NAU NORTHERN ARIZONA UNIVERSITY

Final Design Report
Duncan, Arizona Floodplain Analysis- Highway and Levee Alignment Alternatives
CENE 486C: Capstone

NORTHERN
ARIZONA
UNIVERSITY

College of Engineering,
Informatics, and
Applied Sciences

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Acknowledgements

The team would like to thank our client Phil Ronnerud for the opportunity to work on this project and to help the town of Duncan with a critical problem they are having.

Also, we would like to thank the three previous teams that came before us on this massive project. Without their data, graphs, and analysis we would not had been able to move forward so successfully.

The team would also like to thank our technical advisor Brendan Russo for his dedication of being available to us, helping us, giving us different challenges on transportation designs.

Lastly, our grader, Mark Lamer has been a wonderful support and a person who clarifies things for the team.

1 Project Introduction

The 'Duncan, Arizona Highway and Levee Alignment Alternatives' project consisted of a virtual field investigation, determination of traffic conditions, preliminary data analysis, alignment design alternatives, possible intersection connections, cost assessment, and final design recommendation. Also, the cost of implementation of the final design, summary of engineering work, summary of engineering cost, and appendices showing the work completed.

The team will be designing a highway to overlay a levee to stop flooding in Duncan, AZ. In addition to the highway, the team will be raising any current intersections to meet the height of the highway. The highway will need to be designed at 8.5 feet to stop flooding, but the alternatives will be evaluated at different heights. The highways horizontal and vertical alignments and curvature will be determined using AASHTO standards. Although the team will not be designing the levee, its proposed dimensions will be included in the design. Another possible consideration would be riprap to increase the longevity of the levee. [1]

The designs will follow standards from Arizona Department of Transportation Roadway Design Guidelines [2], American Association of State Highway and Transportation (AASHTO) [3], AASHTO Green Book [4], and Highway Capacity Manual (HCM) [5].

AASHTO is a set of standards used in all highway design and construction throughout the United States. [3] AASHTO Green Book is a policy on geometric design of highways and streets [4]. HCM is a manual for engineers and planners use to assess the traffic of highway projects [2]. A redesign for the designed 25/50/100-year storm levee will be included for cost considerations.

Over the past couple years, the issue of flooding has been analyzed by previous Capstone teams. Their analysis has included modeling of the floodplain using HEC-RAS and Flow-2d. They also presented with different alternatives to prevent flooding and their corresponding cost estimations. Regarding the highway alignment, our team will be incorporating the previous data in our design to ensure the levee meets the height requirements to stop flooding.

1.1 Project Location

Duncan, Arizona located about 300 miles South East of Flagstaff has experienced flooding due to heavy precipitation in the past. This ends up slowing down both the town's economy and traffic. Duncan is located in a floodplain, making it vulnerable to rain upstream. The purpose of the project is to develop a highway that will be on top of a levee. The team's design will include multiple highway alignments for US Highway 70. For this project, the team will only be designing an elevated highway at the design height of a proposed levee. The addition of a levee would restrict the river from flowing into town during times of heavy precipitation. By utilizing the levee as a highway there would be reduced traffic flow along the main street, Railroad Ave. Federal funding would also be used for the highway design.

Figure 1: Project location: Duncan, Arizona [6]

Figure 2: Gila River with in Duncan, Arizona [6]

Figure 3: Current dikes in place. [8]

Figure 4: Location of the current agricultural dike along the Gila River. [8]

2 Existing Conditions

The team virtually visited Duncan, Arizona to analyzes any possible interference with the project to complete the site investigation.

2.1 Virtual Site Investigation

A walkthrough of the site where the team will be designing an all new levee and highway. A visual inspection of the site provides information about nearby issues which may occur such as large trees, boulders and some utility lines which will be required to take note of. The client will also provide information, as well such as their ideal location of the new roadway.

2.2 Traffic Analysis

Average Annual Daily Traffic (AADT) from the Arizona Department of Transportation (ADOT) on US 70 thru the town of Duncan was 2,184 vehicles [Appendix B]. The future AADT will be 2,925[Appendix B]. The AADT for SR 75 that connects to US 70 thru the town of Duncan was 2,792[Appendix B]. The future AADT will be 3,514 [Appendix B]. The team will be using the future AADT when designing the new highway. The team will utilize this data to determine the interacting between drivers and design for the optimal highway design. All information will be analyzed to determine the highways Traffic Characteristics such as Daily Hour Volume (DHV), Projected Traffic Volumes and Service Flow Rates.

2.2.1 Crash Data Analysis

The team analyzed the Crash Data from both ADOT and Dr. Russo in depth data that was given to him from ADOT. For Greenlee County, there was a total of 84 crash in 2017; 3 crashes were specifically in the town of Duncan [Appendix C]. Since 2010, there have been 4 or less crashes in Duncan [Appendix C]. Analyzing the Crash Data will ensure there will not be any interference with design alternatives based on Crashes in the county. In 2017, there were three crashes in the town of Duncan. One was fatal, one resulted in an injury, and one was property damage only. In these crashes, one crash which resulted in death, was alcohol related.

Due to the crash data it was determined that due to such a minimal amount of crashes, there will not be any interference with any intersection recommendation and the new highway designs. A Crash Modification Factor will not be needed to create safer designs.

2.3 Traffic Conditions

Traffic conditions were assessed using highway analysis software. This will provide the team the geometric designs of the highway, intersection, and roadway width.

2.3.1 Traffic Characteristics

The team used information gathered from Arizona Department of Transportation (ADOT), AASHTO, and the Highway Capacity Manual (HCM) guidelines for the work and results in Appendix D. For the analysis, a design speed of 60 mph was used for a two-lane highway for trucks and passenger cars. The dimensions of the road will be 12-foot lanes with a 6-foot shoulder on either side. Due to the road being at an elevation of 8.5 feet, the side slopes of the highway would be 4 Horizontal: 1 Vertical.

2.3.2 Highway Capacity Software (HCS)

The team used Highway Capacity Software (HCS) to perform an analysis for Level of Service (LOS) and to see if the design speed of 60mph for a 20-year life span was met. The information for inputs were computed and/or gathered from the Highway Capacity Manual (HCM) and AASHTO. The results and data used in the HCS are located in Appendix E.

Alternative 1 for raising the current highway results received from inputting data shows this alternative produces a Level of Service (LOS) of A, volume to capacity ratio (v/c) of 0.04, two-way flow rate of 121 vehicles per hour, and meets the design speed of 60mph. (Figure 32)

Alternative 2 for running along agricultural dike results received from inputting data shows this alternative produces a Level of Service (LOS) of A, volume to capacity ratio (v/c) of 0.04, two-way flow rate of 121 vehicles per hour, and meets the design speed of 60mph. (Figure 33)

Alternative 3 for running parallel to railroad on agricultural land results received from inputting data shows this alternative produces a Level of Service (LOS) of A, volume to capacity ratio (v/c) of 0.04, two-way flow rate of 121 vehicles per hour, and meets the design speed of 60mph. (Figure 34)

2.4 Preliminary Data

The design will be based on the AASHTO Greenbook, Arizona Design Standards, and the Highway Capacity Manual. This data will be used to outline the criteria of the new roadway.

2.4.1 Existing Feature Limitations

As part of the design, the team will be considering the existing feature limitations. This will include the homes and businesses that will be affected by our design alternatives, and the railroad that runs parallel to the existing highway. Depending on the alternative, there will be the acquisition of agricultural land, the possibility of connecting intersections, and crossings with overhead power lines.

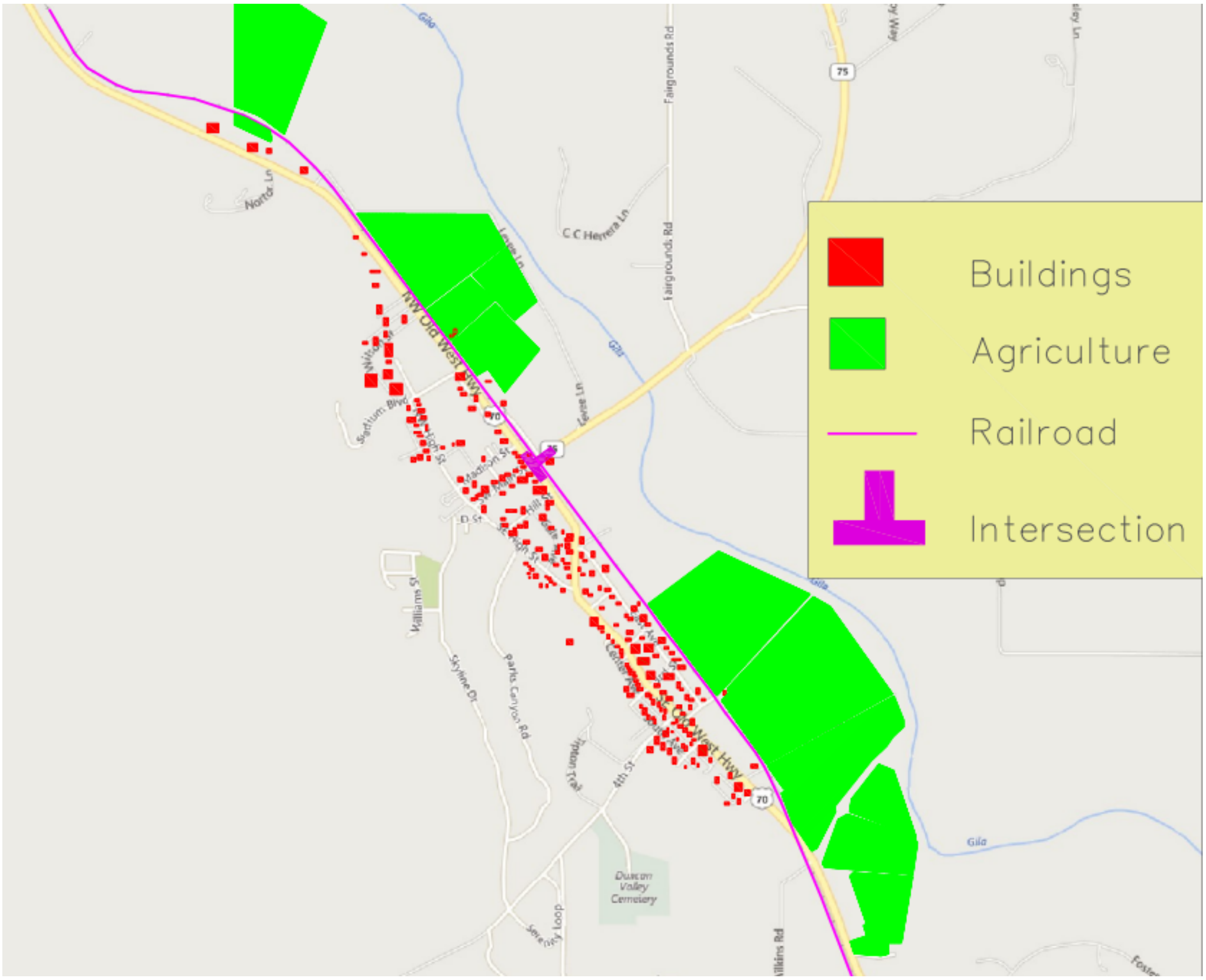


Figure 5: Map of Duncan, AZ Existing Features

2.4.2 Civil 3D Surface Creation

Using the LiDAR the previous Capstone Team collected and in-putting it into Civil-3D to create a surface elevation in order to determine the possible elevation of the roadways.

2.4.3 Schematic for Horizontal Alignment Alternatives

Using the Roadway Design Guidelines and Highway Capacity Manual, the team calculated the necessary corridor size. The following figure below shows the total average width of the corridor to be 99 feet.

Corridor Design	
Turning Lane (12’)	12 feet
Slope (2 sides)	51 feet
Lane Width (2 lanes)	24 feet
Shoulder Width (6’ each side)	12 feet
Total Average Width	99 feet

Figure 6: Corridor Design Options for the different Alternatives

Figure 7 below shows the typical cross section of the levee design. This includes a minimum 10 feet of right-of-way clearance for the sides slopes based on the ADOT guidelines. The slopes of the levee are 4 Horizontal: 1 Vertical. A super-elevation is necessary, but it is incredibly small. This is necessary in order to provide relief from rain. Using the Roadway Design Guidelines it was determined that guardrails are necessary on Alternatives 1 and 2.

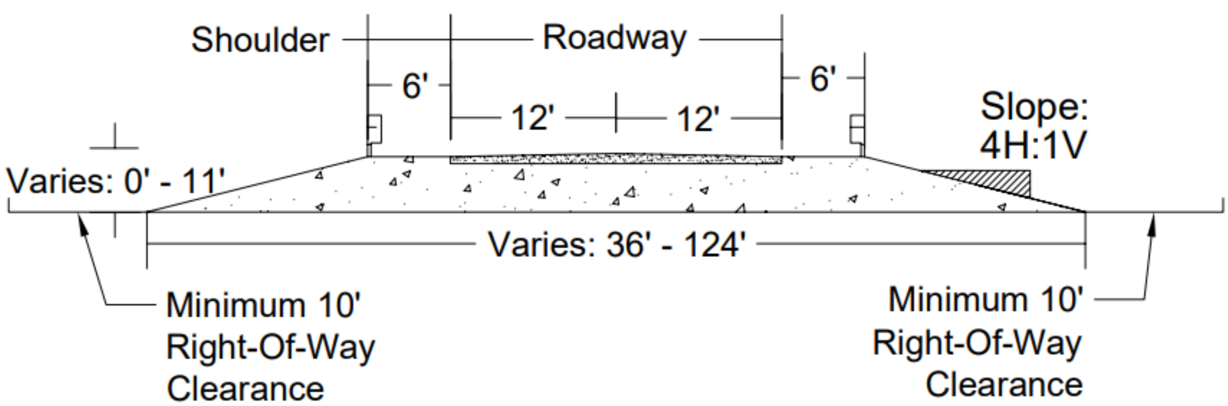


Figure 7: Typical Cross Section of the Levee Design

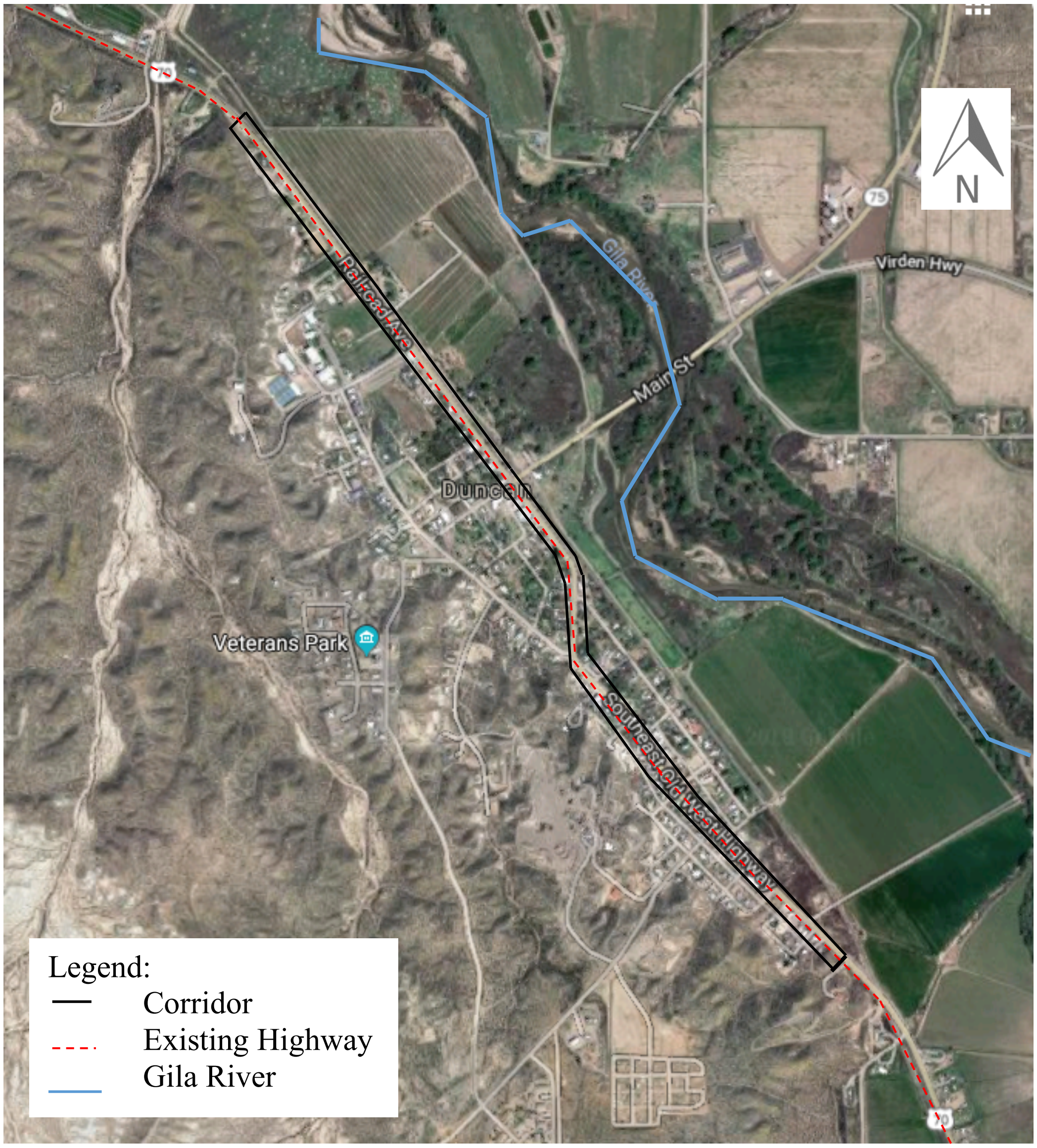


Figure 8: Schematic for Horizontal Alignment Option 1

Alignment Option 1 is raising the current highway, which is US 70, called Railroad Ave. and Southeast Old West Highway. The total width of the corridor is 99 feet at maximum height of 8.5 feet. The corridor design of Alternative 1 would not have any walls to reduce the base width. The slopes would be 1V:4H, which adds the additional 25.5 feet to each side of the elevated highway. With this design, there would be 22 homes that would need to be removed [6]. The Level of Service of Alignment 1 is an A, as shown in Figure 8. There are three access points, a design speed of 60 mph, and a design vehicle of an Interstate Semitrailer with a length of 73.5 feet. The footprint of the alignment would be approximately 925,016 square yards.

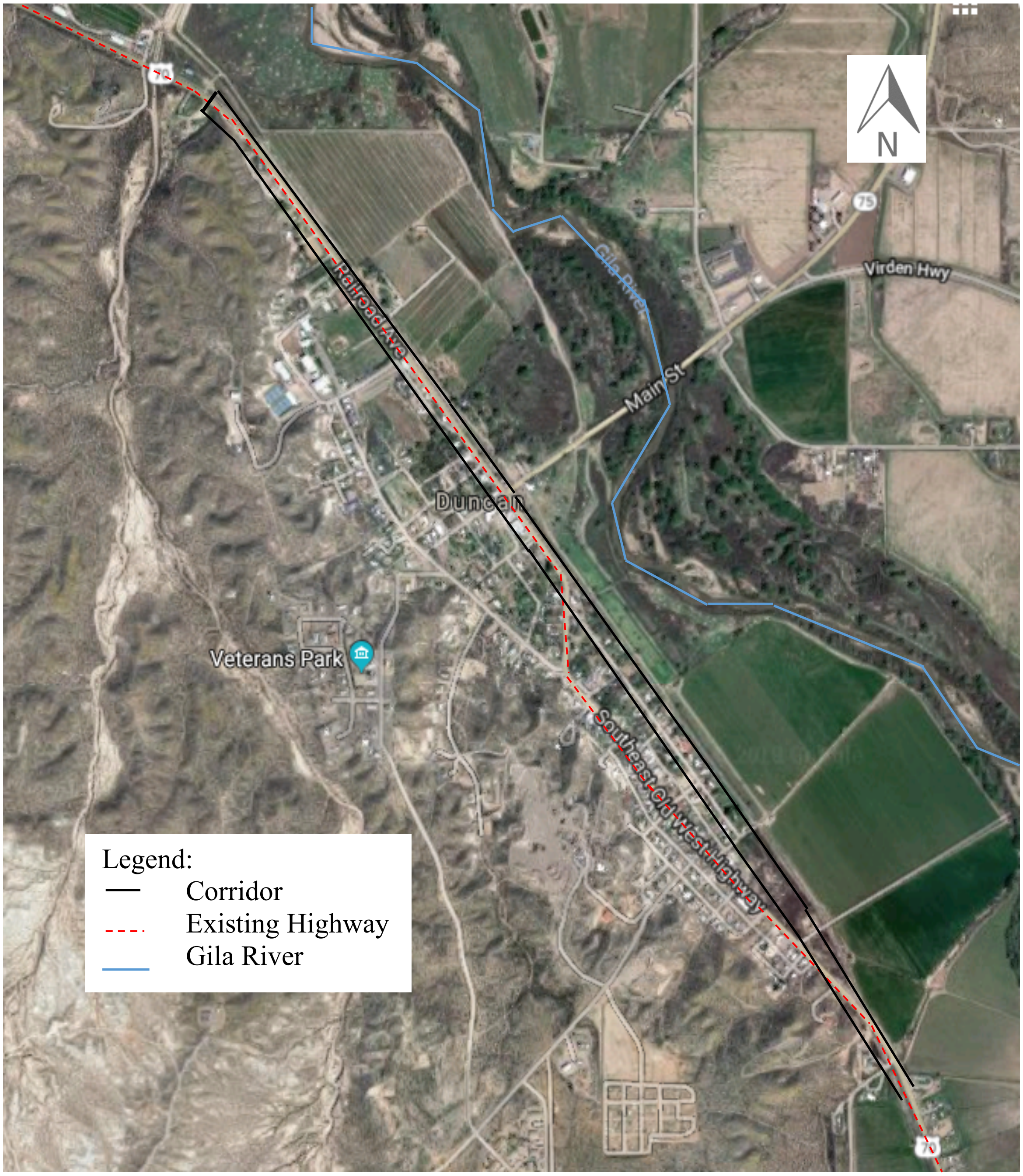


Figure 9: Schematic for Horizontal Alignment Option 2

Alignment Option 2 will be running parallel to the current agricultural dikes on the West side of the railroad. The design will have no walls, therefore, have a 99 foot wide base with slopes of 4H:1V. There will be 41 homes which intersect with the alignment and will have to be removed. The Level of Service will remain an A. The design speed is 60 mph and a design vehicle is an interstate semitrailer with a length of 73.5 feet long. The footprint is 1,078,239 square yards.

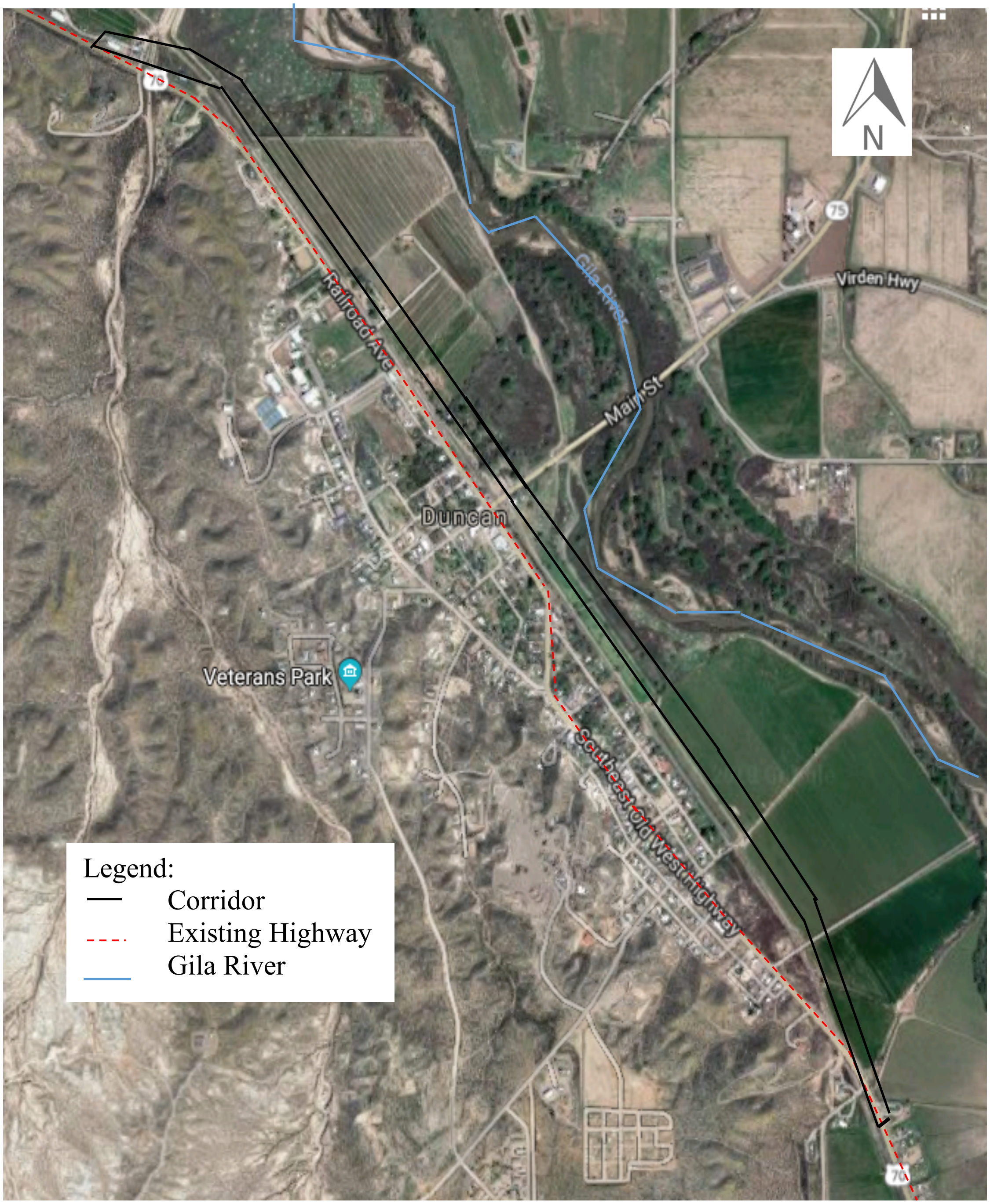


Figure 10: Schematic for Horizontal Alignment Option 3

Alignment Option 3 would run the highway along the railroad and have 2 additional railroad crossings. The total corridor width will be 71.5 feet at maximum height. The corridor will have a max corridor width of 124 feet and have a max height of 11 feet. Both sides of the alignment will be sloped at a 4H: 1V. The Level of Service will remain an A and have a design speed of 60 mph and a design vehicle of an Interstate Semitrailer with a length of 73.5 feet long. The overall footprint of the alignment will be approximately 1,197,437 square yards.

3 Alignment Design Alternatives

3.1 Alternative Design 1- Raising Current Highway

Alternative 1 was designed to follow the current Highway 70 alignment. This alternative was requested by the client. This alternative will not cross the railroad and it does not connect with SR75. This alternative still always some homes to become flooded.

3.1.1 Horizontal Alignment

Figure 11: Alignment Option 1- Horizontal Alignment

Figure 11 shows the horizontal alignment of Option 1. It is approximately 1.3 miles long. It required 1,300 cubic yards of cut material and 85,300 cubic yards of fill material. This alignment alternative also requires the removal of 22 homes.

3.1.2 Vertical Alignment

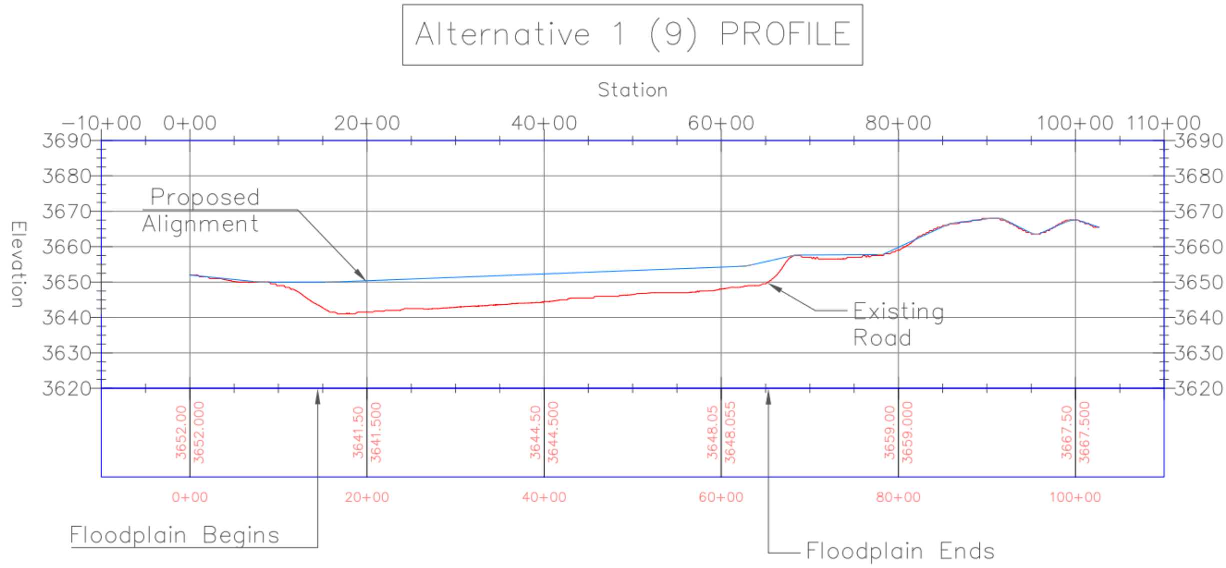


Figure 12: Alignment Option 1- Vertical Alignment

Figure 12 shows the Vertical alignment of Option 1. The maximum existing elevation of 3669 feet. The minimum existing elevation of 3641 feet. The levee elevation runs from 3650-3655 feet.

3.1.3 Property Investigation

For the first alignment, it was determined that 22 homes would be affected by this design. For the analysis it was assumed full takeover of the properties, assuming most townspeople would not want to give up half of their home. This alignment does not require as many homes to be removed due to it meeting grade after the first curve in the existing highway.

3.2 Alternative Design 2- Running Along Agricultural Dike

Alternative 2 was designed to follow the agricultural dike next to the railroad and then meet up with current Highway 70 alignment. This alternative will not cross the railroad and it does not connect with SR75.

3.2.1 Horizontal Alignment

Figure 13: Alignment Option 2- Horizontal Alignment

Figure 13 shows the horizontal alignment of Option 2. It is approximately 1.91 miles long. It required 4,500 cubic yards of cut material and 138,000 cubic yards of fill material. This alignment alternative also requires the removal of 41 homes.

3.2.2 Vertical Alignment

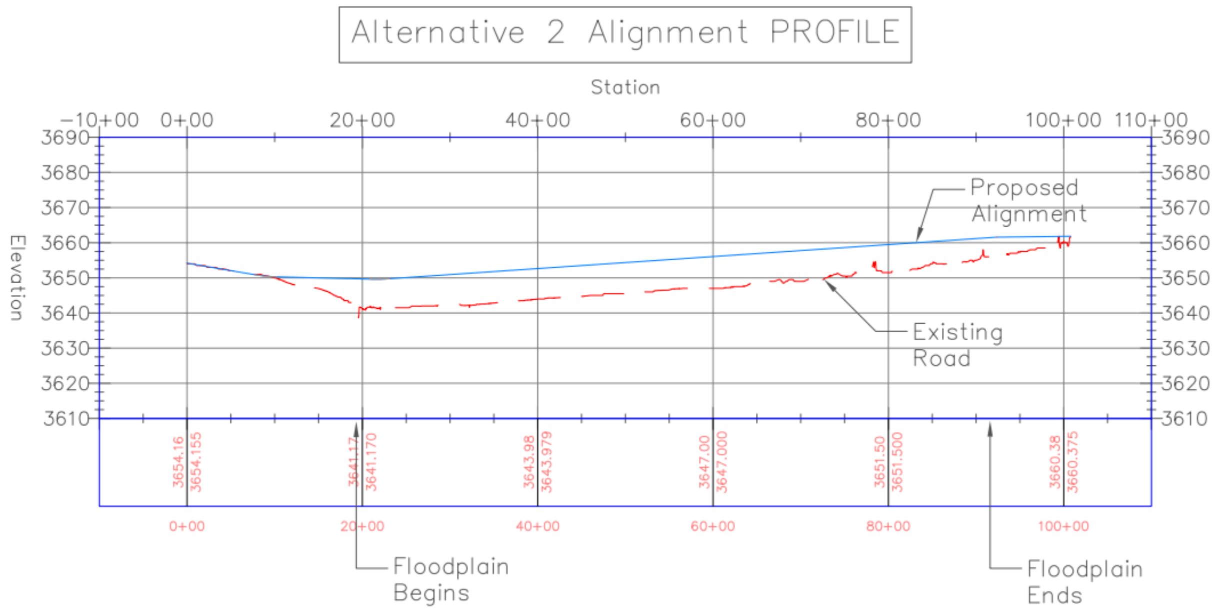


Figure 14: Alignment Option 2- Vertical Alignment

Figure 14 shows the vertical alignment of Option 2. The maximum existing elevation is 3661 feet. The minimum existing elevation is 3641 feet. The levee elevation runs from 3650-3661 feet.

3.2.3 Property Investigation

For the second alignment, the team also assumed total takeover of property which totaled 41 homes. This alignment requires the takeover of significantly more homes due to the fact that it runs along 4th Avenue and does not meet grade until after passing through all of the homes.

3.3 Alternative Design 3- Running Parallel to Railroad on Agricultural Land

Alternative 3 was designed to run parallel to the railroad on agricultural land. This alternative will cross the intersection at the end. This alternative will meet, to create an intersection connection with SR75.

3.3.1 Horizontal Alignment

Figure 15: Alignment Option 3- Horizontal Alignment

Figure 15 shows the horizontal alignment of Option 3. It is approximately 2.12 miles long. It required 1,300 cubic yards of cut material and 171,000 cubic yards of fill material. This alignment alternative also requires the takeover of approximately 26 acres of land. It does not destroy any homes, but it does create only two ways from the highway to access the town. At the top of the alignment there is a sharp turn where the speed will drop down to 20 mph and it has a radius of 176 degrees [5].

3.3.2 Vertical Alignment

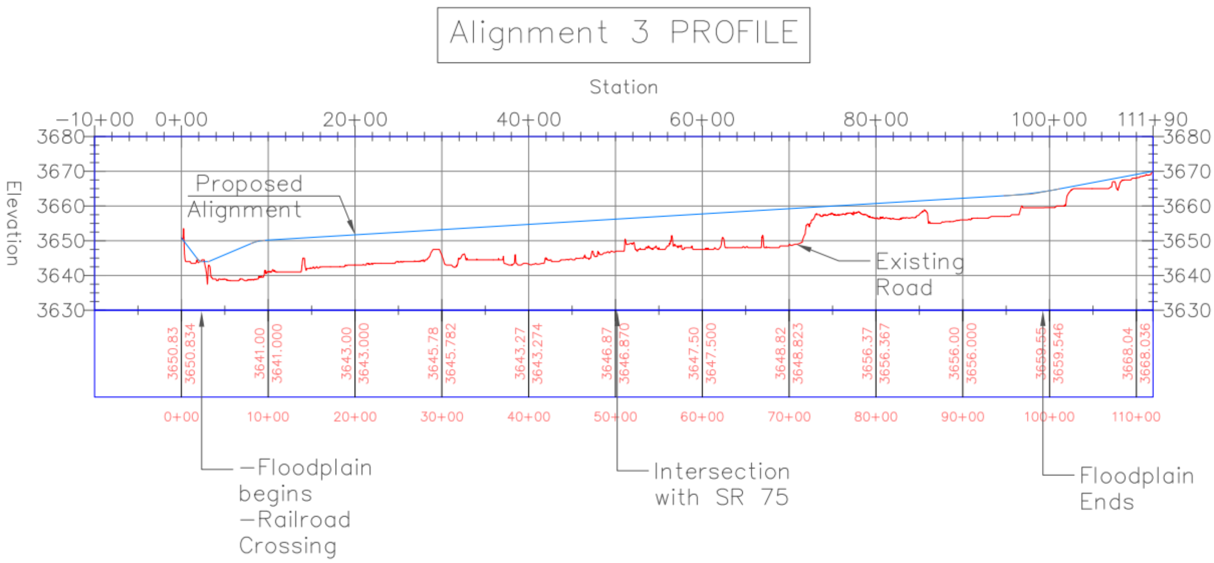


Figure 16: Alignment Option 3- Vertical Alignment

Figure 16 shows the vertical alignment of Option 3. The maximum existing elevation is 3670 feet. The minimum existing elevation is 3638 feet. The levee elevation runs from 3650-3670 feet. The intersection elevation occurs at 3655.7 feet.

3.3.3 Property Investigation

Alignment three will require the least amount of land to be acquired. This alignment will utilize approximately 26 acres of agricultural land and none of the homes will be affected. This alternative will also increase accessibility by including an intersection connection with SR75.

4 Intersections

The intersection of SR75 and US70 will possibly need to be redesigned in the future to improve traffic flow and take the railroad crossing into account without redesign the crossing. An additional turning lane will need to be added with alignment Option 3 in order to go US70 to SR75.

4.1 Intersection Impact Analysis

A future team will need to utilize the Highway Capacity Software to determine the best fit intersection for US70 and SR75. All criteria must be met for ADOT and AASHTO Greenbook. The redesigned intersection must improve traffic flow and potentially include the railroad crossing.

4.2 Intersection Recommendations

After the intersection have been analyzed, recommendation will be based on the safety, cost, and improved traffic flow. If there is no new design, improvements to signage and traffic signals may be recommended to improve traffic flow.

5 Cost of Implementation

The team determined the overall cost of the new alignment designs, which will encompass the land values, material, and labor costs.

5.1 Land Value Assessment

For the land value assessment, the team used Zillow to determine the value of homes that will be affected by each alignment alternative which ranged from $1,400 to $193,000. The total value and number of home affected is shown below in Figures 17 and 18.

	Cost
Range of Housing Cost	$1,400-193,000
Cost Per Acre of Agricultural Land	$13,000

Figure 17: Land Value Assessment Individual Costs

Design Alternative	Cost Per Unit	Total Cost
Alternative 1: Along Existing Highway	22 Homes	$1,430,400
Alternative 2: Along Agricultural Dike	41 Homes	$2,416,400
Alternative 3: Along Agricultural Land	Approximately 26 Acres of Land	$338,000

Figure 18: Land Value Assessment Individual Costs

5.2 Quantity Take-Off

For the quantity take-off the values listed in Figure 19, below was gathered from Mark Lamer. The current cost for cut was reported to by $9 per cubic yard and engineered fill cost $18 per cubic yard. The levee cost was determined to be an estimated $1,922 per linear foot from. This number was generated using an estimated rate of increase. These costs and design values are shown in Figures 19 and 20 with the total cost for each alternative shown in Figure 21.

	Cost
Cut	$9 / Cubic Yard
Fill	$18/ Cubic Yard
Levee	$1,922/ Linear Foot

Figure 19: Design Individual Costs

	Cut (yd^3)	Fill (yd^3)	Levee Length (ft)
Alternative #1	1,229	85,293	6,800
Alternative #2	4,450	138,257	10,077
Alternative #3	1,240	170,939	11,190

Figure 20: Design Parameters

	Material Cut Cost	Material Fill Cost	Levee Length Cost
Alternative #1	$11,054	$1,535,261	$13,069,600
Alternative #2	$40,042	$2,488,615	$19,367,885
Alternative #3	$11,159	$3,076,893	$21,507,665

Figure 21: Total cost from the quantities take off

5.3 Alternatives Total Cost

To determine the total cost for each alternative, the cost of cut and fill was added to the Land Value assessment and cost to build a levee. Due to these values being an estimate, the team added a 20% increase to each cost for a more realistic value. The breakdown of these costs is shown in Figure 22 below.

	Alignment #1	Alignment #2	Alignment #3
Material Cut Cost	$11, 054	$40,042	$11,159
Material Fill Cost	$1,535,261	$2,488,615	$3,076,893
Land Value	$1,430,400	$2,416,400	$338,000
Levee Length Cost	$13,069,600	$19,367,885	$21,507,655
20-Year Maintenance Cost	$1,166,638	$1,145,109	$1,271,619
20% Feasibility Blow-Up	$17,210,315	$25,458,049	$26,205,326
Total Cost	**$20,650,000**	**$30,550,000**	**$31,500,000**

Figure 22: Alternatives Total Cost

6 Final Summary Table

The team decided that due to the drastic measures that will need to be implemented on the town, it would be best suited to let the client and townspeople decide what alignment option would utilized. Figure 23 below shows the total cost, whether agricultural land will be taken or not, the property taken in acres, the number of houses that would need to be removed in order to build the alignments, and how many property owners would be affected from the alignment options. Lastly, the table includes whether the town would be divided because of the implementation of the highway project.

Value	Alignment #1	Alignment #2	Alignment #3
Total Cost	$20,650,000	$30,550,000	$31,500,000
Agricultural Land	N/A	N/A	N/A
Property Taken (Acres)	23.6	23.2	25.7
Houses Taken	22	41	N/A
Properties Taken	30	51	30
Divides the City	Yes	Yes	No

Figure 23: Final Summary Table

7 Summary of Engineering Work

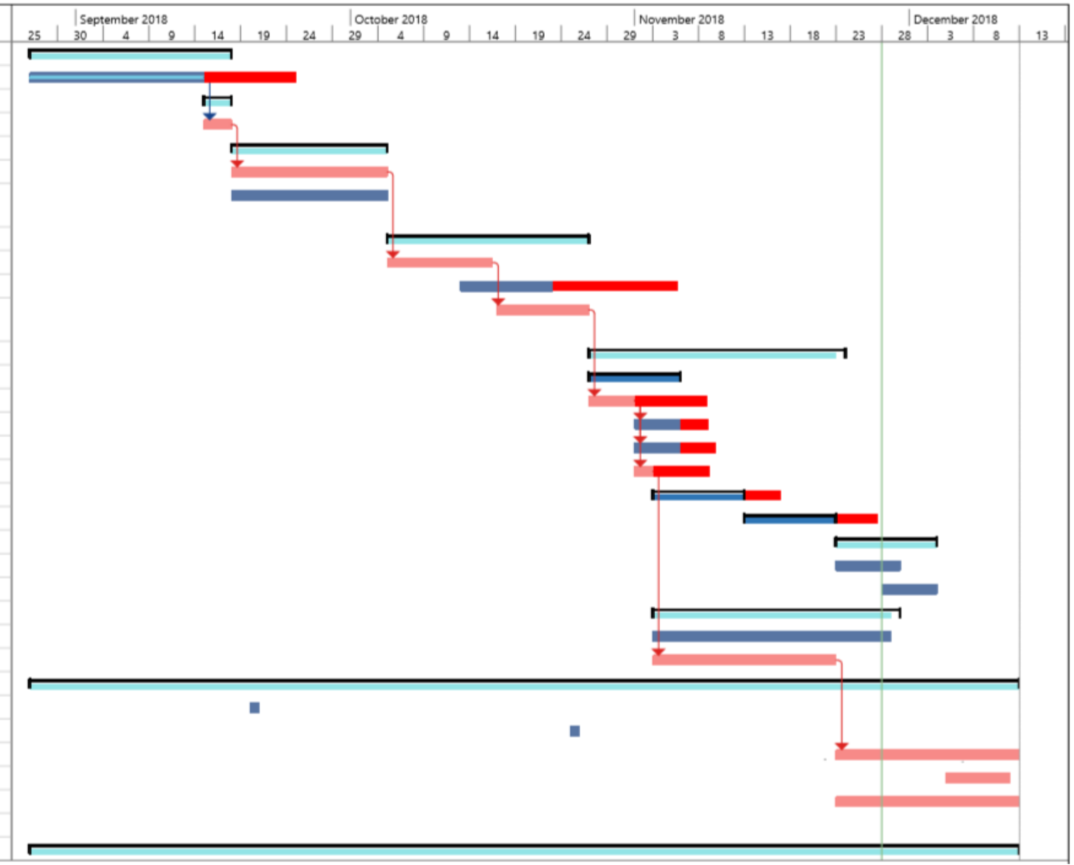
7.1 Changes to Original Scope

The team has made the change from Field Investigation to Virtual Field Investigation. Due to time constraints, the team decided to do a virtual tour of the site to analyze and design for.

7.2 Changes to Original Schedule

The schedule was updated to reflect actual due dates of the deliverables and updated for the team site visit being later in the schedule than originally planned. Also, due to technical difficulties with the Northern Arizona University technology, the team had to extend certain tasks involved with the project which is shown in bold red.

ID	Task Name	Start	Finish
1	**1: Field Investigation**	**Mon 8/27/18**	**Mon 9/17/18**
2	1.1: Site Investigation	Mon 8/27/18	Fri 9/14/18
3	**1.2: Traffic Analysis**	**Sat 9/15/18**	**Mon 9/17/18**
4	1.2.1: Crash Data Analysis	Sat 9/15/18	Mon 9/17/18
5	**2: Traffic Conditions**	**Tue 9/18/18**	**Thu 10/4/18**
6	2.1: Determine Traffic Characteristics	Tue 9/18/18	Thu 10/4/18
7	2.2: Utilize Highway Capacity Software to determine characteristics	Tue 9/18/18	Thu 10/4/18
8	**3: Preliminary Data**	**Fri 10/5/18**	**Fri 10/26/18**
9	3.1: Existing Feature Limitations	Fri 10/5/18	Tue 10/16/18
10	3.2: Civil 3D Surface Creation	Sat 10/13/18	Mon 10/22/18
11	3.3: Schematic for Horizontal Alignment Alternatives	Wed 10/17/18	Fri 10/26/18
12	**4: Alignment Design Alternatives**	**Sat 10/27/18**	**Fri 11/23/18**
13	**4.1: Alternative Design 1**	**Sat 10/27/18**	**Mon 11/5/18**
14	4.1.1: Horizontal Alignment	Sat 10/27/18	Wed 10/31/18
15	4.1.2: Vertical Alignment	Thu 11/1/18	Mon 11/5/18
16	4.1.3: Property Investigation	Thu 11/1/18	Mon 11/5/18
17	4.1.4: Quantities Takeoff	Thu 11/1/18	Fri 11/2/18
18	**4.2: Alternative Design 2**	**Sat 11/3/18**	**Mon 11/12/18**
23	**4.3: Alternative Design 3**	**Tue 11/13/18**	**Thu 11/22/18**
28	**5: Intersection**	**Fri 11/23/18**	**Mon 12/3/18**
29	5.1: Intersection Impact Analysis	Fri 11/23/18	Thu 11/29/18
30	5.2: Intersection Recommendations	Wed 11/28/18	Mon 12/3/18
31	**6: Cost Assessment**	**Sat 11/3/18**	**Thu 11/29/18**
32	6.1: Land Value Assessment	Sat 11/3/18	Wed 11/28/18
33	6.2 Alternatives Total Cost	Sat 11/3/18	Thu 11/22/18
34	**7: Deliverables**	**Mon 8/27/18**	**Wed 12/12/18**
35	7.1: 30% Report	Thu 9/20/18	Thu 9/20/18
36	7.2: 60% Report	Thu 10/25/18	Thu 10/25/18
37	7.3: Final Report	Fri 11/23/18	Wed 12/12/18
38	7.4: Website	Wed 12/5/18	Tue 12/11/18
39	7.5: Final Presentation	Fri 11/23/18	Wed 12/12/18
40	**7.7: Status Update**	**Mon 8/27/18**	**Wed 12/12/18**
45	**8: Project Management**	**Mon 8/27/18**	**Wed 12/12/18**



8 Summary of Engineering Costs

8.1 Staffing

Our project staffing includes a Senior Engineer, a Professional Engineer, an Engineer in Training (EIT), a Drafter, and an Administrator. The senior engineer will be responsible for overseeing all tasks to ensure the project runs smoothly. The Professional Engineer will be responsible for developing plans and making sure tasks are being done correctly. The EIT's will be performing the majority of the legwork for the project.

8.2 Hour Matrix

Proposed Hour Matrix

Task Name	Sr. Engineer	Prof. Engineer	EIT (4 Combined)	Drafter /Tech	Administrator	Task Total
1: Field Investigation	4	24	80	0	0	108
2: Traffic Conditions	2	7	48	0	0	57
3: Preliminary Data	3	10	64	13	0	90
4: Alignment Design Alternatives	7	22	144	29	12	214
5: Intersection	2	5	32	7	2	48
6: Cost Assessment	2	5	32	0	8	47
7: Deliverables	7	22	144	0	20	193
8: Meetings	2	5	34	0	7	48
Total Hours	29	100	578	49	49	**805**

Final Hour Matrix

Task Name	Sr. Engineer	Prof. Engineer	EIT (3 Combined)	Drafter /Tech	Administrator	Task Total
1: Field Investigation	0	3	9	0	0	12
2: Traffic Conditions	2	5	36	0	0	43
3: Preliminary Data	9	27	180	10	0	226
4: Alignment Design Alternatives	5	16	108	22	12	163
5: Intersection	0	1	6	1	2	10
6: Cost Assessment	1	4	24	0	8	37
7: Deliverables	6	18	120	0	20	164
8: Meetings	1	4	26	0	5.1	36
Total Hours	25	78	509	33	47	**691**

The major difference between the proposed and final matrix is when the team changed from a 4-person to a 3-person team.

8.3 Matrix of Engineering Cost and Total Cost of Services

Proposed Cost Matrix

Rate Table					
Staff	**Pay Rate ($/hr.)**	**Multiplier**	**Billing Rate ($/hr.)**	**Hours**	**Cost ($)**
Sr. Engineer	60	3	180	29	$5,220.00
Prof. Engineer	40	2.5	100	100	$10,000.00
EIT	25	2.5	62.5	578	$36,125.00
Drafter/Tech	25	2	50	49	$2,450.00
Administrator	20	2	40	49	$1,960.00
ADOT Coordinator	30	2	60	20	$1,200.00
OTHER EXPENSES					
	Cost ($/mi.)		**Trips**	**Miles**	
Travel	0.7		2	600	$840.00
	Cost ($/night)			**Rooms**	
Hotel	150		-	6	$900.00
				Total Cost	$58,695.00

Final Cost Matrix

Rate Table					
Staff	**Pay Rate ($/hr.)**	**Multiplier**	**Billing Rate ($/hr.)**	**Hours**	**Cost ($)**
Sr. Engineer	60	3	180	25	$4,576.50
Prof. Engineer	40	2.5	100	78	$7,762.50
EIT	25	2.5	62.5	509	$31,781.25
Drafter/Tech	25	2	50	33	$1,640.00
Adminastrator	20	2	40	47	$1,884.00
ADOT Coordinator	30	2	60	20	$1,200.00
				Total Cost	$48,844.25

The biggest difference between the proposed cost and the final cost is that the team was unavailable to make a site visit down to Duncan, AZ. The team supplemented this by doing a virtual site visit. The second difference is, once again, the cost decreased due to the team decreasing to three people.

8.4 Discussion of Engineering Cost and Total Cost of Services

To maintain a safe overhead to keep the Engineering Company, a Rate Table will be utilized to cover all others who are not completely involved in each individual project. There must be a steady stream of income, even when there are no clients. The Rate Table used above is based on a typical rate of the included staff members and a multiplier for additional overhead. Considering both the Senior Engineer and Professional Engineer will only be involved when approval is needed, their hours worked on the project will be minimal; therefore, they would have a higher rate such as three and two and half multiplier. The same can be applied to the EIT, Drafter, Admin, and ADOT Coordinator. The EIT's will be generating the majority of the income, which can cover the overhead (such as Health Insurance, Fees, and other required benefits). In addition to the Rate Table, the updated matrix does not include travel and hotel expenses as the team determined that a virtual field investigation would be sufficient for the project.

9 Conclusion

The team determined that the best option is for the townspeople of Duncan, AZ to decide which alignment option would be best for them. The team completed three alignment options in order to complete flood mitigation for the town. For all three alignments, the team determined that it would need to have property, houses, agricultural land, or a combination of these acquired in order to build out the alignments. A cost analysis was completed, and a final summary table was done in order to allow the town to have the best options to pick from. In the future, other teams would need to complete a levee design, geotechnical report, environmental report, and an intersection design.

10 References

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11 Appendices

11.1 Appendix A- Floodplain Zone

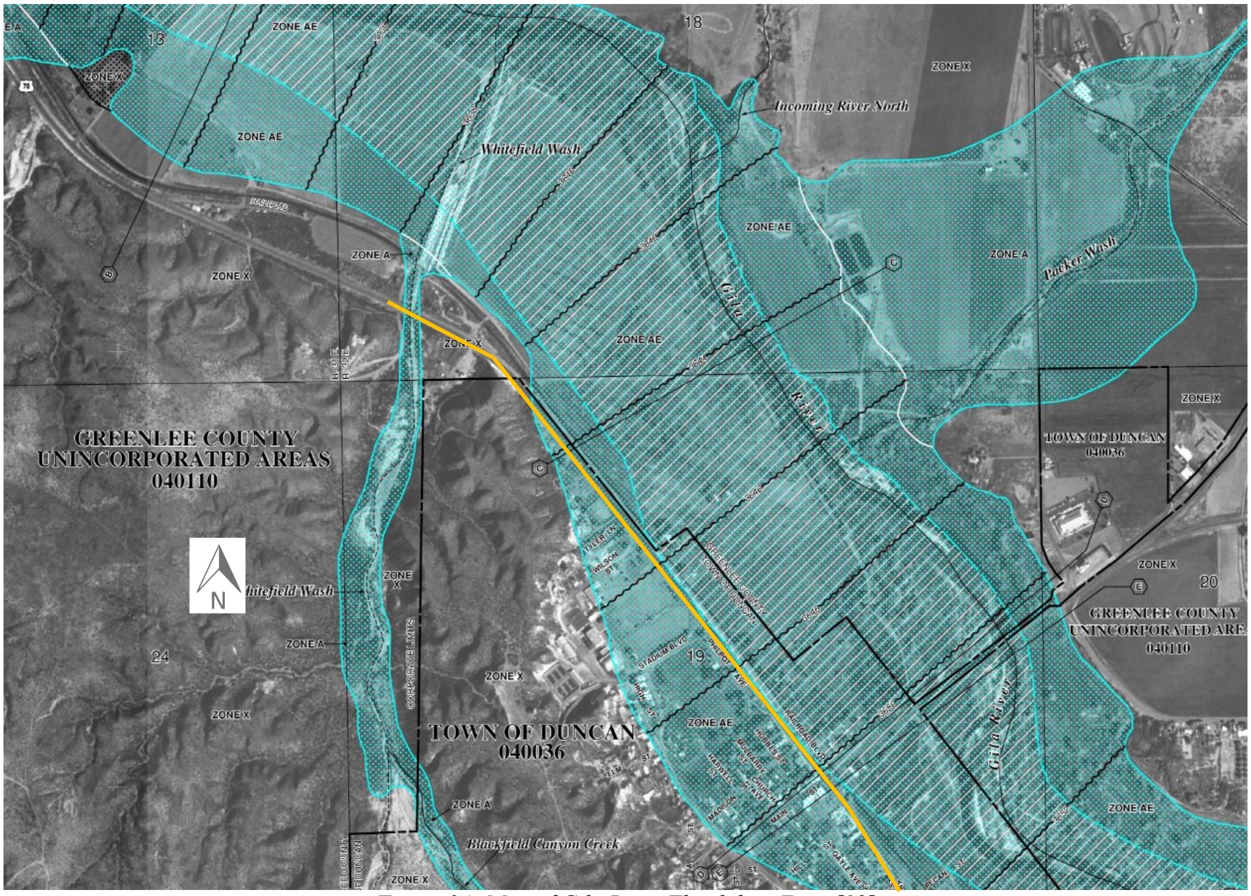


Figure 24: Map of Gila River Floodplain Zone [18]

11.2 Appendix B- Traffic Analysis

Route	BMP	Start	TCS MP	EMP	End	Length	AADT 2017	Growth Factor %	K Factor %	D Factor %	AADT Single Trucks	AADT Combo Trucks	T Factor %	Future AADT
US 70	378.48	Wilson St	378.6	378.91	SR 75 - Duncan	0.43	1,567	1.23	9	54	92	62	9.8	2,210
US 70	379.48	2nd St	379.6	379.8	7th St	0.32	1,516	1.27	9	60	89	59	9.8	2,318
US 70	378.91	SR 75 - Duncan	379.15	379.48	2nd St	0.57	3,470	1.27	8	63	205	135	9.8	4,246
						AVERAGE	2184	1	9	59	129	85	10	2925

Figure 25: Chart of Route US 70 thru Duncan, AZ Traffic Analysis

Route	BMP	Start	TCS MP	EMP	End	Length	AADT 2017	Growth Factor %	K Factor %	D Factor %	AADT Single Trucks	AADT Combo Trucks	T Factor %	Future AADT
SR 75	378.92	US 70 - Duncan	379	379.46	Virden Rd	0.54	2,792	1.17	9	60	165	109	9.8	3,514

Figure 26: Chart of Route SR 75 thru Duncan, AZ Traffic Analysis

11.3 Appendix C- Crash Data Analysis

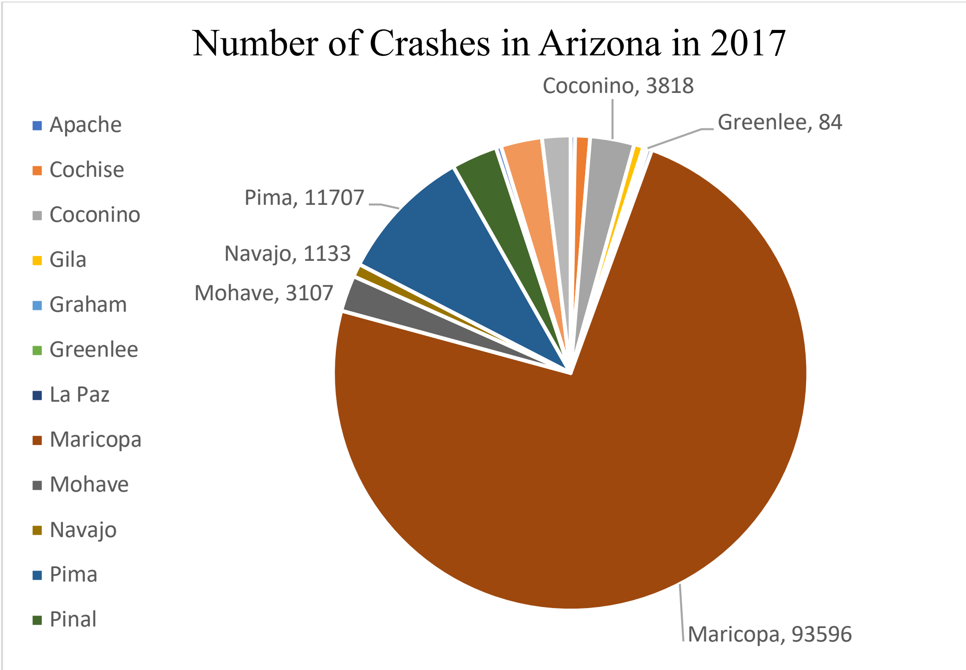


Figure 27: Number of Crashes in Arizona in 2017

Figure 27 shows the number of crashes in Arizona in 2017. For the entire state of Arizona, the total number of crashes for 2017 is 127,064. For the Greenlee County there is a total of 84 crashes and most are not in the town of Duncan.

Figure 28 shows the cost of traffic crashes for Arizona in 2017. The Estimated total cost of crashes for 2017 is $10,324,566,000 and Greenlee County has a total cost of $10,024,000.

County	Cost of Traffic Crashes			
	Fatalities	Injuries	PDO	Total
Apache	$ 272,600,000	$ 21,346,000	$ 956,000	$ 294,902,000
Cochise	$ 127,600,000	$ 48,430,000	$ 3,668,000	$ 179,698,000
Coconino	$ 2,668,000	$ 143,848,000	$ 11,560,000	$ 422,208,000
Gila	$ 168,200,000	$ 44,388,000	$ 2,104,000	$ 214,692,000
Graham	$ 46,400,000	$ 15,774,000	$ 824,000	$ 62,998,000
Greenlee	$ 5,800,000	$ 4,032,000	$ 192,000	$ 10,024,000
La Paz	$ 104,400,000	$ 26,364,000	$ 868,000	$ 131,632,000
Maricopa	$ 2,685,400,000	$ 3,115,590,000	$ 265,236,000	$ 6,066,226,000
Mohave	$ 249,400,000	$ 161,928,000	$ 8,516,000	$ 419,844,000
Navajo	$ 295,800,000	$ 55,676,000	$ 2,976,000	$ 354,452,000
Pima	$ 661,200,000	$ 544,708,000	$ 27,896,000	$ 1,233,804,000
Pinal	$ 411,800,000	$ 160,920,000	$ 10,888,000	$ 583,608,000
Santa Cruz	$ 34,800,000	$ 13,666,000	$ 1,452,000	$ 49,918,000
Yavapai	$ 319,000,000	$ 160,812,000	$ 9,808,000	$ 48,962,000
Yuma	$ 150,800,000	$ 94,454,000	$ 6,344,000	$ 251,598,000
Total	$ 5,535,868,000	$ 4,611,936,000	$ 353,288,000	$ 10,324,566,000

Figure 28: Cost of Traffic Crashes in Arizona in 2017

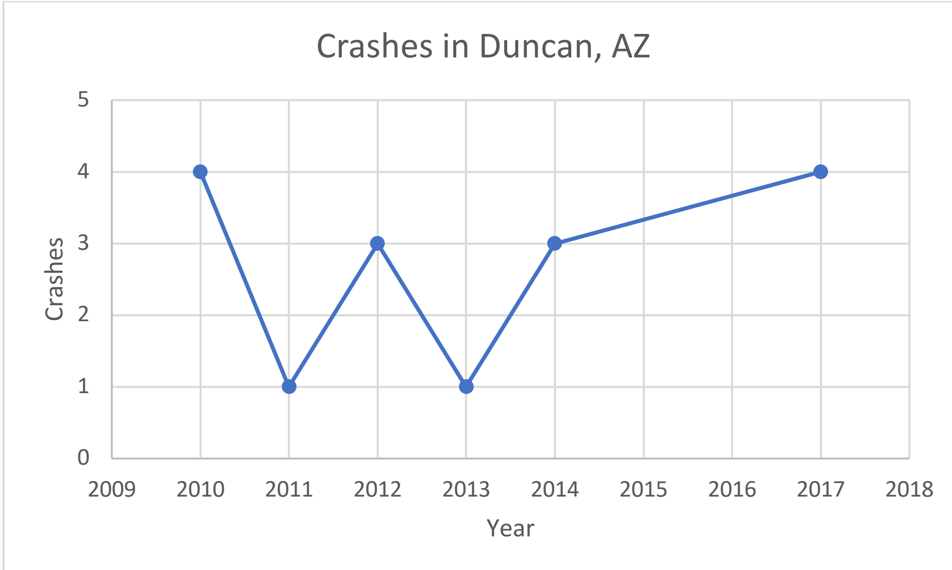


Figure 29: Crashes in Duncan, AZ from 2010-2017

Figure 29 shows the crashes that took place in Duncan from 2010-2017 as that is all the data that is available for the town. The data provided from Dr. Russo shows the yearly crashes in and around Duncan, AZ. Since 2010, there has been 4 crashes or less. Comparing the data to ADOT crash data, there was one that was unaccounted for.

	Number of Crashes				Number of People		Alcohol Related		
County	Total	Fatal	Injury	PDO	Killed	Injured	Crashes	Killed	Injured
Greenlee County	51	0	21	30	0	24	2	0	3
Clifton	30	0	13	17	0	16	4	0	4
Duncan	3	1	1	1	1	2	1	1	0
Total	84	1	35	48	1	42	7	1	7

Figure 30: Crash Types in Arizona in 2017

Figure 20 shows the crash types in Arizona for Greenlee County, the town of Clifton, and the town of Duncan in 2017. In the entire county there is a total of 84 crashes and only 3 in Duncan according to ADOT. With such minimal crashes, there should not be any interferences with any intersection recommendations and the new highway alignment.

11.4 Appendix D- Traffic Characteristics

Terms	Value
Average Annual Daily Traffic (AADT) 2017	2184 Vehicles
Growth Factor	1%
K Factor %	9%
D Factor %	59%
Average Annual Daily Traffic- Single Trucks	129 Vehicles
Average Annual Daily Traffic- Combo Trucks	85 Vehicles
T Factor %	10%
Future Annual Average Daily Traffic	2925 Vehicles

Figure 31: Traffic Characteristics from Arizona Department of Transportation (ADOT)

Figure 31 is data gathered from the Arizona Department of Transportation (ADOT). The average annual daily traffic is the total volume of vehicles for a year divided by 365 days. Using this information, the characteristics of the proposed highway can be determined and analyzed. For the analysis a design speed of 60 mph was used for a two-lane highway for trucks and passenger cars. The dimensions of the road will be 12-foot lanes with a 6-foot shoulder on either side. This information was gained from AASHTO and the Highway Capacity Manual Guidelines due to the road being at an elevation of 8.5 feet, the side slopes of the highway would be 4 Horizontal: 1 Vertical.

The K Factor is the proportion of the average annual daily traffic occurring in one hour. The D Factor is the percent of traffic moving in the peak travel direction. The T Factor is the percent of trucks occurring in one hour.

Terms	Criteria
Existing Speed	45 miles per hour
Estimated Free Flow Speed	39.5 miles per hour
Design Speed	60 miles per hour
Lanes	2
Slopes of Elevated Highway	4 Horizontal: 1 Vertical
Shoulder Length	6 feet on each side
Current LOS	A

Figure 32: Traffic Characteristics from Arizona Department of Transportation (ADOT)

Figure 32 shows the traffic characteristics necessary for the Highway Capacity Software to determine the level of service.

11.5 Appendix E- Highway Capacity Software (HCS)

```
                    HCS+: Two-Lane Highways Release 5.5




Phone:                                  Fax:
E-Mail:

                   Two-Way Two-Lane Highway Segment Analysis

Analyst                 ZONA
Agency/Co.
Date Performed          10/14/2018
Analysis Time Period
Highway                 US 70
From/To
Jurisdiction
Analysis Year           2018
Description  Analyzing current conditions

                                Input Data

Highway class  Class 2
Shoulder width       6.0     ft     Peak-hour factor, PHF       0.88
Lane width           12.0    ft     % Trucks and buses          10      %
Segment length       0.0     mi     % Recreational vehicles     0       %
Terrain type         Level          % No-passing zones          100     %
Grade:  Length               mi     Access points/mi            14      /mi
        Up/down              %

Two-way hourly volume, V    105     veh/h
Directional split       60  /   40  %

                           Average Travel Speed

Grade adjustment factor, fG                     1.00
PCE for trucks, ET                              1.7
PCE for RVs, ER                                 1.0
Heavy-vehicle adjustment factor,                0.935
Two-way flow rate,(note-1) vp                   128     pc/h
Highest directional split proportion (note-2)   77      pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                        -      mi/h
Observed volume, Vf                              -      veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                      60.0    mi/h
Adj. for lane and shoulder width, fLS           0.0     mi/h
Adj. for access points, fA                      3.5     mi/h

Free-flow speed, FFS                            56.5    mi/h

Adjustment for no-passing zones, fnp            2.2     mi/h
Average travel speed, ATS                       53.3    mi/h
```

```
                    Percent Time-Spent-Following

Grade adjustment factor, fG                                   1.00
PCE for trucks, ET                                            1.1
PCE for RVs, ER                                               1.0
Heavy-vehicle adjustment factor, fHV                          0.990
Two-way flow rate,(note-1) vp                                 121     pc/h
Highest directional split proportion (note-2)                 73
Base percent time-spent-following, BPTSF                      10.1    %
Adj.for directional distribution and no-passing zones, fd/np  24.3
Percent time-spent-following, PTSF                            34.4    %

                Level of Service and Other Performance Measures

Level of service, LOS                                         A
Volume to capacity ratio, v/c                                 0.04
Peak 15-min vehicle-miles of travel, VMT15                    0        veh-mi
Peak-hour vehicle-miles of travel, VMT60                      0        veh-mi
Peak 15-min total travel time, TT15                           0.0      veh-h
______________________________________________________________________________

Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.
```

Figure 33: Alternative 1

Figure 33 shows the results of the Highway Capacity Software for Alternative 1. Alternative 1 for raising the current highway had the inputs of shoulder width 6 feet, lane width of 12 feet, terrain is level, and access points per mile is 14. An access point is when another road or significant driveway needs access to the main road. Also, the base-free flow speed (also known as the design speed) is 60mph, direction split of 60/40, and 10% is trucks and busses. The information for inputs was computed and/or gathered from the Highway Capacity Manual (HCM) and AASHTO. The results received from inputting this data conclude that this alternative produces a Level of Service (LOS) of A, volume to capacity ratio (v/c) of 0.04, two-way flow rate of 121 vehicles per hour, and meets the design speed of 60mph.

```
                 HCS+: Two-Lane Highways Release 5.5



Phone:                                  Fax:
E-Mail:

                 Two-Way Two-Lane Highway Segment Analysis

Analyst                  ZONA
Agency/Co.
Date Performed           10/14/2018
Analysis Time Period
Highway                  US 70
From/To
Jurisdiction
Analysis Year            2018
Description  Analyzing current conditions

                              Input Data

Highway class  Class 2
Shoulder width        6.0     ft     Peak-hour factor, PHF       0.88
Lane width            12.0    ft     % Trucks and buses          10      %
Segment length        0.0     mi     % Recreational vehicles     0       %
Terrain type          Level          % No-passing zones          100     %
Grade:  Length                mi     Access points/mi            14      /mi
        Up/down               %

Two-way hourly volume, V    105     veh/h
Directional split       60  /   40  %

                         Average Travel Speed

Grade adjustment factor, fG                      1.00
PCE for trucks, ET                               1.7
PCE for RVs, ER                                  1.0
Heavy-vehicle adjustment factor,                 0.935
Two-way flow rate,(note-1) vp                    128     pc/h
Highest directional split proportion (note-2)    77      pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                          -     mi/h
Observed volume, Vf                                -     veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                       60.0    mi/h
Adj. for lane and shoulder width, fLS            0.0     mi/h
Adj. for access points, fA                       3.5     mi/h

Free-flow speed, FFS                             56.5    mi/h

Adjustment for no-passing zones, fnp             2.2     mi/h
Average travel speed, ATS                        53.3    mi/h
```

```
                       Percent Time-Spent-Following

Grade adjustment factor, fG                                 1.00
PCE for trucks, ET                                          1.1
PCE for RVs, ER                                             1.0
Heavy-vehicle adjustment factor, fHV                        0.990
Two-way flow rate,(note-1) vp                               121     pc/h
Highest directional split proportion (note-2)               73
Base percent time-spent-following, BPTSF                    10.1    %
Adj.for directional distribution and no-passing zones, fd/np 24.3
Percent time-spent-following, PTSF                          34.4    %

              Level of Service and Other Performance Measures

Level of service, LOS                                       A
Volume to capacity ratio, v/c                               0.04
Peak 15-min vehicle-miles of travel, VMT15                  0        veh-mi
Peak-hour vehicle-miles of travel, VMT60                    0        veh-mi
Peak 15-min total travel time, TT15                         0.0      veh-h
______________________________________________________________________________

Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.
```

Figure 34: Alternative 2

Figure 34 shows the results of the Highway Capacity Software for Alternative 2. Alternative 2 for running along agricultural dike had the inputs of shoulder width 6feet, lane width of 12 feet, terrain is level, and access points per mile are 14. An access point is when another road or significant drive way needs access to the main road. Also, the base-free flow speed (also known as the design speed) is 60mph, direction split of 60/40, and 10% is trucks and busses. The information for inputs was computed and/or gathered from the Highway Capacity Manual (HCM) and AASHTO. The results received from inputting this data conclude that this alternative produces a Level of Service (LOS) of A, volume to capacity ratio (v/c) of 0.04, two-way flow rate of 121 vehicles per hour, and meets the design speed of 60mph.

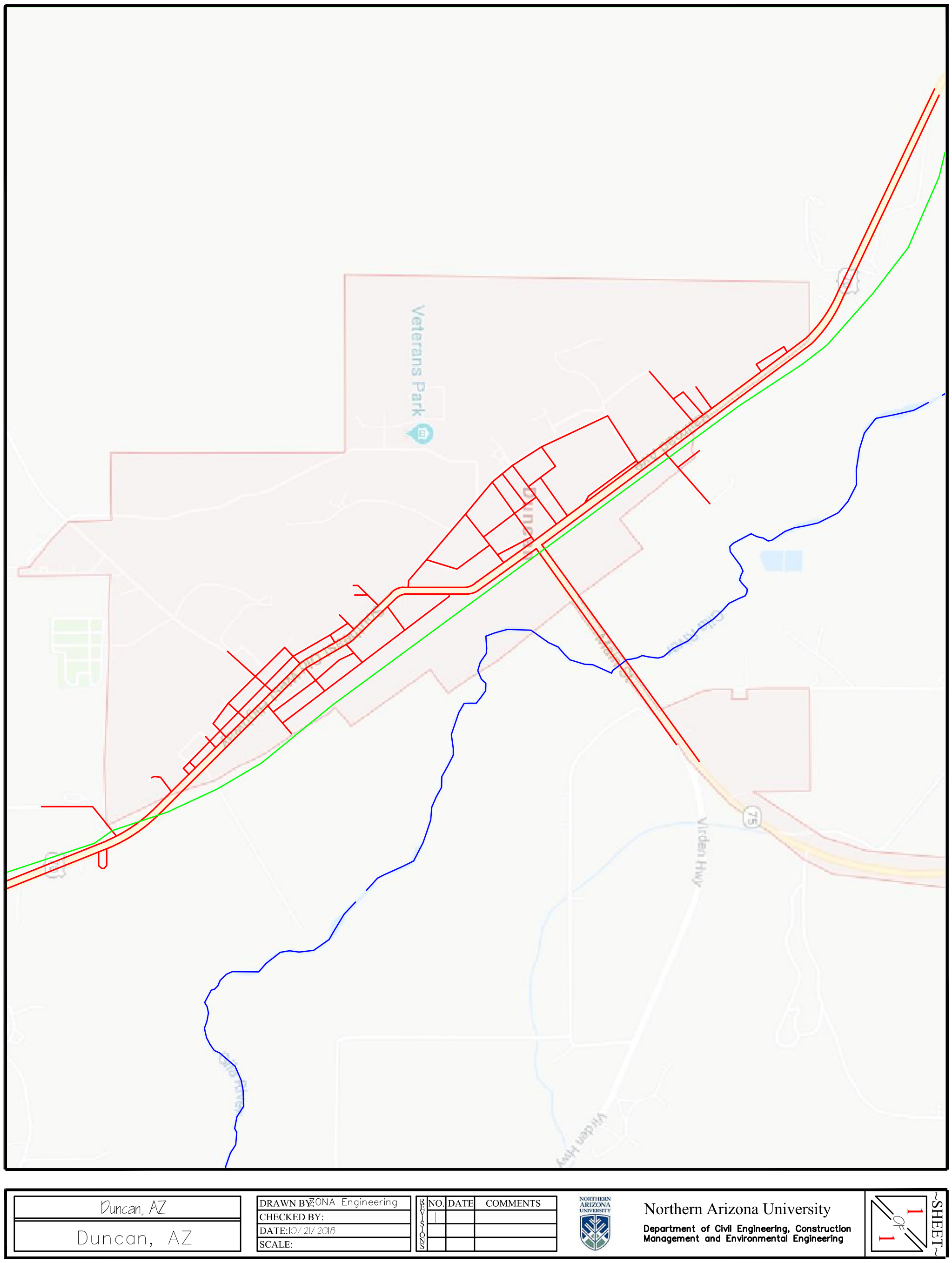
```
                         HCS+: Two-Lane Highways Release 5.5




Phone:                                  Fax:
E-Mail:

___________________Two-Way Two-Lane Highway Segment Analysis__________________

Analyst
Agency/Co.                ZONA
Date Performed            9/30/2018
Analysis Time Period
Highway                   US 70
From/To
Jurisdiction
Analysis Year
Description

___________________________________Input Data_________________________________

Highway class   Class 2
Shoulder width        6.0     ft     Peak-hour factor, PHF       0.88
Lane width            12.0    ft     % Trucks and buses          10      %
Segment length        0.0     mi     % Recreational vehicles     0       %
Terrain type          Level          % No-passing zones          100     %
Grade:  Length                mi     Access points/mi            3       /mi
        Up/down               %

Two-way hourly volume, V    105     veh/h
Directional split       60  /   40  %

                            Average Travel Speed

Grade adjustment factor, fG                       1.00
PCE for trucks, ET                                1.7
PCE for RVs, ER                                   1.0
Heavy-vehicle adjustment factor,                  0.935
Two-way flow rate,(note-1) vp                     128      pc/h
Highest directional split proportion (note-2)     77       pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                          -       mi/h
Observed volume, Vf                                -       veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                        52.0     mi/h
Adj. for lane and shoulder width, fLS             0.0      mi/h
Adj. for access points, fA                        0.8      mi/h

Free-flow speed, FFS                              51.3     mi/h

Adjustment for no-passing zones, fnp              2.2      mi/h
Average travel speed, ATS                         48.0     mi/h
```

```
_________________________Percent Time-Spent-Following________________________

Grade adjustment factor, fG                                     1.00
PCE for trucks, ET                                              1.1
PCE for RVs, ER                                                 1.0
Heavy-vehicle adjustment factor, fHV                            0.990
Two-way flow rate,(note-1) vp                                   121     pc/h
Highest directional split proportion (note-2)                   73
Base percent time-spent-following, BPTSF                        10.1    %
Adj.for directional distribution and no-passing zones, fd/np    24.3
Percent time-spent-following, PTSF                              34.4    %

               Level of Service and Other Performance Measures

Level of service, LOS                                           A
Volume to capacity ratio, v/c                                   0.04
Peak 15-min vehicle-miles of travel, VMT15                      0        veh-mi
Peak-hour vehicle-miles of travel, VMT60                        0        veh-mi
Peak 15-min total travel time, TT15                             0.0      veh-h


Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.
```

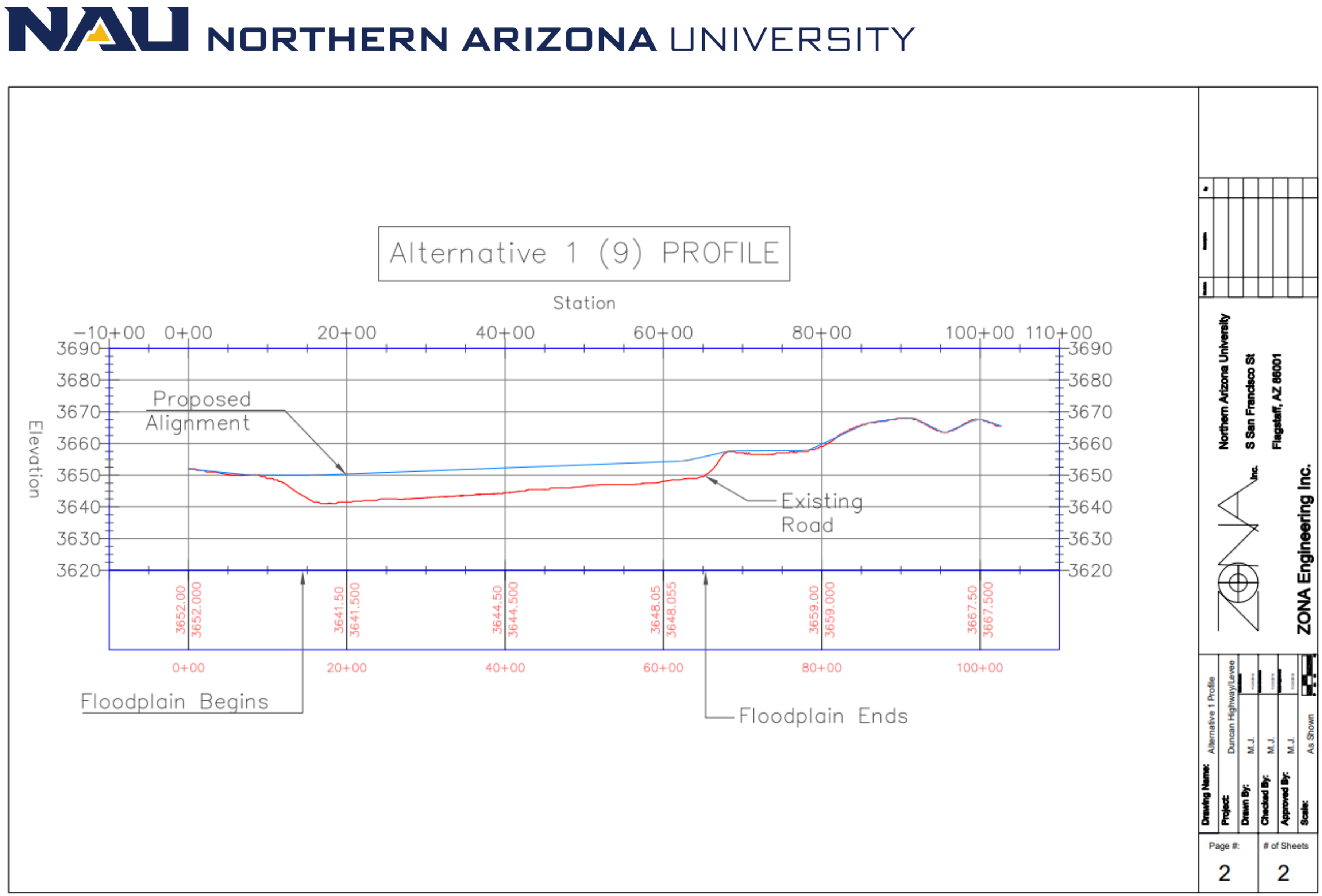
Figure 35: Alternative 3

Figure 35 shows the results of the Highway Capacity Software for Alternative 3. Alternative 3 for running parallel to railroad on agricultural land had the inputs of shoulder width 6 feet, lane width of 12 feet, terrain is level, and access points per mile are 3. An access point is when another road or significant drive way needs access to the main road. In this case, the three access points include the start of the new highway, end of new highway, and highway 75 connecting. Also, the base-free flow speed (also known as the design speed) is 60mph, direction split of 60/40, and 10% is trucks and busses. The information for inputs was computed and/or gathered from the Highway Capacity Manual (HCM) and AASHTO. The results received from inputting this data conclude that this alternative produces a Level of Service (LOS) of A, volume to capacity ratio (v/c) of 0.04, two-way flow rate of 121 vehicles per hour, and meets the design speed of 60mph.

11.6 Appendix H- Civil 3D Creation



11.7 Appendix I- Horizontal and Vertical Alignments


NORTHERN ARIZONA UNIVERSITY
Alternative 1 (9) PROFILE
Station
Elevation
Proposed Alignment
Existing Road
Floodplain Begins
Floodplain Ends
Northern Arizona University
S San Francisco St
Flagstaff, AZ 86001
ZONA Engineering Inc.
Drawing Name: Alternative 1 Profile
Project: Duncan Highway/Levee
Drawn By: M.J.
Checked By: M.J.
Approved By: M.J.
Scale: As Shown
Page #: 2
# of Sheets 2


Road
Existing Levee
Railroad
Floodplain
Gila River
N
0'
800'
1600'
Northern Arizona University
S San Francisco St
Flagstaff, AZ 86001
Inc.
ZONA Engineering Inc.
Drawing Name: Alternative 2
Project: Duncan Highway/Levee
Drawn By: M.J.
Checked By: M.J.
Approved By: M.J.
Scale: As Shown
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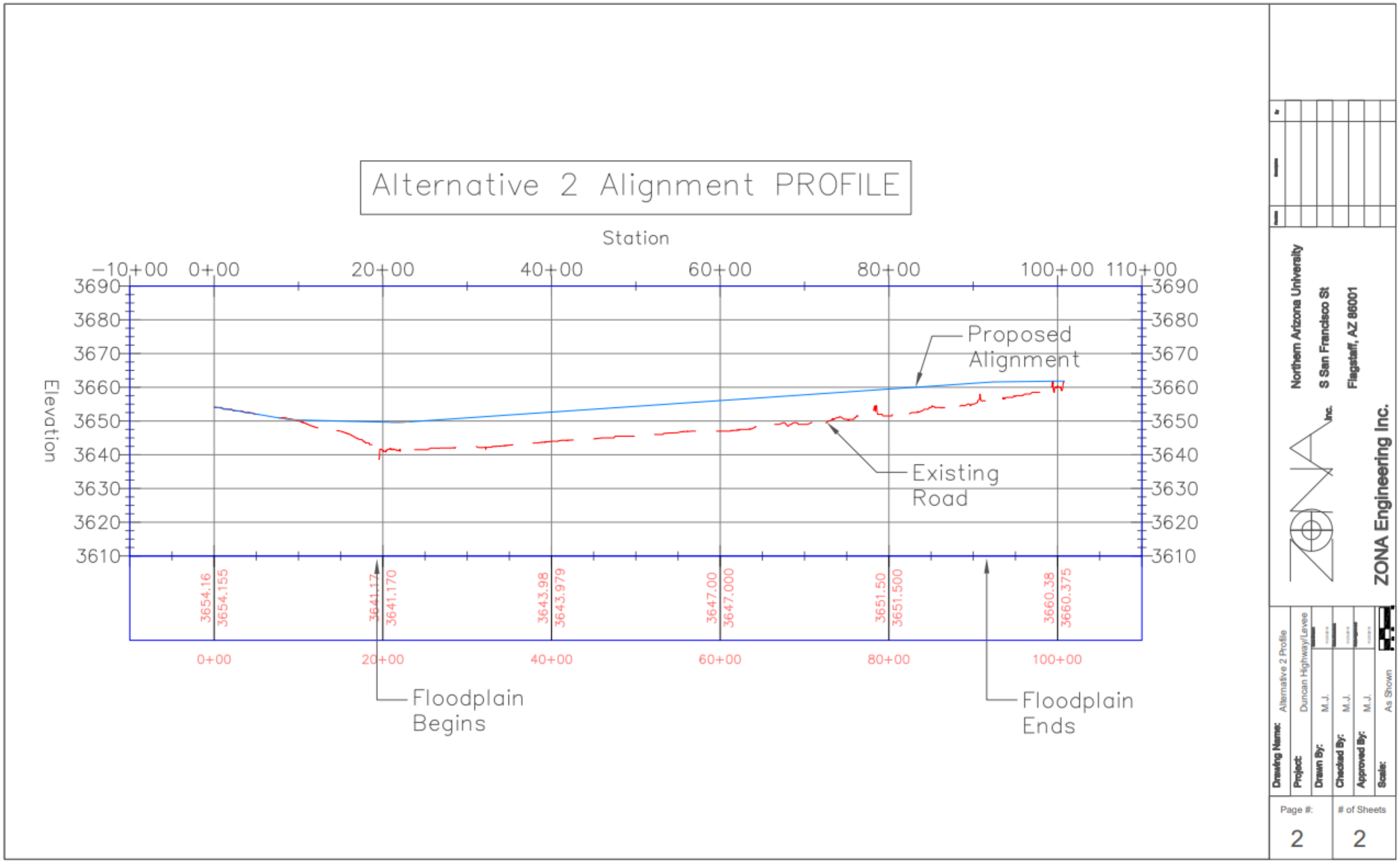
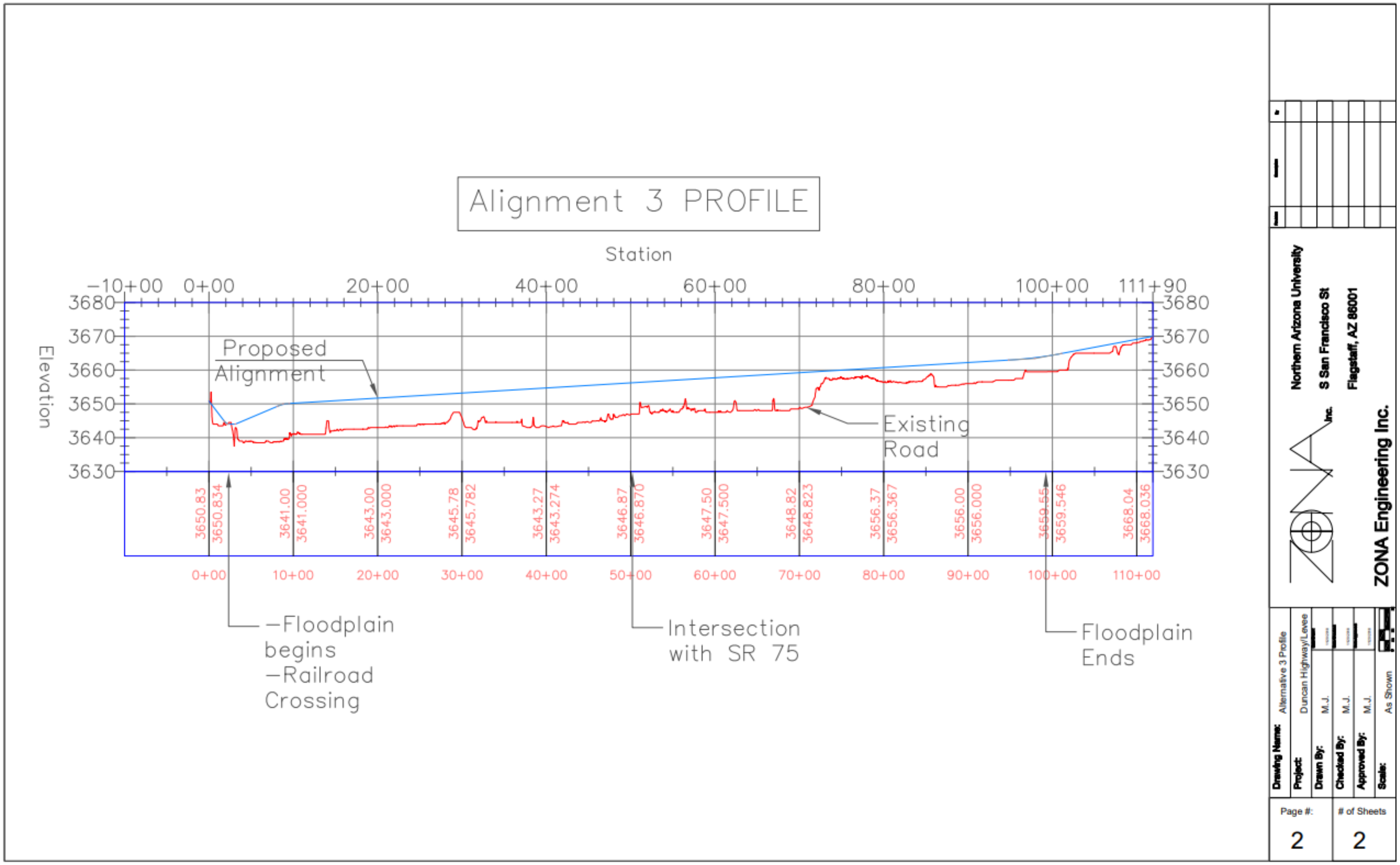
# of Sheets 2



Alternative 2 Alignment PROFILE
Station
Elevation
Proposed Alignment
Existing Road
Floodplain Begins
Floodplain Ends
ZONA Engineering Inc.
Northern Arizona University
S San Francisco St
Flagstaff, AZ 86001
Drawing Name: Alternative 2 Profile
Project: Duncan Highway/Levee
Drawn By: M.J.
Checked By: M.J.
Approved By: M.J.
Scale: As Shown
Page #: 2
# of Sheets 2


Roads
Existing Levee
Railroad
Existing Floodplain
Gila River
N
0'
1000'
2000'
Northern Arizona University
S San Francisco St
Flagstaff, AZ 86001
ZONA Engineering Inc.
Drawing Name: Alternative 3
Project: Duncan Highway/Levee
Drawn By: M.J.
Checked By: M.J.
Approved By: M.J.
Scale: As Shown
Page #: 1
# of Sheets 2



Alignment 3 PROFILE
Station
−10+00
0+00
20+00
40+00
60+00
80+00
100+00
111+90
Elevation
3680
3670
3660
3650
3640
3630
Proposed Alignment
Existing Road
3650.83
3650.834
3641.00
3641.000
3643.00
3643.000
3645.78
3645.782
3643.27
3643.274
3646.87
3646.870
3647.50
3647.500
3648.82
3648.823
3656.37
3656.367
3656.00
3656.000
3659.55
3659.546
3668.04
3668.036
0+00
10+00
20+00
30+00
40+00
50+00
60+00
70+00
80+00
90+00
100+00
110+00
−Floodplain begins
−Railroad Crossing
Intersection with SR 75
Floodplain Ends
Northern Arizona University
S San Francisco St
Flagstaff, AZ 86001
ZONA Engineering Inc.
Drawing Name: Alternative 3 Profile
Project: Duncan Highway/Levee
Drawn By: M.J.
Checked By: M.J.
Approved By: M.J.
Scale: As Shown
Page #: 2
# of Sheets 2