City of Mequon Drainage Capital Improvement Stormwater Study:

Prairie View Lane and Lakeshore Drive

Prepared by FreshWater Engineering

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Contents

1.0 Introduction

FreshWater Engineering (FW) was retained by the City of Mequon (City) to evaluate stormwater management opportunities between Mequon Road and Glen Oaks Lane. FW understands that the neighborhoods surrounding this area have experienced ongoing flooding, with residents reporting water in basements and yards.

A previous study found that these areas were in need of improved stormwater management infrastructure. In 1999, Camp Dresser & McKee (CDM) performed in-depth runoff modeling of the area and compiled a long-term management plan. The study recommendations included channel improvements to add storage and conveyance capacity as well as construction of a detention basin south of Mequon Road between Interstate 43 and the rail line. FW understands these are still planned for future implementation, but the schedule is currently unknown.

FW also understands that an expansion of Interstate 43 has been planned and that this may impact drainage in the area. The project will be required to manage additional stormwater runoff generated by the increased impervious surfaces. It is beyond the scope of the current investigation to provide mitigation for any effects of the expansion project, though there may be opportunities to coordinate with the Interstate 43 project to increase stormwater storage.

The City has asked FW to evaluate short-term improvements to stormwater management in the area. With the understanding that residents are looking to see reductions in flood frequency and magnitudes, the City is in search of cost-effective options that will offer some flood relief. In response, FW has created a stormwater model in HydroCAD and evaluated potential management opportunities to reduce flooding.

FW also understands that there is drain tile running from the wetland areas, but their condition and precise location are unknown. There is also no information regarding condition or invert elevations. As a result, it is not feasible to produce informative model results. Any input parameters for the drain tile condition would be purely speculative, as would the resulting model outputs. Additionally, it will be virtually impossible to achieve the permitting required to install new drain tile in a wetland. Consequently, FW has not investigated any potential options for changes to the drain tile.

2.0 Site Information

The study site is near the Lake Michigan coastline in Mequon, WI (Figure 1). It extends from approximately Mequon Road at the southern extent to Glen Oaks Lane at the northern boundary. The eastern edge of the study area is the boundary between the Lake Michigan and Milwaukee River watersheds; drainage from the study area flows west toward a large wetland site before discharging to the Milwaukee River.

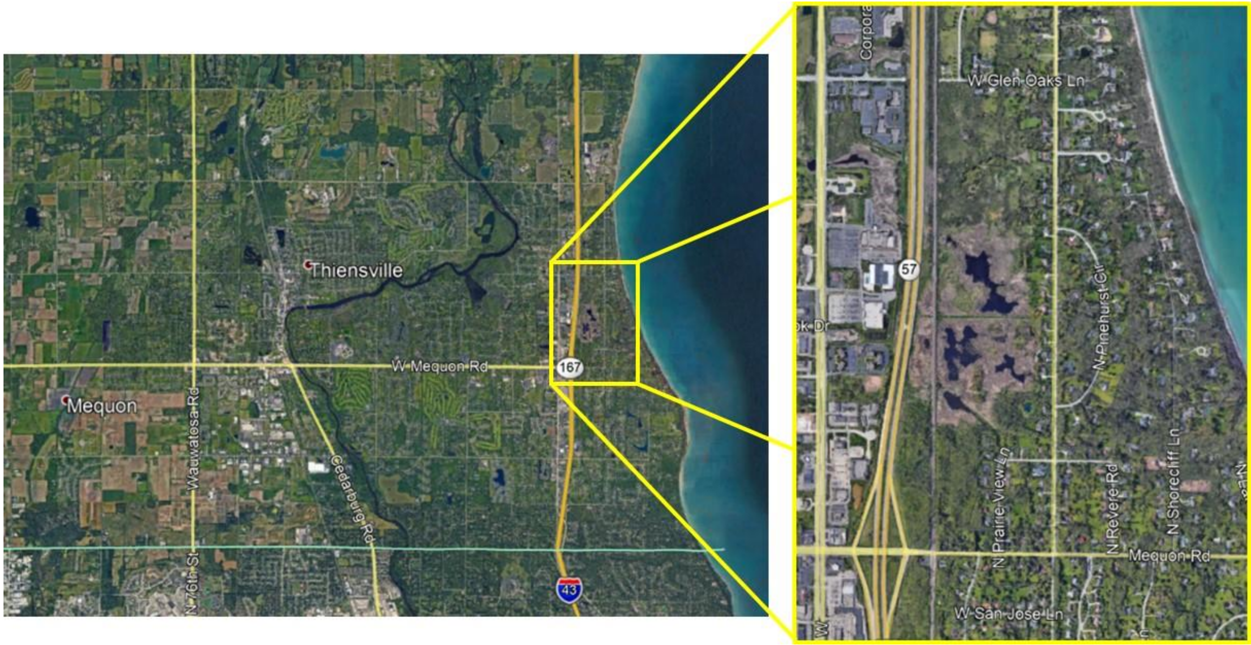

Figure 1. Site location within the City of Mequon, Wisconsin.

Site topography is relatively flat (Figure 2). Because there is limited topographic relief, it is difficult to move stormwater runoff towards the river quickly. Water therefore tends to pool in low-lying areas, often flooding yards and homes. This is of particular concern near the corner of Revere Road and Prairie View Lane, though there are other areas that experience regular flooding as well.

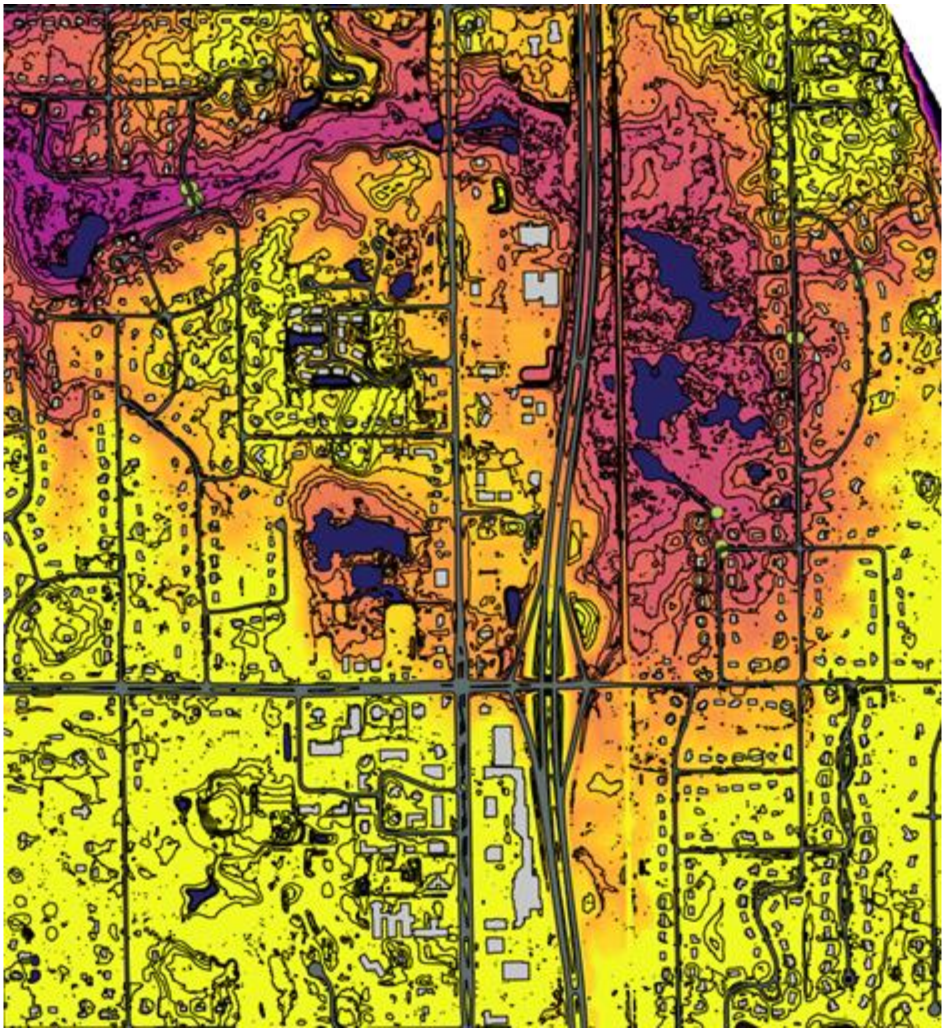

Figure 2. Topographic data for the project site; contour lines are at 2-ft intervals. Paved areas, structures, and water bodies are highlighted for reference.

The site also features significant wetland area. Between Interstate 43 and Lake Shore Drive is a wetland that frequently has standing water. Based on Wisconsin Department of Natural Resources (WDNR) maps, the wetland covers much of the study area. This creates significant challenges for permitting stormwater management improvements, as any dredging or in-stream work would require approval from WDNR and the US Army Corps of Engineers (USACE). Because wetlands offer a range of ecosystem benefits including water treatment, flood storage, and native species habitat, they are protected from development and it may not be feasible to make significant changes to the wetland areas within the project site.

3.0 Model Development

The team relied on *HydroCAD* modeling to evaluate the study site. *HydroCAD* is a stormwater modeling software package that allows engineers to estimate flow volumes, maximum water surface elevations (WSEs), and other hydraulic parameters based on site information.

The *HydroCAD* model is a powerful tool for stormwater assessments, though it is limited in detail. A more detailed analysis of the system would require far more expensive modeling packages and would take longer to develop. For the purposes of this project, FW chose the simplified model because it provides a good baseline of the current system performance and offers broad-scope quantifications of improvements. Before final planning and construction of any stormwater management alternatives, FW recommends a more intensive modeling effort in support of the design work.

FW built two models for this project. The *Existing Conditions* model evaluated the site in its current state. This served as a baseline for comparison against a *Proposed Conditions* model. Model development started with a review of existing information from the City and a site visit. That information was then built into the *Existing Conditions* model and calibrated using results reported from the 1999 CDM model. The final step was to build alternative management solutions into *HydroCAD* to create the *Proposed Conditions* model.

3.1 Data Review & Site Visit

FW began by reviewing data provided by the City. Information included LiDAR (land surface elevation) data, infrastructure information ranging from storm- and sanitary-sewer line placement to culvert locations to a structure inventory. This information was imported to GIS software and used to evaluate flowpaths, identify locations of high flood risk, and measure drainage areas.

Following data review, the team visited the site on September 2nd, 2020. During this visit, team members documented areas of interest including culverts, wetland areas, flowpaths, ditches, and other points that would be of potential value for stormwater modeling and design recommendations. Culvert measurements were taken for input to the model. In addition, the team used topographic surveying equipment to locate inverts and define slopes within the study area.

Figure 3. FW surveyor collecting culvert invert elevation data.

3.2 Existing Conditions Model Development

FW took the field and geographic information system (GIS) data and incorporated it into a *HydroCAD* model. Inputs included culvert sizes, slopes, and roughness parameters; subcatchment areas, curve numbers, and slopes; stream reach dimensions and roughnesses; and pond stage-storage relationships and outlet characteristics. That information is used by the model to determine flow routing, maximum WSE, and potential flood risks.

The model evaluated several rainfall events. Rainfall events were selected based on expected recurrence intervals, with the 2-, 10-, 25-, and 100-year event being set to match those reported by CDM from their 1999 study. Rainfall depths for each event were obtained from the National Weather Service's Precipitation Frequency Data Server at Station No. 47-5477 (Milwaukee North Side). The station is located approximately 8 miles south of the project site. The model used 24-hour durations for simulations, with rainfall depths reported in the table below:

Table 1. 24-hour rainfall depths for 2-, 10-, 25-, and 100-year recurrence intervals as reported by the National Weather Service for Station No. 47-5477 (Milwaukee North Side).

Recurrence Interval [yr]	2	10	25	100
Rainfall Depth [in]	2.64	3.75	4.60	6.16

FW calibrated the model using the reported results from the 1999 CDM model. Calibration data points were available for culverts at Pinehurst Circle, Lake Shore Drive, Interstate 43, and Port Washington Road (County W). Due to an error in the reporting of the 1999 CDM results, calibration to a specified WSE at the Pinehurst Circle culvert location was not possible; the 1999 results indicate a WSE approximately 10 feet above the road surface, so flow volumes alone were used for calibration. Flow volumes are reported in cubic feet per second (cfs). A comparison of results is provided below:

Table 2. Comparison of the 2-, 10-, 25-, and 100-year, 24-hour precipitation event. Reported results from the 1999 CDM model are provided at left; FW model results are in bold at right.

Discharge Results Comparison [cfs]								
Location	**2-Year**		**10-Year**		**25-Year**		**100-Year**	
Pinehurst Circle	1	**0.5**	3	**2.9**	6	**6.0**	12	**13.6**
Lake Shore Drive	2	**2.3**	8	**10.8**	14	**20.8**	49	**45.5**
I-43	25	**23.7**	32	**28.2**	43	**41.3**	64	**66.0**
Port Washington Road	25	**19.8**	37	**28.0**	48	**42.2**	68	**69.7**

Table 3. Water surface elevation (WSE) results comparison of the 2-, 10-, 25-, and 100-year, 24-hour precipitation event. Reported results from the 1999 CDM model are provided at left; FW model results are in bold at right. WSE results from the 1999 model indicate water levels approximately 10 feet above the existing road elevation at the Pinehurst Circle culvert, so these were not used in the calibration process.

WSE Results Comparison [ft NAVD88]								
Location	**2-Year**		**10-Year**		**25-Year**		**100-Year**	
Pinehurst Circle	*672.7**	**634.0**	*673.1**	**664.6**	*673.6**	**665.4**	*675.3**	**668.4**
Lake Shore Drive	663.9	**663.6**	664.9	**664.7**	666.1	**666.4**	667.2	**667.2**
I-43	663.8	**664.1**	664.1	**664.1**	664.4	**664.2**	664.9	**664.8**
Port Washington Road	660.6	**660.5**	661.0	**660.8**	661.3	**661.1**	661.7	**661.7**

3.3 Proposed Conditions *Model Development*

FW used the *Existing Conditions* model as a baseline for evaluating stormwater management alternatives. Changes were made to channel dimensions, storage volumes, and surface roughness parameters to quantify improvement potential. Each alternative was evaluated separately and holistically to determine the approximate overall increase in storage and/or conveyance offered by each modification.

Some assumptions were made due to the simplistic nature of the model. Storage ponds were not explicitly modeled in the *Proposed Conditions* evaluations. Instead, it was assumed that they would be capable of capturing runoff from any upslope areas, and those areas were removed from contributing to stream flows. During especially large events, it is possible that these detention ponds would overflow and contribute some additional runoff to the streams, so it is recommended that specific designs be evaluated in a more detailed manner before implementation. FW also assumed that the culverts along critical flow paths (including, but not limited to, those under private driveways, Pinehurst Circle, Lake Shore Drive, Revere Road, Prairie View Lane, the railroad, Interstate 43, and Port Washington Road) would be well-maintained and clear of obstructions.

The following section explains the individual improvement opportunities that FW considered. More detailed information about the changes made can be found in the appendix.

3.3.1 Modified Ditch Geometry

The simplest modifications are to expand ditches along streets in the project area. These are less likely to require special permitting and can be done relatively easily since they do not require dredging or moving heavy equipment through wetlands. Wider and deeper ditches along Revere Road and Prairie View Lane were evaluated for this improvement option.

The *Existing Conditions* ditches were modeled as parabolic channels with a top widths of 6.00 ft and depths between 1.75 ft and 2.00 ft. They were changed to have top widths of 10.00 ft and depths of 2.50 ft.

3.3.2 Modified Culverts

There are several culverts that FW evaluated within the project area. The culvert at Revere Road and Prairie View Lane was investigated, two others crossing Lake Shore at Revere Road and east of the Milwaukee Metropolitan Sewerage District (MMSD) property, as well as one under Pinehurst Circle. Access to these areas will be relatively simple and will likely not have a significant impact on wetlands.

3.3.2.1 Revere and Prairie View

This culvert is currently a pair of small pipes joining a pair of ditches and flowing under Revere Road.

The culverts in the *Existing Conditions* model were shown as a pair of round 18" corrugated pipes; they were adjusted to be a single round 36" corrugated pipe.

3.3.2.2 Revere and Lake Shore

This culvert in the *Existing Conditions* model is a 24" corrugated pipe. It was changed to a 36" corrugated pipe.

3.3.2.3 Lake Shore west of MMSD Property

This culvert in the *Existing Conditions* model is a 20" corrugated pipe. It was changed to a 36" corrugated pipe.

3.3.2.4 Pinehurst Circle

This culvert in the *Existing Conditions* model is an 18" corrugated pipe. It was changed to a 24" corrugated pipe.

3.3.3 Modified Stream Channel Geometry

As suggested in the 1999 CDM report, stream modifications are also a potential solution. This option may be more difficult from a permitting perspective, as it would require streambank modifications along a significant stretch of the drainage channel. It may also prove difficult to perform, as it may require bringing heavy equipment into a fragile wetland ecosystem.

The *Existing Conditions* channels were modeled as parabolic channels with top widths ranging from 12 ft to 24 ft and depths of 2.5 ft to 3 ft. They were changed to top widths of 20 ft to 30 ft and depths of 3.5 ft. Manning's *n*, a stream roughness parameter, was also decreased from between 0.035 and 0.0500 to between 0.020 and 0.025. This would correspond with removal of vegetation in the channel.

3.3.4 Single Large Detention Pond

The 1999 CDM study suggested the addition of a detention pond in the upstream area of the site. The proposed site was between Interstate 43 and the railroad, south of Mequon Road. This location may be troublesome as it is relatively high in the drainage basin, limiting the amount of water that would be directed to it. CDM envisioned a detention pond capable of holding approximately 90 acre-ft, which would require significant excavation.

3.3.5 Multiple Small Detention Ponds

FW also investigated smaller pond options. These could be located in residents' yards, providing small-scale, scattered detention areas. If neighborhood residents are amenable to this option, it may provide relief at relatively low cost; permitting may be simplified if the ponds are not located in a designated wetland area and proximity to roads would ease heavy machinery access.

The ponds were envisioned to be approximately 1,000 - 1,500 ft^2 in surface area and approximately 3 ft deep when at capacity. This could provide additional storage of 1,500 ft^3 or 0.035 acre-ft per pond.

4.0 *Proposed Conditions* Model Results

FW compared peak discharge volumes and WSEs with and without the treatments, focusing on culvert locations and immediate surroundings.

4.1 Revere Road and Prairie View Lane

The most effective means of lowering WSEs at this location was to install a larger culvert to convey water to the north. Adding the large detention basin made a small difference in WSEs, but significantly reduced flood discharges to the area. Other individual treatment options had little impact on flood conditions.

Table 4. Model water surface elevation (WSE) results for flood reduction with the Large Pond, Culvert Modification, and Combined scenarios at Revere Road and Prairie View Lane. Other treatment options did not show appreciable change in WSE.

Modeled Event	Existing	Lg Pond	Culv Mod	Combined
2-Year WSE [ft NAVD88]	663.2	663.2	**661.9**	**661.5**
10-Year WSE [ft NAVD88]	663.4	**663.3**	**663.3**	**663.1**
25-Year WSE [ft NAVD88]	663.5	663.5	**663.4**	**663.3**
100-Year WSE [ft NAVD88]	663.8	**663.7**	**663.7**	**663.5**

Table 5. Model discharge results with the Large Pond and Combined scenarios at Revere Road and Prairie View Lane. Other treatment options did not show appreciable change in discharge.

Modeled Event	Existing	Lg Pond	Combined
2-Year Discharge [cfs]	16.6	**12.5**	**11.6**
10-Year Discharge [cfs]	44.7	**33.5**	**31.3**
25-Year Discharge [cfs]	71.8	**53.9**	**50.3**
100-Year Discharge [cfs]	129.3	**97.0**	**90.5**

4.2 Revere Road and Lake Shore Drive

The most effective means of lowering WSEs at this location was to install a larger culvert to convey water to the north. Other treatment options had no significant impact on flood conditions.

Table 6. Model water surface elevation (WSE) results for flood reduction with the Culvert Modification, and Combined scenarios at Revere Road and Lake Shore Drive. Other treatment options did not show appreciable change in WSE.

Modeled Event	Existing	Culv Mod	Combined
2-Year WSE [ft NAVD88]	665.8	**665.5**	**665.5**
10-Year WSE [ft NAVD88]	666.3	**666.2**	**666.2**
25-Year WSE [ft NAVD88]	666.4	666.4	666.4
100-Year WSE [ft NAVD88]	666.6	**666.5**	**666.5**

4.3 Lake Shore Drive and MMSD Property

The most effective means of lowering WSEs at this location was to install a larger culvert to convey water to the north. Other individual treatment options had little impact on flood conditions.

Table 7. Model water surface elevation (WSE) results for flood reduction with the Culvert Modification, and Combined scenarios at Lake Shore Drive and MMSD property. Other treatment options did not show appreciable change in WSE.

Modeled Event	Existing	Culv Mod	Combined
2-Year WSE [ft NAVD88]	663.6	663.6	663.6
10-Year WSE [ft NAVD88]	664.6	**664.5**	**664.5**
25-Year WSE [ft NAVD88]	665.4	**665.0**	**665.0**
100-Year WSE [ft NAVD88]	668.4	**666.3**	**666.3**

4.4 Pinehurst Circle

The most effective means of lowering WSEs at this location was to install a larger culvert to convey water to the north. Other individual treatment options had little impact on flood conditions.

Table 8. Model water surface elevation (WSE) results for flood reduction with the Culvert Modification, and Combined scenarios at Pinehurst Circle. Other treatment options did not show appreciable change in WSE.

Modeled Event	Existing	Culv Mod	Combined
2-Year WSE [ft NAVD88]	663.6	**663.7**	**663.7**
10-Year WSE [ft NAVD88]	664.7	**664.6**	**664.6**
25-Year WSE [ft NAVD88]	666.4	**665.3**	**665.3**
100-Year WSE [ft NAVD88]	667.2	**666.7**	**666.7**

5.0 Discussion

FW performed stormwater modeling tasks to evaluate flooding in Mequon, Wisconsin. The model was calibrated to reported results of a 1999 study performed by CDM and used as a basis for long-term stormwater infrastructure improvements. The CDM report indicated that widening stream channels in the study area and excavating a large detention basin would be an effective means of flood mitigation. FW incorporated these into their model to determine their efficacy.

FW modeled several alternatives. These included the aforementioned detention basin and stream widening, along with ditch improvements, smaller ponds on homeowner land, and culvert modifications. The results indicated that the most effective methods of limiting food risk were to increase culvert capacity and add storage capacity in the upstream reaches of the system.

The most effective single alternative for mitigating flood risk is culvert replacement. The model shows that the current culvert configuration does not effectively convey runoff from large events. Once flow exceeds the capacity of the existing corrugated metal pipe (CMP) culverts, water backs up and flows over the road and into yards. Larger culverts would allow more water to flow under the road, minimizing the frequency of flooding in that area. The modeled culverts are still overwhelmed during larger events, but are capable of conveying smaller flows without spilling onto the roadway. During culvert installation, it would be relatively easy to widen ditches in the respective areas. This would further increase storage capacity and make small improvements to conveyance.

Figure 4. Map of study area showing location of proposed ditch modifications (left). Photograph of the existing ditch and culvert looking south towards Revere Road and Prairie View Lane intersection (right).

Adding storage upstream of the large wetlands is an effective way to minimize peak flow rates. The large detention basin is more effective for this purpose than a collection of smaller ponds, largely because it is able to capture runoff from a much larger area. The site proposed during the 1999 study lies between Interstate 43 and the railroad. Creating a large detention basin in this location is perhaps the most feasible option given current land-use, but it would require significant excavation. Runoff enters the area at an elevation of approximately 671 ft NAVD88; surface elevations at the site are as high as 678 ft NAVD88, with most of the site currently lying above the inlet elevation. The remainder of this sub-watershed consists of either developed land or wetland areas; excavation of a storage pond is therefore only feasible at the specified location. In addition, storage volume may be reduced by the upcoming interstate expansion.

The channel and ditch modifications evaluated show limited potential to reduce flooding. Increased cross-sectional area allows additional storage in the stream, but it does not appreciably reduce discharge in the small scales modeled. Widening the channels and managing vegetation helps improve conveyance, reducing flood risk to a small extent. However, that does not appear to be the most effective method available. Given the difficulty of obtaining permits to perform work in wetlands, this should be a low priority in terms of implementation.

Smaller detention ponds may provide small relief from flooding in smaller events. However, this would require community support in the form of private landowners allowing excavation in their yards, many of whom are not directly affected by the current flooding concerns. The addition of new ponds may provide additional habitat and have some ecosystem benefits, but it is not expected to have a large effect on flood severity or duration. Given the limited effect on flood reduction, this is perhaps not a practicable solution to the flooding concerns in the area.

Table 9. Recommended prioritization of selected interventions based on model results.

Modification	Priority	Notes
Culvert Modification	High	- Allows flow through current chokepoint - Still overwhelmed at 10-year event or larger - Could be coupled with ditch modifications
Large Detention Pond	Medium	- Has significant impact on peak discharge - Would require substantial excavation - Inflow at approximately 671 ft NAVD88 - Most of area above inflow, max approx. 677 ft NAVD88
Stream Modification	Low	- Limited effect on flooding, peak discharge - Potentially difficult to obtain permitting
Small Detention Ponds	Not Feasible	- Limited effect on flooding, peak discharge - Would require significant resident support by many who are not currently affected by flooding

Table 10. Benefits matrix showing which areas would see improvements to flood severity and duration for selected interventions.

	Benefit from Intervention			
Modification	**Revere & Prairie View**	**Revere & Lake Shore**	**Lake Shore & MMSD Property**	**Pinehurst**
Culvert Modification	Yes	Yes	Yes	Yes
Large Pond	Yes	No	No	No
Stream Modification	No	No	No	No
Small Ponds	No	No	No	No

5.1 Implementation Costs and Schedule

FW evaluated rough estimates of implementation costs and schedules. These vary from relatively simple culvert modifications with limited need for permitting to a far more involved process for stream modifications as shown in the table below.

Table 11. Order of magnitude estimate for implementation costs and schedules. Duration is the time from the start of engineering design through permit application and construction.

Modification	Approximate Cost	Duration
Culvert Modification	$25,000	2-4 wks
Large Pond	$150,000	10-15 mo
Stream Modification	$120,000	10-15 mo
Small Ponds [price/pond]	$15,000	4-6 mo

5.2 Additional Opportunities

FW also understands that the City is currently evaluating opportunities within the wetland pond areas to reduce neighborhood flooding. FW does not believe there are viable options to perform work within the wetlands as a flood mitigation strategy. Due to the difficulty of obtaining permits for dredging within the wetlands and the minimal flood reduction, there is little reason to pursue earthwork in these areas. FW was also asked about removal of non-native species in the wetlands; while it will likely improve the overall health of that ecosystem, this was not evaluated in the model because there is no reason to expect it to affect flood severity or duration.

The modeling team also considered the existing drain tile at the site. FW understands that the City has very limited information regarding the drain tile. As a result, any modeled outcomes would be purely speculative, and results would have no basis in real-world scenarios. It may be possible to repair an existing system, but there is no reason to believe the City could obtain permitting to install a new one. The combination of invert elevation at the wetland and conveyance capacity of the tile will heavily influence both the starting WSE within the ponds and the discharge out of the system; without that critical information, there is no meaningful way to model the existing drain tile.

As discussed above, the Interstate 43 widening project is outside FW’s scope of work. Water management for that project will be provided by the engineering team working on it. While FW understands there may be some loss of wetland area, it is also standard practice that all road projects address the increased impervious surface area and associated increase in stormwater runoff. Without knowing specifics of the project and how stormwater will be managed, FW is unable to evaluate the potential impact of the widening project.

Appendix

Changes made to the model for various geometry modifications are documented below

Modified Ditch Geometry

Ditches along Prairie View Lane were modeled as parabolic channels with specified top widths and depths, Manning's *n* roughness parameters, and bed slope. Changes to those parameters are shown in Table A1.

Table A1. Ditch parameters simulated in Existing Conditions *and* Ditch Modifications *models.*

	Existing Conditions			Ditch Modifications		
Ditch	**Top Width x Depth [ft]**	**Manning's *n***	**Slope [ft/ft]**	**Top Width x Depth [ft]**	**Manning's *n***	**Slope [ft/ft]**
Prairie View West	6 x 2	0.030	0.0070	10 x 2.5	0.023	0.0080
Prairie View East – South of Revere	6 x 2	0.030	0.0084	10 x 2.5	0.023	0.0090
Prairie View East – North of Revere	6 x 1.75	0.030	0.0053	10 x 2.5	0.023	0.0070

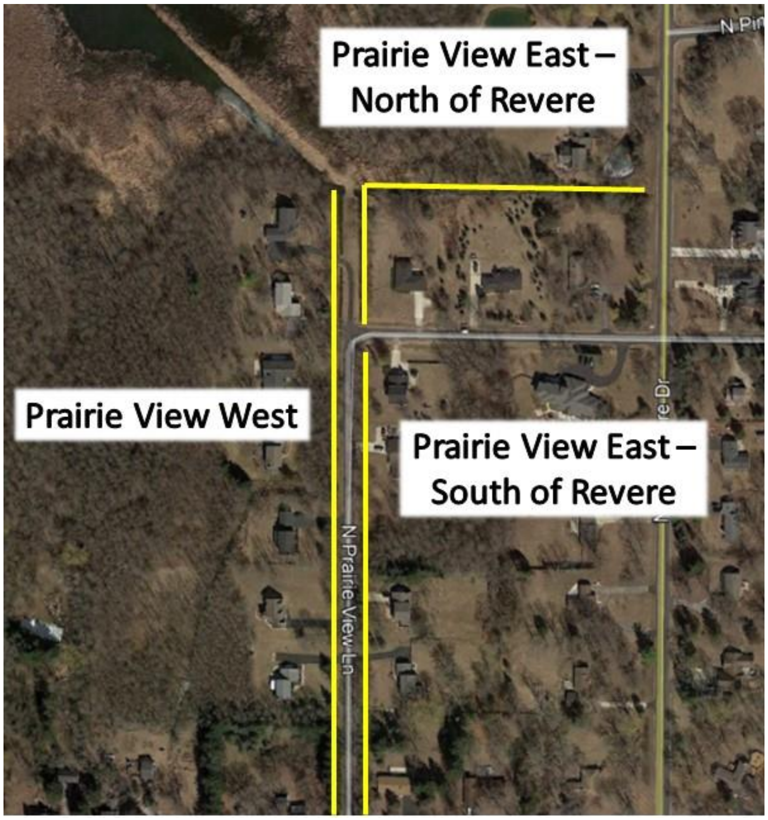

Figure A1. Location of ditches modified in simulations.

Modified Culvert

The culvert at Prairie View Lane and Revere Road was modeled as two 18" CMP culverts for the *Existing Conditions* simulation. It was changed according to Table A2 during simulation of the *Modified Culvert* alternative.

Table A2. Culvert parameters for Existing Conditions *and* Culvert Modifications *model runs.*

CMP Diameter [in]		
Culvert Location	**Existing Conditions**	**Culvert Modifications**
Revere Rd / Prairie View Ln	2 x 18	1 x 36
Revere Rd / Lake Shore Dr	1 x 24	1 x 36
Lake Shore / Wetlands	1 x 20	1 x 36
Pinehurst Cir	1 x 18	1 x 24

Modified Stream Channel

The stream channels in the model were simulated as parabolic channels with specified top widths and depths and Manning's *n* roughness values. The changes to these parameters are shown in the table below.

Table A3. Stream parameters for Existing Conditions *and* Stream Modifications *models.*

	Existing Conditions		Stream Modifications	
Ditch	**Top Width x Depth [ft]**	**Manning's *n***	**Top Width x Depth [ft]**	**Manning's *n***
North of Revere Road to Wetland Ponds	24 x 2.5	0.035	30 x 3.5	0.020
I-43 to Port Wash. Road	12 x 3	0.050	20 x 3.5	0.025

Figure A2. Location of stream segments modified in simulations.

Single Large Detention Pond

This was modeled by estimating area that would drain to the detention pond using topographic information. That area was then removed from the drainage area feeding into the rest of the system. For extremely large events, it is possible the model will under-predict discharge as the basin may spill over with sufficient inflow.

Table A4. Drainage area parameters simulated in Existing Conditions *and* Large Pond *models.*

	Existing Conditions	Large Pond
Drainage Area	**Area [acres]**	**Area [acres]**
Southwest	100	75
Southeast	200	150

Multiple Small Detention Ponds

As with the *Large Pond* model, this was evaluated assuming a certain area of flow would be removed from the system. The area was then removed from drainage, which risks under-prediction of flood discharge during large events. Ponds were assumed to hold runoff from approximately 1/3 of an acre. This model approximated 40 ponds, likely more than can be reasonably anticipated.

Table A5. Drainage area parameters simulated in Existing Conditions *and* Small Ponds *models.*

	Existing Conditions	Small Ponds
Drainage Area	**Area [acres]**	**Area [acres]**
Southwest	100	97
Southeast	200	190

Results

The following tables provide WSE and discharge results from various model runs at culverts within the model domain.

2-Year Event WSE Results Comparison [ft NAVD88]							
Culvert	**Existing Conditions**	**Culvert Modification**	**Large Pond**	**Stream Modification**	**Ditch Modification**	**Small Ponds**	**Combined**
Pinehurst Circle	664.0	664.0	664.0	664.0	664.0	664.0	664.0
Lake Shore Drive	663.6	663.6	663.6	663.6	663.6	663.6	663.6
I-43	664.1	664.1	664.1	664.1	664.1	664.1	664.1
Port Washington Road	660.5	660.5	660.5	**660.6**	660.5	660.5	**660.6**
Revere / Prairie View	663.2	**661.9**	663.2	663.2	663.2	663.2	**661.5**
Revere / Lake Shore	665.8	**665.5**	665.8	665.8	665.8	665.8	**665.5**

2-Year Event Discharge Results Comparison [cfs]							
Culvert	**Existing Conditions**	**Culvert Modification**	**Large Pond**	**Stream Modification**	**Ditch Modification**	**Small Ponds**	**Combined**
Pinehurst Circle	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lake Shore Drive	2.3	2.3	2.3	2.3	2.3	2.3	**2.4**
I-43	23.7	23.7	23.7	23.7	23.7	23.7	23.7
Port Washington Road	19.8	19.8	19.8	**20.8**	19.8	19.8	19.8
Revere / Prairie View	16.6	16.6	**12.5**	16.6	16.6	16.6	**11.6**
Revere / Lake Shore	5.0	5.0	5.0	5.0	5.0	5.0	5.0

10-Year Event WSE Results Comparison [ft NAVD88]							
Culvert	Existing Conditions	Culvert Modification	Large Pond	Stream Modification	Ditch Modification	Small Ponds	Combined
Pinehurst Circle	664.7	**664.6**	664.7	664.7	664.7	664.7	**664.6**
Lake Shore Drive	664.6	**664.5**	664.6	664.6	664.6	664.6	**664.5**
I-43	664.1	664.1	664.1	664.1	664.1	664.1	664.1
Port Washington Road	660.8	660.8	660.8	660.8	660.8	660.8	660.8
Revere / Prairie View	663.4	**663.3**	**663.3**	663.4	663.4	663.4	**663.1**
Revere / Lake Shore	666.3	**666.2**	666.3	666.3	666.3	666.3	**666.2**

10-Year Event Discharge Results Comparison [cfs]							
Culvert	Existing Conditions	Culvert Modification	Large Pond	Stream Modification	Ditch Modification	Small Ponds	Combined
Pinehurst Circle	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Lake Shore Drive	10.8	10.8	10.8	**11.8**	10.8	10.8	**11.4**
I-43	28.2	28.2	28.2	28.2	28.2	28.2	228.2
Port Washington Road	28.0	28.0	28.0	**28.1**	28.0	28.0	28.0
Revere / Prairie View	44.7	44.7	**33.5**	44.7	44.7	44.7	**31.3**
Revere / Lake Shore	13.8	13.8	13.8	13.8	13.8	13.8	13.8

25-Year Event WSE Results Comparison [ft NAVD88]							
Culvert	Existing Conditions	Culvert Modification	Large Pond	Stream Modification	Ditch Modification	Small Ponds	Combined
Pinehurst Circle	666.4	**665.3**	666.4	666.4	666.4	666.4	**666.5**
Lake Shore Drive	665.4	**665.0**	665.4	665.4	665.4	665.4	**665.0**
I-43	664.2	664.2	664.2	664.2	664.2	664.2	664.2
Port Washington Road	661.1	661.1	661.1	661.1	661.1	661.1	661.1
Revere / Prairie View	663.5	**663.4**	663.5	663.5	663.5	663.5	**663.3**
Revere / Lake Shore	666.4	666.4	666.4	666.4	666.4	666.4	666.4

25-Year Event Discharge Results Comparison [cfs]							
Culvert	Existing Conditions	Culvert Modification	Large Pond	Stream Modification	Ditch Modification	Small Ponds	Combined
Pinehurst Circle	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Lake Shore Drive	20.8	20.8	20.8	**21.6**	20.8	20.8	**22.3**
I-43	41.3	41.3	41.3	41.3	41.3	41.3	41.3
Port Washington Road	42.2	**42.1**	42.2	42.2	**42.1**	42.2	42.2
Revere / Prairie View	71.8	71.8	**53.9**	71.8	71.8	71.8	**50.3**
Revere / Lake Shore	22.3	22.3	22.3	22.3	22.3	22.3	22.3

100-Year Event WSE Results Comparison [ft NAVD88]							
Culvert	Existing Conditions	Culvert Modification	Large Pond	Stream Modification	Ditch Modification	Small Ponds	Combined
Pinehurst Circle	668.4	**666.7**	668.4	668.4	668.4	668.4	**666.7**
Lake Shore Drive	667.2	**666.3**	667.2	667.2	667.2	667.2	**666.3**
I-43	664.8	664.8	664.8	664.8	664.8	664.8	664.8
Port Washington Road	661.7	661.7	661.7	661.7	661.7	661.7	661.7
Revere / Prairie View	663.8	**663.7**	**663.7**	663.8	663.8	663.8	**663.5**
Revere / Lake Shore	666.6	**666.5**	666.6	666.6	666.6	666.6	**666.5**

100-Year Event Discharge Results Comparison [cfs]							
Culvert	Existing Conditions	Culvert Modification	Large Pond	Stream Modification	Ditch Modification	Small Ponds	Combined
Pinehurst Circle	13.6	13.6	13.6	13.6	13.6	13.6	13.6
Lake Shore Drive	45.5	45.5	45.5	**47.1**	45.5	45.5	**48.2**
I-43	66.0	66.0	66.0	66.0	66.0	66.0	66.0
Port Washington Road	69.7	69.7	69.7	**69.9**	69.7	69.7	69.7
Revere / Prairie View	129.3	129.3	**97.0**	129.3	129.3	129.3	**90.5**
Revere / Lake Shore	39.9	39.9	39.9	39.9	39.9	39.9	39.9