to redevelopment and BMP additions.

The Virginia Runoff Reduction Method was used to determine appropriate runoff and phosphorus volume reductions for our project. The VRRM users handbook describes the need for a 20% reduction in phosphorus load from the pre-redevelopment site for a site that is sized greater than 1 acre. The handbook also describes the need for a 20% reduction in runoff volume from the pre-redevelopment site conditions. Additionally, the handbook describes standards associated with the chosen BMPs to be employed into our design (bioretention and infiltration trenching).

Appendix D - Technical Deliverables

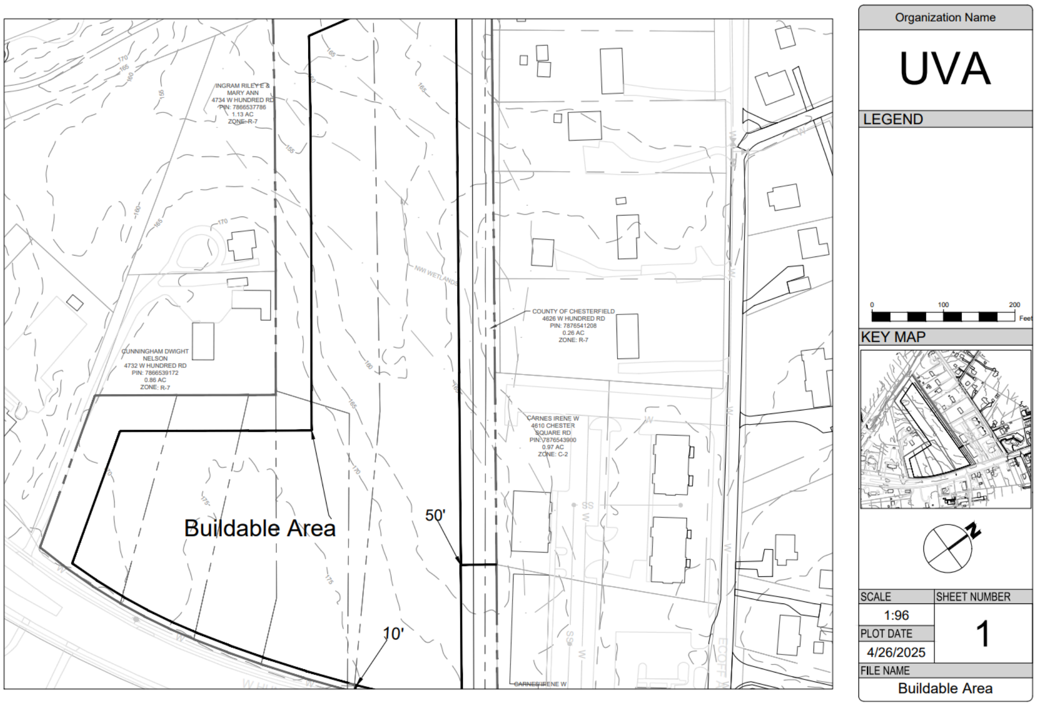

Figure D1: Buildable Area

Figure D2 : Demolition Plan

Figure D3 : Erosion and Sediment Control Plan

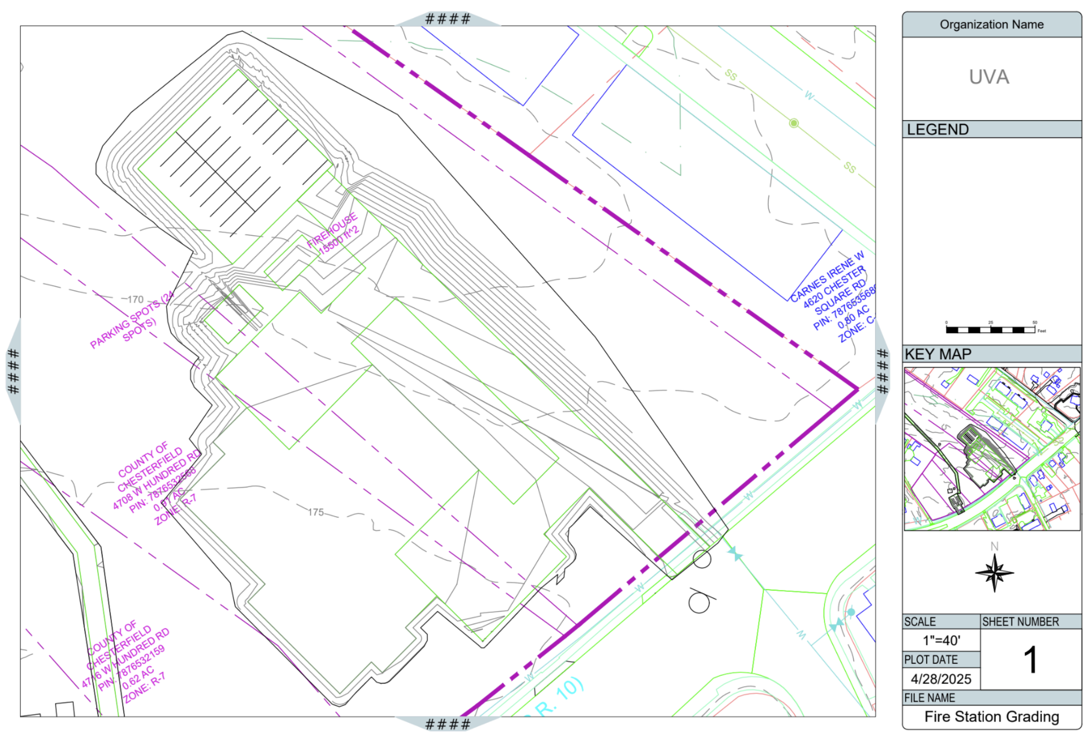

Figure D4 : Grading plan for the Fire Station Area

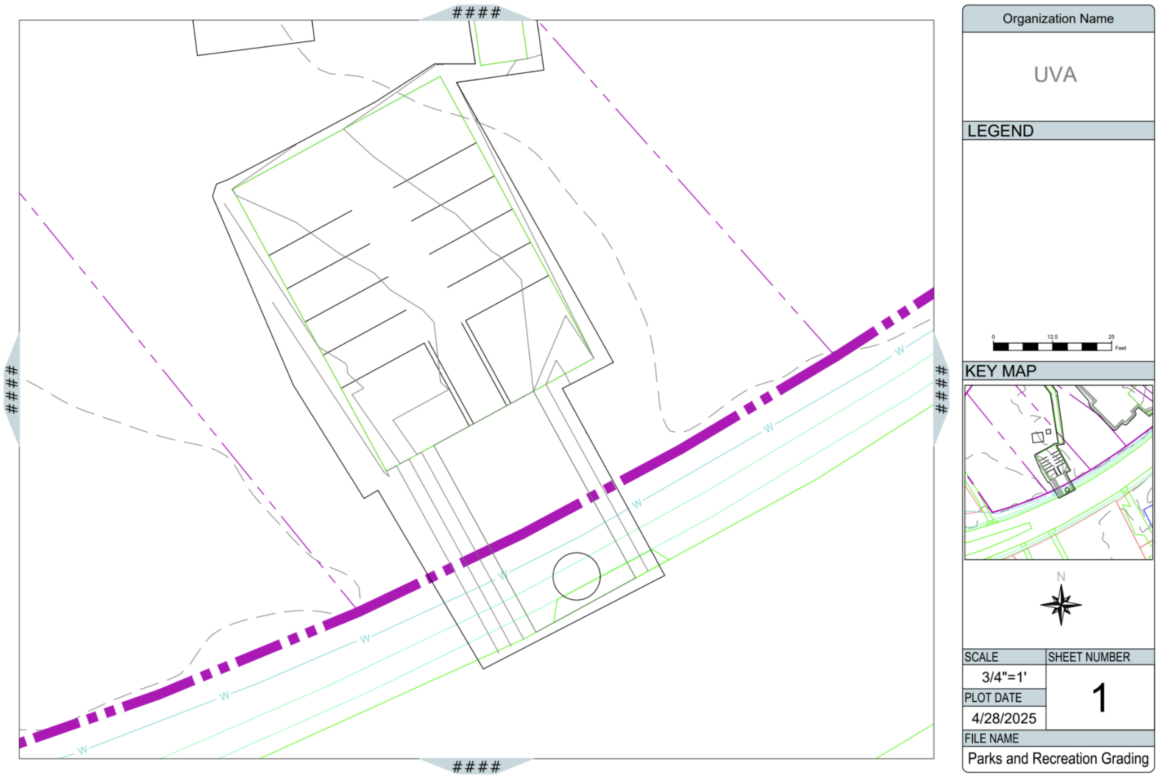

Figure D5 : Grading Plan for the Parks and Recreation Area

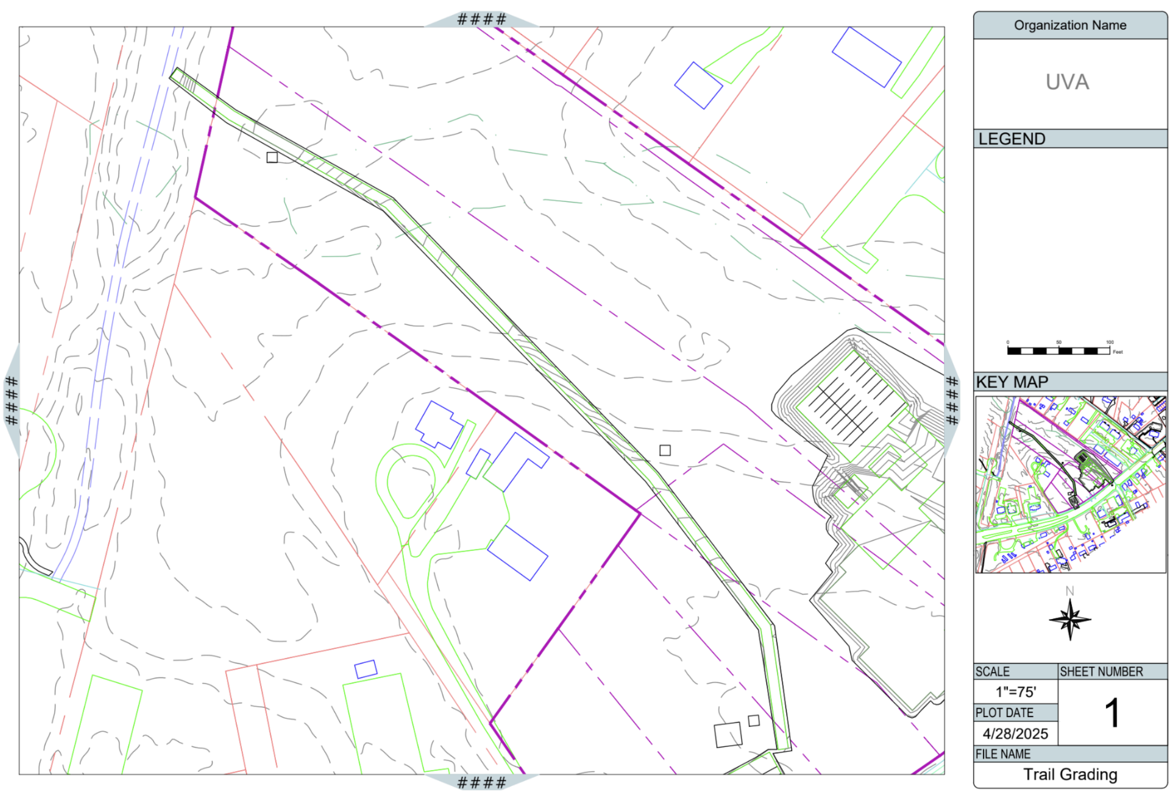

Figure D6 : Grading for the Trail

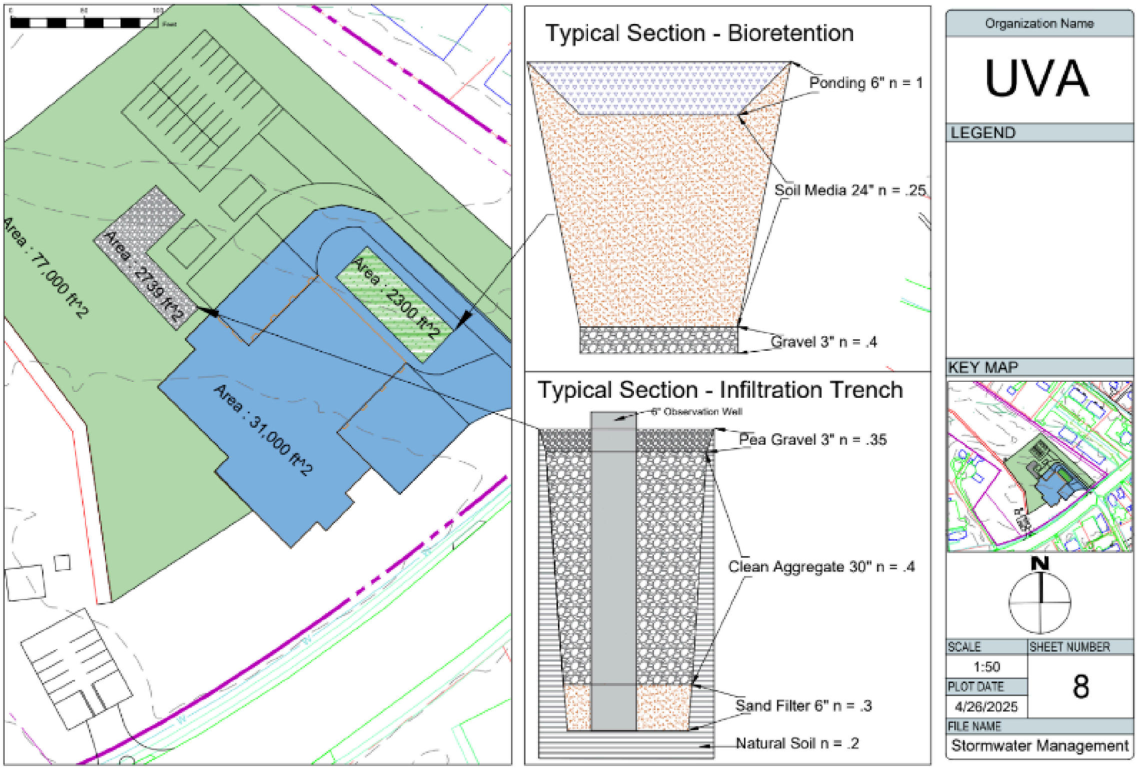

Figure D7 : Stormwater Management

[VRRM Redevelopment]

D8 : VRRM Spreadsheet

Figure D9 : Utilities Plan

Appendix E - Supporting Materials

[Link To Supporting Materials Folder]

Appendix F - Sources

Chesterfield County, Virginia Planning Department Code Portal (2025). Chester, VA.

U.S. Equal Employment Opportunity Commission: U.S. Dept. of Justice: For sale by the U.S. G.P.O., Supt. of Docs, Americans with disabilities act handbook (1992). Washington, D.C.

Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation, Virginia Stormwater Management Handbook (1999). Richmond, VA.

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Virginia Dept. of Transportation, Road Design Manual (2005). Richmond.