MITIGATE THE FLOOD RISK AT THE MOST VULNERABLE PARKING LOT AREA OF THE UNIVERSITY OF TEXAS RIO GRANDE VALLEY EDINBURG CAMPUS

A Thesis

by

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ABSTRACT

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This study focuses on the analysis of the drainage system in the parking lots of the Edinburg campus of the University of Texas Rio Grande Valley. The current project will use the rational method described in the Texas Department of Transportation manual to analyze and determine a solution for the current built drainage system. The primary objective of this study is to offer a practical and comprehensive solution to address the issue of this area that has flooded during heavy rainfall storm events. The proposed solution takes into consideration the building codes of the city of Edinburg and evaluates the cost-effectiveness of the proposed solution. The methodology employed encompasses analyzing lidar information data, gathering topographic data, determining drainage areas, calculating concentration times, examining existing pipes, calculating maximum discharge for a 50-year storm event, and defining the storage required for the current site. This study aims to provide a detailed analysis of the current system and a feasible cost-time-efficient solution with detailed specifications, cost estimation, construction process, and duration of the entire project to facilitate its implementation.

DEDICATION

I would like to express my heartfelt gratitude to God and my beloved family for their unwavering support, love, and encouragement throughout my master's studies. Without their presence and guidance, this achievement would not have been possible. I am especially grateful to my mother, Rosario Posso, and my father, Vinicio Mazon, for their constant belief in my abilities. My sisters, Saskya and Sheyla, have been a source of inspiration and strength for me. Additionally, I am grateful to my dear friends Loreen and Mike Rhodes, Chris Boyd, Gretchen Kimball, Oscar Cordova, and Kimberly Diaz, who have become like a second family to me during this journey. Their continuous motivation, encouragement, and unwavering support have been invaluable in helping me complete this degree. I extend my heartfelt appreciation to all of them for their love and patience.

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I would also like to thank my esteemed dissertation committee members, Dr. Jungseok Ho and Dr. Jongmin Kim. I am grateful for their patience and the wealth of knowledge they shared during our interactions and in the classroom setting. Their expertise and feedback have greatly enriched my research and contributed to the overall quality of my work.

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CHAPTER I

INTRODUCTION

1.1 Background

The Rio Grande Valley (RGV), located in the southernmost region of Texas, consists of four counties: Cameron, Willacy, Starr, and Hidalgo County. The city of Edinburg, situated in Hidalgo County, is home to a significant portion of the RGV population and ranks as the 39th largest city in Texas. According to the last census conducted in 2012, Edinburg had a population of 107,738 individuals(Killian & Li, 2015).

The RGV is characterized by its predominantly flat terrain, with much of the green areas being transformed into residential communities. As a result, flash flooding has become a pressing issue for the local community. The UTRGV Edinburg campus is situated in an area with minimal variation in elevation, leading to the accumulation of water during storm events. Throughout history, the RGV has experienced several natural hazards that have significantly impacted its residents. For instance, in 2019, Hurricane Hanna caused flooding and property and vehicle damage and instilled fear within the community. Approximately 47% of properties in the area have a greater than 26% probability of being severely affected by flooding within the next 30 years (Brodie M., et al., 2016).

The University of Texas Rio Grande Valley (UTRGV) was originally known as the University of Texas Pan American (UTPA). Founded in 1927, UTPA served as a key component of the Texas state university system, catering to the entire Rio Grande Valley and southern Texas. It offered bachelor's, master's, and doctoral programs. Over the years, UTPA experienced significant growth, initially starting with 200 students, and eventually expanding to over 20,000 students, making it one of the ten largest universities in Texas. In 2015, UTPA ceased operations and transitioned into its current institution, the University of Texas Rio Grande Valley (UTRGV) (UTRGV, n.d.).

According to the risk maps provided by FEMA, most of the Edinburg campus of the University of Texas Rio Grande Valley is located in a high-risk zone under certain storm events. This is due to certain flat or low-lying areas that can be inundated with water depths ranging from 1 to 3 feet. To determine these zones prone to flooding, lidar data was used (Federal Emergency Agency, n.d.).

Based on Lidar information and historical events that occurred in the past, the most affected area on the Edinburg campus is the parking lot located in the eastern zone of the university. This parking lot has experienced flooding whenever there is a heavy or prolonged rainfall event, posing risks to students, staff, vehicles, and electronic devices.

According to Dr. Jungseok Ho, an associate professor at UTRGV, flooding is primarily caused by the geographic location of the area and the significant population growth. Due to the relatively flat terrain and the intensity of the storms in the region, this area is particularly prone to flooding (Shipley, 2021).

The flooding in the university parking lots could be attributed to tree removal and the extensive urbanization surrounding the university. Undeveloped land plays a crucial role in absorbing approximately 90% of rainfall. However, during the urbanization process, green areas are replaced by parking lots, streets, and buildings, reducing open space for water absorption. Consequently, the absorption rate during rainfall events decreases from 95% to 35%. The excess runoff caused by reduced absorption is one of the significant factors contributing to flooding. Additionally, the accumulation of debris in these waters can lead to the blockage of drainage systems, further decreasing the capacity of the city's drainage system (Shipley, 2021). These are some of the underlying issues identified in previous flooding incidents in the city of Edinburg.

The drainage system of the city of Edinburg is designed to ultimately discharge into the channels of the Hidalgo County sewer system. The water from the district is eventually distributed to the Laguna Madre's Tidal segment 2491 at the outfall south of Port Mansfield, as depicted in Figure No. 1. Previous studies have indicated that the water in these channels contains bacteria and significantly depressed dissolved oxygen, rendering it unsuitable for supporting marine life or wildlife(Killian & Li, 2015).

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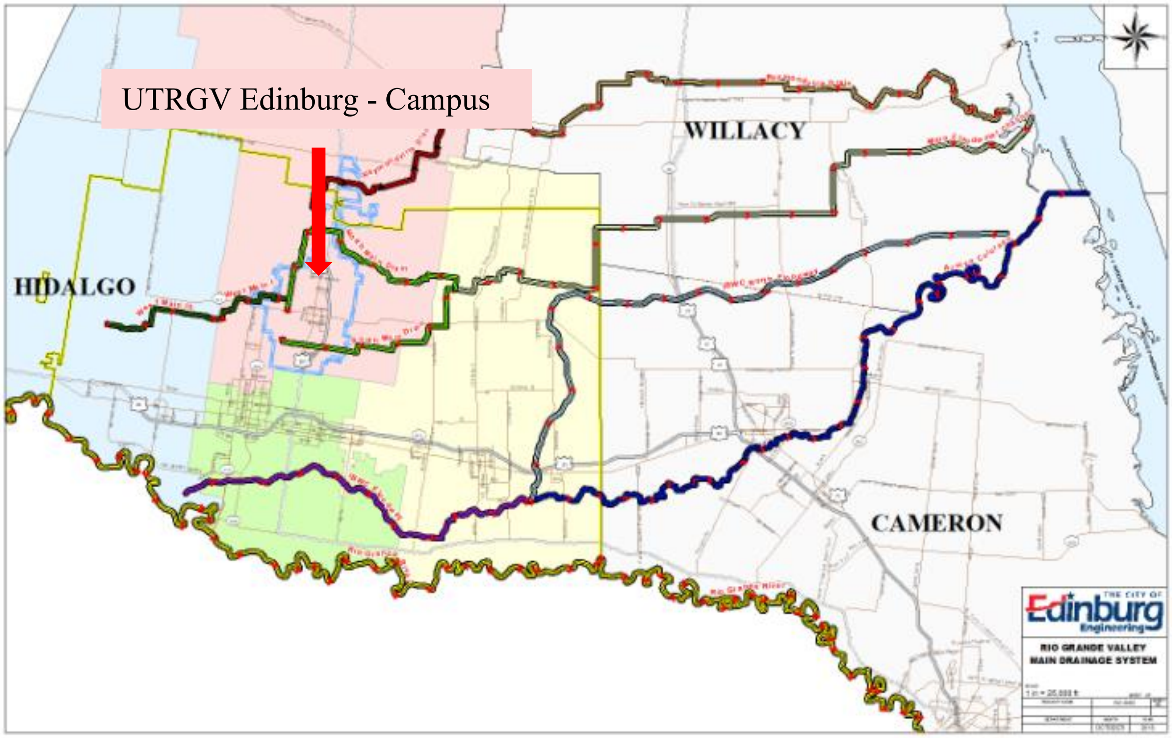


Figure 1: Rio Grande Valley Water Distribution – UTRGV Edinburg Campus (Killian & Li, 2015)

1.2 Objective of Research

The main objective of this research is to define the areas at risk when a storm event occurs and find the solution to solve the flooding problems. Determine the current storm system of the UTRGV and find the possible factors related to the flood problems. Analyze the current and future conditions under 50 and 100-year storm events. Suggest modifications of the current storm system or a different storm system that will mitigate the flooding at the Edinburg campus, providing the timeline and the cost/benefits analysis that will facilitate the implementation and execution of the project.

1.3 Methodology

The methodology employed in this study is based on the Rational Method and the Modified Rational method, which is widely recognized for designing storm drainage systems. This method considers the rainfall intensity, the size, and the topography of the drainage area under investigation, and soil conditions.

The procedure will involve lidar data to identify the area prone to flooding during a 50-year storm event. The Modified Rational Method will then be used to assess current and future conditions and will be applied to estimate the necessary storage capacity for the drainage area. Finally, there will be three solution suggestions depending on the results.

The following steps outline the development and application of the methodology:

1. The study area will be defined using lidar information, including depictions of water depths above the land surface during a 1% and 2% annual chance storm event (FEMA).
2. With the UTRGV boundaries gathered from the parcels available on the GIS Edinburg map, the area's acreage will be obtained, and whether the study area is less than 100 acres, the Rational Method can be applied. Otherwise, according to the Edinburg Code, the SCS (Soil Conservation Service) unit hydrograph methodology shall be used instead.
3. The design rainfall intensity for which the current infrastructure was designed will be evaluated against the current laws and regulations required by the city of Edinburg and Texas department of Transportation. Rainfall intensity refers to the average rainfall rate in inches per hour for a specific duration and frequency. In Texas, rainfall intensity is calculated using the Rainfall-Intensity-Duration-Frequency (IDF) relationship, using the coefficients for a 50-year storm event (NOAA’s National Weather Service, n.d.).

Equation 1: Intensity [in/hr]

$$I = \frac{\mathrm{b}}{(\,t_c + d)^e}$$

Where:

I = Design Rainfall intensity [in/hr]

Tc = Time of concentration (min)

E,b,d = coefficients based on rainfall data

The coefficients for the calculations of the intensity use the Intensity-Duration-Frequency for Hidalgo County, Texas as presented in Table No. 1.

Table 1: Intensity duration Frequency coefficients for Hidalgo County

Recurrence interval	IDF Coefficients		
[Years]	e	b	d
50	0.749	99	9.2
100	0.740	103	9.6

(NOAA's National Weather Service, n.d.)

4. The fourth step is to define the drainage areas using the available topographic information. The drainage area is the total area contributing to the stormwater runoff. It is crucial to determine and analyze the drainage system to identify the outlet and the direction of water flow. If the total area is more than 100 acres, the SCS (Soil Conservation Service) Unit Hydrograph methodology should be employed. Each drainage area is compounded by an inlet in the lowest point of the contributing area and the boundaries of the area are located on the highest points of the area.

5. The next task is to determine the concentration time. The concentration time is the duration for stormwater to travel from the furthest point of the specific drainage area to the collection point or inlet. Here, the velocity is associated with three typical flow regimes:

   - ✓ Sheet Flow: Water flow over a relatively smooth surface with minimal slope. The concentration-time for sheet flow is calculated using empirical equations that consider the slope, roughness, and flow length.
   - ✓ Shallow Concentrated Flow: This occurs when the flow becomes more concentrated and starts to form channels. The concentration-time for shallow concentrated flow is determined by equations that consider the channel slope, cross-sectional shape, and roughness.
   - ✓ Pipe Flow: When stormwater enters a pipe or conduit, the concentration-time can be determined based on the pipe diameter, slope, and roughness(Kenneth M. Kent, 2009).

Calculating the concentration-time for each flow regime can determine an overall concentration time for the drainage area. This information is crucial for designing an effective drainage system that efficiently handles stormwater runoff.

The time of concentration was calculated as shown in equation No. 2.

Equation 2: Equation 2: Time of concentration as per TXDOT Bridge Hydraulic Manual [min or hr]

$$t_C = \frac{L}{60V}$$

Where:

Tc= travel time [min]

L= watercourse Length [ft]

V = average flow velocity [ft/s]

The velocity for overland flow and shallow concentrated flow according to the building code of Edinburg:

$$Velocity\ for\ grassland\ area\ \ 0.15\ [fps]$$

$$Velocity\ for\ overland\ and\ gutter{:}\ \ 0.4\ [fps]$$

$$Velocity\ of\ the\ pipe\ flow{:}\ \ 3\ [fps]$$

6. The next step is to determine the peak flow rate for each drainage area. This involves estimating the maximum rate of stormwater runoff that can be expected during a rainfall event. The peak flow rate can be estimated using the Rational Method formula, as described in Equation No. 3. This formula considers the design rainfall intensity, time of concentration, and the drainage area under study (Texas Department of Transportation, 2009).

Equation 3: Maximum rate runoff [cfs or m3/sec]

$$Q = \frac{\mathrm{CIA}}{Z}$$

Where:

Q = maximum rate runoff [cfs or m3/sec]

C= runoff coefficient – [0.9 for asphalt]

I = Average rainfall intensity [in/hr or mm/hr]

A = Drainage Area [ac]

Z = Conversion Factor, 1 for English, 360 for metric

Plugging the values for C, i, and A, the formula will yield an estimate of the peak flow rate for each drainage area. This information is vital for designing the stormwater drainage system, as it helps determine the capacity and sizing requirements for various components such as pipes, channels, and detention basins (City of Edinburg Council, 2021).

7. To analyze the current storm system the following calculations were developed:

Table 2: Flowrate Determination

[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]
			TIME	RETURN				Results
DRAINAGE AREA	CONTRIBUTING AREA (Acres)	C	(SEE TABLE 1) (minutes)	FREQUENCY (years)	INTENSITY (in./hr.)	FLOWRATE (c.f.s.)	PIPE SIZE (inches)	MIN. SLOPE (FT./FT.)

A: Description of the drainage areas

B: is the contributing drainage area [acre]

C: runoff coefficient for Urban watersheds that was calculated based on the contributing area:

Table 3: Runoff coefficient for Urban Watersheds

Weighted "c" value				
Type of Drainage Area	**"c" value**	**Sf**	**Ac**	**Partial "c"**
Residential				
Single Family (Lots less than 1/4 acre)	0.35	0	0.000	0.000
Single Family (Lots 1/4 to 1/2 acre)	0.3	0.00	0.000	0.000
Single Family (Lots greater than 1/2 acre)	0.25	0	0.000	0.000
Multi-Family (Less than 20 DU / AC)	0.5	0	0.000	0.000
Multi-Family (Greater than 20 DU / AC)	0.55	0	0.000	0.000
Business Districts:	0.75	0	0.000	0.000
Industrial				
Light areas	0.75	0	0.000	0.000
Heavy areas	0.75	0	0.000	0.000
Railroad yard areas	0.2	0	0.000	0.000
Roof/Building areas	0.75	0	0.000	0.000
Parks, cemeteries	0.1	0	0.000	0.000
Unimproved Areas				
Bare Surface	0.3	0	0.000	0.000
Grassland	0.25	48298.07	1.109	0.277

Table 3, cont.

Cultivated	0.2	0	0.000	0.000
Woodlands	0.15	0	0.000	0.000
Streets				
Asphalt	0.9	460,263.62	10.566	9.510
Concrete	0.9	0	0.000	0.000
Drives and walks	0.9	0	0.000	0.000
Total:		508,562	11.675	9.787
Weighted "c":			**0.838**	

Where:

$$CW = (C1A1 + C2A2 + C3A3 + \cdots Cn\ An)\ /\ Total$$

$$CW = Weighted\ Runoff\ Coefficient\ (Composite\ Coefficient)$$

$$An = Area\ of\ n\ term$$

$$Total = Total\ Area\ (acres)$$

Continues the explanation of table No. 2

D: concentration time previously calculate in step (5) for each contributing area

E: Frequency of a 50-year storm event

F: intensity calculated for a 50-year storm event

G: peak flow rate, equation No.

H: current pipe size

I: minimum slope [%], see equation No. 4

Equation 4: Minimum slope [%]

$$S = \left(\frac{\text{peak flowrate}}{\text{n (manning coefficient)}}\right)\text{^2}$$

7.1 Analyze current design with Edinburg Standard Manual

To analyze if the current design is in accordance with the Edinburg standard manual, it is necessary to review the full flow coefficient values and slopes for circular concrete pipes (City of Edinburg Council, 2021). The full flow coefficient represents the hydraulic efficiency of the pipe and is calculated using equation No. 5.

Equation 5: Full flow coefficient

$$Value\ of\ C1 = \left(\frac{1.486}{\text{n (manning coefficient)}}\right) * \text{A} * \text{R}^{\frac{2}{3}}$$

Where:

A: circular area of the pipe (ft)

R: Hydraulic radius (ft)

The full flow coefficient values depend on factors such as pipe diameter, material roughness, and flow conditions.

Table 4: Full flow coefficient values for concrete pipes

D Pipe Diameter (inches)	A Area (feet)	R Hydraulic Radius (ft)	Manning coefficient n	Full flow coefficient C1	Minimum slope [%]
18	1.767	0.375	0.013	105	0.255
21	2.405	0.437	0.013	158	0.255
24	3.142	0.5	0.013	226	0.174
27	3.976	0.562	0.013	310	0.174
30	4.909	0.625	0.013	410	0.129
33	5.94	0.688	0.013	530	0.129
36	7.069	0.75	0.013	666	0.101
42	9.621	0.875	0.013	1006	0.101
48	12.566	1	0.013	1436	0.101
54	15.904	1.125	0.013	1967	0.101
60	19.635	1.25	0.013	2604	0.101

Making the comparison of the calculated full flow coefficient values and slopes of the current design with the requirements stated in the Edinburg standard manual will be determined whether the design meets the specified standards. If the current design aligns with the manual's guidelines, it indicates compliance with the recommended criteria. However, if discrepancies or deviations are found, adjustments or modifications may be necessary to ensure conformity with the Edinburg standard manual.

The final step is to determine the storage volume required for the drainage area. This can be done using the Modified Rational Method. The modified rational method gathers all the previous data calculated such as the peak flow calculated for the design storm and the time of concentration for the specific drainage area. According to the Edinburg manual the storage required is designed for the maximum difference in volume(City of Edinbug Council, 2021). See table No. 5.

Table 5: Modified Rational method calculations

Time	Time	i	Qin	Vin	Qout	Vout	REQ'D V
Minutes	Hour	in/hr	cfs	cf	cfs	cf	cf

Where:

Time: Duration [min & hr.]

I= intensity [50-year event]

Qin= Developed conditions peak discharge [Cdev* i*A]

Vin= Developed conditions runoff volume [Qin*Duration*60]

Qout= pre-developed peak discharge [C*i*A]

Vout= 05 * [duration + tcdev]* Qout *60

ReQ= required storage [Vin-Vout]

CHAPTER II

LITERATURE REVIEW

Urban drainage systems are crucial in effectively mitigating surface runoff in urban areas during intense precipitation. Nevertheless, when the volume of stormwater surpasses the capacity of these systems, it can lead to urban flooding, resulting in disruptions to transportation networks, economic repercussions, and adverse health outcomes. The proliferation of impermeable surfaces in urban landscapes exacerbates the magnitude of surface runoff, hastens its concentration, and heightens the peak flow rate. Consequently, an escalating urgency exists to enhance drainage capacity in rapidly urbanizing regions. Traditionally, this necessitates expanding and modernizing existing storm drainage infrastructure(Kyi et al., 2017).

The implementation of appropriate drainage systems in developed urban environments assumes paramount significance due to the intricate interplay between human activities and the natural water cycle. This interplay manifests in two primary forms: firstly, the extraction of water from the natural water cycle to satisfy human water requirements, and secondly, the transformation of land into impermeable surfaces that divert rainwater away from the natural drainage network.

Urban water managers must reassess prevailing water management practices in the contemporary context of urbanization and climate change, considering economic, environmental, and social considerations. Stormwater management assumes relevance in urban areas equipped with conveyance systems. Beyond its role in flood prevention, stormwater management significantly influences the urban water balance. The proliferation of impermeable land cover amplifies the volume and peak flows of stormwater runoff and diminishes other integral components of the hydrologic cycle(Kyi et al., 2017).

2.1 Rational Method

There are a variety of runoff models that predict the temporal distribution of surface at a catchment outlet based. The first fundamental hypothesis was made by Horton in 1945; he said that the overland flow happened when the rate of rainfall exceeded the infiltration capacity of the soil. Currently, there are different kinds of models available for the calculation of the runoff from a rainfall event. The implementation and applicability of these varieties of models are related to the scale of the catchment. It can differ from small, midsize, or large. In small drainage areas, the effect of the drainage area on rainfall events is abrupt, and the drainage area is small enough that runoff during a short lapse time can be modeled assuming a constant rainfall in space and time. For small areas of less than 100 acres, the rational method is widely used in urban hydrology(Chin, 2013).

The rational method is related to the peak-runoff rate [Qp] to the rainfall intensity Equation No. 3 to calculate the peak-runoff is necessary to account for the drainage area that contributes to the runoff. The requirements for the application of this method are:

1. The period time of the storm exceeds or equals the concentration time of the drainage area.

2. The assumption is that the rainfall is uniformly distributed in the drainage area.
3. Collection losses are combined into the runoff coefficient [C].

In the rational method, the average intensity of a storm event is inversely proportional to the duration of the storm. The rational method is used worldwide to design stormwater systems, such as channels, detention ponds, and even civil structures, including culverts, bridges, and hydraulic systems. With this tool, hydraulic structures can be sized, and storm systems designed even when lacking detailed data at early stages.

This method has been improving over the years to refine its accuracy and manage its limitations.

For the development of these tools, the method uses advanced data and adapts the characteristics of the drainage area, rainfall patterns, and soil properties that help stimulate the accumulation of water response in rainfall events. Currently, the use of satellite images and Lidar information aid in estimating water depths above the land surface during storm events (Hans et al., 2003).

2.2 Modified Rational method

The Modified Rational Method is an adaptation of the Rational Method, which utilizes a simplified equation to estimate the volume of runoff generated by a watershed. This approach considers critical factors, including the watershed's runoff-producing characteristics, the average rainfall intensity during a specific time interval, and the size of the drainage area. In the realm of drainage systems, they are typically structured in a networked arrangement to enable efficient management of water flow (Kyi et al., 2017).

The development of the modified rational method aimed to expand the applicability of the rational method beyond the design of storm sewers and incorporate it into the design of storage systems. Advancements in understanding the rainfall-runoff process have driven the refinement of the rational method. The Wallingford procedure (DoE/NWC 1981) recommends using the modified rational method, which has demonstrated accuracy for catchment sizes up to 200 acres. This approach integrates rainfall runoff with other routing effects, considering the runoff coefficient (C) (Kyi et al., 2017).

2.3 Flooding

Worldwide, Flooding is one of the most high-priced disasters generated by natural hazards. Just one inch can cause up to 25000$ in damage. The United States of America due to its flat topography has been dealing with a wide range of flood hazards, storm surges along the coast and flash flooding(Mark Brodie et al., 2016).

In American history, usually, cities, where most of the land is urbanized, were under flood risk because they were built and developed close to the coast and rivers as a means of transportation and energy generation. For over a century, the US has been dealing with these menaces, and communities have been struggling with floods since the country was discovered. In the US are three different and most known types of floods:

2.3.1 Coastal Flooding

Coastal flooding is flooding that has occurred in land areas adjacent to the coastline due to seawater overflowing onto the land. This occurrence typically happens when coastal regions are exposed to high tides, storm surges, or severe weather events. The consequence is the temporary or permanent submersion of these coastal areas. The impact of coastal flooding on communities along the coast can be highly damaging, leading to infrastructure destruction, erosion of beaches and shorelines, displacement of people, and posing risks to human life and the surrounding ecosystems. Low-lying coastal areas are particularly vulnerable to this type of flooding, and its severity is influenced by various factors, including rising sea levels, the coastal landscape, and prevailing climate conditions.

2.3.2 Fluvial Flooding

Fluvial flooding, or riverine flooding, pertains to the submersion of terrestrial regions due to rivers or streams exceeding their carrying capacity and overflowing into adjacent areas. This natural occurrence is prompted by diverse factors such as intense precipitation, snowmelt, or a combination thereof, leading to an excess volume of water within the river system. As the water levels rise beyond the riverbanks' limits, the surplus water spills over, inundating nearby regions.

2.3.3 Pluvial Flooding

Pluvial flooding is a result from intense precipitation events that surpass the drainage capacity of an area. It diverges from fluvial flooding, which arises from river or stream overflow, as localized rainfall occurrences predominantly drive pluvial flooding. The excessive rainfall surpasses the soil's infiltration capacity and the drainage system's ability to accommodate the water, leading to surface water accumulation and subsequent flooding in low-lying regions, including streets and neighborhoods.

Over the years, flood managing has switched to control water to a wider approach, including building flood resilience through risk communications; more budget has been designated to structural and non-structural mitigation and mitigations and ameliorating recovery and response.

In The United States of America, there are few organizations dedicated to preventing and mitigate flood risk, such as the Federal Emergency Management Agency (FEMA), these organizations oversee providing leadership and managing eminent risk(Kim et al., 2016).

2.4 Flooding events at UTRGV

The UTRGV Edinburg has experienced flooding events throughout the years. The flat topography, intense rainfall events, and limitations of existing drainage systems have been challenging factors in developing a master plan to solve and avoid future flooding events. Edinburg School district and the city documented locations of Flooding from storm events(Kayla St. Germain & Alyssa Robinette, 2022). The UTRGV campus has been identified as an area of concern. Some of the Storm events documented that caused flooding issues in the area were:

- Hurricane Dolly, July 2008 (6-14 in of water)
- Hurricane Alex, July 2010 (5-8 in of water)
- April 2012 and September 2014, tropical storms with intense rainfalls

2.5 Federal Emergency Management Agency (FEMA)

In 1979, President Carter created the Federal Emergency Management Agency (FEMA) to understand and reduce disaster risk, to lead the organization of federal response attempts to secure communities after a natural hazard and contribute with support for communities to overcome and turn into more resilient than before. Their mission is to help individuals and communities after, during, and before disasters.

Due to hurricanes Such as Sandy, FEMA significantly improves the quality and efficiency of disaster management. It accounts for a floodplain management standard that induces stronger, firmer, safer, and more resilient communities.

Floods happen naturally and everywhere, especially where the topography does not differ significantly. River and coastal Flooding are the most frequent types. Heavy rainstorms, poor drainage, deforestation, and urbanization place communities at risk for flood damage.

FEMA has developed flood maps, a tool that individuals and communities utilize to recognize the areas prone to flooding risk. Flood maps show the probability of a specific area flooding. Elevated risk areas are places that have a 1% or higher chance of flooding during a specific storm event. These areas have a probability of one in four flooding during a 100-year storm event.

FEMA has divided the map area into different flood zones; it depends on the risk, the area might have a high, moderate, or low risk of flooding. Low to Moderate-risk floods are designated areas where letters B, C, and X are on FEMA flood maps; this depends on the elevation of each one. See figure No. 2. The risk of being flooded is lower but not eliminated. High-risk flood areas start with the letters A or V on the FEMA maps. Here is where the is a high risk of Flooding during a storm event. In these areas usually is required to purchase flood insurance as a condition to get a loan (FEMA, 2023).

Figure 2: Flood hazard areas (FEMA, 2023)

2.6 Risk Management

Risk management is one of the procedures for operational risks caused by environmental, natural, or even manufactured hazards, of which flood is the leading representative. The result of risk management takes place in three distinct stages:

1. Operational level: related to the operating system
2. Project planning level: utilized when there is already an existing system
3. The project design level characterizes the procedure of reaching an optimal solution for the project in review.

On the first action, the operational level is compounded by four parts: when there is an existing system. During the years and the population growth climate change in land use, the system is no longer efficient and does not meet the people's demands. Later, it brings to the decision whether the system will be developed or not. Into this stage comes the third act, which corresponds to defining an efficient design for an adequate future system (Plate, 2002).

One of the main objectives of flood risk management is to lower the risk for people that live in flood-prone areas during a flood event. Flood hazards are characterized by location (close to a river or coast, elevation, and vulnerability to fast-moving surges and flows, etc.).

Every measure, decision, mitigation action, and risk transfer measure decrease the general risk to some point, although it is almost impossible to eliminate the risk. There are different kinds of solutions to flood risk problems, including structural or nonstructural solutions.

2.7 Flood risk management from an existing system

Flood risk management, in this case, is the process of managing an existing flood risk situation. The planning of a system compounds the process that will reduce the flood risk, which will be the sum of actions to achieve flood disaster mitigation. The objective of this process is to be prepared for a flood and minimize its effects. A risk analysis process needs to be developed in this stage, which is the base for future long-term decisions for the flood protection system. It is necessary to reassess the previous risks continuously. Also, it estimates the hazards according to the newest data available, such as new theoretical developments, boundary conditions, and changes in land use. If an area is flooding, this event is weighted with the frequency of that flood, leading to hazard maps, such as the ones available from FEMA (Le, 2019).

Even when the system works as it is supposed to, there is always a residual risk due to odd floods that exceed the designed flood or also due to technical failure, for example, the Oder River flood in 1997 (Plate, 2002).

FEMA maps are handy for providing flood risk information to households and communities. Although, there are some concerns from stakeholders about the use of these maps used for risk communication. For example, when hurricane Sabrina happened, a flood took place, and it extended beyond the SFHA and created flood depths that exceeded the BFE by a significant amount of feet. The second concern is that maps become outdated after some time. Flood risk might change due to variations in previous surface area, erosion, or/and climate change. For example, it could have been that the surrounding areas of the UTRGV were green before, with a significant number of trees, but since they are developed now, the flood risk has increased, so the map should be updated due to the change of the surface area. Furthermore, a concern must be better captured on the FIRMs of stormwater flooding (Carolyn Kousky, 2020).

Technology has been improving over the years. Currently, digital elevation data are utilized to get the surface flow features. The most used are light detection and ranging (Lidar). Lidar can catch a significant amount of topographic data due to its fine-scale capacity to capture the earth's surface digitally. Elevations are the main factors when extracting surface flow information; high-resolution lidar-derived digital elevation models (DEMs) contribute with the features necessary to incorporate hydrography with elevations, land cover, civil structures, and geospatial details. Entities such as FEMA or the U. S. Geological Survey have established specific drainage methods to obtain continuous surface flow from DEMS. Lidar-derived surface flow network comprises essential information for water resource management compelling flood hazard maps, coastal erosion, and flood inundation. These are valuable tools to understand the surface water movement, the areas prone to flood risk, and how to manage a solve the possible scenarios (Sandra Poppenga et al., n.d.).

2.8 City of Edinburg Storm systems regulations

The city of Edinburg is one of the main components of the McAllen-Edinburg-Mission metropolitan area in the lower Rio Grande Valley, south of Texas. The population in Edinburg City has grown exponentially in the past ten years. It is projected by 2060 to have about 160 000 total population. Population growth is one factor contributing to the area's severity and frequency of flooding and drainage issues. It means that more development has been happening in Edinburg. Thus, the impervious cover increases the quantity of the peak and runoff water discharges. Future developments will depend on the quality of management and maintenance of the current and future drainage system. Therefore, Edinburg adopted a drainage Master Plan and a Standard Manual which all developers, designers, and operators must adopt when developing land (City of Edinburg Council, 2021).

The city of Edinburg Standard Manual for construction and development requirements was created as a component of the Unified Development Code and implemented in 2007.

The drainage master plan highlights that the stormwater runoff created by the developed improvements must be detained on-site and must be analyzed under a 50-year (2%) frequency storm event and discharged into the receiving system at the predeveloped, peak discharged rate should model for a 10-year frequency storm event. Additionally, the drainage report and plans must have some of the following information:

- ✓ Description of the project
- ✓ Location
- ✓ Contributing areas
- ✓ Spot elevations
- ✓ Direction of flow
- ✓ Property lines
- ✓ Existing proposed storm sewer systems
- ✓ Runoff detention
- ✓ Time of concentration
- ✓ Runoff coefficients assumptions
- ✓ Storage volume calculations

To estimate the peak flow, the rational method can be used for land less than 100 acres; the SCS Unit hydrograph shall be used for land more significant than 100 acres.

Further, the Modified Rational Method [MRM] shall be used to calculate the required storage volumes. The storage requirements are estimated by the differences in volume between pre and post developments(Chin, 2013).

CHAPTER III

DESIGN CRITERIA

3.1 Analyze the current conditions of the UTRGV, Edinburg-campus

The university of Texas Rio Grande Valley, Edinburg campus located inside the limits of the Edinburg City. The total area of the campus is approximately 254.25 [AC] as it is shown in figure No. 3

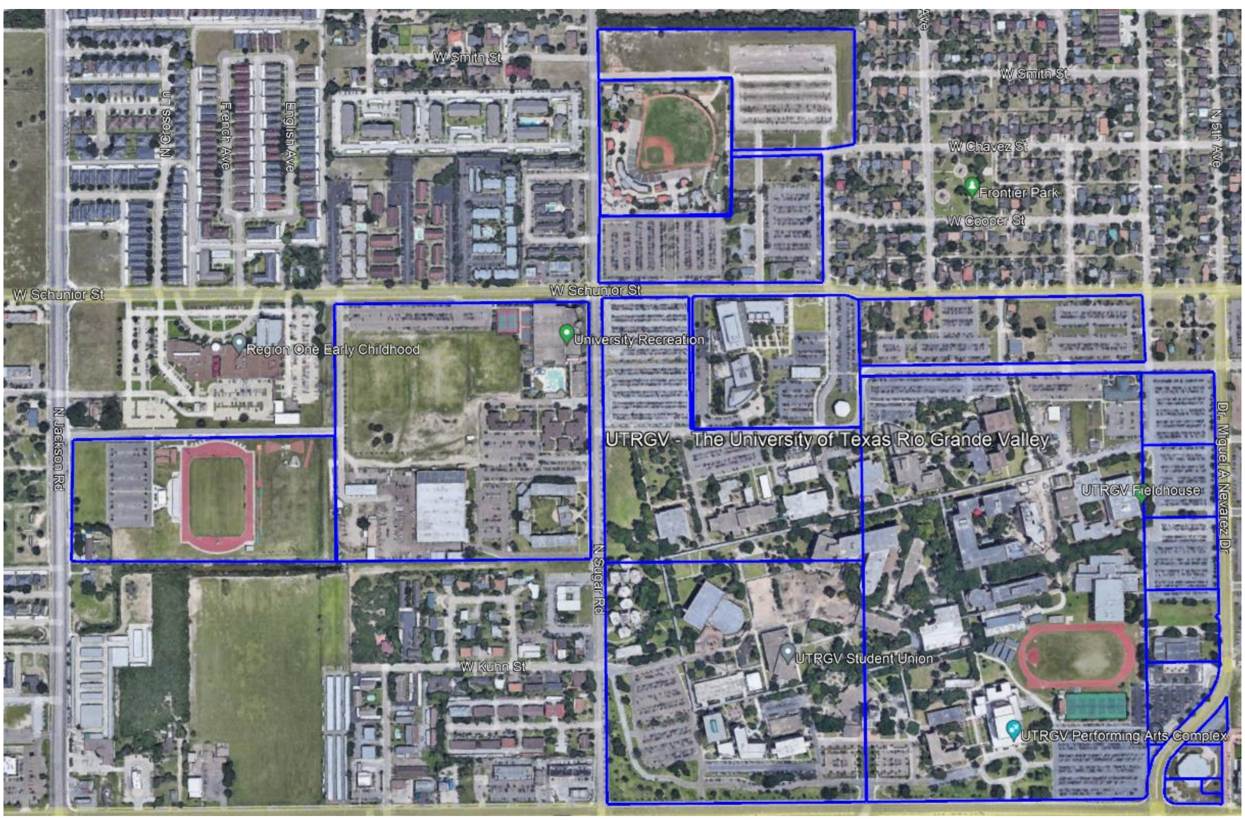


Figure 3: Boundaries of the Edinburg Campus

According to the Edinburg building regulations the minimum slopes of each pipe size are as shown in table No. 6:

Table 6: Minimum Slopes

Pipe diameter, do	Manning roughness, n	Pressure slope	Percent of ratio	Flow
do [in]	n	[%]	1 = flowing full	Q [cfs]
18	0.013	0.255	1	5.3039
24	0.013	0.174	1	9.4356
27	0.013	0.174	1	12.9175
36	0.013	0.129	1	23.935
48	0.013	0.101	1	45.6461
54	0.013	0.101	1	62.49

3.2 Federal Emergency Management Agency (FEMA) flood zone

According to the FEMA historic recorded data in the flood maps, it was determined that the property's flood risk with 201.05 [Ac], belongs to the "zone AH" where flood depths are between 1-3 feet. Hence this area is prone to pond water. However, 53.2 ac are on the west side of the campus and are in zone X, a low-risk zone with average flood depths of less than 1 foot. See table N. 7.

Table 7: Flood Zones

Area [Ac]	Flood Hazard Area
53.2	**Zone X**
201.05	**Zone AH**

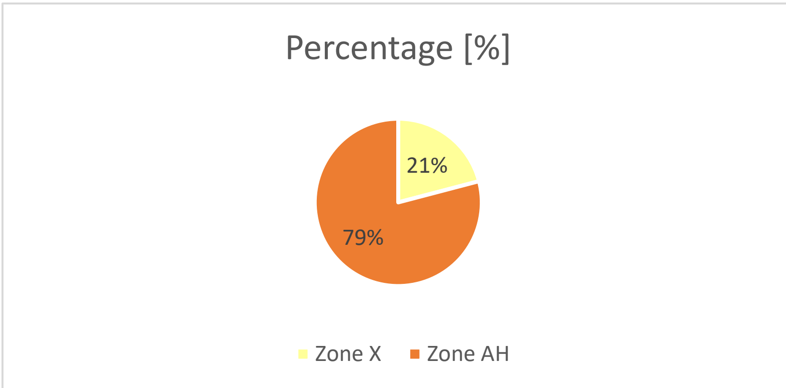


Figure 4: Flood zones

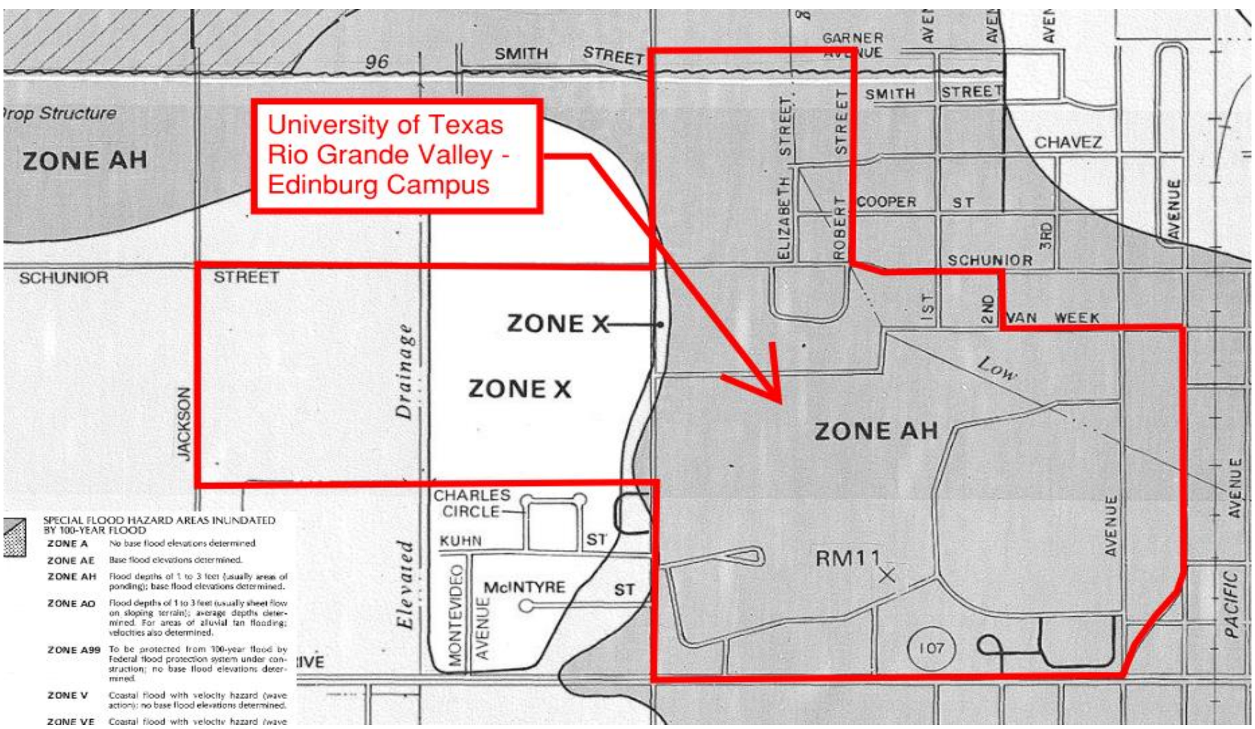


Figure 5: FEMA Panel of the UTRGV -Edinburg

3.3 Edinburg storm sewer system

In the city of Edinburg, the drainage ditches outfall the Hidalgo County Drainage District No. 1 Master Drainage system, which is known as the Floodway Channel network system—the UTRGV outfall to the north main Drain III (Killian & Li, 2015).

See Figure No.4 The storm sewer system surrounding the UTRGV campus starts in zone A, gathers water from the south area of 107 St., goes up north to Schunior st, and outfalls at the City of Edinburg Pond in Chapin Street. However, the internal drainage system of the UTRGV splits and some of the flow outfalls into the City of Edinburg ditch, while the other side also connects to the MS4 drainage system of the city of Edinburg; all the system eventually outfalls on the ditch that belongs to the Hidalgo County.

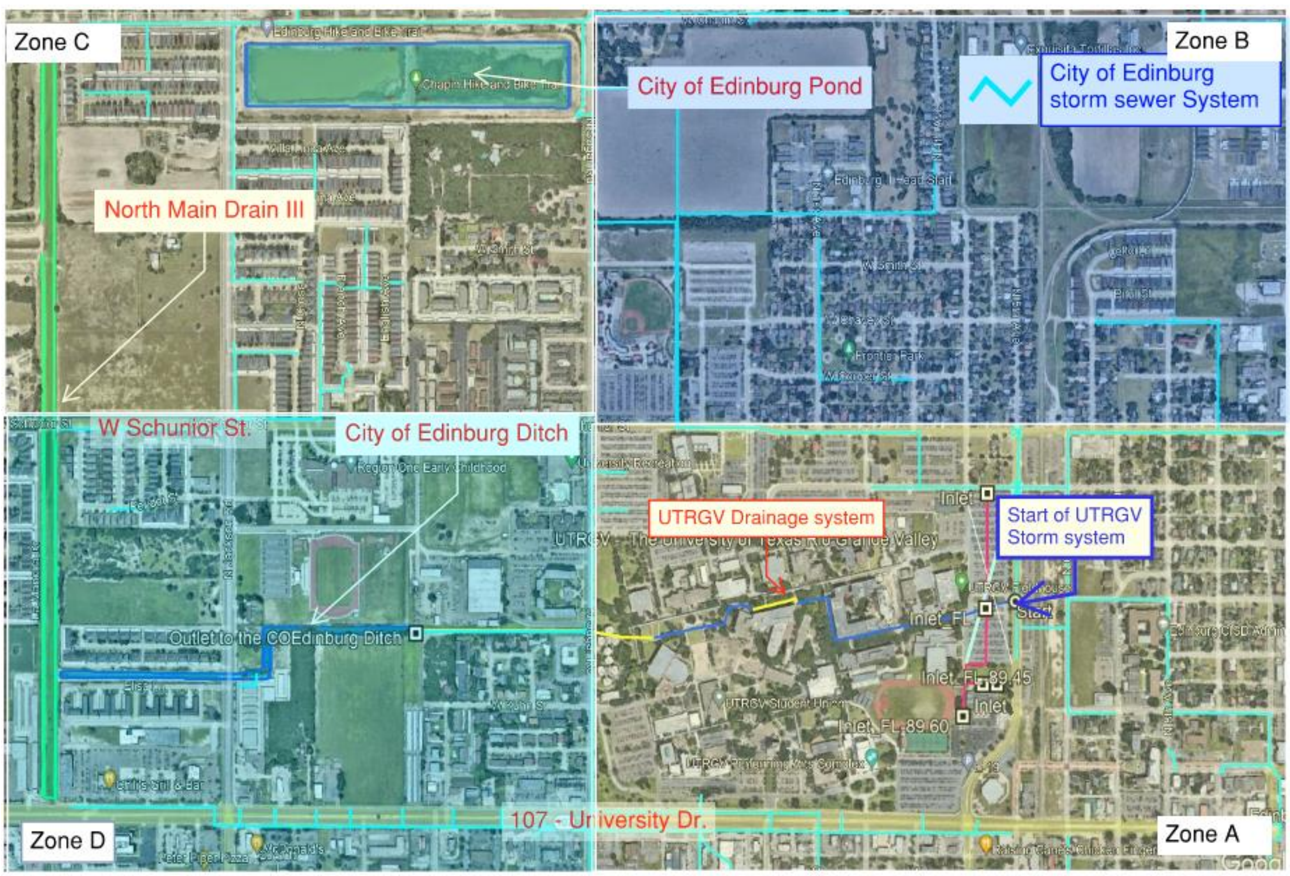


Figure 6: Edinburg Storm Sewer System

3.4 Define the area of study

The engineering design of the UTRGV storm system was developed and designed for a 10-year storm event. According to the Txdot manual and Edinburg code, this drainage storm system shall be designed for a 50-year storm event. Through lidar information, it was possible to determine that the area susceptible to flooding under 50-year storm events was the east parking lot of the UTRGV campus, compounded by approximately 11.675 Acres of land. See Figure No. 8.

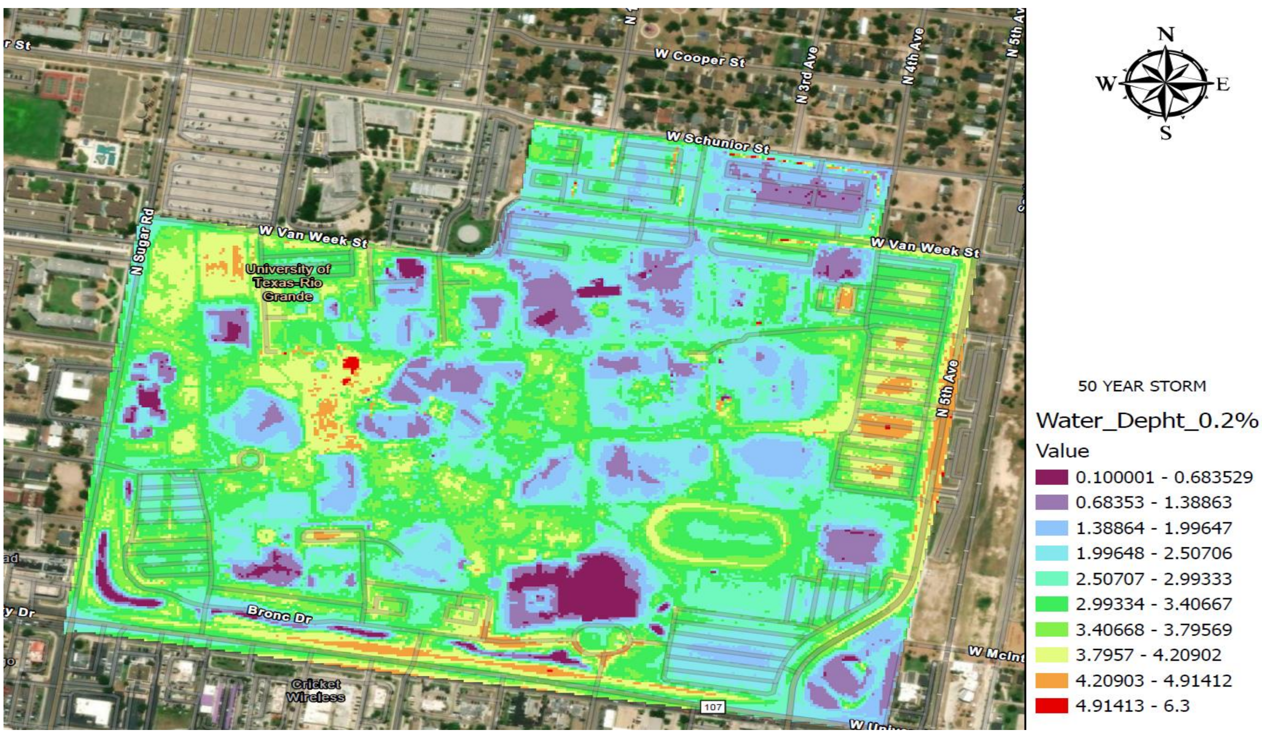


Figure 7: UTRGV FEMA Estimated Based Flood Elevations (50 year-storm)

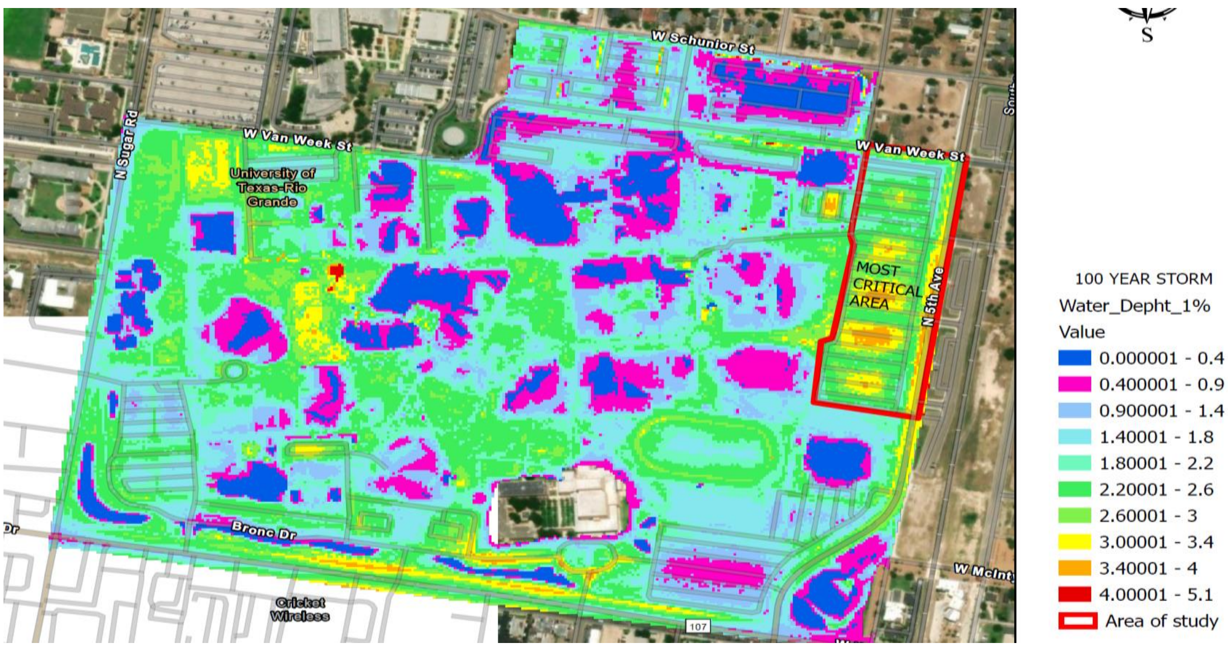


Figure 8: UTRGV FEMA Estimated flood Elevations (100 year-storm)

CHAPTER IV

DATA COLLECTION & ANALYSIS

4.1 Topographic elevations

During a field visit, the topographic elevations of the site were acquired utilizing the Trimble R12i, a cutting-edge surveying instrument known for its precise measurements. The Trimble technology facilitates highly accurate surveying operations in diverse environmental conditions. Equipped with sub-meter, sub-foot, and decimeter accuracy capabilities, the Trimble GPS equipment was employed to determine the elevation points of the designated study area. For visual reference, please refer to Appendix F.

4.2 Drainage areas

The identification of drainage areas was established by utilizing the collected fieldwork elevations. The delineation process involved the assessment of water flow directions within the drainage system, resulting in the demarcation of nine distinct drainage areas. These areas are defined by the boundaries situated at higher elevations, while the low points or inlets are positioned centrally within each area. Notably, the drainage system incorporates three distinct starting points that converge within drainage area 6, ultimately culminating in the outfall connection to the primary pipeline of the UTRGV drainage system. The termination point of this system occurs at the City of Edinburg ditch. For a visual representation, see Figure No. 10.

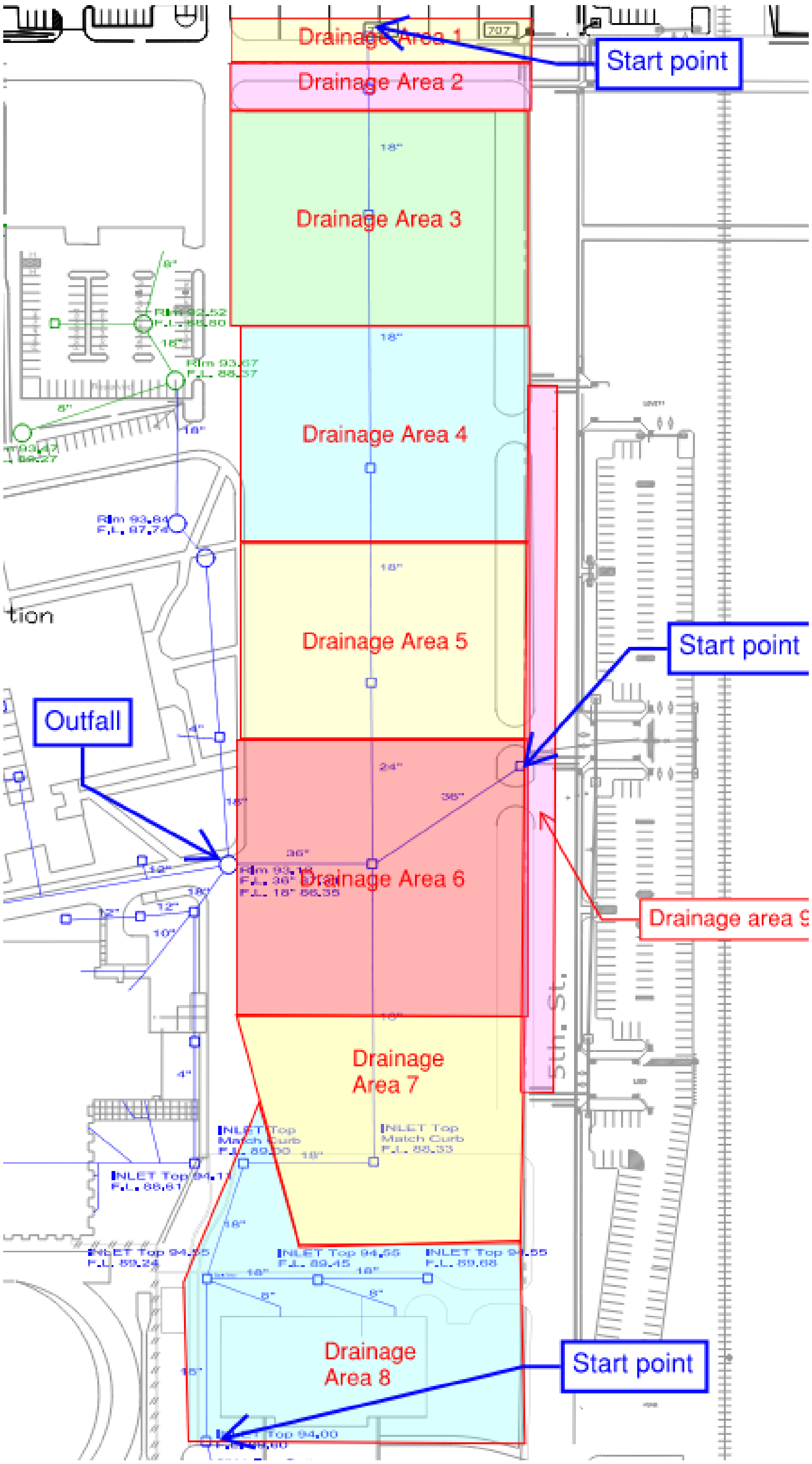


Figure 9: Drainage Areas Division

4.3 Intensity duration-frequency (IDF) curves

The intensity-duration-frequency (IDF) curves elucidate the interrelationship between rainfall intensity, duration, and frequency of rainfall events. These curves used in the design of hydrological, hydraulic, and water resource systems. The utilization of IDF curves spans various purposes, including estimating rainfall occurrences, analyzing climatic patterns, determining design storms, and facilitating the design of urban drainage systems. In the context of this project, the IDF curves are established based on historical data from the "Rainfall Frequency Atlas of the United States" published by the Weather Bureau (NWS). This dataset is the foundation for deriving the IDF relationships necessary for the project's rainfall analysis and design considerations.

The coefficients for 10 (current design), 50 and 100-year storm events on Hidalgo County are:

Table 8: IDF Hidalgo county coefficients for a 10, 50 and 100-year storm events

Hidalgo County Coefficients			
Coefficients	**10% [10-yr]**	**2% [50-yr]**	**1% [100-yr]**
e	0.778	0.749	0.740
b [in]	87.000	99.000	103.000
d [Min.]	9.200	9.200	9.600

The rainfall intensity for a 10, 50 and 100- year storm events are shown in Appendix A.

The Ideal curves of figures 10 & 11 were based on a 24-hour event.

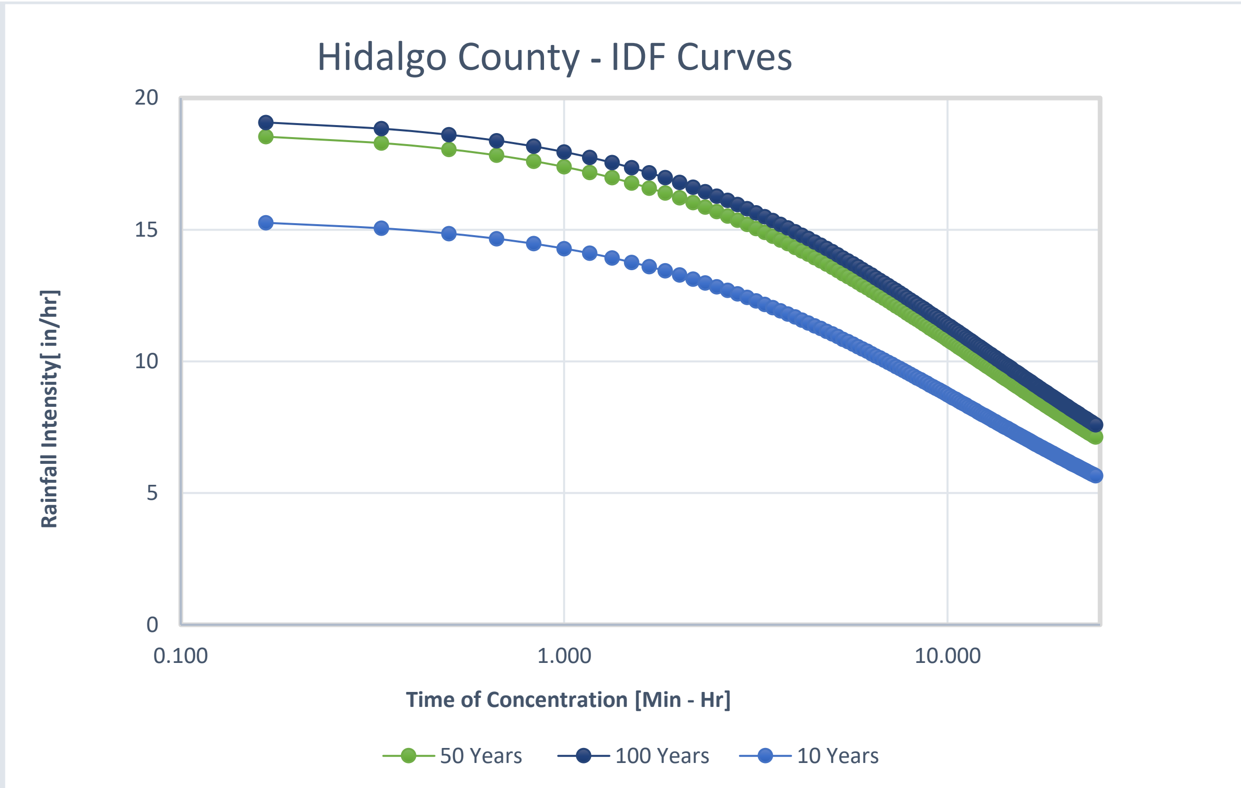


Figure 10: IDF Curves

Figure No. 11 presents the overall configuration of the rainfall intensity-duration-frequency (IDF) curve. As the duration of rainfall approaches zero, the corresponding intensity tends towards infinity. To ensure accuracy and reduce errors, a minimum concentration time of 10 minutes was adopted. Conversely, as the duration of rainfall tends towards infinity, the design rainfall intensity diminishes. It is noteworthy to mention that Texas Department of Transportation (Txdot) imposes an area limitation of 200 acres, whereas the Edinburg manual restricts the area to 100 acres when applying the Rational method calculations. This distinction leads to the derivation of more realistic rainfall intensities in the context of the Edinburg manual.

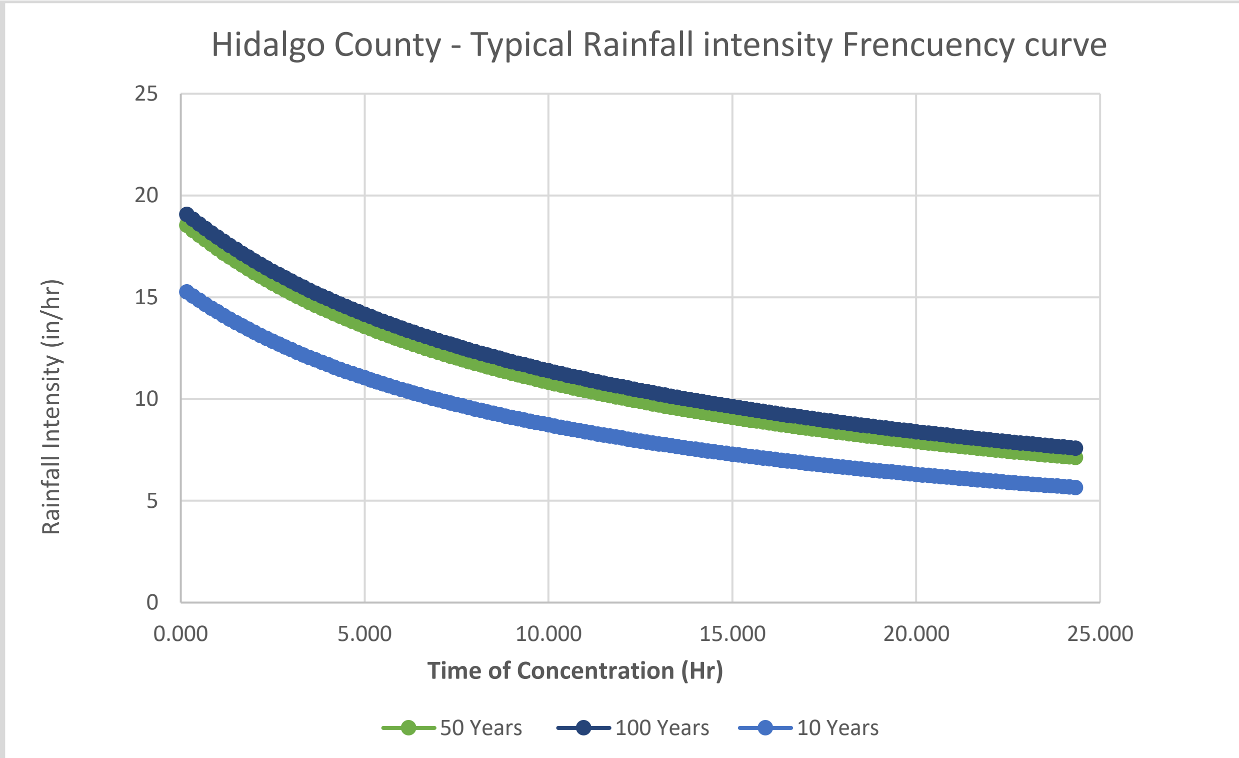


Figure 11: Typical Rainfall Intensity Frequency Curve

4.4 Weighted Runoff coefficient

To ascertain the weighted runoff coefficient, it is imperative to assess the respective proportions of grass and asphaltic areas about the total study area. This investigation quantified the grass area as 48,298.07 square feet, while the asphaltic area amounted to 460,263.62 square feet. Subsequently, the C weighted coefficient was determined, as detailed in Table No. 3.

4.5 Time of concentration

The time of concentration for the drainage system was established utilizing the Rational method. The geometry of the drainage areas played a crucial role in defining the time of concentration. Specifically, the distance from the furthest corner of each drainage area to the corresponding inlet was considered in determining the time of concentration. Further details and specific values can be found in Table No. 9.

Table 9: Time of concentration of the East parking lot of the UTRGV

TIME OF CONCENTRATION								
		OVERLAND FLOW			CHANNEL, PIPE, STREET, FLOW			
DRAINAGE AREA	DESCRIPTION	C	LENGTH (FT.)	TIME (MIN)	LENGTH (FT)	VELOCITY (FPS)	TIME (MIN)	TOTAL TIME (MIN)
D.A.#1	Overland & Gutter	0.817	6.6	0.7	171	0.4	7.1	7.9
D.A.#1-D.A.#2	Pipe Flow	0.817			42.3	3.0	0.2	8.1
D.A.#2	Overland & Gutter	0.817	27	3.0	172	0.4	7.2	10.2
D.A.#2-D.A.#3	Pipe Flow	0.817			186.4	3.0	1.0	11.2
D.A.#3	Overland & Gutter	0.817	28	3.1	182.9	0.4	7.6	10.7
D.A.#3-D.A.#4	Pipe Flow	0.817			226.3	3.0	1.3	12.5
D.A.#4	Overland & Gutter	0.817	28	3.1	182.9	0.4	7.6	10.7
D.A.#4-D.A.#5	Pipe Flow	0.817			165	3.0	0.9	13.4
D.A.#5	Overland & Gutter	0.817	28	3.1	163.4	0.4	6.8	9.9
D.A.#5-D.A.#6	Pipe Flow	0.817			168.6	3.0	0.9	14.3
D.A.#9	Overland & Gutter	0.817	3.5	0.4	403.7	0.4	16.8	17.2
D.A.#9-D.A.#6	Pipe Flow	0.817			177.8	3.0	1.0	18.2
D.A.#8	Overland & Gutter	0.817	212.8	23.6	0	0.4	0.0	23.6
D.A.#8-D.A#7	Pipe Flow	0.817			553.3	3.0	3.1	26.7
D.A.#7	Overland & Gutter	0.816929	27	3.0	224.2	0.4	9.3	12.3
D.A.#7-D.A#6	Pipe Flow	0.816929			321.4	3.0	1.8	28.5
D.A.#6	Overland & Gutter	0.816929	27	3.0	185	0.4	7.7	10.7
D.A.#6-outfal	**Pipe Flow**	**0.816929**			**183.4**	**3.0**	**1.0**	**29.5**

To determine the concentration time the maximum time of each contributing area was taken in account.

The time of concentration for the drainage system is 29.5 minutes.

4.6 Analyze the current and proposed drainage system

This project involved the analysis of three distinct scenarios. The initial scenario pertains to the evaluation of the current storm drainage system, which was designed to accommodate a 10-year storm event. This assessment aims to determine whether the existing drainage system complies with the prevailing regulations. The second scenario examines the existing drainage areas under a more severe 50-year storm event. In this case, the proposed pipe sizes will adhere to the guidelines set forth by the city of Edinburg regulations. The final scenario entails the analysis of the same drainage areas but with the consideration of a more extreme 100-year storm event. If deemed necessary, modifications will be made to the pipeline size within the system to accommodate this higher magnitude of rainfall.

To calculate the slope required on each pipeline, see Equation No. 6

Equation 6: Minimum Slope Required

$$S = \frac{Q}{C1^2}$$

Where:

S: slope [%]

C1: full flow coefficient value for circular pipe. See table No.

Q: flowrate [cfs]

In Tables No. 10, 11 and 12 a comparison was conducted between the minimum design slopes and the Edinburg standard building code. This analysis aimed to determine the appropriate pipe sizes for the existing drainage system. Column (J) denotes the minimum slope permitted by the building code for each storm pipe size. On the other hand, column (L) represents the calculated slope mandated by the design requirements. By evaluating these values, the suitable pipe sizes were determined in accordance with the building code and design specifications.

4.7 10-year storm event (Existing Drainage System)

For the 10-year storm event analysis, the current built design of the storm drainage system will be assessed to determine its compliance with the regulations set by the city of Edinburg and Txdot. This evaluation will involve comparing the design parameters and specifications of the system with the specific requirements outlined in the regulations. Examining factors such as pipe sizes, slopes, capacities, and other relevant criteria will determine whether the current design meets the regulatory standards for the 10-year storm event as stipulated by the city of Edinburg and Txdot.

Table 10: 10-year storm event system analysis

DRAINAGE AREA LOCATION	CONTRIBUTING AREA (acres)	C	TIME (minutes)	FREQUENCY (years)	INTENSITY (in./hr.)	FLOWRATE (c.f.s.)	PIPE SIZE (inches)	MIN. SLOPE (FT./FT.)	DESIGN SLOPE (Ft/Ft)	CHECK DESIGN
D.A.#1	0.18	0.838	7.9	10	9.574	1.44				
D.A.#1-D.A.#2	0.18	0.838	8.1	10	9.472	1.42	18.00	0.018%	0.255%	OK
D.A.#2	0.36	0.838	10.2	10	8.673	2.61				
D.A.#2-D.A.#3	0.54	0.838	11.2	10	8.329	3.76	18.00	0.128%	0.255%	OK
D.A.#3	1.99	0.838	10.7	10	8.481	14.14				
D.A.#3-D.A.#4	2.53	0.838	12.5	10	7.950	16.84	18.00	0.101%	0.129%	OK
D.A.#4	1.83	0.838	10.7	10	8.481	13.00				
D.A.#4-D.A.#5	4.36	0.838	13.4	10	7.698	28.10	42.00	0.078%	0.101%	OK
D.A.#5	1.41	0.838	9.9	10	8.761	10.37				
D.A.#5-D.A.#6	5.77	0.838	14.3	10	7.458	36.06	24.00	0.128%	0.174%	OK
D.A.#9	0.504	0.838	17.2	10	6.814	2.88				
D.A.#9-D.A.#6	0.504	0.838	18.2	10	6.622	2.80	18.00	0.071%	0.255%	OK
D.A.#8	1.845	0.838	23.6	10	5.751	8.89				
D.A.#8-D.A#7	1.845	0.838	26.7	10	5.364	8.30	18.00	0.624%	0.255%	ERROR
D.A.#7	1.849	0.838	12.3	10	7.984	12.38				
D.A.#7-D.A#6	3.695	0.838	28.5	10	5.165	16.00	18.00	2.321%	0.255%	ERROR
D.A.#6	1.708	0.838	10.7	10	8.489	12.16				
D.A.#6-outfal	11.675	0.838	29.5	10	5.059	49.51	36.00	0.553%	0.101%	ERROR

As indicated in Table No. 5, the pipe sizes for drainage areas 5, 7, 7, and 6 were insufficient to meet the current building regulations. Therefore, it was determined that an upsize of the pipe sizes is necessary to comply with the applicable regulations. This modification ensures the drainage system is appropriately designed to accommodate the required flow capacity and effectively manage the anticipated stormwater runoff in these specific drainage areas.

4.8 50-year storm event (Proposed Drainage System)

In the case of the 50-year storm event, the objective is to propose a design for a drainage system that complies with the current regulations. This includes factors such as pipe sizes, slopes, capacities, and other relevant design considerations to ensure that the proposed drainage system meets the regulatory requirements for the 50-year storm event as outlined in the building manual. See table No. 11.

Table 11: 50-year storm event system design

[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]
			TIME	RETURN				Results		
DRAINAGE AREA	CONTRIBUTING AREA (Acres)	C	(SEE TABLE 1) (minutes)	FREQUENCY (years)	INTENSITY (in./hr.)	FLOWRATE (c.f.s.)	PIPE SIZE (inches)	MIN. SLOPE (FT./FT.)	DESIGN SLOPE (Ft/Ft)	ADJUST DESIGN
D.A.#1	0.18	0.838	7.9	50	11.828	1.78				
D.A.#1-D.A.#2	0.18	0.838	8.1	50	11.707	1.76	18.00	0.028%	0.255%	OK
D.A.#2	0.36	0.838	10.2	50	10.756	3.24				
D.A.#2-D.A.#3	0.54	0.838	11.2	50	10.344	4.67	18.00	0.198%	0.255%	OK
D.A.#3	1.99	0.838	10.7	50	10.526	17.55				
D.A.#3-D.A.#4	2.53	0.838	12.5	50	9.891	20.95	36.00	0.099%	0.101%	OK
D.A.#4	1.83	0.838	10.7	50	10.526	16.13				
D.A.#4-D.A.#5	4.36	0.838	13.4	50	9.589	35.01	42.00	0.121%	0.101%	OK
D.A.#5	1.41	0.838	9.9	50	10.860	12.86				
D.A.#5-D.A.#6	5.77	0.838	14.3	50	9.301	44.97	48.00	0.098%	0.101%	OK
D.A.#9	0.504	0.838	17.2	50	8.526	3.61				
D.A.#9-D.A.#6	0.504	0.838	18.2	50	8.294	3.51	18.00	0.112%	0.255%	OK
D.A.#8	1.845	0.838	23.6	50	7.241	11.20				
D.A.#8-D.A#7	1.845	0.838	26.7	50	6.772	10.47	27.00	0.114%	0.174%	OK
D.A.#7	1.849	0.838	12.3	50	9.931	15.40				
D.A.#7-D.A#6	3.695	0.838	28.5	50	6.530	20.22	36.00	0.092%	0.101%	OK
D.A.#6	1.708	0.838	10.7	50	10.536	15.09				
D.A.#6-outfal	11.675	0.838	29.5	50	6.401	62.65	54.00	0.101%	0.101%	OK

4.9 100-year storm event (Proposed Drainage System)

In this case, this is a proposed design drainage system for a 100 year-storm event based on the current regulations of the City of Edinburg. For the analysis of the 100-year storm event, the drainage system and pipe sizes will be evaluated to determine their adequacy. This examination aims to ensure that the system can effectively handle the extreme rainfall associated with a 100-year storm event. If necessary, modifications to the pipe sizes within the system will be proposed to ensure compliance with the requirements for this more severe storm event.

Table 12: 100-year storm system analysis

[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]
			TIME	RETURN				Results		
DRAINAGE AREA	CONTRIBUTING AREA (Acres)	C	(minutes)	FREQUENCY (years)	INTENSITY (in./hr.)	FLOWRATE (c.f.s.)	PIPE SIZE (inches)	MIN. SLOPE (FT./FT.)	DESIGN SLOPE (Ft/Ft)	ADJUST DESIGN
D.A.#1	0.18	0.838	7.9	100	12.410	1.87				
D.A.#1-D.A.#2	0.18	0.838	8.1	100	12.287	1.85	18.00	0.031%	0.255%	OK
D.A.#2	0.36	0.838	10.2	100	11.320	3.41				
D.A.#2-D.A.#3	0.54	0.838	11.2	100	10.900	4.92	18.00	0.220%	0.255%	OK
D.A.#3	1.99	0.838	10.7	100	11.086	18.48				
D.A.#3-D.A.#4	2.53	0.838	12.5	100	10.437	22.11	42.00	0.048%	0.101%	OK
D.A.#4	1.83	0.838	10.7	100	11.086	16.99				
D.A.#4-D.A.#5	4.36	0.838	13.4	100	10.127	36.97	48.00	0.066%	0.101%	OK
D.A.#5	1.41	0.838	9.9	100	11.426	13.53				
D.A.#5-D.A.#6	5.77	0.838	14.3	100	9.832	47.54	54.00	0.058%	0.101%	OK
D.A.#9	0.504	0.838	17.2	100	9.034	3.82				
D.A.#9-D.A.#6	0.504	0.838	18.2	100	8.796	3.72	18.00	0.125%	0.255%	OK
D.A.#8	1.845	0.838	23.6	100	7.705	11.92				
D.A.#8-D.A#7	1.845	0.838	26.7	100	7.217	11.16	27.00	0.130%	0.174%	OK
D.A.#7	1.849	0.838	12.3	100	10.478	16.25				
D.A.#7-D.A#6	3.695	0.838	28.5	100	6.965	21.57	42.00	0.046%	0.101%	OK
D.A.#6	1.708	0.838	10.7	100	11.096	15.89				
D.A.#6-outfal	11.675	0.838	29.5	100	6.830	66.85	54.00	109.000%	0.101%	OK

In table No. 13 is the summary of the current and proposed drainage pipelines for the drainage area of study.

Table 13: summary of drainage system analysis under 10,50 & 100- year storm events

Pipelines size analysis			
Drainage area	10-year analisys	50-year design	100-year Analysis
No.	Size [in]	Size [in]	Size [in]
1	18	18	18
2	18	18	18
3	18	36	42
4	18	42	48
5	24	48	54
6	36	54	54
7	18	36	42
8	18	27	27
9	18	18	18

4.9.1 Storage requirements

To determine the required storage capacity for the parking lot in the present study, the modified rational method was employed, considering both the site's existing and future conditions.

4.9.2 Existing Conditions

The current site consists of a parking lot constructed with asphalt, designed to accommodate a 10-year storm event. This implies that the drainage system was sized to handle the rainfall intensity associated with a 10-year storm, as specified in the Edinburg Standard manual.

4.9.3 Future Conditions

Per the Edinburg Standard manual, any future developments on the site should be designed to withstand a 50-year storm event. This indicates that the stormwater management system for future constructions must effectively manage the higher rainfall intensity associated with a 50-year storm.

Considering these existing and future conditions, the modified rational method will determine the necessary storage capacity to accommodate the stormwater runoff that aligns with the specified storm event requirements.

The proposed drainage for this project consists of surface runoff of 62.65 cubic feet per second during 50-year storm frequency, as it is indicated in table N. 14 there is an increase of 46.41 cubic feet per second.

Table 14: Modified Rational Method, Details of existent and future conditions.

Existing Condition-10 year					
Area:	508,561.69 sf	Int. Coeff. "k"		0.619	
Area:	11.67 ac	Kµ		3.28	
Slope :	0.15 %	Length		1182.58 ft	
Rainfall Intensity (10yr)			5.564 in/hr		
c factor			0.250	asphalt	
Q peak existing condition:			16.24 cfs		
Future Condition-50 year					
Future area:	508,561.69	sf			
Future area:	11.67	ac			
Slope :	15.00%				
tc :	29.52	min			
Rainfall Intensity (50yr)	6.401	in/hr			
c factor	0.838				
Q future cond. = Aci = i *	62.65	*		0.84	
	9.7867717	i			

Applying the modified rational method, for a 50-year storm event at the Hidalgo County, see appendix B.

The storage required for 11.67 ac of the area of study is:

Storage Required:	110148.31	cf
w/ release rate of (10 year):	16.24	cfs

CHAPTER V

SOLUTION FOR CURRENT STORM DRAINAGE SYSTEM

Three possible solution scenarios were developed, and the construction processes for each scenario were detailed. The designs for these scenarios adhere to the regulations set by the city of Edinburg and Txdot, requiring them to be designed for a 50-year storm event.

To outline the construction processes for each scenario, the project management software Ms. Project was employed. This software provides a comprehensive breakdown of the production and activities to be undertaken in each stage of the construction process. By utilizing Ms. Project, the implementation of each scenario can be efficiently managed and executed, ensuring smooth progress throughout the project.

To determine the feasibility and costs associated with each scenario, budget estimates were prepared. The budget calculations were based on current prices for 2023, considering quotations provided by contractors or similar projects in the Rio Grande Valley region of south Texas.

By incorporating the construction process details, cost estimates, and project management techniques, stakeholders can assess each scenario's viability and financial aspects. This comprehensive approach ensures that the proposed solutions are technically sound and economically feasible.

5.1 Modification of the current drainage system of the UTRGV

The current drainage system's initial solution involves increasing the pipes' size throughout the entire system, including manholes, pipes, inlets, and other components contributing to this drainage area. This modification is based on the proposed design to accommodate a 50-year storm event. This project would consist on re-doing the complete storm system contributing to this drainage area falling into the main pipe of the university and also into the city MS4 drainage line.

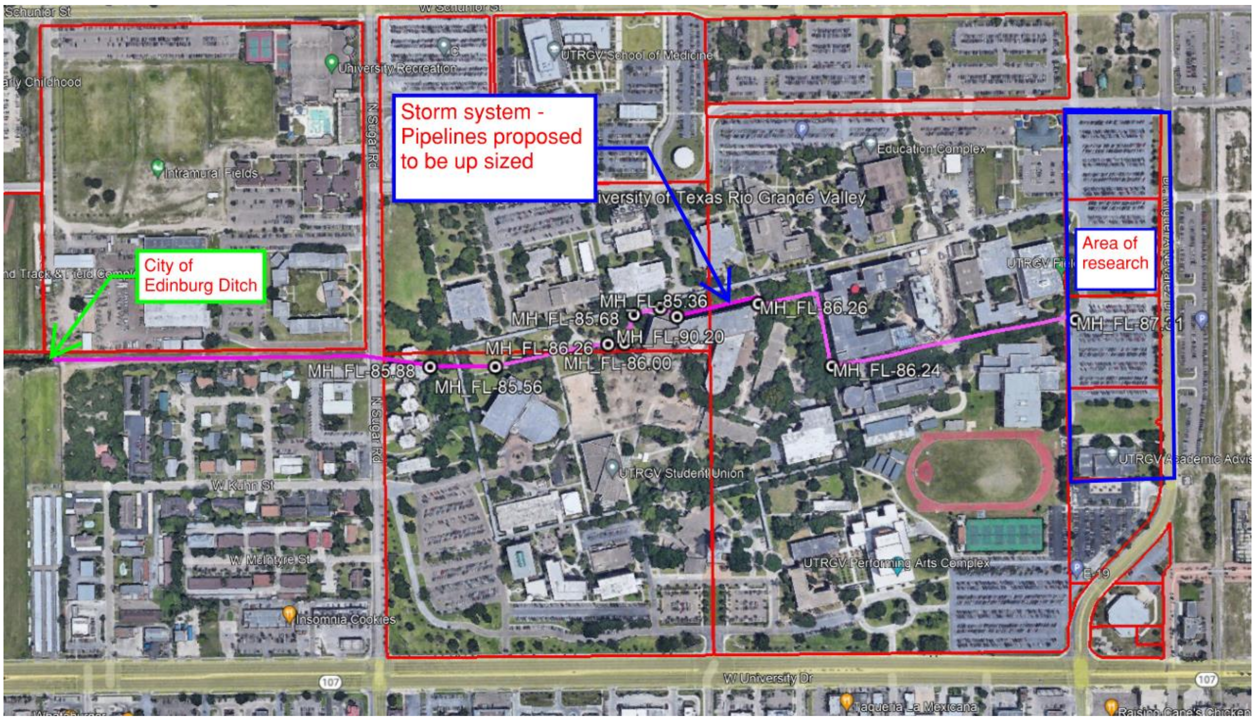


Figure 12: Proposed Drainage Improvements No. 1

Implementing this solution would necessitate undertaking construction activities outlined in detail in Figure No. 8. The construction process is estimated to span approximately one year, considering the various tasks and stages in modifying the drainage system according to the proposed design. See timeline of this project in Appendix C.

This scenario is deemed infeasible due to the significant disruption it would cause to academic activities on campus. The proposed construction process would require the closure of academic facilities for approximately 290 days, which is not a viable option. Maintaining uninterrupted academic activities and minimizing disruptions to students and faculty is crucial in the decision-making process.

In that case, it is necessary to reassess the proposed solution. Exploring alternative solutions to achieve the desired goals without causing extensive disruptions to academic activities is necessary. It is crucial to prioritize the continuity of academic activities and the overall functioning of the campus.

By reassessing the project requirements and constraints, including the need to maintain regular campus operations, alternative approaches can be considered that strike a balance between addressing the drainage system challenges and minimizing disruption to academic activities. This ensures that the overall campus functionality and educational experience are not compromised.

5.2 Tank stormwater modules

The second option for this project was installing underground R tanks beneath the existing parking lots. These R tanks, also known as retention tanks or rainwater harvesting tanks, are designed to capture and store stormwater runoff for later use or gradual release. By implementing this solution, the project aims to enhance the stormwater management capabilities of the site.

Installing R tanks beneath the current parking lots would involve excavation and construction work to create suitable storage chambers. These tanks would effectively collect and store excess rainwater during storm events, helping to alleviate pressure on the existing drainage system and reduce the risk of flooding. The target frequency for these tanks is a 50-year storm event.

One of the key benefits of R-tank modules is their ability to reduce the footprint of underground stormwater storage, thereby resolving utility conflicts and creating additional space for various types of development. These modules are available in five different configurations, ranging from 2 inches to 7 inches in height. Their versatility allows them to support various traffic loads, making them widely used in stormwater management projects.

R-tank modules are wrapped with geotextile fabrics, providing additional filtration and retention capabilities. Depending on the specific requirements, the cover depths can range from 6 inches to over 16 feet deep. The stormwater runoff collected in the R-tank modules can be discharged into a drainage system, infiltrated back into the ground, or stored for future use, offering flexibility in managing stormwater resources.

By adopting this approach, the project would use the space beneath the parking lots to implement sustainable stormwater management practices. This option can contribute to water conservation, mitigate the impact of heavy rainfall events, and potentially provide a supplemental water source for non-potable uses such as irrigation or toilet flushing (Ngu et al., 2016).

Figure 13:R- Tanks

5.2.1 R Tanks timeline of the project

The timeline for implementing this technology in the project is around 10 months. It is necessary to consider that the project's duration may vary depending on the weather and materials availability on the market. See Appendix D.

5.2.2 R-tanks implementation cost

To create a comprehensive budget for the construction process involving R-tanks, a preliminary budget was requested to the Ferguson company. The cost of R-tank modules can vary depending on factors such as the topography of the installation site and the required water storage capacity.

In addition to the cost of R-tank modules, the budget includes additional materials necessary for the installation process. This ensures that all necessary materials are accounted for in the budgeting process.

By considering these factors and obtaining accurate budget estimates from relevant suppliers and contractors, a comprehensive budget for the construction process involving R-tanks can be developed. This ensures that all costs are accounted for and allows for effective financial planning and management throughout the project.

Table 15: Budget for R-Tanks installation

Option 2 - R-Tanks				
Description	**Quantity**	**Unit**	**Unitary Price [$]**	**Total [$]**
Geotechnical studies	1	Ls	$ 5,000.00	$ 5,000.00
R-tank Modules	1	LS	$ 620,000.00	$ 620,000.00
Labor + Installations	3%	%	$ 527,843.75	$ 15,835.31
Excavation & Grading	111125.00	Cf	$ 4.75	$ 527,843.75
Rock material	1	Ls	$ 25,000.00	$ 25,000.00
Management fee	1.5%	%	$ 527,843.75	$ 7,917.66
Asphalt repair	3002.78	SY	$ 5.00	$ 15,013.89
Stripping	1	LS	$ 2,500.00	$ 2,500.00
Total Cost				$1,219,110.61

5.3 Detention pond on site

The third option for resolving the drainage system of the parking lot involves constructing a detention pond on-site based on the 50-year storm event. In the proposed drainage for this study shows a runoff of 62.65 c.f.s for a 50-year storm event. For the proposed system the runoff will run with a 10-year outfall rate from the surrounding areas to the detention pond on site and will outfall on the main pipe of the UTRGV, it will run along the campus east to west and then will discharge with a 42” storm discharge pipe into the existing dich from the city of Edinburg to the Main North Drain.

The detention pond design follows the minimum construction requirements specified by the City of Edinburg. These requirements include adhering to a maximum slope of 3 to 1, which means that for every 3 feet of horizontal distance, the pond is lowered by 1 foot vertically, as illustrated in Figure No. 18 (City of Edinbug Council, 2021).

In addition, Txdot and the City of Edinburg mandate that a minimum space of 24 feet be left on the sides of the detention pond to allow for the circulation of a firetruck in emergencies.

For the pipe outlet, it is necessary to construct a concrete structure known as Rip-Rap. This structure accommodates the pipe that discharges into the detention pond and connects to the drainage system. Refer to Figure No. 19 for visual reference.

The project aims to effectively manage stormwater runoff and mitigate potential flooding issues in the parking lot area by implementing a detention pond and complying with the relevant regulations and design considerations (City of Edinbug Council, 2021).

Figure 14: Rip Rap concrete structure sample

To address the concern of backflow in the discharge pipeline of the detention pond, it is proposed to install a flap valve. Flap valves are designed to control flow and prevent backflow in various environments, including water surfaces, sewers, disposal systems, and aggressive settings where reverse flow must be prevented.

The flap valve automatically opens or closes the gate to control the water flow. It effectively prevents the backward movement of water, ensuring the flow remains in the intended direction. These valves are commonly utilized in reservoirs, tidal basins, ponding basins, waste lines, pump stands, and storm drain systems.

By incorporating a flap valve in the discharge pipeline of the detention pond, the project aims to enhance the functionality and efficiency of the system while mitigating the risk of backflow. This valve ensures that water flows appropriately and prevents any potential backflow, contributing to the overall effectiveness of the stormwater management infrastructure. Please refer to Figure No. 16 for a visual representation of a flap valve.

Figure 15: Flap Valve

5.3.1 Detention Pond timeline

Based on the experience of similar projects carried out in the South Texas, Rio Grande Valley region, the estimated total duration for implementing the water detention well project is approximately 160 days. This duration encompasses various stages, starting from the design period and concluding with the construction of the system.

The timeline for the project may be subject to adjustments based on specific site conditions, project complexity, and unforeseen circumstances that may arise during the construction process. See Appendix C.

5.3.2 Detention Pond development Cost

To determine the budget for the proposed project, it is necessary to consider all the potential costs incurred from the engineering phase to the end construction period.

The cost estimation for this proposed project has been calculated using the current labor and material costs available in The Rio Grande Valley as of 2023. A detailed breakdown of the costs can be found in the provided table, which outlines the various cost components associated with the project.

It is essential to consider that project costs can vary depending on factors such as project size, site conditions, market fluctuations, and specific project requirements. Therefore, the estimated costs in the table serve as a guideline based on the current available data.

The budget calculation considers the comprehensive expenses associated with the project, enabling stakeholders to assess and plan the financial resources required for successful project implementation.

Table 16: Budget of the detention pond development

Detention Pond Budget				
Description	**Quantity**	**Unit**	**Unitary Price [$]**	**Total [$]**
Geotechnical studies	1	Ls	$ 5,000.00	$ 5,000.00
Engineering Fees	0.03	%	$ 527,843.75	$ 15,835.31
Excavation & Grading	111125	Cf	$ 4.75	$ 527,843.75
Rip Rap concrete	400.32	SF	$ 9.00	$ 3,602.88
Flap Valve	1	EA	$ 2,500.00	$ 2,500.00
Asphalt repair	3002.78	SY	$ 5.00	$ 15,013.89
Amenities - Fencing	720	LF	$ 35.70	$ 25,704.00
Total cost				$595,499.83

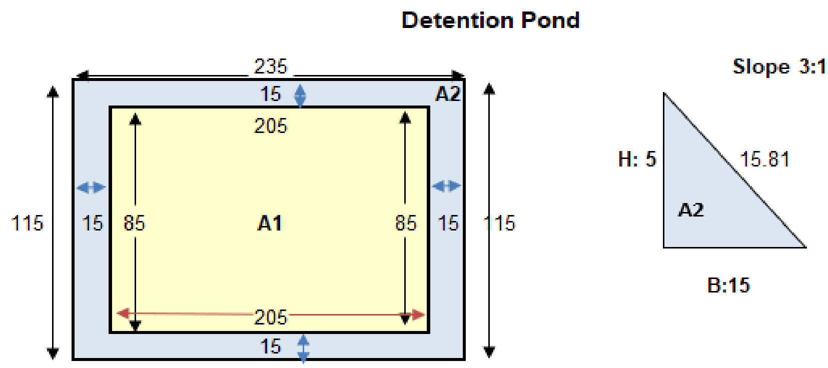
5.3.3 Design specifications

Based on the calculations conducted for the study area, considering the topography of the site and the drainage report, it has been determined that a minimum storage capacity of 110,148.1 cubic feet (cf) is required for the 50-year storm event.

With the given elevations of the site, the detention pit dimensions have been determined to be 235 feet long and 115 feet in width. The slopes of the pond follow a 3:1 ratio, which means that for every 3 feet of horizontal distance, the pond is lowered by 1 foot vertically. These slope specifications help ensure proper water management and drainage.

The detention pond on site, has been designed specifically for the 50-year storm event, has a storage capacity of 111,125 cf. This capacity provides sufficient space to hold the stormwater runoff during the peak flow. Additionally, the well has an additional 977 (cf) of water storage, allowing for extra capacity in a larger storm event.

By designing the detention pond with these specifications, the project aims to effectively manage and store the stormwater runoff, minimizing the risk of flooding and providing adequate storage capacity for the anticipated storm events.



Length				
L1	235-15-15	=	205	[ft]
L2	45-15-15	=	85	[ft]

Figure 16: detention pond specifications

The volume required for the detention pond was calculated as follows:

Table 17: volume capacity of the detention pond

Volume				
VA1	205 x 15 x 5	=	87125	[cf]
VA2	B x H x L x 2	=		[cf]
VA2.1	$\frac{15 \times 5 \times 235 \times 2}{2}$	=	17625	[cf]
VA2.2	15 x 5 x 45 x 2	=	6375	[cf]

Table 17, cont.

2

V total	VA1 + Va2.1 + Va2.2		[cf]
Total Volume		**111.125**	**[cf]**

5.3.4 Detention pond location

The location of the detention well for the proposed drainage system has been determined based on the analysis of the existing drainage system. After careful assessment, it has been identified that drainage areas N5 and N6 exhibit the greatest deficiency in the current system. To address this issue effectively, it has been decided to repurpose an unused green area to construct the detention well.

By strategically placing the detention well in this designated area, the system aims to achieve two main objectives. Firstly, it will serve as a preventive measure against future flooding incidents in the location, thereby improving the overall resilience of the site. Secondly, utilizing the currently unused space will optimize the efficiency of the drainage system, ensuring that it functions effectively.

While constructing the detention well will result in a loss of approximately 44 parking spaces out of a total of 850, this trade-off is necessary to enhance the performance of the drainage system and utilize the available land effectively. Great attention will be given to planning and design considerations to minimize the impact on parking availability and ensure the site functions optimally.

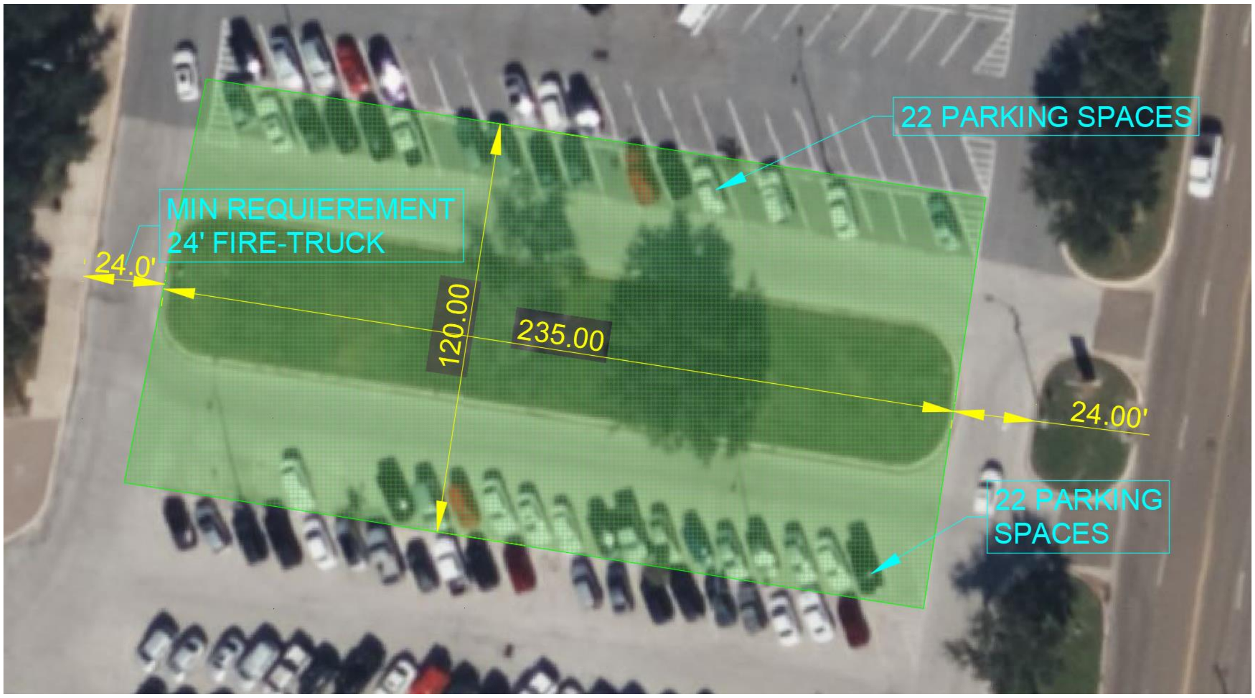


Figure 17: location of the proposed detention pond

5.3.5 Rip – Rap concrete structure detailed

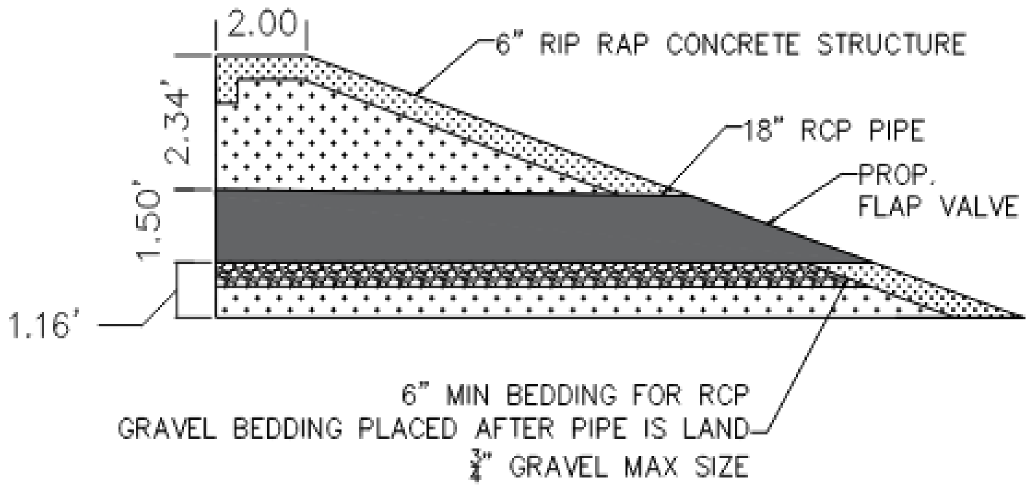


Figure 18: Rip Rap structure detailed (outfall)

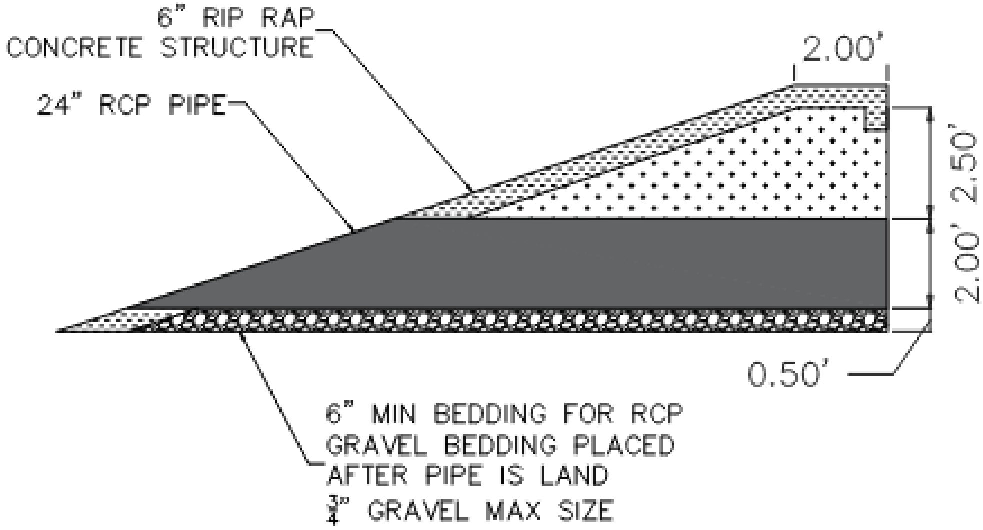


Figure 19: Rip Rap structure (10-year outfall rate)

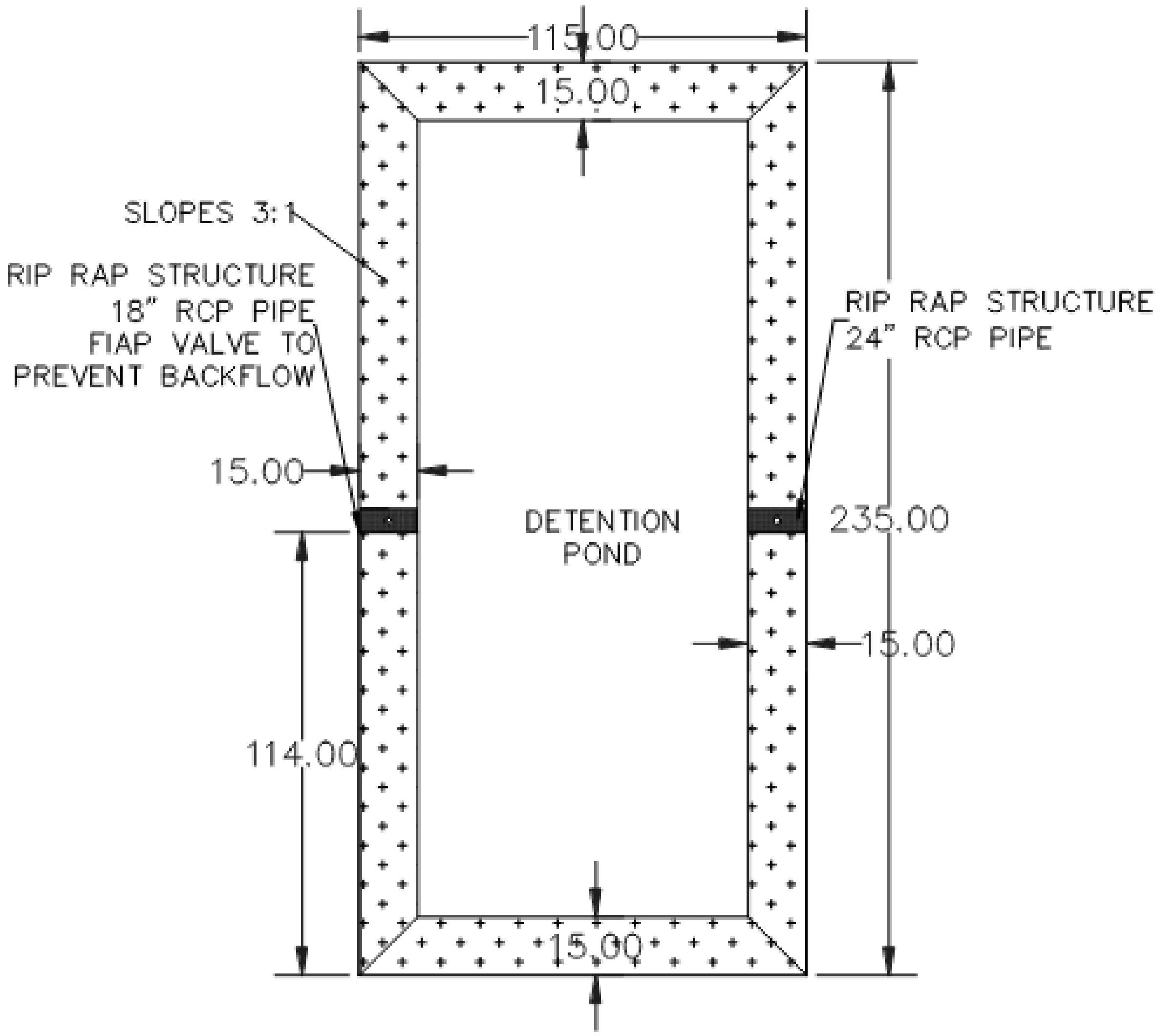


Figure 20: Detailed Detention Pond

CHAPTER VI

CONCLUSIONS & RECOMMENDATIONS

6.1 Summary of findings

The UTRGV parking lots project analysis revealed several key findings and recommendations including the following:

1. Flooding Issue: The eastern parking lot was identified as the most prone to flooding during various storm events, including 10, 50, and 100-year storms. The water levels in this area can reach 3-5 feet, indicating a significant problem with the current drainage system.
2. Rational Method and Manuals: As outlined in the standard manual of Edinburg and the TXdot manual, the rational method assesses the drainage system. This method helped determine the concentration time and peak flow for different storm events. These manuals also emphasize the importance of designing for a 50-year storm in future developments.
3. Topography and Drainage Areas: Field visits were conducted to gather topographical data, enabling the identification of drainage areas. These areas typically have higher elevations at their boundaries and lower elevations where inlets are located.
4. Inefficiency in the System: Based on the analysis, it was determined that the current size of the pipes is the primary factor contributing to the system's inefficiency. Upgrading the

pipe sizes is necessary, or a storage on site to accommodate the required flow rates, prevent flooding, or add storage on site.

5. Drainage Design Modification: The areas of concern, specifically areas 4, 5, and 6, require modifications to the drainage design. These modifications will help mitigate the flooding issues in these areas and ensure effective stormwater management.
6. Storage Requirements: The modified rational method indicates that the entire study area needs approximately 111 cubic feet of storage capacity to effectively manage a 50-year storm event.

Based on the results, three scenario solutions were developed:

1. Upsize the pipes throughout the university from east to west of the entire campus
2. Implementation of R-tanks as underground detention ponds
3. Construction of a detention pond on-site

As highlighted in Summary Table No. 18, it is evident that the existing drainage design of the study area is inadequate to handle a 10-year storm event efficiently. Moreover, the proposed design for a 50-year storm event indicates the need for enlarging the current pipe sizes, like the requirements for a 100-year storm event. Enlarging the pipe sizes will enable the system to adequately handle the increased flow rates and mitigate potential flooding issues associated with these higher magnitude storm events.

These observations underscore the necessity for modifications and improvements in the drainage system to ensure its effectiveness and compliance with the anticipated storm intensities.

Table 18: Evaluation table of proposed solutions

Scenarios	1	2	3
Evaluation type	Upsize whole UTRGV drainge system	Installation of R-tanks	Detention pond on-site
Technically Feasible	NO	YES	YES
Cost efficient	NO	NO	YES

Based on the outcome analysis, it is evident that solution number 1 is not a feasible option due to the substantial disruption of academic activities for an extended duration of approximately 290 days. Moreover, the requirement to demolish the existing drainage system to expand its capacity renders this solution technically inefficient and financially unviable.

Similarly, solution number 2, entailing the implementation of R-tanks for underground detention purposes, was disregarded due to its considerable cost implications. Despite the advantageous characteristics of these systems, such as their ability to store groundwater without occupying usable space, the project budgeting process revealed that this solution did not offer a cost-effective approach.

Conversely, solution number 3, involving designing and constructing an on-site detention pond, emerged as the most suitable choice from both technical and economic perspectives. This solution addresses the drainage issues experienced in the crucial areas 5 to 6. Additionally, it capitalizes on the currently underutilized green area of an existing island within the study site. The design and construction plans for the detention pond adhere to relevant building regulations stipulated by the city and state.

While the drawback of this solution entails the loss of 44 parking spaces, accounting for approximately 5% of the overall parking capacity in the specific sector, it remains the most viable option. See table No. 19. This determination is based on its ability to fulfill the required storage capacity to prevent future flooding events. The comprehensive evaluation of technical feasibility and cost-effectiveness underpins the selection of this solution.

Table 19: Summary of Parking lots

Parking lots		
Current	Lose	New TotaL
850	44	806
100%	5%	95%

Ultimately, implementing the detention pond on-site will equip the educational institution with a robust stormwater management system, ensuring enhanced safety, convenience, and uninterrupted academic operations for the university community, encompassing students, faculty, and staff.

6.2 Recommendation for de development of the project

In order to ensure the successful design and implementation of hydraulic projects, it is recommended to adhere to the regulations set forth by the City and the state, even if it entails additional costs, as this will yield long-term benefits. Prior to construction, it is essential to conduct geotechnical studies to assess soil conditions and inform foundation design decisions. During site excavation, verifying that the slopes conform to the specifications outlined in the construction manual is important. The project manager should diligently execute the details specified in the plans to ensure accurate implementation. Upon project completion, it is crucial to install a fence around the detention pit to prevent the accumulation of debris, which could compromise the drainage system's integrity during storm events. Lastly, regular site maintenance is necessary to ensure the system's efficient functioning over time.

Is recommended to develop the detention pond on site appealing to the eye. Is necessary to get and architecture landscape design, thus the space could be used by the students and as detention. For example, there is a university in Massachusetts that has a detention pond on site and this area is used to decorate the place. See figure No. 21.

Figure 21: Example of an existing detention pond on site

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APPENDIX A

APPENDIX A

DEFINITION OF TERMS

0.2% annual chance storm event: storm event that has a probability of occurrence of 0.2% in a calendar year. Event referred as 500-year flood.

1% annual chance storm event: storm event that has a probability of occurrence of 1 % in a calendar year. Event referred as 100-year flood.

2% annual chance storm event: storm event that has a probability of occurrence of 2 % in a calendar year. Event referred as 50-year flood.

10-year storm event: meteorological event that has a 10% probability of occurring in a calendar year.

High flood risk: refers to an area or location that is particularly susceptible to flooding. Properties that are prone to flooding during 1% annual chance storm event.

Detention pond: stores stormwater runoff during rain events and release it at a controlled rate.

Retention Pond: retains stormwater runoff on a permanent or semi-permanent basis.

FEMA: is the Federal Emergency Management Agency that coordinates and responds to disasters that occur within the United States and overwhelms the resources of local and state authorities.

Flood zone: Special Flood Hazard Areas (SFHAs). Geographic area identified by the Federal Emergency Management Agency (FEMA) as being at risk of flooding.

Zone A: Areas with a high flood risk, typically located near rivers, lakes, and coastal areas. These areas have a 1% or greater chance of flooding in a year.

Zone AE: Have a detailes analysis and base flood elevations (BFEs) determined for the area.

Zone X (shaded): Areas with moderate flood risk, where the 1% annual chance flood is less likely to occur but still possible.

Zone X (unshaded): Areas with minimal flood risk, with a very low 1% annual chance flood.

Lidar: Light detection and ranging, sensing technology that utilizes laser light to precisely measure distances and generate intricate three-dimensional maps of the Earth's surface.

Txdot: Texas department of Transportation.

APPENDIX B

APPENDIX B

LIST OF EQUATIONS

APPENDIX C

APPENDIX C

Table 20: rainfall intensity for a 10, 50 and a 100 year storm events

Tc [Hr]	Tc [Minm	Rainfall Intensity (in/hr)		
		10 Years	50 Years	100 Years
0.167	10	15.26	18.53	19.07
0.333	20	15.05	18.29	18.84
0.500	30	14.85	18.05	18.61
0.667	40	14.66	17.82	18.38
0.833	50	14.47	17.60	18.16
1.000	60	14.28	17.39	17.95
1.167	70	14.10	17.18	17.75
1.333	80	13.93	16.97	17.55
1.500	90	13.76	16.77	17.35
1.667	100	13.60	16.58	17.16
1.833	110	13.44	16.39	16.97
2.000	120	13.28	16.21	16.79
2.167	130	13.13	16.03	16.62
2.333	140	12.98	15.86	16.44
2.500	150	12.84	15.69	16.28
2.667	160	12.70	15.52	16.11
2.833	170	12.56	15.36	15.95
3.000	180	12.43	15.20	15.80
3.167	190	12.30	15.05	15.64
3.333	200	12.17	14.90	15.49
3.500	210	12.04	14.75	15.35
3.667	220	11.92	14.61	15.21
3.833	230	11.80	14.47	15.07
4.000	240	11.69	14.33	14.93
4.167	250	11.57	14.20	14.79
4.333	260	11.46	14.07	14.66
4.500	270	11.35	13.94	14.54
4.667	280	11.25	13.81	14.41
4.833	290	11.14	13.69	14.29
5.000	300	11.04	13.57	14.16
5.167	310	10.94	13.45	14.05
5.333	320	10.84	13.34	13.93
5.500	330	10.75	13.22	13.82
5.667	340	10.65	13.11	13.70
5.833	350	10.56	13.00	13.59

Appendix C, Continuation of Table 20,

‘6.000	360	10.47	12.90	13.49
6.167	370	10.38	12.79	13.38
6.333	380	10.30	12.69	13.28
6.500	390	10.21	12.59	13.18
6.667	400	10.13	12.49	13.08
6.833	410	10.05	12.39	12.98
7.000	420	9.97	12.29	12.88
7.167	430	9.89	12.20	12.79
7.333	440	9.81	12.11	12.69
7.500	450	9.73	12.02	12.60
7.667	460	9.66	11.93	12.51
7.833	470	9.58	11.84	12.42
8.000	480	9.51	11.76	12.34
8.167	490	9.44	11.67	12.25
8.333	500	9.37	11.59	12.17
8.500	510	9.30	11.51	12.08
8.667	520	9.23	11.42	12.00
8.833	530	9.17	11.35	11.92
9.000	540	9.10	11.27	11.84
9.167	550	9.04	11.19	11.76
9.333	560	8.98	11.12	11.69
9.500	570	8.91	11.04	11.61
9.667	580	8.85	10.97	11.54
9.833	590	8.79	10.90	11.46
10.000	600	8.73	10.83	11.39
10.167	610	8.67	10.76	11.32
10.333	620	8.62	10.69	11.25
10.500	630	8.56	10.62	11.18
10.667	640	8.50	10.55	11.11
10.833	650	8.45	10.49	11.05
11.000	660	8.39	10.42	10.98
11.167	670	8.34	10.36	10.91
11.333	680	8.29	10.29	10.85
11.500	690	8.24	10.23	10.79
11.667	700	8.18	10.17	10.72
11.833	710	8.13	10.11	10.66
12.000	720	8.08	10.05	10.60
12.167	730	8.03	9.99	10.54
12.333	740	7.99	9.93	10.48
12.500	750	7.94	9.88	10.42
12.667	760	7.89	9.82	10.37
12.833	770	7.85	9.76	10.31
13.000	780	7.80	9.71	10.25
13.167	790	7.75	9.66	10.20
13.333	800	7.71	9.60	10.14

Appendix C, Continuation of Table 20,

13.500	810	7.67	9.55	10.09
13.667	820	7.62	9.50	10.03
13.833	830	7.58	9.45	9.98
14.000	840	7.54	9.39	9.93
14.167	850	7.49	9.34	9.88
14.333	860	7.45	9.29	9.83
14.500	870	7.41	9.25	9.78
14.667	880	7.37	9.20	9.73
14.833	890	7.33	9.15	9.68
15.000	900	7.29	9.10	9.63
15.167	910	7.25	9.06	9.58
15.333	920	7.22	9.01	9.53
15.500	930	7.18	8.96	9.49
15.667	940	7.14	8.92	9.44
15.833	950	7.10	8.87	9.39
16.000	960	7.07	8.83	9.35
16.167	970	7.03	8.79	9.30
16.333	980	7.00	8.74	9.26
16.500	990	6.96	8.70	9.22
16.667	1000	6.92	8.66	9.17
16.833	1010	6.89	8.62	9.13
17.000	1020	6.86	8.58	9.09
17.167	1030	6.82	8.54	9.05
17.333	1040	6.79	8.50	9.00
17.500	1050	6.76	8.46	8.96
17.667	1060	6.72	8.42	8.92
17.833	1070	6.69	8.38	8.88
18.000	1080	6.66	8.34	8.84
18.167	1090	6.63	8.30	8.80
18.333	1100	6.60	8.26	8.76
18.500	1110	6.57	8.23	8.73
18.667	1120	6.53	8.19	8.69
18.833	1130	6.50	8.15	8.65
19.000	1140	6.47	8.12	8.61
19.167	1150	6.45	8.08	8.58
19.333	1160	6.42	8.05	8.54
19.500	1170	6.39	8.01	8.50
19.667	1180	6.36	7.98	8.47
19.833	1190	6.33	7.94	8.43
20.000	1200	6.30	7.91	8.40
20.167	1210	6.27	7.87	8.36
20.333	1220	6.25	7.84	8.33
20.500	1230	6.22	7.81	8.29
20.667	1240	6.19	7.78	8.26
20.833	1250	6.17	7.74	8.23

Appendix C, Continuation of Table 20,

21.000	1260	6.14	7.71	8.19
21.167	1270	6.11	7.68	8.16
21.333	1280	6.09	7.65	8.13
21.500	1290	6.06	7.62	8.09
21.667	1300	6.04	7.59	8.06
21.833	1310	6.01	7.56	8.03
22.000	1320	5.99	7.53	8.00
22.167	1330	5.96	7.50	7.97
22.333	1340	5.94	7.47	7.94
22.500	1350	5.91	7.44	7.91
22.667	1360	5.89	7.41	7.88
22.833	1370	5.86	7.38	7.85
23.000	1380	5.84	7.35	7.82
23.167	1390	5.82	7.32	7.79
23.333	1400	5.79	7.29	7.76
23.500	1410	5.77	7.27	7.73
23.667	1420	5.75	7.24	7.70
23.833	1430	5.72	7.21	7.67
24.000	1440	5.70	7.18	7.64
24.167	1450	5.68	7.16	7.62
24.333	1460	5.66	7.13	7.59

APPENDIX D

APPENDIX D

Table 21: Modified Rational Method calculation

time	time	i	Qin	Vin	Qout	Vout	REQ'D V
min.	hour	in/hr	cfs	cf	cfs	cf	cf
5	0.08	13.57	132.80	39841	16.24	16820	23021
10	0.17	10.83	105.95	63567	16.24	19256	44311
15	0.25	9.10	89.08	80175	16.24	21692	58483
25	0.42	7.03	68.75	103129	16.24	26564	76565
35	0.58	5.80	56.74	119144	16.24	31437	87708
45	0.75	4.98	48.70	131484	16.24	36309	95175
55	0.92	4.38	42.90	141561	16.24	41181	100381
65	1.08	3.93	38.49	150109	16.24	46053	104056
75	1.25	3.58	35.01	157554	16.24	50925	106628
85	1.42	3.29	32.19	164165	16.24	55797	108368
95	1.58	3.05	29.85	170124	16.24	60669	109455
105	1.75	2.85	27.87	175559	16.24	65542	110017
115	1.92	2.67	26.17	180562	16.24	70414	110148
125	2.08	2.52	24.69	185204	16.24	75286	109918
135	2.25	2.39	23.40	189537	16.24	80158	109379
145	2.42	2.27	22.25	193606	16.24	85030	108576
155	2.58	2.17	21.23	197444	16.24	89902	107541
165	2.75	2.08	20.31	201078	16.24	94775	106303
175	2.92	1.99	19.48	204532	16.24	99647	104886
185	3.08	1.91	18.72	207826	16.24	104519	103307
195	3.25	1.84	18.03	210974	16.24	109391	101583
205	3.42	1.78	17.40	213991	16.24	114263	99728
215	3.58	1.72	16.81	216889	16.24	119135	97754
225	3.75	1.66	16.27	219679	16.24	124008	95671
235	3.92	1.61	15.77	222368	16.24	128880	93488
245	4.08	1.56	15.30	224965	16.24	133752	91213
255	4.25	1.52	14.87	227477	16.24	138624	88853
265	4.42	1.48	14.46	229911	16.24	143496	86415
275	4.58	1.44	14.08	232271	16.24	148368	83902

Appendix D, Continuation of Table 21,

285	4.75	1.40	13.72	234562	16.24	153241	81321
295	4.92	1.37	13.38	236789	16.24	158113	78676
305	5.08	1.33	13.06	238956	16.24	162985	75971
315	5.25	1.30	12.75	241067	16.24	167857	73210
325	5.42	1.27	12.47	243124	16.24	172729	70395
335	5.58	1.25	12.20	245132	16.24	177601	67530
345	5.75	1.22	11.94	247092	16.24	182474	64618
355	5.92	1.19	11.69	249006	16.24	187346	61661
365	6.08	1.17	11.46	250879	16.24	192218	58661
375	6.25	1.15	11.23	252711	16.24	197090	55621
385	6.42	1.13	11.02	254504	16.24	201962	52542
395	6.58	1.10	10.81	256261	16.24	206834	49427
405	6.75	1.08	10.62	257983	16.24	211706	46276
415	6.92	1.07	10.43	259671	16.24	216579	43092
425	7.08	1.05	10.25	261328	16.24	221451	39877
435	7.25	1.03	10.07	262953	16.24	226323	36630
445	7.42	1.01	9.91	264550	16.24	231195	33355
455	7.58	1.00	9.75	266119	16.24	236067	30051
465	7.75	0.98	9.59	267660	16.24	240939	26721
475	7.92	0.97	9.44	269176	16.24	245812	23364
485	8.08	0.95	9.30	270666	16.24	250684	19983
495	8.25	0.94	9.16	272133	16.24	255556	16577
505	8.42	0.92	9.03	273577	16.24	260428	13149
515	8.58	0.91	8.90	274998	16.24	265300	9698
525	8.75	0.90	8.77	276398	16.24	270172	6226
535	8.92	0.88	8.65	277777	16.24	275045	2733
545	9.08	0.87	8.54	279136	16.24	279917	-781
555	9.25	0.86	8.42	280476	16.24	284789	-4313
565	9.42	0.85	8.31	281797	16.24	289661	-7864
575	9.58	0.84	8.21	283100	16.24	294533	-11434
585	9.75	0.83	8.10	284385	16.24	299405	-15021

APPENDIX E

APPENDIX E

	Task Name	Duration	Start	Finish
1	Option 1 - Modify the current Storm system	295 days	Fri 6/2/23	Thu 7/18/24
2	Geotechnical studies	30 days	Fri 6/2/23	Thu 7/13/23
3	Engineering Desgin	70 days	Fri 7/14/23	Thu 10/19/23
4	Demolition	30 days	Fri 10/20/23	Thu 11/30/23
5	Excavation & Gradding	30 days	Fri 12/1/23	Thu 1/11/24
6	Construction of the new storm system	45 days	Fri 1/12/24	Thu 3/14/24
7	Asplhat reipair	30 days	Fri 3/15/24	Thu 4/25/24
8	Amenities repair	30 days	Fri 4/26/24	Thu 6/6/24
9	Landscaping	30 days	Fri 6/7/24	Thu 7/18/24

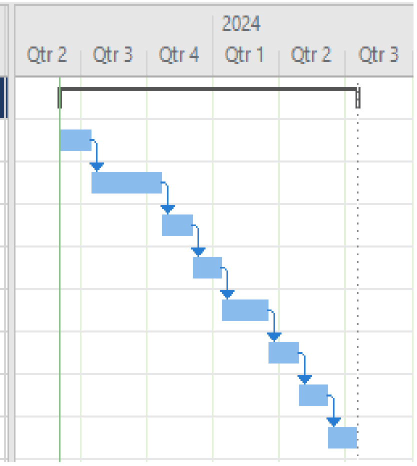

Figure 22: Timeline Scenario No. 1 (Upsize the current drainage system)

APPENDIX F

APPENDIX F

Task Name	Duration	Start	Finish	Cost
UTRGV - West parking lot	**211 days**	**Mon 1/1/24**	**Mon 10/21/2**	**$1,219,112.96**
Project start date	0 days	Mon 1/1/24	Mon 1/1/24	$0.00
Design & inspection period	**60 days**	**Mon 1/1/24**	**Fri 3/22/24**	**$12,920.00**
Engineering Design	30 days	Mon 1/1/24	Fri 2/9/24	$7,920.00
Geotechnical testing	30 days	Mon 2/12/24	Fri 3/22/24	$5,000.00
Construction period	**30 days**	**Mon 3/25/24**	**Fri 5/3/24**	**$527,843.75**
Excavation	30 days	Mon 3/25/24	Fri 5/3/24	$527,843.75
R - Tank installation	**121 days**	**Mon 5/6/24**	**Mon 10/21/2**	**$620,000.01**
Excavate hole to proper cut/elevation	25 days	Mon 5/6/24	Fri 6/7/24	$68,888.89
Place layer of geotextile fabric at excavation	7 days	Mon 6/10/24	Tue 6/18/24	$68,888.89
Place 4” layer of 2B stone (3/4 clean)	7 days	Wed 6/19/24	Thu 6/27/24	$68,888.89
Place second layer of geotextile fabric down and begin to place units	7 days	Fri 6/28/24	Mon 7/8/24	$68,888.89
Wrap the units with the geotextile fabric to keep any stone from being able to enter the system	15 days	Tue 7/9/24	Mon 7/29/24	$68,888.89
Locate the units that will receive the pipe connections and slide pipe through fabrics and secure with pipe boot	15 days	Tue 7/30/24	Mon 8/19/24	$68,888.89
Backfill system in 12” lifts uniformly around the system until stone is flush with top of system	15 days	Tue 8/20/24	Mon 9/9/24	$68,888.89
At this time the R-Tanks should be completely wrapped and we should be preparing to place the 12” top stone on the system	15 days	Tue 9/10/24	Mon 9/30/24	$68,888.89
Start adding the 8-12” minimum soil fill on top of the excavation fabric wrap	15 days	Tue 10/1/24	Mon 10/21/24	$68,888.89
Labor	**211 days**	**Mon 1/1/24**	**Mon 10/21/2**	**$15,835.31**
Material	**7 days**	**Mon 5/6/24**	**Tue 5/14/24**	**$25,000.00**
Asphalt repair	**35 days**	**Mon 1/1/24**	**Fri 2/16/24**	**$15,013.89**
Stripping	**7 days**	**Mon 2/19/24**	**Tue 2/27/24**	**$2,500.00**

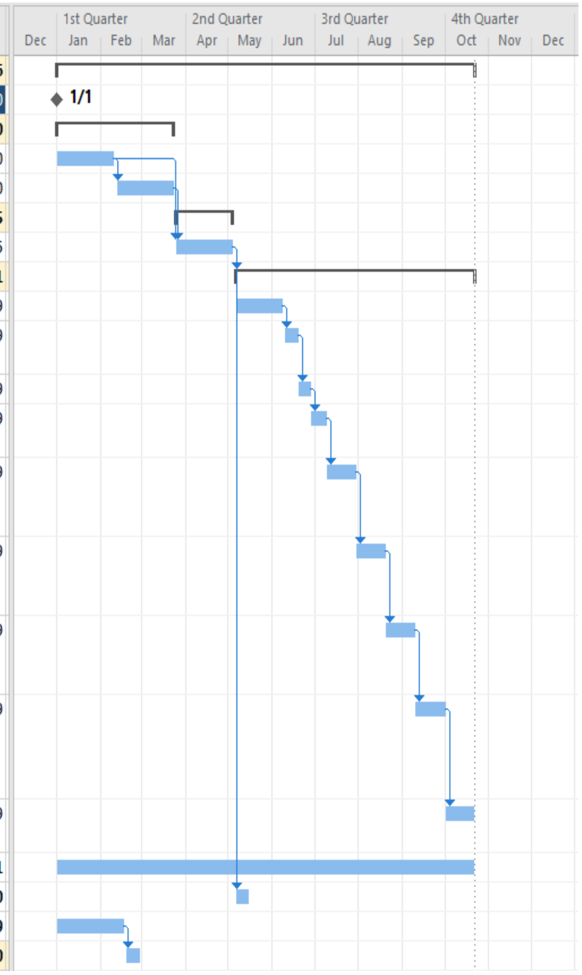

Figure 23: Scenario No. 2 (R-Tanks)

APPENDIX G

APPENDIX G

Task Name	Duration	Start	Finish	Cost	Pr
UTRGV - West parking lot	161 days	Mon 1/1/24	Mon 8/12/24	$595,499.83	
Project start date	0 days	Mon 1/1/24	Mon 1/1/24	$0.00	
Design & inspection period	60 days	Mon 1/1/24	Fri 3/22/24	$20,835.31	
Engineering Design	30 days	Mon 1/1/24	Fri 2/9/24	$15,835.31	
Geotechnical testing	30 days	Mon 2/12/24	Fri 3/22/24	$5,000.00	4
Construction period	101 days	Mon 3/25/24	Mon 8/12/24	$574,664.52	
Excavation	30 days	Mon 3/25/24	Fri 5/3/24	$527,843.75	5
4" Concrete Rip Rap concrete	7 days	Mon 5/6/24	Tue 5/14/24	$3,602.88	7
Flap Valve	4 days	Wed 5/15/24	Mon 5/20/24	$2,500.00	8
Asphalt repair	30 days	Tue 5/21/24	Mon 7/1/24	$15,013.89	9
Amenities - Fencing	30 days	Tue 7/2/24	Mon 8/12/24	$25,704.00	10

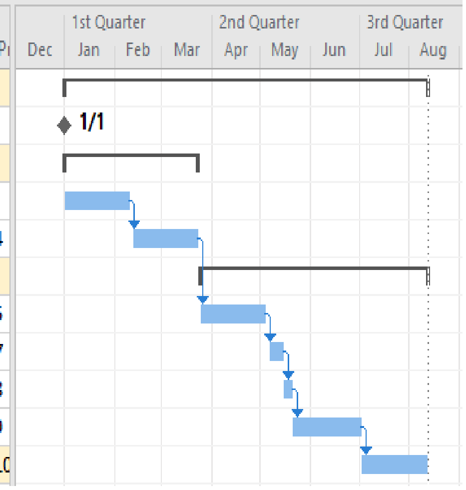

Figure 24: Timeline Scenario No. 3 (Implementation of a detention pond on site)

APPENDIX H

APPENDIX H

TOPOGRAPHY OF THE SITE

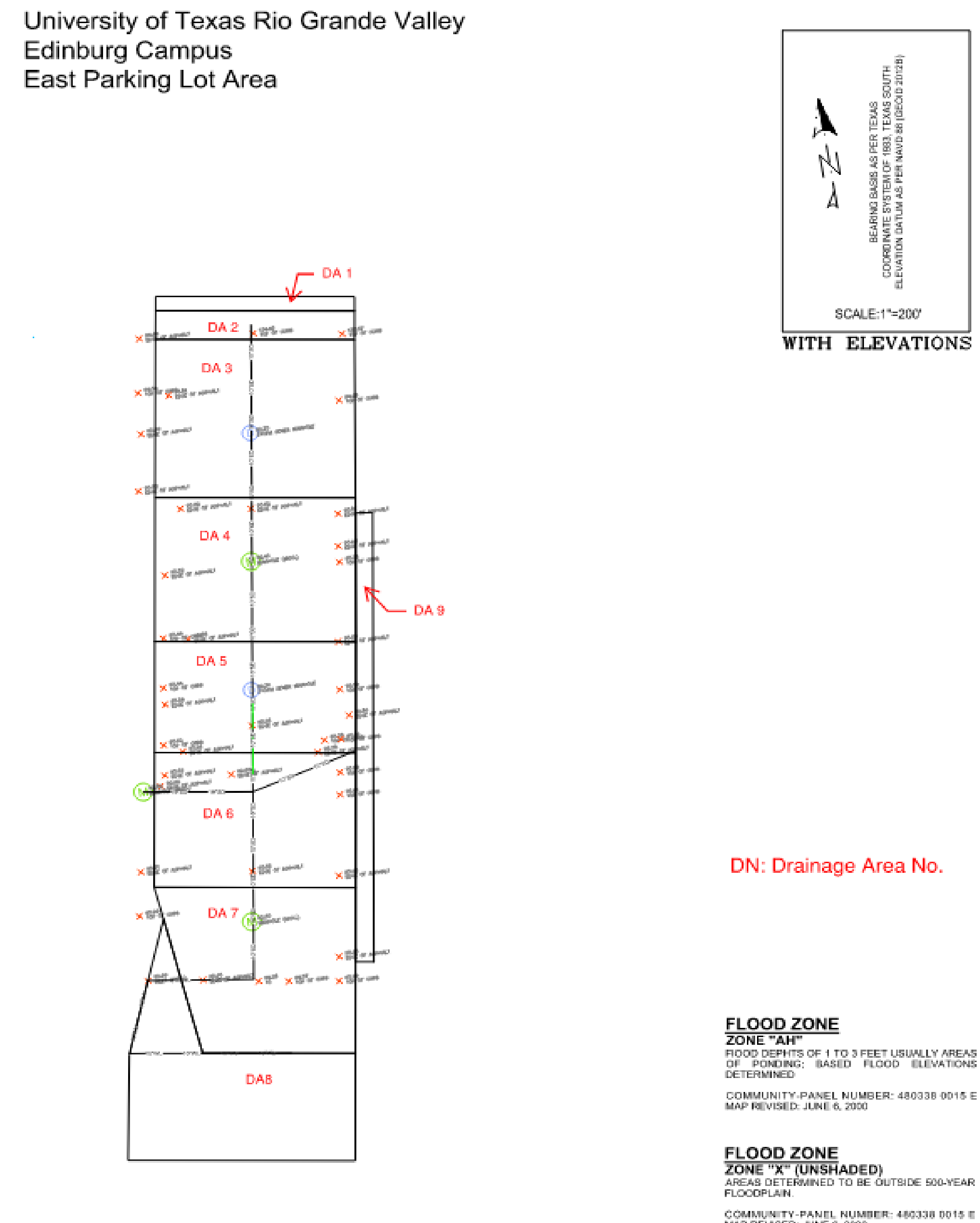

Figure 25: Topography on Site

BIOGRAPHICAL SKETCH

The Author, Mishell C. Mazon Posso was born on June 17th of 1994, in Quito, Ecuador. In 2019, she obtained her bachelor's degree in civil engineering at the Universidad San Francisco de Quito in Ecuador. She was part of various civil projects in her home country such as the construction of the subway of Quito, hydroelectric and land development projects.

Later, in 2021 she relocated to McAllen, Teas and in 2023 she finalized her master's in science in Civil engineering, specialization in Environmental and Water Resources at the University of Texas Rio Grande Valley. Currently she is located at 1200 East Vermont Avenue, 78503, McAllen, Texas.