Technical Paper:

Design of Storm Structures to solve flooding issues

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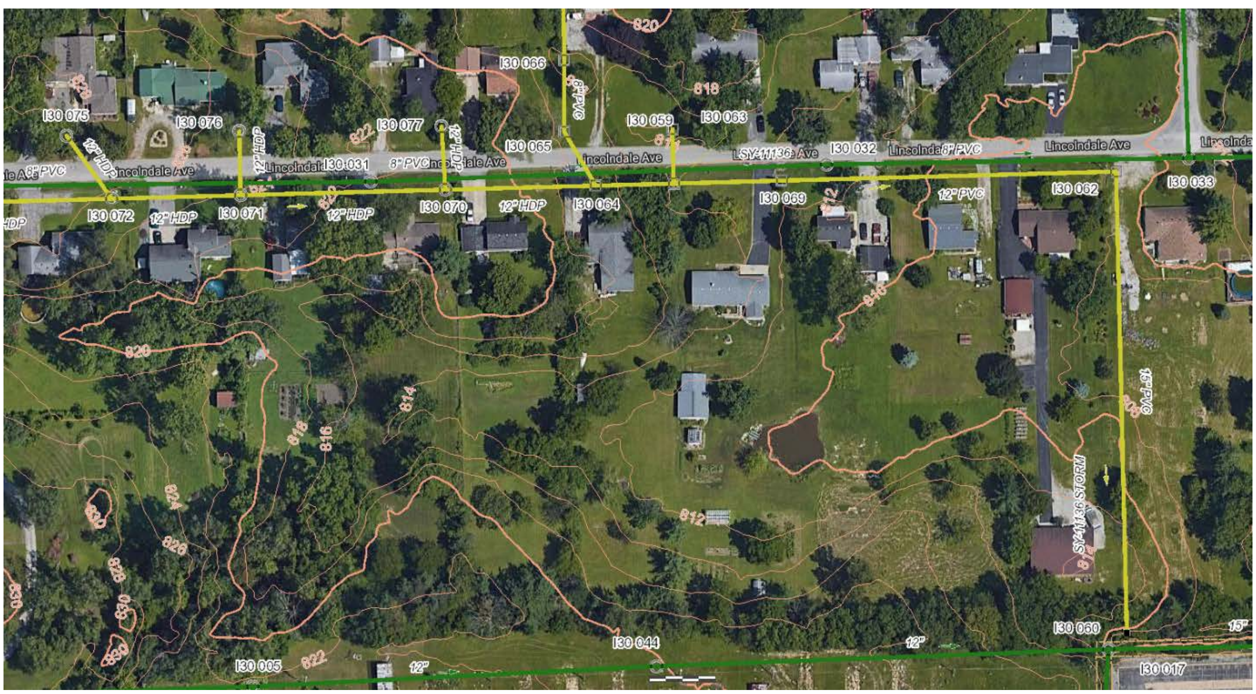
Introduction:

Many places in the United States are struggling with flooding issues. Last year due to an immense rain event, multiples places in Fort Wayne Indiana, have been victim of flooding issues. This include Canterbury green Apartment, and even Ivy Tech community college. The reasons for that lie in the design of storm structures and they pipe capacity. For example, if the company realizing the design of a school, and building construct a storm structure that can sustain a five-year storm event. When they get 2 five-year storm events consecutively, within a period of one year, the design will need to be reviewed and changed over wise it will not be able to handle another 5-year storm event and consequently flooding will occur. One area that I am doing the design for at my work (City Utilities Engineering of Fort Wayne) due to a flooding issue is the area located at Lincolndale in Fort Wayne Indiana. Due to flooding, multiple houses along the road are getting water into their basement; consequently, my job is to find a solution to resolve this issue. So, I will first do a study of the area to determine the different elevations, then I will propose some storm structures to add in the Lincolndale area, and finally, I will calculate the time of travel that it will take for the water to go from one structure to another in addition for the pipe slope to have a capacity that can sustain a 10 years storm event to prevent flooding not only for the present but also for the future.

Study of Lincolndale area

As you may already know, water always flow from a higher point to a lower point. Consequently, to do a study on why we have flooding issues, we need to identify where the highest point and the lowest point is for Lincolndale. To do so, we can use the city interactive map of Fort Wayne Indiana accessible through the following hyperlink (https://maps.cityoffortwayne.org/maps/map.htm).Using this website, we are able to get access to the topographic lines for the Lincolndale area. Those topographic lines are really helpful due to the fact that it shows the highest and lowest elevation which in turn help us identify the highest and lowest point where the water flows in the Lincolndale area as illustrated in the figure 1 below.

Figure 1: Topographic line view of Lincolndale area



From the figure 1 above, we can see that the highest elevation is located at the north-west of Lincolndale and the lowest elevation is located at the south-west of Lincolndale. So, base on those results, we know that the issue of flow movement occurs at the southwest region of Lincolndale. Consequently, we decided to go for a site visit during a rain event and we identified that the structure I30 032 which is a 24” round beehive inlet was completely full of water as shown in figure 2; which means that this structure is enable to take much water, and therefore causes water to rise above the structure which eventually lead to the flooding of the area as illustrated in the figure 3 below.

Figure 2: Structure I30 032

Figure 3: Flooding of the Lincolndale area

Resolution to the Problem

Now that we identified the problem based on the study above, we need to come up with a solution that will not only solve the issue for the present, but also for a longer period of time. Multiple ideas can be regenerate to solve this issue. We can decide to magnify the structure I30 032 to a manhole that will be 48” wide, in addition to increase the diameter of the existing pipe from a 15” PVC (Polyvinylchloride) to an 18” PVC.This hypothesis seems reasonable, it would be able to fix the problem; However, just for the present time and not for the future. The reason for that is because, the ditch where the 18” PVC pipe would discharge would be already undertaking a high volume of water due to other businesses that are being constructed at the moment. Consequently, we came up with a better solution that will be much more costly, but it will be efficient and will be able to sustain a 10-year rain storm event for a longer period of time. The solution that we came up with is to add more structure on the south-east of Lincolndale to direct the water from structure I30 032 to a ditch located at the far southeast of the Lincolndale area. So, using Autodesk Inventor, we drew 10 additional structures on the south-east of Lincolndale in addition to the discharge point (shown in black) as shown in the figure 4 below:

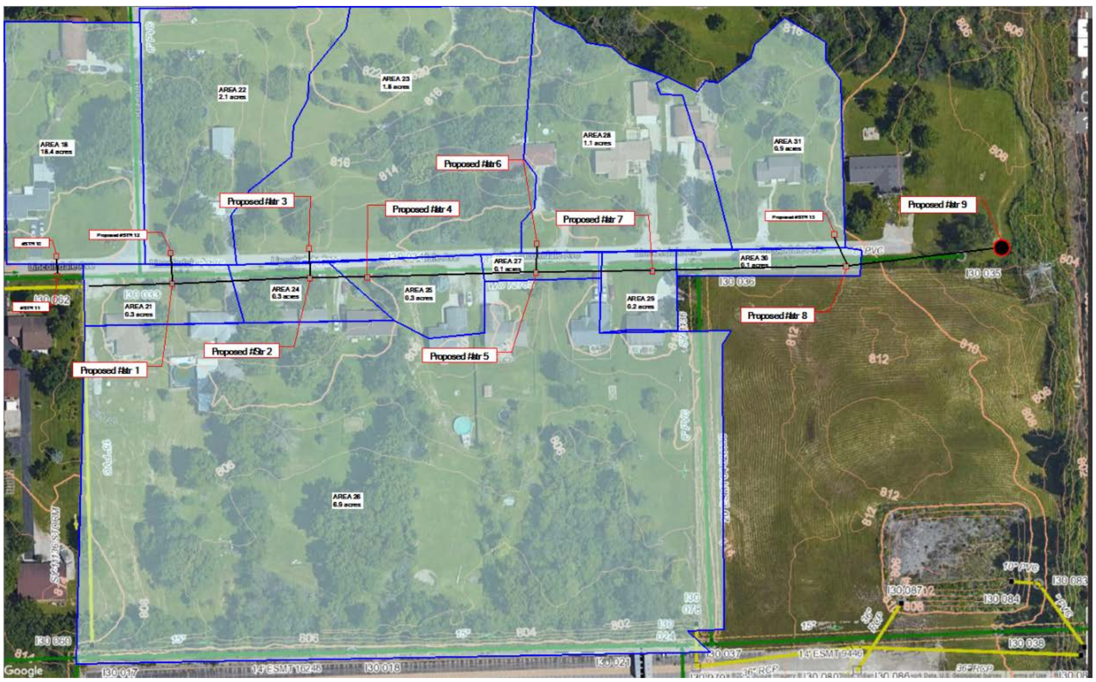
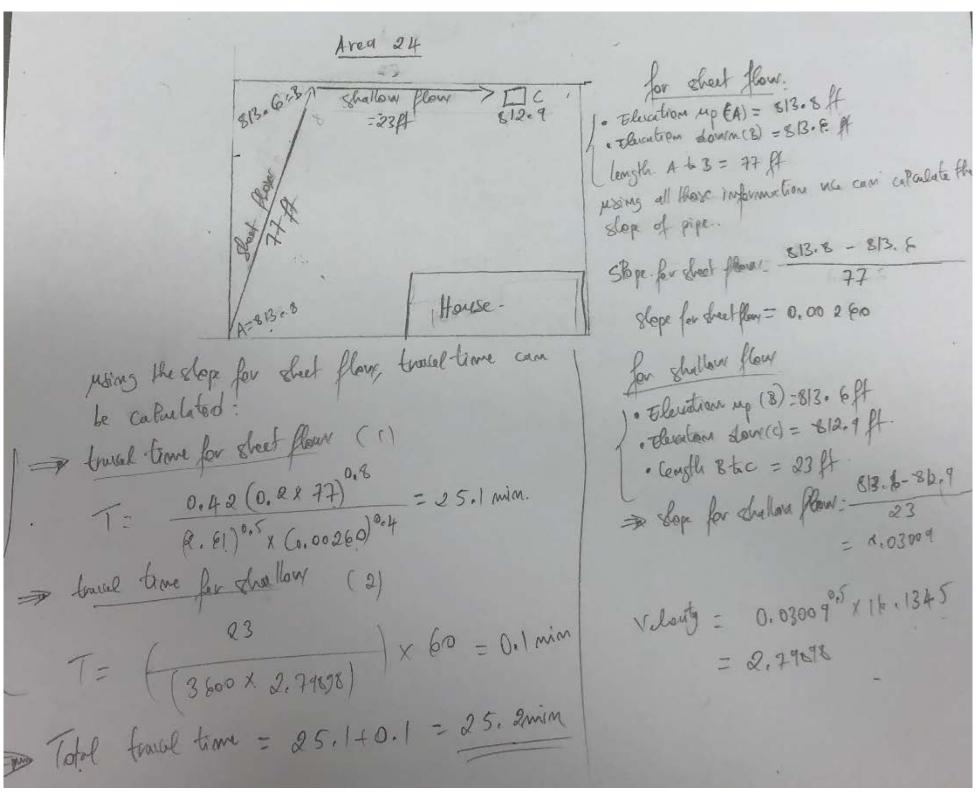


Figure 4: Proposed structure for the South-east region of Lincolndale

From the Figure 4 above, and the emplacement of the structures, we need to do some calculation to identify what type of structures we would need to install in addition to the pipe material and diameter that we will use for the structures. To do so, we need to use the elevation that we obtained from the topographic line and draw a sheet flow and shallow flow for every structure that exist, and that we would like to add on the area and separate them in terms of areas. Consequently, we obtained the figure 5 below:

Figure 5: sheet and shallow flow classified base on area for every structure in Lincolndale

Now, that we drew, the sheet and shallow flow concentration for the Lincolndale area. We need to determine the travel time that it will take for a structure to go from the upstream structure to the downstream structure with the help of the calculations of slope for the sheet and shallow flow. This can be done using the formula illustrated in figure 6 bellow.



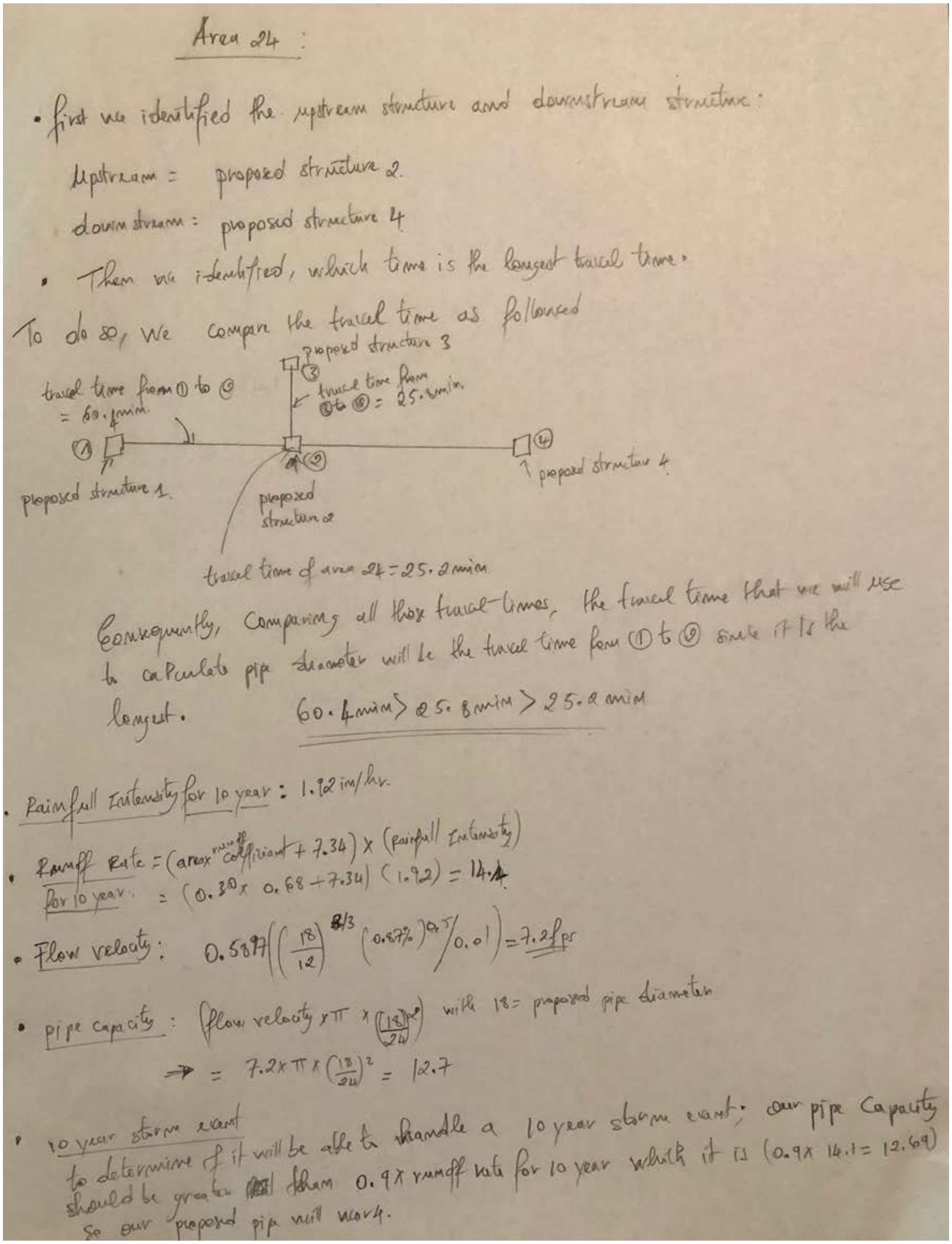
<u>Figure 6:</u> Calculation of slope and travel times for sheet and shallow flow of area 24

Using the same formula that we used to calculate the total travel time of the area 24, we calculated the total travel time of the remaining areas. Consequently, we obtain the excel table

<u>Table 1:</u> total travel of all the areas of Lincolndale

Subarea	Sheet Flow					Shallow Concentrated Flow (Paved/Unpaved)							Total
	Length*	El. Up	El. Dn.	Slope	Travel Time		Length	El. Up	El. Dn.	Slope	Velocity	Travel Time	Trav. Time
	ft	ft	ft	ft/ft	min		ft	ft	ft	ft/ft	ft/sec	min	min
1	2	3	4	5	6		7	8	9	10	10a	11	26
Area 18	306	822.1	816.7	0.01781	35.0	unpaved	298	816.7	809.5	0.02421	2.51050	2.0	**37.0**
Area 19	72	811.4	811.3	0.00182	27.3	unpaved	66	811.3	811.2	0.00152	0.62832	1.7	**29.1**
Area 20	75	811.4	810.8	0.00892	15.0	unpaved	208	810.8	809.0	0.00869	1.50430	2.3	**17.3**
Area 21	57	813.8	813.6	0.00333	17.8	unpaved	63	813.6	811.6	0.03175	2.87475	0.4	**18.2**
Area 22	279	826.7	814.8	0.04251	23.0	unpaved	278	814.8	811.9	0.01043	1.64779	2.8	**25.8**
Area 23	267	823.5	809.6	0.05206	20.4	unpaved	155	809.6	809.5	0.00090	0.48490	5.3	**25.8**
Area 24	77	813.8	813.6	0.00260	25.1	unpaved	23	813.6	812.9	0.03009	2.79898	0.1	**25.2**
Area 25	73	810.7	810.4	0.00372	20.7	unpaved	37	810.4	809.2	0.03155	2.86590	0.2	**20.9**
Area 27	18	810.0	809.8	0.01389	4.0	unpaved	56	809.8	808.5	0.02286	2.43931	0.4	**4.4**
Area 28	262	819.5	809.9	0.03655	23.2	unpaved	41	809.9	809.5	0.01052	1.65496	0.4	**23.6**
Area 29	77	810.9	810.1	0.01136	14.0	unpaved	51	810.1	810.0	0.00118	0.55341	1.5	**15.5**
Area 30	22	812.8	812.7	0.00545	6.8	unpaved	171	812.7	812.2	0.00275	0.84677	3.4	**10.2**
Area 31	283	816.3	813.8	0.00869	43.8	unpaved	91	813.8	811.9	0.02135	2.35773	0.6	**44.4**
Area 32	292	836.1	834.2	0.00645	50.5	unpaved	1698	834.2	810.0	0.01426	1.92673	14.7	**65.2**
Area 33	299	830.3	814.9	0.05148	22.5	unpaved	587	814.9	810.0	0.00837	1.47589	6.6	**29.1**
Area 34	297	834.9	831.2	0.01251	39.3	unpaved	702	831.2	815.8	0.02185	2.38481	4.9	**44.2**
Area 35	83	834.9	831.4	0.04223	8.7	unpaved	754	831.4	817.1	0.01893	2.21996	5.7	**14.4**
Area 36	295	833.2	822.9	0.03500	26.0	unpaved	544	822.9	815.2	0.01422	1.92407	4.7	**30.7**

Now that, we calculated the total travel time of the areas in Lincolndale. We need to know which type of structures we will use for our proposed structures. In addition to which pipe diameter would need to be install. We can obtain all that information by using the total travel time. Therefore, we calculated the slope for the installation of pipes, in addition to identify the pipe capacity for a period of at least 10 years. This was done using the formula below:


Area 24 :

• first we identified the upstream structure and downstream structure:

Upstream = proposed structure 2.

downstream = proposed structure 4

• Then we identified, which time is the longest travel time.

To do so, we compare the travel time as followed

Consequently, comparing all those travel times, the travel time that we will use to calculate pipe diameter will be the travel time from ① to ② since it is the longest.

60.4 min > 25.8 min > 25.2 min

• Rainfall Intensity for 10 year : 1.92 in/hr.

• Runoff Rate for 10 year = (area x runoff coefficient + 7.34) x (rainfall intensity)
= (0.30 x 0.68 + 7.34) (1.92) = 14.1

• Flow velocity: $0.5897\left(\left(\frac{18}{12}\right)^{2/3}(0.87\%)^{0.5}/0.01\right) = 7.2$ fps

• pipe capacity : (flow velocity x π x $\left(\frac{18}{24}\right)^2$) with 18 = proposed pipe diameter
→ = $7.2 \times \pi \times \left(\frac{18}{24}\right)^2 = 12.7$

• 10 year storm event
to determine if it will be able to handle a 10 year storm event; our pipe capacity should be greater than 0.9 x runoff rate for 10 year which it is (0.9 x 14.1 = 12.69)
So our proposed pipe will work.

Figure 7: Formula used to calculate the runoff rate, rainfall intensity flow velocity and pipe capacity for proposed structure in area 4

Using, the same formulas that we did for area 24, we obtained the pipe capacity for all the areas in Lincolndale for our proposed structure and consequently, we obtained the following

			For: "Total Travel Time" use value from worksheet TR55-TDG13 Method T of C Calc.											DESIGN DATE :		5/7/2018					Enter: " *n* " VALUE			0.01				
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
Line	Catchment	Downstream	A_j	C_j	Σ A_j	A_j x C_j	Σ [A_j x C_j]	t_u	T_c	RAINFALL INTENSITY				RUNOFF RATE				Pipe	Pipe	Pipe	Design	T_p	T_t	$Q_{capacity}$	design	fall	Invert Elevation	
ID	From	To	Sub- Area	Runoff	Accum.Area			Total Travel Time*	Total Time of Conc	i_1	i_2	i_5	i_{10}	Q_1	Q_2	Q_5	Q_{10}	Diameter	Slope	Length	Flow Velocity	Travel Time in Pipe Sec.	Total Travel Time	Pipe Capacity	YEAR of storm event	in pipe section	Upper End	Lower End
Name	Structure #	Structure #	(acres)	Coefficient	(acres)			(min.)	(min.)	(in./hr)	(in./hr)	(in./hr)	(in./hr)	(cfs)	(cfs)	(cfs)	(cfs)	(inches)	(%)	(feet)	(fps)	(min.)	(min.)	(cfs)	Designed	(ft)	Ft.	Ft.
Area 18	**#STR10**	#STR 11	18.40	0.30	18.40	5.52	5.52	**37.0**	**37.0**	1.60	1.94	2.41	2.74	**8.8**	**10.7**	**13.3**	**15.1**	**12**	1.00%	25	5.9	0.1	**37.1**	**4.6**	**NG**	0.25		-0.2451
Area19	**I30 069**	I30 062	0.20	0.63	17.40	0.13	6.12	**58.5**	**58.5**	1.10	1.35	1.69	1.95	**6.7**	**8.3**	**10.3**	**11.9**	**15**	0.91%	309	6.5	0.8	**59.3**	**8.0**	**2-yr**	2.81		-2.80849
Area 20	**I30 062**	#STR 1	0.40	0.55	17.80	0.22	6.34	**59.3**	**59.3**	1.10	1.35	1.69	1.95	**7.0**	**8.6**	**10.7**	**12.4**	**15**	1.71%	424	8.9	0.8	**60.1**	**11.0**	**5-yr**	7.24		-7.24305
Area 21	**#STR 1**	#STR 2	0.30	0.60	18.10	0.18	6.52	**60.1**	**60.1**	1.08	1.32	1.66	1.92	**7.0**	**8.6**	**10.8**	**12.5**	**15**	1.81%	157	9.2	0.3	**60.4**	**11.3**	**10-yr**	2.84		-2.84369
Area 22	**#STR 12**	#STR 1	2.10	0.34	2.10	0.71	0.71	**25.8**	**25.8**	1.94	2.33	2.86	3.28	**1.4**	**1.7**	**2.0**	**2.3**	**12**	0.21%	36	2.7	0.2	**26.0**	**2.1**	**10-yr**	0.08		-0.07564
Area 23	**#STR 3**	#STR 2	1.80	0.34	1.80	0.61	0.61	**25.8**	**25.8**	1.94	2.33	2.86	3.28	**1.2**	**1.4**	**1.8**	**2.0**	**12**	1.00%	26	5.9	0.1	**25.9**	**4.6**	**10-yr**	0.26		-0.2596
Area 24	**#STR 2**	#STR 4	0.30	0.68	20.20	0.20	7.34	**60.4**	**60.4**	1.08	1.32	1.66	1.92	**7.9**	**9.7**	**12.2**	**14.1**	**18**	0.87%	78	7.2	0.2	**60.6**	**12.7**	**10-yr**	0.68		-0.68069
Area 25	**#STR 4**	#STR 5	0.30	0.62	20.50	0.19	7.52	**60.6**	**60.6**	1.08	1.32	1.66	1.92	**8.1**	**9.9**	**12.5**	**14.4**	**18**	0.91%	213	7.4	0.5	**61.0**	**13.0**	**10-yr**	1.94		-1.94194
Area 5 , 26	**I30 078**	I30 079	24.30	0.32	24.30	7.78	7.78	**54.0**	**54.0**	1.20	1.47	1.86	2.13	**9.3**	**11.4**	**14.5**	**16.6**	**36**	0.25%	50	6.1	0.1	**54.1**	**43.4**	**10-yr**	0.13		-0.125
Area 27	**#STR 5**	#STR 7	0.10	0.65	20.60	0.07	7.59	**61.0**	**61.0**	1.08	1.32	1.66	1.92	**8.2**	**10.0**	**12.6**	**14.6**	**18**	0.96%	130	7.6	0.3	**61.3**	**13.4**	**10-yr**	1.25		-1.2457
Area 28	**#STR 6**	#STR 5	1.10	0.34	1.10	0.37	0.37	**23.6**	**23.6**	2.04	2.46	2.99	3.43	**0.8**	**0.9**	**1.1**	**1.3**	**12**	0.25%	21	2.9	0.1	**23.7**	**2.3**	**10-yr**	0.05		-0.05298
Area 29	**#STR 7**	#STR 8	0.20	0.67	20.80	0.13	7.72	**61.3**	**61.3**	1.08	1.32	1.66	1.92	**8.3**	**10.2**	**12.8**	**14.8**	**18**	0.96%	215	7.6	0.5	**61.8**	**13.4**	**10-yr**	2.06		-2.06342
Area 30	**#STR 8**	#STR 9	0.10	0.55	20.90	0.06	7.78	**61.8**	**61.8**	1.08	1.32	1.66	1.92	**8.4**	**10.3**	**12.9**	**14.9**	**21**	0.43%	213	5.6	0.6	**62.4**	**13.5**	**10-yr**	0.92		-0.91564
Area 31	**#STR 13**	#STR 8	0.90	0.30	0.90	0.27	0.27	**44.4**	**44.4**	1.43	1.72	2.18	2.49	**0.4**	**0.5**	**0.6**	**0.7**	**12**	0.25%	36	2.9	0.2	**44.6**	**2.3**	**10-yr**	0.09		-0.08913
Area 32		I30 060	40.70	0.80	40.70	32.56	32.56	**65.2**	**65.2**	1.08	1.32	1.66	1.92	**35.2**	**43.0**	**54.0**	**62.5**		1.96%		0.0	#DIV/0!		**0.0**	**NG**			#VALUE!
Area 33		I30 060	17.10	0.80	17.10	13.68	13.68	**29.1**	**29.1**	1.81	2.18	2.68	3.07	**24.8**	**29.8**	**36.7**	**42.0**						#VALUE!					#VALUE!
Area 1		I30 082	34.00	0.41	34.00	13.94	13.94	**94.1**	**94.1**	1.08	1.32	1.66	1.92	**15.1**	**18.4**	**23.1**	**26.8**						#VALUE!					#VALUE!
																												#VALUE!
																												#VALUE!

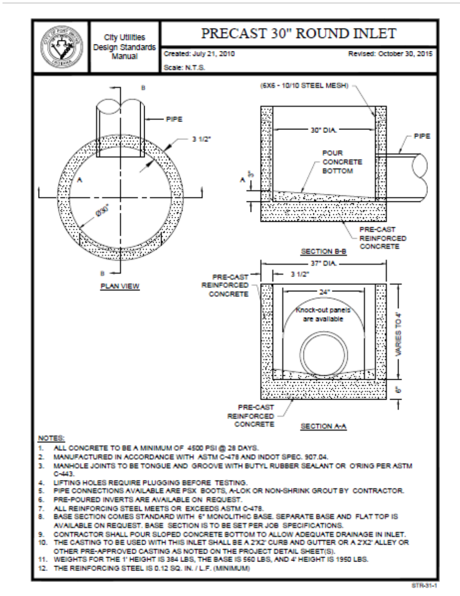
spreadsheet:

<u>Table 2:</u>

<u>Note for table 2:</u>

***Area 32 discharges to an open ditch for which dimensions are needed and modelling this would be the optimum solution*
***Area 33 discharges to an open ditch for which dimensions are needed and modelling this would be the optimum solution*
***Area 1 discharges into open ditch on west side of railroad track into a clooged 36" RCP pipe crossing the railroad track. This will need modelled as well as looking at options to replace the pipe. Will need coordination with County Surveryors office at some point when other issuse are fixed downstream.*

Consequently, we obtained the results above where we have the pipe diameter and material for the construction of the structures in Lincolndale that will be able to fix the problem of flooding issues. Therefore, our calculations are completed and the propositions of the structure that we can install along the Lincolndale area are illustrated below:



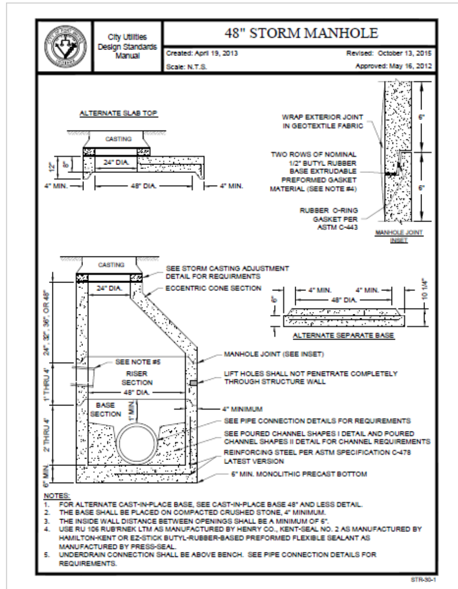


Figure 8: Proposed structure to use for the project on the southeast of Lincolndale

Now, that everything is completed in addition to our proposed structure, the acceptance of the realization of the project will need to be approved by the Board of Public works of the City of Fort Wayne.

Conclusion:

To conclude, Flooding can be a very critical problem. So, in order to fix a flooding issue just like for every problem, we first need to identify the issue, then proposed solutions to the issue and outweigh the proposed solution to make sure that it will fix the issues without causing another issue. The Solution that, that we proposed for Lincolndale is the best solution since it will direct the water to another ditch without causing any harm to the residents or environment. This is still a proposition of the project and the determination to which it will be constructed or not will depend on the fund and other expenses by the Board of Public Work of the City of Fort Wayne.

References:

- Website:

https://maps.cityoffortwayne.org/maps/map.htm

https://www.cityoffortwayne.org/utilities/169-design-and-construction/3261-structures.html

- Application used:

  ArcGIS

  Autodesk Inventor

  Adobe acrobat Pro

  Excel