Gilkey Creek Drain Flood Control Study

PREPARED FOR

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Summary

The goal of this study is to evaluate flood mitigation alternatives to reduce or eliminate flooding along the Gilkey Creek Drain while not adversely impacting downstream reaches of Gilkey Creek in the City of Flint. The drain enters the City of Flint at Center Road. It has been determined not acceptable for a flood mitigation project to increase in flood flow downstream of this location. Additional flow would increase flooding along the Gilkey Creek through the City of Flint.

There is a history of flooding of residential, commercial and recreational property along the Gilkey Creek Drain. Landowners along the Gilkey Creek Drain submitted a petition to the Genesee County Drain Commissioner (GCDC) to complete drainage improvements and mitigate flooding.

In accordance with the Michigan Drain Code, a Board of Determination was convened and public testimony was heard. There was public testimony of flooding. Residents primarily in the vicinity of Lippincott Road, Roat Court, Alcona Street, and Calvin Street testified that flooding of their residential properties occurs. Additionally, there was testimony of flood levels near Bristol Road at the upper end of the Main Branch and also near Arrowhead Drive toward the lower end of the Main Branch. Minutes of this meeting are included in Appendix A.

Based on this testimony, the Board of Determination deemed it necessary for the GCDC to move forward with a drainage improvement project. As the initial step, the GCDC hired Spicer Group to complete a flood control study of the Gilkey Creek. The objective of the flood control study is to identify improvements needed to reduce or eliminate flooding along the Gilkey Creek Drain.

This report outlines the flood control study and provides improvement alternatives. The report also provides planning level cost estimates and a recommendation to implement a flood control project.

An important conclusion of this study is that restoration of the original drainage channel and drain crossing improvements alone will not eliminate flooding for the 10-year design storm event. Regional storm water detention facilities are needed to reduce or eliminate flooding. As a result, it is necessary for the drainage district to acquire property to construct regional storm water detention basins.

Four improvement alternatives to reduce or eliminate flooding are provided in this report. The alternatives include various combinations of channel improvements, crossing improvements and regional storm water detention. The initial planning level cost estimates for feasible alternatives [range from $10 million to $22 million] plus the cost of land acquisition.

The focus of this study is a hydrologic and hydraulic analysis, including computer modeling of the drain to determine the extent of channel, crossing and storm water detention improvements needed to reduce or eliminate flooding. Flood maps were generated to show the extent of flooding for existing conditions and for each of the flood mitigation alternatives, and are included in Appendix B.

This study did not include detailed analyses of land / right-of-way acquisition, land values, wetlands, regulated floodplain impact, environmental impact, contamination or need for environmental remediation. Also not included is a completed design survey, preliminary or final engineering, and utility coordination or constructions documents. These items must be completed, and the estimate of cost updated appropriately, if a project proceeds and the scope of the flood control project alternative is selected.

The following paragraphs discuss in detail the work completed as part of the flood control study and describes the flood mitigation alternatives and cost estimates.

Drain Background

Description of Drain and Drainage District

The Gilkey Creek is an established county drain referred to as Drain No. 0017 Gilkey Creek Drain. The Gilkey Creek is under the jurisdiction of the GCDC pursuant to Public Act 40 of 1956 (Michigan Drain Code). Over the years, drain improvements and maintenance of the drain have been completed by the office of the GCDC.

The Gilkey Creek is located in Genesee County and drains portions of the City of Burton, Davison Township, Atlas Township, and Grand Blanc Township. The Gilkey Creek also flows through the City of Flint. The reach of the drain in the City of Flint was not evaluated as part of the study. The reach of the Main Branch that was evaluated extends from Center Road in the City of Burton to Vassar Road north of its intersection with Maple Road, and the open drain portion of Branch No. 1 from the confluence with the Main Branch in the City of Burton upstream to the I-69 crossing in the City of Burton. The main branch of the Gilkey Creek upstream of Center Street is 7.1 miles long. The open drain portion of Branch No. 1 is 2.0 miles long. The Gilkey Creek has several branches and tributary drains that were not studied as part of this project.

The Gilkey Creek is the primary storm water outlet for an approximately 8.68 square mile drainage district (or watershed). The drainage district consists of a combination of residential, commercial, industrial, agricultural, recreational, and undeveloped land uses. In accordance with the Michigan Drain Code, the property owners, local municipalities, county, state highway department and railroads are subject to special assessments for the cost of a drainage improvement project and maintenance of the drain. The district map in Appendix A shows the location of the drain and drainage district of record. The county drain location and drainage district were provided by GCDC.

Previous Improvement Projects

The design plans for the study reaches were obtained from GCDC and reviewed. Improvements were made in the 1950's and also 1980's. Also, plans for I-69 within the drainage district were obtained from the Michigan Department of Transportation (MDOT) for I-69 crossings of the Main Branch and Branch No. 1.

The 1950's plans appear to include the last comprehensive drainage improvement project along the entire Main Branch of the Gilkey Creek. These improvements included channel cleanout and crossing replacement. The 1980's plans show improvements including channel widening, crossing replacement, sediment removal, and clearing from Center Road to Lippincott Road in the City of Burton. In 2005, the Vassar Branch of the Gilkey Creek was improved which outlets into the Main Branch of the Gilkey Creek Drain at the upper end. Also, since 1983 the GCDC has completed maintenance work on portions of the drain to remove debris and obstructions.

Inspection and Survey of the Drain

2006 Condition Survey & Inspection

A condition survey of the Gilkey Creek was completed as part of this flood control study. The entire length of the Gilkey Creek and Branch No. 1, as described in the project extents, was inspected. Photographs were obtained at drain crossings, influent storm sewers or ditches, locations of excessive sedimentation or debris, eroding banks, and areas of varying vegetative condition. The condition of the drain crossings and channel was summarized and the results of the inspection are provided in the report titled, "Gilkey Creek Drain 2006 Condition Survey".

2006 Hydraulic Survey

A survey of the hydraulic characteristics and geometry of the Gilkey Creek Drain was completed to support the development of hydrology and hydraulics models for the alternatives analyzed. The survey was completed on the Main Branch from Center Road to the upstream end of the drain near Maple Road and on Branch No. 1 from the confluence with the Main Branch to the upstream study limits at the I-69 drain crossing.

Survey Control

The survey was completed using the North American Datum of 1983 (NAD83) and subsequently provided in Michigan State Plane Grid Coordinates, South Zone (2113). All vertical data is referenced to the North American Vertical Datum of 1988 (NAVD88). GPS elevation observations were processed using the NGS 2003 Geoid model. Distance units are international feet.

Drain Centerline

The centerline of the drain was established based upon data available from the GCDC and results of the survey. The Gilkey Creek was assigned river stationing as a means to identify locations along the drain. The maps in the 2006 Condition Survey provide the stationing assigned to the Main Branch and Branch No. 1. The Center Road crossing (the downstream extent of the study) was assigned a station of zero (Sta. 0+00). A point along the drain that is four hundred and fifty feet upstream would be assigned Sta. 4+50, a point two thousand feet upstream would be assigned Sta. 20+00.

Survey of Drain Crossings

The hydraulic survey included obtaining elevations and measuring 51 drain crossings within the project extents, 43 on the Main Branch and 8 on Branch No. 1. Data collected for culverts included measured lengths, sizes, entrance and exit conditions, sediment depths, invert elevations, and centerline of road elevations. Data collected for bridges included measured low-chord profiles, abutment profiles, high-chord profiles, pier widths and locations, lengths along the drain, as well as miscellaneous spot elevations as needed. The information was also imported into HEC-RAS and was used to model the drain. A crossing report summarizing survey data and field observations was developed and is provided in Appendix D.

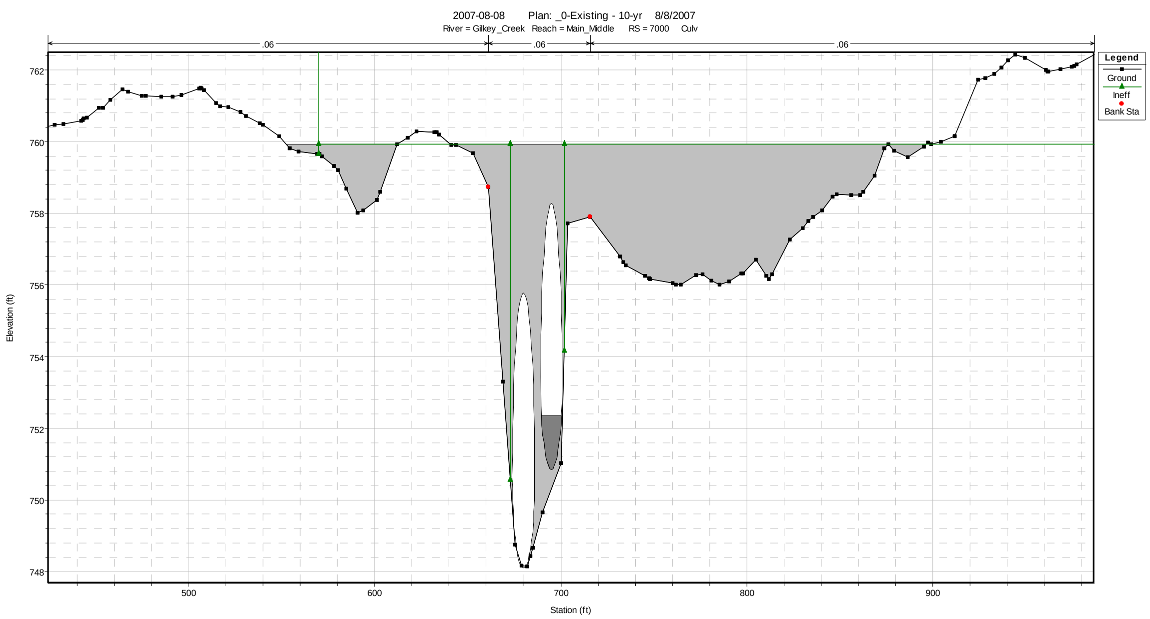

Figure 1: Typical Crossing Surveyed

Survey of Cross Sections

The majority of the Gilkey Creek Drain consists of trapezoidal cross sections typical of constructed open channels. In-stream cross sections were surveyed at 177 locations, including 144 on the Main Branch and 33 on Branch No. 1. Each cross-section was mapped and assigned a river station based upon its location. Beginning at the Center Road crossing, stationing was measured in feet upstream. Obstructions due to sediment bars and debris in the drain are common. A typical cross-section of the Gilkey Creek is shown in Figure 1.

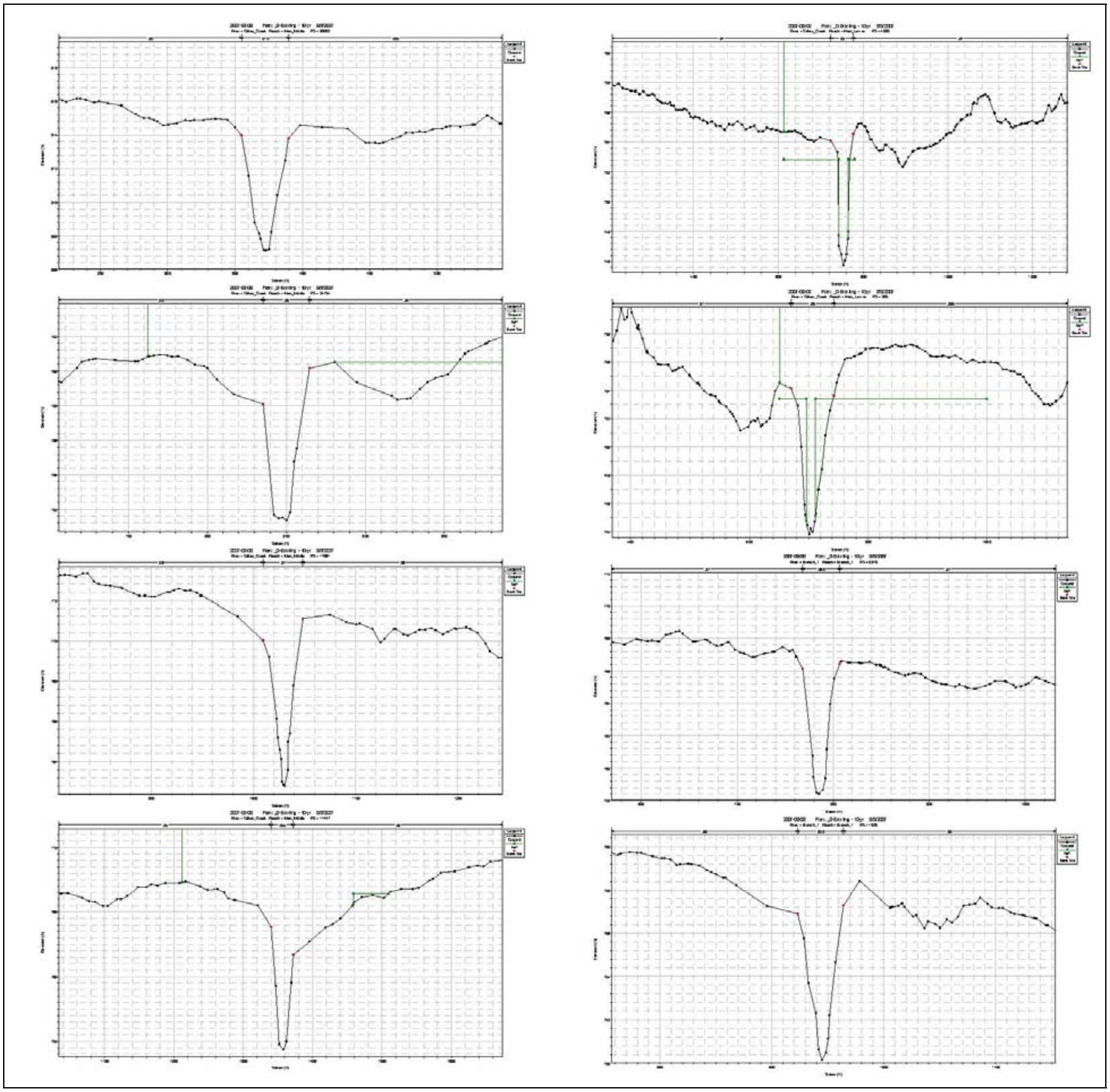

Figure 2: Typical Cross Sections Surveyed

Correlation of Survey Datums

Research was performed to locate FEMA reference marks and control points from previous plans. Control points were researched, recovered where possible and observed during the course of the survey. Previous plans and study datums were converted to this study's vertical datum (NAVD88) based on the available observations and checked with datum conversion software where appropriate. The datum elevation difference in between this study and the FEMA FIS (NGVD29) is 0.49 feet.

The following elevation equation can be used to convert NGVD29 elevations to be consistent with this study:

$$Elev_{NAVD88} = Elev_{NGVD29} - 0.49 \text{ (in feet)}$$

For example, given an NGVD elevation of 800.00 feet, the elevation correlated to this study (NAVD88) is 799.51 feet.

High Water Mark Testimony

Several landowners gave testimony and / or were interviewed providing anecdotal high water mark testimony. Several landowners pointed to specific locations or showed photographs portraying flooding levels. Table 1 shows the most noteworthy testimony regarding high water marks. Elevations for testimony are shown on Table 7.

Location	Landowner Testimony
1304 Arrowhead Dr.	Lost 2 walls in basement
Genesee Street	Flood overtops Genesee Street at I-69 deep enough to make impassable and cause road closure and flood waters to run under overpass.
1241 S. Genesee	Flooded crawl space every spring
1393 Amy	Floods onto property
Roat Ct Home	Floods to bottom edge of siding, 1.5 feet above Grade line (twice in seven years)
1353 Alcona	Floods more than 2' over road, Basement filled up to ceiling Claims 2 foundation failures at adjacent homes and basement flooding of neighbors, Has Photographs and letter from County regarding Flooding
1439 Roat Ct.	Foods all around the house but house is high point so it does not flood flooded worst in 1983
Roat Ct Home	Floods up to 3 trees in front yard
Roat Ct Home	Floods up to second step on side porch about 5 times in last 20 years
1449 Roat Ct	Floods up to Garage 4 times in past 27 years, Does not flood house
Roat Ct Home	Floods so regularly that abandoned basement by filling it and elevating Furnace
1466 Alcona	Basement flooding up to windows
1514 Alcona	Flooded house
1496 Calvin	Property becomes an island during flood events
5128 Lippincott	Has been flooded several times
3472 Dallas	Flooding crosses overtop of Bellingham Road
6204 E. Maple	Parcel flooding every spring due to inadequate C.B.

Table 1: Landowner Testimony of High Water Marks.

Model results were cross-referenced with anecdotal high water mark testimony collected from interviews of landowners. It is estimated to be accurate to approximately 1 foot of the flooding event most memorable to the landowner.

Data Collection and Mapping

Aerial Photographs

The aerial photographs, in combination with field reviews, were used to determine existing land use. Aerial photographs from the State of Michigan, 1997, from Genesee County, 2002, and from Google maps, 2007 were used and each provided advantages for different applications. The State Photos show color infrared reflectance which is useful for reviewing vegetated areas and wet soils. The county photos offer high resolution black and white detail, and the Google maps show true color reflectance and recent changes in land use. These photographs were used in ArcGIS, AutoCAD and in Web browsers as needed.

Flood Mapping

A digital terrain model (DTM) was developed for the Gilkey Creek Drain watershed based upon LIDAR information provided by the GCDC. This DTM was used as the basis of cross-sections outside of the limits of the collected hydraulic survey cross-sections and for the delineation of floodplain extents.

Surveyed cross-sections were extended and elevations assigned based upon the DTM. The water surface profile developed in HEC-RAS was assigned to a new data set and a Triangulated Irregular Network (TIN) was developed to represent the water surface elevation. The USACE's HEC-GeoRAS extension was utilized to create water surface TINs and produce flood maps for each event modeled. All computations involving the DTM were completed in ArcGIS 9.2 using 3D Analyst, Spatial Analyst and HEC-GeoRAS extensions.

Drainage District

The Gilkey Creek Drainage District boundary was provided by the GCDC and is shown on several maps in Appendix E

Soils

Soils information was obtained from the Natural Resources Conservation Service (NRCS) in electronic format. Soils information was analyzed to determine its hydrologic classification (A, B, C, or D). The district is predominantly Group C soils. Table 3 shows the district's distribution for each hydrologic group and includes brief descriptions of each group's drainage characteristics.

Hydrologic Soil Group	District %	Soil Group Drainage Characteristics
Group A	1.5%	Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.
Group B	20.4%	Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
Group C	66.2%	Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
Group D	11.9%	Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have high shrink-swell potential, soils that have a permanent high water table, soils that have a clay pan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Table 2: Hydrologic Soil Groups Summary

Existing Land Use

Existing land use was developed based upon Aerial photographs, field observations, and known development and conditions within the watershed. Land uses were assigned and a land use map was developed. Appendix E includes a copy of the existing land use map.

Future Land Use and Zoning

Zoning ordinances and maps were obtained for the City of Burton, Davison Township, Grand Blanc Township, and Atlas Township. Zoning maps were utilized to determine future land use. Zoning for all municipalities was converted to utilize the zoning codes developed by the City of Burton to aid in data processing. The future land use map is included in Appendix E.

FEMA Flood Insurance Study

A Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for the Gilkey Creek was published and completed in 1980. The study was completed from the Center Road crossing to the upstream end near Maple Road.

In summary, the FIS shows significant floodplain widths near (and downstream of) I-69, near Lippincott and Sitka Roads. The study shows buildings are located within the 100 year flood plain. The study also mentions that during flooding, flow from the Gilkey Creek may flow overland and into the Richards Drain, though this was not modeled. In the FIS, as well as this study, there may be areas of flooding that are not mapped and/or mapped flooding that does not occur due to modeling extents.

USGS Stream Gage

The United States Geological Survey (USGS) maintained a stream gage along the Gilkey Creek from January 1, 1970 thru December 31, 1983. The USGS Gage was located at Latitude 43º01'27", Longitude 83º37'32" NAD27. The gage was for a drainage area of 6.43 square miles and datum was set at 747.56 feet above sea level (NGVD29).
Data collected from this gage was obtained and reviewed. In that time frame, the top ten flood flows for separate storm events recorded in cubic feet per second (cfs) are 334, 250, 218, 218, 184, 165, 147, 144, 140, and 129. Local records were requested from multiple parties for corresponding rainfall records for these storm events but none were able to be obtained or reviewed. The USGS Gage flow rates, FIS flow rates, and those developed as part of this study demonstrate a wide range of flows.

Precipitation Frequencies

Precipitation depths for recurrence frequencies were obtained from Bulletin 71, SCS 92 and previous reports. The 24-hour rain totals for various recurrence intervals are summarized in Table 3.

Recurrence Interval	50%	20%	10%	4%	2%	1%	.5%
Precipitation depth (inches)	2.26	2.75	3.13	3.60	3.98	4.36	4.85

Table 3: Recurrence Frequency Precipitation Depth

Hydrologic Parameters

Drainage Sub-Districts

Drainage sub-districts were developed within the Gilkey Creek Drainage District. Existing records on file at the Genesee County Drain Commissioner's office, USGS topographic maps, contour maps, aerial photographs, and the DTM were reviewed and utilized to delineate sub districts. Appendix E includes the Basis of Hydrology map showing sub districts as modeled in this study. Sub districts were developed for the purpose of hydrologic modeling and were not set up with the intent of a boundary for the purpose of assessment of costs and benefits.

The contributing watershed area was divided into 30 sub districts ranging in area from approximately 9 to 697 acres, with a median area of 165 acres. Each area was assigned hydrologic parameters as discussed in the following sections. It should be noted that various hydrologic methods were reviewed for applicability for the catchments and the following method was selected to maintain consistency with modeling goals and computer models used.

SCS Runoff Curve Numbers

Runoff curve numbers (RCN's) for the Soil Conservation Service (SCS) method were calculated for each sub district. The RCN describes the amount of rainfall that soaks into the ground ("infiltration") and the amount which flows off of the site ("runoff"). In general, impervious areas and poorly drained soils (clay, for example) result in higher RCNs, indicating less precipitation is absorbed by the earth and more precipitation leaves the site on the surface.

For each sub district, a composite RCN was developed based on a breakdown of land use categories and soil types. The RCN is higher for more impervious or paved areas and lower for pervious or vegetated areas. The composite RCN for each sub district was developed by area-weighting the RCN assigned to each land use category. For the future land use conditions, the RCNs would be higher for areas that would be developed in the future. The RCNs used in the HEC-HMS model are presented in Table 5. The location of each sub district is shown on the Basis of Hydrology Map in Appendix E.

Time of Concentration

The time of concentration (T_c) represents the time required for the peak rate of runoff to travel through a subdistrict and discharge to the Gilkey Creek. The time of concentration for each subdistrict was calculated by estimating the velocity of storm water runoff as it traveled through the subdistrict drainage system. The time of concentration was based on the slope and type of the drainage flow paths within the subdistrict. The types of drainage flow paths considered were sheet (overland) flow, concentrated shallow (small tributary or gutter) flow and open channel or pipe flow.

The following assumptions were used to develop travel time estimates for each sub-district:

- No more than 300 feet of sheet flow
- Sheet flow roughness of 0.002
- 2.5 ft/sec velocity in open waterways
- 4.0 ft/sec velocity in storm sewers

Lag time (the time difference from the middle of the storm event to the peak flow occurrence) for existing and future conditions was assumed to be equal and can be found in Table 5. Lag time was estimated as follows:

$$T_{lag} = T_c * 0.6$$

For sub districts with significant drainage ways that were not included in this model (Branch No. 2 and the Richards Branch of the Gilkey Creek Drain), a trapezoidal channel was estimated based upon field observations for a more accurate representation of the T_c.

On-Site Storm Water Detention

Several recently developed subdivisions within the watershed have on-site storm water detention basins as required by the GCDC Storm Water Ordinance. Five existing detention basins were modeled using HEC-HMS software. The five known detention areas were modeled as described in Table 4 and were modeled to have a peak discharge rate of 0.2 cfs per acre. Storage nodes were created in the HEC-HMS model to account for the volume of water in detention.

Detention Type	Sub-District	Area Drained to Detention Area (ac)	CN	Allowable Discharge (cfs)
Residential	3	20	79	4.0
Residential	12	95	79	19.0
Residential	13	55	79	11.0
Residential	18	83	79	16.6
WalMart	26	22	93	4.4

Table 4: Existing Detention Parameters

Detention was modeled in HEC-HMS using two sub districts to represent the pre and post watershed management regulated areas, with a storage node to represent detention. A schematic of this is provided below in Figure 3.

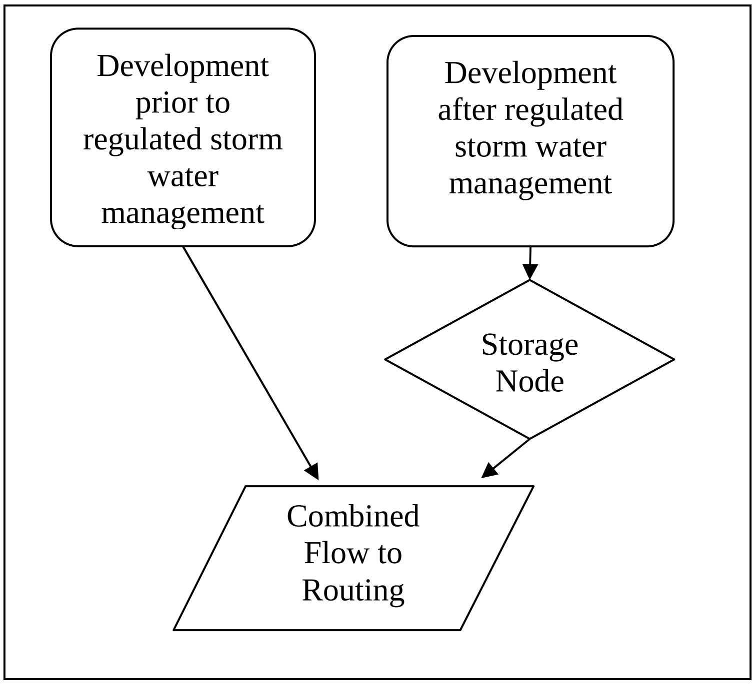

Figure 3: Modeling of Storage in HEC-HMS

Flood Flow Attenuation

Flood attenuation was modeled in HEC-HMS in five (5) locations. Rating curves for the Center Road, railroad, I-69, Genesee, and Lapeer road crossings were developed and utilized to simulate flood attenuation in the existing conditions model.

The DTM model was used to calculate existing floodplain storage capacity. Elevation-storage relationships were calculated using a combination of survey data collected as part of this study and the Genesee County DEM developed from LIDAR data.

Locations for attenuation were based upon crossings observed in preliminary models to either not overtop, or to detain significant volumes of water during flood events.

Hydrologic Modeling

HEC-HMS Model

The computer model was developed and used to simulate storm water runoff for a range of storm events in the Gilkey Creek watershed. The hydrologic model was developed using the Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) program, version 3.0.1. The model, developed by the United States Army Corps of Engineers (USACE), is widely accepted and utilized for this type of application (see Figure 4). In this model, sub basins, junctions, reservoirs, reaches, and diversions were modeled to simulate the various characteristics of the drain's hydrology.

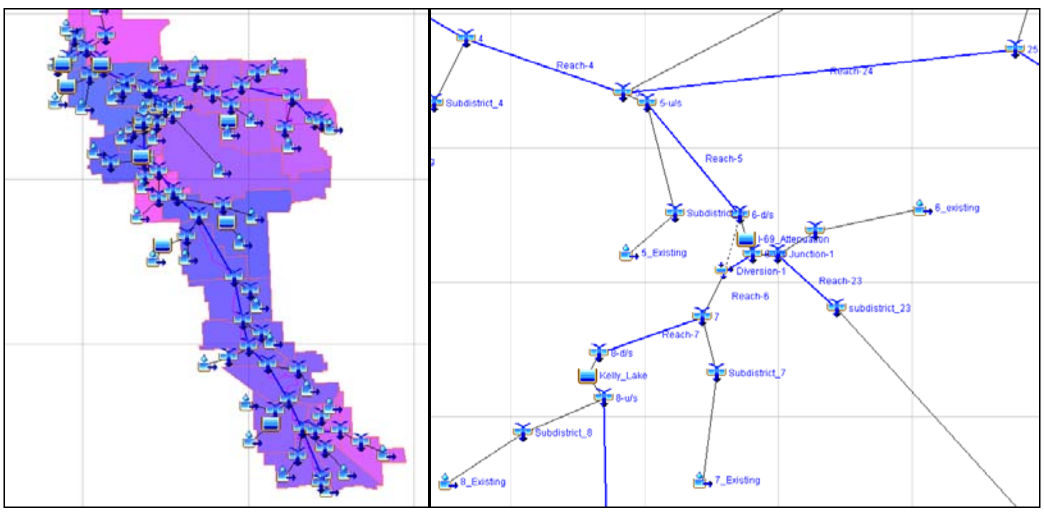

Figure 4: HEC-HMS Existing Conditions Model Overview and detail view near I-69 area.

Routing

Routing performed in HEC-HMS for the Main Branch and Branch No. 1 was completed using the Muskingham-Cunge routing method. Open channels were modeled, using a simplified, typical 8-point cross section and average slope or grade and Manning's "n" value to represent the channel and floodplain for sections of the Gilkey Creek Drain between design points.

Specific design points were identified at 30 locations along the drain. Flow between these points was modeled as follows:

1. Review topographic survey of drain
2. Generate typical cross-section based on survey data

3. Generate typical floodplain based on DTM
4. Set grade for drain based upon topographic survey
5. Assign typical n-values based upon field observations

Base Flow

USGS stream gage data for the Gilkey Creek Drain was analyzed for the entire period of available data. 0.82 cfs (the median value of the approximately 5,000 records) was selected as the base flow for the Gilkey Creek. Base flow was divided among sub districts based upon proportional drainage area. Base flow was modeled in HEC-HMS as constant monthly base flow with no seasonal variation.

Diversion

Diversion was identified to occur at Genesee Road through the I-69 Underpass. This was modeled as a diversion in HEC-HMS according to its physical characteristics and was reviewed carefully with high water mark testimony, and HEC-RAS modeling. This Diversion was reduced or eliminated in all alternatives.

Meteorological Model

The meteorological model was developed utilizing United Stated Department of Agriculture Soil Conservation Service (USDA-SCS) design storm information. A Type II rainfall distribution (recommended by the USDA-NRCS for this region) was selected for the Gilkey Creek watershed.

Sub basin	Sub basin Detention	RCN	Lag Time (min)	Area (Sq. Mi.)
1_Existing	No	85.7	60.8	0.097
2_Existing	No	83.8	63.9	0.726
3_Existing	No	76.7	50.7	0.393
3_res_develop	Yes	79	50.7	0.031
4_Existing	No	79	42.6	0.168
5_Existing	No	78.5	19.4	0.045
6_existing	No	66.1	22.4	0.025
7_Existing	No	79.8	62.8	0.087
8_Existing	No	83.1	41.8	0.108
9_Existing	No	75.9	67.4	0.273
10_Existing	No	79	47.9	0.053
11_Existing	No	78.3	67.4	0.211
12_Existing	No	77.7	89.5	0.57
12_res_develop	Yes	79	89.5	0.148
13_Existing	No	77.7	71.1	0.282
13_res_develop	Yes	79	71.1	0.086
14_Existing	No	80.7	50.8	0.381
15_Existing	No	79.2	57.1	0.342
16_Existing	No	79.2	40.2	0.114
17_Existing	No	77.8	32.4	0.462
18_Existing	No	84.9	54.3	0.192
18_res_develop	Yes	79	54.3	0.13
19_Existing	No	73.9	44.1	0.26
20_Existing	No	79.2	48.6	0.132
21_Existing	No	72.6	103.9	0.256
22_Existing	No	76.7	110	0.27
23_Existing	No	80.6	150	1.092
24_Existing	No	79.2	43.9	0.229
25_Existing	No	71.5	47.6	0.089
26_Existing	No	76.3	92.6	0.505
26-WalMart	No	93	92.6	0.034
27_Existing	No	81.9	72.7	0.331
28_Existing	No	78.4	47.6	0.478
29_Existing	No	78.9	74	0.062
30_Existing	No	76.7	69.3	0.015

Table 5: Hydrologic Parameter Summary for Existing Conditions HEC-HMS Model

Existing Conditions vs. Future Conditions Hydrologic Modeling

An assessment of Future Conditions Land Use was performed and it was determined that future development pressure and current land use regulations from the Municipal zoning ordinances will allow an increase in development and impervious surface areas within the watershed.

It was assumed the GCDC Storm Water Management Standards will remain in place and be enforced for future development, that all future development would be restricted to a discharge rate of 0.2 cfs/ac and therefore that the existing conditions hydrologic characteristics exceed that of regulated future conditions peak allowable flow release rates. It should be noted that the future development will generate more runoff volume and extend the duration of storm water runoff.

For the purposes of this study, the existing conditions hydrology was determined to be acceptable to be utilized for alternative analysis.

Comparison to FEMA FIS Flood Flows

The hydrologic calculations completed as part of this study and report have substantially higher values than those published by FEMA or provided by MDEQ. This has been attributed to changes in land use, less restrictive channel geometry assumptions (hence less in-line attenuation), loss of sub basin ponding area, changes in climate and different computer model algorithms used. Flow rates were rigorously calculated for this project using HEC-HMS (discussed in a subsequent section) and those available from the MDEQ and FEMA are summarized below in Table 6.

Main Branch Station	Modeled Existing Flows (cfs)		FEMA Flows (cfs)		MDEQ Flows (cfs)	
	10 year	100 year	10 year	100 year	10 year	100 year
1+40	866	1256	440	750	440	750
27+45	854	1243	390	660		
61+44	864	1321	345	575		
70+14	689	1043	280	465	280	465
115+59	683	1052	240	400		
130+00	670	1159	215	350	220	350
151+36	662	1137	190	315		
172+50	580	981	145	240		
222+10	511	996	125	205	125	205
285+75	304	563	84	140		

Table 6: Comparison of flow rates

Flow rates provided by the MDEQ and FEMA are based upon the FIS completed in 1978. Since this time, substantial development has occurred in the watershed. This development created increased impervious surface area and altered the drainage patterns resulting in additional runoff from storm events.

As shown, the study's flow rates are substantially higher than those provided by the MDEQ and developed in the FEMA FIS. Landowner testimony obtained during this project indicates that flood levels at or higher than the FEMA 100-year floodplain are reached on a much more frequent basis (every 2 to 5 years). Land use changes, as discussed above, have contributed to an altered floodplain. Hydrology calculations have been checked utilizing several methods to ensure the rates are appropriate. ***Spicer Group recommends that the flow rates included in this study be adopted for design purposes.***

Hydraulic Model Development

A hydraulic computer model was prepared and used to simulate hydraulic characteristics for a range of storm events in the Gilkey Creek Drain. The hydraulic model was developed using the Hydrologic Engineering Center – River Analysis System (HEC-RAS) program, version 3.1.3. The model, developed by the USACE, is widely accepted and utilized for this type of application. Specific model components and parameters are described in the following sections.

Cross Sections

Cross sections of the drain were obtained during the hydraulic survey of the drain. This data was processed and inserted into a HEC-RAS model of the Gilkey Creek. The cross sections in the RAS model were extended utilizing the DTM in HEC-GeoRAS in order to properly model the floodway and drain in HEC-RAS.

Manning's Roughness Coefficient

The Manning's roughness coefficients along the Gilkey Creek Drain were based on the values estimated during the Condition Survey and are outlined on the maps provided in the Condition Survey Report. Vegetation and soil conditions of the stream channel and overbanks were noted during the survey. The observations were compared to text book values to determine the Manning's roughness coefficients to use in the model.

Ineffective Flow Areas

Ineffective flow areas in a floodplain are typically defined as areas with insignificant conveyance capacity and where velocities are very small. Determining and modeling these areas is important to accurately define the flow area of each cross section. The available flow area in part determines the predicted flooding levels along a reach. Areas where flooding occurs but conveyance is restricted by the over bank topography were determined to be ineffective. The areas just upstream and downstream of bridge abutments were determined to be ineffective flow areas since flooding would occur in these areas but conveyance is limited to within the bridge openings.

Drain Crossing Hydraulics

Drain crossings (including inverts, bridge decks, roadway elevations, etc) were surveyed during the hydraulic survey phase. Crossings were measured and their condition and sediment accumulation were noted. The crossings were included in the HEC-RAS model and assigned entrance and exit coefficients, Manning's "n" values, sediment depths, and other geometric information for appropriate modeling.

Boundary Conditions

Boundary conditions are needed to establish the starting water surface for all models at the lower end of the drain system (since it operates in the Sub-Critical Flow Regime). The reaches of the drain connected with junctions contain internal boundary conditions set automatically within the model.

The boundary condition for the downstream end of the model is set based upon a rating curve developed for the Center Road crossing. The rating curve takes into account the culvert, its overtopping stage and flow characteristics should overtopping occur. This crossing is restrictive and represents the downstream extent of modeling efforts and the downstream limit for work proposed under this project. Figure 5 shows the rating curve for Center Road used for alternative analysis.

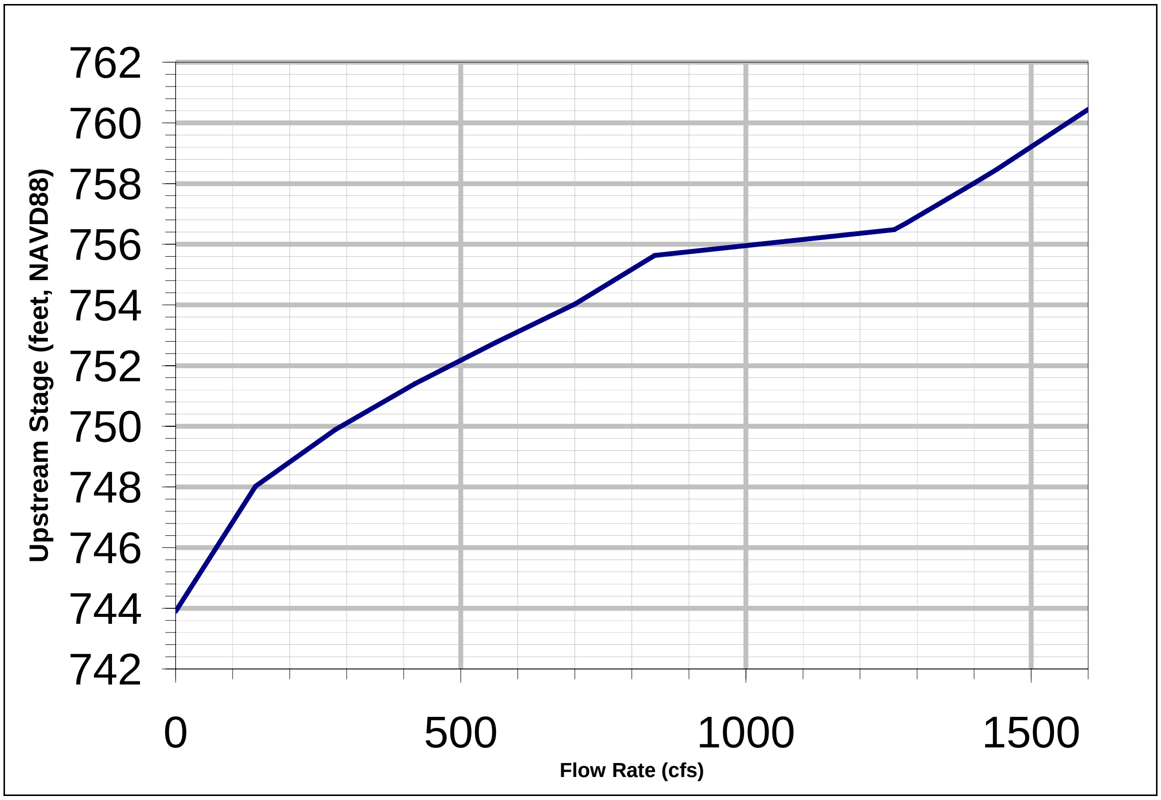

Figure 5: Center Road Rating Curve

HEC-HMS / HEC-RAS Model Interface

The unsteady routed peak flow rates from HEC-HMS were connected to HEC-RAS as steady flow peaks using HEC-DSS. HEC-DSS has been developed by the U.S. Army Corps of Engineers and is widely compatible with their modeling programs. It is designed to store and rapidly access paired data (i.e. time and discharge relationships, stage-storage relationships, etc.). Using this methodology, the modeling results in this study show the peak flow at each location and peak flood event stage. The flood maps are based upon peak stage to most accurately represent the extents of highest modeled flooding; therefore, the maps do not represent the flooding expected to happen at any one instant in time.

Model Calibration

The model was not calibrated to historical precipitation records due to lack of available data and the general purpose for developing the models. Since this study is primarily a comparative analysis of various alternatives, it was determined that the performance differences between alternatives would remain consistent even if there were moderate stage differences between the model and any given specific storm event. The drain was gauged from 1970-1983 by the USGS. Detailed precipitation data was unavailable for this time period, making analysis of rainfall and drain response impossible. Rainfall and flow monitoring were not within the scope of this study.

Correlation of Model with Landowner Testimony

Initially the HEC-RAS model was developed from the data collected and was ran with FEMA FIS study flow rates. The resulting flooding elevations were compared with the Published flood profiles after they were correlated to NAVD88. Table 7 shows the comparison of the FIS modeled flows to the published elevations. It was determined that the model adequately replicated the model performance of the original FIS study.

Station	FIS Simulation Model (NAVD88)	FIS Elevation (NGVD29)	FIS Elevation (NAVD88)	Difference
54+70	756.1	757.9	757.4	1.3
86+60	760.2	761.6	761.1	0.9
123+60	763.4	764.4	763.9	0.5
136+90	765.2	766.3	765.8	0.6
137+60	765.7	766.4	765.9	0.2
139+60	766.3	767.0	766.5	0.2
140+00	766.3	767.4	766.9	0.6
141+10	766.5	767.5	767.0	0.5
142+00	766.9	767.6	767.1	0.2
142+70	767.0	767.7	767.2	0.2
149+40	767.4	767.7	767.2	-0.2
150+70	767.4	767.7	767.2	-0.2
151+30	767.4	767.9	767.4	0
153+40	767.7	768.2	767.7	0
285+90	798.1	800.2	799.7	1.6

Table 7: Summary of modeled FIS flows compared to published flood elevations

High water mark elevations were determined based on landowner testimony, survey data collection and GIS analysis. These were compared to the published FIS flood elevations as shown on Table 8. A key conclusion is that some of the landowner testimony elevations are very near to or exceed the published 100 year floodplain. More important is that many of the comments provided indicated that these levels have occurred many times in the past 10-25 years at a recurrence frequency we estimate to be between 2 to 5 years. This means that it is very likely that the published 100 year flood elevations are met or exceeded as regularly as one might expect a 5 year flood to occur.

Station	Testimonial Elevation (NAVD88)	FIS Elevation (NGVD29)	FIS Elevation (NAVD88)	Difference
54+70	756.0	757.9	757.4	1.4
86+60	760.0	761.6	761.1	1.1
123+60	764.0	764.4	763.9	-0.1
136+90	766.7	766.3	765.8	-0.9
137+60	766.0	766.4	765.9	-0.1
139+60	767.0	767.0	766.5	-0.5
140+00	766.5	767.4	766.9	0.4
141+10	766.7	767.5	767.0	0.3
142+00	766.5	767.6	767.1	0.6
142+70	766.5	767.7	767.2	0.7
149+40	767.0	767.7	767.2	0.2
150+70	767.0	767.7	767.2	0.2
151+30	766.0	767.9	767.4	1.4
153+40	767.0	768.2	767.7	0.7
285+90	796.8	800.2	799.7	2.9

Table 8: Summary of high water marks compared to published 100 year elevations.

When the existing conditions model was run with this study's hydrologic flow rates the modeled flood elevations in fact are consistently higher (2-3 feet) than the high water mark elevations as shown on Table 9. This seemed reasonable considering the frequency described by landowners in relation to the high water marks.

Station	Testimonial Elevation (NAVD88)	Existing Model Elevation (NAVD88)	Difference
54+70	756	759.1	3.1
86+60	760	762.3	2.3
123+60	764	768.5	4.5
136+90	766.7	768.8	2.1
137+60	766	768.8	2.8
139+60	767	768.9	1.9
140+00	766.5	768.9	2.4
141+10	766.7	769	2.3
142+00	766.5	769	2.5
142+70	766.5	769.1	2.6
149+40	767	769.6	2.6
150+70	767	769.6	2.6
151+30	766	769.6	3.6
153+40	767	769.8	2.8
285+90	796.8	799.1	2.3

Table 9: Summary of high water marks (2-5 year frequency) compared to modeled 100 year flood elevations.

In summary, the data shows that the testimony is consistently above the published floodplain elevations but below the modeled existing conditions elevations for the 100 year event.

After the FIS HEC-RAS model was developed, the mapped comparison of the modeled FIS flooding and effective FEMA floodplain were mapped and can be found in Appendix E.

Hydrologic & Hydraulic Model Results

The existing conditions model is based upon channel geometry as-surveyed, channel conditions observed during the condition survey inspection, and existing land use conditions within the watershed. In summary, the existing conditions model results show overtopping of many crossings, widespread flooding, and a higher floodplain elevation that that shown by FEMA. Flooding present between the Richards Branch and Main Branch of the Gilkey Creek suggest split flow may be occurring in this area, though this was not included in the scope of the model. Appendix F contains results from the Existing Conditions model, including profiles and flood maps developed in HEC-RAS and HEC-GeoRAS.

Development of Alternatives

Development of alternatives was designed to take place in a logical, step-wise manner than would allow evaluation of a wide range of project costs while examining the balance between conveyance capacity (i.e. crossing replacement and channel widening) and regional detention facilities.

The stated goal of this project is to reduce flooding in the Gilkey Creek Drainage District and to maintain or reduce flow-rates at the Center Road crossing. The drain enters the City of Flint at Center Road; no project can be considered feasible if it increases the flow reaching the City of Flint. Additional flow out of the district would worsen the flooding problems experienced along the Gilkey Creek through the City of Flint.

The approach taken to alternative development was to begin with a minimal cost, low-impact project (such as a traditional “channel maintenance” project) and build upon this until a solution was reached. The project impact was incrementally increased through crossing replacement and channel work, eventually reaching the level of regional detention facilities.

Alternatives 4 through 7 explore the balance between regional detention and channel widening. While efforts have been made to provide a similar level of service, it should be noted that Alternatives 4 through 7 may all provide some degree of flood control and protection depending upon channel width and detention volumes included in the model.

The following mitigation measures were explored as part of this project:

- Replace crossings in poor physical condition
- Channel clearing and grubbing

- Remove sediment from crossings
- Clean sediment deposits from channel and/or improve entrance conditions for crossings
- Replace crossings creating >1 ft. head loss for the 100 year storm event
- Replace I-69 crossing
- Replace Railroad crossing
- Regional detention at various locations
- Channel widening

Potential detention sites were screened based upon field observations and aerial photographs. Appendix E includes a map of potential detention sites identified as part of this study. No preliminary design work has been completed to identify owners, site layout options, etc. as part of this study.

The following sections provide a brief summary of each model developed, its unique characteristics, notable observations, and conclusions based upon the modeled results. A summary of the alternatives has been provided below in Table 10. The Appendices contain results of modeling the alternatives including profiles and flood maps.

Mitigation Measures	Existing Conditions	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Replace Crossings in Poor Physical Condition	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Channel Clearing & Grubbing, Remove Deadfall & Debris	No	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Clean Sediment Deposits & Improve Crossing Entrance Conditions	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Replace Crossings Creating Significant Headloss for 10 year, Design Storm	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Replace I-69 Crossing	No	No	No	No	No	No	No	**Yes**
Construct Regional Detention Upstream of Lippincott	No	No	No	No	**Yes**	**Yes**	**Yes**	No
Construct Regional Detention at outlet of Richards Branch	No	No	No	No	**Yes**	**Yes**	No	No
Construct Regional Detention on Branch No. 1	No	No	No	No	**Yes**	No	No	No
Construct Regional Detention near Railroad Crossing	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Channel Widening on Branch No. 1	No	No	No	No	No	**Yes**	**Yes**	**Yes**
Channel Widening between Railroad Crossing and I-69	No	No	No	No	No	**Yes**	**Yes**	**Yes**
Add capacity to Railroad Crossing to access regional detention downstream	No	No	No	No	No	No	No	**Yes**
Channel Widening between Lippincott and I-69	No	No	No	No	No	No	No	**Yes**
Establish Wider Channel in Existing Corridor	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Meets Project Goal	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Planning Level Cost Estimate	-	$2.4 Million	$2.9 Million	$6.9 Million	$10.0 Million	$10.0 Million	$10.6 Million	$21.7 Million

Table 10: Summary of Alternatives Modeled.

- Estimates do not include environmental assessment or remediation, wetland mitigation, land and easement acquisition, engineering design, construction administration, etc.

Alternative 1: Address Crossings in Poor Physical Condition

Alternative 1 addresses replacement or removal of crossings in poor physical condition. These crossings were observed during the conditions survey to be in poor crossing and/or headwall condition. Observations included, but were not limited to, headwalls cracking or crumbling, washouts, sinkholes, crushed pipe sections, separated pipe sections, and significant corrosion that may indicate structural damage. The existing channel conditions were maintained for this alternative. It was assumed no grubbing, clearing, or spraying of the channel itself would occur.

Alternative 1 computer model results show reductions in flooding for the upper reaches of the drain, but increased flood elevations in the lower reaches. The improved conveyance allows floodwaters to more rapidly move downstream, resulting in increased flow reaching the City of Flint. Alternative 1 is not a feasible alternative and does not provide reasonable improvement.

Alternative 2: Restore Historic Channel Design Capacity

Alternative 2 builds upon the work included in Alternative 1. In addition to the crossing replacements, Alternative 2 includes restoration of the channel to its original design capacity. Removal of log jams, debris, and brush restores the Manning's "n" value to 0.035 for the entire channel.

Similar to Alternative 1, the computer model results of Alternative 2 show reduction in flood elevations in the upper reaches and increased flooding in the lower reaches. The improved conveyance also moves more water downstream and does not meet the goal of maintaining or reducing flow rates at Center Road, making the alternative infeasible.

Alternative 3: Crossing Conveyance Improvements

Alternative 3 is an addition to the work completed as part of Alternative 2. In addition to replacement of crossings in poor physical condition, and restoration of the channel to design capacity, crossings creating greater than one (1) foot of headloss for the 100 year storm event were replaced accordingly.

Similar to the previous alternatives, Alternative 3 provides reduction in flooding in most areas but increased flooding in the lower reaches of the drain. Again, the increase in flow rate at the Center Road crossing makes this alternative infeasible.

Alternative 4: Regional Detention at 4 Sites

Alternative 4 includes all of the work completed as part of Alternative 3. In addition, regional detention facilities have been included at four (4) locations and total 416 acre-feet of storage.

Alternative 4 computer model results show that this alternative does mitigate flooding for 10 year storm and does not result in increase of flow to the City of Flint. Alternatives 4, 5, 6, and 7 provide a similar level of service (i.e. reduction in flooding) to the district, and maintain the goal of not increasing flow rates downstream of the Center Road crossing.

Alternative 4 will require acquisition of right-of-way and land required for construction of the regional detention facilities.

Alternative 5: Regional Detention at 3 Sites

Alternative 5 includes all of the crossing replacements that mitigate flooding for the 10 year storm from Alternative 3. In addition, Alternative 5 includes channel work to increase the conveyance capacity of the drain without significant widening of the drainage way. A total of 413 acre-feet of storage is provided over 3 sites. Channel widening on the Main Branch between I-69 and the railroad crossing and on Branch No. 1 downstream of the movie theatre parking lot is included in this alternative.

Alternative 5 is a feasible alternative. Flood elevation reduction is achieved for the district, and the downstream conditions are met.

Alternative 5 will require acquisition of right-of-way for channel widening and land acquisition for construction of the regional detention facilities. While less would be required than Alternative 4 there are still a number of easements and acquisitions that would be required. The amount of required land may pose a problem for making this alternative feasible.

Alternative 6: Regional Detention at 2 Sites

Alternative 6 includes the same crossing replacement as Alternative 3, and the channel work of Alternative 5. Detention at the downstream end of the Richards Branch has been removed from the proposed work, resulting in 395 acre-feet of detention at two sites.

Alternative 6 is a feasible alternative. Flood elevation reduction is achieved for the district, and the downstream conditions are met.

Alternative 6 will require acquisition of right-of-way for channel widening and land acquisition for construction of the regional detention facilities. While less would be required than Alternatives 4 and 5 there are still a number of easements and acquisitions that would be required. Coordination of acquisition on this scale could pose problems for construction.

Alternative 7: Regional Detention at 1 Site

Alternative 7 includes the same crossing replacement as Alternative 3. Detention upstream of Lippincott has been removed and channel widening from upstream of Lippincott to the I-69 crossing has been included. A total of 371 acre-feet of detention is planned for a single detention site near the railroad crossing.

Alternative 7 is a feasible alternative. Flood elevation reduction is achieved for the district, and downstream conditions are met.

Alternative 7 requires substantially more right-of-way acquisition for channel widening and more land acquisition for construction of the regional detention facility at the railroad. While less would be required than Alternatives 4 through 6 there are still a number of easements and acquisitions that would be required. Channel widening would likely require relocation of homes and acquisition of easements through a number of properties. Coordination of acquisition on this scale could pose problems for construction.

Results of Modeling Alternatives

Flood Maps of Alternatives

Alternatives modeled have been compiled into the flood maps provided in Appendices C and D for the 10 and 100 year storm events, respectively. On these maps, a comparison can be made between the existing conditions flooding (light blue) and the alternatives flooding (dark blue). Also noted on these maps are the generalized improvements modeled for that specific alternative including channel improvements, crossing improvements and locations of modeled detention basins.

Flow Comparison of Alternatives

Alternatives modeled have been tabulated (see tables in Appendices G and H) to show the comparison of flows modeled, water surface elevations of flooding, initial estimates of channel velocity to be analyzed for the selected alternative and the flooded flow area for each alternative at 51 selected locations. Table 11 shows this tabulation for the 10 year design storm event upstream of Lippincott Road near the location of one of the proposed detention basins. Table 12 shows the same location for the 100 year design storm event.

River	Reach	River Sta	Plan	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Flow Area (sq ft)
Gilkey_Creek	Main_Middle	151+85	Ex - 10 yr	661.52	768.73	1.98	502.94
Gilkey_Creek	Main_Middle	151+85	Alt. 1 - 10 yr	661.52	768.61	2.06	485.32
Gilkey_Creek	Main_Middle	151+85	Alt. 2 - 10 yr	815.08	768.59	2.66	518.02
Gilkey_Creek	Main_Middle	151+85	Alt. 3 - 10 yr	815.08	766.03	4.93	187.83
Gilkey_Creek	Main_Middle	151+85	Alt. 4 - 10 yr	400	763.89	4.16	96.06
Gilkey_Creek	Main_Middle	151+85	Alt. 5 - 10 yr	400	763.9	4.16	96.26
Gilkey_Creek	Main_Middle	151+85	Alt. 6 - 10 yr	400	763.9	4.15	96.28
Gilkey_Creek	Main_Middle	151+85	Alt. 7 - 10 yr	823.19	764.08	3.74	220.12

Table 11: 10 year flow comparison upstream of Lippincott at detention basin

River	Reach	River Sta	Plan	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Flow Area (sq ft)
Gilkey_Creek	Main_Middle	151+85	Ex - 100 yr	1137.15	769.68	2.63	642.94
Gilkey_Creek	Main_Middle	151+85	Alt. 1 - 100 yr	1137.15	769.55	2.72	623.2
Gilkey_Creek	Main_Middle	151+85	Alt. 2 - 100 yr	1405.54	771.59	2.64	956.2
Gilkey_Creek	Main_Middle	151+85	Alt. 3 - 100 yr	1405.54	767.8	5.54	402.3
Gilkey_Creek	Main_Middle	151+85	Alt. 4 - 100 yr	400	764.04	3.99	100.35
Gilkey_Creek	Main_Middle	151+85	Alt. 5 - 100 yr	400	764.05	3.98	100.47
Gilkey_Creek	Main_Middle	151+85	Alt. 6 - 100 yr	400	764.05	3.97	100.65
Gilkey_Creek	Main_Middle	151+85	Alt. 7 - 100 yr	1410.59	765.83	4.36	324.06

Table 12: 100 year flow comparison upstream of Lippincott at detention basin

Note the reduction in flow and flood elevation in alternatives 4, 5 and 6 are due to the modeled detention. Alternative 7 shows a decrease in flooding elevation due to the increased conveyance downstream at this location while showing the increased flows accordingly. This is a good example of the balance that has been modeled between detention storage and conveyance to accomplish lower flooding elevations. Also note the conveyance increases compared to existing conditions.

Detention Basin Storage

Table 13 shows that detention storage volumes modeled in Alternatives 4, 5, 6, and 7 near the Railroad (Crossing No.3), upstream of Lippincott (Crossing No.20), On Branch Number One, upstream of Genesee Road (Crossing No.44) and on the Richards Branch of the Gilkey Creek (Not directly on the Gilkey Creek Drain).

Alternative	Storage (ac-ft) for 100-year, 24-hour Storm Event				Total (ac-ft)
	Railroad	Branch No. 1	Richards Branch	Lippincott	
4	117	138	19	142	416
5	252	0	19	142	413
6	253	0	0	142	395
7	371	0	0	0	371

Table 13: Modeled Detention Storage

This study included screening potential detention sites in relation to proximity to flooding issues and flooding stage and size of land area required for detention spoil deposition, access and security. Appendix E includes a detention screening map showing various lands screened for possible detention basins. This study did not include review of land ownership, acquisition costs or detailed evaluation of specific sites / control structure design. These would be the next steps in considering a selected alternative. Table 14 shows the anticipated land area needed for detention basins for each alternative.

Land Acquisition

Land acquisition analysis has not been performed; however, it may be assumed that Alternatives 5, 6, and 7 require not only land for regional detention, but also land for channel widening to different widths along the drain (see Table 14). It is reasonable to assume existing drain right-of-way exists and is adequate to re-establish the previous design channel (Alternative 4 assumption), though it is obvious in many locations the right-of-way has been encroached upon and action may be required to eliminate those encroachments. Some examples of right-of-way encroachments are near stations 137, 143, 150, 155, 241, 273, and 294. In addition to acquiring new right-of-way as shown in Table 14, relocation / acquisition of structures located on existing right-of-way would be required also.

Alternative	Minimum Acreage Needed (acres)	Length of Drain along Additional Right-of-Way (feet)
4	Not Applicable	Not Applicable
5	15	7,400
6	15	7,400
7	51	21,700

Table 14: Additional Land Acquisition/ Right-of-Way Due to Channel Widening

Alternative	Land Area Required For Detention Basin (acres)				Total (acres)
	Railroad	Branch No. 1	Richards Branch	Lippincott	
4	50	90	15	100	255
5	125	0	15	100	240
6	125	0	0	100	225
7	180	0	0	0	180

Table 15: Detention Basin Land Area Required

Profiles of Alternatives

Alternatives modeled have been compiled into the flood profiles provided in Appendices G and H for the 10 and 100 year storm events, respectively. On these profiles a comparison can be made between the existing conditions flooding (red) and the Alternatives flooding (blue). The profiles include the Main Branch of the Gilkey Creek and Branch No. 1 of the Gilkey Creek to the limits they were studied.

Drain Crossing Improvements

Table 13 show the number of crossing replaced and left in place by alternatives. It is important to note that for Alternative 6, I-69 (Crossing No.7) was not replaced but instead an additional culvert added. We recommend that if this alternative is selected that this be carefully considered and coordinated with MDOT. Table 14 describes for each crossing and alternative the deciding factor for the crossing improvement (physical condition, conveyance capacity, etc.).

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
Crossings Replaced	22	22	46	46	46	47	48
Crossings Remaining	29	29	5	5	5	5	3

Table 16: Summary of Crossing Improvements

Planning Level Estimating

Cost estimates were developed for each of the mitigation alternatives. Estimates are for planning purposes only, intending to provide the magnitude of costs for comparison to other alternatives. Estimates included open drain construction, crossings (furnish and install), soil erosion and sediment control, bridge improvements, and detention basins. They do not include land / right-of-way acquisition, wetlands mitigation, environmental cleanup or environmental remediation, design survey, preliminary or final engineering, and utility coordination or preparation of construction documents, legal, bonding or financial consulting fees.

Open Drain Construction

The primary method of estimating the cost of the channel construction was by determining the number of rods needed along the drain. The unit prices were developed based on calculated volume of earth being removed from each reach and recently bid unit prices for similar work. Items estimated in this fashion include: open channel excavation and spoil hauling/leveling.

The remaining items were estimated in a lump sum fashion. The lump sums were based on previously bid, similar projects with consideration for the length of the reach, the magnitude of proposed improvement to the reach, and the current condition of the reach. Items that were estimated in this fashion are: site clearing, erosion control, seeding and restoration.

Crossings

The cost of the proposed replacements along the drain were calculated using lineal foot unit prices obtained from pipe suppliers and a multiplication factor to account for installation costs. These unit prices were multiplied by the length of the crossing parallel to the drain to obtain the lump sum price found on the cost estimates. These estimates include removal of the existing crossing, installation of the proposed crossing, and pavement repairs required.

Bridge Improvements

The cost of the proposed bridges were calculated by multiplying the deck area of the bridge and planning level unit prices were estimated from experience. These estimates include removal of old bridges, and construction of new bridges including approach work. They do not include additional right-of-way. Once detailed bridge design is determined necessary, bridge estimating should be done that itemizes the many detailed aspects associated with the type of bridge that is proposed.

Detention Basins

Detention basin construction estimates were based on the size of the detention basin. The volume of basins was multiplied by unit prices obtained from previously bid projects of similar nature. Other items used in estimating the detention basin construction costs include spoil leveling, excavation, hydraulic structures, and site cleanup. They were estimated based on the size of the individual site and other considerations that varied from basin to basin.

Future Cost Estimates.

Updates for estimates should be done for the selected alternative after more detailed survey and design work has been completed. These updates should include review and adjustment of unit prices since they change regularly due to market conditions such as wages, fuel prices, and the price of steel.

An assessment of detention sites to evaluate their feasibility for spoil leveling, wetland permitting issues, land acquisition, potential environmental contamination and constructability should be completed. Detailed volume calculations at each site should be determined to estimate the true costs of spoil leveling and hauling, permitting and environmental remediation.

Conclusions and Recommendations

Alternatives 4 through 7 have all been designed to provide a similar level of service to the Gilkey Creek Drainage District. By adjusting the detention volumes and channel widths a level of service for any storm event may be achieved. We recommend Alternative 6 although Alternatives 4, 5, 6 and 7 all achieve flood mitigation.

Alternative 6 requires acquiring easements and land acquisitions for construction of regional detention facilities and drain right-of-way. Alternative 7 requires many bridge/culvert replacements causing a significant increase in construction cost. Therefore it might be efficient from the standpoint of cost to implement Alternative 6.

Recommendation for Future Work

Spicer Group recommends that alternatives be assessed with regard to the number of easements and area of land acquisition that would accompany each alternative and the value of the acquisition. This analysis will allow the Genesee County Drain Commissioner to better estimate the cost of each alternative and evaluate the benefit received, estimate assessments, etc.

The next steps in the project would be a preliminary assessment of detention sites to evaluate their feasibility from the standpoint of spoil leveling, potential wetland permitting issues, land acquisition, potential environmental contamination, and constructability. A preliminary design of each site should be developed to better evaluate the volume of storage possible on each site and the true costs (including permitting, environmental remediation, spoil leveling and hauling, etc).

NO	CROSSING NAME	REACH	STA	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
1	Center Street	Main Branch	0+00							
2	Consumers Power	Main Branch	3+25			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
3	Railroad Tracks	Main Branch	28+50							Conveyance to Regional Detention Site
4	Lift Station Entrance	Main Branch	40+00			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
5	Genesee Road	Main Branch	70+00			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
6	Court Street	Main Branch	76+50			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
7	I-69	Main Branch	78+50						Additonal Culvert Added	Conveyance to Regional Detention Site
8	Genesee Road	Main Branch	86+50			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
9	Footbridge	Main Branch	95+75			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
10	Lapeer Road	Main Branch	115+50	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition

Table 17: Crossing Improvements for Each Alternative

NO	CROSSING NAME	REACH	STA	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
11	Private Drive	Main Branch	119+25	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
12	Private Drive	Main Branch	122+00	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
13	Private Drive	Main Branch	122+75			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
14	Genesee Road	Main Branch	130+00	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
15	Footbridge	Main Branch	133+50			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
16	Private Drive	Main Branch	137+00	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
17	Private Drive	Main Branch	139+50	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
18	Roat Ct	Main Branch	141+50			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
19	Footbridge	Main Branch	146+25			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
20	Lippincott Road	Main Branch	151+50			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
21	Private Drive	Main Branch	155+00			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity

NO	CROSSING NAME	REACH	STA	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
22	Private Drive	Main Branch	157+50	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
23	Private Drive	Main Branch	165+25	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
24	Private Drive	Main Branch	178+00			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
25	Private Drive	Main Branch	198+75	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
26	Private Drive	Main Branch	210+25	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
27	Atherton Road	Main Branch	222+00	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
28	Private Drive	Main Branch	240+50			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
29	Sitka Street	Main Branch	258+50	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
30	Belsay Road	Main Branch	270+75			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
31	Footbridge	Main Branch	272+75			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
32	Bellingham	Main Branch	275+25			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity

NO	CROSSING NAME	REACH	STA	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
33	Footbridge	Main Branch	279+00			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
34	Private Drive	Main Branch	282+25	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
35	Bristol Road	Main Branch	286+00	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
36	Hazel Road	Main Branch	303+50	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
37	Private Drive	Main Branch	324+00	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
38	Private Drive	Main Branch	329+00	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
39	Private Drive	Main Branch	351+50	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
40	Private Drive	Main Branch	358+75	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
41	Pratt Road	Main Branch	367+25	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
42	Private Drive	Main Branch	374+00	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
43	Vassar Road	Main Branch	377+00							

NO	CROSSING NAME	REACH	STA	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
44	Genessee Road	Branch No. 1	6+25	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition	Physical Condition
45	Parking Lot	Branch No. 1	26+75			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
46	Parking Lot	Branch No. 1	32+00			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
47	Private Drive	Branch No. 1	45+75			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
48	Court Street	Branch No. 1	52+50			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
49	Belsay Road	Branch No. 1	66+25			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity
50	Court Street	Branch No. 1	76+00			Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity	Conveyance Capacity