FEASIBILITY STUDY REPORT
Arterial Collector Design & Feasibility Study
Project ID: CEEn_2016CPST_008

by

Sic Parvis Magna Engineering

Shaun Hilton
Joseph Browning/Data Collection
Jordan Arrowchis/Data Analysis
David Michelsen/Design & Drawings

A Capstone project submitted to

Dan Tracer
and
Bluffdale City Engineering

Department of Civil and Environmental Engineering
Brigham Young University

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Introduction

PROJECT TITLE: Arterial Collector Design & Feasibility Study
PROJECT ID: CEEn-2016CPST-008
PROJECT SPONSOR: Bluffdale City Engineering
TEAM NAME: Sic Parvis Magna Engineering

This project entails the design of an access road connecting the existing Bluffs Apartments to Loumis Parkway in Bluffdale, Utah. The residents of the apartment complex have requested a second access road to the apartment complex. Because of this desire, the city has requested a feasibility study for a connector road from Loumis Pkwy and Marketview Dr. The new roadway design allows the residents to enter the apartment complex from Loumis Pkwy. The location of the proposed road is evaluated. The report consists of the consideration, evaluation, and presentation of two proposed roadway designs for the consideration of the city.

This feasibility study includes all the studies that have been performed for this project. This includes the traffic control device recommendations based on traffic counts provided by the city, accident, and sight distance data. These studies are for the safety of the drivers along Loumis Parkway and the new road. The two recommended preliminary road designs are presented along with the feasibility of each roadway. The feasibility of each road is shown through a cost analysis and a construction feasibility analysis.

At the conclusion of this report are the recommendations of the team. These recommendations are based on the safety analysis, cost, and construction feasibility of the proposed roadway.

Schedule

Date	Work to be Completed	Project Work
November 14, 2016	Proposal	
November 21, 2016		Group Meeting, Progress Report
November 28, 2016		
December 5, 2016	Status Report	Group Meeting, Progress Report
December 12, 2016	Traffic Study	Group Meeting
December 19, 2016		Group Meeting, Progress Report
December 26, 2016		
January 2, 2017		Group Meeting, Progress Report
January 9, 2017		Group Meeting
January 17, 2017	Accident Report	Group Meeting, Progress Report
January 23, 2017		Group Meeting
January 30, 2017	Preliminary Roadway Design Cost Analysis Construction Feasibility	Group Meeting, Progress Report
February 6, 2017	Signal Warrant	Group Meeting, Progress Report
February 13, 2017		
February 20, 2017	Feasibility Study	Group Meeting, Progress Report

Site Description

The proposed roadway is located at the Bluffs Apartment complex on Marketview Drive in Bluffdale, UT, shown in Figure 1. Currently, there is an existing service road which acts as an emergency access on the south side of the Bluffs apartments. There is approximately 20’ – 50’ of elevation difference between Loumis Pkwy and the apartment complex depending on location. To the northeast of the Bluffs apartment complex, there are plans for the construction of a shopping center.

Plans for a roundabout north of the Bluffs apartment to allow access to the business center are in progress. The land southwest of the apartment complex is open space, but conversion to a city park is due in the coming months. The land between the apartments and Bangerter Hwy is a detention pond for runoff from the highway.

Figure 1: Google map image of the project site

Traffic Study

With the construction of a new road along Loumis Parkway one factor to be evaluated is increased traffic that will occur on the new road and on Loumis Parkway. The increased trafficking is important to know for the design of the pavement structure, and for the feasibility of building a new road. With the construction of the small business center located to the north of the apartment complex, this will generate a significant amount of traffic. Connecting Loumis Parkway to Marketview Dr. will create a route for the shoppers to use to get to the business center. This could negatively affect the ability of the residents to access their homes with ease, because of the large increase in traffic that would occur.

Table 1 contains the daily traffic volume data for Loumis Parkway. The survey was conducted from 2:00 pm on October 13th, 2016 to 4:26 pm on October 21st, 2016. To obtain this data, the city of Bluffdale used axle sensors that used an algorithm set to a setting of factory default axles. This data allowed us to use the daily traffic totals to calculate an average daily traffic count of 1007 vehicles per day.

Table 1: Summary of Total Volume

Time	Thursday 10/13/2016	Friday 10/14/2016	Saturday 10/15/2016	Sunday 10/16/2016	Monday 10/17/2016	Tuesday 10/18/2016	Wednesday 10/19/2016	Thursday 10/20/2016	Friday 10/21/2016	Hourly Total
12:00 AM		7	7	5	8	6	4	4	4	**45**
1:00 AM		1	5	2	1	1	2	1	4	**17**
2:00 AM		1	6	3	1	2	1	1	0	**15**
3:00 AM		5	3	0	3	1	3	4	3	**22**
4:00 AM		0	1	1	2	0	3	6	2	**15**
5:00 AM		6	5	3	7	5	6	7	6	**45**
6:00 AM		26	8	0	35	36	33	30	30	**198**
7:00 AM		95	16	9	133	123	126	99	83	**684**
8:00 AM		95	23	19	168	142	155	102	49	**753**
9:00 AM		47	46	42	65	66	72	57		**395**
10:00 AM		51	48	27	57	41	37	44		**305**
11:00 AM		59	50	42	44	56	44	43		**338**
12:00 PM		55	70	44	61	70	51	61		**412**
1:00 PM		63	65	71	48	55	63	55		**420**
2:00 PM	0	68	59	53	80	83	73	78		**494**
3:00 PM	94	90	63	58	103	105	92	97		**702**
4:00 PM	146	129	65	81	129	124	132	115		**921**
5:00 PM	206	208	55	62	187	182	212	207		**1319**
6:00 PM	121	142	58	36	124	133	103	89		**806**
7:00 PM	78	71	59	24	55	47	59	52		**445**
8:00 PM	45	34	35	29	36	37	35	41		**292**
9:00 PM	27	31	30	12	13	15	33	34		**195**
10:00 PM	22	25	24	11	16	11	18	11		**138**
11:00 PM	11	18	24	4	8	5	11	4		**85**
Daily Total	**750**	**1327**	**825**	**638**	**1384**	**1346**	**1368**	**1242**	**181**	

Average Daily Traffic **1007**

Table 2 contains the estimated Equivalent Single Axle Loads on Loumis Parkway. The equivalent single axle load is the ratio of a passenger car's weight to a semi-truck's weight. This is an important factor as it allows us to analyze the amount of wearing taking place on the road structure. This data is also used when deciding which type of pavement to use for the road design. The equivalent axle load factors are used to convert the number of axles for a type of vehicle to the amount of equivalent single axle loads. The equivalent single axle load is a standardized weight of 18,000 lb. applied to a single axle with dual tires. The summation of the equivalent single axle loads is a cumulative traffic loading statistic used to estimate the amount

of damage done to the pavement. The vehicle class found in Column 1 of Table 2 is the type of vehicle. There are 13 total vehicle classes designated by the U.S. Department of Transportation based on the load each vehicle carries. The FHWA vehicle classifications are shown in Figure 2.

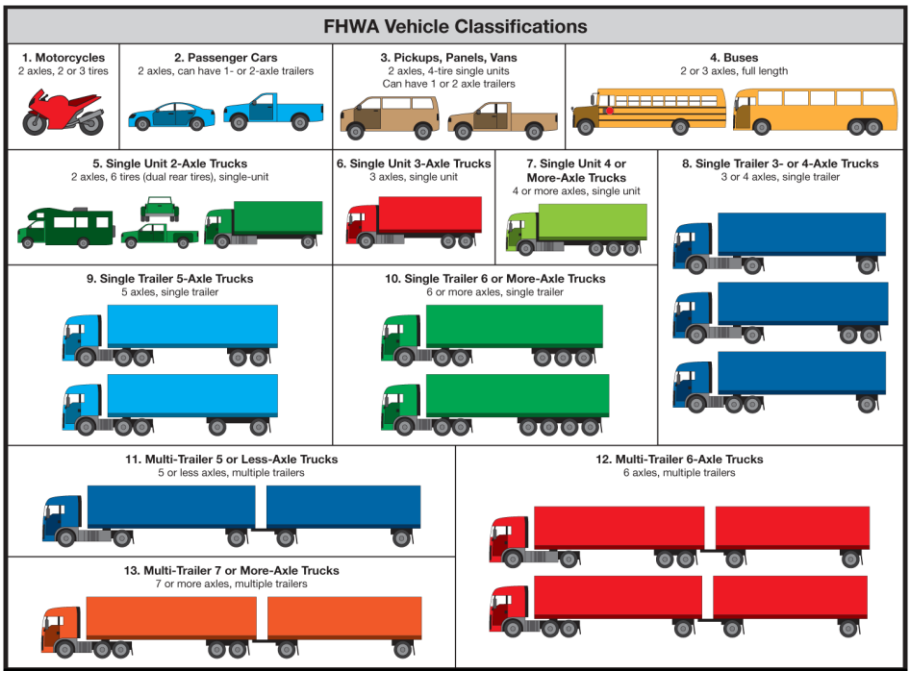


Figure 2: FHWA Vehicle Classifications

Table 2: Estimated Equivalent Single Axle Loads (ESALs)

CLASS	TOTAL VEHICLES	NO. OF AXLES	EALF	ESAL
1	77	154	0.001	0.154
2	6169	12338	0.004	49.352
3	2055	4110	0.004	16.44
4	43	86	0.3	25.8
5	613	1226	0.17	208.42
6	72	216	0.7	151.2
7	23	69	0.7	48.3
8	1	4	0.7	2.8
9	7	35	1.1	38.5
10	1	5	1.1	5.5
TOTAL	9061	18243	4.78	546.47

Table 3 contains the Equivalent Axle Load Factors (EALF) for the ten out of the 13 different FHWA class types that pass through Loumis Parkway. These EALFs were used to calculate the number of Flexible ESALs per class type. Flexible ESALS are used specifically for asphalt, or flexible pavement.

Table 3: Equivalent Axle Load Factors (EALF)

Vehicle Type	FHWA Class	Flexible EALF
Cars & Motorcycles	1, 2	0.001
Pickups, Panel Vans	3	0.004
Buses	4	0.3
2-axle, 6-tire Singles	5	0.17
3-axle or more Singles	6, 7	0.7
4-axle Combos	8	0.7
5-axle or more Combos	9-11	1.1

Table 4 contains a summary of the maximum non-consecutive 8-hour count for Loumis Parkway. These values are the maximum volume count for the specified hour. These are non-consecutive, meaning they come from different days. This data will be used in a later report, which is beyond the scope of this project, to determine whether a signal is warranted for the designed road. This further analysis will be determined by the city if necessary.

Table 4: 8-Hour Maximum Vehicle Count

Hour	# of Vehicles
7:00 AM	133
8:00 AM	168
9:00 AM	65
2:00 PM	80
3:00 PM	103
4:00 PM	129
5:00 PM	187
6:00 PM	124

Table 5 contains a summary of the maximum non-consecutive total hourly volume for a total of 4 hours for Loumis Parkway.

Table 5: 4-Hour Maximum Vehicle Count

Date	Time	Total Vehicles
10/19/2016	7:00 AM	126
10/19/2016	8:00 AM	155
10/19/2016	4:00 PM	132
10/13/2016	5:00 PM	207

As future development in the surrounding regions occurs the proposed road will experience higher volumes of traffic. With the plan to connect this southern community to the proposed shopping center, there will be a significant increase in traffic along Loumis and the new roadway.

Accident Study

With the introduction of a new road into an existing system, the safety impacts should be considered. The impacts will be considered in this study as well as in future studies, performed by the city, for this project. According to the Manual of Uniform Traffic Control Devices (MUTCD) Section 4C.08 Warrant 7, "The Crash Experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principle reasons to consider installing a traffic control signal." The contents of this report include an analysis of related accidents within the area surrounding the proposed location.

The data obtained from UDOT's Vehicle Collisions mapping website (UDOT 2017) is summarized in Table 6. Included with the data is the date of the accident, the type of accident, the weather, the location, and if there was an injury or not. The provided data are accidents that have occurred between January 1, 2013 and October 31, 2016, because this is the range of dates the website provides. In the past four years there have been a total of eight accidents and of these accidents, two have resulted in an injury. One of those accidents happened within the apartment complex and does not pertain to Loumis Pkwy.

Table 6: Summary of Crash Data

Date	Crash Description	Collision Type	Weather	Location	Injury
8/12/2013	Collision with Other Motor Vehicle	Rear to Side	Cloudy	Apartment Complex	No Injury
11/17/2014	Collision with Other Motor Vehicle	Head On	Clear	13975 S 1500 W	No Injury
8/26/2015	Tree/Shrubbery		Clear	13920 S 1300 W	No Injury
2/7/2016	Collision with Other Motor Vehicle	Head On	Clear	Apartment Complex	No Injury
2/20/2016	Collision with Other Motor Vehicle	Angle	Clear	13920 S 1300 W	Injury
4/28/2016	Collision with Other Motor Vehicle	Head On	Clear	Apartment Complex	Injury
8/15/2016	Parked Motor Vehicle	Parked Vehicle	Cloudy	14200 S Loumis Pkwy	No Injury
9/20/2016	Bridge Pier or Support		Clear	13800 S 1300 W	No Injury

For a traffic signal warrant to be justified there are three criteria outlined by the MUTCD which must be met before consideration:

1. Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and
2. Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and

3. For each of any 8 hours of an average day, the vehicles per hour (vph) given in both of the 80 percent columns of Table 7, for both the major and minor road. These major-street and minor-street volumes used should be the same 8 hours. On the minor street, the higher volume shall both be required to be on the same approach during each of the 8 hours.

Table 7: MUTCD 8 Hour Vehicular Traffic Count

Condition A—Minimum Vehicular Volume									
Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%	80%	70%	56%	100%	80%	70%	56%
1	1	500	400	350	280	150	120	105	84
2 or more	1	600	480	420	336	150	120	105	84
2 or more	2 or more	600	480	420	336	200	160	140	112
1	2 or more	500	400	350	280	200	160	140	112

Loumis Pkwy has striping along the roadway to act as a traffic control device. There are no reports that the current conditions are unsatisfactory nor have they failed in any way. Under the current conditions the first criteria is not satisfied.

The second criteria require that there are five or more reported accidents within a twelve-month period resulting in a personal injury or property damage. There have been eight crashes in the last four years with only one accident involving personal injury along Loumis Pkwy. Due to the lack of accidents in this region the second criteria is not satisfied.

The last requirement for the traffic signal warrant is for there to be a significant amount of traffic traveling along the road for any 8-hour period. Total volume data are summarized in Table 1. For these criteria to be met, the total vehicles per hour, for both approaches, must be greater than the 80 percent column and first row of numbers found in Table 7. The requirement in this case is for any given 8-hour period along Loumis Parkway to exceed 400 vehicles per hour. After examination of the data found in Table 1, the volume totals for Monday, Tuesday, Wednesday, and Thursday between 12 and 8 pm the totals exceed 750 vehicles. With the construction of a new access could possibly exceed the required 8-hour amount of 120 vehicles. In this case, these criteria are satisfied under the creation of a new access.

This report evaluates each of the three required criteria outlined by the MUTCD and whether or not the current conditions meet these criteria. It was found that under current conditions the traffic signal warrant is not warranted under crash experience criteria. Details of each criteria are found in the Recommendations section of this report, found on page 22.

With the introduction of a new road into an existing system, the safety impacts should be considered to determine if a signal is needed. By the criteria found in the MUTCD Section 4C.08 Warrant 7, the Crash Experience signal warrant conditions are not satisfied under two of the three required criteria, thus the warrant is not satisfied. According to this study, the accidents do not play a role in the need for a traffic signal at the existing intersection. If a new road is constructed, a follow-up study should be performed in the coming years at the new intersection to ensure that accidents have not increased significantly and that they are mitigated correctly.

Traffic Control Device Study

Due to the nature of the proposed road designs, consideration of a traffic control device would be important to the safety of the intersection. Originally, this analysis was for a traffic signal warrant, but due to the lack of data this warrant was modified to be a traffic control device warrant. With the data that the team had, a signal warrant would not have been met with the two criteria that were used. The two criteria were traffic data and accident data. These two parameters do not provide enough evidence for the need of a traffic signal. This report specifically looks at the need for a stop sign instead of a traffic signal.

The placement of stop signs depends entirely on stopping sight distance. If both Loumis Parkway and the new road were on completely level terrain with no sight obstructions, there would be little to no need for any traffic control devices. However, both recommended options contain obstructions that must be taken into consideration. The private road access option that connects Loumis Parkway directly to the apartment complex faces a very large hill to the east, in addition to a blind curve from the main road approaching from the northeast. The option that connects Loumis Parkway to the shopping center has a view that is obstructed by Bangerter Highway, which is elevated. Figure 3 shows a diagram that illustrates some parameters that are taken into consideration when determining the placement of a traffic control device.

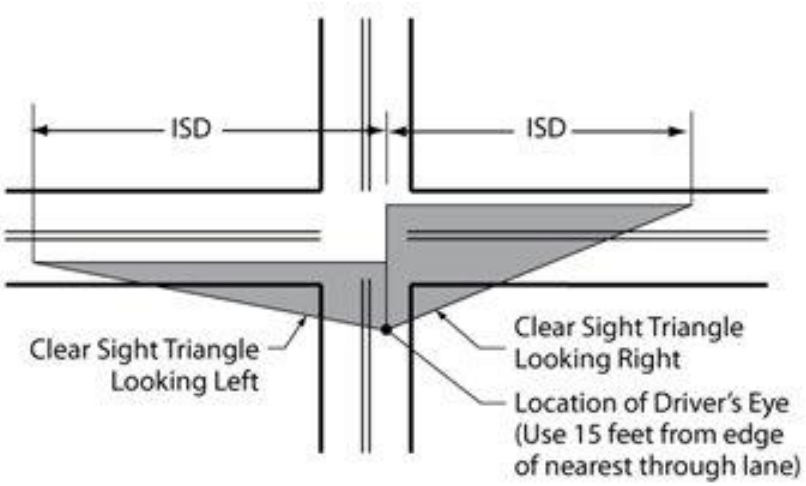


Figure 3: Sight Distance Diagram (U.S. Department of Transportation)

It is estimated that these obstructions would exist roughly 24 feet to the left of the driver on the new road and 20 feet to the right of the driver on Loumis Parkway. These measurements were taken using satellite imagery (Google Earth 2016). Below are the calculations that were made to determine whether a stop sign was warranted in accordance with AASHTO guidelines (AASHTO 2011). d_A is the minimum stopping distance required for a vehicle approaching from the proposed road. A speed of 25mph, a grade of -8.5%, and a conservative reaction time of two seconds are assumed for this equation. This distance is 149.8 feet. The following equations are found in *A Policy on Geometric Design of Highways and Streets* (AASHTO 2011).

$$d_A = 1.47S_A t + \frac{S_A^2}{30(0.348 \mp 0.01G)}$$

d_{Bact} is the distance that a vehicle travelling southwest on Loumis Parkway in the direction of the intersection would have to stop if no stop sign were present. *a* is the distance from the car on the new road to the sight obstruction, which in this case is 24 feet, and *b* is the distance from the car on Loumis Parkway to the sight obstruction, which is 20 feet. The distance that the car on Loumis Parkway has to stop is 27.7 feet.

$$d_{Bact} = \frac{ad_A}{d_A - b}$$

d_{Bmin} is the minimum stopping distance required for the car travelling southwest on Loumis Parkway. This equation works the same way as the calculation of the stopping distance for the car on the new road except for the fact that the grade is assumed to be level. The minimum distance required for the car travelling on Loumis Parkway is 133.4 feet.

$$d_{Bmin} = 1.47S_B t + \frac{S_B^2}{30(0.348 \mp 0.01G)}$$

After making the proper calculations in accordance with guidelines from AASHTO for both recommended designs, it was determined that a stop sign would be required for both of the new proposed road designs. Because the minimum distance required for the car on Loumis Parkway to stop is greater than the distance it has, a stop sign is warranted. The obstructions make this dangerous without some sort of traffic control device, which is why a stop sign must be installed.

Preliminary Roadway Design

The design for the first proposed alignment is for the city-requested connector road using the Bluffdale Typical section for a Minor Collector road. The second proposed alignment is a private road design that will create a second access road for the apartment complex. The private road typical section is on plan and profile sheet PP-2. Figure 4 shows the Minor Collector typical section and Figure 5 shows the private road typical section.

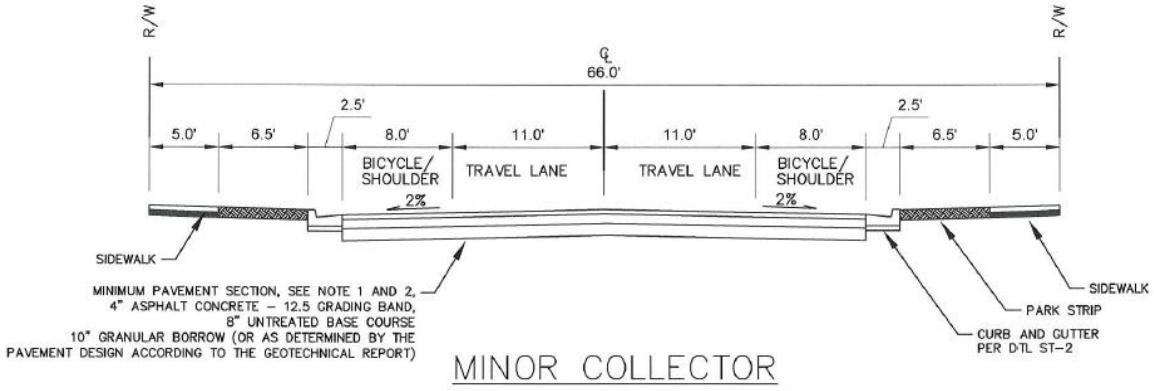


Figure 4: Bluffdale Typical Section

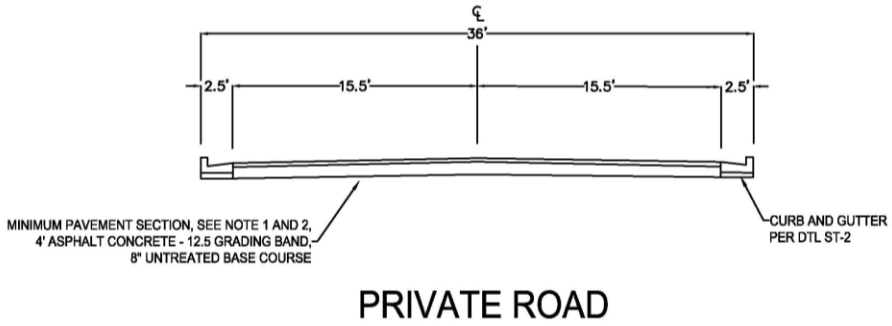


Figure 5: Private Road Typical Section

As part of the preliminary road design, a cost analysis is included in this report. The cost analysis uses 2016 unit prices reported to Provo City for the 2016 Road Rehab Project and Bluffdale City Porter Rockwell Boulevard Segment 3 project. For each of the preliminary roadway designs, costs include construction, property acquisition, safety, ease of access, and ease of maintenance. Ease of access costs are opinions of the team designing these roadways. Ease of maintenance cost uses the team's knowledge of road slopes and accessibility of the roadway for snowplows. Construction costs include items such as cubic yards of excavation, cubic yards of fill, tons of asphalt, linear feet of curb and gutter, square feet of sidewalk, traffic control, and mobilization.

In combination with the cost estimate is a construction feasibility analysis comparing economic and environmental impacts caused during construction of the proposed designs.

Design One

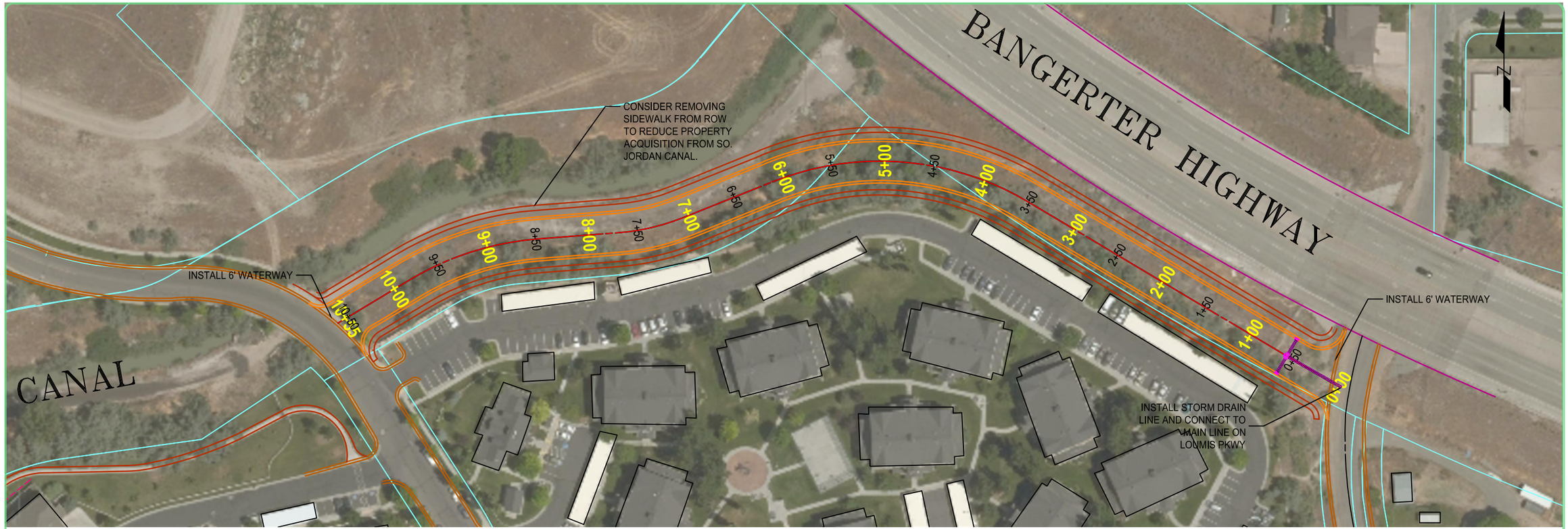
The first design is located along the north side of the apartment complex between the existing apartment buildings and Bangerter Highway. The proposed road would begin on Loumis Pkwy, just south of the Bangerter Highway overpass, and would wind around the complex to connect with the existing entrance road. The roadway would stay on the south side of the existing South Jordan Canal to avoid having to pipe the canal and build a bridge structure. The proposed roadway is outside of the apartment complex to avoid conflict with existing parking structures and roadways.

Using this design would eliminate the need of the city's new park property for the construction of a new road. This would allow for a larger park area, which the residents of the apartment complex and the community would appreciate. This design also allows for the proposed communities to the southeast of the Bluffs Apartment complex to access the proposed business district with ease. The downside of this design is that a large amount of excavation would be required. Loumis Pkwy is a two-lane road with minimum shoulder space and no room for designated or shared turn lanes. The introduction of a new connection road would create delay problems and accident risks along Loumis Pkwy due to turning vehicles obstructing through traffic. The location of the road is adjacent to an overpass and a curve on Loumis Pkwy, which has potential hazard issues.

The plan and profile sheet for design one are on sheet PP-1. The designed roadway was created roadway with slopes that would allow for vehicles to stop on a fairly flat surface at each of the intersections. This increases the amount of material required to be removed from the site, which increases the cost. The properties of the native material needs to be analyzed by a geotechnical study to further determine how much of it must be replaced by a structural layer used for the road base and subbase. The proposed typical section for the roadway has 66 feet of right-of-way. There are many ways to alter this design to save money and to reduce the amount of property acquisition. Removing the park-strip and the sidewalk would reduce the right-of-way to 43 feet. This would help improve the geometric design of the road and reduce the cost of construction.

Reducing the required fill allows the slope of the design to be at an 8.51 percent grade from Loumis Pkwy to the curve of the design. The slope has a gradual transition to a 0.5 percent grade, which is sufficient to remove water from the remainder of the roadway and carry it to Loumis Pkwy. The removal of the detention basin and the construction of an impermeable surface would require some type of drainage device. The design is to install inlets at the end of the new roadway before it reaches Loumis Pkwy and connect into a storm drain main running along Loumis Pkwy. Another drainage structure is a waterway at both ends of the new road to ensure that Marketview Dr and Loumis Pkwy have continuous flow through the intersection.

The main uncertainty that comes with this proposal, however, is that it requires land currently owned by UDOT. This recommendation depends on whether UDOT has plans to widen Bangerter Highway at some point in the future and if there is another option for detaining water. The detention basin located to the north of the apartments detains water from Bangerter Highway which could pose an issue when acquiring that land. However, if they do allow the usage of their property for the construction of this new road, it remains a viable option.



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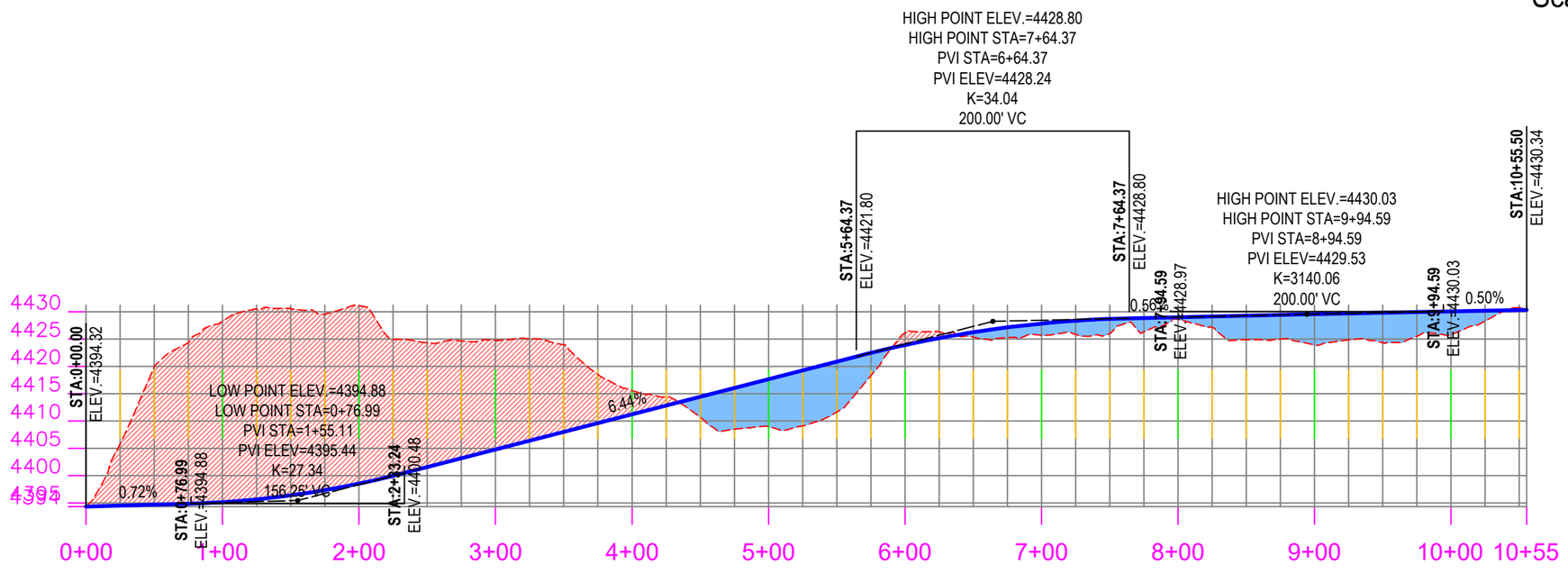


SIC PARVIS MAGNA
GREATNESS FROM SMALL BEGINNINGS

REMARKS

1.

LOUMIS PKWAY
Jan 2017

Design One

Engineering File Number:
-

Drawing: PP-1
Sheet: 1 of 1

Cost Analysis

An important aspect of road design is the cost of construction and maintenance. Because the City of Bluffdale will build this proposed road, money is a critical point, as the funds are from taxpayers. Table 8 is a summary of construction costs of Design 1, based on 2016 unit costs obtained from the Provo City 2016 Road Rehab project and City of Bluffdale Porter Rockwell Boulevard Segment 3 project.

Table 8: Engineer's Estimate for Design One

A-1	Traffic Control	Lump	1	$47,000.00	$47,000.00
A-2	Mobilization and Demobilization	Lump	1	$47,000.00	$47,000.00
A-3	Bituminous Concrete Pavement, PG 64-28	SF	40425	$2.80	$113,190.00
A-4	Untreated Base Course - Grade 3/4	Ton	2322	$16.00	$37,147.99
A-5	Roadway Excavation	Ton	8745	$3.00	$26,234.14
A-6	Granular Borrow	Ton	872	$9.00	$7,852.32
A-7	Concrete Curb and Gutter, Type E	LF	2170	$24.00	$52,080.00
A-8	Concrete Sidewalk, 4" Thick	SF	10570	$4.53	$47,882.10
A-9	6' Waterway - 9" Thick	LF	120	$43.00	$5,160.00
A-10	Cast Iron Detectable Warning Panel	SF	96	$70.00	$6,720.00
A-11	Landscape	SF	13722	$2.25	$30,873.38
A-12	12" Crosswalk & Stop Bar Marking Paint	Foot	38	$1.05	$39.90
A-13	Pavement Marking Paint - White	Gallon	6.5	$21.00	$136.50
A-14	Pavement Marking Paint - Yellow	Gallon	6.5	$21.00	$136.50
A-15	18 Inch - RCP Storm Drain, Class III	LF	100.0	$38.00	$3,800.00
A-16	Single Catch Basin	Each	2.0	$1,594.80	$3,189.60
A-17	60 Inch Dia. Storm Drain Manhole	Each	1	$4,829.80	$4,829.80
A-18	Land Acquisition - So. Jordan Canal	AC	0.8	$90,000.00	$75,621.90
A-19	Land Acquisition - Bluffs Apartment	AC	0.3	$90,000.00	$22,758.26
A-20	Land Acquisition - UDOT	AC	0.6	$90,000.00	$52,704.55
				Total	$584,356.93

The estimate for the preliminary design is roughly $584,000. This could increase with additional storm drain inlets and manholes along the roadway. One variable is the property acquisition from So. Jordan Canal, the Bluffs Apartments and UDOT. The price used for the estimate is $90,000, but the typical prices can range from $75,000-$150,000 per acre. This could greatly affect the cost of the project if the So. Jordan Canal, Bluffs Apartments, and UDOT charge the maximum price. If the price for the property is $150,000, the total cost increases to $685,000. Removal of the sidewalk and park strip will reduce the total cost to $505,000. If a retaining wall is needed, it could add another $180,000 to the project, assuming a unit price of $20 per square foot which may vary. A geotechnical analysis would need to be done to determine whether or not this is necessary.

Another aspect of the cost analysis is the long-term maintenance of the road. This would include snow removal in the winter and surface treatments in the coming years. The snow removal would be important because of the slope of the road. The largest longitudinal slope along the roadway is 5%. This slope of the road would allow the snowplows to access the road without any issues. Overall, the cost of snow removal would fall in with the existing snow

removal plan. Long-term maintenance would require the surface treatment every 7-10 years to keep the road in working condition. These costs would come from the pavement management program and would fall into the yearly scheduled road rehabilitation projects.

Of all the connection roads that could be constructed from Loumis Pkwy and Market St, this is the least expensive and least invasive option. The geometric design of the roadway provides a safe and reliable path of access.

Construction Feasibility

Considering the economic and environmental effects of this new roadway determines the overall feasibility of this design. The reduction of 1.1 acres of open space, which has landscaping, will have negative effects on the environment. Along with the reduction of open space, the construction of the roadway close to the canal would pose some problems with the possibility of pollutants running into the canal. With an average of 6-8 feet of distance from the sidewalk to the edge of the canal, this could be an issue for the stability of the retaining banks.

The two economic impacts are the increase of revenue generated by the shopping center by providing a quicker route and the lowering of property value in the apartment complex. A faster route will not affect the economic value that greatly. Loumis Parkway provides access to Redwood road and in turn, a connection to Marketview Dr. The route cutting through the property around the apartment complex reduces the time of travel by very little. The value of property allows better improvements to be built in the future, which in turn brings greater revenue.

Design Two

Many locations along the south side of the complex were evaluated for the second access road design. However, it was decided that the best design would be to realign and widen the existing service road. The reasoning behind this decision is further explained in the Designs Not Recommended section of the report found on page 24. The problem with the existing service road is that it does not provide enough sight distance for the vehicles trying to exit the apartment complex onto Loumis Pkwy. Redesigning this road would provide adequate sight distance for the curve and would fulfill the request of having a road connecting the apartment complex to Loumis Pkwy. Realigning the intersection also removes the critical hazard points that exist along the first curve of the service road by providing a better turn radius, entrance and exit paths, and facilities.

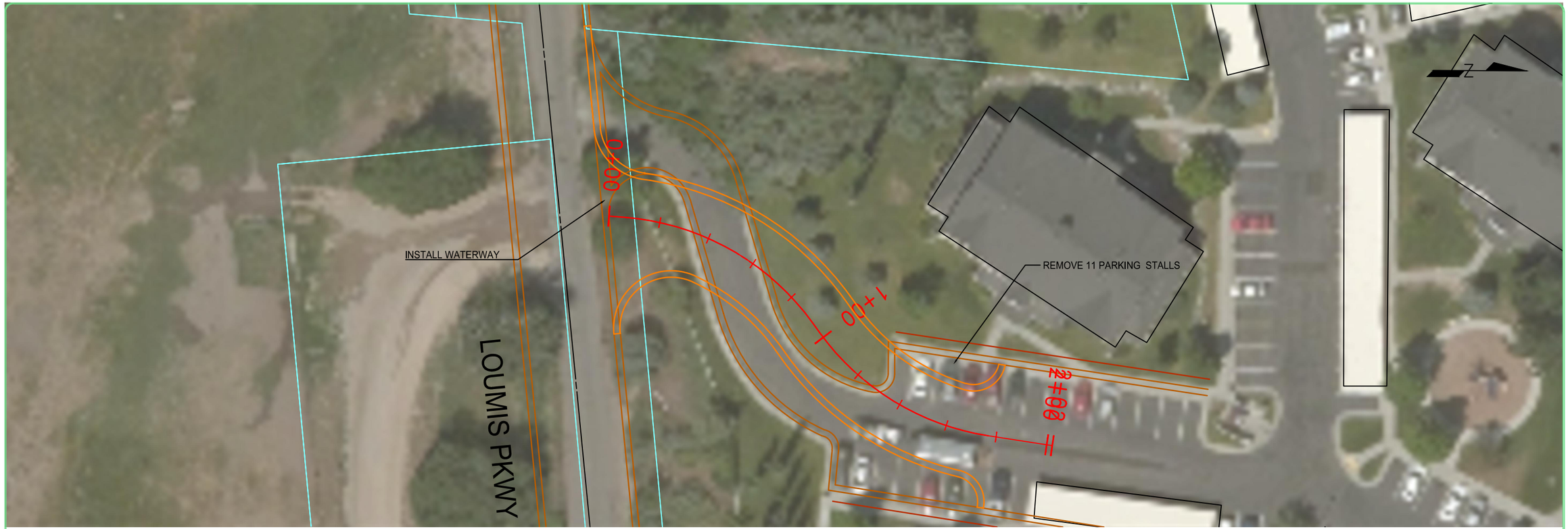
This road design is a private road, but will still adhere to the speed of the public road. Which means that the speed of this design would be 25 mph. The shortness of the intersection to the existing road could possible slow vehicles and provide a safer entrance. Of course this is speculation as the behavior of drivers can full be investigated and comprehended in this report.

One safety measure is to provide a W2-2 warning sign on the north side of the curve of Loumis Pkwy that warns drivers of a side road ahead. This will help warn traffic traveling south along Loumis Pkwy by creating awareness to help prevent potential crashes from happening.

The plan and profile sheet for design two are on sheet PP-2. The designed roadway provides access while minimizing the cost of a new road. The existing service road has provided an area that has an existing grade that is suitable for a new road along the hillside. This is the best location to build a new road because it reduces the least amount of excavation because the design roadway closely matches the existing topography. The proposed typical section for the roadway has 36 feet of right-of-way which does not include sidewalk and park strip. This length is quite a bit smaller than the Bluffdale Typical Section for a residential road, which is 52-55’ wide. The existing roadway widths within the apartment complex are approximately 20 feet. Providing a roadway into the apartment complex, the right-of-way design for this private road is 36 feet wide. The right-of-way does not include a park strip or sidewalk in order to provide wider travel lanes while minimizing the land used for construction. The corrected right-of-way and the realignment also provide better access for emergency vehicles with increased turned radii and wider pavement.

The roadway design has a maximum slope of 10.22%. The short nature of the road does not require the construction of a storm drain system, and the designed roadway drainage plan flows to the existing inlet boxes along Loumis Pkwy.

This roadway design includes the removal of 11 existing parking stalls. The location of the replacement parking stalls should be left to the discretion of the owner.



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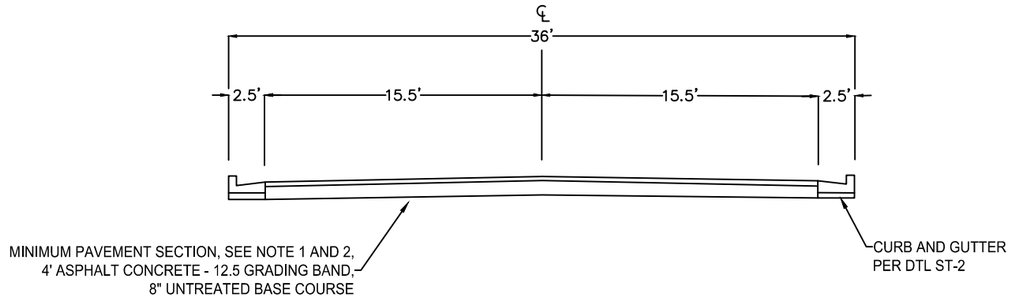
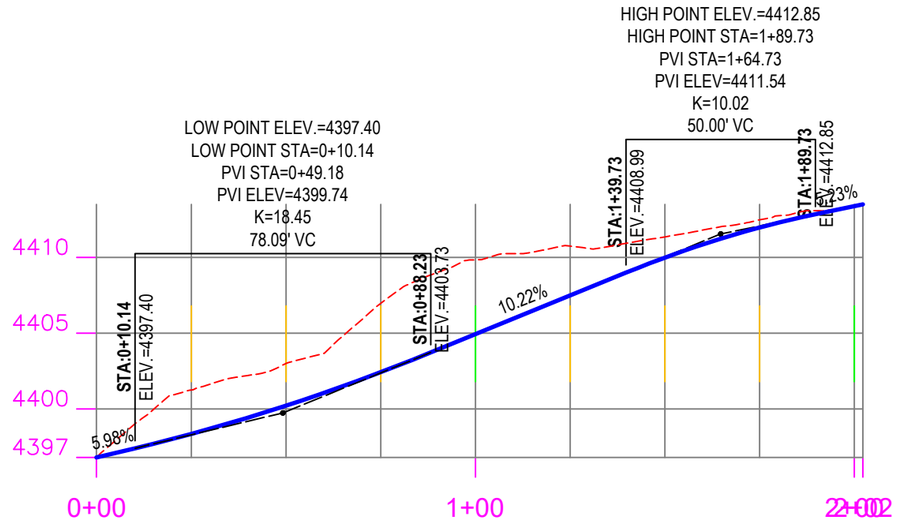


PRIVATE ROAD



SIC PARVIS MAGNA
GREATNESS FROM SMALL BEGINNINGS

REMARKS

1.

LOUMIS PKWAY
Jan 2017

Private Road One

Engineering File Number:
-

Drawing: PP-2
Sheet: 1 of 1

Cost Analysis

Table 9 includes a summary of construction costs of the private road, based on 2016 unit costs.

Table 9: Engineer's Estimate for Private Road One

B-1	Traffic Control	Lump	1	$29,000.00	$29,000.00
B-2	Mobilization and Demobilization	Lump	1	$29,000.00	$29,000.00
B-3	Remove Concrete Curb and Gutter	LF	462	$6.29	$2,905.98
B-5	Bituminous Concrete Pavement, PG 64-28	SF	6025	$2.80	$16,870.00
B-7	Untreated Base Course - Grade 3/4	Ton	305	$16.00	$4,884.27
B-8	Roadway Excavation	CY	916	$3.00	$2,747.40
B-9	Granular Borrow (Required Need)	Ton	872	$9.00	$7,852.32
B-10	6' Waterway - 9" Thick	LF	80	$43.00	$3,440.00
B-11	Concrete Curb and Gutter, Type E	LF	425	$24.00	$10,200.00
B-12	Landscape	SF	425	$2.25	$956.25
B-13	12" Crosswalk & Stop Bar Marking Paint	Foot	16	$1.05	$16.28
B-14	Pavement Marking Paint - White	Gallon	3.0	$21.00	$63.00
B-15	Land Acquisition - Bluffs Apartment	AC	0.1	$90,000.00	$13,016.53
				Total	$120,952.02

The estimate for the preliminary design of our second proposed roadway is roughly $128,000. This could increase with additional storm drain inlets and manholes along the roadway. As can be seen from comparing Table 8 to Table 9, the preliminary cost of design two is 31% of the first design. This is a large amount of money saved and would still provide the access requested by the residence. A downside, however, is that this option provides access to a private parking lot, which means that access will be determined by the owner of the property. Option 1 does not have this issue as it would be a public road.

Another aspect of the cost analysis is the long-term maintenance of the road. This would include snow removal in the winter and surface treatments in the coming years. The road is a private road, which means that the city would not oversee the maintenance and snow removal of the road. These costs would be at the expense of the owner of the apartment contract, which will save money for the city in the long term.

Overall, the costs of this road design are low for a new road, even though there is a substantial amount of money up front. Creating an access road at any other location will have large costs associated with it due to slope stability issues associated with deep excavations. The realignment of the roadway has the greatest benefits, saves the most money, and fulfills the request of the residents.

Designs Not Recommended

This section contains two designs suggested by the City of Bluffdale that were deemed either too expensive and/or not feasible. The previous designs mentioned in this report provide a better alternative to reduce total project cost and meet requested objectives. However, these two designs are worth mentioning to make the recommendation clearer.

The first of these suggestions is to build a road around the west of the apartment complex through the lot where the planned park is located. An approximate cost estimate for the park alternative is shown in Table 10.

Table 10: Engineer's Estimate for Park Road Alternative

C-1	Traffic Control	Lump	1	$46,000.00	$46,000.00
C-2	Mobilization and Demobilization	Lump	1	$46,000.00	$46,000.00
C-3	Bituminous Concrete Pavement, PG 64-28	SF	64600	$2.80	$180,880.00
C-4	Untreated Base Course - Grade 3/4	Ton	86	$16.00	$1,378.13
C-5	Roadway Excavation	CY	16279	$3.00	$48,837.60
C-6	Granular Borrow (Required Need)	Ton	8527	$9.00	$76,744.80
C-7	Concrete Curb and Gutter, Type E	LF	3400	$24.00	$81,600.00
C-8	Concrete Sidewalk, 4" Thick	SF	17000	$4.53	$77,010.00
C-9	6' Waterway - 9" Thick	LF	150	$43.00	$6,450.00
C-10	Cast Iron Detectable Warning Panel	SF	96	$70.00	$6,720.00
C-11	Landscape	SF	17122	$2.25	$38,523.38
C-12	12" Crosswalk & Stop Bar Marking Paint	Foot	66	$1.05	$69.30
C-13	Pavement Marking Paint - White	Gallon	9.0	$21.00	$189.00
C-14	Pavement Marking Paint - Yellow	Gallon	9.0	$21.00	$189.00
C-15	18 Inch - RCP Storm Drain, Class III	LF	1700.0	$38.00	$64,600.00
C-16	Single Catch Basin	Each	8.0	$1,594.80	$12,758.40
C-17	60 Inch Dia. Storm Drain Manhole	Each	4	$4,829.80	$19,319.20
C-18	Land Acquisition - So. Jordan Canal	AC	0.7	$90,000.00	$67,004.13
C-19	Land Acquisition - Bluffs Apartment	AC	0.3	$90,000.00	$25,657.02
C-20	Land Acquisition - Unnamed Canal	AC	0.1	$90,000.00	$11,838.84
C-21	Land Acquisition - Roundabout	AC	0.4	$90,000.00	$34,543.39
C-22	Land Acquisition - Other	AC	0.3	$90,000.00	$23,801.65
				Total	$870,113.85

This estimate does not include the cost for piping the two canals or the costs associated with bridge construction. The storm drain estimate is based on a 1700-foot-long pipe with an inlet box and an accompanying manhole every 400 feet. These prices are a preliminary estimate that will increase with other design issues. With this design, an approximate amount of 38,700 square feet will be removed from the park, which would diminish the park's appeal. This removal of land is a 16% reduction in space for the land owned by the city designated for the park.

Due to the high cost associated with construction, property acquisition, and maintenance, this design is not recommended. This road would be significantly longer, which would increase

material and construction costs. Additionally, at least two bridges or culverts would need to be constructed to cross the South Jordan Canal and a ditch that lines the boundary of the park property. The land required for acquisition would originate from at least three different sources, causing delays and possibly creating other problems associated with property acquisition. South Jordan Canal has regulations for piping and bridging the canal, which would need to be considered and investigated in the design. The maintenance of this road would require more time and money to ensure proper surface treatments and snow removal.

The second of these suggestions is the idea to construct a road at the southern end of the apartment complex, just to the east of the roundabout, as shown in Figure 6. This design removes several parking structures and parking spaces, which would need to be replaced elsewhere.

Figure 6: Southern Design Consideration

A larger problem with this design consideration, however, is the grade. Figure 7 shows a profile view of the design, which has an approximate 24-foot elevation change over a horizontal distance of 129 feet. The road would reach its steepest point at a 38% grade, which is not feasible for normal driving conditions, and would be dangerous in winter months due to icy conditions. This is made particularly precarious by the fact that this grade occurs right before an intersection, which would increase stopping distance. Additionally, 10 feet of soil excavation would occur at its maximum point, which would be expensive relative to Option 2.

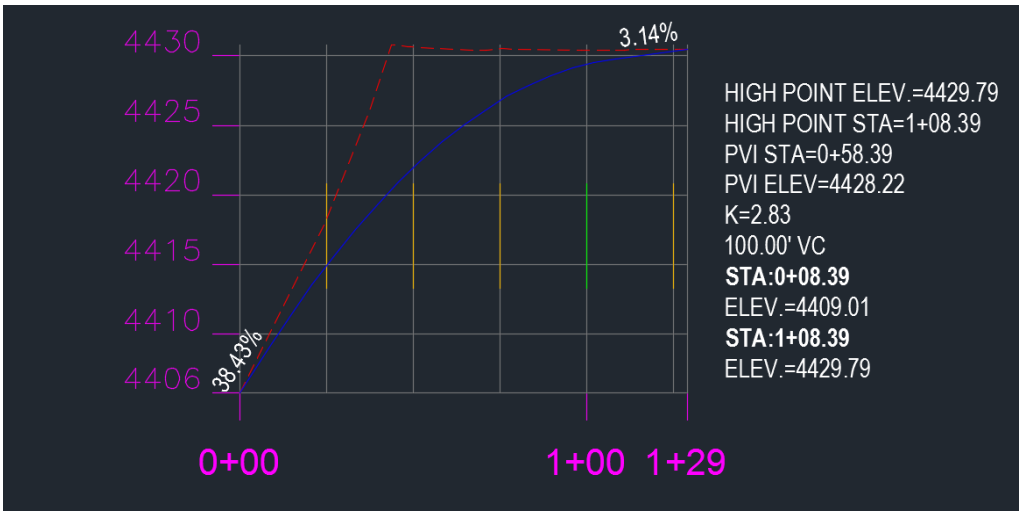


Figure 7: Southern Design Consideration Profile View

Additionally, the road would be constructed in close proximity to the existing apartment buildings. With the amount of soil excavation required, retaining walls or other slope stability measures to prevent foundational damage would need to be implemented. These mitigations and safety measures could pose very expensive studies and construction costs.

Recommendations

The purpose of this project is to evaluate and recommend a design for an access road connecting the existing Bluffs Apartments to Loumis Parkway in Bluffdale, Utah to be considered at a later date. The residents of the apartment complex have requested a second access road to the apartment complex. The city has requested a design of a connector road from Loumis Pkwy and Marketview Dr. The new roadway design allows the residents to enter the apartment complex from Loumis Pkwy.

Through the duration of the analysis and design process, it has been decided that Design Two is the optimal design. Three reasons why this design is the optimal design are its low cost relative to other alignments, feasibility, and that it meets the needs of the residents. The request for this new roadway originated from the residents of the apartment complex, which is why this design has greater appeal as it provides a quick access point from Loumis Pkwy.

Compared to the other cost estimates done for this report, the cost of Option 2 is a fraction of the cost associated with the other designs. Option 2 costs $120,000, while Option 1 costs $584,000. For this reason, and the fact that it meets the basic requirements, Option 2 is the recommended design.

References

American Association of State Highway and Transportation Officials (2011). *A policy on Geometric Design of Highways and Streets,* 6th Ed.

Google Earth (2016). *Google, Inc.*

Federal Highway Administration (2009). *Manual on Uniform Traffic Control Devices*, Rev. 1 and 2.

Utah Vehicle Collisions (2017), UDOT, crashmapping.utah.gov

Appendix A

David Michelsen

dpmichelsen@gmail.com • 801-360-0313 • 909 E 700 N Provo, Utah 84606

Education & Certifications

Engineer in Training

December 2016

FE Civil Engineering - Passed

Bachelor of Civil Engineering — April 2017

Brigham Young University - GPA 3.22

Professional Experience

EIT Civil Department — April 2017 – Present

LEI Consulting, Spanish Fork

- Preliminary and Final Plan Review
- SWPP Plan creation

Engineering Drafter Intern — January 2017 – April 2017

Perigee Consulting, West Jordan

- Site design tasks for commercial and residential land development.
- Design of sites, roads, and utilities.
- Create plan and profile sheets.

Civil Engineering Student Intern — May 20 15 - January 2017

Engineering Division, Provo City

- Designed existing road improvements, curb and gutter, and pipe layout,
- Prepared quantity estimates, traffic control plans, work orders, bond estimates, bid documents, bid specification documents, and plan/profile sheets.
- Carried out speed studies, traffic counts, and pedestrian counts.
- Oversaw the planning of the $150,000 2016 Sidewalk Replacement Project

SWPPP Inspector/Civil Engineering Intern — Dec 2014 - May 2015

Engineering Department, Spanish Fork City

- Approved SWPP Plans submitted
- Enforced SWPP Plans submitted for new development
- Inspected all active construction sites for compliance
- Designed SWPPP Best Management Practices Standards for Spanish Fork.

Voluntary Service Leader

Full Time Volunteer

The Church of Jesus Christ of Latter-day Saints, Eugene, Oregon — Jul 2012 - Jun 2014

- Led a group of 20-24 volunteers, conducted weekly training meetings, followed up on goals, and sent weekly progress reports to the service leader.
- Increased volunteer effectiveness by providing training in individual communication, problem solving, organization, and working strategy skills.

Skills

- AutoCAD Civil 3D – surfaces, alignments, assemblies, corridors, profiles view, and pipe network.
- Autodesk Design Review – quantity take off sheets.
- Synchro, HCS 2010, Kenlayer, Winpass
- Microsoft Office

Joseph Browning

737 N 600 E Apt. 101
Provo, UT 84606
801-821-3198
jbrowning789@gmail.com

Education

- Brigham Young University
  - Major: Civil Engineering
  - Expected Graduation: December 2017
  - GPA: 3.7
  - Applicable Courses:
    - CEEn 361: Introduction to Transportation Engineering
    - CEEn 270: Computational Methods
    - CEEn 562: Traffic Engineering: Characteristics and Operations

Work Experience

- Research Assistant – Brigham Young University
  - June 2015 – December 2015
  - Collected bicycle research data at 15+ locations throughout the state of Utah to determine the effectiveness of existing bicycle infrastructure
  - Proofread reports to UDOT for spelling and grammatical errors
  - Wrote a computer program to ensure 400+ data points had been transferred correctly between Excel spreadsheets
- Research Assistant – Brigham Young University
  - September 2016 – Present
  - Designed a complex intersection including on and off-ramps as a guide for an upcoming class
  - Calibrated 200+ highway curve segments from a computer program developed to identify horizontal curves to determine accuracy
- Teaching Assistant – Brigham Young University
  - January 2017 – Present
  - Aided 30+ students in developing skills for use in Civil 3D software
- Full-Time Missionary – The Church of Jesus Christ of Latter-Day Saints
  - July 2012 – July 2014
  - Tacoma, WA
  - Organized missionary efforts in various cities throughout Western Washington

Skills

- AutoCAD
- ArcMap
- Excel VBA
- Civil 3D

Jordan Arrowchis
737 N 600 E Apt #101, Provo, UT 84606 [residence]
(949) 878-0726, JordanArrowchis@gmail.com

Career Objective

To obtain a position as a Civil Engineer, specializing in the field of transportation.

Work History

Brick Oven Pizza, Provo, UT — July 2016 to Sept 2016

- **Pizza Delivery Driver**
  - Managed all phone calls received by the restaurant and provided timely support.
  - Helped around the restaurant during slow times to positions that were in need of assistance.

DealerSocket, Provo, UT — July 2015 to Jan 2016

- **Hands On Lab Trainer**
  - Conducted daily online training classes to all customers using Dealer Socket's marketing software.
  - Helped establish and make correction to the scripts followed when teaching each specific class.

iPayables, Orem, UT — June 2014 to Jan 2015

- **Data Entry**
  - Provided invoice processing for all clients.
  - Prepared, compiled, and sorted documents for data entry; used scanning equipment for imaging; entered invoice data using in-house software system; reviewed documents for accuracy and made adjustments.

BYU Creamery on the 9th, Provo, UT — Jan 2014 to May 2014

- **Stock Clerk**
  - Worked part time early-morning shift to stock dairy, grocery, and cafeteria locations.
  - Provided janitorial services as needed prior to store opening.

Church of Jesus Christ of Latter-Day Saints, Pocatello, ID — Jan 2012 to Dec 2013

- **Volunteer Missionary**
  - Served full time as church representative planning, teaching, training, and supervising up to 10 other volunteers.

Professional Community Management, Laguna Woods, CA — May 2011 to Dec 2011

- **Clubhouse Aide**
  - Worked 24-36 hours per week preparing events at a retirement community with 18,000 residents.
  - Responsible for opening or closing clubhouse facility, setting up tables and chairs for events including sound equipment, helping residents plan event layouts.

Education

Brigham Young University, Provo, UT

- Expected Graduation 2017, Civil Engineering Major

Aliso Niguel High School, Aliso Viejo, CA

- Graduated 2010, Valedictorian GPA: 4.2

Extracurricular Activities

Eagle Scout, Marching Band, Volleyball Team, Tennis

Computer Skills

Excel, PowerPoint, Basic Programming in C++ and VBA, Revit, AutoCad, ArcGIS, HydroDesktop