Department of
Civil & Environmental Engineering
THE UNIVERSITY OF UTAH

Wakara Way Pedestrian Underpass

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Title Page

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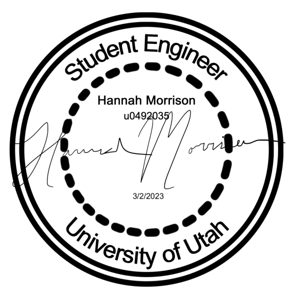

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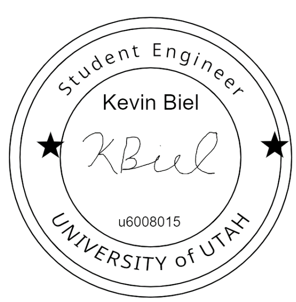

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Executive Summary

Final design of the underpass systems beneath both Wakara Way and Foothill Drive has been completed. The scope of the project includes the underpasses, the connection between them, and a trail connecting to the Red Butte Creek Trail System. Additionally, connections will be made to the existing bus stop on the East side of Foothill drive and the sidewalk that runs parallel to Wakara Way, East of the project site. Utilities including a major sewer line that crosses Wakara Way will need to be rerouted. A maintenance of traffic plan and phased construction strategy have also been developed.

This design was developed with equity and inclusivity of the surrounding community in mind. All trails on the project are ADA compliant so that handicapped individuals and children will be able to access the crossings. Both of the underpasses have been designed in such a way that natural light can enter the facilities. Furthermore, both underpasses are large enough to allow pedestrians to comfortably pass each other going opposite directions. The addition of these underpasses will also allow all individuals crossing both Wakara Way and Foothill Drive to do so safely without the danger of collisions with motor vehicles. Additional seating areas have been provided near Wakara Way and Foothill Drive to add further amenities to the site.

All of the stakeholders involved in this project have also been satisfied. The University of Utah's students and faculty will be able to gain access to Research Park without the danger and discomfort involved with an at grade crossing on a major roadway. Salt Lake City will see a decrease in pedestrian injuries with the addition of a separate grade crossing in the area. UDOT will also be able to time traffic signals in this particular area without the added complication of an at-grade crossing. The design is favorable for Red Butte Steering Commission as well as all federal government entities as the creek will remain undisturbed and there will be no work on federal government property.

Drawing sets from Group 3 and Group 6 have also been combined at this point to allow for a more accurate depiction of what the project will look like upon completion. Both groups have also developed independent cost estimates that will provide an upper and lower bound for the cost of the project. Great effort was put into this project to ensure that the designs of both underpasses were coherent and able to be connected without issue.

All structural components and connector trails were designed in accordance with available codes and requirements put forth by UDOT, Salt Lake City, and the University of Utah. The major benefits of this design in comparison with other options are a reduced traffic impact due to phased construction, the avoidance of federal property, the lack of disturbance near Red Butte Creek, and the addition of park-like areas to encourage the community to actually use the new infrastructure.

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1 Project Summary

1.1 Project Needs Statement

According to data provided by UDOT, Foothill drive services an average of 50,000 vehicles daily. In the fall of 2021, the University of Utah reported they had 34,464 students enrolled with around 85% of those students living off campus and in the fall of 2018 they reported having nearly 30,000 full and part time staff working for the hospital or as academic and administrative staff. In total, almost 60,000 individuals need to commute to and from the University of Utah on a daily basis. The University of Utah married and family housing is located at the intersection of Foothill Drive and Sunnyside Avenue and is currently upgrading to a larger facility which will concentrate student families and graduates in this location, further increasing congestion. Salt Lake City has also expressed plans to build a trail system that follows Red Butte Creek. Currently, a major obstacle in the completion of this trail system is where the creek intersects Foothill Drive. As described in further detail below, Foothill Drive is difficult and uninviting to cross, meaning that the Red Butte Trail may be less utilized to justify its construction or pedestrians and bicyclists will find alternative methods to cross the busy roadway. Ideally, there would be a means in place that would not hinder the flow of traffic and allow pedestrians to freely and safely enjoy the trail.

Due to land and geometric constraints, little more can be added to Foothill drive in terms of additional lanes in order to reduce traffic congestion and commute times. The at-grade crossings require long wait times for pedestrians and bicyclists and slow down north and southbound traffic. The south side of the Wakara Way and Foothill Drive intersection does not have a crosswalk which means that pedestrians may need to cross three separate times in order to get to their desired destination. This may cause pedestrians to seek other forms of transportation or encourage them to cross Foothill or Wakara in an unsafe manner. Foothill Drive has a posted speed limit of 40 mph through the area of interest, combined with the high volume of cars, this may cause many to feel unsafe when faced with needing to cross. This is further emphasized by the fatal pedestrian accident that occurred in this area in 2019. The combination of all of these factors clearly shows a need for improvements at the intersection of Foothill Drive and Wakara Way. Such improvements would include a grade separated crossing that would decrease congestion in the area as well as increase the safety and enjoyment of those wanting to work, study, live, and play here.

1.2 Project Goals and Vision

This project seeks to address all of the concerns raised in the project needs statement. The goal is to implement two underpasses near the intersection of Foothill Drive and Wakara Way in order to improve pedestrian safety, integrate into the future Red Butte Creek trail system, and decrease vehicular traffic along Foothill. One of the underpasses will be underneath Foothill Drive south of the intersection. The second will be underneath Wakara Way east of the intersection. These underpasses will allow people to easily access both sides of Foothill as they won’t need to wait for pedestrian signal lights. This also increases pedestrian safety by separating the level at which vehicles and pedestrians interact with the roadway.

1.3 Project Participants and Organization

The following organizations will be closely involved in constructing and maintaining the project.

- Salt Lake CIty Corporation: They have identified the need for the project. Will be involved in providing funding and maintaining the underpasses long-term.
- UDOT: The Utah Department of Transportation will likely have a monetary stake in the project. The underpasses will directly impact the roadways especially during the construction phase.
- University of Utah: The University of Utah will be involved in the project as it will impact its student body. They may also have a monetary stake in the project if it is something they see as beneficial to them and the students.
- AGEC: Applied Geotechnical Engineering Consultants, INC (AGEC) have provided geotechnical services to analyze soil samples.
- CONTECH: CONTECH has provided consulting in precast concrete options that may be used in the project.
- CVEEN 4900 and 4910 Professional Practice 2022-2023: The 2022-23 Professional Practice class from the University of Utah has provided preliminary research, data collection, and design development.

1.4 Stakeholders

The following groups and individuals will be impacted by the addition of the two underpasses either directly or indirectly.

- Red Butte Steering Committee: This group is concerned with the development of Red Butte Creek and will likely be more involved as the trail is developed.
- Salt Lake County Public Works: The division of the Salt Lake County Public Works is in charge of providing the Salt Lake County Municipal Services District with roads and sidewalks as well as enforcing stormwater management.
- Sunnyside/Salt Lake City residents: This group will be one of the primary users of the underpasses. Their support will be necessary to proceed.
- University Student Apartments/Sunnyside Apartments: These apartments house a large body of married and graduate students that attend the University of Utah. They will also be one of the primary groups targeted to use the underpasses as it will increase ease of access to the University and will increase recreation when the trail is completed.
- Salt Lake City Sustainability Energy & Environment (E&E) Division: The Salt Lake City Sustainability Energy & Environment (E&E) Division ensures that Salt Lake City departments follow environmental guidelines as well as minimize environmental impacts.

Table 1 summarizes the stakeholders and their level of engagement with the proposed project. Each stakeholder is represented in the yellow column, their level of engagement is represented in the blue row. The letter “C” represents their current level of engagement, and “D” represents their desired level of engagement.

	Unaware	Resistant	Neutral	Supportive	Leading
Pedestrians				CD	
Drivers			C	D	
Salt Lake City				C	D
UDOT				C	D
University of Utah				C	D
VA			C	D	
DOD	CD				
Environment			CD		

Table 1: Stakeholder Summary

2 Site Description and Analysis

2.1 Location Description and Usage

A site visit took place on 09/01/2022. This section consists of two parts; the first part will review general findings at the site and the second part will consider aspects related to the underpass construction.

General Findings

The user experience for pedestrians and cyclists who have to cross the road on Foothill Drive is very unsafe and inefficient due to the amount of motor traffic. The poor user experience is especially apparent when attempting to cross the intersection of Foothill Drive and Wakara Way. There is a significant amount of motor traffic in the area. This makes it very uncomfortable to cross and leaves little room for error on the part of the pedestrians or the drivers.

In addition to the challenges that have been identified with the motor traffic, there is also a substantial amount of pedestrian traffic. During the 2-hour visit, there was a constant stream of cyclists and pedestrians. Due to the purpose of the site visit it was impractical to obtain an accurate count. However, this is an important aspect of the design as there will certainly be users of the underpass system.

Any construction that takes place near Red Butte Creek must leave the current area aesthetically appealing. This is still true when considering the proposed design further away from the creek. There is still a large amount of vegetation and the areas near the orthopedic center should still be aesthetically pleasing. Any construction at the site should consider landscaping as an important part of the experience for the end users.

Terrain in the area will present a challenge for any construction efforts in the area. On the north side of Wakara Way there is a large hill that is about 10 feet higher than the surrounding terrain. Unfortunately, this means that any project in the area will require a large amount of earth work. This is because any trails will have to consider ADA compliance. In order to meet the minimum slope requirements there cannot be large elevation differences in relatively small areas. Additionally, the underpass will be placed well below the road surface and further earthwork may be required to create a connection for these various locations.

There are also many utilities present in the project area including buried sewer, gas, water, and electrical utilities. Records showing the location of the utilities will be greatly beneficial. There are also many overhead power lines in the area as shown in photo 2. While the power lines are not critical to the design of the project, they are an important hazard to be aware of during the construction process.

Underpass Considerations

Due to current site conditions the underpass option is the most reasonable choice. During the site visit there was constant traffic and motor vehicles at high rates of speed. For this reason, a cut and cover underpass will make construction faster. Certain travel lanes would need to be closed for shorter periods of time. The underpass may lead to less environmental damage due to the lack of stairs and large footings. An underpass will likely be easier to naturally tie into the trail system on the East side of Foothill Drive.

However, many utilities in the area might need to be crossed. If this is the case, construction could take far longer and have greater risk to the overall cost of the project.

2.2 Soil Borings

Two boreholes were drilled near the project site on 10/27/2022. Drilling operations were performed by AGEC. Below is a summary of the drilling operations. Further lab testing can be found in the appendix.

Two locations were drilled with a small truck mounted rig, Location 1 was on the South side of Red Butte Creek. Location 2 was on the North side of Red Butte Creek. During drilling on location 1, visual inspection of the samples determined the first nine feet of the soil was made up of fill material. This fill was determined to be moist and stiff to a depth of four feet. From six feet to nine feet there was a decrease in the blow count, so the soil was labeled soft and loose at this depth. Additionally, the fill material was 25% gravel, 30% fines, with the other 45% being medium granular material. No plasticity was present in the fill material. Asphalt tailings were located at a depth of five feet and plastic and metal shards were found at a depth of six feet. These observations lend further credence to this layer being man-made fill.

Past the nine foot drilling depth, native soil was located. The native soil was alluvial in nature, due to the proximity of Red Butte Creek. This material was still moist, but was noticeably stiffer, as at the 12 foot depth there was a refusal from the drill rig. A refusal is determined to be when more than 50 blows from the hammer were required to go six inches. 65% of the native material was gravel, 15% were fines, and 20% was medium granular material. Further lab testing will give a more accurate result of the exact contents of the fill and native materials.

Preliminary analysis by the geotechnical professionals on site suggests that the bearing capacity of the alluvial soil will be sufficient to support the footing loads from the pedestrian bridge. This means that over excavation and placement of structural fill likely will not be a requirement. However, further lab testing will be required to verify this analysis. If this holds true, significant cost could be saved on the earth work of the project.

2.3 Geotechnical Report Summary

Based on AGEC's geotechnical report, the most critical part of any foundation system that is present on this project is the layer of fill material. It is recommended that structures should not bear upon the fill material. This is a challenge as the depth of this layer is anywhere from 9 to 28 feet deep. However, since the proposed underpass at Wakara Way is at a much lower elevation than the boring sites, it may prove to be less of a problem. Additionally, the footings for the underpass will be located a further 15 feet below the roadway and it is unlikely the fill material reaches those depths.

Natural soil in the area can sustain structural loads of up to 2,500 psf. This is fairly standard for projects in the Salt Lake Valley and will not influence the design a great deal. Equivalent fluid weights were also given for the surrounding soil. This will allow for the walls of the underpass to have sufficient strength as well as allow for design of the retaining walls in the area. These values are summarized in the table below.

Equivalent Fluid Weights	Condition
40 pcf	Active
55 pcf	At-Rest
300 pcf	Passive

Table 2: Soil Equivalent Fluid Weights

Finally, the geotechnical report indicates that there are no other materials present in the soil that are of concern in terms of concrete or steel corrosion.

2.3 Hydrologic Report

There are several design constraints that were discussed in Mike Guymon's presentation. First, if Salt Lake City is going to be the owner of the new pedestrian crossing there must be access to the new infrastructure, as well as existing utilities in the area, so maintenance can be performed in an efficient manner. This includes other culverts in Research Park, Red Butte Dam, and the Red Butte Water Basin, shown in Figure 3. Furthermore, there must be access to Red Butte Creek so city maintenance crews can monitor and care for the creek. Additionally, other utilities in the area must not be disturbed during construction, or the disruption must be minimal and overseen by Salt Lake City's stormwater inspection team. However, inspection of the utilities map shows that the city does not have buried utilities in the area where the pedestrian crossing will be placed. These constraints are important for the hydrologic design of the underpass as any detention ponds, french drains, or trench drains must be accessible to Salt Lake City.

There is not a great deal of expected flood level precipitation in the area since the creek is so far away from the proposed location of the underpass. However, with a significant increase in hard surfaces in the project area, it has been determined that the most effective way to keep stormwater contained on this site will be the use of detention ponds. Luckily, the bike roundabout that was included in the design is the perfect size to hold a pond that can store 2,000 cubic feet of stormwater. Based upon the detention calculations performed, this will be sufficient.

In addition to the detention ponds, it will also be necessary to install french drains into the bottom of the underpass. This will allow water to drain from the surface of the concrete onto materials that are more conducive to water movement that will be below the underpass. There will also be a drain pipe that runs the length of the underpass that can carry excess water from one side to the other. It is essential to keep standing water off the floor of the underpass to reduce slipping hazards and damage to the walkway.

2.4 Topographic Information

There are significant elevation differences that are present throughout the project area. These are mainly man-made fill slopes from previous construction near Foothill Drive. It is challenging to maintain ADA required sloping on trail systems due to this phenomenon. It makes the design even more challenging when dealing with a below grade structure as even more elevation changes are introduced. For example, on the North side of Wakara Way, there is a hill that is eight feet higher than the existing roadway. This hill is less than 100 feet away from where the entrance to the underpass will be located and the access trail must move through this area. This introduces elevation differences in excess of 20 feet in some areas. Furthermore, there are elevation differences between existing infrastructure that will need to be connected to the Wakara Way underpass. These include the bus stop on the East side of Foothill Drive as well as the existing sidewalk that runs parallel to Wakara Way and continues to Red Butte Creek.

Due to these challenging terrain features, there will be extensive earthwork involved with this project. First and foremost, the existing terrain will require cutting to make the elevations in the area more manageable and allow for more gradual slopes on the ADA access ramps. This type of earthwork will be relatively cheap and is the best method to reduce the impact these elevation differences will have on the final product. Additionally, keystone retaining walls will be a requirement in many of the areas that can not be cut to a more convenient elevation.

These elevation changes also create more drainage issues than would be expected. The underpass will likely be the lowest point on the site and will thus incur a significant amount of stormwater if not drained properly. This made it necessary to include french drains for the structure as well as a buried pipe to more easily move water from one side of the underpass to the other. Detention ponds near the Foothill Drive Underpass as well as the Wakara Way underpass will be necessary to contain as much of the storm water as possible. A topographic map of the project area is included below in Figure 1.

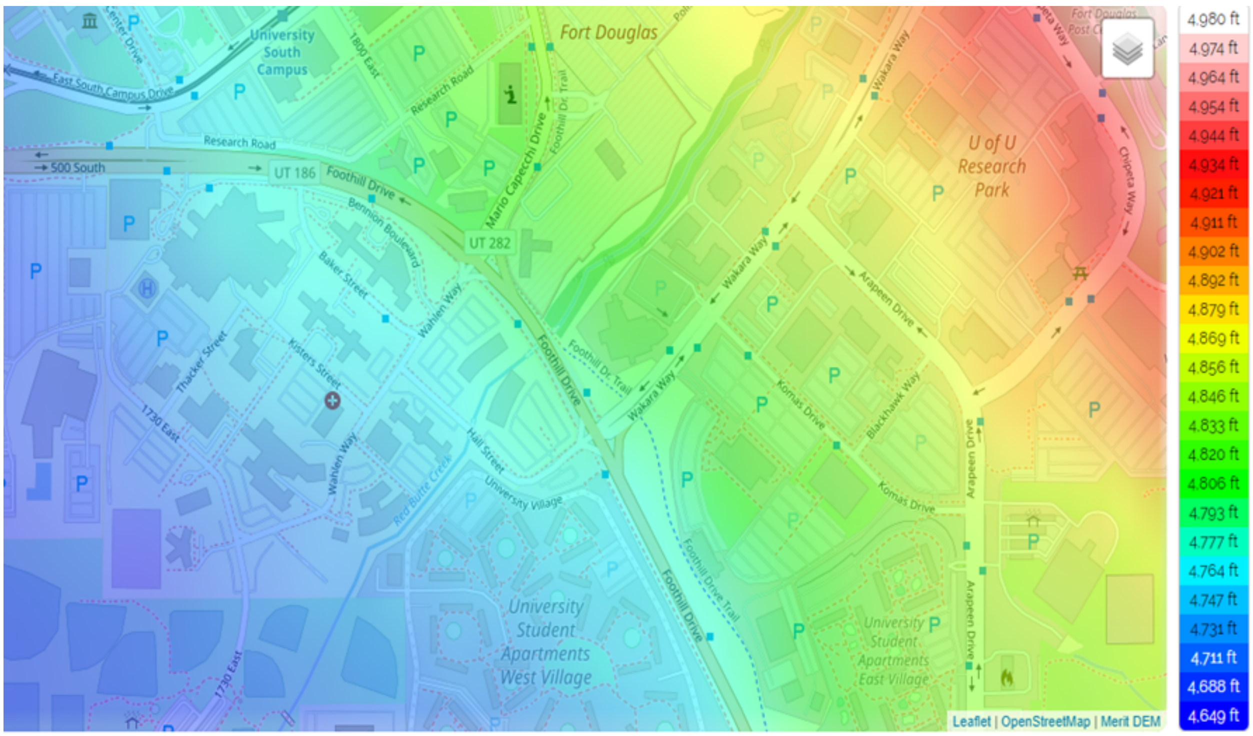


Figure 1: Topographic Map of Project Area

3 Summary of Criteria

3.1 Project Criteria

The purpose of the proposed pedestrian underpass system is to allow for safe and efficient crossing of pedestrians of all ages and abilities. The Wakara Way underpass must connect smoothly with the Foothill Drive underpass, and connect into the trail system by Red Butte Creek. The underpasses should allow for more community engagement with surrounding businesses, public transportation, and education opportunities. This should include students and faculty from the University of Utah, residents of the Sunnyside Community, as well as active transport commuters.

3.2 Basis of Design

While integrating sustainability is still important for this location, it is not as crucial as the underpass is not directly next to Red Butte Creek. This means that environmental interest groups and similar organizations related to the creek are less of a concern. Furthermore, the U.S. Department of Veterans Affairs is also no longer a major stakeholder as this location would not disrupt their property.

This leaves the surrounding community, the University of Utah, UDOT, and Salt Lake City as the leading stakeholders for the project. This project will benefit all of these groups by increasing the accessibility and safety for individuals using alternative modes of transportation, such as walking or biking. It also benefits individuals using public transportation as by having a more thorough and connected crossing and walkway system means that individuals can more easily access the different services and destinations in the area, such as Research Park, the upper campus area of the University of Utah, the University Orthopaedic Center, or Red Butte Creek and its trail.

It was also highly important for the project to be designed to promote inclusivity and equity for all users. This means that pathways were designed wide enough to accommodate a variety of individuals using different modes of transportation, i.e. pedestrian, biker, or an individual using a wheelchair, both directions, and all grades were made to be ADA compliant so all users could comfortably use the underpass network. Additionally, other accessibility features, such as tactile paving, and safety features, such as the skylight and blue light call boxes have also been integrated to help keep individuals safe.

While sustainability is still an important factor when designing the project, the transition to a new location further from the riparian corridor has made it less of a pressing issue. The pathways have been designed in a way to allow for integration of greenspace, rather than just turning the whole area into impervious surfaces. Ensuring proper drainage has also been important in order to not contribute to flooding, which can negatively impact the creek, and damage the infrastructure in the area.

3.3 Decision Criteria

Overall it was important for the design to promote accessibility for all ages, abilities, identities, and skill levels, as well as maintain safety and sustainability. It was also important to minimize disruption to the nearby communities and facilities while increasing the quality of life of the area. The design does this by having walkways that are accommodating which includes ample width and gradual slopes. While an underpass can unfortunately have negative impacts in terms of safety, the design will hopefully mitigate this by ensuring the underpass is well lit and wide, and the installation of call boxes in case of an emergency.

The design also indicates that a precast box would be used for the underpass itself, which will reduce construction time. This means that the University and Sunnyside communities, which experience heavy traffic during peak hours, will experience less disruption. The implementation of a phased MOT plan also will help ensure that the area can still accommodate commuters during construction.On the other hand, the use of a roundabout in the design creates an opportunity to create a usable area with seating and landscaping that can promote native plant life. This helps make the project more than a series of pathways to increase the accessibility to nearby destinations, but also a location for people to enjoy when they are in the area. Furthermore, the retaining walls offer an aesthetic opportunity, as they can be constructed with a variety of materials and be carved or painted to feature patterns or imagery. This will help the area's visual appeal, making it a more desirable location.

3.4 Design Criteria

In order to meet the overall design goals as well as meeting required standards, there were many deliberate choices made when considering specific items. These design features included:

- The 12 ft. width of underpass, this was based on recommendations and requirements from Salt Lake City.
- The 10 ft. clearance of underpass, this was also based on recommendations and requirements from Salt Lake City.
- The 2 ft. shoulders of underpass, this was also based on recommendations and requirements from Salt Lake City.
- The incorporation and design of the detention ponds was based on Salt Lake City stormwater criteria and rainfall map studies.
- The 1 ft. walls on the culvert were based upon UDOT requirements.
- The traffic control plan was based on UDOT practices.

4 Alternative Development

Initially, only bridge concepts were being developed. However, it was determined that bridges interrupted sight lines to existing traffic signals, required large foundation elements, and were more complicated to access. As a result, a separate grade crossing consisting of two underpass systems became the leading alternative for the rest of design.

Once this initial phase of development concluded, the overall design continued relatively smoothly, as the group was aware of the needs for the project and construction methods that would likely be implemented. It was minor details that were altered during the iterations of the design. Elements such as location of the stairway, design of the roundabout and how the layout of the sidewalk to access the buses were finalized by a combination of analyzing the site, discussions within the team, and feedback from the instructional group, stakeholders, and mentors. The overall layout was finalized after consulting with the Foothill Drive underpass team to ensure the design was cohesive.

5 Design Development Summary

5.1 Design Development Process

The design development process for this group was not straightforward as the clients goals and visions changed since the beginning of this project in 2022. Initially only an underpass beside the creek was considered. Later, more alternatives and locations were decided on for further investigation. Group 6 was finally assigned the underpass under Wakara Way connecting to the Group 3 Foothill Drive underpass. The groups made an effort to find feasible alternatives to design issues as soon as they came up in order to catch up to the expectations of group deliverables. The specific strategies used in all of these design scenarios were vocal brainstorming sessions. Some of these specific issues that were addressed in the sessions were:

- Sizing and dimensioning of the underpass itself: Whether this was wall thickness, depth from the top of pavement, or other small dimensioning details, determining these constraints was an essential element of the design development process. It seemed that knowing the specifications for these details would enable the design group to continue on with the design of the rest of the specific construction elements. For example, not knowing the necessary depth prevented the group from determining if the underpass would be interfering with utility lines during the construction phase. In most cases, this information was provided to the group by an outside source like a mentor.
- Location of existing utility lines: Being unable to initially determine where all of the major utility lines were located in this project area, the group had to make a design that would be malleable in case of utility disruption. Upon eventually finding the major lines in tandem with Group 3 and the group mentor, the design had to be slightly altered to allow for the utility lines to remain in their current spots or to prevent excessive amounts of work in rerouting the lines.
- Approval of design choices: Immediate feedback on decisions made were not always available, for example, the decision to include a pedestrian roundabout as part of the trail design. This meant that the group often had to charge ahead with an idea and develop it before receiving feedback and occasionally needing to make last minute changes to appease the client.

While there were many more design issues that were discussed, these three are just examples of what was discussed and how each solution was presented.

5.2 Design Data and Specification Summary

Specific design decisions often had to be made by the group without a specific number given in specifications. Some of the examples follow:

- Box culvert underpass thickness: The wall thickness of the underpass itself had a minimum requirement based on safety, but there was no maximum value. The group ended up deciding on a 1’ thick wall.

- Cost estimate: Part of the design was developing an accurate representation of how much it would cost. The cost estimate, because it can be so volatile depending on area, was made using past project unit prices and UDOT database unit prices.
- Depth of culvert from top of pavement: Again, there is a minimum number given for depth from the top of pavement but no maximum. In order to conserve costs. The minimum value was used again (around 2’ from the bottom of the pavement section). The whole pavement section, including the base course and subgrade, needs to fit on top of the culvert.

While there were many more design justifications, these are the key examples.

5.3 Operations and Maintenance Summary

There are a few operations that will be crucial to the effectiveness of this underpass. As mentioned by the city many times, the idea of an underpass is less appealing to the average pedestrian than an overpass or walkway. Because of this, a higher level of emphasis will need to be put on:

- Maintaining the cleanliness of the underpass: This includes removal of trash, potential graffiti, animal excrement, etc.
- Ensuring drainage is functioning properly: A common reason why underpasses are not used is that they are a magnet for areas of standing water. Ensuring that the drainage being installed to the underpass is sufficient will help entice pedestrians to feel that they can safely use the underground walkway.
- Structural maintenance: It is widely understood in the Civil Engineering field that concrete tends to crack as it ages. This is not a sign of low quality material, but it is rather a common effect of the freezing and thawing cycle. Because of this, cracks are going to appear in the structure over time. Pedestrians can easily be put off by an underground underpass showing signs of aging, and will likely assume that cracking means that the underpass could be susceptible to complete failure. For this reason, it will be important to seal cracks as they appear so that pedestrians feel that they can trust the structure to stay erect as they venture through it.

5.4 Construction Needs and Phasing Summary

Some of the major construction needs will be listed in the cost estimate, however there will be many needs that will have to be individually decided on by the contractor. Some of the major needs from the cost estimate and design that need to be highlighted are as follows:

- Bypass pumping: This will be required during construction of the underpass. The underpass concept passes right through a major sewer line and will disrupt its flow. This line will need to be rerouted and will thus require bypass pumping during the rerouting. This is a major cost to construction companies and the pumping costs can add up very quickly.

- Bus route: There is a bus route on the North side of Wakara Way that will be disrupted during the construction of this half. It will be important for the construction crew to maintain pedestrian access to the bus, whether this is at the current location or a temporary location.
- Construction phasing: There is an initial Maintenance of Traffic plan put into the design, however, the final traffic control and construction phasing ideas will need to be up to the individual contractor that is selected for this job. The initial phasing plan details construction of one half of the road while keeping the other half open, but if the contractor would prefer to close the whole road and work 24 hour days to open it as soon as possible, the city may be willing to modify the phasing and MOT plans.

6 Design Effectiveness Summary

6.1 Design Summary

The final design proposed to address the Red Butte Creek grade separated crossing consists of two underpasses beneath Wakara Way and Foothill Drive. The underpass which will be placed beneath Foothill Drive will be discussed in more detail in the plan set. The focus of this section is the underpass beneath Wakara Way. The design will consist of a 100’ long precast box culvert with a 10’ clearance, 12’ of right-of-way, and 2’ of shoulder on each side. In total this will be a 10’ tall, 16’ wide culvert. This design will allow for plenty of space to allow bicyclists and pedestrians to travel either way comfortably. Exact wall thickness and foundation will be determined by the company contracted to design the precast culvert, for now it is assumed to be 12”. The top of the exterior of the culvert is estimated to be a minimum of 2’ below the roadway, but may need to be lowered in the case that the roadway section is thicker than presumed. A skylight will be installed at approximately the halfway point, located in the median of Wakara Way above the underpass. This will provide natural light during the day and will be lit by energy efficient fluorescent lights that make pedestrians feel safer at night.

The southern exit will be the path interchange that will connect to the sidewalks along Foothill Drive and Wakara Way as well as to the Foothill Drive underpass. The sidewalk will be below grade to maintain ADA compliant grades. This means that either side of the path will utilize tiered retaining walls with landscaping to retain the sail and beautify the trail. The northern exit will include a staircase on the east side that leads up to the main grade and connects to the sidewalk along Wakara Way and the trail that leads to Red Butte Creek. A roundabout is also proposed that will branch off to the bus stop on Foothill Drive and to the Red Butte Creek trail. The roundabout will also include landscaping features and benches/picnic tables to create an environment that will allow recreationists to stop and enjoy the scenery and relax along the trail. Retention ponds have been sized and planned in order to manage stormwater runoff and help with drainage since the majority of the underpass and trail will be below grade.

6.2 Design Effectiveness

Each aspect of the design was chosen with the goals and vision of the project in mind; pedestrian safety, decrease congestion, and connect the Red Butte trail system across Foothill Drive. By placing the crossings below grade, this will protect the pedestrians from the high speed traffic along the main roadways. By removing the need for pedestrians to cross at-grade, the flow of traffic will be improved as the traffic signals will not need to ensure that pedestrians have ample time to cross. This will also mean pedestrians will not need to wait to cross, making the area more accessible and pleasant to use. The primary purpose of constructing the grade separated crossings is to eventually connect the Red Butte Creek trail on either side of Foothill Drive. This trail will attract additional users who will need to easily cross Foothill Drive. The underpasses were chosen to be located at Wakara Way and Foothill Drive since they would not interfere with VA land. The underpasses will be only on University of Utah land and UDOT easements making it easier to coordinate construction and get the necessary permission. The public areas north and south of the underpass are to allow recreationists and locals the opportunity to enjoy the area. They provide a place for trail users to rest and a place for people who live or work nearby to be outside. The underpass should not only be a means of travel, but a way to add beauty to the area and improve the community.

7 Cost Estimate

In order to develop an engineer’s estimate that is more accurate than a simple comparative cost system, it has been determined that it may be beneficial to at least attempt to gain an understanding of the quantity of materials that will be present on this project. These are subject to change, but will allow for a more realistic estimate to be developed. The most important assumptions about quantities will be documented below:

- Both underpasses will be the length of the current roadway measured from the back of the sidewalk on both sides.
- Both underpasses will have walls and decks that are 1’ thick.
- Both underpasses will have cast-in-place wing walls.
- 1’ of structural fill will be required under both underpasses.
- 2’ of road base will be placed atop both underpasses.
- All asphalt trails will be 12’ wide and have 2” gravel underlayment.

Pricing was based off of UDOT’s unit cost database and is subject to change due to the current volatility present in the economy. Additionally, there is a sewer line that will need to be rerouted over the course of construction. It is assumed that this will cost about $100,000.00, this is not a conservative estimate of this cost, but there was not a great deal of data available on potential prices for this relocation.

In terms of material quantity, the following estimate will be fairly accurate considering this stage of design, however, it could be off by 5-10% depending on the component in question. On the other hand, the labor costs are based on a rule of thumb used by many general contractors. This being that for every two dollars spent on material, one dollar should be spent on labor. This is contrived of course, but should allow for the labor costs to be in the ballpark. The major costs that are involved in this project are as follows: Foothill Drive underpass concrete, Wakara Way underpass concrete, and earthwork for the access trails. Unfortunately, these are unavoidable as the underpasses must have walls and decks that are one foot thick concrete and in order to make the access ramps ADA compliant, there will be a substantial amount of earthwork due to the surrounding topography.

It should be noted that Group 3 also has an estimate of the entire project's cost. Group 3's estimate is $6.2 million while Group 6's is $3.4 million. This is not an oversight, but should be taken as a possible range of construction costs. Group 3 was far more conservative with assumed labor costs and the amount of concrete required for the site. It should be taken that the following estimate, found below in Table 3, is the lower bound for the potential cost of this project.

Foothill Drive Underpass			
Material	**Quantity**	**Unit**	**Price**
10'x18' Precast Box Culvert	207	cy	$258,750.00
Reinforcing Steel	36000	LB	$81,000.00
CIP Concrete Floor	39	cy	$48,750.00
CIP Concrete Wing Walls	24	cy	$30,000.00
Structural Fill (under tunnel)	71	cy	$5,680.00
UBC	36	cy	$3,240.00
Granular Borrow Import	72	cy	$6,120.00
Drainage Pipe	120	feet	$27,000.00
Labor			$230,270.00
Other			
Excavation	996	cy	$29,880.00
Asphalt Demo	214	sqyd	$1,712.00

Total Price:
$3,368,942.51

Wakara Way Underpass			
Material	**Quantity**	**Unit**	**Price**
10'x12' Precast Box Culvert	178	cy	$167,500.00
Reinforcing Steel	30000	LB	$67,500.00
CIP Concrete Floor	33	cy	$41,250.00
CIP Concrete Wing Walls	24	cy	$30,000.00
Structural Fill	59	cy	$4,720.00
UBC	30	cy	$2,700.00
Granular Borrow Import	60	cy	$5,100.00
Drainage Pipe	100	feet	$22,500.00
Labor			$170,635.00
Other			
Excavation	830	cy	$24,900.00
Asphalt Demo	178	sqyd	$1,424.00

Asphalt Trails			
Material	**Quantity**	**Unit**	**Price**
Asphalt	240	ton	$32,400.00
Block Retaining Wall	2400	sqft	$156,000.00
Gravel	59	cy	$4,720.00
Earthwork	36,000	cy	$1,080,000.00
Labor			$96,560.00

Other	Price
Mobilization	$297,037.91
Public Information Services	$14,851.90
Traffic Control	$297,037.91
Survey	$29,703.79
Sewer Line Relocation	$100,000.00

Table 3: Cost Summary

8 Work Summary

The way that this group went about working on this project was through a series of meetings and individual work. In most scenarios, the group would be split up and individual assignments were given and then reviewed by other members of the group. In addition to individual assignments, client meetings and mentor meetings were often used to get work done on this project. Once the meetings with clients and mentors were concluded, work would be conducted again and reviewed by others. During meetings, detailed notes were always taken by at least one member of the group. One of the most consistent ways that notes were taken in these meetings was with the following form:

University of Utah
2023 Foothill Boulevard Crossing – Wakara Way Underpass Meeting Minutes
University Project Number: 4910.S23

<u>2023 Foothill Boulevard Crossing – Wakara Way Underpass</u>

January 25, 2023

Agenda:

- Welcome
- Quick Update Between Underpass Groups
  - Wakara Way Group
    - 100' ROW on Wakara Way
  - Foothill Group
    - Debating use of roundabout (waiting for city approval)
    - Finalizing proposed sidewalk location
- Weekly Update with Mentor
  - Retaining walls East of PED roundabout
    - Plan is to remove existing retaining walls and landscaping
  - Adam designed something like this before, will send old plans over
  - Grading along NE side of PED roundabout
    - Current plan is to meet existing sidewalk at grade
    - Can't slope straight from 2:1 slope, likely need a foot or two buffer on each side
    - Will likely need pedestrian fall protection above these walls
  - Cost Estimation
    - First step is getting all relevant line items and their quantities. Mentors can look at UDOT database to get accurate real time unit price numbers.
  - Roundabout is too big for PED, good size for roadway design.
    - People will ride through middle if roundabout is too big, lots of earthwork
  - Contact UDOT Region 2 Engineer for pavement cross section
  - Sent Doug some UDOT bike path specs
  - Best connection for SW sidewalk back to the creek area is as direct as possible.

Page 1 of 2

Figure 2: Meeting Minutes Form (Mentor Meeting Example)

This system of splitting up assignments after meetings and reviewing each other's work functioned well for this group.

Another piece that contributed greatly to the success of the work for this report was the ability to use previous work completed. The instructional team did an outstanding job setting up assignments throughout the semester that each contributed to the final report and final design. Because the assignments were periodically given and in small pieces, when the time came to assemble a final design report, most of the pieces were already 50-75% done. This enabled the group to focus more on the actual design aspect of the final report rather than fretting about many small writing assignments all having to be compiled into one large one.

In some rare cases, work was done by the group in a group setting. With long class periods scheduled throughout the semester, there were a few times where the group reached a point of no longer needing the time to meet, so the group opted to work on reports, assignments, schematic drawings, and general design conditions together in the classroom. This method of work occurred more often early on in the brainstorming and initial conceptual design processes.

In addition, every group began the project working as an individual. During this period, several weeks were spent developing a project needs statement. This was based upon early analysis of the stakeholders, site layout, and determination of design controls. Sustainability models along with preliminary soil investigation followed. Finally, preliminary meetings occurred with Salt Lake City. With this data, the project needs statement was developed.

Groups were formed after the project needs statements were developed. At this point, a basis of design was created. With this basis of design, multiple alternatives to accomplish the task were produced. Further meeting with the city planner allowed for a concept to be chosen from these alternatives. Then schematic design on this concept began. At milestones throughout the overall design, the drawings, and status reports were submitted to Salt Lake City as well as the design advisors allocated to the groups. This cycle of design was repeated several times until all major elements of the project were fleshed out and the final design stage was concluded.

Appendices

Detention Pond Calculations

Pre Development Area		
Area	(SQ. FT.)	Notes
Building	0	Input This Area
Improvements	15000	Input This Area
Landscape	30000	Will be Computed
Total	45000	Input This Area

Post Development Area		
Area	(SQ. FT.)	Notes
Building	0	Input This Area
Improvements	13000	Input This Area
Landscape	78591	Will be Computed
Total	91591	Will be Computed

Allowable Runoff From Municipality		
Allowable Runoff	0.2	cfs/acre

Orifice Calculation Elevations		
Highwater Elev		
Orifice Elev		

80th Percentile Depth		
$P_{80\%}$	0.55	cfs/acre

Table 4: Detention Pond Calculation Inputs

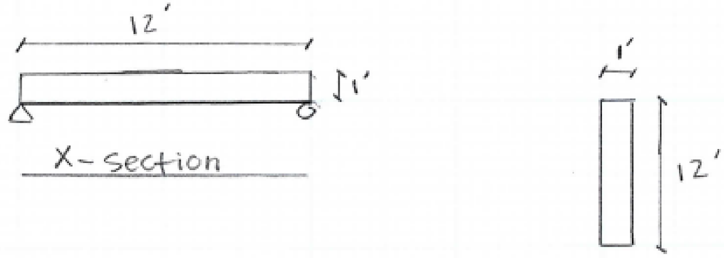
DRAINAGE CALCULATIONS					
					29-Mar-23
Pre-Development Area Analysis					
Area		sq.ft.	Acres		C
Building		0	0.00		0.85
Improvements		15,000	0.34		0.90
Landscape		30,000	0.69		0.15
Total		45,000	1.03		0.40
Post-Development Area Analysis					
Area		sq.ft.	Acres		C
Building		0	0.00		0.85
Improvements		13,000	0.30		0.90
Landscape		78,591	1.80		0.15
Total		91,591	2.10		0.26
100 Year Storage Analysis					
NOAA Precipitation Frequency Data Server					
Latitude: 40.7546°		**Longitude: -111.8328°**			
Allowable Runoff		0.20	cfs/acre		
Time (min.)	I in./hr	Runoff ft³	Allowable ft³		Storage ft³
5	6.740	1,090	126		964
10	5.130	1,660	252		1,407
15	4.240	2,058	378		1,679
30	2.850	2,766	757	>	2,009 <
60	1.770	3,436	1,514		1,922
120	0.993	3,855	3,028		827
180	0.679	3,954	4,542		0
360	0.370	4,309	9,083		0
720	0.226	5,265	18,167		0
1440	0.133	6,196	36,334		0
			Required Detention		**2,009**

Table 5: Detention Pond Requirements

Satisfied by 2121 CF retention pond located on Wakara Way roundabout. See Sheet A103B in the plan set.

Underpass Deck Structural Calculations

1/3



The deck of the underpass will be considered as a 1-way slab

Live Load due to vehicles = 485 psf
Dead Load due to pavement section/soil / self weight = 405 psf

Material: $f'_c = 4{,}000$ psi , $f_s = 60{,}000$ psi
Total depth of slab (h) = 12"

Width of slab (b) = 12"
Effective depth (d) = 10.5"
Length of slab = 12 feet

$\beta = 0.85$

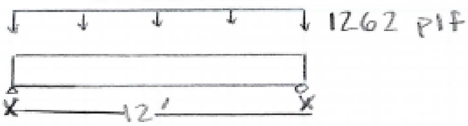
Wu

$L = 485$ psf, $D = 405$ psf $\Rightarrow 485 \frac{lb}{ft^2} \times 1\,ft = 485$ plf = L

$405 \frac{lb}{ft^2} \times 1\,ft = 405$ plf = D

$W_u = 1.2(405\,plf) + 1.6(485\,plf) = 1262$ plf

$$\boxed{W_u = 1262 \frac{lb}{ft}}$$



2/3

Mu

$M_u = W_u \times L^2/8 = 1262\ lb/ft \times (12\ ft)^2/8 = 22{,}716\ lb \cdot ft$

$\underline{M_u = 22.7\ K \cdot ft}$

As

$A_s = M_u/4d = 22.7\ kft/4(10.5'') = 0.54\ in^2$

#6 bar @ 10" O.C. => $\underline{A_s = 0.528''}$

Depth of comp. Zone

$a = A_s \cdot f_y / 0.85 \cdot f'c \cdot b = 0.528\ in^2 \times 60{,}000\ lb/in^2 \Big/ 0.85 \times 4{,}000\ \frac{lb}{in^2} \times 12\ in$

$\underline{a = 0.776''}$

Nominal Moment

$\phi M_n = 0.9 \cdot A_s \cdot f_y \cdot (d - a/2) = 0.9 \times 0.528\ in^2 \times 60{,}000\ \frac{lb}{in^2}\ (10.5'' - (0.776''/2))$

$\phi M_n = 288{,}313\ lb \cdot in\ (\times 1\ Kip/1000\ lb)(\times 1\ foot/12\ in) = \underline{24\ K \cdot ft} = \phi M_n$

$24\ kft > 22.7\ K \cdot ft$

$\phi M_n > M_u$

Flexural strength Sufficient

3/3

Net Tensile Strain

$$\varepsilon_t = \frac{0.003(d-c)}{c}, \quad c = \frac{a}{\beta_1} = \frac{0.776''}{0.85} = 0.91''$$

$$\varepsilon_t = \frac{0.003(10.5'' - 0.91'')}{0.91''} = 0.0316 >> \varepsilon_{ty} + 0.003$$

Tension Controlled

Asmin $= 0.0018 \cdot 60{,}000\,psi \cdot 12'' \times 12'' = 0.259\,in^2$

Transverse Bars

$$\text{Spacing} = 12'' \times \frac{0.2\,in^2}{0.259\,in^2} = 9.25''$$

#4 @ 9" O.C.

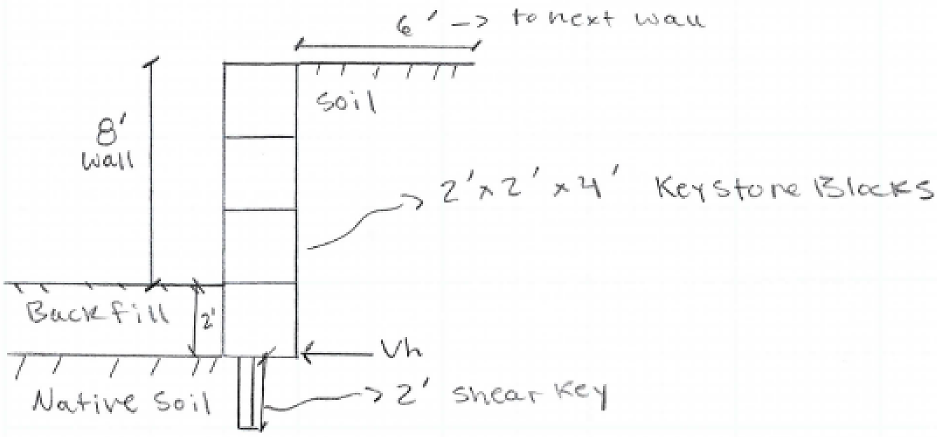
Summary:

Primary Flexural Reinforcement = #6 bar @ 10" O.C.

Transverse Reinforcement = #4 bar @ 9" O.C.

Keystone Wall Calculations

1/2



Active Pressure of Soil = 40 pcf
Passive pressure of soil = 300 pcf
Coefficient of Sliding Friction = 0.3

Keystone Block Weight $= 2' \times 2' \times 1' \times 150 \frac{lb}{ft^3} = 600\,lb$

$600\,lb \times 4$ blocks tall $= 2400\,lb$

$2400\,lb \times 0.3 = 720\,lb$ resisting from friction

$300\,lb/ft^3 \times 4' \times 1' \times 1' = 1200\,lb$ resisting from passive pressure

Total resistance $= 720\,lb + 1200\,lb = \underline{1920\,lb}$

Lateral Earth pressure $= \frac{40\,lb}{ft^3} \times 8' \times \frac{8'}{2} \times 1' = \underline{1280\,lb}$

$$F.S. = \frac{1920\,lb}{1280\,lb} = 1.5$$

Wall Design is Sufficient For Sliding

Moment

2/2

Lateral Earth Pressure = 1280 lb

M_{LEP} = 1280 lb × 2.64' = 3380 lb·ft

Resisting Earth Pressure = 300 lb/ft³ × 6' × $\frac{4'}{2}$ × 1' = 7200 lb

7200 lb × 0.167 = 4800 lb × $\frac{4'}{3}$ = 6400 lb·ft Resisting Moment

$$F.S. = \frac{6400\ lb \cdot ft}{3380\ lb \cdot ft} = 1.9$$

Wall Design is sufficient for Overturning

Applied Geotechnical Engineering Consultants, Inc.

Project Number: 1220771

Project Name: U of U Red Butte Crossing

Engineer: DJN

Date: Dec. 13, 2022

Date Needed:

Date Completed:

LABORATORY TESTING PROGRAM

BORING	DEPTH	MOISTURE	MOISTURE/DENSITY	GRADATION	-200 ONLY	HYDROMETER	ATTERBERG	SPECIFIC GRAVITY	CONSOLIDATION	UNCONFINED	DIRECT SHEAR	TRIAXIAL SHEAR	TRIAXIAL PERM.	PERMEABILITY	GRADIENT RATIO	STD. PROCTOR	MOD. PROCTOR	RELATIVE DENSITY	CBR	SULFATES	RESISTIVITY	PH					REMARKS
B-1	2'		X	X																							
B-1	6'		X	X																							
B-1	10'		X	X																							
B-1	14'		X	X			X		X											X							2 liners can be used
B-1	19'		X	X																							
B-1	24'		X	X																							
B-1	29'		X		X		X																				
B-2	2'		X	X																							
B-2	8'		X	X																							
B-2	16		X	X																							
B-2	28		X	X																							
B-2	30		X	X																							

Applied Geotechnical Engineering Consultants, Inc.

Project Number 1220771 MOISTURE/DENSITY WORKSHEET Sheet prepared by__Date 12/13/22

Project Name U of U Red Butte Crossing Sheet calculated by_____Sheet____of____

IDENTIFICATION		TEST RESULTS			DENSITY DETERMINATION					MOISTURE DETERMINATION				
Boring	Depth, Feet	% M sture	Dry Density (pcf)	SAMPLE DESCRIPTION	Sample Length	Sample Diameter	Set Soil & Tare Wt.	Tare Weight	Wet Soil Weight	Dish Name	Wet Soil & Dish Wt.	Dry Soil & Dish Wt.	Dish Weight	Run By
B-1	2	4.76%	119.04		4.00	1.93	496.38	113.32	383.06		537.33	520.02	156.24	
B-1	6	6.26%	117.65		4.00	1.93	498.17	114.15	384.02		538.91	516.37	156.19	
B-1	10	2.32%	108.20		4.00	1.93	460.34	120.28	340.06		495.67	487.96	155.72	
B-1	14A	4.19%	97.53		4.00	1.93	426.22	114.07	312.15		464.22	451.70	153.11	
B-1	14B	4.19%	92.82		4.00	1.93	417.21	120.15	297.06		464.22	451.70	153.11	
B-1	19	3.23%	104.61		3.87	1.93	439.48	118.53	320.95		474.38	464.34	153.86	
B-1	24	1.39%	106.56		3.83	1.93	435.42	117.64	317.78		469.13	464.78	151.58	
B-1	29	2.10%	121.46		4.00	1.93	505.01	124.09	380.92		300.33	297.25	150.53	
B-2	2	3.34%	109.58		4.00	1.93	473.60	125.77	347.83		498.82	487.59	151.42	
B-2	8	5.49%	115.77		4.00	1.93	489.30	114.16	375.14		526.57	507.05	151.43	
B-2	16	18.23%	81.59		4.00	1.93	413.90	117.59	296.31		448.05	402.44	152.28	
B-2	28	4.98%	102.00		4.00	1.93	443.95	115.02	328.93		480.58	464.98	151.64	
B-2	30	5.56%	126.51		3.96	1.93	526.90	120.81	406.09		564.91	543.57	159.53	

Applied Geotechnical Engineering Consultants, Inc.

Project Number 1220771
Project Name U of U Red Butte Crossin

GRADATION ANALYSIS
WORKSHEET

Sheet prepared by______Date__________
Sheet calculated by_____Sheet____of____

Boring @ Depth	B-2 @ 30			@			@			@			@			@		
Run By																		
Test Type	-200 / Gradation			-200 / Gradation			-200 / Gradation			-200 / Gradation			-200 / Gradation			-200 / Gradation		
Wet Soil & Dish	564.91			0.00			0.00			0.00			0.00			0.00		
Dry Soil & Dish	543.57			0.00			0.00			0.00			0.00			0.00		
Dish Weight	159.53			0.00			0.00			0.00			0.00			0.00		
Dry Soil Wt.	384.04																	
Sieve Size	5.56%	Cum. Wt.	% Pass		Cum. Wt.	% Pass		Cum. Wt.	% Pass		Cum. Wt.	% Pass		Cum. Wt.	% Pass		Cum. Wt.	% Pass
Date and Time of soak																		
No. 4																		
No. 200	301.92	301.9	78.62%															
Pan																		
Gravel			%			%			%			%			%			%
Sand			%			%			%			%			%			%
Silt & Clay	79		%			%			%			%			%			%

Boring @ Depth	@			@			0 @ 0			0 @ 0			0 @ 0			0 @ 0		
Run By													0					
Test Type	-200 / Gradation			-200 / Gradation			-200 / Gradation			-200 / Gradation			-200 / Gradation			-200 / Gradation		
Wet Soil & Dish	0.00			0.00			0.00			0.00			0.00			0.00		
Dry Soil & Dish	0.00			0.00			0.00			0.00			0.00			0.00		
Dish Weight	0.00			0.00			0.00			0.00			0.00			0.00		
Dry Soil Wt.																		
Sieve Size		Cum. Wt.	% Pass.		Cum. Wt.	% Pass.		Cum. Wt.	% Pass.		Cum. Wt.	% Pass.		Cum. Wt.	% Pass.		Cum. Wt.	% Pass.
Date and Time of soak																		
No. 4																		
No. 200																		
Pan																		
Gravel			%			%			%			%			%			%
Sand			%			%			%			%			%			%
Silt & Clay			%			%			%			%			%			%

PLEASE NOTE that only the PERCENT Silt and Clay can be reported unless a #4 sieve is used!!

Applied Geotechnical Engineering Consultants, Inc.

Project Number 1220771

Project Name U of U Red Butte Crossin

GRADATION ANALYSIS
WORKSHEET

Sheet prepared by_____Date__________

Sheet calculated by_____Sheet____of___

Boring @ Depth	B-2 @ 30	@	@	@	@	@
Run By						
Test Type	-200 / Gradation	-200 / Gradation	-200 / Gradation	-200 / Gradation	-200 / Gradation	-200 / Gradation
Wet Soil & Dish	564.91	0.00	0.00	0.00	0.00	0.00
Dry Soil & Dish	543.57	0.00	0.00	0.00	0.00	0.00
Dish Weight	159.53	0.00	0.00	0.00	0.00	0.00
Dry Soil Wt.	384.04					

Sieve Size	5.56%	Cum. Wt	% Pass		Cum. Wt	% Pass		Cum. Wt	% Pass		Cum. Wt	% Pass		Cum. Wt	% Pass		Cum. Wt	% Pass
Date and Time of soak																		
No. 4																		
No. 200	301.92	301.9	78.62%															
Pan																		
Gravel			%			%			%			%			%			%
Sand			%			%			%			%			%			%
Silt & Clay	79		%			%			%			%			%			%

Boring @ Depth	@	@	0 @ 0	0 @ 0	0 @ 0	0 @ 0
Run By					0	
Test Type	-200 / Gradation	-200 / Gradation	-200 / Gradation	-200 / Gradation	-200 / Gradation	-200 / Gradation
Wet Soil & Dish	0.00	0.00	0.00	0.00	0.00	0.00
Dry Soil & Dish	0.00	0.00	0.00	0.00	0.00	0.00
Dish Weight	0.00	0.00	0.00	0.00	0.00	0.00
Dry Soil Wt.						

Sieve Size		Cum. Wt.	% Pass.		Cum. Wt.	% Pass.		Cum. Wt.	% Pass.		Cum. Wt.	% Pass.		Cum. Wt.	% Pass.		Cum. Wt.	% Pass.
Date and Time of soak																		
No. 4																		
No. 200																		
Pan																		
Gravel			%			%			%			%			%			%
Sand			%			%			%			%			%			%
Silt & Clay			%			%			%			%			%			%

PLEASE NOTE that only the PERCENT Silt and Clay can be reported unless a #4 sieve is used!!

Applied Geotechnical Engineering Consultants, Inc.

Project Number 1220771 ATTERBERG LIMITS Sheet prepared by_____Date__________

Project Name U of U Red Butte Crossing WORKSHEET Sheet calculated by_____Sheet____of____

Boring @ Depth	B-1 @ 14		B-1 @ 29							
Sample No./Run by										
Test Type	Plastic Limit	Liquid Limit	Plastic Limit	Liquid Limit	Plastic Limit	Liquid Limit	Plastic Limit	Liquid Limit	Plastic Limit	Liquid Limit
Number of Blows	0		0		0		0		0	
Dish Number										
Wt. of Wet Soil & Dish										
Wt. of Dry Soil & Dish										
Wt. of Dish										
Wt. of Water										
Wt. of Dry Soil & Dish										
Water Content										
Liquid Limit										
Plasticity Index										

Boring @ Depth										
Sample No./Run by										
Test Type	Plastic Limit	Liquid Limit	Plastic Limit	Liquid Limit	Plastic Limit	Liquid Limit	Plastic Limit	Liquid Limit	Plastic Limit	Liquid Limit
Number of Blows	0		0		0		0		0	
Dish Number										
Wt. of Wet Soil & Dish										
Wt. of Dry Soil & Dish										
Wt. of Dish										
Wt. of Water										
Wt. of Dry Soil & Dish										
Water Content										
Liquid Limit										
Plasticity Index										

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Project Number 1220771 SOLUBLE SULFATES Sheet prepared by______Date__________

Project Name U of U Red Butte Crossing WORKSHEET Sheet calculated by_____Sheet____of___

Boring @ Depth	B-1 @ 14		
Dilution (Standard is 30ml/100ml)	None	15ml/100ml	10ml/100ml
Dilution Factor	1	2	3
Turbidity - Soil/Water with $BaCL_2$	29.6		
Turbidity - Soil/Water without BaCL2	2.1		
Turbidity Difference	27.5		
Sulfate, mg from Chart	0.25		
Sulfate, ppm (Chart*100*Dilution Factor)	25	0	0
Sulfate, percent (ppm/10000)	0.0025	0	0

Boring @ Depth	@		
Dilution (Standard is 30ml/100ml)	None	15ml/100ml	10ml/100ml
Dilution Factor	1	2	3
Turbidity - Soil/Water with $BaCL_2$			
Turbidity - Soil/Water without BaCL2			
Turbidity Difference			
Sulfate, mg from Chart			
Sulfate, ppm (Chart*100*Dilution Factor)	0	0	0
Sulfate, percent (ppm/10000)	0	0	0

Boring @ Depth			
Dilution (Standard is 30ml/100ml)	None	15ml/100ml	10ml/100ml
Dilution Factor	1	2	3
Turbidity - Soil/Water with $BaCL_2$			
Turbidity - Soil/Water without BaCL2			
Turbidity Difference			
Sulfate, mg from Chart			
Sulfate, ppm (Chart*100*Dilution Factor)	0	0	0
Sulfate, percent (ppm/10000)	0	0	0

Boring @ Depth	@		
Dilution (Standard is 30ml/100ml)	None	15ml/100ml	10ml/100ml
Dilution Factor	1	2	3
Turbidity - Soil/Water with $BaCL_2$			
Turbidity - Soil/Water without BaCL2			
Turbidity Difference			
Sulfate, mg from Chart			
Sulfate, ppm (Chart*100*Dilution Factor)	0	0	0
Sulfate, percent (ppm/10000)	0	0	0

Boring @ Depth	@		
Dilution (Standard is 30ml/100ml)	None	15ml/100ml	10ml/100ml
Dilution Factor	1	2	3
Turbidity - Soil/Water with $BaCL_2$			
Turbidity - Soil/Water without BaCL2			
Turbidity Difference			
Sulfate, mg from Chart			
Sulfate, ppm (Chart*100*Dilution Factor)	0	0	0
Sulfate, percent (ppm/10000)	0	0	0

Boring @ Depth	@		
Dilution (Standard is 30ml/100ml)	None	15ml/100ml	10ml/100ml
Dilution Factor	1	2	3
Turbidity - Soil/Water with $BaCL_2$			
Turbidity - Soil/Water without BaCL2			
Turbidity Difference			
Sulfate, mg from Chart			
Sulfate, ppm (Chart*100*Dilution Factor)	0	0	0
Sulfate, percent (ppm/10000)	0	0	0

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SIEVE ANALYSIS TEST REPORT

Quality Control

Sample Date 12/13/22

Project Number: 1220771

Project Name : U of U Red Butte Crossing

Client:

Lab Number : A-121322

Sampled by: DJN

Tested by: MD

Sample Location: B-1 @ 2'

Supplier: Liner

Aggregate Size:

Total Dry Mass Of Sample, g 381.1

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
3/4"	92.58
#4	75.52
#8	69.07
#16	64.38
#30	59.41
#50	51.87
#100	44.32
#200	38.12

Sample Remarks:

Reviewed by: TT

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SIEVE ANALYSIS TEST REPORT
Quality Control

Sample Date	12/13/22	**Lab Number :**	B-121322
Project Number:	1220771	**Sampled by:**	DJN
Project Name :	U of U Red Butte Crossing	**Tested by:**	MD
Client:			

Sample Location: B-1 @ 6'
Supplier: Liner
Aggregate Size:

Total Dry Mass Of Sample, g 360.2

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
3/4"	100.00
#4	89.13
#8	85.47
#16	82.64
#30	79.96
#50	75.93
#100	68.00
#200	54.95

Sample Remarks:

Reviewed by: TT

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SIEVE ANALYSIS TEST REPORT
Quality Control

Sample Date 12/13/22
Project Number: 1220771
Project Name : U of U Red Butte Crossing
Client:

Lab Number : C-121322
Sampled by: DJN
Tested by: MD

Sample Location: B-1 @ 10'
Supplier: Liner
Aggregate Size:

Total Dry Mass Of Sample, g 332.2

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
3/4"	82.00
#4	46.11
#8	38.57
#16	32.63
#30	27.03
#50	20.88
#100	15.38
#200	13.11

Sample Remarks:

Reviewed by: TT

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SIEVE ANALYSIS TEST REPORT

Quality Control

Sample Date 12/13/22

Project Number: 1220771

Project Name : U of U Red Butte Crossing

Client:

Lab Number : D-121322

Sampled by: DJN

Tested by: MD

Sample Location: B-1 @ 14'

Supplier: Liner

Aggregate Size:

Total Dry Mass Of Sample, g 298.6

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
3/4"	100.00
#4	100.00
#8	100.00
#16	99.54
#30	97.75
#50	95.80
#100	89.37
#200	73.24

Sample Remarks:

Reviewed by: TT

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SIEVE ANALYSIS TEST REPORT

Quality Control

Sample Date 12/13/22

Project Number: 1220771

Project Name : U of U Red Butte Crossing

Client:

Lab Number : E-121322

Sampled by: DJN

Tested by: MD

Sample Location: B-1 @ 19'

Supplier: Liner

Aggregate Size:

Total Dry Mass Of Sample, g 310.5

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
3/4"	91.47
#4	75.47
#8	67.36
#16	60.33
#30	53.09
#50	42.94
#100	31.92
#200	28.09

Sample Remarks:

Reviewed by: TT

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SIEVE ANALYSIS TEST REPORT

Quality Control

Sample Date 12/13/22
Project Number: 1220771
Project Name : U of U Red Butte Crossing
Client:

Lab Number : F-121322
Sampled by: DJN
Tested by: MD

Sample Location: B-1 @ 24'
Supplier: Liner
Aggregate Size:

Total Dry Mass Of Sample, g 313.2

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
3/4"	83.52
#4	44.65
#8	36.00
#16	29.75
#30	24.96
#50	21.02
#100	14.78
#200	11.99

Sample Remarks:

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SIEVE ANALYSIS TEST REPORT

Quality Control

Sample Date 12/13/22

Project Number: 1220771

Project Name : U of U Red Butte Crossing

Client:

Lab Number : G-121322

Sampled by: DJN

Tested by: MD

Sample Location: B-2 @ 2'

Supplier: Liner

Aggregate Size:

Total Dry Mass Of Sample, g 336.2

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
3/4"	89.18
#4	73.35
#8	66.15
#16	61.04
#30	56.11
#50	49.25
#100	42.89
#200	38.11

Sample Remarks:

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SIEVE ANALYSIS TEST REPORT

Quality Control

Sample Date 12/13/22
Project Number: 1220771
Project Name : U of U Red Butte Crossing
Client:

Lab Number : H-121322
Sampled by: DJN
Tested by: MD

Sample Location: B-2 @ 8'
Supplier: Liner
Aggregate Size:

Total Dry Mass Of Sample, g 355.6

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
1"	86.15
#4	64.69
#8	60.66
#16	56.81
#30	52.57
#50	48.12
#100	44.91
#200	40.40

Sample Remarks:

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SIEVE ANALYSIS TEST REPORT
Quality Control

Sample Date 12/13/22
Project Number: 1220771
Project Name : U of U Red Butte Crossing
Client:

Lab Number : I-121322
Sampled by: DJN
Tested by: MD

Sample Location: B-2 @ 16'
Supplier: Liner
Aggregate Size:

Total Dry Mass Of Sample, g 250.2

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
3/4"	100.00
#4	88.32
#8	79.88
#16	73.94
#30	68.95
#50	65.10
#100	61.24
#200	57.84

Sample Remarks:

Reviewed by: TT

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SIEVE ANALYSIS TEST REPORT

Quality Control

Sample Date 12/13/22

Project Number: 1220771

Project Name : U of U Red Butte Crossing

Client:

Lab Number : J-121322

Sampled by: DJN

Tested by: MD

Sample Location: B-2 @ 28'

Supplier: Liner

Aggregate Size:

Total Dry Mass Of Sample, g 313.3

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
3/4"	91.38
#4	72.10
#8	61.56
#16	53.60
#30	47.11
#50	41.67
#100	34.92
#200	32.28

Sample Remarks:

Reviewed by: TT

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SIEVE ANALYSIS TEST REPORT

Quality Control

Sample Date 12/13/22

Project Number: 1220771

Project Name : U of U Red Butte Crossing

Client:

Lab Number : K-121322

Sampled by: DJN

Tested by: MD

Sample Location: B-2 @ 30'

Supplier: Liner

Aggregate Size:

Total Dry Mass Of Sample, g 384.0

Test performed according to ASTM D75-87, C702-93, C136-93, D-5644 and C7117-90 or D1140-92.

Sieve Size	Percent Passing
1 1/2"	79.75
#4	50.12
#8	40.45
#16	34.76
#30	31.16
#50	28.27
#100	24.07
#200	21.38

Sample Remarks:

Reviewed by: TT

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Consolidation Analysis

Project Number:	1220771	Sample Mold Condition?	Liner
Project Name:	U of U Red Butte Crossing	Pounded, Pressed or Natural?	Natural
Sample Location:	B-1	***Use Moisture Correction?***	No
Sample Depth:	14.00 ft	Actual Percent of Proctor	#####
		Actual Moisture Content:	%
Sample Length:	1.00 in	Proctor Target	
Sample Diameter:	1.93 in	OMC	

Initial Density		**Initial Moisture**	
Volume:	0.001693 ft^3	Wet Weight:	82.54 g
Wet Weight & Ring:	324.23 g	Dry Weight:	69.33 g
Ring Weight:	241.69 g	Water Weight:	13.21 g
Wet Weight:	82.54 g	Moisture Content:	19.05 %
Dry Density:	90.28 pcf		
Bulk Density:	107.48 pcf		

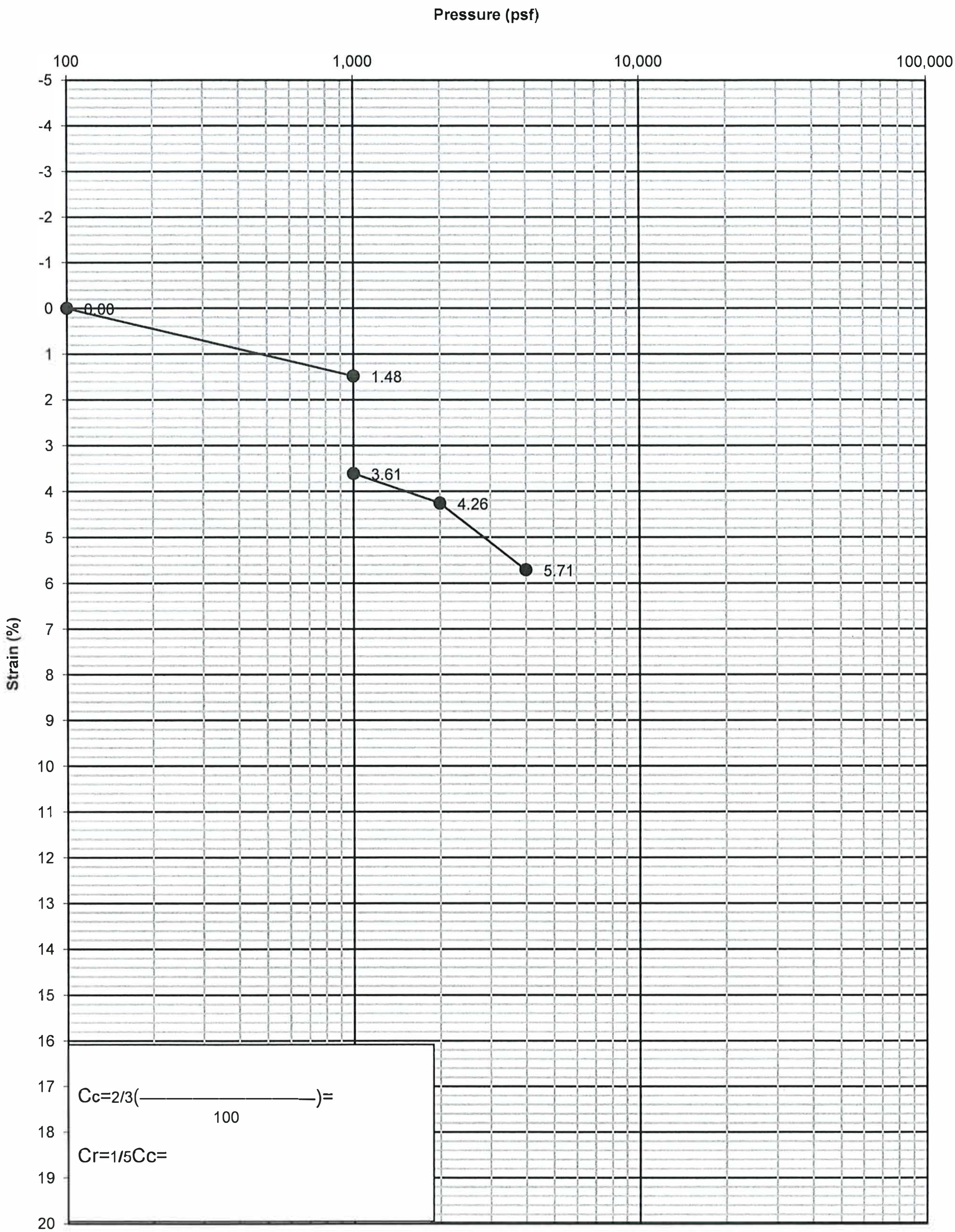
Final Density		**Final Moisture**	
Length:	1.0000 in	Dish & Wet Weight:	91.73 g
Volume:	0.001693 ft^3	Dish & Dry Weight:	76.00 g
Wet Weight & Ring:	337.31 g	Dish Weight:	6.67 g
Ring Weight:	241.69 g	Water Weight:	15.73 g
Wet Weight:	95.62 g	Dry Soil Weight:	69.33 g
Dry Density:	101.49 pcf	Moisture Content:	22.69 %

Dial Readings

Dial Type: Decreases with consolidation

Load (ksf)	Dial Reading	Dial Change	Strain	Pressure (ksf)
0	0.5257	0.0000	0.00	100
1	0.5109	0.0148	1.48	1,000
W	0.4896	0.0361	3.61	1,000
2	0.4831	0.0426	4.26	2,000
4	0.4686	0.0571	5.71	4,000
8			#N/A	8,000
16			#N/A	16,000
4			#N/A	4,000
1			#N/A	1,000

Length Change: 0.0571 in
Collapse: 2.13 %


Pressure (psf)
100
1,000
10,000
100,000
Strain (%)
0.00
1.48
3.61
4.26
5.71
Cc=2/3(—————————)=
100
Cr=1/5Cc=