FLAGSTAFF FAMILY FOOD BANK – FLOOD REMEDIATION PROJECT

Final Design Report

5/12/2016

Erik Henricksen, Elena Smith, Garrett Ribas, Meshal Alotaibi

Table of Contents

Acknowledgments

Dr. Wilbert Odem who provided technical advisement for hydrological analysis. Rick Barrett and Donna Curry from the City of Flagstaff who provided code requirements, topographic maps, and clarification on site assessments based on city records. Joshua Spears for accommodating site visitations and first-hand testimony to the flooding issue.

1.0 Project Description

The Flagstaff Family Food Bank (FFFB) is experiencing flooding damage to their property due to high intensity monsoonal rain events during July and August. Runoff Engineering, Inc.'s task is to remediate flooding issues at the FFFB by developing a design that is inexpensive and adheres to City of Flagstaff (CoF) codes and requirements. Analysis of design alternatives will be conducted in this report and will consist of: topographical studies, hydrological studies, and an economical analysis's. Once design alternatives have been analyzed, a final design recommendation will be presented based on a decision matrix.

1.1 Background

FFFB is located in East Flagstaff at 3805 E. Huntington Drive, just south of Fanning Drive and Route 66. Figure 1.1 shows the project location in the Flagstaff network, while Figure 1.2 shows a more detailed map of the project site location.

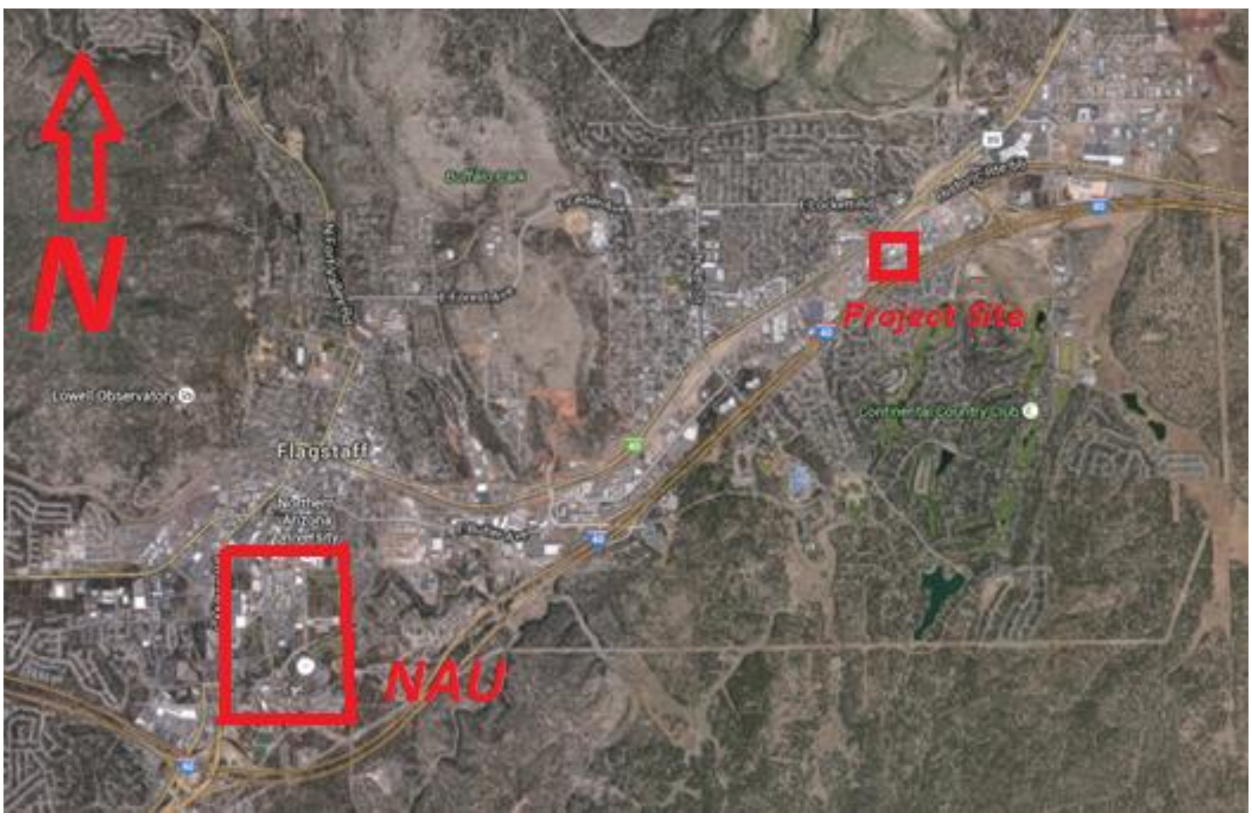


Figure 1.1 - Project Site Location in Relation to Flagstaff Network

Figure 1.2 - Detailed Project Site Location

1.1.1 Current Site Conditions

A site assessment was performed to aid in the analysis of design alternatives based on problematic issues specific to current site conditions. The issues found during site assessments include: the FFFB is located at a confluence point of a historic watershed detailed by Rick Barrett of the City of Flagstaff, the surrounding site conditions are not adequate for flood prevention (retention and maintenance of drains), and impervious slopes and surfaces surrounding the site add to the extent of the flooding issue.

1.1.1.1 Historic Watershed

The FFFB's location is near an historic watershed. The CoF went to great lengths to reroute the runoff into the neighboring Rio de Flag by way of Fanning Drive Drainage System. Figure 1.3 indicates the location of the watershed, highlighted in green, and the Rio de Flag, highlighted in blue.

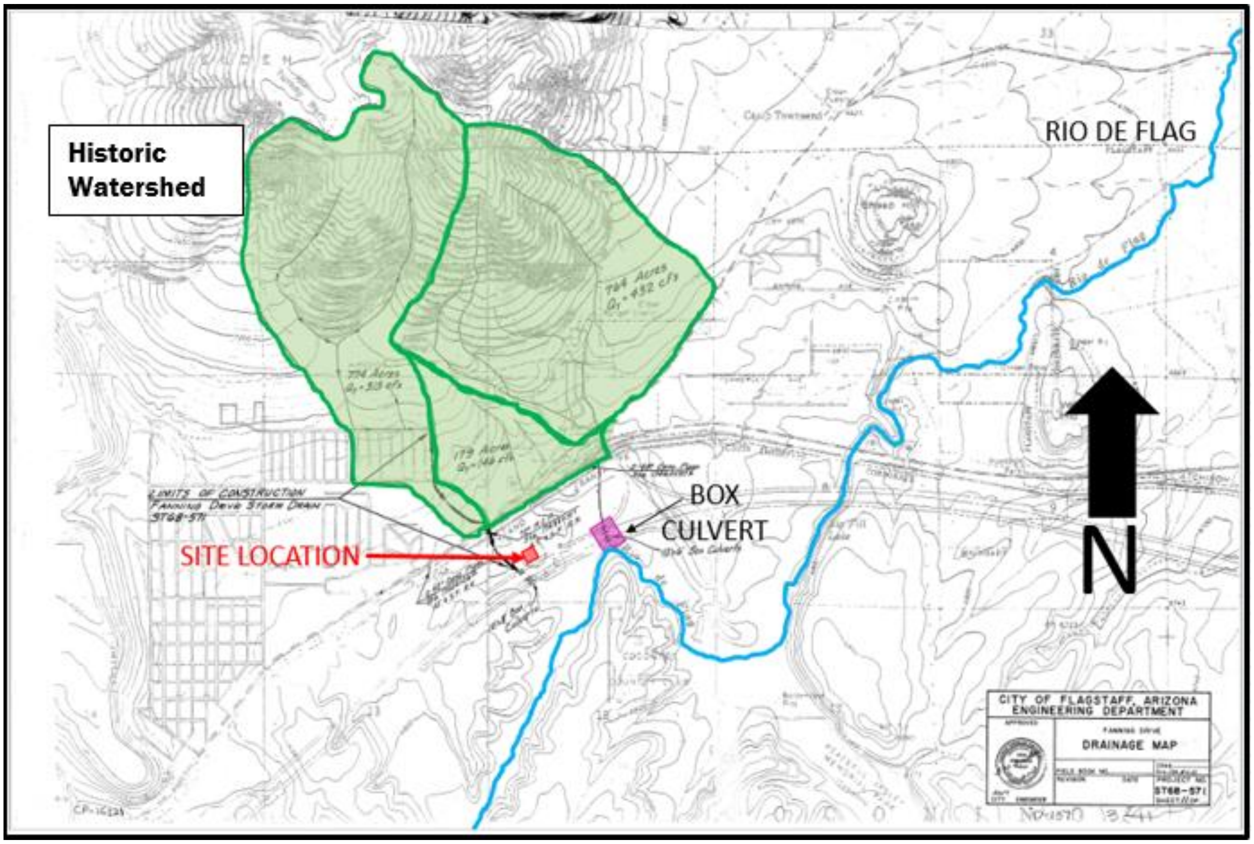


Figure 1.3 - Location of Ancient Watershed

The CoF has made use of two drainage systems, one of which lies to the Northwest of the FFFB's location, which is called the Fanning Drive Drainage System. The Fanning Drive Drainage System begins as a series of open channels, which directs water collected from residential areas, into a stormwater drainage system located on Fanning Drive. From there it directs water to the West of the FFFB site into a box culvert, highlighted in pink. The runoff eventually makes its way into the Rio de Flag, however due to the location of the site, some residual runoff is experienced by the FFFB.

1.1.1.2 Retention and Maintenance of Storm Drains

Additional site specific issues that affect the severity of the flooding are the surrounding site conditions. These conditions include: little to no retention around the site and a frequently clogged storm drain. As provided by the city, Figure 1.4 illustrates the lack of retention in the area (none) and also illustrates the current drain near the site, which is continually clogged and proves ineffective.

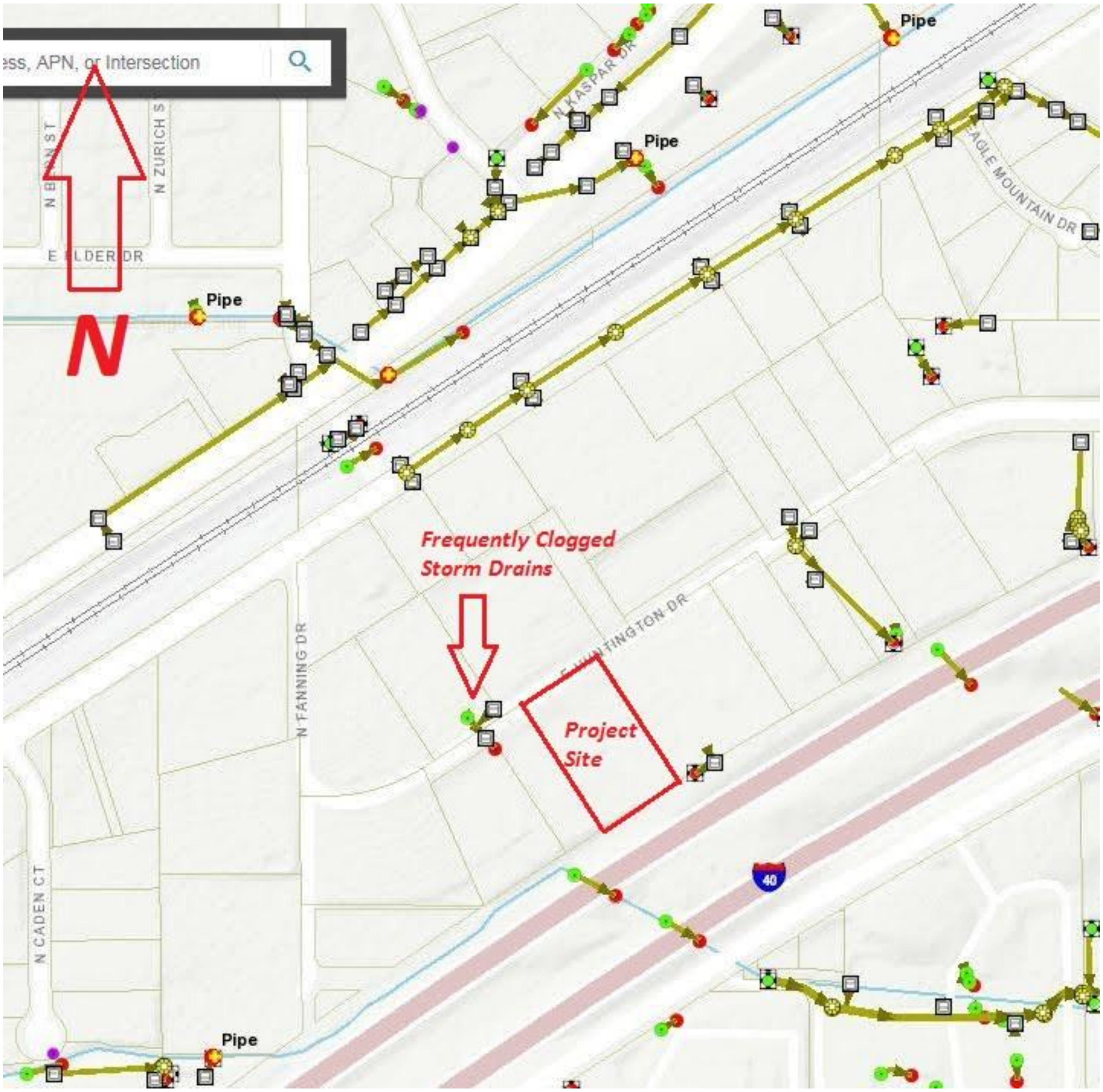


Figure 1.4 - Retention and Storm Drains near FFFB

With no retention nearby, and a storm drain that's function is to drain runoff from the road near the site proving inadequate, flooding rates and intensities are adversely effected on the FFFB site. Additional site specific issues that adversely effects the FFFB flooding problem are the slopes and surfaces that are inherent to the FFFB property, and will be discussed in the following section.

1.1.1.3 Slopes and Surfaces

Another site specific condition that adversely effects the flooding problem on the FFFB site is the amount of impervious surface surrounding the site. With no natural infiltration or drainage on site, a higher volume of storm runoff can accumulate. Additionally, impervious slopes of the property lead water to the FFFB building, escalating the intensity of the flooding issue on site. These impervious surfaces and slope conditions are illustrated in Figure 1.5.

Figure 1.5 - Impervious Slopes & Surfaces

1.1.2 Constraints

Constraints pertaining to the FFFB project includes the City of Flagstaff Stormwater Management Design Manual. The City of Flagstaff uses this design manual to inform designers and engineers of the specifications and criteria that must be met to in order to receive a permit from the city. These criteria include: methods of analysis, minimum and maximum threshold values for acceptable designs, and standards set by the city to ensure continuity between implemented designs and current city infrastructure. Design alternatives addressed in this report adhered to the design codes found in Appendix C, which is a reference guide created by Runoff Engineering in order to adhere to procedures and criteria specified by the CoF.

Another constraint that was excluded from analysis was any criteria or permits needed by the Arizona Department of Transportation (ADOT). Because the property's drainage currently flows into ADOT land, additional permits may be needed. However, Rick Barrett, a City of Flagstaff engineer, informed the team that as long as the flows that were previously coming into and out of the property don't change, ADOT permits would be granted. Additionally, due to the bureaucracy between numerous agencies that would have to be notified in order to obtain ADOT permits, the time frame allotted for the project wouldn't allow it, as well as with geotechnical analysis for retaining walls.

1.1.3 Schedule and Cost of Services

Scheduling and project hours were completed on time for this project, with 666 completed hours out of the estimated 680 hours total. The team divided the schedule it into four parts: project management, research, analysis, and final design. Each member took on a different role each week, and can be seen in Table 1.1. Project Management includes all the initial meetings, a proposed schedule, and any initial documents needed to begin the project. Runoff Engineering's final hours can be seen in Table 1.2.

Each member of the team was assigned a different role to make the organization better. The Senior Engineer (SENG) will focus on everything that is needed to complete the final proposal and final design. The Engineer (ENG) will focus on doing research, gathering data, and all technical aspects of the project. The Lab Technician will focus on handling and working with anything that involves lab work. The Administrative Assistant (AA) will focus on editing the final proposal and website as well as arranging the presentation.

Table 1.1 - Projected Hours and Roles for FFFB Project

Project Management:	Meetings, Scheduling, Documentation			
Research:	Site evaluation, neighborhood survey, codes/legal standards			
Analysis:	Surveying, Geotechnical, Hydrological, Environmental			
Final Design:	Final Proposals, Presentation, Website			
Task	**SENG**	**ENG**	**LAB**	**AA**
Project Management -Meetings -Scheduling -Documentation	22	14	14	20
Research -Site evaluation -Neighborhood survey -Codes/legal standards	15	65		10
Analysis -Surveying -Geotechnical -Hydrological - Environmental		220	80	
Final Design -Final Proposals -Presentation -Website	160	40		20
Subtotal	197	339	94	50
Total (hrs)	**680**			

Table 1.2 - Final Hours for FFFB Project

Task	SENG	ENG	LAB	AA
Project Management **-Meetings** **-Scheduling** **-Documentation**	26	75	14	20
Research **-Site evaluation** **-Neighborhood survey** **-Codes/legal standards**	25	75		10
Analysis **-Surveying** **-Geotechnical** **-Hydrological -** **Environmental**		121	80	
Final Design **-Final Proposals** **-Presentation** **-Website**	160	40		20
Subtotal	211	311	94	50
Total (hrs)	**666**			

Based on the estimated vs. actual total hours completed by each role of Runoff Engineering, Table 1.3 and Table 1.4, respectively, were generated in order to assess the cost of engineering services. The total cost, including overhead, software costs, and travel, totaled $68,282.00 for the estimated cost, and $69,122.00 for the actual cost. Due to the nature of engineering services, and a difference less than 10% ($840.00 difference due to SENG hours), Runoff Engineering, Inc. came within an acceptable cost difference.

Table 1.3 – Estimated Cost of Services

Cost Estimate for Engineering Services				
1.0 Personnel	Classification	Hours	Rate ($/hr)	Cost
	SENG	197	194	$38,218.00
	ENG	339	67	$22,713.00
	LAB	94	48	$4,512.00
	AA	50	56	2,800.00
	Total Personnel			$68,243.00
2.0 Travel	7 Meetings @ 10mi/Meeting	$0.56/mi		$39.00
3.0 Total				$68,282.00

Table 1.4 - Actual Cost of Services

Cost Estimate for Engineering Services				
1.0 Personnel	Classification	Hours	Rate ($/hr)	Cost
	SENG	211	194	$40,934.00
	ENG	311	67	$20,837.00
	LAB	94	48	$4,512.00
	AA	50	56	2,800.00
	Total Personnel			$69,083.00
2.0 Travel	7 Meetings @ 10mi/Meeting	$0.56/mi		$39.00
3.0 Total				$69,122.00

Based on the hours completed, the following schedule, seen in Table 1.4, shows the project was completed on time, with one delay. There was a week delay with the scheduled surveying of the property due to technical difficulties with software, however, the team had implemented one week of float between surveying and beginning the design alternatives section. For this reason, the delay of the surveying did not affect any other scheduling of subsequent tasks, and no additional costs were incurred.

Table 1.5 - Completed Schedule

Items		Dates		Delayed
1.0	Neighborhood Survey (Interviews)	11/2/15 - 11/20/15		On Time
1.1	Interview Neighboring Companies			
1.2	Observe Surrounding Drainage Conditions			
2.0	Researching Permitting/Standards/Codes	1/25/16 - 2/15/16		
2.1	Obtain Flagstaff City Drainage Codes			
2.2	Obtain ADOT Drainage Codes for Near Highways			
2.3	Obtain Property Right Information For Ownership			
3.0	Surveying	2/1/16 - 2/15/16		
3.1	Surveying Property			
3.2	Generate Topographic Maps of Property			
4.0	Design Alternatives	2/22/16 - 4/11/16		
4.1	Hydrologic and Hydraulic Modeling			
4.2	Stormwater Runoff Evaluation			
4.3	Geotechnical Constraints (Retaining Walls)			
4.4	Economic Analysis			
5.0	Project Management	1/25/16 - 5/12/16		
5.1	Project Schedule			
5.2	Website			
5.3	50% Design Report			
5.4	Final Design Report			
5.5	Final Presentation			

2.0 Topographical Analysis

A topographic survey was conducted on the FFFB property. After conducting the survey, a topographic map was generated using AutoCAD Civil 3D. The raw data points used in the creation of the topographic map can be found in Appendix A. The topographic map can be seen in Figure 2.1.

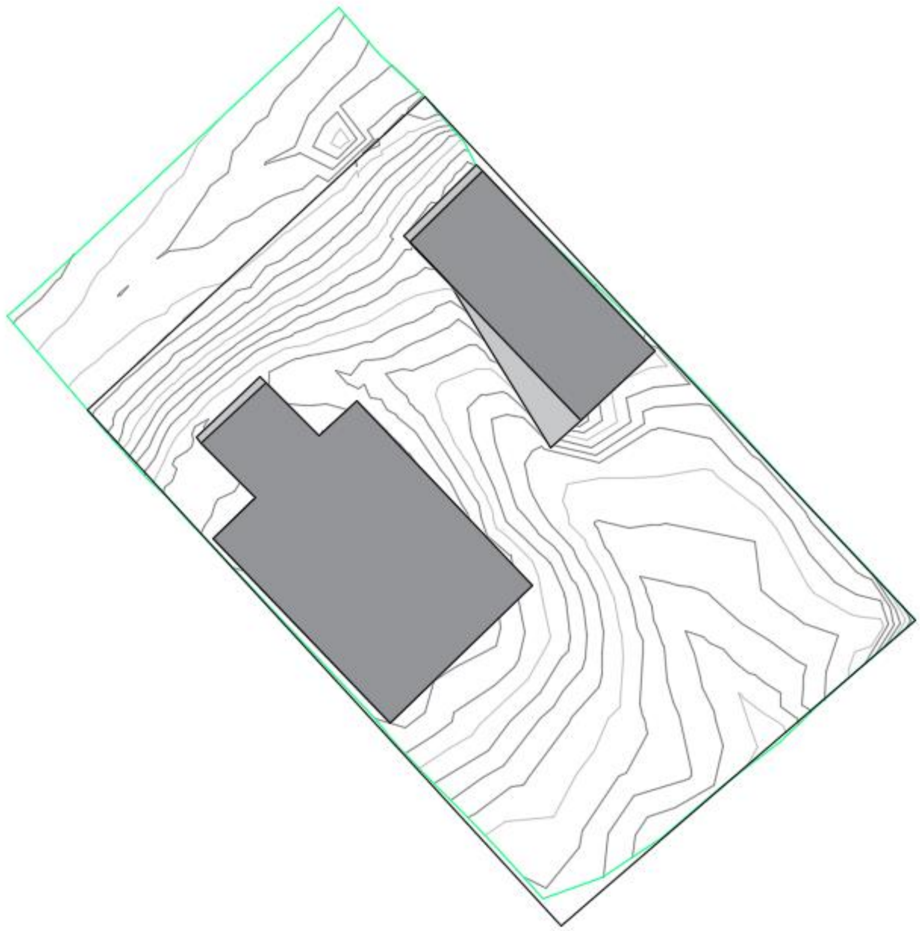


Figure 2.1 - Topographic Map of FFFB Property

The topographic map aided in the analysis of natural flows of stormwater runoff, low points where ponding occurs, building locations and other permanent structures, potential cut/fill values for design alternatives, and slopes of the existing property for hydrological analysis. From the topographic map, it was found that the slope in front of the main building contributes to the flooding issue, as can be seen from the topography of the landscape in Figure 2.1. This creates as a ponding area for the water to form between the slope and the office, causing damages to the property.

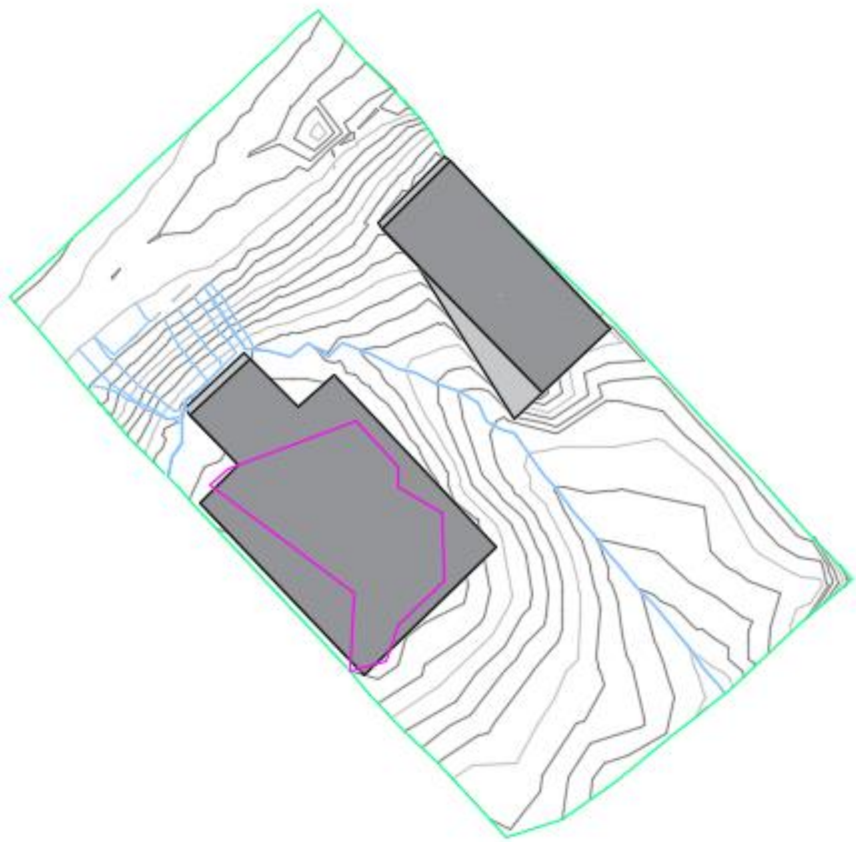


Figure 2.2 - Topographic Map with Critical Catchment/Ponding

Figure 2.2 illustrates where the critical catchment, or ponding, areas are in regards to the existing topography of the site, highlighted in purple. Additionally, the blue lines represent the natural path of the water given the existing topography of the site. It can be seen that the natural catchment area would be where the FFFB building is located, with natural flows that stream from the road directly to the building.

3.0 Hydrological Analysis

The City of Flagstaff Stormwater Management Design Manual was utilized to ensure the CoF standards and procedures for hydrologic analysis were adhered to. From the design manual, the rational formula was implemented to calculate the flow on the FFFB property, and, the sheet flow travel time formula for the area in front of the building. The precipitation data was gathered from NOAA Atlas 14 [1] and the evaluation of a 10 year storm was conducted, per the City of Flagstaff Stormwater Management Design Manual. The following equations were used in the hydrologic calculations for the FFFB site:

Equation 1 $$\boldsymbol{Q = CC_tIA}$$

Q = Maximum Rate of Runoff (ft^3/s)
C = Runoff Coefficient
C_t = Antecedent Precipitation Factor
I = Runoff Intensity (in/hr)
A = Drainage Area Tributary to Design Location (acre)

Equation 2: $$\boldsymbol{T_t = \left[0.007(nL)^{0.8}/(2.0)^{0.5}S^{0.4}\right]}$$

T_t = Sheet Flow Travel Time (hr)
n = Mannings roughness coefficient
L = flow length (ft)
S = land slope (ft/ft)

The runoff calculations encompass the entire property, and the sheet flow travel time is taken from the front of the property where the flooding occurs. A coefficient of 0.825 for asphalt, 1.1 for the antecedent precipitation factor, a runoff intensity of 1.45 in/hr [1], and an area of 1.56 acres were utilized based off CoF recommendations. This yielded a runoff flow of 2.06 ft^3/s.

To calculate sheet flow travel time directly in front of the food bank the Manning's Roughness Coefficient of 0.011 was used, the length from the road to the front of the building was 40.3 ft, and from the topography obtained through surveying, a slope of 0.1 was found. This yielded a sheet flow travel time of 0.0065 hr, or 23 sec, for the front of the FFFB property.

The annual rainfall for the monsoon months of July and August was also tabulated, seen in Figure 3.1, using data from NOAA Atlas 14. Figure 3.1 indicates that the rainfall is significant during the years of 2013 and 2014, with a slight dissipation in 2015. This same pattern can be expected to repeat in the years ahead. Additionally, rainfall in August has become more significant over the last 4 years, and this pattern is expected to repeat itself.

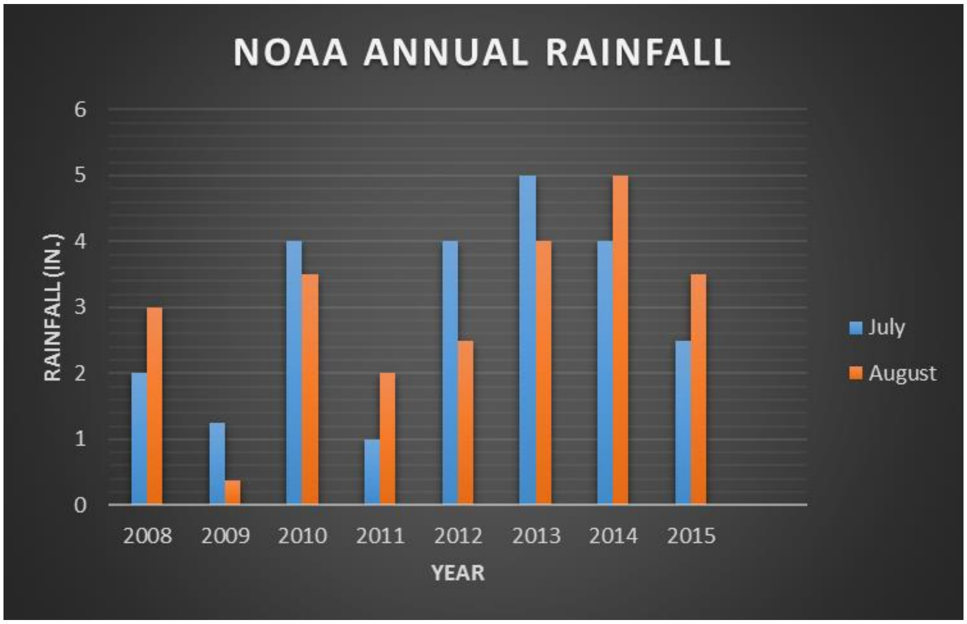


Figure 3.1 - NOAA Annual Rainfall for July and August

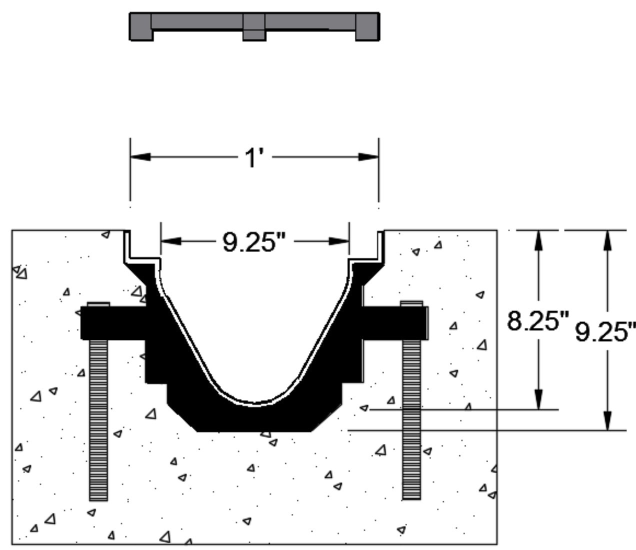
With a known flow of 2.06 ft^3/s coming into the property, Runoff Engineering was able to calculate and analyze different stormwater conveyance systems to alleviate the calculated incoming flow. Because partially full flowing pipes is one of the most common means of flood remediation of a project of this scale, the team calculated pipe sizes that would be able to handle the incoming flow and divert the water off the property according to CoF codes and standards. It was found that a pipe diameter of 12 inches with a design slope of 1% would be needed in order to achieve such results, see Appendix D for calculations. Also from Appendix D are the factor of safety checks for potential retaining walls using an excel calculator based in the Terzaghi method. While geotechnical analysis and subsequent retaining wall refinement is an exclusion for Runoff Engineering, Inc., the sizing of a retaining wall was needed in order to determine overall costs of the flood remediation designs. Section 4.0 will discuss how this information will be used for design alternatives.

4.0 Design Alternatives

Design alternatives have been developed in order to assess the most effective solutions to alleviate the flooding on the FFFB property. The main priority of the FFFB project is to eliminate the ponding and flooding that occurs near the front of the FFFB property. Before a design alternative can be installed, the current slope at the front of the main office must be removed. This will be done by cutting out the current slope for a more favorable slope, in order to control the flow at the front of the property and to mitigate flooding. Once the surface is regraded, design alternatives can be employed. For these design alternatives, Runoff Engineering is proposing two designs: a commercial drain with retaining wall, and a valley gutter with a retaining wall.

4.1 Commercial Drain with Retaining Wall Design Alternative

The first design alternative analyzed was a commercial drainage system with retaining wall. In order to compensate for the 4 foot cut in elevation, and to hold back East Huntington Drive, a retaining wall will be designed and installed at the northwest corridor of the FFFB property, along East Huntington Drive and the adjacent property. In order to divert water away from the main building, a commercial drainage system was chosen specifically to handle demand flows calculated from the hydrological analysis. The commercial drains will be provided by Zurn Industries, a third party engineering contractor that specializes in commercial drainage. From their extensive catalog, Runoff Engineering chose their model 8203 which will be able to handle a flow of 2.226 ft^3/s, which exceeds the 2.06 ft^3/s flow demand on site. Figure 4.1 shows the model 8203 chosen for this design. Furthermore, the commercial drainage will have a 1.04% slope in order to direct water off site. Figure 4.1 illustrates the commercial drainage system design. The highlighted region represents the area that will need to be regraded. It was calculated that approximately 300 cubic yards of soil would have to be removed. The Blue arrows in Figure 4.2 illustrates the path of the water after regrading and installation of the drainage system. It is important to note that the new driveway surface will have a 1% slope toward the commercial drain in order to divert water away from the building and into the drain. Water will enter the drain, then transfer from the drain to an underground pipe network, which will direct the water offsite. A final evaluation of this design is conducted in Section 5.0.



Trench No.	Shallow Inv.	Deep Inv.	Flow (cfs)
8203	8.25"	9.25"	2.226

Figure 4.1 - Cross Sectional View of Commercial Drain

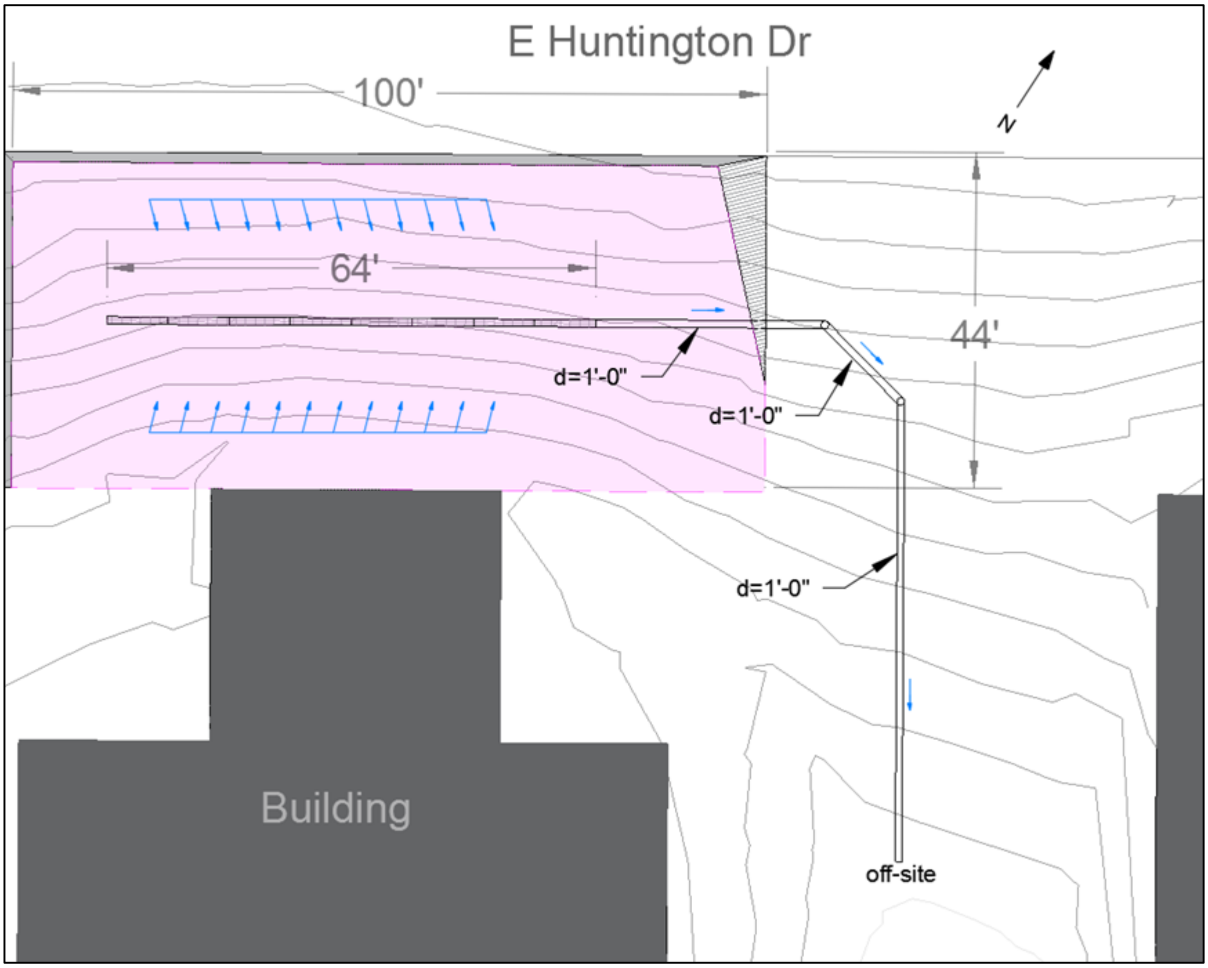


Figure 4.2 - Plan View of Commercial Drain with Retaining Wall

4.2 Valley Gutter with Retaining Wall Design Alternative

The second design alternative analyzed was a valley gutter system with retaining wall. As with the previous design, a retaining wall will be installed at the northwest corridor of the FFFB property, along East Huntington Drive and the adjacent property, in order to compensate for the change in elevation and to hold back East Huntington Drive. In order to divert water away from the main building, a valley gutter was designed specifically to handle demand flows calculated from the hydrological analysis. The dimensions for the valley gutter were determined by calculating the cross sectional area based on the known demand discharge and velocity. The dimensions for the valley gutter are shown in Figure 4.3. The valley gutter will have a 1% slope in order to direct water off site. Figure 4.4 illustrates the plan view of the valley gutter and retaining wall design. The highlighted region represents the area that will need to be regraded. It was calculated that approximately 300 cubic yards of soil would have to be removed. The blue arrows illustrate the path of the water after regrading and installation of the valley gutters. It is important to note that the new driveway surface will have a 1% slope toward the valley gutter in order to divert water away from the building and into the gutter. Water will enter the gutter and be directed offsite. A final evaluation of this design is conducted in Section 5.0.

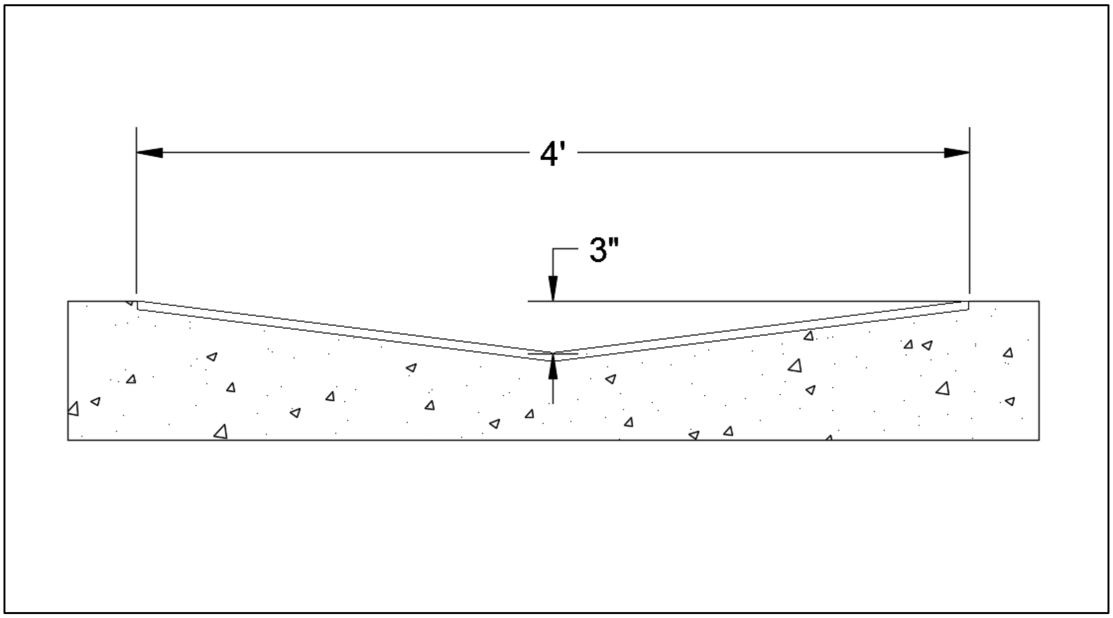


Figure 4.3 - Cross Sectional View of Valley Gutter

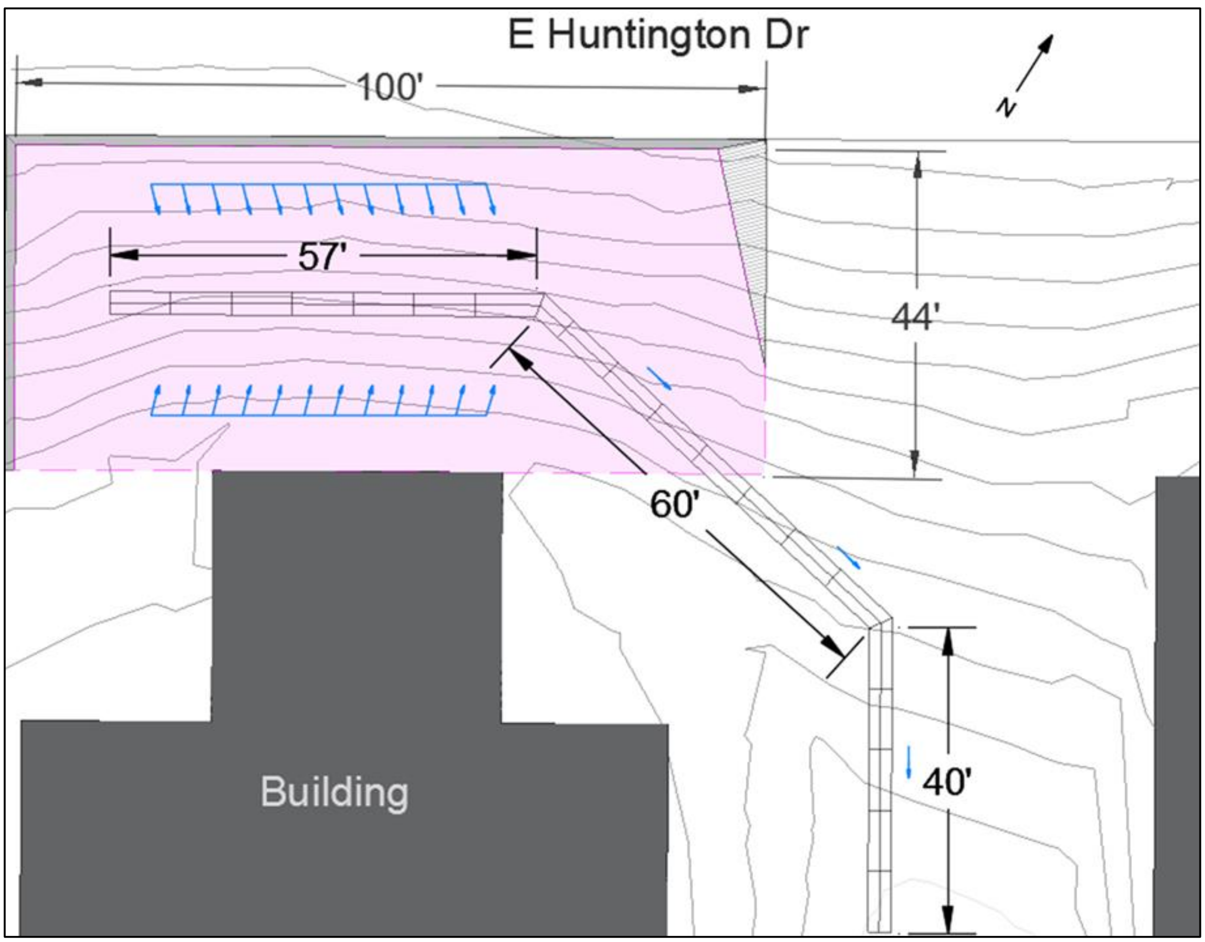


Figure 4.4 - Plan View of Commercial Drain and Retaining Wall Design

4.3 Recommendations to the City of Flagstaff

A synopsis of recommendations intended for the CoF are addressed, which include: curb expansion and gutter, and the implementation of a new retention basin near the FFFB site. These additional alternatives are addressed in order to benefit the entire area on Huntington Drive, because flooding is not only an issue on the FFFB property, but an issue for the neighboring properties. In the past, the CoF has developed recommendations and designs to resolve the flooding problem in regards to the FFFB. For the past several years, flooding has been known to occur not only at the FFFB, but at the neighboring properties as well due to a local catch basin. During high intensity rain events, the catch basin overflows with runoff along E. Huntington Rd. Water accumulates around the catch basin and eventually spreads across the road and onto the neighboring properties. In 2013, the Stormwater Project Manager addressed the concern the FFFB had about the flooding issue, seen in Appendix B. Within this document the Stormwater Project Manager explains the source of the flooding issue and more importantly the recommendation to fix the problem. Since the flooding within the vicinity of the FFFB is shared with neighboring properties, it is a recommendation to the CoF that the catch basin be resized to fit the amount of runoff and that it be properly maintained by the CoF and to refer to the Standard Specifications and Details for the Public Works Construction [2] by the Maricopa Association of Government Specifications (MAG SPECS) for catch basin size and materials. The details within the MAG SPECS are currently followed by the CoF, therefore specifications should be followed accordingly. Another CoF design recommendation is the design submitted by the stormwater division at the CoF. Figure 4.5 illustrates the AutoCAD schematic that details the design.

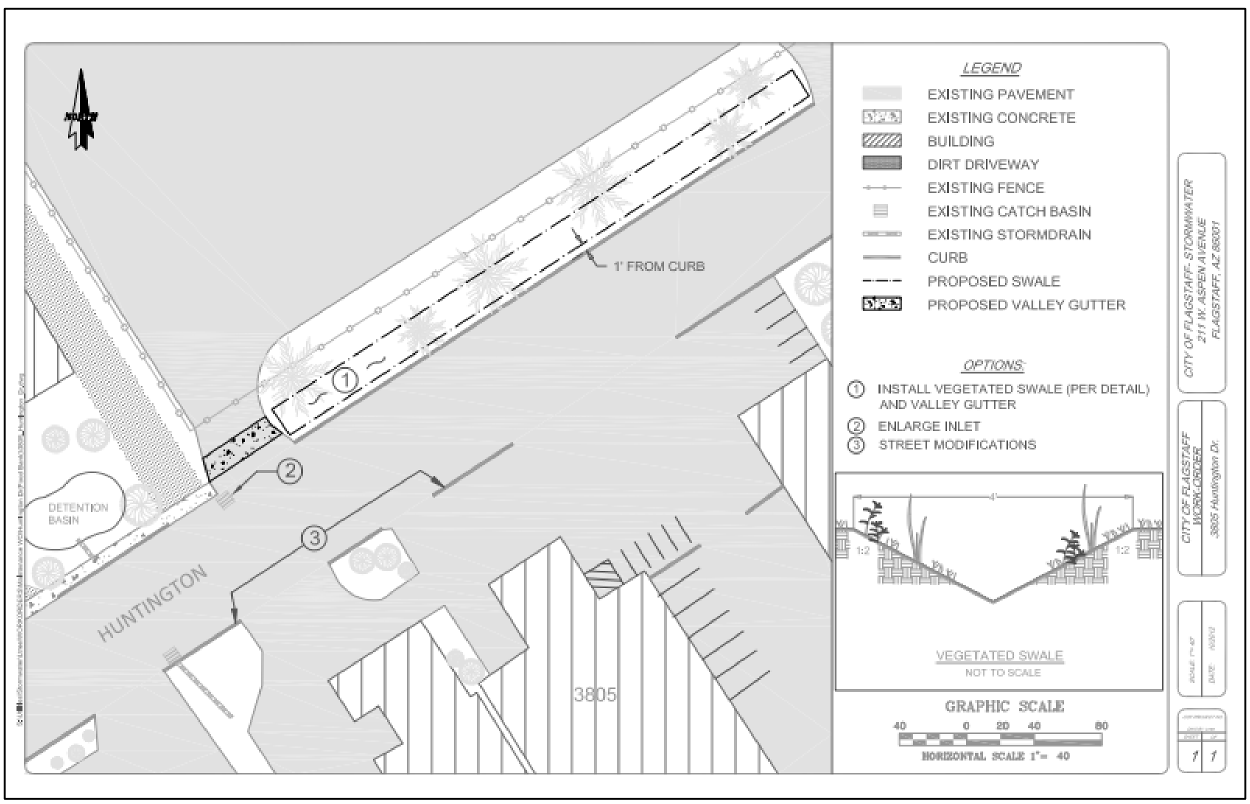


Figure 4.5 - Stormwater Division Detailed AutoCAD Drawing

5.0 Design Assessment

The purpose of the FFFB project is to alleviate the flooding occurring. The client requested that more than one final design option be presented. In order to meet these demands and to ensure flexibility, Runoff Engineering did not select a final design. However, Runoff Engineering has further assessed the design options, in order to assist the client in selecting a design to best suit their needs. Figure 5.1 illustrates the benefits and disadvantages of each design alternative.

Table 5.1 – Benefits vs. Disadvantages of Design Options

Pros and Cons of Design Alternatives		
Design	Benefits	Disadvantages
Commercial Drain w/ Retaining Wall	1. Meets conveyance 2. Runoff is contained 3. Long design lifespan	1. Higher cost 2. Maintenance
Valley Gutter w/ Retaining Wall	1. Cost Efficient 2. Meets and exceeds conveyance	1. Shorter design lifespan 2. Does not contain runoff efficiently

Design option 1, commercial drain with retaining wall, is beneficial because it meets conveyance, it contains the runoff completely, and has a long design lifespan. However, this design trades performance and efficiency with cost and maintenance. Of the two design options, this design will be more expensive to implement and will require periodic maintenance to ensure peak performance. However, of the two options, this design will prove most effective in containing the flow and ensuring it is not disturbed by outside influences such as high volume traffic. From Table 5.2 it can be seen that the overall cost of implementation will be $63,766.00. Some of the larger costs are due to excavation, and the cost of materials for a commercial drainage system.

Table 5.2 – Cost of Implementation of Design 1

Economic Analysis - Design 1				
Task #	Task Describtion	Units	Price/Unit	Total
1	**Excavation**			
	Cut/Fill	8654 ft^3	$2.54 per cub/ft	$22,000
	Repave	3904 ft^2	$3.50 per sq/ft	$13,000
2	**Retaining Wall**			
	Construction			$13,700
	Materials		30-40 per sq/ft	
3	**Drainage Pipes**			
	Commerical		70 plf	$5,600
	Pipe		20 plf	$5,800
4	**Guard Rail**			
	Construction	94.5 ft	$39.00 per ft	$3,666
			TOTAL	$ 63,766.00

Design option 2, a valley gutter with a retaining wall, benefits the client because it is the more cost effective option of the two designs. Furthermore, the design meets and exceeds conveyance. Because the design is open channel and contains the water at the surface, it can handle a slightly larger flow than the commercial drain. However, this does not mean that it is as effective in handling the flow as design option 1. The FFFB is a high traffic area for semi auto trucks. Because the flow will be exposed at the surface, the traffic will disturb the flow and decrease the effectiveness of the valley gutter. Furthermore, the gutter itself will be made of concrete surrounded by asphalt. Over time, the weight from the semi-trucks driving over the gutter may cause the rigid concrete to counteract with the flexible asphalt, causing it to wear and crack, leading to a shorter design lifespan. From Table 5.3 it can be seen that the cost of design option 2 is $7,800.00 cheaper than design option 1, with an overall cost of $55,966.00. While both designs have the same costs for excavation, retaining wall, and guard rail, the majority of the savings is due to the constructability and cost of materials for valley gutters.

Table 5.3 – Cost of Implementation of Design 2

Economic Analysis - Design 2				
Task #	Task Describtion	Units	Price/Unit	Total
1	**Excavation**			
	Cut/Fill	8654 ft^3	$2.54 per cub/ft	$22,000
	Repave	3904 ft^2	$3.50 per sq/ft	$13,000
2	**Retaining Wall**			
	Construction			$13,700
	Materials		30-40 per sq/ft	
3	**Valley Gutter**			
	Construction			
	Materials		10 plf	$3,600
4	**Guard Rail**			
	Construction	94.5 ft	$39.00 per ft	$3,666
			TOTAL	$ 55,966.00

6.0 References

[1] NOAA, "NOAA's National Weather Service - Hydrometerological Design Studies Center," NOAA, 2016. [Online]. Available: http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=pa. [Accessed 1 March 2016].

[2] (January 2016). Publications. Available: https://www.azmag.gov/Communications/publications.asp.

[3] Asahi /America, "Introduction," in *Engineering Design Guide.* Malden, MA: 2013, pp. 11.

[4] (2016). What is Galvanized Steel [Galvanized Steel]. Available: http://www.wisegeek.com/what-is-galvanized-steel.htm#comments.

7.0 Appendices

Appendix A

Point Number	Easting	Northing	Point Elevation	Point Number	Easting	Northing	Point Elevation
1	4889.7982'	4905.3326'	999.67'	100	4980.9166'	4953.5471'	997.91'
2	4874.5987'	4923.9589'	1000.27'	101	4967.6675'	4943.4333'	997.60'
3	4855.6199'	4945.4316'	999.39'	102	4954.8210'	4932.2607'	997.27'
4	4867.1389'	4956.0142'	999.34'	103	4946.8736'	4925.5961'	997.19'
5	4886.6275'	4935.8862'	1000.33'	104	4938.8894'	4919.4657'	997.25'
6	4903.2144'	4917.8233'	999.65'	105	4930.9960'	4912.8782'	997.21'
7	4911.6279'	4925.0884'	999.65'	106	4923.6836'	4905.9813'	997.20'
8	4911.4861'	4925.3986'	1000.13'	107	4916.6513'	4899.3634'	997.53'
9	4911.1824'	4925.7555'	999.63'	108	4909.8166'	4892.5716'	997.82'
10	4895.5025'	4944.5548'	1000.39'	109	4906.2990'	4886.9196'	997.70'
11	4876.1559'	4964.4333'	999.39'	110	4911.0537'	4881.4333'	996.89'
12	4886.3078'	4973.9467'	999.53'	111	4919.3800'	4889.0025'	996.65'
13	4903.7800'	4955.0895'	1000.51'	112	4926.3209'	4896.2652'	996.27'
14	4920.9600'	4934.8865'	999.65'	113	4932.8770'	4902.3257'	996.27'
15	4921.3754'	4934.7087'	1000.13'	114	4940.0166'	4909.9266'	996.23'
16	4921.7092'	4934.4776'	999.73'	115	4947.6115'	4917.1254'	996.33'
17	4931.5671'	4943.7221'	999.84'	116	4954.4982'	4923.2819'	996.38'
18	4931.4709'	4943.9126'	1000.30'	117	4961.9866'	4929.8585'	996.45'
19	4931.0661'	4944.2644'	999.81'	118	4968.9338'	4935.9745'	996.70'
20	4913.2530'	4964.6656'	1000.49'	119	4980.3734'	4946.8714'	997.11'
21	4896.3465'	4983.1888'	999.64'	120	4992.1734'	4957.6973'	997.62'
22	4906.7995'	4993.0310'	999.64'	121	5003.3589'	4968.4611'	997.82'
23	4924.9158'	4974.2076'	1000.51'	122	5014.6121'	4978.8085'	997.91'
24	4942.3562'	4954.1983'	999.89'	123	5025.8852'	4989.6823'	997.56'
25	4951.0729'	4962.3892'	1000.05'	124	5036.5280'	4999.6590'	997.37'
26	4935.0180'	4980.9022'	1000.68'	125	5047.8108'	5008.9978'	997.16'
27	4915.3840'	5001.0237'	999.72'	126	5052.0191'	5013.2017'	997.11'
28	4926.2685'	5011.0833'	999.75'	127	5055.6462'	5008.6268'	996.73'
29	4944.6686'	4992.7647'	1000.73'	128	5048.5974'	5001.8893'	996.71'
30	4962.5436'	4973.1235'	1000.13'	129	5037.9554'	4991.9852'	996.83'
31	4973.2453'	4982.9664'	1000.15'	130	5026.5541'	4981.2960'	997.02'
32	4957.0582'	5000.4040'	1000.79'	131	5014.6415'	4970.0210'	997.52'
33	4937.2482'	5021.4543'	999.95'	132	5001.8467'	4958.0529'	997.18'
34	4948.1935'	5031.5403'	1000.01'	133	4994.8426'	4951.4748'	997.01'
35	4967.2544'	5011.4959'	1001.02'	134	4985.7334'	4943.2783'	996.64'
36	4983.5310'	4992.6647'	1000.24'	135	4979.0930'	4935.9038'	996.32'

37	4992.6621'	5001.6685'	1000.28'	136	4970.6876'	4928.3859'	995.90'
38	4992.9553'	5001.4755'	1000.43'	137	4963.3377'	4921.9220'	995.75'
39	4993.2072'	5001.3069'	1000.23'	138	4956.0635'	4915.0921'	995.65'
40	4979.9893'	5016.9520'	1001.05'	139	4950.1184'	4909.6452'	995.56'
41	4958.4383'	5041.1947'	1000.11'	140	4943.6389'	4903.6143'	995.55'
42	4968.6089'	5050.6589'	1000.19'	141	4936.9942'	4897.3743'	995.38'
43	4987.6206'	5031.2602'	1001.08'	142	4932.8210'	4893.5795'	995.59'
44	5004.7007'	5012.9894'	1000.25'	143	4926.5138'	4887.0036'	995.75'
45	5005.1120'	5012.7638'	1000.74'	144	4918.9785'	4879.9565'	996.29'
46	5005.4088'	5012.6738'	1000.31'	145	4915.6580'	4876.4627'	996.39'
47	5014.8614'	5021.4204'	1000.40'	146	4964.5325'	4911.1192'	995.76'
48	5014.5320'	5021.5333'	1000.88'	147	4970.7844'	4904.1499'	995.57'
49	5014.1157'	5021.8962'	1000.32'	148	4976.8103'	4898.1938'	995.60'
50	4995.9659'	5038.8807'	1001.13'	149	4981.7872'	4893.1558'	995.57'
51	4977.7039'	5059.0876'	1000.18'	150	4983.7110'	4903.6380'	995.58'
52	4989.6261'	5070.1351'	1000.27'	151	4985.9017'	4895.0578'	995.75'
53	5008.7023'	5049.4090'	1001.15'	152	4987.1241'	4908.2711'	995.48'
54	5025.4231'	5032.5091'	1000.32'	153	4980.8693'	4902.0761'	995.55'
55	5025.6464'	5032.1330'	1000.89'	154	4981.9184'	4913.4384'	995.38'
56	5025.8996'	5031.8330'	1000.42'	155	4976.2253'	4907.6273'	995.51'
57	5034.8770'	5040.1901'	1000.97'	156	4975.0978'	4920.6452'	995.11'
58	5034.5884'	5040.3529'	1000.97'	157	4969.3857'	4914.6610'	995.45'
59	5034.1683'	5040.7040'	1000.43'	158	4981.8582'	4925.7676'	995.29'
60	5015.6116'	5058.4213'	1001.23'	159	4975.8810'	4931.4577'	995.95'
61	4998.2048'	5078.0292'	1000.38'	160	4988.3423'	4931.1675'	995.67'
62	5039.0517'	5033.8624'	1000.85'	161	4988.2238'	4931.9224'	995.76'
63	5028.4466'	5023.7089'	999.91'	162	4993.4404'	4924.4123'	995.04'
64	5017.4203'	5013.1556'	999.68'	163	4995.1665'	4939.2823'	996.11'
65	5006.6592'	5002.3625'	999.72'	164	5001.9263'	4931.5683'	995.46'
66	4995.8062'	4992.3090'	999.74'	165	5001.6519'	4945.4087'	996.35'
67	4983.7358'	4981.0856'	999.66'	166	5009.5698'	4937.5211'	995.66'
68	4971.8126'	4969.5027'	999.55'	167	5009.4119'	4951.9096'	996.60'
69	4960.3174'	4958.0574'	999.48'	168	5016.9799'	4943.9609'	995.82'
70	4947.8449'	4947.3573'	999.26'	169	5016.0981'	4958.5917'	996.79'
71	4936.2667'	4936.1215'	999.09'	170	5023.7239'	4950.2988'	995.96'
72	4925.0524'	4923.3957'	998.79'	171	5023.3811'	4964.4413'	996.72'
73	4913.2733'	4913.0294'	998.87'	172	5030.7267'	4956.4710'	996.11'
74	4900.6668'	4901.6161'	999.09'	173	5030.9320'	4970.4278'	996.89'
75	4895.7893'	4898.3251'	999.20'	174	5037.7283'	4963.5643'	996.24'
76	4901.4699'	4892.8653'	998.80'	175	5043.3418'	4957.7249'	996.01'
77	4908.1183'	4898.3574'	998.22'	176	5035.7488'	4950.7180'	995.69'

78	4914.1304'	4903.3162'	998.01'	177	5029.2427'	4944.3039'	995.56'
79	4920.8525'	4910.0713'	997.89'	178	5022.6008'	4937.5089'	995.33'
80	4927.0308'	4916.4972'	997.97'	179	5015.7713'	4930.9925'	995.27'
81	4933.8035'	4923.4198'	998.03'	180	5009.3247'	4924.6595'	994.87'
82	4940.6587'	4930.1167'	998.14'	181	5003.0524'	4918.1082'	994.91'
83	4946.1724'	4935.8857'	998.33'	182	5008.4029'	4912.2855'	995.07'
84	4951.0049'	4942.8955'	998.73'	183	4998.9249'	4909.8732'	995.36'
85	4958.3114'	4950.2172'	998.89'	184	5003.2850'	4906.5744'	995.48'
86	4970.5757'	4960.5544'	998.86'	185	5027.6815'	4978.3966'	997.10'
87	4982.7692'	4970.7869'	999.14'	186	5043.0492'	4992.7219'	996.86'
88	4994.7428'	4980.1901'	999.11'	187	5038.5419'	4966.9590'	996.58'
89	5006.6433'	4990.4917'	999.07'	188	5058.4734'	5007.3882'	996.79'
90	5018.6041'	5000.7372'	998.73'	189	5055.9989'	4948.3406'	995.82'
91	5030.1667'	5010.9119'	998.71'	190	4959.5526'	4912.9302'	995.71'
92	5042.1142'	5023.8027'	998.85'	191	5079.4832'	4923.0909'	995.62'
93	5046.1624'	5027.1284'	999.35'	192	4947.0385'	4901.3598'	995.77'
94	5051.6265'	5020.6563'	997.82'	193	5099.7416'	4901.4549'	995.45'
95	5041.1225'	5009.8525'	997.76'	194	4934.8352'	4889.9224'	995.55'
96	5029.4546'	4998.2343'	997.78'	195	5016.3257'	4887.9382'	995.79'
97	5017.8739'	4986.6380'	998.07'	196	5035.7783'	4867.3094'	995.79'
98	5005.3415'	4975.3695'	998.19'	197	5055.3744'	4846.2142'	995.34'
99	4993.4007'	4964.1415'	998.08'	198	5069.3032'	4858.3079'	993.52'
Point Number	Easting	Northing	Point Elevation	199	5076.2498'	4864.9230'	992.84'
200	5071.5275'	4842.7740'	994.53'	Point Number	Easting	Northing	Point Elevation
201	5082.1843'	4870.5672'	992.40'	300	5204.7992'	4779.6373'	991.43'
202	5079.7249'	4850.6096'	993.35'	301	5187.6848'	4763.3793'	989.79'
203	5089.6542'	4860.0057'	992.31'	302	5162.0364'	4743.5745'	990.36'
204	4985.9426'	4918.3576'	995.08'	303	5136.3662'	4721.7417'	990.01'
205	4993.5059'	4909.6804'	995.47'	304	5111.1172'	4704.5679'	991.02'
206	5047.5381'	4947.7613'	995.14'	305	5085.8233'	4695.9644'	991.45'
207	5053.2133'	4938.6889'	994.75'	306	5066.6619'	4716.3371'	991.57'
208	5058.3012'	4931.0334'	994.40'	307	5054.0376'	4730.4053'	992.48'
209	5062.8990'	4934.5650'	995.12'	308	5037.2355'	4746.2729'	993.59'
210	5063.2325'	4923.1788'	994.00'	309	5022.8316'	4761.7752'	994.80'
211	5068.4067'	4928.2214'	994.98'	310	5013.4728'	4772.9800'	995.01'
212	5068.0933'	4915.7027'	993.62'	311	5035.4119'	4793.9887'	995.19'
213	5074.4303'	4920.9663'	994.88'	312	5057.0922'	4814.3441'	995.50'
214	5073.6576'	4907.0623'	993.26'	313	5093.7679'	4857.1902'	992.14'
215	5080.2663'	4912.0069'	994.47'	314	5101.9815'	4864.1823'	991.73'

216	5079.2636'	4898.3184'	992.81'	315	5109.1622'	4870.1109'	991.85'
217	5086.6371'	4904.4243'	994.42'	316	5116.8411'	4862.4493'	991.67'
218	5085.9706'	4887.9830'	992.43'	317	5109.5806'	4855.6465'	991.42'
219	5093.7362'	4895.3811'	994.06'	318	5101.4689'	4847.4528'	992.20'
220	5078.3924'	4881.9350'	992.49'	319	5107.6669'	4839.2682'	992.11'
221	5076.6068'	4888.3216'	992.57'	320	5116.6889'	4846.2665'	991.23'
222	5071.9339'	4878.5339'	992.82'	321	5125.1454'	4852.1596'	991.44'
223	5063.9272'	4872.4558'	993.55'	322	5132.0895'	4844.0139'	991.24'
224	5057.0374'	4864.7169'	994.61'	323	5124.9481'	4836.8132'	991.07'
225	5051.1290'	4859.7246'	995.23'	324	5116.4203'	4829.4231'	991.84'
226	5041.2044'	4865.8541'	995.55'	325	5123.3111'	4821.6274'	991.55'
227	5043.8072'	4875.7079'	995.07'	326	5131.6563'	4828.6329'	990.87'
228	5052.7705'	4878.2889'	994.23'	327	5140.0606'	4834.4999'	991.10'
229	5059.6205'	4884.3906'	993.46'	328	5145.5396'	4828.3174'	990.95'
230	5066.7572'	4891.3398'	992.90'	329	5138.2403'	4820.8464'	990.65'
231	5072.4291'	4896.8743'	992.63'	330	5130.3000'	4812.6822'	991.17'
232	5068.8719'	4906.7120'	993.18'	331	5136.8767'	4804.4377'	991.02'
233	5063.1847'	4901.8255'	993.00'	332	5145.7921'	4811.7162'	990.52'
234	5057.0406'	4895.8188'	993.37'	333	5153.7400'	4803.0621'	990.36'
235	5051.3399'	4889.1439'	993.82'	334	5144.1428'	4796.1909'	990.75'
236	5044.2344'	4882.5059'	994.69'	335	5163.1411'	4810.6179'	990.77'
237	5037.3240'	4877.1300'	995.40'	336	5171.3833'	4801.3020'	990.75'
238	5025.5455'	4882.6183'	995.74'	337	5162.1474'	4793.4478'	990.18'
239	5030.7940'	4889.6561'	995.29'	338	5152.8654'	4785.8871'	990.55'
240	5037.6236'	4895.2648'	994.61'	339	5161.9835'	4776.3667'	990.40'
241	5045.0197'	4899.8391'	993.92'	340	5170.4997'	4782.8107'	989.98'
242	5052.5247'	4906.2953'	993.54'	341	5174.8635'	4787.6972'	990.37'
243	5059.2393'	4910.7482'	993.45'	342	5181.9755'	4777.5106'	990.19'
244	5057.3385'	4923.1171'	994.01'	343	5177.2784'	4773.9858'	989.83'
245	5050.6509'	4917.5155'	993.85'	344	5170.0158'	4767.3733'	990.22'
246	5043.8115'	4910.8429'	993.80'	345	5176.8324'	4759.9827'	990.03'
247	5035.8679'	4905.3279'	994.28'	346	5184.7735'	4765.2428'	989.72'
248	5031.3129'	4899.7052'	994.81'	347	5188.0583'	4768.7668'	989.90'
249	5028.0767'	4891.3697'	995.31'	348	5185.7720'	4762.5770'	989.60'
250	5020.4389'	4889.0149'	995.73'	349	5148.2125'	4748.4387'	991.05'
251	5020.8903'	4900.0031'	995.22'	350	5124.7305'	4772.1723'	991.64'
252	5014.1880'	4895.6333'	995.70'	351	5107.3847'	4788.5783'	992.63'
253	5027.5978'	4906.0790'	994.61'	352	5092.8372'	4807.0750'	993.80'
254	5035.2386'	4912.0144'	994.17'	353	5095.1018'	4825.7879'	993.49'
255	5043.4600'	4915.7274'	993.90'	354	5087.0592'	4839.3901'	993.64'
256	5050.6559'	4921.8971'	994.09'	355	5071.8821'	4796.7166'	994.63'

257	5058.4439'	4926.0817'	994.08'	356	5094.2367'	4773.9411'	992.62'
258	5044.4779'	4928.9659'	994.51'	357	5117.3770'	4749.7808'	991.57'
259	5052.8729'	4934.3793'	994.56'	358	5095.3168'	4725.4516'	991.80'
260	5037.5866'	4921.9102'	994.34'	359	5073.2187'	4748.3964'	992.66'
261	5031.3026'	4915.1819'	994.18'	360	5051.8018'	4769.4729'	994.26'
262	5024.2698'	4908.0786'	994.73'	361	5030.1290'	4777.1966'	995.22'
263	5015.5951'	4904.1974'	995.17'	362	5108.4781'	4795.5391'	992.65'
264	5010.6031'	4899.4217'	995.67'	363	5115.9226'	4810.2790'	992.21'
265	5005.5486'	4905.4823'	995.50'	364	5113.2267'	4825.8763'	992.18'
266	5009.9110'	4909.3599'	995.05'	365	5102.5183'	4842.7308'	992.29'
267	5016.1323'	4915.3080'	994.83'	366	5111.3632'	4879.9553'	992.08'
268	5021.7701'	4919.5254'	994.35'	367	5134.8236'	4899.5997'	992.55'
269	5028.8412'	4926.3319'	994.67'	368	5158.7051'	4876.0141'	991.89'
270	5037.1439'	4932.2291'	994.75'	369	5135.7990'	4854.0867'	991.45'
271	5044.1716'	4940.6911'	995.01'	370	5156.4397'	4831.1281'	991.10'
272	4956.9170'	4866.3119'	995.60'	371	5180.1447'	4852.1033'	991.57'
273	4946.1950'	4877.3747'	995.32'	372	5199.3530'	4825.7976'	991.85'
274	4948.7154'	4858.5247'	995.71'	373	5180.4076'	4804.5054'	990.89'
275	4935.4650'	4888.9243'	995.30'	374	5193.4120'	4790.7946'	990.80'
276	4940.1541'	4850.6480'	995.59'	375	5215.5618'	4812.1378'	991.63'
277	4928.2246'	4883.5620'	995.39'	376	5230.8854'	4822.3096'	992.44'
278	4922.3820'	4877.9009'	995.77'	377	5237.8485'	4816.0151'	993.45'
279	4918.4876'	4874.1171'	995.96'	378	5230.6353'	4812.3490'	991.78'
280	4924.5239'	4867.4838'	995.25'	379	4999.9580'	5021.1470'	1002.34'
281	4929.3525'	4862.3759'	995.09'	380	5000.0000'	5000.0000'	1000.00'
282	4934.5782'	4856.6999'	995.18'	381	4901.9139'	4905.0865'	999.06'
283	4940.4613'	4861.2388'	995.39'	382	5155.2624'	4816.0813'	990.74'
284	4945.6938'	4865.6148'	995.52'				
285	4942.0150'	4870.5737'	995.31'				
286	4936.5868'	4865.8460'	995.19'				
287	4931.0650'	4871.5764'	995.17'				
288	4935.8767'	4878.1732'	995.22'				
289	4932.7660'	4881.9862'	995.32'				
290	4915.8503'	4878.5492'	996.39'				
291	5115.8177'	4914.9994'	993.88'				
292	5131.3045'	4929.6891'	994.36'				
293	5135.8265'	4932.8528'	993.23'				
294	5156.9065'	4910.3920'	993.10'				
295	5178.0095'	4887.8250'	993.17'				
296	5200.8811'	4863.2176'	993.22'				
297	5224.5676'	4837.8776'	993.26'				

298	5245.4991'	4815.4490'	994.99'
299	5221.7144'	4794.9074'	992.24'

Appendix B

June 6, 2013

David L. Merritt
PO Box 1076
Carefree, AZ 85377

RE: Historic Flooding at 3805 E. Huntington Drive

Dear Mr. Merritt:

I am contacting you in regards to a significant flooding problem that has been occurring for several years at 3805 E. Huntington Drive adjacent to your property. This is the location of the Northern Arizona Food Bank. For the last several years, the Food Bank has experienced large volumes of stormwater runoff onto their lot and into their building as a result of monsoonal storm events in July and August. Flooding is the result of a historic undersized catch basin and stormdrain system on the north side of Huntington (see map with stormdrains). In addition to being undersized, the catch basin also becomes significantly clogged due to debris runoff from adjoining parcels, adding to increases in volume running onto 3805 E. Huntington.

In response to the Food Bank's concerns, the City of Flagstaff Stormwater Department is seeking a solution to alleviate the flooding at this location. We have proposed a solution to route excessive flows from Parcel 113-23-020 and landscapes to a detention basin that is located on your property just outside City right-of-way. This is the simplest and most cost-effective solution for the City to assist the Food Bank with their flooding concerns and improve flooding in this area.

In order to complete this project, we are requesting a Drainage Easement (DE) from you to use the detention basin on your property. It appears the detention basin is not being used to capture and hold stormwater runoff as it was designed for. The DE is granted to enable the COF to locate, operate, repair, replace, alter and maintain drainage services of all types. The DE is attached to this letter and will require your notarized signature before returning it to me. We have a notary in City Hall if it is easier for you to have it notarized there. You could also drop it off there for me, saving you postage.

If you have any questions, concerns, or prior knowledge regarding the detention basin, please feel free to contact me. We would greatly appreciate your help in solving this citizen flooding challenge.

Sincerely,

Kyle Brown
Stormwater Project Manager

cc: file

Appendix C

Flagstaff Family Food Bank – Flood Remediation Project

ERIK HENRICKSEN, ELENA SMITH, GARRETT RIBAS, MESHAL ALOTAIBI

Contents

Title 13
ENGINEERING DESIGN STANDARDS AND SPECIFICATIONS FOR NEW INFRASTRUCTURE

According to 13-08-001-0001 Stormwater Management

The design and construction of all public and private stormwater management facilities shall be in accordance with these regulations and with the City of Flagstaff Stormwater Management Design Manual and these Standards. In the event of a conflict, the more stringent regulation shall apply.

City of Flagstaff Stormwater Management Design Manual (2000)

Criteria That affects Design Based on Design Manual

- Chapter 2 Drainage Reports and Plans - presents criteria for submittals of drainage reports, floodplain studies, grading and drainage plans, and public drainage improvement plans.
    - 2.1 Drainage Report Requirements
        - 2.1.3 Drainage Report Content and Format
    - 2.3 Grading and Drainage Plans
        - 2.3.1 Grading and Drainage Plan Requirements
    - 2.4 Public Improvement Plans - Drainage Facilities

- Chapter 3: Hydrology - provides an overview of urban hydrologic methods and procedures which is intended to provide the design engineer with guidance to the methods and procedures, their data requirements, and their applicability and limitations.
    - 3.3 HEC-1 METHOD

- Chapter 5: Culverts - present policies and criteria for the design and construction of roadway culverts, which is based on FHWA (Federal Highway Administration) Hydraulic Design Series No. 5 (HDS-5), *Hydraulic Design of Highway Culverts,* 1985.
    - 5.1 Policies
    - 5.2 Culvert Design Criteria
        - 5.2.1 Design Storm Criteria
        - 5.2.3 Headwater and Tailwater Conditions

        - 5.2.4 Inlet and Outlet Treatment
        - 5.2.5 Culvert Material and Installation
    - 5.3 Culvert Design Procedure

- Chapter 6: Pavement Drainage - presents design criteria and procedures, street drainage requires consideration of surface drainage, gutter flow, and drainage inlet capacity. The design of these components is dependent upon the design frequency and the allowable spread of stormwater on the pavement surface.

  Effective drainage of urban streets is essential to the maintenance of roadway service levels and traffic safety. Water on streets can interrupt traffic, reduce skid resistance, increase the potential for hydroplaning, limit visibility due to splash and spray, cause difficulty in steering a vehicle, and cause a nuisance and possible hazard to pedestrian traffic.

    - 6.1 Policies
    - 6.2 Street and Gutter Drainage
        - 6.2.1 Design Frequency and Allowable Spread
        - 6.2.2 Longitudinal and Transverse Slope
        - 6.2.3 Gutter Flow
        - 6.2.4 Curb and Gutter Terminations
        - 6.2.5 Rural Street Drainage and Roadside Channels
    - 6.3 Drainage Inlets
        - 6.3.1 Inlet Types
        - 6.3.2 Allowable Spread and Flow Depth
        - 6.3.3 Inlet Locations
        - 6.3.4 Grate Inlets
        - 6.3.5 Curb Opening Inlets
        - 6.3.6 Combination Inlets
        - 6.3.7 Slotted Drain Inlets
        - 6.3.9 Inlet Clogging
    - 6.4 Inlet Spacing Procedure on Continuous Grade

- Chapter 7: Storm Drains - presents policies and criteria for the design and construction of public storm drain systems, while private storm drain systems should also be designed in accordance with this chapter to ensure continuity with public systems. Procedures for sizing storm drains and computing the energy losses and hydraulic grade line through a storm drain system are also presented.

Storm drains are generally that portion of roadway drainage system that are design to collect surface water through drainage inlets and convey the water through closed conduits to an outfall.

- 7.1 Policies
- 7.2 Storm Drain Design Criteria
    - 7.2.1 Design Velocity and Slope
    - 7.2.2 Alignment
    - 7.2.3 Storm Drain Conduit Size
    - 7.2.4 Storm Drain Conduit
    - 7.2.5 Separation Requirements
    - 7.2.6 Storm Drain Outfalls
- 7.4 Maintenance Considerations
- 7.5 Storm Drain Hydraulics
    - 7.5.1 Open Channel vs. Pressure Flow
    - 7.5.2 Hydraulic Capacity
- 7.7 Hydraulic Grade Line Evaluation
    - 7.7.1 Open Channel Flow
    - 7.7.2 Energy Losses
    - 7.7.3 Controlling Water Surface Elevation
    - 7.7.4 Hydraulic Grade Line Evaluation Procedure

- Chapter 8: Storage and Detention Facilities - provides policies for storage and detention facilities. In the absence of regional detention facilities and due to inadequate downstream capacities of existing streets, storm drain systems or channels, local on-site or sub-regional detention facilities are necessary to attenuate the increased runoff caused by development.

  Urbanization and other land development activities, including construction of roads, changes natural pervious areas into impervious, altered surfaces. In addition, natural drainage systems are often replaced by lined channels, storm drains, and curbed streets. The result of such activities is an increase in the volume of runoff, peak discharge rates, erosion, and non-point source pollution due to the reduction in infiltration and natural vegetation. The temporary storage of stormwater runoff can reduce the extent of downstream flooding, soil erosion, sedimentation, and surface water pollution. Detention facilities can also be used to reduce the costs associated with large storm drain systems.

    - 8.1 Policies
    - 8.3 Detention Volume Estimation

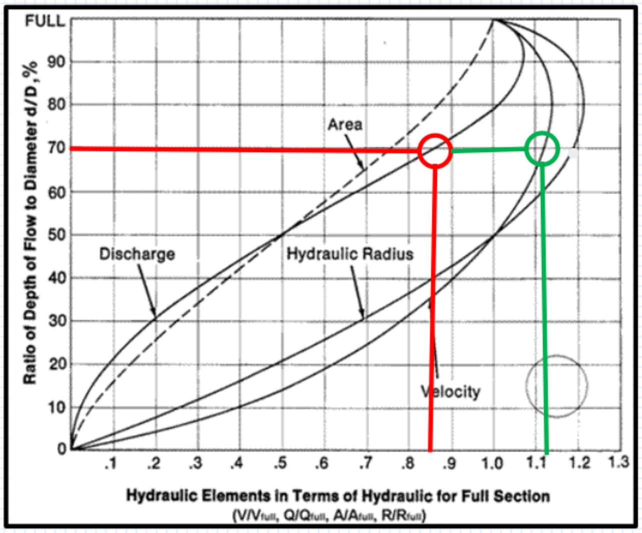
- Chapter 10: Erosion and Sediment Control - presents criteria that represents the minimum requirements necessary for controlling erosion and sedimentation from construction activities.
    - 10.1 Policies
    - 10.2 General Guidelines
    - 10.3 Design Criteria
        - 10.3.1 Stabilization
        - 10.3.2 Protection of Adjacent Property
        - 10.3.5 Vegetative Cover
        - 10.3.6 Storm Water Pollution Prevention Plans

- Chapter 11 Energy Dissipaters - presents information and design procedures which are based on FHQA, HEC-14, *Hydraulic Design of Energy Dissipaters for Culverts and Channels*.

  In general, an energy dissipater is any device designed to protect downstream areas from erosion by reducing the velocity of flow to acceptable limits. High exit velocities and flow expansion turbulence at conduit outlets often result in local scour, channel degradation, and conduit failure. Typical rock riprap aprons may be appropriate where moderate outlet velocities exist, however, they are not suitable for outlet velocities exceeding ten feet per second. Riprap basins or concrete energy dissipaters may be required to reduce high velocity outlet flows to acceptable limits.

    - 11.1 General
    - 11.2 Dissipater Type Selection
    - 11.3 Conduit Outlet Structures

Appendix D



Continuity and Manning Equation:

$$Q = VA = A\left(\frac{1}{n}\right)R^{2/3}S^{1/2}$$

$$\frac{Q_{actual}}{Q_{full}} = 0.85$$

$$\frac{V_{actual}}{V_{full}} = 1.12$$

Q = 2.06 ft³/s

PIPE SIZING (1% DESIGN SLOPE)

$\frac{d}{D}$=0.70 (CODE)

$\frac{Q_{Actual}}{Q_{full}}$ = 0.85 (CHART)

$$Q_{full} = \frac{2.06\,\frac{ft^3}{s}}{0.85} = 2.42\,\frac{ft^3}{s}$$

$$Q = VA = A\frac{1}{n}R^{2/3}S^{1/2}$$

$R_{full} = \frac{D}{4}$

n=0.01

Solving for D:

$$2.42\frac{ft^3}{s} = \frac{\pi D^2}{4}\left(\frac{1}{0.01}\right)\left(\frac{D}{4}\right)^{2/3}(0.01)^{1/2}$$

$$2.42\frac{ft^3}{s} = 3.12D^{8/3}$$

$$D = 0.9\,ft \approx 1ft.or\ 12\ in$$

Verification:

$$\frac{V_{actual}}{V_{full}} = 1.12(Chart)$$

$$V_{full} = \frac{1}{n}R_{full}^{2/3}S^{1/2} = \frac{1}{0.01}\left(\frac{1ft}{4}\right)^{2/3}(0.01)^{1/2}$$

$$V_{full} = 3.97\frac{ft}{s}$$

$$\frac{V_{actual}}{V_{full}} = 1.12(Chart) \rightarrow V_{actual} = 1.12(3.97\ ft/s)$$

$$\frac{V_{actual}}{V_{full}} = 4.44\frac{ft}{s} > 2.0\frac{ft}{s} \therefore Self\ cleaning\ (Code)$$

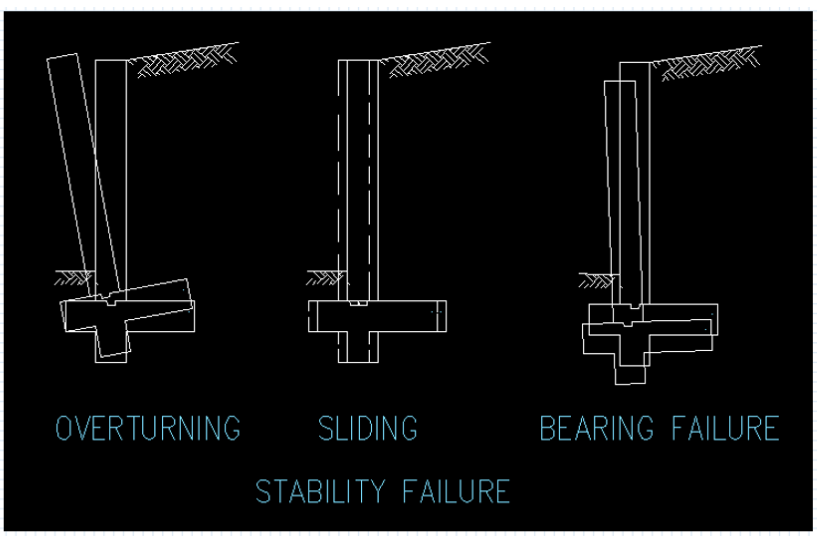


Table 3: FS for Overturning = 3.3 > 2

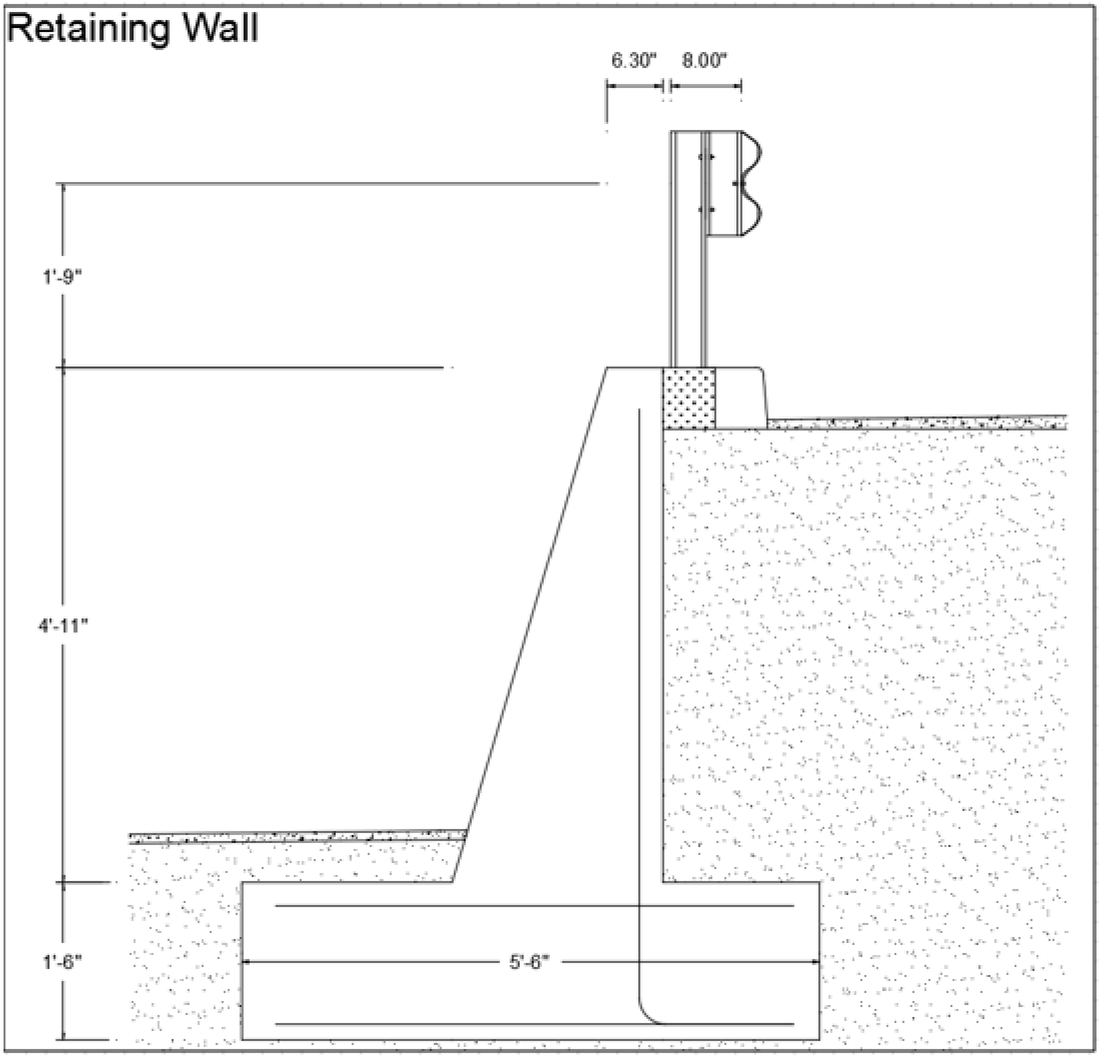
M_R	14491.8	lb*ft	
M_O	4384.867	lb*ft	
FS	3.304958	CHECK >2	yes

Table 4: FS for Sliding = 1.73 > 1.5

F'_d	1547.60	plf	
F'_R	2672.268	plf	
FS	1.726718	CHECK>1.5	yes

Table 5: FS for Bearing Capacity = 7.22 > 3

I	13.86	ft⁴	
q_{com}	2004.681	psf	
q_{max}	1119.701	psf	
q_{min}	442.4897	psf	
q_u	8086.759	psf	
FS	7.222247	CHECK>3	yes


Retaining Wall
6.30"
8.00"
1'-9"
4'-11"
1'-6"
5'-6"