STORM WATER DRAINAGE SYSTEM ANALYSIS AND DESIGN FOR CROSBY, TEXAS

[redacted]

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EXECUTIVE SUMMARY

A storm water collection system for a residential development in Crosby, Texas within Harris County has been designed. The storm water collection system successfully collects all runoff from a 2-year design storm, meaning a 50% annual exceedance probability, with no impact downstream.

The analysis was completed by first determining parameters including maximum flow capacity and velocity, elevations at each inlet, and minimum pipe diameters depending on the flow and velocity characteristics. Based on these assumptions and additional research, a model was generated in SWMM, a storm water system analyses program, and the inlets were sized. The approximate preliminary cost is $[redacted], which accounts for the cost of materials, excavation, backfill, contingencies, and engineering.

INTRODUCTION

Project Name and Purpose

The purpose of the "Newport Storm Water Collection System and Analysis for Crosby, Texas" is to create and analyze a storm water collection system that can drain runoff in a safe manner without major local flooring that does not have significantly impact downstream. This was done using the computer program SWMM from the Environmental Protection Agency.

Project Limits

The proposed development is located in Crosby, TX in Harris County within a neighborhood called Newport. The proposed development would be an addition to the Newport neighborhood bounded by Jolly Boat Dr. and Golf Club Dr, seen below in Figure 1.

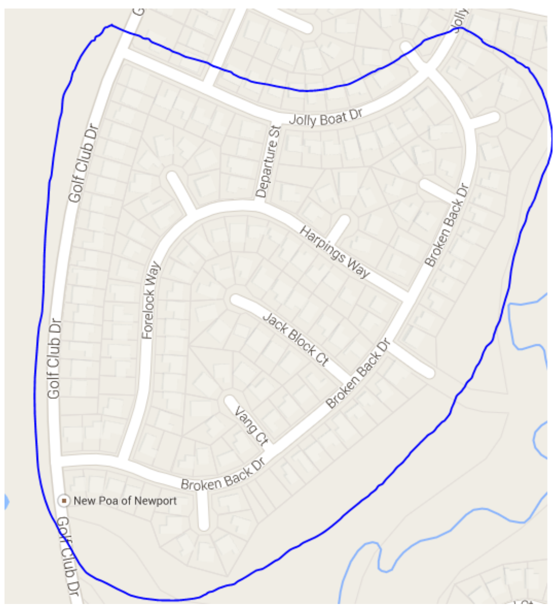

Figure 1. Project limits in Crosby, Texas

Assumptions and Constraints

The limits of the project include: the system must rely completely on gravity, the velocity in the pipes must be between 3 and 8 feet per second during the specified design storm, and the pipes must have a minimum back fill of 3 feet (Lincoln.) Additionally, no more than 700 ft of pavement can drain to an outlet from either side for a total of 1400 ft. Furthermore, minimum slopes must be met dependent on the pipe diameter used.

To design the proposed development, some assumptions had to be made. The most reasonable inlets to use were curb inlets since all the residential lots drain to the streets. Due to how close together the runoff volumes and times of concentration were between the predevelopment and post development, it was determined that there is no need for a detention structure.

A third party company does the pavement and construction, thus no costs are assumed for those portions of the project.

Location and Topography

The proposed development is a neighborhood within Crosby, Texas located in southeast Texas in Harris County as seen in Figure 1. The topography is relatively level to gently undulating with elevations in the proposed development ranging between 39 ft and 50 ft.

Land Use

The current land use for the proposed development is currently forestland. It is undeveloped and is covered by trees, bushes, and thick grass. The soil is mostly clay loams and clays.

HYDROLOGY

Analysis Objective

Using a topographical map created by Lidar, the area of the proposed development was analyzed in order to determine the demand for the storm water drainage system. For this subdivision, 13 drainage areas were delineated to drain into 13 inlet sets for the transportation of the water to an outfall located in the south east corner of the development.

Hydrologic Methodology

As per regulations set by Harris Country, the storm water drainage system was designed using a 2-year storm. In order to create the system, a hyetograph, or a graph showing rainfall for a given frequency, was created to determine the flow rate for each inlet. For this development located in Crosby, Texas, the depth for a 2-year, 24-hour storm is 4.2 inches of rainfall. Using this depth and a SCS type II curve for Texas, a hyetograph with cumulative depths was generated. Based on the cumulative depths, the amount of rainfall could be calculated generating the amount of rainfall at each time. The largest amount of rainfall for a 3-hour period begins at 10.5 hours and ended at 13.5 hours from a 24-hour rainfall event.

The next step in designing the storm water drainage system was to identify the locations of the inlets. Using a topographical map created with Lidar, general locations of inlets were chosen. These locations were then altered based on the requirement that no more than 700 ft of pavement drain into the outlet from each direction using AutoCad to measure lengths. After determining the locations of the inlets, the subcatchment areas, or the watershed areas draining to the inlet were delineated. This was done using the topographical map to determine the direction the water would flow. Next, the amount of flow the inlet would have to accommodate for was determined; this was computed using the rational method. Computations for the rational method involved determining the runoff coefficient for the site location, which was chosen as 0.4 based on the proposed development being single-family residential use. Then the area of each delineated subcatchment was measured in square feet then converted to acres. The time of concentration was calculated using the Kerby method for which the dimensionless retardance coefficient, N, was chosen to be 0.2 for poor grass or moderately packed surfaces. The based on the longest flow path for the drainage area, and then was used along with parameters for intensity for Harris County to calculate the intensity.

HYDRAULICS

Analysis Objective

Using SWMM, software used to analyze storm water collection systems, a storm water collection system was created to address flooding at peak flow. Based on a 2 year, 24 hour rainfall event, pipe slopes for a given size must have a minimum slope while the flow velocities must be kept within specified guidelines with backfill requirements met.

Hydraulic Method

Storm Water Management Model (SWMM), uses a series of subcatchment areas, junctions, and links that can be adjusted to fit design requirements. Data, including elevation, subcatchment area, flow rate, pipe length, and diameter, can be entered into the model to generate flow depths and velocities.

The first step to creating the model was to set the defaults, which in this case were: percent slope, percent impervious set at 38%, infiltration model of “CURVE_NUMBER”, conduit roughness of 0.01, flow units of cubic feet per second (cfs), routing method of dynamic wave, and the force main equation of Hazen-Williams.

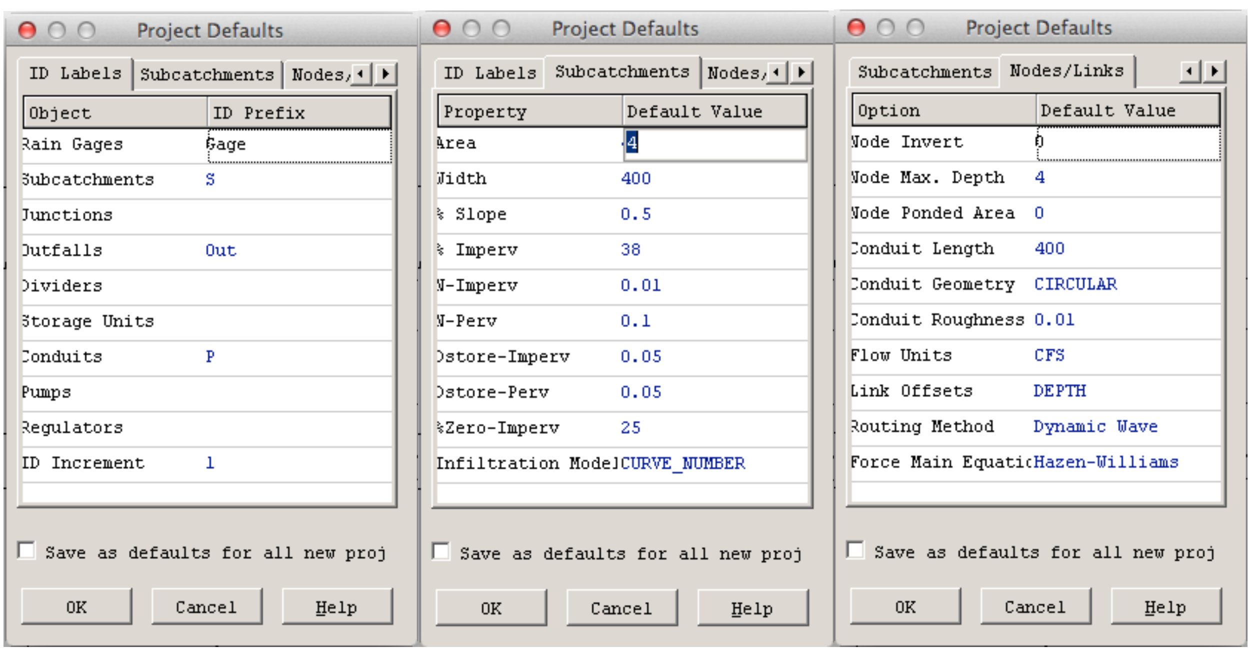

Figure 2. Project defaults

In order to create the model, an image of the proposed development was saved as a jpg file and uploaded as the background. The image allowed the design engineers to draw the storm water distribution system with subcatchment areas and the proposed roadways as guidelines. The number of pairs of inlets used for this setup is 13. Based on the location of inlets and topography, the sizes of subcatchment areas were determined. The curve number used for infiltration was determined from USDA's Web Soil Survey, which related soil properties for the subdivision. Using the class D given from this and the National Engineering Handbook that incorporated residential properties and streets, the curve number was determined to be 87.

Based on the subcatchment areas, the flow rate into each pair of inlets could be determined based on the 2-year design storm. A hyetograph representing a 2-year design storm for Harris County was created in which the peak rainfall depths were used for a 3-hour period. Creating a hyetograph allowed for values to be inputted into the rain gage, in which all values were considered to be negligible while the 3 hour rainfall depths were used.

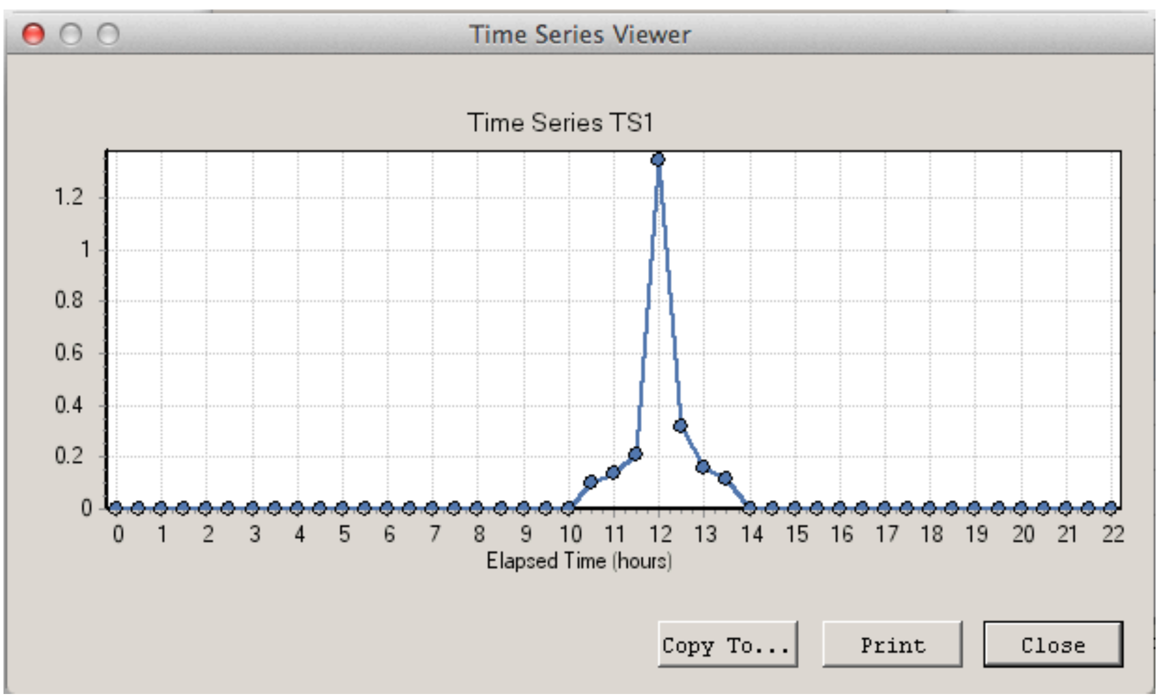

Figure 3. Rain gage time series

The elevations of each inlet were determined to find the depths of pipes based on backfill requirements of three feet minimum. The location of the outfall, at the southeast corner of the subdivision, was determined to be 25 feet. Based on minimum slopes for a given pipe size, SWMM will output velocities and overflowing pipes, also known as flooding. The flow rate velocities must be at a minimum of 3 feet per second and a maximum of 8 feet per second with no flooding. Pipe diameters and elevations could be adjusted to accommodate appropriate velocities and water surface elevations. To decrease costs, the backfill was minimized by maximizing elevations of junctions while the smallest pipe diameters were used.

In order to size the inlets, the inlet capacity was determined. The inlets used were curb-on-grade and the capacity for 10, 15, and 20 foot inlets were computed. Using the flow capacities for these inlets, the drainage areas for the different sized inlets were determined by the rational method. The inlets for the development were then chosen based on the calculated flow and area for each subcatchment.

Pipe lengths were estimated from an online map source according to the determined location of the inlets. The subcatchments and pipe layout, along with areas and lengths are shown in Figure 4.

RESULTS AND RECOMMENDATIONS

Description

The layout for the proposed storm water drainage system is shown below in Figure 4.

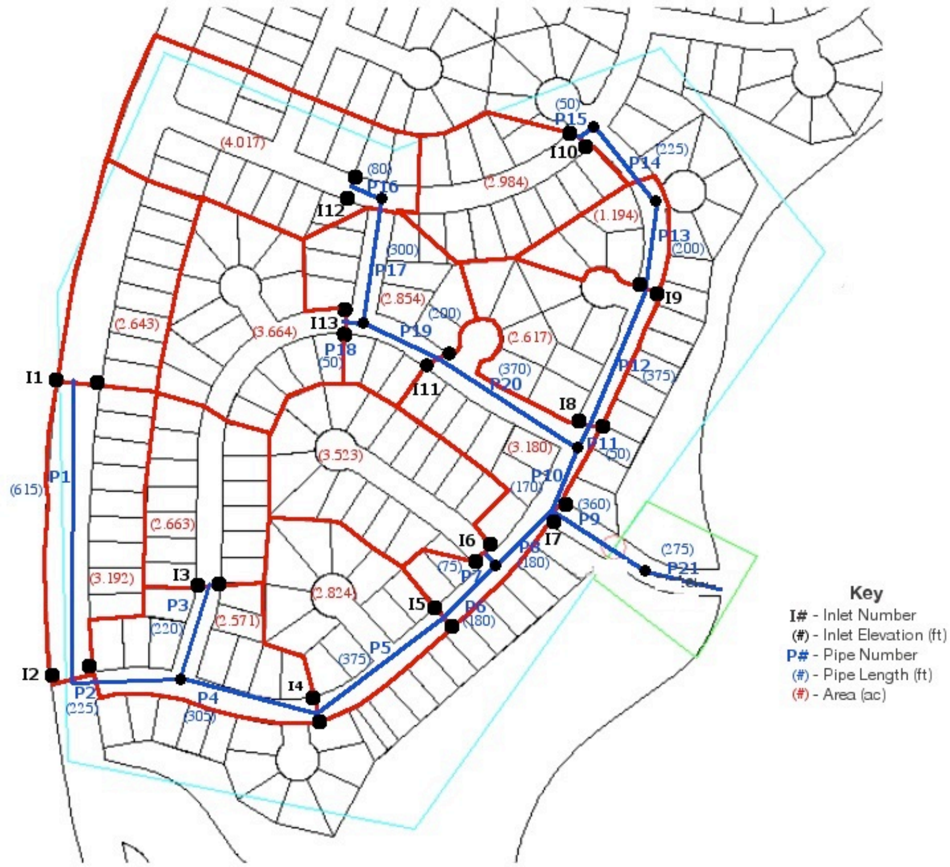

Figure 4. Proposed layout

The network consists of 13 inlets and 8 junctions, which resulted in 21 total nodes for the setup. The outfall is shown on the east most part of the subdivision. A total of 21 concrete pipes were called for. As shown, they follow the layout of the street to facilitate maintenance. Of these, three had a 10-inch, ten had a 12-inch, four had a 15-inch, two had an 18-inch, and two had a 21-inch diameter. The minimum slopes were verified according to regulation for each pipe based on these diameters. Of the 13 inlet pairs, 12 of them will be 20 ft curb-on-grade while the other one will be a 10 ft curb-on-grade.

With this system and the peak hours of the 2-year 24-hour duration storm, the network met all requirements and successfully transported the excess rainwater to the gully.

There was no flooding at any of the inlets or nodes. However there was slight surcharge at a few of them. However the height above the crown did not reach levels were there would be backflow into the streets. These values can be seen in Figure 5.

Summary Results

Node Surcharge — Click a column header to sort the

Node	Type	Hours urcharge	Max Height Above Crown	Min Depth Below Rim
I5	JUNCTIO	0.13	0.786	1.714
I6	JUNCTIO	0.25	1.190	1.977
I7	JUNCTIO	0.27	0.744	3.006
I8	JUNCTIO	0.33	1.753	1.247
I11	JUNCTIO	0.19	1.715	1.285
I13	JUNCTIO	0.07	0.623	2.377
15	JUNCTIO	0.27	1.217	1.283
16	JUNCTIO	0.30	1.464	0.536
20	JUNCTIO	0.11	1.545	1.455

Figure 5. Node surcharge

Pipe velocities also remained within the required range, as seen in Figure 6. Those with lowest velocities were the pipes leading from outlying inlets. The highest velocities were those in the pipes leading all the storm water to the outfall. This was expected since these are the ones that collect the flows. These pipes also tended to be the steepest because of the elevation of the gully compared to the rest of the subdivision.

The path that was most troublesome was the one leading from the west most inlets to the outfall on the east side of the subdivision. The node elevations and pipe diameters had to be fine tuned to achieve appropriate flow patterns. The water surface elevation profile for this path, is represented in Figure 7. Note that this is the flow pattern for the very peak of the rainfall data.

Summary Results

Link Flow — Click a column header to sort the column.

Link	Type	Maximum |Flow| CFS	Day of Maximum Flow	Hour of Maximum Flow	**Maximum Velocity**	Max / Full Flow	Max / Full Depth
P3	CONDUIT	1.40	0	12:30	3.18	0.52	0.76
P1	CONDUIT	1.15	0	12:30	3.25	0.50	0.62
P18	CONDUIT	1.56	0	12:35	3.27	0.24	1.00
P17	CONDUIT	1.77	0	12:33	3.30	0.47	0.79
P2	CONDUIT	2.72	0	12:30	3.55	0.49	0.60
P7	CONDUIT	1.86	0	12:29	3.58	0.57	1.00
P13	CONDUIT	1.42	0	12:30	3.73	0.43	0.50
P14	CONDUIT	1.43	0	12:30	3.95	0.46	0.47
P4	CONDUIT	4.08	0	12:30	4.13	0.85	0.86
P19	CONDUIT	3.09	0	12:34	4.34	0.94	1.00
P5	CONDUIT	5.52	0	12:35	4.43	0.78	0.96
P11	CONDUIT	3.51	0	12:28	4.47	0.54	1.00
P6	CONDUIT	6.64	0	12:35	4.58	0.65	1.00
P12	CONDUIT	2.10	0	12:32	4.68	0.51	0.77
P15	CONDUIT	1.44	0	12:30	4.91	0.22	0.40
P16	CONDUIT	1.70	0	12:30	5.24	0.33	0.48
P20	CONDUIT	4.26	0	12:29	5.85	1.02	1.00
P10	CONDUIT	7.73	0	12:29	6.30	1.70	1.00
P8	CONDUIT	8.01	0	12:33	6.52	1.28	1.00
P21	CONDUIT	17.18	0	12:31	7.35	1.36	0.93
P9	CONDUIT	17.20	0	12:29	7.36	1.58	0.93

Figure 6. Link flow

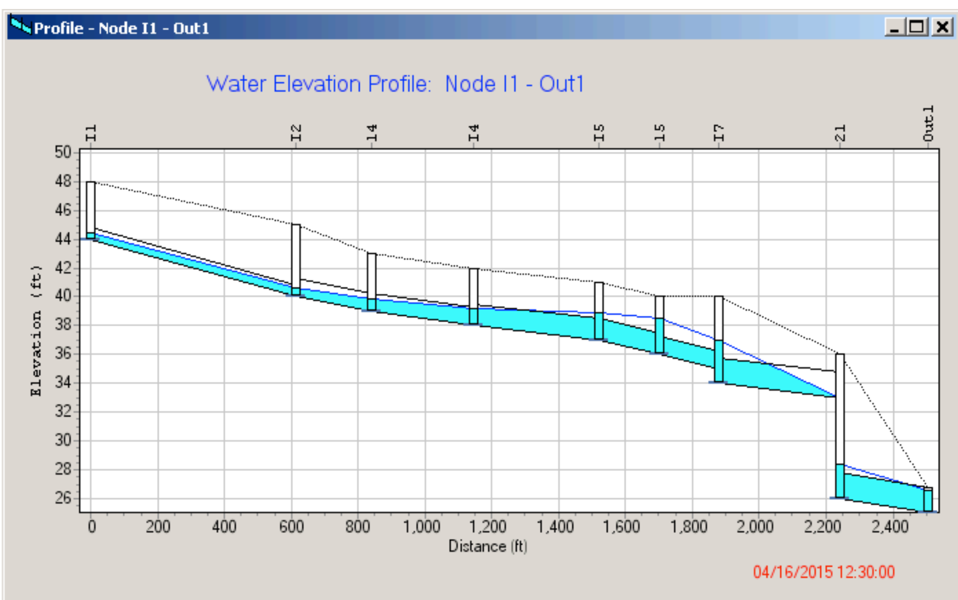

Figure 7. Profile from I1 to Outfall

Recommendations

For the proposed project, all pipes should follow the roadways in the neighborhood with the lengths shown in Figure 4. Pipe material will be reinforced concrete and should have the corresponding diameters as shown in Appendix C. There will be 13 pairs of inlets, whose locations are also shown in the figure in Appendix C. These choices ensure proper functioning of the storm water collection system for this subdivision in Harris County, since all requirements are met.

Cost Analysis

The total volume to be excavated will be approximately [redacted] cubic yards. It will cost $[redacted] per cubic yard for the first [redacted] cubic yards and $[redacted] per cubic yard for the remaining volume. Backfilling the total volume will cost $[redacted] per cubic yard. The 10 inch diameter non-reinforced concrete pipe will cost $[redacted] per linear foot; the 12 inch, 15 inch, 18 inch, and 21 inch diameter reinforced concrete piping will cost $[redacted], $[redacted], $[redacted], and $[redacted] per linear foot respectively. Type A-1 manholes with a diameter of [redacted] ft were selected. Each manhole will cost $[redacted] plus $[redacted] per vertical foot. The 10 ft curb–on-grade inlets will cost $[redacted] plus $[redacted] per vertical foot while the 20 ft curb-on-grade inlets will cost $[redacted] plus $[redacted] per vertical foot. A storm water pollution prevention plan is to be considered and will cost $[redacted]. Grubbing, clearing, pavement and the cost of the total land were not included in this analysis because it is to be subcontracted out. After contingencies and engineering, the project will require funds of approximately $[redacted]. The preliminary cost estimation is shown in Table 1.

Table 1. Preliminary Cost Estimate

LAND				
Description	**Unit**	**Qty.**	**Unit Cost**	**Total Cost**
EXCAVATION:	CY	[redacted]	[redacted]	[redacted]
	CY	[redacted]	[redacted]	[redacted]
Excavation Subtotal				[redacted]
BACKFILL:	CY	[redacted]	[redacted]	[redacted]
Backfill Subtotal				[redacted]
UTILITIES				
Description	**Unit**	[redacted]	**Unit Cost**	**Total Cost**
DRAINAGE				
10-in RCP	LF	[redacted]	[redacted]	[redacted]
12-in RCP	LF	[redacted]	[redacted]	[redacted]
15-in RCP	LF	[redacted]	[redacted]	[redacted]
18-in RCP	LF	[redacted]	[redacted]	[redacted]
21-in RCP	LF	[redacted]	[redacted]	[redacted]
Pipeline Subtotal				[redacted]
2-ft Diameter Manhole				
6-ft Depth	EA	[redacted]	[redacted]	[redacted]
6.25-ft Depth	EA	[redacted]	[redacted]	[redacted]
6.5-ft Depth	EA	[redacted]	[redacted]	[redacted]
6.75-ft Depth	EA	[redacted]	[redacted]	[redacted]
7-ft Depth	EA	[redacted]	[redacted]	[redacted]
7.5-ft Depth	EA	[redacted]	[redacted]	[redacted]
12.25-Depth	EA	[redacted]	[redacted]	[redacted]
Manhole Subtotal				[redacted]
10-ft Inlet				
6.75-ft depth	EA	[redacted]	[redacted]	[redacted]
10-ft Inlet Subtotal				[redacted]
20-ft Inlet				
6-ft Depth	EA	[redacted]	[redacted]	[redacted]
6.25-ft Depth	EA	[redacted]	[redacted]	[redacted]
6.5-ft Depth	EA	[redacted]	[redacted]	[redacted]
7-ft Depth	EA	[redacted]	[redacted]	[redacted]
7.25-ft Depth	EA	[redacted]	[redacted]	[redacted]
8-ft Depth	EA	[redacted]	[redacted]	[redacted]
20-ft Inlet Subtotal				[redacted]
ADDITIONAL ITEMS				
Pollution Prevention	EA	[redacted]	[redacted]	[redacted]
Pollution Prevention Subtotal				[redacted]
			Subtotal	[redacted]
			Contingencies (15%)	[redacted]
			Engineering (15%)	[redacted]
			TOTAL	[redacted]