Valley Mede Hydrology/Hydraulic Study and Concept Mitigation Analysis for Plumtree Branch and Little Plumtree Branch

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Executive Summary

Recent flooding events within the Valley Mede, Chatham, and Nob Hill neighborhoods in Ellicott City, Howard County, Maryland have caused significant damage to residential and commercial areas. This study is being completed to evaluate the cause of flooding and associated mitigation options within this portion of the Plumtree Branch watershed. The channels included in the study area are Plumtree Branch, and its unnamed tributary, referred to as Little Plumtree Branch. This study includes a hydrologic analysis which utilizes TR-55 and TR-20 methodology, along with 1-D HEC-RAS models to evaluate the channel hydraulics. Hydrologic calibration was completed utilizing the 2016 Piedmont-Blue Ridge Fixed Region Regression Equations for a single drainage area to the downstream study limit; no stream gages are available within the study reach. Discharges were calibrated per the 2016 Maryland Hydrology Panel Report. The hydrology of the flooding event of July 30, 2016 was also synthesized to calibrate the hydraulic model against observed flooding conditions during the event. National Weather Service (NWS) estimates were used as part of the hydrologic calibration of this storm synthesis.

For the hydraulic modeling, the drainage area was sub-divided into 10 sub-areas. An existing conditions 1-D hydraulic model was completed for each reach of Plumtree Branch and Little Plumtree Branch utilizing version 5.0.3 of HEC-RAS. Discharges computed from the subdivided and reach routed watershed in TR-20 were used for five (5) flow change locations on Plumtree Branch and two (2) flow change locations on Little Plumtree Branch. The existing hydraulic models were calibrated utilizing anecdotal information from the July 30, 2016 storm event, which was collected from homeowners throughout each study reach. Water surface elevations and floodplain extents were considered during model development as model parameters such as bank points, ineffective areas, and Manning's 'n' (roughness) values were refined. With the existing conditions hydraulic modeling completed, proposed mitigation options within each sub-watershed of Plumtree Branch and Little Plumtree Branch were evaluated.

Flood mitigation approaches in the report focused on a goal of reducing the 100-year event flows as close as possible to the 10-year event flows, a similar approach to the 2016 Ellicott City Hydrology/Hydraulic Study and Concept Mitigation Analysis (McCormick Taylor, 2016). In the interest of achieving this reduction with as few discrete project sites as possible (i.e. cost-benefit efficiency) stormwater quantity management opportunities focused on larger facilities in-line with existing stream channels, particularly in the Plumtree Branch watershed in the open space areas near Michaels Way. In the Little Plumtree Branch sub-watershed, where space was not available for sufficient storage management with traditional ponds, conveyance improvements were evaluated to reduce flooding. Conveyance improvements such as modifying culvert structures and adding storm drain diversions were also considered on Plumtree Branch.

The combined effects of the conceptual improvements noted above were run through 1-D hydraulic models to demonstrate the resulting reduction in flooding elevations relative to existing conditions. Proposed conditions analyses were run for the 2-, 10-, 50-, and 100-year events. The results of the hydraulic analysis are discussed in Section 4 of this report. Nine (9) proposed options were evaluated for Plumtree Branch and five (5) proposed options were evaluated on Little Plumtree Branch. Proposed options were evaluated independently, with one combination "build-out" on each branch. Proposed options provide varying reductions in water surface elevations (WSEL) throughout the study area of each reach.

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1. Introduction

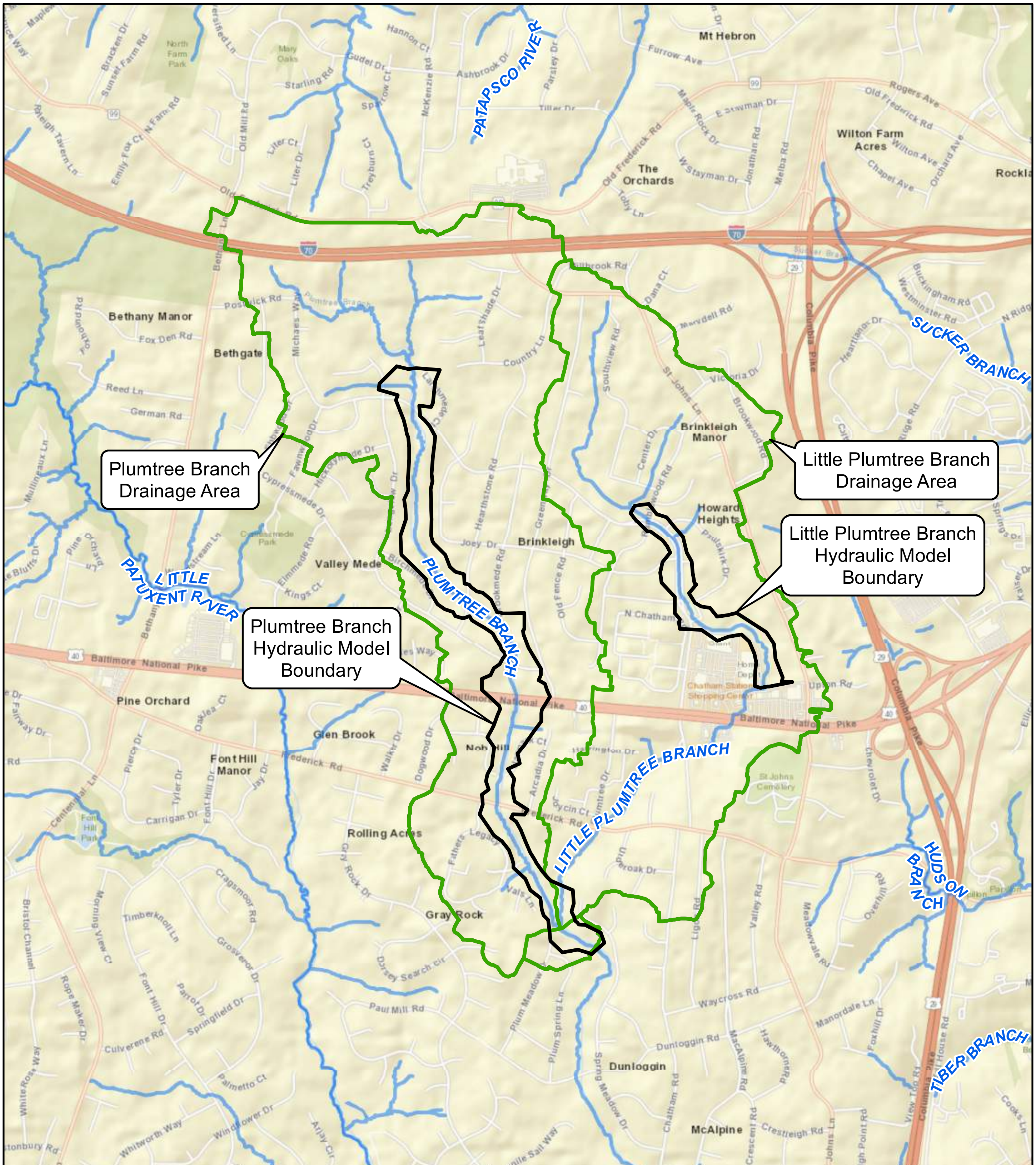
Plumtree Branch and an unnamed tributary to Plumtree Branch are incorporated within the Valley Mede, Chatham, and Nob Hill neighborhoods in Ellicott City, Howard County, Maryland. The neighborhoods have experienced several large floods since their construction began over 40 years ago. Major floods to date include Hurricane Agnes in 1972, Tropical Storm Lee in 2011, and the July 30, 2016 storm event. Homes constructed within and near the FEMA 100-year floodplain along Plumtree Branch from Frederick Rd. upstream to Hearthstone Rd., along with other areas of the neighborhood, have experienced flooding. The study is a result of the recent flooding event in July 2016. The confined nature of the channel through large portions of the reaches contributes to flooding events on both Plumtree Branch and its unnamed tributary, which will be referred to as Little Plumtree Branch throughout the remainder of this report. The continued development within the watershed, only some of which is managed for runoff quantity control, also plays a role. The severe flooding experienced during the July 30, 2016 storm event where over 6 inches of rain fell in approximately 2 hours was an extreme example with a recurrence probability of 0.1% based on 3-hour National Oceanic and Atmospheric Administration (NOAA) Precipitation Data for the region. During this storm event, a number of homes along Plumtree Branch experienced flooding, and significant roadway flooding occurred on North Chatham Rd. near its intersection with Paulskirk Dr.

This study includes a hydrologic analysis of the overall watershed along with a detailed hydrologic analysis of Plumtree Branch and Little Plumtree Branch individually. A hydraulic analysis of both Plumtree Branch and Little Plumtree Branch using 1-D steady state flow models in HEC-RAS evaluates the existing condition of channel along with conceptual improvement options.

1.1. Project Location

The project is located in Ellicott City, Howard County, MD. See the vicinity map of ***Figure 1.1*** for reference of the project location and study area. The total study area, which extends to a study point on Plumtree Branch 750 linear feet downstream of the Little Plumtree Branch confluence, encompasses a 1.98 square mile drainage area. Plumtree Branch and Little Plumtree Branch are evaluated independently hydrologically and hydraulically in this study. The channels run through developed areas including residential, commercial, and institutional properties south of I-70 and west of US-29.

Runoff from the Plumtree Branch watershed, with upland boundaries extending north of I-70, flows through a relatively flat channel with wider floodplains in the upland areas. Near Hearthstone Rd., flow becomes confined in a narrow channel with homes and buildings near the channel banks; it travels through several roadway culvert crossings toward US 40 and through Frederick Rd. Downstream of Frederick Rd., the channel and floodplain widens again through the confluence with Little Plumtree Branch and to the downstream study limit. On Little Plumtree Branch, flow travels through a confined channel which meanders through residential areas and is then piped over 1,200 linear feet via an extensive storm drain network under US 40 and the large commercial areas north and south of US 40. Downstream of the US 40 outfall, flow on Little Plumtree Branch again enters a natural channel with wider floodplains through the confluence with Plumtree Branch. Flood mitigation options on both Plumtree Branch and Little Plumtree Branch will evaluate several alternatives including upsizing culverts, adding conveyance, and providing stormwater quantity management. In addition, small storm drain improvements were considered for their potential impact on localized concerns but are not evaluated in detail in this report.



Drainage Area
Study Area
Watercourse

N

0 1,000 2,000 Feet

1 inch = 2,000 feet

Valley Mede Flood Study
Figure 1.1
Vicinity map

1.2. Project Goals

The goals of this study include the following:

- Develop hydrology for the Plumtree Branch and Little Plumtree Branch watersheds. This hydrology includes a synthesis of the July 30, 2016 event.
- Develop a 1-D hydraulic floodplain model for the reaches upstream of Dunloggin Road.
- Develop potential improvements to the hydrology of the Plumtree Branch and Little Plumtree Branch (additional management of stormwater quantity) and the hydraulics of the conveyance network through the neighborhood (improvements to channels, culverts and storm drain systems to increase conveyance through this area), and define limitations of the existing network.
- Quantify the potential positive impacts to flood elevation and frequency as a result of the conceptual improvements noted in the report, using the baseline hydrologic and hydraulic models developed for existing conditions as a means of comparison.
- Reduce the 100-year discharges to the 10-year discharges where feasible.

In addition to the goals defined above, this effort will generate a baseline model that can be used to examine various combinations of mitigation measures summarized in this report, such that the model can be a tool in a long term master planning effort for the Valley Mede and surrounding communities.

1.3. Previous Studies

Previous studies have been completed in the Valley Mede neighborhood due to the increasing frequency of flooding events. In 1992, a study was completed to investigate the causes of increased flooding in the Valley Mede neighborhood and specifically at the home at 3238 Brookmede Road. The study, completed by the Department of Public Works of Howard County, primarily focused on causes of increased flooding associated with development within the watershed. Included were potential solutions to reduce flooding within the Valley Mede neighborhood which incorporated the addition of stormwater management ponds and upsizing the culverts across Brookmede Road. Based on the hydrologic and hydraulic analysis in the study, one of the four evaluated ponds was recommended along with a sediment removal program. No ponds were constructed as a result of this study. (Howard County, MD 1992)

A 2012 case study, commissioned by the Howard County Office of Emergency Management, was completed following 2011 Tropical Storm Lee, which occurred September 7, 2011. The goal of this study was "to capture all available information on the local impacts of Tropical Storm Lee to make appropriate preparedness, response, and mitigation improvements in the future." The Plumtree Branch and specifically the Valley Mede area were included as part of this case study. (S&S Planning and Design, LLC, 2012)

An additional study of the Brookmede Rd. crossing was completed by Howard County in 2013 as a result of additional homeowner flooding complaints. The study evaluated the impact of an additional 48 inch RCP culvert at this stream crossing for a reduction in flooding of the driveway adjacent to the channel. The study determined a third culvert would only provide relief for a 5- to 7-year storm event. With the additional culvert, water surface elevations during these events were reduced and the driveway was no longer inundated as compared to existing conditions. The additional culvert would not reduce flooding for frequent events (1- and 2-year) as they do not overtop the driveway in existing conditions. Large events (10-year and greater) will still overtop the driveway with the addition of a third 48 inch RCP at the Brookmede Rd. crossing. (Howard County, MD 2013)

1.4. Neighborhood History

The neighborhoods within this study area, particularly on Plumtree Branch, began significant development primarily in the late 1960s and early 1970s. Along Plumtree Branch, the early sections of the residential areas began with construction along the US 40 corridor and what were originally farm roads, such as Greenway Dr. North of US 40, expansion and development continued north (upstream) centralized along Greenway Dr. and Longview Dr. Through the 1980s, a majority of the remaining area along Plumtree Branch was developed. During this time, there were few regulations for stormwater therefore minimal infrastructure was installed and no stormwater quantity management was implemented (MDE). A few stormwater ponds were installed in the mid to late 1980s throughout the upper portion of the watershed, but many homes along the channel, and within the 100-year floodplain, were constructed prior to the initial FEMA FIRM maps becoming effective in December 1986 (2400440017B and 2400440023B). Through the early 1990s, the remainder of the neighborhood was built out with the exception of the open space parcels near I-70. North of the area at Birchmede Dr., homes were constructed on both sides of Plumtree Branch outside of the 100-year floodplain after the FEMA mapping became effective; however, storm drain infrastructure was still limited.

Development along Little Plumtree Branch also began around the same time period as Plumtree Branch. This includes N. Chatham Rd. and the residential and commercial areas along its right-of-way. Development continued along N. Chatham Rd. and north along Little Plumtree Branch, with expansions east and west toward the Plumtree Branch neighborhoods and US 29. Most of the watershed was developed by 1990 when there was no effective FEMA FIRM mapping along Little Plumtree Branch. Similar to Plumtree Branch, storm drain infrastructure was minimal, but a few ponds are present in the watershed as water quality management and local ordinances became effective during the development completed in the mid-1980s (MDE).

1.5. FEMA Studies

The Federal Emergency Management Agency (FEMA) has conducted a detailed floodplain study for the Plumtree Branch and an approximate study for its tributary, Little Plumtree Branch. In the Valley Mede neighborhood, the current 100-year floodplain for Plumtree Branch on the DFIRM map, updated in 2013, is designated as Zone AE. The 100-year floodplain is delineated on the Little Plumtree Branch of the DFIRM map; the FEMA designation of this floodplain is Shaded Zone X. The FEMA Zone AE is a mapped area of the 100-year floodplain (1% annual chance flooding) which is derived from a detailed model and includes base flood elevations (BFEs). On Little Plumtree Branch, the flood zone is a Shaded Zone X, which includes the area of the 100-year floodplain (1% annual chance flooding), with average depths less than 1 ft. As described in the 2013 Flood Insurance Study Report, Volume 1, the FEMA discharges on Plumtree Branch and Little Plumtree Branch were developed utilizing GISHydro2000. Within GISHydro2000, the Fixed Region Regression Equations (FRRE) for the Piedmont physiographic region were utilized for both existing and ultimate land use development conditions.

2. Hydrologic Analysis

Hydrologic flow quantities for this study were determined based on a calibration of the total watershed to the downstream study point. One TR-20 model was developed to represent the entire watershed, and sub-areas were added representing Plumtree Branch and Little Plumtree Branch to provide a detailed analysis of the channels in the hydraulic model. To their confluence, the drainage areas of Plumtree Branch and Little Plumtree Branch are 1.10 square miles and 0.86 square miles, respectively. To the downstream study point, the total watershed is 1.98 square miles and is 37% impervious. Hydrology for the Plumtree

Branch watershed was initially developed using GISHydro2000 and verified using TR-55 methodology. The drainage area was modified and delineated based on GIS contours, storm drain infrastructure, and topography data along with field reconnaissance. The soils were determined from GIS data in conjunction with the Web Soil Survey Hydrologic Soil Group mapping. Land use was determined based on existing and ultimate development conditions. The verified Runoff Curve Numbers (RCN) and times of concentration (Tc) along with the overall drainage area and sub-drainage areas were input into the TR-20 models. TR-20 was used to determine the discharges at the various study points within the watershed following the hydrologic calibration.

Peak discharge estimates were made for the Plumtree Branch watershed and sub-drainage areas using the NRCS TR-20 model and calibrated with the Fixed Region Regression Equations (FRRE). The Tasker program was used within GISHydro2000 to determine the 67% (one standard error) of the FRRE results. These values, displayed later in this section of the report, were utilized in the calibration of the TR-20 discharges. No gages are available within the watershed to aide in calibration of the hydrologic model. Sub-drainage areas on both the Plumtree Branch and Little Plumtree Branch were evaluated for flow changes in the hydraulic model.

2.1. Runoff Curve Number

The runoff curve number (RCN) was initially calculated for the watershed using GISHydro2000 with the 2010 Maryland Department of Planning Land Use and SSURGO Soils. The land use was then verified using Howard County GIS land use coding, property lines, aerial imagery, and Howard County zoning. Existing land use along with ultimate development was computed for the watershed for comparison. The RCN was computed by applying land use in "good condition" but was ultimately calibrated using "fair conditions." This is further described in section 2.3.4. Hydrologic Calibration. ***Tables 2.1*** and ***2.2*** display the land use for existing and ultimate conditions.

2.1.1. Existing Development Conditions

The existing watershed development conditions were computed using residential, commercial, industrial/institutional, open space, crop land, and impervious area for major highways and interstates. Land use was coded in MicroStation based on the Howard County GIS land use layer and modified based on the aerial imagery and property lines of actual land use development existing conditions. The RCN for the entire watershed is 75 for existing development conditions, "good condition" and 79 for existing development conditions, "fair conditions." ***Table 2.1*** summarizes the existing development land use within the total drainage area.

Table 2.1: Existing Land Use

Existing Land Use	Percent of Drainage Area
Impervious – (Major Highways)	2%
Open Space	13%
Residential - 1/2 acre	63%
Residential - 1/8 acre or less	8%
Row crops - straight row (SR)	3%
Urban district - commercial/business	8%
Urban district - industrial	3%

2.1.2. Ultimate Development Conditions

The RCN was also computed for ultimate conditions of the watershed. While a majority of the watershed is already developed or currently under construction, most areas of existing woods, open space, and crop land could be urbanized in the future. Based on zoning and known development plans, these areas were coded as residential (1/2 acre and 1/8 acre) in the ultimate development model. The exception within the watershed was an area of BGE property with large overhead utilities, which remains open space in ultimate conditions. The RCN for the entire watershed is 77 for ultimate development conditions, “good conditions” and 81 for ultimate development conditions, “fair conditions.” ***Table 2.2*** summarizes the ultimate conditions land use within the total drainage area.

Table 2.2: Ultimate Land Use

Ultimate Land Use	Percent of Drainage Area
Impervious – (Major Highways)	2%
Open Space	<1%
Residential - 1/2 acre	71%
Residential - 1/8 acre or less	16%
Urban district - commercial/business	8%
Urban district - industrial	3%

2.2. Soils

The hydrologic soil groups within the watershed are Type A, B, C, and D. The primary soil type in the drainage area is Type B. Type A and B soils are indicative of higher infiltration rates and lower runoff volumes. Aside from the significant amount of Type A and B soils, the drainage area exemplifies traditional characteristics of an urban watershed in the Piedmont Region with areas of steep slopes and a large area of impervious cover. ***Table 2.3*** below summarizes the percentage of each soil type.

Table 2.3: Hydrologic Soil Groups within the Drainage Area

Hydrologic Soil Group	Percent of Drainage Area
Type A	11%
Type B	51%
Type C	19%
Type D	19%

2.3. TR-20 Analysis

The TR-20 model is a synthetic hydrograph method based on a dimensionless unit hydrograph and synthetic or natural rainstorms. This method is the baseline for SHA hydrologic analyses for the existing and ultimate development conditions. Inputs required by the program include drainage area, RCN, Tc, antecedent moisture content, and rainfall depth.

2.3.1. Drainage Areas/Subareas

As previously stated, the watershed was originally delineated using GISHydro2000 and hand modified based on GIS contours, topography, and storm drain networks. A single drainage area to Study Point A was used for calibration only. Sub-areas, which were hand delineated based on GIS contour data and topography, were utilized to develop flow change locations for the hydraulic models. Hydrology maps are included in ***Appendix A***; a drainage area summary map in ***Figure 2.1*** on the following page displays the watershed with the Study Points as described below for reference.

The following sub-drainage areas will be used:

Study Point A: Plumtree Branch approximately 750 linear feet downstream of the Little Plumtree Branch Confluence

Study Point B: Plumtree Branch at confluence with Little Plumtree Branch

Study Point C: Plumtree Branch at US 40

Study Point D: Plumtree Branch upstream of Hearthstone Rd

Study Point E: Little Plumtree Branch at Michaels Way

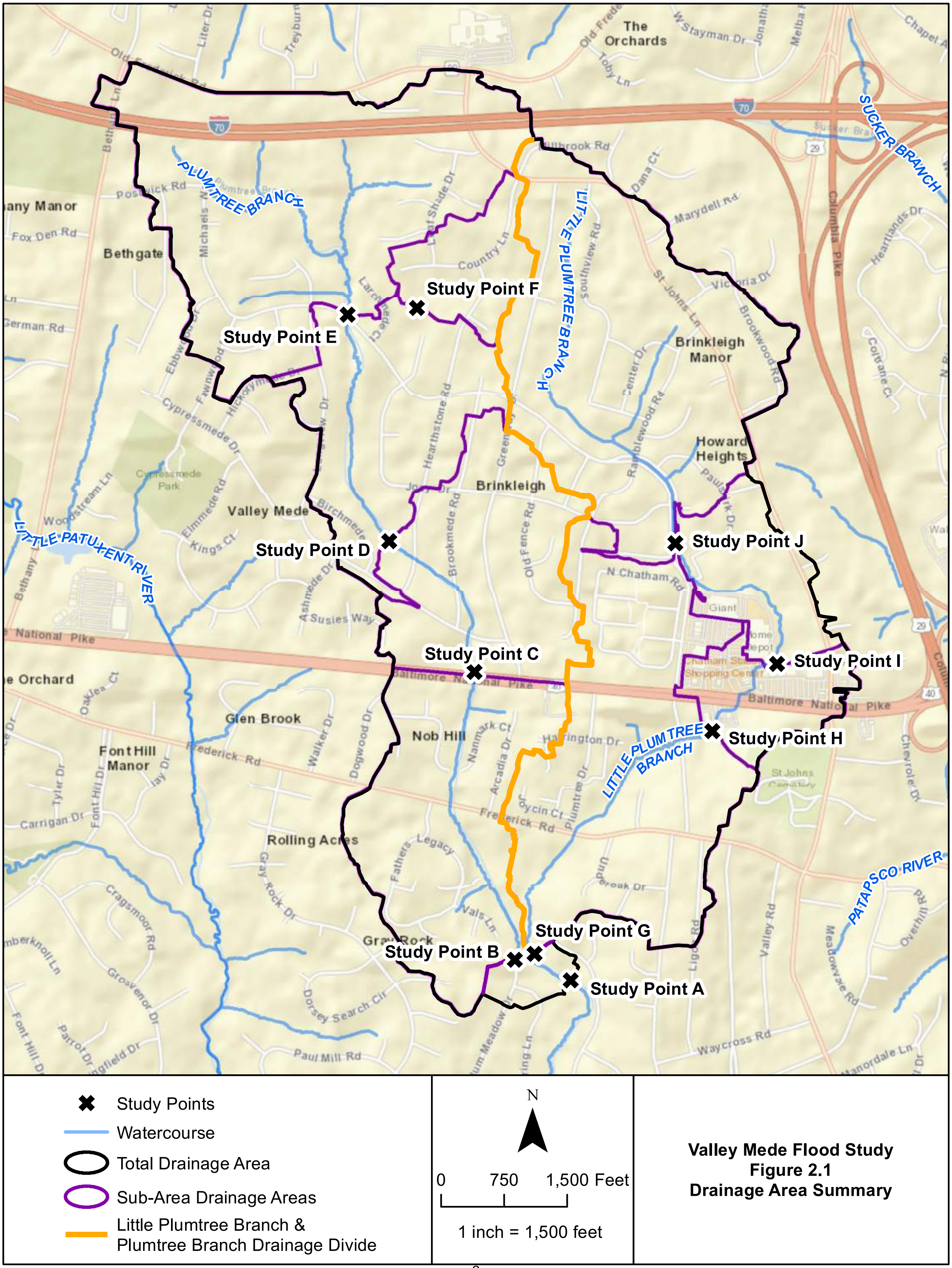
Study Point F: Storage at Country Lane Ponds

Study Point G: Little Plumtree Branch at confluence with Plumtree Branch

Study Point H: Little Plumtree Branch downstream of US 40

Study Point I: Little Plumtree Branch upstream of US 40

Study Point J: Little Plumtree Branch at N. Chatham Rd



Valley Mede Flood Study
Figure 2.1
Drainage Area Summary

2.3.2. Time of Concentration

Time of concentration is the time required for runoff to travel from the hydraulically most distant part of the drainage area to a point of investigation in the watershed. TR-55 methodology was used to compute time of concentration from flow path hydraulics. A maximum of 100 ft of overland flow was considered for this study. The land slope was calculated based on GIS topography. For the overall watershed (Study Point A as a single drainage area), the Tc path follows overland and shallow concentrated flow before entering channel flow in Plumtree Branch. Due to the linear nature of the watershed, the flow path from any point will reach channel flow quickly via overland, concentrated, and/or storm drain flow. The Tc to Study Point A as a single drainage area is 1.160 hours (69.6 minutes). The Tc for each sub-drainage area is included in the TR-20 schematic in ***Figure 2.4*** and in the hydrology map of ***Appendix A***.

2.3.3. Rainfall Duration and Distribution (NOAA Atlas 14)

The standard Howard County centroid NOAA C Atlas 14 rainfall data and NOAA C rainfall distribution along with the point specific NOAA Atlas 14 rainfall and distributions developed in GISHydro2000 for the watershed outlet point were used to calibrate the hydrologic model of the watershed. Ultimately, the standard Howard County centroid NOAA C Atlas 14 rainfall data and NOAA C rainfall distribution was selected for the hydraulic modeling of Plumtree Branch and Little Plumtree Branch because it resulted in more conservative discharges for the larger storms being evaluated. Rainfall volumes used in the hydrologic analyses are included in ***Table 2.4*** below.

Table 2.4: Howard County NOAA C Rainfall Volumes

Return Period (year)	Rainfall Volume (in)
2	3.19
10	4.91
50	7.23
100	8.47

The rainfall volume and distribution were also developed for the July 30, 2016 storm event. The resulting discharges from this data will be used to calibrate the hydraulic model based on known water surface extents from flooding evidence. A distribution with 3 minute (0.05 hr) intervals was developed for the 6.60 inches of rain that fell over approximately 4 hours. Data for this rainfall event was collected from the National Weather Service at the rain gauge ELY2M located in Ellicott City, MD. A TR-20 with this rainfall distribution and volume run through the sub-divided and reach routed watershed is included in ***Appendix D***.

2.3.4. Hydrologic Calibration

The discharges for the 1.98 square mile watershed were calibrated using the 2016 Fixed Region Regression Equations (FRRE) for Rural and Urban Watersheds in the Piedmont-Blue Ridge Region, along with the commonly used peak rate factor of 484. The FRRE, displayed in ***Table 2.5***, plus one standard deviation (67%) were considered the acceptable range for the discharges. Existing development conditions were used as a basis for the hydrologic modeling for the total Plumtree Branch watershed, and included in the calibration, but will not be used for the hydraulic analysis. Ultimate development conditions land use will be used since changes in the watershed land use are anticipated and the ultimate development provides conservative flows. Calibration was completed using a method described in the 2016 Hydrology Panel Report for small urban watersheds (under 2 square miles) with primarily A and B soils. Since over 50% of the soils are Type B and 11% are Type A, this calibration method, which calls for modifying the RCN for each land use type from “good condition” to “fair” or “poor condition,” was used for the land use conditions. The RCN for the ultimate development land use with "good conditions" is 76.66 and increased to 81.06 in the conversion to ultimate land use in "fair condition."

Table 2.5: 2016 Piedmont-Blue Ridge Fixed Region Regression Equations

Piedmont-Blue Ridge Region Fixed Region Regression Equation	Standard error (percent)	Equivalent years of record
$Q_{1.25} = 283.3\ DA^{0.724}\ (LIME+1)^{-0.124}\ (IA+1)^{0.143}(FOR+1)^{-0.412}$	44.3	2.8
$Q_{1.50} = 352.4\ DA^{0.704}\ (LIME+1)^{-0.131}\ (IA+1)^{0.123}(FOR+1)^{-0.373}$	40.9	3.2
$Q_{2} = 453.4\ DA^{0.683}\ (LIME+1)^{-0.140}\ (IA+1)^{0.105}(FOR+1)^{-0.334}$	37.5	3.7
$Q_{5} = 746.8\ DA^{0.640}\ (LIME+1)^{-0.158}\ (IA+1)^{0.083}(FOR+1)^{-0.249}$	31.9	9.2
$Q_{10} = 972.3\ DA^{0.615}\ (LIME+1)^{-0.169}\ (IA+1)^{0.076}(FOR+1)^{-0.195}$	29.6	16
$Q_{25} = 1{,}327.6\ DA^{0.593}\ (LIME+1)^{-0.182}\ (IA+1)^{0.074}(FOR+1)^{-0.145}$	29.0	25
$Q_{50} = 1{,}608.2\ DA^{0.576}\ (LIME+1)^{-0.191}\ (IA+1)^{0.073}(FOR+1)^{-0.103}$	29.8	31
$Q_{100} = 1{,}928.5\ DA^{0.561}\ (LIME+1)^{-0.198}\ (IA+1)^{0.073}(FOR+1)^{-0.067}$	31.8	34
$Q_{200} = 3{,}153.5\ DA^{0.550}\ (LIME+1)^{-0.222}\ (FOR+1)^{-0.090}$	35.7	32
$Q_{500} = 3{,}905.3\ DA^{0.533}\ (LIME+1)^{-0.233}\ (FOR+1)^{-0.045}$	42.0	30

Discharges computed to Study Point A as a single drainage area utilizing the existing land use RCN with both "good" and "fair conditions" are summarized in ***Table 2.6*** and shown graphically in ***Figure 2.2***. The existing land use in "good conditions" falls within the acceptable range, but when the RCN is modified based on "fair conditions," the 2-year and 10-year discharges are above the plus one standard deviation. Although the discharges developed from the existing conditions RCN analysis fall within the calibration range, hydrologic models for the flood study using ultimate land use conditions were completed to account for additional development within the watershed. Discharges displayed in ***Table 2.7*** and shown graphically in ***Figure 2.3*** were also computed to Study Point A as a single drainage area with ultimate land use development in both "good conditions" and "fair conditions". In "good conditions", only the discharges from the 2-year storm event fall within the acceptable calibration range. The 10-, 50-, and 100-year discharges are below the FRRE results. When the ultimate land use is modified to "fair conditions," the discharges for all four storm events fall within the acceptable range of the FRRE plus one standard deviation. Based on these results, the ultimate development land use, "fair conditions" RCN will be utilized to develop hydraulic modeling discharges.

Table 2.6: Existing Land Use Calibration with Fixed Region Regression Equation Discharges (cfs)

	2-YR	**10-YR**	**50-YR**	**100-YR**
Existing LU, Good Conditions	584	1339	2474	3105
Existing LU, Fair Conditions	765	1583	2759	3399
Existing FRRE Discharges	425	1150	2340	3060
Plus One Standard Deviation	615	1540	3150	4200

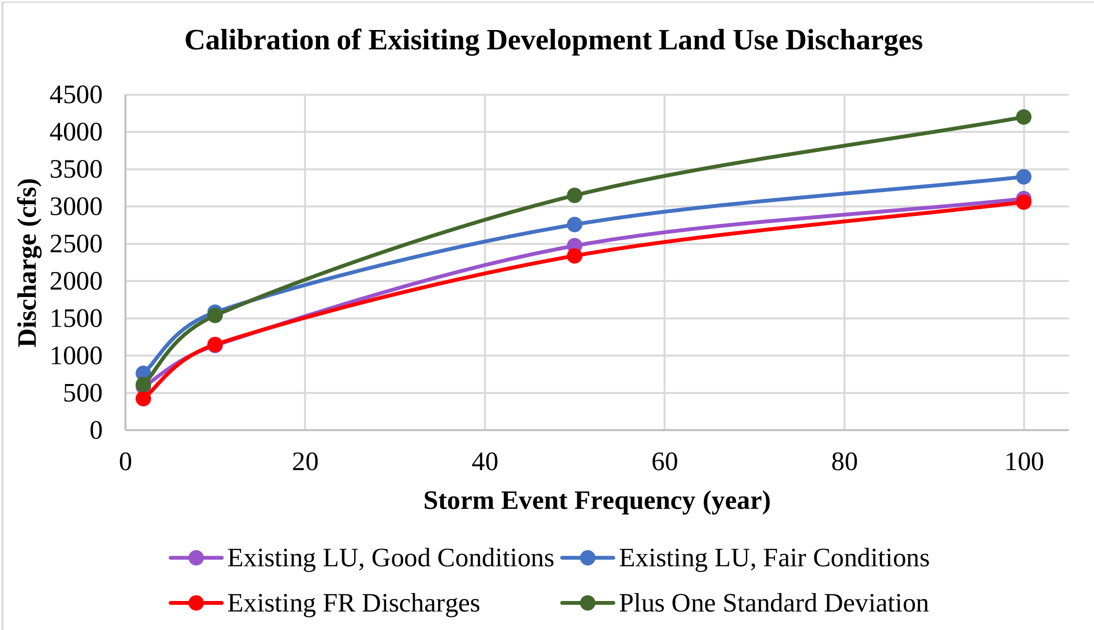


Figure 2.2: Calibration Graph of Existing Land Use with Fixed Region Regression Equation Discharges

Table 2.7: Ultimate Land Use Calibration with Fixed Region Regression Equation Discharges (cfs)

	2-YR	10-YR	50-YR	100-YR
Ultimate LU, Good Conditions	648	1428	2582	3214
Ultimate LU, Fair Conditions	824	1657	2842	3485
Ultimate FRRE Discharges	625	1430	2620	3280
Plus One Standard Deviation	908	1930	3530	4520

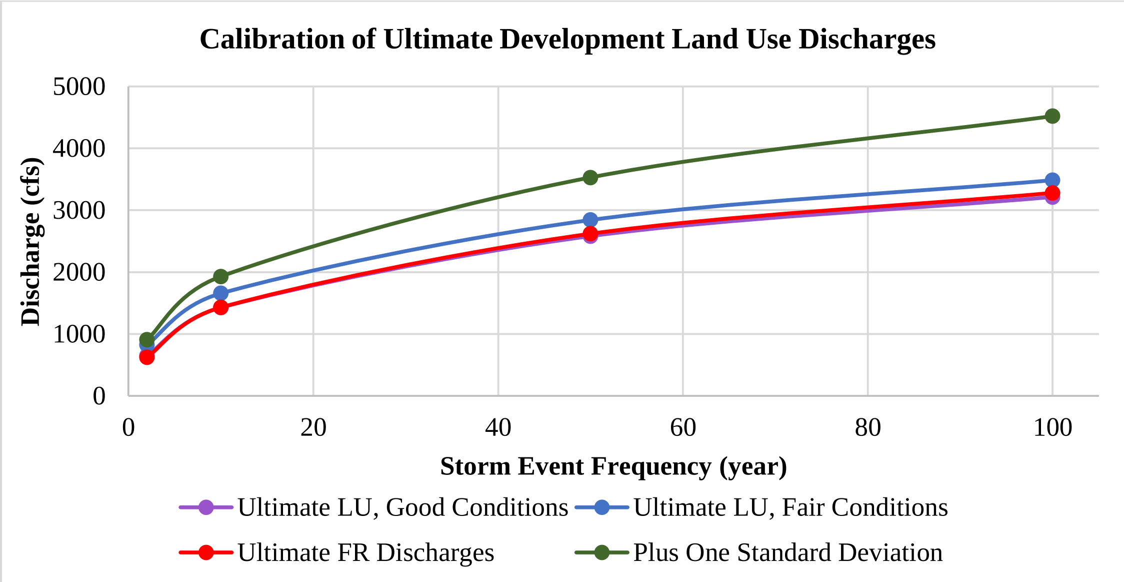


Figure 2.3: Calibration Graph of Ultimate Land Use with Fixed Region Regression Equation Discharges

2.3.5. Reach Routing

Following the calibration of the overall watershed, a total of ten (10) sub-areas were delineated within the existing conditions of the Plumtree Branch watershed for hydraulic model flow changes. As described in Section 2.3.1., there are five (5) study points on the Plumtree Branch and four (4) study points on the Little Plumtree Branch to their confluence, along with an additional study point approximately 750 linear feet downstream on Plumtree Branch. The drainage areas that were delineated based on the study point locations are reach-routed to the proceeding downstream study point and the 'addhyd' function in TR-20 was used to cumulatively add the discharges downstream. The runoff from the drainage area of Study Point I (upstream of US 40) was not reach routed to Study Point H (downstream of US 40) due to the storm drain network between these two sub-areas. The timing would be very quick due to the immediate access into the piped channel, so these sub-areas are directly combined with the 'addhyd' function. A schematic of the TR-20 is provided in ***Figure 2.4*** for reference. The TR-20 output files are included in ***Appendix D***.

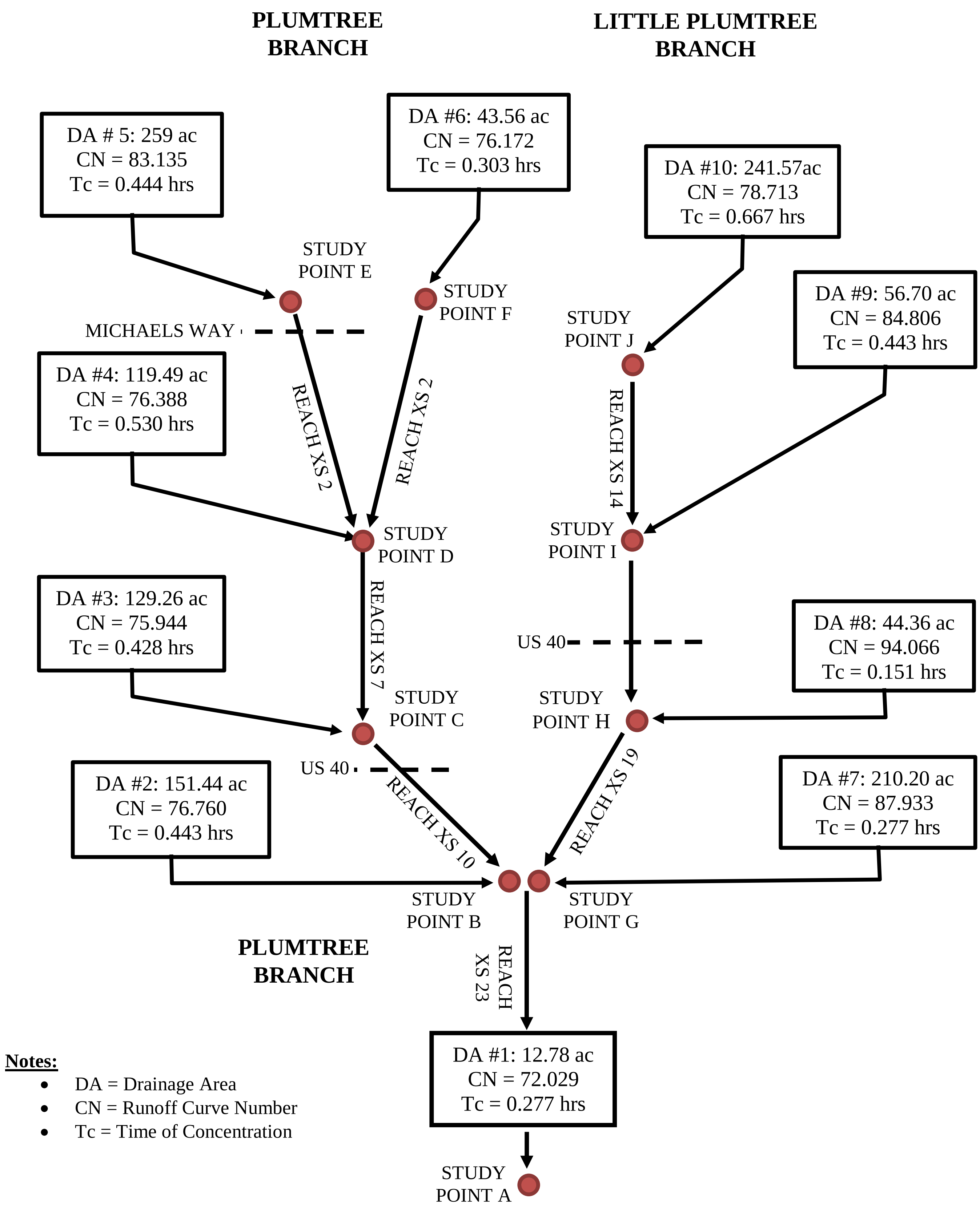


Figure 2.4: TR-20 Schematic for the Existing Conditions Hydrologic Analysis

2.3.6. Storage Routing

No storage routing was computed for the existing conditions hydrologic model. There are 16 ponds within the watershed of the study area. The existing ponds collect runoff from a total contributing area of 0.3 square miles (194.4 acres) and provide 9.7 ac-ft of storage. One pond in each of the Plumtree Branch and the Little Plumtree Branch watersheds was evaluated for potential influence on hydraulic modeling. In particular, the 100-year was evaluated for flow attenuation and influence on discharge rates to the channel. The ponds with the largest drainage areas in each watershed were chosen for a preliminary investigation. As labeled on the hydrology maps, included in ***Appendix A*** for reference, these were Ponds D and H. For consistency based on hydrologic calibration, ultimate land use in fair conditions was used for runoff curve number developments of the pond drainage areas. Pond storage was computed at its current condition using GIS contour data, assuming sediment may have filled the bottoms; pond riser and barrel data was extracted from as-built plans. Elevation data from the as-builts was converted from NGVD 1929 to NAVD 88 using the North American Vertical Datum Conversion (VERTCON) as necessary.

The contributing drainage area to Pond D, which is located within the headwaters of Plumtree Branch near Hearthstone Road, is 25.3 acres. Pond routing was evaluated for Pond D during the 100-year storm and resulted in an inflow rate of 123 cfs and outflow rate of 118 cfs. For the 100-year storm event the pond provides attenuation of 5 cfs. The existing facility provides nominal flow attenuation based on the preliminary analysis and therefore the impact other facilities in the watershed were not evaluated further at this stage.

In Little Plumtree Branch, Pond H, which is located off Misty Wood Lane, has a 25.2 acre drainage area and inflow and outflow discharges of 134 cfs and 113 cfs, respectively for the 100-year storm event. Based on the preliminary analysis of these two facilities (Ponds D and H), the attenuation in ponds within the watershed has limited impacts on the hydrologic model for the 100-year storm event. Based on these results, the existing stormwater management ponds in the watershed were not evaluated for this study. Drainage area information, pond hydraulic calculations, and the subsequent TR-20 for Ponds D and H are included in ***Appendices B and D***. A brief summary of the existing ponds within the watershed is included in ***Table 2.8*** below for reference.

Table 2.8: Preliminary Existing Pond Summary

	Pond	Location	Drainage Area (ac)	Existing Storage (ac-ft)	As-Built Available
Plumtree	A	Green Shade Court	18.1	0.22	F-84-206
	B	Still Leaf Lane	9.0	0.20	F-86-053
	C	Country Lane	13.4	1.60	F-87-213
	D	Hearthstone Road	25.3	0.49	F-87-213
	E	Ramblewood Road	5.5	0.74	F-95-092
	F	Susie's Way	7.0	0.40	F-96-056
	G	Lutheran Village	60.2	1.22	SDP-08-075
	P	Miller Branch Library	4.7	1.78	SDP-09-058
Little Plumtree	H	Misty Wood Lane	26.1	0.83	F-88-179
	I	N. Chatham Road (north of Paulskirk)	5.7	0.26	N/A
	J	N. Chatham Road (east of N. Chatham)	2.0	0.28	N/A
	K	N. Chatham Road (Chatham Garden Apartments)	2.0	0.10	N/A
	L	N. Chatham Road (Church of the Resurrection)	5.9	0.36	SDP-01-120; SDP-89-076
	M	First Evangelical Lutheran Church	2.8	0.19	SDP-87-183
	N	Split Rail Lane (Governor's Landing)	3.7	0.65	SDP-79-071
	O	Miller Branch Library	3.0	0.34	SDP-09-058

2.4. Discharge Summary

From the calibration of the single drainage area using TR-20 for the watershed, discharges at all of the study points to be used as flow changes in the hydraulic model were developed. ***Table 2.9*** below summarizes the hydrologic characteristics of each sub-area within the Plumtree Branch watershed in this study and provides the discharges to be used in the hydraulic model. The discharges shown at each study point are the cumulative flow to that point in the channel, not the runoff from the individual drainage area. Refer to the TR-20 schematic in ***Figure 2.1*** for reference of the contributing area to each study point.

Table 2.9: Sub-Drainage Area Hydrologic and Discharge Summary

Study Point	Sub-Area (acres)	RCN	Tc (hrs)	TR-20 XS	2-Yr (cfs)	10-Yr (cfs)	50-Yr (cfs)	100-Yr (cfs)	7/30/16 Storm (cfs)
Study Point A	12.78	72.029	0.277	025	581	1316	2351	2995	3782
Study Point B	151.44	76.760	0.443	012	295	741	1395	1765	2157
Study Point C	129.26	75.944	0.428	009	334	772	1391	1736	2002
Study Point D	119.49	76.388	0.530	006	321	719	1263	1578	1757
Study Point E	259.00	83.135	0.444	001	307	596	995	1200	1333
Study Point F	43.56	76.172	0.303	003	44	96	172	213	223
Study Point G	210.20	87.933	0.277	021	437	824	1339	1684	1865
Study Point H	44.36	94.066	0.151	018	213	442	803	1002	1219
Study Point I	56.70	84.806	0.443	016	190	403	741	927	1058
Study Point J	241.57	78.713	0.667	013	189	397	698	862	945

3. Hydraulic Modeling

The hydraulic analysis was performed using the Army Corp of Engineers HEC-RAS (Hydrologic Engineering Center River Analysis System) computer program, Version 5.0.3. Models for Plumtree Branch and Little Plumtree Branch were examined for both existing conditions and flood mitigation options for this study. Data used to develop the models includes cross sections, Manning's "n" values, loss coefficients and boundary conditions. The models were run under a mixed flow regime with the ultimate development land use peak discharges calibrated in the hydrologic analysis. Running the models with the mixed flow regime allows the program to utilize both subcritical and supercritical conditions in the channel. The transition between the two types of flows is anticipated at locations where the channel transitions from shallow and fast flow to deeper depths and slower flow.

3.1. Hydraulic Analysis: Plumtree Branch

The hydraulic model for Plumtree Branch was completed over a channel length of approximately 10,350 linear feet. The upstream limits of the reach are 600 ft upstream of Michaels Way; the downstream limit of the hydraulic analysis is 620 ft downstream of the confluence with Little Plumtree Branch. The cross sections were spaced approximately 150 ft apart. In some areas, cross sections were modeled closer to every 50 ft to evaluate areas in more detail where there are roadway crossings, homes within the floodplain, or a change in channel morphology. A map of the HEC-RAS cross section layout with flow change locations identified is shown in ***Figure 3.1***. Additional details including cross section labels and the resulting floodplain extents are included in the hydraulic maps of ***Appendix G***.

3.1.1. Cross Section Data

Cross section information was provided by field topographic survey and supplemented by Howard County LiDAR data. Plumtree Branch was modeled as one reach and includes 86 cross sections. The surveyed cross sections were all extended into the LiDAR data. Elevation data was merged to ensure a smooth transition between the survey and GIS data. Cross section names (River Stations) are representative of the channel distance along Plumtree Branch from behind 3750 Spring Meadow Dr.

3.1.2. Boundary Conditions

Boundary conditions are required for the HEC-RAS models to compute the flow profiles and were applied as described below. River Stations are identified on the Floodplain Maps in ***Appendix G***.

- Downstream (River Station 63): Normal depth method; channel slope used to approximate energy slope of 0.0035.
- Upstream (River Station 10286): Critical depth method.

3.1.3. Manning's "n" Values

The Manning's roughness coefficient, 'n', is an estimate of the resistance to flow for a given area. Factors which may affect the roughness include bed material, vegetation, channel irregularities, and obstructions to flow. The Manning's roughness values were assigned based on field investigations, aerial imagery, and topographic survey data. Although the study area has a diverse landscape, the cross sections largely remain in the vegetated floodplains and grassed yards. Roughness values were defined based on the different surface conditions at each individual cross section.

Roughness values were assigned within the models as follows:

- Channel 'n' values: 0.04 (natural channel)
- Overbank 'n' values: 0.075 to 0.085 (vegetated and wooded areas)

3.1.4. Computational Loss Coefficients

Energy losses occur between cross sections due to expansion and contraction of flow. Gradual transitions between sections were modeled as 0.1 and 0.3 for contraction and expansion, respectively. Cross sections located immediately upstream or downstream of a structure were assigned contraction and expansion coefficients of 0.3 and 0.5, respectively.

3.1.5. Existing Structures

Structure data was input into the HEC-RAS model to depict the existing crossings on Plumtree Branch. The dimensions and elevations of the culvert and bridge openings were surveyed and represented in the model. There are eight structure crossings on Plumtree Branch within the study reach. At River Stations 9650, 6250, 5650, and 5000, the structures are twin round or elliptical culverts (Michaels Way, Hearthstone Rd., Brookmede Rd., and Longview Dr.). Between Brookmede Rd. and Longview Dr. at River Station 5500, there is a private driveway access bridge. Downstream of the Longview Dr. crossing is the US 40 culvert (River Station 4400), which is a concrete box culvert. At River Station 2900 there is a large CMP arch culvert at the Frederick Rd. crossing, and the final structure at River Station 1850 is a pedestrian bridge. The structure openings modeled on Little Plumtree Branch are summarized in ***Table 3.1*** below.

Table 3.1: Existing Channel Crossing Culverts and Bridges of Plumtree Branch

River Station	*Crossing*	*Material and Type*	*Opening*
9650	Michaels Way	Twin CMP Pipe Arch	5'11" x 8'7"
6250	Hearthstone Road	Twin RCP Round	4'
5650	Brookmede Road	Twin RCP Round	4'
5500	Private Driveway	Steel/wood bridge*	11’6” x 21’
5000	Longview Drive	Twin CMP Pipe Arch	4' x 6'
4400	US 40	Concrete Box Culvert	5' x 8'
2900	Frederick Road	CMP Pipe Arch	8'3" x 12.78'
1850	Pedestrian Bridge	Steel Bridge*	16’ x 120’

*Bridge dimension is deck width x span width

In addition to the structures that are in-line with the stream channel, there are also structures within the floodplains. Any homes, sheds, or other buildings located in the floodplain were included in the HEC-RAS model. If a cross section intersects a building or structure, it is modeled as an obstruction in that cross section; if the cross section is up- or downstream of the structure and would be impacted by the ineffective flow area resulting from that structure, ineffective areas were added to the cross section. In HEC-RAS, ineffective flow indicates areas where water is present, but is not actively being conveyed.

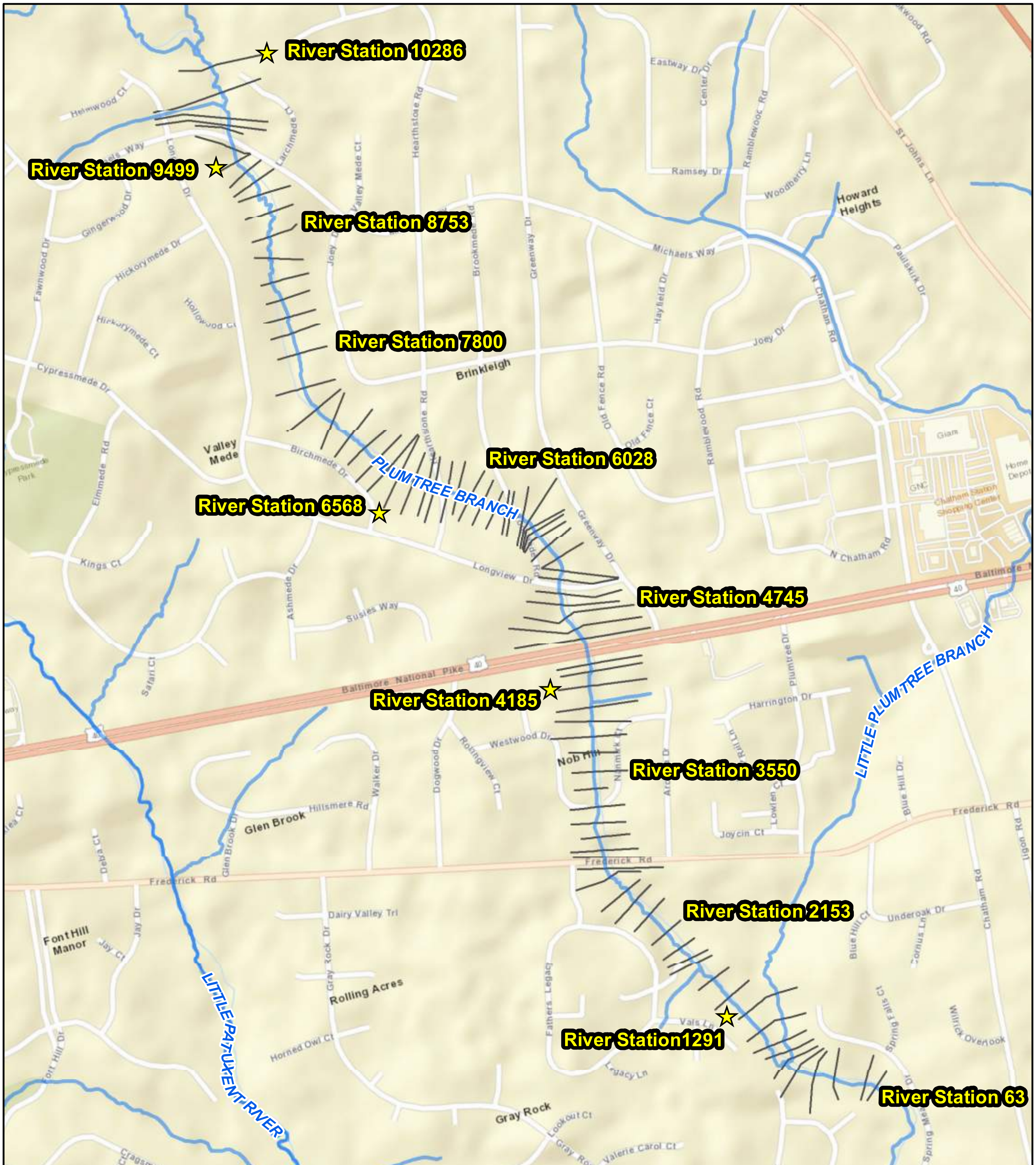
3.1.6. Existing Conditions HEC-RAS

The HEC-RAS analysis for the existing conditions was conducted for the mixed flow regime. The mixed flow regime allows flows to pass through critical depth and evaluates both subcritical and supercritical flow. The existing conditions model includes five flow change locations. The first, at the upstream limit of the reach, is the discharge resulting from Study Point E in the hydrologic analysis. The second flow change is located downstream of Michaels Way at River Station 9499; the flow increase at this location accounts for the drainage area through Study Point D. The third flow change is located at River Station 6568, which is 290 ft upstream of the Hearthstone Rd. crossing and accounts for discharges to Study Point C. The fourth flow change is located at River Station 4185, just downstream of the US 40 crossing; this flow accounts for discharges on Plumtree Branch up to the confluence with Little Plumtree (Study Point B). The fifth and final flow change is located at River Station 1291, which is the first cross section in the model that extends over both Plumtree Branch and Little Plumtree Branch; this flow change includes the discharges to the downstream study limit (Study Point A). Discharges used in the existing conditions model are displayed in ***Table 3.2***.

Table 3.2: Existing Conditions Discharges for Plumtree Branch (cfs)

Study Point	*River Station Applied*	*2-Year*	*10-Year*	*50-Year*	*100-Year*	*7/30/2016*
Study Point E	**10286**	307	596	995	1200	1333
Study Point D	**9499**	321	719	1263	1578	1757
Study Point C	**6568**	334	772	1391	1736	2002
Study Point B	**4185**	295	741	1395	1765	2157
Study Point A	**1291**	581	1316	2351	2995	3782

The existing conditions HEC-RAS model displays areas of current flooding. The model was calibrated based on known flood elevations and extents from the July 30, 2016 storm. Homeowner descriptions and sketches of the flooding aided in the calibration of model inputs such as Manning’s ‘n’ values, bank points, and flow change locations. The existing conditions model shows the impacts of the backwater conditions at the structures of Hearthstone Rd., Longview Dr., US 40, and Frederick Rd. In the 1-D steady state HEC-RAS analysis, most of the structures are overtopped by smaller storms such as the 10-year event, but also have significant backwater from the nearby structures and the confined channel. Maps of the existing 10- and 100-year floodplains are included in ***Appendix G***. The Plumtree Branch existing conditions HEC-RAS profile, cross sections, and report are included in ***Appendix H***.



Watercourse

HEC-RAS Cross Section

Flow Change Location

N

0 500 1,000 Feet

1 inch = 1,000 feet

Valley Mede Flood Study
Figure 3.1
Plumtree Branch
Hydraulic Model Map

3.2. Hydraulic Analysis: Little Plumtree Branch

The hydraulic model for Little Plumtree Branch was completed over a channel length of approximately 4,030 linear feet. The upstream limit of the reach is 250 ft upstream of the Ramblewood Road and N. Chatham intersection; the downstream limit of the hydraulic analysis is at the 60” culvert located behind the Chatham Station Shopping Center at 9180 Baltimore National Pike (US 40) in Ellicott City, MD. The downstream limit of the detailed study for Little Plumtree Branch was set at this culvert due to its negligible impact upstream within the area of concern. Initially, the complex culvert that carries Little Plumtree Branch under US 40 was included in the model, but once removed, it did not impact the conditions upstream. A map of the HEC-RAS cross section layout is included in the floodplain maps of ***Appendix G***.

3.2.1. Cross Section Data

Little Plumtree Branch was modeled as one reach and includes 30 cross sections. Cross section information was provided by field topographic survey and supplemented by Howard County LiDAR data. Cross section names (River Stations) are representative of the channel distance from the Little Plumtree Branch confluence with Plumtree Branch. The cross sections on Little Plumtree Branch are spaced approximately every 150 ft; in some areas to account for additional details at structures or stream morphology changes, cross sections were evaluated closer to every 50 ft. A map of the HEC-RAS cross section layout with flow change locations identified is shown in ***Figure 3.2***. Additional details including cross section labels and the resulting floodplain extents are included in the hydraulic maps of ***Appendix G***.

3.2.2. Boundary Conditions

Boundary conditions are required for the HEC-RAS models to compute the flow profiles and were applied as described below.

- Downstream (River Station 5442): Normal depth method; channel slope used to approximate energy slope of 0.00278.
- Upstream (River Station 9415): Critical depth method.

3.2.3. Manning’s “n” Roughness Values

The Manning’s roughness coefficient, ‘n’, is an estimate of the resistance to flow for a given area. Factors which may affect the roughness include bed material, vegetation, channel irregularities, and obstructions to flow. The Manning’s roughness values were assigned based on field investigations, aerial imagery, and field topographic survey data. Given the diverse landscape of the modeled area, a wide range of roughness values were defined, representing different surface conditions.

Roughness values were assigned within the models as follows:

- Channel ‘n’ values: 0.016 (concrete) to 0.04 (natural channel)
- Overbank ‘n’ values: 0.025 (paved surfaces) to 0.085 (wooded areas)

3.2.4. Computational Loss Coefficients

Energy losses occur between cross sections due to expansion and contraction of flow. Gradual transitions between sections were modeled as 0.1 and 0.3 for contraction and expansion, respectively. Cross sections located immediately upstream or downstream of a structure were assigned contraction and expansion coefficients of 0.3 and 0.5, respectively.

3.2.5. Existing Structures

Structure data was input into the HEC-RAS model to depict the existing crossings on Little Plumtree Branch. The dimensions and elevations of the culvert openings were surveyed and represented in the model. There are three structure crossings on Little Plumtree Branch within the study reach; at River Station 9100 there is a box culvert at the intersection of Ramblewood Rd. and N. Chatham Rd., at River Station 7800 there is a double CMP arch culvert under N. Chatham Rd., and at River Station 7400 there is a RCP culvert for the Church of the Resurrection/Resurrection-St. Paul School. The structure openings modeled on Little Plumtree Branch are summarized in ***Table 3.3*** below.

Table 3.3: Existing Channel Crossing Culverts of Little Plumtree Branch

River Station	*Crossing*	*Material and Type*	*Opening (h x w)*
9100	Ramblewood Rd. / N. Chatham Rd.	Concrete Box Culvert	4’ x 10’
7800	N. Chatham Rd.	Twin CMP Arch Culverts	6.50’ x 9.23’
7400	Private Driveway for School/Church	RCP Culvert	5.5’

In addition to the structures that cross the stream channel, there are also structures within the channel overbanks or floodplain areas. Any homes, sheds, or other buildings located in the floodplain were included in the HEC-RAS model. If a cross section intersects a building or structure, it is modeled as an obstruction in that cross section; if the cross section is up- or downstream of the structure and would be impacted by the ineffective flow area resulting from that structure, ineffective areas were added to the cross section. In HEC-RAS, ineffective flow indicates areas where water is present, but is not actively being conveyed.

3.2.6. Existing Conditions HEC-RAS

The HEC-RAS analysis for the existing conditions was conducted in a mixed flow regime. The model includes two flow changes. The first, at the upstream limit of the reach, is the discharge resulting from Study Point J in the hydrologic analysis. The second flow change location is at River Station 7645, which is located between the N. Chatham Rd. and Private Driveway crossings. The second flow change includes the hydrology through Study Point I on Little Plumtree Branch. Discharges used in the existing conditions model are displayed in ***Table 3.4***. The existing conditions model demonstrates the impact the structures and confined channel have on the water surface profiles.

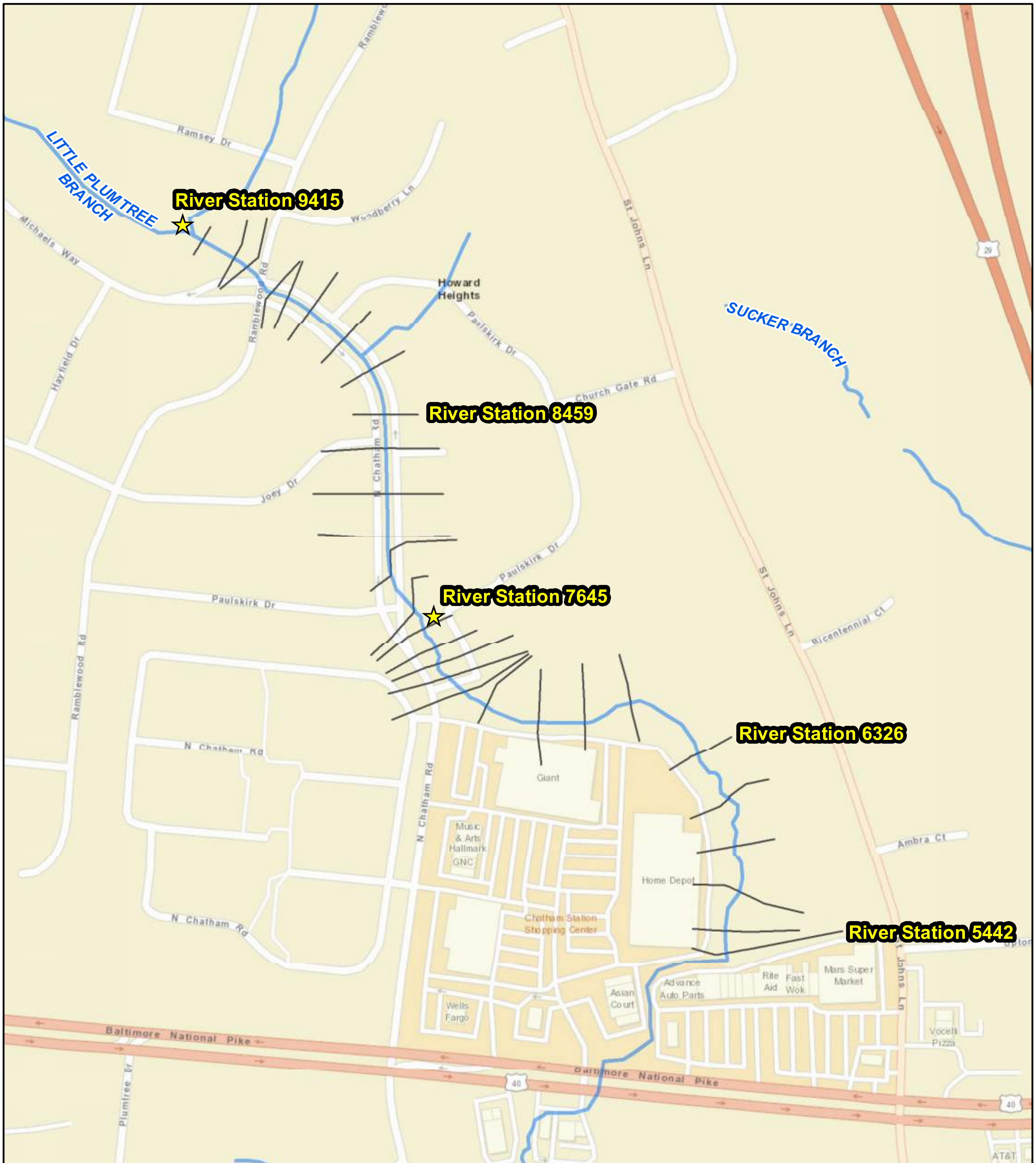
Table 3.4: Existing Discharges for Little Plumtree Branch (cfs)

Study Point	*River Station Applied*	*2-Year*	*10-Year*	*50-Year*	*100-Year*	*7/30/2016*
Study Point J	**9415**	189	397	698	862	945
Study Point I	**7645**	190	403	741	927	1058

The existing conditions model of Little Plumtree Branch includes additional ineffective areas and lateral structures to model flow escaping the channel. Ineffective areas and obstructions were added to cross sections that intersect homes and other structures or their associated contraction and expansion areas. Additional ineffective flow areas were added to cross sections that intersect existing stormwater management facilities. Ponds on both sides of N. Chatham Rd. north of the intersection with Paulskirk Dr were modeled as ineffective areas in River Stations 8010 and 7921. The facility in the left overbank of

River Station 6690 was also modeled ineffective, although the water surface elevations of the modeled storm events do not reach this elevation. The existing conditions model includes lateral weirs between River Stations 7735 and 7437 and River Stations 7358 and 7216. At the six cross sections included in this range, the right bank points were shifted to the top of the channel and the lateral weirs were added along the right bank points. In this area, downstream of the N. Chatham Rd. culvert through 120 ft downstream of the School/Church driveway, any flow that escapes the confined channel and reaches N. Chatham Rd. leaves the channel and does not re-enter Little Plumtree Branch until a point south of US 40. The lateral weirs in this area were set to the bank point elevation and the tailwater connection was set to out of the system. Weir flow does not occur until the 50-year storm event and during the 50-year event, 5 cfs escapes the channel. During the 100-year storm and the July 30, 2016 event, a total of 24 cfs and 45 cfs, respectively, is removed from the system due to roadway overtopping modeled via the lateral weirs.

The existing HEC-RAS analysis provides insight on the current conditions of Little Plumtree Branch within the study reach during storm events. There is significant backwater at all three of the structures included in this study; Ramblewood Rd./N. Chatham Rd., N. Chatham Rd., and the School/Church driveway. The Ramblewood Rd. culvert is overtopped by the 10-year storm and all those above. Within the concrete channel downstream of the Ramblewood Rd. culvert, most storm profiles experience a hydraulic jump as a result of the N. Chatham Rd. backwater. Flow overtops the concrete channel and flows into the roadway behind the N. Chatham Rd. structure, although the culvert itself is not overtopped. Downstream of the N. Chatham Rd. culvert, the channel is narrow and the flow is confined, which influences the water surfaces around the N. Chatham Rd. structure. At the School/Church private driveway, all of the storms overtop the structure, but there is no hydraulic jump. Downstream of this crossing, flow continues in the confined channel. Maps of the existing 10- and 100-year floodplains are included in ***Appendix G***. The Little Plumtree Branch existing conditions HEC-RAS profile, cross sections, and report are included in ***Appendix H***.



Watercourse

HEC-RAS Cross Sections

Flow Change Locations

N

0 250 500 Feet

1 inch = 500 feet

Valley Mede Flood Study
Figure 3.2
Little Plumtree Branch
Hydraulic Model Map

4. Conceptual Improvements

4.1. Plumtree Mitigation Options and Results

The Plumtree Branch drainage area is highly developed, consisting largely of residential neighborhoods with a few institutional and commercial parcels. Currently undeveloped areas in the Plumtree Branch watershed are located near I-70 at the top of the drainage area or along the stream. This study focused on two types of conceptual improvements, stormwater quantity management that would reduce the flow in the flooded areas and improving conveyance through structure replacements and storm drain improvements. The mitigation options were evaluated individually within this study to provide a comparison for each improvement to the baseline existing conditions. To summarize the improvements along Plumtree Branch, the study reach was divided into three zones described below. ***Figure 4.1*** displays the zones along Plumtree Branch.

Zone 1: River Stations 10286 – 6296 (Upstream study limit to Hearthstone Road)

Zone 2: River Stations 6197 – 4550 (Hearthstone Road to US 40)

Zone 3: River Stations 4344 – 63 (US 40 to Downstream study limit)

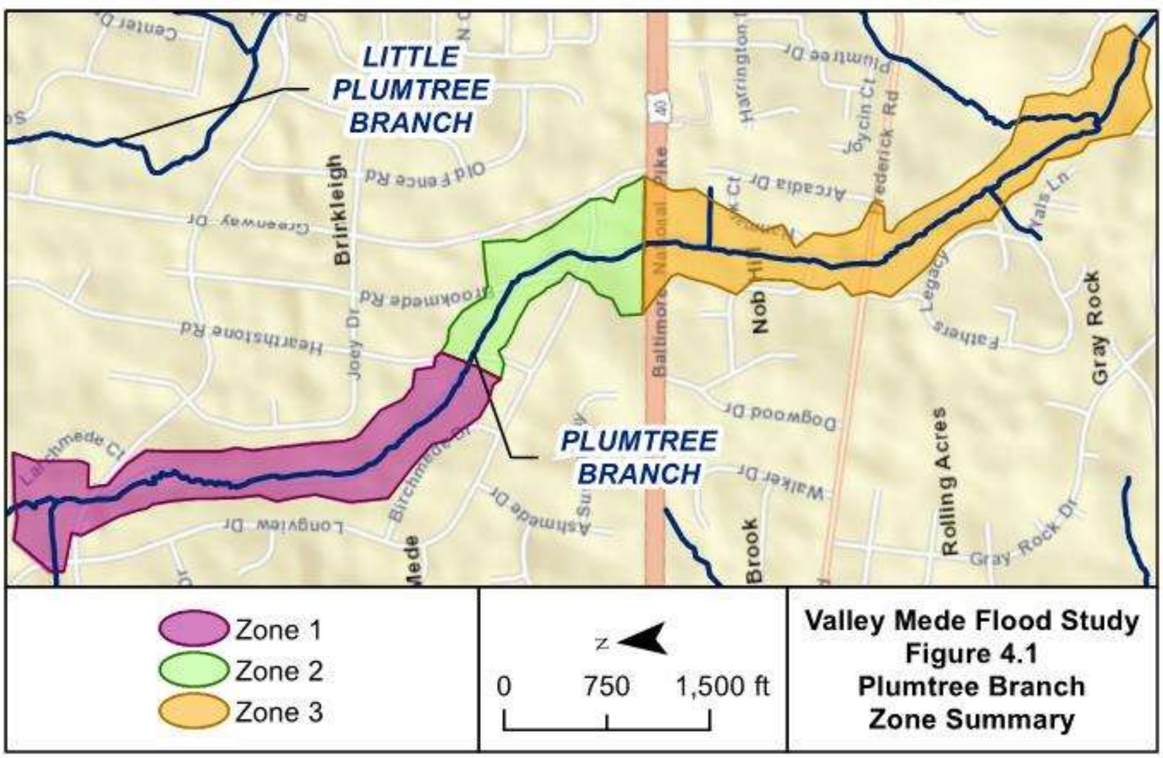


Figure 4.1: Plumtree Branch Zone Summary

Due to the highly urbanized watershed, space for storage is limited; proposed storage options are online in the Plumtree Branch channel upstream and downstream of Michaels Way. One offline storage area was also evaluated in the open space area south of Country Lane. Two existing facilities would be combined and expanded to provide a reduction in the 100-year storm event discharges to the maximum extent possible. Proposed conveyance improvements focused on converting culvert crossings to bridges from Hearthstone Road through Frederick Road and adding storm drain improvements to divert a portion of the channel flow. Nine mitigation options were evaluated along Plumtree Branch and are summarized below:

A: US 40 Bridge

B: Five Culverts to Bridges

C: Additional Culvert- Hearthstone Road to US 40

D: Storm Drain Extension- Greenway Drive

E: Plumtree Storage- above Michaels Way (Pond 1)

F: Plumtree Storage- between Hearthstone Road and Michaels Way (Ponds 2-4)

G: Country Lane Ponds Retrofit (Pond 5)

H: Bridges, Ponds 1-5, and Additional Culvert from Hearthstone Road

I: Undeveloped Parcel Preservation

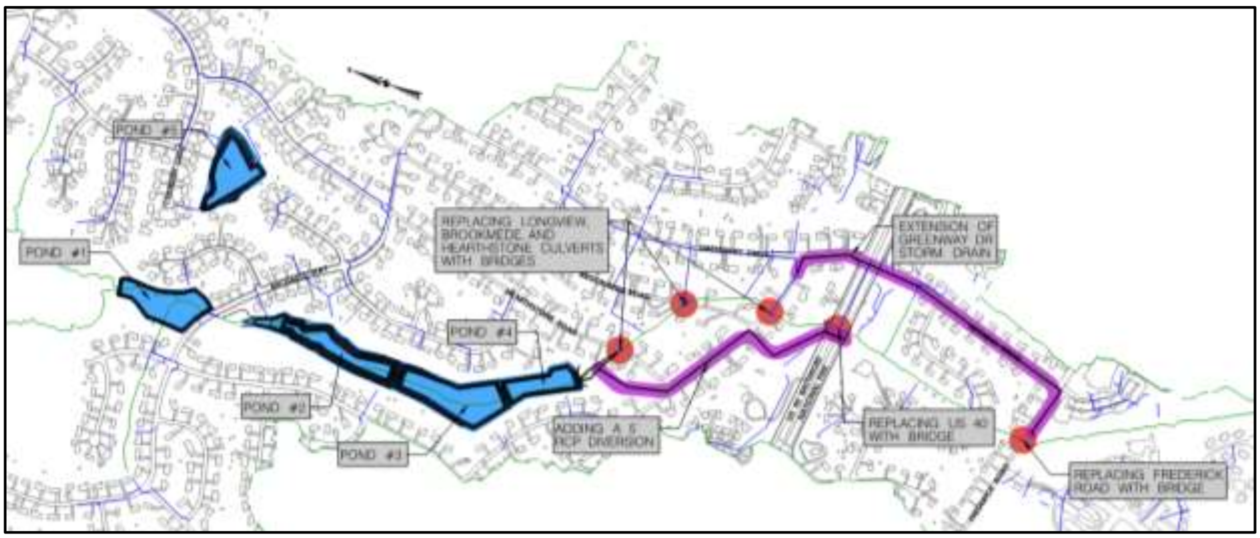


Figure 4.2: Proposed Mitigation Options – Plumtree Branch

4.1.1. Option A: US 40 Bridge

Option A includes replacement of the existing US 40 concrete box culvert with a single span bridge structure approximately 50 ft in width. In this model, the existing Plumtree Branch discharges (***Table 3.2***) were utilized to determine the hydraulic effects of the increased geometric opening. Contraction and expansion coefficients remain the same as existing conditions, but the ineffective area locations were adjusted based on the updated structure opening width.

The resultant changes in water surface elevation within each zone for this option are summarized in ***Table 4.1*** below. The bridge would provide improved conveyance and eliminate roadway overtopping at the US 40 structure due to significant change in the backwater condition. There are negligible changes in WSEL in Zones 1 and 3; significant changes occur in Zone 2. The maximum average water surface elevation change in Zone 2 is 2.10 ft (10-year); however, significantly larger reductions occur upstream of the US 40 structure and through Longview Dr. Despite the large decrease in WSEL upstream of US 40 due to the improved conveyance, the WSEL for all storms ties back into existing immediately downstream of the US

40 crossing in the 1-D steady state model. The HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.1: Option A Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	0.00	0.00	0.00	-0.01 to 0.00	0.00 to 0.00	0.00 to 0.00
2	0.66	2.10	1.57	-0.01 to 2.54	0.00 to 8.27	0.00 to 6.41
3	0.00	0.00	0.00	0.00 to 0.00	0.00 to 0.00	0.00 to 0.04

4.1.2. Option B: Five Culverts to Bridges

Option B includes replacement of the existing culverts at Hearthstone Rd., Brookmede Rd., Longview Dr., US 40, and Frederick Rd. with single span bridges. In this model, the existing Plumtree Branch discharges (***Table 3.2***) are utilized to determine the hydraulic effects of the increased geometric openings at the five structures. The bridge opening widths were modeled as the approximate width of the existing channel at each structure. Contraction and expansion coefficients remain the same as existing conditions, and ineffective areas were modified as necessary based on the proposed bridge opening widths.

The improved conveyance through the bridges at all of these crossings results in a decrease in WSEL from Frederick Rd. upstream through Hearthstone Rd., and several hundred feet upstream of Hearthstone Rd. Localized reductions in WSEL due to improved conveyance through the proposed bridges occur for all storm events and are summarized in ***Table 4.2*** below. The WSEL changes in Zone 1 occur directly upstream of Hearthstone Rd. and are more significant for the 2-year and 10-year storms due to the reduction of backwater conditions and these storms no longer overtopping Hearthstone Rd. Zone 2 experiences the highest average WSEL reductions for all storms and is most significant between Longview Dr. and US 40. The remaining area of Zone 2, between Hearthstone Rd. and Longview Dr., has reductions that are greater in magnitude at each of the structures. Brookmede Rd. is still overtopped by all storms above the 2-year event, so impacts in this portion of Zone 2 are not as significant as other areas. Reductions in Zone 3 are concentrated between US 40 and Frederick Rd., with the largest reductions just upstream of the Frederick Rd. structure. No changes in WSEL occur below Frederick Rd. The potential improvements between US 40 and Hearthstone Rd. in Option B associated with the replacement of the smaller roadway crossings are reliant on the improvement to the US 40 structure. Without a modification to the US 40 culvert, the backwater condition continues to impact the upstream roadway crossings. The HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.2: Option B Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	0.84	0.84	0.41	0.00 to 4.44	-0.02 to 3.83	0.00 to 1.92
2	1.27	3.51	2.12	-0.06 to 2.84	0.00 to 8.27	0.00 to 6.41
3	0.01	0.27	0.08	0.00 to 0.07	0.00 to 2.09	0.00 to 0.62

4.1.3. Option C: Additional Culvert- Hearthstone Rd. to US 40

Option C evaluates the addition of a diversion pipe 2,150 ft in length upstream of Hearthstone Rd. and outfalling downstream of the US 40 crossing. The existing discharges (***Table 3.2***) are used in this option and the diversion pipe is modeled as a 5 ft RCP culvert in a lateral weir between River Stations 6350 and 6454. The culvert inverts were based on the existing grade at the upstream and downstream locations. The entrance loss coefficient is set to 0.5 (square edge entrance with headwall) to provide a conservative result. At the downstream end of the diversion culvert, in order to outfall downstream of US 40, a jack and bore is likely required through the US 40 roadway embankment. See ***Figure 4.3*** for the proposed location of the diversion culvert.

Figure 4.3: Option C Storm Drain Diversion Culvert from Hearthstone Rd to US 40

The 5 ft diversion pipe removes 123 cfs during the 2-year event and 205 cfs for the 10-, 50-, and 100-year events. The flow reduction from the diversion reduces the backwater at the roadway crossings in Zones 1 and 2, especially for the 2- and 10-year events. Brookmede Rd. is no longer overtopped by the 2-year storm and US 40 is no longer overtopped by the 10-year event; the 100-year continues to overtop all of the structures in Zones 1 and 2 as in existing conditions with minimal WSEL reductions throughout the reach. There are slight increases in WSEL up to 0.05 ft in Zone 3 for all storm events, occurring just downstream of US 40 where the diverted flow is reintroduced; the proposed WSEL ties back into existing by River Station 4185. ***Table 4.3*** summarizes the changes in WSEL as impacted by Option C. The HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.3: Option C Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	0.80	0.13	0.06	0.00 to 3.76	-0.01 to 0.42	0.00 to 0.21
2	1.72	1.51	0.20	0.86 to 3.13	0.29 to 4.20	0.12 to 0.37
3	0.00	0.00	0.00	-0.01 to 0.01	-0.04 to 0.00	-0.05 to 0.00

4.1.4. Option D: Storm Drain Extension- Greenway Drive

Option D evaluates the extension of the existing storm drain along Greenway Dr. 2,660 ft to divert flow downstream of the Frederick Rd. crossing. The existing storm drain system collects runoff from the intersections of Joey Dr. at Brookmede Rd., Greenway Dr., and Old Fence Rd. and continues down Greenway Dr. with additional inflows from Old Fence Rd. and Old Fence Ct as well as the Ramblewood Rd. cul-de-sac. An inlet structure in front of 3214 Greenway Dr. has 3 inflows and 1 outlet pipe that continues down Greenway, but the western inflow connects to another storm drain network in front of 3217 Brookmede Rd. which flows toward an outfall in Plumtree Branch behind 3225 Hearthstone Rd. The exact connection between the Greenway Dr. inlet and the Brookmede Rd. storm drain is unknown and was assumed to be a divide in the network. The backyards of the homes along Brookmede Rd. and Greenway Dr. should be further evaluated for additional storm drain infrastructure that will better define the network in this area if this option is pursued. In existing conditions, the storm drain network along Greenway Dr. continues to the intersection of Longview Dr. and Greenway Dr. and connects into the Plumtree Branch cross culvert under Longview Dr. The concept proposal connects a new 5’ storm drain at the last inlet in the existing network in front of 9501 Longview Dr. The new storm drain flows back toward Greenway Dr., and continues south down Greenway Dr. toward and under US 40; downstream of US 40, the storm drain continues another 1,600 ft down Arcadia Dr., turns down Frederick Rd., and outfalls downstream of the Frederick Rd. crossing. See ***Figure 4.4*** for reference. The proposed storm drain is a bold black line, highlighted in purple.

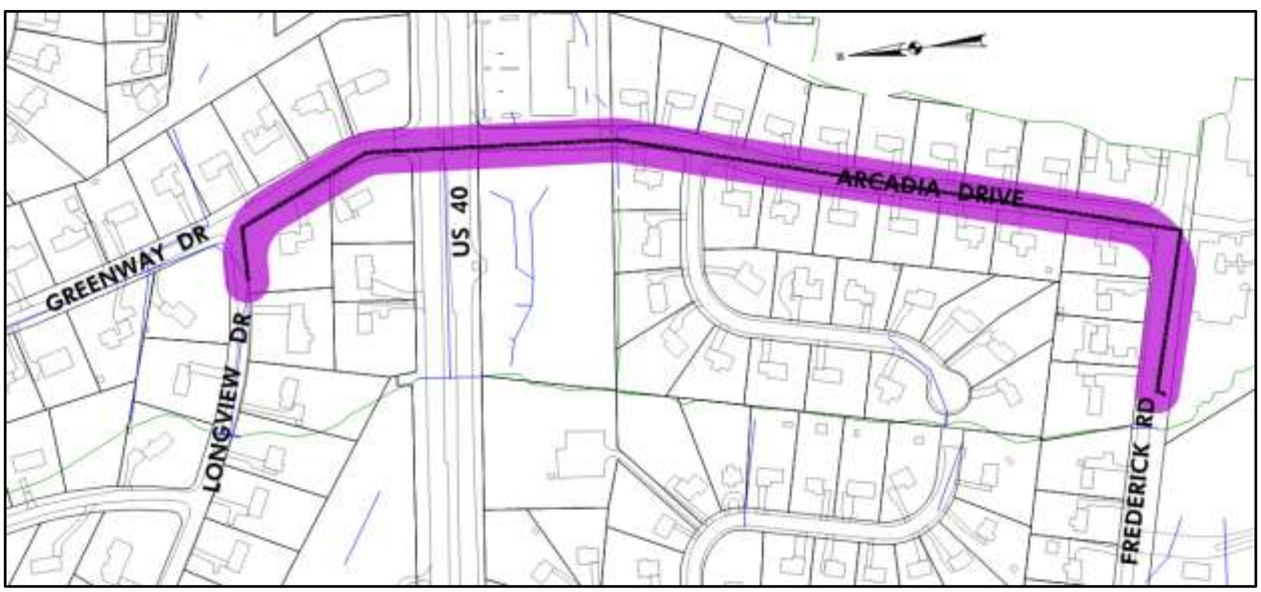


Figure 4.4: Option D Storm Drain Extension from Greenway Drive

The 5' storm drain was modeled as a flow reduction in the HEC-RAS model since the network is offline and will not divert flow directly from the stream as the culvert in Option C. A sub-drainage area was delineated to the storm drain network, ignoring the connection of the inlets on Greenway Dr. and Brookmede Rd due to unknown details. The drainage area (70 ac) is identified by Drainage Area 3a to Study Point C-1 since it is a sub-area of Drainage Area 3 and only used in the Option D analysis. The discharges for Study Point C-1 based on the ultimate land use RCN are shown in ***Table 4.4***. The proposed storm drain was evaluated in HY-8 to determine the maximum discharge of 159 cfs based on estimated pipe inverts, inlet elevation, and the proposed culvert length of 2,660 ft. A maximum flow of 159 cfs was then removed from the existing Plumtree Branch flows in the HEC-RAS model at River Stations 6568 and 4185. The 2- and 10-year flows to the storm drain network (Study Point C-1) are less than 159 cfs, so the discharges for those storm flows were entirely removed at the two flow change locations. An additional flow change downstream of Frederick Rd. at River Station 2759 was added to this model to reintroduce the diverted flow. The discharges used in Option D are displayed in ***Table 4.5***.

Table 4.4: Study Point C-1 Discharges (cfs)

2-YR	*10-YR*	*50-YR*	*100-YR*
67	146	260	321

Table 4.5: Option D Discharges (cfs)

Study Point	*River Station Applied*	*2-YR*	*10-YR*	*50-YR*	*100-YR*
Study Point E	**10286**	307	596	995	1200
Study Point D	**9499**	321	719	1263	1578
Study Point C*	**6568***	267	626	1232	1577
Study Point B*	**4185***	228	595	1236	1606
Study Point B	**2759**	295	741	1395	1765
Study Point A	**1291**	581	1316	2351	2995

*Discharges computed as:
Existing condition - Greenway Storm Drain Discharges through the 10-year
Existing condition - 159cfs (pipe capacity) above 10-year

The extension of the Greenway Dr. storm drain network reduces flows to Longview Dr. by 67 cfs and 146 cfs for the 2- and 10-year storms, respectively, and 159 cfs for the 50- and 100-year storms. The changes in WSEL due to the storm drain network extension are summarized below in ***Table 4.6.*** On average, the largest reductions in WSEL occur in Zone 2 for the model. However, the maximum reduction for the 2-year storm is in Zone 1 directly upstream of Hearthstone Rd. The broadest overall impact for this option occurs for the 10-year event with the maximum reductions occurring between US 40 and Longview Dr in Zone 2. When comparing Option D with the previous three options discussed, the magnitudes of the localized maximum reductions are smaller. Additionally, the 100-year storm has minimal WSEL reductions with a maximum reduction of only 0.28 ft. For all three of these storms, there is a small increase in Zone 3 (0.03 ft – 0.08 ft) at River Station 2827, downstream of Frederick Rd., as the diverted flow is reintroduced in the channel and the WSEL profile ties back into existing. The storm drain analysis computations including the drainage area, TR-20, and HY-8 along with the HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.6: Option D Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	0.54	0.09	0.05	0.00 to 2.21	-0.01 to 0.30	0.00 to 0.17
2	0.87	1.10	0.14	0.44 to 1.86	0.19 to 3.09	0.08 to 0.28
3	0.16	0.29	0.09	-0.08 to 0.51	-0.06 to 1.07	-0.03 to 0.31

4.1.5. Option E: Plumtree Storage- above Michaels Way (Pond #1)

Option E assesses the impact of adding storage in the County owned parcel upstream of Michaels Way. The concept grading accounts for storage from elevation 388 ft to elevation 396 ft, totaling to 22.70 ac-ft. The existing Michaels Way culverts were modeled in HY-8 to extract elevation discharge data and combine it with the proposed storage to develop a structure table for the TR-20 hydrologic model. With the new structure table, a reduction in flow is observed downstream of Michaels Way. The potential storage at this location requires additional survey and detailed analysis to ensure sufficient freeboard can be provided as the 100-year currently overtops the roadway. Based on the concept analysis, the discharges applied for Option E are displayed in ***Table 4.7***.

Table 4.7: Option E Discharges (cfs)

Study Point	***River Station Applied***	***2-YR***	***10-YR***	***50-YR***	***100-YR***
Study Point E	**10286**	307	596	995	1200
Study Point D	**9499**	210	544	1038	1384
Study Point C	**6568**	232	610	1152	1517
Study Point B	**4185**	227	609	1166	1529
Study Point A	**1291**	586	1265	2188	2798

The storage above Michaels Way has an impact on nearly every cross section for all of the storm events, which is summarized in ***Table 4.8*** below. During all storm events, the largest WSEL decrease occurs at the upstream most cross section (River Station 10286), which is due to the proposed storage area grading. There is a slight increase directly above Michaels Way, which is attributed to the reduced channel slope upstream of the structure and a less abrupt transition into the backwater condition when compared to the existing conditions profile. In Zone 1 at Hearthstone Rd. and at the structures throughout Zone 2, localized peak reductions occur for the 2- and 10-year events where backwater is reduced. The 100-year continues to overtop all of the structures in Zone 2. WSEL reductions are observed throughout Zone 3 for the 10- and 100-year events due to the flow reduction from the storage in this option, but for the 2-year event, WSEL increases up to 0.03 ft are observed downstream of River Station 1463, where the flow change includes a slight increase in discharge compared to the existing conditions. The Pond 1 computations including the concept grading, stage-storage, HY-8, and TR-20 along with the HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.8: Option E Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	1.27	0.46	0.30	-0.20 to 5.42	-0.10 to 3.64	-0.11 to 2.60
2	1.38	1.23	0.21	0.68 to 2.64	0.24 to 3.42	0.14 to 0.38
3	0.31	0.40	0.30	-0.03 to 0.61	0.06 to 1.11	0.17 to 0.46

4.1.6. Option F: Plumtree Storage- between Hearthstone Rd. and Michaels Way (Ponds 2-4)

Option F evaluates the impact on Plumtree Branch of grading ponds in series (Ponds 2, 3, and 4) downstream of Michaels Way. Concept grading for three ponds in series with weir structures between them was completed to the edge of the parcels the stream runs through. While Howard County owns the parcel immediately downstream of Michaels Way, there is a large 11.9 ac parcel from approximately River Station 8374 to River Station 6454 that is privately owned. The proposed storage areas of each pond are summarized in ***Table 4.9*** below. The bottom elevation of each storage area was based on maintaining the invert of the Hearthstone Rd. crossing with minimal grading in the channel between 3222 and 3230 Hearthstone Rd. The existing channel slope between Michaels Way and Hearthstone Rd. is 0.5%, and although not shown on the proposed grading and profile, a natural pilot channel would be graded at a slope close to the existing channel slope to maintain base flow on Plumtree Branch.

Table 4.9: Ponds 2-4 Summary

Storage ID	***Storage Volume (ac-ft)***	***Storage Elevation Range (ft)***
Pond 2	41.80	369 - 386
Pond 3	56.50	368 – 378
Pond 4	33.53	367 - 376

The hydraulic analysis of the storage areas in series requires an iterative process to account for the impacts of the tailwater condition on the pond weir structure tables. During this analysis, the 1-year and 200-year storms were added to the TR-20 to provide additional calibration data outside of the storms used for the data analysis. The rainfall volume for these storm events was obtained from the Howard County, MD data from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) NOAA 14 rainfall data. Discharge-storage-elevation data was initially developed based on the resulting HEC-RAS weir elevation-discharge without any flow changes. TR-20 tables were then iteratively modified using the TR-20 resulting discharges in HEC-RAS and continuously extracting the weir data from HEC-RAS. Once the change in stage and discharge data was less than 1%, the TR-20 structure table was considered final and the resulting discharges were used in the model. Flow change locations were added based on the weir structures and storage areas in the channel. The discharges used in Option F are displayed in ***Table 4.10*** below.

Table 4.10: Option F Discharges (cfs)

Study Point	*River Station Applied*	*2-YR*	*10-YR*	*50-YR*	*100-YR*
Study Point E	**10286**	307	596	995	1200
Pond 2	**9499**	289	633	1118	1437
Pond 3	**7954**	164	347	862	1287
Pond 4	**7030**	144	289	778	1203
Study Point C	**6568**	149	307	798	1134
Study Point B	**4185**	206	404	774	1066
Study Point A	**1291**	589	1171	2027	2624

The ponds downstream of Michaels Way provide 130 ac-ft storage, resulting in WSEL reductions throughout a majority of the Plumtree Branch study area as summarized in ***Table 4.11*** below. The maximum decreases in WSEL for all storm events are in Zone 1 within the area of significant grading between River Stations 7548 and 9301. There are also significant reductions in WSEL in Zone 2 for the 2- and 10-year events, with localized decreases upstream of the structure crossings in this zone. The localized decreases upstream of the culverts are a result of flow reductions and improved conditions and reduced backwater effects. Zone 3 reductions are minimal with the largest reduction occurring directly upstream of Frederick Rd. for the 10-year storm event. Computations for ponds 2-4 including the concept grading, stage-storage, and TR-20 along with the HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.11: Option F Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			**Range of Water Surface Elevation Change (ft)**		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	5.19	3.58	2.06	0.00 to 12.50	0.00 to 10.03	-0.04 to 7.82
2	2.56	4.69	0.66	0.68 to 4.28	1.60 to 8.12	0.46 to 1.14
3	0.42	1.04	0.88	-0.04 to 0.83	0.18 to 2.73	0.00 to 1.50

4.1.7. Option G: Country Lane Ponds Retrofit (Pond #5)

Option G evaluates the storage potential of retrofitting two existing stormwater management facilities near Country Lane. In the proposed concept, the two facilities are combined and a significant amount of grading is proposed within the existing wooded open space on the County parcel. The proposed pond bottom is graded to elevation 400 ft and provides 22.90 ac-ft of storage in the facility as compared to the 2.09 ac-ft currently provided in the two existing ponds. The pond was modeled in HY-8 with a 3 ft RCP culvert through the embankment to maintain low flow and allow storage during high flow events. Ultimately, a weir or riser structure would be designed to maximize storage while complying with Pond Code 378 regulations. For concept, the headwater elevation-discharge data from HY-8 was combined with the storage for a TR-20 structure table. The hydrologic analysis for Option G shows a decrease in discharge downstream of the proposed combined pond. The Option G discharges applied in HEC-RAS are displayed in ***Table 4.12*** below.

Table 4.12: Option G Discharges (cfs)

Study Point	*River Station Applied*	*2-YR*	*10-YR*	*50-YR*	*100-YR*
Study Point E	**10286**	307	596	995	1200
Study Point D	**9499**	303	660	1190	1474
Study Point C	**6568**	315	716	1330	1651
Study Point B	**4185**	281	684	1345	1694
Study Point A	**1291**	588	1267	2334	2969

The storage provided in Option G results in lower discharges and WSEL reductions throughout a majority of Plumtree Branch. The average reductions are less than 0.5 ft, with a maximum reduction of 1.11 ft during the 10-year event in Zone 2. The overtopping conditions at most of the structures remain the same as existing conditions with minor decreases in backwater WSEL, with the exception of the 10-year storm no longer overtopping US 40. In Zone 3, minimal reductions occur with a maximum decreases for the 2- and 10-year events just upstream of Frederick Rd. During the 2-year event, there are WSEL increases up to 0.04 ft downstream of River Station 1463, where the flow change includes a slight increase in discharge compared to the existing conditions. The WSEL changes for Option G are summarized in ***Table 4.13*** below. The Pond 5 computations including the concept grading, stage-storage, HY-8, and TR-20 along with the HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.13: Option G Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			**Range of Water Surface Elevation Change (ft)**		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	0.21	0.10	0.11	0.00 to 0.67	0.00 to 0.18	-0.01 to 0.21
2	0.32	0.40	0.09	0.11 to 0.67	0.07 to 1.11	0.06 to 0.15
3	0.05	0.19	0.07	-0.04 to 0.13	0.06 to 0.48	0.02 to 0.14

4.1.8. Option H: Bridges, Ponds 1-5, and Additional Culvert from Hearthstone Road

Option H includes the proposed concepts of Options B, C, E, F, and G. This provides the maximum storage and conveyance improvements modeled for the Plumtree Branch. The structures are modified to bridges between Frederick Rd. and Hearthstone Rd., the 5’ diversion culvert near Hearthstone Rd. is added as a lateral weir with a culvert, and the storage from ponds 1-5 is included. Similar to Option F, the hydrology for Option H was completed through an iterative process using the weir discharge-elevation data and TR-20. The discharges applied in HEC-RAS are displayed in ***Table 4.14***.

Table 4.14: Option H Discharges (cfs)

Study Point	*River Station Applied*	*2-YR*	*10-YR*	*50-YR*	*100-YR*
Study Point E	**10286**	307	596	995	1200
Pond 2	**9499**	134	293	529	662
Pond 3	**7954**	110	260	514	649
Pond 4	**7030**	106	255	510	645
Study Point C	**6568**	110	271	542	691
Study Point B	**4185**	201	391	758	963
Study Point A	**1291**	585	1159	2021	2567

Option H provides significant reductions in WSEL, largely in Zones 1 and 2 of the study reach, as shown below in ***Table 4.15***. The highest average reductions are approximately 6 ft and occur in Zone 1, with maximum reductions occurring at River Station 8987. These maximum decreases are attributed to the storage grading along with the flow reductions. Significant reductions also occur in Zone 2 with localized decreases at each of the structure crossings in this zone for the 2-year event, but overall increasing reductions moving downstream from Hearthstone Rd. through US 40 for 10- and 100-year events. The magnitudes of reductions in Zone 3 are less than Zones 1 and 2, with larger reductions just upstream of Frederick Rd. During the 2-year event, there are WSEL increases up to 0.02 ft downstream of River Station 1463, where the flow change includes a slight increase in discharge compared to the existing conditions. The reductions throughout Plumtree Branch for Option H correspond to the combined effects of the various strategies being implemented such as reducing the peak discharges in the upstream portion of the watershed and improving conveyance through structures along the reach. The TR-20 for Option H along with the HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.15: Option H Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			**Range of Water Surface Elevation Change (ft)**		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	6.62	6.27	5.55	-0.43 to 14.49	-0.10 to 13.41	-0.06 to 11.03
2	3.45	6.41	5.57	1.78 to 5.47	2.54 to 10.60	2.68 to 9.88
3	0.44	1.12	1.25	-0.02 to 0.79	0.19 to 3.21	0.36 to 2.20

Along with reductions in WSEL, Option H significantly reduces the discharges along Plumtree Branch. In ***Table 4.16***, the percent change in discharge is summarized for the flow change locations that are comparable to the existing conditions hydraulic model. The largest discharge reductions, around 60%, result in the 100-year flow being reduced below the existing 10-year at River Stations 9499 and 6568. Since some flow is diverted and not stored, the discharge reduction in the downstream limit of the study is not as significant, although the upstream storage does still provide reductions above 10% at River Station 1291. The minor increase in discharges for the 2-year storm can be attributed to the timing of the flow through the watershed.

Table 4.16: Discharge Reduction from Existing Conditions

Study Point	*River Station*	*2-YR*	*10-YR*	*50-YR*	*100-YR*
Study Point E	**10286**	0%	0%	0%	0%
Pond 2	**9499**	58%	59%	58%	58%
Study Point C	**6568**	67%	65%	61%	60%
Study Point B	**4185**	32%	47%	46%	45%
Study Point A	**1291**	-1%	12%	14%	14%

4.1.9. Option I: Undeveloped Parcels Preservation

Option I assesses the impact of preserving undeveloped parcels within the headwaters of the Plumtree Branch drainage area. For hydrologic modeling calibration, the undeveloped parcels near I-70 were coded utilizing ultimate zoning, as 1/8th acre residential lots with no stormwater management to provide conservative discharges for the study. In Option I, the parcels are coded as woods in good condition, which reduces the Runoff Curve Number (RCN) to 72 within Drainage Area 5 in the TR-20 analysis. The hydrologic computations for Option I are included in ***Appendix H***. The resulting discharges applied in Option I are displayed below in ***Table 4.17***.

Table 4.17: Option I Discharges (cfs)

Study Point	*River Station Applied*	*2-YR*	*10-YR*	*50-YR*	*100-YR*
Study Point E	**10286**	173	418	790	996
Study Point D	**9499**	188	559	1078	1389
Study Point C	**6568**	214	626	1219	1566
Study Point B	**4185**	208	613	1243	1581
Study Point A	**1291**	580	1263	2272	2818

Option I results in a decrease in WSEL throughout Plumtree Branch. In Zone 1, the reductions for all of the storms are consistent throughout the reach length, with the exception of the 2-year reductions just upstream of Hearthstone Rd. At this structure and for nearly 500 ft upstream, the backwater is reduced by over 3 ft for the 2-year event. The reductions throughout Zone 2 are similar to Zone 1, with consistent reductions for the 100-year event. Larger reductions for the 10-year event occur upstream of US 40 and at all of the structures for the 2-year event. Zone 3 WSEL reductions are largest upstream between Frederick Rd. and US 40 for all storm events. Below the pedestrian bridge, WSEL reductions for the 2-year event are negligible. The HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.18: Option I Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	1.26	0.43	0.28	0.26 to 3.70	0.19 to 1.42	0.13 to 1.58
2	1.65	1.10	0.18	0.83 to 3.04	0.19 to 3.09	0.10 to 0.30
3	0.42	0.39	0.23	0.00 to 0.81	0.07 to 1.08	0.12 to 0.36

4.1.10. Plumtree Branch Summary

The flood mitigation options presented in this report were modeled and evaluated for their potential impact on the conditions of Plumtree Branch. The options, presented independently and as a large combination, show potential improvements that would reduce the WSEL during storm events along Plumtree Branch. Hydraulic mapping is included in ***Appendix G*** and summary tables of hydraulic results are included in ***Appendix H***. Providing storage areas within the channel will help to reduce the downstream discharges, which improves the conveyance at structure crossings and reduces the impact of flood events. Improving the roadway structures that cross Plumtree Branch reduces the backwater effects and WSELs throughout the channel, but provides more localized impacts immediately upstream of the structures. Storm drain diversions improve conditions, but will decrease the time of concentration for some of the discharges; pushing flow downstream quicker will need further evaluation, although the 1-D steady flow HEC-RAS models used in this report show little to no impact of this flow shift. A preliminary cost estimate of the mitigation options evaluated on Little Plumtree Branch is summarized in ***Table 4.19***.

Table 4.19: Preliminary Cost Estimate of Plumtree Branch Mitigation Options

Mitigation Option	***Preliminary Cost Estimate***
Structure Replacement: Hearthstone Rd.	$2.5 M
Structure Replacement: Brookmede Rd.	$2.5 M
Structure Replacement: Longview Dr.	$2.5 M
Structure Replacement: US 40	$7.5 M
Structure Replacement: Frederick Rd.	$3 M
5 Storage Ponds	$14 M
Hearthstone Rd. Diversion	$1.7 M
Greenway Dr. Storm Drain Extension	$2.4 M

4.1.11. Unsteady Flow Analysis

The 1-D steady state HEC-RAS hydraulic model has limitations as computations do not account for potential flood wave attenuation within the channel which may be associated with backwater effects at structures or wide floodplains throughout the reach. In order to provide a more accurate representation of the conditions downstream of a structure replacement, an unsteady flow model was completed on Plumtree Branch for the existing conditions geometry and Option A, the US 40 culvert replacement. HEC-RAS 1-D unsteady flow models require boundary conditions that differ from the steady state flow model. Inflow hydrographs were extracted from a TR-20 and set as boundary conditions at the same flow change locations as the steady state model. The upstream boundary condition was set as a flow hydrograph at 3 minute intervals; within the channel reach, four additional lateral inflow hydrographs were added at the flow change locations to inject additional runoff into Plumtree Branch. Normal depth was set as the downstream boundary condition, similar to the steady state flow model, with an approximated friction slope of 0.0035 ft/ft.

The existing conditions unsteady flow model required minor geometry modifications to ensure the model remained stable. Culvert structures are required to have positive slope in the downstream direction for the unsteady modeling to remain stable. Due to flat areas along Plumtree Branch, several crossings were modified from the survey results to ensure positive slope through the structure. The upstream inverts were modified at Hearthstone Rd. (culvert #1), Brookmede Rd. (culverts #1 and #2), and Longview Dr. (culverts #1 and #2); upstream inverts were increased to 0.01 ft above the surveyed downstream inverts at each culvert. In addition to invert modifications, interpolated cross sections were added to the geometry to allow the model to run and remain stable. Cross sections were added between River Stations 9817, 9762, and 9732, and between River Stations 5209 and 5107.

The existing conditions unsteady flow model was compared to the steady flow existing conditions model on Plumtree Branch for reference. The unsteady flow analysis allows the discharge to change throughout the reach due to the inclusion of the timing of runoff as well as accounting for the storage areas in cross sections and backwater conditions from structures. When comparing the existing conditions unsteady flow WSEL results to the steady flow WSEL, for the 2-year event increases occur up to 0.69 ft and decreases up to 0.75 ft occur; for the 10-year WSEL increases are up to 0.74 ft with decreases up to 3.60 ft; during the 100-year event, WSEL increases occur up to 0.69 ft and decrease by a maximum 0.57 ft. Decreases in WSEL around 3.5 ft for the 10-year event occur between US 40 and Longview Dr. where the storage behind US 40 in the unsteady flow model impacts the discharge through the culvert and ultimately the WSEL.

The unsteady flow model was evaluated for the impact of the US 40 structure replacement by comparing the discharges and WSEL throughout the reach for the existing geometry and Option A geometry. The flow conditions including boundary conditions and inflow hydrographs were the same for both geometries. The Option A geometry is the same as the unsteady existing conditions geometry, with the US 40 culvert modified to a bridge structure. The results of the unsteady flow model show an increase in WSEL below US 40 due to discharge fluctuations associated with storage along the reach and behind structures. The Option A steady state flow model shows no change in WSEL downstream of the US 40 structure due to the constant flow through the cross sections and structures in both existing and proposed conditions. The unsteady flow model provides a more accurate representation of the scenario due to the reduction in backwater behind the US 40 structure and change in discharges through the cross sections, structures, and particularly downstream of the proposed US 40 bridge included in Option A.

A summary of the WSEL comparisons between the existing conditions unsteady flow and Option A unsteady flow is displayed in ***Table 4.20***. In Zone 1, there are no changes from the existing conditions for the 2-, and 10-year storms and a negligible 0.01 ft increase at two sections during the 100-year event for the unsteady comparison. In Zone 2, the largest WSEL reductions occur for each storm event. For the 2-year event in Zone 2, reductions in WSEL over 0.1 ft are observed from upstream of US 40 through the private driveway bridge off of Brookmede Dr. For the 10- and 100-year events, the reductions are observed between US 40 and Longview Dr, with minor fluctuations around 0.01 to 0.03 upstream of Longview Dr to Hearthstone Rd. In Zone 3, there is a WSEL increase in all of the cross sections during all of the storm events evaluated. The unsteady flow model demonstrates the potential impacts downstream of US 40 with the bridge replacement as the storage behind the structure is reduced and additional discharge is conveyed through the enlarged structure open. The detailed analysis utilizing the unsteady flow model at US 40 demonstrates the potential downstream impacts of any structure conveyance improvements. With an improved crossing condition, upstream storage is reduced, and discharge is moved downstream at a faster rate. Any pursued option which focuses only on enlarging structure crossings should be evaluated in detail for potential downstream impacts.

Table 4.20: Unsteady Flow Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	0.00	0.00	0.00	0.00 to 0.00	0.00 to 0.00	-0.01 to 0.00
2	0.44	0.94	1.31	0.00 to 2.16	-0.05 to 4.73	-0.15 to 5.97
3	-0.04	-0.45	-0.20	-0.09 to 0.00	-1.15 to -0.08	-0.26 to -0.02

4.2. Little Plumtree Mitigation Options and Results

The Little Plumtree Branch drainage area is completely developed, consisting largely of residential neighborhoods, schools, and churches. There is no existing open space to provide large storage areas to retain stormwater runoff, so improvements are limited to conveyance improvements to the existing culverts. As with Plumtree Branch, the mitigation options on Little Plumtree Branch were evaluated individually within this study to provide a comparison for each improvement to the baseline existing conditions. Little Plumtree Branch has been divided into two zones to summarize the hydraulic modeling results as described below. ***Figure 4.5*** displays the zones along Little Plumtree Branch.

Zone 1: River Stations 9415 – 7921 (Upstream study limit to N. Chatham Rd)

Zone 2: River Stations 7735 – 5442 (N. Chatham Rd to Downstream study limit)

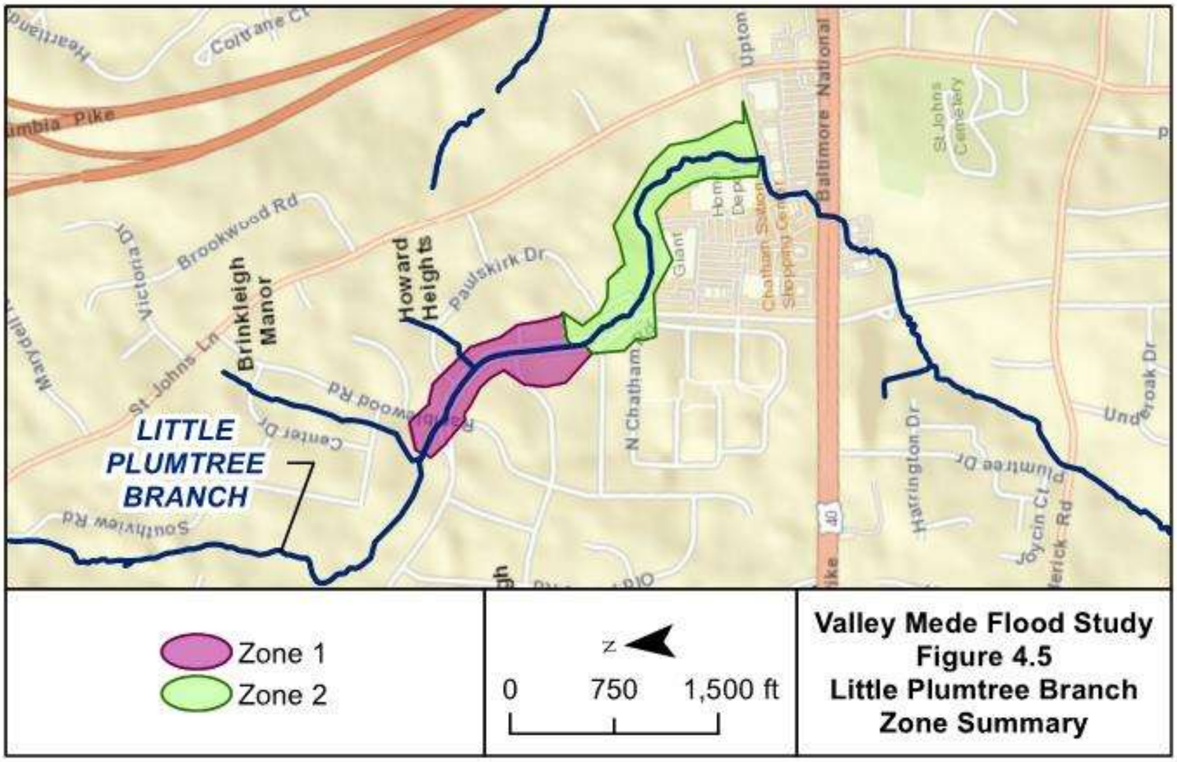


Figure 4.5: Little Plumtree Branch Zone Summary

As mentioned, improvements on Little Plumtree Branch focused on structural changes to existing culverts due to limited space for storage. The structures between Ramblewood Rd and the private driveway to the School/Church along N. Chatham Rd. are evaluated in the hydraulic study. In addition, a diversion pipe was evaluated for potential flow reduction through the area of concern at N. Chatham Rd. and the private driveway. Three scenarios were evaluated for their potential to reduce the backwater at the existing structures during storm events. The mitigation options evaluated include:

R: Culverts to Bridges

S: N. Chatham Rd. Parkway

T: Bypass Pipe

U: Culverts to Bridges and Bypass Pipe

V: Channel Grading

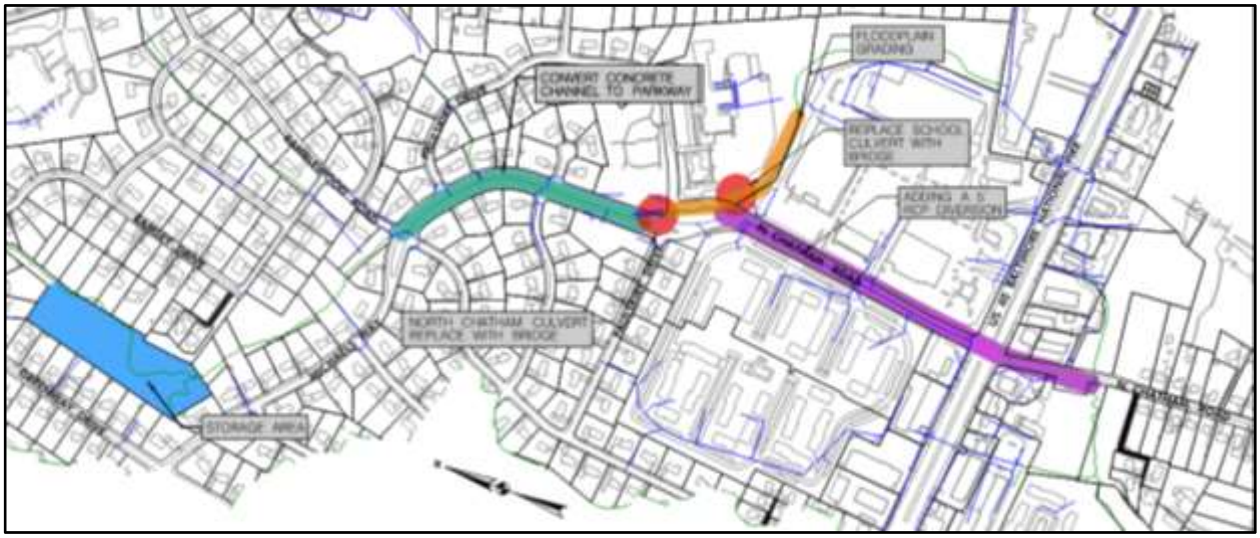


Figure 4.6: Proposed Mitigation Options – Little Plumtree Branch

4.2.1. Option R: Culverts to Bridges

Option R on Little Plumtree Branch evaluates the impact of modifying the N. Chatham Rd, double CMP arch culvert and the private driveway RCP culvert to the School/Church to bridges. The existing discharges displayed in ***Table 3.4*** were used in Option R. The bridge modifications were based on the existing channel and roadway data. At N. Chatham Rd., the bridge opening width is 65 ft and the bridge thickness was assumed to be 3 ft to estimate the high and low chord data. The private driveway culvert was replaced with a bridge with an opening width of 27 ft and a 2 ft bridge thickness. At both of the bridge structures, the modeling approach was edited to pressure and/or weir flow to account for any overtopping of the structures during high flow events. Although N. Chatham Rd. is overtopped beyond the channel extents in several cross sections, the roadway culvert is not overtopped. The structure at the School/Church entrance is overtopped by the 50- and 100-year events.

The conversion of the culverts to bridges on Little Plumtree Branch results in a localized area of WSEL reductions for the 2-, 10-, and 100-year storm events, but there are also areas of no change and increases in WSEL as summarized in ***Table 4.21*** below. In Zone 1 there are negligible changes in WSEL for all storm events up to the cross section directly upstream of the N. Chatham Rd. crossing. The area of largest WSEL reductions for all storm events is primarily in Zone 2 extending from the N. Chatham Rd. crossing to the upstream side of the School/Church private driveway crossing. The average reduction in WSEL is greatest for the 10-year storm and occurs in Zone 2 with a maximum reduction of 2.52 ft. Downstream of the private driveway crossing, the WSEL changes fluctuate between increases up to 0.25 ft and decreases down to 0.32 ft. Increases in WSEL downstream of the School/Church crossing are attributed to additional flow staying in the channel rather than overtopping onto N. Chatham Rd. when compared to existing conditions where a portion of the flow leaves the system. The HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.21: Option R Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	0.04	0.05	0.12	-0.01 to 0.46	-0.01 to 0.55	-0.02 to 1.54
2	0.41	0.26	0.04	-0.20 to 2.52	-0.25 to 1.57	-0.14 to 0.64

4.2.2. Option S: N. Chatham Rd. Parkway

Option S assesses the impacts to the floodplain of the conversion of the existing concrete channel along N. Chatham Rd. into a parkway. The existing discharges displayed in ***Table 3.4*** were used in Option S. In this scenario, the culverts at the N. Chatham Rd. and Ramblewood Rd. and at N. Chatham Rd. are removed and replaced with a triple box culvert. Above the box culvert, the roadway and open space could be modified to provide a pedestrian friendly area for the neighborhood. The proposed concrete box culverts used in this option are 10 ft wide and 5 ft tall. The reach lengths between River Stations 9224 and 7735 were shortened to account for the reduced sinuosity in the concrete structures and the total length of each culvert in this option is 1,250 ft. The River Station names remain the same as existing even though the reach lengths were modified to allow cross section data to be compared in existing and proposed options.

The conversion of the existing concrete channel into a parkway with a triple cell box culvert only provides a significant WSEL reduction in Zone 1, upstream of the Ramblewood Rd. and N. Chatham Rd. intersection. In Zone 2, downstream of the proposed triple cell box culvert, the WSEL impacts vary per storm event. As shown in the ranges listed in the summary table (***Table 4.22***), the WSEL changes fluctuate between increases and decreases in Zone 2 with the greatest range occurring during the 10-year storm event. The HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.22: Option S Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	1.02	1.94	1.46	0.26 to 1.94	0.93 to 3.04	0.57 to 2.64
2	0.02	0.04	0.07	-0.21 to 0.32	-0.25 to 0.36	-0.04 to 0.24

4.2.3. Option T: Bypass Pipe

Option T includes the analysis of adding a bypass pipe from upstream of the private School/Church driveway and outfalling downstream of US 40. The existing discharges displayed in ***Table 3.4*** were used in Option T. In this scenario, a 5 ft RCP culvert is added to the lateral weir at River Station 7717. Since the model truncates prior the Little Plumtree Branch crossing at US 40, the tailwater connection of this bypass pipe is out of the system. If pursued, this culvert could be evaluated to connect to existing storm drain along N. Chatham Rd., or extended as a new storm drain system.

The bypass pipe along N. Chatham Rd. in Option T results in WSEL fluctuations throughout Zone 1 for all of the storm events, with the largest reductions occurring just upstream of the N. Chatham Rd. culvert. The impact of the bypass pipe reduces the WSEL during all storm events at all cross sections in Zone 2 of

Little Plumtree Branch and removes up to 100 cfs for the 2- through 100-year events. ***Table 4.23*** provides a summary of the WSEL changes for Option T. The HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference

Table 4.23: Option T Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	0.02	0.01	0.01	-0.01 to 0.29	-0.01 to 0.15	-0.02 to 0.13
2	0.35	0.25	0.21	0.05 to 0.55	0.04 to 0.61	0.09 to 0.27

4.2.4. Option U: Culverts to Bridges and Bypass Pipe

Option U combines the replacement of culverts with bridges in Option R with the bypass pipe in Option T. The bridge modifications are identical to the geometry in Option R and the 5 ft bypass pipe in the lateral weir structure as in Option T. The combination of these options provides the greatest impact on WSEL reductions for each of the 2-, 10-, and 100-year storm events.

Similar to Option T, during all storm events, there are minor fluctuations of WSEL increases and decreases in Zone 1 upstream of the N. Chatham Rd. crossing. The maximum decrease in Zone 1 for all storms occurs immediately upstream of the N. Chatham Rd. structure. Downstream of this crossing through the rest of Zone 2 there are reductions in WSEL for all storm events. During the 2-year event, there is one cross section with a 0.02 ft increase in Zone 2 of the reach at River Station 6690. However, this is at a location of a significant grade change and channel slope and could be addressed with channel improvements or refining the model with additional surveyed cross sections. While the average reduction in WSEL is 0.64 ft or smaller for all storm events, each storm experiences higher magnitude reductions at localized areas, with a maximum reduction of 2.79 ft occurring during the 2-year event. The changes in WSEL for each zone on Little Plumtree Branch are summarized in ***Table 4.24*** below. The HEC-RAS profile, cross sections, and report are included in ***Appendix H*** for reference

Table 4.24: Option U Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			Range of Water Surface Elevation Change (ft)		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	0.05	0.06	0.13	-0.01 to 0.66	-0.01 to 0.72	-0.02 to 1.75
2	0.64	0.48	0.28	-0.02 to 2.79	0.01 to 1.65	0.13 to 0.88

4.2.5. Option V: Channel Grading

Option V includes grading along Little Plumtree Branch downstream of the N. Chatham Rd. culvert to approximately 475 ft downstream of the School/Church entrance crossing. The confined channel is altered by widening the section of channel to allow for additional floodplain storage. This will allow for improved conveyance throughout the lower reach. Floodplain grading is proposed in the existing open and forested space between the channel and impervious surface of the School/Church parking lot. Floodplain benches were added with slopes of 3:1 to extend back to existing grade near the parking lot. A floodplain bench at elevation 388 is proposed between N. Chatham. Rd. and the School/Church entrance.

Downstream of the School/Church crossing, a bench at elevation 385 is proposed. Similar to Option R, the culvert structure at the School/Church driveway is also modified in this option. The structure is modified to a bridge to improve conveyance to the widened downstream channel and floodplain.

This mitigation option aims to expand the channel and floodplain in an area where the existing conditions restrict flow. When compared to the existing conditions of Little Plumtree Branch, there are significant decreases in water surface elevations in Zones 1 and 2, with maximum reductions over 1.5 ft for all storm events in Zone 2. During the 2-year and 10-year events, there are reductions from just upstream of N. Chatham Rd. to approximately 475 ft downstream of the School/Church driveway with maximum reductions at River Station 7437 immediately upstream of the School/Church crossing. For the 100-year event, WSEL decreases occur along the same section of Little Plumtree Branch, although the reductions are smaller in magnitude. The improvements in this option do not result in WSEL reductions along the existing concrete channel on N. Chatham Rd. Roadway overtopping still occurs as in existing conditions. In the downstream area of Zone 2, there are small increases in WSEL up to 0.07 ft. These increases are a result of the modified channel and bridge structure providing additional conveyance. When compared to existing conditions, this proposed option keeps more of the flow in the channel rather than overtopping onto N. Chatham Rd. and temporarily leaving Little Plumtree Branch. A summary of the WSEL changes for Option V are shown below in ***Table 4.25*** and HEC-RAS details including the channel profile, cross sections, and report are included in ***Appendix H*** for reference.

Table 4.25: Option V Water Surface Elevation Change Summary

	Average Water Surface Elevation Reduction (ft)			**Range of Water Surface Elevation Change (ft)**		
Zone	**2 YR**	**10 YR**	**100 YR**	**2 YR**	**10 YR**	**100 YR**
1	0.07	0.05	0.04	0.00 to 0.89	0.00 to 0.70	0.00 to 0.50
2	0.79	0.80	0.48	0.00 to 3.47	0.00 to 2.78	-0.07 to 1.54

4.2.6. Little Plumtree Branch Summary

The proposed options on Little Plumtree Branch aim to reduce the backwater effects and roadway flooding around the N. Chatham Rd. culvert. The channel in this area is confined downstream of the N. Chatham Rd. structure, and has a relatively flat slope of 0.005 ft/ft. Due to these existing constraints, the structure replacements have little impact on the WSEL throughout the channel aside from localized WSEL reductions at the structures themselves. Even with floodplain grading in the confined area, the upstream reach of the channel continues to overtop N. Chatham Rd. Improvements in the downstream section of the reach will not eliminate the roadway topping in the concrete channel; a flow reduction upstream of this area is necessary to negate this issue. With limited open space for upstream storage, flood relief at this location is minimal for large storm events.

Converting the N. Chatham Rd culvert into a parkway provides relief of the backwater above Ramblewood Rd./N. Chatham Rd., but at the downstream end, the results do not vary significantly from existing conditions. The channel continues to restrict flow causing backwater and a hydraulic jump within the proposed greenway culvert. The addition of the 5 ft bypass pipe provides the most substantial impacts to Little Plumtree Branch due to the reduction of discharge in the channel. Removing flow from the channel results in improved conditions at the structures. The combination of the bridges and the bypass pipe provide the greatest WSEL reductions over the majority of the channel reach due to the reduction in flow and the improved conveyance of the bridges. With more storm events passing through the culverts instead of overtopping, the WSELs are reduced. The steady state model indicates no negative impacts downstream with the conveyance improvements for this study. Hydraulic mapping of all mitigation options is included in ***Appendix G*** and summary tables of hydraulic results are included in ***Appendix H***. A preliminary cost estimate of the mitigation options evaluated on Little Plumtree Branch is summarized in ***Table 4.26***.

Table 4.26: Preliminary Cost Estimate of Little Plumtree Branch Mitigation Options

Mitigation Option	***Preliminary Cost Estimate***
Structure Replacement: N. Chatham Rd.	$3 M
Structure Replacement: School/Church	$2 M
Hearthstone Rd. Diversion	$4.4 M
N. Chatham Rd. Parkway	$26 M
Channel Grading	$2 M

4.3. Floodproofing and Localized Storm Drain Improvements

The flood mitigation options evaluated for Plumtree Branch and Little Plumtree Branch have a holistic approach for improving conditions throughout each sub-watershed. Additional options, such as floodproofing, raising homes, and storm drain improvements, also have potential to reduce the flooding impacts in the Valley Mede, Chatham, and surrounding neighborhoods. FEMA documents including the "Homeowner's Guide to Retrofitting" (third edition) and "Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures" (third edition) provide detailed information on floodproofing and retrofitting methods for residential structures. While retrofit projects would require meeting any legal standards within the community and requirements of the National Flood Insurance Program (NFIP), there are opportunities for financial assistance for certain retrofit methods as referenced in the Homeowner's Guide to Retrofitting. Retrofitting a structure per FEMA guidance reduces the risk of future flood impacts and potentially reduces the flood insurance premium.

On Plumtree Branch between Michaels Way and Frederick Rd., there are 16 homes along the channel that intersect the current 100-year FEMA floodplain (Zone AE) and an additional 5 homes that are completely surrounded by the 100-year FEMA floodplain. An additional 10 homes in this region along Plumtree Branch are within close proximity to the 100-year FEMA floodplain. These homes could be considered for structure elevating, wet or dry floodproofing methods, utility relocation, or barriers. FEMA strongly encourages raising structures to provide protection for the Design Flood Elevation (DFE) or the Base Flood Elevation (BFE) plus 1 ft. The final elevation of the living space should be determined through the homeowner, designer, and local officials.

In addition to floodproofing, localized storm drain improvements have the potential to provide flooding relief of frequent storm events in contained areas. Opportunities for localized storm drain improvements are numerous throughout the watershed due to the minimal infrastructure currently in place as a result of the age of the neighborhoods. Storm drain improvements include the potential to enlarge or expand existing storm drain pipes and inlets, add new storm drain networks, or relocate existing outfalls. Areas of localized storm drain improvements would provide relief for localized concerns during more frequent events, such as the 1- and 2-year events and will require a case-by-case evaluation. Localized storm drain improvements may be further evaluated beyond the efforts of this study.

5. Summary

The Valley Mede flood study evaluates the existing conditions and proposed flood mitigation options on Plumtree Branch and its unnamed tributary, referred to as Little Plumtree Branch located in Ellicott City, MD. The standard storm events including the 2-, 10-, 50-, and 100-year recurrence intervals, along with the July 30, 2016 storm were analyzed in each channel. Hydrologic analysis was based on TR-55 and TR-20 methodology with calibration methods based on guidance in the 2016 Maryland Hydrology Panel Report. 1-D hydraulic modeling was completed using HEC-RAS version 5.0.3. on each reach. The flood mitigation options evaluated within the hydraulic models on Plumtree Branch and Little Plumtree Branch maintain a holistic approach to reducing flood potential within the residential and commercial areas along each channel.

The underlying goal of the flood mitigation options was to reduce the 100-year storm event discharges and corresponding water surface elevations down to the 10-year levels. Stormwater management options (storage via ponds) and conveyance improvements (culvert upsizing and replacement, additional storm drain) were evaluated on both reaches. On Plumtree Branch, several large storage ponds in combination with conveyance improvements (structure modifications and additional storm drain diversions) provided a significant reduction in discharges and water surface elevations for all storm events. On Little Plutmtree Branch, only conveyance options were evaluated and minimal reductions in water surface elevation were observed with the proposed improvements. The Maryland State Highway Administration and Howard County will review the results of this study in combination with community feedback and the preliminary cost estimates of the mitigation options prior to providing further recommendations.

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