36th Street NW Study

(Frazer Ave. NW to Market Ave. N)

City of Canton, Ohio

February 27th, 2019

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Purpose of this Study:

The vicinity of 36th Street NW, between Frazer Avenue and Market Avenue, has been plagued by localized flooding for several years. Runoff generally drains from west to east to Logan Avenue, then north on Logan to mid-block between 36th Street and 37th Street where it continues to flow east through properties toward 37th Street and Market Avenue. There is a small existing storm sewer at the intersection of 36th Street and Logan Avenue, but it is severely undersized and insufficient to handle the majority of runoff from the 36th Street watershed. The rest of 36th Street has no storm water drainage infrastructure at all, and as a result, existing pavement is in very poor condition. During heavy rain events, flooding occurs along 36th Street, at Logan Avenue, along Logan Avenue between 36th Street and 37th Street, and along the properties east of Logan Avenue between 36th Street and 37th Street. ***See Appendices A and B.***

To alleviate the flooding, the City of Canton plans to construct a storm sewer system along 36th Street to drain runoff to the existing Market Avenue 36-inch diameter storm sewer. Full-depth roadway reconstruction is proposed as well as a reduction in pavement width to improve pavement conditions and reduce runoff. The existing water main will be replaced as well as portions of existing sanitary sewer mains. The general limits of the project will consist of 36th Street NW between Frazer Avenue and Market Avenue along with portions of intersecting streets within these limits extending up to 350 feet. ***See Appendix C.***

Although above-ground detention is preferable to underground detention for several reasons, there is no available space within the immediate project vicinity to construct an above-ground detention basin. Therefore, the proposed storm sewer will be oversized to provide underground detention within the project limits. This requires evaluation of the size and length the storm sewer needs to be to manage runoff from the 2-, 5-, 10-, 25-, 50-, and 100-year storm events. In addition, the storm sewer is intended to divert runoff from primarily following the existing drainage path from the low point in Logan Avenue between 36th Street and 37th Street, and instead direct it easterly, "bucking grade" along 36th Street, and discharging it by direct connection to the Market Avenue system. Thus, evaluation of the capacity of the Market Avenue system is essential to determine corresponding allowable discharge rates from the proposed 36th Street system. Ultimately, the proposed 36th Street storm sewer will depend on the desired level of protection to be provided for respective storm events as well as the corresponding construction impacts and costs.

The City of Canton Engineering Department retained the services of the Osborn Engineering Company to assist in this study.

Watersheds:

Two main watersheds were delineated as part of this study:

1. ***Market Avenue watershed:*** Approximately 33.5 acres drain to the existing storm sewer along the east side of Market Avenue adjacent to 36th Street.
2. ***36th Street watershed:*** Approximately 54.8 acres drain to the area that will be discharged by the proposed 36th Street storm sewer to the existing Market Avenue storm sewer.

Currently, runoff from the 36th Street and Market Avenue vicinity eventually discharges to a ravine north of 37th Street on the east side of Market Avenue and ultimately to a tributary of the Middle Branch Nimishillen Creek.

The watersheds were mainly determined from record drawing information and the USGS StreamStats website. While delineating the watershed areas, some assumptions were made that most front yard areas of homes drain out to the streets. Also, some street intersections within proximity to the upper limits of the watershed were field-verified to confirm which direction runoff drains. ***See Appendix D.***

Discharge and Storage Analysis:

Peak discharge (flow) rates for the 2- through 100-year storm events for both watersheds were calculated by using the Rational Method. The following values were used:

1. ***Market Avenue watershed:***
   Area = 33.45 acres; Runoff Coefficient = 0.3 (single-family residential); Time of Concentration = 30 minutes.
2. ***36th Street watershed:***
   Area = 54.8 acres; Runoff Coefficient = 0.3 (single-family residential); Time of Concentration = 18 minutes.

The minimum Market Avenue "just full" (non-pressurized) storm sewer capacity adjacent to 36th Street is approximately 47.8 cfs and was determined using Manning's Equation. In addition, utilizing as-built top of structure (rim/grate) elevations, pipe sizes, and invert elevations, maximum allowable pressurized flow capacity was estimated in the Market Avenue system to be 49.9 cfs without surcharging out of tops of structures. Comparing this information to peak discharge estimates, there is available capacity in the system to take on additional flows from the 36th Street watershed during the 2- through 100-year storm events.

Since an oversized storm sewer is proposed along 36th Street in order to provide detention storage, the Modified Rational Method was utilized to estimate required storage volumes for the 2- through 100-year storm events. In short, the Modified Rational Method as typically applied is different from the standard Rational Method in that rather than determining maximum peak discharges from the watershed, it instead determines maximum storage volumes required for storm events based on varied storm durations and maximum allowable discharge rates. Thus, for detention purposes, the Modified Rational Method results in trapezoidal "inflow hydrographs" based on longer storm durations but lower peak flows, and a triangular "outflow hydrograph" based on allowable discharge rates. The estimated storage volumes required for detention are the differences in areas *between* the respective inflow and outflow hydrographs for each storm event. In contrast, the standard Rational Method results in triangular hydrographs with shorter storm durations, higher peak flows, and lower storage volumes, but this method was never intended to be used for detention purposes because it underestimates required storage volumes. The additional capacity available in the Market Avenue storm sewer under pressurized conditions was used as the allowable outflows for the 2- through 100-year storm events for the Modified Rational Method analysis. ***See Appendix E***.

Table 1 summarizes the estimated discharge rates, capacities, and storage volumes required for the 2- through 100-year storm events.

Table 1

Watersheds, Discharges, Capacities, & Storage Requirements									
Storm Event	Market Avenue					36th Street NW			
	Watershed	Storm Sewer (adjacent to 36th St.)				Watershed	Underground Storage System		
	Rational Method Peak Discharge	"Just Full" (Manning's)		Maximum Allowable Pressure Flow		Rational Method Peak Discharge	Modified Rational Method		
		Capacity	Available Capacity	Capacity	Available Capacity		Allowable Discharge Out	Peak Discharge In	Storage Volume
(yr)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cf)
2	19.9	48.2	28.2	49.9	30.0	44.8	30.0	38.7	16,476
5	24.6	48.2	23.5	49.9	25.3	54.6	25.3	36.5	36,500
10	28.2	48.2	19.9	49.9	21.7	61.9	21.7	34.6	55,107
25	32.9	48.2	15.3	49.9	17.1	71.2	17.1	29.2	85,106
50	36.3	48.2	11.8	49.9	13.6	78.1	13.6	24.1	115,788
100	39.7	48.2	8.4	49.9	10.2	84.8	10.2	18.8	158,631

Proposed Storm Sewer Options:

Alignment of a new storm sewer along 36th Street requires consideration of locations of underground utilities and potential conflicts with those utilities and service laterals. Major underground utilities within the project limits are sanitary sewer, water, and gas. There is an existing 6-inch water main and 4-inch gas main located along the north side of 36th Street, and an existing 8-inch sanitary sewer main located along the center of 36th Street. Since the existing water main is proposed to be replaced as part of this project, the new water main will need to be located under the south side of the street. In order to satisfy Ohio EPA sewer separation requirements and to avoid existing utilities as much as possible, this forces the proposed storm sewer to be located under the north side of the street.

Typical design standards require storm sewer systems to be designed to handle peak discharges from a 10-year storm event under "just-full" (non-pressurized) conditions, while ensuring the hydraulic grade line stays below structure top elevations during the 25-year storm event. The standard Rational Method is typically used to determine peak discharges for storm sewer design.

For evaluation and comparison purposes only, a "typical" storm sewer trunk size was estimated. The flattest slope of 0.48% for the existing sanitary sewer main within the project limits in the vicinity of Logan Avenue was used to also represent the flattest slope of the proposed storm sewer. As a result, this project would require a 48-inch diameter storm sewer to convey the 10-year peak discharge of 61.9 cfs under "just-full" conditions for a typical storm sewer design with no downstream flow restrictions.

However, a "typical" storm sewer design is not applicable for this project. Since in-line detention storage is desired and the Market Avenue system capacity is limited to different rates for different storm events (thus directly impacting the amount of storage volume required), a relatively larger and deep storm sewer is needed.

Osborn Engineering prepared plan and profile sheets along 36th Street between Frazer Avenue and Market Avenue. Existing utilities (gas, water, and sanitary sewer) were plotted in profile view from record information. Due to its relatively large size needed to provide in-line detention and to avoid utility conflicts as much as possible, the top of the storm sewer will need to be below the elevation of the bottom of the sanitary sewer along 36th Street. For analysis purposes and considering the aforementioned Ohio EPA sewer separation requirements and the desire to avoid existing utility conflicts as much as possible, a single-barrel storm sewer was assumed having the same diameter for the entire run of storm sewer main. However, several options with various diameters were evaluated.

Table 2 shows the runoff storage volume required for the 2- through 100-year storm events and the various sizes and corresponding lengths that would be needed to meet those storage requirements.

Table 2

Storm Event Storage Volumes & Lengths of Pipe Needed							
Storm Event	Storage Volume Required	Pipe Diameter (inches) Options					
		36	42	48	60	72	84
(yr)	(cf)	Length of Pipe (feet) Needed to Provide Required Storage					
2	16,476	2,330.9	1,712.5	1,311.1	839.1	582.7	428.1
5	36,500	5,163.7	3,793.7	2,904.6	1,858.9	1,290.9	948.4
10	55,107	7,796.0	5,727.7	4,385.3	2,806.6	1,949.0	1,431.9
25	85,106	12,040.0	8,845.7	6,772.5	4,334.4	3,010.0	2,211.4
50	115,788	16,380.7	12,034.8	9,214.1	5,897.0	4,095.2	3,008.7
100	158,631	22,441.7	16,487.8	12,623.5	8,079.0	5,610.4	4,121.9

Table 3 shows street segments within the project limits, corresponding segment lengths, and maximum storage volumes that can be provided by the various pipe diameter options. The maximum length of storm sewer that can be provided within all segments of the project limits is 4,355 feet. ***See Appendix F.***

Table 3

Street Lengths & Storage Volumes Based on Pipe Sizes										
Street Segment				Pipe Diameter (inches) Options						
Street	From	To	Length	36	42	48	60	72	84	
			(ft)	Maximum Potential Storage Volume (cf) Available						
36th	Market	Logan	935	6,609	8,996	11,750	18,359	26,437	35,983	
36th	Logan	E. Harvard	500	3,534	4,811	6,283	9,817	14,137	19,242	
36th	E. Harvard	Harvard	200	1,414	1,924	2,513	3,927	5,655	7,697	
36th	Harvard	W. Harvard	150	1,060	1,443	1,885	2,945	4,241	5,773	
36th	W. Harvard	Yale	370	2,615	3,560	4,650	7,265	10,462	14,239	
36th	Yale	36th (bend)	270	1,909	2,598	3,393	5,301	7,634	10,391	
36th	36th (bend)	(south)	200	1,414	1,924	2,513	3,927	5,655	7,697	
Logan	36th	(north)	350	2,474	3,367	4,398	6,872	9,896	13,470	
Logan	36th	(south)	300	2,121	2,886	3,770	5,890	8,482	11,545	
Harvard	36th	(north)	350	2,474	3,367	4,398	6,872	9,896	13,470	
E. Harvard	36th	(south)	300	2,121	2,886	3,770	5,890	8,482	11,545	
W. Harvard	36th	(south)	260	1,838	2,501	3,267	5,105	7,351	10,006	
Yale	36th	(south)	170	1,202	1,636	2,136	3,338	4,807	6,542	
		Totals =	4,355	30,784	41,900	54,727	85,510	123,135	167,600	
		Storm Event	Storage Volume Required	Enough Storage Provided?						
		(yr)	(cf)							
		2	16,476	Yes	Yes	Yes	Yes	Yes	Yes	
		5	36,500	No	Yes	Yes	Yes	Yes	Yes	
		10	55,107	No	No	No	Yes	Yes	Yes	
		25	85,106	No	No	No	Yes	Yes	Yes	
		50	115,788	No	No	No	No	Yes	Yes	
		100	158,631	No	No	No	No	No	Yes	

Table 3 also shows that when the same size of storm sewer is placed under all street segments within the project limits, minimum required pipe sizes range from 36-inches up to 84-inches to detain runoff for the 2- through 100-year storm events. Thus, as long as the project limits do not increase and only a single-barrel same-size storm sewer is used, providing storage capacity for the 100-yr storm event can only be achieved by utilizing an 84-inch storm sewer (i.e. it would be impossible to install enough single-barrel 60-inch pipe within the project limits to provide storage for a 50-or 100-year storm event; a 60-inch pipe can only provide storage for up to and including the 25-year storm).

Although the proposed storm sewer will need to be deep due to the existing sanitary sewer main along 36th Street, there are a couple of intersecting streets within the project limits that do not have sanitary sewer: Logan Avenue both north and south of 36th Street and Yale Avenue south of 36th Street. As such, the storm sewer can be much shallower within these street segments.

Recommended Storm Sewer Size for Detention:

Upon consideration of the above information and options, 60-inch diameter High-Density Polyethylene (HDPE) storm sewer pipe is recommended for the following reasons:

1. Since storm water detention is a goal of this project, temporary storage of storm water in HDPE pipe is strongly preferred over larger diameter pipes such as reinforced concrete pipe (RCP) or corrugated metal pipe (CMP). Underground storage within HDPE pipe is industry-standard; storage within CMP is not considered a viable option.
2. HDPE pipe has a longer design life and is less prone to deterioration compared to RCP.
3. HDPE costs are typically less expensive than RCP.
4. 60-inch is the largest diameter that can currently be obtained in HDPE pipe.
5. Utilizing 60-inch HDPE pipe under all street segments provides storage for just above the 25-year storm event and maximizes the project footprint; providing substantial flood control improvement over existing conditions.
6. Although protection could be provided for greater storms (50- or 100-yr events) if larger RCP storm sewer is utilized, respective costs would dramatically increase above the cost of 60-inch HDPE.

Another important design consideration for the proposed storm sewer is to ensure that there is enough inlet capacity to allow peak flows from the 25-year storm event to be able to enter into the system. This means that inlet (catch basin) grate capacities will need to be checked and larger grates or additional inlets need to be provided to accomplish this design component. The critical location where runoff drains to is Logan Avenue, so it is especially crucial to ensure sufficient inlet capacity here to allow water to get into the system.

During more extreme storms beyond the 25-year event, temporary surcharging of both the proposed 36th Street storm sewer and the existing Market Avenue storm sewer may occur. Any excess flows exceeding the capacity of the 36th Street storm sewer will continue to follow the existing drainage path from Logan Avenue to the east through properties between 36th Street and 37th Street (however, these flows will be significantly reduced from what is currently experienced). It is important to design a designated "overflow" point, such as a curb cut, along Logan Avenue mid-block between 36th Street and 37th Street to minimize street flooding and promote usage of the existing drainage path. ***See Appendix G***. Table 4 summarizes the proposed storm water detention results.

Table 4

Summary of Proposed Storm Water Detention							
Storm Event	Existing *Maximum* Peak Discharge* from 36th St Watershed	Proposed Discharge to Market Ave System	Runoff Storage Volume Required	Runoff Storage Volume Provided	% of Required Runoff Volume Detained	Runoff Volume Not Detained	Approx. *Maximum* Overflow Discharge* at Logan Ave
(yr)	(cfs)	(cfs)	(cf)	(cf)	(%)	(cf)	(cfs)
2	44.8	17.1	34,658	85,510	100.00%	0	0.0
5	54.6	17.1	51,028	85,510	100.00%	0	0.0
10	61.9	17.1	64,885	85,510	100.00%	0	0.0
25	71.3	17.1	85,106	85,510	100.00%	0	0.0
50	78.1	17.1	102,870	85,510	83.12%	17,360	13.2
100	84.8	17.1	123,135	85,510	69.44%	37,625	25.9
* Based on Rational Method							

Restrictor Plate Orifices:

In order for the proposed storm sewer to provide effective storage of the 25-year storm event without surcharging at manholes or catch basins, several restrictor plates with smaller diameter orifices will need to be installed at critical manhole locations. In addition to staying below the sanitary sewer main as previously indicated, the top of the run of storm sewer within each section must also be kept below the top of manhole elevation where the section's orifice is located (these considerations can be better visualized as shown on the plan and profile sheets).

The bottom elevation of the orifices must match the invert elevation of their respective manhole's out-letting storm sewer. Sizing of the orifice diameters needs to be based on a combination of two factors:

1. Maximum hydraulic head possible within each section without surcharging out of the top of structures. This is the vertical distance from the lowest top of structure elevation within the respective section of storm sewer to the bottom of orifice elevation.
2. Allowable discharge at the respective restrictor plate/orifice location based on corresponding percentage of 36th Street watershed draining to the orifice location (e.g. if 50% of the watershed drains to the restrictor plate location, then the orifice needs to be designed to allow no more than 50% of the total allowable flow from the 36th Street watershed).

Table 5 shows six restrictor plates/orifices that would be needed within manhole structures along key locations within the proposed 36th Street storm sewer. The key locations generally coincide with street intersections or where topography indicates the need for one based on potential surcharging out of the tops of structures. ***See Appendix H.***

At each proposed location, the corresponding portion of the total 54.8-acre 36th Street drainage area is shown along with its respective percentage of the total area. These percentages were then used to calculate the allowable discharges from each orifice based on the maximum allowable discharge of 17.1 cfs for the entire 36th Street watershed for a 25-year storm event. Using each of the six orifice's allowable discharges and the respective maximum head available within the manhole structures, approximate orifice diameters were calculated using the orifice equation. Thus, at the most downstream end of the storm sewer where the sixth orifice will be located (just prior to connection to the Market Avenue storm sewer), the orifice is sized to pass the maximum allowable 25-year storm discharge of 17.1 cfs under maximum head conditions.

In lieu of restrictor plate orifices, removable stoplogs may be a better option to help facilitate inspection and maintenance of the storm sewer. If utilized, it is essential to design the stoplogs to operate similarly to the orifices in accordance with allowable discharges at respective locations.

Table 5

Detention Design Parameters								
Target Storm Event Detention =	25	year						
Corresponding Maximum Allowable Discharge =	17.1	cfs						
Restrictor Plate (Orifice)								
No.	**Location along 36th St.**	**Contributing 36th Street Drainage Area**		**Corresp. Allowable Discharge**	**Maximum Allowable Water Surface Elelvation (Top of Structure)**	**Approx. Pipe/ Orifice Invert Elev.**	**Maximum Head**	**Approx. Orifice Diameter**
		(acres)	(% of total)	(cfs)	(ft)	(ft)	(ft)	(in)
1	at Yale (Sta. 6+53)	10.85	19.80	3.4	1186.2	1170.0	16.2	5.57
2	at Sta. 8+23	11.65	21.26	3.6	1177.5	1162.9	14.6	5.92
3	at W. Harvard (Sta. 11+03)	23	41.97	7.2	1172.5	1155.7	16.8	8.03
4	at E. Harvard (Sta. 14+03)	32.7	59.67	10.2	1165	1150	15	9.85
5	at Logan (Sta. 18+83)	50.25	91.70	15.7	1156	1144.2	11.8	12.97
6	at Market (Sta. 28+18)	54.8	100.00	17.1	1149.2	1135.7	13.5	13.10

It is important to design the six restrictor plate orifices to be attached to the "downstream" sides of the respective manhole structures for two reasons:

1. Maximum head values used to design orifice diameters were based on the lowest top of manhole structures in the sections in which the orifices are located. In all cases except for the orifice at Logan Avenue, the manholes with the lowest top elevations are at the same locations of the proposed restrictor plates. This means that with the restrictor plate attached to the "downstream" side of the manhole, the maximum hydraulic head available is determined from the same manhole (i.e. if the restrictor plate orifices were located on the "upstream" sides of the manholes, then the maximum hydraulic head values would need to be based on the next highest upstream top of structure elevations).
2. It is preferable that hydrostatic pressure pushes the restrictor plates against the downstream side of the manholes, not away from the "upstream" sides of the manholes.

Storm Water Pollution Prevention:

Any construction activity that will disturb one or more acres of land is subject to regulation under Ohio EPA's National Pollutant Discharge Elimination System (NPDES) Construction Storm Water Permit. This permit requires the implementation of a Storm Water Pollution Prevent Plan (SWPPP) and appropriate best management practices (BMPs) to reduce and control storm water pollution related to construction activities and typically post-construction runoff as well. The proposed 36th Street project will disturb more than one acre and thus will be subject to the permit. However, since there will be no installation of any additional impervious surfaces, but rather a reduction through reduced pavement widths, post-construction pollution prevention BMPs are not required. A SWPPP showing the implementation of BMPs for pollution prevention of runoff only during construction will be required.

Sump Pump Discharges:

There are a few known problematic locations within the project limits where sump pumps discharge frequently out to the street, either over sidewalks or directly to the edge of pavement. These are problematic in that without an existing drainage system for the street, pavement and sidewalks are constantly wet and deteriorate much faster. In the winter, these discharges freeze, thus resulting in hazardous conditions. It is a goal of this project to provide a direct connection of sump pump discharges into the proposed storm sewer at catch basins, as well as to provide an emergency relief at the curb.

Proposed Pavement Reduction:

The existing pavement width along 36th Street is excessively wide, especially west of Logan Avenue. East of Logan, the pavement is approximately 30-feet wide. This is acceptable and is sufficient to allow for parking on both sides of the street within this residential, low-traffic neighborhood. West of Logan Avenue, however, the pavement is wider, averaging around 36 feet. The intersections of East Harvard and West Harvard Boulevards are also extremely wide. Thus, the excess pavement along 36th Street means more storm water runoff which only exacerbates flooding, more pavement to maintain, salt, and plow, and as a result, higher associated operation and maintenance costs.

As part of this project, the City of Canton proposes that 36th Street undertakes a "road diet" and reduces the portions of excessive pavement widths but still maintains the ability to park on both sides of the street. The goal is to use the existing pavement widths east of Logan Avenue as the benchmark and provide the same 30-foot wide pavement width along the remainder of the corridor within the project limits. In rare cases where parked vehicles are immediately across from each other on opposite sides of the street, traveling vehicles may have to "take turns" to proceed. This is no different than what may currently occur east of Logan Avenue, and is appropriate for this neighborhood which has minimal traffic volume.

Roadway Reconstruction:

With the proposed pavement reduction, full-depth roadway reconstruction will also occur. This will result in new roadway base material, new pavement, underdrains, and new curbs for 36th Street between Frazer Avenue and Market Avenue and portions of intersecting streets within the projects limits.

Water Line Replacement:

As part of this project, the City of Canton also plans to replace the existing 6-inch water main under the north side of 36th Street as well as under Harvard Avenue and Logan Avenue between 36th Street and 37th Street. Since the existing water main is located under the north side of 36th Street, the proposed water line will need to be placed under the south side of 36th Street in order to maintain continuous water service to residents during construction. As a result, the proposed storm sewer will need to be located under the north side of the street (thus, the existing water main will need to be removed to install the storm sewer).

Sanitary Sewer Repairs:

The City of Canton Collection Systems Department evaluated the condition of the existing 8-inch sanitary main. It has been determined that there are four sections of sanitary sewer that will need to be replaced along 36th Street as part of the project:

1. 30-ft of 8-in sewer from 89-ft to 119-ft east of sanitary manhole #9411
2. 12-ft of 8-in sewer from 88-ft to 100-ft east of sanitary manhole #8804
3. 44-ft of 8-in sewer from 72-ft to 116-ft east of sanitary manhole #8809
4. 25-ft of 8-in sewer from 220-ft to 245-ft east of sanitary manhole #8811

An extra 5-feet on each end of the repair sections should be planned for replacement, for a total of approximately 151-feet of 8-inch sanitary sewer.

In addition, a spray-on polymer liner (e.g. "OBIC Armor"; "Spectrashield"; etc.) is proposed to be used on each sanitary sewer manhole within the project limits to prevent infiltration and corrosion.

Conclusion and Summary:

The City of Canton desires to address the flooding and associated problems along 36th Street NW between Frazer Avenue and Market Avenue and the surrounding vicinity. After consideration of the results of this study, a project is proposed featuring the major components as shown in Table 6.

Table 6

Proposed 36th Street NW Project Summary	
Major Component	**Description**
Project Limits	36th St between Frazer Ave and Market Ave; portions of Yale Ave, West Harvard Blvd, Harvard Blvd, East Harvard Blvd, and Logan Ave up to 350 feet
Storm Sewer	4,355 feet of 60-inch HDPE pipe trunk line to tie into existing Market Ave storm sewer; Curb inlet catch basins throughout project limits
Storm Water Detention	Utilize 60-inch storm sewer with 6 restrictor plate orifices/stoplogs to provide underground detention for up to and including the 25-year storm event
Storm Water Pollution Prevention	During construction only; No post-construction storm water treatment required
Pavement Width Reduction	Reduce 36th St pavement width to 30 feet between Frazer Ave and Logan Ave
Roadway Reconstruction	Full depth pavement replacement and new curbs along 36th Street and portions of intersecting streets within the project limits
Water Line Replacement	36th St between Frazer Ave and Market Ave; Harvard Ave between 36th St and 37th St; Logan Ave between 36th St and 37th St
Sanitary Sewer Repairs	Replace approximately 151 feet of 8-inch sewer; line all sanitary manholes
Preliminary Estimated Cost	**$4,500,000** (Approx. $2,000,000 of this cost is the 60-inch storm sewer)

See Appendix I for plan and profile sheets showing the proposed storm sewer under 36th Street.

Due to the preliminary estimated cost of $4,500,000 and projected funding resources, this project is proposed to be constructed in two phases:

1. Phase 1 – Logan Avenue NW to Market Avenue
2. Phase 2 – Frazer Avenue NW to Logan Avenue

The general strategy for design, funding, and construction of this project is:

Timeframe	Project Aspect	Description
2019	Design	June - August: Engineering design/plans preparation for OPWC submission for Phase 1
2019	Apply for Funding	September: Apply for OPWC funding for Phase 1
2019-2020	Design	Detailed engineering design (complete Phase 1 & Phase 2)
2020	Apply for Funding	September: Apply for OPWC funding for Phase 2
2020-2021	Construction	September 2020: Earliest construction start for Phase 1
2021-2022	Construction	September 2021: Earliest construction start for Phase 2

Above-Ground Option for Storm Water Detention:

The main objective of a proposed project along 36th Street NW is to alleviate flooding and improve drainage. Improving drainage is accomplished by providing a storm sewer. Alleviating flooding is typically accomplished by providing storm water detention, and the preferred option is to construct an above-ground detention basin. Above-ground detention is preferred over underground detention for the following reasons:

1. **Relatively less expensive:** The majority of costs associated with above ground detention consists of excavation. Excavation costs are almost always less expensive than costs associated with the installation of underground detention facilities.
2. **Provide storage for greater storm events:** Much more storage volume can be provided in an above-ground detention basin compared to underground detention facilities. Thus, greater flood protection during greater storm events can be provided in above-ground versus underground detention.
3. **Easier to maintain:** With above-ground detention, maintenance-related issues can be easily seen and addressed. With underground detention, it is difficult to see and know when maintenance issues arise.

With that being said, the overall recommendation of this study is to provide underground detention by installing a 60-inch diameter storm sewer that will provide flood protection for up to and including the 25-year storm event. This is mainly because there is no room within the project limits to provide above-ground detention without impacting existing houses or streets.

However, if above-ground detention was to be pursued, the closest location that could potentially be utilized without impacting existing houses or streets is the ravine on the east side of Market Avenue north of 37th Street at the outlet of the existing Market Avenue storm sewer. ***See Appendix J***. The following critical aspects would also need to be considered:

1. The project limits would need to be increased.
2. The property where the detention basin would be located would need to be acquired.
3. The detention basin would need to be designed for the entire contributing drainage area (watershed), which is much larger than just the 36th Street watershed.
4. 100-year storm protection would be recommended since this is the standard for above-ground detention.
5. A storm sewer large enough to convey the 100-year peak discharge of 84.8 cfs from 36th Street at Logan Avenue would need to be constructed to discharge to the detention basin. This would require at least 2,030 feet of 42-inch diameter storm sewer (to handle the 36th Street watershed only).
6. If the discharges from the 36th Street watershed were to be combined with the Market Avenue watershed, approximately 820 feet of the existing Market Avenue storm sewer would need to be replaced (upsized).
7. Additional impacts to Market Avenue would occur.
8. Additional costs would be incurred.

Due to these additional considerations, above-ground detention is not recommended.

Appendices:

A. Existing Flooding Map
B. Market Heights Neighborhood Association Report (courtesy of Marcy Mertes; resident)
C. Project Limits Map
D. Watersheds Map
E. Discharge Analysis
F. Street Segment Length Map
G. Recommended 60" Storm Sewer Footprint Map
H. Restrictor Plate Orifices Location Map
I. 36th Street NW Typical Section and Plan & Profile Sheets
J. Potential Location for Above-Ground Detention
K. Preliminary Cost Estimate

Appendix A.
Existing Flooding Map

P:\Canton – City of\J20170744.000 Market Heights 36th NW Street Storm Water Study\Drawings\Trans\J20170744_36th & Market_WaterShed & Storm Sewer Maps.dwg 30-Jan-19 5:04 PM

CITY OF CANTON	APPENDIX A EXISTING FLOODING MAP 36TH STREET NW	CALCULATED CES CHECKED DW	0 150 75 300 HORIZONTAL SCALE IN FEET	N

Appendix B.
Market Heights Neighborhood Association Report
(courtesy of Marcy Mertes; resident)

MARKET HEIGHTS – on a normal day of rain.....

Market Height Neighborhood Association is working to prevent flight from the city of Canton. The water issues in the streets does not encourage people to buy homes here.

WE NEED YOUR HELP.

Situation has been present for 15+ years and getting worse

Corner of 36th Street and Harvard

- Road is patched 2-3 times a year (2x in the past month)
- Water pools until high enough to go over road
- After a rain - water continues to run down north side of 36th and pools for several days
- High traffic intersection

MARKET HEIGHTS – on a 10 year rain.....

Corner of 36th Street and Logan

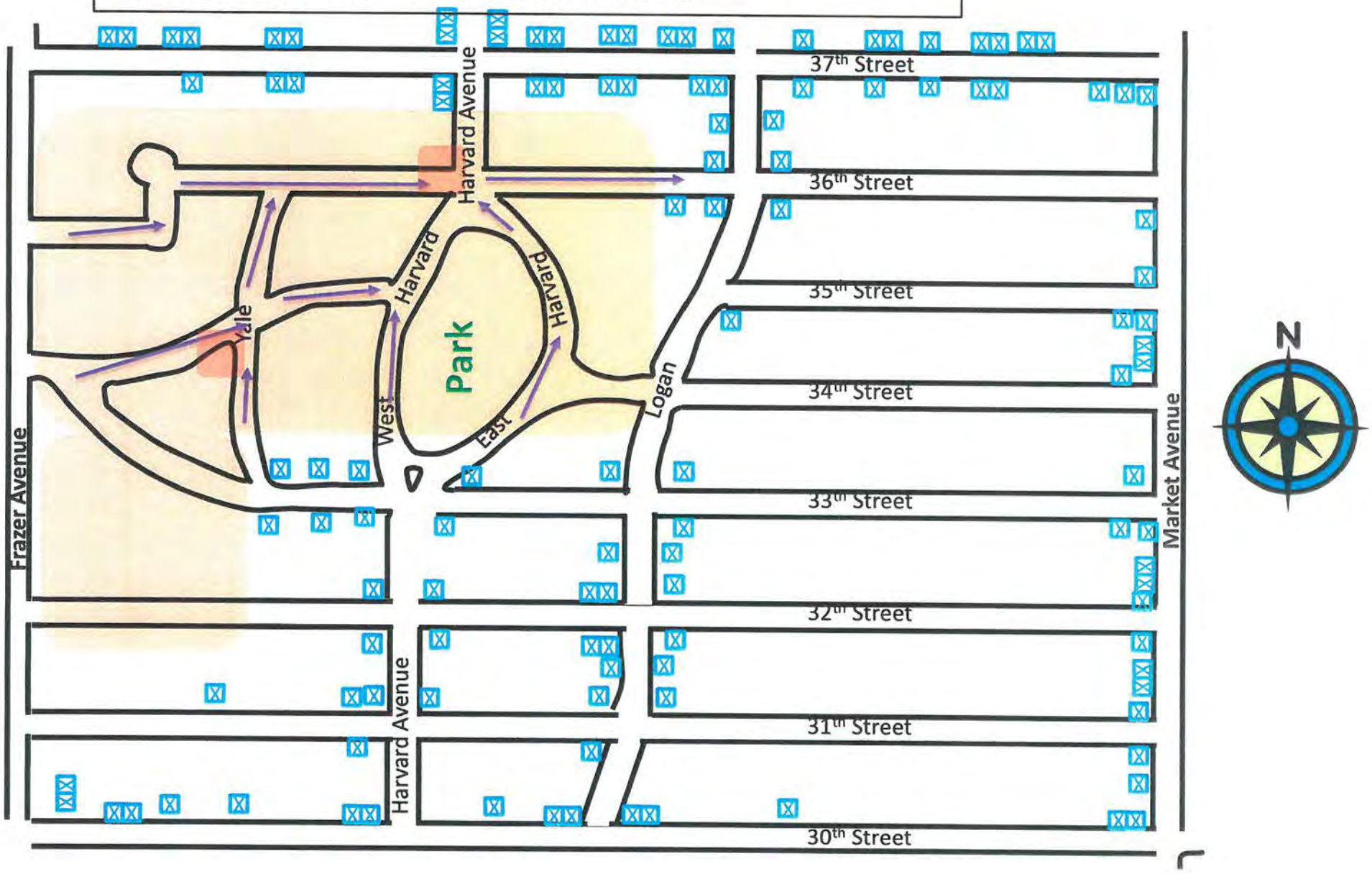
MARKET HEIGHTS

Many runners, strollers, walkers, and school buses utilize this corner and can not walk on the sidewalk due to the "pond" that is there for days during and after a rain fall of any amount. This does not encourage people to buy homes in the Canton City neighborhood of Market Heights

Corner of 36th Street and Harvard

- Road is patched 2-3 times a year (2x in the past month)
- Water pools until high enough to go over road
- After a rain - water continues to run down north side of 36th and pools for several days
- High traffic intersection
- **Situation has been present for 15+ years and getting worse**

MARKET HEIGHTS – location of culverts



Culvert

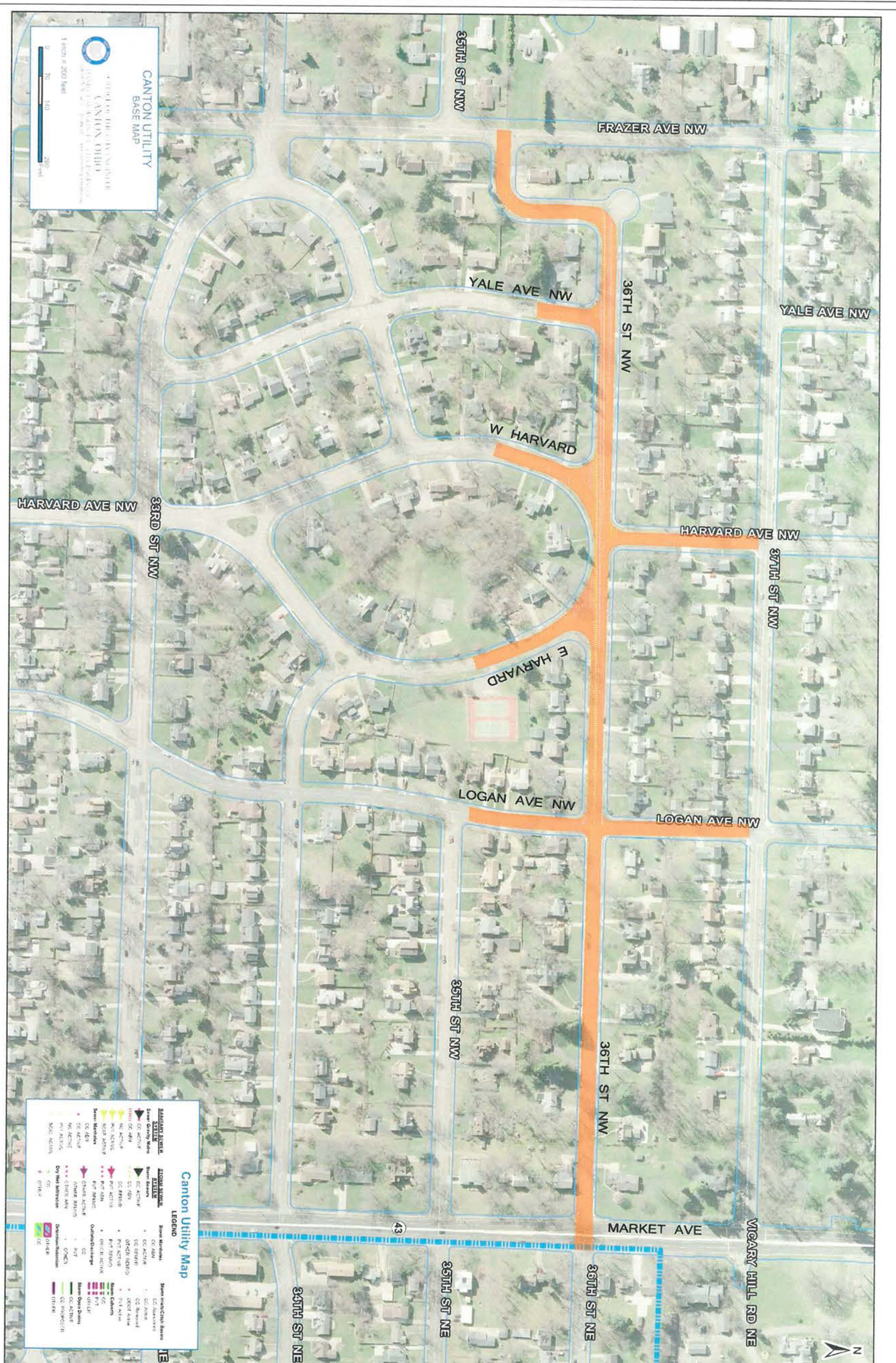
Affected Area

Direction of water flow

Pooling of water

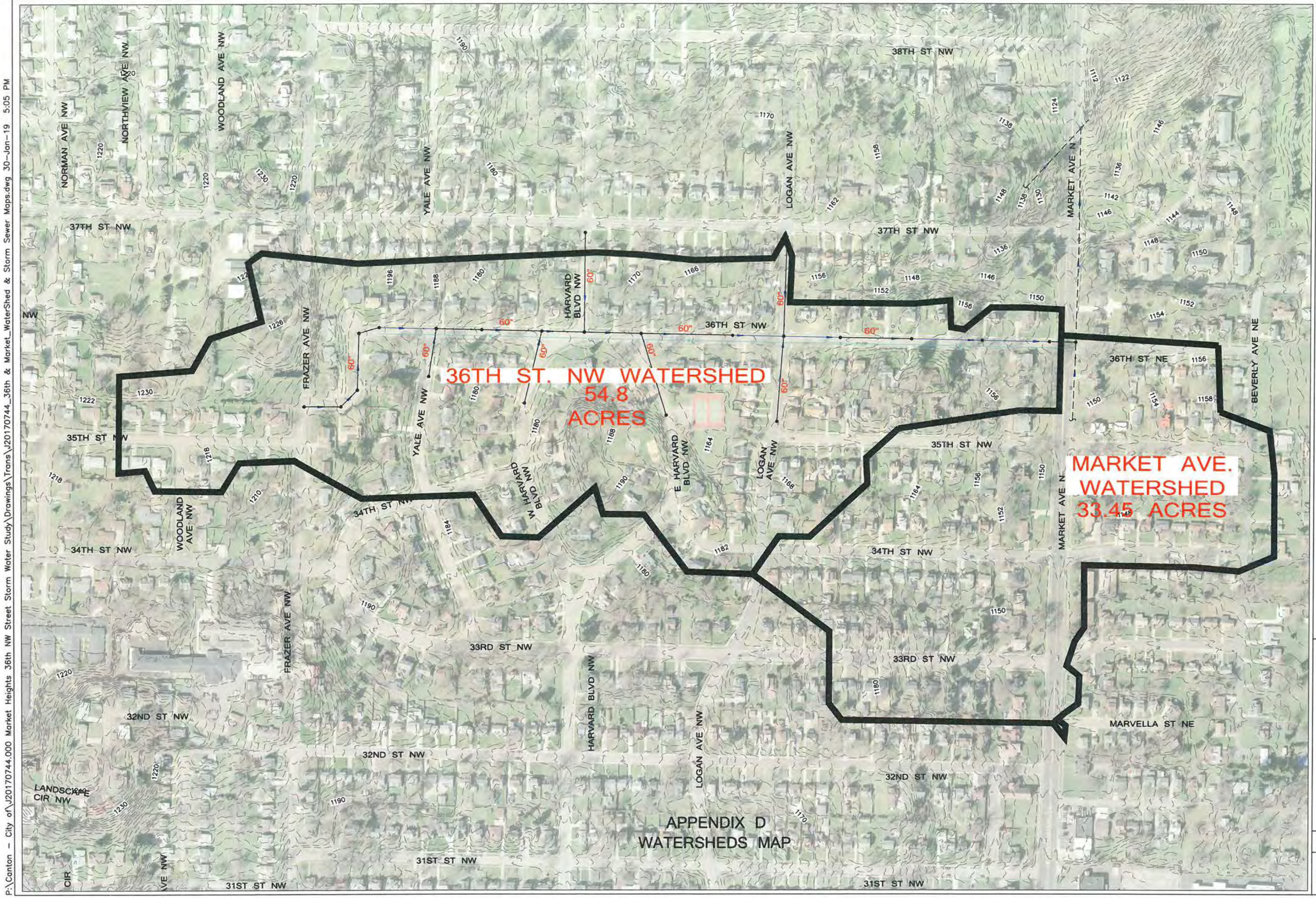
Appendix C.
Project Limits Map

P:\Canton – City of\J20170744.000 Market Heights 36th NW Street Storm Water Study\Drawings\Trans\J20170744_36th & Market_WaterShed & Storm Sewer Maps.dwg 30-Jan-19 5:04 PM



CITY OF CANTON	APPENDIX C PROJECT LIMITS MAP 36TH STREET NW	CALCULATED CES CHECKED DW	0 150 75 300 HORIZONTAL SCALE IN FEET	N

Appendix D.
Watersheds Map



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N

0 75 150 300
HORIZONTAL SCALE IN FEET

CALCULATED CES
CHECKED DW

APPENDIX D
WATERSHEDS MAP 36TH STREET NW

CITY OF CANTON

1
1

Appendix E.
Discharge Analysis

MODIFIED RATIONAL METHOD

Used for Estimating Detention Facility Storage Volumes in Ohio
Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S
Version 1/9/2017

SITE INPUT INFORMATION		
Site Name & Location:	Market Ave watershed draining to vicinity of 36th St	
Date:	11/5/2018	
Input By:	CDB	
Ohio Rainfall Area (Intensity Zone):	A	**(Select A,B,C, or D)**
Note: The Rainfall Intensity Area value can be found from Figure 1101-3 in Ohio Department Of Transportation's Location & Design Manual - Volume II - Drainage Design.		
Note:	Canton is in Area "A".	
Pre-Developed Conditions		
Time of Concentration, T_c=	30	**minutes (range 10 to 200)**
Drainage Area, A =	33.450	**acres (should not exceed 30)**
Composite Runoff Coefficient, C =	0.3	**(range 0.00 to 1.00)**
Post-Developed Conditions		
Time of Concentration, T_c=	30	**minutes (range 10 to 200)**
Drainage Area, A =	33.450	**acres (should not exceed 30)**
Composite Runoff Coefficient, C =	0.3	**(range 0.00 to 1.00)**

EXISTING DOWNSTREAM SYSTEM		
Description of existing downstream system (i.e. ditch, storm sewer, stream, etc.) that the site will discharge to:		
Area discharges into existing 36" storm sewer along E side of Market Ave. The HGL slope (without exceeding rim elevations along Market Ave just north of 33rd St) results in a "pressurized" capacity of approx. 49.9 cfs.		
Minimum capacity ("chokepoint") of downstream system =	49.9	**cfs (assuming "open channel flow" conditions)**
Approx. which storm event can the downstream system *adequately* convey without flooding?	100	**year storm runoff (MUST consider runoff from *entire* contributing drainage area)**
Is the above "chokepoint" capacity based on approximated or surveyed data?	Surveyed	**data**

PRE-DEVELOPED PEAK FLOWS (BASED ON RATIONAL METHOD)

Storm	Area (Intensity Zone) A			Area (Intensity Zone) B			Area (Intensity Zone) C			Area (Intensity Zone) D		
Event	*i*	*Peak Flow*	*Volume*	i	Peak Flow	Volume	i	Peak Flow	Volume	i	Peak Flow	Volume
(Year)	*(in/hr)*	*(cfs)*	*(cf)*	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)
2	*1.99*	*19.92*	*35,856*	2.06	20.70	37,255	2.22	22.32	40,169	2.27	22.77	40,988
5	*2.46*	*24.64*	*44,350*	2.53	25.43	45,779	2.70	27.05	48,681	2.70	27.05	48,681
10	*2.81*	*28.24*	*50,832*	2.91	29.16	52,480	3.06	30.75	55,359	3.13	31.46	56,622
25	*3.27*	*32.85*	*59,133*	3.37	33.83	60,887	3.55	35.56	64,035	3.62	36.37	65,470
50	*3.62*	*36.31*	*65,350*	3.68	36.93	66,470	3.88	38.94	70,090	4.02	40.30	72,543
100	*3.96*	*39.72*	*71,492*	4.08	40.96	73,764	4.18	41.90	75,424	4.37	43.86	78,956

Note: Volumes for pre- and post-developed peak flows are based on "3 Point Triangular Hydrographs" derived from application of standard Rational Method

POST-DEVELOPED PEAK FLOWS (BASED ON RATIONAL METHOD)

Storm	Area (Intensity Zone) A			Area (Intensity Zone) B			Area (Intensity Zone) C			Area (Intensity Zone) D		
Event	*i*	*Peak Flow*	*Volume*	i	Peak Flow	Volume	i	Peak Flow	Volume	i	Peak Flow	Volume
(Year)	*(in/hr)*	*(cfs)*	*(cf)*	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)
2	*1.99*	*19.92*	*35,856*	2.06	20.70	37,255	2.22	22.32	40,169	2.27	22.77	40,988
5	*2.46*	*24.64*	*44,350*	2.53	25.43	45,779	2.70	27.05	48,681	2.70	27.05	48,681
10	*2.81*	*28.24*	*50,832*	2.91	29.16	52,480	3.06	30.75	55,359	3.13	31.46	56,622
25	*3.27*	*32.85*	*59,133*	3.37	33.83	60,887	3.55	35.56	64,035	3.62	36.37	65,470
50	*3.62*	*36.31*	*65,350*	3.68	36.93	66,470	3.88	38.94	70,090	4.02	40.30	72,543
100	*3.96*	*39.72*	*71,492*	4.08	40.96	73,764	4.18	41.90	75,424	4.37	43.86	78,956

MODIFIED RATIONAL METHOD

Used for Estimating Detention Facility Storage Volumes in Ohio
Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S
Version 1/9/2017

SITE INPUT INFORMATION		
Site Name & Location:	36th St NW vicinity of Logan Ave	
Date:	11/21/2018	
Input By:	CDB	
Ohio Rainfall Area (Intensity Zone):	A	**(Select A,B,C, or D)**
Note: The Rainfall Intensity Area value can be found from Figure 1101-3 in Ohio Department Of Transportation's Location & Design Manual - Volume II - Drainage Design.		
Note:	Canton is in Area "A".	
Pre-Developed Conditions		
Time of Concentration, T_c=	18	**minutes (range 10 to 200)**
Drainage Area, A =	54.800	**acres (should not exceed 30)**
Composite Runoff Coefficient, C =	0.3	**(range 0.00 to 1.00)**
Post-Developed Conditions		
Time of Concentration, T_c=	18	**minutes (range 10 to 200)**
Drainage Area, A =	54.800	**acres (should not exceed 30)**
Composite Runoff Coefficient, C =	0.3	**(range 0.00 to 1.00)**

EXISTING DOWNSTREAM SYSTEM		
Description of existing downstream system (i.e. ditch, storm sewer, stream, etc.) that the site will discharge to:		
Area is proposed to discharge into existing 36" storm sewer at Market Ave.		
Maximum capacity of downstream system =	49.9	**cfs**
Approx. which storm event can the downstream system *adequately* convey without flooding?	2	**year storm runoff (MUST consider runoff from *entire* contributing drainage area)**
Is the above "chokepoint" capacity based on approximated or surveyed data?	Surveyed	**data**

PRE-DEVELOPED PEAK FLOWS (BASED ON RATIONAL METHOD)

Storm	*Area (Intensity Zone) A*			Area (Intensity Zone) B			Area (Intensity Zone) C			Area (Intensity Zone) D		
Event	*i*	*Peak Flow*	*Volume*	i	Peak Flow	Volume	i	Peak Flow	Volume	i	Peak Flow	Volume
(Year)	*(in/hr)*	*(cfs)*	*(cf)*	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)
2	*2.72*	*44.76*	*48,337*	2.83	46.50	50,224	3.04	49.97	53,985	3.10	50.99	55,067
5	*3.32*	*54.56*	*58,921*	3.43	56.33	60,834	3.64	59.86	64,652	3.64	59.86	64,652
10	*3.77*	*61.93*	*66,880*	3.88	63.86	68,967	4.09	67.24	72,620	4.19	68.92	74,434
25	*4.34*	*71.27*	*76,971*	4.46	73.34	79,211	4.68	76.91	83,064	4.79	78.82	85,126
50	*4.75*	*78.13*	*84,382*	4.86	79.93	86,325	5.09	83.62	90,312	5.27	86.56	93,484
100	*5.16*	*84.81*	*91,592*	5.31	87.24	94,218	5.48	90.01	97,216	5.70	93.67	101,164

Note: Volumes for pre- and post-developed peak flows are based on "3 Point Triangular Hydrographs" derived from application of standard Rational Method

POST-DEVELOPED PEAK FLOWS (BASED ON RATIONAL METHOD)

Storm	*Area (Intensity Zone) A*			Area (Intensity Zone) B			Area (Intensity Zone) C			Area (Intensity Zone) D		
Event	*i*	*Peak Flow*	*Volume*	i	Peak Flow	Volume	i	Peak Flow	Volume	i	Peak Flow	Volume
(Year)	*(in/hr)*	*(cfs)*	*(cf)*	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)
2	*2.72*	*44.76*	*48,337*	2.83	46.50	50,224	3.04	49.97	53,985	3.10	50.99	55,067
5	*3.32*	*54.56*	*58,921*	3.43	56.33	60,834	3.64	59.86	64,652	3.64	59.86	64,652
10	*3.77*	*61.93*	*66,880*	3.88	63.86	68,967	4.09	67.24	72,620	4.19	68.92	74,434
25	*4.34*	*71.27*	*76,971*	4.46	73.34	79,211	4.68	76.91	83,064	4.79	78.82	85,126
50	*4.75*	*78.13*	*84,382*	4.86	79.93	86,325	5.09	83.62	90,312	5.27	86.56	93,484
100	*5.16*	*84.81*	*91,592*	5.31	87.24	94,218	5.48	90.01	97,216	5.70	93.67	101,164

MODIFIED RATIONAL METHOD

Used for Estimating Detention Facility Storage Volumes in Ohio

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

DIFFERENCES BETWEEN AREAS UNDER PRE-DEVELOPED & POST-DEVELOPED PEAK Q HYDROGRAPHS (BASED ON RATIONAL METHOD)

Storm Event	*Area (Intensity Zone) A*	Area (Intensity Zone) B	Area (Intensity Zone) C	Area (Intensity Zone) D
	Volume	Volume	Volume	Volume
(Year)	*(cf)*	(cf)	(cf)	(cf)
2	*0*	0	0	0
5	*0*	0	0	0
10	*0*	0	0	0
25	*0*	0	0	0
50	*0*	0	0	0
100	*0*	0	0	0

Note: The above chart is provided to show how the standard Rational Method can be misapplied and result in severely underestimated storage volumes when compared to volumes determined from application of the *Modified* Rational Method.

DETENTION CRITERIA

Storm Event	Pre-Developed Peak Flow from Site	Down-stream System "Choke-point" Capacity	Proportional Flow from Site Allowed in Downstream System	*Recom-mended* Allowable Detention Facility Outflow*	Selected Detention Facility Outflow	Max. Post-Developed Peak Flow to Detention Facility	Maximum % Reduction in Post-Dev. Peak Flow
(Year)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(%)
2	*44.76*	*49.90*	*44.76*	***44.76***	30.00	*44.76*	*32.97*
5	*54.56*	*49.90*	*44.76*	***44.76***	25.30	*54.56*	*53.63*
10	*61.93*	*49.90*	*44.76*	***44.76***	21.70	*61.93*	*64.96*
25	*71.27*	*49.90*	*44.76*	***44.76***	17.10	*71.27*	*76.01*
50	*78.13*	*49.90*	*44.76*	***44.76***	13.60	*78.13*	*82.59*
100	*84.81*	*49.90*	*44.76*	***44.76***	10.20	*84.81*	*87.97*

ESTIMATES OF REQUIRED DETENTION STORAGE VOLUMES AND CORRESPONDING CRITICAL DURATIONS, INTENSITIES, & PEAK INFLOWS (BASED ON *MODIFIED* RATIONAL METHOD)

Storm Event	*Area (Intensity Zone) A*				Area (Intensity Zone) B				Area (Intensity Zone) C				Area (Intensity Zone) D			
	Volume	*Critical Duration*	*Resulting Intensity*	*Resulting Peak Inflow*	Volume	Critical Duration	Resulting Intensity	Resulting Peak Inflow	Volume	Critical Duration	Resulting Intensity	Resulting Peak Inflow	Volume	Critical Duration	Resulting Intensity	Resulting Peak Inflow
(Year)	*(cf)*	*(min)*	*(in/hr)*	*(cfs)*	(cf)	(min)	(in/hr)	(cfs)	(cf)	(min)	(in/hr)	(cfs)	(cf)	(min)	(in/hr)	(cfs)
2	***16,476***	***23***	***2.353***	***38.68***	18,562	24	2.381	39.14	22,947	26	2.439	40.09	24,223	26	2.489	40.91
5	***36,500***	***35***	***2.222***	***36.54***	38,954	35	2.294	37.71	44,025	37	2.350	38.64	44,025	37	2.350	38.64
10	***55,107***	***47***	***2.101***	***34.55***	58,150	48	2.136	35.11	63,656	50	2.185	35.92	66,171	51	2.208	36.30
25	***85,106***	***76***	***1.779***	***29.24***	88,247	75	1.838	30.21	94,291	74	1.935	31.81	97,934	78	1.913	31.45
50	***115,788***	***119***	***1.463***	***24.05***	117,134	118	1.475	24.24	122,331	106	1.654	27.19	129,351	113	1.651	27.14
100	***158,631***	***200***	***1.142***	***18.78***	156,375	177	1.237	20.34	159,576	183	1.225	20.13	169,424	184	1.274	20.95
	Maximum Volume =		***158,631***	***cubic feet***	Maximum Volume =		158,378	cubic feet	Maximum Volume =		159,576	cubic feet	Maximum Volume =		169,424	cubic feet

Caution! A critical duration of 200 minutes exists for selected intensity area (zone). Further evaluation is advised since spreadsheet does not evaluate durations longer than 200 minutes. Storage routing calculations MUST be performed to ensure estimated detention volume is adequate! Tailwater must be taken into consideration when routing!

RAINFALL INTENSITY EQUATION

i=a/(t+b)^c

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) A						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	46.184	56.985	64.167	66.528	65.702	64.489
b =	9.000	10.250	11.000	11.000	10.750	10.500
c =	0.859	0.851	0.842	0.811	0.782	0.754

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) B						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	47.987	60.684	73.126	75.841	65.621	85.047
b =	9.000	10.500	12.000	12.000	10.000	13.250
c =	0.859	0.858	0.863	0.833	0.781	0.806

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) C						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	56.299	67.933	84.550	95.736	96.783	80.436
b =	10.000	11.000	13.000	14.000	14.000	11.500
c =	0.876	0.869	0.882	0.871	0.850	0.794

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) D						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	57.448	67.933	79.192	87.886	95.169	91.982
b =	10.000	11.000	12.000	12.750	13.500	13.000
c =	0.876	0.869	0.864	0.849	0.839	0.810

Note: The above values are taken from Ohio Department Of Transportation's Location and Design Manual - Volume II - Drainage Design. The user must ensure the above values are consistent with values from the current edition of the manual and revise them as necessary.

RATIONAL METHOD PEAK FLOW HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	18	minutes	Time of Concentration, T_c	=	18	minutes
Drainage Area, A	=	54.8	acres	Drainage Area, A	=	54.8	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

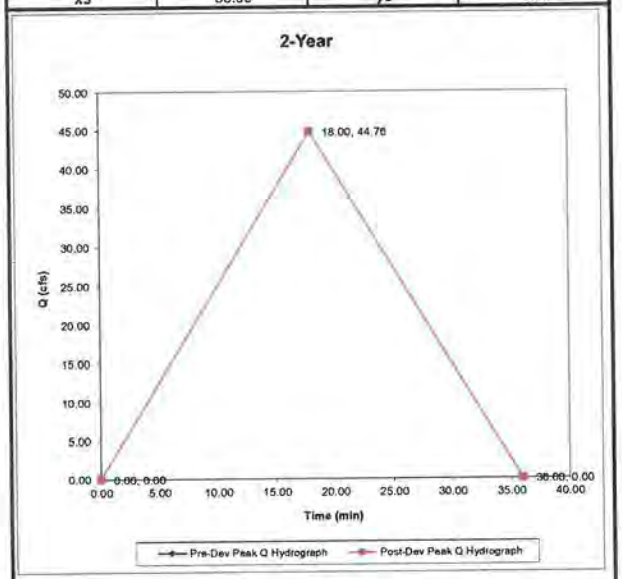
2-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	44.76
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	44.76
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	48,336.55
Post-Developed Peak Q Hydrograph Area (cf) =	48,336.55
Difference Between Hydrograph Areas (cf) =	0.00

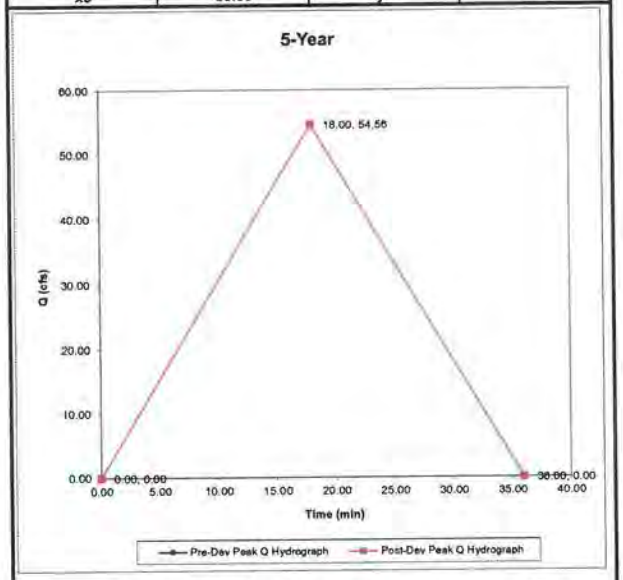
5-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	54.56
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	54.56
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	58,920.91
Post-Developed Peak Q Hydrograph Area (cf) =	58,920.91
Difference Between Hydrograph Areas (cf) =	0.00

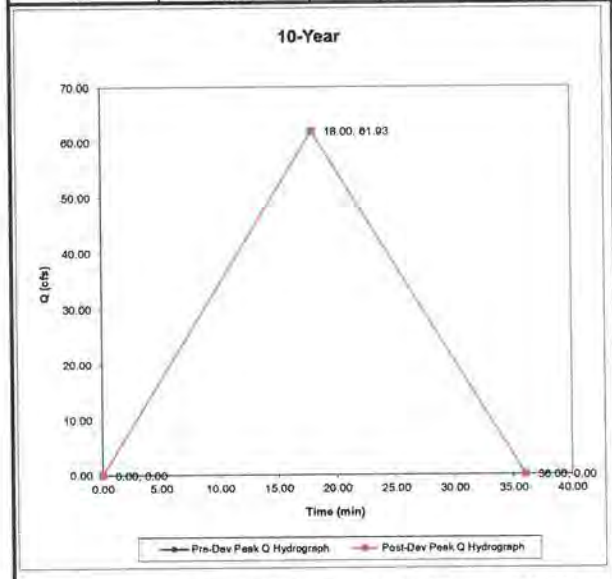
10-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	61.93
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	61.93
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	66,880.30
Post-Developed Peak Q Hydrograph Area (cf) =	66,880.30
Difference Between Hydrograph Areas (cf) =	0.00

RATIONAL METHOD PEAK FLOW HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	18	minutes	Time of Concentration, T_c	=	18	minutes
Drainage Area, A	=	54.8	acres	Drainage Area, A	=	54.8	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

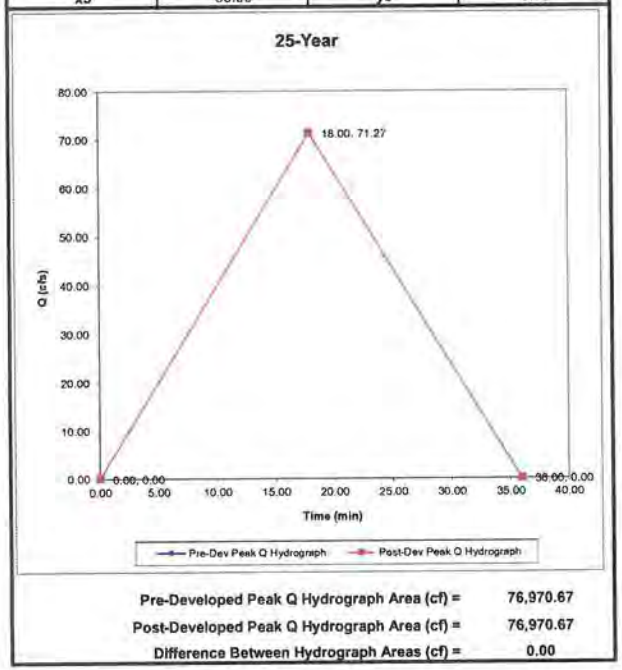
25-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	71.27
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	71.27
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) = 76,970.67
Post-Developed Peak Q Hydrograph Area (cf) = 76,970.67
Difference Between Hydrograph Areas (cf) = 0.00

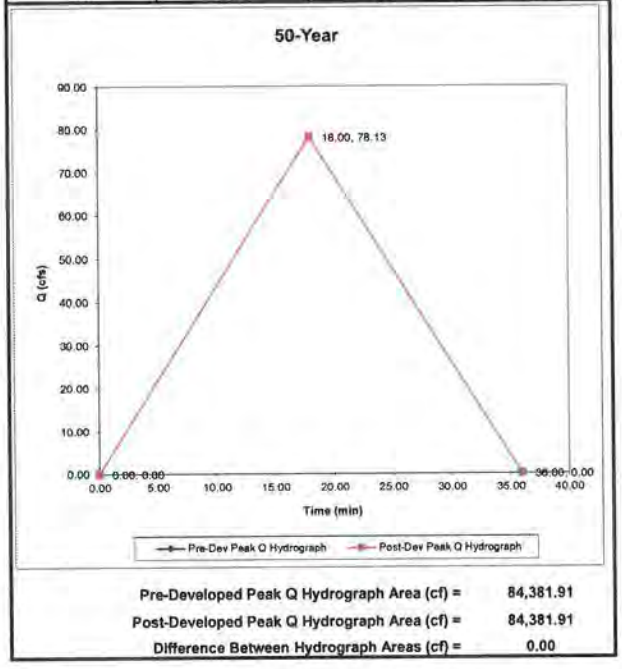
50-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	78.13
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	78.13
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) = 84,381.91
Post-Developed Peak Q Hydrograph Area (cf) = 84,381.91
Difference Between Hydrograph Areas (cf) = 0.00

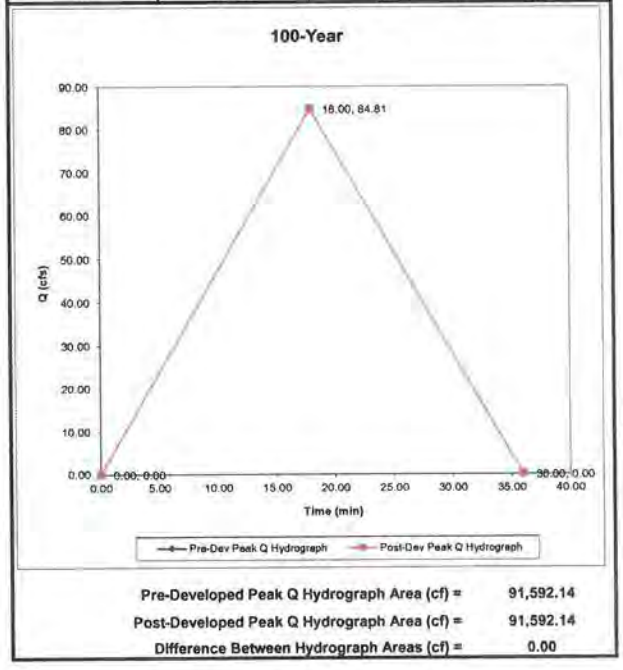
100-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	84.81
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	84.81
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) = 91,592.14
Post-Developed Peak Q Hydrograph Area (cf) = 91,592.14
Difference Between Hydrograph Areas (cf) = 0.00

MODIFIED RATIONAL METHOD HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	18	minutes	Time of Concentration, T_c	=	18	minutes
Drainage Area, A	=	54.8	acres	Drainage Area, A	=	54.8	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

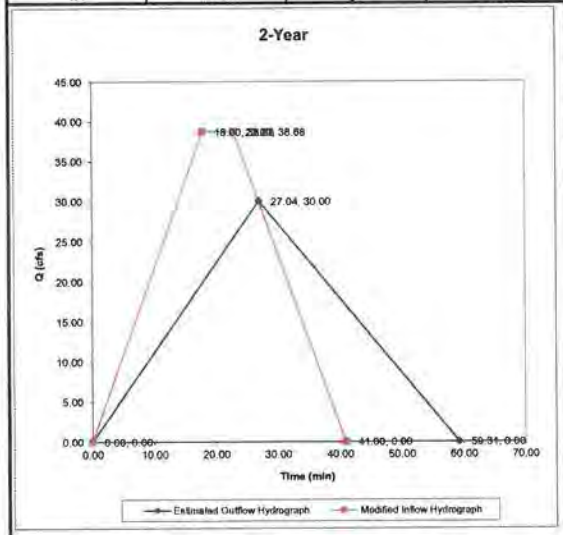
2-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	27.04	y2	30.00
x3	59.31	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	38.68
x3	23.00	y3	38.68
x4	41.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	53,376.32
Area under Estimated Outflow Hydrograph (cf) =	53,376.32
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	16,476.32
Critical Duration (min) =	23.00
Storm Duration Factor (SDF) =	1.28

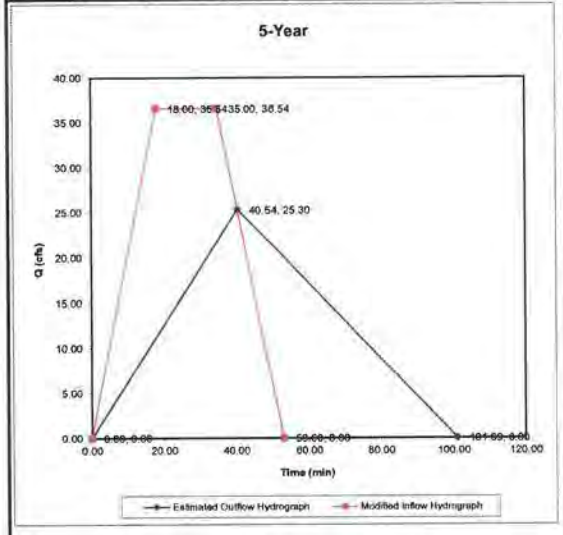
5-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	40.54	y2	25.30
x3	101.09	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	36.54
x3	35.00	y3	36.54
x4	53.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	76,727.36
Area under Estimated Outflow Hydrograph (cf) =	76,727.36
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	36,500.36
Critical Duration (min) =	35.00
Storm Duration Factor (SDF) =	1.94

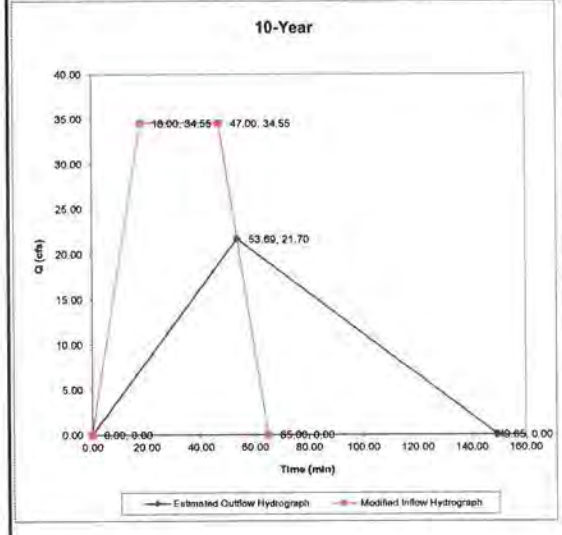
10-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	53.69	y2	21.70
x3	149.65	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	34.55
x3	47.00	y3	34.55
x4	65.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	97,421.83
Area under Estimated Outflow Hydrograph (cf) =	97,421.83
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	55,106.83
Critical Duration (min) =	47.00
Storm Duration Factor (SDF) =	2.61

MODIFIED RATIONAL METHOD HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	18	minutes	Time of Concentration, T_c	=	18	minutes
Drainage Area, A	=	54.8	acres	Drainage Area, A	=	54.8	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

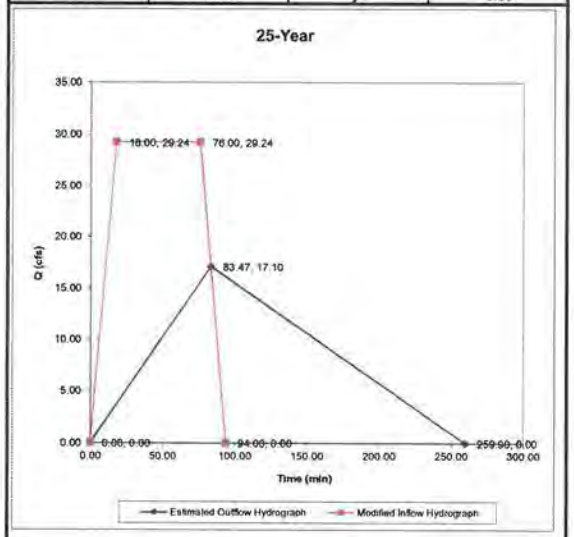
25-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	83.47	y2	17.10
x3	259.90	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	29.24
x3	76.00	y3	29.24
x4	94.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	133,327.89
Area under Estimated Outflow Hydrograph (cf) =	133,327.89
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	85,105.89
Critical Duration (min) =	76.00
Storm Duration Factor (SDF) =	4.22

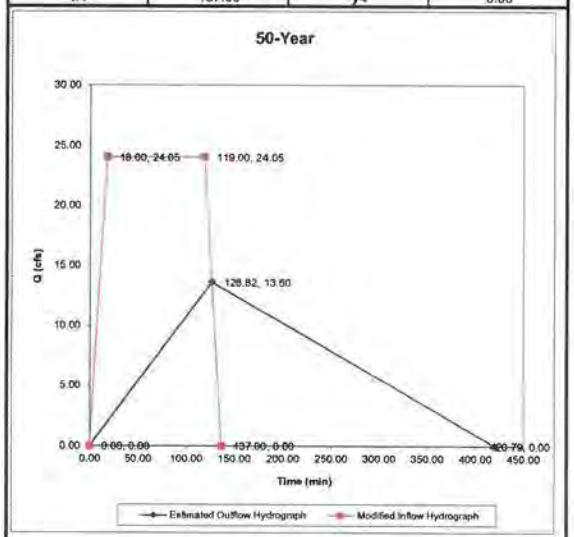
50-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	126.82	y2	13.60
x3	420.79	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	24.05
x3	119.00	y3	24.05
x4	137.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	171,683.54
Area under Estimated Outflow Hydrograph (cf) =	171,683.54
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	115,787.54
Critical Duration (min) =	119.00
Storm Duration Factor (SDF) =	6.61

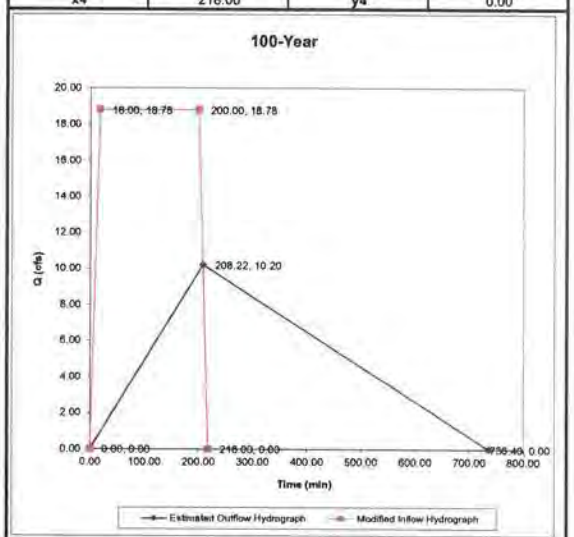
100-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	208.22	y2	10.20
x3	736.40	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	18.78
x3	200.00	y3	18.78
x4	218.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	225,339.13
Area under Estimated Outflow Hydrograph (cf) =	225,339.13
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	158,631.13
Critical Duration (min) =	200.00
Caution! Above critical duration is at maximum. Further evaluation needed.	
Storm Duration Factor (SDF) =	11.11

MODIFIED RATIONAL METHOD

Used for Estimating Detention Facility Storage Volumes in Ohio
Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S
Version 1/9/2017

SITE INPUT INFORMATION		
Site Name & Location:	36th St and Market Ave watershed	
Date:	11/21/2018	
Input By:	CDB	
Ohio Rainfall Area (Intensity Zone):	A	**(Select A,B,C, or D)**
Note: The Rainfall Intensity Area value can be found from Figure 1101-3 in Ohio Department Of Transportation's Location & Design Manual - Volume II - Drainage Design.		
Note:	Canton is in Area "A".	
Pre-Developed Conditions		
Time of Concentration, T_c=	30	**minutes (range 10 to 200)**
Drainage Area, A =	88.250	**acres (should not exceed 30)**
Composite Runoff Coefficient, C =	0.3	**(range 0.00 to 1.00)**
Post-Developed Conditions		
Time of Concentration, T_c=	30	**minutes (range 10 to 200)**
Drainage Area, A =	88.250	**acres (should not exceed 30)**
Composite Runoff Coefficient, C =	0.3	**(range 0.00 to 1.00)**

EXISTING DOWNSTREAM SYSTEM		
Description of existing downstream system (i.e. ditch, storm sewer, stream, etc.) that the site will discharge to:		
Both watersheds will discharge into existing 36" storm sewer at Market Ave which has a maximum pressurized flow capacity of 49.9 cfs prior to surcharging out of top the top of the MH at Market Ave just north of 33rd St.		
Maximum capacity of downstream system =	49.9	**cfs**
Approx. which storm event can the downstream system *adequately* convey without flooding?	2	**year storm runoff (MUST consider runoff from *entire* contributing drainage area)**
Is the above "chokepoint" capacity based on approximated or surveyed data?	Surveyed	**data**

PRE-DEVELOPED PEAK FLOWS (BASED ON RATIONAL METHOD)

Storm Event	Area (Intensity Zone) A			Area (Intensity Zone) B			Area (Intensity Zone) C			Area (Intensity Zone) D		
	i	*Peak Flow*	*Volume*	i	Peak Flow	Volume	i	Peak Flow	Volume	i	Peak Flow	Volume
(Year)	*(in/hr)*	*(cfs)*	*(cf)*	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)
2	***1.99***	***52.55***	***94,597***	2.06	54.61	98,290	2.22	58.86	105,975	2.27	60.08	108,138
5	***2.46***	***65.00***	***117,007***	2.53	67.10	120,778	2.70	71.35	128,434	2.70	71.35	128,434
10	***2.81***	***74.50***	***134,108***	2.91	76.92	138,457	3.06	81.14	146,050	3.13	82.99	149,383
25	***3.27***	***86.67***	***156,007***	3.37	89.24	160,637	3.55	93.86	168,942	3.62	95.96	172,728
50	***3.62***	***95.78***	***172,412***	3.68	97.42	175,365	3.88	102.73	184,915	4.02	106.33	191,387
100	***3.96***	***104.79***	***188,614***	4.08	108.12	194,609	4.18	110.55	198,989	4.37	115.73	208,306

Note: Volumes for pre- and post-developed peak flows are based on "3 Point Triangular Hydrographs" derived from application of standard Rational Method

POST-DEVELOPED PEAK FLOWS (BASED ON RATIONAL METHOD)

Storm Event	Area (Intensity Zone) A			Area (Intensity Zone) B			Area (Intensity Zone) C			Area (Intensity Zone) D		
	i	*Peak Flow*	*Volume*	i	Peak Flow	Volume	i	Peak Flow	Volume	i	Peak Flow	Volume
(Year)	*(in/hr)*	*(cfs)*	*(cf)*	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)
2	***1.99***	***52.55***	***94,597***	2.06	54.61	98,290	2.22	58.86	105,975	2.27	60.08	108,138
5	***2.46***	***65.00***	***117,007***	2.53	67.10	120,778	2.70	71.35	128,434	2.70	71.35	128,434
10	***2.81***	***74.50***	***134,108***	2.91	76.92	138,457	3.06	81.14	146,050	3.13	82.99	149,383
25	***3.27***	***86.67***	***156,007***	3.37	89.24	160,637	3.55	93.86	168,942	3.62	95.96	172,728
50	***3.62***	***95.78***	***172,412***	3.68	97.42	175,365	3.88	102.73	184,915	4.02	106.33	191,387
100	***3.96***	***104.79***	***188,614***	4.08	108.12	194,609	4.18	110.55	198,989	4.37	115.73	208,306

MODIFIED RATIONAL METHOD

Used for Estimating Detention Facility Storage Volumes in Ohio
Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S
Version 1/9/2017

DIFFERENCES BETWEEN AREAS UNDER PRE-DEVELOPED & POST-DEVELOPED PEAK Q HYDROGRAPHS (BASED ON RATIONAL METHOD)

Storm Event	*Area (Intensity Zone) A*	Area (Intensity Zone) B	Area (Intensity Zone) C	Area (Intensity Zone) D
	Volume	Volume	Volume	Volume
(Year)	*(cf)*	(cf)	(cf)	(cf)
2	*0*	0	0	0
5	*0*	0	0	0
10	*0*	0	0	0
25	*0*	0	0	0
50	*0*	0	0	0
100	*0*	0	0	0

Note: The above chart is provided to show how the standard Rational Method can be misapplied and result in severely underestimated storage volumes when compared to volumes determined from application of the *Modified* Rational Method.

DETENTION CRITERIA

Storm Event	Pre-Developed Peak Flow from Site	Down-stream System "Choke-point" Capacity	Proportional Flow from Site Allowed in Downstream System	*Recom-mended* Allowable Detention Facility Outflow*	Selected Detention Facility Outflow	Max. Post-Developed Peak Flow to Detention Facility	Maximum % Reduction in Post-Dev. Peak Flow
(Year)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(%)
2	*52.55*	*49.90*	*52.55*	***49.90***	49.90	*52.55*	*5.05*
5	*65.00*	*49.90*	*52.55*	***49.90***	49.90	*65.00*	*23.24*
10	*74.50*	*49.90*	*52.55*	***49.90***	49.90	*74.50*	*33.02*
25	*86.67*	*49.90*	*52.55*	***49.90***	49.90	*86.67*	*42.43*
50	*95.78*	*49.90*	*52.55*	***49.90***	49.90	*95.78*	*47.90*
100	*104.79*	*49.90*	*52.55*	***49.90***	49.90	*104.79*	*52.38*

ESTIMATES OF REQUIRED DETENTION STORAGE VOLUMES AND CORRESPONDING CRITICAL DURATIONS, INTENSITIES, & PEAK INFLOWS (BASED ON *MODIFIED* RATIONAL METHOD)

Storm Event	*Area (Intensity Zone) A*				Area (Intensity Zone) B				Area (Intensity Zone) C				Area (Intensity Zone) D			
	Volume	*Critical Duration*	*Resulting Intensity*	*Resulting Peak Inflow*	Volume	Critical Duration	Resulting Intensity	Resulting Peak Inflow	Volume	Critical Duration	Resulting Intensity	Resulting Peak Inflow	Volume	Critical Duration	Resulting Intensity	Resulting Peak Inflow
(Year)	*(cf)*	*(min)*	*(in/hr)*	*(cfs)*	(cf)	(min)	(in/hr)	(cfs)	(cf)	(min)	(in/hr)	(cfs)	(cf)	(min)	(in/hr)	(cfs)
2	***6,649***	***22***	***2.418***	***64.01***	9,972	22	2.445	64.72	16,936	25	2.500	66.18	16,962	25	2.551	67.53
5	***27,232***	***29***	***2.508***	***66.41***	30,960	29	2.589	68.55	38,648	31	2.639	69.87	38,648	31	2.639	69.87
10	***44,723***	***34***	***2.602***	***68.89***	49,268	35	2.637	69.81	57,393	37	2.682	71.03	60,965	37	2.744	72.64
25	***69,575***	***42***	***2.658***	***70.38***	74,645	43	2.693	71.29	84,013	44	2.767	73.78	88,432	45	2.808	74.34
50	***90,522***	***50***	***2.648***	***70.09***	93,132	50	2.681	70.98	104,372	50	2.822	74.71	112,566	52	2.849	75.42
100	***113,637***	***59***	***2.634***	***69.74***	119,875	58	2.731	72.30	123,728	58	2.773	73.41	136,634	56	2.816	74.55
	Maximum Volume =		***113,637***	***cubic feet***	Maximum Volume =		119,875	cubic feet	Maximum Volume =		123,728	cubic feet	Maximum Volume =		136,634	cubic feet

Storage routing calculations MUST be performed to ensure estimated detention volume is adequate! Tailwater must be taken into consideration when routing!

RAINFALL INTENSITY EQUATION

i=a/(t+b)^c

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Version 1/9/2017

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) A						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	46.184	56.985	64.167	66.528	65.702	64.489
b =	9.000	10.250	11.000	11.000	10.750	10.500
c =	0.859	0.851	0.842	0.811	0.782	0.754

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) B						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	47.987	60.684	73.126	75.841	65.621	85.047
b =	9.000	10.500	12.000	12.000	10.000	13.250
c =	0.859	0.858	0.863	0.833	0.781	0.806

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) C						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	56.299	67.933	84.550	95.736	96.783	80.436
b =	10.000	11.000	13.000	14.000	14.000	11.500
c =	0.876	0.869	0.882	0.871	0.850	0.794

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) D						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	57.448	67.933	79.192	87.886	95.169	91.982
b =	10.000	11.000	12.000	12.750	13.500	13.000
c =	0.876	0.869	0.864	0.849	0.839	0.810

Note: The above values are taken from Ohio Department Of Transportation's Location and Design Manual - Volume II - Drainage Design. The user must ensure the above values are consistent with values from the current edition of the manual and revise them as necessary.

RATIONAL METHOD PEAK FLOW HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	30	minutes	Time of Concentration, T_c	=	30	minutes
Drainage Area, A	=	88.25	acres	Drainage Area, A	=	88.25	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

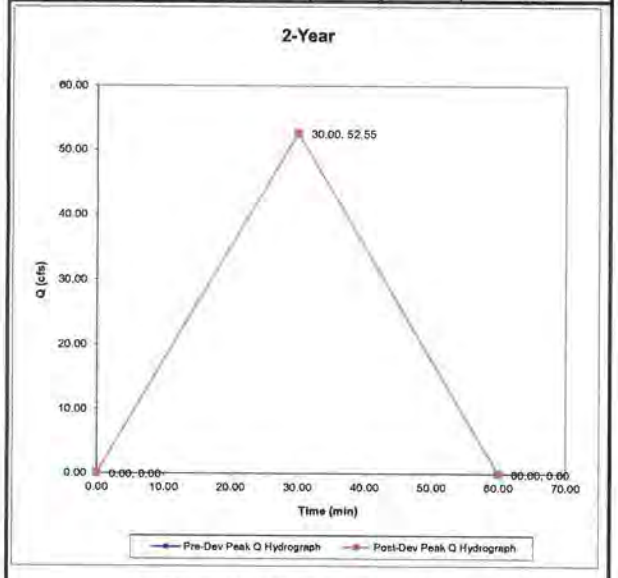
2-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	52.55
x3	60.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	52.55
x3	60.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	94,596.60
Post-Developed Peak Q Hydrograph Area (cf) =	94,596.60
Difference Between Hydrograph Areas (cf) =	0.00

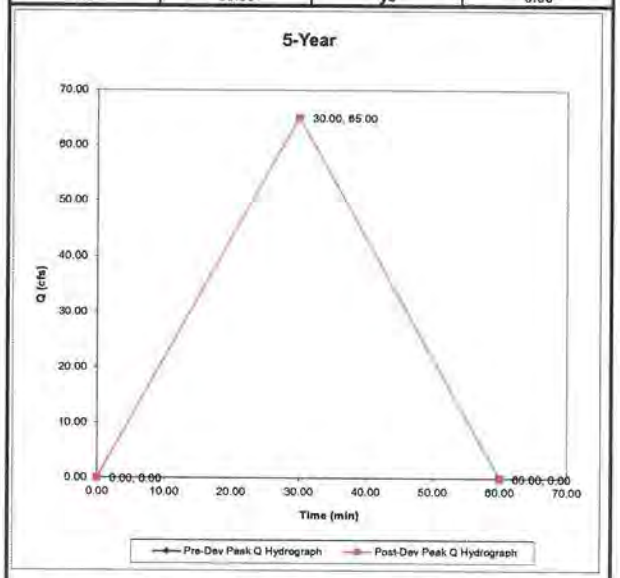
5-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	65.00
x3	60.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	65.00
x3	60.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	117,007.38
Post-Developed Peak Q Hydrograph Area (cf) =	117,007.38
Difference Between Hydrograph Areas (cf) =	0.00

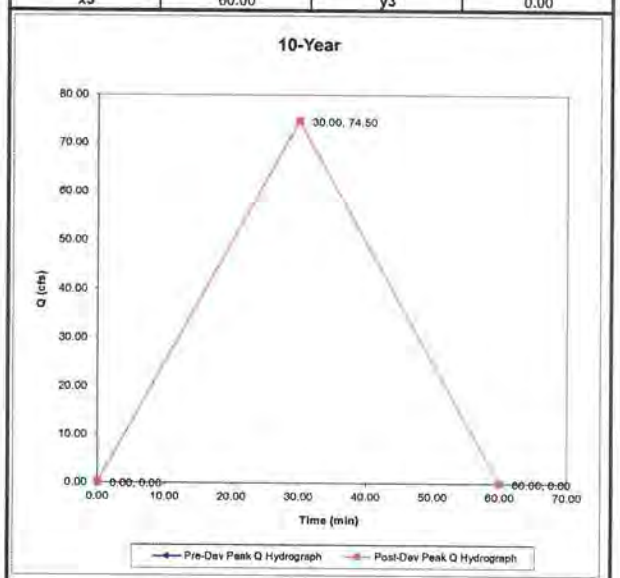
10-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	74.50
x3	60.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	74.50
x3	60.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	134,108.47
Post-Developed Peak Q Hydrograph Area (cf) =	134,108.47
Difference Between Hydrograph Areas (cf) =	0.00

RATIONAL METHOD PEAK FLOW HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	30	minutes	Time of Concentration, T_c	=	30	minutes
Drainage Area, A	=	88.25	acres	Drainage Area, A	=	88.25	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

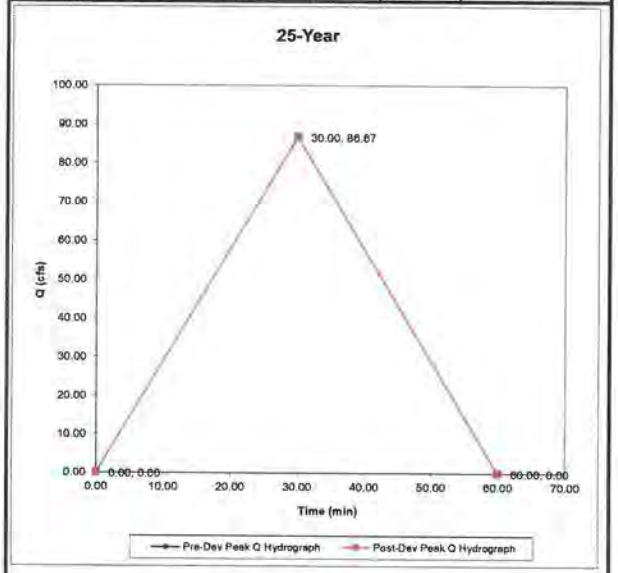
25-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	86.67
x3	60.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	86.67
x3	60.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	156,007.41
Post-Developed Peak Q Hydrograph Area (cf) =	156,007.41
Difference Between Hydrograph Areas (cf) =	0.00

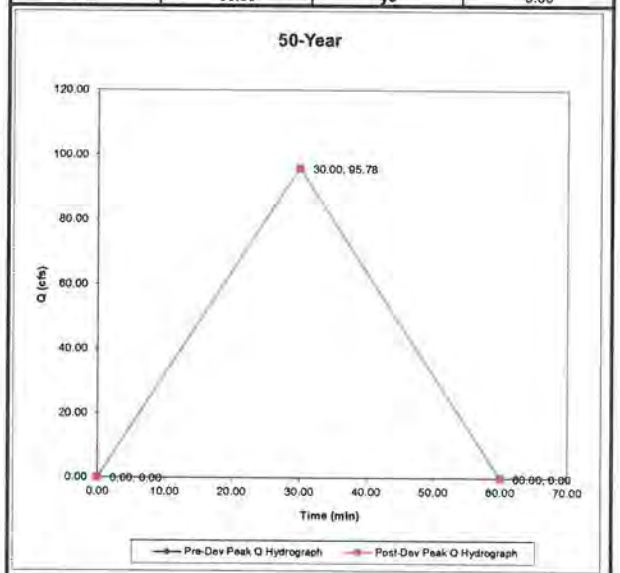
50-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	95.78
x3	60.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	95.78
x3	60.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	172,411.91
Post-Developed Peak Q Hydrograph Area (cf) =	172,411.91
Difference Between Hydrograph Areas (cf) =	0.00

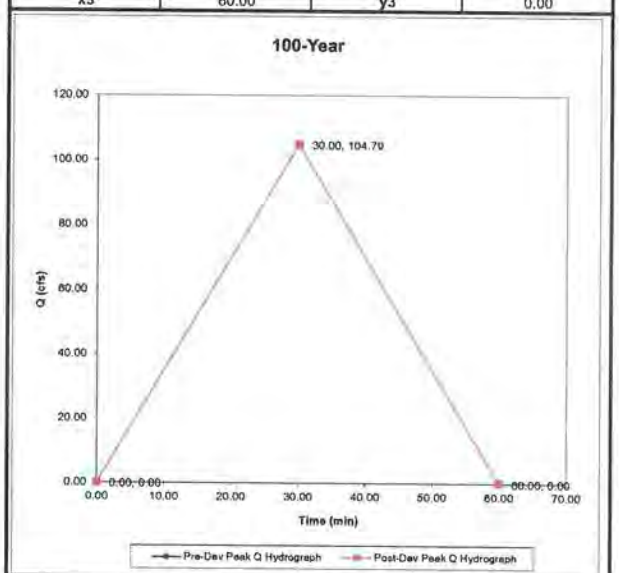
100-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	104.79
x3	60.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	104.79
x3	60.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	188,613.61
Post-Developed Peak Q Hydrograph Area (cf) =	188,613.61
Difference Between Hydrograph Areas (cf) =	0.00

MODIFIED RATIONAL METHOD HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	30	minutes	Time of Concentration, T_c	=	30	minutes
Drainage Area, A	=	88.25	acres	Drainage Area, A	=	88.25	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

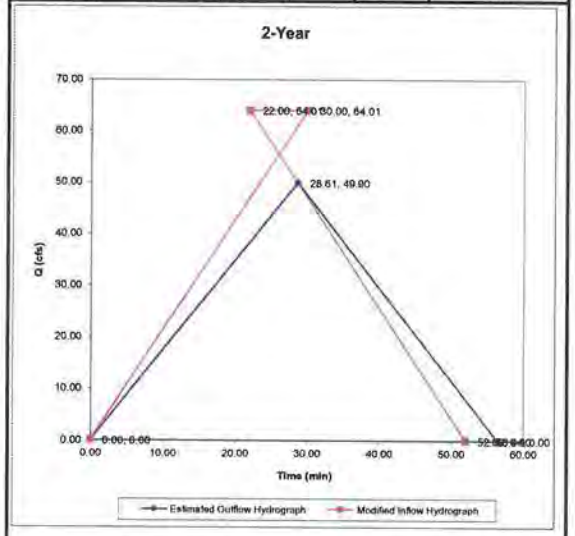
2-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	28.61	y2	49.90
x3	56.44	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	64.01
x3	22.00	y3	64.01
x4	52.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	84,493.20
Area under Estimated Outflow Hydrograph (cf) =	84,493.20
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	6,649.20
Critical Duration (min) =	22.00
Storm Duration Factor (SDF) =	0.73

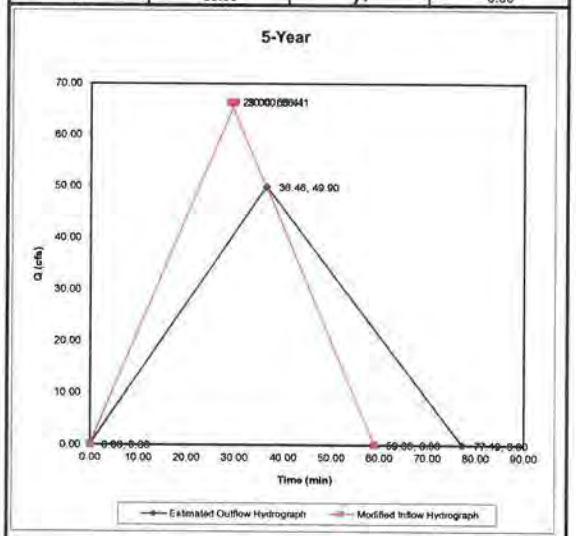
5-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	36.46	y2	49.90
x3	77.19	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	66.41
x3	29.00	y3	66.41
x4	59.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	115,554.86
Area under Estimated Outflow Hydrograph (cf) =	115,554.86
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	27,231.86
Critical Duration (min) =	29.00
Storm Duration Factor (SDF) =	0.97

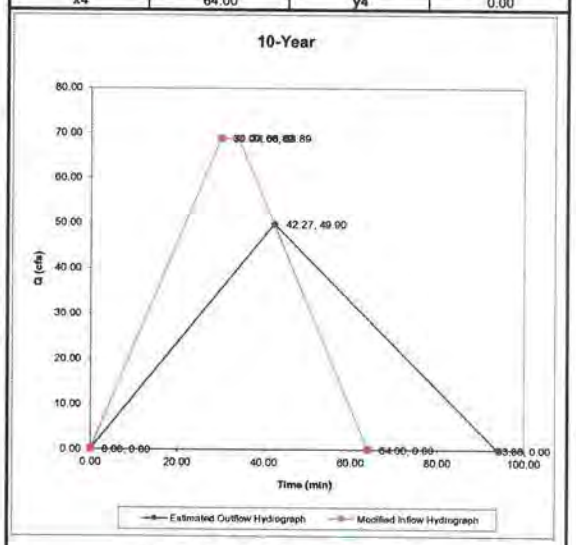
10-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	42.27	y2	49.90
x3	93.88	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	68.89
x3	34.00	y3	68.89
x4	64.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	140,531.26
Area under Estimated Outflow Hydrograph (cf) =	140,531.26
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	44,723.26
Critical Duration (min) =	34.00
Storm Duration Factor (SDF) =	1.13

MODIFIED RATIONAL METHOD HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	30	minutes	Time of Concentration, T_c	=	30	minutes
Drainage Area, A	=	88.25	acres	Drainage Area, A	=	88.25	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

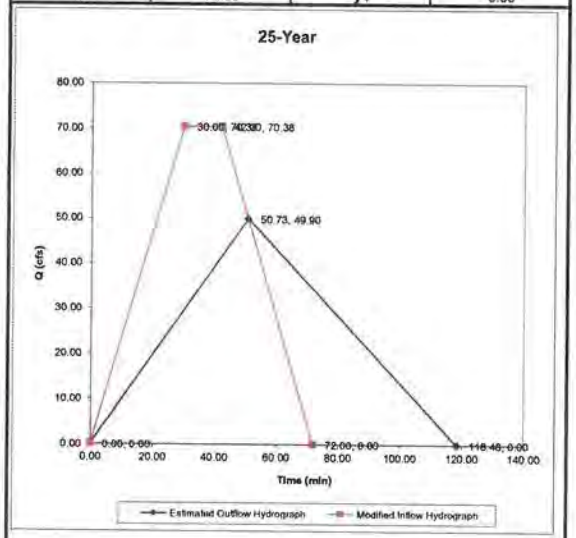
25-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	50.73	y2	49.90
x3	118.48	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	70.38
x3	42.00	y3	70.38
x4	72.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	177,359.01
Area under Estimated Outflow Hydrograph (cf) =	177,359.01
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	69,575.01
Critical Duration (min) =	42.00
Storm Duration Factor (SDF) =	1.40

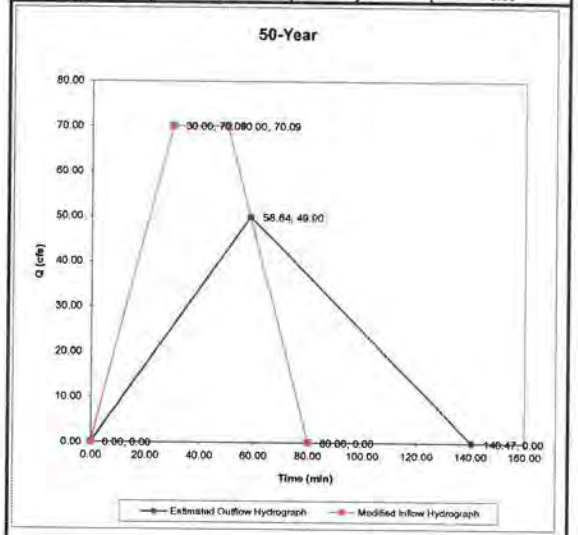
50-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	58.64	y2	49.90
x3	140.47	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	70.09
x3	50.00	y3	70.09
x4	80.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	210,282.25
Area under Estimated Outflow Hydrograph (cf) =	210,282.25
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	90,522.25
Critical Duration (min) =	50.00
Storm Duration Factor (SDF) =	1.67

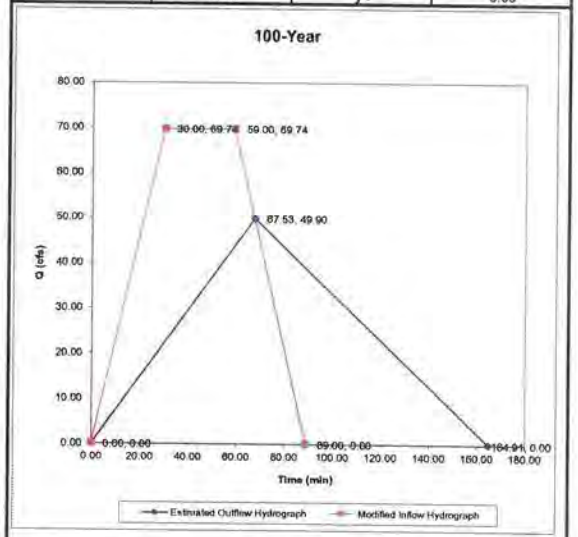
100-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	67.53	y2	49.90
x3	164.91	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	30.00	y2	69.74
x3	59.00	y3	69.74
x4	89.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	246,870.01
Area under Estimated Outflow Hydrograph (cf) =	246,870.01
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	113,637.01
Critical Duration (min) =	59.00
Storm Duration Factor (SDF) =	1.97

MODIFIED RATIONAL METHOD

Used for Estimating Detention Facility Storage Volumes in Ohio
Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S
Version 1/9/2017

SITE INPUT INFORMATION		
Site Name & Location:	36th St NW vicinity of Logan Ave (recommended detention criteria)	
Date:	11/21/2018	
Input By:	CDB	
Ohio Rainfall Area (Intensity Zone):	A	**(Select A,B,C, or D)**
Note: The Rainfall Intensity Area value can be found from Figure 1101-3 in Ohio Department Of Transportation's Location & Design Manual - Volume II - Drainage Design.		
Note:	Canton is in Area "A".	
Pre-Developed Conditions		
Time of Concentration, T_c=	18	**minutes (range 10 to 200)**
Drainage Area, A =	54.800	**acres (should not exceed 30)**
Composite Runoff Coefficient, C =	0.3	**(range 0.00 to 1.00)**
Post-Developed Conditions		
Time of Concentration, T_c=	18	**minutes (range 10 to 200)**
Drainage Area, A =	54.800	**acres (should not exceed 30)**
Composite Runoff Coefficient, C =	0.3	**(range 0.00 to 1.00)**

EXISTING DOWNSTREAM SYSTEM		
Description of existing downstream system (i.e. ditch, storm sewer, stream, etc.) that the site will discharge to:		
Area is proposed to discharge into existing 36" storm sewer at Market Ave. During the 25-year storm, it is estimated that the Market Avenue system has 17.1 cfs of available capacity (under pressurized flow).		
Maximum capacity of downstream system =	17.1	**cfs**
Approx. which storm event can the downstream system *adequately* convey without flooding?	25	**year storm runoff (MUST consider runoff from *entire* contributing drainage area)**
Is the above "chokepoint" capacity based on approximated or surveyed data?	Surveyed	**data**

PRE-DEVELOPED PEAK FLOWS (BASED ON RATIONAL METHOD)

Storm Event	Area (Intensity Zone) A			Area (Intensity Zone) B			Area (Intensity Zone) C			Area (Intensity Zone) D		
	i	*Peak Flow*	*Volume*	i	Peak Flow	Volume	i	Peak Flow	Volume	i	Peak Flow	Volume
(Year)	*(in/hr)*	*(cfs)*	*(cf)*	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)
2	***2.72***	***44.76***	***48,337***	2.83	46.50	50,224	3.04	49.97	53,965	3.10	50.99	55,067
5	***3.32***	***54.56***	***58,921***	3.43	56.33	60,834	3.64	59.86	64,652	3.64	59.86	64,652
10	***3.77***	***61.93***	***66,880***	3.86	63.86	68,967	4.09	67.24	72,620	4.19	68.92	74,434
25	***4.34***	***71.27***	***76,971***	4.46	73.34	79,211	4.68	76.91	83,064	4.79	78.82	85,126
50	***4.75***	***78.13***	***84,382***	4.86	79.93	86,325	5.09	83.62	90,312	5.27	86.56	93,484
100	***5.16***	***84.81***	***91,592***	5.31	87.24	94,218	5.48	90.01	97,216	5.70	93.67	101,164

Note: Volumes for pre- and post-developed peak flows are based on "3 Point Triangular Hydrographs" derived from application of standard Rational Method

POST-DEVELOPED PEAK FLOWS (BASED ON RATIONAL METHOD)

Storm Event	Area (Intensity Zone) A			Area (Intensity Zone) B			Area (Intensity Zone) C			Area (Intensity Zone) D		
	i	*Peak Flow*	*Volume*	i	Peak Flow	Volume	i	Peak Flow	Volume	i	Peak Flow	Volume
(Year)	*(in/hr)*	*(cfs)*	*(cf)*	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)	(in/hr)	(cfs)	(cf)
2	***2.72***	***44.76***	***48,337***	2.83	46.50	50,224	3.04	49.97	53,965	3.10	50.99	55,067
5	***3.32***	***54.56***	***58,921***	3.43	56.33	60,834	3.64	59.86	64,652	3.64	59.86	64,652
10	***3.77***	***61.93***	***66,880***	3.86	63.86	68,967	4.09	67.24	72,620	4.19	68.92	74,434
25	***4.34***	***71.27***	***76,971***	4.46	73.34	79,211	4.68	76.91	83,064	4.79	78.82	85,126
50	***4.75***	***78.13***	***84,382***	4.86	79.93	86,325	5.09	83.62	90,312	5.27	86.56	93,484
100	***5.16***	***84.81***	***91,592***	5.31	87.24	94,218	5.48	90.01	97,216	5.70	93.67	101,164

MODIFIED RATIONAL METHOD

Used for Estimating Detention Facility Storage Volumes in Ohio
Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S
Version 1/9/2017

DIFFERENCES BETWEEN AREAS UNDER PRE-DEVELOPED & POST-DEVELOPED PEAK Q HYDROGRAPHS (BASED ON RATIONAL METHOD)

Storm Event	*Area (Intensity Zone) A Volume*	Area (Intensity Zone) B Volume	Area (Intensity Zone) C Volume	Area (Intensity Zone) D Volume
(Year)	*(cf)*	(cf)	(cf)	(cf)
2	*0*	0	0	0
5	*0*	0	0	0
10	*0*	0	0	0
25	*0*	0	0	0
50	*0*	0	0	0
100	*0*	0	0	0

Note: The above chart is provided to show how the standard Rational Method can be misapplied and result in severely underestimated storage volumes when compared to volumes determined from application of the *Modified* Rational Method.

DETENTION CRITERIA

Storm Event	Pre-Developed Peak Flow from Site	Down-stream System "Choke-point" Capacity	Proportional Flow from Site Allowed in Downstream System	*Recom-mended* Allowable Detention Facility Outflow*	Selected Detention Facility Outflow	Max. Post-Developed Peak Flow to Detention Facility	Maximum % Reduction in Post-Dev. Peak Flow
(Year)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(%)
2	*44.76*	*17.10*	*44.76*	***17.10***	17.10	*44.76*	*61.79*
5	*54.56*	*17.10*	*54.56*	***17.10***	17.10	*54.56*	*68.66*
10	*61.93*	*17.10*	*61.93*	***17.10***	17.10	*61.93*	*72.39*
25	*71.27*	*17.10*	*71.27*	***17.10***	17.10	*71.27*	*76.01*
50	*78.13*	*17.10*	*71.27*	***17.10***	17.10	*78.13*	*78.11*
100	*84.81*	*17.10*	*71.27*	***17.10***	17.10	*84.81*	*79.84*

ESTIMATES OF REQUIRED DETENTION STORAGE VOLUMES AND CORRESPONDING CRITICAL DURATIONS, INTENSITIES, & PEAK INFLOWS (BASED ON *MODIFIED* RATIONAL METHOD)

Storm Event	*Area (Intensity Zone) A*				Area (Intensity Zone) B				Area (Intensity Zone) C				Area (Intensity Zone) D			
	Volume	*Critical Duration*	*Resulting Intensity*	*Resulting Peak Inflow*	Volume	Critical Duration	Resulting Intensity	Resulting Peak Inflow	Volume	Critical Duration	Resulting Intensity	Resulting Peak Inflow	Volume	Critical Duration	Resulting Intensity	Resulting Peak Inflow
(Year)	*(cf)*	*(min)*	*(in/hr)*	*(cfs)*	(cf)	(min)	(in/hr)	(cfs)	(cf)	(min)	(in/hr)	(cfs)	(cf)	(min)	(in/hr)	(cfs)
2	***34,658***	***38***	***1.691***	***27.80***	37,145	39	1.726	28.37	42,432	42	1.767	29.05	43,927	43	1.773	29.15
5	***51,028***	***49***	***1.767***	***29.05***	53,699	50	1.796	29.52	59,262	52	1.858	30.50	59,262	52	1.855	30.50
10	***64,885***	***59***	***1.794***	***29.49***	67,882	59	1.847	30.36	73,717	61	1.889	31.21	76,485	63	1.899	31.23
25	***85,106***	***76***	***1.779***	***29.24***	88,249	75	1.838	30.21	94,291	78	1.936	31.87	97,934	78	1.913	31.45
50	***102,870***	***93***	***1.742***	***28.64***	104,327	93	1.758	28.90	110,462	86	1.931	31.75	116,886	91	1.925	31.65
100	***123,135***	***115***	***1.687***	***27.73***	124,931	104	1.828	30.05	127,461	106	1.827	30.04	136,793	109	1.878	30.88
	Maximum Volume =		***123,135***	***cubic feet***	Maximum Volume =		124,931	cubic feet	Maximum Volume =		127,461	cubic feet	Maximum Volume =		136,793	cubic feet

Storage routing calculations MUST be performed to ensure estimated detention volume is adequate! Tailwater must be taken into consideration when routing!

RAINFALL INTENSITY EQUATION

i=a/(t+b)^c

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Version 1/9/2017

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) A						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	46.184	56.985	64.167	66.528	65.702	64.489
b =	9.000	10.250	11.000	11.000	10.750	10.500
c =	0.859	0.851	0.842	0.811	0.782	0.754

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) B						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	47.987	60.684	73.126	75.841	65.621	85.047
b =	9.000	10.500	12.000	12.000	10.000	13.250
c =	0.859	0.858	0.863	0.833	0.781	0.806

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) C						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	56.299	67.933	84.550	95.736	96.783	80.436
b =	10.000	11.000	13.000	14.000	14.000	11.500
c =	0.876	0.869	0.882	0.871	0.850	0.794

RAINFALL INTENSITY EQUATION CONSTANTS FOR OHIO						
Area (Intensity Zone) D						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
a =	57.448	67.933	79.192	87.886	95.169	91.982
b =	10.000	11.000	12.000	12.750	13.500	13.000
c =	0.876	0.869	0.864	0.849	0.839	0.810

Note: The above values are taken from Ohio Department Of Transportation's Location and Design Manual - Volume II - Drainage Design. The user must ensure the above values are consistent with values from the current edition of the manual and revise them as necessary.

RATIONAL METHOD PEAK FLOW HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	18	minutes	Time of Concentration, T_c	=	18	minutes
Drainage Area, A	=	54.8	acres	Drainage Area, A	=	54.8	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

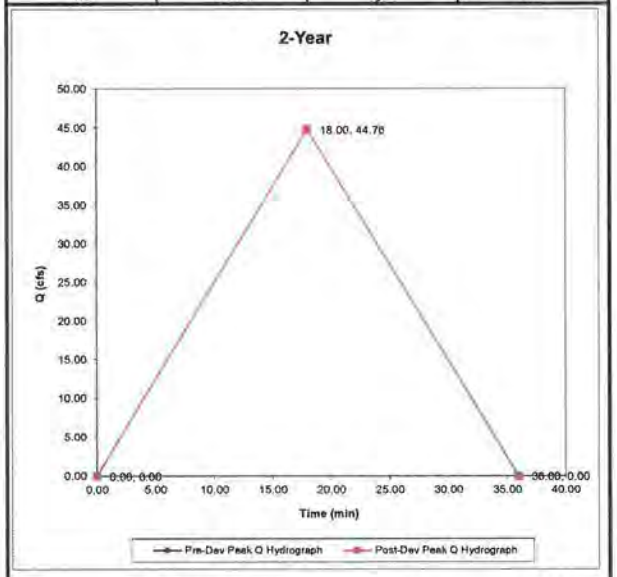
2-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	44.76
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	44.76
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	48,336.55
Post-Developed Peak Q Hydrograph Area (cf) =	48,336.55
Difference Between Hydrograph Areas (cf) =	0.00

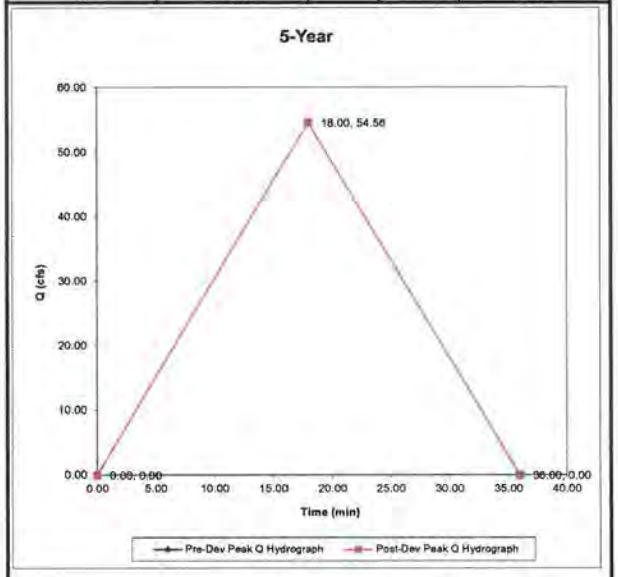
5-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	54.56
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	54.56
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	58,920.91
Post-Developed Peak Q Hydrograph Area (cf) =	58,920.91
Difference Between Hydrograph Areas (cf) =	0.00

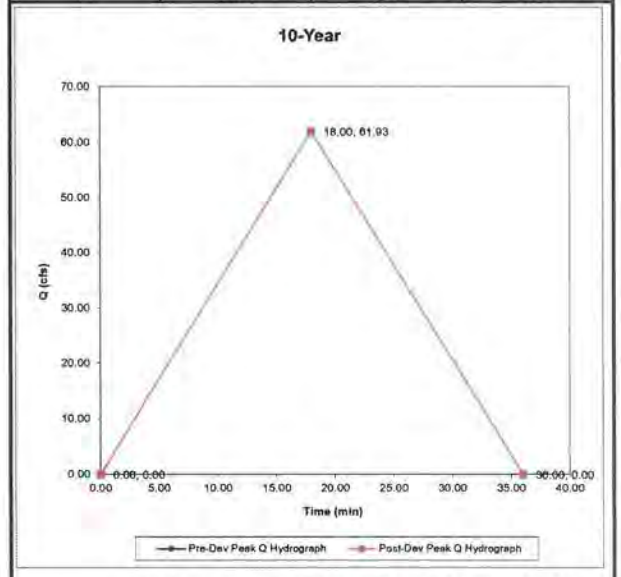
10-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	61.93
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	61.93
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	66,880.30
Post-Developed Peak Q Hydrograph Area (cf) =	66,880.30
Difference Between Hydrograph Areas (cf) =	0.00

RATIONAL METHOD PEAK FLOW HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	18	minutes	Time of Concentration, T_c	=	18	minutes
Drainage Area, A	=	54.8	acres	Drainage Area, A	=	54.8	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

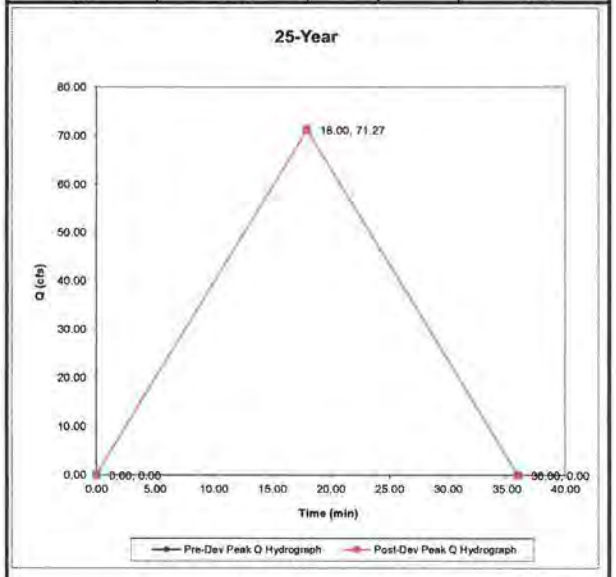
25-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	71.27
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	71.27
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	76,970.67
Post-Developed Peak Q Hydrograph Area (cf) =	76,970.67
Difference Between Hydrograph Areas (cf) =	0.00

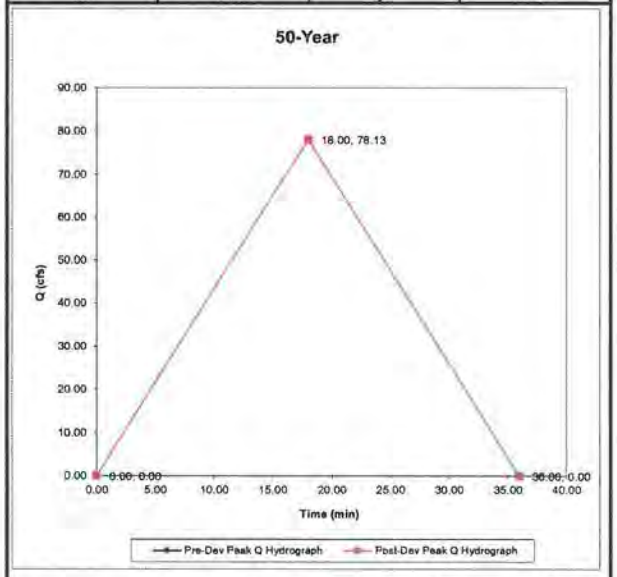
50-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	78.13
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	78.13
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	84,381.91
Post-Developed Peak Q Hydrograph Area (cf) =	84,381.91
Difference Between Hydrograph Areas (cf) =	0.00

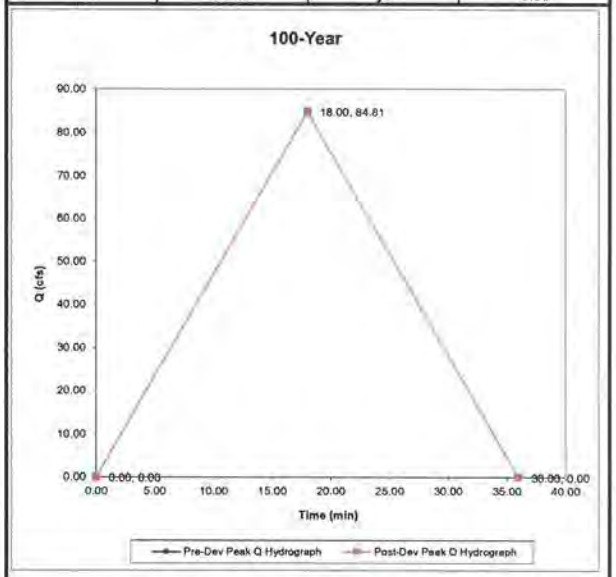
100-Year Storm Event

Pre-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	84.81
x3	36.00	y3	0.00

Post-Developed Peak Flow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	84.81
x3	36.00	y3	0.00



Pre-Developed Peak Q Hydrograph Area (cf) =	91,592.14
Post-Developed Peak Q Hydrograph Area (cf) =	91,592.14
Difference Between Hydrograph Areas (cf) =	0.00

MODIFIED RATIONAL METHOD HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	18	minutes	Time of Concentration, T_c	=	18	minutes
Drainage Area, A	=	54.8	acres	Drainage Area, A	=	54.8	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

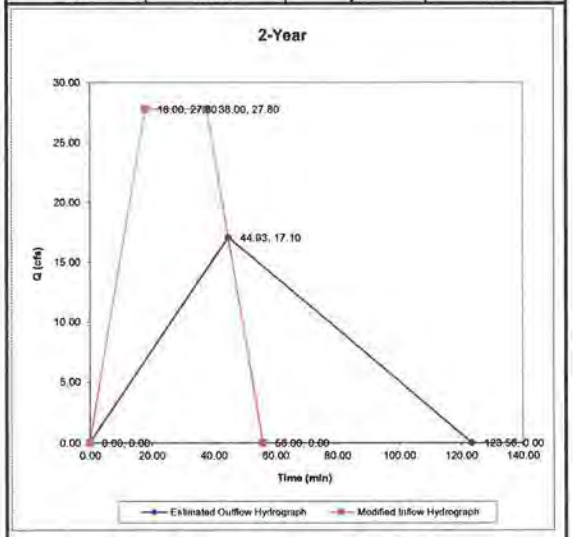
2-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	44.93	y2	17.10
x3	123.56	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	27.80
x3	38.00	y3	27.80
x4	56.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	63,386.41
Area under Estimated Outflow Hydrograph (cf) =	63,386.41
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	34,658.41
Critical Duration (min) =	38.00
Storm Duration Factor (SDF) =	2.11

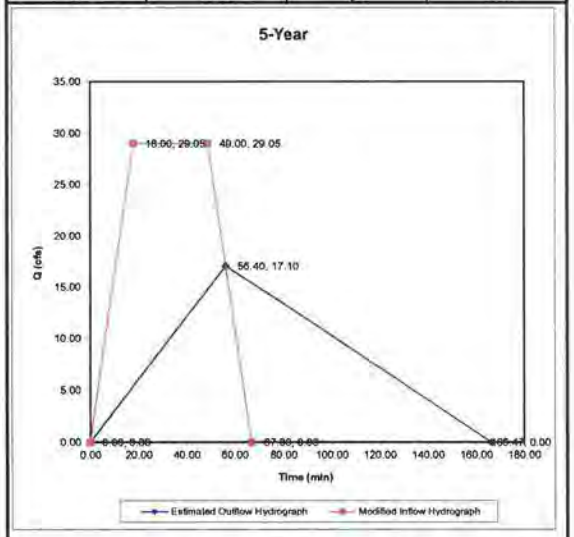
5-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	56.40	y2	17.10
x3	166.47	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	29.05
x3	49.00	y3	29.05
x4	67.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	85,398.83
Area under Estimated Outflow Hydrograph (cf) =	85,398.83
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	51,027.83
Critical Duration (min) =	49.00
Storm Duration Factor (SDF) =	2.72

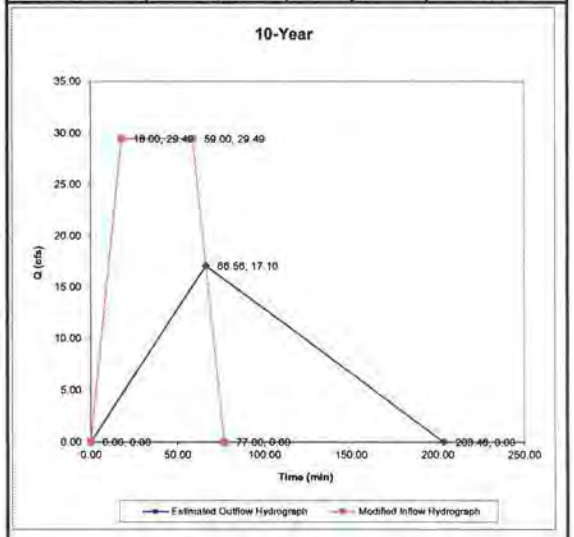
10-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	66.56	y2	17.10
x3	203.48	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	29.49
x3	59.00	y3	29.49
x4	77.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	104,386.48
Area under Estimated Outflow Hydrograph (cf) =	104,386.48
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	64,885.48
Critical Duration (min) =	59.00
Storm Duration Factor (SDF) =	3.28

MODIFIED RATIONAL METHOD HYDROGRAPHS
for Ohio Rainfall Intensity Area (Zone) "A"

Spreadsheet created by Christopher D. Barnes, PE, CPESC, CPSWQ, CMS4S

Version 1/9/2017

Pre-Developed Conditions				Post-Developed Conditions			
Time of Concentration, T_c	=	18	minutes	Time of Concentration, T_c	=	18	minutes
Drainage Area, A	=	54.8	acres	Drainage Area, A	=	54.8	acres
Composite Runoff Coefficient, C	=	0.3		Composite Runoff Coefficient, C	=	0.3	

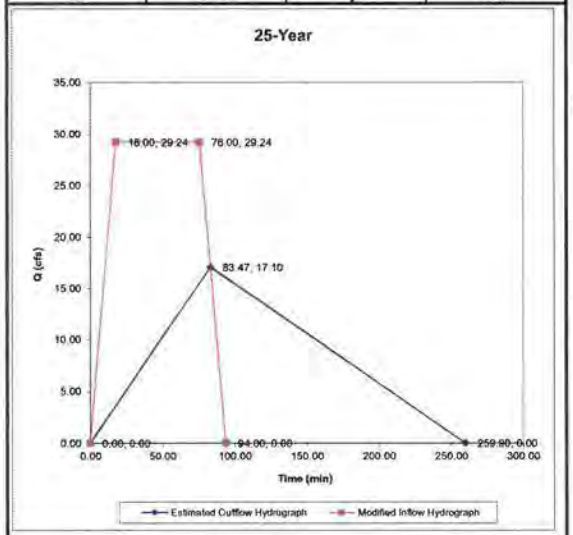
25-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	83.47	y2	17.10
x3	259.90	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	29.24
x3	76.00	y3	29.24
x4	94.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	133,327.89
Area under Estimated Outflow Hydrograph (cf) =	133,327.89
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	85,105.89
Critical Duration (min) =	76.00
Storm Duration Factor (SDF) =	4.22

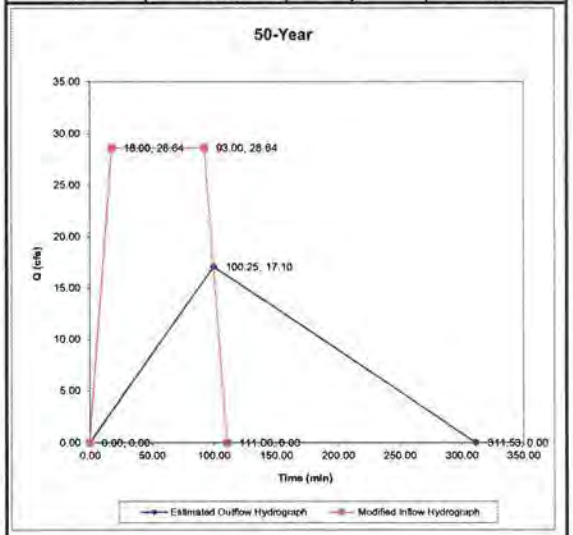
50-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	100.25	y2	17.10
x3	311.53	y3	0.00

Modified Inflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	28.64
x3	93.00	y3	28.64
x4	111.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	159,812.93
Area under Estimated Outflow Hydrograph (cf) =	159,812.93
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	102,869.93
Critical Duration (min) =	93.00
Storm Duration Factor (SDF) =	5.17

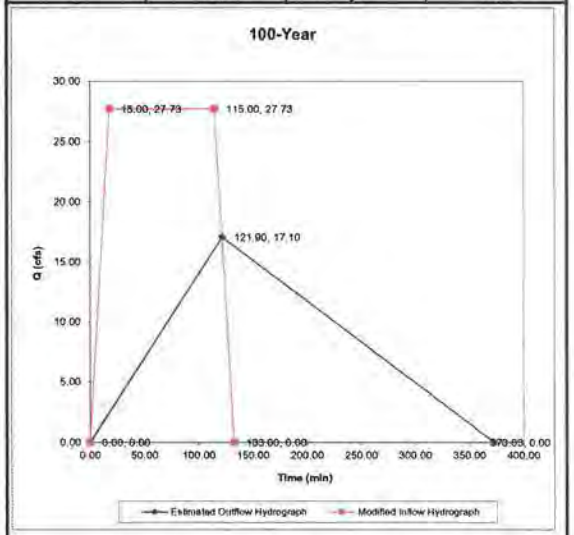
100-Year Storm Event

Estimated Outflow Hydrograph Points & Values

Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	121.90	y2	17.10
x3	373.03	y3	0.00

Modified Inflow Hydrograph Points & Values

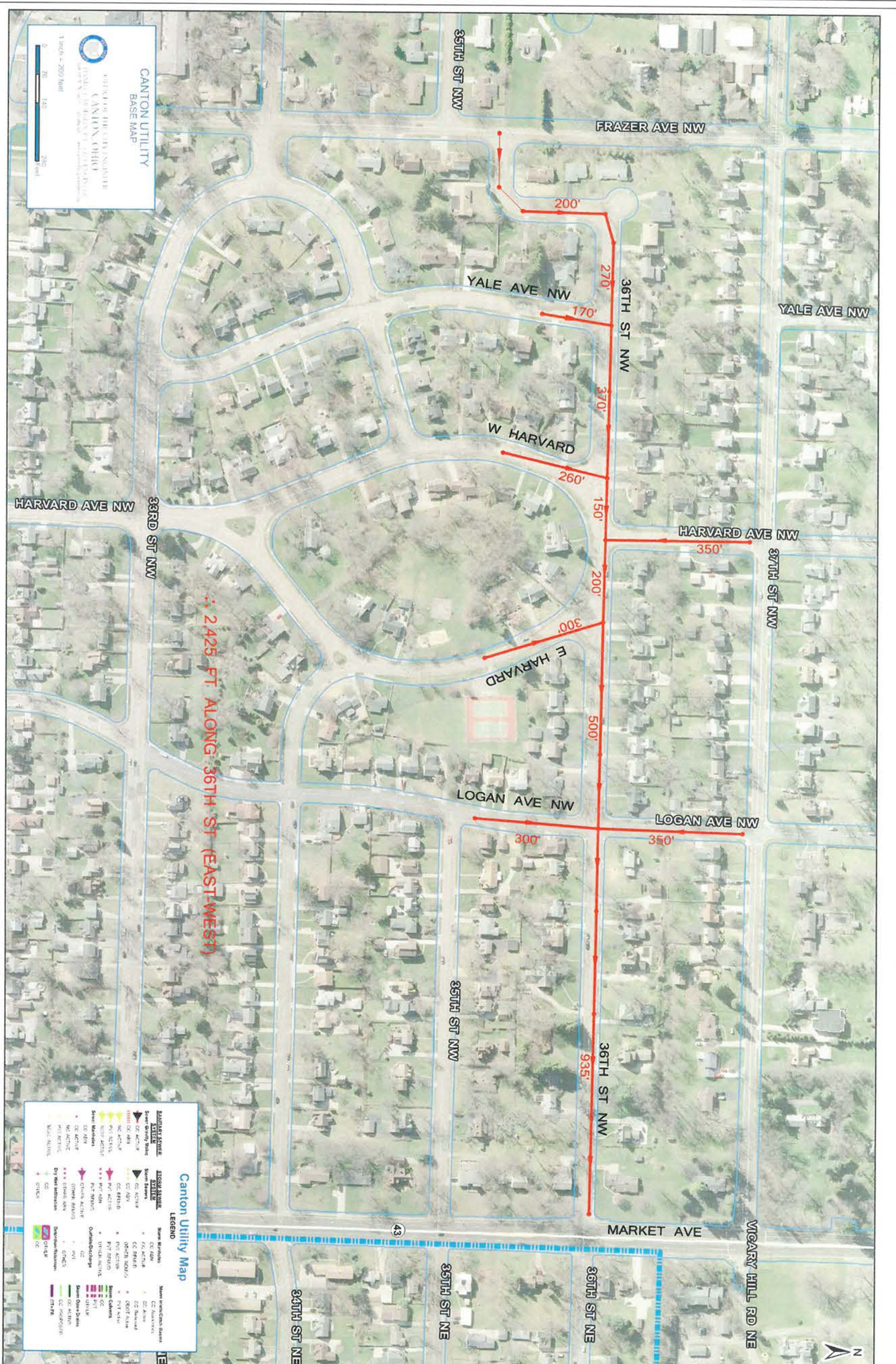
Time coordinate	(min)	Q coordinate	(cfs)
x1	0.00	y1	0.00
x2	18.00	y2	27.73
x3	115.00	y3	27.73
x4	133.00	y4	0.00



Area under Modified Inflow Hydrograph (cf) =	191,363.53
Area under Estimated Outflow Hydrograph (cf) =	191,363.53
Area under Mod. Inflow Hyd. & above Est. Outflow Hyd. (cf) =	123,134.53
Critical Duration (min) =	115.00
Storm Duration Factor (SDF) =	6.39

Appendix F.
Street Segment Length Map

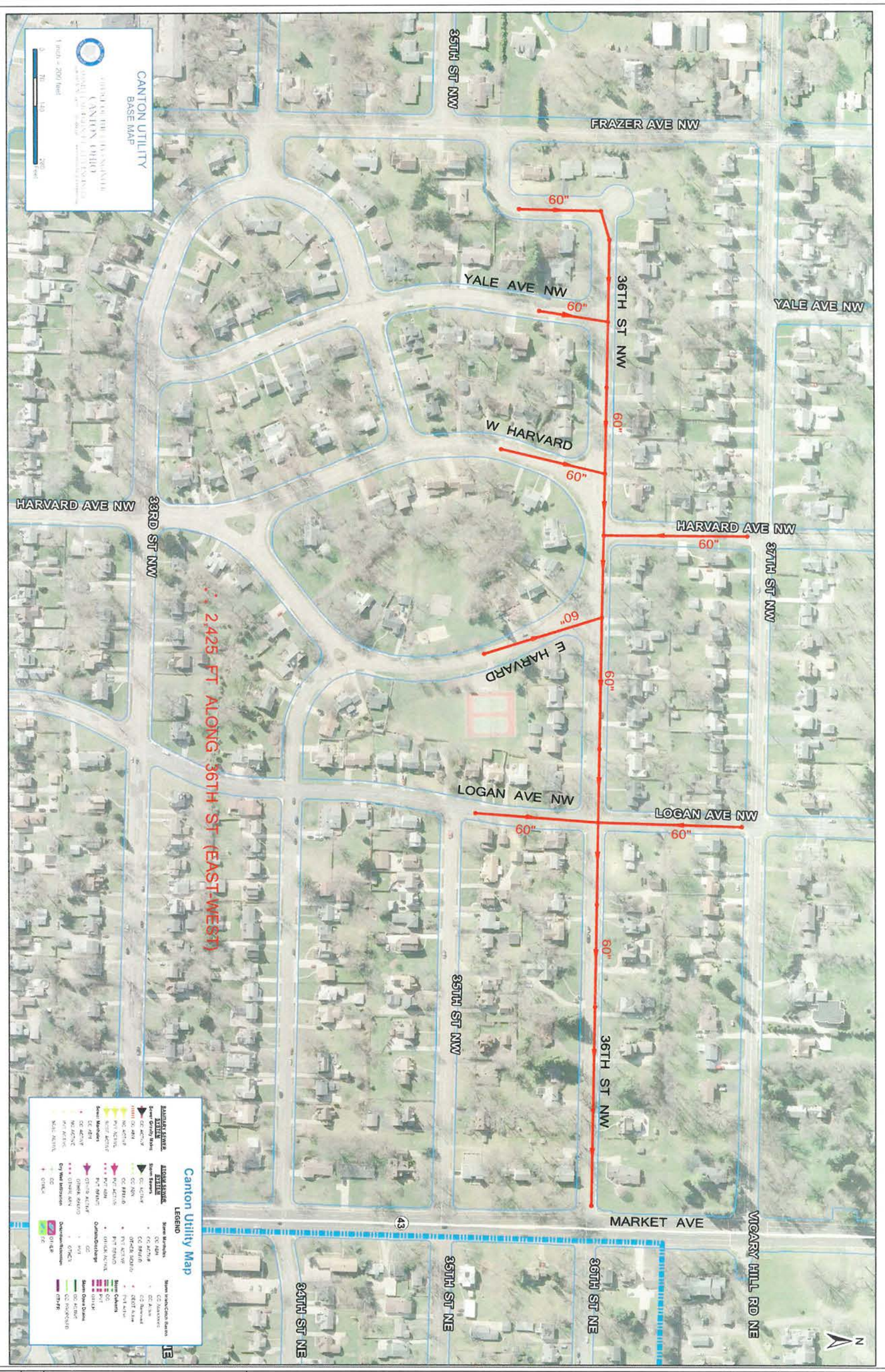
P:\Canton – City of\J20170744.000 Market Heights 36th NW Street Storm Water Study\Drawings\Trans\J20170744_36th & Market_WaterShed & Storm Sewer Maps.dwg 30-Jan-19 5:06 PM



7	CITY OF CANTON	APPENDIX F STREET SEGMENT LENGTH MAP 36TH STREET NW	CALCULATED CES; CHECKED DW; HORIZONTAL SCALE IN FEET 0 150 75 300; N

Appendix G.
Recommended 60" Storm Sewer Footprint Map

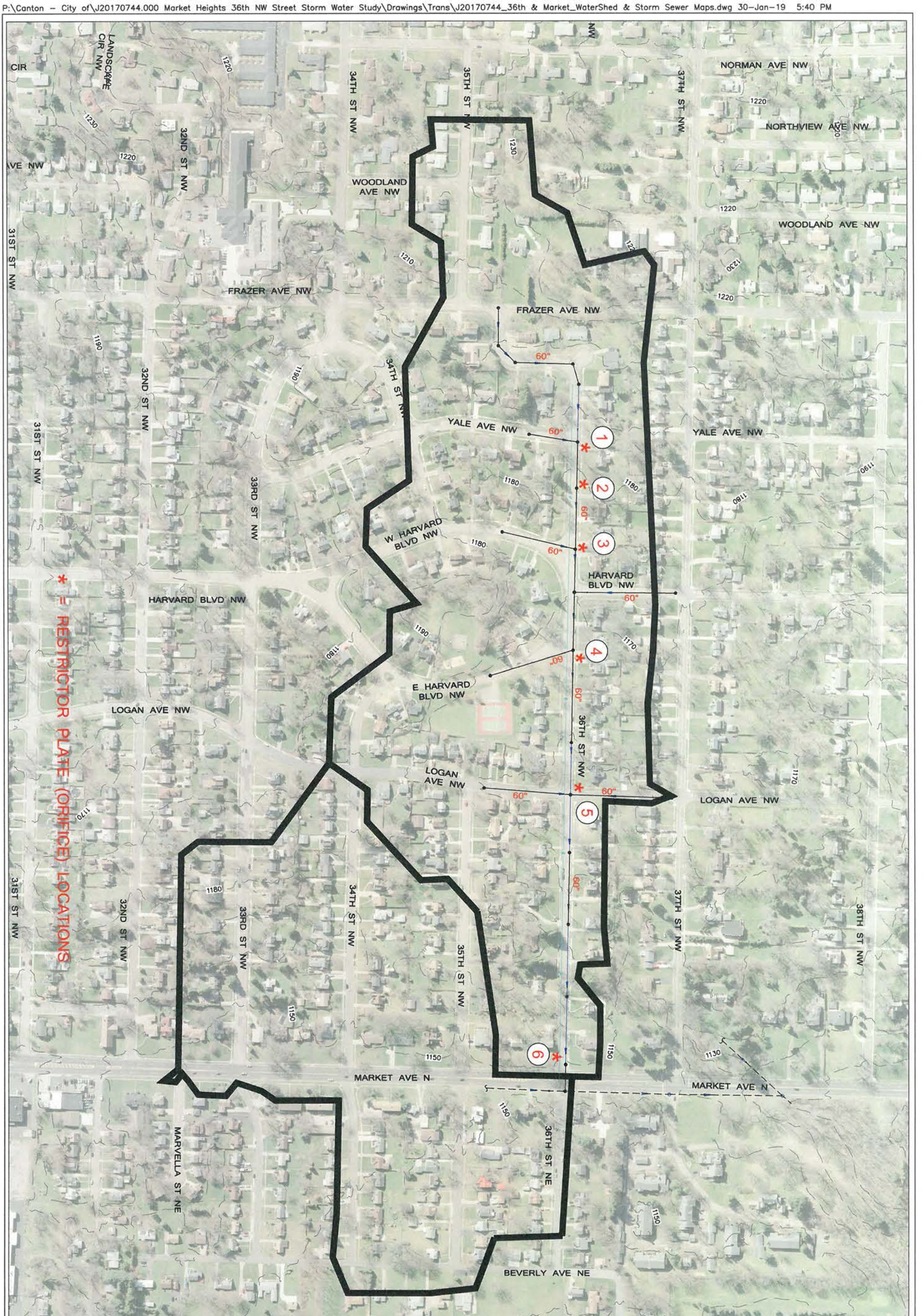
P:\Canton – City of\J20170744.000 Market Heights 36th NW Street Storm Water Study\Drawings\Trans\J20170744_36th & Market_WaterShed & Storm Sewer Maps.dwg 30-Jan-19 5:06 PM



1 / 1	CITY OF CANTON	APPENDIX G RECOMMENDED 60" STORM LENGTH MAP 36TH STREET NW	CALCULATED CES CHECKED DW	0 150 75 300 HORIZONTAL SCALE IN FEET

Appendix H.
Restrictor Plate Orifices Location Map

P:\Canton – City of\J20170744.000 Market Heights 36th NW Street Storm Water Study\Drawings\Trans\J20170744_36th & Market_WaterShed & Storm Sewer Maps.dwg 30-Jan-19 5:40 PM

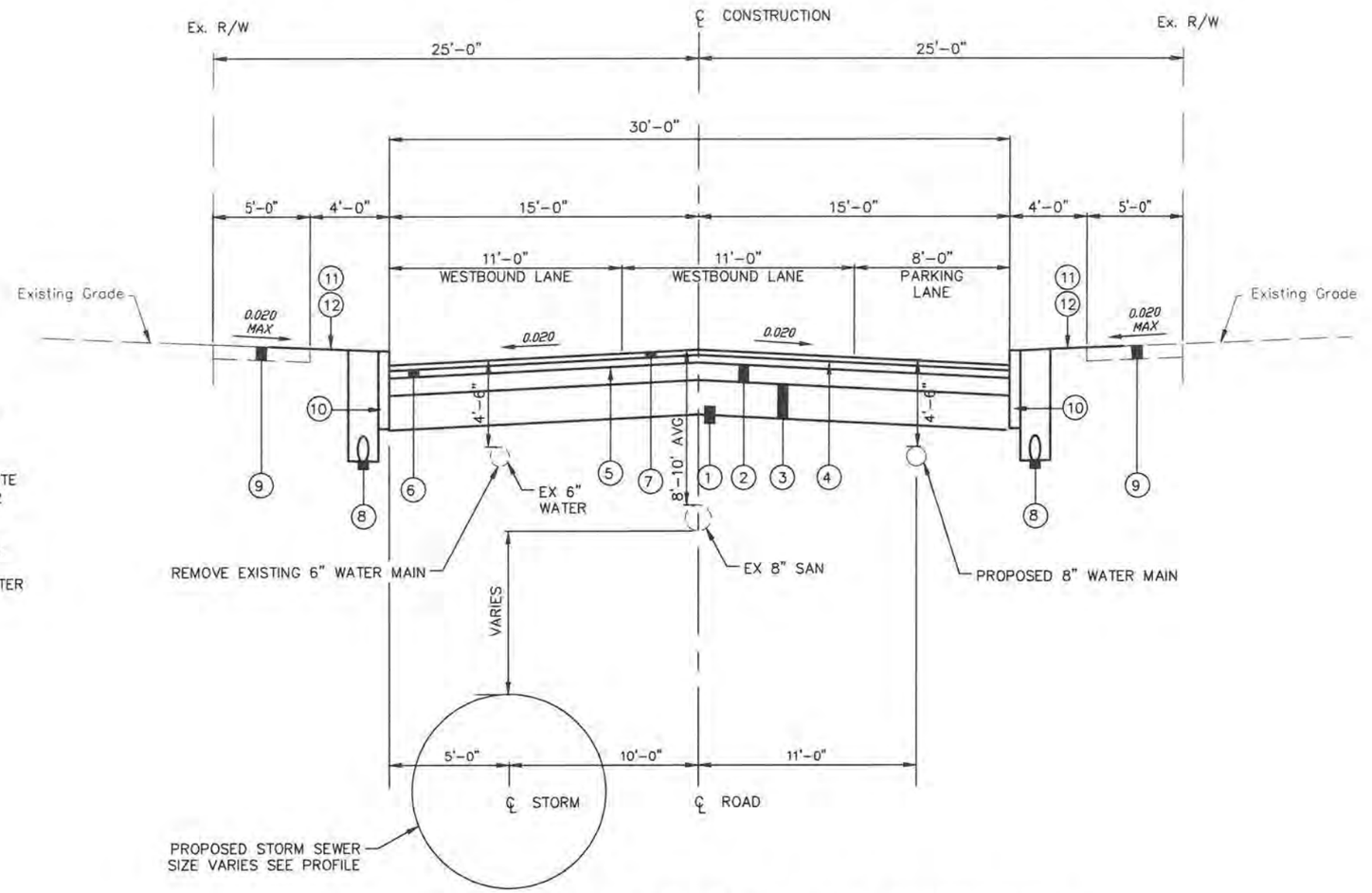


CITY OF CANTON	APPENDIX H RESTRICTOR PLATE ORIFICIES LOCATION MAP 36TH STREET NW	CALCULATED CES	0 150	N
		CHECKED DW	75 300 HORIZONTAL SCALE IN FEET	

Appendix I.
36th Street NW Typical Section and Plan & Profile Sheets

PROPOSED LEGEND

(1) ITEM 204 – SUBGRADE COMPACTION
(2) ITEM 301 – 4" ASPHALT CONCRETE BASE
(3) ITEM 304 – 6" AGGREGATE BASE
(4) ITEM 407 – TACK COAT FOR INTERMEDIATE COURSE
(5) ITEM 407 – TACK COAT, 702.13
(6) ITEM 441 – 1-1/2" ASPHALT CONCRETE INTERMEDIATE COURSE, TYPE 2, (448), PG 64-22
(7) ITEM 441 – 1-1/2" ASPHALT CONCRETE SURFACE COURSE, TYPE 1, (448), PG 64-22
(8) ITEM 605 – 6" SHALLOW PIPE UNDERDRAIN WITH FILTER FABRIC
(9) ITEM 608 – CONCRETE WALK, AS PER PLAN
(10) ITEM 609 – CURB, TYPE 6
(11) ITEM 653 – 4" TOPSOIL FURNISHED AND PLACED
(12) ITEM 659 – SEEDING AND MULCHING, CLASS 1



36th STREET NW - PROPOSED TYPICAL SECTION (LOOKING EAST)

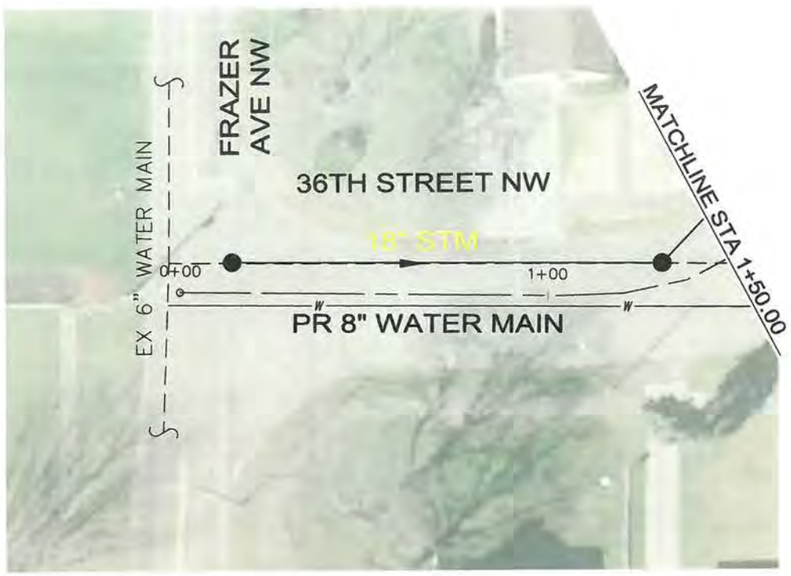
P:\Canton - City of\J20170744.000 Market Heights 36th NW Street Storm Water Study\Drawings\Trans\J20170744_Typical Section.dwg 30-Jan-19 6:10 PM

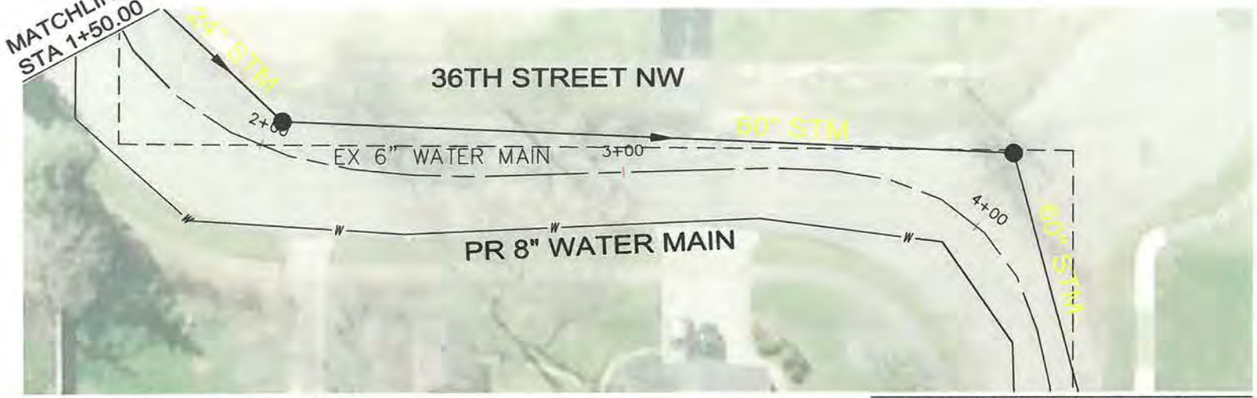
CALCULATED CES
CHECKED DW
NOT TO SCALE

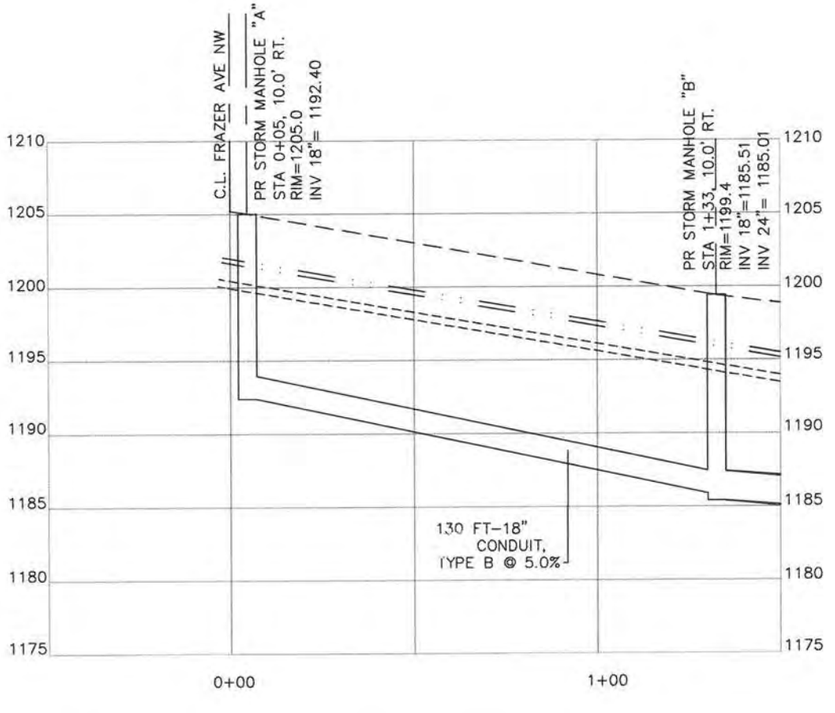
36TH STREET NW
TYPICAL SECTION DETAIL

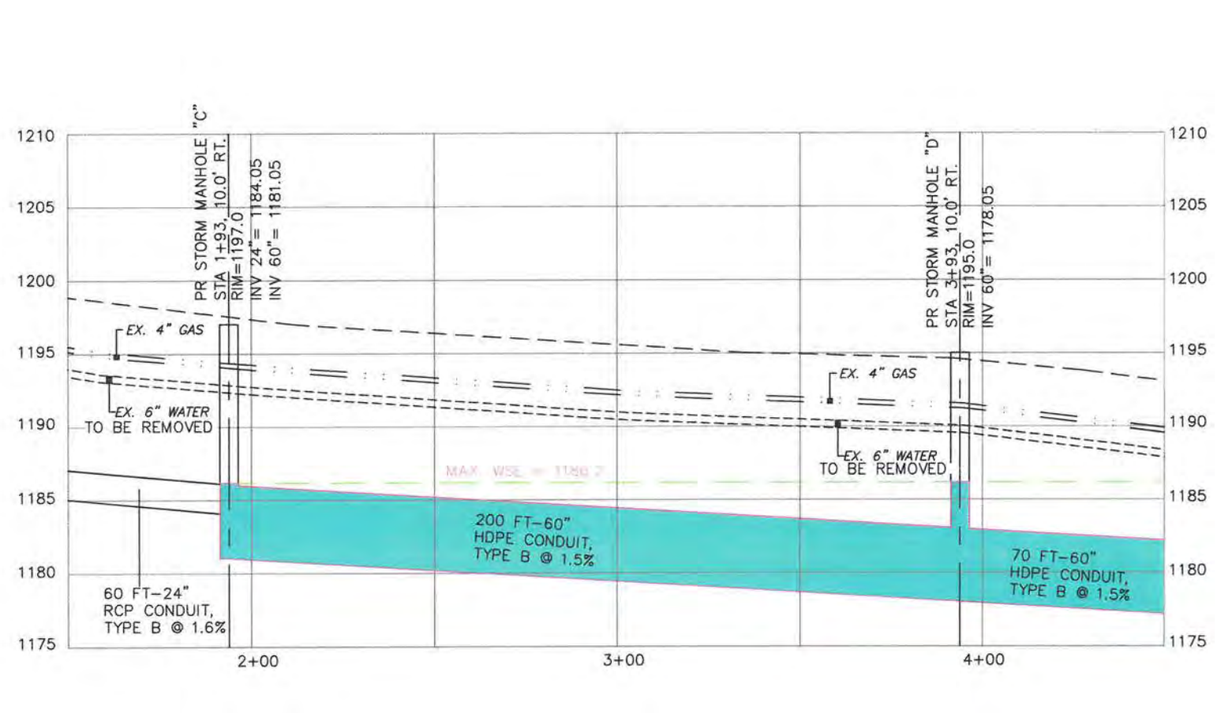
CITY OF CANTON

1/1









HORIZONTAL SCALE IN FEET
0 10 20 40
CALCULATED CES
CHECKED DW

60" STORM SEWER 36TH STREET NW
PLAN AND PROFILE SHEET

CITY OF CANTON

1 / 6

P:\Canton - City of\J20170744.000 Market Heights 36th NW Street Storm Water Study\Drawings\Trans\J20170744_PLAN AND PROFILE SHEET 1.dwg 31-Jan-19 12:45 PM

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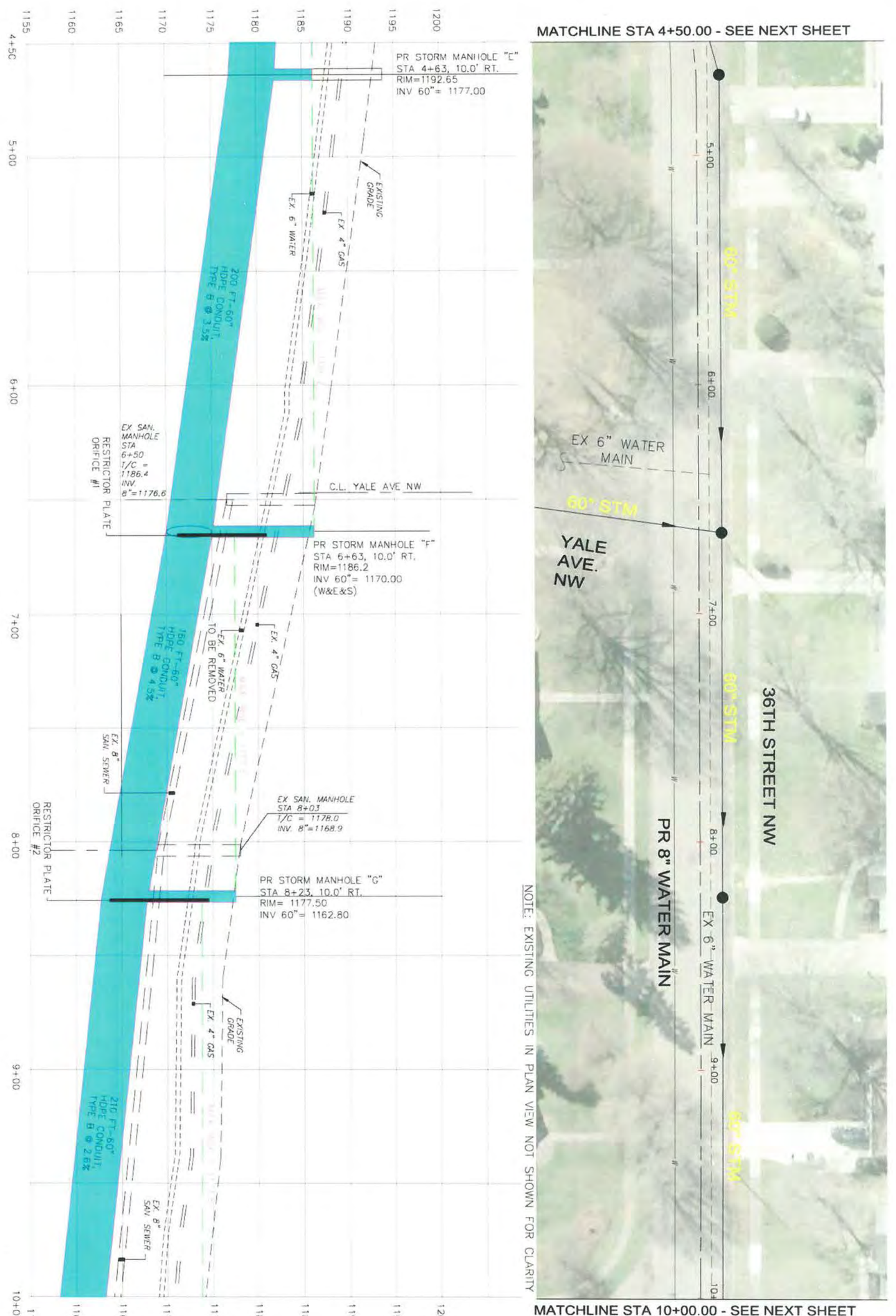
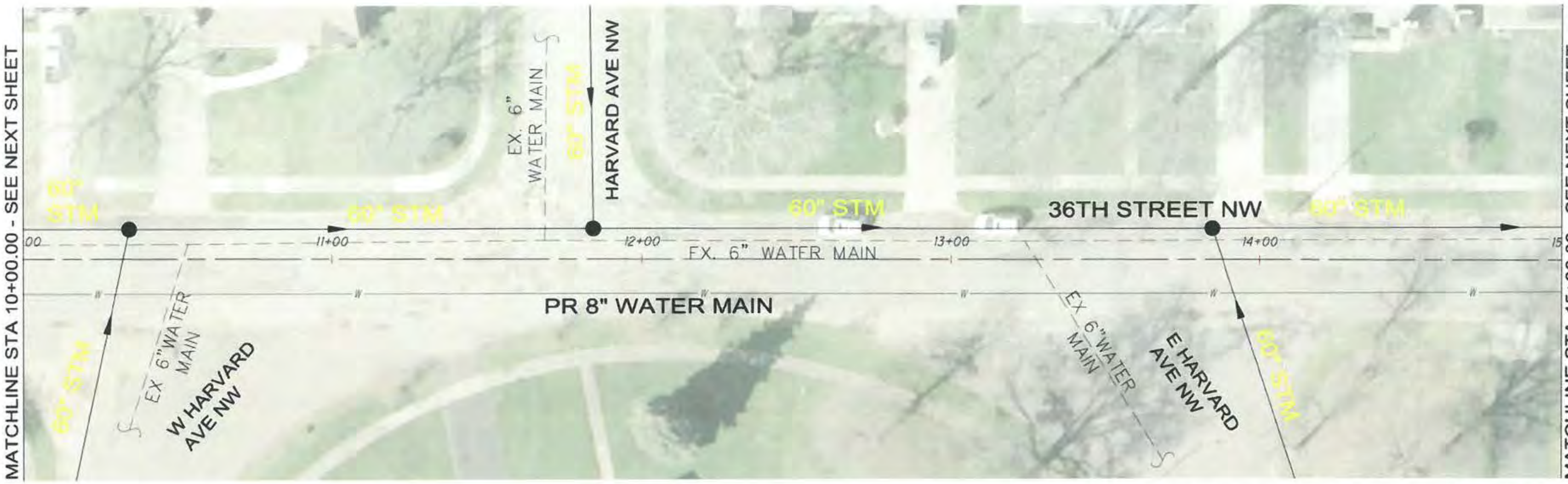
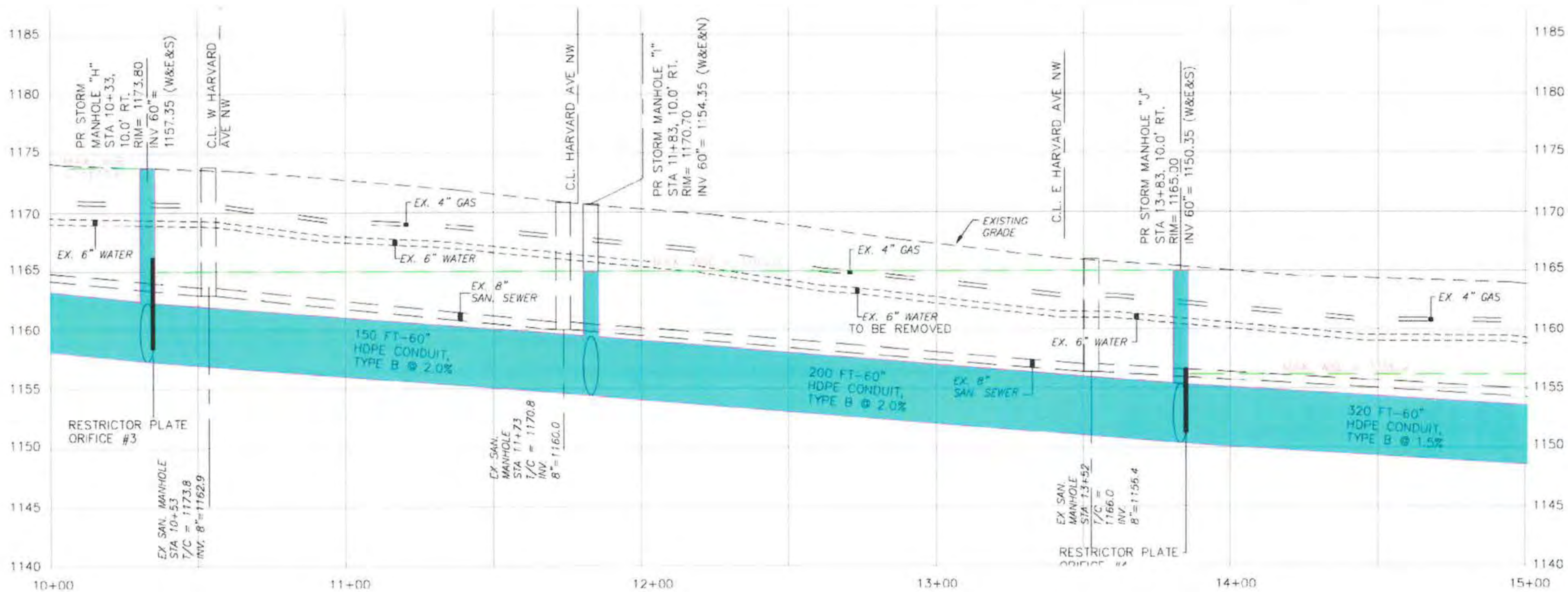


2/6	CITY OF CANTON	60" STORM SEWER 36TH STREET NW PLAN AND PROFILE SHEET	CALCULATED CES CHECKED DW HORIZONTAL SCALE IN FEET



NOTE: EXISTING UTILITIES IN PLAN VIEW NOT SHOWN FOR CLARITY



HORIZONTAL SCALE IN FEET 0 10 20 40

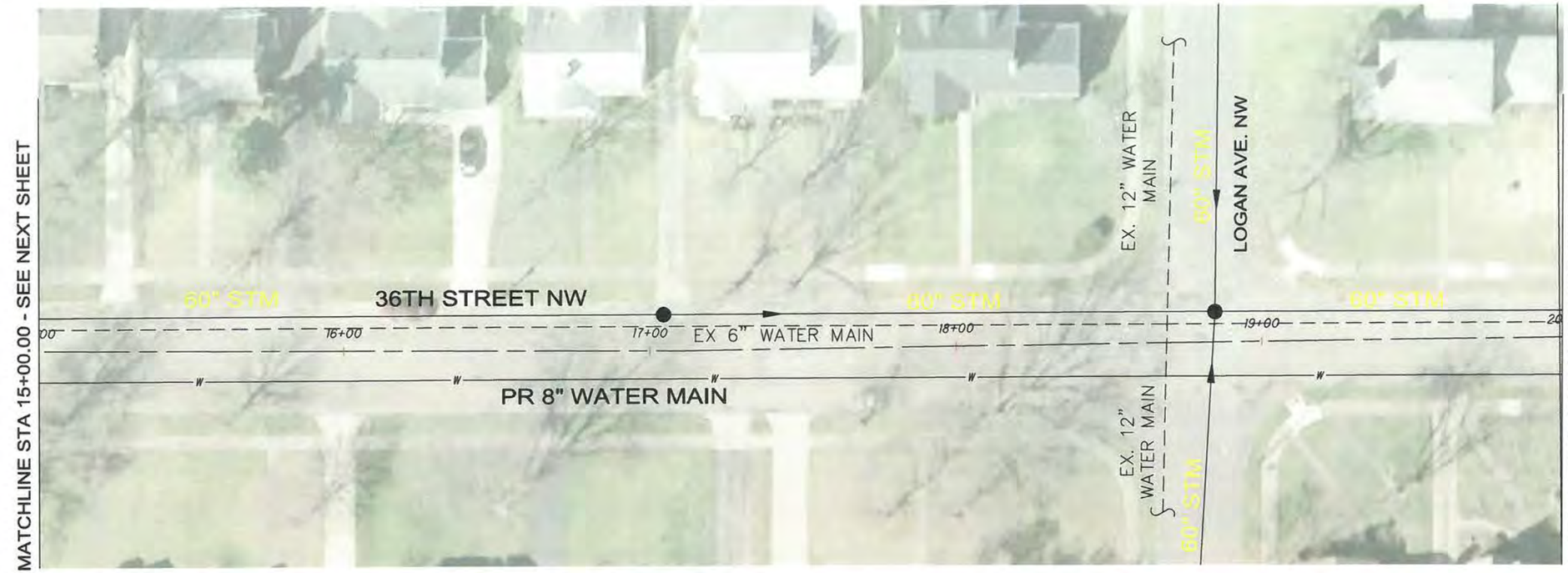
CALCULATED CES CHECKED DW

60" STORM SEWER 36TH STREET NW PLAN AND PROFILE SHEET

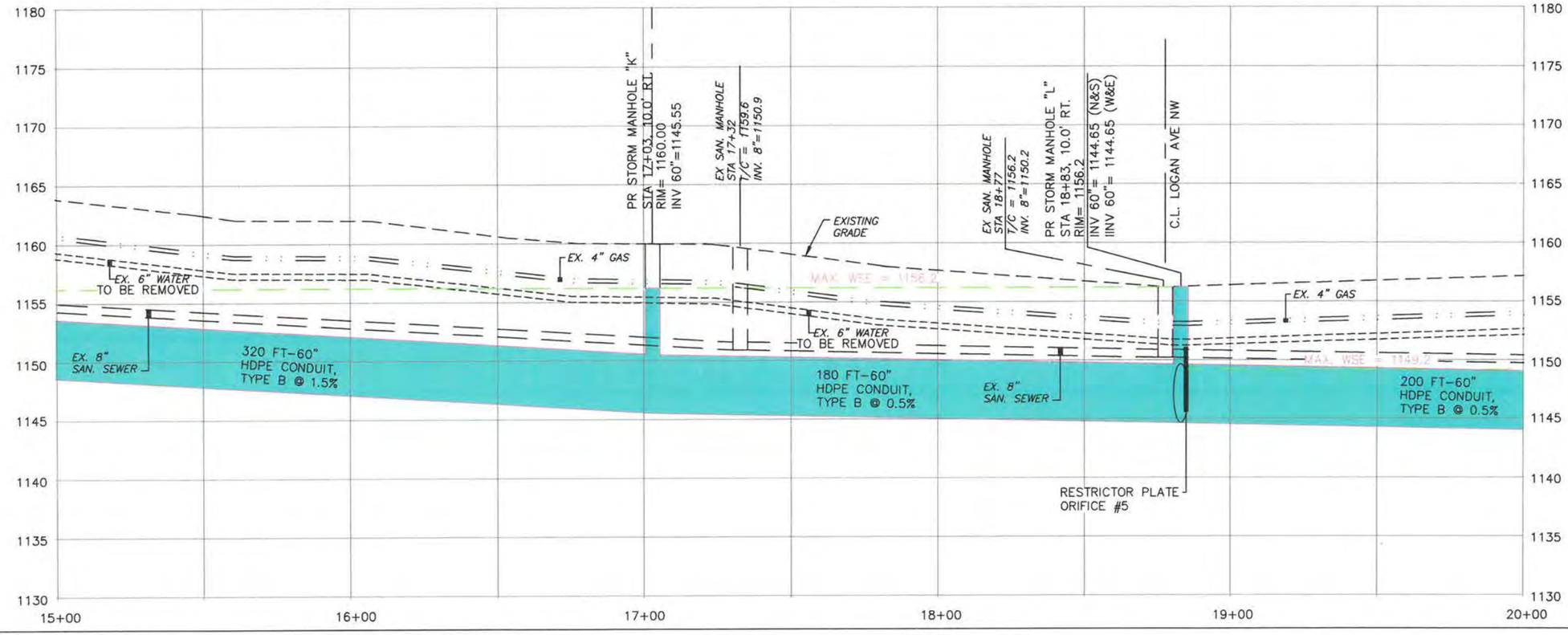
CITY OF CANTON

3 / 6

P:\Canton - City of\J20170744.000 Market Heights 36th NW Street Storm Water Study\Drawings\Trans\J20170744_PLAN AND PROFILE SHEET 3.dwg 31-Jan-19 10:51 AM



NOTE: EXISTING UTILITIES IN PLAN VIEW NOT SHOWN FOR CLARITY



N

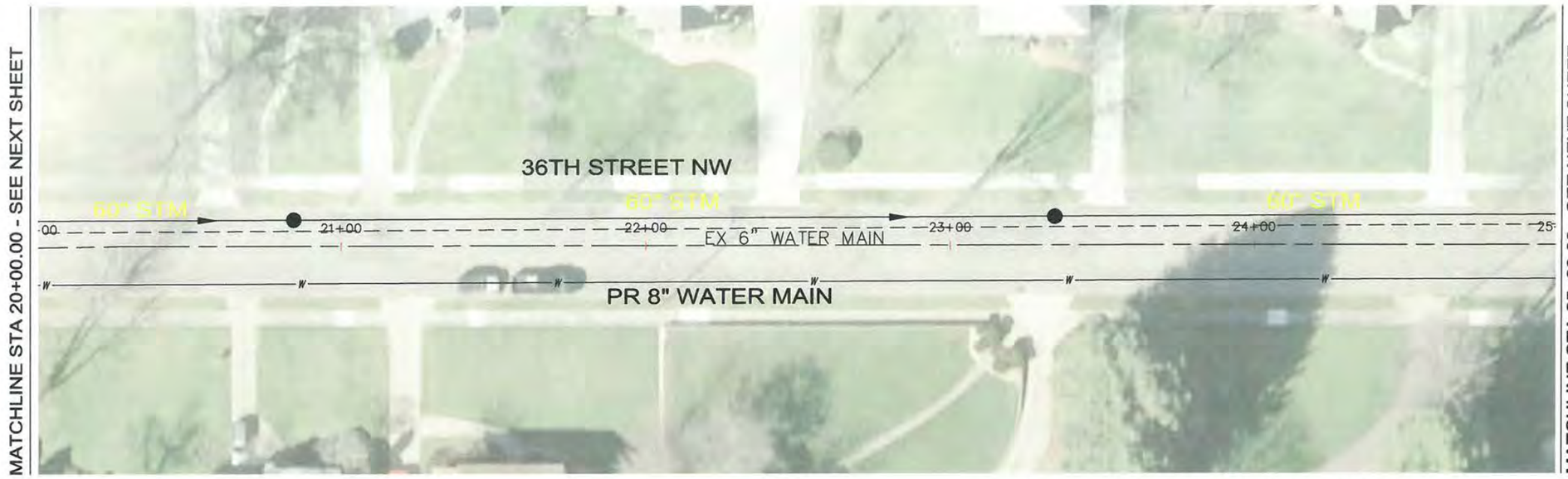
0 10 20 40 HORIZONTAL SCALE IN FEET

CALCULATED CES
CHECKED DW

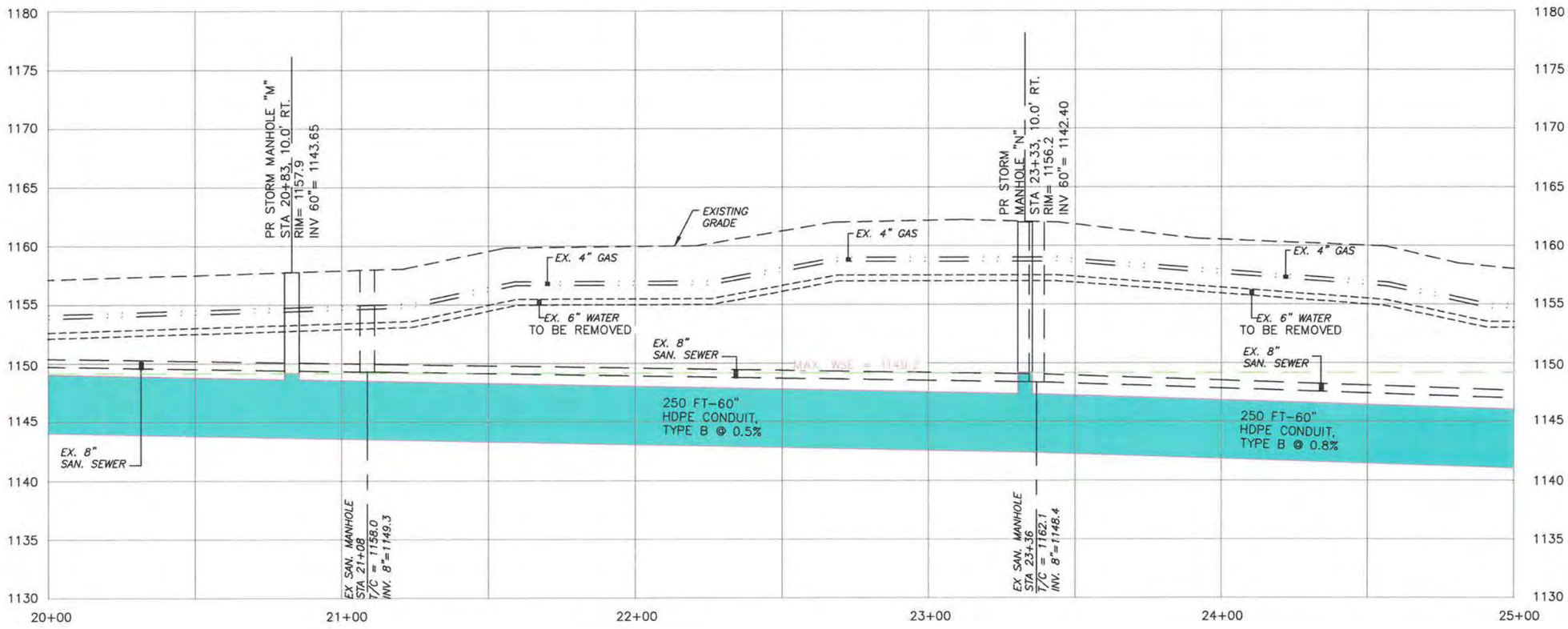
60" STORM SEWER 36TH STREET NW
PLAN AND PROFILE SHEET

CITY OF CANTON

4
6



NOTE: EXISTING UTILITIES IN PLAN VIEW NOT SHOWN FOR CLARITY



HORIZONTAL SCALE IN FEET
0 10 20 40

CALCULATED CES
CHECKED DW

60" STORM SEWER 36TH STREET NW
PLAN AND PROFILE SHEET

CITY OF CANTON

5/6

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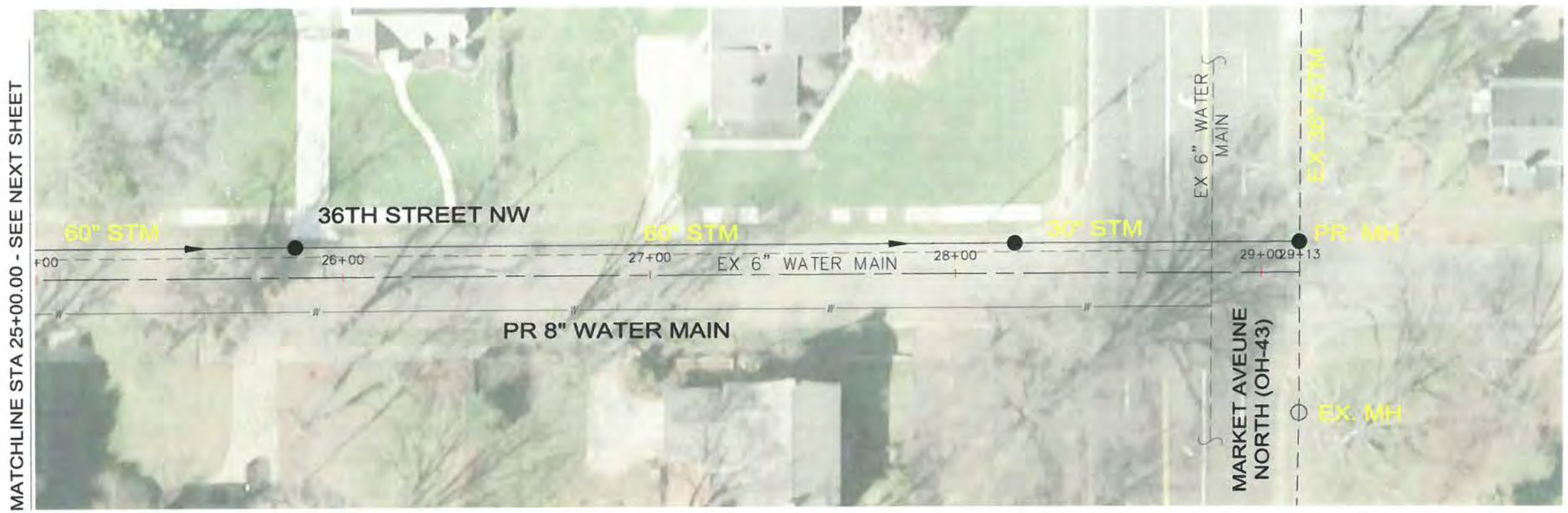
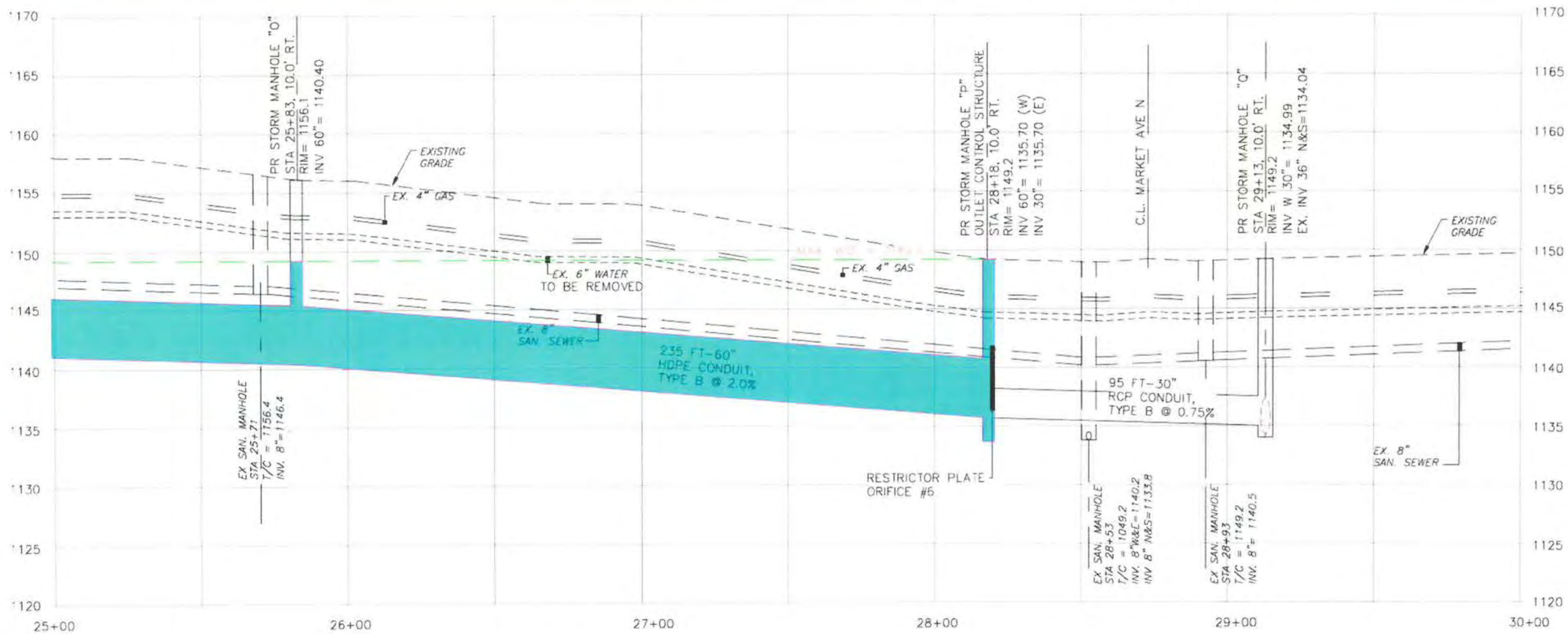


NOTE: EXISTING UTILITIES IN PLAN VIEW NOT SHOWN FOR CLARITY



0 10 20 40
HORIZONTAL SCALE IN FEET

CALCULATED CES
CHECKED DW

60" STORM SEWER 36TH STREET NW PLAN AND PROFILE SHEET

CITY OF CANTON

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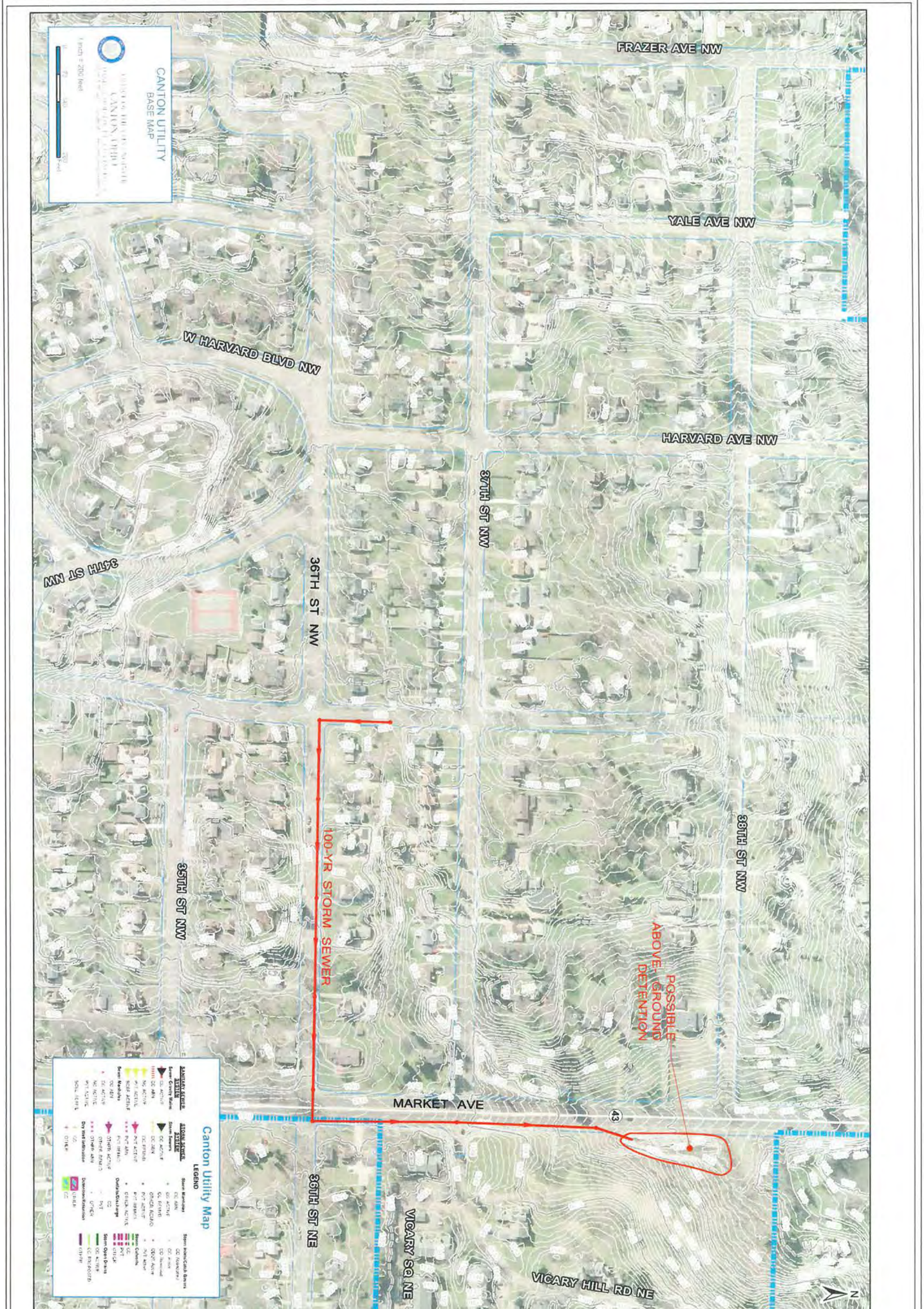
Appendix J.
Potential Location for Above-Ground Detention

P:\Canton – City of\J20170744.000 Market Heights 36th NW Street Storm Water Study\Drawings\Trans\J20170744_36th & Market_WaterShed & Storm Sewer Maps.dwg 30-Jan-19 5:42 PM



1/1	CITY OF CANTON	APPENDIX J POTENTIAL LOCATION FOR ABOVE GROUND DETENTION 36TH STREET NW	CALCULATED CES CHECKED DW	0 150 75 300 HORIZONTAL SCALE IN FEET

Appendix K.
Preliminary Cost Estimate

36th St NW Storm Sewer Road Reconstruction Project

Engineer's Opinion of Preliminary Probable Construction Costs

REF NO.	ITEM NUMBER	ITEM EXTENSION	ITEM DESCRIPTION	UNIT	ESTIMATED QUANTITY	UNIT PRICE DOLLARS I CTS	UNIT PRICE DOLLARS I CTS	UNIT PRICE ESTIMATED DOLLARS I CTS	ITEM TOTAL
			ROADWAY						
1	202	23000	PAVEMENT REMOVED	SQ. YD.	14,085			$ 8.24	$ 116,060.40
2	202	30000	WALK REMOVED, AS PER PLAN	SQ. FT.	31,375			$ 1.50	$ 47,062.50
3	202	32500	CURB AND GUTTER REMOVED, AS PER PLAN	FOOT	6,275			$ 5.00	$ 31,375.00
4	202	98100	REMOVAL MISC.: DRIVEWAY APRON	SQ. YD.	800			$ 12.50	$ 10,000.00
5	204	10000	SUBGRADE COMPACTION	SQ. YD.	11,865			$ 1.71	$ 20,289.15
6	204	13000	EXCAVATION OF SUBGRADE	CU. YD.	791			$ 12.00	$ 9,492.00
7	204	30010	GRANULAR MATERIAL, TYPE B	CU. YD.	791			$ 33.24	$ 26,292.84
8	204	50000	GEOTEXTILE FABRIC, 712.09 TYPE D	SQ. YD.	1,186			$ 1.50	$ 1,779.00
9	608	13001	4" CONCRETE WALK, AS PER PLAN	SQ. FT.	31,375			$ 4.50	$ 141,187.50
10	SPECIAL		CURB RAMP, AS PER PLAN	CORNER	16			$ 1,000.00	$ 16,000.00
11	623	38501	MONUMENT ASSEMBLY, AS PER PLAN	EACH	11			$ 500.00	$ 5,500.00
					SECTION TOTAL ROADWAY :				$ 425,038.39
			EROSION CONTROL						
12	653	10001	TOPSOIL FURNISHED AND PLACED	CU. YD.	219			$ 35.00	$ 7,665.00
13	659	10001	SEEDING AND MULCHING, AS PER PLAN	SQ. YD.	1,989			$ 2.00	$ 3,978.00
14	832	30001	EROSION CONTROL, AS PER PLAN	LUMP	1			$ 10,000.00	$ 10,000.00
15	832	30001	STORM WATER POLLUTION PREVENTION PLAN	LUMP	1			$ 6,000.00	$ 6,000.00
					SECTION TOTAL EROSION CONTROL :				$ 27,643.00
			DRAINAGE						
16	202	35100	PIPE REMOVED, 24" AND UNDER	FOOT	300			$ 14.11	$ 4,233.00
17	202	58300	CATCH BASIN OR INLET REMOVED	EACH	6			$ 346.13	$ 2,076.78
18	605	11100	6" SHALLOW PIPE UNDERDRAINS WITH FILTER FABRIC	FOOT	6,275			$ 8.00	$ 50,200.00
19	611	01400	6" CONDUIT, TYPE E	FOOT	100			$ 8.54	$ 854.00
20	611	04400	12" CONDUIT, TYPE B, 706.02	FOOT	500			$ 73.08	$ 36,540.00
21	611	07400	18" CONDUIT, TYPE B, 706.02	FOOT	130			$ 93.49	$ 12,153.70
22	611	10400	24" CONDUIT, TYPE B, 706.02	FOOT	60			$ 131.60	$ 7,896.00
23	611	13400	30" CONDUIT, TYPE B, 706.02	FOOT	95			$ 136.04	$ 12,923.80
24	611		**60" HDPE CONDUIT, TYPE B, 706.02**	**FOOT**	**4,355**			**$ 450.00**	**$ 1,959,750.00**
25	611	98101	CURB CATCH BASIN	EACH	30			$ 2,500.00	$ 75,000.00

26	611	99574	MANHOLE	EACH	17			$	3,500.00	$ 59,500.00
27	611	99574	MANHOLE (OUTLET CONTROL STRUCTURE W / WEIR WALL)	EACH	6			$	4,500.00	$ 27,000.00
28	611	99820	MISCELLANEOUS METAL (SEWER)	POUNDS	500			$	1.00	$ 500.00
29	611	99900	DRAINAGE STRUCTURE, MISC: ADJUSTING STREET CASTINGS TO GRADE (SEWER), AS PER PLAN	EACH	13			$	400.00	$ 5,200.00
							SECTION TOTAL DRAINAGE :			$ 2,253,827.28
			WATER LINE							
30			REMOVAL EXISTING 6" DIP WATER MAIN (MARKET TO FRAZER)	FOOT	2,950			$	20.00	$ 59,000.00
31			REMOVAL EXISTING HYDRANT ASSEMBLY	EACH	3			$	500.00	$ 1,500.00
32			8" DIP WATER MAIN WITH PREMIUM BACKFILL	FOOT	2,925			$	90.00	$ 263,250.00
33			6" FIRE HYDRANTS ASSEMBLY INCLUDING TEE & BRANCH	EACH	10			$	5,500.00	$ 55,000.00
34			TAPPING SLEEVES AND VALVES (MARKET AVE & FRAZER)	EACH	2			$	5,000.00	$ 10,000.00
35			GATE VALVES	EACH	10			$	1,500.00	$ 15,000.00
36			WATER MAIN CROSS FITTINGS (LOGAN AVE)	EACH	1			$	1,200.00	$ 1,200.00
37			WATER MAIN TEE FITTINGS	EACH	5			$	1,200.00	$ 6,000.00
38			WATER MAIN BENDS & THRUST BLOCKS	EACH	10			$	600.00	$ 6,000.00
39			1 INCH HOUSE SERVICE CONNECTION (LONG)	EACH	30			$	1,750.00	$ 52,500.00
40			1 INCH HOUSE SERVICE CONNECTION (SHORT)	EACH	24			$	1,500.00	$ 36,000.00
41			TESTING AND CHLORINATION	LUMP	1			$	-	$ -
41A			3% INFLATION	LUMP	1			$	15,163.50	$ 15,163.50
							SECTION TOTAL WATERLINE :			$ 505,450.00
			SANITARY							
42A	611	01800	8" CONDUIT, TYPE B	FOOT	151			$	67.51	$ 10,194.01
42B			RELINING OF EXISTING SANITARY SEWER MANHOLE (SPECTRASHIELD)	EACH	15			$	2,000.00	$ 30,000.00
							SECTION TOTAL SANIATRY :			$ 40,194.01
			PAVEMENT							
43	301	46000	4" ASPHALT CONCRETE BASE, PG 64-22	CU. YD.	1,305			$	110.00	$ 143,550.00
44	304	20000	AGGREGATE BASE	CU. YD.	1,977			$	50.00	$ 98,850.00
45	407	10000	TACK COAT FOR INTERMEDIATE COURSE	GAL.	1,186			$	2.00	$ 2,372.00
46	407	14000	TACK COAT, 702.13	GAL.	1,186			$	2.00	$ 2,372.00
47	441	50301	1-1/2" ASPHALT CONCRETE INTERMEDIATE COURSE, TYPE 2 (448), PG 64-22,	CU. YD.	577			$	160.00	$ 92,320.00
48	441	50100	1-1/2" ASPHALT CONCRETE SURFACE COURSE, TYPE 1, PG 64-22	CU. YD.	412			$	170.00	$ 70,040.00

36th St NW Storm Sewer Road Reconstruction Project

Engineer's Opinion of Preliminary Probable Construction Costs

49	452	12011	6" NON-REINFORCED CONCRETE PAVEMENT, CLASS QC1 (FOR DRIVES),	SQ. YD.	800			$	35.00	$ 28,000.00
50	609	26000	CURB, TYPE 6	FOOT	6,275			$	25.00	$ 156,875.00
							SECTION TOTAL PAVEMENT :			$ 594,379.00
			TRAFFIC CONTROL							
51	630	02100	GROUND MOUNTED SUPPORT, NO. 2 POST	FOOT	112			$	7.64	$ 855.68
52	630	80100	SIGN, FLAT SHEET	SQ. FT.	40			$	15.30	$ 612.00
53	630	85000	REMOVAL OF GROUND MOUNTED SIGN AND STORAGE	EACH	8			$	18.42	$ 147.36
54	630	86002	REMOVAL OF GROUND MOUNTED POST SUPPORT AND DISPOSAL	EACH	8			$	13.79	$ 110.32
55	644	00500	STOP LINE	FOOT	72			$	5.89	$ 424.08
56	644	00600	CROSSWALK LINE	FOOT	640			$	2.61	$ 1,670.40
							SECTION TOTAL TRAFFIC CONTROL :			$ 3,819.84
			MAINTENANCE OF TRAFFIC							
57	410	12000	TRAFFIC COMPACTED SURFACE, TYPE A OR B	CU. YD.	100			$	20.00	$ 2,000.00
58	614	11000	MAINTAINING TRAFFIC, AS PER PLAN	LUMP	1			$	25,000.00	$ 25,000.00
59	614	11110	LAW ENFORECMENT OFFICER WITH PATROL CAR	HOUR	40			$	75.00	$ 3,000.00
60	614	11110	LAW ENFORCEMENT OFFICER	HOUR	0			$	45.00	$ -
61	614	13000	ASPHALT CONCRETE FOR MAINTAINING TRAFFIC	CU. YD.	100			$	200.00	$ 20,000.00
62	614	26200	WORK ZONE STOP LINE, CLASS 1, 642 PAINT	FOOT	72			$	3.00	$ 216.00
63	616	10000	WATER	M GAL	36			$	50.00	$ 1,800.00
64	616	20000	CALCIUM CHLORIDE	TON	9			$	700.00	$ 6,300.00
							SECTION TOTAL MAINTENANCE OF TRAFFIC			$ 58,316.00
			MISCELLANEOUS							
65	619	16010	FIELD OFFICE, TYPE B	MONTHS	0				$1,500.00	$ -
66	623	10000	CONSTRUCTION LAYOUT STAKES AND SURVEYING, AS PER PLAN	LUMP	1				$35,000.00	$ 35,000.00
67	624	10000	MOBILIZATION	LUMP	1				$110,000.00	$ 110,000.00
68	SPECIAL		PRE CONSTRUCTION VIDEO TAPING OF RIGHT OF WAY	LUMP	1				$1,000.00	$ 1,000.00
69	SPECIAL		PROJECT SIGN	EACH	2				$1,500.00	$ 3,000.00
							SECTION TOTAL MISCELLANEOUS			$ 149,000.00
							GRAND SUB TOTAL :			$ 4,057,667.52
							10% CONTINGENCY			$ 405,766.75
							CONSTRUCTION GRAND TOTAL ESTIMATED (ITEMS 1-69) :			$ 4,463,434.27