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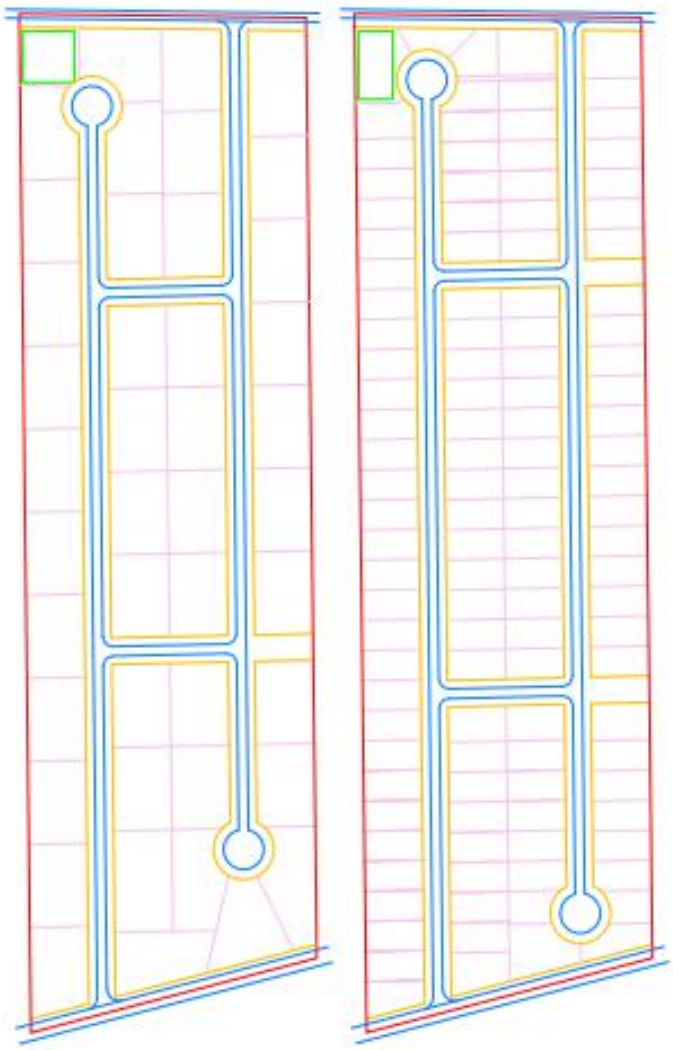

Subdivision Site Design in Antwerp Township

Site Development Plan

ABSTRACT

Design and development of a subdivision on an empty plot of land off Red Arrow Highway in Antwerp Township, MI.

Alec DenBraber
Kaitlyn Rogosch
Peyton Smith
Zach Turner

Acknowledgements

Thank you to Wightman for providing this project for us and sponsoring us along the way. Special thanks to Paul Harvey and Paul Schram for meeting bi-weekly with our team to answer questions and provide us with the extra guidance we needed to complete this project. This project has taught our team a lot about site development planning that will prepare us for work in the professional workspace.

Also, thank you to Dr. Hains and Dr. Kwigzile for being available to answer any questions we had and providing us with all the necessary resources to stay on schedule and complete our project. We are grateful for the knowledge we have acquired from your classes and are sure it will help us in the future workplace.

Executive Summary

For our senior design project, we worked with Wightman to design a subdivision on an empty plot of land in Antwerp Township near Paw Paw High School. The main components of our design are transportation, water resources (for the sewer and stormwater system), and construction. Our focus is to give the owner alternatives for the design of the subdivision with respect to the road layout and public versus private water and sewer systems. Primarily, we used AutoCAD to design and display the deliverables. Other resources utilized throughout the project include the Antwerp Township zoning ordinances and land division regulations, MDOT road design manuals, and the 10 state standards for stormwater and sewer. Through our design, we determined that the most cost effective design for the developer is the public utility design due to the higher number of parcels, lower cost per parcel to develop, and higher potential for future expansion.

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1. Introduction

1.1 Description of Project and Background

A developer has asked Wightman to develop a site design to create a subdivision on a 40-acre parcel of land in Antwerp Township, MI. The goal was to create an effective, sustainable, and aesthetically pleasing design that maximizes profit to the developer. The land is currently undeveloped agricultural space, meaning there will be no existing infrastructure to avoid or remove. The parcel is also neighboring a larger parcel to the east which will be developed in the future, so this subdivision will need to be developed with this expansion in mind. Figure 1.1.1 highlights in purple the 40-acre parcel to be designed and 137-acre parcel highlighted in blue represents the land for future expansion. Therefore, the success of this project is important to warrant investing in the expansion of the subdivision. If families move into the area after the completion of the initial project and are happy with the subdivision, more residents will be drawn to the area, meaning that there will be demand for more new housing in the future.

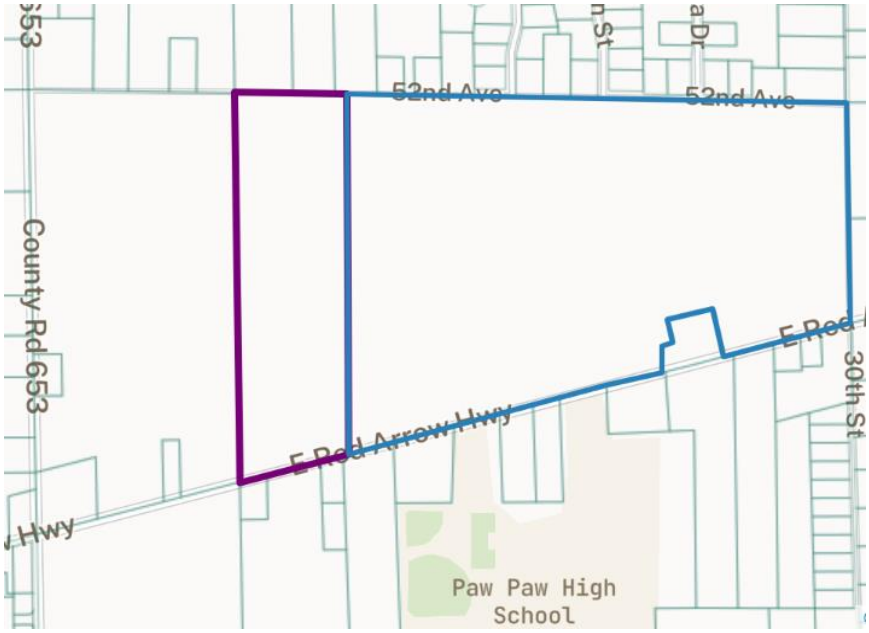

Figure 2.1.1 *Parcel Map*

The subdivision will be a community for families since the parcel is across the street from Paw Paw High School, easily within walking distance. Figure 1.1.1 also depicts Paw Paw High School to the south of the parcel. Allowing students to get to school on foot or bicycle safely is important for students without cars, those without a driver's license, and for parents who are unable to provide transportation for their children before and after school. Walking to school is also a great opportunity for students to get exercise during the day, improving their overall health. Due to this, it will need to be a safe, walkable community. The project also minimizes the impact on the surrounding environment by controlling runoff and maintaining green spaces.

This project is important for the development of the community, providing housing for families near the school. Available and affordable housing is important for the economy, allowing people and families to move to the area, fill job openings, and create growth through their purchases and spending locally. Developing this site economically is important in keeping housing costs low to encourage incoming residents to choose this location. The development should also be done sustainably so that the community will be a safe and comfortable living space for families to settle in for generations without experiencing extreme maintenance needs from excessive deterioration.

1.2 Scope of Work

The scope of this project includes transportation, water resources, and a construction estimate. Other aspects such as environmental sustainability will be discussed. The goal is to provide the best design that is aesthetically pleasing while maximizing the profits to the developer. To cover the transportation aspect, a roadway and pavement design have been

created. Private and public wastewater systems have been compared under water resources. Also, a retention pond design and storm pipe sizing have been created. The construction aspect includes cost, scheduling, and planning of the project. The cost estimates helped in establishing the final design recommendation. Scheduling and planning were established before we began this project to help us stay on track during the project development. This site design does not include any design of houses, that will be the responsibility of the developer once the roadway and utilities have been constructed.

1.3 Deliverables

The deliverables for this project include a zoning constraints summary, preliminary drawings of site layouts, roadway cross section details, sanitary sewer design calculations, water main schematic design/layout, stormwater design calculations, and cost estimating. AutoCAD was utilized to design and display all deliverable requirements listed above. A cost estimate was completed to display the financial breakdown of the deliverables. Following the completion of the deliverables, this final report was created with all relevant documents. A design poster with a project summary, important drawings, cost estimates, and comparisons was also created. At the completion of the project, a team presentation was given to summarize our findings and provide a recommendation to stakeholders and sponsors.

1.4 Project Constraints

There are minimal restraints on this project due to the lack of existing structures or utilities on or near the project site. One restraint, however, will be to minimize the impact to traffic on the bordering roads, especially Red Arrow Highway, due to its importance as a major arterial road for the area. The lot sizing, utility spacing, and other requirements set by Van Buren

County and Antwerp Township set other restraints for our design, limiting our design choices for all steps of this project. Furthermore, we are required to keep access to not only the roads to the north and south of the neighborhood, but also the future road to the east. The Paw Paw utility location at the eastern village limit poses a constraint on our public utility design, requiring utility lines to be extended an extra mile to the site. Finally, a major constraint for the storm design is that all storm water must be kept on site, rather than draining to a remote facility. This constraint required us to design a full retention pond for water evaporation and infiltration while fully kept within the parcel.

2. Engineering Analysis

2.1 Private vs. Public Water and Sewer

After speaking with our sponsor, we limited our alternatives to two designs, public water and sewer or private water and sewer through septic tanks and wells. We compared private water and sewer per parcel to public water and sewer for all parcels within the site boundaries. Each design includes zoning ordinance research, roadway and parcel layouts, sewer and water (for one alternative), stormwater design, and cost estimates for both designs. These alternatives were analyzed to select the design which maximizes profits for the developer based on the differences in minimum parcel size and dimensions and the differences in utility system design.

3. Site Plan

3.1 Zoning and Land Division Research

When researching the regulations for Antwerp Township subdivision developments, we discovered a list of guidelines to follow for the layout designs. The plot is currently zoned as AG, Agricultural and Open Space Residential, but will be rezoned to R-2, Single-Family Residential, to be developed for this project. As shown in Table 3.1.1, this gives us specific lot area and width requirements, which differ from private sewer and water systems as shown in Table 3.1.2. To summarize the tables, for the public utility site layout, the minimum required lot area is 8,750 ft^2 with 70 ft minimum lot width, and for the private utility site layout, the minimum required lot area is 30,000 ft^2 with 100 ft minimum lot width. These width requirements apply to any side of a lot facing a street, so corner lots must meet the minimum on both sides (5.7.C). Furthermore, the land division ordinance requires lot depth to width ratios to be below four to one (3.2.E.1). Considerations for the roadway placement include a minimum block length of 500 ft (5.6.B) and a maximum block length of 1,320 ft (5.6.C), with intersections at no less than 80° (5.2.A) and cul-de-sac streets no more than 600 ft long (5.1.B.9). The right of way was designed as the typical 66 ft, 75 ft at the cul-de-sacs (5.1.C.4). A final thing to consider is that the placement of roads should give access to the major roadways to the north and south (5.1.B.5), discourage through traffic (5.1.B.2), and be designed to make possible roadway connections to future developments to the east (5.1.B.3).

Table 3.1.1 *Minimum Lot Areas and Widths for Public Utilities*

	R-2		R-3 (two-family only)	
	Min. Lot Area (sq. ft.)	**Min. Lot Width (ft.)**	**Min. Lot Area Per Unit (sq. ft.)**	**Min. Lot Width (ft.)**
Public Water Only	12,000	80	12,000	80
Public Sewer Only	10,000	80	10,000	80
Both Public Water and Sewer	8,750	70	8,750	70

Table 3.1.2 *Minimum Lot Areas and Widths for Private Utilities*

		AG	R-1	R-2	R-3		
					Single Family	Two Family	Multi-Family
Min. Lot Area (sq. ft.)		43,560[1]	43,560	30,000[2]	20,000	30,000/unit[2]	[3]
Min. Width (ft.)		175	175	100	100	100	150
Maximum Building Height	In stories	2.5	2.5	2.5	2.5	2.5	3
	In feet	30	30	30	30	30	35
Minimum Front Yard Setback (ft.)[4]		60	50	40	40	40	40
Minimum Rear Yard Setback (ft.)		20	20	15	15	30	[5]
Minimum Side Yard Setback (ft.)		20	20	15	15	12	[5] [6]

3.2 Site Layout 1: Public Water and Sewer

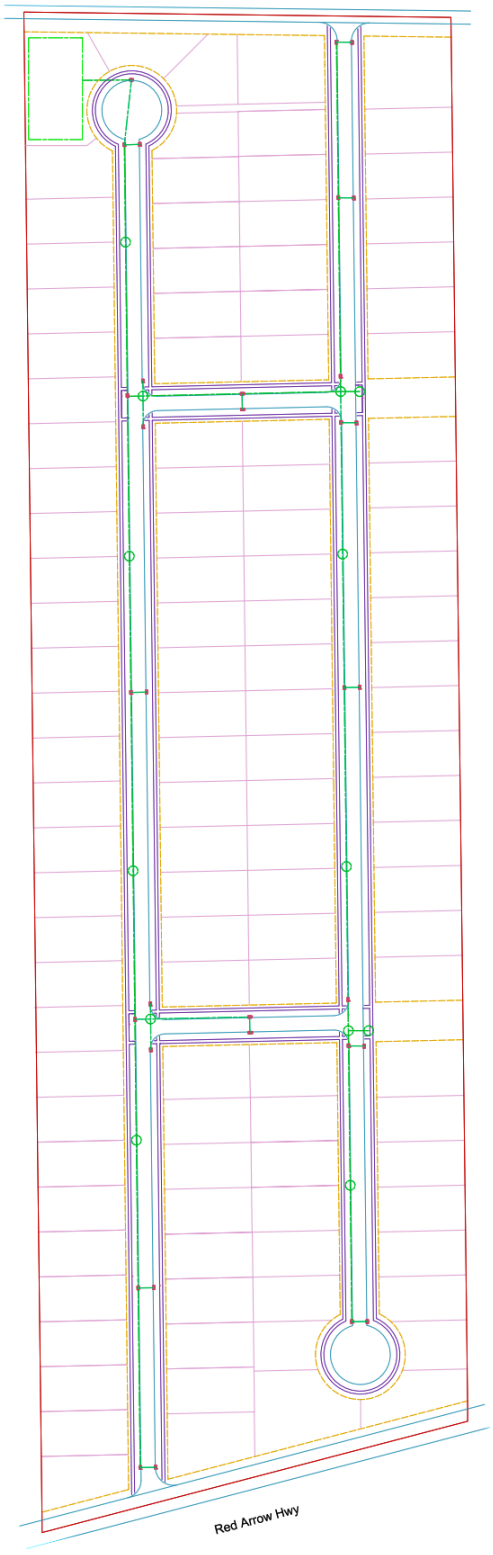

Figure 3.2.1 Public Utility Parcel Layout

In order to meet minimum lot width requirements and fit the lots to the parcel, this layout was designed with lots greater than the minimum lot area, with the base dimensions of the lots at 75 ft by 145 ft, 10,875 ft^2 in total. This layout includes 116 lots with a 170 ft by 90 ft retention pond in the northwest corner. The road layout was designed to allow access to both Red Arrow Hwy and 52nd Ave, while discouraging through traffic by requiring vehicles to stop and turn twice to get between the major roads. In addition, two cul-de-sacs, one in the northwest corner and one in the southeast corner, have been included in the design to provide for easy firetruck and school bus access. This design has a block length of 1,041 ft in the center block, 573 ft of road to the northwest cul-de-sac, and 588 ft to the southeast cul-de-sac, all within the township requirements. The smallest lot is 8,912 ft^2 and the largest is 18,404 ft^2 with an average lot size of 11,121 ft^2.

3.3 Site Layout 2: Private Water and Sewer

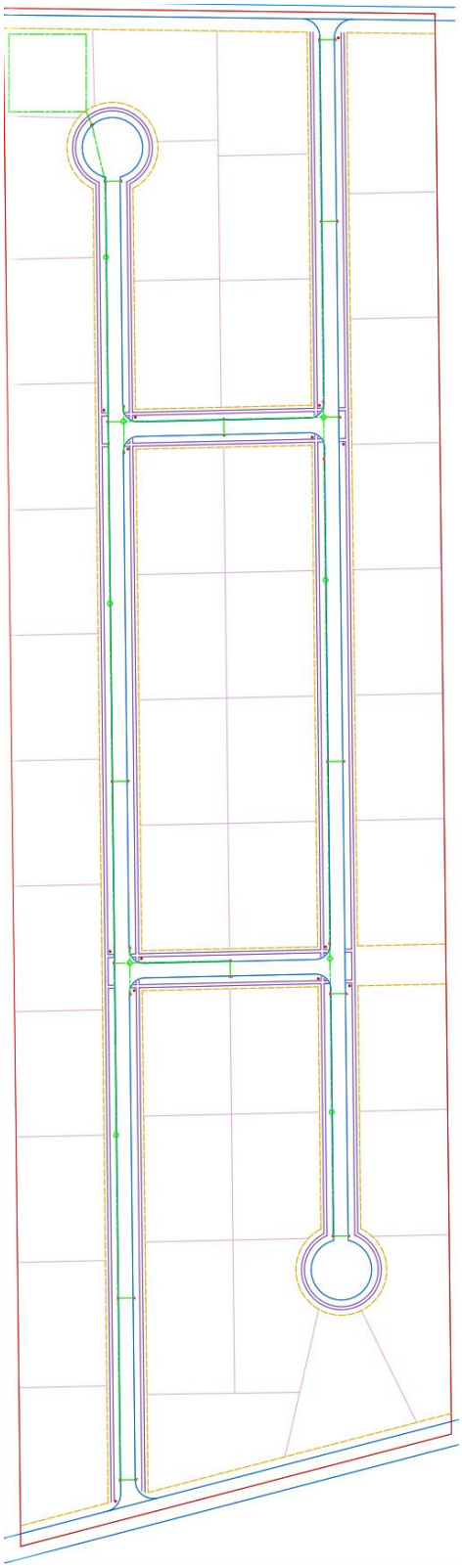

Figure 3.2.2 Private Utility Parcel Layout

For private utility systems, the lots are much larger due to the extra space needed for the septic tanks and wells, typically 145 ft by 207 ft, and 30,015 ft^2. This layout includes 43 lots with a 131 ft by 131 ft retention pond in the northwest corner. Like site layout 1, the road layout is designed to give access to both major streets while discouraging through traffic. This design also contains two cul-de-sacs, one in the northwest corner and one in the southeast corner, to provide easy access for firetrucks and school buses This design has a block length of 894 ft in the center block, 465 ft of road to the northwest cul-de-sac, and 501 ft to the southeast cul-de-sac, all within the township requirements. The smallest lot is 30,013 ft^2 and the largest is 38,383 ft^2 with an average lot size of 30,654 ft^2.

4. Transportation Design

4.1 Pavement Design

To prove that the pavement design is adequate, the following calculations were performed to find the design and required structural numbers. If the design structural number is greater than or equal to the required structural number, then the pavement design is adequate. First, the average daily traffic is solved using the assumption that our design hourly volume, peak hour traffic is one car per household and 15% of ADT.

$$Design\ Hourly\ Volume = \frac{43}{0.15} = 286.67$$

$$Design\ Hourly\ Volume = \frac{116}{0.15} = 773.33$$

We have assumed 0% for the truck factor and that there is no growth rate because the neighborhood is already filled. Since there are two lanes, one in each direction, the lane distribution factor is 0.5. The equivalent single axial load (ESAL) is determined using the variables provided in Table 4.1.1 and the following equation:

$$ESAL = ADT_0 \times T \times T_f \times G \times D \times L \times 365 \times Y$$

Table 4.1.1 *ESAL Equation Variables*

Private		Public	
ADT_0	286.67	ADT_0	773.33
T	-	T	-
T_f	-	T_f	-
G	-	G	-
D	-	D	-
L	0.5	L	0.5
Y	20	Y	20

$$ESAL(Private) = 286.67 \times 0.5 \times 365 \times 20 = 1{,}046{,}333.3$$

$$ESAL(Public) = 773.33 \times 0.5 \times 365 \times 20 = 2{,}822{,}666.7$$

Next, the design and required structural numbers (SN) are calculated. The required structural number is calculated using the following equation and variable listed in Table 4.1.2. Appendix # shows the tables in which the variables listed in Table 4.1.2 have been pulled from.

$$SN = a_1 D_1 \times a_2 D_2 m_2 \times a_3 D_3 m_3 \times a_4 D_4 m_4$$

Table 4.1.2 *Design Structural Number*

Design SN					
a_1	0.42	D_1	2	m_1	-
a_2	0.36	D_2	2.5	m_2	1
a_3	0.18	D_3	6	m_3	1
a_4	0.1	D_4	12	m_4	1
				Design SN	4.02

Solving for SN:

$$SN = (0.42 \times 2) \times (0.36 \times 2.5 \times 1) \times (0.18 \times 61 \times 1) \times (0.1 \times 12 \times 1)$$

$$SN = 4.02$$

We have designed the pavement for the public utilities site as it yields a higher ESAL. The design SN was solved using Solver in Microsoft Excel and the following equation:

$$\log_{10}(W_{18}) = Z_R S_0 + 9.36 \log_{10}(SN + 1) - 0.2 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.4 + \frac{1094}{(SN+1)^{5.19}}}$$

$$+ 2.32 \log_{10}(M_R) - 8.07$$

In Solver, the set objective is set to:

$$\log_{10}(2822666.67) = 6.45$$

Next the changing variable cell was set, Solver calculated a SN of 3.77. Figure 4.1.1 shows the Solver parameters and Table 4.1.3 shows the variables needed.

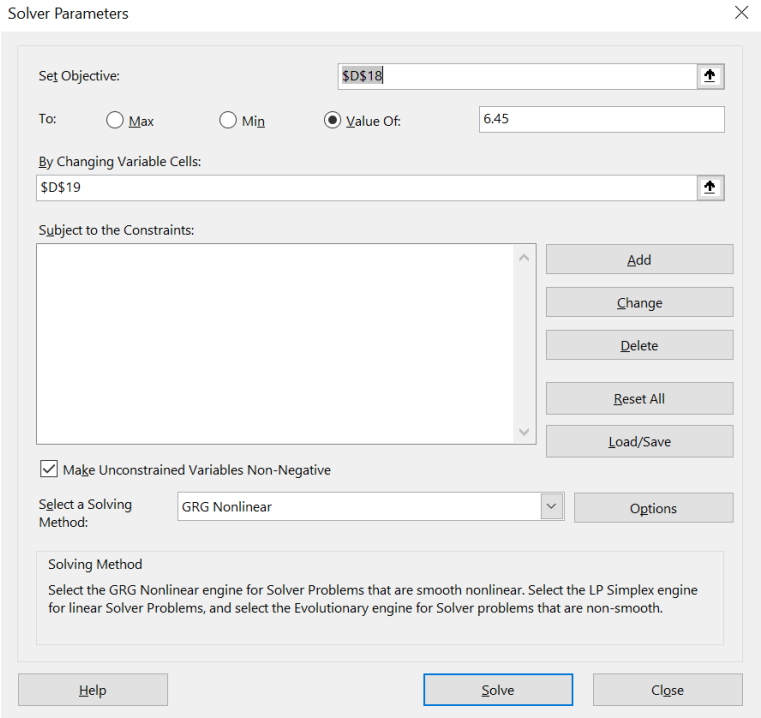

Figure 4.1.1 *Excel Solver for Required Structural Number*

Table 4.1.3 *Required Structural Number Variables*

Required SN	
W_{18}	2822666.67
Z_R	-0.841
S_0	0.45
ΔPSI	1.7
M_R	7760
$Log_{10}(W_{18})$	6.4500003
Required SN	3.77

Now, comparing the design and required structural numbers:

$$Design\ Sn\ \geq Required\ SN$$
$$4.02\ \geq 3.77$$

Therefore, the pavement design with 4.5in HMA is adequate. Figure 4.1.2 shows the designed pavement cross section.

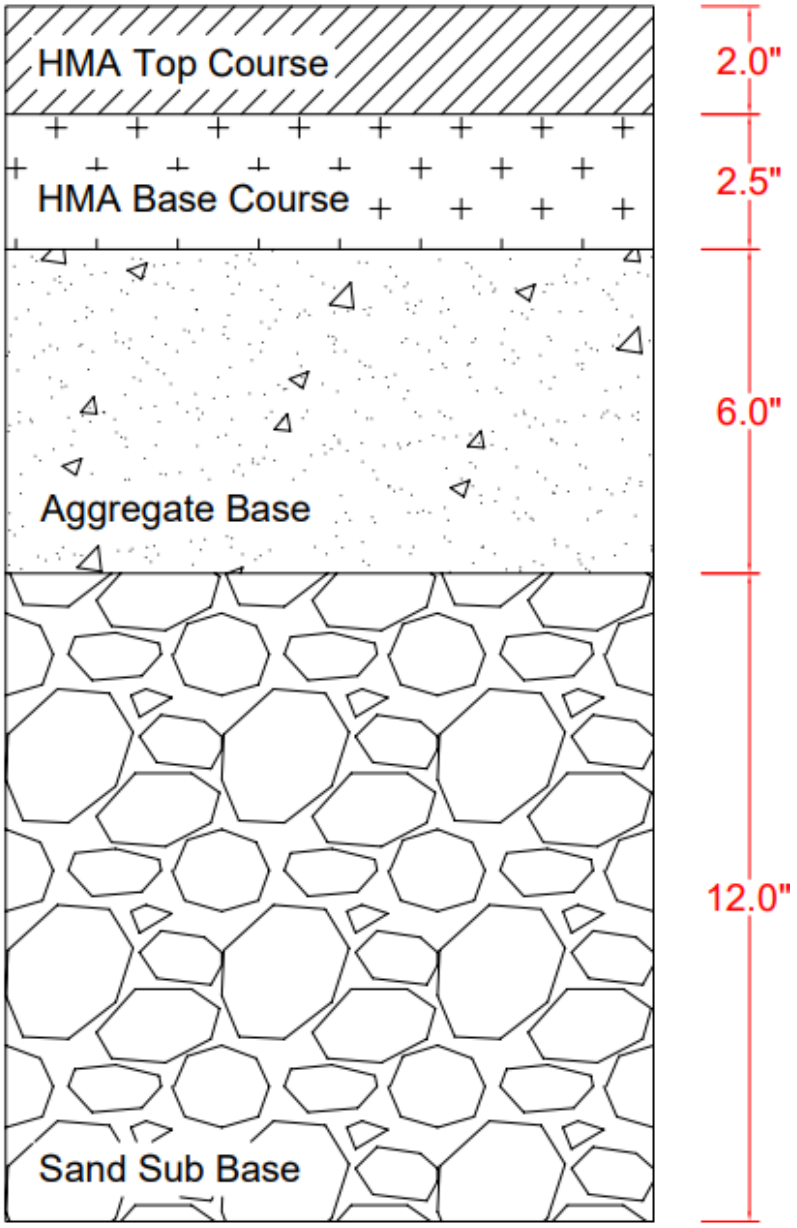

Figure 4.1.2 *Pavement Design Cross Section*

4.2 Roadway Design

To design the roadway for both site layouts, the Antwerp Township Zoning Ordinance, MDOT documents, Manual of Uniform Traffic Control Devices, and the Geotechnical Design of Highways and Streets textbook (Green Book) were used to determine minimum the roadway design requirements. The layouts involving two cul-de-sacs and two crossroads each as shown in figures 4.2.2 and 4.2.3 were designed to be aesthetically pleasing while abiding by specific roadway design requirements. According to the Antwerp Township Zoning Ordinance, section 3.17.M requires that the right-of-way shall have a minimum width of 66 ft. Thus, the width right-of-way for both site layouts is 66 ft. This section of the zoning ordinance also requires that a private road not exceed 2500 ft in length. This is another reason for adding the two crossroads to the design. Within the right-of-way are 5ft sidewalks, 2ft curbs and 12ft lanes. Figure 4.2.1 depicts a cross section used for both the private and public layout. There is a 4 in sidewalk with a grade of 1%. The 12 ft wide lanes have a grade of 2%. The curbs have been designed as rolled to reduce the amount needed to be demolished when installing driveways. Figure 4.2.4 shows details of our cul-de-sac design, including the 50 ft road radius and 75 ft right of way radius. Figure 4.2.5 shows details of our intersection design, such as the sidewalk and crosswalk layout and the turn radii.

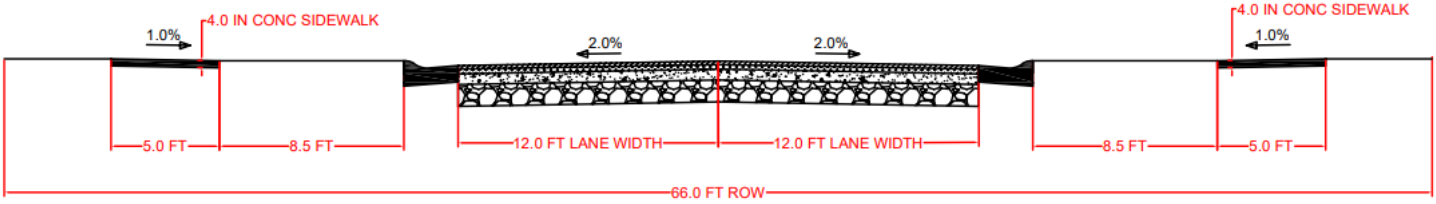

Figure 4.2.1 *Roadway Cross Section*

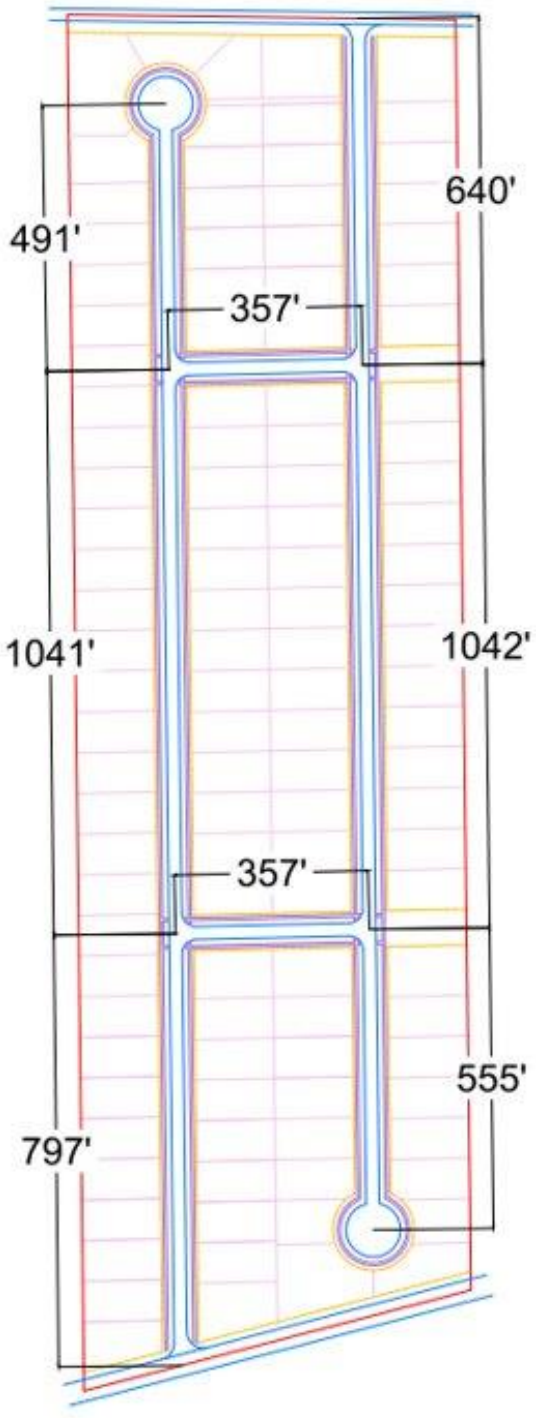

Figure 4.2.2 Public Utility Roadway Dimensions

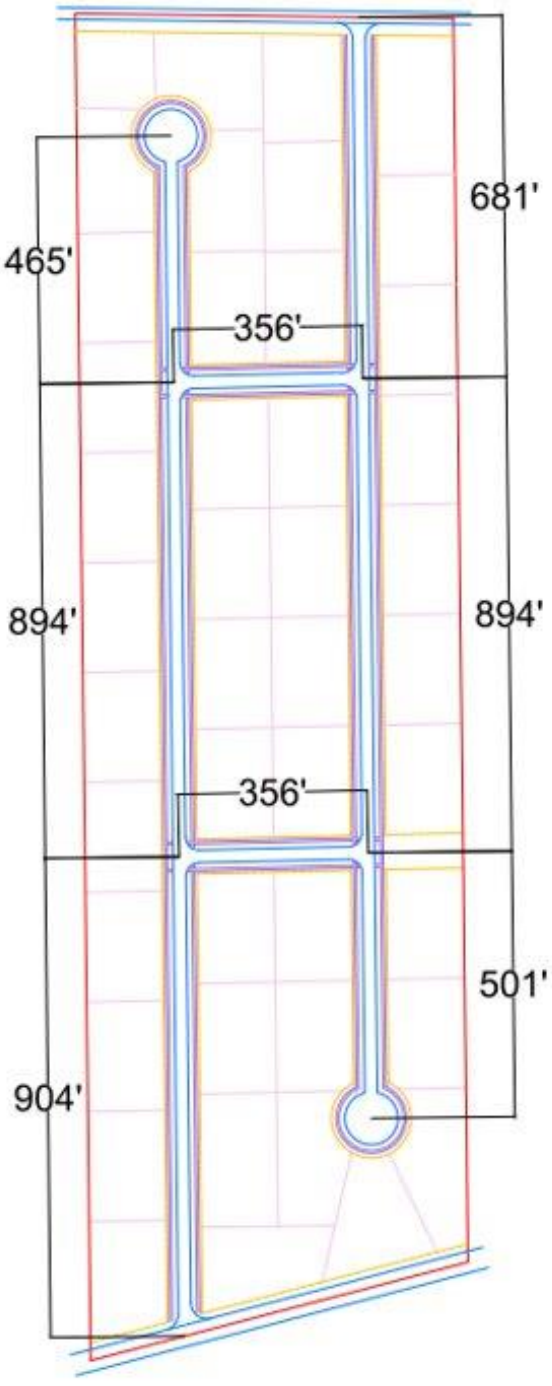

Figure 4.2.3 Private Utility Roadway Dimensions

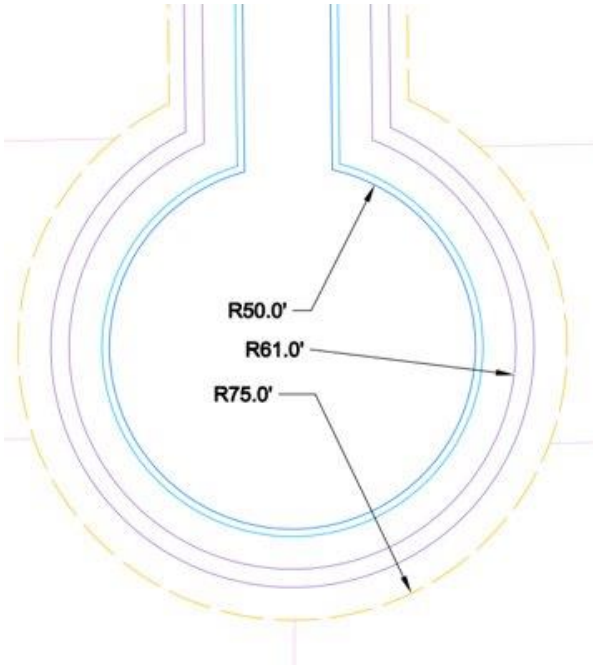

Figure 4.2.4 Cul-De-Sac Details

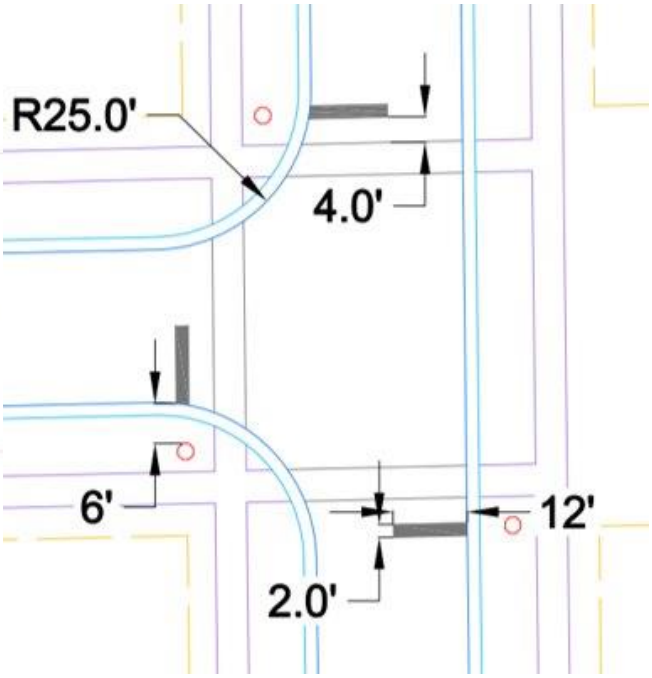

Figure 4.2.5 Intersection Details

4.3 Pavement Markings

At each intersection of the residential crossroads, Red Arrow Hwy, and 52rd Ave, 24-inch-wide stop bars have been placed 4ft away from the crosswalk. The 5ft wide crosswalks are designated by two parallel, 6-inch-thick white lines. These minimum dimensions were pulled from the MDOT PAVE-945-D which can be found in Appendix C. Since the posted speed limit is only 25 mph, it is not necessary to provide solid white lines or double yellow lines separating the lanes.

To make the sidewalks safe for everyone walking in and crossing the streets ADA detectable warning surfaces have been placed before each crosswalk. There are 28 detectable

warning surfaces, 24 inches wide, on each layout. The guidelines followed for placement and sizing of these warning surfaces can be found in Appendix D.

Stop bar is a pavement marking type non-reflective paint 24 inches.

4.4 Signage

Signs are important in controlling the traffic flow for both drivers and pedestrians. Stop signs have been placed and each intersection on both the private and public layouts. Therefore, creating four, 3-way stops on each design. Stop signs have also been placed at each exit from the development onto Red Arrow Highway and 52nd Ave. In total, there are 14 stop signs on each layout. According to MDOT Traffic Sign Design, Placement, and Application Guidelines, Table 4.4.1, provided in Appendix C, states the standard sign sizes for a single lane, non-freeway. Dimensions for a stop sign are 30 inch by 30 inch and for a speed limit sign are 24 inch by 30 inch. The Manual on Uniform Traffic Control Devices (MUTCD) specifies the standard height for all residential road signs to be 7 ft. MDOT Sign-140-A specifies that D3-1 signs will be placed 6 inches above the stop signs. This standard will be applied when it comes to the street name signs that will be placed above the stop signs. MDOT Sign-120-E shows the requirements for the spacing of speed limit signs between the sidewalk and curb. The speed limit signs have been placed 3 ft away from the curb and 4 ft away from the sidewalk therefore meeting the minimum MDOT requirements. These dimensions can be found in Figure 4.1.1 in Appendix C. MUTCD also specifies the placement of stop signs. According to MUTCD, the intersections in our design are considered wide throat intersections. The placement for the stop signs follows Figure 4.4.2.

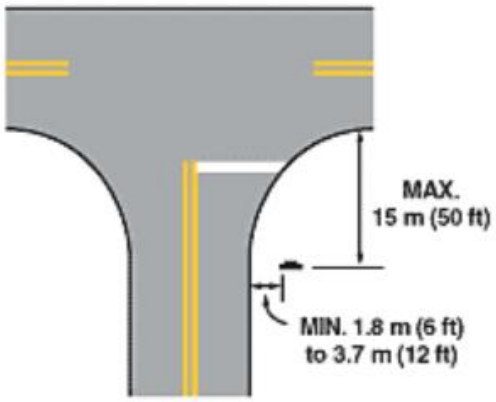

Figure 4.4.2 *Road Turn Radius*

On page 47 of MDOT Traffic Sign Design, Placement, and Application Guidelines, it is stated that a speed limit sign should be used on all single lane roadways. This document is also provided in Appendix C. Therefore, a speed limit sign has been placed at both entrances to each development providing a total of two speed limit signs per alternative. The posted speed limit for each development is 25 mph. In Michigan, the assumed speed limit is typically 25 mph in a neighborhood when speed limit signs are not provided. Considering the roadway characteristics and amount of pedestrian activity, a 25 mph speed limit is adequate.

5. Utility Design for Parcels

5.1 Private Sewer and Water System

For the private layout, the lots were designed to be larger to account for a private well and sanitary system to be installed on each lot. We got in contact with a local company out of Three Rivers who informed us that an 80ft well would be sufficient for the area and they provided us with a quote to install.

The private sanitary system was designed in order to get an accurate estimate for each lot. The system was made to hold up to a 5-bedroom house on the parcel. The system included all necessary items in order to be functional including the septic tank, distribution box, and all the pieces required for the drainage field. See section 7.4 for a further breakdown of the private sanitary system.

5.2 Public Sewer and Water System

In order to connect the houses in this neighborhood to public water and sanitary systems, the Village of Paw Paw systems must be extended from the eastern village limits to our site. This includes approximately one-mile extension for each. Once this has been completed, the systems will flow through the neighborhood as shown in figure # in appendix A. This includes water on the west side of the road in blue and sanitary on the east side in pink. The larger blue circles are fire hydrants, with no house more than 500 ft away from a hydrant, while the smaller blue circles are gate valves for water shut off in case of breaks or maintenance. We also designed the water main to create a loop in order to hold better water pressure with minimal stubs, which is placed along a 12-foot easement to the north. The pink circles along the sanitary line are the placement

of sanitary manholes for access and maintenance, placed a maximum of 400 feet apart, and along lot lines whenever possible. Both of these systems are also placed to allow for eastern expansion in the future, as the water main is run across the road and capped on the east side and a sanitary manhole is placed to be easily tapped into, as shown in the figure 5.1.1. Basic calculations were performed for pipe sizing, along with some assumptions due to the lack of water system data from Paw Paw, to determine that we will design for 12-inch ductile iron water main and 10-inch PVC sanitary main. This is based off average household use for sanitary and required fire flow for water. Further details can be found in appendix G.

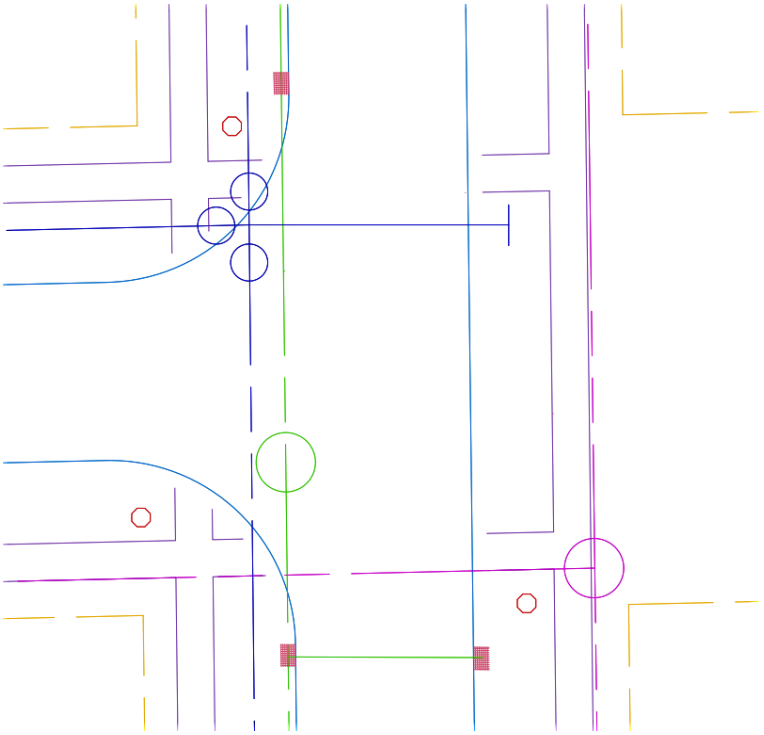

Figure 5.1.1 Utility Expansion Details

6. Storm Water

Antwerp Township is located within the Paw Paw River watershed as seen in Figure 6.1.1. Due to the site constraints, we are limited to constructing a retention pond to manage rainfall runoff. The storm water calculations found in Appendix F use the SCS Curve Number Method that was selected from the Van Buren County Drain Commissioner Site Development Rules. From the use of the SCS Method, storm hydrographs were produced by solving for the peak discharge rates (cfs) and the time-to-peak (hr) of a 24-hr, 100-yr rainfall event. Once these values were obtained, they were plugged into a storm hydrograph. The area highlighted in green, as shown in Figures 6.1.2 & 6.1.3, is the maximum amount of runoff that needs to be retained by the retention pond. The maximum retention pond volume varies between the public layout and private layout due to the change in impervious area across the 40-acre parcel. As noted previously, the private layout is designed for 43 houses while the public is designed for 116 houses.

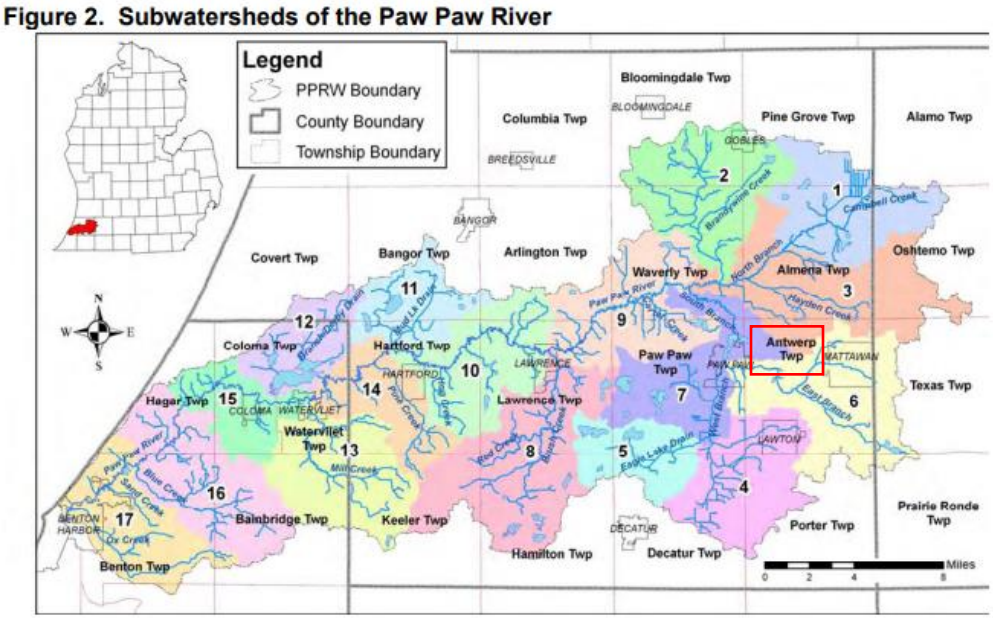

Figure 6.1.1 – Subwatersheds of the Paw Paw River

6.1 Retention Pond Design

Following the Van Buren County Drain Commissioner Site Development Rules (in Appendix E), the retention ponds were constrained to a max depth of 6 feet. Along with a 4:1 (H:V) ratio to allow for mowing up to the water's edge. It must be noted that well boring logs from around the 40-acre parcel were used in determining a soil grade of B. With the use of the storm hydrographs, a volume of 69,836 ft^3 was calculated for the private layout, and 80,336 ft^3 was calculated for the public layout. A truncated square pyramid was selected as the pond shape for the private layout. A truncated rectangular pyramid was selected as the pond shape for the public layout. The use of a truncated rectangular pyramid was needed to optimize the number of parcels and the roadway design in the public layout. These shapes ensure that the constraints above can be attained mathematically. Appendix F provides the calculations for both the private and public pond designs.

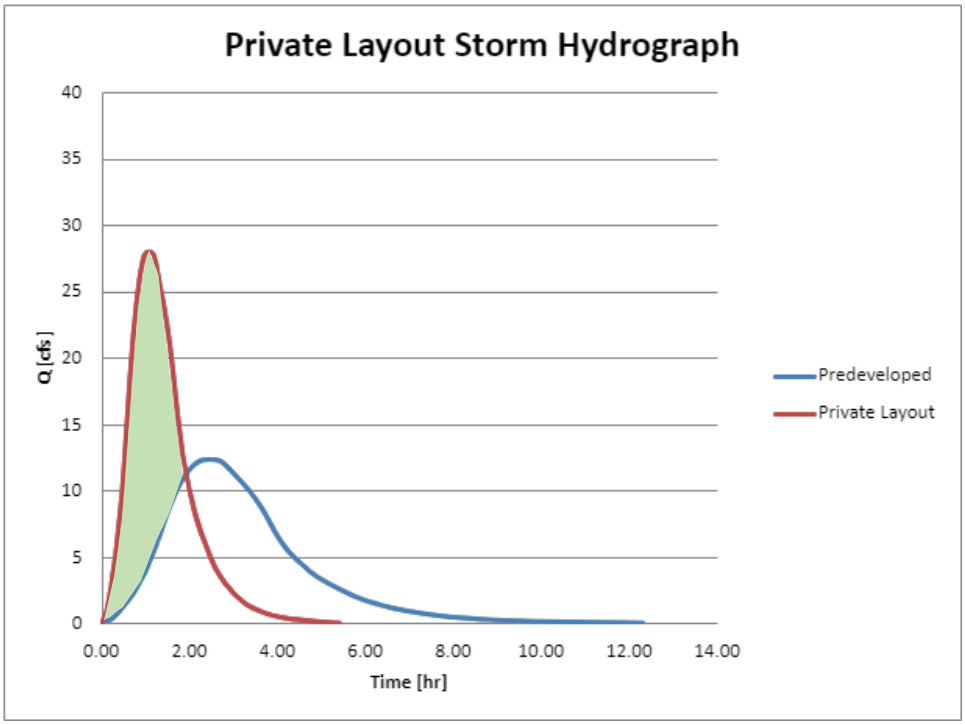

Figure 6.1.2 – Storm Hydrograph

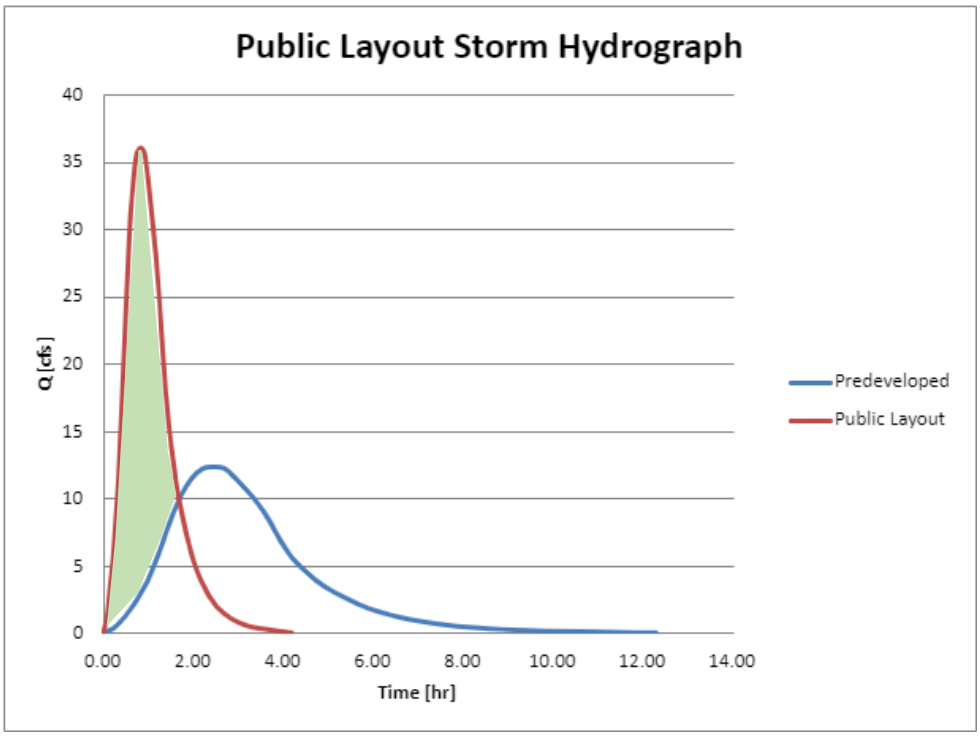

Figure 6.1.3 – Storm Hydrograph

6.2 Catch Basins

In total, there are 33 catch basins on both the private and public water and sewer layouts. The basins are located a maximum of 800 ft apart, a maximum continuous flow of 400 ft from a high point in the middle as required by the Van Buren County Engineering Standards. These are placed along the west side of the road along the main storm line, as well as with smaller structures on the east side of the road, connected by shallow structures and 24 ft pipes to the west structures. Catch basin spacing was also affected by the requirement of 300 ft maximum spacing between storm structures along the main line, some of which are manholes and some are catch basins.

6.3 Storm Pipe

From the storm water calculations in Appendix F, a peak runoff rate of 27.97 cfs for the private layout and 36.02 cfs for the public layout were obtained. These two values are essential in calculating the required storm inlet pipe into the retention pond. Due to current availability in the market, the use of rubber joint concrete piping was selected for ease of procurement. Manning's equation was used in Appendix F to obtain the inlet pipe sizing. The inlet pipe for the private layout was calculated at 21 inches in diameter. The inlet pipe for the public layout was calculated at 24 inches in diameter. Placement of the pipe throughout the neighborhood can be seen in the final drawings in Appendix A.

7. Cost Estimation

7.1 Earthwork Estimation

Table 7.1.1: Public Earthwork Estimation Summary

Public Earthwork Summary					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
015433204260	Rent Bulldozer, 200 HP (for Excavation)	1.3	Days	$1,957.27	$ 2,544.45
022113130800	Survey and Mark Property Lines	6334	L.F.	$ 1.37	$ 8,677.58
311313100400	Brush Clearing (Medium), 200 HP Bulldozer w/ Ball and Chain	40	Acres	$1,385.66	$ 55,426.40
				Total	**$ 66,648.43**

Table 7.1.2: Private Earthwork Estimation Summary

Private Earthwork Summary					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
015433204260	Rent Bulldozer, 200 HP (for Excavation)	1	Days	$1,957.27	$ 1,957.27
022113130800	Survey and Mark Property Lines	6334	L.F.	$ 1.37	$ 8,677.58
311313100400	Brush Clearing (Medium), 200 HP Bulldozer w/ Ball and Chain	40	Acres	$1,385.66	$ 55,426.40
				Total	**$ 66,061.25**

Summaries of the earthwork estimations for both the public and private layouts are shown in Table 7.1.1 and Table 7.1.2 above respectively. The earthwork costs discussed in this section are applicable for both the public and private lots. The overall price includes clearing brush, surveying and marking the perimeter of the property, and excavating the retention pond. All costs will be the same for both lots except for the excavation of the retention pond, as the sizing of the pond differs. To simplify this section, we assumed all permits have been paid for and approved already. Full reports for this section generated from RSMeans can be found in Table H.1 and Table H.2 in the appendix.

Due to the enormous cost to remove and replace the topsoil with material such as loam, we decided to avoid that cost. Using the boring log from the well data from Figure H.1 in the appendix, we determined that the sand/gravel that is currently on site is sufficient to build on if compacted. When compacted, sand/gravel holds together well and makes for a good soil to

support a foundation because of its non-water retaining properties, according to the foundation experts at Ramjack referenced below. In order to use this log, we assumed that the soil conditions on site have not changed significantly since the data was taken in 2005.

The only equipment that will be brought to site to complete this work is a 200 HP bulldozer. This will be used for both the site clearing and retention pond excavation. An equipment operator and a laborer will be required to run the bulldozer. The surveying crew will be using an electronic level and consist of a chief of party, an instrument man, and one rodman/chainman. All labor costs are included in the estimation.

Due to the lack of appropriate line items available in RSmeans, the cost for the retention pond excavation had to be calculated by hand using data from similar specs found in the appendix. See the supporting calculations below for our quantity inputs into those line items.

Retention Pond Estimation (Using the CAT D6 XE Track-Type Tractor)

Private Site Layout- Pond Volume = 2,587 yd^3

Public Site Layout- Pond Volume = 2,975 yd^3

Private Site Layout- Surface Area Covered = 131'x131' = 17,161 ft^2

Public Site Layout- Surface Area Covered = 170' x 90' = 15,300 ft^2

Blade Capacity = 7.5yd^3

Blade Width = 10.5ft

Travel Speed = 4mph

Turnaround time in between passes (assumed) = 60secs

Private

$$Passes\ Required = \frac{131ft}{10.5ft} = 12.48\ Passes \rightarrow 13\ Passes$$

$$\frac{Time}{Pass} = \frac{131ft}{5280ft} = .025miles$$

$$\frac{.025miles}{4mph} = .006hrs * \frac{3600secs}{HR} = \frac{21.82sec}{pass}$$

$$21.82sec + 60\,\text{sec}\ (for\ the\ turnaround\ time) \sim 82\frac{sec}{pass}$$

$$Assume\ machine\ uses\ full\ blade\ capacity\ and\ takes\ 7.5\frac{yd^3}{pass}$$

$$\frac{2587yd^3}{7.5\frac{yd^3}{pass}} = 345\ passes * 82\frac{sec}{pass} = 28{,}285\ secs = 7.86\ HRS \sim 8HRS = \mathbf{1\ day}$$

Private

$$Passes\ Required = \frac{90ft}{10.5ft} = 8.57\ Passes \rightarrow 9\ Passes$$

$$\frac{Time}{Pass} = \frac{170ft}{5280ft} = .032miles$$

$$\frac{.032miles}{4mph} = .008hrs * \frac{3600secs}{HR} = \frac{28.98sec}{pass}$$

$$28.98sec + 60\ \text{sec}\ (for\ the\ turnaround\ time) \sim 89\frac{sec}{pass}$$

$$Assume\ machine\ uses\ full\ blade\ capacity\ and\ takes\ 7.5\frac{yd^3}{pass}$$

$$\frac{2975yd^3}{7.5\frac{yd^3}{pass}} = 397\ passes * 89\frac{sec}{pass} = 35{,}303\ secs = 9.81\ HRS \sim \mathbf{1.3\ days}$$

7.2 Transportation Estimation

Table 7.2.1: Public Transportation Estimation Summary

Public Transportation Summary					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
015433203400	Rent Vibratory Roller, 125 HP	2	Day	$ 697.40	$ 1,394.80
022113130800	Survey and Stake Perimeter of Pavement	10666	L.F.	$ 1.37	$ 14,612.42
312216100100	Fine Grading Base Level	45050	S.Y.	$ 0.73	$ 32,886.50
320610100310	Cast in Place Sidewalks	53394	S.F.	$ 4.36	$ 232,797.84
321216140025	Asphalt Paving, 4" HMA	65833	S.F.	$ 2.96	$ 194,865.68
321216140030	Asphalt Paving, 5" HMA	65833	S.F.	$ 3.38	$ 222,515.54
321613130404	Cast in Place Curbs and Gutters	10666	L.F.	$ 12.66	$ 135,031.56
8037010	Streetscape Detectable Warning Surface	240	S.F.	$ 31.50	$ 7,560.00
8120216	Pavement Marking, Stop Bar	168	L.F.	$ 6.50	$ 1,092.00
				Total	**$ 842,756.34**

Table 7.2.2: Private Transportation Estimation Summary

Private Transportation Summary					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
015433203400	Rent Vibratory Roller, 125 HP	2	Day	$ 697.40	$ 1,394.80
022113130800	Survey and Stake Perimeter of Pavement	10250	L.F.	$ 1.37	$ 14,042.50
312216100100	Fine Grading Base Level	42331	S.Y.	$ 0.73	$ 30,901.63
320610100310	Cast in Place Sidewalks	51141	S.F.	$ 4.36	$ 222,974.76
321216140025	Asphalt Paving, 4" HMA	67368	S.F.	$ 2.96	$ 199,409.28
321216140030	Asphalt Paving, 5" HMA	67368	S.F.	$ 3.38	$ 227,703.84
321613130404	Cast in Place Curbs and Gutters	10250	L.F.	$ 12.66	$ 129,765.00
8037010	Streetscape Detectable Warning Surface	240	S.F.	$ 31.50	$ 7,560.00
8120216	Pavement Marking, Stop Bar	168	L.F.	$ 6.50	$ 1,092.00
				Total	**$ 834,843.81**

Summaries of the transportation estimates for both the public and private layouts are shown in Table 7.2.1 and Table 7.2.2 above respectively. The cost codes used for the estimation are the same for both layouts but with different quantities depending on the item. Twelve-digit line numbers reflect cost codes from RSMeans and eight-digit numbers are from MDOT's cost estimation sheets referenced below. Full reports for this section generated from RSMeans can be found in Table H.3 and Table H.4 in the appendix.

Numbers taken from our design on AutoCAD that will be used in some of our estimations in this section and that have been used as inputs into RSMeans are listed below:

- Public
    - Perimeter of the Asphalt = 10,666 ft
    - Area of the Asphalt = 131,666 ft^2 = 14,630 yd^2
    - Area of Right of Way = 405,453 ft^2 = 45,050 yd^2
    - Area of Sidewalks = 53,394 ft^2
- Private
    - Perimeter of the Asphalt = 10,250 ft
    - Area of the Asphalt = 134,736 ft^2 = 14,971 yd^2
    - Area of Right of Way = 380,979 ft^2 = 42,331 yd^2
    - Area of Sidewalks = 51,141 ft^2

Once again, RSMeans did not have an appropriate cost code to estimate the compaction of the base ground or the asphalt. In order to input the estimated cost to compact into RSMeans, we determined the estimated amount of days it would take to complete the work for both the soil and asphalt compaction using specs for similar machines found in Figure H.2 and Figure H.3 in the appendix respectively. Consulting with our project sponsor, we determined that the soil would only need to be compacted under the area of the pavement. The calculation for the soil compaction is shown below (note that five passes was determined by the experts from GX Contractors referenced below and shown in Figure H.4 of the appendix).

Soil Compacting Cost (Using the Dynapac CA250D)

$$Given: Speed = 10\frac{KM}{Hr} \sim 6mph = 31{,}680\frac{ft}{HR}, \qquad Drum\ Width = 2{,}130mm \sim 7ft,$$

$$Road\ Width = 24ft, \qquad Five\ Passes\ Required,$$

$$Road\ Length = 5291ft, \qquad Assume\ 60\ Seconds\ to\ Turnaround$$

$$Number\ of\ Rows\ Required = \frac{24ft}{7ft} = 3.43\ \rightarrow 4\ Rows\ Required$$

$$Total\ Feet\ to\ Cover = 5291\ ft * 4\ Rows * 5\ Passes = 105{,}820\ ft$$

$$Time\ to\ Cover\ Road = \frac{105{,}820ft}{31{,}680\frac{ft}{HR}} = 3.34\ HRS$$

$$Turnaround\ Time = 60\frac{Sec}{Turn} * 20\frac{Turns}{Road} * 4\ Roads = 4800\ \text{sec} = 1.33HRS$$

$$Total\ Time = 3.34\ HRS + 1.33\ HRS = 4.67\ HRS\ \rightarrow \mathbf{1\ Day}$$

The time for the soil compaction was rounded up to the nearest day to stay on the conservative side and to account for any errors that may have occurred in our estimation.

The estimated time to compact the asphalt is shown below.

Compacting Cost (Using the BOMAG BW190AD-4 HF)

$$Area\ of\ Asphalt\ to\ Compact = 14630\ yd^2$$

$$Area\ Coverage = 2{,}965\frac{yd^2}{HR}$$

$$\frac{14630\ yd^2}{2{,}695\frac{yd^2}{HR}} = 5.43\ HRS \sim \mathbf{1\ Day}$$

Once again, the time to compact the asphalt was rounded up to the nearest day for the same reasons as the soil compaction. Both the compactor for the soil and asphalt have the same amount of HP, and RSMeans did not have codes that differentiated a soil versus asphalt compactor, so we used the same line number for both items, totaling to a 2-day rental.

Reviewing the other costs included in Table 7.2.1 and Table 7.2.1, the costs to survey and stake as well as place the curb and gutters used the linear feet of the perimeter of the pavement. The fine grading cost covers the entire right away. The total surface area of the sidewalks on each lot are shown above, and the numbers shown in the tables are factoring in a thickness of 4 inches. The detectable warning surfaces were quoted from MDOT. Each one is 2ft x 5ft and there are 24 of them needed per lot equating to the 240 S.F. total shown above. The only pavement markings that were required are 2ft x 12ft stop bars. Using a cost code from MDOT, we determined that 168ft of 2ft stop bars are required for the fourteen stop signs per lot.

The last cost to discuss is the duplicate cost shown in the tables for asphalt paving. Referring to the transportation design in section 4, our team designed an HMA thickness of 4.5 inches. In order to utilize the line items provided by RSMeans, we put both the cost codes for 4- and 5-inch HMA in our estimation, then put half the area of the pavement in the quantity column to closely estimate the cost for 4.5 inches of HMA.

The equipment that will be brought to site includes two 125HP vibratory rollers (one for soil compaction and one for asphalt), a 30,000lb grader, and a 130HP asphalt paver, as well as the same survey crew described in section 7.1. The cost of labor for the appropriate size of a crew for each line item and piece of equipment is factored into the costs already.

7.3 Public Stormwater & Utilities Estimation

Table 7.3.1: Public Stormwater & Utilities Estimation Summary

Public Stormwater & Utilities					
Public Water					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
00000001	Fire Hydrant	6	Ea	$6,000.00	$ 36,000.00
00000002	12" Ductile Iron End Cap	3	Ea	$ 121.66	$ 364.98
00000009	1" Copper Water House Connections	8468	L.F.	$ 42.77	$ 362,176.36
00000014	Valve Assembly: 4" to 12" Gate Valve	17	Ea	$1,479.00	$ 25,143.00
312316136080	Excavating Trench	4668	B.C.Y.	$ 5.02	$ 23,433.36
312323131300	Backfill w/ Dozer	5688	L.C.Y.	$ 1.50	$ 8,532.00
331413158040	Water Piping Fitting, 90 degree, Ductile Iron, 12" Diameter	2	Ea	$ 790.38	$ 1,580.76
331413158240	Water Piping Fitting, Tee, Ductile Iron, 12" Diameter	3	Ea	$1,299.64	$ 3,898.92
8230166	Water Supply, Ductile Iron, 12" diameter	5111	L.F.	$ 98.88	$ 505,375.68
				Total	**$ 966,505.06**
Public Sanitary					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
00000003	Sanitary Sewer Manholes, 48" Diameter, 8' Deep	13	Ea	$6,060.00	$ 78,780.00
00000010	6" PVC Sewer House Connections	8468	L.F.	$ 57.03	$ 482,930.04
312316136352	Excavating Trench w/ Trench Box	8612	B.C.Y.	$ 8.16	$ 70,273.92
312323131300	Backfill w/ Dozer	100666	L.C.Y.	$ 0.16	$ 15,999.00
4027001	Public Sanitary, PVC Piping, 10" Diameter	4844	L.F.	$ 78.69	$ 381,174.36
				Total	**$ 1,029,157.32**
Public Storm System					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
00000008	Catch Basin, Drop Inlet 48", Precast, 12-24" Pipes	33	Ea	$8,745.00	$ 288,585.00
312316136352	Excavating Trench w/ Trench Box	9995	B.C.Y.	$ 8.16	$ 81,559.20
312323131300	Backfill w/ Dozer	11839	L.C.Y.	$ 1.50	$ 17,758.50
330561101110	Storm Manholes, 48" ID, 4' Deep	13	Ea	$1,289.90	$ 16,768.70
334211603960	Public Storm Piping, RCP, O-Ring, 24" Diameter	5622	L.F.	$ 78.08	$ 438,965.76
				Total	**$ 843,637.16**
Connection to Paw Paw's Water and Sanitary					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
00000001	Fire Hydrant	8	Ea	$6,000.00	$ 48,000.00
00000003	Sanitary Sewer Manholes, 48" Diameter, 8' Deep	12	Ea	$6,060.00	$ 72,720.00
00000014	Valve Assembly: 4" to 12" Gate Valve	11	Ea	$1,479.00	$ 16,269.00
312316131352	Excavating Trench w/ Trench Box	8444	B.C.Y	$ 9.09	$ 76,755.96
312316136080	Excavating Trench	4731	B.C.Y	$ 5.02	$ 23,749.62
312323131300	Backfill w/ Bulldozer	16224	L.C.Y	$ 1.50	$ 24,336.00
4027001	Public Sanitary, PVC Piping, 10" Diameter	4750	L.F.	$ 78.69	$ 373,777.50
8230166	Water Supply, Ductile Iron, 12" diameter	5109	L.F.	$ 98.88	$ 505,177.92
				Total	**$ 1,140,786.00**
Total Cost for Public Stormwater & Utilities =					**$ 3,980,085.54**

A summary of the public stormwater and utilities estimate is shown in Table 7.3.1 above. This estimate is separated into four different sections; public water, public sanitary, the public storm system, and connecting the water and sanitary lines to the village of Paw Paw. As previously stated, those utilities do not currently come to our site, so that connection will be the biggest cost difference between the public and private layout. Twelve digit line items were taken from RSMeans, seven digit items were taken from MDOT, and eight digit line items were taken from other sources that will be referenced in the appendix. Some items required an assumed inflation percentage of 3% per year. Full RSMeans estimate reports can be found in Tables H.5-8 in the appendix.

For public water, it was determined that a little over 5,000 ft of 12" pipe was needed on the lot using our design in AutoCAD. Following local ordinance stated in the sections above, we needed 6 fire hydrants (quoted from Longs Peak Water District cited in Figure H.6 in the appendix) and 17 gate valves (quoted from Fairfax County's 2022 Unit Price sheet shown in Figure H.7 in the appendix). The cost for 1" copper pipe connection was quoted from the City of Rockville's standard prices in 2010 and factored for inflation (see Figure H.8 in the appendix). The average length of the connection required was found to be 73 ft (33ft plus an additional 40ft for the minimum front yard setback). Lastly, three end caps, and two 90 degree and T-fittings were needed to complete the design. The water pipe's excavation and backfill cost was determined using a 5 ft depth and width for the entire site.

Our AutoCAD design determined that we needed just under 4,900 ft of 10" pipe for public sanitary, which will be set an average of 8ft deep on site with a 6ft wide trench. Design codes sited in previous sections determined the need for 13 sanitary manholes, which we estimated from the City of Rockville's standard prices in 2010 and factored for inflation as well

(see Figure H.8 in the appendix). The sanitary house connects were estimated using the same conclusions as the public water from the same figure.

Public storm pipe was assumed to be set at an 8ft average as well with a 6ft wide trench for 5,622 ft. Per local ordinance, 13 manholes and 33 catch basins were needed to complete the system. The catch basins were quoted from Fairfax County and shown in Figure H.9 in the appendix.

To determine the length of pipe needed to connect public water and sanitary lines to our site, our sponsor helped us locate the ends of both lines near the Paw Paw village limits. The ends of both those lines can be found in Figure H.10 and Figure H.11 in the appendix on a google maps snip. Once those were determined, we calculated the length of pipe needed to be about 5,100ft and 4,750ft of water and sanitary pipe respectively. See Figure H.12 and Figure H.13 in the appendix for proof of those calculations. The depths of those pipes were assumed to be the same as our on-site estimates. The other necessary items installed on the way to our site were estimated using the same codes and estimation sheets cited in this section above.

7.4 Private Stormwater & Utilities Estimation

Table 7.4.1: Private Stormwater & Utilities Estimation Summary

Private Stormwater & Utilities					
Private Storm System					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
00000008	Catch Basin, Drop Inlet 48", Precast, 12-24" Pipes	33	Ea	$8,745.00	$ 288,585.00
312316136352	Excavating Trench w/ Trench Box	9392	B.C.Y.	$ 8.16	$ 76,638.72
312323131300	Backfill w/ Bulldozer	11269	L.C.Y.	$ 1.50	$ 16,903.50
330561101110	Storm Manholes, 48" ID, 4' Deep	10	Ea	$1,289.90	$ 12,899.00
334211603970	Public Storm Piping, RCP, O-Ring, 21" Diameter	5283	L.F.	$ 68.06	$ 359,560.98
				Total	**$ 754,587.20**
Private Utilities System					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
00000007	Installation of an 80' Well	43	Ea	$8,000.00	$ 344,000.00
333413130060	1,500 Gallon Septic Tank, Precast Concrete	43	Ea	$1,805.36	$ 77,630.48
333413130910	Septic Tank, Concrete Riser, 24"x8"	43	Ea	$ 157.12	$ 6,756.16
333451102200	Drainage Field & Septic Tank, Excavation	4042	C.Y.	$ 11.08	$ 44,785.36
333451102600	Drainage Fill, Gravel Fill	2623	C.Y.	$ 37.51	$ 98,388.73
333451130015	Drainage Field Distribution Box, 5 Outlets	43	Ea	$ 116.45	$ 5,007.35
334116103000	Perforated Vitrified Clay Piping	7095	L.F.	$ 9.51	$ 67,473.45
				Total	**$ 644,041.53**
Total Cost for Private Stormwater & Utilities =					**$ 1,398,628.73**

A summary of the private stormwater and utilities estimate is shown in Table 7.4.1 above. This estimate is separated into two different sections being the private stormwater system and the private utilities. The installation of a private well and sanitary system for each lot will be the largest difference between the two layouts for this section. Twelve-digit line items were taken from RSMeans and eight-digit line items were taken from other sources that will be referenced in the appendix. Some items required an assumed inflation percentage of 3% per year. Full RSMeans estimate reports can be found in Table H.9 and Table H.10 in the appendix.

From an estimation standpoint, the public and private stormwater system does not differ at all, other than the use of 21in diameter pipe versus the 24in diameter pipe used in the public system. 5,283 LF of pipe was needed along with 10 manholes and 33 catch basins.

The cost to install an 80ft deep well on each lot was quoted from C&B Pump Service LLC located in Three Rivers Michigan. The private sanitary was designed for up to a 5-bedroom

home on each lot with the basis of design shown in Figure H.14 in the appendix. With a 5-bedroom home (citing Table H.11 in the appendix), the lot requires a minimum of a 1,500-gallon septic tank. The size of the concrete riser was selected based on the recommendation from Flohawks plumbing and septic cited in Figure H.15 in the appendix. The surface area of the drainage field was determined from Table H.12 in the appendix from the University of Nebraska. For a 5-bedroom home and a perc rate of 5-10mins based off the soil on our site, the required square footage of the drainage field is 825 ft^2. To find the amount of pipe needed, we designed the field to be 25ft x 33ft, exactly hitting the required square footage.

We decided to implement a 2ft depth to our drainage field based off the recommendation found in Figure H.16 in the appendix. Using this number, our cost to excavate is shown below:

$$C.Y\ to\ Excavate = \ Gravel\ to\ add\ per\ Lot = \ 825\ ft^2 * \ 2ft = 1650\ ft^3 \sim 61\ C.Y.$$

$$Assume\ septic\ tank\ is\ 5ft\ tall, needs\ to\ be\ buried\ 2\ ft\ deep, and\ is\ 12ft\ x\ 7ft$$

$$Septic\ Tank\ Excavation = \ 7ft * 9ft * 14ft = 882ft^3 \sim 33\ C.Y\ per\ Lot$$

$$Total\ Excavation\ per\ Lot = \ 61\ C.Y. + 33\ C.Y. = 94\ C.Y.$$

Finally, for a distribution box with 5 outlets, for perforated pipe to go the full length of the plot on average, there is 165 L.F. of pipe per lot required.

Adding this all together, for one lot to have a well, 1,500 gallon septic tank, a concrete riser, a 5 outlet distribution box, 94 C.Y. of excavation, 61 C.Y. of gravel fill, and 165 L.F. of perforated clay drain pipe, the total cost per lot comes to a total of $14,977.71.

7.5 Miscellaneous Cost Estimation

Table 7.5.1: Public Miscellaneous Estimation Summary

Public Miscellaneous					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
00000011	Stop Sign	14	Ea	$ 375.00	$ 5,250.00
00000012	Speed Limit Sign	2	Ea	$ 400.00	$ 800.00
00000013	Street Sign	12	Ea	$ 295.00	$ 3,540.00
323113150100	Chain Link Fence, 6' high (for pond)	525	L.F.	$ 17.45	$ 9,161.25
329333100300	Blue Cedar Evergreen Trees	31	Ea	$ 331.60	$ 10,279.60
329343200300	Ornamental Birch Tress	32	Ea	$ 208.76	$ 6,680.32
329343200800	Elm Trees	32	Ea	$ 529.84	$ 16,954.88
329343202800	Canopy Willow Trees	31	Ea	$ 208.76	$ 6,471.56
				Total	**$ 59,137.61**

Table 7.5.2: Private Miscellaneous Estimation Summary

Private Miscellaneous					
Line Number	Description	Quantity	Unit	Unit Price	Price w/ O&P
00000011	Stop Sign	14	Ea	$ 375.00	$ 5,250.00
00000012	Speed Limit Sign	2	Ea	$ 400.00	$ 800.00
00000013	Street Sign	12	Ea	$ 295.00	$ 3,540.00
323113150100	Chain Link Fence, 6' high (for pond)	529	L.F.	$ 17.45	$ 9,231.05
329333100300	Blue Cedar Evergreen Trees	13	Ea	$ 331.60	$ 4,310.80
329343200300	Ornamental Birch Tress	13	Ea	$ 208.76	$ 2,713.88
329343200800	Elm Trees	14	Ea	$ 529.84	$ 7,417.76
329343202800	Canopy Willow Trees	13	Ea	$ 208.76	$ 2,713.88
				Total	**$ 35,977.37**

Summaries of the miscellaneous estimates for both the public and private layouts are shown in Table 7.5.1 and Table 7.5.2 above. The cost codes used for the estimation are the same for both layouts but with different quantities depending on the item. Once again, twelve-digit line numbers reflect cost codes from RSMeans and eight-digit numbers are from other sources referenced below. Full reports for this section generated from RSMeans can be found in Table H.13 and Table H.14 in the appendix.

The L.F. of the retention pond fence was taken from our design in AutoCAD and differ only slightly between layouts. Estimations for the signs were taken from trafficsigns.us referenced below. Using Figure H.17 in the appendix, the calculations for our sign estimates are shown below:

$$Stop\ Sign = \$125\ (Sign) + \$100\ (Post) + \$150\ (Foundation) = \$375\ per\ Sign$$

$$Speed\ Limit\ Sign = \frac{(24x30)in^2}{144} = 5ft^2 * \frac{\$36}{ft^2} = \$150\ Sign$$

$$Speed\ Limit\ Sign = \$150\ (Sign) + \$100\ (Post) + \$150\ (Foundation) = \$400\ per\ Sign$$

$$Street\ Sign = \frac{(6x36)in^2}{144} = 1.5ft^2 * \frac{\$30}{ft^2} = \$45\ Sign$$

$$Speed\ Limit\ Sign = \$45\ (Sign) + \$100\ (Post) + \$150\ (Foundation) = \$295\ per\ Sign$$

Four different types of trees were required on each lot per the local ordinance described in section 9 of the report. The types of trees selected include Blue Cedar Evergreen, Ornamental Birch, Elm, and Canopy Willow Trees. The cost for the public layout is greater than the private's estimate due to the more trees required with the more parcels on the public layout.

8. Analysis of Alternatives

Table 8.1: Total Public & Private Estimation Summary

	Public	Private
Earthwork	$ 66,648.43	$ 66,061.25
Transportation	$ 842,756.34	$ 834,843.81
Stormwater/Utilities	$ 3,980,085.54	$ 1,398,628.73
Miscellaneous	$ 59,137.61	$ 35,977.37
Total	**$ 4,948,627.92**	**$ 2,335,511.16**

Table 8.2 Breakdown of the estimate into cost per parcel

	Total Cost	Number of Parcels	Average Parcel Size	Cost Per Parcel
Public Layout	$ 4,948,628	116	0.25 Acres	$ 42,661
Private Layout	$ 2,335,511	43	0.75 Acres	$ 54,314

Though the private layout appears to be the obvious choice to make given that it is less than half the cost of the public layout, Table 8.2 above factors in the amount of parcels we are able to create in each layout. Looking at this, we can see that the average cost per parcel is about $12,000 less than the private lot.

Table 8.3 Decision matrix

	Public	Private	Weight	Weighted Public	Weighted Private
Cost Per Parcel	4	3	50%	2	1.5
Constructability	2	4	20%	0.4	0.8
Potential for Expansion	5	3	20%	1	0.6
Sustainability	3	3	10%	0.3	0.3
Total				**3.7**	**3.2**

Shown in Table 8.3, our decision matrix scores each item in the far-left column on a scale of 1 to 5. Each item is weighted based on the needs of our developer. The cost per parcel was given a weight of 50% as this was the main reason for our analysis. Both the constructability and potential for expansion were given a weight of 20% as these both pertain to the future needs of our developer. Sustainability rounds out the rest of the weight at 10%, as with any good design, this is a crucial thing to consider.

The cost per parcel's scores are based on the numbers totaled in Table 8.2. For constructability, the scores were based on the theoretical difficulty of construction for both layouts, with the major factor being the mile-long construction required on Red Arrow Hwy for the public lot. Two items were considered for the potential for expansion scores. First the public layout allowed for two access points to the neighboring 100-acre lot while the private only allowed for one. Most importantly, in the event that the developer decided for another public layout on the 100-acre lot, the cost for this would be minimal per parcel compared to the public layout for this project since the utility lines would already be right next door. This would also be

cheaper compared to a future private layout on the 100-acre lot per parcel. Finally, both the public and private layout received equal scores for sustainability. They both meet the current needs of the area while in their own unique ways (described in section 9) do not prevent the needs of future generations to be met.

Adding up all the scores and factoring the weights allocated, we get our final engineering design recommendation being the Public Layout.

9. Elements of Sustainability

As engineers, we have an ethical obligation to include elements of sustainability in all our designs. According to ASCE Cannon 1, “engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties”. Therefore, elements of sustainability have been considered and designed for in both site layouts. First, we considered the potential for future expansion to the east of the parcel. This will minimize future demolition and material waste as we have left open land within the right of way for expansion. This undeveloped land will remain green space until further expansion is necessary.

The Antwerp Township Zoning Ordinance specifies location and minimum requirements for plants within the right if way and on the properties. Important zoning ordinance references are found in Appendix A. Following the requirements of section 12.1.F of the Antwerp Township Zoning Ordinance we have added a canopy tree between the right of way and street on each parcel. According to section 12.1.E we cannot plant more than 30% of the same species of trees or shrubs on the development. Following Table 12-7 of the Antwerp Township Zoning Ordinance, we have used a variety of trees at the specified minimum calipers and heights. Each tree has been drawn into the site layout with a caliper of 5ft for better visualization on the AutoCAD drawing but should follow the table when installed by the developer.

Table 9.1 Minimum Plant Size at Installation

Table 12-7 Minimum plant size at installation			
Plant Material	**Minimum Caliper Size**	**Minimum Height**	**Minimum Spread**
Canopy Tree	2.5 inches		
Ornamental Tree	2 inches		
Evergreen Tree		6 feet	
Shrubs			24 inches

Along with the addition of trees and shrubs along the right of way, we have added trees into the design surrounding the retention pond based on section 12.1.J of the Antwerp Township Zoning Ordinance. For the sidewalks, roadways, and driveway, we suggested using recycled concrete aggregate for the subbases. By using recycled aggregate, the amount of concrete being landfilled is greatly reduced. This also helps to reduce the economic impact of the project. Lastly, we have designed for rolled curbs which minimizes the amount of demolition needed when driveways are added.

10.0 Summary and Conclusions

Two proposed layouts for a 40-acre parcel of land in Antwerp Township have been designed. Leaving access points on each layout for the possibility of future expansion was suggested and applied. The public utilities layout was designed for 116 parcels whereas the private layout was designed for 43 parcels. Each layout includes two cul-de-sacs, a retention pond, and two through streets. Following roadway and zoning requirements, the layout was created. Water resources was used to design a retention pond for each layout and storm pipe sizing for the public layout. Lastly, cost estimates were created to better determine which alternative would maximize profits to the owner. In analyzing our alternatives, we have concluded that the public utilities layout would yield the greatest profit to the developer.

References

- Antwerp Township Zoning Ordinance
- https://antwerptownship.com/wp-content/uploads/2019/09/Antwerp-ZO-amended-8-13-19.pdf
- https://cbpumpservice.com/
- https://www.epa.gov/septic/types-septic-systems
- https://www.fairfaxcounty.gov/landdevelopment/sites/landdevelopment/files/assets/documents/pdf/publications/unit-price-schedule.pdf
- https://flohawks.com/septic-tank-risers-pros-and-cons/#:~:text=Typically%2C%20risers%20are%208%20to,the%20opening%20of%20the%20riser.
- Manual of Uniform Traffic Control Devices
- https://mutcd.fhwa.dot.gov/
- MDOT Rainfall Intensity Report
- https://www.michigan.gov/documents/MDOT_MS4_Final_Report_Rainfall_Intensity_91935_7.pdf
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- A Policy on Geometric Design of Highways and Streets, 6th Edition
- Regrid
- https://regrid.com/

- Ten States Standards
- https://www.health.state.mn.us/communities/environment/water/docs/tenstates/tenstatestan2014.pdf
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- http://www.trafficsign.us/signcost.html
- https://inspectapedia.com/septic/Septic_Tank_Size_Tables.php
- Van Buren County Drain Commissioner
- https://water.unl.edu/article/wastewater/drainfield-size-design
- Project No (vanburencountymi.gov)
- Different soils and how they affect foundations
- https://www.ramjack.com/about/news-events/2015/august/different-soils-how-they-affect-foundations/#:~:text=Loam%20is%20a%20good%20soil,of%20their%20stability%20and%20depth.
- MDOT Traffic Sign Design, Placement, and Application Guidelines

Appendix A: Final Layout Drawings

Appendix B: Zoning and City Ordinances

9. The required plants shall be distributed throughout the buffer area. Plants may be arranged formally, or may be planted for a more random, natural effect.

10. Buffer Alternatives.

    a. Berms may be constructed in the buffer area, subject to Planning Commission approval. Where a berm, at least three feet in height, is constructed for at least 85 percent of the length of the buffer, the minimum planting requirements may be reduced by 50 percent.

    b. As an alternative, a screen wall six feet in height may be allowed in the buffer area, subject to Planning Commission approval. Screen walls shall be architectural block, brick, wood, or poured concrete that has an applied textured pattern. No other type of fence or wall can be used to meet this requirement. If a screen wall is utilized, the landscape requirements may be reduced by 75 percent.

E. Minimum plant requirements

1. Unless site conditions require otherwise, no more than 30 percent of the total trees or shrubs used on a site shall be of a single species.

2. The minimum plant size at the time of installation shall comply with Table 12-7:

Table 12-7 Minimum plant size at installation

Plant Material	Minimum Caliper Size	Minimum Height	Minimum Spread
Canopy Tree	2.5 inches		
Ornamental Tree	2 inches		
Evergreen Tree		6 feet	
Shrubs			24 inches

3. Existing healthy and desirable trees to be preserved may satisfy the landscaping regulations of this Section as shown in Table 12-8. Each credit may be applied toward fulfilling the requirements set forth in this Section (i.e., 1 credit equates to 1 equivalent tree).

Table 12-8 Credit for existing landscaping

Tree Material	Minimum Caliper	Minimum Height	Credits
Canopy Tree	4 to 8 inches		1
	Greater than 8 inches		2
Ornamental Tree		6 to 10 feet	1
		Greater than 10 feet	2
Evergreen Tree		6 to 12 feet	1
		Greater than 12 feet	2

F. Residential development.

1. In all residential subdivisions, land divisions, and site condominiums, a minimum of one canopy tree shall be planted per dwelling unit, between the right-of-way and the street and shall be spaced evenly, except where site conditions warrant greater or lesser spacing.

2. In all multi-family developments, a minimum of one canopy tree per 4,500 square feet of gross lot area and one shrub per 1,000 square feet of gross lot area shall

Figure B1 Zoning Ordinance Vegetation Requirements

i. All landscaped islands and peninsulas shall be protected by raised curbs; dub-downs are permitted to facilitate drainage and irrigation.

ii. Islands or peninsulas may be combined to provide an expanded planting area.

iii. Trees shall be planted at least three feet from the edge of the curb or pavement to avoid contact with vehicles.

iv. Landscape islands and peninsulas shall conform to the requirements of Table 12-9:

Table 12-9 Parking Lot Island and Peninsula Landscaping Requirements	
Minimum Size	150 square feet; 75 square feet if irrigated
Minimum Width	9 feet
Required Depth	2 feet shorter than adjacent parking space
Required Radii	Minimum 10 feet at ends facing main circulation aisles, minimum 1 foot for others

3. Landscaping shall be arranged so as not to obscure traffic signs or fire hydrants, or obstruct drivers' sight distance within the parking lot and at driveway entrances, in accordance with Section 3.12.

I. Outdoor storage areas. When permitted, outdoor storage areas shall be screened by buildings and by a continuous landscaped buffer at least 10 feet wide, measured perpendicular to the outdoor storage area. This buffer area shall contain:

1. A screen wall or fence at least six feet in height, along with any combination of the following, in numbers sufficient to provide an effective screen, as approved by the Planning Commission:
   a. Berms
   b. Canopy, evergreen and ornamental trees
   c. Shrubs
2. If the property is adjacent to land in another district and a buffer is required according to Section 12.1.D above, that buffer shall be considered to meet the requirements of this Subsection, provided that the screen wall or fence required above is constructed.

J. Detention and retention ponds. Detention and retention ponds shall be landscaped and graded in the following manner:

1. Plantings shall be non-invasive, hardy, and suitable for the EPA Southern Michigan/Northern Indiana Drift Plains Eco-Region.
2. Planting and landscape design for detention and retention ponds shall comply with best practices outlined in the *Low Impact Development Manual for Michigan and the Michigan Nonpoint Source Best Management Practices Manual*, as amended. Native plants and vegetation are encouraged
3. Ponds shall be designed to not require fencing whenever possible by utilizing a gradual slope not to exceed 5:1. If fencing is unavoidable the use of ornamental fencing shall be used with appropriate landscaping to provide attractive views to the pond.
4. To the extent possible, pond configuration shall be incorporated into the natural topography of the site and shall not be permitted in the front yard. Where these requirements are not practical, the pond shall be

Figure B2 Zoning Ordinance Vegetation Requirements Continued

shaped to emulate a natural formed 'free form' depression and shall be part of the natural landscape and open space system of the site.

5. The edge of the pond shall consist of sculptured landforms to filter and soften views of the pond.
6. Plantings shall replicate a natural environment. Trees and shrubs shall be clustered around the basin and contain a variety of plant material.
7. Trees must be planted above the freeboard line of the pond. Shrubs planted below the freeboard line of the pond must be tolerant of wet or moist soil conditions. The location of plant material shall consider the need to provide access for and minimize disruption of plant material during routine pond maintenance.

[Amended 4/10/18]

K. Screening

1. Screening shall be required in the following situations, except as may be provided elsewhere in this Section.
   a. Around all trash dumpsters in all Districts.
   b. Around any designated loading/unloading area.
2. Solid waste dumpsters may be located in buffers as required by this Section, provided that they are screened in accordance with this Subsection. The Planning Commission may require additional landscaping around the enclosure, depending upon its location within the buffer and its visibility from adjacent rights-of-way and adjacent properties. Loading/unloading areas may not be located within a required buffer.
3. Screening shall be required, even if the surrounding area or adjacent parcels are unimproved.
4. When any developed parcel changes to a more intense land use or a special land use or site plan approval is required, screening shall be provided in accordance with this Chapter.
5. Screening requirements.
   a. Unless otherwise permitted, in accordance with this Section, a required screen shall be comprised of a solid, sight-obscuring fence or wall meeting the following specifications:
      i. Six feet high.
      ii. Enclosed on all sides and not containing any openings other than a gate for access, which shall be closed at all times when not in use. However, this standard shall not apply to a screen around loading/unloading areas.
      iii. Constructed of masonry, treated wood, or other material approved by the Planning Commission if determined to be durable, weather resistant, rust proof, and easily maintained. Chain link and barbed wire fences are not permitted.
      iv. Gate openings shall be protected by bollards or other protection to prevent vehicles from damaging the enclosure. The Planning Commission may require bollards or other protection to be placed within a trash dumpster enclosure to protect it from being damaged by the trash receptacle.
   b. If approved by the Planning Commission, the required screen may be comprised of berms or plant material, in combination with or as a

Figure B3 Zoning Ordinance Vegetation Requirements Continued

Land Division Ordinance	3.2.E.1	The ratio of depth to width of any parcel created by the division, combination or boundary line adjustment shall not exceed a four to one ratio exclusive of road easement or road right-of-way
Land Division Ordinance	3.2.E.2	On a corner lot, as defined by the Zoning Ordinance, the depth to width ratio shall be determined according to the narrowest frontage
Land Division Ordinance	3.2.A	All parcels resulting from a land division or boundary line adjustment shall be required to have frontage on an improved public road under the jurisdiction of the VBCRC or an approved private road as described herein in order to be considered —accessible
Land Division Ordinance	5.7.C	Corner lots shall have extra width to permit required minimum front yard building setbacks from both streets.
Land Division Ordinance	5.9.12	Street trees of a variety and size in accordance with the standards adopted by the Township may be planted between the street curb and sidewalk. The location of street trees shall be approved by the Van Buren County Road Commission so as not to interfere with clear vision areas.
Zoning Ordinance	3.7.A	In all zoning districts, **no lot or parcel shall be created whose depth exceeds four times its width**, unless the parcel (whether it is the remaining parcel or not) is over 10 acres in area; unless it is approved according to the requirements of the Township Land Division and Subdivision Ordinance.
Zoning Ordinance	3.8	In the case of lots abutting cul-de-sac streets, the minimum required lot width shall be measured at the required front setback distance for buildings and structures. **Cul-de-sac lots shall have a minimum width of 40 feet at the front lot line**
Zoning Ordinance	3.24.D	Area Computation. The minimum area of the site condominium unit shall be equivalent to the minimum lot area and lot width requirements for the development district where the project is located. Areas within a public or private road right-of-way or equivalent easement or dedication shall not be included in the calculation of minimum condominium lot area or determination of dwelling density for a site.

Table B1 Parcel Layout Design Requirements

Land Division Ordinance	5.1.B.2	Local or minor streets: **Such streets shall be so arranged as to discourage their use by through traffic.**
Land Division Ordinance	5.1.B.3	**The arrangement of streets shall provide for the continuation of streets** from adjoining areas into new subdivisions, unless otherwise required by the Van Buren County Road Commission.
Land Division Ordinance	5.1.B.4	Where adjoining areas are not subdivided, the arrangement of streets in new subdivisions shall be extended to the boundary line of the tract to make provision for the future projection of streets into adjacent areas. Stub streets shall terminate within a temporary easement of adequate design to allow for temporary construction of a turnaround which can accommodate service and emergency vehicles.

Land Division Ordinance	5.1.B.5	**Subdivisions shall be designed so that there will be more than a single means of access to the lots therein**. This shall be accomplished through connection to streets in adjoining subdivisions; **providing stub streets for future extension i**nto subdivisions of adjacent property that can be reasonably expected to connect to the public street system; provision of an additional means of access for emergency vehicles only; or other means of providing more than one access
Land Division Ordinance	5.1.B.9	Cul-de-sac and dead-end streets: A dead-end street system with only one access to the public street system, including cul-de-sac streets, shall not be more than 600 feet in length cumulatively. **No individual cul-de-sac street shall be longer than 600 feet**, measured along the center line from the center point of the intersection at the beginning of the cul-de-sac street to the center point of the cul-de-sac.
Land Division Ordinance	5.1.C.2	Street gradients: a. Maximum Grades: Street grades shall not exceed five percent on either local streets or collector streets. b. Minimum Grades: No street grade shall be less than 0.5 percent.
Land Division Ordinance	5.1.C.3	Street alignment: a. Horizontal Alignment: When street lines deflect from each other by more than 10 degrees in alignment, the centerlines shall be connected by a curve with a minimum radius of 500 feet for arterial streets, 300 feet for collector streets and 150 feet for local or minor streets. Between reverse curves, on minor streets, there shall be a minimum tangent distance of 100 feet, and on collector and arterial streets, 200 feet. b. **Vertical Alignment**: Minimum sight distances shall be 200 feet for minor streets and 300 feet for collector streets, or the requirements of the VBCRC, whichever is more restrictive.
Land Division Ordinance	5.1.C.4	Cul-de-sac streets shall terminate with an adequate turnaround with a **minimum radius of 75 feet for right-of way and 50 feet for pavement**, or the requirements of the VBCRC, whichever is more restrictive.
Land Division Ordinance	5.2.A	Angle of intersection Streets shall intersect at 90 degrees or closely thereto and in no case at less than 80 degrees.
Land Division Ordinance	5.2.B	Sight triangles: Minimum clear sight distance at all minor street intersections shall meet VBCRC requirements.
Land Division Ordinance	5.2.C	Number of streets: No more than two streets shall cross at any one intersection.
Land Division Ordinance	5.2.D	T" intersections: Except on arterials and certain collector streets, "T" intersections shall be used where practical.
Land Division Ordinance	5.2.F	Paved and curbed approach. All new public and private road connections to existing paved public roads under the jurisdiction of the Township, VBCRC or Michigan Department of Transportation shall be paved and

		shall have curbs meeting the specifications of the agency with jurisdiction over the existing road.
Land Division Ordinance	5.3.B	Sidewalks: Sufficient rights-of-way shall be provided so that sidewalks may be installed on both sides of all streets.
Land Division Ordinance	5.6.A	Arrangements: A block shall be so designed as to provide two tiers of lots, except where lots back onto an arterial street, natural feature or subdivision boundary.
Land Division Ordinance	5.6.B	**Blocks shall not be less than 500 feet long**, measured from the centerlines of the intersecting streets.
		The **maximum length allowed for residential blocks shall be 1,320 feet**, measured from the centerlines of the intersecting streets.
Land Division Ordinance	5.6.C	
VBT Eng Standards	VII.A.1	Residential and industrial subdivision streets shall be surfaced with bituminous pavement or Portland cement concrete pavement, curbed with Portland cement concrete curb and gutter sections, and provided with enclosed storm drainage systems and shall be approved by the township Engineer.

Table B2 Road Design Requirements

VBT Eng Standards	III.A.1.d	Ten inch diameter mains are not allowed
VBT Eng Standards	III.A.1.e	Water mains shall be placed on the west side or north side of the road to the extent possible. Mains shall be placed according to the typical cross sections shown in Appendix B. The following is a summary of the spacing requirements: i. 60-foot wide right-of-way 8 feet inside right-of-way ii. 86-foot wide right-of-way 10 feet inside right-of-way iii. 120-foot wide right-of-way 22 feet inside right-of-way
VBT Eng Standards	III.A.1.g	Water mains in new developments shall be installed from boundary to boundary in abutting roads and interior streets. Water main stubs shall be provided to property lines at locations designated by the township engineer for future extension. Water main stubs shall terminate with a hydrant, followed by a gate valve in well
VBT Eng Standards	III.A.1.h	**Wherever possible water main shall be constructed outside of paved parking areas, streets, and drives**. Sand or other porous material approved by the township Engineer shall be required full depth of trenches that are within three feet of all streets, alleys, existing driveways and sidewalks, and all parking areas (public or private).
VBT Eng Standards	III.A.1.j	Provide six feet of minimum cover below proposed ground surface at water main location. Provide seven feet of minimum cover below proposed ground surface when proposed water main is within 32 feet of centerline on section line roads, or within 19 feet of centerline on 1/4 line roads.
VBT Eng Standards	III.A.1.p	A minimum of 18 inches of vertical clearance shall be provided between either the water main or service and any other underground utility as measured from outside of pipe to outside of pipe. In general, water mains should cross over top of sanitary sewer utilities.
VBT Eng Standards	III.A.1.q	A minimum of **ten feet of horizontal separation shall be provided between water mains and sanitary sewer lines, storm sewer lines, or other water mains**. This is measured from outside of pipe to outside of pipe and should be shown on the plans.
VBT Eng Standards	III.A.1.r	The maximum length of dead-end mains are as follows: i. **450 feet for 8-inch mains**. ii. 1,000 feet for 12-inch mains.
VBT Eng Standards	III.A.1.v	All public water mains must be located in an easement or public right-of-way. The easement descriptions shall include hydrants and extend a minimum of six feet beyond the hydrant on any lead. Standard easement forms are in Appendix A. **The minimum easement width shall be 12 feet for the permanent easement** and 20 feet for the construction easement. The submittal of the easement will be required prior to township scheduling a preconstruction meeting.
VBT Eng Standards	III.A.2.a.i	Gate valve spacing is regulated by providing the following provisions: i. **in the event of a breakage: a) No more than 24 single family units will lose service**

VBT Eng Standards	III.A.2.a.ii	No more than four valves shall have to be closed to isolate the break. Where possible, three valves should isolate the break.
VBT Eng Standards	III.A.2.a.iii	There shall be valves on tees feeding dead end mains.
VBT Eng Standards	III.A.2.a.iv	On line **valve spacing shall be a maximum of 800 feet** (500 feet in commercial and industrial zoned districts).
VBT Eng Standards	III.A.2.a.vi	Gate valves shall generally be placed near tees to isolate sections of mains as noted above.
VBT Eng Standards	III.A.2.b	Gate valves shall be located so they will not be in the sidewalk or in driveways
VBT Eng Standards	III.A.2.e	Valves in wells and hydrants shall be placed on all dead end mains for future extension.
VBT Eng Standards	III.A.3.d	Generally, hydrants are to be placed five feet behind the curb on the north side or west side of the road.
VBT Eng Standards	III.A.3.e	Hydrants are to be located at least ten feet from driveways.
VBT Eng Standards	III.A.3.g	Detached single and two-family dwelling unit buildings and buildings less than 5,000 square feet that have moderate to light fire loading: **Hydrants shall be placed so that no part of any buildings is more than 500 feet from a hydrant.** This distance shall be measured along the shortest feasible exterior route for laying fire hose.
VBT Eng Standards	IV.A.2.f	Sanitary sewers shall be placed on the east side or south side of the road to the extent possible. Sewers shall be placed according to the typical cross sections shown in Appendix B. The following is a summary of the spacing requirements: i. 60-foot wide right-of-way 2 feet outside right-of-way ii. 86-foot wide right-of-way 9 feet inside right-of-way iii. 120-foot wide right-of-way 12 feet inside right-of-way
VBT Eng Standards	IV.A.2.h	**Sewers shall be constructed outside of paved parking areas, streets, and drives wherever possible.**
VBT Eng Standards	IV.A.2.i	Stubs for future extensions shall be provided to the property lines at locations designated by the township Engineer.
VBT Eng Standards	IV.A.3.f	**Minimum size for public sanitary sewer shall be ten inches in diameter.**
VBT Eng Standards	IV.A.3.m	Unless otherwise approved, no sanitary sewer shall have less than six feet of cover. In general, sanitary sewers shall have a minimum of eight feet of cover below finished road surface grade.
VBT Eng Standards	IV.A.3.n	Unless otherwise approved, the top of any sanitary sewer shall be at least ten feet below finished grade elevation at the building setback line of each fronting property which the sewer is designed to serve.
VBT Eng Standards	IV.A.3.p	Sanitary sewers and services should cross other utilities, including storm sewer, water, gas, and electric, with a minimum of 18 inches of clearance measured from outside of pipe to outside of pipe.

VBT Eng Standards	IV.A.4.a	**Manholes shall generally be placed at maximum intervals of 400 feet** and at every change of grade, alignment, pipe size, and at each junction of sewers. Manholes must be placed in locations accessible by sewer cleaning equipment.
VBT Eng Standards	IV.A.4.c	Manholes shall not be located in drives or approaches.
VBT Eng Standards	IV.A.4.d	Generally, **manholes shall be located on lot lines.**
VBT Eng Standards	V.A.1.a	An underground drainage system will be required. All run-off generated on-site, and all run-off from off-site, must be accommodated for and discharged in a controlled manner.
VBT Eng Standards	V.A.1.b	In streets. Storm sewers shall be placed on the east side or south side of the road to the extent possible. Sewers shall be placed according to the typical cross sections shown in Appendix B. The following is a summary of the spacing requirements: i. 60-foot wide right-of-way 8 feet inside right-of-way ii. 86-foot wide right-of-way 16 feet inside right-of-way iii. 120-foot wide right-of-way 22 feet inside right-of-way
VBT Eng Standards	V.A.2.g	**The minimum size for storm sewer is 12 inches in diameter.**
VBT Eng Standards	V.A.2.h	The minimum cover for storm sewer shall be 2.5 feet. Cover should be at least four feet wherever possible.
VBT Eng Standards	V.A.3.a	The **maximum distance between manholes must not exceed 300 feet** for 36-inch diameter conduits and smaller, and 100 additional feet for every 1-foot of diameter for closed conduits over 36 inches in diameter. Maximum distance shall not exceed 500 feet.
VBT Eng Standards	V.A.3.b	All structures must be a minimum of four feet deep.
VBT Eng Standards	V.A.3.d	Manholes are to be located at: i. All changes in alignment. ii. Points where the size of the sewer changes. iii. Points where the grade of the sewer changes. iv. Junctions of sewer lines. v. Street intersections or other points where catch basins or inlets are to be connected.
VBT Eng Standards	V.A.3.e	All manholes shall be a minimum of 48 inches in diameter.
VBT Eng Standards	V.A.3.f	Catch basins are to be located as follows: i. All low points in gutters and swales. ii. Upstream of street intersections (at or ahead of the spring point of street returns where possible). **When drainage is required to go around a corner, a maximum distance of 150 feet between the high point and the corner catch basin is allowed. iii. Maximum intervals of 400 feet along a continuous slope**. iv. Upstream of driveways where possible. v. Generally, the flows to be accommodated shall not exceed the intake capacity of the cover. Catch basin cover capacities shall be determined by assuming a value of 0.011 cfs per square inch of opening.

VBT Eng Standards	V.A.3.g	Catch basins with an inlet pipe shall have a minimum diameter of 48 inches.

Table B3 Utility Design Requirements

<table>
<tr><td>Zoning Ordinance</td><td>12.1.E</td><td>Unless site conditions require otherwise, no more than 30 percent of the total trees or shrubs used on a site shall be of a single species.</td></tr>
<tr><td>Zoning Ordinance</td><td>12.1.E</td><td>
<table>
<tr><th colspan="4">Table 12-7 Minimum plant size at installation</th></tr>
<tr><th>Plant Material</th><th>Minimum Caliper Size</th><th>Minimum Height</th><th>Minimum Spread</th></tr>
<tr><td>Canopy Tree</td><td>2.5 inches</td><td></td><td></td></tr>
<tr><td>Ornamental Tree</td><td>2 inches</td><td></td><td></td></tr>
<tr><td>Evergreen Tree</td><td></td><td>6 feet</td><td></td></tr>
<tr><td>Shrubs</td><td></td><td></td><td>24 inches</td></tr>
</table>
</td></tr>
<tr><td>Zoning Ordinance</td><td>12.1.F</td><td>In all residential subdivisions, land divisions, and site condominiums, a minimum of one canopy tree shall be planted per dwelling unit, between the right-of-way and the street and shall be spaced evenly, except where site conditions warrant greater or lesser spacing.</td></tr>
<tr><td>Zoning Ordinance</td><td>12.1.J</td><td>Planting and landscape design for detention and retention ponds shall comply with best practices outlined in the Low Impact Development Manual for Michigan and the Michigan Nonpoint Source Best Management Practices Manual, as amended. Native plants and vegetation are encouraged</td></tr>
<tr><td rowspan="2">MDOT Traffic Sign Design, Placement, and Application Guidelines</td><td rowspan="2">Table 1</td><td>Stop Sign: 30 in by 30 in</td></tr>
<tr><td>Speed Limit: 24 in by 30 in</td></tr>
<tr><td>MDOT Traffic Sign Design, Placement, and Application Guidelines</td><td>Page 47</td><td>The 24-inch by 30-inch Speed Limit (R2-1) sign shall be used for all single lane roadways.</td></tr>
<tr><td>FHWA - MUTCD</td><td>Chapter 2A</td><td>The distance from the bottom edge of the sign to the surface of the sidewalk is shown as a dimension no less than 2.1 m (7 ft). The distance from the edge of the pavement to the near edge of the sign is shown as a dimension no less than 0.6 m (2 ft).</td></tr>
<tr><td>FHWA - MUTCD</td><td>Chapter 2A</td><td>The distance from the edge of the east-west road (the top of the T), at the point where the southeast corner radius meets the tangent section of the east-west roadway, to the sign is shown as a dimension of MAX. 15 m (50 ft). The distance from the edge of the north-south roadway to the nearest edge of the sign is shown as a dimension of MIN. 1.8 m (6 ft) to 3.7 m (12 ft).</td></tr>
<tr><td>VBT Eng Standards</td><td>VI.A.2</td><td>Maximum side slopes of retention ponds shall be one vertical to six horizontal. Anything greater shall require approval of the township Engineer and shall be fenced. When fencing is required by this article the proposed materials, gates and access shall be approved by the township Engineer. A 4-foot minimum height is required.</td></tr>
</table>

Table B4 Landscaping Design Requirements

Appendix C: Pavement Design

$$ESAL = (ADT_0)(T)(T_f)(G)(D)(L)(365)(Y)$$

in which:

ADT_0 = average daily traffic at the start of the design period

T = percentage of trucks in the ADT

T_f = truck factor, or the number of 18 kip ESALs per truck

G = traffic growth factor

D = directional distribution factor

L = lane distribution factor

Y = design period in years

Figure C1 Equivalent Single Axel Load Equation

Table C1 Reliability Levels

Table C-2. Suggested levels of reliability for various functional classifications (AASHTO, 1993).

Functional classification	Recommended level of reliability	
	Urban	Rural
Interstate and other freeways	85 - 99.9	80 - 99.9
Principal arterials	80 - 99	75 - 95
Collectors	80 - 95	75 - 95
Local	50 - 80	50 - 80

Table C2 Standard Normal Deviate

Table C-3. Standard normal deviates for various levels of reliability.

Reliability (%)	Standard normal deviate (Z_R)	Reliability (%)	Standard normal deviate (Z_R)
50	0.000	93	-1.476
60	-0.253	94	-1.555
70	-0.524	95	-1.645
75	-0.674	96	-1.751
80	-0.841	97	-1.881
85	-1.037	98	-2.054
90	-1.282	99	-2.327
91	-1.340	99.9	-3.090
92	-1.405	99.99	-3.750

The AASHTO design equations also require specification of the overall standard deviation S_0. For flexible pavements, values for S_0 typically range between 0.35 and 0.50, with a value of 0.45 commonly used for design.

Serviceability

Serviceability is quantified by the Present Serviceability Index, *PSI*. Although *PSI* theoretically ranges between 5 and 0, the actual range for real pavements is between about 4.5 to 1.5.

The initial serviceability index p_o corresponds to road conditions immediately after construction. A typical value of p_o for flexible pavements is 4.2. The terminal serviceability index p_t is defined as the lowest serviceability that will be tolerated before rehabilitation or reconstruction becomes necessary. A terminal serviceability index of 2.5 or higher is recommended for design of major highways. Thus, a typical allowable serviceability loss due to traffic for flexible pavements can be expressed as:

$$\Delta PSI = p_t - p_o = 4.2 - 2.5 = 1.7 \quad (C.5)$$

Table C3 Resilient Modulus for Types of Soil

Type of Soil	Subgrade Strength	K Value Range (pci) (Rigid Pavement)	Resilient Modulus MR, (psi) (Flexible Pavement	CBR
Silts and clays of high compressibility (liquid limit >= 50), natural density (not recommended for subgrades without treatment)	Very Low	50 - 100	1000 - 2700	3 or less
Fine grain soils in which silt and clay size particles predominate (low compressibility, liquid limit < 50)	Low	100 - 150	2700 - 4000	3 to 5.5
Poorly grades sands and soils that are predominately sandy with moderate amounts of silts and clays (well drained)	Medium	150 - 220	4000 - 5700	5.5 to 12
Gravely soils, well graded sands, and sand gravel mixtures relatively free of plastic fines	High	220 – 250+	>5700	>12

Table C4 Static k Value for Soil Types

AASHTO class	Soil description	USCS classification	Dry density (lb/ft^3)	CBR (%)	Static k value (psi/inch)
Coarse grained soils					
A-1-a, well graded	Gravel	GW, GP	125 - 140	60 - 80	300 - 450
A-1-a, poorly graded			120 - 130	35 - 60	300 - 400
A-1-b	Coarse sand	SW	110 - 130	20 - 40	200 - 400
A-3	Fine sand	SP	105 - 120	15 - 25	150 - 300
A-2 soils (granular materials with high fines)					
A-2-4, gravelly	Silty gravel	GM	130 - 145	40 - 80	300 - 500
A-2-5, gravelly	Silty sandy gravel				
A-2-4, sandy	Silty sand	SM	120 - 135	20 - 40	300 - 400
A-2-5, sandy	Silty gravelly sand				
A-2-6, gravelly	Clayey gravel	GC	120 - 140	20 - 40	200 - 450
A-2-7, gravelly	Clayey sandy gravel				
A-2-6, sandy	Clayey sand	SC	105 - 130	10 - 20	150 - 350
A-2-7, sandy	Clayey gravelly sand				
Fine grained soils					
A-4	Silt	ML, OL	90 - 105	4 - 8	25 - 165
	Silt/sand/gravel mix		100 - 125	5 - 15	40 - 220
A-5	Poorly graded silt	MH	80 - 100	4 - 8	25 - 190
A-6	Plastic clay	CL	100 - 125	5 - 15	25 - 225
A-7-5	Moderately plastic elastic clay	CL, OL	90 - 125	4 - 15	25 - 215
A-7-6	Highly plastic elastic clay	CH, OH	80 - 110	3 - 5	40 - 220

Approximate relationship of k to MR: $k=MR/19.4$

$$\log_{10}(W_{18}) = Z_R S_0 + 9.36 \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN + 1)^{5.19}}} + 2.32 \log_{10}(M_R) - 8.07$$

in which:

W_{18} = number of 18 kip equivalent single axle loads (ESALs)
Z_R = standard normal deviate (function of the design reliability level)
S_0 = overall standard deviation (function of overall design uncertainty)
ΔPSI = allowable serviceability loss at end of design life
M_R = subgrade resilient modulus
SN = structural number (a measure of required structural capacity)

Figure C2 AASHTO Required Structural Number Equation

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

- $SN = a_1d_1 + a_2d_2m_2 + \ldots + a_nd_nm_n$
  - Where
    - a = layer structural coeff.
    - d = layer thickness
    - m = layer drainage coeff.

- HMA Structural Coefficients (a)
  - HMA Top & Leveling Course = 0.42
  - HMA Base Course = 0.36
  - Cement Stabilized Base = 0.26
  - ASCRL = 0.30
  - Asphalt/Emulsion Stabilized Base = 0.20
  - Crush and Shaped HMA = 0.20
  - Rubblized Concrete = 0.18
  - Dense-Graded Aggregate Base = 0.14
  - Open-Graded Aggregate Base = 0.13
  - Sand Subbase = 0.10
- Drainage Coefficients (m)
  - All Layers = 1
  - 16" OGDC = 1.1

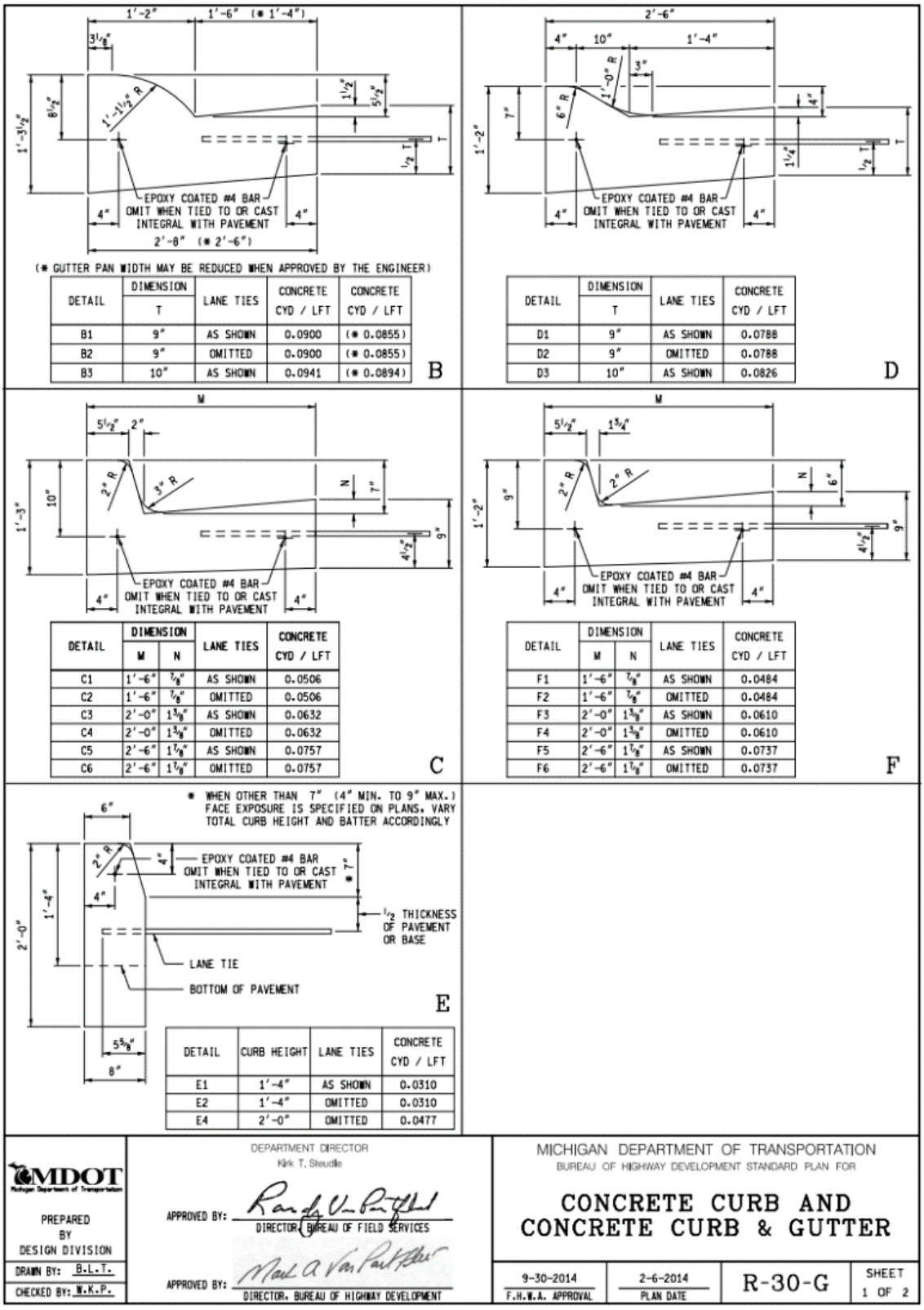
Figure C3 Design Structural Number Equations

Table C5 Required Structural Number Calculations for Public Utility Neighborhood

1. W18 [Accumulated ESALs]	2,822,634				
Z_r	-0.84	ZR			
Std Dev	0.45	S			
ΔPSI	1.70	DPSI			
2. Subgrade M[r]	7760	psi			
	Surface mix	Base mix	P.A.B.	subbase	
a[i]	0.42	0.36	0.18	0.11	
D[i], inches	2.00	2.50	6.00	12.00	inches
m[i]		1.00	1.00	1.00	
3. Reliability, %	80	R			
4. Initial and terminal serviceability	Po	Pt			
ΔPSI	4.20	2.50			
Provided SN	4.14				
Required SN (Solver will fill in)	**3.77**	Adequate			
log10(W18) =	6.45	left side			
	6.45	right side			
target cell	0.00				

Table C6 Required Structural Number Calculations for Private Utility Neighborhood

1. W18 [Accumulated ESALs]	1,046,346				
Z_r	-0.84	ZR			
Std Dev	0.45	S			
ΔPSI	1.70	DPSI			
2. Subgrade M[r]	7760	psi			
	Surface mix	Base mix	P.A.B.	subbase	
a[i]	0.42	0.36	0.18	0.11	
D[i], inches	2.00	2.50	6.00	12.00	inches
m[i]		1.00	1.00	1.00	
3. Reliability, %	80	R			
4. Initial and terminal serviceability	Po	Pt			
ΔPSI	4.20	2.50			
Provided SN	4.14				
Required SN (Solver will fill in)	**3.20**	Adequate			
log10(W18) =	6.02	left side			
	6.02	right side			
target cell	0.00				



DETAIL	DIMENSION T	LANE TIES	CONCRETE CYD / LFT	CONCRETE CYD / LFT
B1	9"	AS SHOWN	0.0900	(* 0.0855)
B2	9"	OMITTED	0.0900	(* 0.0855)
B3	10"	AS SHOWN	0.0941	(* 0.0894)

DETAIL	DIMENSION T	LANE TIES	CONCRETE CYD / LFT
D1	9"	AS SHOWN	0.0788
D2	9"	OMITTED	0.0788
D3	10"	AS SHOWN	0.0826

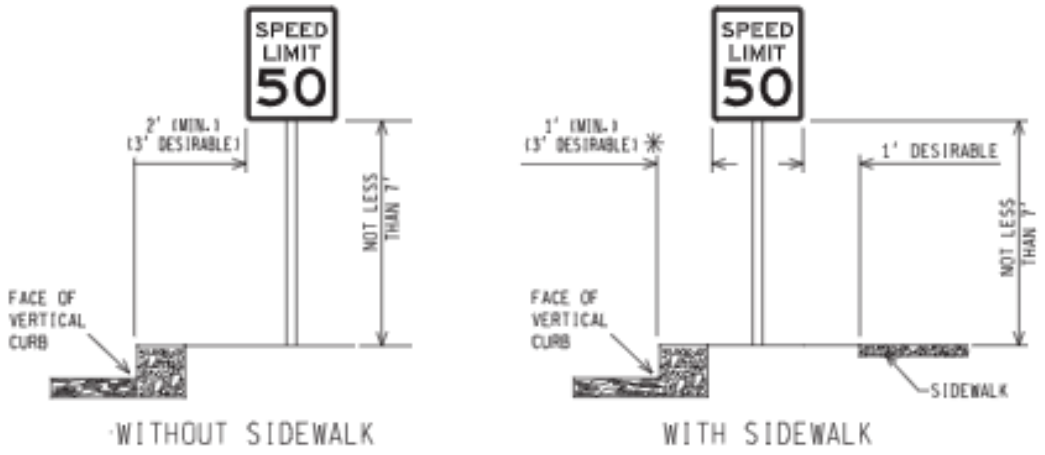
DETAIL	DIMENSION M	DIMENSION N	LANE TIES	CONCRETE CYD / LFT
C1	1'-6"	7/8"	AS SHOWN	0.0506
C2	1'-6"	7/8"	OMITTED	0.0506
C3	2'-0"	1 3/8"	AS SHOWN	0.0632
C4	2'-0"	1 3/8"	OMITTED	0.0632
C5	2'-6"	1 7/8"	AS SHOWN	0.0757
C6	2'-6"	1 7/8"	OMITTED	0.0757

DETAIL	DIMENSION M	DIMENSION N	LANE TIES	CONCRETE CYD / LFT
F1	1'-6"	7/8"	AS SHOWN	0.0484
F2	1'-6"	7/8"	OMITTED	0.0484
F3	2'-0"	1 3/8"	AS SHOWN	0.0610
F4	2'-0"	1 3/8"	OMITTED	0.0610
F5	2'-6"	1 7/8"	AS SHOWN	0.0737
F6	2'-6"	1 7/8"	OMITTED	0.0737

DETAIL	CURB HEIGHT	LANE TIES	CONCRETE CYD / LFT
E1	1'-4"	AS SHOWN	0.0310
E2	1'-4"	OMITTED	0.0310
E4	2'-0"	OMITTED	0.0477

Figure C4 Concrete Curb Dimensions

Appendix D: Pavement Markings, Signage, and ADA Requirments



✳WHEN DIRECTED BY THE ENGINEER, 1' IS PERMITTED IN AREAS WHERE SIDEWALK OR UTILITY POLES ARE CLOSE TO CURB PER MMUTCD.

NOTE: SLOPING CURBS SHOULD BE TREATED AS FLAT.

Figure D1 Speed Limit Sign Requirements

As an incentive to local road agencies to consider trailblazer signing, the department will furnish route markers with the necessary supplemental panels for initial installations, as well as for replacement signs needed in the future. Local officials will install and maintain trailblazer assemblies at locations they deem necessary.

SPEED LIMIT SIGNS

The 24-inch by 30-inch Speed Limit (R2-1) sign shall be used for all single lane roadways. For multi-lane roadways a 30 inch by 36-inch sign shall be used. This does not preclude the case of a 36 inch by 48-inch size sign when engineering judgment indicates the larger size is needed for effectiveness.

1. Statewide: Signs displaying the statewide speed limit should be located beyond major state trunkline highway junctions, at the end of reduced speed zones, and at state trunkline highway entrances to the state. If none of the above conditions are met, then signs should be placed at least every ten miles.

2. Reduced Speed Zones Determined by Traffic Control Order: The first speed limit sign shall be placed at the point of change from one speed limit to another or as near there as possible. Additional sign locations within a zone should include positions just beyond major streets or highways if practical.

RESERVED PARKING FOR PERSONS WITH DISABILTIES

A RESERVED PARKING for person with disabilities (R7-8) sign shall be used for each parking space reserved for use by disabled persons per Section MCL 257.674(S)."

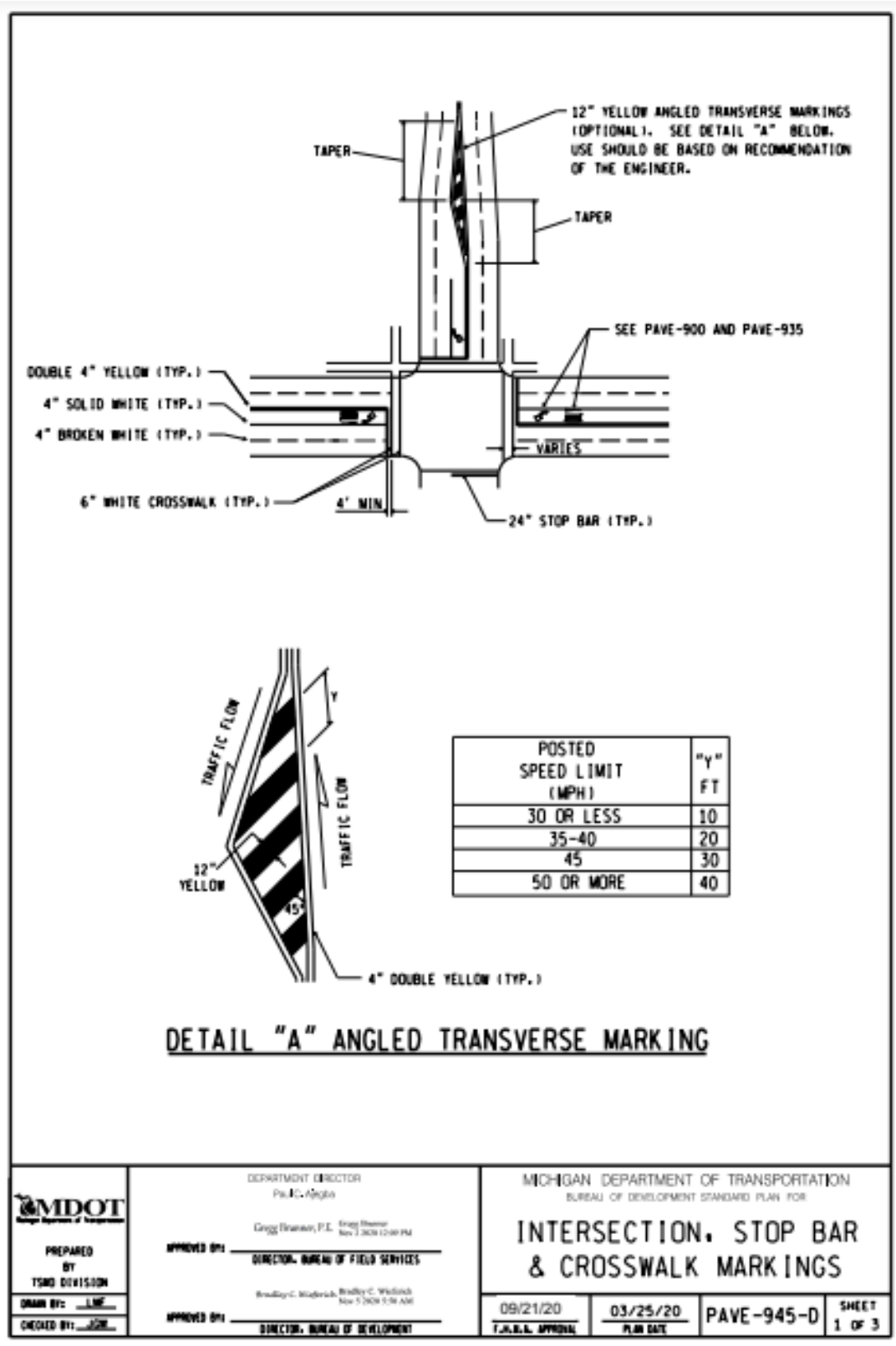
Where parking spaces that are reserved for persons with disabilities are designated to accommodate wheelchair vans, a VAN ACCESSIBLE (R7-8P) plaque shall be mounted below the R7-8 sign. The R7-8 sign shall have a green legend and border and a white wheelchair symbol on a blue square, all on a white background. The R7-8P plaque shall have a green legend and border on a white background.

STOP AHEAD AND SIGNAL AHEAD SIGNS

Unless noted otherwise within these guidelines, Stop Ahead signs should only be used when there is limited sight distance or significant crash history. A Stop Ahead sign should be a minimum of 36". The Stop Ahead and the stop sign it is being used with should be the same size.

Unless noted otherwise within these guidelines, Signal Ahead signs are to be used where there is limited sight distance, a significant crash history, or at the first signal approached when entering an urban area. Many existing Signal Ahead signs are obsolete because the urban area they are used for has expanded beyond the limits of the sign.

Figure D2 Speed Limit Sign Requirements Continued



POSTED SPEED LIMIT (MPH)	"Y" FT
30 OR LESS	10
35-40	20
45	30
50 OR MORE	40

Figure C3 Intersection Requirements

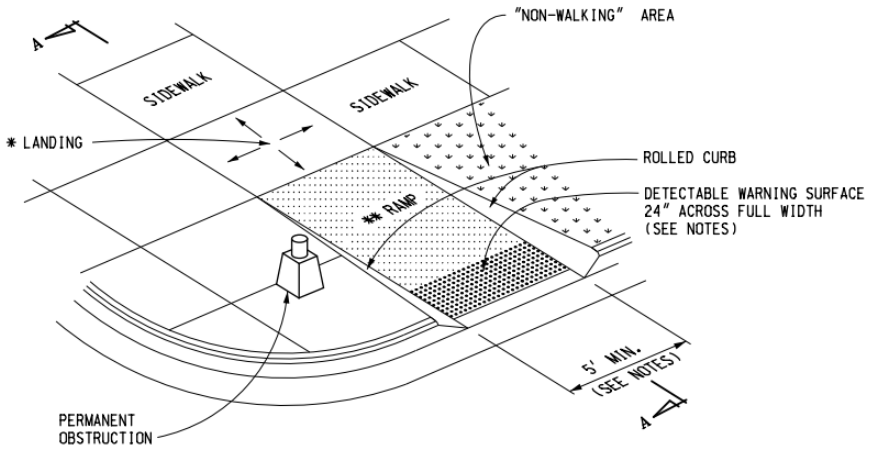


Figure C4 MDOT Curb Ramp Opening Requirement

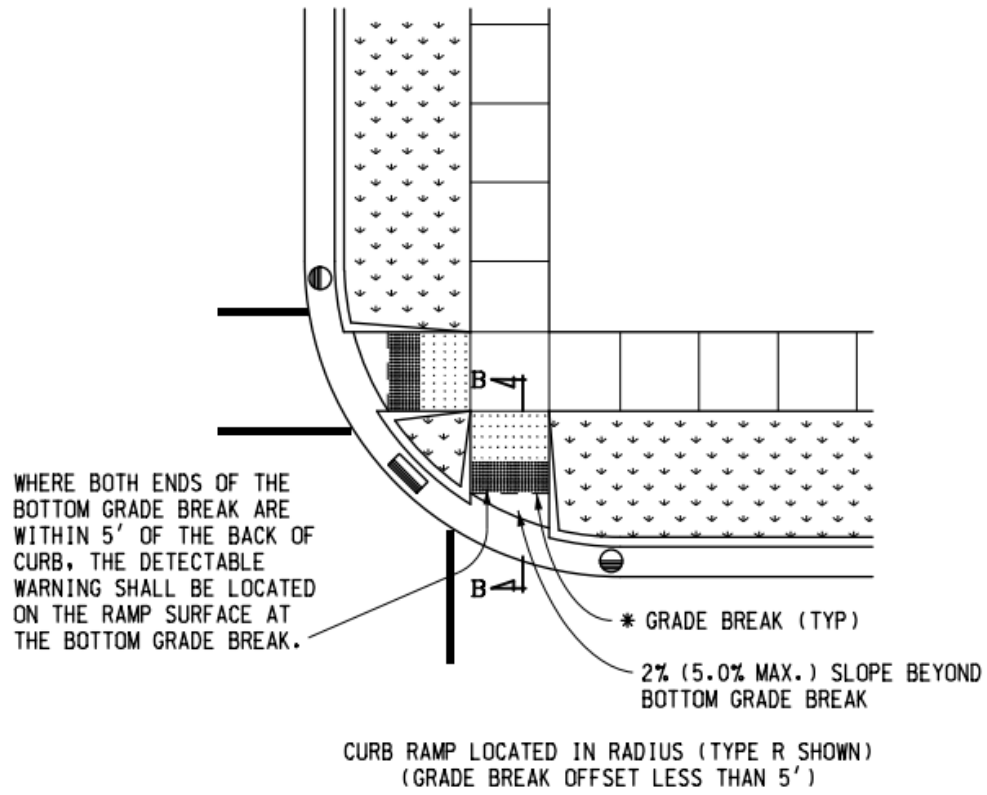
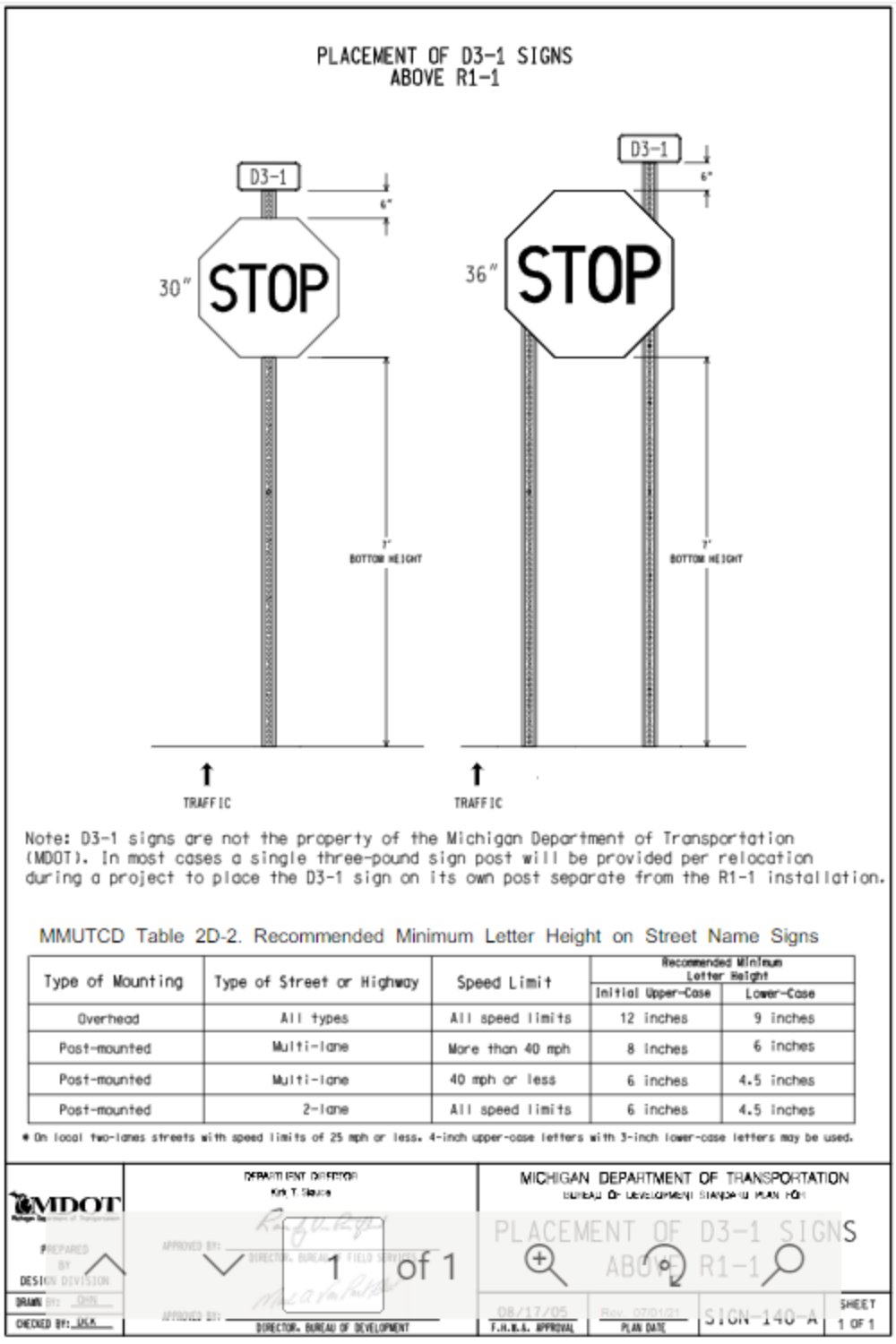


Figure C5 MDOT Curb Ramp Opening Requirement Continued



Note: D3-1 signs are not the property of the Michigan Department of Transportation (MDOT). In most cases a single three-pound sign post will be provided per relocation during a project to place the D3-1 sign on its own post separate from the R1-1 installation.

MMUTCD Table 2D-2. Recommended Minimum Letter Height on Street Name Signs

Type of Mounting	Type of Street or Highway	Speed Limit	Recommended Minimum Letter Height	
			Initial Upper-Case	Lower-Case
Overhead	All types	All speed limits	12 inches	9 inches
Post-mounted	Multi-lane	More than 40 mph	8 inches	6 inches
Post-mounted	Multi-lane	40 mph or less	6 inches	4.5 inches
Post-mounted	2-lane	All speed limits	6 inches	4.5 inches

* On local two-lanes streets with speed limits of 25 mph or less, 4-inch upper-case letters with 3-inch lower-case letters may be used.

MDOT
DEPARTMENT DIRECTOR
Kirk T. Steudle
MICHIGAN DEPARTMENT OF TRANSPORTATION
BUREAU OF DEVELOPMENT STANDARD PLAN NO.
PREPARED BY DESIGN DIVISION
APPROVED BY: DIRECTOR, BUREAU OF FIELD SERVICES
APPROVED BY: DIRECTOR, BUREAU OF DEVELOPMENT
1 of 1
PLACEMENT OF D3-1 SIGNS ABOVE R1-1
DRAWN BY: DMS
CHECKED BY: JSA
08/17/05 F.H.W.A. APPROVAL
Rev. 07/01/21 PLAN DATE
SIGN-140-A
SHEET 1 OF 1

Figure C6 Stop Sign Requirements

Appendix E: Stormwater Design Requirements

III. DESIGN PROCESS

The storm water site design process is summarized in the steps below. This process is intended to minimize negative impacts from development sites that could be avoided through proper planning.

A. Identify Sensitive Areas

Identify existing sensitive areas on the site plan that may require special consideration or pose a challenge for storm water management. For the purpose of these rules, sensitive areas include:

- Floodplains (and flood prone areas)
- Riparian areas
- Wetlands
- Rivers, streams and natural drainage ways
- Lakes and ponds
- Soils and topography (steep, erodible)
- Groundwater supplies (springs, wellhead protection areas)

Non-structural BMPs such as "Minimize Soil Compaction and Total Disturbed Area," Protect Natural Flow Pathways," Protect Sensitive Areas (including Riparian Buffers)," "Native Revegetation" and "Storm Water Disconnection" may be selected for use to reduce the amount of storm water controls necessary for the site.

B. Determine Standards

Adequate storm water runoff controls are required to reduce channel erosion, maintain groundwater recharge, prevent overbank flooding and meet pollutant removal goals. Storm water is managed onsite through all of the following standards:

- Stream Protection
- Flood Control
- Water Quality
- Pre-treatment

A summary of the minimum required storm water standards is provided in ***Table 1*** and shown graphically in ***Figure 1***.

Determine the storm water standards applicable to the site. A Storm Water Worksheet for individual sites is included as ***Worksheet 1*** located at the end of this section. A separate worksheet may be needed for each discharge location.

Figure E.1 Stormwater Design Standards

Table E.1 Storm Pipe Sizing Criteria

Standard	Applies	Sizing Criteria
Stream Protection	New and redevelopments that discharge to streams and rivers (directly, or through a storm sewer or ditch)	Retain the difference in 2-year pre-development and post-development runoff volumes onsite. **OR** Extended detention of the 1-year, 24-hour rainfall event for a period of 24 hours.
Flood Control	All new and redevelopments. May be waived for direct discharges to large lakes and rivers if no negative impacts, or if provided in a regional facility with adequate upstream infrastructure.	Retention or detention of the 25-year rainfall event with a maximum release rate of 0.13 cfs/acre. If retention of the total stream protection volume is provided, the maximum release rate may be increased to the pre-development 25-year peak rate. Identify overland flow routes and the extent of high water levels for the 100-year rainfall event to ensure no adverse impacts offsite or internal to the site.
Water Quality "first flush"	All new and redevelopments	Treat the first 0.5 inch of runoff from the directly connected impervious area. Provide minimum volume of 750 cubic feet per acre for directly connected disturbed pervious areas (i.e. lawns).
Pre-treatment	Detention basins Retention basins Infiltration practices Bioretention/rain garden Constructed filters Water quality swales	Sediment forebay: 30% of the water quality volume. **OR** Vegetated filter strips and vegetated swales meeting minimum length, slope and vegetated cover requirements. **OR** Water quality device

Figure 2 – County Watershed Map

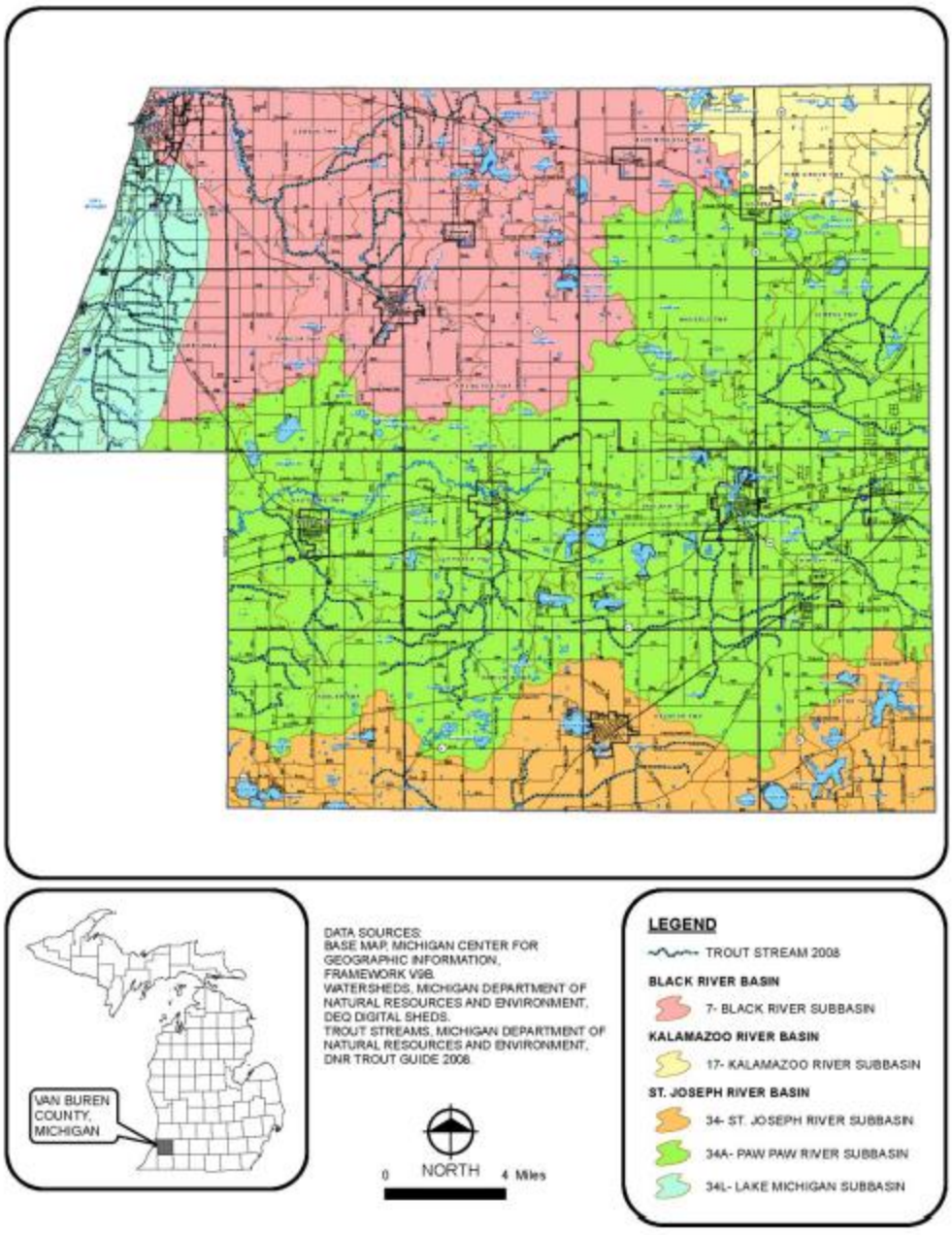


Figure E.2 County Watershed Map

PART 3:
STORM WATER DESIGN CRITERIA

I. SOILS INVESTIGATION

A. Qualifications

Soils investigation by a qualified geotechnical consultant is required for retention and detention basins, infiltration practices, bioretention / rain gardens, constructed filters, planter boxes and pervious pavement to determine the site soil infiltration characteristics and groundwater level. The geotechnical consultant shall be a professional engineer, soil scientist, or professional geologist.

B. Background Evaluation

An initial feasibility investigation shall be conducted to screen proposed BMP sites. The investigation involves review of the following resources:

- County Soil Survey prepared by the NRCS and USDA Hydrologic Soil Group (HSG) classifications.
- Existing soil borings, wells or geotechnical report on the site.
- Onsite septic percolation testing.
- Regional groundwater data (Michigan Groundwater Mapping Project website http://gwmap.rsgis.msu.edu/).
- Cyclical groundwater levels (http://waterdata.usgs.gov/mi/nwis/gw).

C. Test Pit / Soil Boring Requirements

A test pit (excavated hole) or soil boring shall be used for geotechnical investigation. Test pits may typically be selected for shallower investigations in locations where groundwater is sufficiently low. The minimum number of test pits or soil borings shall be determined from ***Table 4***.

Table 4 – Minimum Number of Soil Tests Required

Type of BMP	Test Pit / Soil Boring	Depth of Test Pit / Soil Boring	Field Permeability Test
Retention basins Infiltration beds Rain garden Pervious pavement	1 soil boring per 5,000 square feet of bottom area; 2 minimum	8 feet below proposed bottom	1 test per soil boring
Infiltration trench Bioswale	1 soil boring per 100 linear feet of BMP; 2 minimum	8 feet below proposed bottom	1 test per soil boring
Dry well Planter box	1 soil boring minimum	5 feet below proposed bottom	1 test per soil boring
Detention basins	1 soil boring per 10,000 square feet of bottom area; 1 minimum	5 feet below proposed bottom	Not Applicable

Figure E.3 Soils Stormwater Design Standards

F. Design Infiltration Rates

A conservative value for the infiltration rate is used in calculating the storage volume of infiltration BMPs due to the uncertanty that the soil will infiltrate at the design rate during the time the basin is filling. The maximum allowable soil infiltration rate used to size the storage volume of the BMP shall be 0.52 inches per hour, except that 1.04 inches per hour may be used where soil borings indicate sand or gravel free of any other soil seams.

Where field permeability testing is not performed, the design infiltration rates provided in ***Table 5*** shall be used to calculate the minimum infiltration area of the BMP necessary to drain in the allotted drawdown time.

Table 5 – Design Infiltration Rates by USDA Soil Texture Class

Soil Texture Class	Effective Water Capacity[1] (inches per inch)	Design Infiltration Rate[2] (inches per hour)	Hydrologic Soil Group[1]
Gravel	0.40	3.60	A
Sand	0.35	3.60	A
Loamy Sand	0.31	1.63	A
Sandy Loam	0.25	0.50	A
(Medium) Loam	0.19	0.24	B
Silty Loam / (Silt)	0.17	0.13	B
Sandy Clay Loam	0.14	0.11	C
Clay Loam	0.14	0.03	D
Silty Clay Loam	0.11	0.04	D
Sandy Clay	0.09	0.04	D
Silty Clay	0.09	0.07	D
Clay	0.08	0.07	D

[1]Source: Appendix D.13, Table D.13.1, *Maryland Stormwater Design Manual*, Maryland Department of Environment, 2000. (Rawls, Brakensiek and Saxton, 1982.)
[2]Source: Table 2, *Site Evaluation for Stormwater Infiltration (1002)*, Wisconsin Department of Natural Resources, Conservation Practice Standards, 2004. (Rawls, 1998.)

Infiltration is the process by which water on the ground surface enters the soil. *Infiltration rate* is a measure of the rate at which soil is able to absorb rainfall or irrigation in inches per hour. The rate decreases as the soil becomes saturated. The design infiltration rate assumes saturated conditions and closely approximates the *hydraulic conductivity* (typically given in feet per day) of the near-surface soil.

The *effective water capacity* of a soil is the fraction of the void spaces available for water storage, measured in inches per inch.

Table 5 provides design values of the effective water capacity (void ratio) and the infiltration rate of the specific soil textural groups. The soil textures presented in ***Table 5*** correspond to the soil textures of the USDA Soil Textural Triangle included as ***Figure 3***.

The least permeable soil horizon within four (4) feet below the proposed BMP bottom elevation shall be used to select the design infiltration rate.

Figure E.4 Design Infiltration Rates

II. CALCULATION METHODOLOGY

A. Calculating Runoff

1. Rainfall Loss Equations and Runoff Coefficients

a. **The Rational Method** may be used to calculate storm water runoff and generate peak discharges to size conveyance and storage systems. The peak runoff rate is given by the equation:

$$Q = C\ I\ A$$

where:
Q = peak runoff rate (cubic feet per second)
C = weighted runoff coefficient of the drainage area
I = average rainfall intensity for a storm with a duration equal to the time-of-concentration of the drainage area (inches per hour)
A = drainage area (acres)

Runoff coefficients for various land uses and surface types are included in ***Table 6***.

Table 6 – Rational Method Runoff Coefficients

Type of Development	Runoff Coefficients
Downtown Business	0.70 to 0.95
Neighborhood Business	0.50 to 0.70
Single family Residentail	0.30 to 0.50
Multi-units (detached)	0.40 to 0.60
Multi-units (attached)	0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment	0.50 to 0.70
Light Industrial	0.50 to 0.80
Heavy Industrial	0.60 to 0.90
Park, Cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad Yard	0.20 to 0.35
Unimproved	0.10 to 0.30
Character of Surface	
Asphalt and Concrete Pavement	0.70 to 0.95
Brick Pavement	0.70 to 0.85
Roofs	0.75 to 0.95
Lawns, Sandy Soil Flat 2%	0.05 to 0.10
Lawns, Sandy Soil Average 2% to 7%	0.10 to 0.15
Lawns, Sandy Soil Steep 7%	0.15 to 0.20
Lawns, Heavy Soil Flat 2%	0.13 to 0.17
Lawns, Heavy Soil Average 2% to 7%	0.18 to 0.22
Lawns, Heavy Soil Steep 7%	0.25 to 0.35

Source: *Design and Construction of Sanitary and Storm Sewers*, American Society of Civil Engineers and the Water Pollution Control Federation, 1969.

Figure E.5 Runoff Calculation Standards

b. **The Runoff Curve Number Method**, developed by the NRCS, may be used to calculate storm water runoff to generate peak discharges and runoff volumes. This method must be used when it is necessary to calculate runoff volumes for stream protection. The formulas are as follows:

$$Q_v = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

where:
Q_V = surface runoff volume (inches)
P = rainfall (inches)
S = potential maximum retention after runoff begins (inches)

and where:

$$S = \frac{1000}{CN} - 10$$

Surface runoff volumes are calculated separately for impervious and pervious areas.

Curve Number (CN) values shall be taken from Technical Release No. 55 (TR-55). Standard values are summarized in ***Table 7*** for convenience.

(1) Pre-development conditions shall consist of a "Meadow" cover type for all existing land covers other than woods. For existing woods use the "Woods" cover types for "good" hydrologic conditions.

(2) Open space in "fair" condition shall be used for post-development pervious areas that are not receiving non-structural BMP credits.

c. **The Michigan Modified Unit Hydrograph** formula shall be used with the Runoff Curve Number Method to generate peak storm water runoff rates:

$$Q = 238.6\ A\ Qv\ Tc^{-0.82}$$

where:
Q = peak runoff rate (cubic feet per second)
K = 238.6 constant reflecting shape of the unit hydrograph including unit conversion factors
A = drainage area (square miles)
Qv = surface runoff volume (inches)
Tc = time-of-concentration (hours)

Figure E.6 Runoff Calculation Standards

2. Time-of-Concentration

a. **Rational Method:** Overland flow time may be calculated using the nomograph shown as ***Figure 4***. A minimum of 15 minutes shall be used. Channel flow shall be calculated using Manning's equation.

b. **Runoff Curve Number Method:** Travel time shall be calculated using NRCS TR-55 methodology as outlined below.

The flow path is split into three sections – sheet flow, shallow concentrated flow, and open channel flow. In each flow regime the velocity and/or travel time are computed. The time-of-concentration is then the sum of the travel times.

(1) For sheet flow the travel time (in hours) is given as:

$$\frac{0.007(nL)^{0.8}}{P_2^{0.5}s^{0.4}}$$

where n is Manning's factor, L is the flow length (feet), P_2 is the 2-year precipitation depth, and s is the slope (feet/foot).

(2) Shallow concentrated flow velocities are calculated for paved and unpaved surfaces. The velocities are given as:

$$v = \begin{matrix} 16.1345s^{0.5} & Unpaved \\ 20.3282s^{0.5} & Paved \end{matrix}$$

where s is the slope (feet/foot) and v is the velocity in feet per second. The flow length (feet) is then divided by the velocity (feet per second) to obtain travel time in hours.

(3) Open channel flow uses Manning's equation to calculate the velocity based on slope, flow area, and wetted perimeter. The flow length (feet) is then divided by the velocity (feet per second) to obtain travel time in hours.

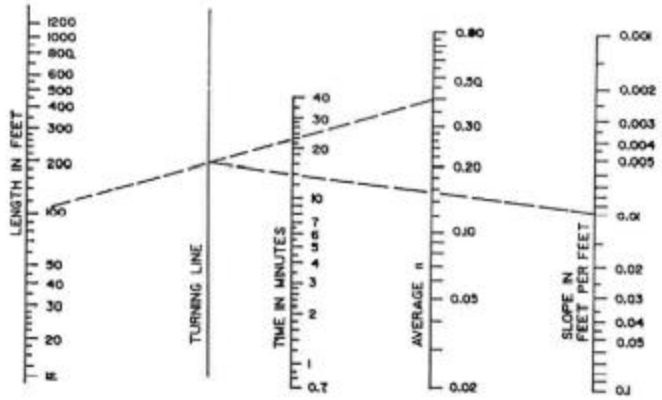
c. **BMP residence time** shall be calculated as the storage volume divided by the 10-year peak flow rate.

Figure E.7 Runoff Calculation Standards

Figure 4 – Nomograph to Comupte Time of Concentration for Overland Flow

The following is a table used for determining n.

TYPE OF SURFACE	n VALUE
Smooth impervious Surface	0.02
Smooth bare packed soil	0.10
Poor grass, cultivated row crops or moderately rough bare surface	0.20
Pasture or average grass	0.40
Deciduous Timberland	0.60
Conifer Timberland, Deciduous Timberland with deep forest litter or dense grass	0.80



Example: N=0.40, L=100', S=0.01 feet/foot and tc=13.6 minutes

Chart is printed from the following equation.

$$tc = \left(\frac{2\,Ln}{3\sqrt{S}}\right)^{x} \qquad x = \frac{1}{2.14}$$

Taken from ENGINEER'S NOTEBOOK

"Time of concentration for overland flow" W.S. Kerby, J.M. Asce, Hydrologist, Servis, Van Doren & Hazard, Engineers, Topeka, Kansas.

The variables needed to compute time of concentration for a proposed development are its length, slope, and surface retardants. These variables can be computed from field survey notes.

The length L is the distance from the extremity of the development area in a direction parallel to the slope until a defined channel is reached. The units are in feet. Overland flow will become channel flow within 1,200 feet in almost all cases. Time of concentration is the sum of overland flow and channel flow.

The slope S is the difference in elevation between the extremity of the drainage area and the point in question divided by the horizontal distance. The units are in feet/foot.

The surface retardants coefficient, n, is the average surface retardants value of the overland flow.

Figure E.8 Nomograph Flow Standards

Zone 8						
Duration (min)	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
5	0.35	0.42	0.48	0.55	0.61	0.66
10	0.53	0.65	0.74	0.85	0.93	1.01
15	0.63	0.78	0.89	1.03	1.14	1.24
30	0.85	1.07	1.24	1.45	1.61	1.77
60 (1-hr)	1.16	1.48	1.74	2.10	2.37	2.64
120 (2-hr)	1.38	1.76	2.08	2.52	2.87	3.23
180 (3-hr)	1.52	1.94	2.29	2.59	2.96	3.35
360 (6-hr)	1.79	2.27	2.68	3.24	3.72	4.22
720 (12-hr)	2.07	2.61	3.06	3.74	4.27	4.84
1080 (18-hr)	2.25	2.83	3.31	4.06	4.64	5.24
1440 (24-hr)	2.69	3.36	3.92	4.82	5.51	6.25

Zone 9						
Duration (min)	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
5	0.34	0.42	0.48	0.55	0.60	0.66
10	0.53	0.65	0.73	0.84	0.92	1.00
15	0.63	0.78	0.89	1.03	1.13	1.23
30	0.84	1.07	1.23	1.44	1.60	1.75
60 (1-hr)	1.16	1.48	1.74	2.08	2.35	2.62
120 (2-hr)	1.36	1.74	2.05	2.49	2.84	3.20
180 (3-hr)	1.49	1.91	2.26	2.55	2.92	3.30
360 (6-hr)	1.72	2.19	2.58	3.14	3.61	4.10
720 (12-hr)	1.97	2.48	2.92	3.53	4.04	4.57
1080 (18-hr)	2.14	2.68	3.14	3.81	4.35	4.91
1440 (24-hr)	2.56	3.20	3.73	4.50	5.15	5.85

Zone 10						
Duration (min)	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
5	0.33	0.40	0.45	0.52	0.57	0.62
10	0.50	0.62	0.70	0.80	0.88	0.96
15	0.60	0.74	0.84	0.98	1.08	1.17
30	0.81	1.02	1.17	1.37	1.52	1.67
60 (1-hr)	1.11	1.41	1.66	1.97	2.23	2.48
120 (2-hr)	1.29	1.66	1.96	2.36	2.69	3.03
180 (3-hr)	1.42	1.82	2.15	2.43	2.78	3.14
360 (6-hr)	1.63	2.08	2.45	2.97	3.40	3.87
720 (12-hr)	1.86	2.34	2.75	3.39	3.88	4.39
1080 (18-hr)	2.02	2.54	2.97	3.60	4.11	4.65
1440 (24-hr)	2.42	3.02	3.52	4.24	4.85	5.50

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Figure E.8 Zone Storm Durations

Retention Basins

A. Summary

Description:	Provides storm water storage without a surface outlet
Types:	Dry Basin; Wet Pond
Pretreatment Required:	Yes
Maintenance Plan:	Yes
Easement Required:	Yes
Calculation Credits:	
Volume Reduction	Count volume stored and infiltrated
Rate Reduction	Designed for flood control: 100%
Water Quality	Count volume stored and infiltrated

B. Sizing Calculations

1. Determine contributing site drainage area.

2. Use the Rational Method spreadsheet, or the Green Calculator to calculate the required storage volumes for flood control as outlined in "Flood Control Using Retention Basins" (page 47).

3. Calculate the minimum infiltration area required to drain the required storage volume in the specified drawdown time using the design infiltration rate of the underlying soil.

$$A = [V_s / (i \times t_d)] \times 12$$

where:
A = minimum infiltration area (square feet)
V_s = storage volume (cubic feet)
i = design infiltration rate of soil (inches per hour) from ***Table 5***
t_d = maximum allowable drawdown time (hours)
12 = factor to convert inches to feet

4. Drawdown time shall be no more than 72 hours.

5. The infiltration area shall be defined as the bottom of the basin.

6. Stream protection and water quality volumes may be included in the flood control volume.

7. Size forebay(s) for pre-treatment using equation given in "Calculating Storage Volumes and Release Rates" (page 44).

Figure E.9 Retention Pond Design Requirements

Retention Basins (continued)

C. Design Requirements

1. Siting
   a. Soil borings are required as outlined in "Soils Investigation" (page 34).
      (1) A minimum of 4 feet is required between the bottom of dry retention basins and the highest known groundwater elevation.
   b. Setbacks shall be as follows:
      (1) Adjacent property line: 10 feet
      (2) Building foundation: 30 feet
      (3) Private well: 50 feet
      (4) Public well: 200 feet from Type I or Type IIa wells, 75 feet from Type IIb or Type III wells (Safe Drinking Water Act, Act 399, PA 1976)
      (5) Septic system drainfield: 100 feet
2. Sizing and Configuration
   a. General
      (1) Where water quality and stream protection are provided through retention, these volumes may be included in the flood control volume.
      (2) Where steeper side slopes than those specified are unavoidable, safety railing, fencing or other access barriers may be approved.
   b. Dry Basin
      (1) The design high water depth should generally not exceed 10 feet above the bottom of the basin.
      (2) Side slopes shall not be steeper than 3:1 (H:V). Where basins are to be maintained as a mown lawn, side slopes shall be no steeper than 4:1 (H:V) to facilitate mowing.
      (3) The bottom of dry retention basins shall be flat to encourage uniform ponding and infiltration.
      (4) The bottom of dry retention basins shall be scarified to a depth of 4 to 6 inches after final grading has been established.
      (5) Care must be taken during the excavation and finishing process to make sure that soil compaction does not occur.
   c. Wet Pond (no surface water outlet)
      (1) The design high water depth should generally not exceed 10 feet above the permanent pool elevation.
      (2) Where excavation and reshaping of the retention area is necessary, side slopes shall not be steeper than 3:1 (H:V). Where basins are to be maintained as a mown lawn to the water's edge, side slopes shall be no steeper than 4:1 (H:V) to facilitate mowing.
      (3) Where excavation and reshaping of the retention area is necessary, permanent pools deeper than 4 feet shall have two safety ledges each between 6 and 8 feet wide. One shall start at the normal water surface and extend up to the pond side slopes at a maximum slope of 15%. The other shall extend from the water surface into the pond to a depth of 12 inches at a slope of 15%.
      (4) Warning signs prohibiting swimming and skating shall be posted for wet ponds.

Figure E.10 Retention Pond Design Requirements

Appendix F: Retention Pond and Storm Water Piping Calculations

SCS Method Based on a 24-hr, 100-yr storm:
(Appendix E Provides Requirements)

Predeveloped Land Calculations:

Table F.1 – Predeveloped Site

Predeveloped Site				
	Variable	**Units**	**Values**	**Equations**
Surface Runoff	Q	in	1.92	Q = ((P-0.2S)^2)/(P+0.8S)
Rainfall	P 100yr, 24 hr (in)	in	6.25	
Curve Number	CN		58	
Potential Maximum Retention After Runoff Begins	S	in	7.24	S = 1000/CN - 10
Peak Runoff Rate	Qv	cfs	12.32	Qv = 238.6AQTc^-0.82
K = 238.6 constant reflecting shape of the unit hydrograph including unit conversion factors	K		238.6	
Drainage Area	A	sq. mi.	0.0625	
Surface Runoff	Q	in	1.92	
Time-of-Concentration	Tc	hr	2.79	Tc = (L^0.8(S+1)^0.7)/1140Y^0.5
Flow Length	L	ft	2442	
Potential Max Retention	S	in	7.24	
Slope in Percent	Y		0.5	
Peak Discharge	qp	cfs	12.32	
Area	A	mi^2	0.0625	
	Q	in	1	
Time-to-Peak	tp	hr	2.46	tp = 484AQ/qp

Private Layout Calculations:

Table F.2 – Private Site Layout

Private Site Layout				
	Variable	**Units**	**Values**	**Equations**
Surface Runoff	Q	in	3.12	Q = ((P-0.2S)^2)/(P+0.8S)
Rainfall	P 100yr, 24 hr (in)	in	6.25	
Curve Number	CN		71	Avg. = (69*37.05)+(98*2.95)/40
Potential Maximum Retention After Runoff Begins	S	in	4.06	S = 1000/CN - 10
Peak Runoff Rate	Qv	cfs	27.97	Qv = 238.6AQTc^-0.82
K = 238.6 constant reflecting shape of the unit hydrograph including unit conversion factors	K		238.6	
Drainage Area	A	sq. mi.	0.0625	
Surface Runoff	Q	in	3.12	
Time-of-Concentration	Tc	hr	1.86	Tc = (L^0.8(S+1)^0.7)/1140Y^0.5
Flow Length	L	ft	2442	
Potential Max Retention	S	in	4.06	
Slope in Percent	Y		0.5	
Peak Discharge	qp	cfs	26.54	
Area	A	mi^2	0.0625	
	Q	in	1	
Time-to-Peak	tp	hr	1.08	tp = 484AQ/qp

Public Layout Calculations:

Table F.3 – Public Site Layout

Public Site				
	Variable	**Units**	**Values**	**Equations**
Surface Runoff	Q	in	3.68	Q = ((P-0.2S)^2)/(P+0.8S)
Rainfall	P 100yr, 24 hr (in)	in	6.25	
Curve Number	CN		77	Avg. = (75*36.85)+(98*3.15)/40
Potential Maximum Retention After Runoff Begins	S	in	3.02	S = 1000/CN - 10
Peak Runoff Rate	Qv	cfs	36.02	Qv = 238.6AQTc^-0.82
K = 238.6 constant reflecting shape of the unit hydrograph including unit conversion factors	K		238.6	
Drainage Area	A	sq. mi.	0.0625	
Surface Runoff	Q	in	3.68	
Time-of-Concentration	Tc	hr	1.66	Tc = (L^0.8(S+1)^0.7)/1140Y^0.5
Flow Length	L	ft	2442	
Potential Max Retention	S	in	3.02	
Slope in Percent	Y		0.5	
Peak Discharge	qp	cfs	35.76	
Area	A	mi^2	0.0625	
	Q	in	1	
Time-to-Peak	tp	hr	0.84	tp = 484AQ/qp

Retention Pond Volume Calculations:

A series of three right triangles were placed within the storm hydrograph in order to calculate the green highlighted area under the curve as shown in Figures 6.1.2 & 6.1.3.

Private Layout:

Triangle 1 = (1/2) * 1.37 * 12 = 8.22 cfs*hr

Triangle 2 = (1/2) * (27.97 – 12) * (1.08 – 0.54) = 4.31 cfs*hr

Triangle 3 = (1/2) * (27.97 – 12) * (1.94 - 1.08) = 6.87 cfs*hr

Total Area = 8.22 + 4.31 + 6.87 = 19.4 cfs*hr

Storage Volume of Pond, V_s = 19.4 cfs*hr * 3600 s = **69,836 ft^3**

Infiltration Area = $\frac{V_s}{i* t_d} * 12 \ \frac{in}{ft} = \frac{69{,}836 \ ft^3}{0.52*72 \ hr} * 12 \ \frac{in}{ft}$ = 22,383 ft^2

Public Layout:

Triangle 1 = (1/2) * 11 * (1.60 – 0.34) = 6.93 cfs*hr

Triangle 2 = (1/2) * (0.84 – 0.34) * (36.02 – 11.17) = 6.26 cfs*hr

Triangle 3 = (1/2) * (1.60 – 0.84) * (36.02 – 11.89) = 9.12 cfs*hr

Total Area = 6.93 + 6.26 + 9.12 = 22.32 cfs*hr

Storage Volume of Pond, V_s = 22.32 cfs*hr * 3600 s = **80,336 ft^3**

Infiltration Area = $\frac{V_s}{i* t_d} * 12 \ \frac{in}{ft} = \frac{80{,}336 \ ft^3}{0.52*72 \ hr} * 12 \ \frac{in}{ft}$ = 25,748 ft^2

Retention Pond Sizing Calculations:

Private Retention Pond:

Known Information:

V = 69,836 ft^3

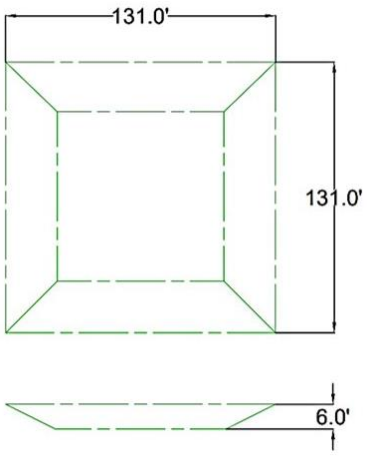

Figure ….

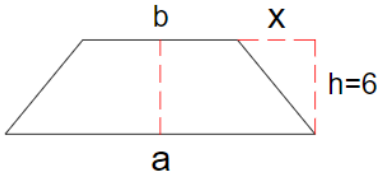

Figure ….

$\frac{1}{4} - \frac{h}{x}$: $\frac{1}{4} - \frac{6'}{x}$: $\frac{1}{4}$x = 6’ : x = 24’

$\frac{a}{2} - \frac{b}{2}$ = x : a – b =2x : a – b = 2(24’) : a = 48’ + b

V = $\frac{1}{3}(a^2 + ab + b^2)$h : V = 66^2 + 288b +4608 : 69,836 ft^3 (required) = 66^2 + 288b + 4608

b = 83’ and a = 131’

Public Retention Pond:

Known Information:

V = 80,336 ft^3

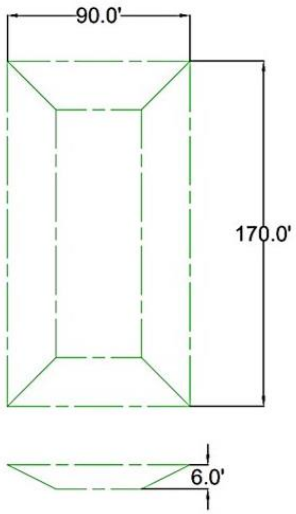

Figure ….

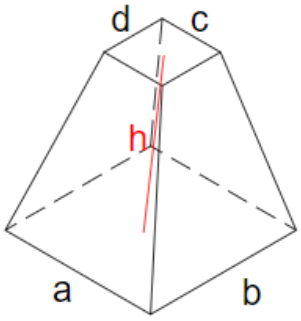

Figure …

$$V = \frac{h}{3}(ab + cd + (ad + bc)/2)$$

80,336 ft^3 (required) < $\frac{1}{3}(90 * 170 + 66 * 146 + (90 * 146 + 170 * 66)/2)$ = 80,632 ft^3

Drainpipe Sizing Calculations:

Manning's Equation: $Q = \frac{1.49 * A * R^{\frac{2}{3}} * S^{\frac{1}{2}}}{n}$

Private Layout:

Known Information:

Discharge (Q_{req}) = 27.97 cfs

Manning's Coe. (n) = 0.015

Slope (S) = 0.12 ft/ft

Calculate A & R values:

Select Pipe Size = 21"

Radius (r) = (21"/2)/12" = 0.875 ft

Height of Fill (h) = 2*0.875 ft -1 = 0.75 ft

phi = $2*\cos^{-1}(((0.875\text{ ft} - 0.75\text{ ft})/0.875\text{ ft}))$ = 2.86 rad

Wetted Area (A) = $3.14*0.875\text{ ft}^2 - 0.875\text{ ft}^2 * (2.86\text{ rad} - \sin(2.86\text{ rad}))/2 = 1.42\text{ ft}^2$

Wetted Perimeter (P) = (2*3.14*0.875 ft) – (0.875 ft * 2.86 rad) = 2.99 ft

Hydraulic Radius (R) = 1.42 ft^2 / 2.99 ft = 0.47 ft

$Q = \frac{1.49 * 1.42 * 0.47^{\frac{2}{3}} * 0.12^{\frac{1}{2}}}{0.015}$ = 29.68 cfs > Q_{req} = 27.97 cfs

Public Layout:

Known Information:

Discharge (Q_{req}) = 36.02 cfs

Manning's Coe. (n) = 0.015

Slope (S) = 0.17 ft/ft

Calculate A & R values:

Select Pipe Size = 24"

Radius (r) = (24"/2)/12" = 1 ft

Height of Fill (h) = 2*1 ft -1 = 1 ft

phi = $2*\cos^{-1}(((1\text{ ft} - 1\text{ ft})/1\text{ ft}))$ = 3.14 rad

Wetted Area (A) = $3.14*1\text{ ft}^2 - 1\text{ ft}^2 * (3.14\text{ rad} - \sin(3.14\text{ rad}))/2 = 1.57\text{ ft}^2$

Wetted Perimeter (P) = (2*3.14*1 ft) – (1 ft * 3.14 rad) = 3.14 ft

Hydraulic Radius (R) = 1.57 ft^2 / 3.14 ft = 0.5 ft

$$Q = \frac{1.49*1.42*0.47^{\frac{2}{3}}*0.12^{\frac{1}{2}}}{0.015} = 40.49 \text{ cfs} > Q_{req} = 36.02 \text{ cfs}$$

Appendix G: Water and Sanitary

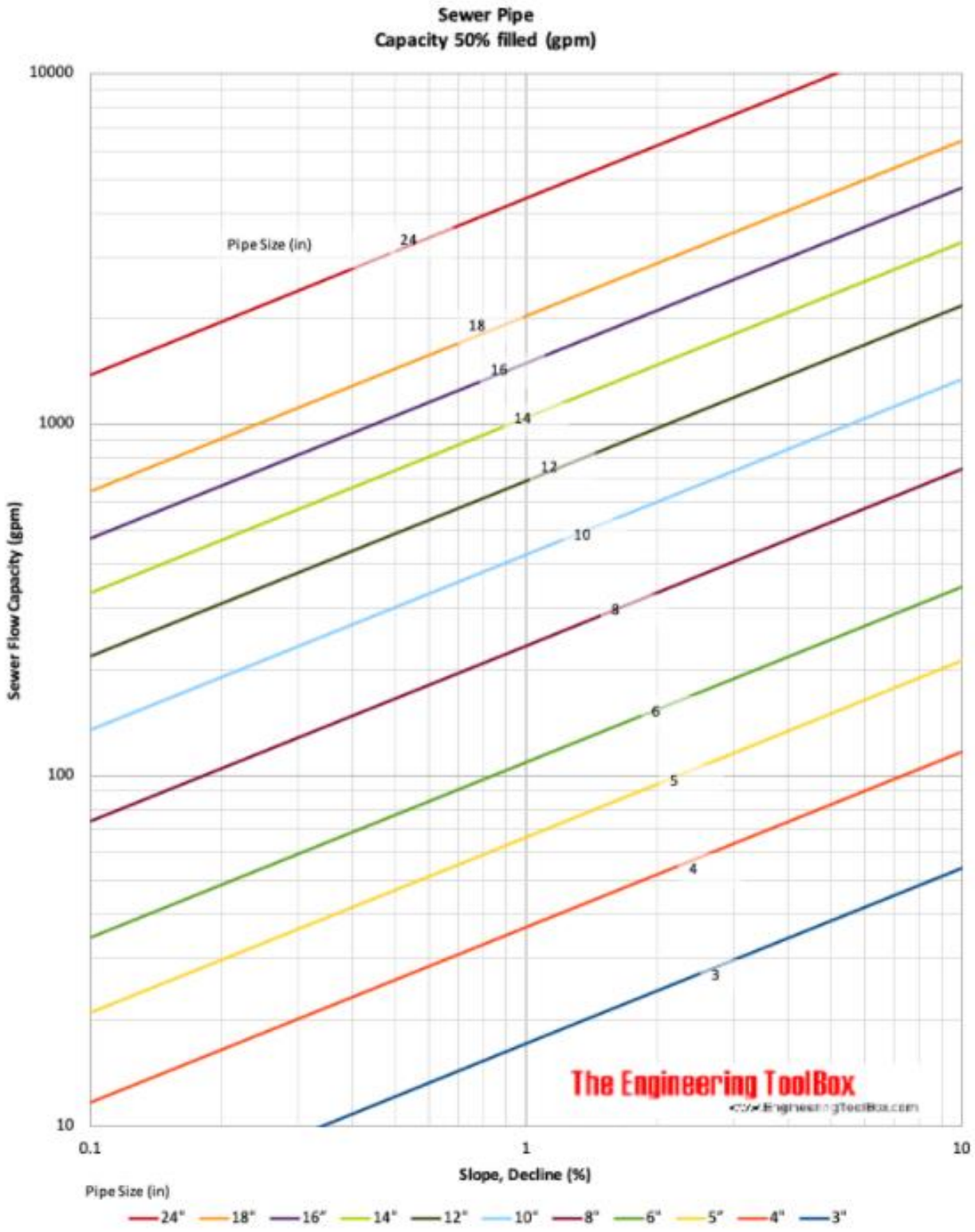

Figure G.1 Sanitary Main Pipe Sizing

c. Wastewater collection systems shall be based on an average daily flow of 100 gallons per capita per day for single and multi-family areas.

d. Commercial and industrial areas shall be designed based on an average daily flow of 940 gallons per day per acre. The area to be used shall be based on the total area of the property, excluding right-of-ways.

e. The peaking factor to be used shall be calculated using the following formula.

$$PF = \frac{18 + \sqrt{P}}{4 + \sqrt{P}}$$

Where: PF = Peaking Factor
P = Population, in thousands

f. Minimum size for public sanitary sewer shall be ten inches in diameter.

g. Minimum design velocity for sanitary sewers shall be two feet per second with pipe flowing full, based on Kutter's formula using an "n" value of 0.013.

h. Maximum design velocity for sanitary sewers shall be 12 feet per second with pipe flowing full.

i. The following table represents the minimum and maximum grade for public sanitary sewers.

Size	Minimum Grade	Maximum Grade
10-inch	0.30%	6.2%
12-inch	0.22%	6.0%
15-inch	0.16%	3.6%
18-inch	0.12%	2.8%
21-inch	0.10%	2.2%

Figure G.2 Sanitary Main Pipe Sizing Requirements

Table G.1 Water Main Pipe Sizing

Pipe Size (inch)	Maximum Flow (gal/min) (l/s)	Velocity (ft/s) (m/s)	Head Loss (ft_{H2O}/100ft, m/100m)
2	45	4.3	3.9
2 1/2	75	5.0	4.1
3	130	5.6	3.9
4	260	6.6	4.0
6	800	8.9	4.0
8	1600	10.3	3.8
10	3000	12.2	4.0
12	4700	13.4	4.0
14	6000	14.2	4.0
16	8000	14.5	3.5
18	10000	14.3	3.0
20	12000	13.8	2.4
24	18000	14.4	2.1

k. Determining water supplies for firefighting purposes shall be as determined by the Insurance Services Office formula:

$$F = 18C\sqrt{A}$$

where: F = Fire Flow, gallons per minute
C = Constant *(see table below)*
A = Effective Area (includes all floors, excluding the basement), square feet

Construction	Class	C Value
Wood Frame	Class 1	1.5
Ordinary Joisted Masonry	Class 2	1.0
Non-Combustible Masonry	Classes 3 and 4	0.8
Fire-Resistant	Classes 5 and 6	0.6

Figure G.3 Water Main Sizing Requirements for Fire Flow

Appendix H: Cost Estimation

Water Well And Pump Record

Completion is required under authority of Part 127 Act 368 PA 1978.
Failure to comply is a misdemeanor.

Import ID:

Tax No:	Permit No: 04-830	County: Van Buren	Township: Antwerp

Town/Range:	Section:	Well Status:	WSSN:	Source ID/Well No:
03S 13W	8	Active		

Well ID: 80000007871

Elevation:
Latitude: 42.22356031
Longitude: -85.8549697
Method of Collection: Address Matching-House Number

Distance and Direction from Road Intersection:
EAST OF COUNTY ROAD 653 ON RED ARROW HIGHWAY

Well Owner: JOHN SZEWCZYK

Well Address:	Owner Address:
31240 RED ARROW HWY PAW PAW, MI 49079	31240 RED ARROW HWY PAW PAW, MI 49079

Drilling Method: Rotary
Well Depth: 133.00 ft. Well Use: Household
Well Type: Replacement Date Completed: 1/7/2005

Casing Type: PVC plastic Height:
Casing Joint: Solvent welded/glued
Casing Fitting: None

Diameter: 5.00 in. to 113.00 ft. depth

Borehole: 8.50 in. to 133.00 ft. depth

Pump Installed: Yes Pump Installation Only: No
Pump Installation Date: HP: 0.75
Manufacturer: A.Y. McDonald Pump Type: Submersible
Model Number: 21075K-2 Pump Capacity: 8 GPM
Drop Pipe Length: 120.00 ft. Pump Voltage:
Drop Pipe Diameter: Drilling Record ID:
Draw Down Seal Used: No

Pressure Tank Installed: Yes
Pressure Tank Type: Unknown
Manufacturer: Well-Rite-Flexcon
Model Number: WR-120 Tank Capacity: 33.0 Gallons
Pressure Relief Valve Installed: No

Static Water Level: 48.00 ft. Below Grade
Well Yield Test: Yield Test Method: Other
Pumping level 108.00 ft. after 3.00 hrs. at 10 GPM

Formation Description	Thickness	Depth to Bottom
Sand & Gravel Medium	83.00	83.00
Gray Silt & Clay Soft	29.00	112.00
Sand Fine	21.00	133.00

Screen Installed: Yes Filter Packed: Yes
Screen Diameter: 5.00 in. Blank:
Screen Material Type: PVC-slotted
Screen Installation Type: Attached

Slot	Length	Set Between
15.00	20.00 ft.	113.00 ft. and 133.00 ft.

Fittings: None

Well Grouted: Yes Grouting Method: Unknown

Grouting Material	Bags	Additives	Depth
Bentonite slurry	7.00	None	0.00 ft. to 105.00 ft.

Geology Remarks:

Wellhead Completion: Pitless adapter, 12 inches above grade

Nearest Source of Possible Contamination:

Type	Distance	Direction
Septic tank	50 ft.	South

Drilling Machine Operator Name: JASON FOUNE
Employment: Employee

Contractor Type: Water Well Drilling Contractor Reg No: 80-2159
Business Name: FOUNE WELL DRILLING INC.
Business Address:

Abandoned Well Plugged: Yes

Casing Diameter: 2 in. Casing Removed: No
Plugging Material: Bentonite chips/pellets
No. of Bags: 2.00 Well Depth: 80 ft.

Water Well Contractor's Certification

This well was drilled under my supervision and this report is true to the best of my knowledge and belief.

Signature of Registered Contractor Date

General Remarks: 2 2" WELLS IN PIT, DROP PIPE AND EJECTOR NEED TO BE REMOVED FROM SECOND WELL
Other Remarks: Yield Test Method:AIR AND TEST PUMP

Figure H.1: 2005 Well Record for Soil Boring Log

Figure H.2: 200 HP Bulldozer Spec used for Retension Pond Excavation

D6/D6 XE

Track-Type Tractors

Technical Specifications

Configurations and features may vary by region. Please consult your Cat® dealer for availability in your area.

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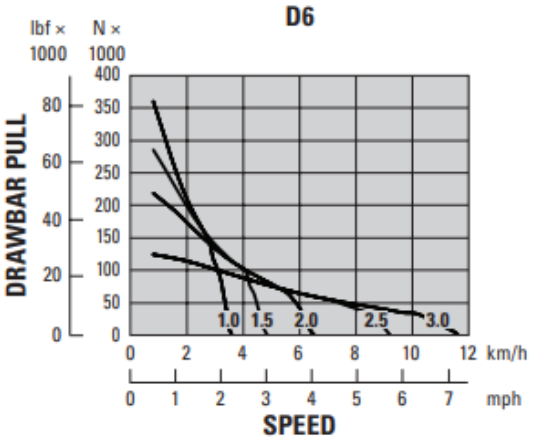
CAT®

D6/D6 XE Track-Type Tractors Specifications

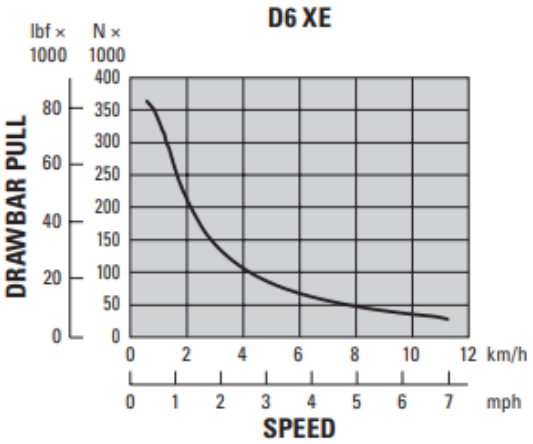
Maximum Drawbar Power		
D6	114 kW	153 hp
D6 XE	119 kW	160 hp

D6 Travel Speed		
1.0 Forward	3.6 km/h	2.2 mph
1.5 Forward	4.9 km/h	3.0 mph
2.0 Forward	6.5 km/h	4.0 mph
2.5 Forward	9.2 km/h	5.7 mph
3.0 Forward	11.7 km/h	7.2 mph
1.0 Reverse	3.6 km/h	2.2 mph
1.5 Reverse	4.9 km/h	3.0 mph
2.0 Reverse	6.5 km/h	4.0 mph
2.5 Reverse	8.7 km/h	5.4 mph
3.0 Reverse	11.7 km/h	7.2 mph



NOTE: Usable pull will depend on traction and weight of machine.

D6 XE Travel Speed		
1.0 Forward	3.6 km/h	2.2 mph
1.5 Forward	4.9 km/h	3.0 mph
2.0 Forward	6.5 km/h	4.0 mph
2.5 Forward	9.2 km/h	5.7 mph
3.0 Forward	11.7 km/h	7.2 mph
1.0 Reverse	3.6 km/h	2.2 mph
1.5 Reverse	4.9 km/h	3.0 mph
2.0 Reverse	6.5 km/h	4.0 mph
2.5 Reverse	9.2 km/h	5.7 mph
3.0 Reverse	11.7 km/h	7.2 mph



NOTE: Usable pull will depend on traction and weight of machine.

- The fully automatic D6 4-speed transmission, with lock-up clutch torque divider, continuously optimizes gear and engine speed for the application.
- The D6 XE Electric Drive power train has no gears to shift. The dozer automatically optimizes power and efficiency for the application and provides constant power to the ground.
- Thirty ground speed selections are available for both power trains, from 0.0 to 3.0 in 0.1 increments.

D6/D6 XE Track-Type Tractors Specifications

Hydraulic Controls – Maximum Operating Flows

	D6 (1,900 rpm engine speed*)		D6 XE (1,700 rpm engine speed*)	
Implement Pump Maximum Flow	212 L/min	56 gal/min	212 L/min	56 gal/min
Steering Pump Maximum Flow	198 L/min	52 gal/min	240 L/min	63 gal/min
Fan Pump Flow at Maximum Fan (1,550 rpm)	42 L/min	11 gal/min	—	—
Fan Pump Flow at Maximum Fan (1,625 rpm)	—	—	44 L/min	12 gal/min

*Engine speed varies with load and travel speed. A high idle/low working load speed shown.

Hydraulic Controls – Maximum Operating Pressures

Implement Relief*	27 600 ± 500 kPa	4,000 ± 73 psi
Steering – D6 (89 cc pump)**		
Electronic Relief	42 500 ± 1000 kPa	6,168 ± 145 psi
System Maximum Relief	47 800 ± 1000 kPa	6,938 ± 145 psi
Steering – D6 XE (100 cc pump)***		
Electronic Relief	44 500 ± 1000 kPa	6,459 ± 145 psi
System Maximum Relief	47 800 ± 1000 kPa	6,938 ± 145 psi

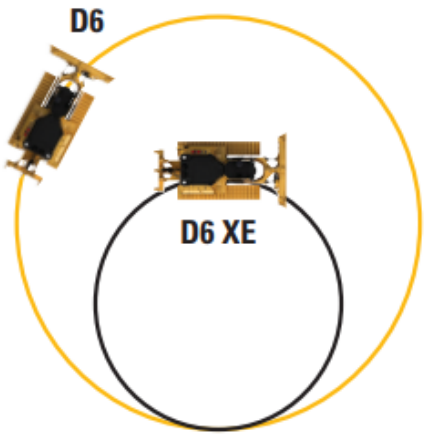
*Implement relief pressure increased over prior model D6 tractors. Consult with your dealer prior to using older vintage or third party implements.

**The same differential steering system is used for both power trains. This system maintains full power to both tracks to provide best-in-class turning with a loaded blade.

***The D6 XE power train utilizes a larger steering pump and enhanced steering controls to provide more steering power, compared to the D6 power train, to turn larger loads and to improve maneuverability. This includes the ability to counter-rotate in gear.

Steering

The D6 XE power train provides up to a 45 percent steering radius reduction compared to the D6. The D6 XE offers in-gear counter rotation for increased maneuverability.



D6/D6 XE Track-Type Tractors Specifications

D6/D6 XE*

	Operating Weight**	22 130 kg	48,788 lb
	Shipping Weight***	19 178 kg	42,280 lb
	Ground Pressure (ISO 16754)	54 kPa	7.9 psi
	Undercarriage (Standard)	42 Section with 8 Bottom Rollers	
1	Track Gauge	1.930 m	76 in
2	Width of Maximum Track Shoe	0.610 m	24 in
3	Width over Tracks	2.540 m	100 in
	Width over Trunnions	2.692 m	106 in
4	Length of Track on Ground	2.964 m	116.7 in
	Ground Contact Area (ISO 16754)	3.992 m²	6188 in²
	Track Pitch	0.2028 m	7.9 in
	Grouser Height (Moderate Service)	0.065 m	2.6 in
	Ground Clearance	0.361 m	14.2 in
	Oscillation at Front Idler	0.103 m	4.0 in
5	Machine Height****	3.172 m	124.9 in
6	Length of Machine without Blade	4.730 m	186.2 in

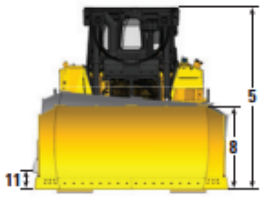
All dimensions above with HDXL undercarriage with Moderate Service shoes of maximum width for configuration, 6 SU blade, and calculated per ISO 16754 unless otherwise specified.

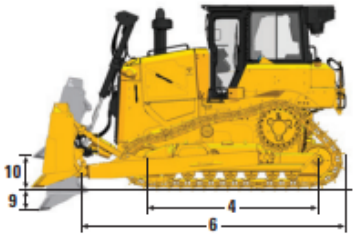
*XE power train adds 0.7 kPa (0.1 psi) and 273 kg (600 lb) to the published ground pressure and weights.

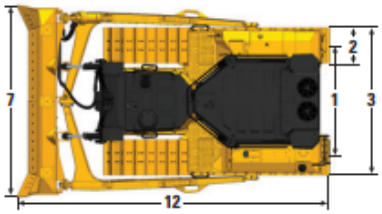
**Operating weight includes blade, lubricants, coolant, full fuel tank, ROPS/FOPS cab, drawbar, and 75 kg (165 lb) operator.

***Shipping weight includes blade lift cylinders, lubricants, coolant, 10% fuel, ROPS/FOPS cab, and drawbar.

****Machine height from tip of grouser to top of Product Link™ Antenna. For sweeps, add 66 mm (2.6 in) to overall machine height. For forestry sweeps, add 122 mm (4.8 in). With Extreme Service Track Shoes add 12 mm (0.5 in). When Cat Grade with 3D antennas are installed there is no addition to machine height.







Blades

	Configuration	6 SU		6A	
	Capacity (ISO 9246)	5.7 m³	7.5 yd³	4.2 m³	5.5 yd³
7	Width across End Bits	3.312 m	10.87 ft	4.389 m	14.40 ft
	Width without End Bits	3.246 m	10.65 ft	4.250 m	13.94 ft
	Width across End Bits (Blade Angled)	N/A		3.982 m	13.06 ft
	Width without End Bits (Blade Angled)	N/A		3.858 m	12.66 ft
	Maximum Blade Angle	N/A		25 degrees	
8	Height	1.408 m	4.62 ft	1.150 m	3.77 ft
9	Dig Depth	0.502 m	19.8 in	0.595 m	23.4 in
10	Lift Height	1.180 m	46.5 in	1.084 m	42.7 in
11	Maximum Tilt at Blade Corner	0.564 m	22.2 in	0.599 m	23.6 in
	Maximum Tilt Angle	9.8 degrees		7.8 degrees	
	Pitch Adjustment	±4.2 degrees		N/A	
12	Length of Machine (Blade Straight)	5.436 m	17.83 ft	5.377 m	17.64 ft
	Length of Machine (Blade Angled)	N/A		6.418 m	21.06 ft
	Weight (Blade)	1385 kg	3,053 lb	1265 kg	2,789 lb
	Weight (Blade and Push Arms)	2620 kg	5,777 lb	3406 kg	7,509 lb

Table H.1: RSMeans Public Earthwork Estimation Report

4850 Excavating and Grading Pricing

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber		Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 01	**General Requirements**					
015433204260		Rent dozer, crawler, torque converter, diesel 200 HP, Incl. Hourly Oper. Cost.	1.30	Day	$1,957.27	$2,544.45
Division 01	**General Requirements Subtotal**					**$2,544.45**
Division 02	**Existing Conditions**					
022113130800		Boundary & survey markers, property lines, perimeter, cleared land	6,334.00	L.F.	$1.37	$8,677.58
Division 02	**Existing Conditions Subtotal**					**$8,677.58**
Division 31	**Earthwork**					
311313100400		Selective clearing, brush, medium clearing, with dozer, ball and chain, excludes removal offsite	40.00	Acre	$1,385.66	$55,426.40
Division 31	**Earthwork Subtotal**					**$55,426.40**
Grand Total						**$66,648.43**

Table H.2: RSMeans Private Earthwork Estimation Report

4850 Excavating and Grading Pricing

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber		Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 01	**General Requirements**					
015433204260		Rent dozer, crawler, torque converter, diesel 200 HP, Incl. Hourly Oper. Cost.	1.00	Day	$1,957.27	$1,957.27
Division 01	**General Requirements Subtotal**					**$1,957.27**
Division 02	**Existing Conditions**					
022113130800		Boundary & survey markers, property lines, perimeter, cleared land	6,334.00	L.F.	$1.37	$8,677.58
Division 02	**Existing Conditions Subtotal**					**$8,677.58**
Division 31	**Earthwork**					
311313100400		Selective clearing, brush, medium clearing, with dozer, ball and chain, excludes removal offsite	40.00	Acre	$1,385.66	$55,426.40
Division 31	**Earthwork Subtotal**					**$55,426.40**
Grand Total						**$66,061.25**

Table H.3: RSMeans Public Transportation Estimation Report

4850 Transportation Pricing

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber		Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 01	**General Requirements**					
015433203400		Rent, smooth drum vibratory roller, 125 H.P., Incl. Hourly Oper. Cost.	2.00	Day	$697.40	$1,394.80
Division 01	**General Requirements Subtotal**					**$1,394.80**
Division 02	**Existing Conditions**					
022113130800		Boundary & survey markers, property lines, perimeter, cleared land	10,666.00	L.F.	$1.37	$14,612.42
Division 02	**Existing Conditions Subtotal**					**$14,612.42**
Division 31	**Earthwork**					
312216100100		Fine grading, for roadway, base or leveling course, large area, 6,000 S.Y. or more	45,050.00	S.Y.	$0.73	$32,886.50
Division 31	**Earthwork Subtotal**					**$32,886.50**
Division 32	**Exterior Improvements**					
320610100310		Sidewalks, driveways, and patios, sidewalk, concrete, cast-in-place with 6 x 6 - W1.4 x W1.4 mesh, broomed finish, 3,000 psi, 4" thick, excludes base	53,394.00	S.F.	$4.36	$232,797.84
321216140025		Asphaltic concrete paving, parking lots & driveways, 6" stone base, 2" binder course, 2" topping, no asphalt hauling included	65,833.00	S.F.	$2.96	$194,865.68
321216140030		Asphaltic concrete paving, parking lots & driveways, 6" stone base, 3" binder course, 2" topping, no asphalt hauling included	65,833.00	S.F.	$3.38	$222,515.54
321613130404		Cast-in place concrete curbs & gutters, concrete, wood forms, straight, 6" x 18", includes concrete	10,666.00	L.F.	$12.66	$135,031.56
Division 32	**Exterior Improvements Subtotal**					**$785,210.62**
Division 80						

8037010		Streetscape Detectable Warning Surface	240.00	S.F.	$31.50	$7,560.00
Division 80	**Subtotal**					**$7,560.00**
Division 81						
8120216		Pavt Mrkg, Type NR, Paint, 24 inch, Stop Bar	168.00	L.F.	$6.50	$1,092.00
Division 81	**Subtotal**					**$1,092.00**
Grand Total						**$842,756.34**

Table H.4: RSMeans Private Transportation Estimation Report

4850 Private Transportation Pricing

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber		Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 01	**General Requirements**					
015433203400		Rent, smooth drum vibratory roller, 125 H.P., Incl. Hourly Oper. Cost.	2.00	Day	$697.40	$1,394.80
Division 01	**General Requirements Subtotal**					**$1,394.80**
Division 02	**Existing Conditions**					
022113130800		Boundary & survey markers, property lines, perimeter, cleared land	10,250.00	L.F.	$1.37	$14,042.50
Division 02	**Existing Conditions Subtotal**					**$14,042.50**
Division 31	**Earthwork**					
312216100100		Fine grading, for roadway, base or leveling course, large area, 6,000 S.Y. or more	42,331.00	S.Y.	$0.73	$30,901.63
Division 31	**Earthwork Subtotal**					**$30,901.63**
Division 32	**Exterior Improvements**					
320610100310		Sidewalks, driveways, and patios, sidewalk, concrete, cast-in-place with 6 x 6 - W1.4 x W1.4 mesh, broomed finish, 3,000 psi, 4" thick, excludes base	51,141.00	S.F.	$4.36	$222,974.76
321216140025		Asphaltic concrete paving, parking lots & driveways, 6" stone base, 2" binder course, 2" topping, no asphalt hauling included	67,368.00	S.F.	$2.96	$199,409.28
321216140030		Asphaltic concrete paving, parking lots & driveways, 6" stone base, 3" binder course, 2" topping, no asphalt hauling included	67,368.00	S.F.	$3.38	$227,703.84
321613130404		Cast-in place concrete curbs & gutters, concrete, wood forms, straight, 6" x 18", includes concrete	10,250.00	L.F.	$12.66	$129,765.00
Division 32	**Exterior Improvements Subtotal**					**$779,852.88**
Division 80						

8037010		Streetscape Detectable Warning Surface	240.00	S.F.	$31.50	$7,560.00
Division 80	**Subtotal**					**$7,560.00**
Division 81						
8120216		Pavt Mrkg, Type NR, Paint, 24 inch, Stop Bar	168.00	L.F.	$6.50	$1,092.00
Division 81	**Subtotal**					**$1,092.00**
Grand Total						**$834,843.81**

Figure H.3: 125 HP Roller used for Soil Compaction

Dynapac CA250D

Single drum vibratory rollers

Atlas Copco

Technical data

Masses

Max. operating mass	12,100 kg
Operating mass (incl. ROPS)	11,200 kg
Operating mass (incl. Cab)	11,350 kg
Module mass (front/rear)	6,300/4,900 kg

Traction

Speed range	0 -10 km/h
Tyre size (8 ply)	23.1x26
Theor. gradeability	57 %
Vertical oscillation	±9°

Compaction

Static linear load	30.0 kg/cm
Nominal amplitude (high/low)	1.7/0.8 mm
Vibration frequency (high/low amplitude)	33/33 Hz
Centrifugal force (high/low amplitude)	248/121 kN

Engine

Manufacturer/Model	Cummins 4BT 3.9-C
Type	Water cooled turbo Diesel
Rated power, SAE J1995	76 kW (102 hp) @ 2,200 rpm

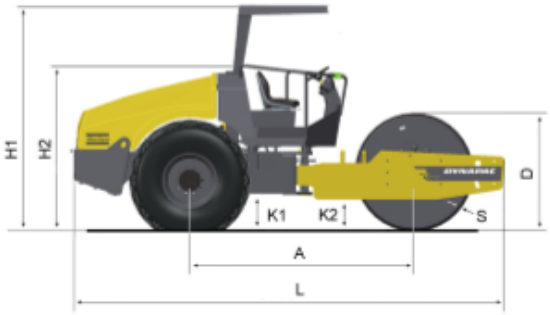
Hydraulic system

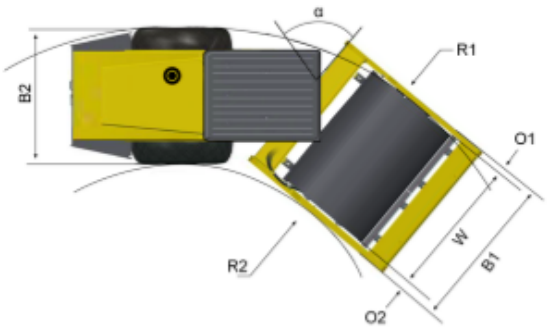
Driving	Axial piston pump with variable displacement. Axial piston motor with constant displacement.
Vibration	Axial piston pump with variable displacement. Axial piston motor with constant displacement.
Steering	Gear pump with constant displacement.
Parking/ Emergency brake	Failsafe multidisc brake in rear axle.
Service brake	Hydrostatic in forward and reverse lever.

Dynapac CA250D

Single drum vibratory rollers

Technical data





Dimensions	
A. Wheelbase	2,879 mm
B1. Width, front	2,324 mm
B2. Width, rear	2,130 mm
D. Drum diameter	1,523 mm
H1. Height, with ROPS	2,952 mm
H2. Height, w/o ROPS/cab	2,190 mm
K1. Ground clearance	453 mm
K2. Curb clearance	400 mm
L. Length	5,550 mm
O1. Overhang, right	97 mm
O2. Overhang, left	97 mm
R1. Turning radius, outside	5,400 mm
R2. Turning radius, inside	3,100 mm
S. Drum shell thickness	25 mm
W. Drum width	2,130 mm
α. Steering angle	±38°

CA250 is a typical utility machine, designed for long working days in tough applications.It is utilized for compaction of most types of soil. Typical applications are road building, airfields, dams, harbors and industrial sites. The CA250 is available with smooth drum as well as padfot drum with or without drum drive.

+ Add to compare

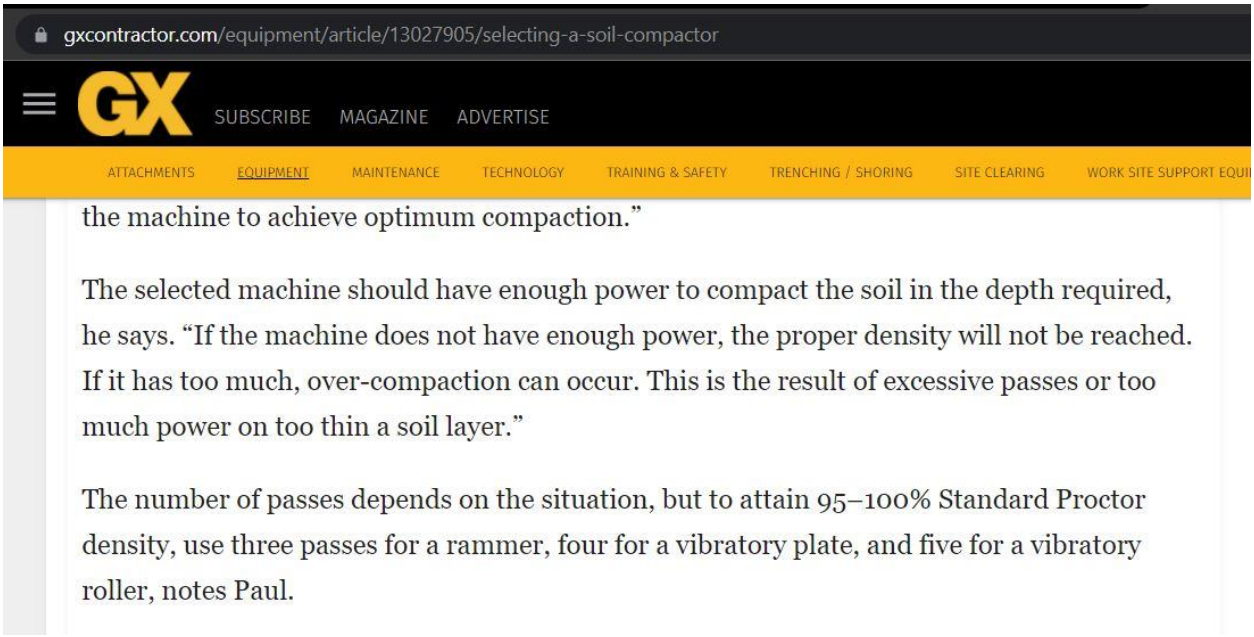


Figure H.4: Source to Determine 5 Passes for Soil Compaction

Figure H.5: 125 HP Roller Spec used for Asphalt Compaction Estimation

BOMAG
FAYAT GROUP

Tandem Vibratory Rollers

BW161AD-4, BW190AD-4 HF

BW161AD-4 - ASPHALTIC CONCRETE (material weight 140 lb/cu ft, 10 impacts/foot)						
# passes	rolling speed	area coverage	"productivity in tons/hr by lift thickness, 100% efficiency"			
	(mph)	sq yd/hr	1.5 inches	2 inches	2.5 inches	3 inches
3	3.4	3662	289	385	481	578
5	3.4	2197	173	231	289	347
7	3.4	1570	124	165	206	248

BW190AD-4 HF - ASPHALTIC CONCRETE (material weight 140 lb/cu ft, 10 impacts/foot)						
# passes	rolling speed	area coverage	"productivity in tons/hr by lift thickness, 100% efficiency"			
	(mph)	sq yd/hr	1.5 inches	2 inches	2.5 inches	3 inches
3	3.5	4491	402	536	670	804
5	3.5	2695	241	322	402	482
7	3.5	1925	172	230	287	344

Note: Repeat number of passes over the same area is required to achieve specified compaction efficiency/density. Successive passes over same area results in reduced area coverage and productivity. Rolling speed selected provides impact spacing of a minimum of 10 impacts per foot at high vibration frequency setting. Actual compaction efficiency is determined by job conditions.

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Technical Specifications
BW161AD-4, BW190AD-4 HF

Shipping dimensions
in cubic feet (m³) without/with ROPS

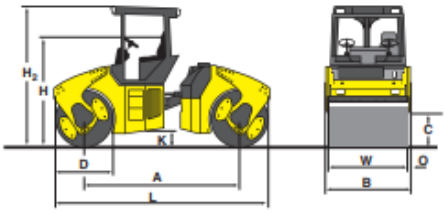
BW161AD-4	681.4 (19.30)	881.1 (24.95)
BW190AD-4 HF	799.9 (22.65)	1034.4 (29.29)

Standard Equipment

- ☑ Hydrostatic travel and vibration drive
- ☑ 2 amplitudes / 2 frequencies
- ☑ Hydrostatic articulated steering
- ☑ Crab steer right / left 6.7° (170mm)
- ☑ Automatic vibration operation
- ☑ Individual drum vibration control
- ☑ Operator's platform with:
  - two (2) steering wheels
  - adjustable seating position
- ☑ 2 travel levers with integrated switches for vibration
- ☑ Vehicle electronics with modular circuit technology
- ☑ High capacity plastic water tanks
- ☑ Pressurized water spray with 2 spray pumps
- ☑ Folding scraper design
  4 integrated worklights
  - Indicator and hazard lights
- ☑ ROPS / FOPS with seat belt
- ☑ Back-up alarm

Optional Equipment

- ☐ Speedometer
- ☐ Edge cutter
- ☐ ROPS cabin with seat belt with / without heating plus outside mirror
- ☐ Rotary beacon
- ☐ Special painting



Dimensions in inches (mm)

	A	B	C	D	H	H₂	K	L	O	W
BW161AD-4	129.9 (3300)	72.44 (1840)	27.56 (700)	48.03 (1220)	91.34 (2320)	118.11 (3000)	15.75 (400)	177.95 (4520)	3.15 (80)	66.1 (1680)
BW190AD-4 HF	129.9 (3300)	85.04 (2160)	28.15 (715)	48.03 (1220)	91.34 (2320)	118.11 (3000)	13.78 (350)	177.95 (4520)	3.15 (80)	78.74 (2000)

Technical data			BOMAG BW161AD-4		BOMAG BW190 AD-4 HF	
Weights						
Basic weight with ROPS	lbs	(kg)	19511	(8850)	25353	(11500)
Operating weight	lbs	(kg)	21826	(9900)	26015	(11800)
Axle load (front)	lbs	(kg)	11079	(5025)	12895	(5849)
Axle load (rear)	lbs	(kg)	10748	(4875)	13120	(5951)
Average static linear load	pli	(kg/cm)	165.1	(29.5)	165.2	(28.75)
Dimensions						
Rolling width	in	(mm)	66.1	(1679)	78.7	(2000)
Transport height	in	(mm)	118.11	(3000)	118.11	(3000)
Track radius, inner	in	(mm)	173.2	(4400)	166.93	(4240)
Driving Characteristics (depending on site conditions)						
Speed (1)	mph	(kmph)	0-3.5	(0-5.7)	0-3.5	(0-5.7)
Speed (2)	mph	(kmph)	0-7.0	(0-11.3)	0-7.0	(0-11.3)
Max. gradeability	%		40		40	
Drive						
Engine manufacturer			Deutz		Deutz	
Type			TCD 2011 L04		TCD 2012 L04	
Tier Compliance			Tier 3		Tier 3	
Cooling			water		water	
Number of cylinders			4		4	
Performance SAE J1349	hp	(kW)	99	(75)	134	(100)
Speed	rpm		2300		2300	
Fuel			diesel		diesel	
Electric equipment	V		12		12	
Drive system			hydrostatic		hydrostatic	
Drum driven			f + r		f + r	
Brakes						
Service brake			hydrostatic		hydrostatic	
Parking brake			SAHR		SAHR	
Steering						
Steering system			oscillating, articulating		oscillating, articulating	
Steering method			hydrostatic		hydrostatic	
Steering / Oscillating angle +/-	degrees		30 / 6		30 / 6	
Vibratory System						
Vibrating drum			f, r, f + r		f, r, f + r	
Drive system			hydrostatic		hydrostatic	
Frequency - (high/low)	vpm	(Hz)	3000/2400	(50/40)	3600/2880	(60/48)
Amplitude - (low/high)	in	(mm)	0.015/0.036	(0.39/0.91)	0.015/0.034	(0.37/0.86)
Centrifugal force - (low/high)	lbs	(kN)	18884/28324	(84/126)	28800/40950	(128/182)
Water Spray System						
Type of system			pressurized		pressurized	
Back-up system			2nd pump		2nd pump	
Capacities						
Fuel	gal	(l)	52.8	(200)	52.8	(200)
Water	gal	(l)	264.2	(1000)	264.2	(1000)
Engine oil	gal	(l)	2.5	(9.5)	2.5	(9.5)

Technical modifications reserved. Machines may be shown with options.

B36H-3763 1M0414TTPPG

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92009, 92015 - R0

Table H.5: RSMeans Public Water Estimation Report

4850 Public Stormwater & Utilities

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 00					
00000001	Fire Hydrant Material and Install	6.00	Ea.	$6,000.00	$36,000.00
00000002	Taylor Made Plastics 12 in. Bell End Pipe Plug for Ductile Iron	3.00	Ea.	$121.66	$364.98
00000009	1" Copper Water House Connections	8,468.00	L.F.	$42.77	$362,176.36
00000014	Valve Assembly with Valve Box: 4" to 12" Gate	17.00	Ea.	$1,479.00	$25,143.00
Division 00 Subtotal					**$423,684.34**
Division 31 Earthwork					
312316136080	Excavating, trench or continuous footing, sand and gravel, 1/2 C.Y. excavator, 4' to 6' deep, excludes sheeting or dewatering	4,668.00	B.C.Y.	$5.02	$23,433.36
312323131300	Backfill, bulk, up to 300' haul, dozer backfilling, excludes compaction	5,688.00	L.C.Y.	$1.50	$8,532.00
Division 31 Earthwork Subtotal					**$31,965.36**
Division 33 Utilities					
331413158040	Water supply distribution piping, fitting, 90 degree bend or elbow, mechanical joint, ductile iron, cement lined, AWWA C110, 12" diameter, class 50 water piping	2.00	Ea.	$790.38	$1,580.76
331413158240	Water supply distribution piping, filling, wye or tee, ductile iron, cement lined, mechanical joint, AWWA C110, 12" diameter, class 50 water piping	3.00	Ea.	$1,299.64	$3,898.92
Division 33 Utilities Subtotal					**$5,479.68**
Division 82					
8230166	12" Ductile Iron Water Main	5,111.00	L.F.	$98.88	$505,375.68
Division 82 Subtotal					**$505,375.68**
Grand Total					**$966,505.06**

Table H.6: RSMeans Public Sanitary Estimation Report

4850 Public Sanitary Estimate

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 00					
00000003	Sanitary sewer manholes, 48" diameter, 8' deep	13.00	Ea.	$6,060.00	$78,780.00
00000010	6" PVC Sewer House Connection	8,468.00	L.F.	$57.03	$482,930.04
Division 00 Subtotal					**$561,710.04**
Division 31 Earthwork					
312316136352	Excavating, trench or continuous footing, sand and gravel, 1/2 C.Y. excavator, 4' to 6' deep, includes trench box, excludes dewatering	8,612.00	B.C.Y.	$8.16	$70,273.92
312323131300	Backfill, bulk, up to 300' haul, dozer backfilling, excludes compaction	10,666.00	L.C.Y.	$1.50	$15,999.00
Division 31 Earthwork Subtotal					**$86,272.92**
Division 40					
4027001	10" PVC Sanitary Pipe	4,844.00	L.F.	$78.69	$381,174.36
Division 40 Subtotal					**$381,174.36**

Grand Total **$1,029,157.32**

Table H.7: RSMeans Public Storm System Estimation Report

4850 Public Storm System

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 00					
00000008	Catch Basin, Drop Inlet 48", Cast In Place & Precast 12"-24" Pipes	33.00	Ea.	$8,745.00	$288,585.00
Division 00 Subtotal					**$288,585.00**
Division 31 Earthwork					
312316136352	Excavating, trench or continuous footing, sand and gravel, 1/2 C.Y. excavator, 4' to 6' deep, includes trench box, excludes dewatering	9,995.00	B.C.Y.	$8.16	$81,559.20
312323131300	Backfill, bulk, up to 300' haul, dozer backfilling, excludes compaction	11,839.00	L.C.Y.	$1.50	$17,758.50
Division 31 Earthwork Subtotal					**$99,317.70**
Division 33 Utilities					
330561101110	Storm drainage manholes, frames and covers, concrete, precast, 4' ID, 4' deep, excludes footing, excavation, backfill, frame and cover	13.00	Ea.	$1,289.90	$16,768.70
334211603960	Public storm utility drainage piping, slotted reinforced concrete pipe (RCP) class 4 O-Ring, 24" diameter, excludes excavation or backfill	5,622.00	L.F.	$78.08	$438,965.76
Division 33 Utilities Subtotal					**$455,734.46**
Grand Total					**$843,637.16**

Table H.8: RSMeans Paw Paw Connection Estimation Report

4850 Paw Paw Connection for Water and S

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber		Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 00						
00000001		Fire Hydrant Material and Install	8.00	Ea.	$6,000.00	$48,000.00
00000003		Sanitary Sewer Manholes, 48" Diameter, 8' Deep	12.00	Ea.	$6,060.00	$72,720.00
00000014		Valve Assembly with Valve Box: 4" to 12" Gate	11.00	Ea.	$1,479.00	$16,269.00
Division 00	**Subtotal**					**$136,989.00**
Division 31	**Earthwork**					
312316131352		Excavating, trench or continuous footing, common earth, 1/2 C.Y. excavator, 4' to 6' deep, includes trench box, excludes dewatering	8,444.00	B.C.Y.	$9.09	$76,755.96
312316136080		Excavating, trench or continuous footing, sand and gravel, 1/2 C.Y. excavator, 4' to 6' deep, excludes sheeting or dewatering	4,731.00	B.C.Y.	$5.02	$23,749.62
312323131300		Backfill, bulk, up to 300' haul, dozer backfilling, excludes compaction	16,224.00	L.C.Y.	$1.50	$24,336.00
Division 31	**Earthwork Subtotal**					**$124,841.58**
Division 40						
4027001		10" Diameter PVC Sanitary Pipe	4,750.00	L.F.	$78.69	$373,777.50
Division 40	**Subtotal**					**$373,777.50**
Division 82						
8230166		12" Diameter Ductile Iron Water Main	5,109.00	L.F.	$98.88	$505,177.92
Division 82	**Subtotal**					**$505,177.92**
Grand Total						**$1,140,786.00**

LONGS PEAK WATER DISTRICT

9875 Vermillion Road • Longmont, CO 80504 • (303) 776-3847 office • (303) 776-0198 fax

FIRE HYDRANT INSTALLATION REVIEW

(For fire hydrants not related to new subdivision construction)

Information for Applicant:

Most fire hydrants within the District are installed by developers, as part of new subdivision construction. The District will install fire hydrants where possible, and when requested by an Applicant who is willing to pay the costs of the fire hydrant including materials, installation and fire hydrant fee costs.

This form is for an individual or group of individuals to request and receive approval to have a fire hydrant installed at a specific location and are willing to pay the costs and fees associated with such an installation.

The hydrant, if approved, will be installed by either District crews or a contractor hired by the District to complete the installation. All installations will be in accordance with District Standards and Specifications.

Cost of Fire Hydrants:

Generally, the base cost of a fire hydrant including materials, installation and fees is about $6,000. Of course every situation is different and costs of a fire hydrant will vary depending upon line size, location, complexity of installation and other factors. All costs associated with a fire hydrant installation will be the responsibility of the Applicant.

Figure H.6 shows the fire hydrant quote from Longs Peak Water District

WATER SYSTEM - MISCELLANEOUS	$	-	
Jack and bore casing (3/8" wall thickness), 16" - 30" ID (6" - 12" carrier pipe)	$	693	LF
01" Service Connection (Incl Corp. Stop, Tubing, Meter)	$	797	EA
Jack Pit	$	5,233	EA
Fire Hydrant Assembly (4): with 20 LF 6" Dip	$	5,324	EA
Valve Assembly with valve box: 3" Ball	$	451	EA
Valve Assembly with valve box: 4" to 12" Gate	$	1,479	EA
Valve Assembly with valve box: 14" to 24" Butterfly	$	8,455	EA
Wet Tap of Live Line - Grass Area, 6" to 12" Tap & in Street Patch	$	5,082	EA

Figure H.7 shows the gate valve estimate from Fairfax County's 2022 Unit Price Sheet

Section 5

Water and Sewer

ITEM	UNIT	UNIT COST
Water Line		
4" DIP Water Main (CL52)	LF	$100.00
6" DIP Water Main (CL52)	LF	$130.00
8" DIP Water Main (CL50)	LF	$135.00
10" DIP Water Main (CL50)	LF	$140.00
12"DIP Water Main (CL50)	LF	$150.00
1" Copper Water House Connections	LF	$30.00
2" Copper Water House Connections	LF	$45.00
Fire Hydrants	EA	$4,500.00
Low Cradle, Encasement, or Blocking	CY	$600.00
Water Valves		
4"	EA	$1,200.00
6"	EA	$1,500.00
8"	EA	$1,750.00
12"	EA	$2,800.00
16"	EA	$4,000.00
18"	EA	$5,000.00
24"	EA	$8,000.00
Wet Taps		
Wet Taps Up to 12" Diameter	EA	$4,000.00
Wet Taps Over 12" Diameter, Under 24" Diameter	EA	$7,000.00
Wet Tap 24" Diameter	EA	$10,000.00
Sewer Line		
8" PVC Sewer Main	LF	$50.00
10" PVC Sewer Main	LF	$70.00
12" PVC Sewer Main	LF	$110.00
15" PVC Sewer Main	LF	$130.00
4" PVC Sewer House Connection	LF	$35.00
6" PVC Sewer House Connection	LF	$40.00
Sewer Manholes		
48" Diameter - 8' or Less	EA	$4,250.00
48" Diameter, Each Vertical Foot Over 8' of Depth	VF	$350.00
60" Diameter - 8' or Less	EA	$4,500.00
60" Diameter, Each Vertical Foot Over 8' of Depth	VF	$500.00
Drop Manhole	EA	$5,000.00
Transition Manhole	EA	$3,300.00
Flushing Manhole for Pressure Sewer	EA	$4,900.00

Figure H.8 shows the water and sanitary house connect estimate, as well and the sanitary manhole estimate from the City of Rockville's standard price sheet 2010

STORM SEWER - PRECAST DROP INLETS	$	-	
Curb Drop Inlets, Precast, 12"-30" Pipes	$	8,397	EA
Curb Drop Inlets, Precast, 36"-48" Pipes	$	12,002	EA
Drop Inlet 48", Cast In Place & Precast 12"-24" Pipes	$	8,745	EA

Figure H.9 shows the catch basin estimate from Fairfax County's 2022 Unit Price Sheet

Figure H.10 shows the end of the public water line in Paw Paw. The hydrant on the left side of the image marks the end water line.

Figure H.11 shows the end of the public sanitary in Paw Paw. The manhole in the center of the road marks the end of the line.

Figure H.12 shows the calculated distance of water pipe needed to reach our site

Figure H.13 shows the calculated distance of sanitary pipe needed to reach our site

Table H.9: RSMeans Private Storm Estimation Report

4850 Private Stormwater and Utilities

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 00					
00000008	Catch Basin, Drop Inlet 48", Cast In Place & Precast 12"-24" Pipes	33.00	Ea.	$8,745.00	$288,585.00
Division 00 Subtotal					**$288,585.00**
Division 31 Earthwork					
312316136352	Excavating, trench or continuous footing, sand and gravel, 1/2 C.Y. excavator, 4' to 6' deep, includes trench box, excludes dewatering	9,392.00	B.C.Y.	$8.16	$76,638.72
312323131300	Backfill, bulk, up to 300' haul, dozer backfilling, excludes compaction	11,269.00	L.C.Y.	$1.50	$16,903.50
Division 31 Earthwork Subtotal					**$93,542.22**
Division 33 Utilities					
330561101110	Storm drainage manholes, frames and covers, concrete, precast, 4' ID, 4' deep, excludes footing, excavation, backfill, frame and cover	10.00	Ea.	$1,289.90	$12,899.00
334211603970	Public storm utility drainage piping, slotted reinforced concrete pipe (RCP) class 4 O-ring, 21" diameter, excludes excavation or backfill	5,283.00	L.F.	$68.06	$359,560.98
Division 33 Utilities Subtotal					**$372,459.98**
Grand Total					**$754,587.20**

Table H.10: RSMeans Private Utilities Estimation Report

4850 Private Well and Sewer

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 00					
00000007	Installation of an 80' well for a residential home	43.00	Ea.	$8,000.00	$344,000.00
Division 00 Subtotal					**$344,000.00**
Division 33 Utilities					
333413130060	Utility septic tank and effluent wet well, septic tanks precast concrete, 1,500 gallon, excludes excavation or piping	43.00	Ea.	$1,805.36	$77,630.48
333413130910	Utility septic tank, concrete riser, 24" x 8" with standard lid	43.00	Ea.	$157.12	$6,756.16
333451102200	Drainage field, & septic tank, excavation, 3/4 C.Y. bucket, excavation with backhoe	4,042.00	C.Y.	$11.08	$44,785.36
333451102600	Drainage fill, septic tanks gravel fill, run of bank, excludes excavation or piping	2,623.00	C.Y.	$37.51	$98,388.73
333451130015	Utility septic tank tile drainage field, septic tanks distribution boxes, concrete, 5 outlets, excludes excavation or piping	43.00	Ea.	$116.45	$5,007.35
334116103000	Subdrainage piping, vitrified clay, foundation drain, perforated, 5' lengths, 4" diameter, C700, excludes excavation and backfill	7,095.00	L.F.	$9.51	$67,473.45
Division 33 Utilities Subtotal					**$300,041.53**
Grand Total					**$644,041.53**

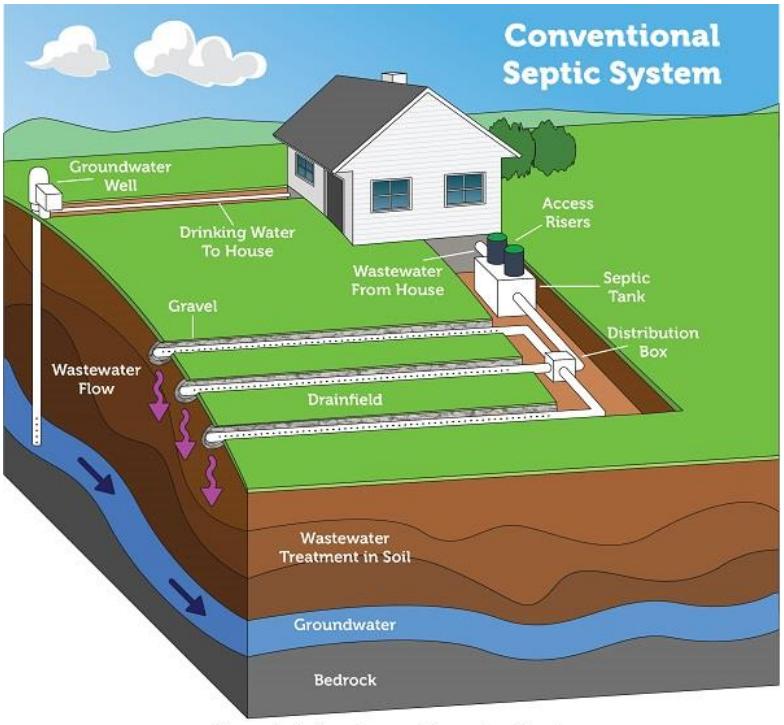

Figure H.14 shows the basis of design for our private sanitary system for each lot

Table H.11 shows the size of septic tank required for a home based on the number of bedrooms

Table of Required Septic Tank Size Based on Number of Bedrooms in a Home

How big does our septic tank need to be based on the number of bedrooms in the home? Some jurisdictions use the number of bedrooms rather than number of occupants or estimated daily wastewater flow to guide homeowners and septic installers in choosing a septic tank size.

Septic Tank in Gallons Size Based on Number of Bedrooms		
Number of bedrooms	**Minimum Septic Tank Capacity (Gallons)**	**Minimum Septic Tank Liquid Surface Area (sq.ft.)**
0 bedrooms	750 gal. (2) - obsolete in NYS	
1, 2, or 3 bedrooms	1,000 gallons	27 sq.ft.
4 bedrooms	1,200 gallons	34 sq.ft.
5 bedrooms	1,500 gallons	40 sq.ft.
6 bedrooms	1,750 gallons	47 sq.ft.

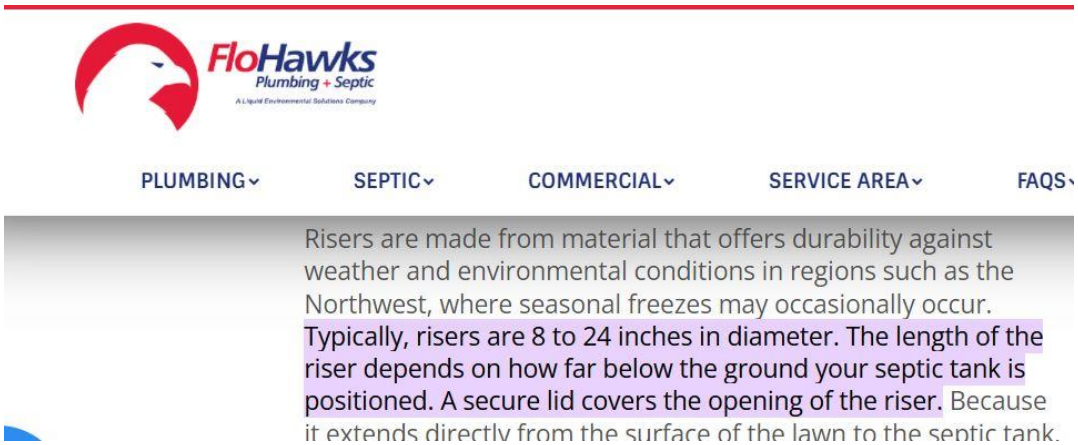

Figure H.15 shows the basis of our selection of the concrete riser from Flohawks

Table H.12 shows the required SF for a drainage field based on perc rate and number of rooms

Square Feet of Drain Field Trench Required for Single Family Dwelling

Number of Bedrooms	1	2	3	4	5	6	7	8	9
Perc Rate in Minutes Per Inch	200 gpd	300 gpd	400 gpd	500 gpd	600 gpd	700 gpd	800 gpd	900 gpd	1000 gpd

<5 Systems must be designed with a 12 inch loamy sand liner that would have a percolation rate of 15 to 20 minutes per inch and shall be designed at the 11-20 minute per inch level

5-10	165	330	495	660	825	990	1155	1320	1485
11-20	210	420	630	840	1050	1260	1470	1680	1890
21-30	250	500	750	1000	1250	1500	1750	2000	2250
31-40	275	550	825	1100	1375	1650	1925	2200	2475
41-50	330	660	990	1320	1650	1980	2310	2640	2970
51-60	350	700	1050	1400	1750	2100	2450	2800	3150

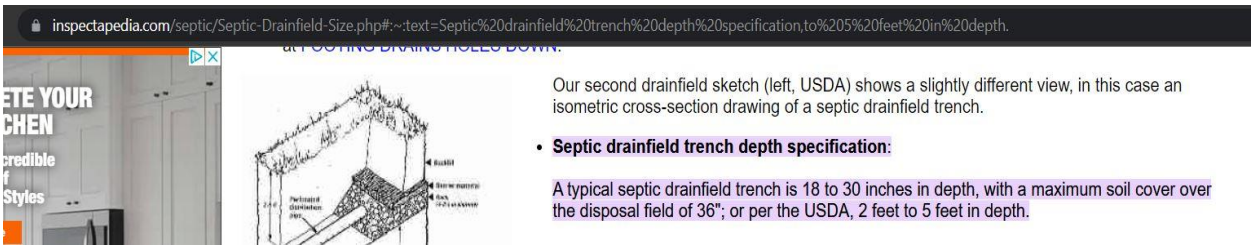

Figure H.16 explains the typical depth of a drain field on a lot

Table H.13: RSMeans Public Miscellaneous Estimation Report

4850 Public Miscellaneous

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 00					
00000011	Stop Sign, includes sign, post, foundation, and installation	14.00	Ea.	$375.00	$5,250.00
00000012	Speed Limit Sign, includes sign, post, foundation, and installation	2.00	Ea.	$400.00	$800.00
00000013	Street Signs, includes sign, post, foundation, and installation	12.00	Ea.	$295.00	$3,540.00
Division 00 Subtotal					**$9,590.00**
Division 32 Exterior Improvements					
323113150100	Chain link fence, galvanized steel, 11 ga. wire, 1-5/8" post 10'OC, 1-3/8" top rail, 2" corner post, 6' high, excludes excavation	525.00	L.F.	$17.45	$9,161.25
329333100300	Shrubs and trees, evergreen, in prepared beds, cedar, blue, B&B, 8' - 10', in prepared beds	31.00	Ea.	$331.60	$10,279.60
329343200300	Deciduous trees, birch, balled & burlapped (B&B), 6' - 8', 3 stems, in prepared beds	32.00	Ea.	$208.76	$6,680.32
329343200800	Deciduous trees, elm, balled & burlapped (B&B), 8'-10', in prepared beds	32.00	Ea.	$529.84	$16,954.88
329343202800	Deciduous trees, willow, balled & burlapped (B&B), 6' - 8', 1" caliper, in prepared beds	31.00	Ea.	$208.76	$6,471.56
Division 32 Exterior Improvements Subtotal					**$49,547.61**
Grand Total					**$59,137.61**

Table H.14: RSMeans Private Miscellaneous Estimation Report

4850 Private Miscellaneous

Year 2022

Unit Detail Report

Prepared By: Yufeng Hu Dept of Civil and Construction Engineeri

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 00					
00000011	Stop Sign, includes sign, post, foundation, and installation	14.00	Ea.	$375.00	$5,250.00
00000012	Speed Limit Sign, includes sign, post, foundation, and installation	2.00	Ea.	$400.00	$800.00
00000013	Street Signs, includes sign, post, foundation, and installation	12.00	Ea.	$295.00	$3,540.00
Division 00 Subtotal					**$9,590.00**
Division 32 Exterior Improvements					
323113150100	Chain link fence, galvanized steel, 11 ga. wire, 1-5/8" post 10'OC, 1-3/8" top rail, 2" corner post, 6' high, excludes excavation	529.00	L.F.	$17.45	$9,231.05
329333100300	Shrubs and trees, evergreen, in prepared beds, cedar, blue, B&B, 8' - 10', in prepared beds	13.00	Ea.	$331.60	$4,310.80
329343200300	Deciduous trees, birch, balled & burlapped (B&B), 6' - 8', 3 stems, in prepared beds	13.00	Ea.	$208.76	$2,713.88
329343200800	Deciduous trees, elm, balled & burlapped (B&B), 8'-10', in prepared beds	14.00	Ea.	$529.84	$7,417.76
329343202800	Deciduous trees, willow, balled & burlapped (B&B), 6' - 8', 1" caliper, in prepared beds	13.00	Ea.	$208.76	$2,713.88
Division 32 Exterior Improvements Subtotal					**$26,387.37**
Grand Total					**$35,977.37**

Note that inflation, labor cost changes, and fluctuations in commodities markets and metal value may make some of these figures quickly obsolete. Use with caution.

- Sign panels:
  - Regulatory, warning, marker, and small guide signs on flat sheet panels: $25 to $35 per square foot
  - Larger guide signs on extruded panels or frames: $30 to $40 per square foot
- Sign Posts:
  - U-channel posts: $100 to $150 each per post (10 - 14 ft length)
  - Square tube posts: $13 to $20 per foot
  - Large Steel Breakaway Posts: $40 to $50 per foot
  - Cantilever Sign: $50,000 to $60,000 per structure
  - Sign Bridge: $80,000 to $100,000 per structure
- Foundations:
  - Square Tube: $150 to $250 per foundation
  - Large Steel Breakaway Post: $1,000 to $1,500 per foundation
  - Cantilever or Bridge: $10,000 to $12,000 per foundation

Note: if you're evaluating the replacement cost of an existing sign, you must take into account the extra labor and transportation costs involved, along with the relative urgency of sign replacement.

This is why Stop signs are considered among the most expensive signs. Due to their critical importance in intersection safety, they should be replaced as soon as is reasonably feasible - even if that means driving hundreds of miles round trip at any hour of the day or night, at $1.50 per mile for the truck and $40 - $75 per hour overtime for each sign crewperson. Taking this into account, a simple $125 STOP sign suddenly becomes a multi-thousand-dollar expense.

Figure H.17 shows the basis of our sign estimations