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Midwest Roadside Safety Facility Expansion for Enhanced Research Capabilities

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An Undergraduate Honors Thesis
Submitted in Partial fulfillment of
University Honors Program Requirements
University of Nebraska-Lincoln

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Personal Statement

Unlike some firms that have engineers that specialize in certain subsets of engineering, much of the technical work done by Group 1, also known as Zana Engineering, was done collaboratively as a group. We decided to work this way to allow for everyone an opportunity to understand and gain knowledge of the entire scope of the project. This also allowed for easier sharing of ideas as well as a way to hold one another accountable for completion (although this was never a concern). Collaborative group work also allowed for the group to help on certain parts quickly if there were any problems or concerns without having to be caught up on any certain part. Additionally, we were each able to utilize our skillset from previous and current classes to make adjustments and additions to the design as needed. I appreciated the fact that everyone was able to bring a unique perspective to each aspect of this project.

Individually, my first task was to take meeting notes as well as facilitate and coordinate a regularly scheduled meeting. Additionally, I found myself heading the work for our initial design of the parking lot for the building as well as determining permitting requirements regarding wetlands, city parking lot standards, building design criteria, and any other requirement for the parking lot or airport. However, after meeting with Cody from Midwest Roadside Safety, we found that a parking lot was unnecessary for the scope of this project. I redirected my attention to assisting in the design of the building columns and foundations. Isaac and I created the column layouts and beam designs for the structure, as well as additional CAD work on the building foundation. Once this was complete, I wrote and edited a significant portion of our project report.

My role as an Honors student was a bit more than might typically be asked of for a student. On top of my own contributions to the technical and design work on this project, I was expected to be a leader for my team. I embodied leadership throughout this project through my keeping of the meeting minutes, organization of meetings, leading the Zana Engineering team through our class presentations, and taking the role of primary contact for faculty and staff. I have also taken on the responsibility of making final edits and submissions of our report and supporting documents. Working and leading the Zana Engineering team through this project was a great experience - I could not have asked for a better group.

Joseph (L.J.) Hajduch

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ZANA ENGINEERING

LJ Hajduch, Isaac Hansen, Jeff Schroeder, Hozhin Sleman, Ben Wortman

CIVE 489-150 Senior Design Project

Final Design

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Abstract

As Civil Engineering students, this group was tasked with designing and proposing an engineering solution to a real-world problem. In this case, the Midwest Roadside Safety Facility (MwRSF) in Lincoln, Nebraska was looking for a planned proposal to add an additional building to their property for the purpose of additional research and office space. The group decided on the name Zana Engineering – Zana translating to “highly educated” in Kurmanji – to function as the organization responsible for creating this proposal and presentation. Zana Engineering designed this plan on several key factors, most significantly utility, affordability, safety, sustainability, functionality, longevity, and the possibility of future expansion. In order to fully analyze the scope of this project, the team utilized various site and soil profiles, maps, and multiple design manuals. Additionally, the team utilized AutoCAD 3D and Revit software to create the proposed designs. The team found that the ideal solution was to create a three-story multifunctional complex with a basement. The design incorporates design and research space for graduate students, office space for employees and faculty, a viewing deck for crash testing, and additional storage space. The building is located on the Northwest corner of the Lincoln Airport, with additional open space to the North and West of the proposed location to allow for future expansion. The total cost of the project was estimated to be $23,960,550 completed in roughly 18 months.

Key Words:

Design, proposal, plan, superstructure, foundation

Executive Summary

Zana Engineering is submitting a design report at the request of Midwest Roadside Safety Facility (MwRSF) for the design of the large-scale commercial building that has been proposed and accepted. This building will be a relocated facility for the Midwest Roadside Safety group. Midwest Roadside safety is currently based in Whitter Hall on UNL's campus in Lincoln, NE. This expansion will allow the group to relocate to the Northwest corner of Lincoln airport. This relocation will provide various benefits, such as a larger research space, closer proximity to crash tests, and allowing outside investors to tour an updated private facility. The following report is intended to assist in selecting a consultant for the design and construction oversight. Enclosed is research conducted based on site conditions, a proposed design by the engineering team, the characteristics, cost of engineering services, and other deliverables completed by the Zana Engineering team.

Introduction

Zana Engineering is thrilled to be able to work with the Midwest Roadside Safety Facility to deliver the design of and construction of a new facility. This new facility for the Midwest Roadside Safety Facility (MwRSF) will be located at its current test site at 4630 NW 36th street. This is located adjacent to Lincoln airport. Currently, MwRSF is operating from office space located in Whitter Hall on UNL's Lincoln campus. In addition, their vehicle preparation shop, vehicle crash site, and supporting equipment for conducting research and gathering data is currently being completed at the 4630 NW 36th street location. The students and staff working for the MwRSF would benefit greatly from adding a new multiuse facility near the test site.

At Zana Engineering, we have completed the structural design of a three-story building and additional parking in the area. Regarding the building, the third floor of the building will include laboratories and research space for graduate students consisting of a graduate lounge and a handful of private offices for higher-ranking professionals. This floor is dedicated primarily to university graduate students working with the MwRSF. The second floor will have general space to be used by undergraduate research along with a handful of private offices again for higher-ranking professionals. The main floor will be towards office space for the MwRSF full-time staff and additional lab space. All floors will consist of conference rooms, restrooms, and a kitchen to support everyday activities at the workplace. Additional design aspects include an outdoor hangar for vehicles and equipment at the test site, rainwater runoff and drainage, and transportation to and from the facility.

Project Background and Site Overview

MwRSF test site is for design, evaluation, simulation, component testing, full-crash testing, and implementation of roadside safety devices. The Midwest Roadside Safety Facility is leading the industry in using this technology to design and produce first-class roadside barrier systems. These systems are designed to capture and redirect vehicles impacting a more considerable number of conditions that may be experienced in practice adjacent to the nation's highway. This research supports high-speed motorsports applications at speeds up to 150 mph, heavy trucks contain the systems for 80,000-lb tractor-trailer vehicles impacting at a speed of 50 mph and a wide array of safety devices for passenger vehicles. An aerial view of the current MwRSF site can be seen in *Figure 1* and *Figure 2* show the 100' x 125' building location in green.

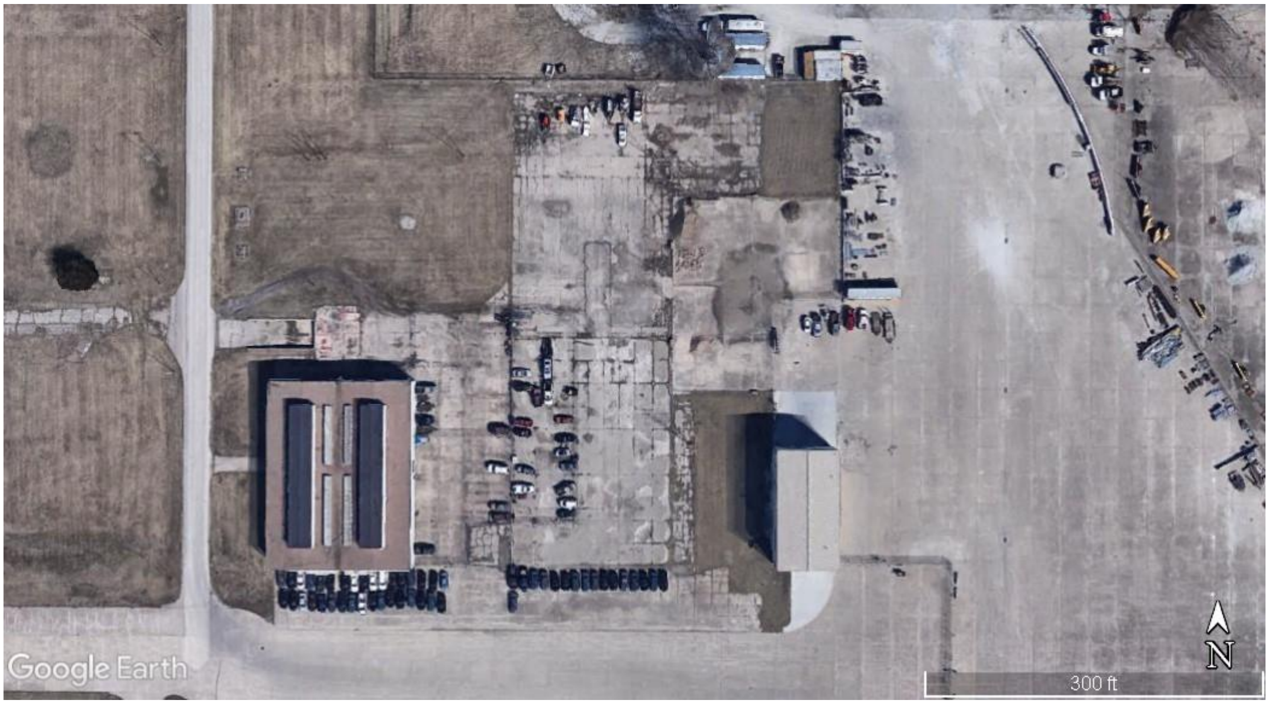


Figure 1. Aerial View of Project Site

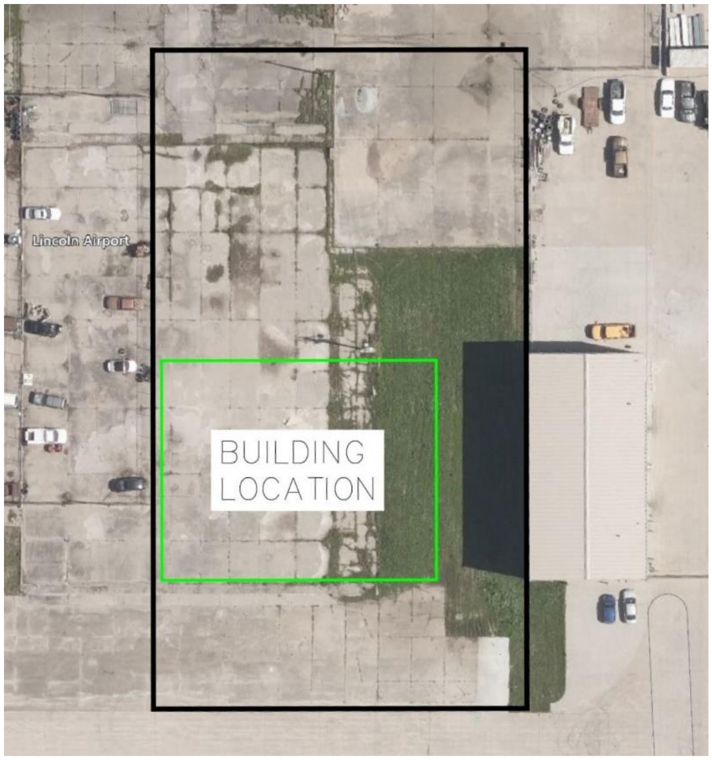


Figure 2. Building Location (100’ x 125’ shown in green)

The new multi-model access facility will support existing MwRSF research and engineering project development as well as expand research in areas such as, agricultural applications, and interaction with transportation systems, commercial trucking and automation, electrical vehicle implementation, civil infrastructure construction, and automation, and defense and security applications. The new facility dramatically expands UNL’s existing research capabilities and ensures the university is poised to capture the rapidly evolving transportation landscape development.

The objective of this project is to design a whole facility to accommodate MwRSF and partner research needs. This building consists of a ground floor office and a small construe testing laboratory with conference rooms, additional offices, conference rooms, and lab space for partner research agencies. The total design effort includes the consideration of rainwater runoff and drainage, the power, office and laboratory space structural design, transportation to and from the facility, and observation area. An effort to add a large conference auditorium adjacent to the laboratory space is anticipated, so the new facility's design should include the construction of an adjacent auditorium capable of seating about 180 people.

Additionally, the Zana Engineering team has analyzed the potential social, cultural, and economic impacts created by this project. The primary social impact of this project is that more frequent and large-scale opportunities for students, faculty, and professionals to network and interact will be made possible through the creation of this facility. This project will have a minimal cultural impact on society in general. However, there are significant ways in which this project will have a cultural impact on the Transportation Engineering community at the University of Nebraska-Lincoln.

This project will create a leading research center for crash mitigation and testing, allowing Midwest Roadside Safety to increase its presence within the UNL Engineering community. This will also create students and faculty to visit the site more often, further strengthening ties. Perhaps the most significant societal impact of this project lies in the scope of economics. The addition of this building to the Midwest Roadside Safety site allows tallows the company to more revenue through the ability to perform more work, as well as the ability to obtain more funding with the increased cooperation between Midwest Roadside Safety and the University of Nebraska-Lincoln. This project will also provide an opportunity to create more jobs or research opportunities for students.

Research

Zana engineering has considered many of the requests of the owner of the project. The project is looking to satisfy a wide variety of requirements that span many different specialties. However, based on the research the firm has conducted, it can be shown that all these considerations will be met with reasonable effort.

As it is understood the following aspects of the expansion will be most important for creating a facility that will allow Midwest Roadside Safety to continue to be a global leader in crash testing and safety research. They are listed below along with the research that Zana engineering has done to ensure smooth incorporation of these elements

Currently the project footprint is not located within a wetland defined by the U.S Army Corps of Engineers. There are some wetlands adjacent to the project scope towards the west side along a nearby drainage ditch. Runoff from the building site does go towards this ditch and Zana engineering will investigate the required permits if needed to allow the project to proceed. A map of wetlands within our area of interest can be found in *Figure 3.*

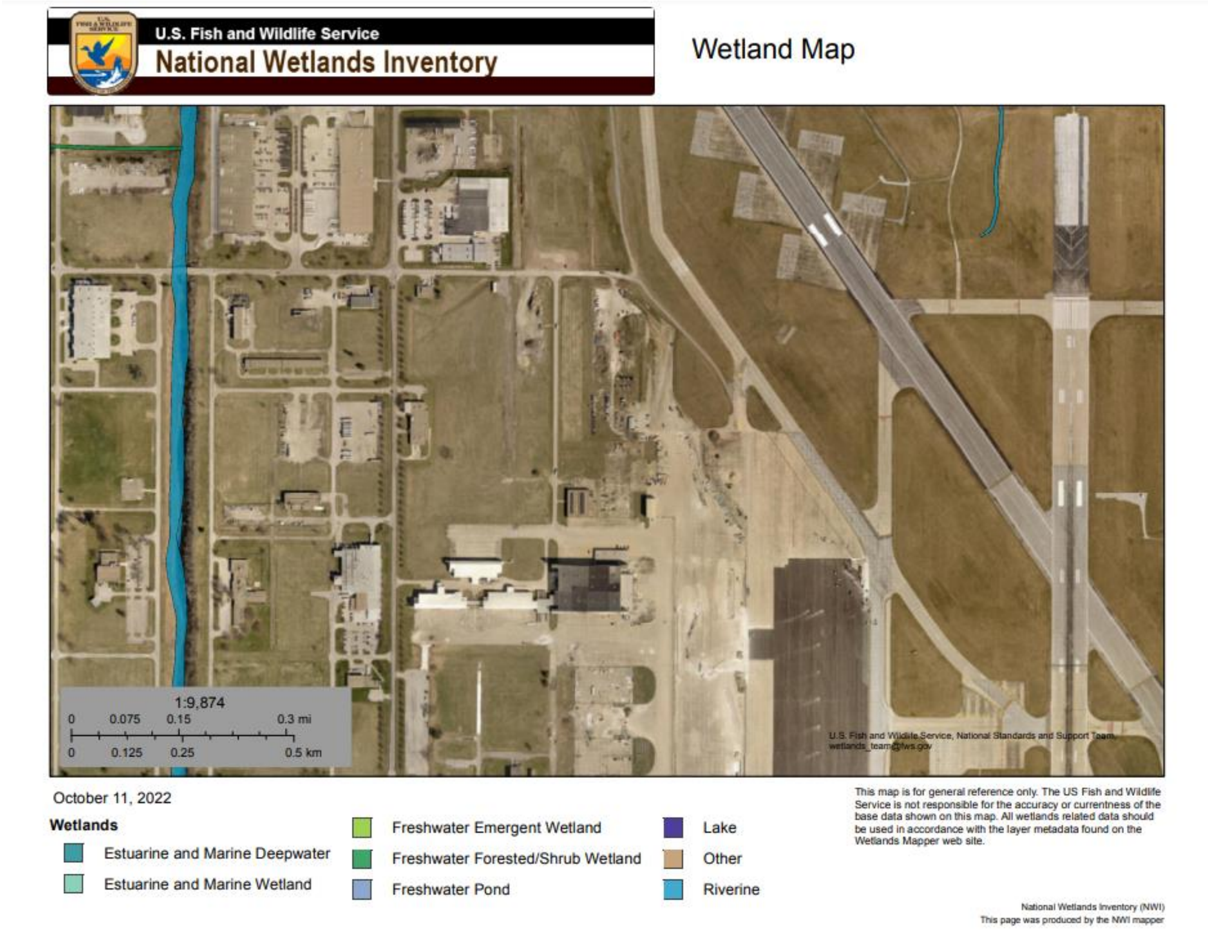


Figure 3. Map of Wetlands Within Area of Interest

It is not anticipated that the expansion will increase traffic in the surrounding area to a significant degree so the current access to the site would need to be reconsidered. Through on-site visits, it has been determined that the traffic is low but would see an increase in large vehicles as a planned loading dock has been incorporated.

Based on existing property boundaries it has been determined that there should not be a conflict with the neighboring building to the west in the case of future expansion. Furthermore, it is recommended to move the building at a distance of at least 50 ft from the existing one to allow for equipment and materials to pass through this clear zone.

Further research into the soil profile and existing grades shows that it can be expected to discover silts and loamy silts on the project site. Based on this initial survey it can be anticipated that minimal excavation may be necessary for the construction of the footing. However, because existing grades on site are very shallow, a raised foundation may be needed for the site to drain properly and avoid water damage. This soils map and area soil profile can be seen in *Figure 4* and *Figure 5*, respectively.

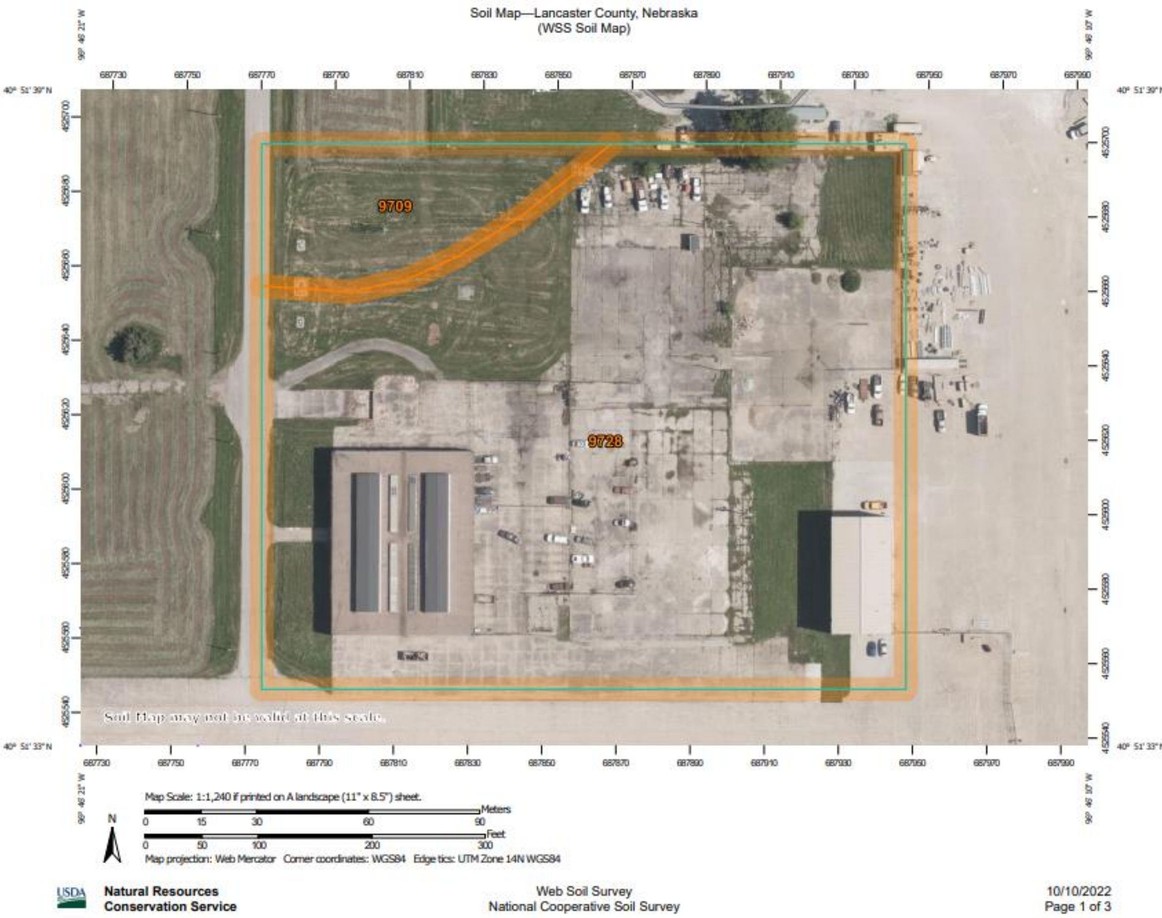


Figure 4. Soil Map of Area of Interest

Lancaster County, Nebraska

9709—Urban land-Kennebec complex, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 1ts15
Elevation: 1,000 to 1,500 feet
Mean annual precipitation: 30 to 32 inches
Mean annual air temperature: 52 to 55 degrees F
Frost-free period: 160 to 180 days
Farmland classification: Not prime farmland

Map Unit Composition

Urban land: 55 percent
Kennebec, occasionally flooded, and similar soils: 45 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Urban Land

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear

Typical profile

H1 - 0 to 60 inches: variable

Description of Kennebec, Occasionally Flooded

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Silty alluvium

Typical profile

H1 - 0 to 36 inches: silt loam
H2 - 36 to 60 inches: silt loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 36 to 72 inches
Frequency of flooding: None, Occasional
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: Very high (about 12.4 inches)

Figure 5. Area Soil Profile

Currently there are existing water and electricity utilities within the area. It is not anticipated that the cost to extend these to the new expansion would be a major cost or setback. There are nearby specialty contractors within the area that can accomplish this.

As the project is located within the airport, there are reasonable concerns regarding the maximum height a building could be constructed without interfering with the space owned above-said elevation. Lincoln airport shows what space there are imposed regulations and there are also nearby examples with the hanger to the south and the police impound lot to the west. The hangar to the south is constructed higher than the anticipated expansion.

The City of Lincoln has a standard building code for commercial buildings that will be used to guide the design process and ensure that certain standards of care are up to the expectations provided by the City of Lincoln.

Overall, based on the research and conclusions drawn hereby, Zana Engineering is providing a design for the anticipated expansion that will satisfy the elements requested by the project owner. Along with this, it will meet the necessary requirements put forth by all Authority having Jurisdictions.

-Traffic/parking standard
-City of Lincoln Design Standards for Zoning Regulations.
- NDOT Roadway Design Manual

Project Plan and Design

The total design for the project has been completed by the engineering team. Shown below in *Figure 6.* is a plan view of the building layout with the existing shop of the east side of the property and an appreciable gap between the project and existing. Details for various design aspects are enclosed below. They have been broken down into individual elements such as the design of the foundation, traffic studies, superstructure design and hydrology considerations. Along with this there is provided a construction timeline and cost estimate as the project moves towards bid. The cost estimate should assist the owner is bid selection and provide a reasonable idea of the cost for the scope of work anticipated. Construction methods have been estimated and detailed to provide the cost breakdown.

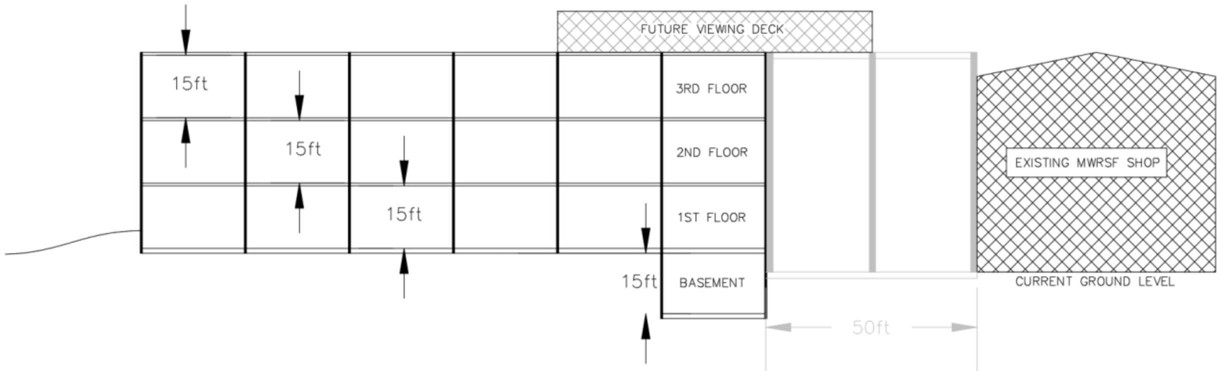


Figure 6. Overall Building Planview

Exterior Design

Zana Engineering designed the exterior of the building, and it will be design of glass as shown on *Figure 7.* below. Shatterproof glass was chosen for the exterior because while it keeps the aesthetic of the building, it also can withstand large impacts without breaking. This will prove to be cost efficient as less maintenance will be needed during the life of the building.

Figure 7. Building Exterior Design

Interior Design

As per MwRSF's request, the interior of the new building is designed and shown in *Figure 8.* Columns are spaced at 25 ft and shown in red. The first floor consists of lab space and five 15ft x 15ft offices for site work and research. A kitchen, restroom, stairs, and elevator are designed on all three building floors. The second floor consists of undergrad research space, and it will be organized as cubic space for undergrad students to do research, a conference room 25ft x 30ft as per request of MwRSF for staff meetings, a video analysis room for research as well, and seven offices for staff. On the third floor, there are five more offices and open space as graduate research space for graduate student staff, and there is a 25ft x 50ft conference room on the third floor that can be used as a wall screen for presentations and large group meetings before accessing the viewing deck to view crash tests. As safety is the priority, Zana Engineering added basement space to the design of this building; the basement will be located only underneath the office, kitchen, and restrooms and not the lab space due to lab weight. The basement will be used for emergencies, and it is enough space for people to stay there in those situations.

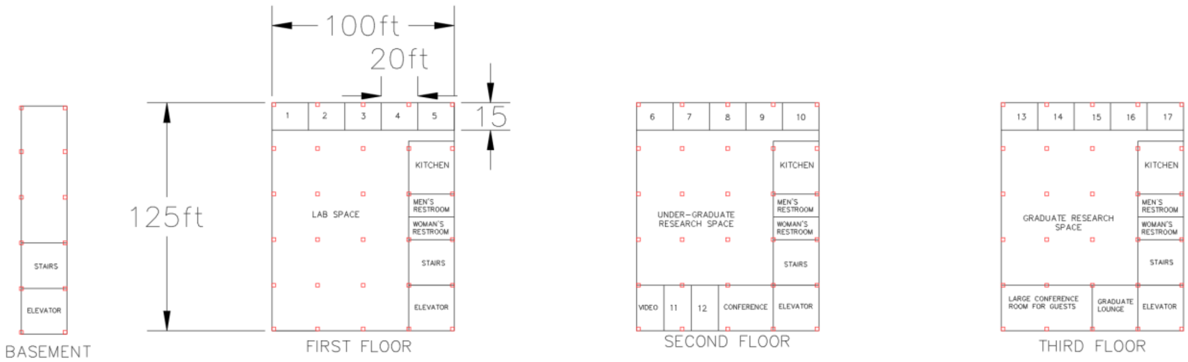


Figure 8. Building Floor Plan

Site Grading

The current site is relatively flat; a topological survey of the area shows a grade change of fewer than 10-foot over the length of the project. Major grading will be required for the over excavation of the building pad. Soils on site are highly compressible and will be replaced with structural fill. The total cut to be removed and replaced is anticipated at 6,500 C.Y based on an anticipated excavation depth of 10 ft. and a project area of 17,300 sq. ft. The final grades will match closely to the existing ones, will reduce the need for additional import/export of material and keep the building on grade with nearby structures. Only minor grading will be required around the building footprint to provide drainage for the structure. Refer to *Figure 9.* for the topographic survey provided by ARCGIS Maps.

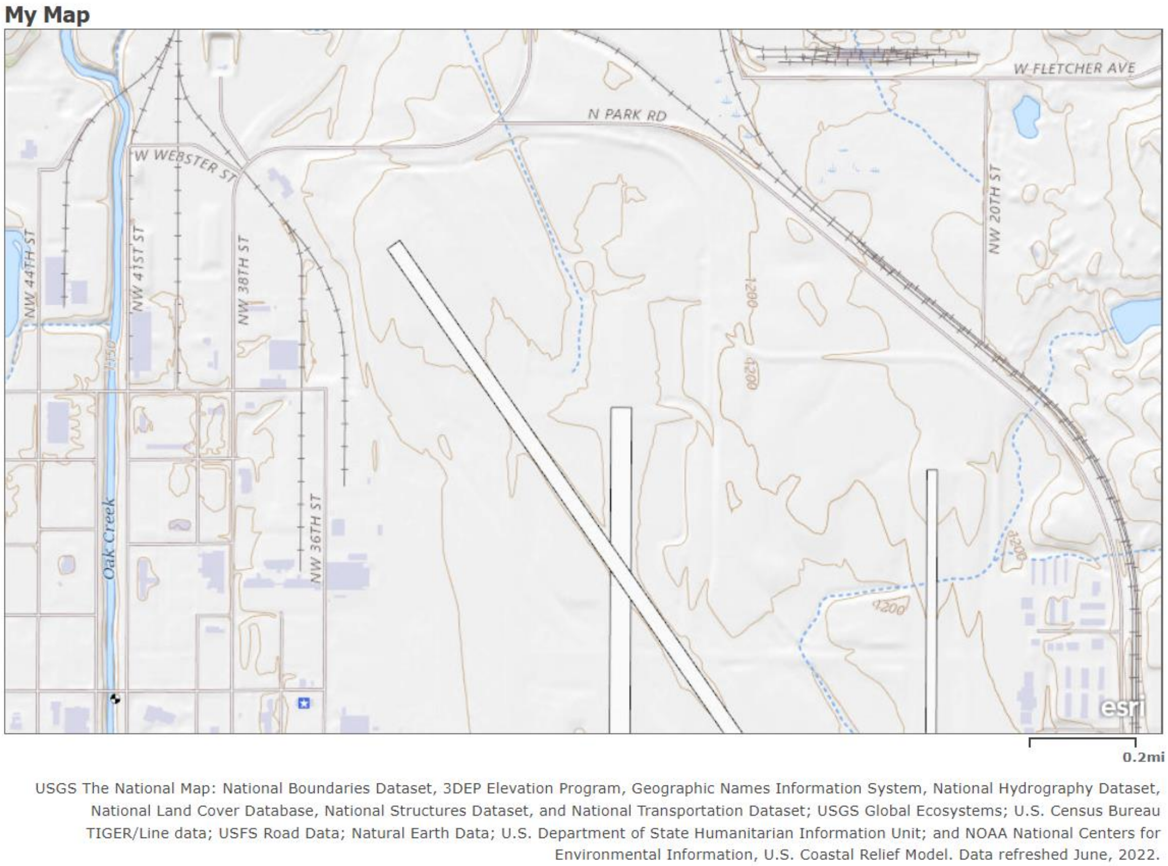


Figure 9. Topographic Map of Project Site

Superstructure Design

The design of the superstructure was based on a 3-story, multi used building with a walkout deck attached. Constraints such as what types of equipment will be used, and the space required to operate said equipment controlled large parts of this design. First a ceiling height of 15 ft. was chosen so that the large testing equipment anticipated would have no issues being transported and moved once within the building. This also helped to provide adequate height to allow the walkout balcony to overhang the existing shed on the east of the property. Next a column spacing of 25 ft. was selected to provide aesthetic qualities as well as not overcrowding the space with columns. Nearby structures in the area such as UNL's Engineering library have used similar column spacings for spaces that have uses aligning with this project. Based on these parameters a building plan view is provided *Figure 10.* below.

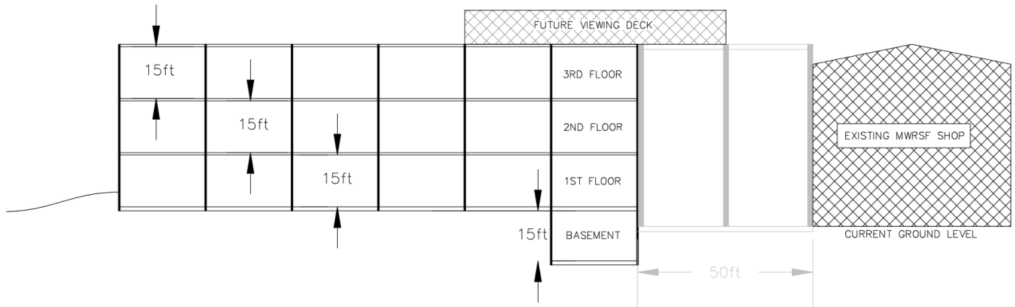


Figure 10. Building Layout for Superstructure Design

Next, the team designed a slab for the building floors. Based on a span length of 25 ft. the required depth of the slab will be eight in. on all floors. This was based on designating the space as office space for all levels, excluding the first, which received a more severe designation. The slab was designed for deflection. *Figure 11.* and *Figure 12.* are typical sections of the floor and a slab. A plan set with the details provided is provided. A different slab depth was selected for the storm shelter to accommodate a higher strength requirement.

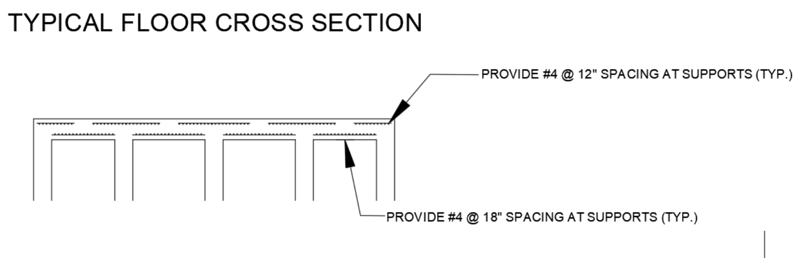


Figure 11. Typical Floor Section

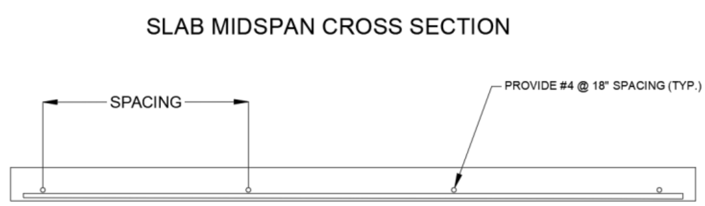


Figure 12. Typical Slab Section

Beams and girders for the building were sized for the selected loads for the building. A beam spacing of 12.5 ft. was chosen to provide an economical section while reducing the total lbs. of steel required. A beam bay is shown below in *Figure 13.*, cross sections for this is shown in the accompanying *Figure 14.* There is approximately 120,700 lbs. of steel estimated in the beams alone for the project.

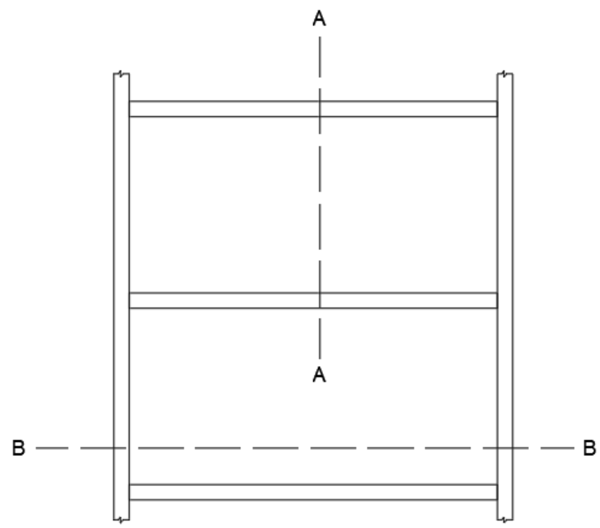


Figure 13. Typical Bay Section

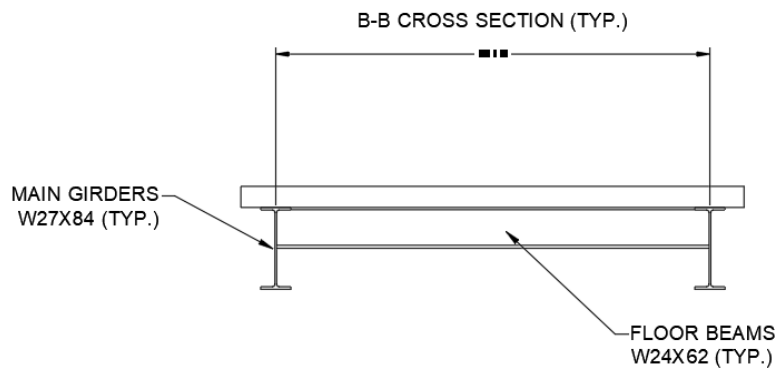


Figure 14. Cross Section of Bay Section

<u>*Foundation Design*</u>

For this design of a foundation, the bearing capacity of the soil was estimated based on boring logs and typical soil properties. Due to the low blow counts, it is anticipated that settlement concerns will dominate the design of the footing. Blow counts are low for a significant portion of the depth, and so the foundation team has determined that removal of unsuitable material would be the most cost-effective solution instead of driving piling. To create a consistent base material underneath all square and strip footings the Zana will require 5 ft. of over excavation underneath all structural elements and replacement will high quality structural fill. This will increase the capacity of the soil and reduce settlement issues. Based on structural fill properties the design bearing capacity used for design was 5000 pounds per square-foot (psf) calculated from Terzaghi's method with provides a conservative answer.

Show below in *Figure 15*. shows a column layout. The additional basement along the east end will require a strip footing to accommodate loads. The types of foundations designed for this building were a strip for the basement and a square footing for columns in the remaining portion of the building based on a worst-case loading scenario. The structural team found the design load to subjected to an interior column on the first floor and used this to design both the strip and square footings. For the design of strip footing in the basement, it was first designed as a retaining wall due to the possibility of a surcharge from the adjacent driveways on the east side. Along with this, it was checked for capacity against the vertical loads anticipated.

The design team has called for a strip footing 10 ft. wide and 2 ft. thick. It will be the height of a full depth basement wall to provide cover as a storm shelter. The square footing has been designed to be a 7 ft. x 7ft. pad at a depth of 5 ft. below the floor slab.

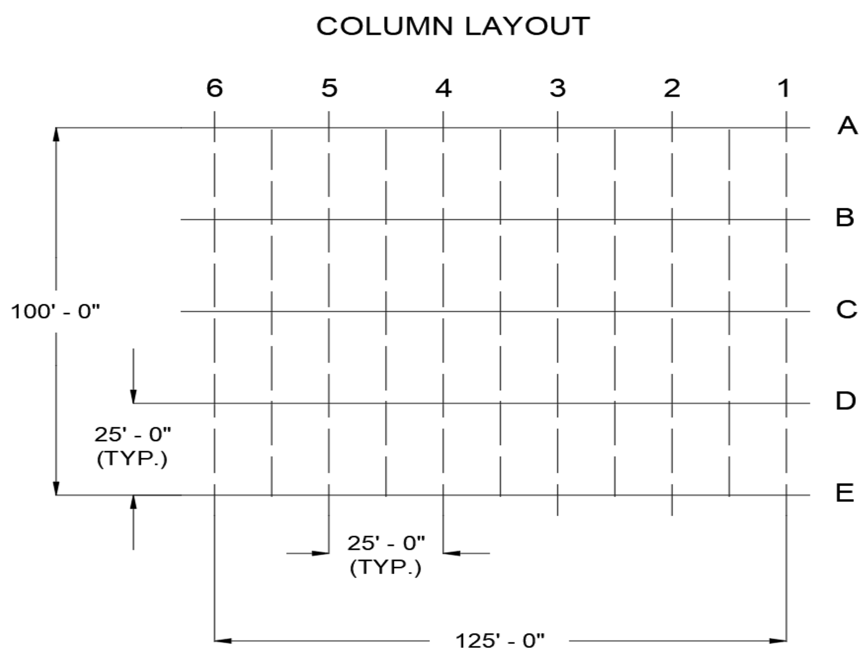


Figure 15. Foundation Column Layout

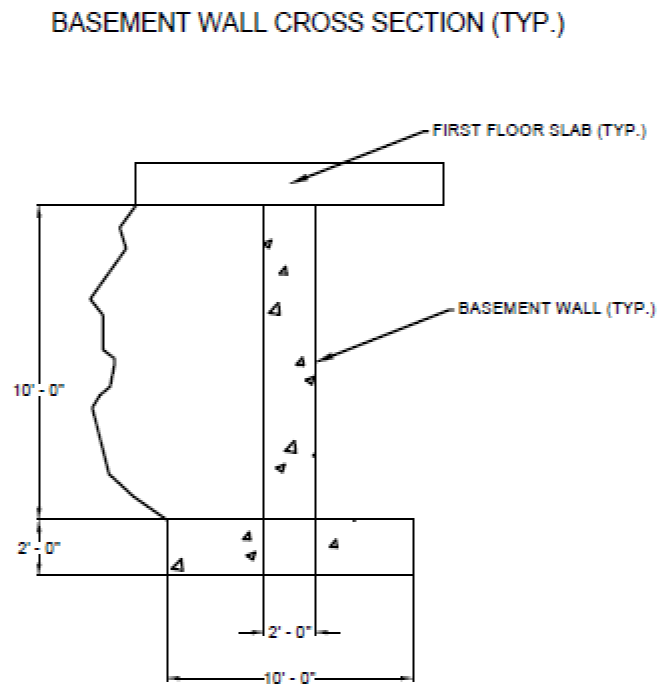


Figure 16. Typical Basement Wall Cross-Section

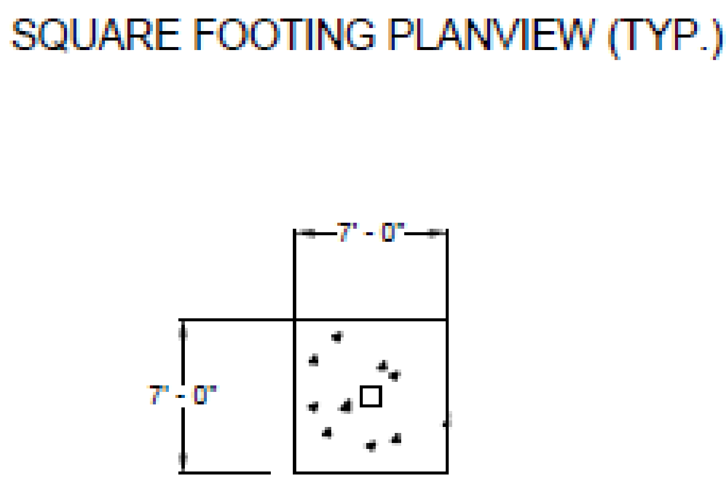


Figure 17. Typical Square Footing

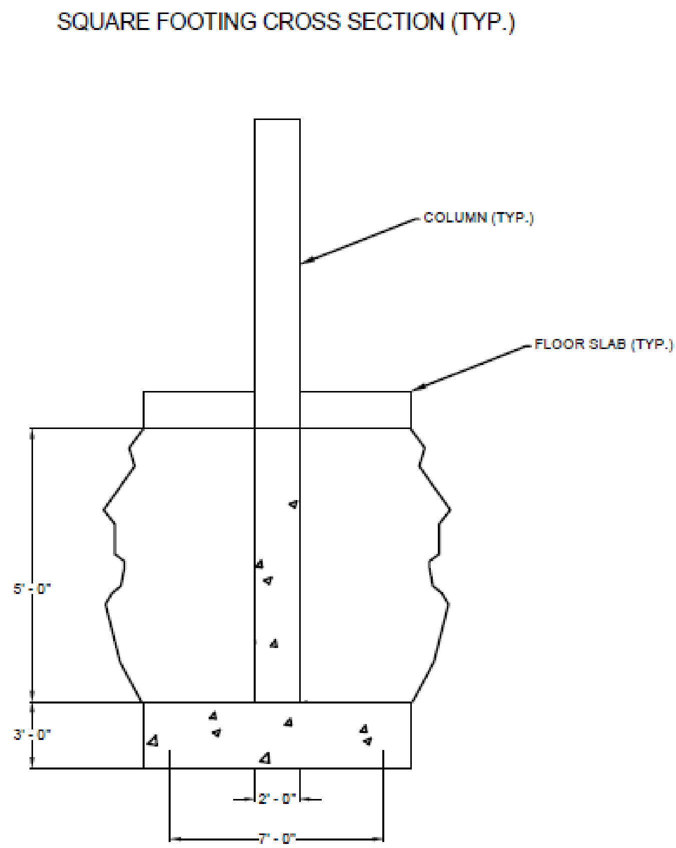


Figure 18. Typical Square Footing Cross-Section

Overhang/Walkout Viewing Platform Design

An overhang and walkout viewing platform has been taken into consideration per the request of the MwRSF. Unfortunately, these features will be planned as a potential project phase to be completed as future work. This overhang balcony concept will span fifty feet between the new facility and the existing shop. It will need to be designed to be supported with slender columns on a 25 foot spacing, but that is subject to change. The area under the overhang will be available to use as open garage space that is protected from the elements. Above the overhang, there will be a walkout viewing area for guests. This area is designed to accommodate any guests that MwRSF might host, specifically when hosting a crash testing event. The balcony will carry a load of about 100 people, and it is designed to allow for enhanced viewing of MwRSF's crash tests.

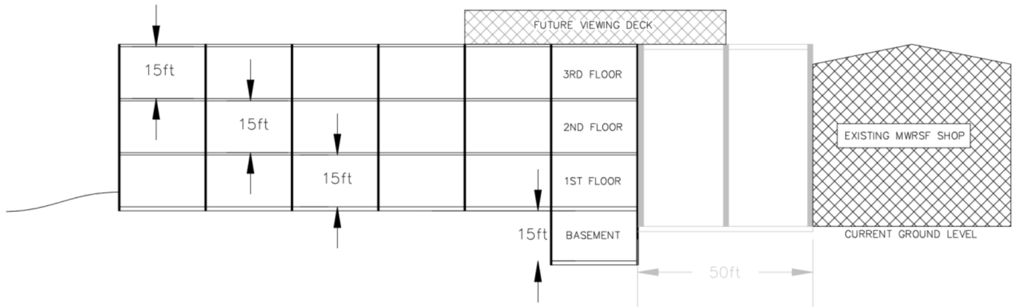


Figure 19. Side Profile of New and Existing Proposed Buildings (Looking from South)

Traffic Study

With the addition of a new building, traffic in the area around it will increase. Because of the purpose of the building, to relocate faculty and graduate students, it is reasonable to assume that most of the new trips generated from the building will be traveling between UNL's city campus and the new site. There are three intersections that were chosen along the most common route between campus and the site and these intersections were chosen because they are all stop-sign controlled. They are shown in *Figure 20.* Stop-sign controlled intersections benefit areas with low amounts of traffic, however increased traffic can affect the delay that users experience and ultimately warrant a redesign of the intersection.

Figure 20. Intersections Impacted

Figure 20. identifies where the intersections are about the project site, shown in red. To find the level of service of each intersection, the physical characteristics of each intersection were described in *Figure 21.* Each intersection is stop-controlled with multiple turning movements. Daily turning movement counts were found using data from the Nebraska Department of Transportation and are shown in *Figure 22.* In a stop-controlled intersection, the movement with the longest delay is the left-hand turn lane. during the peak hour. Using the daily turning movement, the delay in seconds can be calculated, and, using the level of service criteria in Appendix, the level of service of each intersection can be found.

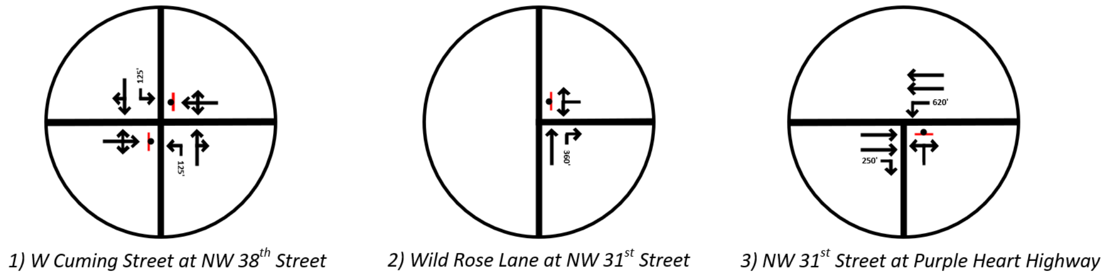


Figure 21. Intersection Physical Characteristics

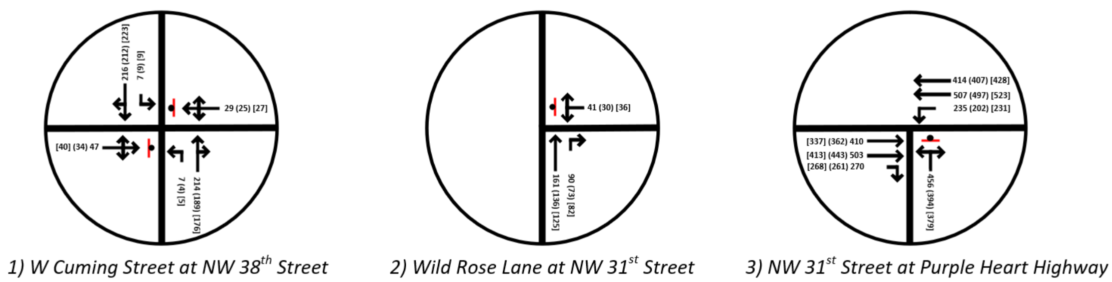


Figure 22. Intersection Turning Movements

It was determined that the delay of each intersection was less than 10 seconds per vehicle giving them all a level of service of A.

In order to estimate the trips generated from the creation of a new building, the ITE Trip Generation manual was used. The trip generation of a large office building is based on the square footage of the building. Our building is approximately 37,500 square feet; therefore, the estimated daily trips is 800. This is a bit conservative, but it will be sufficient in order to estimate the impact of the new building. Adding 800 daily trips to each intersection gives new turning movement counts that give a new level of service. It was determined that the trips will not create a large enough delay in any intersection to change the level of service. Each intersection will be sufficient to withstand the projected trips. One thing to consider with this traffic study is the impact that the future auditorium will have on each intersection presented.

<u>*Hydraulics*</u>

Expected runoff was calculated for the anticipated site to estimate the impact the building would have on existing utilities. The building pad will impact approximately 0.32 acres. Due to the small nature of the site, the rational method will be a valid method to estimate a design runoff. The City of Lincoln Drainage Criteria Manual requires sites to be designed for a 10-year storm. IDF curves provided for the area provide an intensity of rainfall of 6 in/hr. based on an 8 min storm. A conservative estimate for a runoff coefficient comes in at 0.9, and so using the rational method, a design runoff is estimated at 2 cubic feet per-second (cfs). Using culvert nomographs in appendix F of NDOT's drainage manual a culvert less than 12" would be required to accommodate the flow. This is not practical for the project, and so at this time, a storm sewer will not be designed.

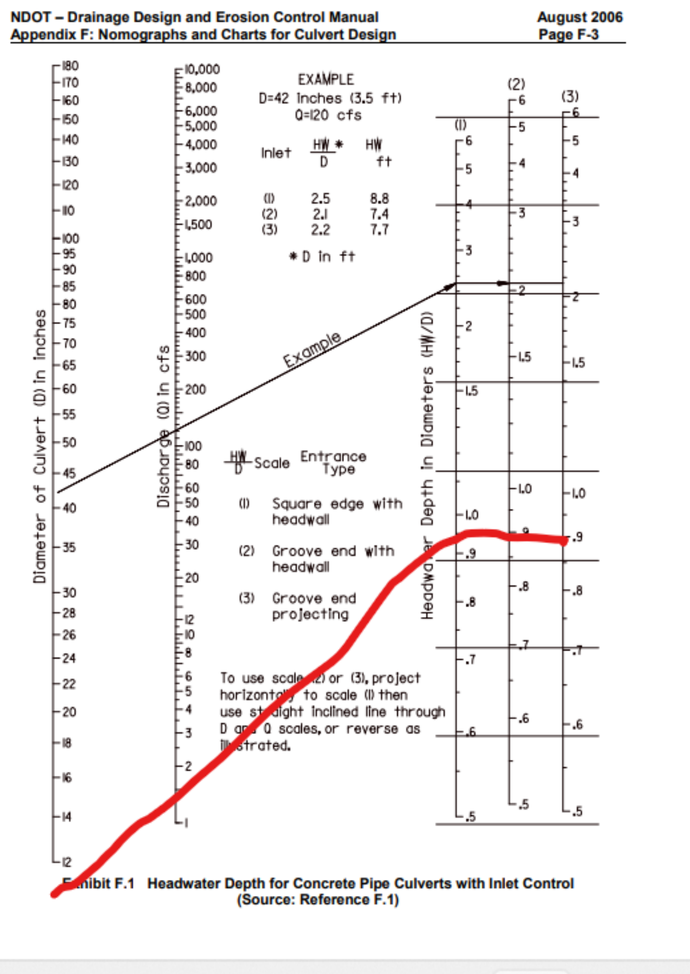


Figure 23. Culvert Nomographs

Construction Methods and Phasing

This section of the report will detail the possible equipment necessary to complete the scope of work requested. Phasing for the project provides an outline for the timeline to completion. The first phase of the job will be the removal of existing pavement on the site. It is anticipated that a skid steer will be used as the pavement is at a reasonable depth so that more expensive machinery will not be needed. After the removal of pavement, the site utilities will have to be relocated temporarily. This work will potentially be done by a subcontractor. Equipment such as trench boxes, excavators and boring machines are anticipated to complete the work.

Timeline and Cost Estimate

A construction timeline for the completion of this project is shown in *Figure 24*. The engineering team anticipates the project going forward with bid procurement upon approval of the engineering design from the project owner. Tasks for the completion of this project have been estimated based on the scope of work being requested and the design provided by the engineer. Currently the team estimates a time of completion of the work to be at 18 months

Start Date: 3/1/2022

End Date: 8/1/2023

As of December 2022, Zana Engineering has completed a full holistic design of the Midwest Roadside Expansion requested by the owner. The estimated time for bid procurement and selection is 1 month from notice to proceed. The cost estimate provided in figure xx shows a breakdown of the elements in the project. The list is in chronological order. Costs were estimated based on material quantities, previous experience, and market rates based on the state of Nebraska website for labor.

Total cost: $23,960,550

Total sq. ft.: 37,500

Cost per sq. ft.: $650

This cost estimate and cost per sq. ft. is in line with similar structures in the Lincoln market. The UNL's Link that has recently finished stage one, was built at a price of $860 per sq. ft., which is comparable to the estimate provided. The additional cost in that scenario could be due to the removal of the existing structure on the UNL campus and increased difficulty in mobilizing equipment. The full cost estimate breakdown can be seen in *Table 1*.

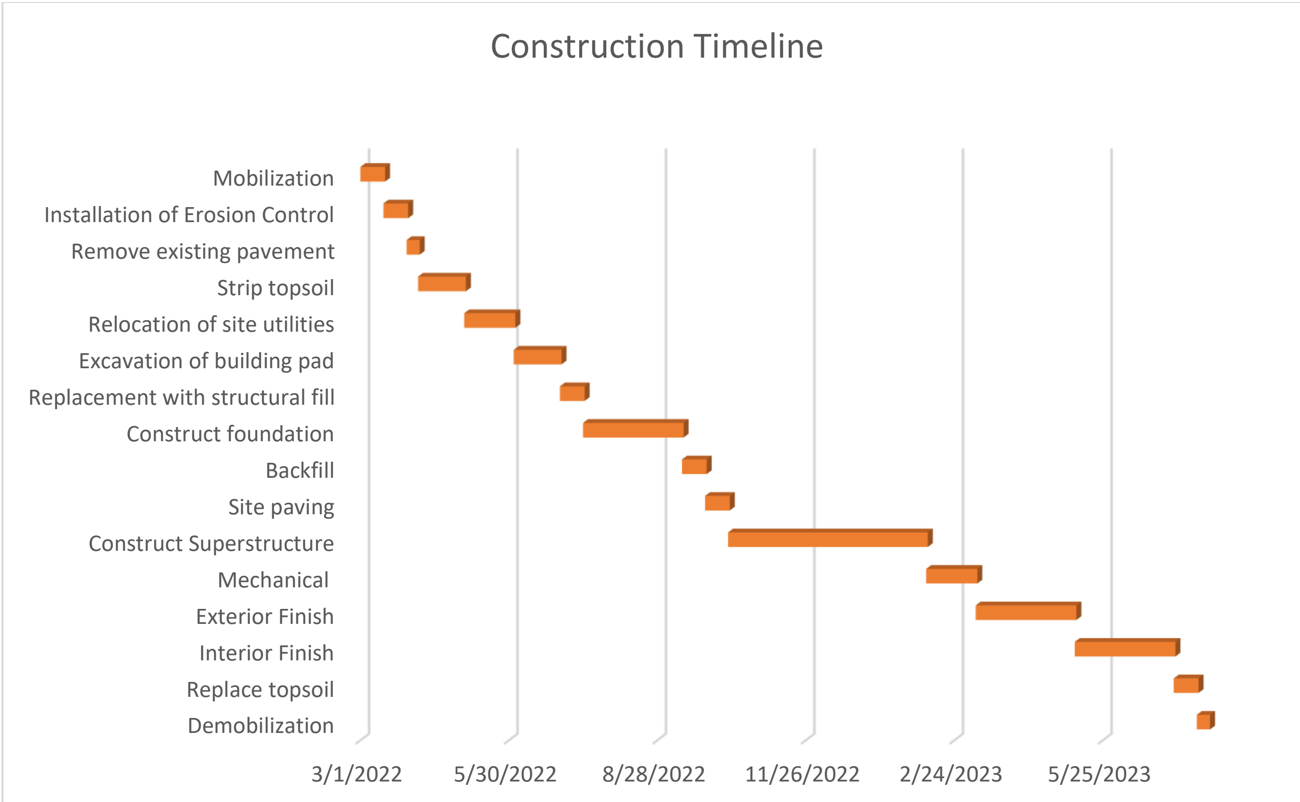


Figure 24. Construction Timeline

Table 1. Estimated Construction Costs

Item/Description	Quanity	Unit	Unit Cost	Total
Mobilization	1.00	LS	30000.00	$30,000.00
Installation of Silt Fence	2,000.00	LF	4	$8,000.00
Remove existing pavement	1,000.00	S.Y	10	$10,000.00
Salvage and Replace topsoil	1,500.00	S.Y	20	$30,000.00
Relocation of site utilities	1.00	LS	30000	$30,000.00
Excavation of building pad	1.00	LS	50000	$50,000.00
Replacement with Structural fill	4,750.00	C.Y	70	$332,500.00
Construct Foundation	1.00	LS	4000000	$4,000,000.00
Backfill	1.00	LS	5000	$5,000.00
Site Paving Asphalt	500.00	S.Y	70	$35,000.00
Construct Superstructure	1.00	LS	5000000	$5,000,000.00
Mechanical	1.00	LS	4500000	$4,500,000.00
Exterior Finish	90,000.00	SF	60	$5,400,000.00
Interior Finish	90,000.00	SF	50	$4,500,000.00
Replace topsoil	0.50	Acres	100	$50.00
Demobilization	1.00	LS	30,000	$30,000.00
			Total Cost	$23,960,550.00
	Total Estimated Construction Cost			$23,960,550.00

Summary

The report encloses the design provided by the engineering firm. It includes details about impacts the structure will have on the surrounding community and for the university and those that will work within the building itself.

Overall, Zana Engineering is committed to creating a safe, creative, innovative, and affordable design that will serve Midwest Roadside Safety Facility for years to come. There is plentiful experience and knowledge that the team here will draw on to provide a design that meets the wants and needs of MwRSF. There is a need to quickly provide new space for every growing demand for increased roadway safety. This expansion will allow MwRSF to provide innovative research and development that will benefit the country. Along with this, it will be important for those working towards these developments to have a place that is easily accessible, capable of supporting the needed research equipment, and can provide space for meetings, clients, third parties or potential investors.

Zana engineering is experienced in the design and construction of large-scale commercial buildings and will use over 50 years of experience to meet these demands. The relationships created with local companies in the area will allow the team to effortlessly communicate with contractors to secure potential bids and benefit the owner. The team here will be excited to work with MwRSF as they continue to invest in breakthrough research that protects the country.

Appendixes

Appendix A - Research

Traffic Study

TRIP GENERATION LOOK-UP TABLE FOR SELECTED SIZES OF A COMMERCIAL OFFICE

SIZE OF GROSS LEASABLE AREA IN SQUARE FEET	TRIP GENERATION $Ln(T) = 0.756\ Ln(x) + 3.95$
25,000	592
30,000	679
35,000	763
40,000	845
45,000	923
50,000	1,000
55,000	1,074
60,000	1,147
65,000	1,219
70,000	1,289
75,000	1,358
80,000	1,426
85,000	1,493
90,000	1,559
95,000	1,624
100,000	1,688
110,000	1,814
120,000	1,938
130,000	2,059
140,000	2,177
150,000	2,294
160,000	2,409
170,000	2,522
180,000	2,633
190,000	2,743
200,000	2,851
210,000	2,958
220,000	3,064
230,000	3,169
240,000	3,273
250,000	3,375
265,000	3,527
280,000	3,677
295,000	3,825
310,000	3,971
325,000	4,116
340,000	4,259
355,000	4,400
370,000	4,540
385,000	4,678
400,000	4,815
425,000	5,041
450,000	5,264
475,000	5,483
500,000	5,700
525,000	5,914
550,000	6,126
575,000	6,335
600,000	6,543
625,000	6,748
650,000	6,951
675,000	7,152

Ln = Natural Logarithm (see notes for Table 1); T = Trips; x = Gross Leasable Area in 1,000 square feet

Level of Service	Average Total Delay (s/veh)
A	≤ 5
B	> 5 and ≤ 10
C	> 10 and ≤ 0
D	> 20 and ≤ 30
E	> 30 and ≤ 45
F	≥ 45

Appendix B - Project Plan and Design

Superstructure

Assumptions

1) Design based on ACI 318 code
2) Dead load includes self-weight plus mechanical which is assumed 20 psf
3) Live load 100 psf for an office space based on International Building Code

Slab

One way slab check – $\frac{L}{B} \geq 2$, $\frac{25}{12.5} = 2$ therefore the slab will act as a one way

Preliminary slab thickness, designed for interior slab and applied throughout structure

$$\frac{L}{24} = 12.5 * \frac{12}{24} = 7 \; in.$$

Cover requirements from ACI 318 – 19

Cover = 3/4 in

$$L_L = 100 \; psf = 100 \; plf$$

$$D_L = 150 * \frac{7}{12} + 20 = 107.5 \; plf$$

$$W_U = 1.2D_L + 1.6L_L = 1.2(107.5) + 1.6(100) = 290 \frac{lbs}{ft} \;\; = 0.29 \frac{k}{ft}$$

$$Postive \; design \; moment = \frac{wl^2}{14} = 0.29 * \frac{12.5^2}{14} = 3.2 \;\; (k * ft)$$

$$Negative \; design \; moment = \frac{wl^2}{10} = 0.29 * \frac{12.5^2}{10} = -4.5 \;\; (k * ft)$$

Midspan Slab

$$Midspan \; longitudinal \; steel = \; 0.9A_sF_y0.9d = M$$

$$0.9 * As * 60 * 0.9 * \left(7 - \frac{3}{4} - \frac{1}{4}\right) = 3.2 * 12$$

$$A_s = 0.13 \; in^2$$

$Minimum \; spacing \; assuming$ #4 bar

$$S = 0.196 * \frac{12}{A_s} = 0.196 * \frac{12}{.13} = 18.1 \; in.$$

Provide #4 rebar on 18 in. centers at midspan

Support Slab

$$Support \; longitudinal \; steel = \; 0.9A_sF_y0.9d = M$$

$$0.9 * As * 60 * 0.9 * \left(7 - \frac{3}{4} - \frac{1}{4}\right) = 4.5 * 12$$

$$A_s = 0.19\ in^2$$

$Minimum\ spacing\ assuming$ #4 bar

$$S = 0.196 * \frac{12}{A_s} = 0.196 * \frac{12}{.19} = 12.4\ in.$$

Provide #4 rebar on 12 in. centers at support sections

Transverse reinforcement for creep and shrinkage

$$A_s = 0.0018bh = 0.0018 * 12 * 7 = 0.15\ in.$$

$$S = 0.196 * \frac{12}{A_s} = 0.196 * \frac{12}{.15} = 14\ in.$$

Provide #4 transverse reinforcement at 14 in. on center for all sections

Beams
Assumptions

1) L = 25 ft.
2) Tw = 12.5 ft.
3) Assume 24x62 preliminary

Loads

$$W_{slab} = 0.15 * \frac{7}{12} * 12.5 = 1.095 \frac{k}{ft}$$

$$W_{beam} = 62 \frac{lbs}{ft}$$

$$Mechanical = 20 * 12.5 = 250 \frac{lbs}{ft}$$

$$L_l = 100 * 12.5 = 1250 \frac{lbs}{ft}$$

Design Load

$$W_U = 1.2D_L + 1.6L_L = 1.2(1095 + 62) + 1.6(250 + 1250) = 3800 \frac{lbs}{ft} = 3.8 \frac{k}{ft}$$

Deflection limit

$$L_L = \frac{L}{360} = 25 * \frac{12}{360} = 0.84\ in.$$

$$\Delta = \frac{5wl^2}{384EI} = 5 * \left(\frac{3.8}{12}\right) * \frac{(25 * 12)^4}{384 * 29000 * 0.84} = 1371\ in^4$$

$$Based\ on\ I\ of\ 1371\ in^4\ the\ preliminary\ beam\ 24x62\ is\ adequate$$

Girders

Assumptions

1) L = 25 ft.
2) Tw = 12.5 ft.
3) Assume 27x84 preliminary

Loads

$$W_{slab} = 0.15 * \frac{7}{12} * 25 = 2.1875 \frac{k}{ft}$$

$$W_{beam} = 84 \frac{lbs}{ft}$$

$$Mechanical = 20 * 12.5 = 500 \frac{lbs}{ft}$$

$$L_l = 100 * 12.5 = 2500 \frac{lbs}{ft}$$

Design Load

$$W_U = 1.2D_L + 1.6L_L = 1.2(2187.5 + 87.5) + 1.6(500 + 2500) = 7530 \frac{lbs}{ft} = 7.53 \frac{k}{ft}$$

Deflection limit

$$L_L = \frac{L}{360} = 25 * \frac{12}{360} = 0.84\ in.$$

$$\Delta = \frac{5wl^2}{384EI} = 5 * \left(\frac{7.53}{12}\right) * \frac{(25 * 12)^4}{384 * 29000 * 0.84} = 2750\ in^4$$

$$Based\ on\ I\ of\ 2750\ in^4\ the\ preliminary\ beam\ 27x84\ is\ adequate$$

Column

An interior column was designed for the calculations shown below, this design was used for the rest of the structure.

$$Ta = 25 * 25 = 625\ ft.$$

$$L_L = 100\,psf * 625ft^2 = 62.5\,kips$$

$$Mechanical = 20 * 625 = 12.5\,kips$$

$$Slab = 0.150 * \frac{7}{12} * 625 = 55\,kips$$

$$Girders = 2 * 84 * 12.5 = 2.1\,kips$$

$$Beams = 6 * 62 * 12.5 = 4.7\,kips$$

$$W_U = 1.2(2.1 + 4.7 + 55 + 12.5) + 1.6(62.5) = 200{,}000\,lbs \; = 200\,\frac{kips}{floor}$$

Pick column size based on charts and figures in AISC manual, required information is unbraced length and column load

3rd floor column at 15’ unbraced length and a load of 200 kips

W 12x40

2nd floor column at 15’ unbraced length and load of 400 kips

W 12x53

1st floors column at 15, unbraced length and load of 600 kips

W 12x65

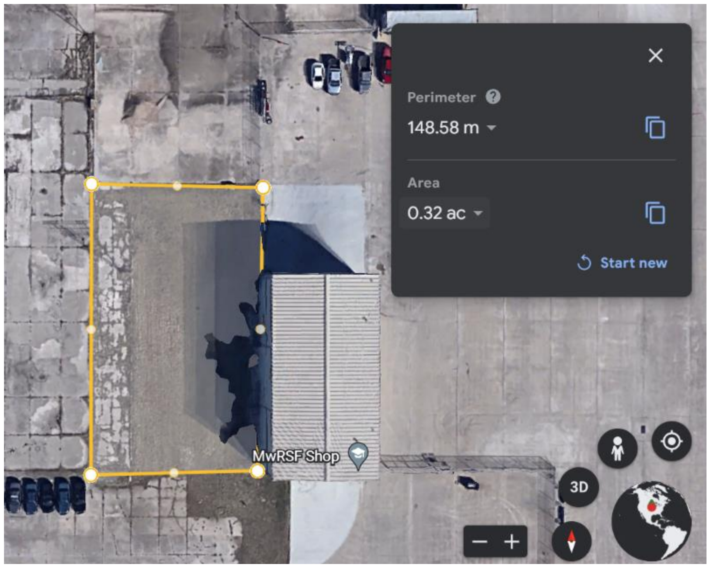
<u>*Substructure*</u>

Hydraulics

Assumptions

1) Use rational method to estimate site runoff, based on impact area less than 640 acres
2) Use City of Lincoln hydrology code for the design
3) Estimate pipe size based on NDOT culvert nomographs
4) Culvert headwater to pipe diameter ratio = 1 which will be a conservative assumption

$$Q = CIA$$



$$A = 0.32\ acres$$

Table 2-3 Recommended Coefficient Of Runoff Values For Various Selected Land Uses

Description of Area	Runoff Coefficients
Business: Downtown areas	0.70-0.95
Neighborhood areas	0.50-0.70
Residential: Single-family areas	0.30-0.50
Multi units, detached	0.40-0.60
Multi units, attached	0.60-0.75
Suburban	0.25-0.40
Residential (1 acre lots or larger)	0.30-0.45
Apartment dwelling areas	0.50-0.70
Industrial: Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.40
Railroad yard areas	0.20-0.40
Unimproved areas	0.04-0.38 (see Table 2-4)

Source: Hydrology, Federal Highway Administration, HEC No. 19, 1984

$$C = 0.9$$

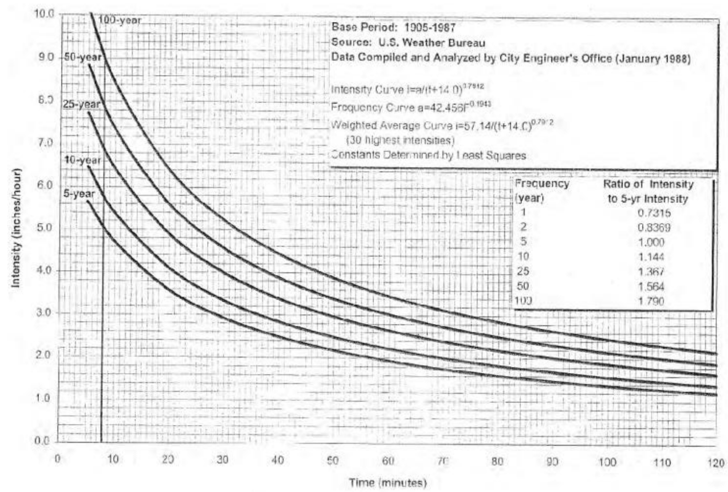
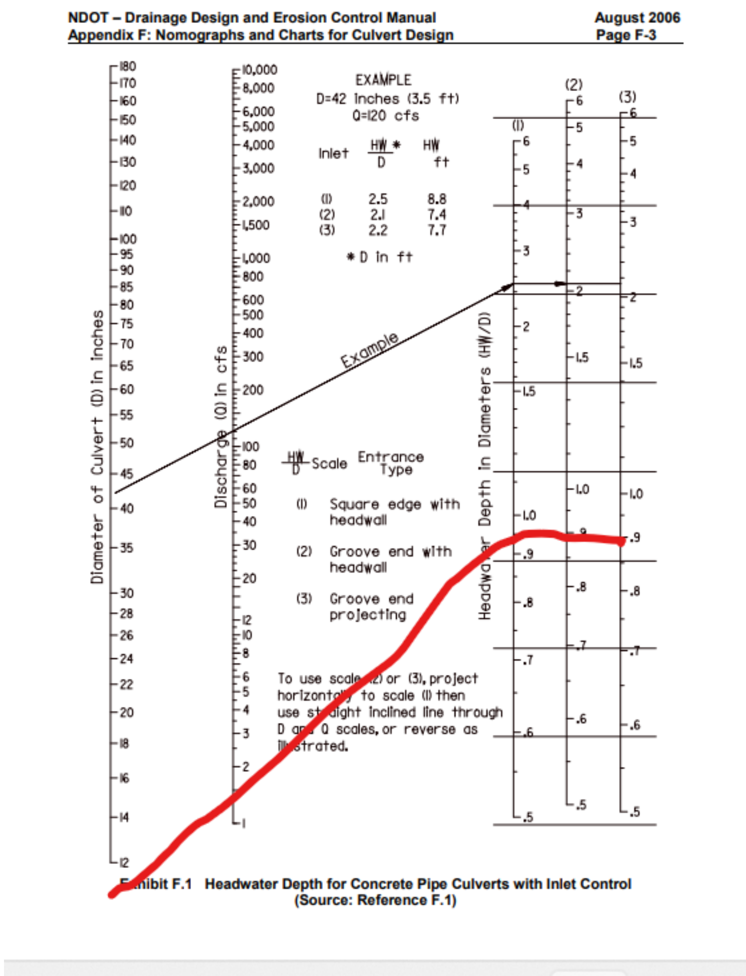


Figure 2-3 Intensity-Duration-Frequency Curves
Lincoln, Nebraska

$$I = 5.8\frac{in}{hr}$$

$$Q = 0.9 * 5.8 * 0.32 = 1.67\ cfs$$



Pipe size required based on design flow and hydraulic conditions would be less than 12"

Foundation: Spread Footing

$\gamma_{soil} = 110\, {}^{lb}/_{ft}{}^{3}$

$\varphi = 33°$

Depth of footing = 5 ft

Footing thickness = 1.5 ft

$q_n = 1.3 \times c' \times N_c + \theta'_{zD} \times N_q + 0.4 \times \gamma' \times B \times N_\gamma$

$N_q = 32.2$ $\quad N_\gamma = 33.3$ (Factors from $\varphi = 33°$)

$\theta'_{zD} = 110\, {}^{lb}/_{ft} \times 5\, ft = 0.55\, {}^{k}/_{ft}{}^{2}$

$\gamma' = 110\,{}^{lb}/_{ft} = 0.11\,{}^{k}/_{ft}\,3$

c' = 0

$q_n = 17.710 + 1.4652B$ (Bearing Capacity)

$P_n = q_n \times A = 17.710B^2 + 1.4652B^3$

$P_u + \gamma_D \times W_f \leq \varphi \times P_n$ (LRFD)

$600 + 1.2(1.5 \times B^2 \times 0.15) \leq 0.5(17.710B^2 + 1.4652B^3)$

$B = 6.67\,ft \approx 7\,ft$

Therefore, 7 x 7 ft footings were chosen

Foundation: Basement Walls

$k_a = tan^2\left(45 - \frac{33}{2}\right) = 0.307$

$\theta'_v = 11 \times 110 = 1{,}210\,psf$

$\theta'_h = 0.307 \times 1{,}210 = 371.47\,psf$

$P_{a1} = 0.5 \times 371.47 \times 11 = 2{,}043.09\,{}^{lb}/_{ft}$

$q = 250\,psf$

$\theta_a = 0.307 \times 250 = 76.75\,psf$

$P_{a2} = 11 \times 76.75 = 844.25\,{}^{lb}/_{ft}$

$M_o = \left(2043.09 \times {}^{11}/_{3}\right) + \left(844.25 \times {}^{11}/_{2}\right) = 12{,}134.705\,{}^{lb \cdot ft}/_{ft}$

Area		Weight		Arm	Moment
1.5 x 10	15	15 x 150	2250	7.75	17437.5
1 x 11.5	11.5	11.5 x 150	1725	0.5	862.5
3 x 10	30	30 x 150	4500	10	45000

$M_R = 63{,}300\,{}^{lb \cdot ft}/_{ft}$

$F_{overturn} = {}^{63{,}300}/_{12{,}134.705} = 5.2$

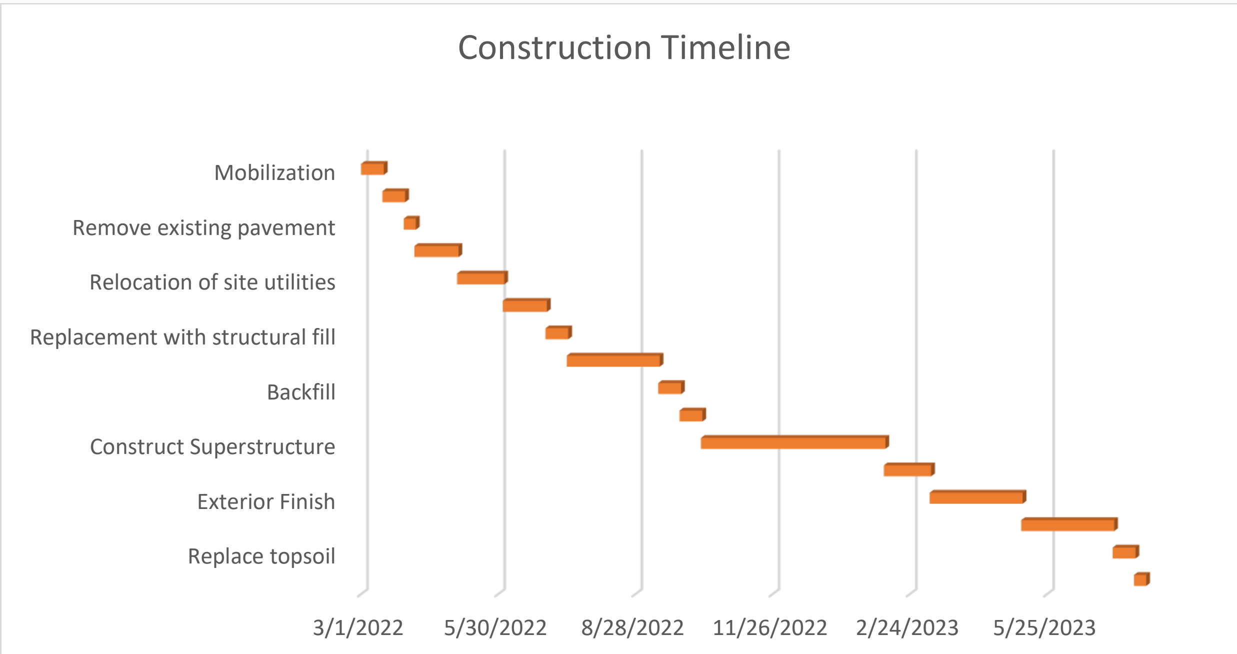
$F_{sliding} = {}^{4{,}133.5}/_{2{,}887.34} = 1.43$

$$q_{max,toe} = \left({}^{48,975}/_{11.5}\right) \times \left(1 + {}^{4.71}/_{6}\right) = 7,601.77psf$$

$$e = \frac{11.5}{2} - \frac{63,300 - 12,134.705}{48,975} = 4.71\ ft$$

Therefore, a 10-foot deep 2-feet wide retaining wall with a 2-foot thick 10 foot wide footing. The wall will have 5-feet of the footing on either side of it.

Appendix D Cost Estimate



Item/Description	Quanity	Unit	Unit Cost	Total
Mobilization	1.00	LS	30000.00	$30,000.00
Installation of Silt Fence	2,000.00	LF	4	$8,000.00
Remove existing pavement	1,000.00	S.Y	10	$10,000.00
Salvage and Replace topsoil	1,500.00	S.Y	20	$30,000.00
Relocation of site utilities	1.00	LS	30000	$30,000.00
Excavation of building pad	1.00	LS	50000	$50,000.00
Replacement with Structural fill	4,750.00	C.Y	70	$332,500.00
Construct Foundation	1.00	LS	4000000	$4,000,000.00
Backfill	1.00	LS	5000	$5,000.00
Site Paving Asphalt	500.00	S.Y	70	$35,000.00
Construct Superstructure	1.00	LS	5000000	$5,000,000.00
Mechanical	1.00	LS	4500000	$4,500,000.00
Exterior Finish	90,000.00	SF	60	$5,400,000.00
Interior Finish	90,000.00	SF	50	$4,500,000.00
Replace topsoil	0.50	Acres	100	$50.00
Demobilization	1.00	LS	30,000	$30,000.00
			Total Cost	$23,960,550.00
	Total Estimated Construction Cost			$23,960,550.00

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