THE UNIVERSITY OF MEMPHIS

CIVL 4199 – CIVIL ENGINEERING SENIOR DESIGN

REST AREA ADJACENT TO PROPOSED I-69

Interim Design Report

Senior Design Report

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Disclaimer: This report is student work. The contents of this report reflect the views of the students who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the views of the University of Memphis. The recommendations, drawings and specifications in this report should not be used without consulting a professional engineer.

ACKNOWLEDGEMENTS

We would like to express the deepest appreciation to the owner, Dr. David Arellano, who has guided and assisted on the foundation of 901 Designs research and design. Without his guidance and persistent progress report requirements this project would not have been possible.

We are also immensely grateful Dr. Adel Abdenlnaby and Mohamed Osman for meeting with us and guiding us in the correct direction for structural design and self-sustainable design.

We would also would like to thank all of our faculty mentors in advance who are on standby to help us because they will be called upon to help 901 Design before the final design is complete. 901 Design is also grateful for Huan Ngo, Project Engineer of the Interim Report, for editing and compiling all the data into a sound document. Although any errors are our own and should not tarnish the reputations of these esteemed persons.

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CHAPTER 1: INTRODUCTION

The introduction is intended to provide an overview of the project as well as a summary of services that are to be provided throughout the project. Since this is an interim report, not only are the services identified for the entire project but a summary of services, up through October 22, 2018, are provided.

1.1 Purpose of report

This interim report has been prepared for the client, and it will serve as the progress report from the beginning of the project through October 22nd, 2018. The following report will include all alternative analyses that have been considered and evaluated at this current date. This does not include any alternative analyses that are yet to be evaluated after the submission of this report. At the end of the report, current progress in the form of design drawings and calculations will be provided for the work that has been done.

1.2 Project overview

The scope of the project is to design a rest area along I-69 for TDOT. Design aspects include the following: water resource, geotechnical, structural, environmental, transportation, and more. Water and sewage facilities make up the environmental design. The structural engineer chooses the site location and designs the restroom building. Transportation design focuses on exits, entrances, parking, and pavement. Drainage and storm water management are included in the water resources design. Subsurface exploration of the site is handled by the geotechnical engineer, who is also responsible for retaining walls, foundations and building slabs. Several remaining facets left to the design group include but are not limited to: picnic tables, shelters, sidewalks, benches, trash collectors, onsite and imported fill requirements. All items must meet Self Sustainability Building (SSB) goals by minimizing carbon footprint and maximizing its LEED rating. In addition, rest area design must consider: minimizing land use, compliance with Americans with Disabilities Act (ADA), and the reduction of operational, maintenance, and construction costs. Feasible examples of attaining LEED ratings and SSB goals could include: grey or rain water recycling, recyclable pavement materials, alternative energy sources, LEED certified building materials, landscaping, and vegetation. Facility aging must be considered in design choices for the rest area to mitigate rising O&M costs over time. Finally, the rest area must be well lit, adequately secured, and include all relevant emergency response technologies.

1.3 Existing site conditions

The following information has been compiled by 901 Design to provide an overall condition report of the proposed location for the project. A reconnaissance visit was made to observe any issues that were not reviewed from provided files. During the reconnaissance visit, photographs were taken of the property; however, the property is currently private which limited the range of the photography.

Limitation on site use

The proposed site for the rest stop will be constructed on farmland in a rural area. The land has no structural obstructions above grade that will cause any limitations in which this land could be used. Subgrade structures and utilities will have to be verified and worked around but. No limitations on land use are expected to rise from subgrade structures/utilities.

Access to existing roadways

Access to the rest stop site lies adjacent to Wilkerson Rd. Currently, there are no access points to the property except a dirt field roadway that seems to be used currently by farm equipment. Access points to and from the site need to be constructed in order to minimize impacts on traffic in the area.

Zoning

The proposed site encompasses 2 separate land parcels. The parcel numbers are:

- D0105 00006 and is owned by Robbin James G Living Trust.
- D0105 00015 and is owned by Rozelle Street Corp.

Both land parcels are zoned as farmland.

Setbacks

The setback for this project is 150 feet from each side of the interstate's centerline. This setback is so that TDOT will have room to add more lanes on the side of the interstate if traffic demands increase in the future. Currently, the proposed site is being used as farmland and has no development structures nor other utilities on the site.

Condition of existing structures

There are no existing structures on the site.

Geotechnical issues

Geotechnical Issues with this site are the soil properties. The site is located on a corn field that the soil is tilled at the beginning of each season and probably contains more organic material than average. To keep these characteristics from compromising our structure and roadway foundations we will need to remove the affected surface of the soil.

Hydrologic concerns

Some of the hydrologic concerns arise from the fact that the site is farm land. The site is relatively flat which doesn't promote runoff and could be exposed to flooding from Cole and Royster Creek.

Topography

Partial of the site topography is in possession of the group via a drawing under the format of AutoCAD file. However, the full site topography can be obtained from the service of U.S. Geological Survey (USGS) under the format of Quadrangle map with 7.5 minutes series. From the USGS directory website, the following topography maps are obtained containing the contour of the current site topography:

- TN_Brunswich_20160407_TM_geo.pdf
- TN_Drummonds_201305506_TM_geo.pdf
- TN_Millington_20160407_TM_geo.pdf
- TN_Munford_20160407_TM_geo.pdf

By compiling these files together, an image of the file topography can be shown in the following figure:

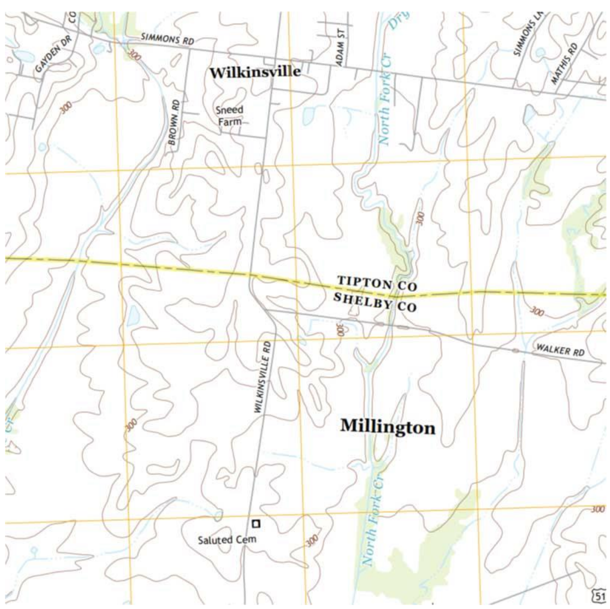

Figure 1. Site Topography

In addition, after the site reconnaissance, several real-time photos were taken for the help of visualizing how the site would be in the real world. The following pictures show the site reconnaissance photos.

Figure 2.a. Site Photo 1

Figure 2.a. Site Photo 1

Figure 2.a. Site Photo 1

Figure 2.a. Site Photo 1

Figure 2. Photos from Site Reconaissance Visit

Availability of utilities

The site currently has no utilities in the vicinity for immediate use. An initial survey provided by a TDOT contractor, who is no longer in service, was used to identify whether utilities were currently in the area. The survey indicates that there are potable water lines along Simmons Road due north of the proposed rest area site. However, those utilities are in the Tipton County jurisdiction and will not be used for this project. The designers have identified potable water supply provided by the Millington Water Treatment plant located parallel to Wilkerson Road that will be utilized for potable water supply to the site.

Transportation

The following drawing is a proposed preliminary design of the rest area layout based on the guidance of several states Department of Transportation.

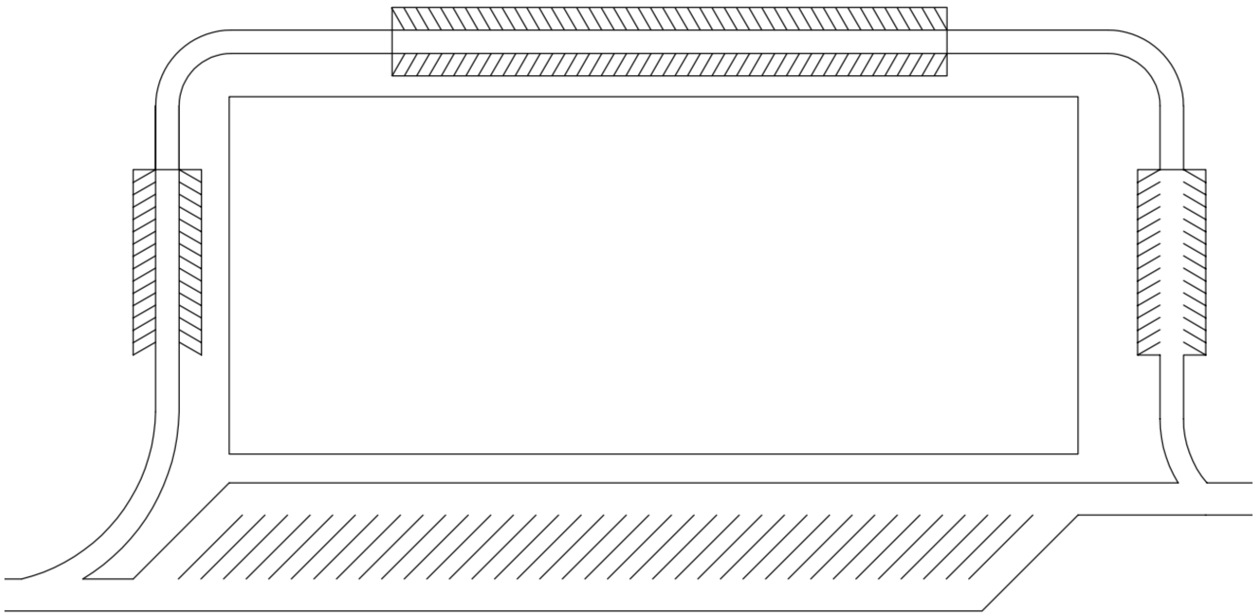

Figure 3. Preliminary Rest Area Site Layout

1.4 Summary of scope of services

The scope of services is the official description of the work that is to be completed during the contract. This section is to clarify all work that will be performed from the beginning of the project through the completion of the project for the design of a rest area adjacent to proposed I-69.

The following is a list of services that 901 Design will perform to complete the design of a rest area adjacent to proposed I-69:

- Site Selection: 901 Design will select a location from the given project criteria. A typical rest area requires approximately 12.5 acres of land, this is only an approximation and 901 Design can choose a location less than or greater than 12.5 acres if it meets all other criteria.
- Structural Design: Building plans with a full structural analysis of the building's structural frame. A detailed plan of the building dimensions and floorplan. Included in the structural analysis will be the various load case combinations that the building will be subjected to. Footing size recommendations will be provided. A thorough

assessment will be conducted for the structural frame as well as the roof type for the structure.

- Transportation Design: The transportation section will provide the following services: overall site layout design, car and truck parking lot design, and entrance and exit ramp design. In addition, 901 Design will also perform vehicle queuing analysis and Level of Service analysis for the section of the proposed I-69 Highway associated with the rest area.
- Water Resources Design: Drainage analysis of the existing site and post development will be done, so that it can be compensated for during and after development. The storm water analysis will be done, so designs can be made per the TDOT requirements.
- Geotechnical Design: A bore plan has been submitted to the owner for the required subsurface soil analysis. When the soil analysis is completed, a foundation design will be chosen based on existing soil parameters. The foundation will be analyzed for settlement and bearing capacity. The settlement analysis will include primary consolidation, elastic settlement, and secondary settlement. The bearing capacity analysis will examine the total stress and effective stress of the designed foundation. The type of foundation will be selected based on the highest score of the alternative analysis.
- Other Design Considerations: In addition to the services listed above, 901 Design will consider design methods that will allow the facility to meet the the client's self-sustaining building goal as well as implementing design methods to minimize the carbon footprint and maximize the LEED rating.

1.5 Summary of scope that has been completed through the alternative analysis

The scope of services that has been completed through the alternative analysis is the official description of the work that has been completed up through October 22, 2018. This section is to clarify all work that has been performed from the beginning of the project through October 22, 2018 for the design of a rest area adjacent to proposed I-69.

The following is a list of services that 901 Design has completed up through October 22, 2018 for the design of a rest area adjacent to proposed I-69:

- Site Selection: 901 Design has selected a location based off the given project criteria. Given the project criteria, having to keep a minimum distance of 3,000 feet away from any highway intersections, the desired location will be located approximately 3,800 feet south of Walker Road along the projected I-69.
- Structural Design: A conceptual building design with bathroom floorplan, that has not been analyzed and structural members have not been assigned. Load cases are in progress with spreadsheets consisting of load combination calculations. Settlement and footing size spreadsheet with calculations are in progress.
- Transportation Design: The following section has been completed up to the time of this report: Site Layout Alternative Analysis, Car Parking Alternative Analysis, and a Preliminary Engineering Design of Horizontal Alignment of Entrance and Exit.
- Water Resources Design: A conceptual set of storm water designs have been created. Calculations done to completion are not required for this alternative analysis. Each design has been assessed conceptually on the constraints created by the water resources engineer and the best option has been chosen.

1.6 Limitations to scope of services

The limitations to the scope of services are identified so the client can know what is expected from 901 Design. 901 Design consists of five Civil Engineering Major undergraduate students who are in their final semester at the University of Memphis. 901 Design does not have any licensed professional engineers on staff; therefore, the limitations to the scope of services will include but are not limited to the following:

- Inexperience – 901 Design does not have a licensed engineer on staff for any of the disciplines required to complete this project. All work (drawings, calculations, assessments, etc.) are not reviewed by an experienced, licensed engineer.
- Time – 901 Design has been given approximately three months to complete this project. This time frame dramatically impacts the research, calculations, analyses, drawings, preparation, and overall completed project. 901 Design will attempt to work a minimum of 12 hours per week to complete the project within the time frame allowed.
- Guidance – 901 Design will have the availability of the University of Memphis faculty to assist in any issues that may arise. A mentor has been assigned to 901

Design; however, their expertise is not in design work. The lack of a design mentor will impact the overall quality of the final project.

1.7 Organization of report

This report consists of nine chapters which will cover the analytical process, up through October 22, 2018, that 901 Design has considered. Here is an overview of the content of each presented chapter:

- Chapter One: *Introduction* – this chapter introduces the project and gives an overview of the services to be provided for the duration of the project as well as an overview of the services that have been completed up through October 22, 2018.
- Chapter Two: *Project Conceptualization* – this chapter defines the decision statements that will be addressed in the alternative analysis.
- Chapter Three: *Design Alternatives* – this chapter lists the design alternatives that 901 Design has taken into consideration.
- Chapter Four: *Fatal Flaw Screening Analysis* – this chapter will go through the decision statements presented in Chapter One, and with the use of the fatal flaw screening method, will eliminate any screened out alternative options.
- Chapter Five: *Alternative Analysis* – this chapter will carefully evaluate the remaining design alternatives. Using the alternative analysis matrix, each remaining design alternative will be evaluated with specific criteria that pertains to each individual analysis. The criteria will be weighted to prioritize the importance of each listed criteria. 901 Design will assign a higher weighted value to those criteria that are of greater priority.
- Chapter Six: *Summary of Additional Preliminary Engineering Design* – this chapter will summarize the progress, up through October 22, 2018, that pertains to each discipline within the project.
- Chapter Seven: *Summary* – this chapter will summarize:
    - the decision statements and recommended best alternative for each
    - any additional preliminary engineering design work
    - remaining scope of services for the project, timeline for project completion, and anticipated final design completion date and presentation date.

- Chapter Eight: *Bibliography* – this chapter presents the works cited page for this report.
- Chapter Nine: *Appendices* – this chapter will provide any drawings and calculations that have been done up through October 22, 2018.

CHAPTER 2: PROJECT CONCEPTUALIZATION

Definition of decision statement

The following decision statements will be assessed by 901 Design. These statements are to meet the given project criteria, which will be defined after each statement. To minimize cost, 901 Design will develop design alternatives in any applicable decision statements. The design alternatives will be furthered assessed with a clear decision summary to follow in chapter seven.

2.1 Decision Statement 1 – Site Selection

2.1.1 Owner's goals and objectives

A site will be selected for the design of a rest area along the projected I-69. This site will be accessible to vehicles from the south-bound lane. The site will include a rest room facility to accommodate the needs of the traffic that flows through that section of the projected interstate. On-site parking will be available for both passenger vehicles and trucks. The landscaping to be done at the site will try to take advantage of existing natural features and vegetation.

2.1.2 Constraints

A site will be selected with approximately 12.5 acres of land, this is an approximation and 901 Design may choose a site with more or less acreage depending on the needs of the controlling traffic volume. An attempt will be made to locate a site away from any adjacent residential and industrial land uses but still allowing access to nearby connections to municipal water and sewer systems. Finally, the site will be located no more than an approximate 3,000 feet away from any highway intersections.

2.1.3 Existing conditions

All land along the projected I-69 is private property and 901 Design had limited access available for reconnaissance visits. Photographs from the one reconnaissance visit can be found above in the existing conditions section of the introduction.

2.1.4 Future needs

The projected I-69 may need to expand in the future. In such a case, the Right-of-Way from the centerline of I-69 has been set at 150'. The site selection cannot be within the Right-of-Way.

2.1.5 No build alternative

The no build alternative is not an option for this project. A rest area has been identified as a need along the projected segment of I-69.

2.2 Decision Statement 2 – Structural Frame

2.2.1 Owner's goals and objectives

A rest room facility must be designed to service to needs of the average daily traffic that will flow through the projected segment of I-69. While designing a facility that meets the needs of the travelers, 901 Design will consider the client's self-sustaining building criteria. The facility must also meet local codes and regulations.

2.2.2 Constraints

Scheduling and inexperience are the main constraints. 901 Design has approximately three months to design a structure. With no experienced engineers on staff, 901 Design must rely on their previous school work to navigate the necessary codes in the design process. 901 Design will work a minimum of 12-hour weeks to conduct as much research as they can, so a final design can be presented by November 28, 2018.

2.2.3 Existing conditions

A structure does not currently exist.

2.2.4 Future needs

The structure's frame should be low maintenance over the duration of the structure's life. 901 Design will make efforts to identify a solution that minimizes operation and maintenance costs for the structure's frame.

2.2.5 No build alternative

The no build alternative is not an option for this project. A rest area has been identified as a need along the projected segment of I-69.

The no build alternative is not an option for this project. A rest area has been identified as a need along the projected segment of I-69.

2.3 Decision Statement 3 – Foundation

2.3.1 Owner's goals and objectives

A foundation must be designed to accommodate the structure for the proposed I-69 rest area.

2.3.2 Constraints

There are no constraints on cost, so the controlling aspect on which the foundation will be chosen will be primarily based on the results of the subsoil investigation.

2.4 Decision Statement 4 – Car Parking

The area designated for car parking is among the most important element within the design of the safety rest area. Every person starts and ends each trip as a pedestrian. While arriving at the rest area, private vehicle are accessed into the parking lot which then allow the its vehicle operator to successively leave their car and utilize the remaining usage of the rest area. Therefore, a well-designed parking lot serves as a “screening” criteria for an overall excellent rest area. The major design concept, which is highly related to quality of the parking lot, is parking module. The term parking module refers to the basic layout of one aisle with a set of parking stalls whose locations are defined relatively to the aisle.

2.4.1 Owner’s goals and objectives

Within the scope of car parking module design, the following, but not limited to, general objectives should be taken into consideration when performing an alternative analysis or conceptual design:

- To ensure the minimum number of parking lots as required by the user demand
  To minimize the area of construction
- To minimize traffic circulation pattern conflict which reduce the potential for accident
- To facilitate the process of entering/exiting the parking spaces
- To minimize the walking distances between the main building and the parking lot
- To maximize pedestrian safety

2.4.2 Constraints

The first main concern when designing a car parking lot is the size and the geometric of the area designated to it. 901 Design needs to be informed whether the final acquired land capital is sufficient to support the demand which can be calculated via the ADT. 901 Design also has an objective to minimize any modification to the current landscape, natural features such as tree, river, grading. These elements can limit the number of viable alternatives for car parking design.

2.4.3 Existing conditions

During the site reconnaissance visit and the given information from the owner, 901 Design is able to confirm that the acquired land is sufficient to accommodate the sizing demand required such as parking spaces, overall area. The site reconnaissance also allows 901 Design to acknowledge that the site is uniformly covered with small bush of tree and any car parking alternative would require the same amount of work to facilitate the land suitable for it.

2.4.4 Future needs

With a continuing increasing in the number of vehicle miles travelled, especially those associated to interstate travelling and freight traffic, the demand for rest area usage are increasing greatly to the near future .With a self-sustainability objective embedded in the design, 901 Design has accounted for the future demand of rest area usage when coming up with an alternative. The design is taking into consideration of annual daily traffic provisioned for the upcoming 30 years instead of the current statistics.

2.4.5 No build alternative

Car parking lot is a mandatory part of the rest area since unlike drive through facilities, vehicle operators need to safely park their car in order to access other utilities of the rest area. Therefore, the No Build Alternative will be eliminated without any further consideration necessary.

2.5 Decision Statement 5 – Pavement

2.5.1 Owner's goals and objectives

The pavement design for the project should be done in a manner that meets all design regulations and codes. In addition, it should incorporate the reuse of aggregate materials so as to maximize the LEED ratings as much as possible.

2.5.2 Constraints

901 Design has staff members with background knowledge of pavement design but does not have an in depth knowledge of the LEED criteria in order to obtain the highest rating possible for the pavement aspects of the design.

2.5.3 Existing conditions

The proposed site location currently is undeveloped and is being used for farm land. No paved roads exist on the site location but there are some farm roads on site that is currently used for farming equipment.

2.5.4 Future needs

The pavement is to be designed to accommodate passenger cars and tractor trucks. Also, the pavement design needs to incorporate the ability to be easily maintained as well as be reconstructed as cheap as possible at the end of its design life.

2.6 Decision Statement 6 – Sanitary Sewer

The Environmental aspects of the I-69 Rest Area Design Project encompasses 2 main design categories. They are Potable Water Supply and Sanitary Sewer. Potable water supply has to be provided according to the 2012 IPC therefor no alternative analysis was performed for this section. An alternative analysis was performed for the Sanitary Sewer. There are 2 options to consider. One option is to tie into an existing public sanitary sewer system which will transport wastewater to a treatment plant to be disposed of and the other is to install a septic sewer system which will treat and dispose of the wastewater on site. After performing an alternative analysis, the designer recommends a septic tank system to be utilized to handle the rest areas sewer needs. Also, a grey water recycling analysis was performed in guidance with section 1302 to determine that grey water recycling is recommended not to be performed for flushing but can be performed for watering needs.

2.6.1 Owner's goals and objectives

TDOT's goal for this project is to have a rest area that has the highest possible LEED rating, meeting the Self-Sustaining Building criteria, meet all local and state codes, and reducing overall rest area cost which is a driving force that results in closures of rest areas throughout the state of Tennessee as rest areas age.

2.6.2 Expectations of Stakeholder

It is expected that the proposed sanitary sewer system meets all local codes and regulations and does not have a negative impact on the environment. The rest area will be constructed in an area that is currently being used as farm land and has no current sewer system which indicates a sewer system will need to be supplied either by on site treatment or constructing pipelines to tie into an existing public system offsite. Due to code restraints, there is no option for the "no build" statement as it pertains to sanitary sewer.

2.6.3 Constraints

Section 701.2 of the International Plumbing Code requires that the rest area building shall be connected to public sewer, where available, or have an appropriate sewage disposal system in accordance with the International Private Sewage Disposal Code. Currently, there are no readily available sanitary sewer utilities provided at the proposed site. Grey water recycling, which is being considered, is also governed by the 2012 International Plumbing Code. Section 1302.1 of the 2012 IPC requires that grey water recycling systems used for flushing to have a collection reservoir not less than 50 gallons and shall be sized to limit the retention time of grey water to 72 hours. In addition to 1302.1, 1302.2-4 requires that grey water has to be disinfected, made up with potable water, and colored in order to be used for flushing. Section 1303 governs grey water usage for landscape watering. The constraints for watering are comparable to grey water usage for flushing except no disinfection is required but the retention time is limited to just 24 hours instead of 72 hours.

2.6.4 Future needs

Given the large number of rest areas that TDOT has had to close in the past few years due to increasing cost to keep the rest areas up, the utilities for the rest areas needs to be designed in a manner that reduces, where possible, increased systems cost as the facility ages.

2.6.5 No build alternative

The no build alternative is not an option for this project.

2.7 Decision Statement 7 – Storm Water

2.7.1 Owner's goals and objectives

The stormwater system must be able to limit the impact of flooding or standing water on people and I-96 vehicle traffic, and it must keep the site of the rest stop dry. 901 Design will do the required work will abiding the local code and considering the self-sustainability criteria.

2.7.2 Constraints

Scheduling and inexperience are the main constraints. With no experienced engineers on staff, 901 Design must rely on their previous school work and a staff member who teaches similar subjects to navigate the necessary codes in the design process. The engineering team only has three months to complete the entire design of the rest area. When creating a storm water storage system, most of the other engineering aspects need definitive numbers before any real work can begin. 901 Design will work approximately 12-hour weeks to conduct as much research as they can, so a final design can be presented by November 28, 2018.

2.7.3 Existing conditions

There are no current stormwater systems or drainage devices in place.

2.7.4 Future needs

The stormwater system should be low maintenance over the length of the structures life. 901 Design will identify ways to minimize the maintenance costs.

2.7.5 No build alternative

The no build alternative is not an option for this project. A rest area has been identified as a need along the projected segment of I-69.

2.8 Decision Statement 8 – Site Layout

The layout of entire rest area will fundamentally affect the usage and performance of the site. The selected alternative shall be in compliant with the existing topography of the site. In addition, it shall be designed to provide the most area of usage with the least modification of existing environment and building construction.

2.8.1 Owner's goals and objectives

The site layout goals and objectives shall conform to general objective of the owner and rest area design which is self-sustainability and minimizing environmental impact to achieve the LEED standard. However, within the scope of site layout, these objectives can be elaborated further which specifically apply to the design of site layout alone. The following information are the specific goals and objectives of the site layout:

- To provide a sufficient number of car, truck parking spaces
- To provide amble landscaping area to avoid overcrowded of usage
- To facilitate the needs of future expansion
- To minimize the total cost of construction which mainly comes from road alignment
- To be safely secure and protected from vandalism

2.8.2 Constraints

The general acquired land is the main concern when developing alternatives for site layout. The acquired land's size, its distinct geometric, and surrounding natural features can limit the options available for site layout. However, during the site reconnaissance visit, 901 Design are able to determine that there is no limitation so far with regards to the given site. Therefore, the alternatives are developed and suggested with little to no consideration of limited resources.

2.8.3 Existing conditions

The acquired land is a farm land as described in section X. The grading of the land is fairly even and 901 Design concludes that it is appropriate for constructing a new rest area.

2.8.4 Future needs

Within the calculation to determine the minimum requirement for size of the rest area, 901 Design has taken into consideration of the increasing demand for up to 30 years. This will allow the site to provide sufficient services without being overcrowded for at least the near future.

2.8.5 No build alternative

The site layout is a mandatory section of the rest area and without it, rest area cannot function as it should be. Therefore, “No Build Alternative” is immediately eliminated without any future consideration.

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CHAPTER 3: DESIGN ALTERNATIVES

This chapter defines the design alternatives that 901 Design will analyze. This section will not show any assessment of the alternatives. Only a definition will be provided to give the client clarity on 901 Design's intent.

3.1 Decision Statement 1 – Site Selection

3.1.1 Site Location 1

Site Location 1 is located at 1,100 feet south of Walker Road along the projected I-69.

3.1.2 Site Location 2

Site Location 2 is located at 3,800 feet south of Walker Road along the projected I-69.

3.1.3 Site Location 3

Site Location 3 is located at 2,000 feet north of Wells Road along the projected I-69.

3.2 Decision Statement 2 – Structural Frame

3.2.1 ASTM A992 – ASTM A992:

Steel beam is the most commonly used beam in construction.

3.2.2 Reinforced Concrete:

A typical concrete mix with a density of approximately 150 pcf will be used when evaluating.

3.2.3 Framing Lumber

Light structural lumber is mainly used in residential construction. It is milled from softwood trees (spruce, fir and pine) that are sawn and machine-planed to standard dimensions (2x4", 2x6", 2x8", etc.). Wood as a framing material is advantageous in that it doesn't undergo much transformation during processing, it has a low embodied energy, it's a renewable resource and it stores carbon.

3.3 Decision Statement 3 – Foundation

3.3.1 Slab Foundation

A slab foundation is a large, thick slab of concrete that is typically 4"-6" thick in the center and poured directly on the ground. The edges of the slab are thicker (as wide as 24") to allow for extra strength around the perimeter. Many foundations utilize post tension cables or reinforced with steel rebar to make the slab extremely sturdy and capable of bearing the load applied by the structure. The concrete slab is generally positioned on a layer of sand to improve drainage conditions and to act as a cushion. The slab foundation is primarily the cheapest in overall construction cost.

3.3.2 Continuous Wall Foundation

A continuous spread footing that is mainly used to provide a stable base around the perimeter of a building. Spread footings are often used in conjunction with interior spot footings. The spread footing supports the weight of the exterior or foundation walls. The thickness of the footing provides the necessary strength for that support. The width of the footing base provides a large area with which to transfer the weight from the walls to the ground.

3.3.3 Deep Foundation

- A deep foundation uses the friction of the subsoil or the bearing capacity of the deeper layer of soil to transfer the weight of the building to the ground. There are many types of piles that can be used for this type of foundation. Another deep foundation alternative that could be the used is drilled shafts. Drilled shafts are like piles with the exception that they are not drove into the ground like piles. The shafts are drilled to the specified depth, usually accompanied with a caisson to prevent cave in, rebar is added, and concrete is poured.

3.4 Decision Statement 4 – Car Parking

3.4.1 Alternative 1: Conventional Parking

This alternative shows the conventional layout of car parking which is widely used in commercial buildings. The alternative feature a 90o degree parking angle, two-way traffic, and a rectangular layout. Each parking stall are located adjacent to each other with respect to the longer side, forming a column of parking stalls. An aisle will be constructed between these columns so vehicle can access into the parking stall. There are 4+1/2+1/2 columns of parking stall each with 14 car parking spaces which combine into an aggregate sum of 140 car parking spaces. Figure 3 shows the general geometric of alternative 1:

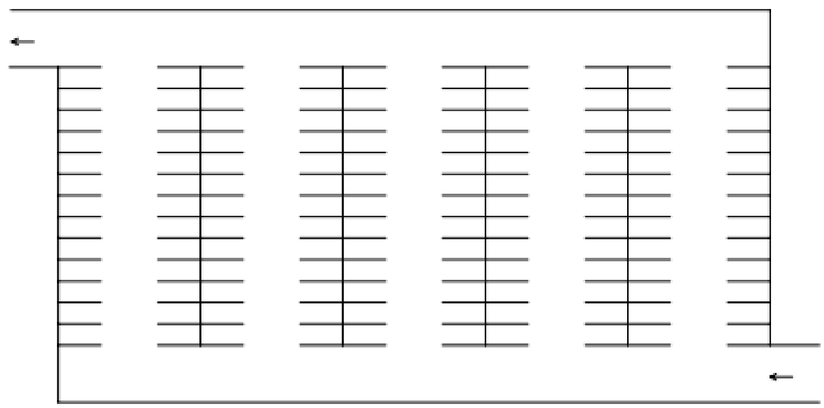


Figure 3. Alternative 1 Conventional Parking

The technical drawing of the parking lot will be provided in Appendix C.1. This alternative has the following advantages and disadvantages:

Advantages of alternative 1

- It is familiar to most of vehicle operators.
- It provides two-way traffic circulation throughout the parking lot.
- It does not raise any difficulties in construction compared to other alternative.

Disadvantages of alternative 1

- It requires larger area to accommodate the same number of parking lot which ultimately results in higher cost of construction, impervious area.
- Distances from each parking location to the rest area vary greatly.
- Vehicle operator has a harder time to park the car because of the larger turning radius.
- The parking layout does not provide the most comfortability for pedestrian.

3.4.2 Alternative 2: Angular Parking

This alternative's design emphasizes the characteristic of one-way traffic flow within the rest area. The alternative features a 45^0 degree angular parking, one-way traffic, and a rectangular layout. A 45^0 degree angular parking allows vehicle operator to pull into and out of the parking lot with less effort and higher precision, safety, and visibility compared to alternative 1. These advantages are emphasized further because the natural traffic characteristic of the rest area which is low turn over rate, high traffic volume circulation. Compared to alternatives 1, alternative 2 does not require as much aisle width because it serves only one way of traffic. However, it also raise potential hazard to unfamiliar vehicle operator in which they may drives into the wrong direction and disrupt the homogenous traffic flow. Figure 4. shows the general geometric of alternative 2:

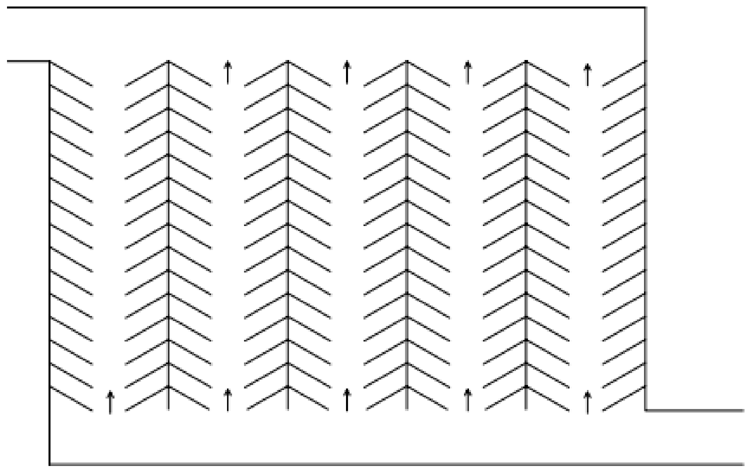


Figure 4. Alternative 2 Angular Parking

The technical drawing of the parking lot will be provided in Appendix C.2. This alternative has the following advantages and disadvantages:

Advantages of alternative 2:

- Vehicle operator can park in an easier manner because of the smaller turning radius
- The car parking layout promotes a homogenous flow with no cross traffic which ultimately results in less delay time in the situation of traffic congestion or queuing.

Disadvantages of alternative 2:

- Vehicle can only access the parking lot from one direction which may cause uneasiness for unexperienced vehicle operator
- The layout does not optimally utilize the geometry and area usage of a typical rest area overall site layout
- It is harder to construct
- Distances from each parking location to the rest area vary greatly
- The parking layout does not provide the most comfortability for pedestrian

3.4.3 Alternative 3: Angular Parking Along Curb Side of Alignment

This alternative incorporates the advantages of alternative 3 of angular parking and an optimum land usage of utilizing the parking along curb side of alignment. The alternative features a 700 degree angular parking, one-way traffic throughout the parking area. Compared to two other alternatives, alternative 3 utilizes the road alignment as its aisle which immensly reduce the area of construction. Traffic flow is forced to follow only one pattern but this feature actually serves as an advantage of alternative 3. The rationale is that it obviates traffic pattern conflict and promotes a uniform flow of traffic which is perfectly suitable for the characteristic of one-way traffic and low turn over rate of the rest area. Figure 5. shows the general geometric of alternative 3:

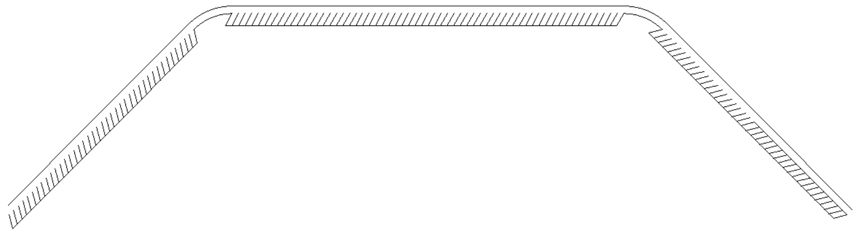


Figure 5. Alternative 3 Angular Along the Curb Parking

The technical drawing of the parking lot will be provided in Appendix C.3. This alternative has the following advantages and disadvantages:

Advantages of alternative 3:

- Distances from each parking lot to the rest area does not vary much, provides closer and easier access to the main building
- The parking lot is located right at the curb of the alignment which facilitates the driver in identifying vacant lot.
- Vehicle operator can park in an easier manner because of the smaller turning radius
- The car parking layout promotes a homogenous flow with no cross traffic which ultimately results in less delay time in the situation of traffic congestion or queuing.
- The entire parking lot requires a significant less area which ultimately decreases the construction, operation, and maintenance cost, as well as impervious area

Disadvantages of alternative 3:

- The capacity for expansion of the parking lot is dictated by the length of the alignment
- Future expansion or modification of current alignment configuration is prohibitive given parking lots are bounded to it.

The most appropriate alternative given the unique circumstances of the project can be selected among the three alternatives based on a process of objectively judging each alternative's performance within the following criteria. These criteria can be categorized into two types: mandatory criteria and desirable criteria which will be discussed further in the next section.

3.5 Decision Statement 5 – Pavement

Pavements are generally classified as 2 types, rigid or flexible. 901 Design recommends constructing a flexible pavement for the rest area based on the alternative analysis matrix that was performed. The construction of rigid pavements is generally time consuming, labor intensive, and the most expensive to initially construct.

3.5.1 Flexible

Flexible pavements are designed to depend on subbase layers to transfer the load in a prismatic downward fashion until the loads dissipates as depth of sub layers increase. They are also less labor intensive and easier to construct. Flexible pavements typically do not hold up as long to distresses as rigid pavements do but can be easily repaired as most damages occur to the wearing course. Flexible pavements are also easy to rebuild at the end of their design life through a milling and overlay process commonly used in pavement construction practices.

3.5.2 Rigid Pavements

Rigid Pavements are constructed out of concrete and are designed to carry the entire load produced by traffic without the use of subbases. Rigid pavements also have to be demolished and completely rebuilt at the end of the design life. However, due to their rigidity, rigid pavements usually incur less damage during their life span, as compared to flexible pavements, and provide a good ride quality. Flexible pavements are constructed from aggregates coated in asphalt.

3.6 Decision Statement 6 – Sanitary Sewer

There are 2 options that were chosen for Sanitary Sewer Design Alternatives. The options are to either tie into an existing public sewer or to install an on-site septic system. Based on the alternative analysis matrix and selection process, the designer recommends installing an on-site septic system.

3.6.1 Sanitary Tie-in

The option to tie into a public sanitary sewer was considered as it would provide access to a public sewer system which would treat the wastewater from the rest area. This option would require constructing a pipeline as well as any lift stations needed to accommodate the transfer of the wastewater to the nearest public sanitary sewer location. This option has a high initial cost during construction of the system but would have a less cost associated with it to operate and maintain the system over its life span. O & M costs occurred for this system would include things like blockage removals and damages to the piping that may occur during operation. The owner would only be responsible for the O & M on their sewer lines before the tie in to the main sewer system. However, the owner would have to construct the sewer main and lift stations for the public works supplier which contributes to a much higher construction cost. Also, this option would have to be reviewed and approved by the public works supplier as additional waste could overload the public Wastewater Treatment Plant (WWTP). This system provides cost efficiency, low maintenance, self-functionality and longevity for the life of the system.

3.6.2 Septic System

An on-site septic system was considered as a second option as it provides many benefits. A septic system is a type of treatment system which has a buried underground tank that receives wastewater from the facility it supports. Solids settle in the bottom of the septic tank while the remaining fluids are treated to remove contaminates that are harmful to the environment before being released back into the environment. After treatment, the water is funneled into the ground by the use of a French drain. This system provides a low cost of construction as it is constructed on site. Unlike the sanitary sewer tie option, the owner is responsible for the entire system. Longevity of the system is reduced as the tank will eventually have to be replaced when its design life ends. Self-functionality is also reduced as the solids would have to be removed from the system periodically for the system to work properly. This adds to extra O & M cost not associated with the tie-in to public system option.

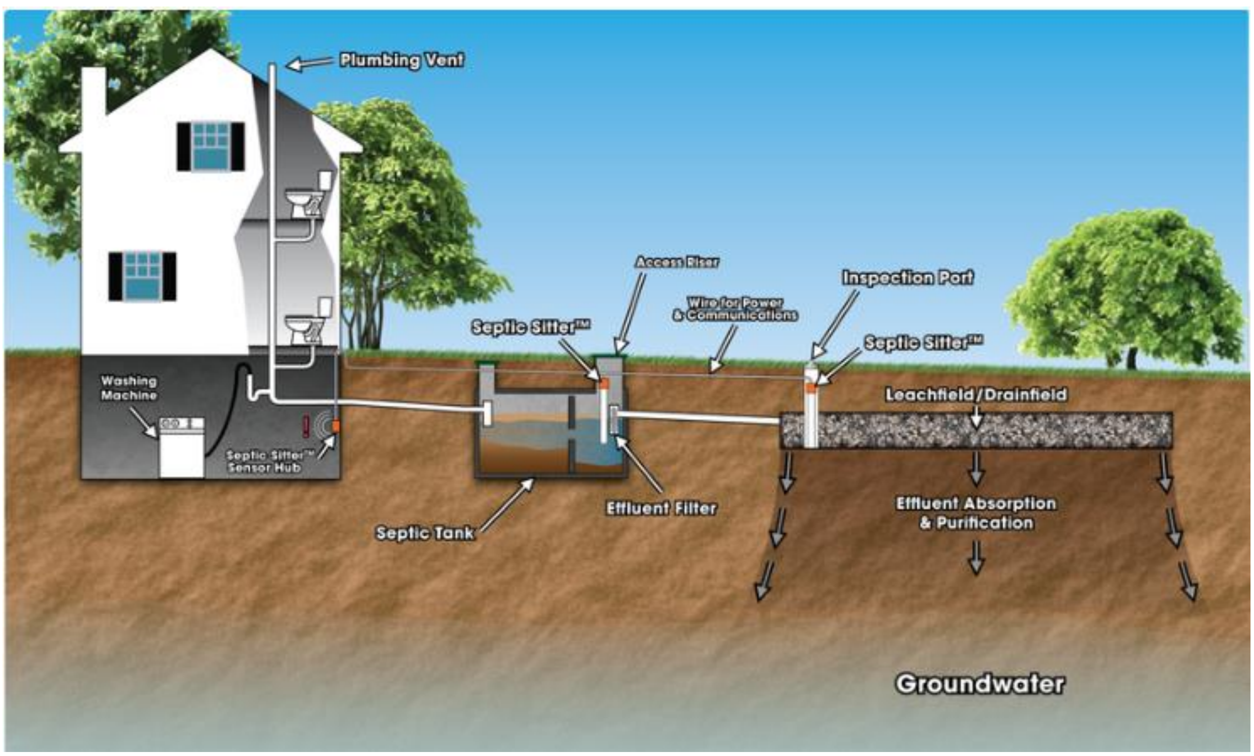


Figure 6. Typical Septic Tank System

3.7 Decision Statement 7 – Storm Water

3.7.1 Conveyance System Parallel Storage

This system is incorporated into the design of roadside ditches and the existing storm water system. The parallel system typically consists of a proposed conveyance system retrofitted with an overflow device that carries excess storm water runoff to a parallel pipe that reconnects with the system releasing the storm water at a controlled rate (CTEIT Department). An example of a conceptual layout of a conveyance system with parallel storage can be seen in figure 7.

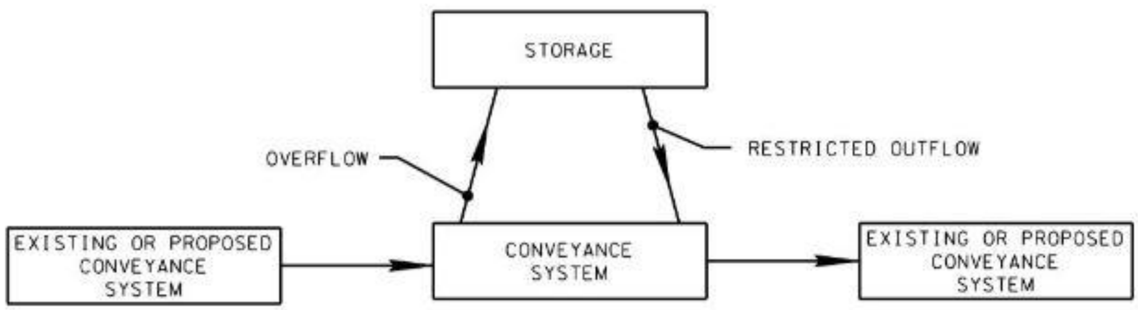


Figure 7. Storage Parallel to Conveyance System

3.7.2 Detention Basin

This system is a dry detention basin. It is a surface reservoir that is used to detain stormwater runoff and release it at a maximum rate that is equal to or less than the pre-developed runoff rate. TDOT requires the basin to have a dry bottom between rainfall events (CTEIT Department). An example of a conceptual dry detention facility can be seen in figure 8.

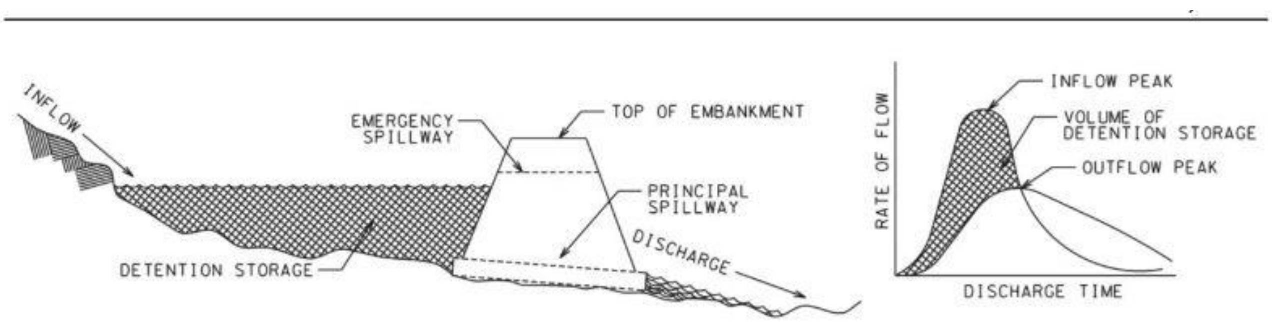


Figure 8. Typical Dry Detention Facility

3.7.3 Extended Detention Basin

This system is a retention facility that provides water quality and quantity features in its design by slowly releasing the storm discharge over a period of days using a drawdown device. Extended detention facilities allow sediment and other pollutants to settle out over time which helps improve water quality (CTEIT Department). A conceptual layout of an extended dry detention facility can be seen in figure 9 below.

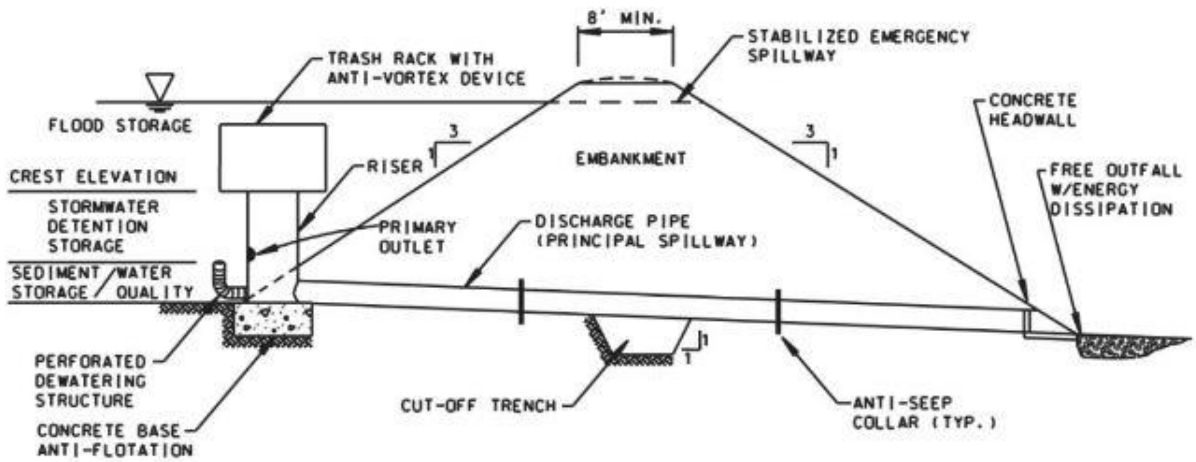


Figure 9. Typical Extended Dry Detention Facility

3.8 Decision Statement 8– Site Layout

3.8.1 Outward-Oriented Design

This alternative locates the major-used building away from both the car and truck parking area. The alternative has the following feature:

- A 90^o degree parking angle for 140 car parking stalls
- A 45^o degree parking angle featuring pull in and through for 35 truck parking slot
- An aggregate sum of over 6 acres of main area usage.
- Allowance of two-way traffic within the car parking area.

Figure 10 shows the general geometric of site layout 1:

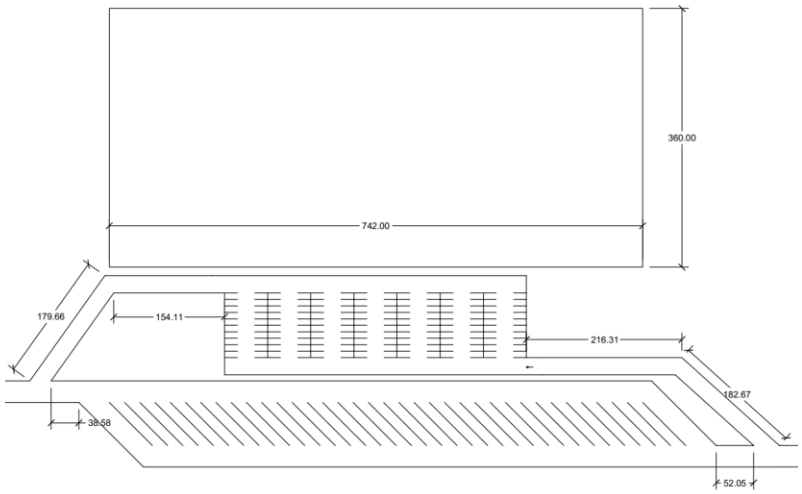


Figure 10. Outward-Oriented Site Layout

The technical drawing of the site layout will be provided in Appendix C.4. The following information shows the advantages and disadvantages of alternative 1.

Advantages of alternative 1:

- The site is open freely forward, providing large amount of area thus would avoid the situation of crowded area due to future demand.
- Future expansion is possible with only few modifications to the existing facility.
- Alignment construction is decrease compared to alternative 1
- It promotes a more pedestrian friendly layout compared to alternative 1 due to the layout not being surrounded by traffic.

Disadvantages of alternative 1:

- Access from truck parking area to the major-used building is prohibitive due to the greater distances.
- Truck drivers must cross the alignment of car parking although additional traffic control devices such as pedestrian crossing will be provided.
- The building is prone to wild life invasion or vandalism if any.

3.8.2 Inward-Oriented Design

In this alternative, the majority of building area is located between the two parking lot of truck and car. The alternative has the following feature:

- A 70^{o} degree parking angle located on the curb of the alignment for 140 car parking slot

- A 30° degree parking angle for pull in and through for 35 truck parking slot
- An aggregate sum of over 6 acres of main area usage.
- One-way traffic which promotes uniformity

Figure 11 shows the general geometric of site layout 1:

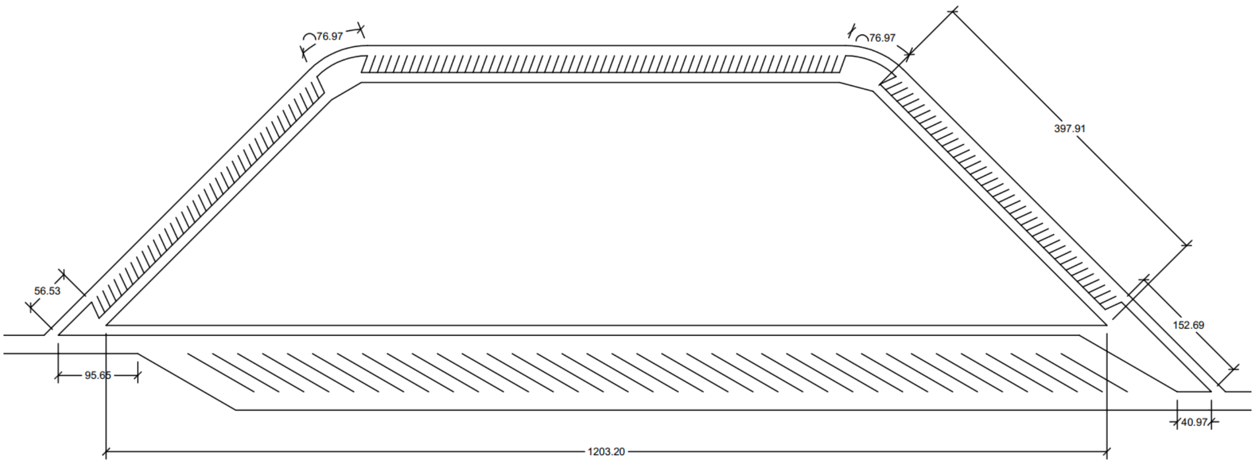


Figure 11. Inward-Oriented Site Layout

The technical drawing of the site layout will be provided in Appendix C.5. The following information shows the advantages and disadvantages of alternative 2.

- It provides easy access to both car and truck driver.
- It protects the majority of buildings from vandalism, wild animal if any
- The distances from parking space to the site are relatively short

Disadvantages of alternative 2

- The layout must be carefully designed to accommodate the demand within the confined area. The entire may suffer from concentrated activity results from pedestrian traffic.
- Future expansion opportunity is prohibitive.

3.8.3 Mixed Design

This design incorporates the characteristic of alternative 1 and 2. The car parking lot is now located side by side with respect to one length of the rest stop area of usage. In addition, the truck parking area is also located near the area of usage with respect to the other length. The alternatives have the following features:

- A 45° degree parking angle located on the curb of the alignment for 140 car parking slot
- A 45° degree parking angle for pull in and through for 35 truck parking slot
- An aggregate sum of over 6 acres of main area usage.

- Both car and truck parking lots are located near the rest area
- Road Alignment surround the main area of usage which creates a protection from vandalism

Figure 12 shows the general geometric of site layout 1:

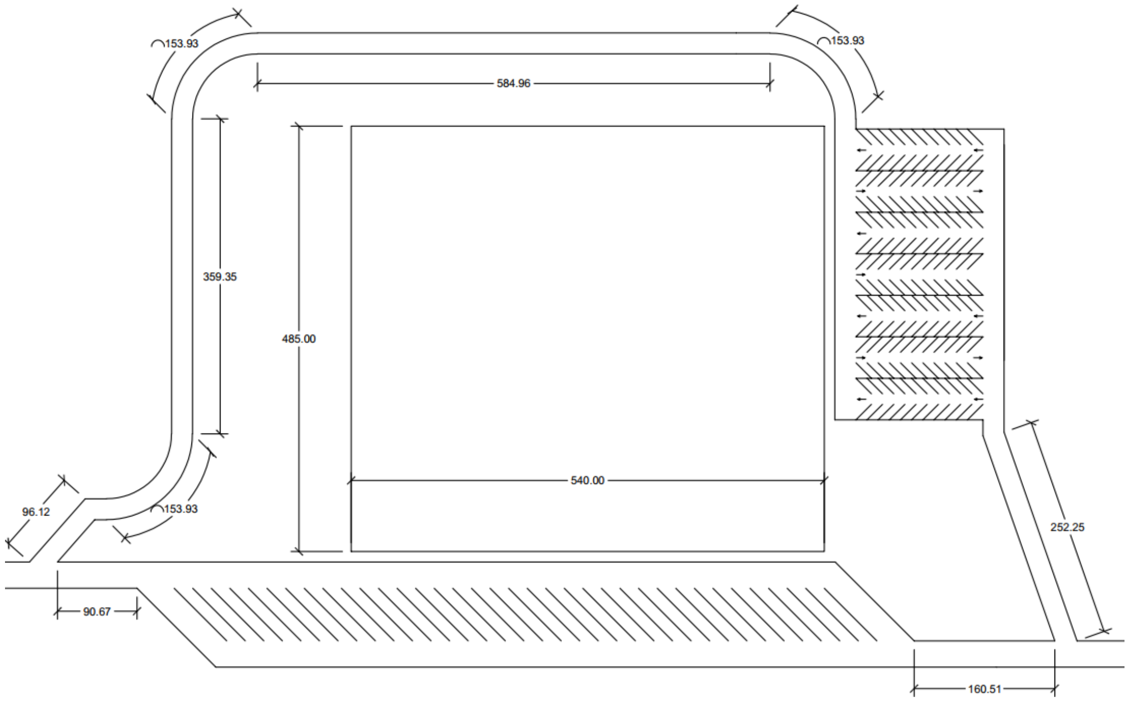


Figure 12. Mixed Design Site Layout

The technical drawing of the site layout will be provided in Appendix C.6. The following information shows the advantages and disadvantages of alternative 2.

Advantages of alternative 3

- Easy access to the rest area for both truck and car drive without any confliction with the traffic
- The layout has a potential for future expansion up to some certain extent. However, if more space is needed, it would requires less modification compared to alternative 1.

Disadvantages of alternative 3

- The area is not sufficiently utilized with several unused spaces
- The length of the required alignment is longer compared to other alternatives
- The area is confined with the alignment; thus, the frequency of traffic is high which is not as pedestrian friendly compared to other alternatives.
- The layout consists of many twist, which may raise potential hazard to vehicle operator

CHAPTER 4: FATAL FLAW SCREENING ANALYSIS

This chapter will be the screening phase that will discard any alternative design options that are unfeasible or undesirable with respect to the owner's goals and objectives. Remaining alternatives will proceed to the next phase of the analysis.

4.1 Decision Statement 1 – Site Selection

4.1.1 Mandatory Criteria 1

The site must be located on the south-bound side of the projected I-69

4.1.2 Mandatory Criteria 2

The site must be approximately 3,000 feet away from any highway intersections.

4.1.3 *Results of Screening Analysis*

Considering the mandatory criteria, the only viable option that remains is Site Location 2.

4.2 Decision Statement 2 – Structural Frame

4.2.1 Mandatory Criteria 1

The structure must be constructed with the given materials to ensure the safety of the individuals who use the rest area.

4.2.2 Mandatory Criteria 2

The structure must be repairable after construction. The cause of external forces may result in the repair of the structural frame and given the material, the frame must be repairable.

4.2.3 Results of Screening Analysis

Considering the mandatory criteria, all three alternatives pass the fatal flaw screening and will be assessed in the alternative analysis.

4.3 Decision Statement 3 – Foundation

4.3.1 Mandatory Criteria 1

The foundation must be able to support the applied load of the building without compromising the bearing capacity of the soil. Total stress analysis and effective stress analysis will be completed to ensure the soil can support the designed foundation.

4.3.2 Mandatory Criteria 2

The foundation must be able to supports the applied load of the building without surpassing the allowable settlement. Primary consolidation, elastic settlement, and secondary settlement will be examined to ensure allowable settlement is not exceeded.

4.3.3 Mandatory Criteria 3

The cost of the foundation will be considered. Which foundation can handle the settlement and bearing capacity requirements and be the most cost-effective.

4.3.4 Results of Screening Analysis

This section will be completed immediately after the Soil Investigation Report is returned.

4.4 Decision Statement 4 – Car Parking

4.4.1 Mandatory Criteria 1: Walking Distances

This criteria aims to limit the walking distances from each parking spot to the site location. If the walking distance exceeds a certain value, a passenger loading zones will be required thus is not desirable. In addition, it is not likely that a vehicle driver would walk 15 minutes to the main building for only 15 minutes usage of the rest area. Within this project, the maximum walking distance is designed as the 10^{th} percentile of the walking distances data. Table 1 shows the walking distances distribution in five different cites Atlanta, Pittsburgh, Dallas, Denver, and Seattle.

Table 1. Distribution of Walking Distance

Distance		% Walking This Distance or Further	
Feet	Miles	Mean	Range
0	0	100	
250	0.05	70	60-80
500	0.1	50	40-60
750	0.14	35	25-45
1000	0.19	27	17-37
1500	0.28	16	8-024
2000	0.38	10	5-015
3000	0.57	4	0-8
4000	0.76	3	0-6
5000+	0.95	1	0-2

Definition: Within the car parking module, the distance from each parking stall to the main area shall not exceed the 50^{th} percentile of the Table 1 data which is 500 feet. The distance is measured from the centroid of the parking stall into the edges of main area of usage.

Evaluation: The following shows statistics for walking distance for each alternative. These alternatives can be determined via the technical drawing provided in APPENDIX C: The distances are then compared with the benchmark of 2,000 ft. After the comparison, 901 Design concludes that all three alternatives satisfy the mandatory criteria 1 of walking distances.

Table 2. Walking Distances of Three Alternatives

Alternative 1			**Alternative 2**			**Alternative 3**		
Distance	Frequency	<500	Distance	Frequency	<500	Distance	Frequency	<500
146	10	Yes	154	14	Yes	12	140	Yes
137	10	Yes	141	14	Yes			
128	10	Yes	128	14	Yes			
119	10	Yes	115	14	Yes			
110	10	Yes	103	14	Yes			
101	10	Yes	90	14	Yes			
92	10	Yes	77	14	Yes			
83	10	Yes	64	14	Yes			
74	10	Yes	52	14	Yes			
65	10	Yes	39	14	Yes			
56	10	Yes						
47	10	Yes						
38	10	Yes						
29	10	Yes						

4.4.2 Mandatory Criteria 2: Number of Car Parking Spaces

The parking area shall satisfy both the minimum required car parking lot or the owner's objective of 140 parking lot. The minimum required car parking lot is a function of which variable is the annual daily traffic. Tennessee Department of Transportation (TDOT) has made available of the data as shown in the following table:

Table 3. Annual Daily Traffic Data from TDOT

Build Alternatives by Node			
		Analysis Years	
From	to	Year 2010 (ADT)	Year 2030 (ADT)
A (SR 385)	B (South of SR 59)	A (19288)	B (35150)
B (South of SR 59)	D (South of Hatchie River)	A (15280)	B (29730)
D (South of Hatchie River)	K (North of Hatchie River)	A (25470)	B (49550)

In order to achieve self-sustainability, 901 Design utilizes the provision ADT of the year 2030 instead of 2010 to accommodate the demand for rest area usage. The calculation of minimum car parking spaces will be shown in detail in Appendix C.11. The result of the calculation is 91 parking spaces which is lower than the desire number of the owner. Therefore, the final car parking lot requirement shall conform to the owner's objective which is 140 parking spaces.

Definition: Car parking alternative shall provide a minimum of 140 car parking space.

Evaluation: The following table is a comparison of car parking alternatives to the requirement:

Table 4. Screening of Mandatory Criteria 2

	Alternative 1	Alternative 2	Alternative 3
Number of car parking spaces	140	140	140
Requirement	140	140	140
Satisfy or not	Yes	Yes	Yes

After the comparison, 901 Design concludes that all three alternatives satisfy the mandatory criteria 2 of number of parking spaces.

4.4.3 Mandatory Criteria 3: User comfort factor

This criteria measures the easiness of the user to pull into or out of the parking lot. It correlates with the Level of Service approach as many have seen when analyzing segment of roadways. The following table shows the correspondence between User Comfort Factor, Level of Service, and practical vehicle operator's experience:

Table 5. Elaboration of User Comfort Factor

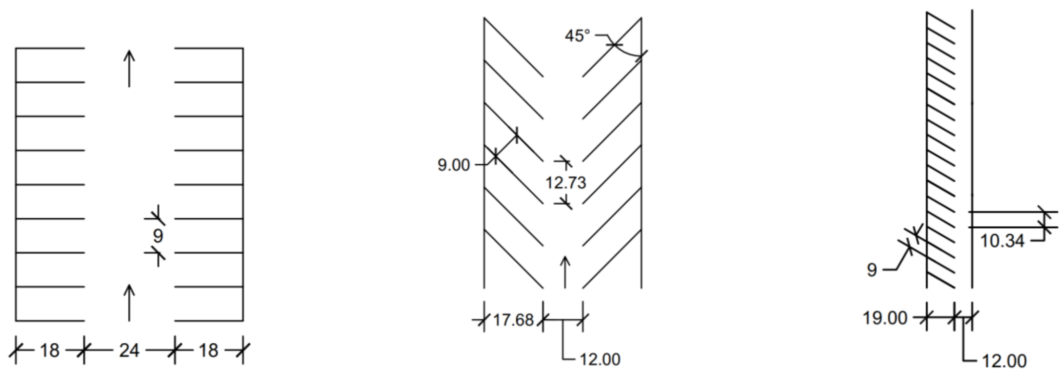
User Comfort Factor (UCF)	Level of Service	Easiness of Parking
4	A	Excellent
3	B	Good
2	C	Acceptable

The user comfort factor can be determined by the geometric characteristic of the parking lot. In general, a bigger parking stall would result in an easier process of pulling into or out of. Moreover, smaller parking angle will also contribute significantly to the easiness of parking, but it may come at the cost of the area of usage. The main characteristics that will determine the value of UCF are parking angle, Stall Width Projection (WP), Vehicle Projection (VP), and Aisle Width

(AW). A traffic engineering guideline (Roess, et al. 2004) is developed for determining the UCF as a function of which variables are the above characteristic. This information will be sufficiently elaborated in Appendix C.7. Rest area are a facility with typical low turnover rate. The term turnover rate represents the duration in which the car arrives, parks, and departs the parking lot. Unlike area with high turnover rate such as office building where employee parks their car from the morning until late in the afternoon, rest are serves user who only parks in an average of 30 minutes. Because the frequency of pulling in and out of the parking lot is high, a user comfort factor of at least 3 is acceptable.

Definition: Car parking alternative shall have a minimum user comfort factor of 3.

Evaluation: The following figures are an extract of each alternative which delineates the geometric characteristic of each respectively:



Alternative 1 Alternative 2 Alternative 3

Figure 13. Parking Stall Geometry

The following tables are comparisons of 3 alternatives with the mandatory criteria 3:

Table 6. Screening of Mandatory Criteria 3

Screening of Alternative 1

Description	Alternative 1	Requirement	Satisfy or not
Parking Angle	90	90	Yes
Parking Stall Width	9	8’-9”	Yes
Aisle Width	25’	25’	Yes
Vehicle Projection	18’	18’	Yes
Stall Width Projection	9	8’-9”	Yes

Screening of Alternative 2

Description	Alternative 2	Requirement	Satisfy or not
Parking Angle	45	45	Yes
Parking Stall Width	9	8’-9”	Yes

Aisle Width	12’	12’* (Adjusted for 1 way traffic)	Yes
Vehicle Projection	18’	17’-7”	Yes
Stall Width Projection	13’	12’-4”	Yes

Screening of Alternative 3

Description	Alternative 3	Requirement	Satisfy or not
Parking Angle	70	70	Yes
Parking Stall Width	9	8’-9”	Yes
Aisle Width	12’	12’* (Adjusted for 1 way traffic)	Yes
Vehicle Projection	19’	17’-7”	Yes
Stall Width Projection	10’	9’-4”	Yes

After the comparison, 901 Design concludes that all three alternatives satisfy the mandatory criteria 3 of user comfort factor.

4.4.4 Results of Screening Analysis

After the comparison between each alternative and each mandatory criterion independently, 901 Design concludes all three car parking alternatives satisfy the requirement and will be examined further in the alternative analysis section to select the most suitable alternative.

4.5 Decision Statement 5 – Pavement

4.5.1 Mandatory Criteria 1

The pavement must be able to support the loads of both passenger cars and tractor trucks.

4.5.2 Mandatory Criteria 2

The pavement must be able to utilize recyclable materials to increase LEED rating.

4.5.3 Results of Screening Analysis

Neither of the alternatives were screened out due to fatal flaws. Both, rigid and flexible pavements, are able support loads from both types of traffic as well as be constructed of recycled materials. There are no options available to construct pavements that were ruled out by the fatal flaw screenings.

4.6 Decision Statement 6 – Sanitary Sewer

4.6.1 Mandatory Criteria 1

The sanitary sewer system must meet the 2012 International Plumbing Code or 2012 Private Sewage Disposal Code where applicable.

4.6.2 Mandatory Criteria 2

The system must be able to handle the design loads of the facility.

4.6.3 Mandatory Criteria 3

The sanitary sewer system must be hidden from sight of its users and not produce unpleasant smells in the area.

4.6.4 Results of Screening Analysis

Given the nature of sanitary sewer systems, there are only 2 options available. They are to install septic tank to dispose of waste or either to utilize a public sanitary waste system. Both options meet the criteria of the fatal flaw screenings and no options are ruled out.

4.7 Decision Statement 7 – Storm Water

4.7.1 Mandatory Criteria 1

The storm water system must be able to hold all the runoff required by TDOT's drainage code.

4.7.2 Mandatory Criteria 1

The storm water system must be able to keep a certain amount of water from flooding the highway required by TDOT's drainage code.

4.7.3 Results of Screening Analysis

Considering the required material, all the alternatives are viable options.

4.8 Decision Statement 8 – Site Layout

A site layout should be designed in accordance to the desire of the owner as well as legal requirement. This layout refers to how each section of the area such as car parking lot, truck parking lot, main area of usage is located relatively to each other. The requirement is meant to ensure the optimum safety of the user of the rest area. The following section will be devoted to determining mandatory criteria that any alternative shall conform to. Alternatives that does not meet one of any requirements shall be eliminated immediately and no further considerations are required.

4.8.1 Mandatory Criteria 1: Site Capacity

With the given annual daily traffic provided by the Tennessee Department of Transportation, the site shall provide up to some certain capacity, each from several perspective such as number of car parking lot, truck parking lot, and main area of usage. The higher the number of ADT implies a high usage of rest area; thus the capacity should be large enough to accommodate such demand. In addition, with an objective of self-sustainability based design, the site shall be provisioned to provide services to the demand not only from the current time, but also until 30 years beyond now.

Definition: A parking layout alternative shall provide at least the following capacity: 140 Car Parking Spaces, 35 Truck Parking Spaces, and 6 Acres area of usage.

Evaluation: The following table is a comparison of 3 alternatives with the mandatory criteria 1. The exact dimension is calculated via AutoCAD software.

Table 7. Screening of Mandatory Criteria 1

	Alternative 1	Requirement	Satisfy or not
Number of car parking spaces	140	140	Yes
Number of truck parking spaces	35	35	Yes
Main area of usage (acres)	267,120	261,360	Yes

	Alternative 2	Requirement	Satisfy or not
Number of car parking spaces	140	140	Yes
Number of truck parking spaces	35	35	Yes
Main area of usage (acres)	265,708	261,360	Yes

	Alternative 3	Requirement	Satisfy or not
Number of car parking spaces	140	140	Yes
Number of truck parking spaces	35	35	Yes
Main area of usage (acres)	261,900	261,360	Yes

After the comparison, 901 Design concludes that all three alternatives satisfy the mandatory criteria 3 of user comfort factor.

4.8.2 Mandatory Criteria 2: Separation of Car and Truck Parking

Rest area serves multiple types of vehicle and the two most common type are car and truck. The parking layout shall separate two parking lots designated to each type of vehicle. The practice of separating car and truck parking facilities enhance the following advantages:

- Promotes homogenous circulation pattern for each type of vehicle
- Avoid confusion for truck driver when accessing the facilities and vice versa
- Efficiently utilizes the area of construction
- Facilitates for angle truck parking, which immensely enhance the easiness of pulling-in-through parking type

Definition: The site layout alternative shall provide two different and separated parking lot for car parking and truck parking respectively.

Evaluation: The following table is a comparison of 3 alternatives with mandatory criteria 2:

Table 8. Screening of Mandatory Criteria

	Alternative 1	Alternative 2	Alternative 3
Designated Car Parking	Yes	Yes	Yes
Designated Truck Parking	Yes	Yes	Yes
Two Parking are Separated	Yes	Yes	Yes

After the comparison, 901 Design concludes that all three alternatives satisfy the mandatory criteria 3 of user comfort factor.

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CHAPTER 5: ALTERNATIVE ANALYSIS

This chapter presents the evaluation of the different choices available to achieve the project's objectives. It is an analytical comparison of different factors like operational cost, risks, effectiveness as well as the shortfalls in an operational capability. It requires different tools such as life-cycle costing, sensitivity analysis, and cost-benefit analysis. With alternative analysis, options to the solution are identified to satisfy the needs of the project. A rating system will be used to evaluate the alternatives. In addition to the ratings, each decision statement will assign an importance weight factor to the listed criteria. Higher importance weight factors will indicate a greater priority for that specific criteria. Higher overall ratings will indicate the best option.

5.1 Decision Statement 1 – Site Selection

5.1.1 Alternative Analysis Summary

Site Location 2 was determined after conducting the fatal flaw process. The other alternatives did not meet the mandatory criteria.

5.2 Decision Statement 2 – Structural Frame

An overall rating system with values 1-3 will be used. There are three alternatives to choose from. The research done will allow 901 Design to rank the alternatives in a 1^{st}, 2^{nd}, 3^{rd}, capacity. This will simplify the results and minimize objective rankings.

5.2.1 Evaluation Criteria 1 - Cost

Estimated overall costs for framing the rest area structure. Direct estimates are not available; however, research was done to compare the alternatives. Lower estimated costs receive a higher rating. Based off the below information, the following ratings have been determined: 1) Concrete 2) Steel 3) Wood.

- Steel - A large majority of all steel manufactured today comes from recycled materials; A992 steel. This recycling usage makes the material much cheaper when compared to other materials. Although the price of steel can fluctuate, it typically remains a less expensive option compared to reinforced concrete (Brakefield n.d.).
- Concrete - A large cost benefit to concrete is the fact that its price remains relatively consistent. On the other hand, concrete also requires ongoing maintenance and repairs, meaning added costs throughout its lifetime. Supply-and-demand may also impact the availability of concrete. Even though it can be poured and worked with

directly onsite, the process to completion can be lengthy and could accrue higher labor costs (Brakefield n.d.).

- Wood - Steel framing is much more expensive than wood framing. The material's costs are higher, and the labor is more expensive because most contractors are not as familiar with using steel ("Compare 2018 Average Steel vs Wood House Framing Costs - Pros versus Cons of Steel and Wood House Framing - Price Comparison" n.d.).

5.2.2 Evaluation Criteria 2 - Maintenance

The estimated cost of maintenance for each material after completion. Lower estimates receive a higher rating. Based off the below information, the following ratings have been determined: 1) Wood 2) Steel 3) Concrete.

- Steel - Steel-framed buildings with metal building components often have paneling and roof warranties that last 40 to 50 years. There is no splitting, warping, molding, mildewing, or cracking, so lifetime maintenance and upkeep costs of a steel-framed building are minimal (Team n.d.).
- Concrete - With proper construction and care, reinforced concrete is water resistant and will not corrode. However, it's important to note that the steel reinforcement inside should never be exposed. If exposed, the steel becomes compromised and can easily corrode, compromising the strength of the structure (Brakefield n.d.).
- Wood - A traditional wood-framed building requires a new coat of paint at least every four to seven years, with touch-ups on a regular basis. The average roof lasts for about 15 years or so. Wood also tends to crack, warp, split, mold, and rot (Team n.d.).

5.2.3 Evaluation Criteria 4 - Strength

What are the overall yielding tensile and compressive strengths of the materials. Higher values will receive a higher rating. Based off the below information, the following ratings have been determined: 1) Wood 2) Concrete 3) Steel.

- Steel – Tensile strength: 50 ksi. Compressive strength: 50 ksi. Structural steel is extremely strong, stiff, tough, and ductile; making it one of the leading materials used in commercial and industrial building construction (Brakefield n.d.).

- Concrete - Tensile strength: Very low, not available. Compressive strength: 4 ksi. Concrete is a composite material consisting of cement, sand, gravel and water. It has a relatively high compressive strength but lacks tensile strength. Concrete must be reinforced with steel rebar to increase a structure's tensile capacity, ductility and elasticity (Brakefield n.d.)
- Wood - Pound for pound, wood framing materials are extremely strong; however, wood does not behave in a predictable manner, like steel and concrete. Wood frames are vulnerable to earth's elements and can become warped very quickly. Analyzing a wood structure would not be an easy task due to the high rate of unpredictability.

5.2.4 Evaluation Criteria 4 – Environmental Considerations

Comparing the alternatives, which material will leave the least negative impact on the environment. Materials that leave a lesser impact on the environment will receive a higher rating. Based off the below information, the following ratings have been determined: 1) Wood 2) Concrete 3) Steel.

- Steel - Steel is 100% recyclable and 85% of steel is recycled at the end of its life. Due to its magnetic properties, steel is easy to separate from other debris and making the recycling process more efficient. In addition, the energy used to produce recycled steel is about one-third of what is required to produce virgin steel from iron ore.

  According to the BRE index, steel only has 11 Eco-points per ton, lower and better than concrete (Team n.d.).
- Concrete - Some sources say up to 50% of concrete is crushed and recycled; 40% is down-cycled to be used for hardcore in substructure works or road construction. The remaining 10% is waste that goes to the landfill. The BRE group has developed a rating system called Eco-points to compare the environmental impact of certain materials. The higher the number, the higher the impact.

  Reinforced concrete has 12.57 Eco-points per ton (Team n.d.).
- Wood - Once a wooden building has reached the end of its lifecycle there isn't much to be done with it aside from demolition and/or incineration due to the fact

that treated wood used in the construction industry cannot be recycled (“Steel vs Wood” 2017).

5.2.5 *Evaluation Criteria 5 - Constructability*

The estimated scheduled time for how long it will take to construct the building frame. Lower estimates receive a higher rating. Based off the below information, the following ratings have been determined: 1) Wood 2) Steel 3) Concrete.

- Steel - With steel frames and panels, you can have all of that done before it ever gets to your job site and the erection can be completed using a set of instructions and relatively untrained hands. The members and panels have often been pre-constructed at the manufacturer to make sure of hole spacing and fit (Team n.d.).
- Concrete - According to Alfred G. Gerosa, President of Concrete Alliance Inc. in New York, concrete buildings can be constructed up to twice as fast as a steel structure. In a process called the 2-Day Cycle, cast-in-place reinforced concrete buildings can rise as fast as one floor every other day (Team n.d.)
- Wood - Wood-framed buildings require skilled laborers who must spend time cutting lumber to size, framing, and drilling holes for wiring among other things (Team n.d.).

5.2.6 *Evaluation Criteria 6 – Design Flexibility*

During the design phase, what are the potential solutions that could be developed using each material. Higher values will receive a higher rating. Based off the below information, the following ratings have been determined: 1) Wood 2) Concrete 3) Steel.

- Steel - Steel has the highest strength to weight ratio of any construction material available today. Lower floor to floor heights can easily be created using girder slab, staggered truss, and castellated beam construction. Extremely long open spans are possible using steel that would not be feasible in concrete (Team n.d.).
- Concrete - Concrete can be molded into any shape and pre-casting of walls for tilt-up construction has become common. Construction with cast-in-place reinforced concrete for high rises can yield more rentable space due to lower floor to floor heights (Team n.d.).

- Wood - Again, the issue with wood is the unpredictability factor. There are many possible framing solutions using wood, but the problem still lies in the uncertainty of how that structure with withstand certain loads.

5.2.7 Weighting of Criteria Importance

The client's goals and objectives were taken into consideration while developing the weighting system for the above decision statement. Although this project does not have a budget, 901 Design still made it a top priority to minimize costs for the client. Overall cost was the main consideration for determining the importance of each listed criteria. A secondary goal was to produce a low maintenance structure that would achieve a self-sustaining building. The strength and durability of the building can also help achieve the secondary goal of producing a low maintenance structure. Finally, the client would like a final product that yields a higher LEED rating.

Taking this all into consideration, the following weighting system was developed for this decision statement (the higher the weighted value, the more important the criteria is to the project):

1. Design Flexibility
2. Constructability
3. Environmental Considerations (3rd goal – LEED)
4. Strength (2nd goal – SSB)
5. Maintenance (2nd goal – SSB)
6. Cost (1st goal – minimize cost)

5.2.8 Alternative Selection Matrix

Table 9 below shows the results from the alternative analysis preformed for this decision statement. The ratings are valued from 1-3. 901 Design decided that since there are three options within this decision statement, having a rating system 1-3 would simplify the rankings. All three materials were directly compared to one another and were then ranked in a 1st, 2nd, 3rd, place capacity. The results from the matrix show that steel is the best design option.

Table 9. Structural Frame Alternative Analysis Matrix

		Steel		Concrete		Wood	
Criteria	Weight	Score	(Weighted)	Score	(Weighted)	Score	(Weighted)
Cost		2	(12)	1	(6)	3	(18)
Maintenance		2	(10)	3	(15)	1	(5)
Strength		3	(12)	2	(8)	1	(4)
Environmental Considerations		3	(9)	2	(6)	1	(3)
Constructability		2	(4)	3	(6)	1	(2)
Design Flexibility		3	(3)	2	(2)	1	(1)
Total [Max: 35 (140)]		15	(50)	13	(43)	8	(33)

5.2.9 Alternative Analysis Summary

Steel has high tensile strength and has a high strength to weight ratio. This will allow the structure to use less material when constructing the actual frame. Steel can also be easily fabricated and produced off-site and then assembled on-site, saving time and increasing overall efficiency of the construction process. Structural steel is relatively cheap compared to other building materials which will ultimately save on overall costs.

Steel is an alloy of iron which makes it susceptible to corrosion. This can be solved to some extent using anti-corrosion applications. The manganocene costs are higher than concrete. Buckling in steel structures is a concern if the length of steel columns become large.

5.3 Decision Statement 3 – Foundation

5.3.1 Evaluation Criteria 1: Cost

The cost for the overall construction of the foundation. This will include the cost of all materials used in construction, and the cost of any site preparation work if necessary.

5.3.2 Evaluation Criteria 2: Longevity

This is a measure on how long the foundation will be able to withstand the surrounding environment. Possible extreme weather conditions such as earthquakes or floods will not be considered in this evaluation. The foundation will be constructed out of concrete. Poured concrete foundations generally last a minimum of 50 years. Some foundations fail sooner due to soil conditions. differential settlement or expansive soils can decrease the longevity of foundations.

5.3.3 Evaluation Criteria 3: Constructability

The constructability aspect is a measure of how easily the foundation could be constructed. determining any obstacles that could potentially delay the construction completion date. Pouring a slab foundation is generally the easiest foundation to construct. The slab doesn't require the preparation work that the other foundations will require.

5.3.4 Evaluation Criteria 4: Construction time

The construction time will encompass the time from start to finish of the foundation construction. This will also include the cut and fill preparation work if it's necessary to build the available type of foundation.

5.3.5 Evaluation Criteria 4: Construction time

Maintenance will include the required upkeep for each possible foundation type, in addition to utility repair access

5.3.6 Alternative Selection Matrix

The scores for each alternative are displayed on the bottom row of the table. It is a possibility that one alternative can score very well, but due to the subsurface soil conditions at the site location, that alternative may not be considered as a viable option. The alternative selection matrix will be completed immediately after the Subsurface Investigation Report is returned.

5.4 Decision Statement 4 – Parking

5.4.1 Evaluation Criteria 1: Parking efficiency

Definition: The alternatives which yields the minimum ratio of parking efficiency will receive a score of 5 out of 5. The two other alternatives will be graded of which score is an inverse relationship to the percentage of its ratio over the best alternative's parking efficiency ratio. For example, if the best alternative yields a result of 200 square foot per space and the current alternative yields 300 square foot, the current alternative will receive a score of 3.33.

Evaluation: Table 10. shows the comparison between three alternative and the associated score. The area of the parking lot can be calculated from the technical drawing in appendix A.

Table 10. Alternatives Evaluation of Criteria 1

	Alternative 1	Alternative 2	Alternative 3
Area (sqft)	52,200	63,883	44,874
Parking Space	140	140	140
Parking Efficiency (sqft per space)	373	456	321
Score (Out of 5)	4.3	3.5	5

5.4.2 Evaluation Criteria 2: Optimum Parking Angle

Within the alternative 1, 2, and 3, there are three different value of parking angle which is 90, 45, and 70. This section of the alternative analysis serves as a small case study comparing these three parking variations to find the most efficient alternative. First, the mechanism of which the car is pulling into the parking lot must be understood. The understanding of this mechanism will explain how the minimum aisle width is a function of which variable is the parking angle. This geometric parameter is ultimately directly related to the overall size of the parking lot. Appendix C.8 will provide the rationale of the minimum required parking area as a function of parking angle.

Definition: The alternatives which yields the minimum of parking area will receive a score of 5 out of 5. The two other alternatives will be graded accordingly of which score is an inverse relationship to the percentage of its ratio over the best alternative's parking area. For example, if the best alternative yields a result of 200 square foot and the current alternative yields 300 square foot, the current alternative will receive a score of 3.33.

Evaluation: Table 11. shows the comparison between three alternatives and the score

Table 11. Alternatives Evaluation of Criteria 2

	Alternative 1	Alternative 2	Alternative 3
Parking Angle	90	45	70
Aggregate Area per Number of Parking Stall	274.99	280.87	269.98
Score (Out of 5)	4	3	5

5.4.3 Evaluation Criteria 3: Distances to Rest Area

The car parking lot should be designed in such a way that it minimizes the walking distances from the parking area to the main building where most of the rest area functionality are located. In addition, the standard deviation taken from the set of walking distances should be minimized if possible, which indicate a fairly uniform and equal working distance. The following information shows the disadvantages of longer walking distances.

- Vehicle operators tend to find a parking lot closer to the main building in the case of nonuniform walking distance. A failure of doing so would results in a U-turn which ultimately disrupt greatly the smooth circulation pattern of the traffic.
- Higher vehicle-pedestrian conflict which yields a higher threats for pedestrian

Definition: The criteria can be measured by two different parameter which is the mean and standard deviation from a set of distances from each parking lot to the main building area. The alternative which gives the least combination of mean and standard deviation of distances is desirable. Each parameter is associated with two different weight respectively of which values add up into 1. Equation 1 shows how the weighted score is evaluated.

$V = w_1 Mean + w_2 Stdev$ where $w_1 + w_2 = 1$ Equation 1

Three difference scenarios of weight would be tested for the analysis. The best alternative would be given a score of 5, followed by the second and the third with a score of 4 and 3 respectively.

Evaluation: Table 12. shows the weighted score of three alternative

Table 12. Alternatives Evaluation of Criteria 3

	Alternative 1		Alternative 2		Alternative 3	
Characteristic	Mean	Stdev	Mean	Stdev	Mean	Stdev
	88	36.41	96	36.69	12	0
Weighted Score						
W1/W2	V	Score	V	Score	V	Score
0.5/0.5	61.95	4	66.48	3	6	5
0.7/0.3	72.17	4	78.4	3	8.4	5
0.3/0.7	51.73	4	54.57	3	3.6	5

All of the situation yields the same results for the analysis which alternative 1, 2, and 3 receives a score of 4,3, and 5 respectively.

5.4.4 Evaluation Criteria 4: Cross Traffic Conflict

This criteria measures how many cross-traffic conflicts are there within the car parking lot.

Definition: The alternative which yields the lowest number of traffic conflict will receives a score of 5, followed by the second and third alternative with a score of 4 and 3 respectively.

Evaluation: Table 13. shows the weighted score of three alternative

Table 13. Alternatives Evaluation of Criteria 4

	Alternative 1	Alternative 2	Alternative 3
Number of conflict traffic	10	7	1.5*
Score	3	4	5

*Alternative 3 does not require a stop sign. However due to the geometric characteristic of its alignment, there would be 3 yield signs upon entering three different section of the parking lot.

5.4.5 Weighting of Criteria Importance

There are four evaluation criteria of the car parking alternative analysis which are Parking Efficiency, Parking Angle, Walking Distance, and Cross Traffic Conflict. These four criteria can be categorized into two main section which are economic section and safety section. Within the economic section which consists of Parking Efficiency and Parking Angle, the Parking Efficiency is ranked higher than the Parking Angle. Within the safety section which consists of Walking Distance and Cross Traffic Conflict, the Walking Distance is ranked higher than the Cross Traffic Conflict. According to the objectives of the client, 901 Designs concludes that both the economic section and safety section are equally important, which leads to the following weighting of criteria importance:

Table 14. Weighting of Criteria Car Parking Alternative

Criteria	Weight
Parking Efficiency	2
Parking Angle	1
Walking Distance	2
Cross Traffic Conflict	1

5.4.6 Alternative Selection Matrix

The following table represents the results from the alternative analysis performed within the car parking analysis. Three alternatives are ranked accordingly to their Total Score. After careful considerations, 901 Design concludes that the Alternative 3 Angular Parking along the curb is the most suitable alternative for this project

Table 15. Car Parking Alternative Analysis Matrix

		Alternative 1		**Alternative 2**		**Alternative 3**	
Criteria	Weight	Score (Weighted)		Score (Weighted)		Score (Weighted)	
Parking Efficiency	2	4.3	(9)	3.5	(7)	5	(10)
Parking Angle	1	4	(4)	3	(3)	5	(5)
Walking Distance	2	4	(8)	3	(6)	5	(10)
Cross Traffic Conflict	1	3	(3)	4	(4)	5	(5)
Total [Max: 20 (30)]		15.3	(24)	13.5	(20)	20	(30)

5.5 Decision Statement 5 – Pavement

An Alternative Analysis Matrix was constructed to help determine which option to choose that would best meet the design objectives. Overall, there was 5 criteria used to analyze the alternatives. The criteria were weighted 1-5 with 1 being the least important of the criteria in respect to meeting the owner's goals and 5 being the most important. (Note that weightings were weighted as they pertained to each other.) After the weightings were assigned, rankings were assigned to each of the criteria. Rankings were valued on a scale of 1-4 where: 1 is strongly disagree; 2 is disagree; 3 is agree; 4 is strongly agree.

Unlike weightings, rankings were assigned to each criterion by how well the option fit the criterion. (Note the ratings for each option were analyzed separately from the other option. i.e. both options can have a rating of 4 for a criterion as it does not depend on the other option.) In order to make understanding easier, the evaluation criteria will be discussed from most important to least important according to the matrix.

5.5.1 Evaluation Criteria 1: Construction Cost

Construction Cost is defined by how much the pavement materials and labor will cost for the project. Cost was determined to be of such importance because pavements are expensive to build regardless as to which type is being constructed. 901 Design anticipates that the cost of pavement will be the costliest part of the project. The cost of pavement construction is also a factor that will change greatly when comparing the rigid and flexible pavement options. Rigid pavements require labor crews to construct forms, place re-bar, dowel bars, and wire welded mesh. The placement of these items is tedious which adds significantly to cost.

5.5.2 Evaluation Criteria 2: Ease of Construction

Ease of construction is defined by how easy it is to construct and how long construction will take to complete the pavement. Pavement is a critical task in the construction phase of the project and delays due to pavement construction can have a negative impact on the overall success of the rest area. (Concrete could delay other workers from accessing the site during construction for a month possibly.)

5.5.3 Evaluation Criteria 3: Maintenance

Maintenance of the pavement. Rest areas typically have one lane in and out of facility during operation. It is not desired to have long delays or closures due to having to repair the entrances and exits to the facility.

5.5.4 Evaluation Criteria 4: Water Retention

Water retention is the defined by how effective water can be captured and stored from the pavement. The ability to store and reuse water from pavements for watering needs will help the facility achieve a higher LEED rating.

5.5.5 Evaluation Criteria 5: Serviceability

Serviceability is a level of service measure (LOS) of the ride quality that a pavement gives to passengers. It is undesirable to have a surface with a LOS lower than 2.5. Pavements decrease in their LOS over time. Potholes, uneven slabs, pumping, and alligator cracking are some types of distress that results in low LOS ratings causing wear and tear on passenger's vehicles as well as giving them a "bumpy" ride.

5.5.6 Weighting of Criteria Importance

Cost of construction was weighted as 5. The cost of constructing the pavement is expected to be more than other parts of the project. Therefore, 901 Design feels it is important that the design be as least expensive as possible while still meeting the client's goals.

Ease of construction was weighted as 4. Ease of construction is rated at the second most important criterion. This is because the pavement sections that will be constructed surrounds the site. A pavement that takes a long time to construct could delay other aspects of the project, causing the overall construction to fall behind schedule. It is important for the pavement also to be constructed in a manner that doesn't block access to other areas on the site as well or worse, block complete access to the site due to concrete curing processes.

Maintenance was weighted as a 3. Pavements typically require seasonal maintenance and repairs, typically in the spring due to freeze thaw cycles, which pushes this criterion further down the list. Maintenance that does need to be performed on the pavement needs to be done in manner that does not prevent passenger access to the rest area during normal operating hours. It would be ideal that pavement be designed in a manner that would allow reconstruction processes to be performed during closed hours of the rest area without hindering normal hours the rest area would be in use.

Water Retention was weighted at 2 and is the next to last item of importance. It is desired to retain as much runoff as possible from the pavement in order to recycle it for landscaping uses to maximize the LEED rating. Water can be collected from each type of pavement. However, the cost of the drainage systems that would be needed could cause an increase in construction cost.

Pavements that provide the option to have a permeable surface not only reduces drainage outlets that have to be constructed but also reduces the chances of vehicles skidding when braking as well as hydroplaning during heavy rainfall events. One drawback with such pavements is the fact that are permeable have more maintenance requires as they are at a higher exposure to damage during freeze thaw cycles.

Serviceability was weighted as a 1 and is the least important of the previously mentioned criteria. It is not least important because of its un-importance to the project but rather because both pavement types are capable of yielding a high level of service. Serviceability is important to the over well-being of the rest as passengers expect a smooth ride when traveling. Also, poor serviceability is undesired on entrance and exit ramps as cars are accelerating and decelerating in these areas. Roughness and debris on the driving surfaces in these areas due to potholes, cracks, spalling etc. can lead reduced performances of vehicles and increase the risks of accidents. The flexible option was given a rating of 4 whereas the rigid option was given a rating of 1. Generally speaking, flexible pavements is the cheapest type of pavement to construct and rigid pavements are the most expensive. The maximum and minimum ends of the rating system was chosen because there really are no in between options to choose from when considering if there is another type of pavement that is more cost effective than these 2 options.

5.5.7 Alternative Matrix Selection

Based on the results of the alternative matrix, 901 Design will be recommending that a flexible pavement be constructed for the rest area. This is mostly due to the ratings given for Cost of Construction and Ease of Construction. The flexible option was rated as a 4 for each section while the rigid was rated at a 1. A 4 was given to the flexible pavements because it is the cheapest and easiest pavement to construct currently in pavement construction practices. A 1 was given to rigid pavement because rigid pavements have a high cost of construction and takes a lot longer to construct. Both options scored 4’s in the water retention and serviceability categories due to the fact that both options can meet the criteria nearly equally over the life of the pavements. Flexible pavements were rated at a 2 in terms of maintenance. This was due to the fact that flexible pavements require annual maintenance as the pavement ages as potholes and fatigue crack becomes an issue for flexible pavements due to freeze thaw cycles. The rigid option was rated as 3. Rigid pavements don’t experience as much distresses as flexible pavements do but the distresses they do experience often are not able to be repaired quickly. Common distresses experience by rigid pavements are spalling joints, corner breaks, and longitudinal/transverse cracks. These distresses typically do not decrease the pavement condition index (PCI) when initially formed and can still perform with a high LOS with these distresses present. It is lengthy process to repair these distresses and will almost always have to be done during closed hours.

The total score for the flexible and rigid design options are 54 and 30 respectively. The flexible option out scores the rigid option by 24 points. This is largely due to the fact of the construction costs. When removing the construction cost criteria, the flexible option is still the highest scoring option by a score of 30-25 which still suggests that the flexible option is to be recommended.

Table 16. Pavement Alternative Analysis

		Flexible		**Rigid**	
	Weight	Score	(Weighted)	Score	(Weighted)
Cost of Construction	5	4	(20)	1	(5)
Ease of Construction	4	4	(16)	1	(4)
Water Retention	2	4	(8)	4	(8)
Maintenance	3	2	(6)	3	(9)
Serviceability	1	4	(4)	4	(4)
Total		18	(54)	13	(30)

5.6 Decision Statement 6 – Sanitary Sewer

An Alternative Analysis Matrix was constructed to determine which option would best meet the design objectives. Six different criteria were used to define and analyze the alternatives. The criteria were weighted 1-6 with 1 being the least important of the criteria in respect to meeting the owner’s goals and 6 being the most important. After the weightings were assigned, rankings were assigned to each of the criteria for each option. Rankings were valued on a scale of 1-4 where: 1 is strongly disagree; 2 is disagree; 3 is agree; 4 is strongly agree.

Unlike weightings, rankings were assigned to each criterion by how well the option fit the criterion. (Note the ratings for each option were analyzed separately from the other option. i.e. both options can have a weighting of 4 for a criterion as it does not depend on the rating of the other option.) The evaluation criteria will be discussed from most important to least important according to the matrix.

5.6.1 Evaluation Criteria 1: Feasibility

Feasibility is measure of how easy it is to design the system the most feasible option would give the designers the optimal chance of obtaining a finished product in this short amount of time given the lack of knowledge the designers have. The Sanitary Tie-in option was given a 2 for the ranking whereas the septic system was given a 4. The sanitary required much more design work and drawings. These include sewer pipe profiles, manhole designs, pump designs, and locating the nearest utilities to tie in to. On the other hand, the septic system can be built on site. Many septic tank suppliers have tanks designed to meet codes and just requires sizing. Also, the drawings and specs are also provided by the manufacturer. All the aforementioned items also help contribute to lower construction cost which is the next criteria.

5.6.2 Evaluation Criteria 2: Construction Cost

Construction Cost is defined by how much the option will cost and was given the second most important weighting (5). Cost was determined to be of such importance given that TDOT is a state entity that receives funding through federal grants, where available, and through taxes. Neither of these two sources of money is easy to get more of to pay for additional projects. The Sewer System tie in option was given a rating of 2 for this criterion whereas the septic system was given a 4. In general, constructing a pipeline, lift stations, and buying pumps are all things that will significantly add to the cost of the project considering that the nearest tie in location will be nearly a mile away from the site. Also, designing each of these aspects add to additional design costs in terms of research and labor. The septic system option alleviates the cost associated with the previously mentioned items.3

5.6.3 Evaluation Criteria 3: Self-Functional

Self-Functional is the ability of the system to operate as designed with minimal input and was assigned a weighting of (4). It was clearly defined in the project statement that SSB and LEED ratings were important to TDOT's goals which would naturally yield the question as to why this criterion wasn't given a (6). Simply stated, it does the design team no good to come up with a plan so elaborate that the project can't be finished nor something so expensive that can't be constructed or, even worse, be shut down due to O & M increases. The less self-functional an option is increasing the amount of money and resources TDOT has to supply to maintain the system and reduces their goal of attaining a higher SSB rating. The sanitary tie in option was given a 4 (strongly agree) given the fact that after initial construction costs, the system will function with very little input. The septic system on the other hand was given a rating of 4. This is due to the fact that once constructed, the system operates on gravity requiring no more input to function.

5.6.4 Evaluation Criteria 4: Maintenance

Maintenance is defined by the amount of routine maintenance required to up keep the system and was given a weighting of (3). It is closely related to the self-functional criterion. The difference in the two is the fact that any system will need some maintenance regardless of how it functions. Sanitary sewer was given a rating of 4 because maintenance is minimal. TDOT would be responsible for damages or blockages that occur during use for only their lines only. These types of issues due happen but are not expected to be considered routine maintenance. The septic system was given a rating of 2 due to the fact that it is known that periodic removal of solids will have to be performed. In addition, TDOT is responsible for the entire system if problems with it arise.

5.6.5 Evaluation Criteria 5: Cost of Design Life

Cost of Design Life is how much the system is expected to cost over the life of the design and was given a weighting of (2). The designer understands that TDOT has had to shut down rest areas throughout the state due to increasing cost over the life span of rest areas. However, this criterion is rated as low on the scale as it is primarily because each of the criteria mentioned up until now implicitly has cost over its design life in it already. For instance, a self-functional system has a lower cost of operation. The maintenance criterion also screens out some cost because a system with a lot of maintenance requirements has a higher cost associated with it. The sanitary sewer was given a rating of 4 whereas the septic system was given a 3.

5.6.6 Evaluation Criteria 6: Longevity

Longevity of the system is defined by how long the design life of the system will last and was given a weighting of (1). This criterion ranks the lowest not because of unimportance but more so due to the fact that either system can outperform or under perform its design life depending on its use and level of servicing administered to the system. The design life of the septic tie in can be expected to be around 50 years as long as it hasn’t been exposed to a number of severe clogs or grease dumped down the drains. Therefor it was given a rating of 4. The typical design life of a septic system can be expected around 25 years but can last a lot longer than that if it is serviced properly. Given the fact that routine maintenance is expected the septic tank is exposed to damage when servicing is done and therefore is given a rating of 3.

5.6.7 Alternative Selection Matrix

Table 17. Sewer System Analysis

		Sanitary Tie In		**Septic System**	
Criteria	Weight	Score	(Weighted)	Score	(Weighted)
Cost of Design Life	2	4	(8)	3	(6)
Construction Cost	5	2	(10)	4	(20)
Feasability	6	2	(12)	4	(24)
Longevity	1	4	(4)	3	(3)
Self Functional	4	4	(16)	4	(16)
Maintenance	3	4	(12)	4	(12)
Total		20	(62)	22	(81)

5.6.8 Alternative Analysis Summary

According to the alternative analysis matrix for sewer systems, the designer is recommending installing a septic system. This is due to the fact that the septic system scores and 81 versus 62 of the tie in option. The biggest contributors to this conclusion are due to the cost of construction and feasibility. If cost of construction were to be removed from the system, then the septic system would still be the optimum choice by a score of 61-52. Similarly, if feasibility were removed, the septic system would still be the optimum choice by a score of 57-50. Choosing the septic system is concluded due to the fact that the sewer tie in option cost more to construct given that there is no current facilities in the vicinity to tie into and designing such a system in such a short period greatly reduces the design group’s ability to provide a final product.

5.7 Decision Statement 7 – Storm Water

5.7.1 Evaluation Criteria 1 – Cost

Estimated overall costs for storm water system building labor. Direct estimates are not available; however, research was done to compare the alternatives. The lower the estimated cost, the higher the rating. Each alternative has been assessed and rated based on the information given below.

- Conveyance System Parallel Storage: The conveyance system is a series of ditches that connect to the existing storm water system. The parallel portion is for overflow storage that gets filled back into the system at a controlled rate. This structure doesn’t require a lot of construction work, so it is the cheapest option regarding building labor.

- Detention Basin: The detention basin is an earthen area excavated to create a pond, and a concrete structure like a culvert to control the overflow. This option is the second in cost.
- Extended Detention Basin: The extended detention basin made the same way as a detention basin, but it has extra parts like the dewatering structure. These extra parts make this option costlier than a regular detention basin, but they also make it better for the environment. This option is the most expensive because of the construction of a dewatering structure.

5.7.2 Evaluation Criteria 2 – Material Cost

Estimated overall costs for the storm water system not including the cost of construction. Direct estimates are not available; however, research was done to compare the alternatives. Each alternative has been assessed and rated based on the information given below.

- Conveyance System Parallel Storage: The only thing that will have a significant cost is the concrete storage for overflow.
- Detention Basin: The material cost for the detention basin is more expensive than the conveyance system because it requires more concrete for the structure.
- Extended Detention Basin: The material cost for this structure is the most expensive because of the extra area added for dewatering.

5.7.3 Evaluation Criteria 3 – Longevity

Estimated time each structure will withstand natural wear and tear. Direct estimates are not available; however, research was done to compare the alternatives. Each alternative has been assessed and rated based on the information given below.

- Conveyance System Parallel Storage: The longevity of the conveyance system is only a little less than a detention basin. Ditches don’t stay as dry as the detention basin, so they could erode more.
- Detention Basin: The longevity of a detention basin is high because it stays dry between rainfall events which helps the land keep its shape and not erode.
- Extended Detention Basin: The longevity of an extended detention basin is high because of the same reason standard detention basins do. Both the standard and extended detention basin have the same longevity.

5.7.4 Evaluation Criteria 4 – Maintenance

Estimated level of maintenance required for each structure, and the cost for the maintenance. Direct estimates are not available; however, research was done to compare the alternatives. Each alternative has been assessed and rated based on the information given below.

- Conveyance System Parallel Storage: The least amount of maintenance required for the storm water options is for the conveyance system and parallel storage. The only things that may need to be maintained is the erosion control of the ditches. The storage should not need any maintenance, but if it does it will be very minimal.
- Detention Basin: Maintenance for the detention basin is summarized to erosion control and concrete repair. There should not be a lot of maintenance required because it has a high longevity.
- Extended Detention Basin: The maintenance for the extended detention basin is the same as the traditional detention basin.

5.7.5 Evaluation Criteria 5 – Constructability

Estimated amount of time required to construct each structure. Direct estimates are not available; however, research was done to compare the alternatives. Each alternative has been assessed and rated based on the information given below.

- Conveyance System Parallel Storage: The constructability of the concrete storage container is the hardest part of a conveyance system, and it is not that hard. This is the option that will take the least amount of time to construct.
- Detention Basin:
- Extended Detention Basin: Since this is just a detention basin with extra parts, it has the same ease of construction as the detention basin.

5.7.6 Weighting of Criteria Importance

The client's goals and objectives were taken into consideration while developing the weighting system for the above decision statement. Although this project does not have a budget, 901 Design still made it a top priority to minimize costs for the client. Overall cost was the main consideration for determining the importance of each listed criteria. A secondary goal was to produce a storm water system that can withstand natural wear and tear over time and require little maintenance. A final goal was construction time for the system.

Taking this all into consideration, the following weighting system was developed for this decision statement (the higher the weighted value, the more important the criteria is to the project):

- Constructability
- Maintenance
- Longevity
- Material Cost
- Cost

5.7.7 Alternative Selection Matrix

Table 18. Stormwater Alternative Analysis Matrix

		Conveyance System Storage		**Detention Basin**		**Extended Detention Basin**	
Criteria	Weight	Score	(Weighted)	Score	(Weighted)	Score	(Weighted)
Cost	5	5	(25)	4	(20)	3	(15)
Material Cost	4	4	(16)	3	(12)	2	(8)
Longevity	3	3	(9)	4	(12)	4	(12)
Maintenance	2	4	(8)	3	(6)	3	(6)
Constructability	1	5	(5)	3	(3)	3	(3)
Total		21	(63)	17	(53)	15	(44)

5.7.8 Alternative Analysis Summary

Although none of the alternative analysis options have self-sustainability components, there still is a clear choice for the best alternative analysis. The conveyance system that has parallel overflow storm water storage is much easier to construct than any of the other options. It is the only option that does connect to the existing city storm water system.

5.8 Decision Statement 8 – Site Layout

5.8.1 Evaluation Criteria 1: Length of Alignment

This criteria measures the rest area's total length of the alignment for both car and truck's route. One should be aware that this does not include the alignment length of the entrance and the exit from and to the connected interstate. These alignment will be equal among three alternatives so their characteristic are independent with the outcome of this alternative analysis. A shorter total length of alignment is desirable mainly because of the lower cost of construction. In addition, lower travelling distance for vehicle operator is also a latent benefit because of being more suitable for low turnover rate facility, reducing driver's confusion and potential traffic conflict hazard.

Definition: The alternatives which yields the minimum total alignment length will receive a score of 5 out of 5. The two other alternatives will be graded of which score is an inverse relationship to the percentage of its ratio over the best alternative's alignment length. For example, if the best alternative yields a result of 200 foot of alignment length and the current alternative yields 300 foot, the current alternative will receive a score of 3.33.

Evaluation: Table 19 shows the comparison between three alternative and the associated score. The alignment length is measured directly from the technical drawing in APPENDIX C:.

Table 19. Alternative Evaluation of Criteria 1

	Alternative 1	Alternative 2	Alternative 3
Length of Alignment	824	501	2006
Score	3.04	5	1.25

5.8.2 Evaluation Criteria 2: Distance between car and truck parking lots with main area

This criteria measures both the distance from the car parking lot to the main area and truck parking lot to the main area. The objective is to minimize the walking distance for pedestrian which will make the rest area more appealing and increases public positive perception of convenience and user friendly.

Definition: The alternative which gives the least combination of car parking distance and truck parking distance is desirable. Each parameter is associated with two different weight respectively of which values add up into 1. Equation 2. shows how the weighted score is evaluated.

$$V = w_1 d_1 + w_2 d_2 \text{ where } w_1 + w_2 = 1 \qquad \text{Equation 2}$$

Three different scenarios of weight would be tested for the analysis. The best alternative would be given a score of 5, followed by the second and the third with a score of 4 and 3 respectively.

Evaluation: The technical drawing in AutoCAD allows 901 Design to accurately locate the centroid of each element. However, these centroids are presented in Cartesian Coordinates relative to AutoCAD Cartesian system. The detail calculation will be presented in Appendix C.9. Table 20. shows the calculated distances three alternative and the associated score.

Table 20. Alternative Evaluation of Criteria 2

	Alternative 1		Alternative 2		Alternative 3	
Characteristic	Car	Truck	Car	Truck	Car	Truck
	261	399	100	199	385	322
Weighted Score						
W1/W2	V	Score	V	Score	V	Score
0.5/0.5	330.0	4.0	149.5	5.0	353.5	3.0
0.7/0.3	302.4	4.0	129.7	5.0	366.1	3.0
0.3/0.7	357.6	3.0	169.3	5.0	340.9	4.0
Average		3.7		5.0		3.3

5.8.3 Evaluation Criteria 3: Future Expansion

The self-sustainability is greatly emphasized in the objectives of this project. Therefore, it is desirable if the site layout is oriented in a manner which facilitate for future expansion. Future expansion can be in forms of either expanding car or truck parking spaces or main area of the building. In addition, if possible, the site should not be confined with road alignment. The rationale is if additional infrastructure within the confined space, some modification to the current alignment would be necessary. Therefore, it certainly affects or even prohibit the circulation of traffic and put the rest area in a state of temporary inactive.

Definition: Each alternative will be evaluated based its capability of expanding. Moreover, the only modification to the current alignment is only extending the alignment along its direction and the modification is limited up to two alignments. The alternative will be given a score of 5 if all car parking, truck parking, and main area parking can be expanded. The alternative will be given a score of 3 if only the main area can be expanded. Finally, the alternative will be given a score of 1 of none of the element can be extended.

Evaluation: Table 21. shows the comparison between three alternative

Table 21. Alternative Evaluation of Criteria 3

	Alternative 1	Alternative 2	Alternative 3
Car Parking	Yes	No	Yes
Truck Parking	Yes	No	No
Main Area	Yes	No	Yes
Score	5	1	3

5.8.4 Evaluation Criteria 4: Truck Driver Circulation

This criteria's objective is to prevent the potential conflict of traffic between truck driver and other traffic within the area. Truck drivers often spends an extensive time driving compared to small vehicle operator which may leads to a reduction in consciousness. If possible, the truck parking lot should be located closely to the rest area. To be more specific, truck driver do not have to walk cross the car parking lot which may raise potential cross traffic conflict with cars in order to ensure their safety.

Definition: Alternative of which truck parking lot is directly connected to the main area of usage without the need of crossing car parking lot will receives a score of 5. On the other hand, alternative of which layout force truck driver to cross car parking lot in order to get into the rest area shall receive a score of 1.

Evaluation: Table 22. shows the comparison between three alternative

Table 22. Alternatives Evaluation of Criteria 4

	Alternative 1	Alternative 2	Alternative 3
Conflict between truck driver and car parking	Yes	No	No
Score	1	5	5

5.8.5 Evaluation Criteria 5: Security

Because the rest area design is to be self-sustaining and the less requirement for human supervision is desirable. The rest area may be prone to vandalism and the probability is even higher if it is located to nearby urbanized area. In order to prevent the act of vandalism by itself, the road alignment, if possible, should confine over the main area of usage. This road alignment along with the additional natural feature along the curbs such as trees will act as barrier and significantly discourage vandalism.

Definition: Alternative of which alignment is surrounding the main area of usage will be graded a score of 5. Alternative of which alignment does not surround the main area of usage will be graded a score of 1.

Evaluation: Table 23. shows the comparison between three alternatives

Table 23. Alternative Evaluation of Criteria 5

	Alternative 1	Alternative 2	Alternative 3
Main area surrounded by road alignment	No	Yes	Yes
Score	1	5	5

5.8.6 Weighting of Criteria Importance

There are five evaluation criteria of the site layout alternative analysis which are Length of Alignment, Relative Distance between Main Area, Future Expansion, Truck Driver Circulation, and Security. 901 Design has taken into the consideration of owner's objectives of which the most important elements are economic and user's safety. These objective are directly corelates to Length of Alignment, Relative Distance between Main Area, and Truck Driver Circulation. Therefore, these criteria will receives a weight higher than the others. The following table shows the weighting of criteria importance:

Table 24. Weighting of Site Layout Criteria

Criteria	Weight
Length of Alignment	2
Relative Distance between Main Area	2
Future Expansion	1
Truck Driver Circulation	2
Security	1

5.8.7 Alternative Selection Matrix

The following Table represents the results from the alternative analysis performed within the site layout analysis. Three alternatives are ranked accordingly to their Total Score. After careful considerations, 901 Design concludes that the Alternative 2 Inward-Oriented Design is the most suitable alternative for this project.

Table 25. Site Layout Alternative Analysis Matrix

Criteria	Weight	Alternative 1 Score (Weighted)		Alternative 2 Score (Weighted)		Alternative 3 Score (Weighted)	
Length of Alignment	2	3.04	(6)	5	(10)	1.25	(3)
Relative Distance between Main Area	2	3.7	(7)	5	(10)	4	(8)
Future Expansion	1	5	(5)	1	(1)	3	(3)
Truck Driver Circulation	2	1	(2)	5	(10)	5	(10)
Security	1	1	(1)	5	(5)	5	(5)
Total [Max: 25 (40)]		13.7	(21)	21	(36)	18.3	(29)

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CHAPTER 6: SUMMARY OF ADDITIONAL PRELIMINARY DESIGN

This chapter summarizes the additional design work that 901 has completed up through October 22, 2018. Each discipline will provide a summary of the work that has been done and will provide any drawings, calculations, sketches, etc. to the appendix section of this report.

6.1 Structural

The structural work done up to this point has been mainly conceptual. A preliminary structure has been designed (SEE APPENDIX A) but structural members have not been assigned to the structure. Load combinations are in progress, a spreadsheet has been developed (SEE APPENDIX A) to determine all load combinations, both LRFD and ASD.

The design of the building and bathroom floor plan took the International Building Code (IBC) of 2012("Searchable platform for building codes" n.d.), International Plumbing Code (IPC) of 2012("Searchable platform for building codes" n.d.), International Fire Code (IFC) of 2012("Searchable platform for building codes" n.d.), and the 2010 Americans with Disabilities Act (ADA)("Searchable platform for building codes" n.d.) standards into consideration to develop the preliminary structure and bathroom floor plan designs.

The building has been classified according to section 503 of the IBC. 901 Design determined that for this project, the building is classified as follows:

- Group: A-3
- Type of Construction: Type V – B

With the above classification, the building cannot exceed a maximum height of 40 feet or a maximum area of 6,000 ft^2.

From section 1021 of the IBC, the number of exits needed for the building are two. The building may have more but at a minimum, need two exits. The preliminary structure reflects these criteria.

Calculations were done in accordance with the AASHTO book "Guide for Development of Rest Areas on Major Arterials and Freeways" to determine how many urinals and water closets are needed for the bathrooms (SEE APPENDIX). A total ADT of 35,150 was used and then halved two reflect only the south-bound traffic (given during the TDOT presentation in class on September 17, 2018).

The bathroom floor plan utilized the IBC, IPC, and ADA to determine dimensions. Aisle widths are in accordance with section 1017.3 from the IBC. Aisles must cannot be less than 36 inches. Locations for the water closets are in accordance with section 604.2 from the ADA. The centerline of the water closet shall be 17 inches minimum and 19 inches maximum from the side wall. Clearances around the water closets are in accordance with section 604.3 from the ADA. Clearance around a water closet shall be 60 inches minimum measured perpendicular from the side wall and 56 inches minimum measured perpendicular from the rear wall. Wheelchair accessible water closets conform to section 604.8.1.1 of the ADA. Wheelchair accessible compartments shall be 60 inches wide minimum measured perpendicular to the side wall, and 59 inches deep minimum for wall-hung water closets measured perpendicular to the rear wall. Partitions for urinals and water closets are in accordance with section 405.3.1 from the IPC. A minimum of 15 inches is needed from centerline of urinal or water closet to adjacent partitions or walls. There shall be not less than 21 inches of clearance in front of the water closet or urinal. Water closet compartments shall be not less than 30 inches in width and not less than 56 inches in depth for wall-hung water closets.

The preliminary calculations done for structural loads are in accordance with “Minimum Design Loads for Buildings and Other Structures.” At this point, the snow load has been determined, wind load is in progress, and the rest of the calculations are setup in Excel (SEE APPENDIX).

6.2 Transportation

The preliminary engineering design and calculation of the horizontal alignment for rest area entrance ramp will be shown in the Appendix C.10.

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CHAPTER 7: SUMMARY

This chapter summarizes: the decision statements with recommendations for the best alternative, any additional preliminary engineering design work that has been completed up through October 22, 2018, and the remaining scope of services for the project, timeline for project completion, and anticipated final design completion date and presentation date.

According to the alternative analysis matrix for sewer systems, the designer is recommending installing a septic system. This is due to the fact that the septic system scores and 81 versus 62 of the tie in option. The biggest contributors to this conclusion is due to the cost of construction and feasibility. If cost of construction were to be removed from the system, then the septic system would still be the optimum choice by a score of 61-52. Similarly, if feasibility were removed, the septic system would still be the optimum choice by a score of 57-50. Choosing the septic system is concluded due to the fact that the sewer tie in option cost more to construct given that there is no current facilities in the vicinity to tie into and designing such a system in such a short period greatly reduces the design group's ability to provide a final product.

Grey Water Recycling:

Grey Water Recycling can be performed to help reduce the amount of potable water being used and help the building SSB and LEED rating. Also, this process will help reduce the amount of loading placed on the sewer system. Grey water is provided by sinks from handwashing for the rest area. It can be used to flush toilets, urinals and for landscape watering. Grey water is collected, treated and stored for its future use. However, due to the constraints of the 2012 IPC and grey water analysis, it is recommended that grey water recycling not be performed. This is concluded by the fact that according to the analysis performed, there is not enough grey water supplied from the building to meet the demand of flushing requirements. Grey water usage for watering is suggested as the grey water supply does not have to meet the need of demand. If there is not enough grey water in store for watering then the facility can use other watering needs until enough grey water is available.

According to the matrix analysis for pavement design, 901 design is recommending that a flexible pavement be designed be utilized for this project. Flexible pavements have several benefits over rigid pavements. The flexible pavement offers a lower cost to construct, can be easily repaired, does not restrict access to the site during construction, and can be completely recycled at the end of its design life. 901 Design believes these advantages will serve in the best interest of TDOT for the life of this project.

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APPENDIX A: STRUCTURAL

A.1 Combination Loads

Combination Loads

Loads (kips)	
D	
L	
L_r	
S	28.91
W	16.57
E	

LRFD		
1.4D	1	0.00
1.2D + 1.6L + 0.5 (L_r or S or R)	2	14.45
1.2D + 1.6(L_r or S or R) + (L or 0.5W)	3	54.54
1.2D + 1.0W + L + 0.5(L_r or S or R)	4	31.02
1.2D + 1.0E + L + 0.2S	5	5.78
0.9D + 1.0W	6	16.57
0.9D + 1.0E	7	0.00

Symbols	
A_k	Load or load effect arising from extra ordinary event A
D	Dead load
D_i	Weight of ice
E	Earthquake load
F	Load due to fluids with well-defined pressures and max. heights
F_a	flood load
H	Load due to lateral earth pressure, ground water pressure, or pressure of bulk materials
L	Live Load
L_r	Roof Live Load
R	Rain Load
S	Snow Load
T	Self-Straining Load
W	Wind Load
W_i	Wind-on-ice determined in accordance with Chapter 10

Building Dimensions	
Length (ft)	55.33
Width (ft)	52.25
Height (ft)	18.00

ASD		
D	1	0.00
D + L	2	0.00
D + (L_r or S or R)	3	28.91
D + 0.75L + 0.75(L_r or S or R)	4	21.68
D + (0.6W or 0.7E)	5	9.94
D + 0.75L + 0.75(0.6W) + 0.75(L_r or S or R)	6a	29.14
D + 0.75L + 0.75(0.7E) + 0.75S	6b	21.68
0.6D + 0.6W	7	9.94
0.6D + 0.7E	8	0.00

Roof Area (ft^2)	
A_r	2891

Wall Area (ft^2)	
A_{north}	996
A_{south}	996
A_{east}	941
A_{west}	941

A.2 Wind Load

Wind Load

Basic Wind Speed (See Figure 26.5-1A) (Risk Category II. See Snow Loads)		
V	115	mph

Wind Directionality Factor (Section 26.6, Table 26.6-1)		
K_d	0.85	

Exposure Category (See Section 26.7	
Surface Roughness	C
Exposure Category	C

Topographic Factor (See Section 26.8)		
K_{zt}	1.0	

Gust Effect Factor (See Section 26.9)		
G	0.85	

Enclosure Classifcation (See Section 26.10)
Partially Enclosed

Velocity Pressure Exposure (Table 27.3-1)		
$q_z = 0.00256K_zK_{zt}K_dV^2$		
q_z	24.46	
q_h	26.48	

Internal Pressure Coefficient (See Section 26.11 , Table 26.11-1)		
GC_{pi}	0.55	Towards
GC_{pi}	-0.55	Away

Velocity Pressure Exposure Coefficient (See Table 27.3-1)		
K_z	0.85	
K_h	0.92	

External Pressure Coefficient (Wall) (See Figure 27.4-1)		
C_p	0.8	Windward use q_z
C_p	-0.5	Leeward use q_h
C_p	-0.7	Side use q_h

External Pressure Coefficient (Roof) (See Figure 27.4-1)		
C_p	-0.77	Smaller Windward C_p
C_p	-0.25	Larger Windward C_p
C_p	-0.46	Leeward use q_h

P value roof windward		
p = qGCp-qi(GCpi)		
p	-5.64	Larger C_p
p	-17.29	Smaller C_p

Structure Flexible/Rigid (See Section 29.9.3)		
n_a = 22.2/h^(0.8)		
n_a	1.69	Rigid

Wind Design Pressure			
$p = qGC_p$			psf
Windward (South Wall) use q_z	p	16.63	psf
Leeward (North Wall) use q_h	p	-11.25	psf
Side Walls (East/West Wall) use q	p	-15.75	psf
Windward (South Roof)	p	-5.64	psf
	p	-17.29	psf
Leeward (North Roof)	p	-10.27	psf

Areas			Wind Loads		
$A_{south\ wall}$	996	ft^2	$W_{south\ wall}$	16566	pounds
$A_{north\ wall}$	996	ft^2	$W_{north\ wall}$	-11206	pounds
$A_{east/west\ wa}$	941	ft^2	$W_{east/west\ w}$	-14816	pounds
$A_{south\ roof}$	1445	ft^2	$W_{south\ roof}$	-8145	pounds
$A_{south\ roof}$	1445	ft^2	$W_{south\ roof}$	-24997	pounds
$A_{north\ roof}$	1445	ft_2	$W_{north\ roof}$	-14848	pounds

Symbols	
V	Basic wind speed obtained from Figure. 26.5-1A in mph.
K_d	Wind directionality factor in Table 26.6-1
K_{zt}	Topographic factor as defined in Section 26.8
G	Gust-effect factor
q_z	Velocity pressure evaluated at height z above ground, in psf
q_h	Velocity pressure evaluated at height z=h, in psf.
Gc_{pi}	Product of internal pressure coefficient and gust-effect factor to be used in determination of wind loads for buildings
K_z	Velocity pressure exposure coefficient evaluated at height z.
K_h	Velocity pressure exposure coefficient evaluated at height z=h
C_p	External pressure coefficient to be used in determination of wind loads for buildings.
p	Design pressure to be used in determination of wind loads for buildings, in psf
n_a	Approximate lower bound natural frequency (Hz) from Section 26.9.2

A.3 Snow Load

Snow Load

Ground Snow Load from Fig. 7-1		
P_g	10	psf

Snow Load		
S	28910	pounds

Minimum Snow Load for Low-Slope roofs (θ is less than 15 degrees, and P_g </= 20 psf) $P_m=I_sP_g$		
I_s	1.0	Table 1.5-1 and 1.5-2
P_m	10	psf

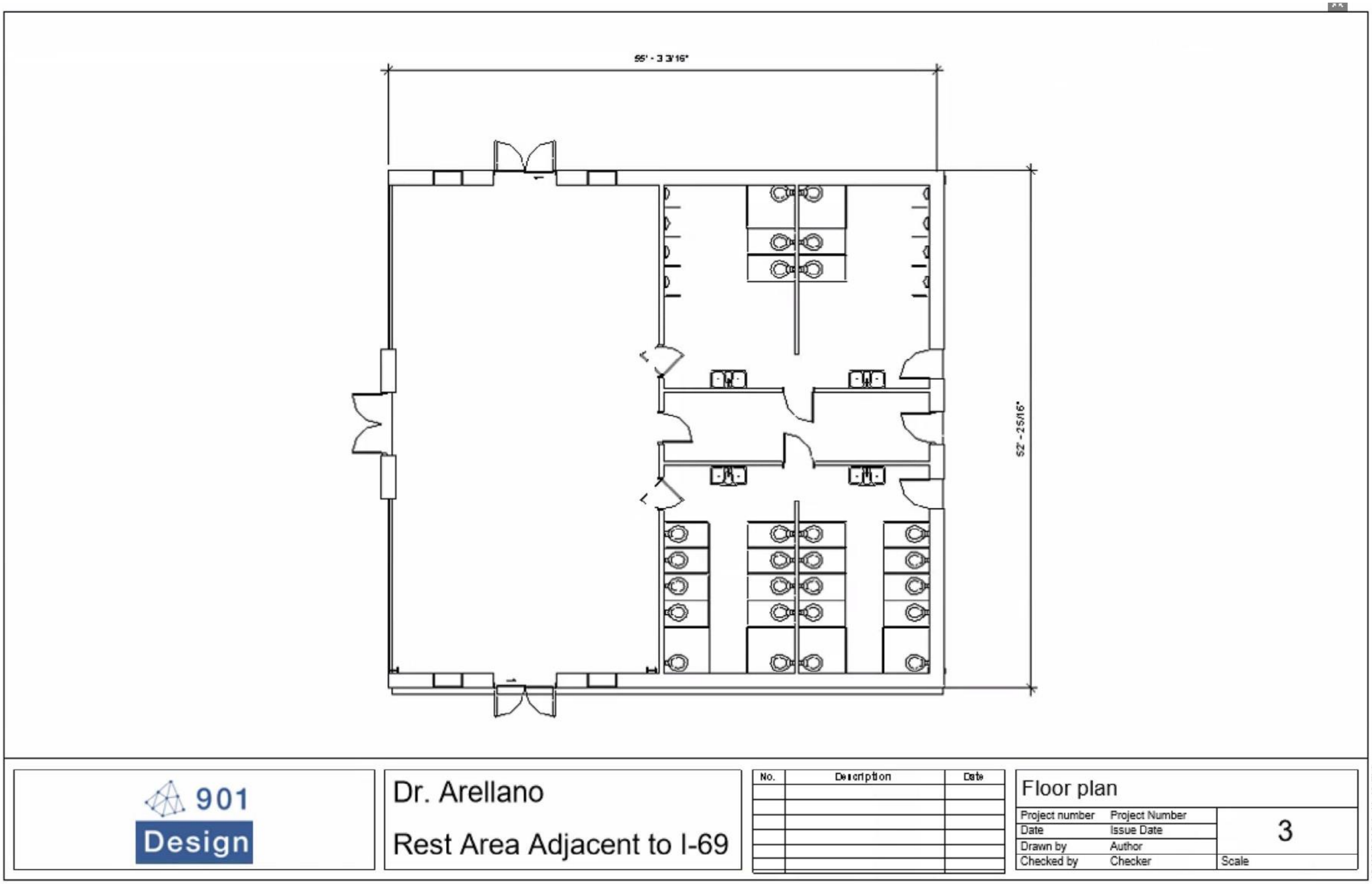
θ	11.1	degrees

Symbols	
C_e	Exposure Factor as determined from Table 7-2
C_s	Slope Factor as determined from Fig. 7-2
C_t	Thermal factor as determined from Table 7-3
h	Vertical separation distance in feet (m) between the edge of a higher roof including any parapet and the edge of a lower adjacent roof excluding any parapet
h_b	height of balanced snow laod determined by dividing p_s, by γ, in ft (m)
h_c	clear height from top of balanced snow load to (1) closest point on adjacent upper roof, (2) top of parapet, or (3) top of a projection on the roof, in ft (m)
h_d	height of snow drift, in ft (m)
h_o	height of bobstruction above the surface of the roof, in ft (m)
I_s	importance factor as prescribed in Section 7.3.3. Tables 1.5-1 and 1.5-2 (Shown below)
l_u	length of the roof upwind of the drift, in ft (m)
P_d	maximum intensity of drift surcharge load, in lb/ft^2
P_f	snow load on flat roofs ("flat"=roof slope </= 5 degrees), in lb/ft^2
P_g	ground snow load as determined from Fig. 7-1 and Table 7-1; or a site-specific analysis, in lb/ft^2
P_m	minimum snow load for low-slope roofs, in lb/ft^2
P_s	sloped roof (balanced) snow load, in lb/ft^2
s	horizontal separation distance in feet between the edges of two adjacent buildings
S	roof slope run for a rise of one
θ	roof slope on the leeward side, in degrees
w	width of snow drift, in ft
W	horizontal distnce from eave to ridge, in ft
γ	snow density, in lb/ft^3 as determined from Eq. 7.7-1

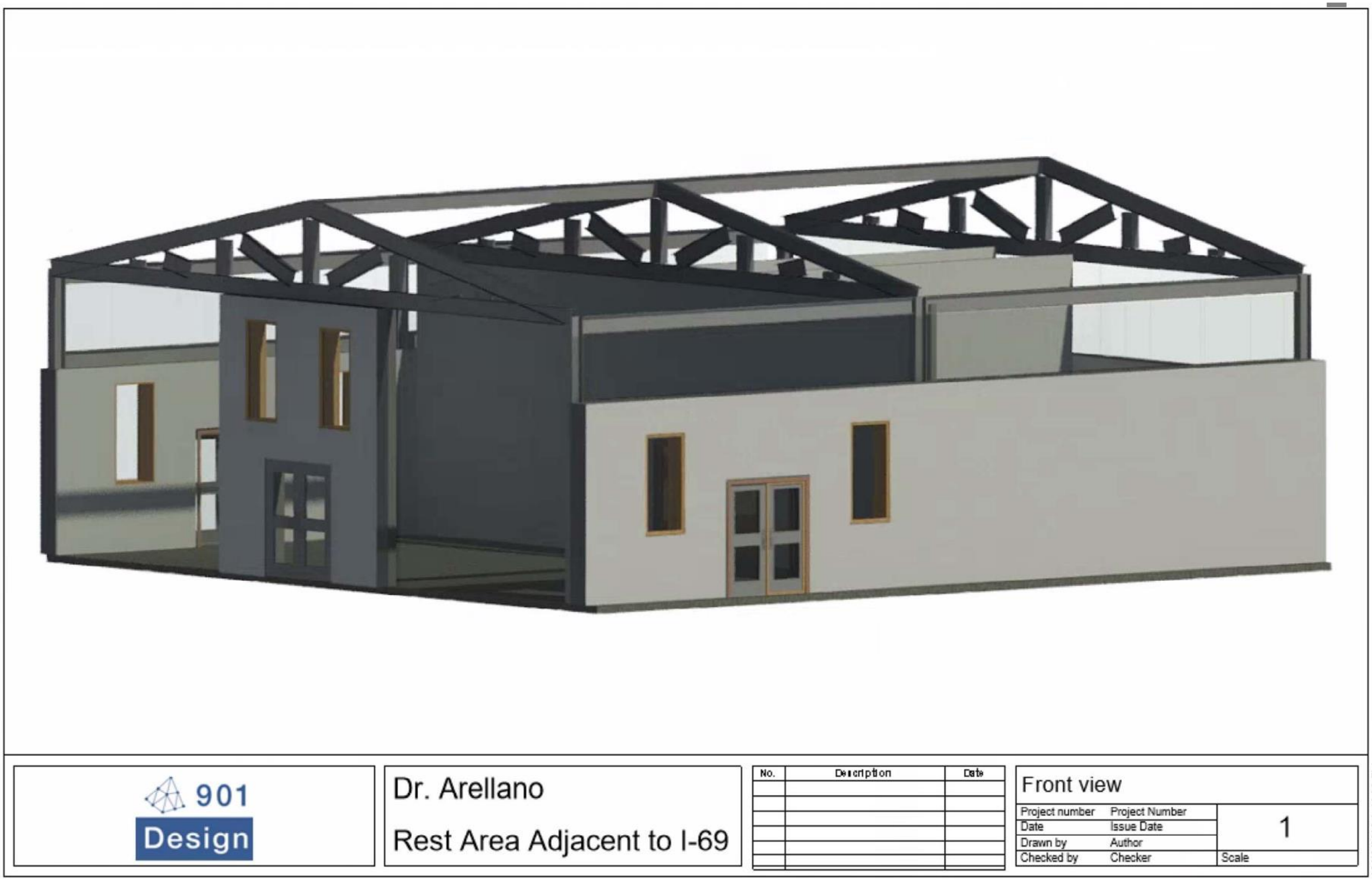
A.4 Rest Room Water Closet Calculation

Restroom Stalls	T_1=A*UV*B*PF*P*UHF	T=Total Toilets	32.90		
		A= 1 way Design Year ADT	17575.00	T_1	
		UV= 1.3 Restroom users per vehicle			
		B= .15= Ratio of Design hourly volume to ADT		T_2	32.90
	or	PF= 1.8= Peak Factor			
		P= Total % of traffic stopping at rest area	0.16	T_3= A*P*.0117	32.90
		UHF= 30= Restroom users per hour per fixture based on 2 min cycle			
	T_2=(S*1.3*1.5*1.8*P)/30				
	W= T * .6	W= Number of women's toilets		W=	19.74
	M= T * .4	M= Total number of men's toilets & urinals		M=	13.16

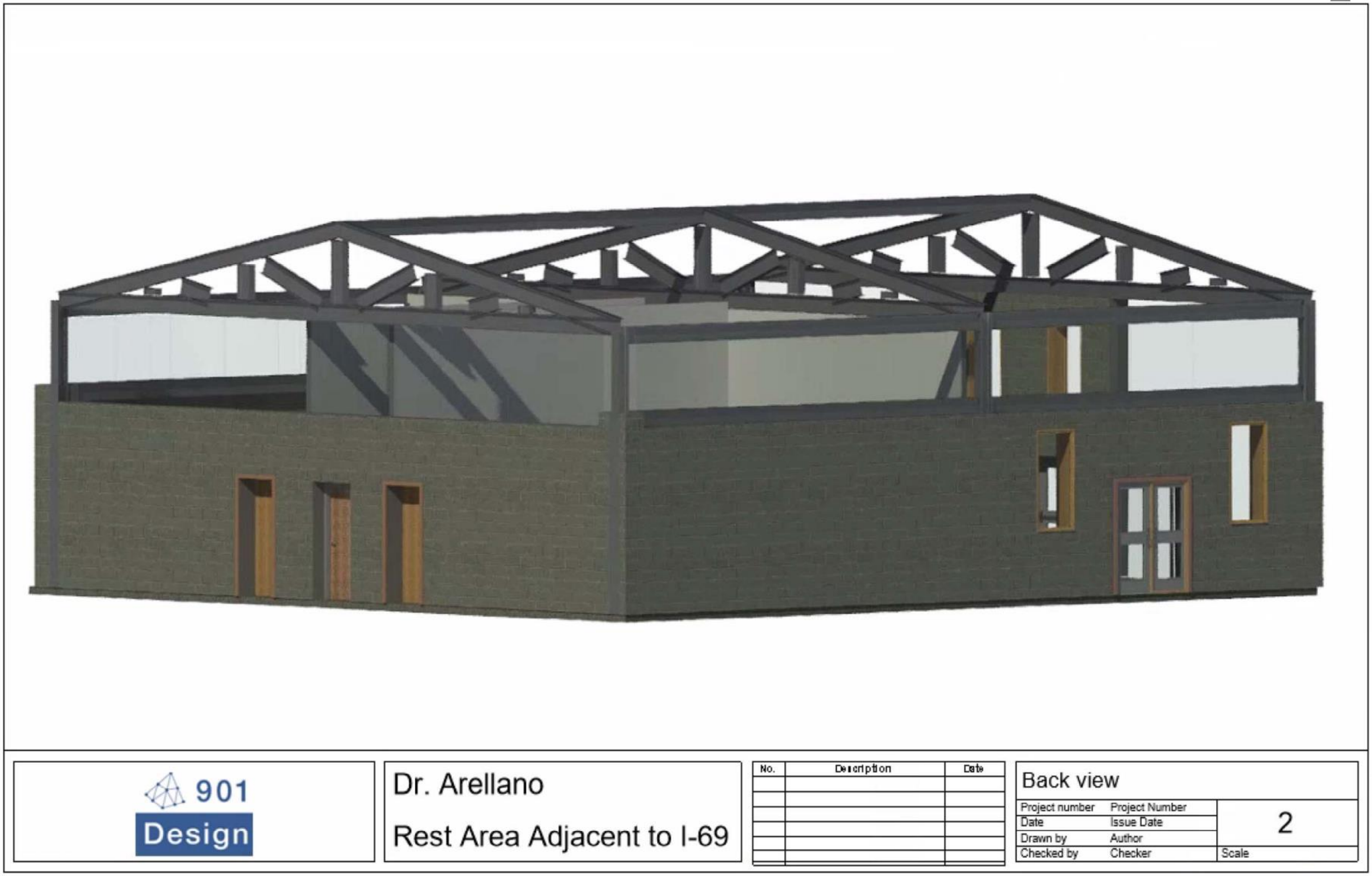
A.5 Building Floor Plan



A.6 Building Front Façade



A.7 Building Back façade



APPENDIX B: BOREHOLE PLAN

THE UNIVERSITY OF MEMPHIS

CIVL 4199 – CIVIL ENGINEERING SENIOR DESIGN

Geotechnical Investigation Boring Plan:

I-69 Proposed Rest Area

Date Submitted: October 19, 2018

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Available Subsurface Information

A site visit was made on September 17, 2018. The information collected from the site visit is that the location is existing farm land and has minimal elevation change. The site is private property, so observations could only be made from the shoulder of Wilkinsville Road. Information on the Soil surface was available on the Tennessee Virtual Archive (TeVA). TeVA's website displays a Shelby County Tennessee soil map of 1916. The map specifies the primary surface soils that are present around the proposed construction site location. These soils are shown to be predominately silt loam and Memphis silt loam. Additional information pertaining to the subsurface soil was found on the Web Soil Survey website. The data displayed below corresponds to the proposed construction site location.

Typical Subsoil Profile	
Depth	**Soil Type**
0 to 7 inches	Silt Loam
7 to 28 inches	Silt Loam
28 to 50 inches	Silt Loam
50 to 60 inches	Silt Loam

Table 1. Soil Typical Profile

Preliminary Model of Subsurface

The subsurface model displayed below (Figure 1.) corresponds to the information gathered from Web Soil Survey. The first 5 ft. of soil consist of silt loam. The location has an annually fluctuating ground water level that varies between 1 ft. to 2 ft 4 in. in depth. Silt soils are not ideal for shallow foundations and will most likely need to be cut and filled with more stable material. Silt soil has a tendency to retain moisture and drains poorly. The retention of water causes the silty soil to expand, pushing against a foundation and weakening it, making it not ideal for support. However, Loam is the ideal soil type. Typically, it's a combination of sand, silt and clay. Loam is great for supporting foundations because of its evenly balanced properties, especially how it maintains water at a balanced rate. Loam is a good soil for supporting a foundation and should allow the engineer to design a shallow foundation. The laboratory testing results will determine if the silt loam near the surface will need to be cut and filled with new soil.

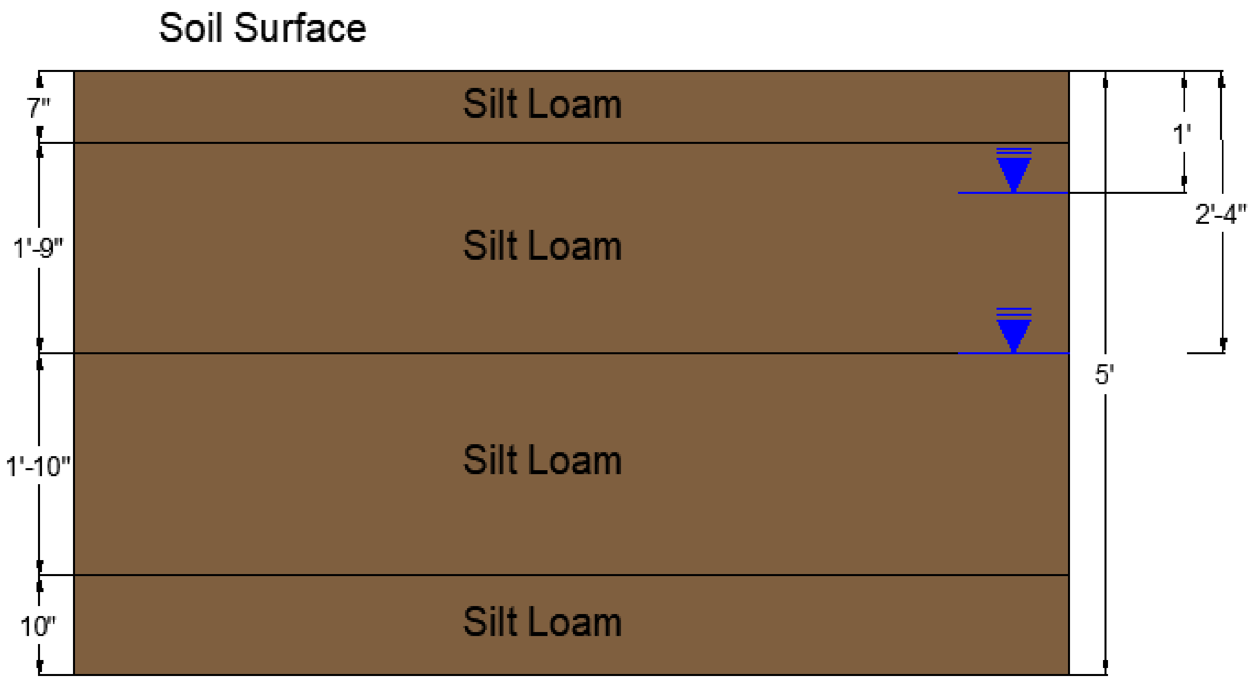


Figure 1. Interpreted Soil Profile

Required Soils Needed for Design and Construction

With the proposed site being in Shelby County Tennessee, sand's, silt's, and clays are all possible subgrade soils. A slab or continuous wall foundation was originally planned for this building. This plan is possible if lab tests conclude the existing soil is capable of supporting a shallow foundation. If the lab tests conclude the soil is not capable of supporting the shallow foundation, the location must undergo preliminary earth work before the foundation could be constructed. Preliminary earth work would involve removing the undesirable soil and replacing it with the appropriate soil type necessary to meet the foundations needs. If the silt loam soil is shown through laboratory testing to be a unstable soil and earth work/cut and fill is greater than a depth of 10 ft., the excessive preparation work may make a shallow foundation unappealing. If the situation occurs, where the sub soil is inferior in bearing capacity and settlement, a deep foundation will need to be considered. Firm clays, loam, or sand near the soil surface would be ideal for a shallow/continuous wall foundation.

Proposed Boring Location Plan

The construction site for the proposed I69 rest area has been chosen. However, the layout for the building and parking lot has not been finalized. For this reason, the boreholes for this project will be laid out in a grid pattern that extends 200 meters (656 ft. 2 in.) by 400 meters (1312 ft. 4 in.). The proposed rest area layout is approximately 180 meters (590 ft. 6 in.) by 300 meters (984 ft. 3 in.). The larger borehole grid pattern will allow the engineers to change the layout of the rest area and may alleviate the need for drilling more boreholes. The grid spacing was chose based off the Table 2. shown below.

Table 12.2 Approximate Spacing of Boreholes (Das)	
Type of project	Spacing (m)
Multistory building	10 – 30
One-story industrial plants	20 – 60
Highways	250 – 500
Residential subdivisions	250 – 500
Dams and dikes	40 – 80

Table 2. Borehole Spacing

The type of construction for the I-69 rest area is similar to a residential subdivision, but if a spacing of 250 meters (820 ft. 3 in.) was chosen there would only be one borehole within the proposed site layout, and most of the soil borings would be on the outer bounds of the proposed layout. For those reasons, a grid spacing between the boreholes will be 100 meters (328 ft. 1 in.). This spacing will result in a more detailed subsurface investigation, see the attached map (Figure 2.) for borehole locations. The number of boreholes confined to the grid will be 14. The center of the grid will overlap with the center of the proposed site layout maximizing the subsurface soil sampling for the available building area. There will be 4 additional boreholes for the building that will be placed 5 ft. away from the corners of the proposed building location. There is a total of 18 boreholes that will complete the subsoil investigation. After all soil sample are recovered, the boreholes confined to the grid will be backfilled with bentonite pellets. The 4 boreholes for the proposed building subsoil investigation will be backfilled with grout. Prior to soil investigation boring, surveyors will be hired to locate and stake the proposed borehole locations.

Boring Depths

The depth of boreholes will be calculated according to Sowers and Sowers (1970). The calculations in the table below represent two types of buildings. Both calculations will be examined, and the most practical borehole depth will be chosen.

$Db=3S^{0.7}$	(for light steel or narrow concrete buildings)	Equation (12.1) Das
$Db= 6S^{0.7}$	(for heavy steel or wide concrete buildings)	Equation (12.2) Das

Table 2. Boring Depth Equations

Where:

Db = depth of boring (m)

S = number of stories

The borehole depth for light steel buildings results in a depth of 3 meters (9.84 ft.). The borehole depth for heavy steel buildings results in a depth of 6 meter (19.69 ft.). If the light steel calculation was chosen for the borehole depth, assuming Web Soil Survey's data is correct, the engineer would only gain information on the next 5 ft. of subsoil. There will be large stresses placed on the soil from the building and the tractor trailer parking lot. For this reason, the borehole depth for the grid will comply with the heavy steel building calculation. The depth of the boreholes confined to the grid will be 20 ft. in depth. The boreholes that are placed for the building will have locations that diverge from the grid and will go down to deeper depths. The building boreholes will have a minimum depth of 20 ft. If firm soil is not found in the first 20 ft., the borings shall continue until firm ground is reached. The deeper depth of the building boreholes is meant to protect the building from any unexpected soil layers that could increase the settlement.

Field Tests

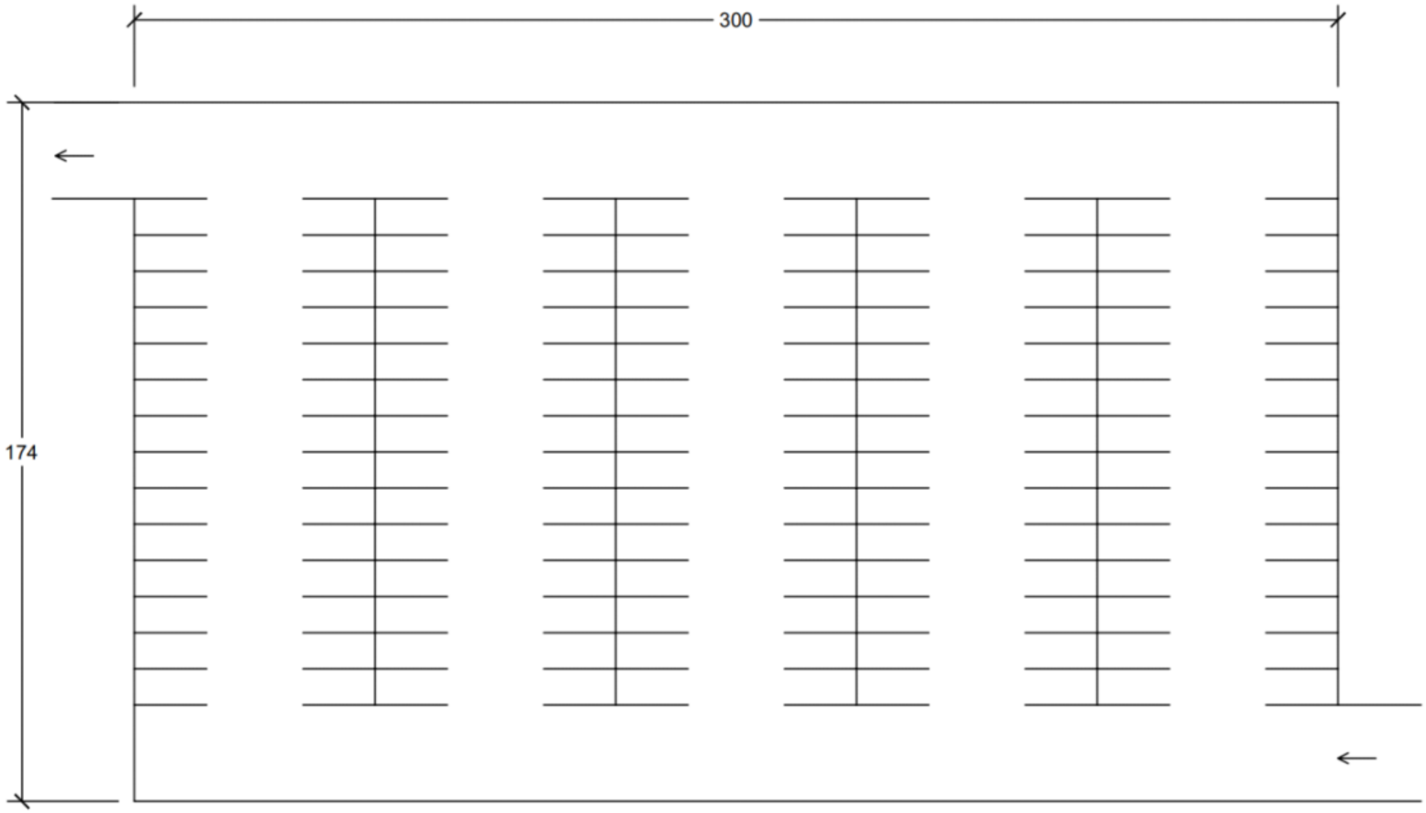
Field testing will be performed to gain information on the subsoil's friction angle (ø'), unit weight (γ), and ground water level. The test that will be completed in the field is the Standard Penetration Test (SPT). The SPT samples will be recovered every 1.5 meters (5 ft.). If soil sample recovery is unsuccessful due to a granular type of soil, it is advised that a spring core catcher be placed inside the split spoon sampler. The results of the SPT will give the soils N-value that will allow the engineer to determine the soils unit weight (γ), and friction angle (ϕ'). When cohesive soil is encountered, Soil samples will be recovered using thin walled tubes/Shelby tubes. Like the SPT, the Shelby tube samples will be recovered every 1.5 meters (5 ft.) when applicable. The unit weight of the soil and the ground water level are necessary for calculating the effective stress (σ'_o) of the soil. The Shelby tubes will allow the lab to receive undisturbed soil samples for testing consolidation, and undrained shear strength.

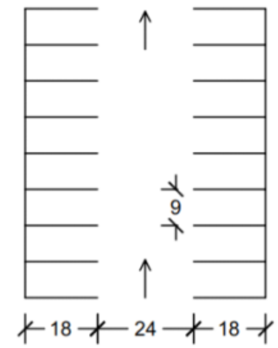
Laboratory Tests

The lab tests will allow the engineer to obtain the remaining soil parameters that are necessary to size the building foundation based on settlement and bearing capacity. The tests to be performed in the laboratory will include the in-situ water content test, sieve analysis, Atterberg limits, consolidation test, and the unconfined compressive test. All tests will be executed in compliance with ASTM specifications. The in-situ water content test is necessary for the engineer to understand the natural subsoil conditions that will influence the soils strength, settlement, and bearing capacity. A sieve analysis will also be completed to attain information on the subsoil particle gradation. The soil samples will also be tested for Atterberg Limits. The Atterberg limits test will allow the computation of the subsoils Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI). With Sieve Analysis and Atterberg Limits tests completed, the recovered subsoil samples will then be assigned the appropriate soil classification. Disturbed soil samples recovered from the SPT will suffice for in-situ water content, sieve analysis, and Atterberg Limit tests. The one-dimensional consolidation test, and the unconfined compressive strength test will both be performed using the soil samples recovered by Shelby tubes. The consolidation test will quantify both the ultimate amount of settlement and the time rate of settlement in the soil layers. Using laboratory derived parameters, field settlement behavior of the soil layer can be predicted. The results from the consolidation test will allow the calculation of the compression index (C_c), recompression index (C_r), and void ratio (e_o). The Unconfined compressive strength test will be performed to measure the unconfined compressive strength (qu) and undrained shear strength (su) of normally consolidated and slightly over consolidated cylindrical specimens of cohesive soil. The information attained from the unconfined compressive test is used to estimate the bearing capacity of spread footings and other structures when placed on deposits of cohesive soil. The completion of the previously described tests will allow the engineer to size a foundation based on bearing capacity and settlement.

APPENDIX C: TRANSPORTATION

C.1 Car Parking Alternative 1: Conventional Parking

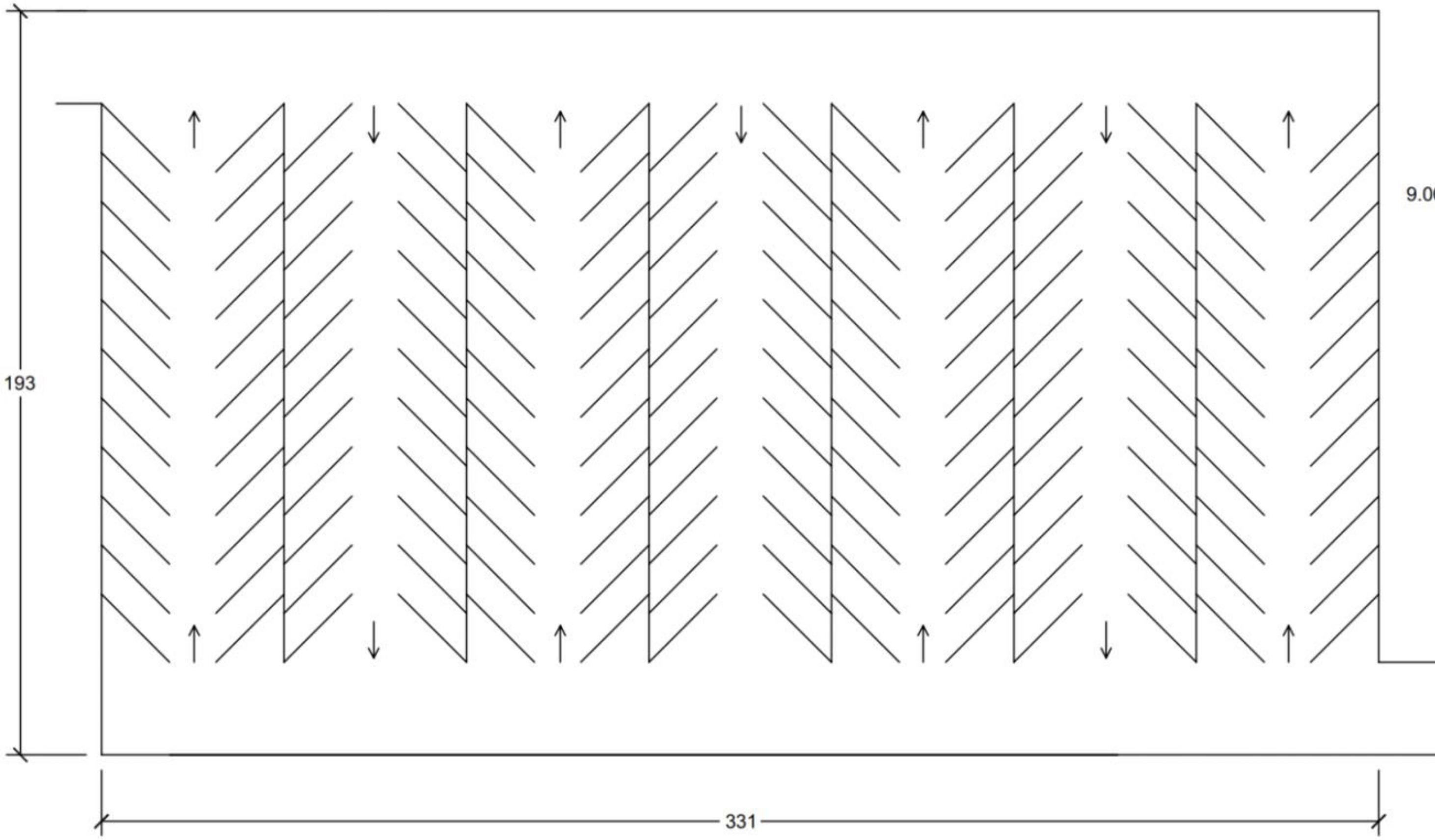


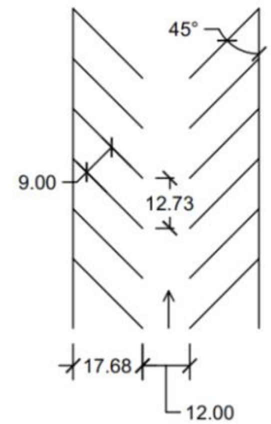


Parking Stall Geometry:
- Parking Angle: 90 Degree
- Parking Stall Width: 9'
- Aisle Width: 24'
- Vehicle Projection: 18'
- Stall Width Projection: 9'

Parking Layout Features:
- 140 Parking Spaces
- 4+1/2+1/2 parking columns of 14 parking space per column
- Area: 52,200 squarefeet
- Parking Efficiency: 373 sqft per space
- Pedestrian Parking lot walking distance:
- Mean: 88ft Standard Deviation: 36.41
- Number of stop sign required: 10

C.2 Car Parking Alternative 2: Angular Parking





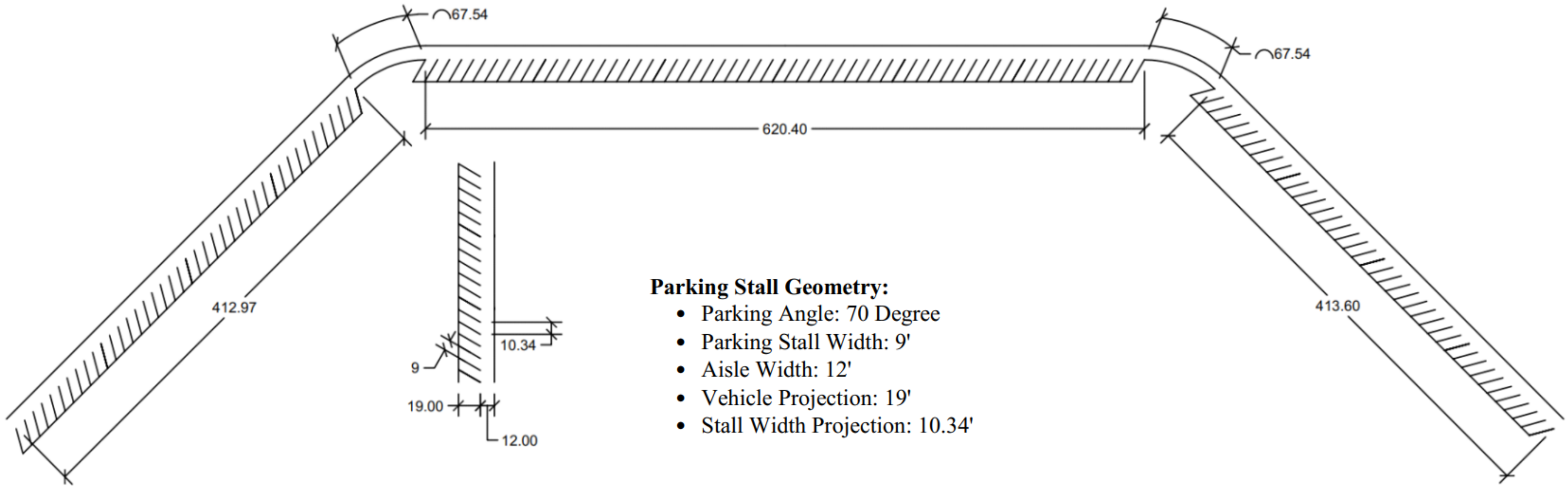
Parking Stall Geometry:

- Parking Angle: 45 Degree
- Parking Stall Width: 9'
- Aisle Width: 12' (one-way traffic)
- Vehicle Projection: 17.68'
- Stall Width Projection: 12.73'

Parking Layout Features:

- 140 Parking Spaces
- 6+1/2+1/2 parking columns of 10 parking space per column
- Area: 68,883 square feet
- Parking Efficiency: 456 sqft per space
- Pedestrian Parking lot walking distance:
  Mean: 96 ft Standard Deviation: 36.69
- Number of stop sign required: 7
- One-Way Traffic within the aisle
- Two-Way traffic in the top and bottom road alignment

C.3 Car Parking Alternative 3: Angular Parking Along the Curb



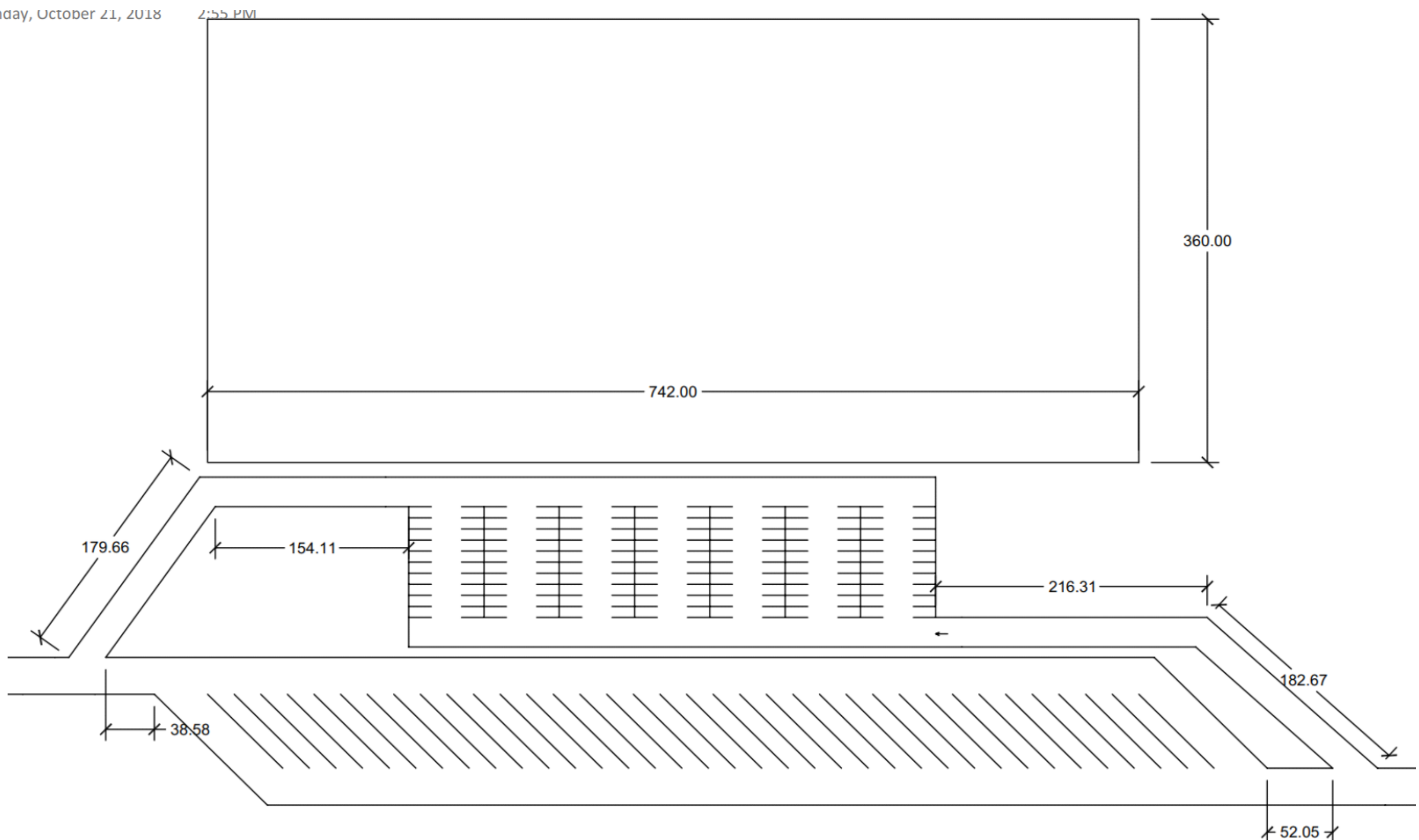
Parking Stall Geometry:

- Parking Angle: 70 Degree
- Parking Stall Width: 9'
- Aisle Width: 12'
- Vehicle Projection: 19'
- Stall Width Projection: 10.34'

Parking Layout Features:

- 140 Parking Spaces
- 60 Parking Lots on the left and right alignment; 80 parking lots in the center alignment
- Area: 44,874 squarefeet
- Parking Efficiency: 321 sqft per space
- Pedestrian Parking lot walking distance:
  Mean: 12ft Standard Deviation:0
- Number of yield sign required: 3

C.4 Site Layout Alternative 1: Outward-Oriented Design

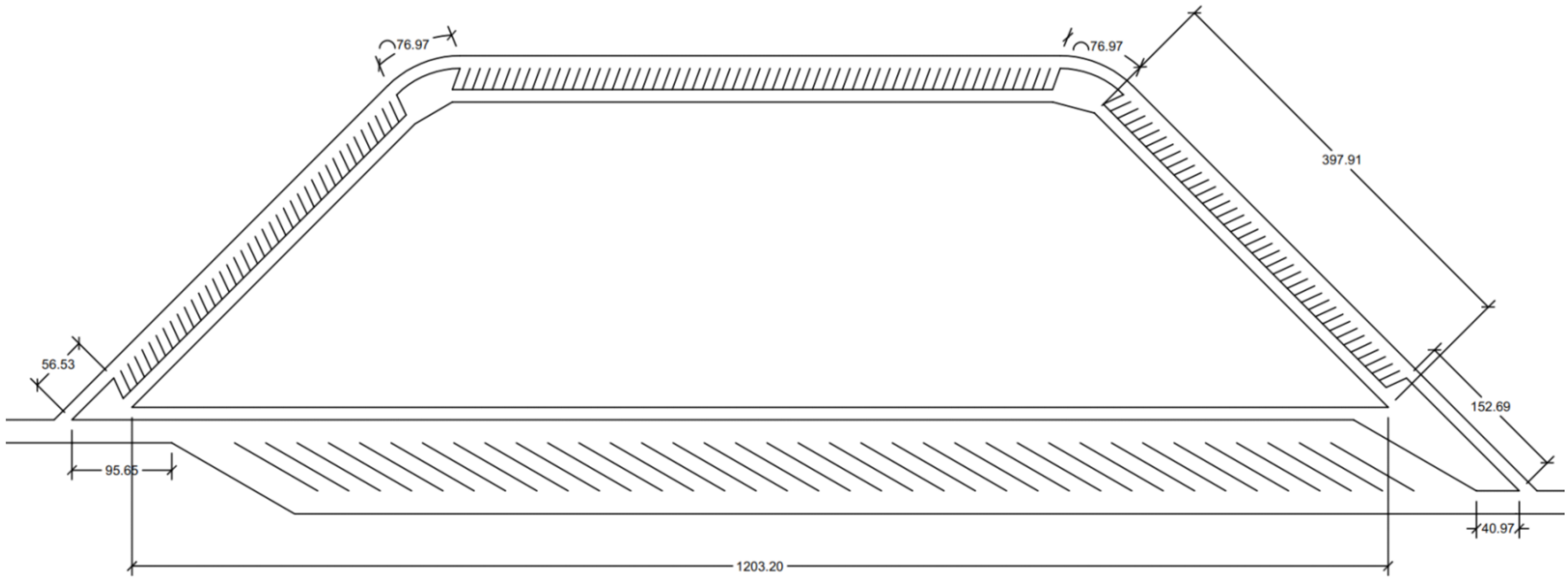


Parking Layout Features:

- Car Parking Alternative 1 for 140 Car Parking Stalls
- 45 Degree Parking Pull in and through for 35 Truck Parking Stalls
- A Total of 267,120 square feet of main area of usage (larger than 6 acres)

- A total of 824 ft road alignment
- Distance from Car Parking Lot to Main Area: 261
- Distance from Truck Parking Lot to Main Area: 399
- Two traffic in Car Parking Lot

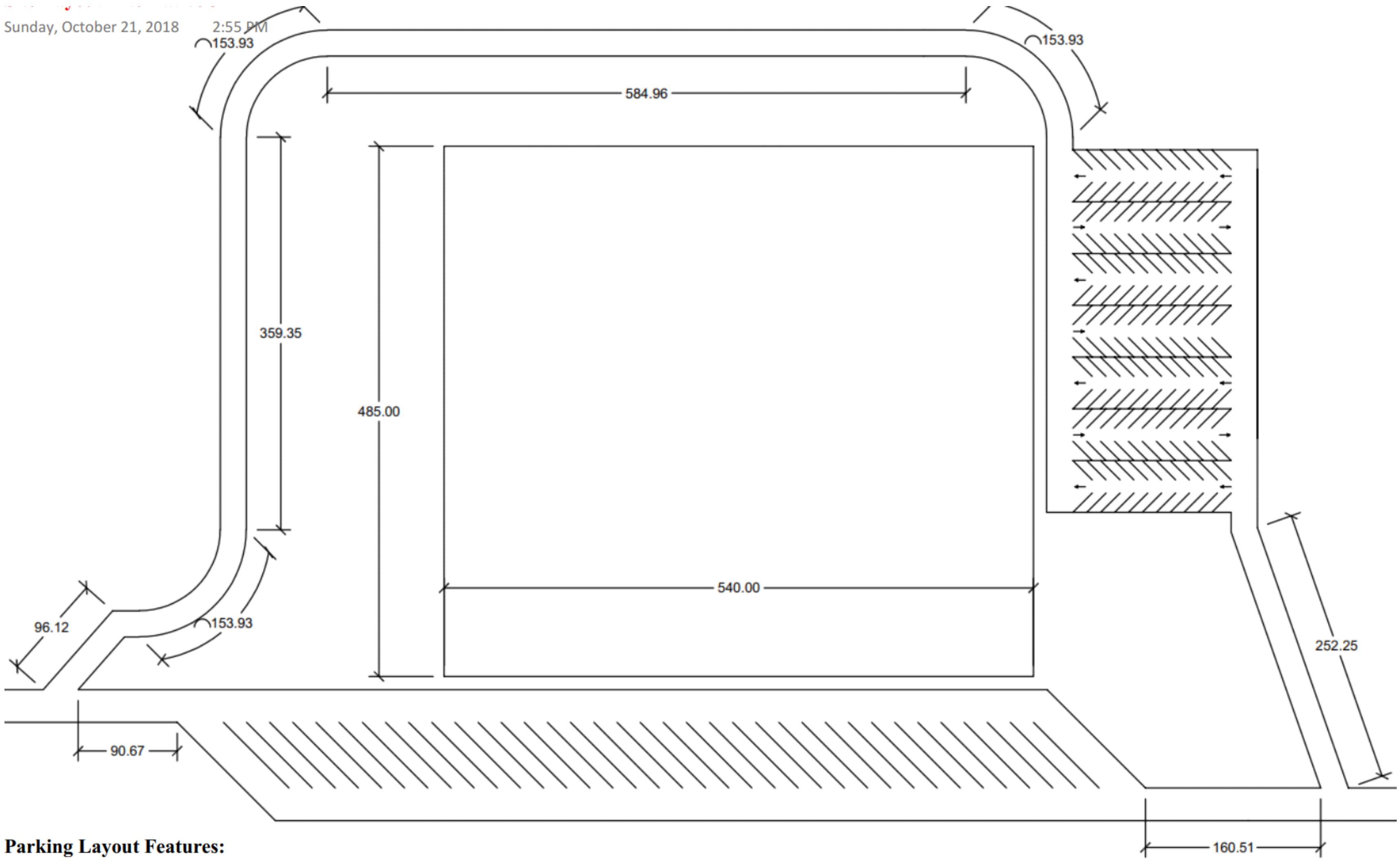
C.5 Site Layout Alternative 2: Inward-Oriented Design



Parking Layout Features:

- Car Parking Alternative 3 for 140 Car Parking Stalls
- 30 Degree Parking Pull in and through for 35 Truck Parking Stalls
- A Total of 265,708 square feet of main area of usage (larger than 6 acres)
- A total of 501 ft road alignment
- Distance from Car Parking Lot to Main Area: 100
- Distance from Truck Parking Lot to Main Area: 199
- One way traffic throughout

C.6 Site Layout Alternative 3: Mixed Design



Parking Layout Features:

- Car Parking Alternative 2 for 140 Car Parking Stalls
- 45 Degree Parking Pull in and through for 35 Truck Parking Stalls
- A Total of 261,900 square feet of main area of usage (larger than 6 acres)
- A total of 2,006ft road alignment
- Distance from Car Parking Lot to Main Area: 385 ft
- Distance from Truck Parking Lot to Main Area: 322ft

C.7 User Comfort Guidelines

*Adopt from

Guidelines: By comparing the design of the car parking lot versus the User Comfort Factor Grading Requirement shown in Table 2, One can determine the user comfort factor of it. User Comfort Factor relates to the ease of pulling into and out of the parking stall. The parameter is one of the performance measurement for car parking lot, which is equivalent to the analogy of Level of Service and Roadway performance measurement

Note: The aisle width as represented in Figure 1 and Table 2 refers to two-way traffic. If in the case the design is based on one-way traffic, the aisle width dimension can be reduced by half.

User Comfort Factor (UCF)	Level of Service	Easeness of Parking
4	A	Excellent
3	B	Good
2	C	Acceptable

Table 1. User Comfort Factor Definition

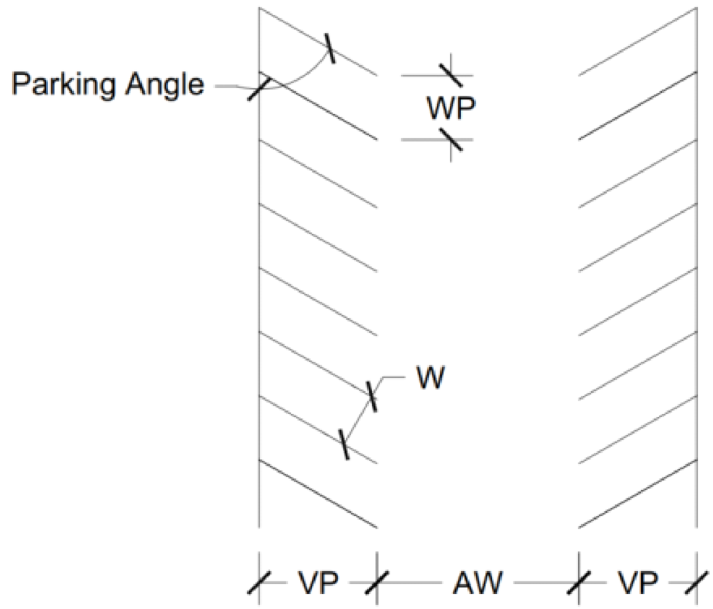


Figure 1. Geometry of Parking Stall

Table 2. User Comfort Factor Requirement

Parking Angle	Stall Width Projection (WP)	Vehicle Projection (VP)	Aisle Width (AW)	Stall Width Projection (WP)	Vehicle Projection (VP)	Aisle Width (AW)	Stall Width Projection (WP)	Vehicle Projection (VP)	Aisle Width (AW)
	User Comfort Factor 4 : w = 9'-0"			**User Comfort Factor 3: w = 8'-9"**			**User Comfort Factor 2: w = 8'-6"**		
45	12'-9"	17'-7"	14'-8"	12'-4"	17'-7"	13'-8"	12'-0"	17'-7"	12'-8"
50	11'-9"	18'-2"	15'-3"	11'-5"	18'-2"	14'-3"	11'-1"	18'-2"	13'-3"
55	11'-0"	18'-8"	15'-8"	10'-8"	18'-8"	14'-8"	10'-5"	18'-8"	13'-8"
60	10'-5"	19'-0"	16'-6"	10'-1"	19'-0"	15'-6"	9'-10"	19'-0"	14'-6"
65	9'-11"	19'-2"	17'-5"	9'-8"	19'-2"	16'-5"	9'-5"	19'-2"	15'-5"
70	9'-7"	19'-3"	18'-6"	9'-4"	19'-3"	17'-6"	9'-1"	19'-3"	16'-6"
75	9'-4"	19'-1"	19'-10"	9'-1"	19'-1"	18'-10"	8'-10"	19'-1"	17'-10"
90	9'-0"	18'-0"	26'-0"	8'-9"	18'-0"	25'-0"	8'-6"	18'-0"	24'-0"

C.8 Optimum Parking Stall Analysis

Optimum Parking Stall

Sunday, October 21, 2018 2:30 PM

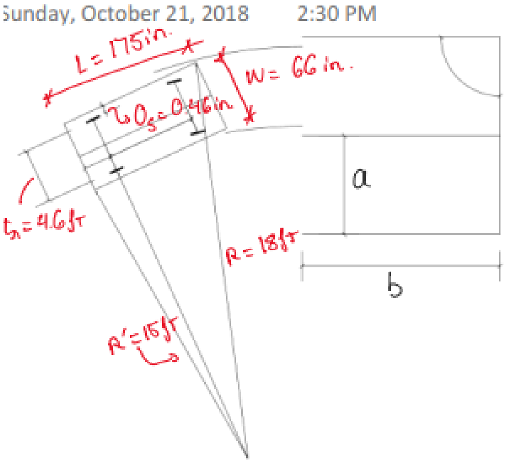


Figure. Minimum Turning Paths Into Stall

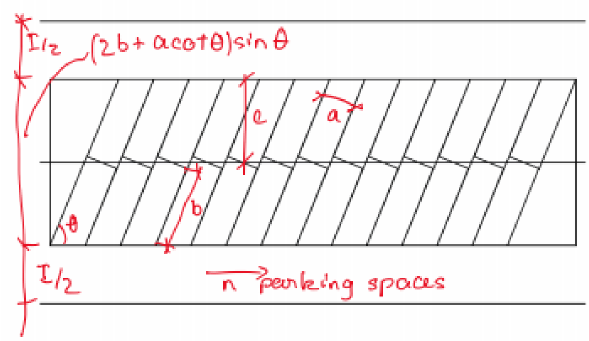
- The assumption for small vehicles dimension are given in the picture on the left. The data is extracted from a study of Weant (1984)
- Ricker (1948) computed aisle width as a function of parking angle θ:

$$I = R' + C + \sin\theta\sqrt{R^2 - (r + t_n + O_s + i - c)^2} - \cos\theta(r + t_n + O_s + a) \quad (1)$$

which: • C: clearance between cars = 1 ft
• i: intercar distances = $a - 2O_s - t_n = 2.3$ ft

Plug in the number

$$I = 2.04a + 1.15a\sin\theta - 1.7a\cos\theta \quad (2)$$



Overall area:

$$A = \frac{an}{\sin\theta}\left(\sin\theta(2b + a\cot\theta) + I_\theta\right)$$

There are 2n parking stall

=> Unit area:

$$A' = \frac{A}{2n} = \frac{a}{2\sin\theta}\left(\sin\theta(2b + a\cot\theta) + I_\theta\right)$$

Assume $b = 1.8a$

$$A = f(\theta) = a^2\left(\frac{1.02}{\sin\theta} - 0.35\cot\theta + 2.375\right)$$

In this project:

Stall Width = a = 9'

- Alternative 1:

$$A_1 = f(90) = 274.99\ ft^2$$

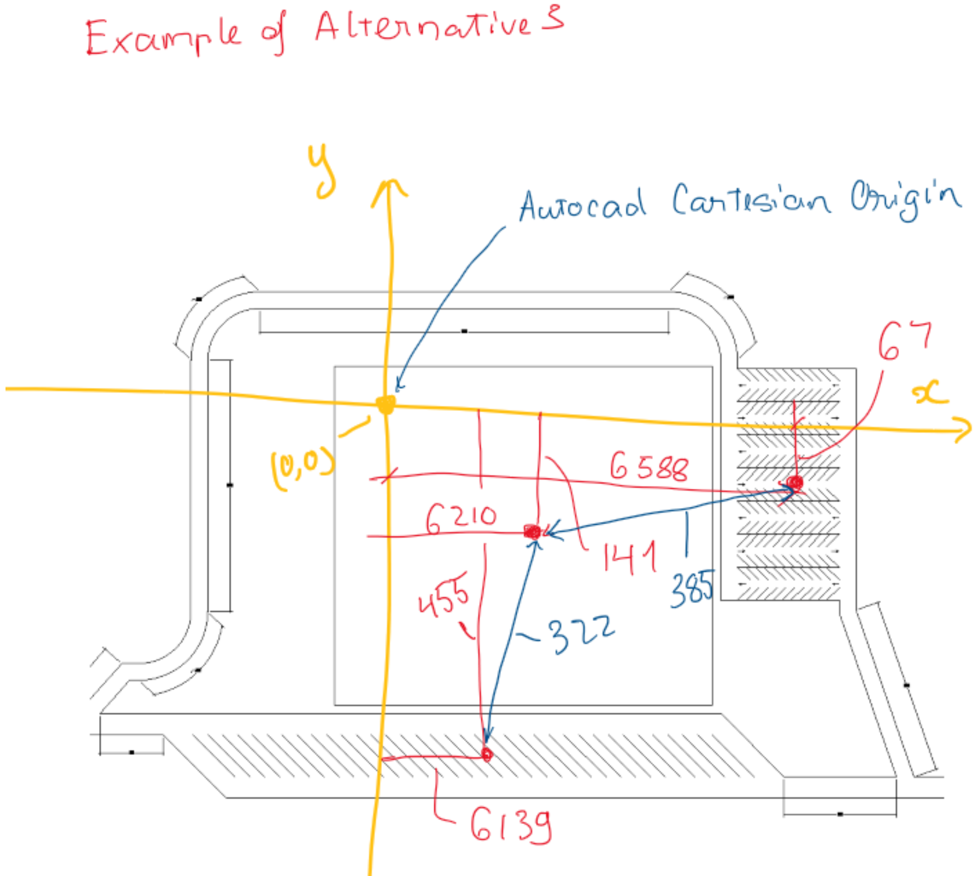
- Alternative 2:

$$A_2 = f(45) = 280.87\ ft^2$$

- Alternative 3:

$$A_3 = f(70) = 269.98\ ft^2$$

C.9 Distances Between Area Analysis



For $A(x_A; y_A)$ and $B(x_B; y_B)$:

$$\Rightarrow AB = \sqrt{(x_A - x_B)^2 + (y_A - y_B)^2}$$

	Alternative 1		
	Car parking lot centroid	Truck parking lot centroid	Main area of usage of centroid
X (ft)	7471.1265	7501.8304	7471.8304
Y (ft)	314.3169	177.0102	575.3169
Distance from car parking to main area	261.0009492		
Distance from truck parking to main area	399.4348849		

	Alternative 2		
	Car parking lot centroid	Truck parking lot centroid	Main area of usage of centroid
X (ft)	5834.2752	5897.4696	5836.1337
Y (ft)	807.224	518.2629	707.4529
Distance from car parking to main area	99.78840823		
Distance from truck parking to main area	198.8842596		

	Alternative 3		
	Car parking lot centroid	Truck parking lot centroid	Main area of usage of centroid
X (ft)	6588.6545	6139.1757	6210.1757
Y (ft)	-67.5232	-455.3977	-140.8977
Distance from car parking to main area	385.5256403		
Distance from truck parking to main area	322.4147174		

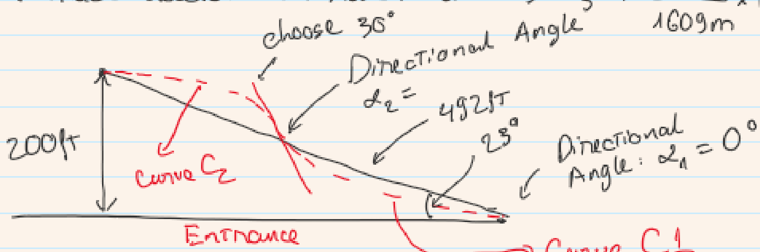
*Figure is not to scale

C.10 Horizontal and Vertical Alignment of Entrance and Exit Ramp

Monday, October 22, 2018 9:30 AM

Given:
- Parking lot speed limit: $v_2 = 20$ mph
- Highway speed limit: $v_1 = 70$ mph
- Radius design speed: 55 mph.
- Buffer from highway to rest area: $D = 200$ ft
- Truck deceleration rate: $a = 3\ m/s^2 \times \frac{1\ \text{miles}}{1609\ \text{m}} \times \left(\frac{3600\ \text{s}}{1\ \text{hr}}\right)^2 = 24{,}164\ \frac{\text{miles}}{\text{hr}^2}$

ITE 1999



- Deceleration distances:

$$d_{min} = \frac{V_2^2 - V_1^2}{2a} = \frac{20^2 - 70^2}{2\times(-24{,}164)} = 0.0931\ \text{miles} = 492\ \text{ft}$$

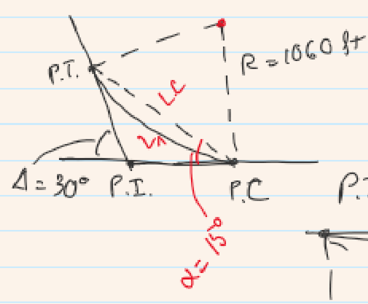
Curve C1

Green Book Min Radius:

$R = 1060$ ft for $v = 55$ mph

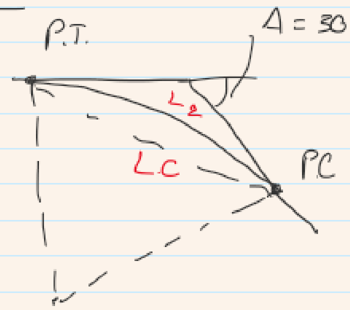
Degree of Curve: $D = \frac{5729.58}{1060} = 5.405$

$L_1 = 100\frac{\Delta}{D} = 100 \times \frac{30}{5.405} = \boxed{555\ \text{ft}}$



$L_1 + L_2 = 555 \times 2 = 1110 > d_{min} = 492$ ft

Curve C2:



Superelevation profile shall be provided later

*Figure Not To Scale

C.11 Parking Capacity Calculation

Parking capacity

Publication BM (DM-2)

Monday, October 22, 2018 11:50 AM

Given:

Parameter	Definition	Value
ADT	Average daily Traffic (30 year projection)	35,150 (Collected From TDOT)
K	Ratio of Design hour Volume	0.12 (Rural Area)
D	Directional Distribution	0.6 (Common Value)
P_{stop}	% of vehicle stop at rest area	9% (Rural Area)
P_{car}	Percentage of cars	
P_{truck}	Percentage of Trucks	
T_{stay}	length of Stay	0.5 (30 min)

Output

N_{car}	Number of car parking spaces	0.8
N_{truck}	Number of truck parking spaces	0.2

Calculations:

Peak Hour Directional Traffic: $PHD = ADT \times K \times D = 35{,}150 \times 0.12 \times 0.6 = 2530.8$

Number of Parking spaces: $N = PHD \times P_{stop} \times T_{stay} = 35{,}150 \times 9\% \times 0.5 = 113.8 \rightarrow 114$

↳ Number of car parking: $N_{car} = 114 \times 0.8 = 91$ spaces

Truck parking: $N_{truck} = 114 - 91 = 23$ spaces

Owner's objectives: $N_{car} = 140$; $N_{truck} = 35$

$\rightarrow$ $N_{car} = 140$

$N_{truck} = 35$