RFP #2022-03

CHARLESTOWN WATERSHED MASTER PLAN TECHNICAL MEMO

Charlestown, MD

DECEMBER 2023

ORIGINAL

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1. Executive Summary

The hydrologic and hydraulic (H&H) analysis performed as part of the Charlestown Watershed Master Plan project provides the Town of Charlestown with a better understanding of the flood hazards within the identified study area boundary as well as the Town itself. In addition, the analysis will help the Town forecast flood vulnerabilities for a range of precipitation events; identify mitigation opportunities; and begin planning for future mitigation strategies.

The project consisted of a community survey, two community workshops, steering committee meetings, and flood simulation for existing and future conditions.

1.1 Stakeholder Input

Data was gathered from a variety of stakeholders via a community survey, two community workshops, and steering committee meetings. Seventy-four (74) responses to the community survey and feedback received during both community workshops were used to validate the model and inform the development of mitigation strategies.

1.2 Flood Simulation

A two-step H&H analysis was conducted to quantify flood risk within the study area and Town of Charlestown. The first step incorporated a 2D rain-on-grid HEC-RAS model to simulate the combined overland stormwater (pluvial) and coastal flooding for the entire study area. The second step included development of 2D PCSWMM models for three (3) smaller sub-areas within the Town to incorporate the underground stormwater system.

1.3 Mitigation Strategies

Project locations were identified and prioritized using a combination of the model results, community feedback, and input from Town stakeholders. Project locations were prioritized using a variety of metrics including but not limited to the degree of flood threat, critical infrastructure impacts, town access, project co-benefits, design/construction requirements, public acceptance, and permitting requirements. Concepts were developed for the two (2) highest ranked projects and one (1) additional project identified by the Town prior to the start of the project.

2. Purpose & Objectives

This technical memo summarizes the results of the hydrologic and hydraulic (H&H) analysis performed for the 8.2-square mile sub-watershed of the North East River watershed (Figure 1) and within the Town of Charlestown to better understand current and future flood risk. Specific project objectives include:

- **Perform 2D flood modeling** to forecast flood vulnerabilities for a range of precipitation events for current and future land use scenarios;
- **Evaluate stormwater runoff scenarios against sea-level rise (SLR) and storm surge conditions** in the coastal portion of the watershed;
- **Develop stormwater concepts** which include new green and/or gray infrastructure projects;
- **Support the creation of a new Watershed Master Plan (WMP)** for the Town that identifies recommendations for changes to stormwater and floodplain management regulations, areas to improve the existing stormwater infrastructure, and locations for new structural or non-structural practices to improve conveyance.

3. Study Area

The study area is an 8.2-square mile sub-watershed of the North East River watershed located in Cecil County, MD (Figure 1). The watershed is vulnerable to riverine, coastal, and pluvial (urban stormwater) flooding. The Town of Charlestown is a rural community, approximately 1.5 square miles, located within the study area.

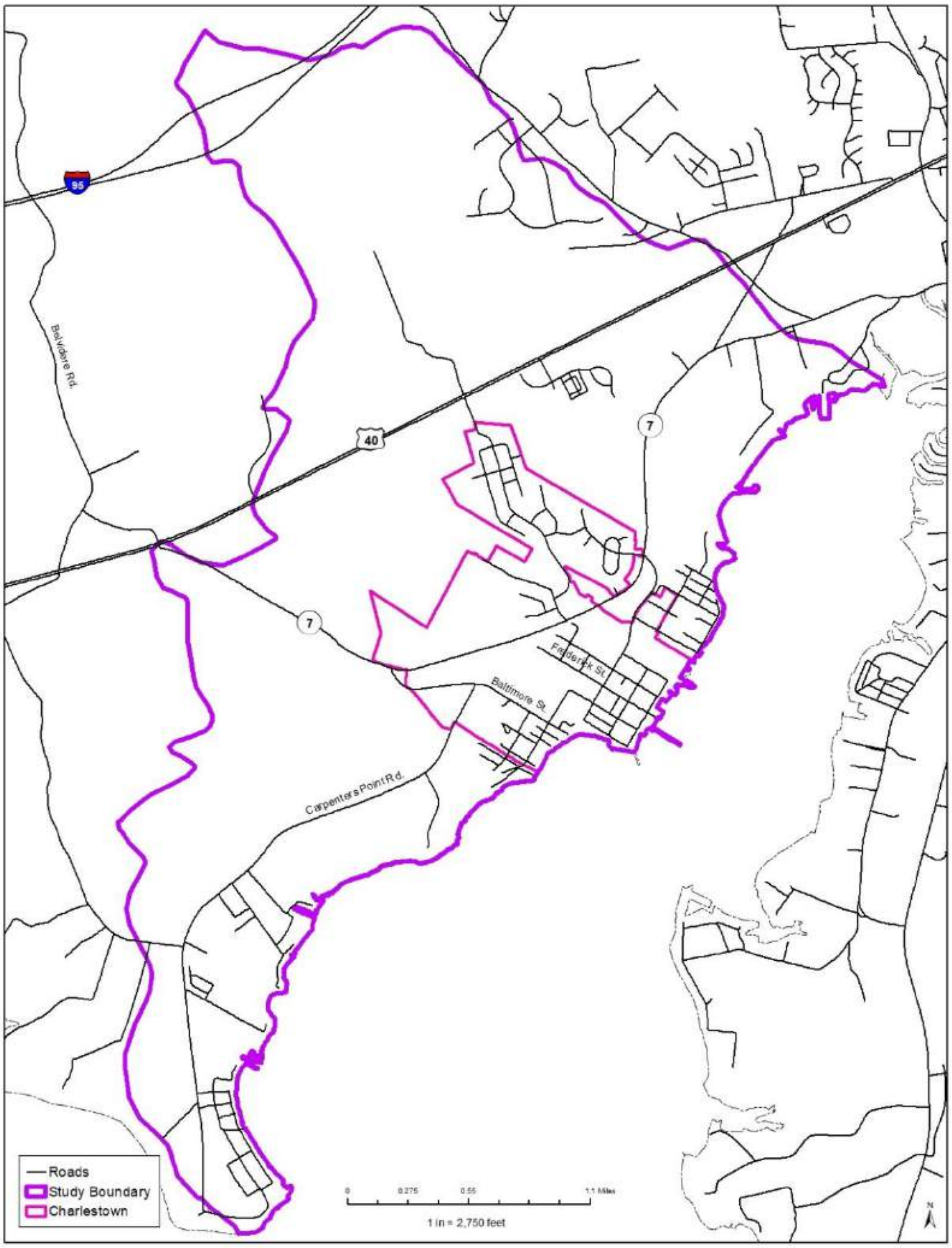

Figure 1: Study Area Vicinity Map

4. Stakeholder Input

Data was gathered from stakeholders via a community survey, community workshops, and steering committee meetings.

4.1 Community Survey

The community survey served as one of the project's public involvement tools to provide valuable data for model validation and to solicit input from the community on known flooding areas. The Town of Charlestown developed the survey and included a copy with utility bills that were mailed to residents within the study area. A total of 74 responses were received (Figure 2).

Figure 2: Community Survey Results

The survey responses and material provided by respondents (i.e. photos and maps) were consolidated into a GIS format and used to validate the existing condition H&H model and develop preliminary project locations. Examples of photos received are provided in Figures 3-5.

Figure 3: Photo of flooding from Peddlers Creek at Route 7 culvert

Figure 4: Photo of flooding in homeowner's backyard

Figure 5: Photo of backyard flooding

Although the level of detail in each survey varied, the general trends can be summarized as follows.

4.1.1 Flooding Issues

When asked if there are flooding issues on their property, the respondents reported:

- 43 out of 74 (58%) responded "yes"
- 31 out of 74 (42%) responded "no"

4.1.2 Flooding Frequency

When asked how often flooding was observed on their property, the respondents reported:

- 24 out of 74 (32%) responded only with "heavy rain"
- 12 out of 74 (16%) responded with "every rain"
- 2 out of 74 (3%) responded with high tides or storm surge
- 13 out of 74 (18%) responded that their property does not experience flooding
- 23 out of 74 (31%) had no response for this question

4.1.3 Flooding Depths

When asked to describe the typical depth, extent, and duration of flooding, the respondents reported:

- 9 out of 74 (12%) reported depths ranging from 0.5" to 2"
- 4 out of 74 (5%) reported depths ranging from 3" to 6"
- 15 out of 74 (20%) reported depths greater than 6"
- 18 of 74 (24%) responded not applicable or none
- 28 of 74 (38%) had no response for this question

4.1.4 Causes of Flooding

When asked what the potential cause of the flooding was, the respondents reported:

- 22 of 74 (30%) reported flooding comes from a neighboring property
- 7 of 74 (9%) reported flooding is a result of heavy rain
- 6 of 74 (8%) reported flooding is a result of the property's location within the landscape (e.g., located at the bottom of a hill)
- 14 of 74 (19%) reported flooding is due to poor drainage or lack of/damaged/inadequate drainage infrastructure
- 6 of 74 (8%) reported flooding is due to high tides, streams overflowing their bank, or storm surge
- 24 out of 74 (32%) responded not applicable or none

Note: respondents could select more than one cause of flooding

4.2 Community Workshops

Two community workshops were hosted by the Town to solicit input from residents and provide project updates (Figure 6). The first meeting was held on November 16, 2022 and the second meeting was held on June 5, 2023.

Figure 6: Dewberry and the Town present the project to community residents during Community Workshop #1.

Both Community Workshops were hybrid events with Town and Dewberry staff facilitating in-person and online attendees. During the workshops, the Town introduced the project and Dewberry provided an overview of the project approach and timeline. We summarized the desktop and data review collection process including how existing data and previous studies were being incorporated; provided an overview of the modeling approach and results; shared examples of potential mitigation strategies (including physical and regulatory approaches); facilitated breakout groups to discuss known flooding locations (Figure 7); and encouraged attendees to provide their perception of the benefits of watershed planning, the challenges to fixing flooding/watershed issues, and preferred mitigation strategies through a "dot" exercise. During the "dot" exercise, attendees were asked to select their top three (3) benefits of watershed planning, challenges to fixing flooding/watershed issues, and preferred mitigation strategies (Figures 8-10). Data on known flooding issues was digitized in GIS and used as part of the planning process to select project locations as discussed in Section 6.1 (Figure 11).

4.3 Steering Committee Meetings

The Town established a Steering Committee for the project comprised of a wide variety of stakeholders including but not limited to staff from the Town, Cecil County, Maryland Department of Environment (MDE), Maryland Department of Natural Resources (DNR), Cecil Land Trust (CLT), U.S. Army Corps of Engineers (USACE), Elk and North East Rivers Watershed Association, University of Maryland – Sea Grant Extension, and Cecil County Public Schools (CCPS). Regular touch points were scheduled with the Steering Committee to provide project updates and seek feedback and consensus on project prioritization metrics and priority projects selected for concept.

Known flooding issues were captured on large scale maps distributed throughout the meeting room using pens and post-it notes. Results were digitized into GIS.

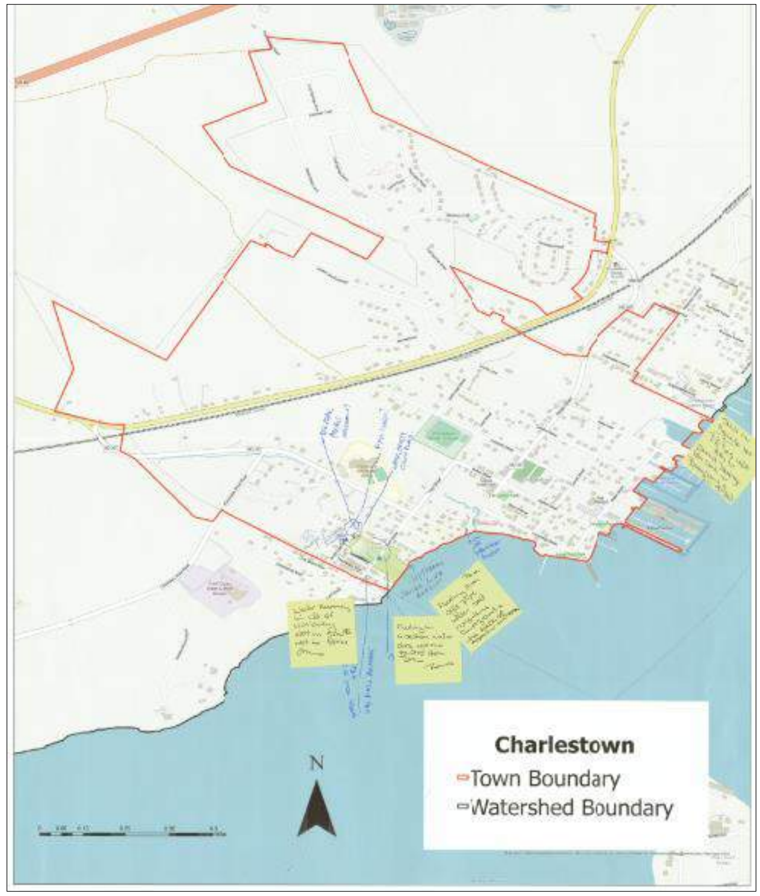

Figure 7: Example of known flooding issues identified during Community Workshops

Top five (5) "Benefits of Watershed Planning":

- Shoreline Protection
- Control Flood Risk
- Clear Water
- Property Values
- Quality of Life

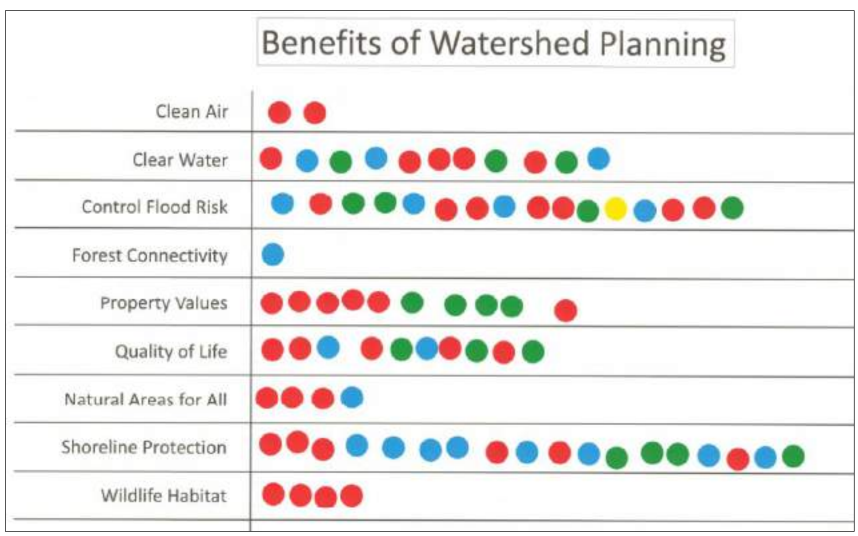

Figure 8: Benefits for watershed planning from Community Workshop attendees

Top four (4) Challenges to "Fixing Flooding/ Watershed Issues":

- Private Property
- Funding
- Development
- Public Support

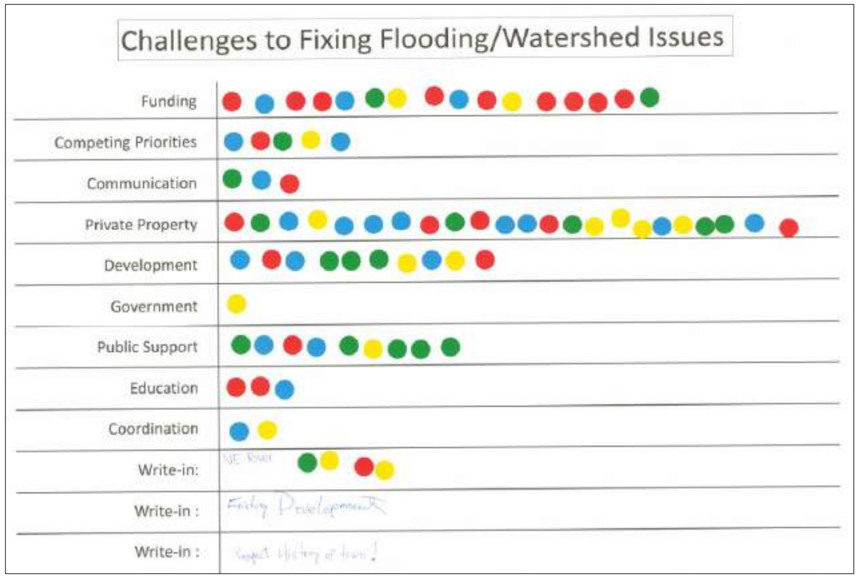

Figure 9: Challenges to fixing flooding/watershed issues from Community Workshop attendees

Top four (4) "Mitigation Strategies to Solve Flooding Challenges":

- Rain Gardens
- Microbioretentions
- Filtering Devices
- Wet Ponds

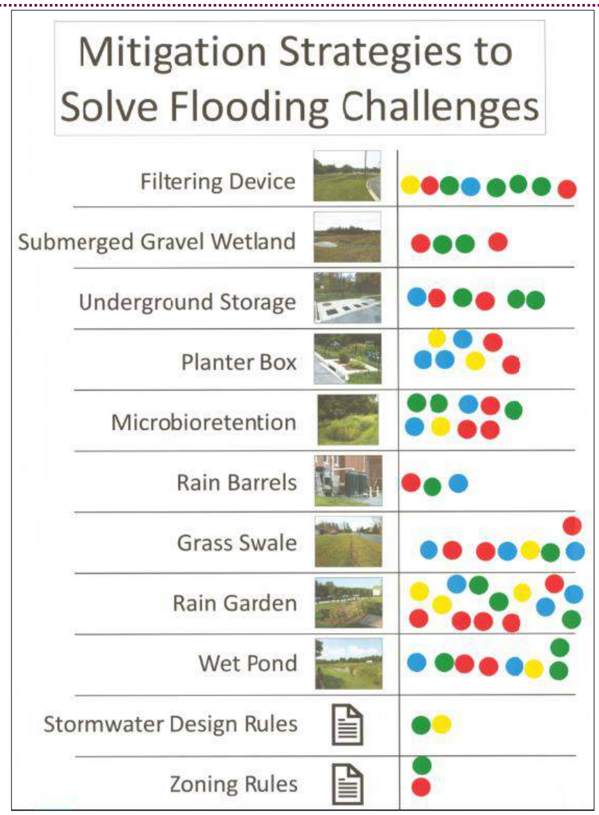

Figure 10: Preferred mitigation strategies from Community Workshop attendees

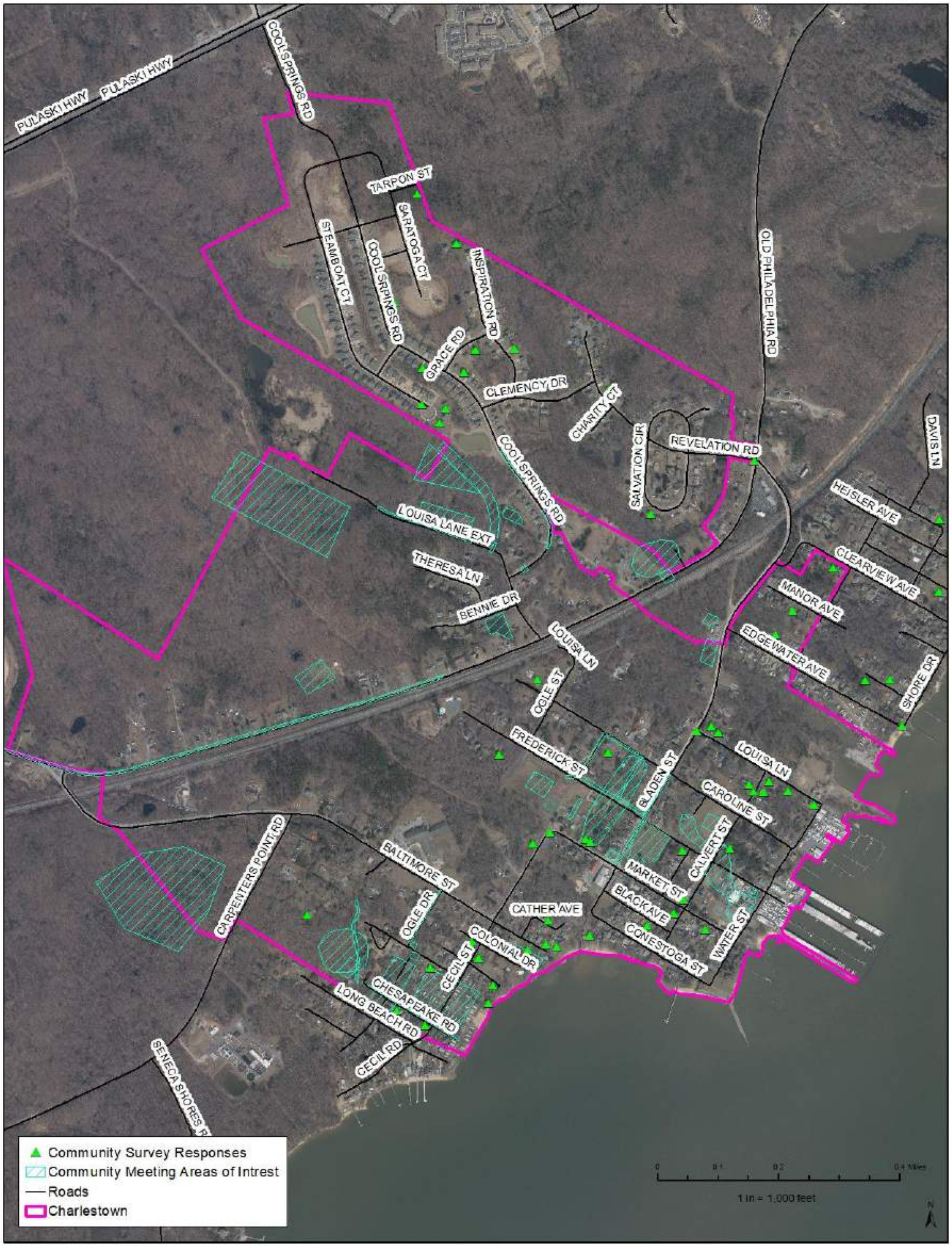

Figure 11: Digitized areas of known flooding issues collected during Community Workshops #1 & #2

5. Flood Simulation

A two-step hydrologic and hydraulic (H&H) analysis was conducted to quantify flood risk in the Town of Charlestown. First, a 2D rain-on-grid HEC-RAS model was used to simulate the combined overland stormwater (pluvial) and coastal flooding for the entire watershed. Then, smaller 2D PCSWMM models were developed in three sub-areas for more refined flood simulation and incorporation of the underground stormwater system. Resultant flood maps were analyzed to understand the potential impact of flooding on buildings, roads, and critical infrastructure in the town. Available GIS data from Cecil County Website was utilized to inform parts of the modeling.

5.1 Model Scenarios

Twelve storm scenarios were selected for modelling to show both existing and future flood conditions based on a variety of climate and occurrence factors.

Time period: Four time periods were selected to show how flooding currently affects the town and how much it will change in future conditions. The existing time period is for 2022. The three future time periods describe the mid-century (2050), mid-end of century (2080), and end-of century (2100) scenarios.

Storm Frequency and Duration: The 10-year (10% annual exceedance probability) and 100-year (1% annual exceedance probability) design storms were selected to show how low and high frequency storms affect the town. The 25-year (4% annual exceedance probability) was also selected to model the existing stormwater system. The storm duration chosen for all scenarios was 24-hours. This value is based off the watershed size as mentioned in the HEC-HMS Technical Reference Manual, which suggests using a 24-hour storm for Maryland watersheds between 2 and 50 square miles. Additionally, much of the design of the Unites States stormwater drainage system plans on the 24-hour event, so this is assumed to align with the current infrastructure in the town.

Emissions: Representative Concentration Pathway (RCP) 8.5 was used as the emissions scenario when determining future rainfall increases and sea level rise. RCP 8.5 represents the growing emissions pathway, or the “worst-case” scenario, as opposed to the stabilized RCP 4.5 scenario. According to the Guidance for Using Maryland’s 2018 Sea Level Rise Predictions (McClure et al, 2022), experts believe actual emissions will be between RCP 4.5 and RCP 8.5 and using RCP 8.5 “may be appropriate for projects with long timeframes, very low flood risk tolerance, and little or no adaptive capacity”.

Tidal Conditions: Mean high high water (MHHW) and 10-year storm surge were chosen as the moderate and extreme tidal scenarios, respectively. MWWH refers to the average of the highest water height each day, while the 10-year storm surge refers to the 10% annual exceedance probability and describes the more extreme tidal conditions. Each is discussed further in Section 5.2.3.

Land Cover: Two data sources were used to describe the existing and future land cover for the model. The National Land Cover Dataset (NLCD) describes the 2019 land use. The Integrated Climate and Land-Use Scenarios (ICLUS) describes the future estimated land use types based on the time period. The use of land cover in the model is described further in Section 5.2.4.

Table 1 outlines the twelve scenarios that were modelled based on the factors previously mentioned. Scenarios 1, 2, 4, 5, 8, and 9 describe moderate scenarios, with smaller storms and MHHW sea levels. Scenarios 3, 6, 7, 10, and 11 represent extreme scenarios, with larger storms and storm surge tides.

Table 1: Storm scenarios selected for modelling

SCENARIO	TIME PERIOD	FREQUENCY (YR)	DURATION (HR)	TIDE	LAND USE
1	2022	10	24	MHHW	NLCD 2019
2	2022	25	24	MHHW	NLCD 2019
3	2022	100	24	10yr surge	NLCD 2019

Table 1: Storm scenarios selected for modelling

SCENARIO	TIME PERIOD	FREQUENCY (YR)	DURATION (HR)	TIDE	LAND USE
4	2050	10	24	MHHW	NLCD 2019
5	2050	10	24	MHHW	ICLUS 2050
6	2050	100	24	10yr surge	NLCD 2019
7	2050	100	24	10yr surge	ICLUS 2050
8	2080	10	24	MHHW	NLCD 2019
9	2080	10	24	MHHW	ICLUS 2080
10	2080	100	24	10yr surge	NLCD 2019
11	2080	100	24	10yr surge	ICLUS 2080
12	2100	100	24	MHHW	ICLUS 2100

5.2 General Model Inputs

5.2.1 Topography

Existing Digital Elevation Model (DEM) data were downloaded from the Cecil County website. The cell size is 1 meter. The DEM is shown in Figure 12.

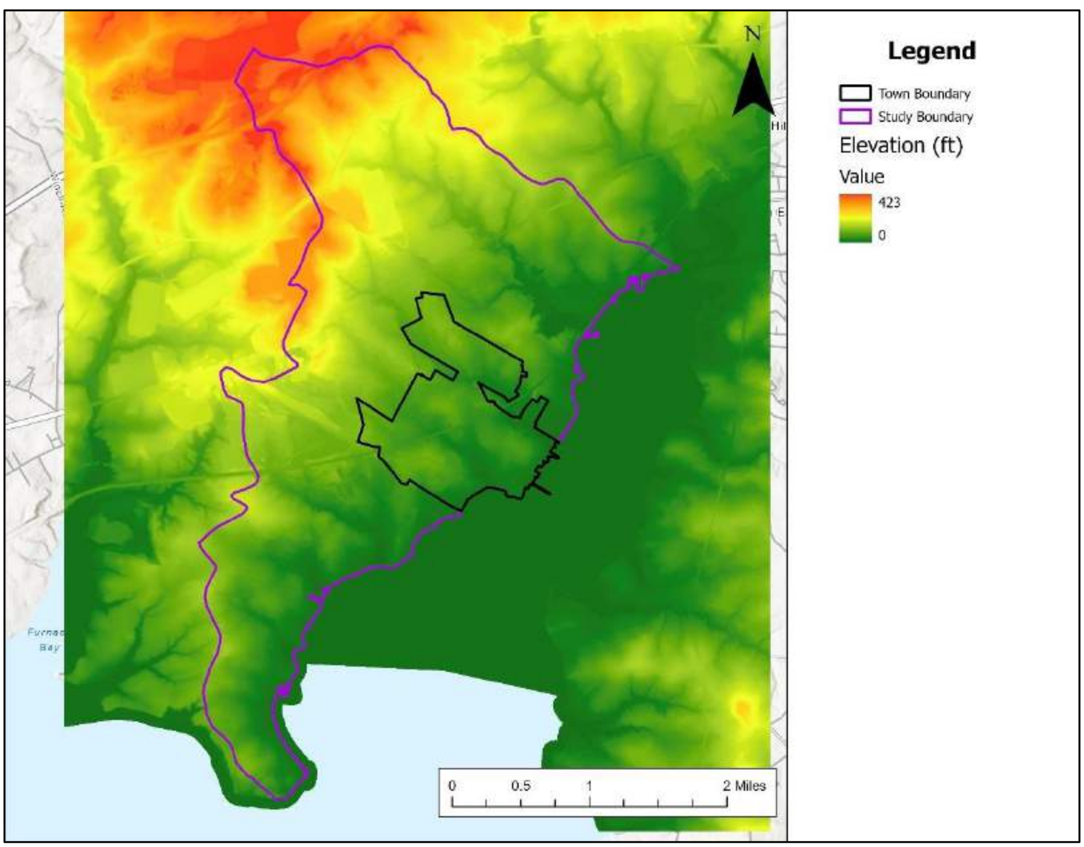

Figure 12: DEM of Study Area

5.2.2 Rainfall

The flood model simulates stormwater flooding with a “rain-on-grid” modeling approach. The rain-on-grid approach adds or “rains” the appropriate amount of rainfall onto the surface of each grid cell at each model time step. During the model simulation, rainfall ponds and/or moves from model grid cell to grid cell based on the governing hydraulic equations which account for topography, differences in water surface elevation, and surface roughness. The rainfall timestep was set to six minutes, which was sufficiently short to capture the rise and fall of rainfall during the storm. **Note:** the rain-on-grid approach used here is substantially different than the approach used in traditional FEMA models, which only simulate the effect of changing river flows on flooding.

Existing Rainfall: The total rainfall (inches) was evaluated for 3 different storm scenarios – the 10-, 25-, and 100-year, 24-hour rain events – to be modeled as part of the existing conditions (2022) analysis. These scenarios were chosen to represent a range of potential extreme storm events. The NOAA Atlas-14 dataset was used to get cumulate rainfall totals across the study area.

The storm events were assumed to have an SCS Type-II temporal distribution, which is typical for the mid-Atlantic region (USDA-SCS, 1986). The distribution shape is illustrated in Figure 13. The rainfall at grid cells between the three points was spatially interpolated. **Note:** a large fraction of rain falls during the middle of the storm between the 10th and 14th hours.

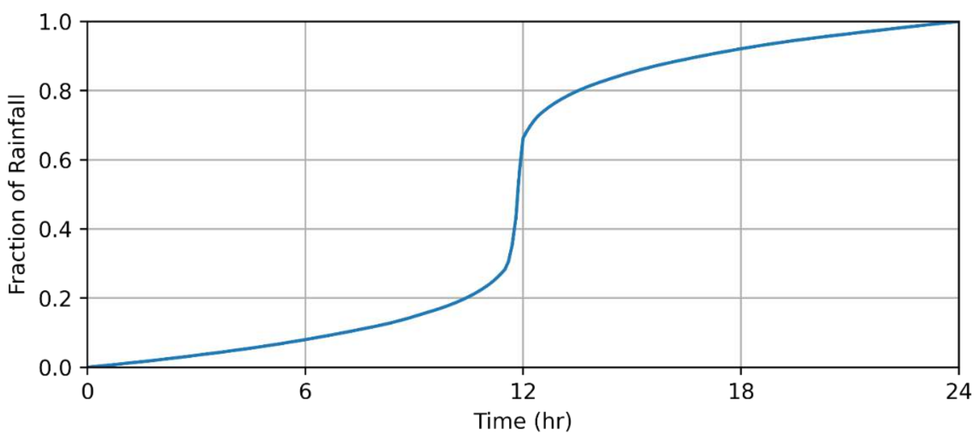

Figure 13: Cumulative rainfall during a 24-hour event used in the pluvial model, based on the SCS Type-II distribution

Future Rainfall: Rainfall increases for the mid-century and end-of-century scenarios were calculated using the Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) Projected Intensity-Duration-Frequency (IDF) Curve Data Tool for the Chesapeake Bay Watershed and Virginia. The tool estimates the median county change factor (50^{th} percentile) for the three return periods using the high emissions (RCP 8.5) scenario. Each value from the existing rainfall dataset was adjusted by the county change factor nearest Cecil County for the appropriate storm frequency. The rainfall increases are shown in Table 2.

Table 2: Rainfall increases for mid-century and end-of-century conditions.

TIME PERIOD	FREQUENCY (YR)	RAINFALL INCREASE (%)
2050	10	11
	100	9
2080	10	16
	100	18

Source: https://midatlantic-idf.rcc-acis.org/

5.2.3 Tidal Elevations

The eastern part of the study area is tidally influenced by the North East River and would be impacted by sea level rise (SLR). The MHHW and 10-year storm surge were chosen as the moderate and extreme tidal scenarios, respectively.

Mean High High Water: As previously stated, MHHW refers to the average of the highest water height each day and was calculated using NOAA's Online Vertical Datum Transformation tool for 1994, which is close enough to 2000 to assume no difference, along with NOAA's Relative Sea Level Trend slope to determine the additional sea level rise from 2000 to 2022. The two values were added to get a current existing tidal elevation (2022). Maryland's 2018 Sea Level Projections Guide (McClure et al, 2022) was used to estimate the average sea level rise heights above 2000 levels using the Baltimore Tide Gauge, which is closest to the study area. Low tolerance for flood risk was assumed as this project pertains to community assets and residential areas. The 2050 and 2080 values were added to the MHHW value to get future scenario sea level rise estimates. RCP 8.5 was assumed for all conditions.

Storm Surge: The 10-year storm surge refers to the 10% annual exceedance probability and describes the more extreme tide conditions. The storm surge elevations were determined based on the FEMA flood insurance study for Cecil County (USACE, 2013).

Table 3 shows the tidal elevations for each scenario, which are used as boundary conditions in the models.

Table 3: Tidal values for existing, mid-century and end-of-century conditions.

TIME PERIOD	TIDE CONDITION	TIDAL ELEVATION (FT)
2022	MHHW	1.555
	10yr surge	5.57
2050	MHHW	3.625
	10yr surge	7.78
2080	MHHW	6.025
	10yr surge	10.27
2100	MHHW	7.815

5.2.4 Land Cover/Manning's n

The 2019 National Land Cover Dataset (NLCD) and the Integrated Climate and Land-Use Scenarios (ICLUS) datasets were used for existing and future land cover in the model, respectively. Manning's n values were assigned to each grid cell in the model mesh based on its land use class. In addition, the Manning's n values along the stream beds of larger rivers, including Red Rum Creek and Peddlers Creek, were overwritten to values ranging from 0.03 to 0.04. The stream bed areas were manually delineated using Google Earth imagery.

Existing Land Cover (NLCD): The Manning's n values assigned to land use codes from the NLCD are provided in Table 4 and shown in Figure 14.

Table 4: Manning's N values for NLCD Land Cover

LAND USE CODE	LAND USE DESCRIPTION	MANNING'S N
11	Open Water	0.035
21	Developed, Open Space	0.04
22	Developed, Low Intensity	0.09
23	Developed, Medium Intensity	0.12
24	Developed, High Intensity	0.16
31	Barren Land Rock/Sand/Clay	0.0265
41	Deciduous Forest	0.15
42	Evergreen Forest	0.12
43	Mixed Forest	0.14
52	Shrub/Scrub	0.115
71	Grassland/Herbaceous	0.0375
81	Pasture/Hay	0.0375
82	Cultivated Crops	0.04
90	Woody Wetlands	0.0975
95	Emergent Herbaceous Wetlands	0.0625

Future Land Cover (ICLUS): The 2050 and 2080 ICLUS datasets (USEPA, 2016) are based on the RCP 8.5 emissions scenario. Manning's n values assigned to land use codes from the ICLUS are provided in Table 5. The 2050 and 2080 ICLUS data are shown in Figure 15 and Figure 16, respectively.

Table 5: Manning's N values for ICLUS Land Cover

LAND USE VALUE	CLASS NAME	MANNING'S N
0	Natural Water	0.035
2	Wetlands	0.0975
4	Timber	0.15
5	Grazing	0.0375
7	Cropland	0.04
8	Mining, barren land	0.0265
9	Parks, golf courses	0.04
10	Exurban, low density	0.09
11	Exurban, high density	0.12
12	Suburban	0.09
13	Urban, low density	0.09
14	Urban, high density	0.16
15	Commercial	0.16
16	Industrial	0.16
17	Institutional	0.16
18	Transportation	0.16

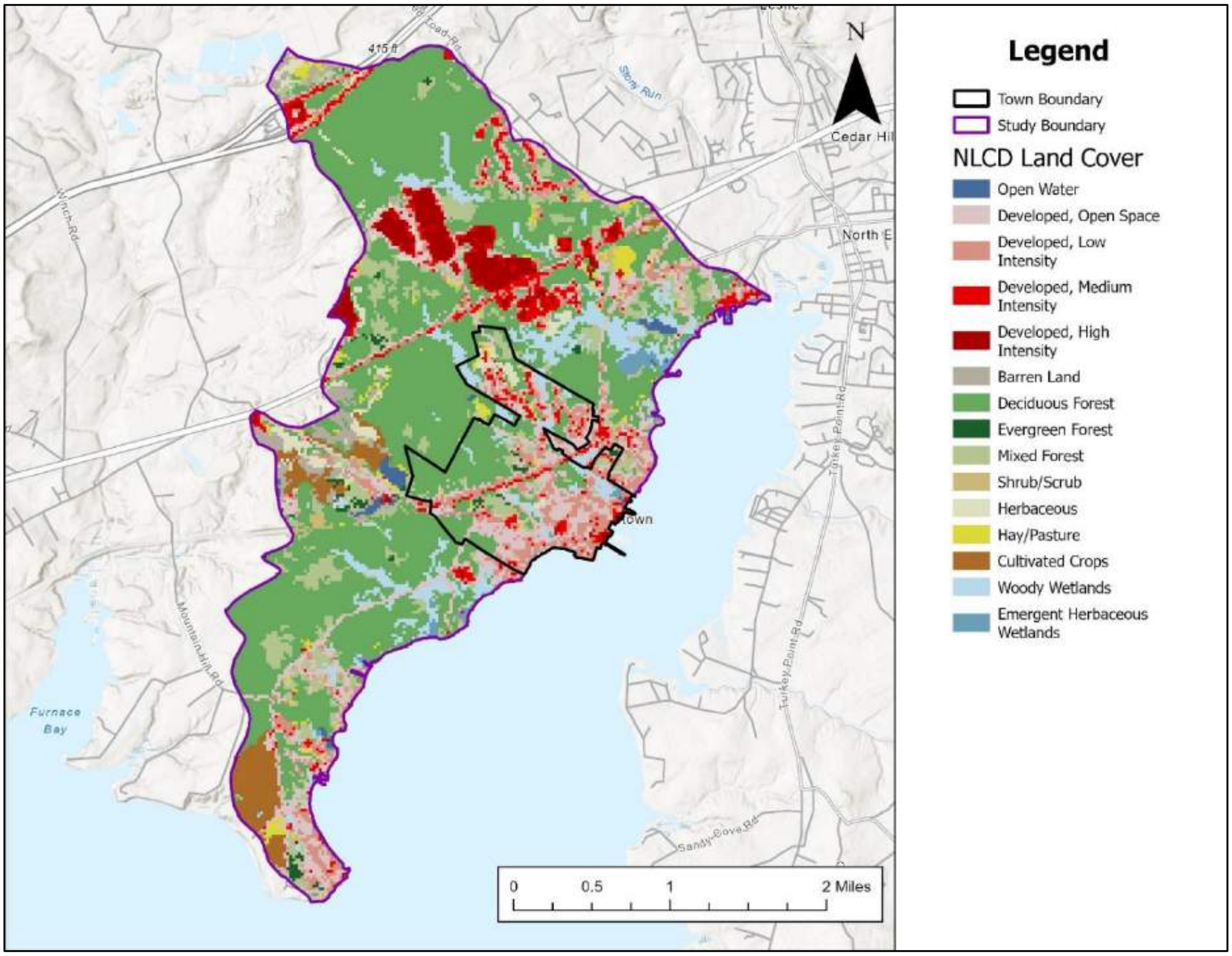

Figure 14: Map of Land Use/ Cover dataset from the NLCD dataset

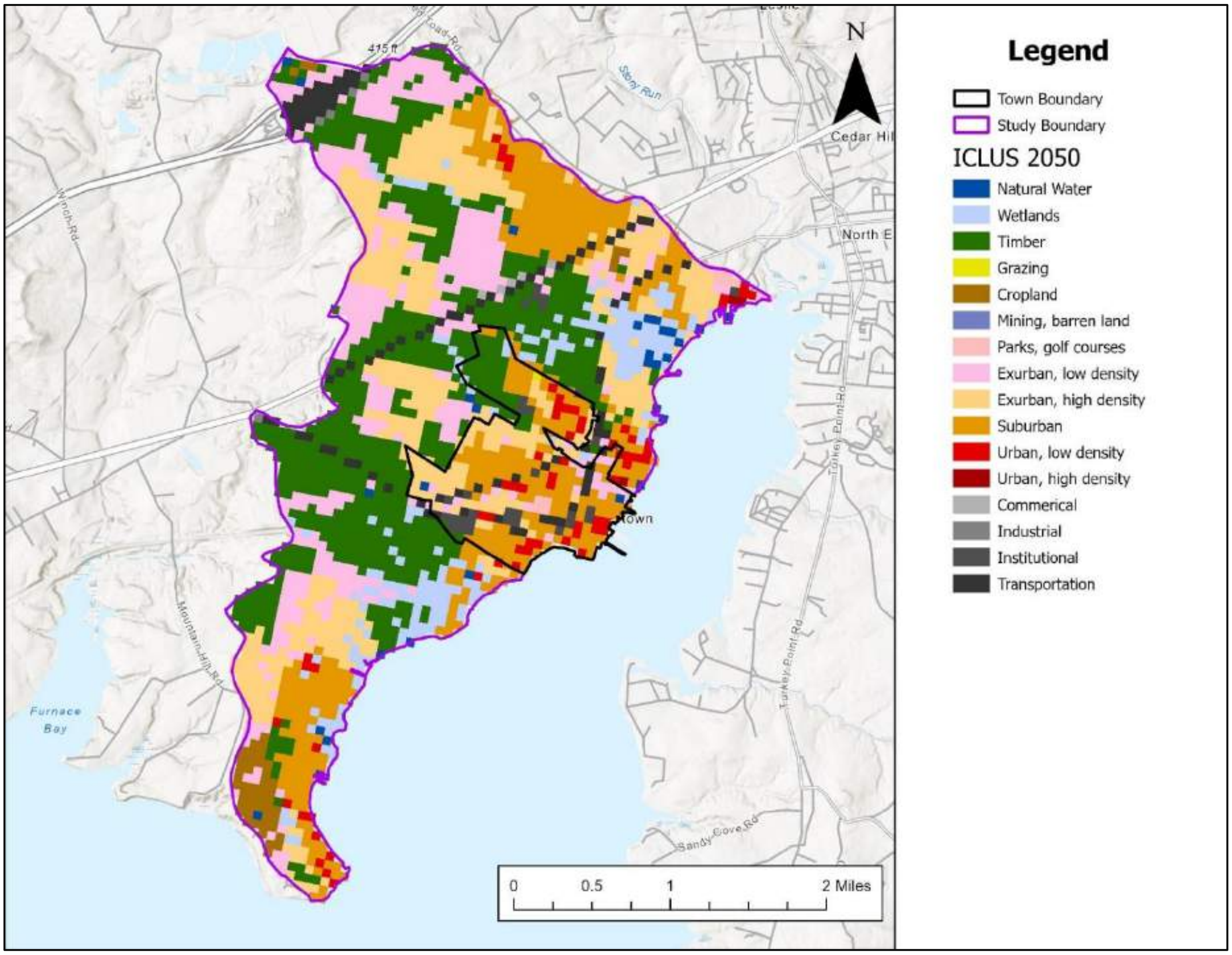

Figure 15: Map of 2050 Land Use/ Cover dataset from the ICLUS dataset

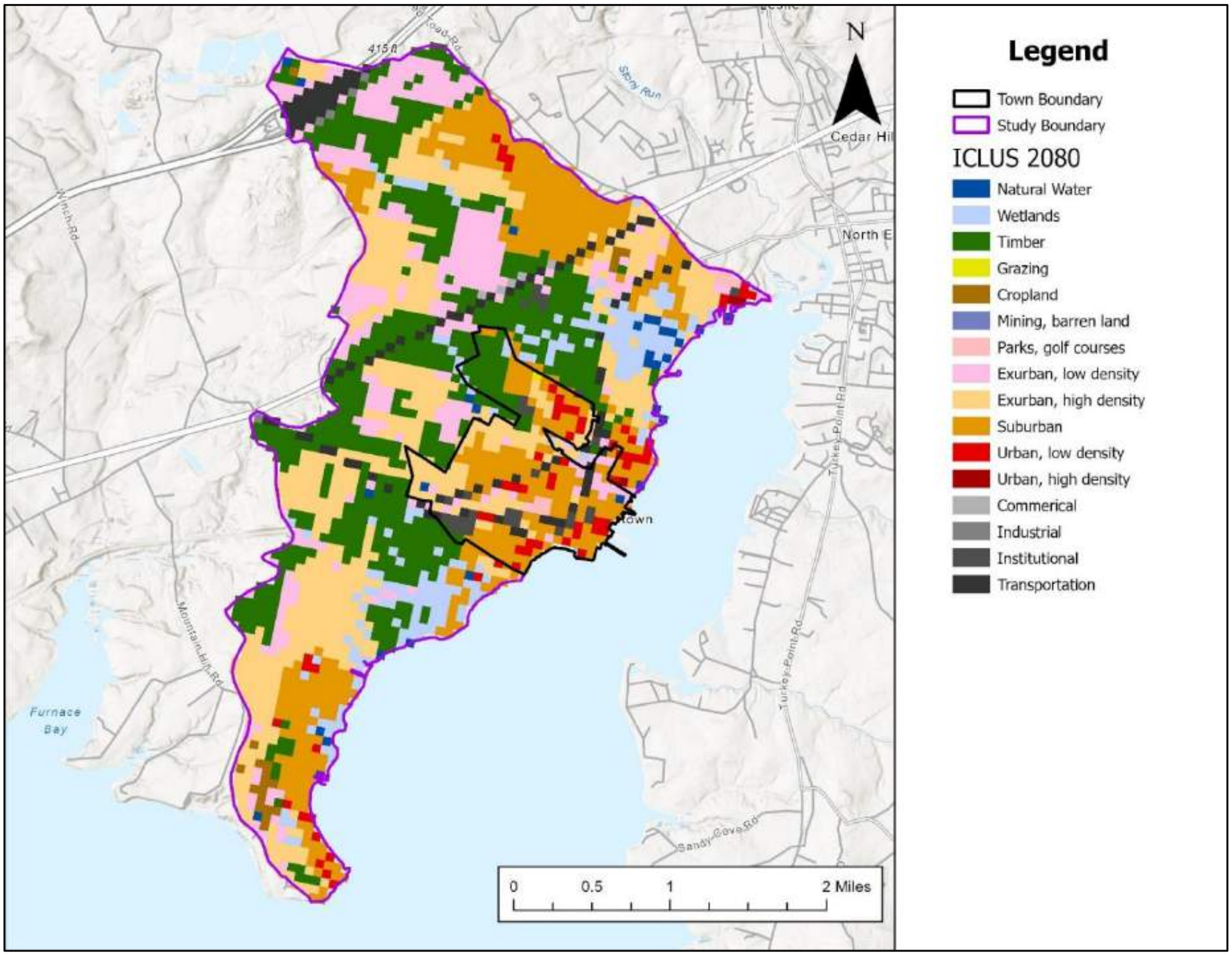

Figure 16: Map of 2080 Land Use/ Cover dataset from the ICLUS dataset

5.2.5 Infiltration/Curve Number

Rainfall infiltration was modeled using the SCS curve number approach. The method is described in detail in the HEC-RAS Version 6 Hydraulic Reference Manual (USACE, 2020). Briefly, the infiltration model effectively reduces the amount of rainfall falling on each grid cell depending on its SCS curve number, which is derived from the SSURGO hydrologic soil classification and land use from the 2019 NLCD. The QGIS Plug-in Tool 'Curve Number Generator,' which uses these datasets, was utilized to create the curve number grid for the project area. Higher SCS curve numbers are associated with less infiltration and greater runoff. More urbanized land uses tend to have higher SCS curve numbers, while less urbanized land uses tend to have lower SCS curve numbers. The final curve numbers used in the infiltration model are shown in Figure 17.

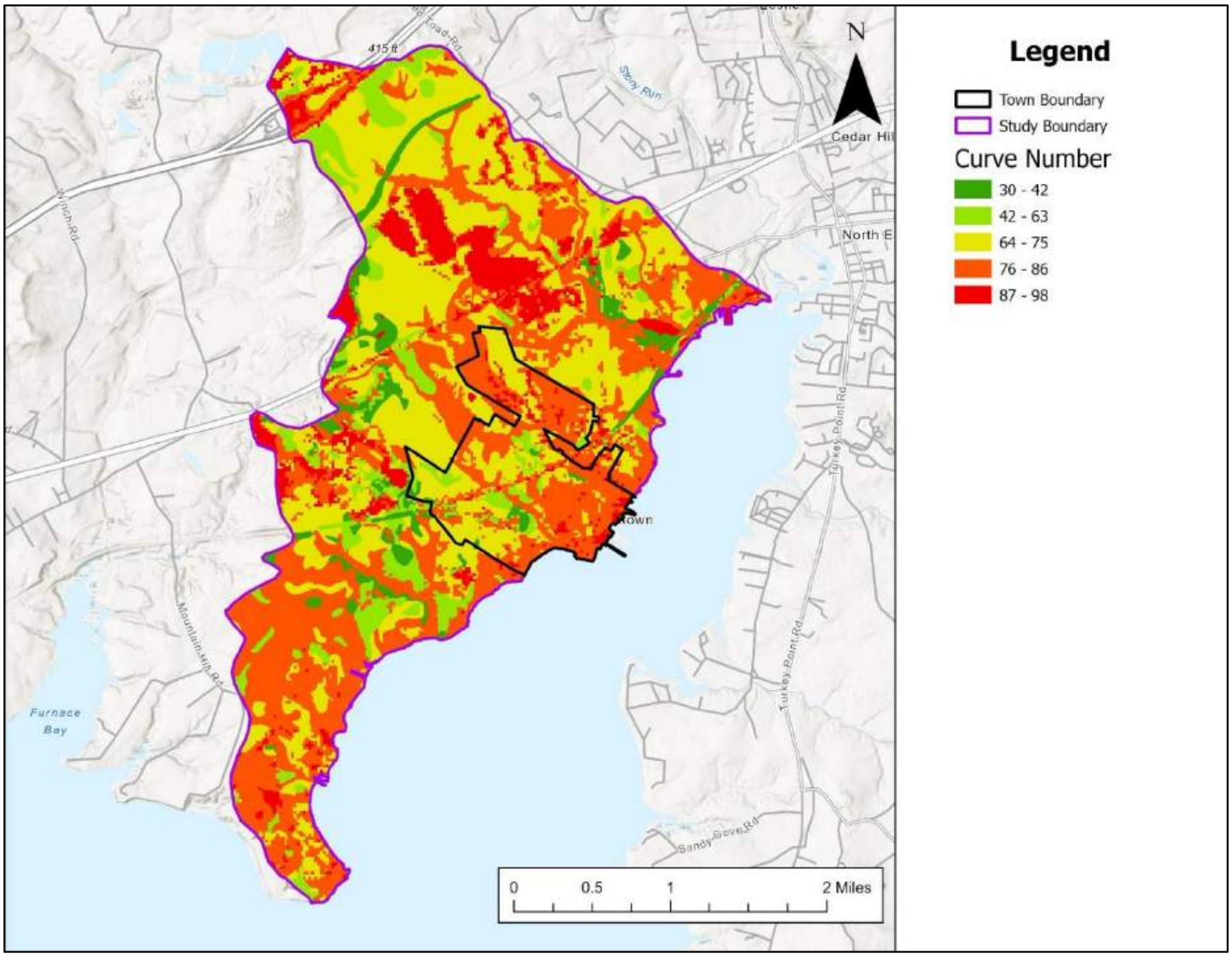

Figure 17: Map of land use Curve Number.

5.3 Model Setup – HEC-RAS

The watershed-scale modeling was conducted using a U.S. Army Corps of Engineer HEC-RAS Version 6.3 2-dimensional (2D) unsteady flow model. The open-source model and documentation were downloaded from https://www.hec.usace.army.mil/software/hec-ras/download.aspx. This model does not include the underground stormwater system – it assumes that stormwater infrastructure is all blocked.

5.3.1 Model Area

The HEC-RAS model includes the entire 8.2-square mile study area, shown in Figure 1. The model area includes the entire Town of Charlestown as well as upstream areas that flow through the town. The area does not have any inflows.

5.3.2 Model Mesh

A model mesh (also called a model grid) was created using HEC-RAS automated mesh generation tools and minor manual adjustments. The model mesh represents the land surface being modeled. The average model mesh resolution was set to 30 feet, so the average grid size is 30 feet by 30 feet. Breaklines were placed along the corridor of major streams and roadways to improve the resolution of the flood model in these important areas. In addition, breaklines were added to enforce ridges and other hydraulic barriers. The final model mesh contains 273,432 cells with 16 breaklines. Figure 18 shows an overview of the mesh in the model with the breaklines (red).

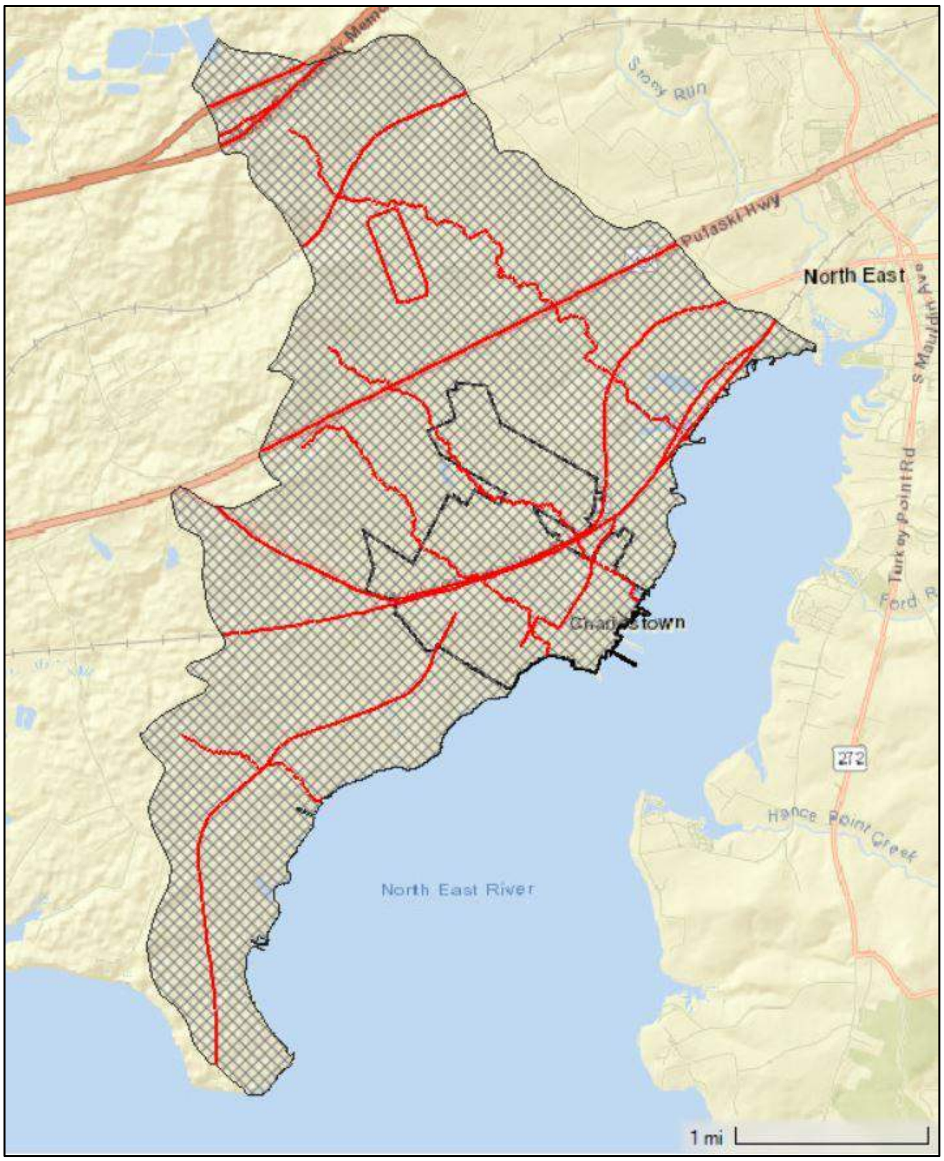

Figure 18: HEC-RAS 2D mesh in RAS Mapper

5.3.3 Boundary Conditions

The model boundary conditions determine how water flows at the edges of the model grid. On the inland perimeter, the model edge was assigned a normal flow boundary condition. The model edge at the outflow of the North East River was assigned a fixed tidal elevation based on the values from Table 3 in Section 5.2.3. There were no inflows to the HEC-RAS model since the model domain consists of the entire isolated watershed.

5.3.4 Hydraulic Structures

The model mesh was manually adjusted to make sure that flows can pass through large bridges and major culverts. For many bridges, no adjustment was needed because the bridge deck was already removed or "burned out" of the DEM. For other bridges with intact decks, the mesh near bridges was adjusted to ensure that water could pass. While this method prevents unrealistic ponding upstream of structures, it may not realistically simulate local hydraulic conditions that affect flooding such as flow constriction, expansion, and backwater as discussed in Section 7.1. In addition, several no-flow barriers or "breaklines" were added along other high-elevation barriers that were too small to be represented by the 30-foot grid cells.

5.3.5 Model Evaluation

The flood model performance was evaluated by (1) comparing the flows at various locations in the model to flows from USGS StreamStats, (2) comparing the 100-year simulation results to the existing FEMA flood model to ensure consistency, (3) comparing the 100-year simulation results to the Maryland Coast Smart Coastal Ready Action Boundary (CS-CRAB) data, and (4) comparing the flooding results to community survey data. All evaluations suggest that the model performed reasonably well.

USGS StreamStats: The USGS StreamStats was used to validate model results along streams. The USGS StreamStats web tool provides estimates of the flow frequency curves for streams in the study area based on USGS regional regression equations. Reference lines were drawn at various locations in the model on different streams (Figure 19) and 100-year, existing condition flows were compared to the estimated flows from StreamStats at the corresponding locations. Some of the StreamStats corresponding locations had errors within the flow estimates, so those locations were not compared. Table 6 shows the comparison at the four locations where StreamStats estimates did not give errors. The standard error that StreamStats notes for the regions in the study area are 37.5 (Piedmont and Blueridge Rural Region) and 44.2 (Eastern Coastal Plain Region). The percent error between the model and StreamStats flows for all four reference lines are under 20% (with three of the four even below 5%), so the model results are validated by the StreamStats results.

Table 6: Comparison of model flows to StreamStats flows

REFERENCE LINE	MODEL FLOW (CFS)	STREAMSTATS FLOW (CFS)	PERCENT ERROR (%)
1	2081.53	2140	2.73
2	1284.12	1600	19.74
3	672.73	701	4.03
4	516.77	534	3.23

In addition, USGS gage 01496080 (Northeast River Tributary near Charlestown, MD), is located within the study area and was compared to model flows. The location of the gage is Reference Line 2 in Figure 19. The maximum flow of the gage is 700 cfs, while the model results show a higher maximum flow of 1,284.12 cfs at Reference Line 2. However, the gage only has flow data from 1967 to 1976, and multiple factors could have changed since then to affect the flow (e.g., land use changes, higher precipitation, etc.), so comparing model flows to the gage flow data may not be accurate.

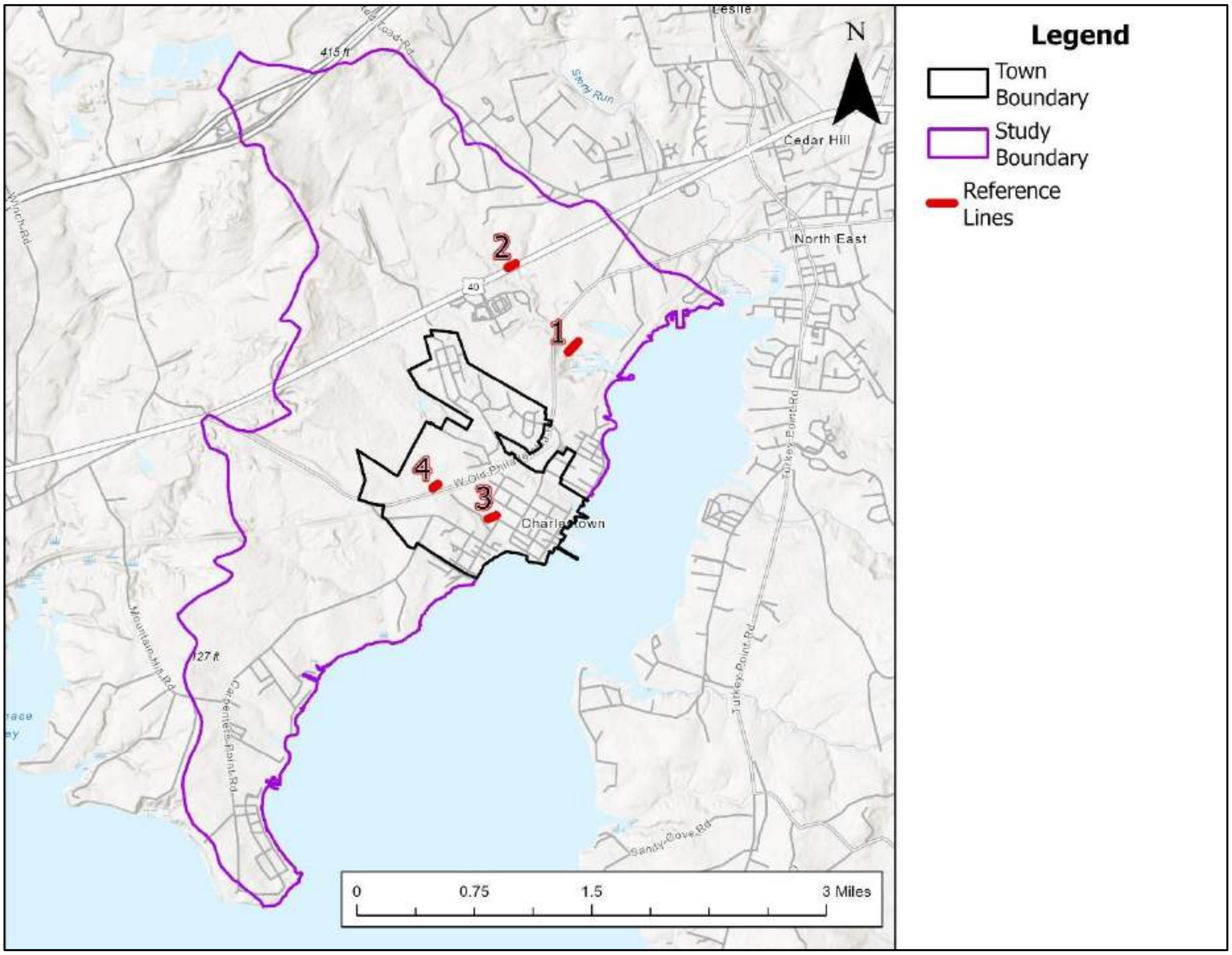

Figure 19: Locations of Reference Lines in HEC-RAS model

<u>**FEMA Flood Maps**</u>**:** Figure 20 shows a comparison between the 100-year floodplain simulated in this study and the effective 100-year FEMA floodplain. As expected, this study and the FEMA study show a nearly identical floodplain in the areas that were modeled by FEMA (i.e., along the North East River corridors). However, the floodplain area in this study is significantly larger. This study includes the riverine sources of flooding in the FEMA model plus additional sources of flooding, such as flooding in the smaller tributaries and other pluvial (stormwater) flooding.

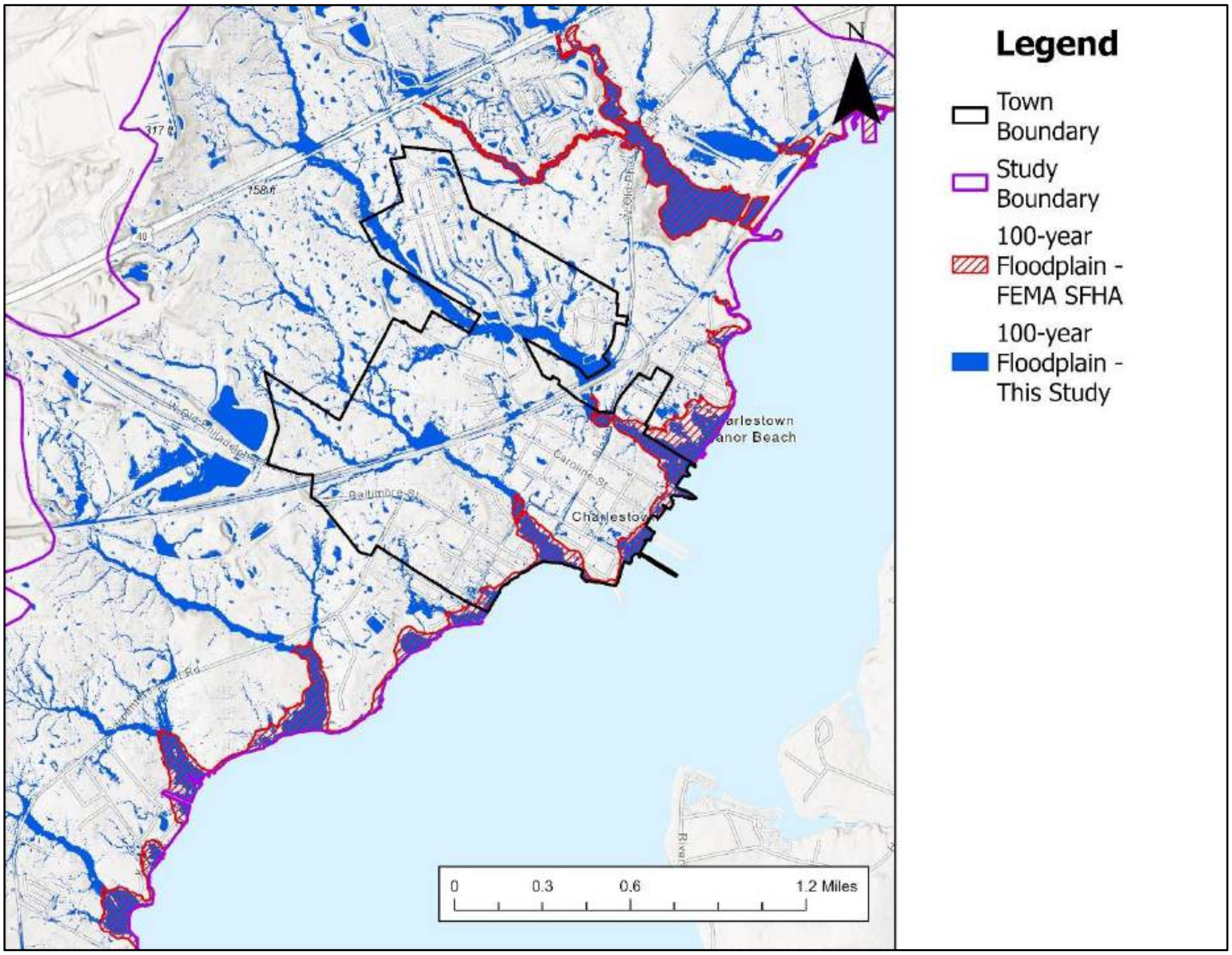

Figure 20: Comparison with FEMA 100-year floodplain

Sea-Level Rise (SLR)/CoastSmart Climate Ready Action Boundary (CS-CRAB): The CS-CRAB shows the depth of flooding that would occur assuming a 3 foot (vertical and associated horizontal) increase in water surface elevation above the current effective 100-year FEMA floodplain and is used to inform state siting and design criteria. Figure 21 shows a comparison between the extent of the floodplain simulated in this study (100-year existing conditions and 100-year 2080 ICLUS conditions) and the extent of the CS-CRAB within the Town of Charlestown. Both the CS-CRAB inundation and the model results show areas of concern from tidal flooding in the same general locations. The CS-CRAB inundation boundary is larger than the 100-year existing conditions inundation. This is expected since the CS-CRAB represents future sea-level rise and is comparable inundation to the 100-year 2080 model results. **Note:** the CS-CRAB boundary is generated using a very large cell size (approximately150 feet), so it provides only a rough comparison and an over-estimate to model results which use a much smaller cell size (3 feet).

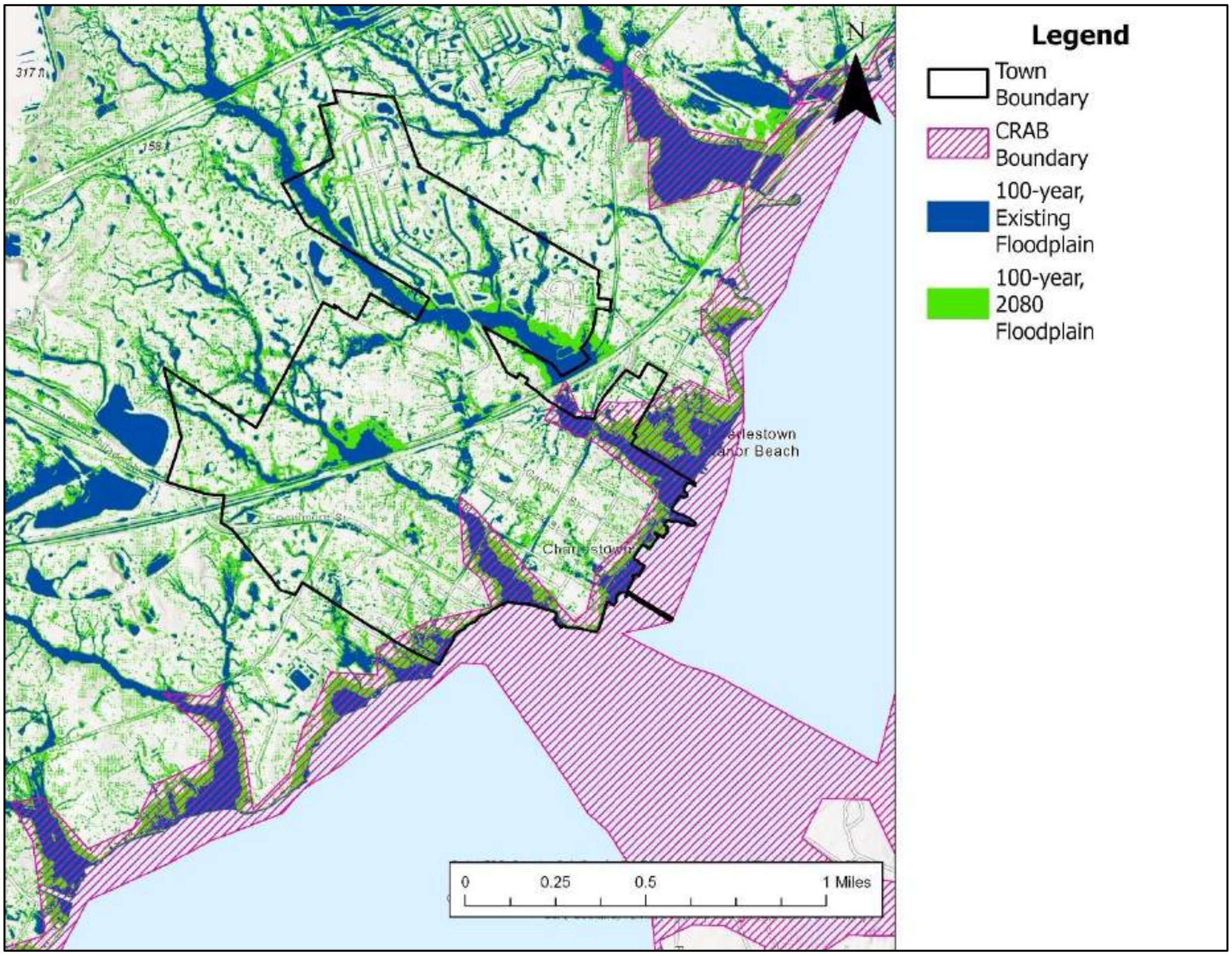

Figure 21: Comparison with CS-CRAB boundary

Community Survey Data: The results from the Community Survey indicating known locations of flooding were compared to model results. Figure 22 shows the results compared to the 100-year, 24-hour, existing conditions flood depths. The comparison also includes locations of flooding hotspots in the town. A majority of the survey and hotspot locations that indicate flooding also show flooding in the model. Furthermore, locations that note no flooding also match up with no or less than 0.2 feet of flooding in the model results.

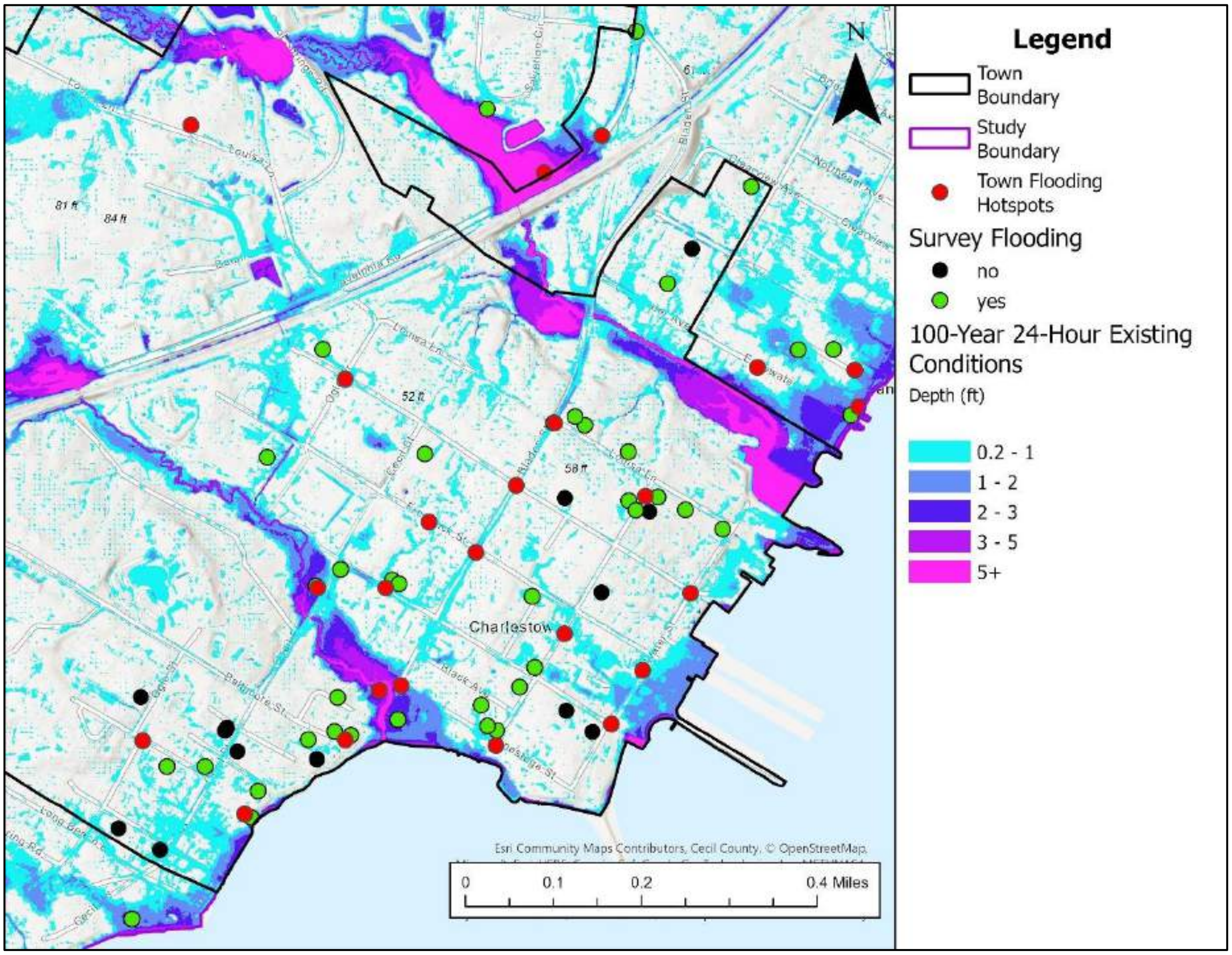

Figure 22: Comparison with community survey results and town flooding hotspots

5.4 Model Setup – PCSWMM

The sub-watershed scale modeling was conducted using 2D PCSWMM models. The PCSWMM user interface runs the open-source U.S. EPA Stormwater Management Model (SWMM), which is used throughout the U.S. for planning, analysis, and design related to stormwater runoff, gray infrastructure, and stormwater control structures such as pipes and storm drains. Three sub-areas, located inside the study area and covering the majority of the urban portion of the Town of Charlestown, were modelled. The PCSWMM models include the stormwater drainage network.

5.4.1 Model Areas

Three model areas (Figure 23) were delineated for the 2D PCSWMM stormwater models based on the results of the HEC-RAS model and feedback from Town stakeholders. The areas are (1) Red Rum, which includes Red Rum Creek and is located on the southwestern portion of the Town of Charlestown along the North East River, (2) Peddlers Creek Downstream, which includes the portion of Peddlers Creek downstream of W Old Philadelphia Road (MD 7) and is located on the eastern portion of the Town along the North East River, and (3) Peddlers Creek Upstream, which includes the portion of Peddlers Creek upstream of W Old Philadelphia Road (MD 7) and is located on the northern portion of the Town, inland from the North East River. Each area is approximately 0.25 to 0.5 square miles and includes residential areas of the town.

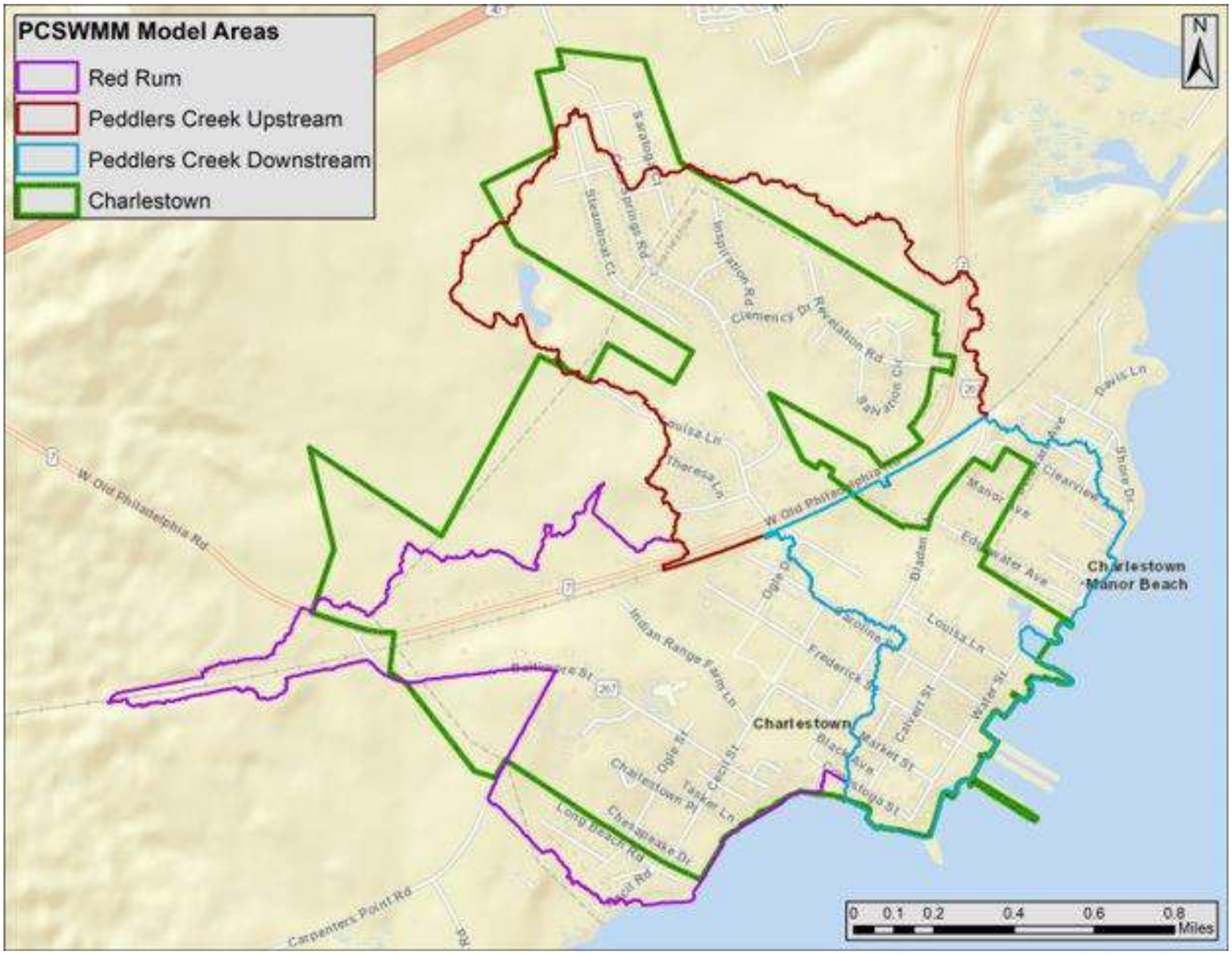

Figure 23: PCSWWM Study Areas

5.4.2 Boundary Conditions

Model boundary conditions were added to specify how water flows at the edges of the model grid.

Downstream: The Red Rum and Peddlers Creek Downstream models include downstream boundary outfalls along the coast of the North East River. These outfalls are fixed tidal elevations based on the values from Table 3 in Section 5.2.3. The Peddlers Creek Upstream model includes normal depth boundary outfalls at the outlet of the large culvert along W Old Philadelphia Road (MD 7).

Inflows: The Red Rum and Peddlers Creek Upstream models include inflows into the model at the locations where streams enter the model boundaries. The flows were extracted as hydrographs from the HEC-RAS model at the respective locations. The Peddlers Creek Downstream model includes inflows from the Peddlers Creek Upstream model. The outflow from the Peddlers Creek Upstream PCSWMM model was extracted as a hydrograph for each scenario and entered into the Peddlers Creek Downstream model at the exit of the culvert along W Old Philadelphia Road (MD 7), where the model boundary starts.

5.4.3 Mesh

A model mesh was created using PCSWMM 2D automated mesh generation tools and minor manual adjustments. The average model mesh was hexagonal with a resolution of 30 feet. Refinement regions of 15 feet resolution were placed around key features including the stormwater infrastructure network to improve the resolution of the model in these areas. In addition, obstructions were blocked out of the mesh to simulate water flowing around the buildings. The obstructions are from the Maryland building footprints dataset.

5.4.4 Stormwater System

The PCSWMM model uses existing data to represent the performance of the 1-D stormwater drainage network including grass swales, best management practices (BMPs), catch basins, pipes, manholes, and outfalls. This information comes from stormwater infrastructure GIS files provided by the Town and generated by KCI in 2019. Catch basins and manholes are represented as junctions in the models, and pipes and grass swales are represented by conduits. The models incorporate detailed design information about the stormwater infrastructure such as inlet size, pipe dimensions, and pipe inverts. Much of this data comes from the stormwater infrastructure data files. A field survey was performed at the beginning of the study to obtain missing inlet invert elevations. In cases where there were data gaps, reasonable assumptions were made based on best available engineering data:

- Missing inverts were assigned to 3 feet based on nearby invert elevations and the majority of the stormwater inlet data.
- Missing pipe diameters were estimated based on the diameters of nearby pipes.
- Grass swale dimensions were not provided. An assumption of 3-foot wide and 2-foot deep was made, unless Google Earth imagery appeared a specific swale to have different dimensions.

Roughness values were assigned to each of the conduits based on guidance from the PCSWMM User's Manual for closed conduits. Table 7 shows the Manning's N values for the different conduit types.

Table 7: Manning's N values for conduits in the PCSWMM models

CONDUIT TYPE & MATERIAL	MANNING'S N
Open Grass Swale	0.025
Pipe - Concrete	0.013
Pipe – Corrugated Metal	0.024
Pipe - HDPE	0.013
Pipe - PVC	0.013

Figure 24 shows the 1-D drainage network in the Peddlers Creek Upstream model area.

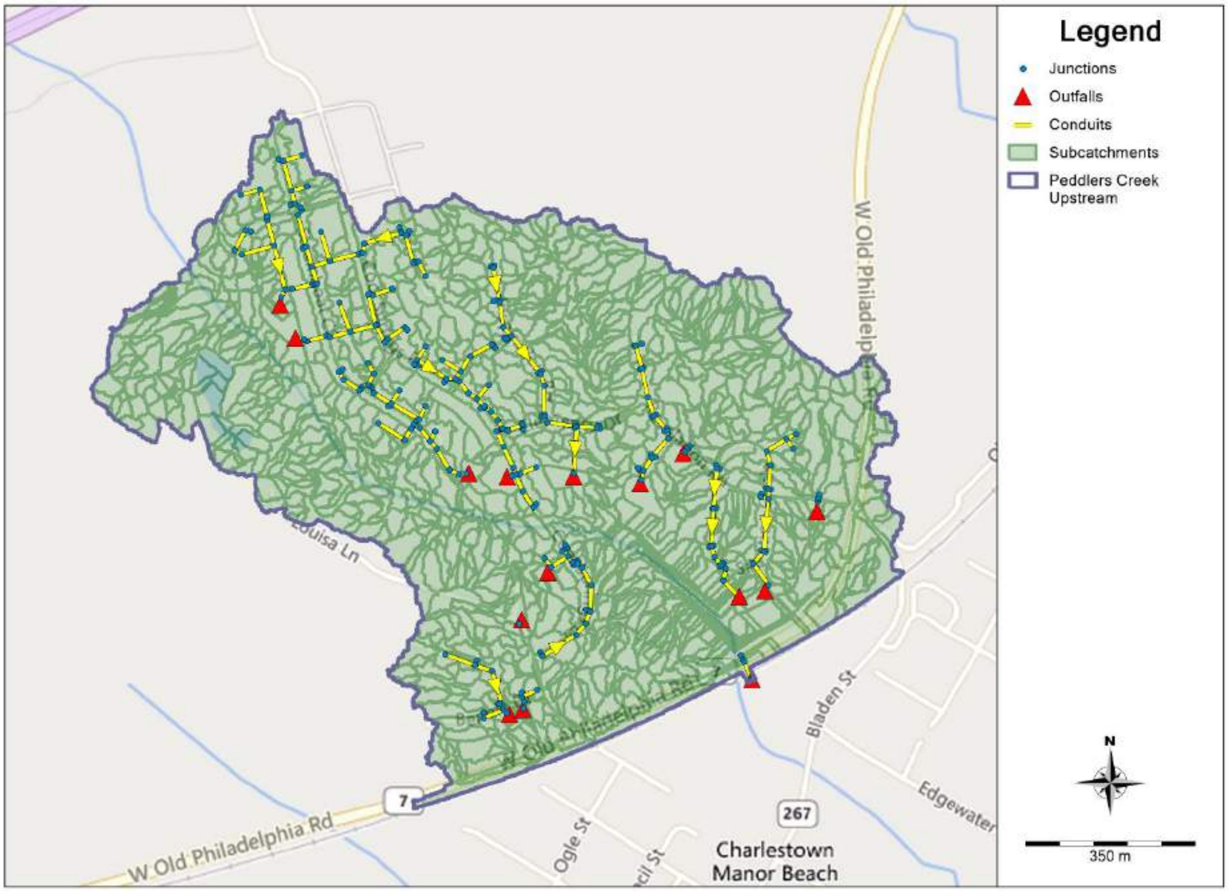

Figure 24: 1-D Stormwater network in Peddlers Creek Upstream PCSWMM model

5.4.5 Model Evaluation

The flood model performance was evaluated by (1) comparing the flood inundations and depths to the HEC-RAS model results and (2) comparing the flooding results to the Community Survey and feedback received during Community Workshop #2. Both evaluations suggest that the model performed reasonably well.

HEC-RAS Model Results: Model results for the PCSWMM models show similar locations of flooding to the HEC-RAS model and the FEMA floodplains; however, the flood inundations and depths in the PCSWMM models are slightly smaller overall. This is expected, as the PCSWMM models consider the runoff that is captured by the underground stormwater network, while the HEC-RAS models assume no runoff is captured into the stormwater network.

Figure 25 shows the inundation comparison for the 100-year, 24-hour, existing storm scenario, near W Old Philadelphia Road and Bladen Street. The overall inundations are similar, but since the PCSWMM models (Peddlers Creek Upstream and Downstream, in this example) incorporate the culverts and pipe network, flow is not as constricted at the raised roads and railroads as with the HEC-RAS model.

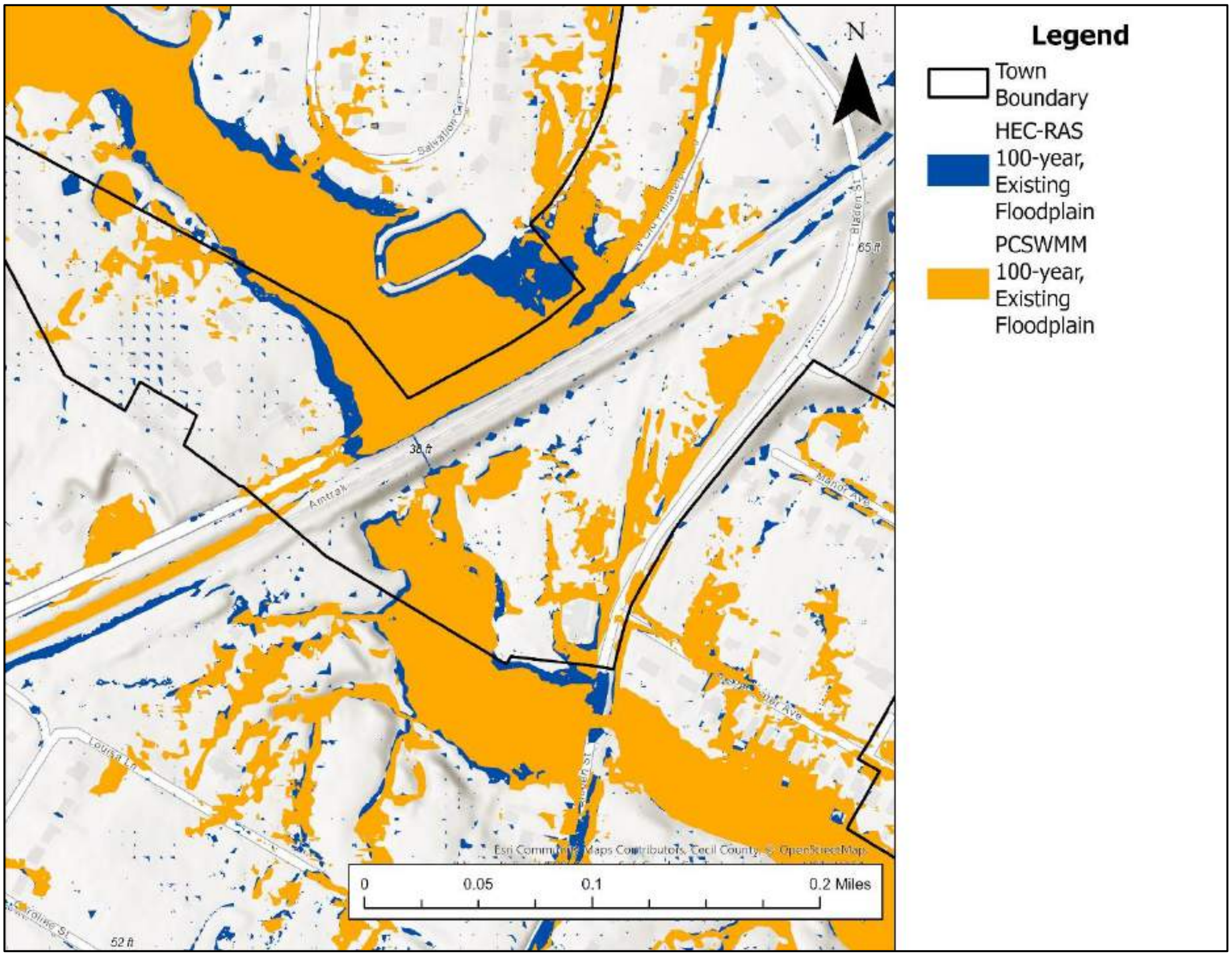

Figure 25: Comparison of the HEC-RAS and PCSWMM model at W Old Philadelphia Road

Community Workshop: In addition to comparison with the HEC-RAS results, model results were validated by Community Survey results and community input at the Community Meeting #2 workshop.

5.5 Simulation Results Summary

The simulation results illustrate flooding impacts when the stormwater system does not work at all (HEC-RAS model results) and when the stormwater system works perfectly (PCSWMM model results). The combination of results allows for the best assessment of the stormwater and coastal flood risks within the Town.

Each model simulation produces maps of the maximum flooding extent and the maximum flood depth across the study area for the twelve rainfall scenarios listed in Table 1. The maximum flood extent and depth was determined using the outputs of all model timesteps during the entire event. Therefore, the maximum extent and flood depth in one region of the model might not occur at the same time as in another region of the model. Figure 26 and Figure 27 show the composite flood maps for the 100-year, existing scenarios for each of the four models.

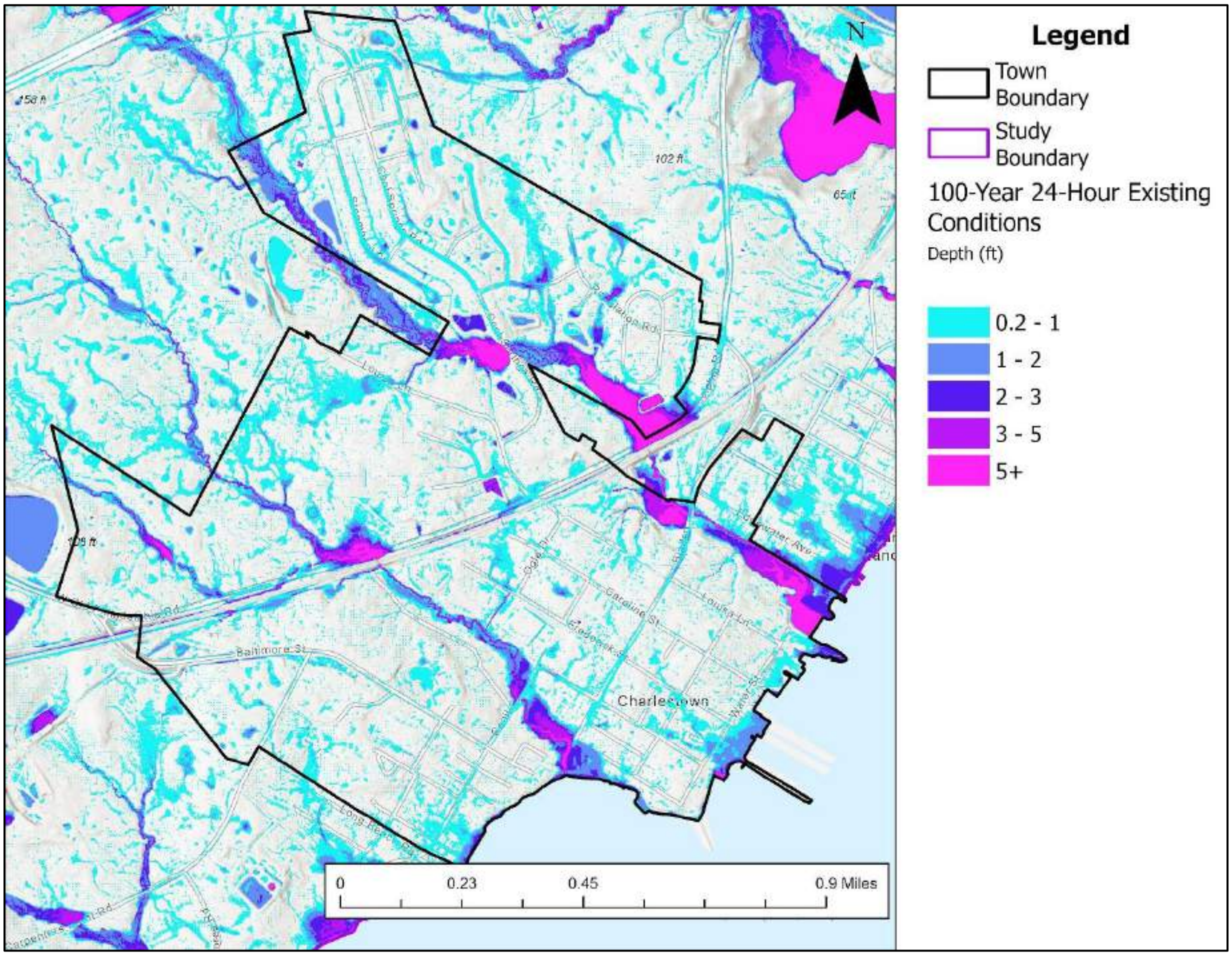

Figure 26: HEC-RAS 100-year existing conditions composite flood map

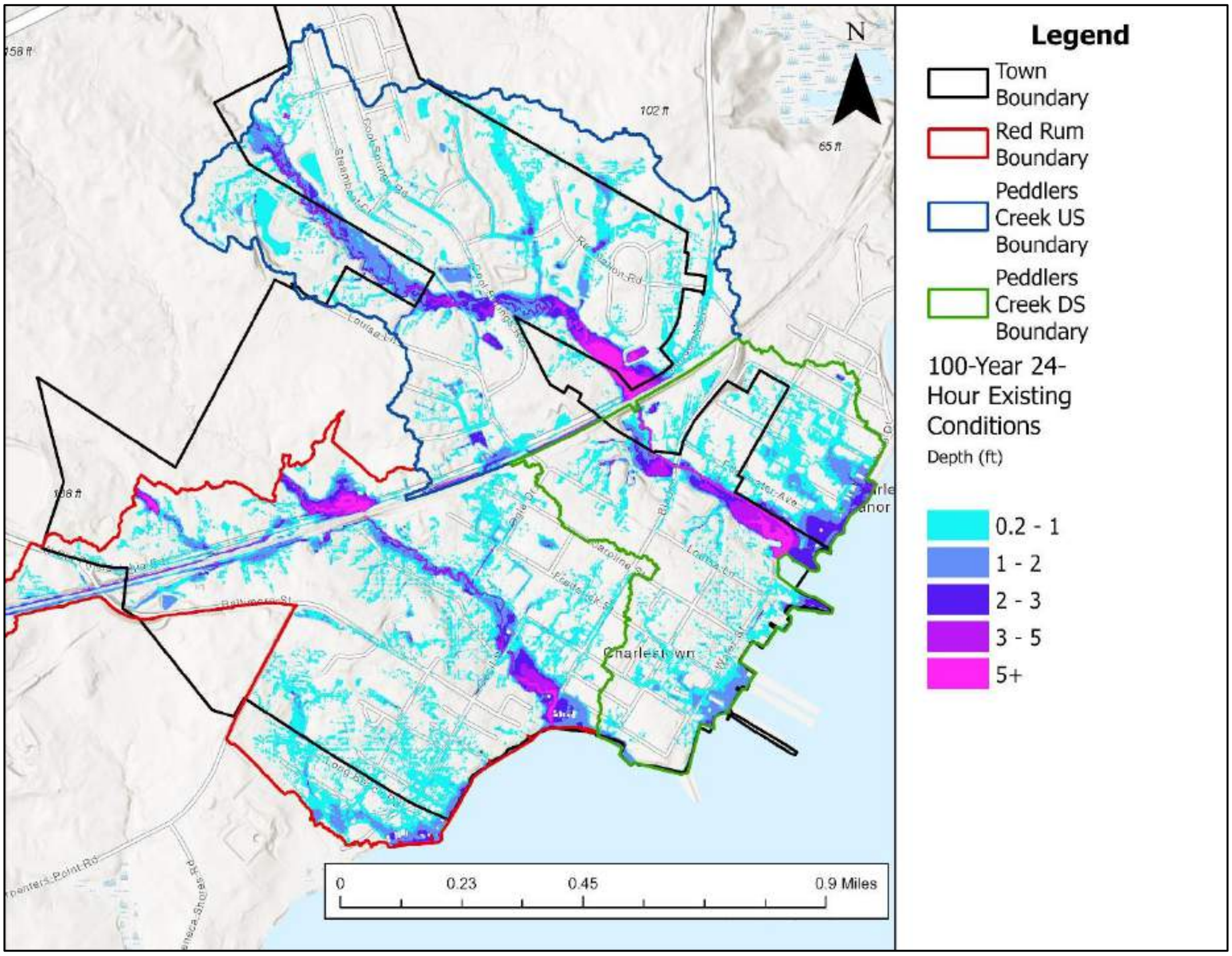

Figure 27: PCSWMM combined 100-year existing conditions composite flood map

6. Mitigation Strategies

6.1 Project Identification

Project locations were identified, in collaboration with the Town, using the mapped results from the Community Survey, locations of known flooding issues from the Community Workshops, and the modeling results (Figure 28). Dewberry performed a GIS desktop review of each project location to document likely causes of flooding and mitigation strategies. Our review assessed the feasibility of project implementation and whether the proposed project should be considered for concept development. The projects were also grouped by general location to assist with determining project dependencies. A project was noted as having no concept potential if the mitigation strategy included only maintenance activities (e.g., inlet or pipe cleaning), the project was already slated to be addressed (e.g., the Town received grant funds to develop final designs for the Athletic Complex), the project would have a more localized impact (e.g., it would address flooding issues on one private property), or the project is outside of the Town's jurisdiction (e.g., increasing the capacity of a culvert under a state-owned road). The final list of potential projects identified during the Watershed Master Plan process is provided in Table 8.

6.2 Project Prioritization

Dewberry coordinated with Town staff to develop metrics for prioritizing projects being considered for concept development. Each prioritization metric/ranking component was assigned a weight and three-point numerical ratings were established. Table 9 provides a summary of the prioritization metrics, weights, and ratings. The projects were assigned a numerical rating for each prioritization metric. The value for each prioritization metric was calculated by multiplying the metric's weight by the assigned numerical rating for the project. The prioritization metric values were added together to obtain the Total Combined Score. Project locations receiving a higher score were considered to be better candidates than those receiving lower scores. The list of ranked projects is provided in Table 10.

6.3 Project Concepts

Three (3) projects were selected for concept development:

- **The Holloway Beach Community Storm Drain Improvement Project:** The project encompasses two primary areas of concern identified through the Community Surveys, Community Workshops, and modeling effort: Chesapeake Road Storm Drain Improvements and Charlestown Place Drainage Improvements. A concept plan was developed for the Chesapeake Road Storm Drain Improvements which addresses flooding issues identified along Chesapeake Road, S. Ogle Street, and Cecil Street (Appendix A). If additional funding becomes available in the future, the drainage system along Charlestown Place, Cecil Street, and Beach Road should be evaluated further for retrofit opportunities.
- **The Trinity Woods/FEMA Property Project:** The project encompasses several opportunities in and around the Trinity Woods subdivision that were identified through the community surveys, community workshops, and modeling effort: Trinity Woods SWM #1/FEMA Property Project, Trinity Woods SWM #2 & #3 BMP Retrofits, Trinity Woods Upland Retrofits, and Peddlers Creek Stream Restoration/Floodplain Reconnection. A concept plan was developed for one approach for the Trinity Woods SWM #1/FEMA Property project with alternative restoration approaches discussed in the concept package (Appendix B). If additional funding becomes available, additional opportunities to provide water quantity and quality management should be evaluated further.
- **The Avalon Park Shoreline Stabilization Project:** The project includes the proposed removal of an existing, failing bulkhead and shoreline stabilization project which incorporates a walkable rock jetty, planted wetland areas, beach/kayak launch, planted upland areas, and permeable walkway (Appendix C). The project was identified and selected for concept development by the Town of Charlestown before the start of the Watershed Master Plan. As such, it was not included in the prioritization matrix (Table 10).

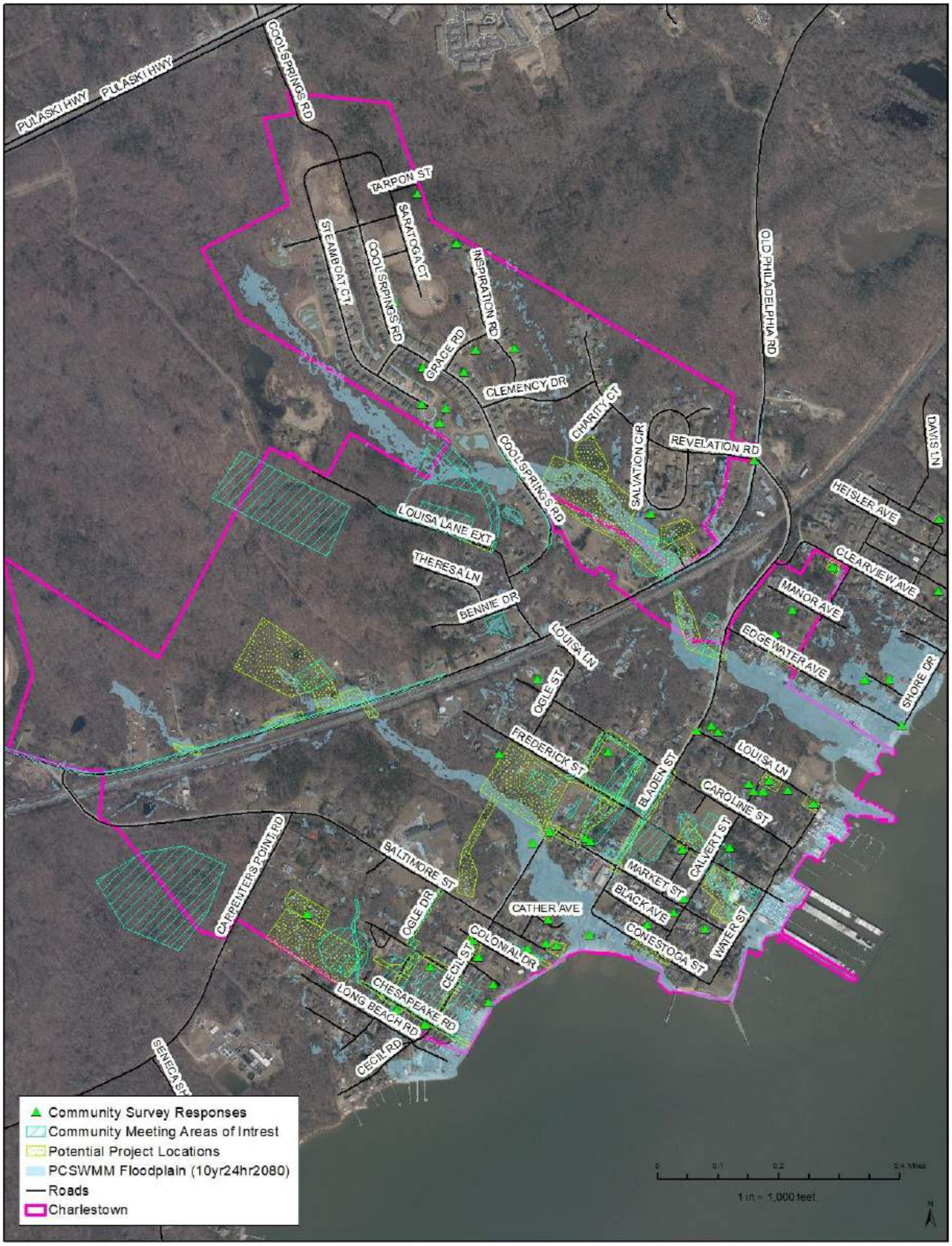

Figure 28: Mapped potential project locations

Table 8: Project List for Potential Concept Development

SITE ID	PROJECT NOTES	PROJECT DESCRIPTION	COMMENT	CONCEPT POTENTIAL?	PROJECT GROUPING
Holloway Beach Community Storm Drain Improvement Project					
RRC-005	Notes indicate blocked inlet at Chesapeake and Ogle. Evaluate inlet and storm drain capacity. Evaluate feasibility of constructing a facility in the vicinity of the inlet.	Storm drain installation and cleaning	Combine with RRC-007, RRC-011, RRC-009, RRC-018, RRC-004, RRC-016, RRC-017	Yes	Group A
RRC-016	Potential Beach Road ROW project; remove or block culverts under Ogle Street.	Storm drain installation	Combine with RRC-007, RRC-011, RRC-009, RRC-018, RRC-004, RRC-017, RRC-005	Yes	Group A
RRC-018	Overland runoff flows in direction of Ogle St flooding houses in area of Ogle St and Long Beach Rd	Regrade for positive drainage	Combine with RRC-007, RRC-011, RRC-009, RRC-017, RRC-004, RRC-016, RRC-005	Yes	Group A
RRC-004	Evaluate existing inlet and storm drain at SE corner of Ogle. May be able to incorporate storm drain cleaning here in conjunction with SD improvements at Chesapeake/Charlestown/Cecil.	Storm drain installation and cleaning	Combine with RRC-007, RRC-011, RRC-009, RRC-018, RRC-017, RRC-016, RRC-005	Yes	Group A
RRC-018	Chesapeake Road is not properly crowned; runoff is pooling on road instead of collecting in catch basins	Road resurfacing	Combine with RRC-007, RRC-011, RRC-009, RRC-017, RRC-004, RRC-016, RRC-005	Yes	Group A
RRC-009	Community survey noted flooding at 419 Charlestown Pl. Evaluate whether flow can be intercepted and directed to existing inlets.	Storm drain installation	Combine with RRC-007, RRC-011, RRC-017, RRC-018, RRC-004, RRC-016, RRC-005	Yes	Group A
RRC-011	Existing low sidewalk along Cecil St EB. Evaluate feasibility of installing curb inlets along the sidewalk to reduce flow running down Tasker Ln. Could it connect to inlet at 201 Cecil St?	Storm drain installation	Combine with RRC-007, RRC-017, RRC-009, RRC-018, RRC-004, RRC-016, RRC-005	Yes	Group A
RRC-007	There is an existing inlet located DS at 392 Chesapeake Rd. Evaluate whether additional inlets/SD can be placed along Cecil St to capture US flow and outfall into existing inlet.	Storm drain installation	Combine with RRC-017, RRC-011, RRC-009, RRC-018, RRC-004, RRC-016, RRC-005	Yes	Group A
RRC-017	Add additional inlets along Cecil between Beach Rd & Chesapeake: Evaluate storm drain capacity of pipe along Chesapeake between Cecil and the river; flooding likely due to surcharging during higher tide events combined with storm events; will need to determine project extent for the concept and include all other options as future recommendations.	Storm drain installation and cleaning; road resurfacing	Combine with RRC-007, RRC-011, RRC-009, RRC-018, RRC-004, RRC-016, RRC-005	Yes	Group A
Trinity Woods/FEMA Property Project					
PCU-002	Trinity Woods Detention Basin Retrofit 1. Combine with project at FEMA buyout property.	Pond retrofit	Combine with PCU-004 & PCU-003 Include as future recommendation	Yes	Group B
PCU-003	Trinity Woods Detention Basin Retrofit 2. Combine with project at FEMA buyout property.	Pond retrofit	Combine with PCU-004 & PCU-002 Include as future recommendation	Yes	Group B
PCU-004	Flood study previously performed; flooding is due to undersized culvert crossing state road & R/R. Evaluate feasibility of providing some storage on Town property. Potential to combine with two pond retrofits for additional storage.	Pond retrofit	Combine with PCU-002 and PCU-003	Yes	Group B
Fireman's Field/Wellwood Restaurant Improvements					
PCD-007	Evaluate feasibility of adding green stormwater infrastructure (bioswale, permeable pavers, etc.)	Green stormwater infrastructure	Combine with PCD-008	Yes	Group C
PCD-008	Replace & resize cross culvert on south side of Frederick St and crossing Calvert Street; regrade downstream swale where pipe discharges; add driveway culvert beneath Wellwood driveway entrance; evaluate feasibility of providing underground storage beneath Wellwood parking lot; plant trees in Fireman's field; add permeable paver walkway to promote use and provide outreach opportunities; and evaluate opportunity to add storage in southeast corner of field at Frederick and Calvert intersection	Storm drain installation; green stormwater infrastructure	Combine with PCD-007	Yes	Group C
Calvert Street/Conestoga Street Storm Drain Improvements					
PCD-001	South side of Conestoga. Survey notes an existing inlet at corner of Conestoga & Calvert St that is not maintained. Evaluate condition of inlet and its outfall. Can another inlet be placed at low point in front of houses that noted flooding and connected to inlet?	Storm drain installation and cleaning	Combine with PCD-001B	Yes	Group D
PCD-001B	North side of Conestoga. Survey notes an existing inlet at corner of Conestoga & Calvert St that isn't maintained. Evaluate condition of inlet and where it outfalls. Can another inlet be placed at low point in front of houses that noted flooding and connected to inlet?	Storm drain installation and cleaning	Combine with PCD-001	Yes	Group D
Charlestown ES Pond Retrofit					
RRC-010	Potential to retrofit existing school pond to capture more flow from Baltimore St and provide more storage? Evaluate all inflows and outfall of facility, and adjacent hydrography line.	Pond retrofit	Unlikley to have a measurable impact to the floodplain. Diverting runoff from roadway does not appear feasible.	Yes	Group E

Table 8: Project List for Potential Concept Development

SITE ID	PROJECT NOTES	PROJECT DESCRIPTION	COMMENT	CONCEPT POTENTIAL?	PROJECT GROUPING
MD 7 Improvements					
RRC-003	Street view shows a type of landscaped pond. Investigate whether this was landscaped by the homeowners and for what purpose. Is there potential to retrofit for additional storage? Also check condition of culverts connecting each segment.	Pond retrofit	Positive impacts to overall floodplain unlikely, other than for immediate homeowners and possibly from the roadway. Overall flooding is likely due to the undersized SHA culvert - no jurisdiction	Yes	Group F
Non-concept Projects					
RRC-023	Potential location for new swale; located on Frederick St, between Bladen St and Cecil St	Storm drain installation/improvements	Athletic Complex project	No	Group G.1
RRC-024	Potential location for new swale; located along Caroline St and Cecil St	Storm drain installation/improvements	Athletic Complex project	No	Group G.1
RRC-025	Flooding at this location gets 12-15 feet wide; located between Market St and Frederick St; consider removing pipe & re-directing to Athletic Complex	Storm drain installation/improvements	Athletic Complex project	No	Group G.1
RRC-022	General location of Bealle Alley; conservation grading?	Storm drain installation/improvements	Athletic Complex project	No	Group G.1
RRC-012	Survey notes there is an existing inlet at corner of Cecil and Market	Storm drain cleaning	Athletic Complex project	No	Group G.1
RRC-021	Athletic Complex & neighbors stream restoration & SWM BMPs design	Various	Athletic Complex project	No	Group G.1
RRC-015	Upsize culvert under MD 7	Storm drain improvements	Include as a prioritized project for the Town to work on with SHA	No	Group G.2
RRC-002	Check condition and sizing of driveway culvert. Potential to add storage anywhere in this area? Also check condition of SHA culverts DS for any blockages/issues.	Storm drain improvements	Include as a prioritized project for the Town to work on with SHA	No	Group G.2
PCD-002	Evaluate any opportunity for stream restoration or storage facility upstream of SHA culvert to reduce some impacts downstream.	Stream restoration/floodplain reconnection	Include as a prioritized project for the Town to work on with SHA	No	Group G.2
PCD-009	Permeable sidewalk on Bladen St between Caroline St and Market St; potential location for new rain gardens?	Green stormwater infrastructure	Include as a prioritized project for the Town to work on with SHA. This could possibly be good for green streets grant?	No	Group G.2
RRC-001	Contours show high point here. Investigate reason for high point. Is there a potential to excavate to provide storage upstream of culvert? Also check condition of DS SHA culvert. Private property - may need permission to enter area.	Storm drain improvements	Include as a prioritized project for the Town to work on with SHA	No	Group G.2
PCU-001	Location of storm drain; recent repaving affects drainage	Road resurfacing	Maintenance	No	Group G.3
PCD-006	726 Calvert Street - survey notes a culvert was not installed under the driveway for the "yellow house" across the street, causing water to not be conveyed properly resulting in 2-3 ft of flooding on their property	Storm drain improvements	Maintenance	No	Group G.3
RRC-008	Survey from 50 Carpenters Point Rd noted flooding only during heavy storms from US props. They have a retention pond in front yard. Is there potential for retrofit? Also evaluate condition of driveway culvert conveying stream.	Storm drain improvements	Maintenance	No	Group G.3
PCD-005	83 Clearview Ave - survey notes an underground pipe from neighbor's property drains directly to side of their house and causes flooding in heavy rainfall	Storm drain improvements	Maintenance	No	Group G.3
PCD-003	Culvert may be buried according to street view. Potential to regrade swale along Edgewater Ave and promote positive drainage from 96 Edgewater Ave who reported flooding in survey.	Storm drain improvements	Maintenance	No	Group G.3
RRC-020	Location of clogged 6" concrete pipe, 6" deep, possibly due to construction grading; located between Baltimore St and Colonial Dr	Storm drain improvements	Maintenance	No	Group G.3
PCD-004	7 Louisa Lane - survey notes driveway culvert drains to sediment filled swale; note a rain garden below property in Avalon	Storm drain improvements	Maintenance	No	Group G.4
RRC-013	304 Baltimore St - survey notes they installed dry creek beds, french drains, gutters, ditches, and regraded lawn for flooding from Baltimore St			No	Group G.4
RRC-019	Potential site for new Dog Park/Retention Pond near Charlestown Pl and Ogle St; expressed interest in rain garden/pond specifically	SWM pond retrofit and culvert analysis	Removed from consideration; not feasible. Alternatives to be evaluated.	No	Group G.4
RRC-014	409 Bayview Ave - survey notes rear drainage system installed in 1975: "stone garden underground swale"	Storm drain installation and cleaning	Maintenance	No	Group G.4
RRC-006	Large area of town-owned property. Investigate "underground stream" and marshland conditions. Any opportunity for stream restoration or storage to lighten some impacts downstream?	Stream/wetland restoration		No	Group G.4

Table 9: Project Prioritization Matrix

RANKING COMPONENTS	WEIGHT	RATING			REMARKS
		1	2	3	
Degree of Threat	15	Minor	Moderate	Major	Ranking Component Description: Evaluates the impact of flooding on the project location using the percentage of the area and depths from the PCSWMM model (as described below) Rating Descriptions: **Minor** = the proposed project area addresses flooding which causes minimal or no property damage, but possibly some public threat or inconvenience. Flood depths generally less than 6". **Moderate** = the proposed project area addresses flooding which causes some inundation of structures and roads near streams. The area may experience some evacuations of people and/or transfer of property to higher elevations. Flood depths generally between 6"-18". **Major** = the proposed project area addresses flooding which causes extensive inundation of structures and roads. The area may experience significant evacuations of people and/or transfer of property to higher elevations. Flood depths generally greater than 18".
Impact to Critical Infrastructure	12	No	-	Yes	Ranking Component Description: Evaluates whether the proposed project location is within 400 feet (upstream or downstream) of critical infrastructure. NOTE - this does not include roadways as that is evaluated under Town Access. Rating Descriptions: **No** = there is no critical infrastructure located within 400 feet of the proposed project location. **Yes** = there is critical infrastructure located within 400 feet of the proposed project location.
Town Access	20	Minor	Moderate	Significant	Ranking Component Description: Evaluates whether the proposed project location addresses flooding which impedes town access based on how much of the road is flooding, depths from the PCSWMM model (as described below), and proximity to the road (<= 100 feet). Rating Descriptions: **Minor** = the proposed project addresses flooding which causes minimal impacts to town access. Flood depths addressed by the project are generally less than 6". **Moderate** = the proposed project addresses flooding which causes some inundation of primary access routes but roads are still passable by emergency vehicles. Flood depths addressed by the project are generally between 6" and 18". **Significant** = the proposed project addresses flooding which causes complete blockage of primary access routes. Roads are impassable. Flood depths addressed by the project are generally greater than 18".
Water Quality/Wildlife Habitat	10	None	Provides only water quality OR wildlife habitat	Provides both water quality AND wildlife habitat	Ranking Component Description: Evaluates whether there is potential to provide water quality and/or wildlife habitat within the project location. Rating Descriptions: Swales or pipes will have no habitat improvement unless setback distance from edge of pavement to building footprint is >30 feet.
Co-benefits	3	No	-	Yes	Ranking Component Description: Evaluates whether there is potential for co-benefits to be included as part of the project. Project co-benefits may include transportation considerations (e.g., traffic calming, pedestrian safety improvements), increasing tree canopy, improvements to neighborhood/property aesthetics, economic benefits (e.g., increases to property values, job creation). NOTE - water quality, wildlife habitat, and education/outreach co-benefits are incorporated into other ranking components and should not be considered here.
Design & Construction Requirements	9	Project requires contracted design and construction for implementation	Project requires contracted construction for implementation	Project can be implemented using in house staff and/or volunteers	Ranking Component Description: Evaluates whether the project will require contracted design and/or construction services. If swales or pipes were visible during field investigation then rating of 1 or 2, depending on potential project complexity (e.g., percent slope, wetlands present, etc.). 15% slope is considered steep.
Public Acceptance	5	Low	Moderate	High	Ranking Component Description: Based on feedback received on community surveys, during the Community Meetings, and during the Wade In. Rating Descriptions: **Low =** no surveys received or public comments provided adjacent to proposed project location **Moderate =** one survey received or public comment provided adjacent to proposed project location **High =** two or more surveys received or public comments provided adjacent to proposed project location

Table 9: Project Prioritization Matrix

RANKING COMPONENTS	WEIGHT	RATING			REMARKS
		1	2	3	
Public Visibility/Outreach Opportunity	4	Low	Moderate	High	Ranking Component Description: Evaluates how visible the project location is from public right-of-way, how many properties are adjacent to the proposed project location, and whether there are opportunities to incorporate education/outreach components. Rating Descriptions: **Low** = Proposed project location is not visible from public right-of-way, only one property adjacent to proposed project location, project will have minimal opportunities for education/outreach. **Moderate** = Proposed project location is somewhat visible from public right-of-way, proposed project location is adjacent to a couple of properties, there are some opportunities for education/outreach. **High** = Proposed project location is highly visible and/or in the public right-of way, several properties are adjacent to the proposed project location, there is significant opportunity for education/outreach.
Utility Conflicts	8	Extensive	Minor	None	Ranking Component Description: Evaluates the potential for utility conflicts. Based on field visits, CecilMaps, street view (where available), etc.Rating Descriptions: **Extensive** = 2 or more utilities are located within the proposed project location; significant design and construction efforts may be required to move multiple utilities (i.e. sewer) **Minor** = Only 1 utility is located within the proposed project location and it will not require significant design and construction (i.e. cable) **None** = There are utility conflicts within the proposed project location.
ROW Requirements/Property Ownership	7	Easement required	Temporary construction access easement only	No additional ROW requirements	Ranking Component Description: Evaluates property ownership of the proposed project location. Ranking Descriptions: **Easement Required** = The proposed project location is on private property(ies) and the Town will be required to obtain an easement(s) from the current property owner(s) for project implementation **Temporary Construction Access Only** = The proposed project location is on Town-owned property but in order to access the site for construction, a temporary easement will need to be acquired
Local/State/Federal Permitting Requirements	7	High	Moderate	Low	Ranking Component Description: Evaluates the potential permitting required to implement projects within the proposed project location based on desktop analysis (e.g., forest, wetlands, floodplain, Critical Area impacts). Ranking Descriptions: **High** = extensive permitting requirements including full wetland/stream permitting, forest resource ordinance, NOI for construction requiring public comment, Critical Area permitting, etc. **Moderate** = significant permitting requirements including minor stream/wetland impacts, FRO, Critical Area, NOI for construction under the public comment threshold. **Low** = minor permitting requirements, likely just local permitting for grading and stormwater management review
	100				
TOTAL SCORE =	**300**				

Low score = bad candidate = low priority
High score = good candidate = high priority
Take the Rating Score multiplied by the weight

Table 10: Prioritized projects

POTENTIAL PROJECT PRIORITY MATRIX RANKINGS	DEGREE OF THREAT		TOWN ACCESS		PROJECT CO-BENEFITS		DESIGN & CONSTRUCTION REQUIREMENTS		PUBLIC ACCEPTANCE		PUBLIC VISBILITY/ OUTREACH OPPORTUNITY		IMPACT TO CRITICAL INFRASTRUCTURE		WATER QUALITY/WILDLIFE HABITAT		UTILITY CONFLICTS		ROW REQUIREMENTS/ PROPERTY OWNERSHIP		PERMITTING REQUIREMENTS		TOTAL SCORE
	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	RATING	SCORE	
METRIC WEIGHT	15		20		3		9		5		4		12		10		8		7		7		
Project Name																							
Holloway Beach Community Storm Drain Improvement Project	3	45	3	60	1	3	1	9	3	15	3	12	1	12	1	10	1	8	2	14	3	21	**209**
Trinity Woods/FEMA Property Project	3	45	1	20	3	9	1	9	3	15	2	8	3	36	3	30	3	24	3	21	1	7	**224**
Firemen's Field/Wellwood Restaurant Improvements	2	30	2	40	3	9	1	9	3	15	3	12	1	12	3	30	2	16	1	7	2	14	**194**
Calvert Street/Conestoga Street Storm Drain Improvements	1	15	1	20	3	9	1	9	3	15	3	12	1	12	1	10	2	16	2	14	2	14	**146**
Charlestown ES Pond Retrofit	1	15	1	20	3	9	1	9	1	5	3	12	3	36	3	30	3	24	1	7	2	14	**181**
MD 7 Improvements	2	30	1	20	3	9	1	9	1	5	1	4	1	12	3	30	1	8	1	7	3	21	**155**

7. Conclusion

7.1 Limitations of Work

This study was performed using a state-of-practice flood model with readily available topography and other data. Although the modeling results should constitute the best-available estimates of pluvial, riverine, and coastal flooding across the study area, it was necessary to make several assumptions that contribute to the overall uncertainty of the results including:

- The area of the study was too expansive to ground-truth; the best-available DEM was used in the model and was assumed to represent actual ground conditions;
- In the HEC-RAS model, bridges, culverts, and other structures were modeled as generic flow passages that do not necessarily capture actual local hydraulic features as flow contraction and backwater; and
- Stormwater infrastructure was modeled assuming “typical” or average performance which may differ from actual site conditions.

To reduce model uncertainty and produce a better picture of the overall pluvial flood hazard, future work should consider addressing these limitations:

- Improve the model mesh resolution, which may require breaking up larger watersheds into smaller watersheds to maintain reasonable model run times;
- Add additional detail to stormwater infrastructure, bridges, and other hydraulic structures including invert elevations and structure dimensions;
- Add additional rainfall and event duration scenarios to simulate the effect of different antecedent moisture conditions, which controls soil infiltration, as well as potential future changes in climate and land use.

7.2 Recommendations for Future Work

Notwithstanding the limitations discussed above, this study provides insight into how local floodplain managers can act to reduce flood risk in the study area under current and projected conditions. These include:

- **Pluvial Flood Risk:** Understand that the pluvial (urban stormwater) flood risk extends beyond the FEMA floodplain.
  - Use the flood maps produced by this study to help planners understand the true nature and extent of flood risk.
  - Educate residents and other stakeholders about potential flooding outside of the FEMA floodplain.
  - Continue supporting studies that go beyond riverine flooding to capture the full regional flood risk.
- **Stormwater Management:** Recognize that the implementation of BMPs that capture runoff can significantly reduce the flood risk to nearby assets.
  - Use the flood maps produced by this study to help identify areas where BMP implementation has the greatest impact on flood risk and prioritize those areas for future BMP placement and design.
  - Concentrate installation of new BMPs outside of the 100-year floodplain.
  - Consider using the flood maps to identify special development zones where higher stormwater management quantity control standards should be considered to help reduce additional flooding from development.
  - Consider using the future (2050 and 2080) flood maps when designing BMPs to prepare for increased future precipitation and runoff

- **Future Land Use Changes:** Anticipate potentially significant population growth and land development in the northern region of the study area by the end of the century.
  - Continue supporting stormwater management policies that minimize impacts on local hydrology, in order to prevent any increase in flood risk.
  - Continue to foster a collaborative relationship between the Town of Charlestown and Cecil County to identify and protect key forested areas upstream of the Town of Charlestown.
- **Sea Level Rise:** Recognize that BMP implementation alone will likely not be enough to address projected SLR in the region.
  - Consider implementing policies which increase the base flood elevation (BFE) requirements for new construction to elevations at or above those determined by CS-CRAB.
  - Evaluate feasibility and prioritization of elevating roads and critical infrastructure based on elevations from CS-CRAB.
  - Consider concentrating funds to elevate existing structures above CS-CRAB elevations.

8. References

Cecil County GIS Data. Available at: https://www.ccgov.org/government/land-use-development-services/gis/available-gis-data

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USGS StreamStats. Available at: https://www.usgs.gov/streamstats

APPENDIX A:

CHESAPEAKE ROAD STORM DRAIN IMPROVEMENTS

Introduction

The Holloway Beach Community Storm Drain Improvement Project encompasses two primary areas of concern identified through the community surveys, community workshops, and modeling effort: Chesapeake Road Storm Drain Improvements and Charlestown Place Drainage Improvements. A concept plan was developed for the Chesapeake Road Storm Drain Improvements which addresses flooding issues identified along Chesapeake Road, S. Ogle Street, and Cecil Street. If additional funding becomes available in the future, the drainage system along Charlestown Place, Cecil Street, and Beach Road should be evaluated further for retrofit opportunities.

Site Name: Chesapeake Road Storm Drain Improvements

General Project Information:	
Project Location:	Chesapeake Rd. S. Ogle St. Cecil St.
Northing/Easting:	1599288.55/ 694756.55
PCSWMM Sewershed:	Red Rum Creek
Prioritization Score:	209
Planning Level Cost Estimate:	$609,865

Required Permitting:	
Charlestown SWM Review:	X
Erosion & Sediment Control (ESC):	X
Grading Permit:	X
Joint Permit Application (JPA)/ General Waterway Construction Permit:	
Construction NOI:	X
Chesapeake Bay Critical Area:	X
Forest Resource Ordinance:	
MDE Dam Safety:	

Vicinity map for the Holloway Beach Community Storm Drain Improvement Project

Existing Site Conditions

The Chesapeake Road Storm Drain Improvement project is located in the Holloway Beach area of Charlestown and includes Chesapeake Road (from S. Ogle Street to its terminus at the North East River), S. Ogle Street (between Charlestown Place and Chesapeake Road), and Cecil Street (between Beach Road and Chesapeake Road). Four (4) community surveys were submitted with specific information about flooding issues occurring within the project area. In addition, multiple Community Workshop attendees marked the area as a concern for flooding during both Community Workshops.

Flow through Holloway Beach runs generally from north/northwest to south/southeast. Existing stormwater infrastructure (based on as-built plans and GIS information) includes:

- S. Ogle Street: The only existing stormwater infrastructure along S. Ogle Street are two cross culverts located approximately 250 feet south of Charlestown Place (Photo 1*). The culverts convey flow from the northwest side of S. Ogle Street into the Holloway Beach campground resulting in flooding issues within the campground.
- Charlestown Place: Flow along Charlestown Place is conveyed via a roadside swale located on the north side of the roadway. A second, less defined swale forms on the south side of the roadway approximately 150 feet northwest of Cecil Street. Flows from the north side of the road drain into an existing storm drain system at the intersection of Charlestown Place and Cecil Street (Photo 2*). Flows from the south side of the road are conveyed along Cecil Street

via a swale and eventually enters the storm drain system at the entrance to the Holloway Beach campground, approximately 200 feet south of the Charlestown Place/Cecil Street intersection. The storm drain system conveys the flow east and outfalls directly into the North East River.

- Cecil Street: Flow along Cecil Street, from Charlestown Place and north, is conveyed via a roadside swale, located on the northwest side of the roadway, for approximately 200 feet where it enters a storm drain system and is conveyed along Beach Road to the North East River (Photo 3*). The Beach Road storm drain system includes a 24" CMP. Flow along Cecil Street, between Beach Road/Holloway Campground entrance and Chesapeake Road, is collected by two (2) storm drain inlets and conveyed through an existing storm drain system (12" HDPE) to the existing storm drain system along Chesapeake Road (Photo 4*). Inlets are Nyloplast 15" inlets and drain basins.
- Chesapeake Road: Flow along Chesapeake Road is collected by seven (7) storm drain inlets and conveyed through an existing storm drain system that runs along the north side of the roadway. Inlets are Nyloplast 15" inlets and drain basins. The storm drain system includes a 15" HDPE between S. Ogle Street and Cecil Street (Photo 5*) and increases to a 21"x15" CMP between Cecil Street and the North East River (Photo 6* and Photo 7).

*Note: Photos 1 – 6 courtesy of Google Street View.

Proposed Conditions

The Chesapeake Road Storm Drain Improvement project proposed improvements include:

- S. Ogle Street: The existing cross culverts will be either abandoned in place or removed and replaced by a storm drain system placed on the northwest side of the road. An inlet, placed approximately 250 feet south of Charlestown Place, will collect and convey flow into a proposed 15" HDPE. The proposed 15" HDPE will connect to the Chesapeake Road storm drain network via a proposed inlet located at the northwest corner of the S. Ogle Street/Chesapeake Road intersection.
- Cecil Street: The existing 12" HDPE pipe will be replaced by a 15" HDPE and extended north approximately 70 feet to a new inlet proposed on the southside of the entrance drive to the Holloway Beach campground. In addition, a new inlet and 15" HDPE is proposed within the Holloway Beach campground to collect and convey runoff into the Cecil Street storm drain network. The two (2) existing inlets along Cecil Street will be maintained in proposed conditions. They should be cleaned, and the condition evaluated during final design to determine whether replacement is necessary. A new inlet is proposed approximately 50 feet north of the Cecil Street/Chesapeake Road intersection. An 18" HDPE pipe will connect from this inlet to the proposed storm drain system along Chesapeake Road.
- Chesapeake Road: The existing 15" HDPE and two (2) storm drain inlets, located between S. Ogle Street and Cecil Street, will be maintained in proposed conditions. The existing pipe and inlets should be cleaned, and their condition evaluated during final design to determine whether replacement is necessary. One (1) additional inlet is proposed for installation approximately 200 feet southeast of the S. Ogle Street/Chesapeake Road intersection between two existing storm drain inlets. A shallow, concrete valley gutter is proposed along the north side of the roadway, between S. Ogle Street and Cecil Street, to help collect and convey flows into the storm drain inlets. The existing 21"x15" CMP pipe (between Cecil Street and the North East River) will be replaced by dual 18" HDPE pipes. The final design should consider installation of a backflow preventer at the outfalls of the 18" HDPE pipes. Chesapeake Road, between S. Ogle Street and the North East River, will be regraded to provide positive drainage towards the proposed concrete valley gutter.

Anticipated Site Constraints

There are existing water and sanitary sewer lines along S. Ogle Street, Chesapeake Street, and Cecil Street. In addition, there are water line connections from the main water line to houses along Chesapeake Street. The location and depth of the sewer and water lines will need to be determined during final design to minimize impacts. There are existing overhead utility lines and poles located along the north side of Chesapeake Road and west side of Cecil Street which will need to be evaluated during final design. Impacts to existing parking, driveways, and other areas outside of the right-of-way will need to be evaluated.

Summary of Results

Preliminary computations were performed based on available GIS storm drain information, GIS contours, and as-built plans for the area. Some assumptions were made when there were discrepancies in the data regarding pipe invert elevations, slopes, and top of structure elevations. The analysis was conducted based on the 10-year storm, 10-year storm with Climate Change Factors (via the Mid-Atlantic Projected IDF Curve Data Tool, 2050-2100 Prediction Period), and the 25-year storm. An analysis of the existing storm drain system indicates that the existing 21"x15" CMP beginning south of Cecil Street and outfalling into the North East River does not have adequate capacity in any of the three events analyzed (10-year, 10-year climate change, and 25-year). The existing 12” HDPE pipes along Cecil Street do not have capacity during the 10-year climate change and the 25-year events. Additionally, the hydraulic grade line (HGL), which is a measure of the water surface elevation within a pipe under pressure, is showing surcharging along the entire existing system during the 25-year storm. At some locations along Chesapeake Road, the HGL elevation measured 15 to 20 feet above the ground level. This means that during high storms, when the pipes are flowing full, stormwater has the potential to flow out of the inlets and spread across the roadway. An analysis of the existing inlets along Chesapeake Road and Cecil Street showed that the existing inlets capture between 20 to 40% of flow draining to them during the 10-year storm, bypassing the rest to the next downstream inlet. Horizontal spreads at these inlets varied between 15 to 20 feet.

Upgrading the existing 21”x15” CMP to a dual 18” HDPE pipe and upgrading the existing 12” HDPE pipes along Cecil Street to 15” and 18” HDPE pipes, will give the system adequate capacity in the 10-year, 10-year climate change, and 25-year storms. Additionally, the HGL elevations were significantly reduced and results showed that no more surcharging would occur above the top elevation at the inlets. Adding additional inlets along Chesapeake Road and Cecil Street, as well as upsizing the existing 15” Nyloplast drain basins to 24” Nyloplast drain basins, improves the efficiency and capture of the inlets, reduces bypass, and reduces the horizontal spread along the roadway. Note that these results are preliminary and should be re-examined once survey has been obtained.

Photo 1: S. Ogle Street facing south at approximate location of the existing cross culverts

Photo 2: Charlestown Place at Cecil Street intersection facing north

Photo 3: Cecil Street facing north looking towards Holloway Beach campground entrance

Photo 4: Cecil Street at Chesapeake Road intersection facing south

Photo 5: Chesapeake Road at Cecil Street intersection facing northwest towards Ogle Drive

Photo 6: Chesapeake Road at Cecil Street intersection facing southeast towards the North East River

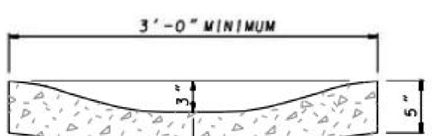
Photo 7: Outfall of Chesapeake Road storm drain system

NOTES:

1. EXISTING INFORMATION SUCH AS CONTOURS, STORM DRAIN, AND UTILITIES ARE BASED ON AVAILABLE GIS DATA AND AS-BUILT PLANS. NO SURVEY HAS BEEN OBTAINED.

2. CHESAPEAKE ROAD SHALL BE REGRADED FOR POSITIVE DRAINAGE TOWARDS CONCRETE VALLEY GUTTER AND INLETS ALONG CHESAPEAKE ROAD. MILL EXISTING PAVEMENT AND REGRADE VIA WEDGE/LEVEL. ADDITIONAL GRADING MAY BE NECESSARY TO TIE-IN EXISTING DRIVEWAYS.

3. INSTALL BACKFLOW PREVENTORS AT DOWNSTREAM END OF DUAL 18" PIPES.



VALLEY GUTTER

STRUCTURE TABLE	
STRUCTURE	NOTES
EX-I-1	UPSIZE TO TYPE S DOUBLE GRATE INLET
EX-I-2	UPSIZE TO TYPE S DOUBLE GRATE INLET
EX-I-3	UPSIZE EX 15" NYLOPLAST GRATE TO 24" GRATE
EX-I-4	UPSIZE EX 15" NYLOPLAST GRATE TO 24" GRATE
EX-I-5	UPSIZE EX 15" NYLOPLAST GRATE TO 24" GRATE
EX-I-6	UPSIZE EX 15" NYLOPLAST GRATE TO 24" GRATE
EX-I-7	REPLACE PROJECTING PIPE WITH TYPE K INLET
EX-I-8	UPSIZE EX 15" NYLOPLAST GRATE TO 24" GRATE
EX-I-9	UPSIZE EX 15" NYLOPLAST GRATE TO 24" GRATE
I-10	PROPOSED TYPE K INLET
I-11	PROPOSED 24" NYLOPLAST DRAIN BASIN
I-12	PROPOSED TYPE S DOUBLE GRATE INLET
I-13	PROPOSED TYPE S DOUBLE GRATE INLET
I-14	PROPOSED TYPE K INLET
JB-1	PROPOSED STANDARD 5'X5' CONCRETE JUNCTION BOX
OUTFALL	PROPOSED MODIFIED ENDWALL FOR DUAL PIPES

LEGEND	
— — — —	RIGHT-OF-WAY / PARCELS
—10—	EXISTING CONTOURS
EX. 15"HDPE	EXISTING STORM DRAIN
18"HDPE	PROPOSED STORM DRAIN
(hatched)	CHESAPEAKE ROAD REPAVING AREA
(blue)	CONCRETE VALLEY GUTTER

60' 0 60' 120'

SCALE: 1" = 60'

FOR INFORMATIONAL PURPOSES ONLY.
NOT FOR CONSTRUCTION.

Dewberry®
Dewberry Engineers
10461 MILL RUN CIRCLE
SUITE #300
OWINGS MILLS, MARYLAND 21117
PHONE: 410.265.9500
FAX: 410.265.8875

BY: aconley -

WATERSHED MASTER PLAN
CHARLESTOWN, MD

CHESAPEAKE ROAD / CECIL STREET

DRAINAGE DESIGN CONCEPT

SCALE 1" = 60' ADVERTISED DATE ____ CONTRACT NO. ____

DESIGNED BY AC
DRAWN BY AC
CHECKED BY ND

COUNTY CECIL COUNTY
LOGMILE ____
HORIZONTAL SCALE ____
VERTICAL SCALE ____

DRAWING NO. DD – 01 OF 01

SHEET NO. 1 OF 1

CHESEAPEAKE ROAD DRAINAGE IMPROVEMENTS

EXISTING AND PROPOSED
STORM DRAIN COMPUTATIONS

Dewberry

STORM SEWER DESIGN

SHEET ______ OF ______

DATE ____________

DESIGNED BY AC
CHECKED BY
RAINFALL FACTOR 10-Year Storm Existing

CONTRACT
PROJECT Chesapeak Road Drainage Improvements

Ref: FORM SHA - 61.1-492

Intensity values from NOAA Atlas 14 Point Precipitation Frequency Estimates

Structure		Contributing Area				10 Year Runoff					Pipe								Remarks
From	To	C Area (#)	A Area Acres	C Runoff Coeff.	ΔCA	ΣA	ΣCA	Tc Time Conc. Min.	i*if Rainfall Intensity in/hr	Q Flow Rate cfs	Pipe Size in.	Type	n Mann-ing's Coef.	So Slope *	L Length Ft.	Vo Vel. Ft/sec	Time in Pipe Min.	Capac. Full cfs	
EX-I-7	EX-I-6	EX-I-7	1.66	0.31	0.52	1.66	0.52	21.00	3.90	2.01	15	HDPE	0.0130	0.013	61	5.11	0.20	7.39	
EX-I-6	EX-I-5	EX-I-6	0.28	0.46	0.13	1.94	0.64	21.20	3.88	2.50	15	HDPE	0.0130	0.021	156	6.46	0.40	9.44	
EX-I-5	EX-I-4	EX-I-5	0.48	0.43	0.20	2.42	0.85	21.60	3.85	3.27	15	HDPE	0.0130	0.020	129	6.83	0.31	9.06	
EX-I-4	EX-I-3	EX-I-4	0.15	0.49	0.08	2.57	0.92	21.92	3.82	3.53	15	HDPE	0.0130	0.010	113	5.38	0.35	6.46	
EX-I-3	EX-MH-1	EX-I-3	0.16	0.53	0.08	2.73	1.01	22.27	3.79	3.82	18	HDPE	0.0130	0.009	21	5.27	0.07	9.75	
EX-MH-1	EX-I-2	EX-MH-1	0.00	0.00	0.00	3.90	1.56	22.33	3.79	5.92	18	HDPE	0.0130	0.009	30	5.88	0.09	9.75	
EX-I-2	EX-I-1	EX-I-2	5.16	0.37	1.91	9.06	3.47	22.42	3.78	13.13	18	CMP	0.0240	0.012	205	3.92	0.87	6.35	21"x15" CMP
EX-I-1	EX-OUT	EX-I-1	0.41	0.50	0.20	9.47	3.68	23.29	3.70	13.61	18	CMP	0.0240	0.015	145	4.45	0.54	6.95	21"x15" CMP
EX-I-9	EX-I-8	EX-I-9	0.99	0.49	0.49	0.99	0.49	5.00	6.49	3.16	12	HDPE	0.0130	0.010	33	5.12	0.11	3.56	slope assumed
EX-I-8	EX-MH-1	EX-I-8	0.17	0.40	0.07	1.16	0.55	5.11	6.49	3.60	12	HDPE	0.0130	0.011	99	5.42	0.30	3.67	

Dewberry

SHEET ______ OF ______

DATE ______

STORM SEWER DESIGN

DESIGNED BY AC

CHECKED BY

RAINFALL FACTOR 10-Year Storm Existing - Climate Change Factors

CONTRACT

PROJECT Chesapeak Road Drainage Improvements

Ref: FORM SHA - 61.1-492

Climate Change Factors from Mid-Atlantic Projected IDF Curve Data Tool, RCP 8.5, Median Percentile, 2050-2100 Prediction Period

Structure		Contributing Area				10 Year Runoff						Pipe									
From	To	C Area (#)	A Area Acres	C Runoff Coeff.	ΔCA	ΣA	ΣCA	Tc Time Conc. Min.	i*if Rainfall Intensity in/hr	CC Factor Intensity (i * 1.17)	Q Flow Rate cfs	Pipe Size in.	Type	n Mann-ing's Coef.	So Slope *	L Length Ft.	Vo Vel. Ft/sec	Time in Pipe Min.	Capac. Full cfs	Remarks
EX-I-7	EX-I-6	EX-I-7	1.66	0.31	0.52	1.66	0.52	21.00	3.90	4.56	2.35	15	HDPE	0.0130	0.013	61	5.34	0.19	7.39	
EX-I-6	EX-I-5	EX-I-6	0.28	0.46	0.13	1.94	0.64	21.19	3.88	4.54	2.92	15	HDPE	0.0130	0.021	156	6.70	0.39	9.44	
EX-I-5	EX-I-4	EX-I-5	0.48	0.43	0.20	2.42	0.85	21.58	3.85	4.50	3.82	15	HDPE	0.0130	0.020	129	7.11	0.30	9.06	
EX-I-4	EX-I-3	EX-I-4	0.15	0.49	0.08	2.57	0.92	21.88	3.83	4.48	4.14	15	HDPE	0.0130	0.010	113	5.59	0.34	6.46	
EX-I-3	EX-MH-1	EX-I-3	0.16	0.53	0.08	2.73	1.01	22.22	3.80	4.44	4.48	18	HDPE	0.0130	0.009	21	5.49	0.06	9.75	
EX-MH-1	EX-I-2	EX-MH-1	0.00	0.00	0.00	3.90	1.56	22.28	3.79	4.44	6.94	18	HDPE	0.0130	0.009	30	6.10	0.08	9.75	
EX-I-2	EX-I-1	EX-I-2	5.16	0.37	1.91	9.06	3.47	22.36	3.79	4.43	15.38	18	CMP	0.0240	0.012	205	3.92	0.87	6.35	21"x15" CMP
EX-I-1	EX-OUT	EX-I-1	0.41	0.50	0.20	9.47	3.68	23.24	3.72	4.35	15.98	18	CMP	0.0240	0.015	145	4.45	0.54	6.95	21"x15" CMP
EX-I-9	EX-I-8	EX-I-9	0.99	0.49	0.49	0.99	0.49	5.00	6.49	7.59	3.69	12	HDPE	0.0130	0.010	33	5.16	0.11	3.56	slope assumed
EX-I-8	EX-MH-1	EX-I-8	0.17	0.40	0.07	1.16	0.55	5.11	6.49	7.59	4.21	12	HDPE	0.0130	0.011	99	5.33	0.31	3.67	

Dewberry

STORM SEWER DESIGN

SHEET ______ OF ______

DATE ______

DESIGNED BY AC

CHECKED BY ______

RAINFALL FACTOR 25-Year Storm Existing

CONTRACT ______

PROJECT Chesapeak Road Drainage Improvements

Ref: FORM SHA - 61.1-492

Intensity values from NOAA Atlas 14 Point Precipitation Frequency Estimates

Structure		Contributing Area				25 Year Runoff					Pipe								
From	To	C Area (#)	A Area Acres	C Runoff Coeff.	ΔCA	ΣA	ΣCA	Tc Time Conc. Min.	i*if Rainfall Intensity in/hr	Q Flow Rate cfs	Pipe Size in.	Type	n Mann-ing's Coef.	So Slope *	L Length Ft.	Vo Vel. Ft/sec	Time in Pipe Min.	Capac. Full cfs	Remarks
EX-I-7	EX-I-6	EX-I-7	1.66	0.31	0.52	1.66	0.52	21.00	4.39	2.27	15	HDPE	0.0130	0.013	61	5.29	0.19	7.39	
EX-I-6	EX-I-5	EX-I-6	0.28	0.46	0.13	1.94	0.64	21.19	4.38	2.82	15	HDPE	0.0130	0.021	156	6.68	0.39	9.44	
EX-I-5	EX-I-4	EX-I-5	0.48	0.43	0.20	2.42	0.85	21.58	4.34	3.69	15	HDPE	0.0130	0.020	129	7.05	0.31	9.06	
EX-I-4	EX-I-3	EX-I-4	0.15	0.49	0.08	2.57	0.92	21.89	4.32	3.99	15	HDPE	0.0130	0.010	113	5.54	0.34	6.46	
EX-I-3	EX-MH-1	EX-I-3	0.16	0.53	0.08	2.73	1.01	22.23	4.29	4.33	18	HDPE	0.0130	0.009	21	5.44	0.06	9.75	
EX-MH-1	EX-I-2	EX-MH-1	0.00	0.00	0.00	3.90	1.56	22.29	4.28	6.70	18	HDPE	0.0130	0.009	30	6.05	0.08	9.75	
EX-I-2	EX-I-1	EX-I-2	5.16	0.37	1.91	9.06	3.47	22.37	4.28	14.85	18	CMP	0.0240	0.012	205	3.92	0.87	6.35	21"x15" CMP
EX-I-1	EX-OUT	EX-I-1	0.41	0.50	0.20	9.47	3.68	23.25	4.20	15.45	18	CMP	0.0240	0.015	145	4.45	0.54	6.95	21"x15" CMP
EX-I-9	EX-I-8	EX-I-9	0.99	0.49	0.49	0.99	0.49	5.00	7.28	3.54	12	HDPE	0.0130	0.010	33	5.17	0.11	3.56	slope assumed
EX-I-8	EX-MH-1	EX-I-8	0.17	0.40	0.07	1.16	0.55	5.11	7.28	4.04	12	HDPE	0.0130	0.011	99	5.42	0.30	3.67	

Dewberry

STORM SEWER DESIGN

SHEET ______ OF ______

DATE ______

DESIGNED BY AC
CHECKED BY
RAINFALL FACTOR 10-Year Storm Proposed

CONTRACT
PROJECT Chesapeak Road Drainage Improvements

Ref: FORM SHA - 61.1-492

Intensity values from NOAA Atlas 14 Point Precipitation Frequency Estimates

Structure		Contributing Area				10 Year Runoff					Pipe								Remarks
From	To	C Area (#)	A Area Acres	C Runoff Coeff.	ΔCA	ΣA	ΣCA	Tc Time Conc. Min.	i*if Rainfall Intensity in/hr	Q Flow Rate cfs	Pipe Size in.	Type	n Mann-ing's Coef.	So Slope *	L Length Ft.	Vo Vel. Ft/sec	Time in Pipe Min.	Capac. Full cfs	
I-10	EX-I-7	I-10	2.35	0.33	0.77	2.35	0.77	24.00	3.70	2.87	15	HDPE	0.0130	0.010	218	5.10	0.71	6.46	
EX-I-7	EX-I-6	EX-I-7	1.66	0.31	0.52	4.01	1.29	24.71	3.63	4.69	15	HDPE	0.0130	0.013	61	6.37	0.16	7.39	
EX-I-6	I-11	EX-I-6	0.28	0.46	0.13	4.29	1.42	24.87	3.62	5.13	15	HDPE	0.0130	0.021	76	7.80	0.16	9.44	
I-11	EX-I-5	I-11	0.19	0.44	0.08	4.48	1.50	25.03	3.60	5.40	15	HDPE	0.0130	0.021	83	7.89	0.18	9.44	
EX-I-5	EX-I-4	EX-I-5	0.29	0.42	0.12	4.77	1.62	25.21	3.58	5.82	15	HDPE	0.0130	0.020	129	7.89	0.27	9.06	
EX-I-4	EX-I-3	EX-I-4	0.15	0.49	0.08	4.92	1.70	25.48	3.56	6.04	15	HDPE	0.0130	0.010	113	5.98	0.31	6.46	
EX-I-3	JB-1	EX-I-3	0.16	0.53	0.08	5.08	1.78	25.80	3.53	6.29	18	HDPE	0.0130	0.006	7	5.08	0.02	8.14	
JB-1	EX-I-2	JB-1	0.00	0.00	0.00	9.02	3.40	25.82	3.53	5.99	18	HDPE	0.0130	0.008	26	5.63	0.08	9.40	DUAL 18"
EX-I-2	EX-I-1	EX-I-2	0.10	0.63	0.06	9.12	3.46	25.90	3.52	6.09	18	HDPE	0.0130	0.012	188	6.60	0.47	11.72	DUAL 18"
EX-I-1	EX-OUT	EX-I-1	0.34	0.51	0.18	9.47	3.64	26.37	3.47	6.32	18	HDPE	0.0130	0.015	145	7.54	0.32	12.82	DUAL 18"
I-14	I-13	I-14	0.77	0.47	0.36	0.77	0.36	5.00	6.49	2.34	15	HDPE	0.0130	0.010	86	4.84	0.30	6.46	
I-13	EX-I-9	I-13	0.14	0.47	0.06	0.90	0.42	5.30	6.35	2.69	15	HDPE	0.0130	0.010	60	4.95	0.20	6.46	
EX-I-9	EX-I-8	EX-I-9	0.09	0.46	0.04	0.99	0.47	5.50	6.30	2.94	15	HDPE	0.0130	0.010	29	5.07	0.10	6.46	slope assumed
EX-I-8	I-12	EX-I-8	0.17	0.40	0.07	1.16	0.53	5.59	6.28	3.35	15	HDPE	0.0130	0.010	54	5.25	0.17	6.46	
I-12	JB-1	I-12	2.78	0.39	1.08	3.94	1.62	5.76	6.25	10.11	18	HDPE	0.0130	0.013	48	7.04	0.11	11.98	
										*FLOW IS SPLIT IN HALF FOR DUAL 18" PIPES									

Dewberry

STORM SEWER DESIGN

SHEET ________ OF ________

DATE ____________

DESIGNED BY AC

CHECKED BY

RAINFALL FACTOR 10-Year Storm Proposed - Climate Change Factors

CONTRACT

PROJECT Chesapeak Road Drainage Improvements

Ref: FORM SHA - 61.1-492

Climate Change Factors from Mid-Atlantic Projected IDF Curve Data Tool, RCP 8.5, Median Percentile, 2050-2100 Prediction Period

Structure		Contributing Area				10 Year Runoff						Pipe								
From	To	C Area (#)	A Area Acres	C Runoff Coeff.	ΔCA	ΣA	ΣCA	Tc Time Conc. Min.	i*if Rainfall Intensity in/hr	CC Factor Intensity (i * 1.17)	Q Flow Rate cfs	Pipe Size in.	Type	n Mann-ing's Coef.	So Slope *	L Length Ft.	Vo Vel. Ft/sec	Time in Pipe Min.	Capac. Full cfs	Remarks
I-10	EX-I-7	I-10	2.35	0.33	0.77	2.35	0.77	24.00	3.70	4.33	3.35	15	HDPE	0.0130	0.010	218	5.31	0.68	6.46	
EX-I-7	EX-I-6	EX-I-7	1.66	0.31	0.52	4.01	1.29	24.68	3.64	4.25	5.49	15	HDPE	0.0130	0.013	61	6.78	0.15	7.39	
EX-I-6	I-11	EX-I-6	0.28	0.46	0.13	4.29	1.42	24.83	3.62	4.24	6.01	15	HDPE	0.0130	0.021	76	8.10	0.16	9.44	
I-11	EX-I-5	I-11	0.19	0.44	0.08	4.48	1.50	24.99	3.61	4.22	6.33	15	HDPE	0.0130	0.021	83	8.19	0.17	9.44	
EX-I-5	EX-I-4	EX-I-5	0.29	0.42	0.12	4.77	1.62	25.16	3.59	4.20	6.81	15	HDPE	0.0130	0.020	129	8.16	0.26	9.06	
EX-I-4	EX-I-3	EX-I-4	0.15	0.49	0.08	4.92	1.70	25.42	3.56	4.17	7.08	15	HDPE	0.0130	0.010	113	5.91	0.32	6.46	
EX-I-3	JB-1	EX-I-3	0.16	0.53	0.08	5.08	1.78	25.74	3.53	4.13	7.37	18	HDPE	0.0130	0.006	7	5.22	0.02	8.14	
JB-1	EX-I-2	JB-1	0.00	0.00	0.00	9.02	3.40	25.76	3.53	4.13	7.02	18	HDPE	0.0130	0.008	26	5.83	0.07	9.40	DUAL 18"
EX-I-2	EX-I-1	EX-I-2	0.10	0.63	0.06	9.12	3.46	25.84	3.52	4.12	7.14	18	HDPE	0.0130	0.012	188	6.86	0.46	11.72	DUAL 18"
EX-I-1	EX-OUT	EX-I-1	0.34	0.51	0.18	9.47	3.64	26.30	3.48	4.07	7.41	18	HDPE	0.0130	0.015	145	7.53	0.32	12.82	DUAL 18"
I-14	I-13	I-14	0.77	0.47	0.36	0.77	0.36	5.00	6.49	7.59	2.73	15	HDPE	0.0130	0.010	86	5.04	0.28	6.46	
I-13	EX-I-9	I-13	0.14	0.47	0.06	0.90	0.42	5.28	6.35	7.43	3.15	15	HDPE	0.0130	0.010	60	5.23	0.19	6.46	
EX-I-9	EX-I-8	EX-I-9	0.09	0.46	0.04	0.99	0.47	5.48	6.31	7.38	3.44	15	HDPE	0.0130	0.010	29	5.35	0.09	6.46	slope assumed
EX-I-8	I-12	EX-I-8	0.17	0.40	0.07	1.16	0.53	5.57	6.29	7.36	3.93	15	HDPE	0.0130	0.010	54	5.52	0.16	6.46	
I-12	JB-1	I-12	2.78	0.39	1.08	3.94	1.62	5.73	6.25	7.32	11.84	18	HDPE	0.0130	0.013	48	6.93	0.12	11.98	
											*FLOW IS SPLIT IN HALF FOR DUAL 18" PIPES									

Dewberry

STORM SEWER DESIGN

SHEET ______ OF ______

DATE ______

DESIGNED BY AC

CHECKED BY

RAINFALL FACTOR 25-Year Storm Proposed

CONTRACT

PROJECT Chesapeak Road Drainage Improvements

Ref: FORM SHA - 61.1-492

Intensity values from NOAA Atlas 14 Point Precipitation Frequency Estimates

Structure		Contributing Area				10 Year Runoff					Pipe								Remarks
From	To	C Area (#)	A Area Acres	C Runoff Coeff.	ΔCA	ΣA	ΣCA	Tc Time Conc. Min.	i*if Rainfall Intensity in/hr	Q Flow Rate cfs	Pipe Size in.	Type	n Mann-ing's Coef.	So Slope *	L Length Ft.	Vo Vel. Ft/sec	Time in Pipe Min.	Capac. Full cfs	
I-10	EX-I-7	I-10	2.35	0.33	0.77	2.35	0.77	24.00	4.19	3.25	15	HDPE	0.0130	0.010	218	5.27	0.69	6.46	
EX-I-7	EX-I-6	EX-I-7	1.66	0.31	0.52	4.01	1.29	24.69	4.12	5.32	15	HDPE	0.0130	0.013	61	6.54	0.16	7.39	
EX-I-6	I-11	EX-I-6	0.28	0.46	0.13	4.29	1.42	24.84	4.11	5.83	15	HDPE	0.0130	0.021	76	8.04	0.16	9.44	
I-11	EX-I-5	I-11	0.19	0.44	0.08	4.48	1.50	25.00	4.09	6.14	15	HDPE	0.0130	0.021	83	8.14	0.17	9.44	
EX-I-5	EX-I-4	EX-I-5	0.29	0.42	0.12	4.77	1.62	25.17	4.07	6.61	15	HDPE	0.0130	0.020	129	8.11	0.27	9.06	
EX-I-4	EX-I-3	EX-I-4	0.15	0.49	0.08	4.92	1.70	25.44	4.05	6.87	15	HDPE	0.0130	0.010	113	5.93	0.32	6.46	
EX-I-3	JB-1	EX-I-3	0.16	0.53	0.08	5.08	1.78	25.76	4.01	7.15	18	HDPE	0.0130	0.006	7	5.19	0.02	8.14	
JB-1	EX-I-2	JB-1	0.00	0.00	0.00	9.02	3.40	25.78	4.01	6.82	18	HDPE	0.0130	0.008	26	5.78	0.07	9.40	DUAL 18"
EX-I-2	EX-I-1	EX-I-2	0.10	0.63	0.06	9.12	3.46	25.85	4.00	6.93	18	HDPE	0.0130	0.012	205	6.81	0.50	11.72	DUAL 18"
EX-I-1	EX-OUT	EX-I-1	0.34	0.51	0.18	9.47	3.64	26.35	3.95	7.19	18	HDPE	0.0130	0.015	145	7.48	0.32	12.82	DUAL 18"
I-14	I-13	I-14	0.77	0.47	0.36	0.77	0.36	5.00	6.49	2.34	15	HDPE	0.0130	0.010	86	4.84	0.30	6.46	
I-13	EX-I-9	I-13	0.14	0.47	0.06	0.90	0.42	5.30	7.12	3.02	15	HDPE	0.0130	0.010	60	5.17	0.19	6.46	
EX-I-9	EX-I-8	EX-I-9	0.09	0.46	0.04	0.99	0.47	5.49	7.07	3.29	15	HDPE	0.0130	0.010	29	5.28	0.09	6.46	slope assumed
EX-I-8	I-12	EX-I-8	0.17	0.40	0.07	1.16	0.53	5.58	7.05	3.76	15	HDPE	0.0130	0.010	54	5.46	0.16	6.46	
I-12	JB-1	I-12	2.78	0.39	1.08	3.94	1.62	5.75	7.01	11.34	18	HDPE	0.0130	0.013	48	7.09	0.11	11.98	
										*FLOW IS SPLIT IN HALF FOR DUAL 18" PIPES									

CHESEAPEAKE ROAD DRAINAGE IMPROVEMENTS

EXISTING AND PROPOSED
HYDRAULIC GRADE LINE COMPUTATIONS

SHEET ________ OF ________

HYDRAULIC GRADIENT FOR STORM SEWERS

DATE ____________

DESIGNED BY	AC	CONTRACT	
CHECKED BY		PROJECT	Chesapeak Road Drainage Improvements
RAINFALL FACTOR	25-Year Storm		
	Existing		

Ref: FORM SHA - 61.1-493

Structure		25 Year Runoff				Pipe								Hydraulic Gradient		
From	**To**	**ΣCA**	**Tc, min**	**Rainfall intensity i, in/hr**	**Q, cfs**	**Size, in. (dia)**	**Mannings n**	**So, Slope**	**Sf, Frictional Slope**	**Vf, Vel ft/sec**	**L, Length ft.**	**Dn, Normal Depth**	**Kb**	**Description of Loss**		**Elevation**
EX-OUT	EX-I-1	3.68	23.25	4.20	15.45	18	0.0240	0.0150	0.0737	8.74	145	1.250		***Starting HGL -------------------->***	2.25	2.25
						(21"x15")						(pipe full)		***Hf ------------------------------->***	10.69	12.94
														Dn ------------------------------->	1.25	4.92
EX-I-1	EX-I-1	-	-	-	-	-	-	-	-	-	-		0.50	***Hb ------------------------------->***	0.59	13.54
														Top Elevation ------------------>	-	5.50
EX-I-1	EX-I-2	3.47	22.37	4.28	14.85	18	0.0240	0.0120	0.0681	8.40	205	1.250		***Starting HGL -------------------->***	-	13.54
						(21"x15")						(pipe full)		***Hf ------------------------------->***	13.96	27.50
														Dn ------------------------------->	1.25	6.65
EX-I-2	EX-I-2	-	-	-	-	-	-	-	-	-	-		0.82	***Hb ------------------------------->***	0.90	28.40
														Top Elevation ------------------>	-	8.50
EX-I-2	EX-MH-1	1.56	22.29	4.28	6.70	18	0.0130	0.0090	0.0041	3.79	30	0.900		***Starting HGL -------------------->***	-	28.40
														Hf ------------------------------->	0.12	28.52
														Dn ------------------------------->	0.90	6.40
EX-MH-1	EX-MH-1	-	-	-	-	-	-	-	-	-	-		0.95	***Hb ------------------------------->***	0.21	28.73
														Top Elevation ------------------>	-	9.00
EX-MH-1	EX-I-3	1.01	22.23	4.29	4.33	18	0.0130	0.0090	0.0017	2.45	21	0.691		***Starting HGL -------------------->***	-	28.73
														Hf ------------------------------->	0.04	28.77
														Dn ------------------------------->	0.69	7.94
EX-I-3	EX-I-3	-	-	-	-	-	-	-	-	-	-		0.50	***Hb ------------------------------->***	0.05	28.81
														Top Elevation ------------------>	-	9.50
EX-I-3	EX-I-4	0.92	21.89	4.32	3.99	15	0.0130	0.0100	0.0038	3.25	113	0.711		***Starting HGL -------------------->***	-	28.81
														Hf ------------------------------->	0.43	29.24
														Dn ------------------------------->	0.71	8.79
EX-I-4	EX-I-4	-	-	-	-	-	-	-	-	-	-		0.50	***Hb ------------------------------->***	0.08	29.33
														Top Elevation ------------------>	-	10.50
EX-I-4	EX-I-5	0.85	21.58	4.34	3.69	15	0.0130	0.0200	0.0033	3.01	129	0.553		***Starting HGL -------------------->***	-	29.33
														Hf ------------------------------->	0.42	29.75
														Dn ------------------------------->	0.55	10.64
EX-I-5	EX-I-5	-	-	-	-	-	-	-	-	-	-		0.50	***Hb ------------------------------->***	0.07	29.82
														Top Elevation ------------------>	-	12.50
EX-I-5	EX-I-6	0.64	21.19	4.38	2.82	15	0.0130	0.0210	0.0019	2.30	156	0.471		***Starting HGL -------------------->***	-	29.82
														Hf ------------------------------->	0.30	30.11
														Dn ------------------------------->	0.47	14.39
EX-I-6	EX-I-6	-	-	-	-	-	-	-	-	-	-		0.50	***Hb ------------------------------->***	0.04	30.15
														Top Elevation ------------------>	-	16.00
EX-I-6	EX-I-7	0.52	21.00	4.39	2.27	15	0.0130	0.0130	0.0012	1.85	61	0.476		***Starting HGL -------------------->***	-	30.15
														Hf ------------------------------->	0.08	30.23
														Dn ------------------------------->	0.48	16.98
EX-I-7	EX-I-7	-	-	-	-	-	-	-	-	-	-		0.50	***Hb ------------------------------->***	0.03	30.26
														Top Elevation ------------------>	-	16.50
EX-MH-1	EX-I-8	0.55	5.11	7.28	4.04	12	0.0130	0.0110	0.0128	5.14	99	1.000		***Starting HGL -------------------->***	-	28.73
												(pipe full)		***Hf ------------------------------->***	1.27	30.00
														Dn ------------------------------->	1.00	8.50
EX-I-8	EX-I-8	-	-	-	-	-	-	-	-	-	-		0.50	***Hb ------------------------------->***	0.21	30.21
														Top Elevation ------------------>	-	9.50
EX-I-8	EX-I-9	0.49	5.00	7.28	3.54	12	0.0130	0.0100	0.0099	4.51	33	0.814		***Starting HGL -------------------->***	-	28.40
														Hf ------------------------------->	0.33	28.72
														Dn ------------------------------->	0.81	8.48
EX-I-9	EX-I-9	-	-	-	-	-	-	-	-	-	-		0.50	***Hb ------------------------------->***	0.16	28.88
														Top Elevation ------------------>	-	9.50

HYDRAULIC GRADIENT FOR STORM SEWERS

SHEET ________ OF ________

DATE ________________

DESIGNED BY AC
CHECKED BY
RAINFALL FACTOR 25-Year Storm
Proposed

CONTRACT ________
PROJECT Chesapeak Road Drainage Improvements

Ref: FORM SHA - 61.1-493

Structure		**25 Year Runoff**				**Pipe**								**Hydraulic Gradient**		
From	**To**	**ΣCA**	**Tc, min**	**Rainfall intensity i, in/hr**	**Q, cfs**	**Size, in. (dia)**	**Mannings n**	**So, Slope**	**Sf, Frictional Slope**	**Vf, Vel ft/sec**	**L, Length ft.**	**Dn, Normal Depth**	**Kb**	**Description of Loss**		**Elevation**
EX-OUT	EX-I-1	3.64	26.35	3.95	7.19	18	0.0130	0.0150	0.0047	4.07	145	0.802		*Starting HGL ------------------->*	2.50	2.50
						dual pipe								*Hf ------------------------------->*	0.68	3.18
														Dn ------------------------------->	0.80	4.47
EX-I-1	EX-I-1	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.13	4.60
														Top Elevation ------------------>	-	5.50
EX-I-1	EX-I-2	3.46	25.85	4.00	6.93	18	0.0130	0.0120	0.0044	3.92	205	0.839		*Starting HGL ------------------->*	-	4.60
						dual pipe								*Hf ------------------------------->*	0.89	5.49
														Dn ------------------------------->	0.84	6.24
EX-I-2	EX-I-2	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.12	6.36
														Top Elevation ------------------>	-	8.50
EX-I-2	JB-1	3.40	25.78	4.01	6.82	18	0.0130	0.0080	0.0042	3.86	26	0.948		*Starting HGL ------------------->*	-	6.36
						dual pipe								*Hf ------------------------------->*	0.11	6.47
														Dn ------------------------------->	0.95	6.55
JB-1	JB-1	-	-	-	-	-	-	-	-	-	-		1.00	*Hb ------------------------------->*	0.23	6.78
														Top Elevation ------------------>	-	9.50
JB-1	EX-I-3	1.78	25.76	4.01	7.15	18	0.0130	0.0060	0.0046	4.05	7	1.090		*Starting HGL ------------------->*	-	6.78
														Hf ------------------------------->	0.03	6.81
														Dn ------------------------------->	1.09	8.34
EX-I-3	EX-I-3	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.13	8.47
														Top Elevation ------------------>	-	9.50
EX-I-3	EX-I-4	1.70	25.44	4.05	6.87	15	0.0130	0.0100	0.0113	5.60	113	1.120		*Starting HGL ------------------->*	-	8.47
														Hf ------------------------------->	1.28	9.74
														Dn ------------------------------->	1.12	9.20
EX-I-4	EX-I-4	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.24	9.99
														Top Elevation ------------------>	-	10.50
EX-I-4	EX-I-5	1.62	25.17	4.07	6.61	15	0.0130	0.0200	0.0105	5.38	129	0.788		*Starting HGL ------------------->*	-	9.99
														Hf ------------------------------->	1.35	11.34
														Dn ------------------------------->	0.79	10.87
EX-I-5	EX-I-5	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.23	11.56
														Top Elevation ------------------>	-	12.50
EX-I-5	I-11	1.50	25.00	4.09	6.14	15	0.0130	0.0210	0.0090	5.00	83	0.738		*Starting HGL ------------------->*	-	11.56
														Hf ------------------------------->	0.75	12.31
														Dn ------------------------------->	0.74	12.56
I-11	I-11	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.19	12.75
														Top Elevation ------------------>	-	15.00
I-11	EX-I-6	1.42	24.84	4.11	5.83	15	0.0130	0.0210	0.0081	4.75	76	0.714		*Starting HGL ------------------->*	-	12.75
														Hf ------------------------------->	0.62	13.37
														Dn ------------------------------->	0.71	14.63
EX-I-6	EX-I-6	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.17	14.81
														Top Elevation ------------------>	-	16.00
EX-I-6	EX-I-7	1.29	24.69	4.12	5.32	15	0.0130	0.0130	0.0068	4.33	61	0.787		*Starting HGL ------------------->*	-	14.81
														Hf ------------------------------->	0.41	15.22
														Dn ------------------------------->	0.79	15.29
EX-I-7	EX-I-7	-	-	-	-	-	-	-	-	-	-		1.50	*Hb ------------------------------->*	0.44	15.72
														Top Elevation ------------------>	-	16.50
EX-I-7	I-10	0.77	24.00	4.19	3.25	15	0.0130	0.0100	0.0025	2.65	218	0.627		*Starting HGL ------------------->*	-	15.72
														Hf ------------------------------->	0.55	16.28
														Dn ------------------------------->	0.63	17.63
I-10	I-10	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.05	17.68
														Top Elevation ------------------>	-	22.00
JB-1	I-12	1.62	5.75	7.01	11.34	18	0.0130	0.0130	0.0117	6.42	48	1.000		*Starting HGL ------------------->*	-	6.78
														Hf ------------------------------->	0.56	7.34
														Dn ------------------------------->	1.00	7.32
I-12	I-12	-	-	-	-	-	-	-	-	-	-		0.59	*Hb ------------------------------->*	0.38	7.72
														Top Elevation ------------------>	-	9.40
I-12	EX-I-8	0.53	5.58	7.05	3.76	15	0.0130	0.0100	0.0034	3.07	54	1.000		*Starting HGL ------------------->*	-	7.72
														Hf ------------------------------->	0.18	7.90
														Dn ------------------------------->	1.00	7.96
EX-I-8	EX-I-8	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.07	8.04
														Top Elevation ------------------>	-	9.50
EX-I-8	EX-I-9	0.47	5.49	7.07	3.29	15	0.0130	0.0100	0.0026	2.68	29	0.814		*Starting HGL ------------------->*	-	8.04
														Hf ------------------------------->	0.08	8.11
														Dn ------------------------------->	0.81	8.17
EX-I-9	EX-I-9	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.06	8.22
														Top Elevation ------------------>	-	9.60
EX-I-9	I-13	0.42	5.30	7.12	3.02	15	0.0130	0.0100	0.0022	2.46	60	0.814		*Starting HGL ------------------->*	-	8.22
														Hf ------------------------------->	0.13	8.35
														Dn ------------------------------->	0.81	8.87
I-13	I-13	-	-	-	-	-	-	-	-	-	-		1.29	*Hb ------------------------------->*	0.12	8.99
														Top Elevation ------------------>	-	10.00
I-13	I-14	0.36	5.00	6.49	2.34	15	0.0130	0.0100	0.0013	1.90	86	0.814		*Starting HGL ------------------->*	-	8.99
														Hf ------------------------------->	0.11	9.10
														Dn ------------------------------->	0.81	9.83
I-14	I-14	-	-	-	-	-	-	-	-	-	-		0.50	*Hb ------------------------------->*	0.03	9.86
														Top Elevation ------------------>	-	12.00
														Starting HGL ------------------->	-	9.86

CHESEAPEAKE ROAD DRAINAGE IMPROVEMENTS

EXISTING AND PROPOSED
INLET COMPUTATIONS

INLET SPACING (10-YEAR STORM)
EXISTING CONDITIONS

PROJECT NAME: Chesapeake Road Drainage Improvements

INLET NO.	AREA (ac)	C	Tc (min)	RAINFALL INTENSITY (in/hr)	Q (cfs)	TOTAL Q (with bypass)	INLET TYPE	CROSS SLOPE	STREET GRADE	INLET LENGTH (ft)	SPREAD (ft)	PICKUP %	BYPASS TO INLET NO.	BYPASS Q (cfs)	REMARKS
EX-I-1	0.41	0.50	5.00	6.49	1.33	9.23	YARD	0.020	0.016	2.00	14.05	38%	OUTFALL	5.74	Bypass continues down Chesapeake Rd
EX-I-2	5.16	0.37	19.20	4.04	7.71	10.10	YARD	0.008	0.016	2.00	25.77	22%	EX-I-1	7.90	
EX-I-3	0.16	0.53	5.00	6.49	0.55	3.01	NYLOPLAST 15" DRAIN BASIN	0.008	0.016	1.25	16.37	21%	EX-I-2	2.39	
EX-I-4	0.15	0.49	5.00	6.49	0.48	3.20	NYLOPLAST 15" DRAIN BASIN	0.010	0.016	1.25	14.57	23%	EX-I-3	2.46	
EX-I-5	0.48	0.43	5.00	6.49	1.34	3.59	NYLOPLAST 15" DRAIN BASIN	0.008	0.016	1.25	17.48	24%	EX-I-4	2.72	
EX-I-6	0.28	0.46	5.00	6.49	0.84	2.84	NYLOPLAST 15" DRAIN BASIN	0.010	0.016	1.25	13.93	21%	EX-I-5	2.25	
EX-I-7	1.66	0.31	21.00	3.90	2.00	2.00	N/A	0.020	0.016	N/A	N/A	0%	EX-I-6	2.00	No inlet found; buried projecting pipe suspected
EX-I-8	0.17	0.40	5.00	6.49	0.44	2.99	NYLOPLAST 15" DRAIN BASIN	0.008	0.010	1.25	17.73	21%	EX-I-1	2.36	
EX-I-9	0.99	0.49	5.00	6.49	3.15	3.15	NYLOPLAST 15" DRAIN BASIN	0.008	0.010	1.25	18.18	19%	EX-I-8	2.54	

INLET SPACING (10-YEAR STORM)
PROPOSED CONDITIONS

PROJECT NAME: Chesapeake Road Drainage Improvements

INLET NO.	AREA (ac)	C	Tc (min)	RAINFALL INTENSITY (in/hr)	Q (cfs)	TOTAL Q (with bypass)	INLET TYPE	CROSS SLOPE	STREET GRADE	INLET LENGTH (ft)	SPREAD (ft)	PICKUP %	BYPASS TO INLET NO.	BYPASS Q (cfs)	REMARKS
EX-I-1	0.34	0.51	5.00	6.49	1.13	1.97	TYPE S DOUBLE GRATE INLET	0.020	0.016	5.50	7.87	90%	OUTFALL	0.20	UPSIZE TO TYPE DOUBLE GRATE
EX-I-2	0.10	0.63	5.00	6.49	0.41	2.80	TYPE S DOUBLE GRATE INLET	0.020	0.016	5.50	8.93	85%	EX-I-1	0.42	UPSIZE TO TYPE DOUBLE GRATE
EX-I-3	0.16	0.53	5.00	6.49	0.55	0.70	NYLOPLAST 15" DRAIN BASIN	0.020	0.016	2.00	5.34	83%	EX-I-2	0.12	UPSIZE TO 24" NYLOPLAST
EX-I-4	0.15	0.49	5.00	6.49	0.48	0.79	NYLOPLAST 15" DRAIN BASIN	0.020	0.016	2.00	5.59	81%	EX-I-3	0.15	UPSIZE TO 24" NYLOPLAST
EX-I-5	0.29	0.42	5.00	6.49	0.79	1.15	NYLOPLAST 15" DRAIN BASIN	0.020	0.016	2.00	6.43	73%	EX-I-4	0.31	UPSIZE TO 24" NYLOPLAST
EX-I-6	0.28	0.46	5.00	6.49	0.84	0.96	NYLOPLAST 15" DRAIN BASIN	0.020	0.016	2.00	6.01	74%	I-11	0.25	UPSIZE TO 24" NYLOPLAST
EX-I-7	1.66	0.31	21.00	3.90	2.00	2.00	TYPE K INLET	0.020	0.016	3.00	7.92	94%	EX-I-6	0.12	
EX-I-8	0.17	0.40	5.00	6.49	0.44	0.83	NYLOPLAST 15" DRAIN BASIN	0.008	0.010	2.00	11.03	49%	EX-I-1	0.42	UPSIZE TO 24" NYLOPLAST
EX-I-9	0.09	0.46	5.00	6.49	0.27	0.77	NYLOPLAST 15" DRAIN BASIN	0.008	0.010	2.00	10.72	50%	EX-I-8	0.39	UPSIZE TO 24" NYLOPLAST
I-10	2.35	0.33	24.00	3.70	2.87	2.87	TYPE K INLET	N/A	N/A	3.00	N/A*	100%	EX-I-2	0.00	*DITCH INLET AT LOW POINT, SPREAD WOULD LIKELY BE IN GRASS AREA, NOT ROADWAY
I-11	0.19	0.44	5.00	6.49	0.54	0.80	NYLOPLAST 15" DRAIN BASIN	0.020	0.016	2.000	5.620	55%	EX-I-5	0.36	UPSIZE TO 24" NYLOPLAST
I-12	2.78	0.39	11.40	5.25	5.69	5.69	TYPE S DOUBLE GRATE INLET	0.008	0.010	5.500	N/A*	60%	EX-I-2	2.28	*SPREAD WOULD LIKELY BE IN GRASSED AREA, NOT ROADWAY.
I-13	0.14	0.47	5.00	6.49	0.43	1.74	TYPE S DOUBLE GRATE INLET	0.008	0.010	5.500	14.550	71%	EX-I-9	0.51	
I-14	0.77	0.47	5.00	6.49	2.35	2.35	TYPE K INLET	N/A	N/A	3.00	N/A*	44%	I-13	1.32	*INLET NOT LOCATED ALONG ROADWAY

PROJECT: Chesapeake Road Drainage Improvements Concept

CHARLESTOWN WATERSHED MANAGEMENT PLAN - COST ESTIMATE

Date: 12/27/2023

Item Number	Description	Unit	Estimated Quantity	Unit Price	Total Cost
Cat. 100	**Preliminary**				
1001	Construction Stakeout	LS	1	$2,500.00	$2,500
1002	Mobilization	LS	1	$15,000.00	$15,000
1003	Maintenance of Traffic	LS	1	$5,000.00	$5,000
				Sub-Total	***$22,500***
Cat. 200	**Grading**				
2001	Class 1 Excavation	CY	1200	$50.00	$60,000
2002	Select Borrow	CY	885	$50.00	$44,250
2003	Utility Test Pit Excavation	CY	5	$200.00	$1,000
				Sub-Total	***$105,250***
Cat. 300	**Drainage**				
3001	Erosion & Sediment Control	LS	1	$15,000.00	$15,000
3002	15 Inch HDPE	LF	446	$60.00	$26,760
3003	18 Inch HDPE	LF	766	$75.00	$57,450
3004	Nyloplast 24" Drain Basin, Ductile Iron Frame and Grate	EA	7	$2,500.00	$17,500
3005	Standard Type S Inlet, Double Grate	EA	3	$5,000.00	$15,000
3006	Custom Type S Inlet, Double Grate with Junction Box	EA	1	$8,000.00	$8,000
3007	Standard Double or Single Opening Type K Inlet	EA	3	$5,000.00	$15,000
3008	5 FT X 5 FT Standard Concrete Junction Box	EA	1	$8,000.00	$8,000
3009	Custom Type C Endwall for Double 18 Inch Pipes	EA	1	$8,000.00	$8,000
3010	Mix 6 Concrete for Miscellanous Structures (Concrete Gutter)	CY	30	$150.00	$4,500
3011	Flowable Backfill for Pipe Abandonment	CY	20	$200.00	$4,000
				Sub-Total	***$179,210***
Cat. 500	**Paving**				
5001	Standard Milling Asphalt Pavement Over 1 Inch to 2.5 Inch Depth	SY	2050	$5.00	$10,250
5002	Superpave Asphalt Mix 9.5MM for Wedge/Level, PG 64S-22, Level 2	TN	375	$100.00	$37,500
					$0
				Sub-Total	***$47,750***
Cat. 700	**Landscaping**				
7001	Furnished Topsoil 2" Depth	SY	1450	$5.00	$7,250
7002	Turfgrass Establishment	SY	1450	$5.00	$7,250
7003	Type A Soil Stabilization Matting	SY	1450	$5.00	$7,250
				Sub-Total	***$21,750***
Sub-total (all categories)					***$376,460***
Contingency (35%)					***$131,761***
Design (20%)					***$101,644***
Total:					**$609,865**

NOTES:

1. Cost assumes all excavation is removed from site and all fill is purchased
2. Quantities are estimated based on limited site information
3. Unit prices include O&P of 15%

Dewberry

APPENDIX B:

TRINITY WOODS SWM #1/FEMA PROPERTY PROJECT

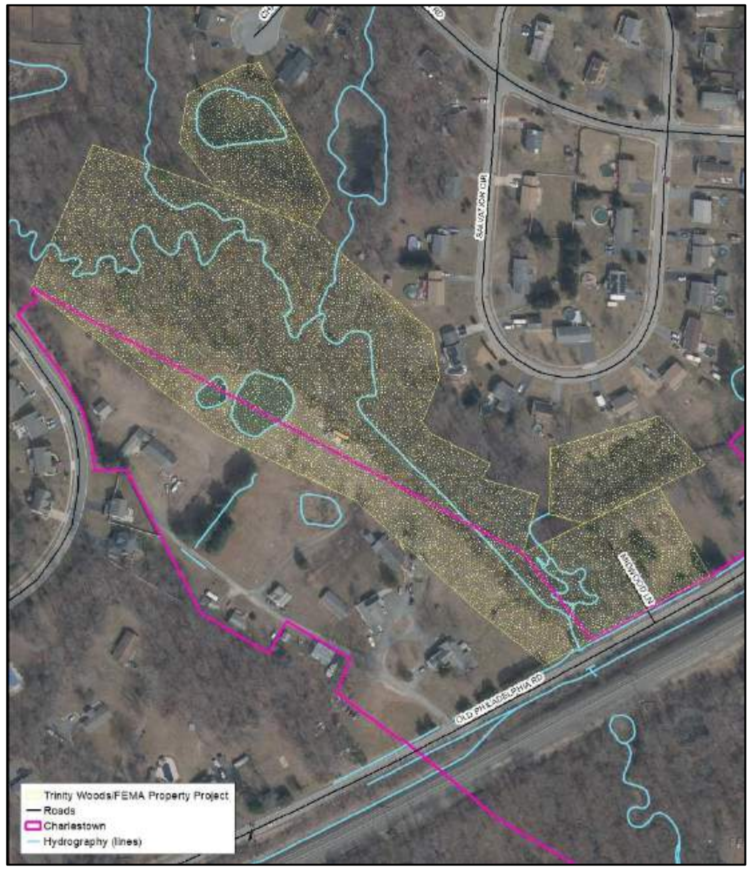
Introduction

The Trinity Woods/FEMA Property Project encompasses several opportunities in and around the Trinity Woods subdivision that were identified through the community surveys, community workshops, and modeling effort: Trinity Woods SWM #1/FEMA Property Project, Trinity Woods SWM #2 & #3 BMP Retrofits, Trinity Woods Upland Retrofits, and Peddlers Creek Stream Restoration/Floodplain Reconnection. A concept plan was developed for one approach for the Trinity Woods SWM #1/FEMA Property project with alternative restoration approaches described below. If additional funding becomes available, additional opportunities to provide water quantity and quality management should be evaluated further.

Site Name: Trinity Woods SWM #1/FEMA Property Project

General Project Information:	
Project Location:	1243 W. Old Philadelphia Road
Northing/Easting:	1601495.50/ 698733.62
PCSWMM Sewershed:	Peddlers Creek Upstream
Prioritization Score:	224
Planning Level Cost Estimate:	$987,802

Required Permitting:	
Charlestown SWM Review:	X
Erosion & Sediment Control (ESC):	X
Grading Permit:	X
Joint Permit Application (JPA)/ General Waterway Construction Permit:	X
Construction NOI:	X
Chesapeake Bay Critical Area:	X
Forest Resource Ordinance:	X
MDE Dam Safety:	X



Vicinity map for the Trinity Woods/FEMA Buyout Property Project

Existing Site Conditions

The point of interest (POI) for the Trinity Woods SWM #1/FEMA Property project is located on the east side of the mainstem of Peddlers Creek at the existing 48” cross culvert under W. Old Philadelphia Road (MD 7). Immediately downstream of the State Highway Administration (SHA) culvert, is a second 48” culvert which conveys the mainstem of Peddlers Creek under the existing Amtrak railroad (Photo 1*). A consultant for SHA completed a hydrologic and hydraulic investigation of the flooding conditions in April 2001 and at that time determined the culvert was undersized. Recurring flooding continues to be a reported problem at this location due to the undersized culverts (Photo 2). The Town of Charlestown should continue to work to partner with SHA and Amtrak to evaluate and implement options to increase the capacity of the 48” cross culverts under MD 7 and the Amtrak railroad.

The property adjacent to Peddlers Creek on the east (1243 W. Old Philadelphia Road) was purchased through a FEMA buyout program due to repetitive loss from flooding (Photo 3). The property is now owned by the Town of Charlestown. There is no existing infrastructure located on the property. The Trinity Woods stormwater management facility (SWM) #1 is located on the lot immediately north of 1243 W. Old Philadelphia Road. It was designed in 1992 as an extended detention dry pond. There are two inflow points to the facility – Inflow #1 is a 30” CMP that drains into the northwest corner of the facility and Inflow #2 is a 24” CMP that drains into the northeast corner of the facility. Both inflows convey stormwater flows from Salvation Circle. Water within the facility is conveyed through a pilot channel to a 42” CMP riser with a 36” CMP principal spillway. The facility has an 8’ emergency spillway designed for the 100-year storm event. According to a July 2022 facility inspection, the pond is overgrown with trees and other vegetation. The pipes, flared end sections, riprap outfalls, riser, and principal spillway are clogged and in poor condition showing signs of corrosion. The entire facility needs maintenance.

Runoff from the north side of Revelation Road and the rear of houses along Salvation Circle and W. Old Philadelphia Road (northeast of 1243 W. Old Philadelphia Road) is conveyed to the POI via an undefined channel. Runoff flows south along an existing sewer easement. The undefined channel takes an almost 90-degree turn to the east between 1227 and 1237 W. Old Philadelphia Road and discharges to a roadside ditch on the northwest side of MD 7 (Photo 4*). Several reports of backyard flooding were received from residents in this area. Runoff from W. Old Philadelphia Road is conveyed to the POI via a roadside ditch (Photo 5*).
*Note: Photos 1, 4, and 5 courtesy of Google Street View.

Proposed Conditions

Several options were explored during the concept design. In the short-term, the Trinity Woods SWM #1/FEMA Property project is intended to reduce flooding impacts to the east of the POI and provide the needed maintenance for Trinity Woods SWM #1. Depending on the final design approach, the retrofit may also provide water quality treatment for existing untreated impervious. Additional approaches for consideration during the final design stage are also provided.

The Trinity Woods SWM #1/FEMA Property project includes retrofitting the Trinity Woods SWM #1 into a multi-cell pond. The existing facility will be retrofitted to current Maryland SWM design standards. Forebays at Inflows #1 and #2 will be added to provide pre-treatment for flows from Salvation Circle. A second pond cell will expand the facility's storage capacity and will capture redirected flows from Revelation Road. The existing CMP riser and principal spillway will be removed, and a weir constructed between the two pond cells. All flow will be discharged via a new riser and principal spillway located in the second pond cell. Drainage channel improvements are proposed along the existing sewer easement to capture flows from the existing storm drain under Revelation Road. The final design of the proposed drainage channel will need to consider the location and depth of the existing sewer line and potential private property and tree impacts. The improved drainage channel will convey flow to a proposed catch basin which will re-direct runoff to the second pond cell via a proposed 24" RCP pipe. The multi-cell pond approach was selected for expanding Trinity Woods SWM #1 primarily because of the existing ten-foot fill embankment on the south side of the pond. Impacts to this existing embankment would require significant earthwork in order to maintain the storage capacity of the existing pond. Any work within Trinity Woods SWM #1 and the addition of the second pond cell will require review from MDE Dam Safety.

Additional approaches for consideration during final design include:

- Peddlers Creek Stream Restoration/Floodplain Reconnection: The headwaters of Peddlers Creek are located outside Town boundaries, north of Pulaski Highway (US 40) within the Principio Business Park. The drainage area (~600 acres) south of US 40 is largely forested and undeveloped. The portion of Peddlers Creek north of MD 7 (approximately 3200 linear feet), is largely located on property owned by the Trinity Woods and Cool Springs subdivision. A stream assessment should be performed to assess the current condition of the stream. If the stream is in poor condition, a stream restoration/floodplain reconnection/wetland complex project would provide more access to the floodplain in areas upstream of the MD 7/Amtrak culverts, increasing the storage area for flood waters during times of peak flow.
- Trinity Woods SWM #2 & #3 BMP Retrofits: The Trinity Woods Subdivision includes two additional existing SWM facilities that were designed prior to current Maryland SWM design standards – SWM #2 designed in 2006 and SWM #3 designed in 2000. Both facilities should be evaluated for retrofit opportunity to provide additional water quality and quantity treatment.
- Trinity Woods Upland Retrofits: A broader assessment and feasibility study should be performed to evaluate opportunities to install green infrastructure practices in open space areas throughout the community.

NOTE: One of the main sources of flooding at this location is due to the undersized culverts at MD 7 and the Amtrak railroad. The solutions proposed above can be used to help alleviate the impacts of the flooding, but this area will likely continue to experience flooding during large storm events due to the bottlenecking occurring at these culverts. Coordination with SHA and Amtrak should occur separately regarding upsizing these culverts for adequate conveyance during large storm events.

Anticipated Site Constraints

There are several site constraints which could impact the feasibility of a project in this location:

- Sanitary Sewer/Water Lines: There are existing water and sanitary sewer lines throughout the project area. There is a sanitary sewer line that runs east/west from Revelation Road to a junction with another sewer line that runs north/south between Salvation Court and MD 7. A water line runs north/south parallel to this second sewer line and connects to a water line that runs along MD 7. The location and depth of the sewer and water lines will need to be determined during final design to minimize impacts.

- Dam Embankment: The Trinity Woods SWM #1 facility includes a fill embankment and based on the preliminary analysis, it appears it could be classified as a significant or high hazard dam based on its height. A full analysis using MDE's Dam Breach Analysis and Hazard Classification Resources, including MDE's Guidance for Completing a Dam Breach Analysis for Small Ponds and Dams in Maryland (2018) should be performed. This could impact cost and schedule for design, permitting, and construction.
- Natural Resources: There are mapped wetlands, wetland buffers, and existing forest on 1243 W. Old Philadelphia Road property and adjacent to Trinity Woods SWM #1. The area along the existing sanitary sewer line that runs behind the houses where the proposed drainage channel modifications are located appears to have trees in existing conditions. The final design should minimize impacts to wetlands, wetland buffers, and trees/forest to the greatest extent practicable.

Summary of Results

Preliminary computations were performed based on available GIS storm drain information, GIS contours, and as-built plans of the area. The purpose of the analysis was to compare the existing and proposed peak discharges at the POI located just upstream of the existing 48" cross culverts, to see how flows from the east could be attenuated to reduce impacts to already strained conditions at the existing culverts. The drainage area to this POI is 35.23 acres, which is a fraction of the total 608 acres that drains to the culverts. The analysis was conducted in HydroCAD, which utilizes TR-20 methodology.

In existing conditions, the existing Trinity Woods SWM Pond #1 captures flow from 10.48 acres of the Trinity Woods neighborhood and has an existing storage capacity of 3.37 acre-feet. The remaining area bypasses the pond and flows to the POI unmanaged. In proposed conditions, Trinity Woods SWM Pond #1 will be retrofit and expanded into a two-cell pond, with a concrete weir between the two cells. The proposed second cell will receive previously unmanaged flow from the channel within the sewer easement, diverting flow away from MD-7 and the homes upstream of 1243 W. Old Philadelphia Road. The proposed two-cell pond will have the capacity to provide 5.65 acre-feet of storage, and the total area being managed by the ponds will be 23.62 acres.

Results of the HydroCAD analyses show that the proposed design will reduce peak discharges to the POI in the 10-, 50-, and 100-year storms, and are summarized in the table below. The peak discharge for the drainage area not draining into Trinity Woods SWM Pond #1 is also greatly reduced, mitigating the impacts of potential flooding along MD 7 from the northeast. Note that these results are preliminary and should be evaluated further once survey has been obtained and the pond can be designed/modeled in more detail.

	10-YEAR PEAK DISCHARGE	50-YEAR PEAK DISCHARGE	100-YEAR PEAK DISCHARGE
Overall POI Existing	44.13 cfs	76.90 cfs	94.34 cfs
Overall POI Proposed	27.36 cfs	68.46 cfs	81.23 cfs
Bypass (unmanaged) Existing	42.65 cfs	75.03 cfs	92.31 cfs
Bypass (unmanaged) Proposed	20.76 cfs	36.07 cfs	44.21 cfs

Photo 1: Peddlers Creek crossing at MD 7 and Amtrak cross culvert

Photo 2: Photo submitted by resident of flooding at the MD 7/Peddlers Run crossing

Photo 3: 1243 W. Old Philadelphia Road facing northeast looking towards Peddlers Creek

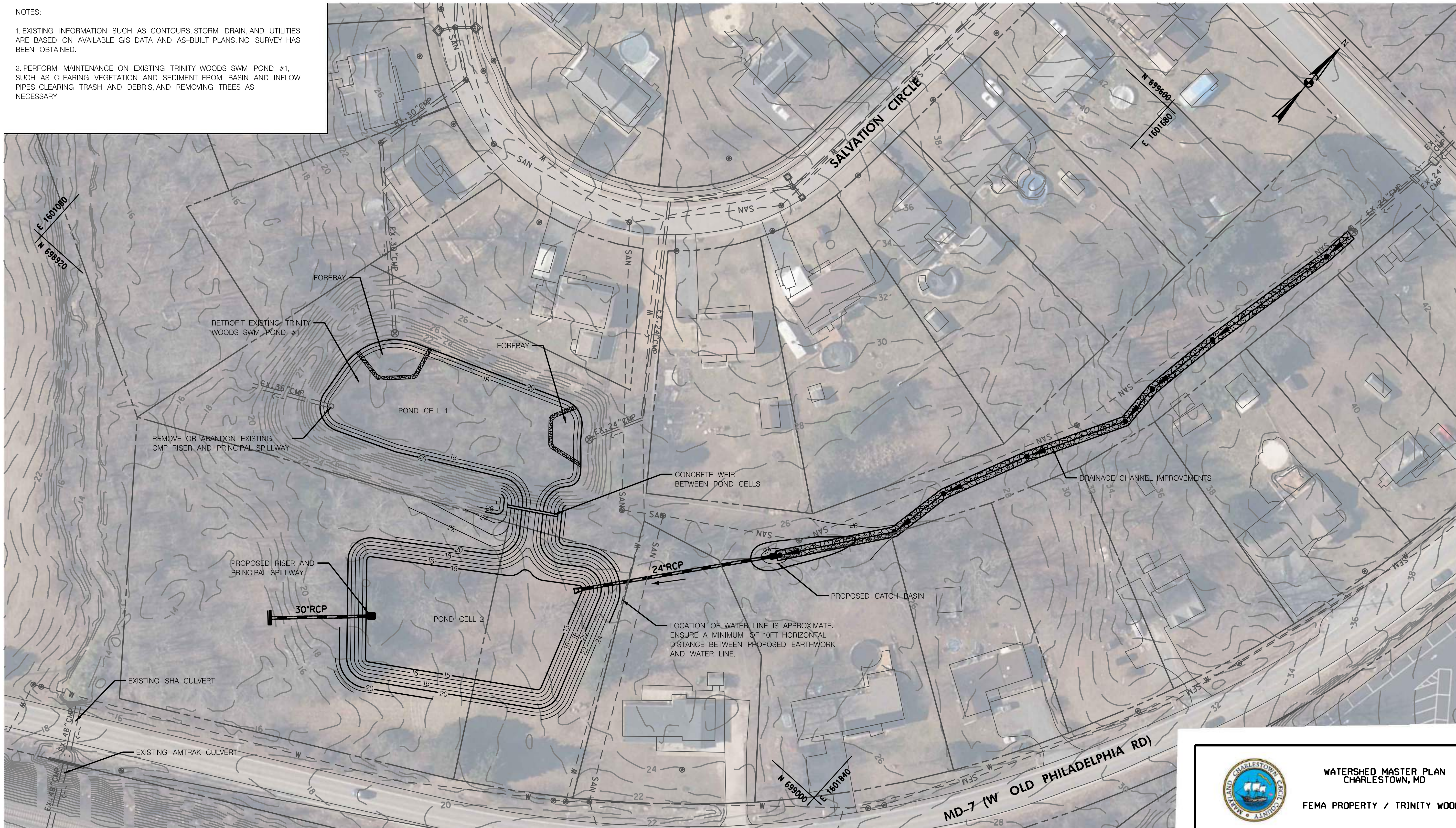
Photo 4: Ditch which conveys runoff between 1227 and 1237 W. Old Philadelphia Road

Photo 5: Roadside ditch which conveys runoff from MD 7 to Peddlers Creek

NOTES:

1. EXISTING INFORMATION SUCH AS CONTOURS, STORM DRAIN, AND UTILITIES ARE BASED ON AVAILABLE GIS DATA AND AS-BUILT PLANS. NO SURVEY HAS BEEN OBTAINED.

2. PERFORM MAINTENANCE ON EXISTING TRINITY WOODS SWM POND #1, SUCH AS CLEARING VEGETATION AND SEDIMENT FROM BASIN AND INFLOW PIPES, CLEARING TRASH AND DEBRIS, AND REMOVING TREES AS NECESSARY.



75' 0 75' 150'

SCALE: 1" = 75'

FOR INFORMATIONAL PURPOSES ONLY. NOT FOR CONSTRUCTION.

Dewberry®
Dewberry Engineers
10461 MILL RUN CIRCLE
SUITE #300
OWINGS MILLS, MARYLAND 21117
PHONE: 410.265.9500
FAX: 410.265.8875

LEGEND

—15—	EXISTING CONTOURS	—20—	PROPOSED CONTOURS
EX. 15"HDPE	EXISTING STORM DRAIN	18"HDPE	PROPOSED STORM DRAIN
– – – –	RIGHT-OF-WAY / PARCELS	[riprap symbol]	RIPRAP FOR CHANNEL LINING

WATERSHED MASTER PLAN
CHARLESTOWN, MD

FEMA PROPERTY / TRINITY WOODS

STORMWATER DESIGN CONCEPT

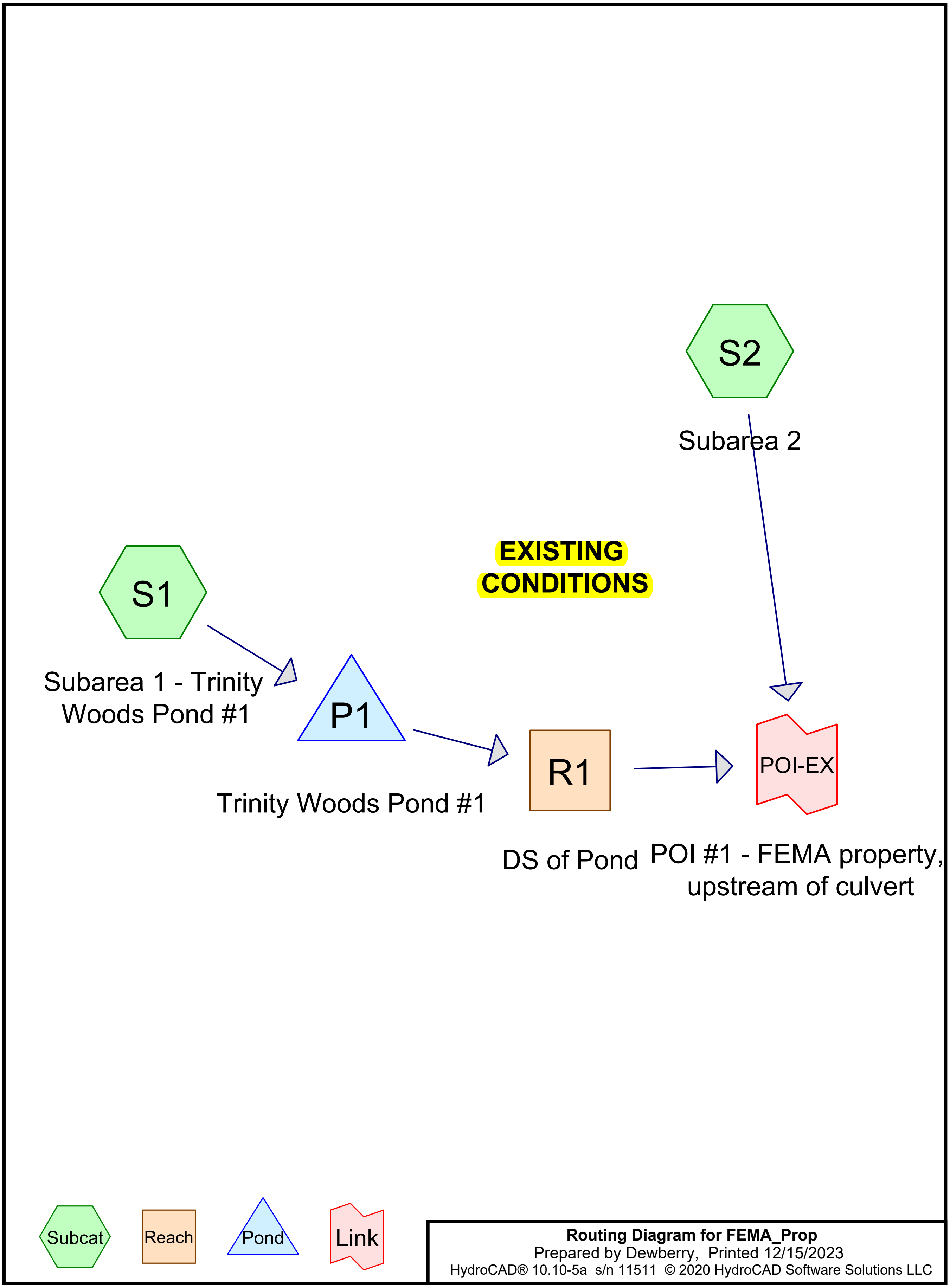
SCALE 1" = 75' ADVERTISED DATE ______ CONTRACT NO. ______

DESIGNED BY AC
DRAWN BY AC
CHECKED BY ND

COUNTY CECIL COUNTY
LOGMILE ______
HORIZONTAL SCALE ______
VERTICAL SCALE ______

DRAWING NO. SW- 01 OF 01 SHEET NO. 1 OF 1

BY: aconley -



Routing Diagram for FEMA_Prop
Prepared by Dewberry, Printed 12/15/2023
HydroCAD® 10.10-5a s/n 11511 © 2020 HydroCAD Software Solutions LLC

Project Notes

Rainfall events imported from "NRCS-Rain.txt" for 5006 MD Cecil

Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	10-Year	NOAA 24-hr	C	Default	24.00	1	4.87	2
2	50-Year	NOAA 24-hr	C	Default	24.00	1	7.01	2
3	100-Year	NOAA 24-hr	C	Default	24.00	1	8.12	2

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
1.022	72	1/3 acre lots, 30% imp, HSG B (S1, S2)
16.021	81	1/3 acre lots, 30% imp, HSG C (S1, S2)
1.541	86	1/3 acre lots, 30% imp, HSG D (S1, S2)
0.914	61	>75% Grass cover, Good, HSG B (S2)
0.075	74	>75% Grass cover, Good, HSG C (S2)
0.081	98	Paved parking, HSG B (S1, S2)
3.089	98	Paved parking, HSG C (S1, S2)
0.058	98	Paved parking, HSG D (S1, S2)
1.953	55	Woods, Good, HSG B (S1, S2)
7.764	70	Woods, Good, HSG C (S1, S2)
2.715	77	Woods, Good, HSG D (S1, S2)
35.233	**78**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
3.970	HSG B	S1, S2
26.949	HSG C	S1, S2
4.314	HSG D	S1, S2
0.000	Other	
35.233		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	1.022	16.021	1.541	0.000	18.584	1/3 acre lots, 30% imp	S1, S2
0.000	0.914	0.075	0.000	0.000	0.989	>75% Grass cover, Good	S2
0.000	0.081	3.089	0.058	0.000	3.228	Paved parking	S1, S2
0.000	1.953	7.764	2.715	0.000	12.432	Woods, Good	S1, S2
0.000	**3.970**	**26.949**	**4.314**	**0.000**	**35.233**	**TOTAL AREA**	

Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

SubcatchmentS1: Subarea 1 - Trinity Runoff Area=10.482 ac 39.75% Impervious Runoff Depth=2.96"
Flow Length=1,450' Tc=22.1 min CN=82 Runoff=24.90 cfs 2.588 af

SubcatchmentS2: Subarea 2 Runoff Area=24.751 ac 18.73% Impervious Runoff Depth=2.43"
Flow Length=2,891' Tc=28.4 min CN=76 Runoff=42.65 cfs 5.010 af

Reach R1: DS of Pond Avg. Flow Depth=0.13' Max Vel=1.30 fps Inflow=1.92 cfs 2.578 af
n=0.030 L=340.0' S=0.0113 '/' Capacity=74.01 cfs Outflow=1.92 cfs 2.578 af

Pond P1: Trinity Woods Pond #1 Peak Elev=22.37' Storage=64,308 cf Inflow=24.90 cfs 2.588 af
Outflow=1.92 cfs 2.578 af

Link POI-EX: POI #1 - FEMA property, upstream of culvert Inflow=44.13 cfs 7.587 af
Primary=44.13 cfs 7.587 af

Total Runoff Area = 35.233 ac Runoff Volume = 7.598 af Average Runoff Depth = 2.59"
75.01% Pervious = 26.430 ac 24.99% Impervious = 8.803 ac

Summary for Subcatchment S1: Subarea 1 - Trinity Woods Pond #1

Segment C-D is average pipe size and average slope.

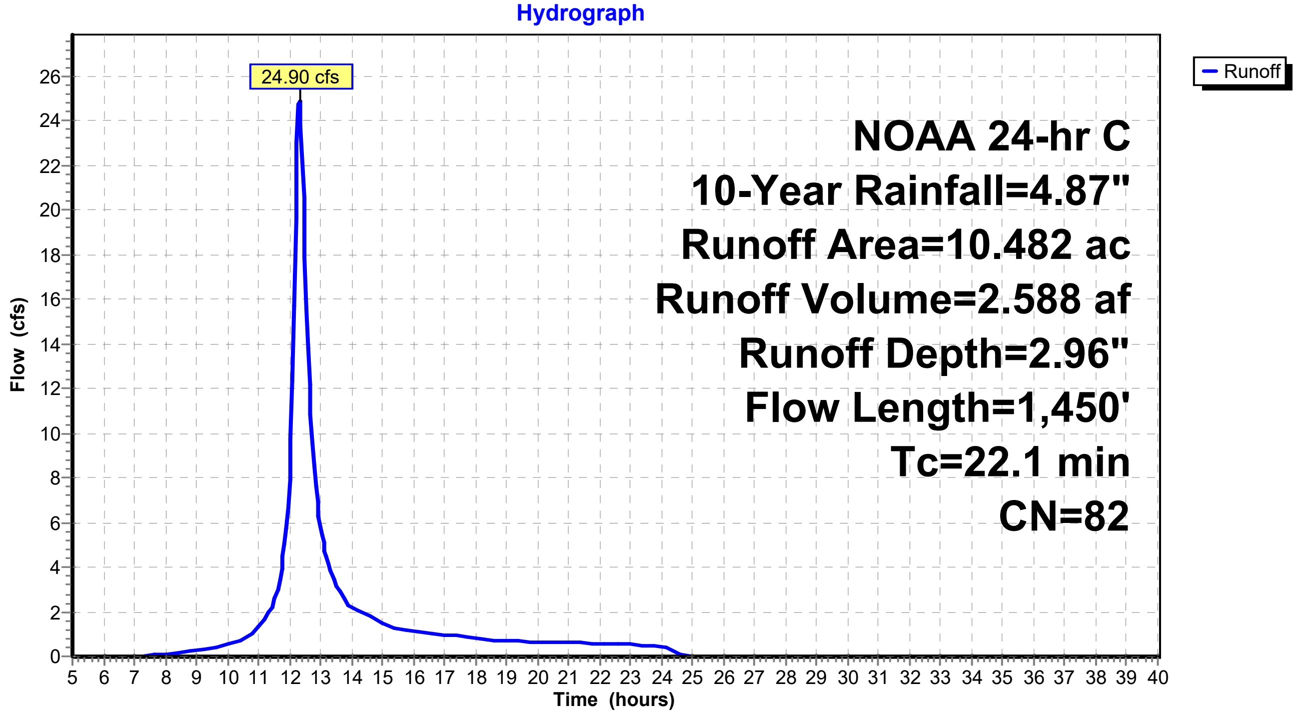
Runoff = 24.90 cfs @ 12.32 hrs, Volume= 2.588 af, Depth= 2.96"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 10-Year Rainfall=4.87"

Area (ac)	CN	Description
0.014	98	Paved parking, HSG B
1.774	98	Paved parking, HSG C
0.023	98	Paved parking, HSG D
0.375	72	1/3 acre lots, 30% imp, HSG B
7.105	81	1/3 acre lots, 30% imp, HSG C
0.372	86	1/3 acre lots, 30% imp, HSG D
0.417	55	Woods, Good, HSG B
0.177	70	Woods, Good, HSG C
0.225	77	Woods, Good, HSG D
10.482	82	Weighted Average
6.315		60.25% Pervious Area
4.167		39.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.2	100	0.1000	0.15		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
0.5	124	0.0600	3.94		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
10.4	1,226	0.0300	1.96	0.02	**Pipe Channel, C-D (outfall to pond)** 1.5" Round Area= 0.0 sf Perim= 0.4' r= 0.03' n= 0.013 Concrete pipe, bends & connections
22.1	1,450	Total			

Subcatchment S1: Subarea 1 - Trinity Woods Pond #1



Summary for Subcatchment S2: Subarea 2

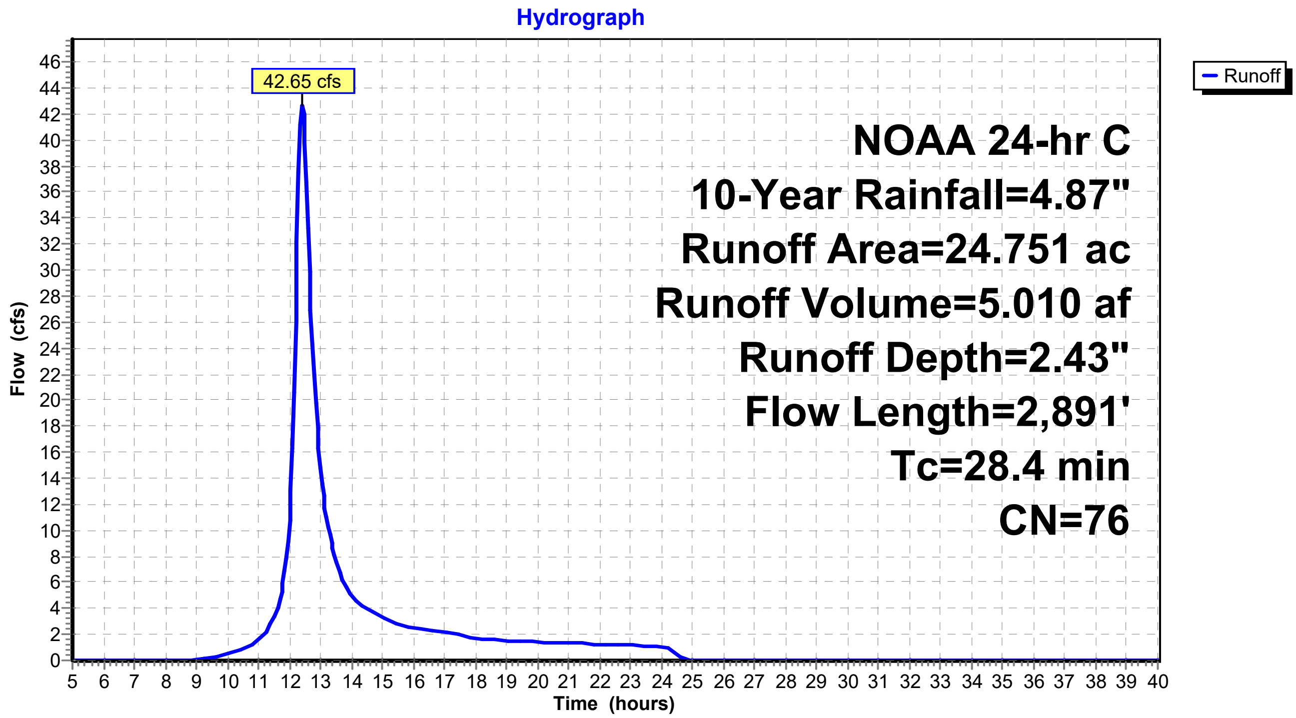
Runoff = 42.65 cfs @ 12.41 hrs, Volume= 5.010 af, Depth= 2.43"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 10-Year Rainfall=4.87"

Area (ac)	CN	Description
0.067	98	Paved parking, HSG B
1.315	98	Paved parking, HSG C
0.035	98	Paved parking, HSG D
0.914	61	>75% Grass cover, Good, HSG B
0.075	74	>75% Grass cover, Good, HSG C
0.647	72	1/3 acre lots, 30% imp, HSG B
8.916	81	1/3 acre lots, 30% imp, HSG C
1.169	86	1/3 acre lots, 30% imp, HSG D
1.536	55	Woods, Good, HSG B
7.587	70	Woods, Good, HSG C
2.490	77	Woods, Good, HSG D
24.751	76	Weighted Average
20.114		81.27% Pervious Area
4.637		18.73% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.8	100	0.0500	0.11		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
5.5	923	0.0300	2.79		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
1.4	322	0.0300	3.85	4.81	**Trap/Vee/Rect Channel Flow, C-D** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
0.6	387	0.0300	10.30	18.19	**Pipe Channel, D-E** 18.0" Round Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.013 Concrete pipe, bends & connections
6.1	1,159	0.0200	3.14	3.93	**Trap/Vee/Rect Channel Flow, E-F (POI)** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
28.4	2,891	Total			

Subcatchment S2: Subarea 2



Summary for Reach R1: DS of Pond

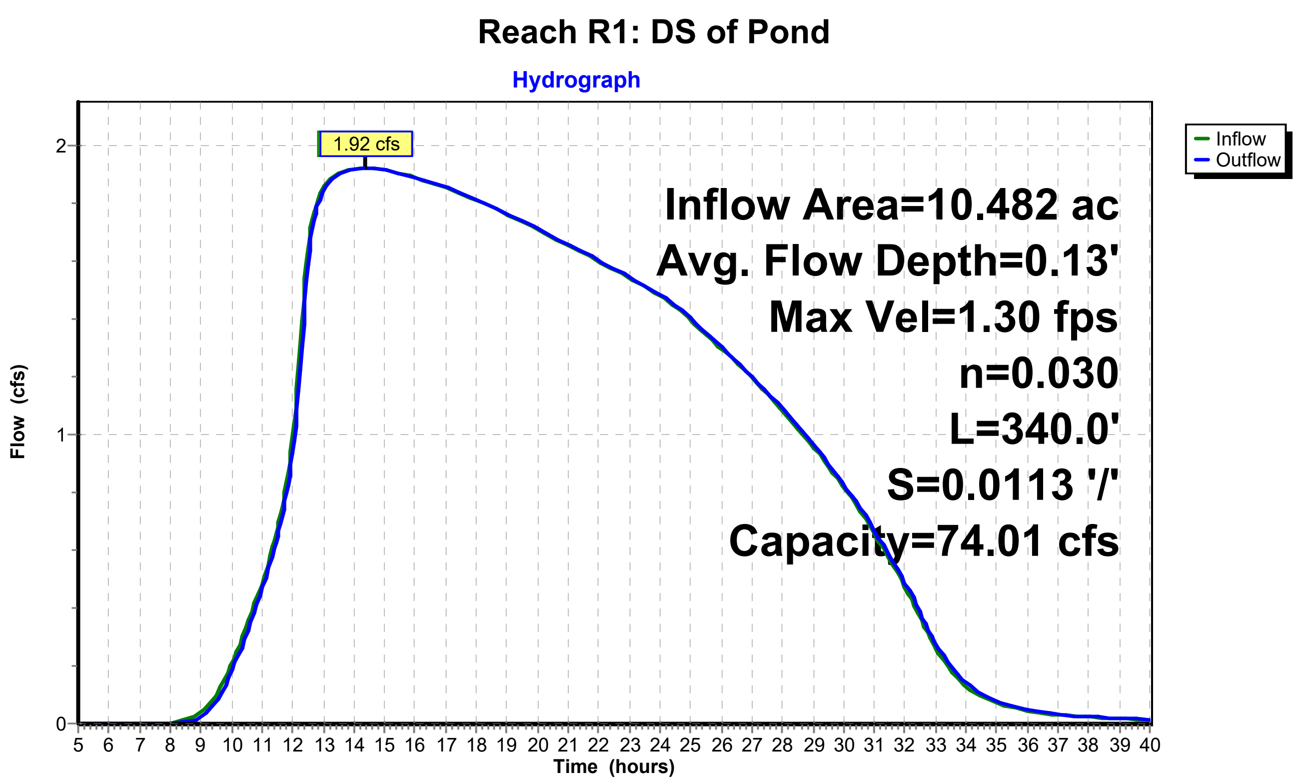
Inflow Area = 10.482 ac, 39.75% Impervious, Inflow Depth > 2.95" for 10-Year event
Inflow = 1.92 cfs @ 14.36 hrs, Volume= 2.578 af
Outflow = 1.92 cfs @ 14.40 hrs, Volume= 2.578 af, Atten= 0%, Lag= 2.8 min

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.30 fps, Min. Travel Time= 4.4 min
Avg. Velocity = 0.88 fps, Avg. Travel Time= 6.4 min

Peak Storage= 503 cf @ 14.40 hrs
Average Depth at Peak Storage= 0.13' , Surface Width= 12.14'
Bank-Full Depth= 1.00' Flow Area= 18.0 sf, Capacity= 74.01 cfs

10.00' x 1.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 8.0 '/' Top Width= 26.00'
Length= 340.0' Slope= 0.0113 '/'
Inlet Invert= 17.85', Outlet Invert= 14.00'

‡



Summary for Pond P1: Trinity Woods Pond #1

Inflow Area = 10.482 ac, 39.75% Impervious, Inflow Depth = 2.96" for 10-Year event
Inflow = 24.90 cfs @ 12.32 hrs, Volume= 2.588 af
Outflow = 1.92 cfs @ 14.36 hrs, Volume= 2.578 af, Atten= 92%, Lag= 122.1 min
Primary = 1.92 cfs @ 14.36 hrs, Volume= 2.578 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 22.37' @ 14.36 hrs Surf.Area= 20,080 sf Storage= 64,308 cf

Plug-Flow detention time= 400.3 min calculated for 2.578 af (100% of inflow)
Center-of-Mass det. time= 397.9 min (1,233.4 - 835.4)

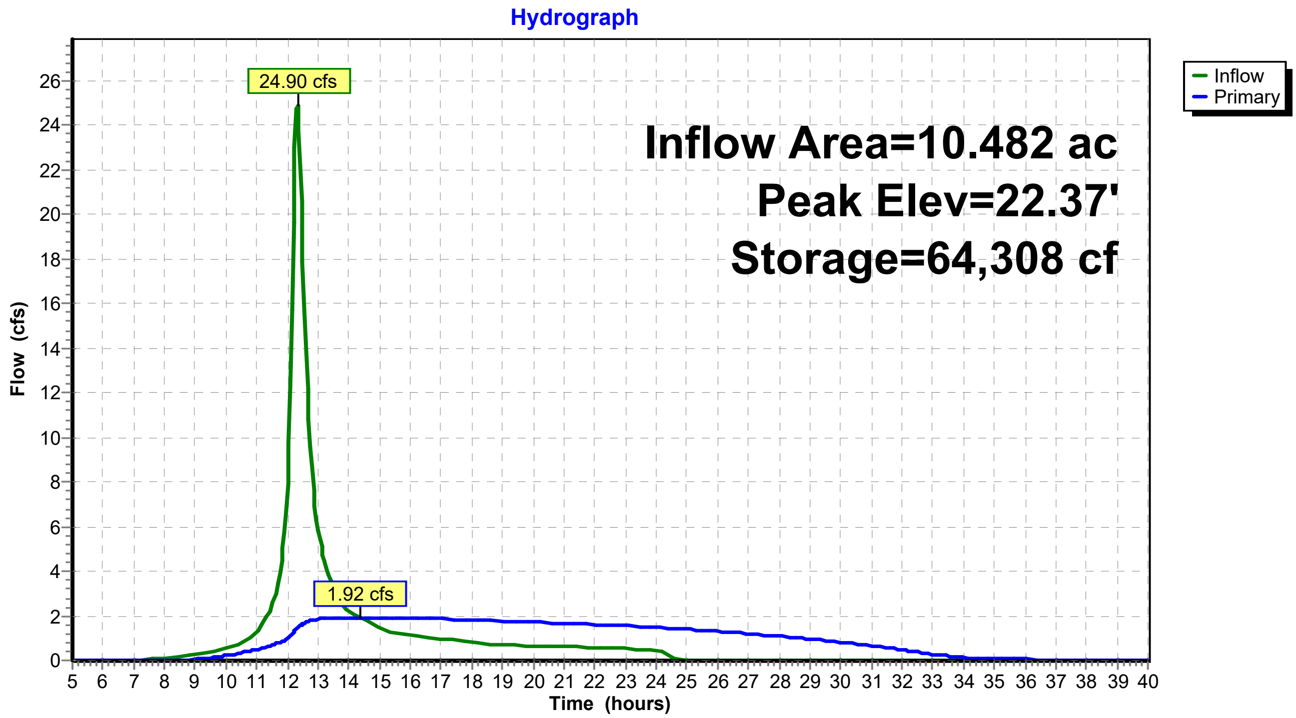
Volume	Invert	Avail.Storage	Storage Description
#1	18.00'	146,776 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
18.00	5,296	0	0
19.00	10,800	8,048	8,048
20.00	15,897	13,349	21,397
21.00	17,900	16,899	38,295
22.00	19,525	18,713	57,008
23.00	21,031	20,278	77,286
24.00	22,435	21,733	99,019
25.00	23,872	23,154	122,172
26.00	25,335	24,604	146,776

Device	Routing	Invert	Outlet Devices
#1	Primary	18.00'	**30.0" Round Culvert** L= 47.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 18.00' / 17.85' S= 0.0032 '/' Cc= 0.900 n= 0.024 Corrugated metal, Flow Area= 4.91 sf
#2	Device 1	18.00'	**6.0" Vert. Low Flow Pipe** C= 0.600 Limited to weir flow at low heads
#3	Device 1	24.20'	**42.0" Horiz. Top of Riser** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=1.92 cfs @ 14.36 hrs HW=22.37' TW=17.98' (Dynamic Tailwater)
└1=**Culvert** (Passes 1.92 cfs of 32.41 cfs potential flow)
  ├2=**Low Flow Pipe** (Orifice Controls 1.92 cfs @ 9.77 fps)
  └3=**Top of Riser** (Controls 0.00 cfs)

Pond P1: Trinity Woods Pond #1

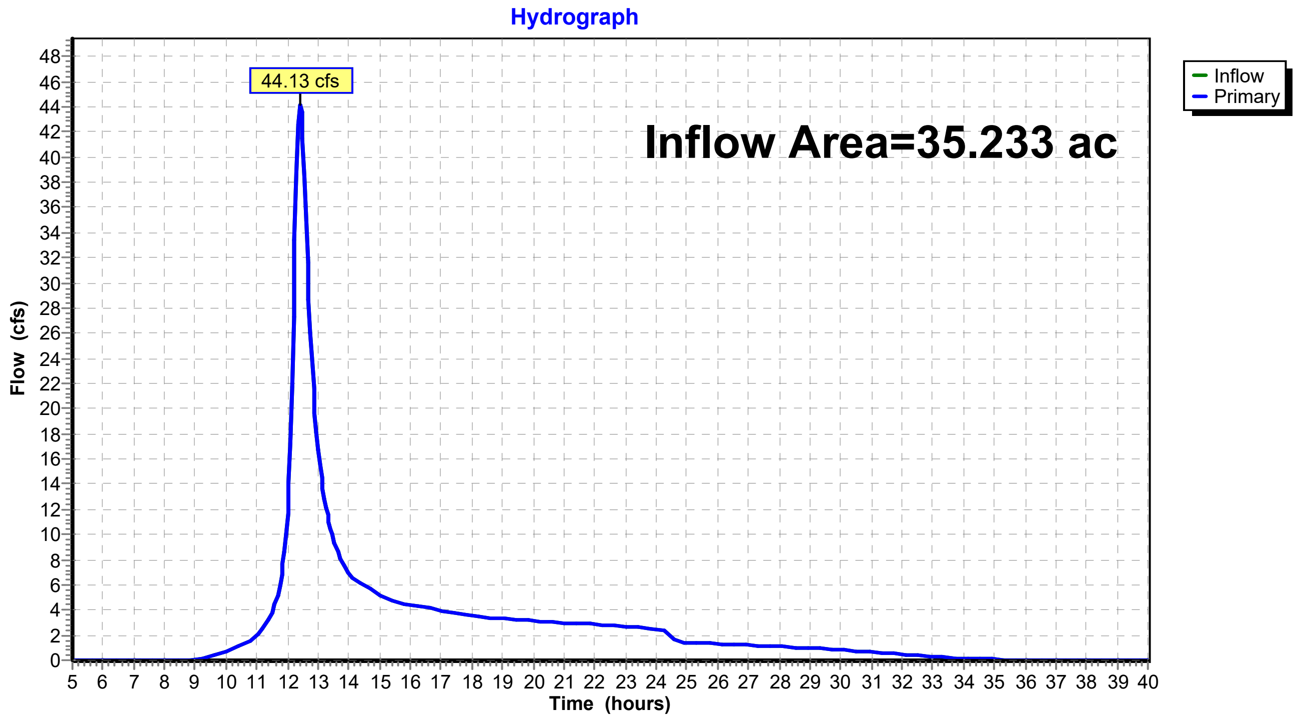


Summary for Link POI-EX: POI #1 - FEMA property, upstream of culvert

Inflow Area = 35.233 ac, 24.99% Impervious, Inflow Depth > 2.58" for 10-Year event
Inflow = 44.13 cfs @ 12.41 hrs, Volume= 7.587 af
Primary = 44.13 cfs @ 12.41 hrs, Volume= 7.587 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs

Link POI-EX: POI #1 - FEMA property, upstream of culvert



Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

SubcatchmentS1: Subarea 1 - Trinity Runoff Area=10.482 ac 39.75% Impervious Runoff Depth=4.93"
Flow Length=1,450' Tc=22.1 min CN=82 Runoff=40.85 cfs 4.302 af

SubcatchmentS2: Subarea 2 Runoff Area=24.751 ac 18.73% Impervious Runoff Depth=4.27"
Flow Length=2,891' Tc=28.4 min CN=76 Runoff=75.03 cfs 8.799 af

Reach R1: DS of Pond Avg. Flow Depth=0.24' Max Vel=1.82 fps Inflow=5.10 cfs 4.271 af
n=0.030 L=340.0' S=0.0113 '/' Capacity=74.01 cfs Outflow=5.09 cfs 4.268 af

Pond P1: Trinity Woods Pond #1 Peak Elev=24.38' Storage=107,656 cf Inflow=40.85 cfs 4.302 af
Outflow=5.10 cfs 4.271 af

Link POI-EX: POI #1 - FEMA property, upstream of culvert Inflow=76.90 cfs 13.068 af
Primary=76.90 cfs 13.068 af

Total Runoff Area = 35.233 ac Runoff Volume = 13.102 af Average Runoff Depth = 4.46"
75.01% Pervious = 26.430 ac 24.99% Impervious = 8.803 ac

Summary for Subcatchment S1: Subarea 1 - Trinity Woods Pond #1

Segment C-D is average pipe size and average slope.

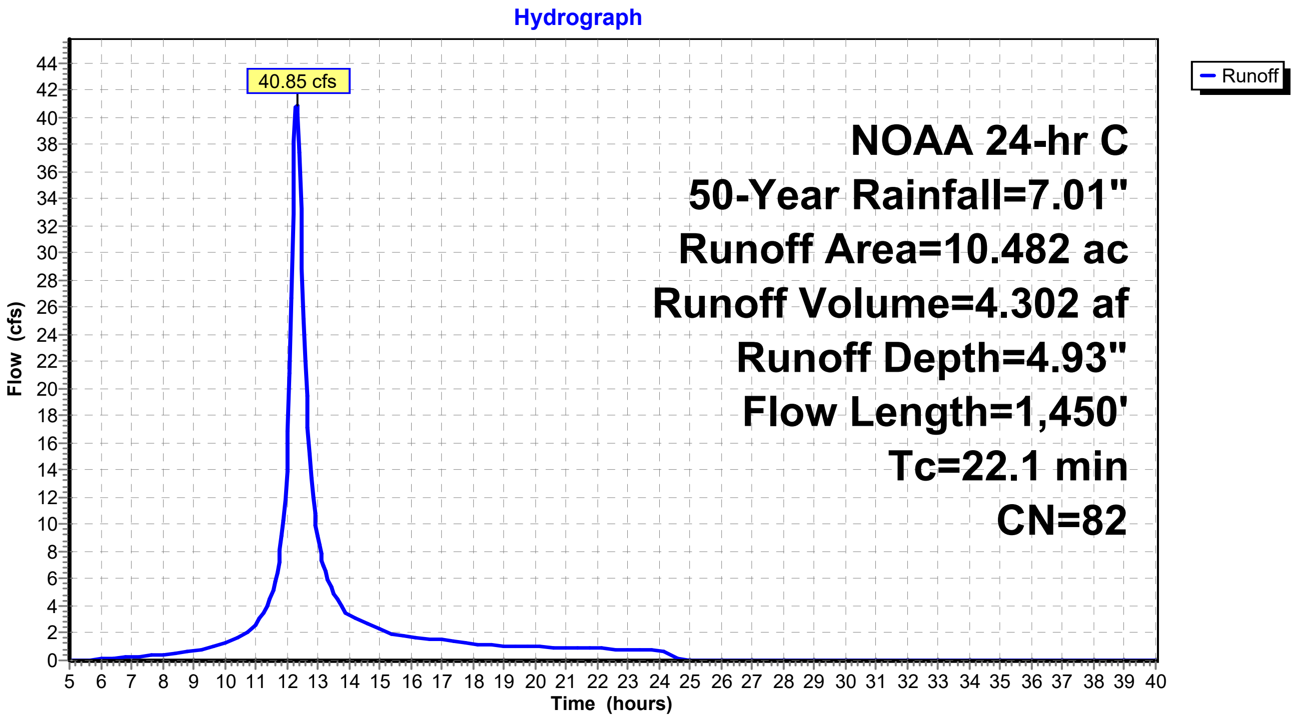
Runoff = 40.85 cfs @ 12.32 hrs, Volume= 4.302 af, Depth= 4.93"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 50-Year Rainfall=7.01"

Area (ac)	CN	Description
0.014	98	Paved parking, HSG B
1.774	98	Paved parking, HSG C
0.023	98	Paved parking, HSG D
0.375	72	1/3 acre lots, 30% imp, HSG B
7.105	81	1/3 acre lots, 30% imp, HSG C
0.372	86	1/3 acre lots, 30% imp, HSG D
0.417	55	Woods, Good, HSG B
0.177	70	Woods, Good, HSG C
0.225	77	Woods, Good, HSG D
10.482	82	Weighted Average
6.315		60.25% Pervious Area
4.167		39.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.2	100	0.1000	0.15		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
0.5	124	0.0600	3.94		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
10.4	1,226	0.0300	1.96	0.02	**Pipe Channel, C-D (outfall to pond)** 1.5" Round Area= 0.0 sf Perim= 0.4' r= 0.03' n= 0.013 Concrete pipe, bends & connections
22.1	1,450	Total			

Subcatchment S1: Subarea 1 - Trinity Woods Pond #1



Summary for Subcatchment S2: Subarea 2

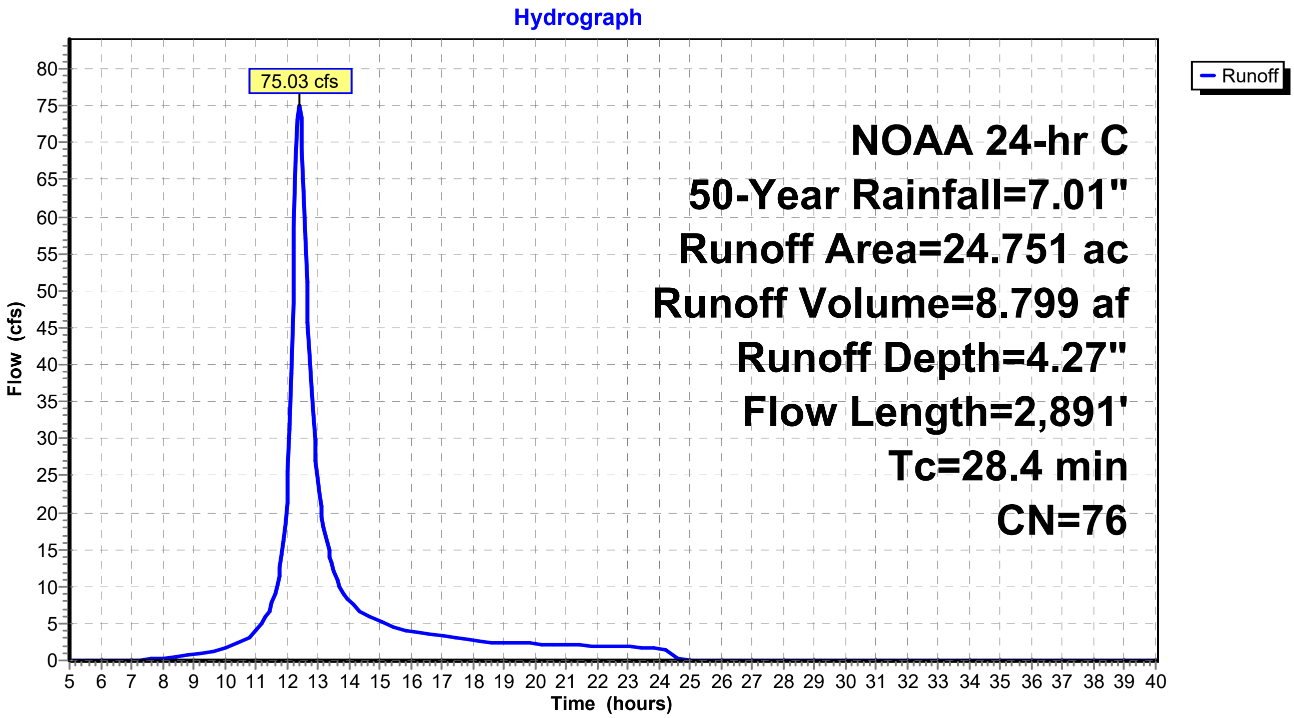
Runoff = 75.03 cfs @ 12.40 hrs, Volume= 8.799 af, Depth= 4.27"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 50-Year Rainfall=7.01"

Area (ac)	CN	Description
0.067	98	Paved parking, HSG B
1.315	98	Paved parking, HSG C
0.035	98	Paved parking, HSG D
0.914	61	>75% Grass cover, Good, HSG B
0.075	74	>75% Grass cover, Good, HSG C
0.647	72	1/3 acre lots, 30% imp, HSG B
8.916	81	1/3 acre lots, 30% imp, HSG C
1.169	86	1/3 acre lots, 30% imp, HSG D
1.536	55	Woods, Good, HSG B
7.587	70	Woods, Good, HSG C
2.490	77	Woods, Good, HSG D
24.751	76	Weighted Average
20.114		81.27% Pervious Area
4.637		18.73% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.8	100	0.0500	0.11		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
5.5	923	0.0300	2.79		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
1.4	322	0.0300	3.85	4.81	**Trap/Vee/Rect Channel Flow, C-D** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
0.6	387	0.0300	10.30	18.19	**Pipe Channel, D-E** 18.0" Round Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.013 Concrete pipe, bends & connections
6.1	1,159	0.0200	3.14	3.93	**Trap/Vee/Rect Channel Flow, E-F (POI)** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
28.4	2,891	Total			

Subcatchment S2: Subarea 2



Summary for Reach R1: DS of Pond

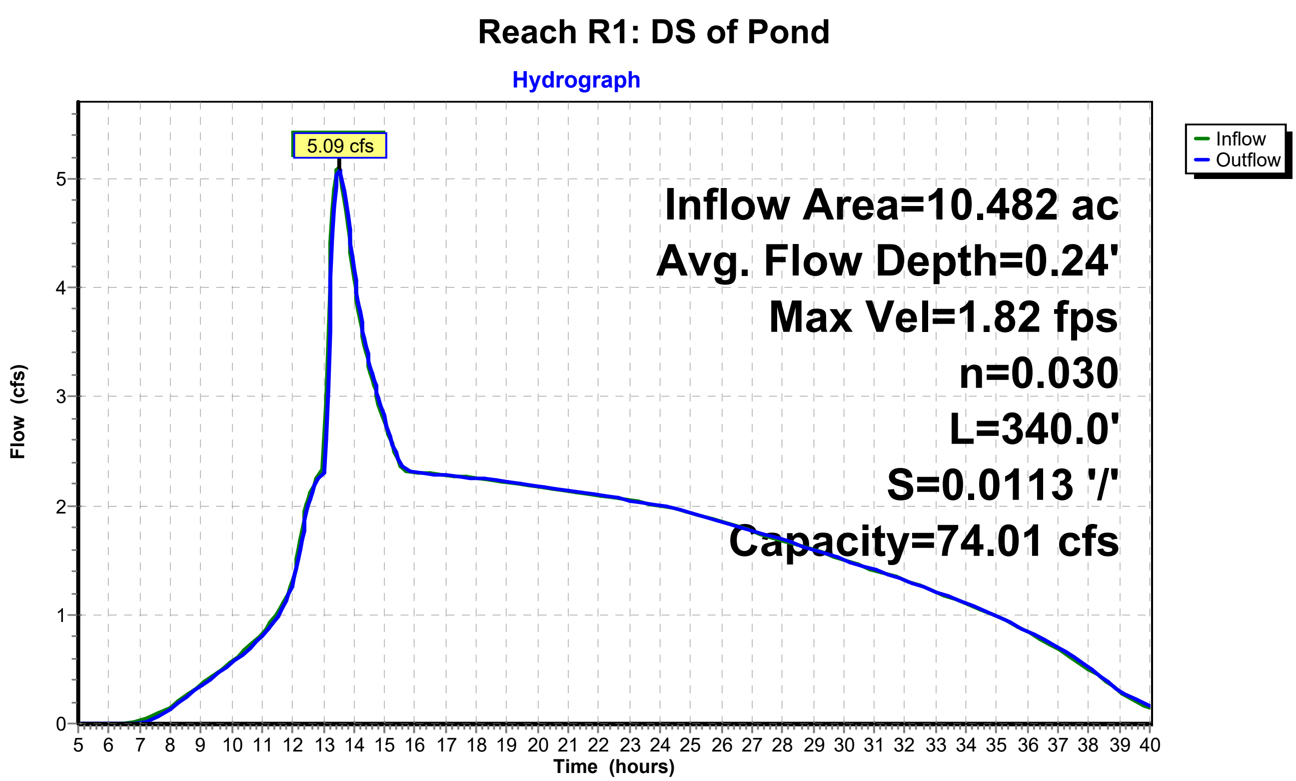
Inflow Area = 10.482 ac, 39.75% Impervious, Inflow Depth > 4.89" for 50-Year event
Inflow = 5.10 cfs @ 13.49 hrs, Volume= 4.271 af
Outflow = 5.09 cfs @ 13.52 hrs, Volume= 4.268 af, Atten= 0%, Lag= 2.2 min

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.82 fps, Min. Travel Time= 3.1 min
Avg. Velocity = 1.10 fps, Avg. Travel Time= 5.1 min

Peak Storage= 951 cf @ 13.52 hrs
Average Depth at Peak Storage= 0.24' , Surface Width= 13.76'
Bank-Full Depth= 1.00' Flow Area= 18.0 sf, Capacity= 74.01 cfs

10.00' x 1.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 8.0 '/' Top Width= 26.00'
Length= 340.0' Slope= 0.0113 '/'
Inlet Invert= 17.85', Outlet Invert= 14.00'

‡



Summary for Pond P1: Trinity Woods Pond #1

Inflow Area = 10.482 ac, 39.75% Impervious, Inflow Depth = 4.93" for 50-Year event
Inflow = 40.85 cfs @ 12.32 hrs, Volume= 4.302 af
Outflow = 5.10 cfs @ 13.49 hrs, Volume= 4.271 af, Atten= 88%, Lag= 70.1 min
Primary = 5.10 cfs @ 13.49 hrs, Volume= 4.271 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 24.38' @ 13.49 hrs Surf.Area= 22,982 sf Storage= 107,656 cf

Plug-Flow detention time= 499.8 min calculated for 4.264 af (99% of inflow)
Center-of-Mass det. time= 495.8 min (1,316.5 - 820.7)

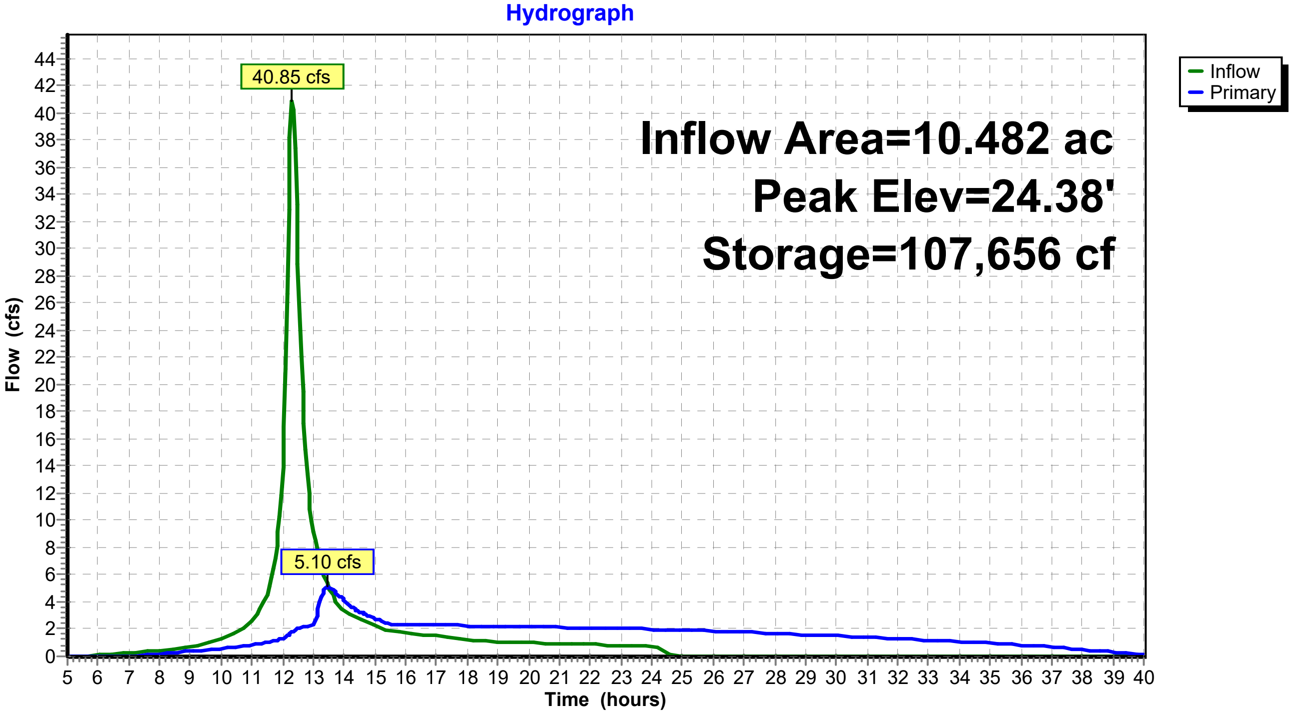
Volume	Invert	Avail.Storage	Storage Description
#1	18.00'	146,776 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
18.00	5,296	0	0
19.00	10,800	8,048	8,048
20.00	15,897	13,349	21,397
21.00	17,900	16,899	38,295
22.00	19,525	18,713	57,008
23.00	21,031	20,278	77,286
24.00	22,435	21,733	99,019
25.00	23,872	23,154	122,172
26.00	25,335	24,604	146,776

Device	Routing	Invert	Outlet Devices
#1	Primary	18.00'	**30.0" Round Culvert** L= 47.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 18.00' / 17.85' S= 0.0032 '/' Cc= 0.900 n= 0.024 Corrugated metal, Flow Area= 4.91 sf
#2	Device 1	18.00'	**6.0" Vert. Low Flow Pipe** C= 0.600 Limited to weir flow at low heads
#3	Device 1	24.20'	**42.0" Horiz. Top of Riser** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=5.09 cfs @ 13.49 hrs HW=24.38' TW=18.08' (Dynamic Tailwater)
└**1=Culvert** (Passes 5.09 cfs of 45.79 cfs potential flow)
 ├**2=Low Flow Pipe** (Orifice Controls 2.34 cfs @ 11.92 fps)
 └**3=Top of Riser** (Weir Controls 2.75 cfs @ 1.39 fps)

Pond P1: Trinity Woods Pond #1

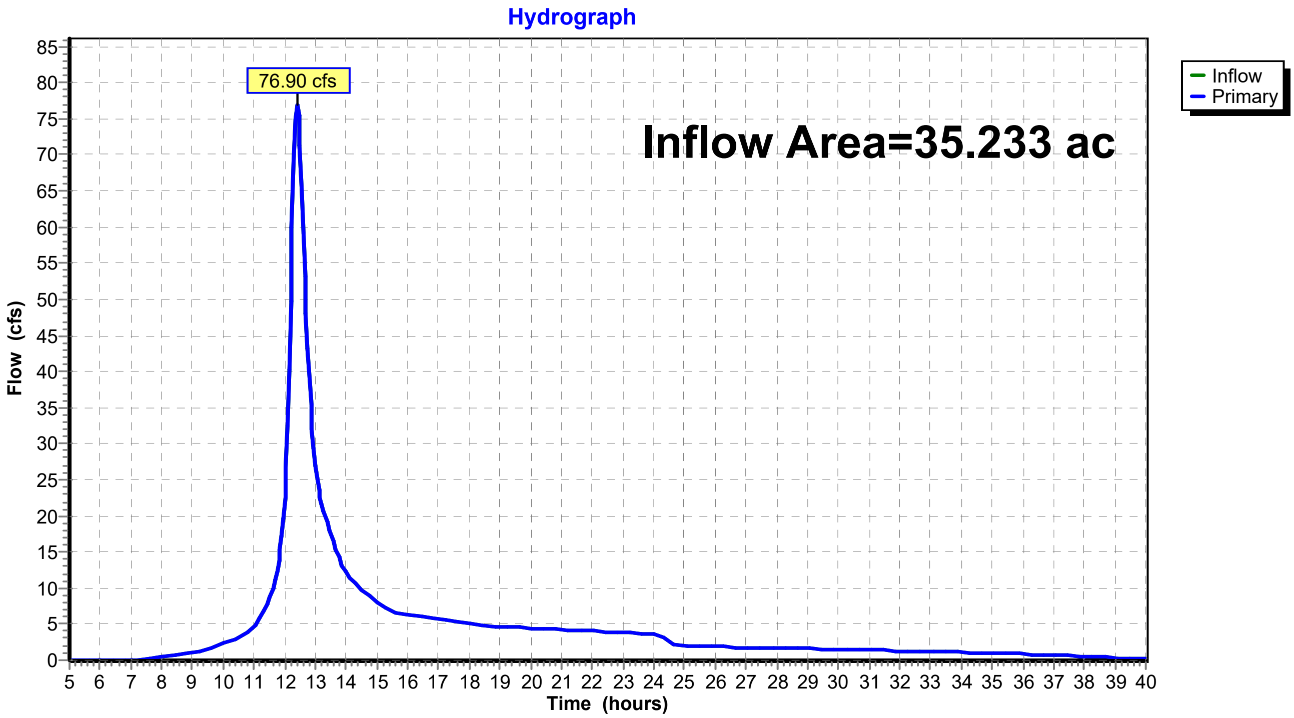


Summary for Link POI-EX: POI #1 - FEMA property, upstream of culvert

Inflow Area = 35.233 ac, 24.99% Impervious, Inflow Depth > 4.45" for 50-Year event
Inflow = 76.90 cfs @ 12.40 hrs, Volume= 13.068 af
Primary = 76.90 cfs @ 12.40 hrs, Volume= 13.068 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs

Link POI-EX: POI #1 - FEMA property, upstream of culvert



Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

SubcatchmentS1: Subarea 1 - Trinity Runoff Area=10.482 ac 39.75% Impervious Runoff Depth>5.97"
Flow Length=1,450' Tc=22.1 min CN=82 Runoff=49.17 cfs 5.218 af

SubcatchmentS2: Subarea 2 Runoff Area=24.751 ac 18.73% Impervious Runoff Depth=5.27"
Flow Length=2,891' Tc=28.4 min CN=76 Runoff=92.31 cfs 10.864 af

Reach R1: DS of Pond Avg. Flow Depth=0.42' Max Vel=2.52 fps Inflow=14.03 cfs 5.174 af
n=0.030 L=340.0' S=0.0113 '/' Capacity=74.01 cfs Outflow=13.96 cfs 5.171 af

Pond P1: Trinity Woods Pond #1 Peak Elev=24.67' Storage=114,406 cf Inflow=49.17 cfs 5.218 af
Outflow=14.03 cfs 5.174 af

Link POI-EX: POI #1 - FEMA property, upstream of culvert Inflow=94.34 cfs 16.035 af
Primary=94.34 cfs 16.035 af

Total Runoff Area = 35.233 ac Runoff Volume = 16.082 af Average Runoff Depth = 5.48"
75.01% Pervious = 26.430 ac 24.99% Impervious = 8.803 ac

Summary for Subcatchment S1: Subarea 1 - Trinity Woods Pond #1

Segment C-D is average pipe size and average slope.

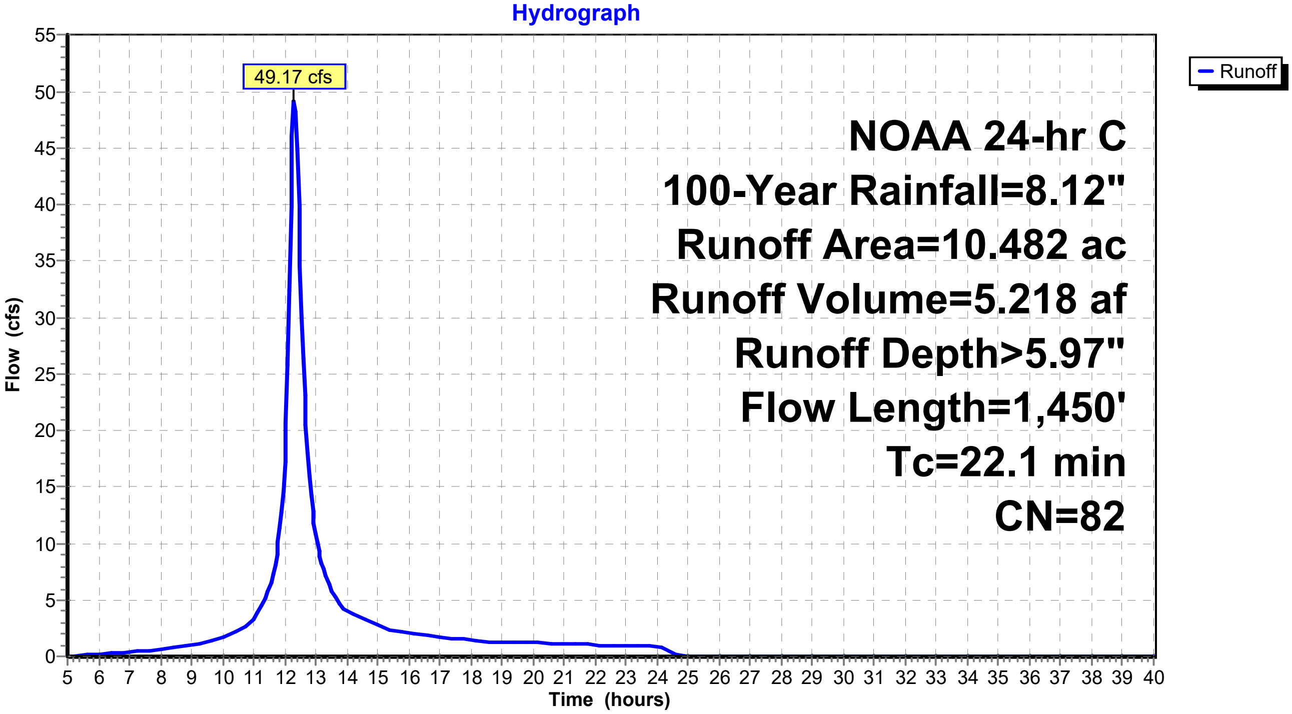
Runoff = 49.17 cfs @ 12.32 hrs, Volume= 5.218 af, Depth> 5.97"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 100-Year Rainfall=8.12"

Area (ac)	CN	Description
0.014	98	Paved parking, HSG B
1.774	98	Paved parking, HSG C
0.023	98	Paved parking, HSG D
0.375	72	1/3 acre lots, 30% imp, HSG B
7.105	81	1/3 acre lots, 30% imp, HSG C
0.372	86	1/3 acre lots, 30% imp, HSG D
0.417	55	Woods, Good, HSG B
0.177	70	Woods, Good, HSG C
0.225	77	Woods, Good, HSG D
10.482	82	Weighted Average
6.315		60.25% Pervious Area
4.167		39.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.2	100	0.1000	0.15		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
0.5	124	0.0600	3.94		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
10.4	1,226	0.0300	1.96	0.02	**Pipe Channel, C-D (outfall to pond)** 1.5" Round Area= 0.0 sf Perim= 0.4' r= 0.03' n= 0.013 Concrete pipe, bends & connections
22.1	1,450	Total			

Subcatchment S1: Subarea 1 - Trinity Woods Pond #1



Summary for Subcatchment S2: Subarea 2

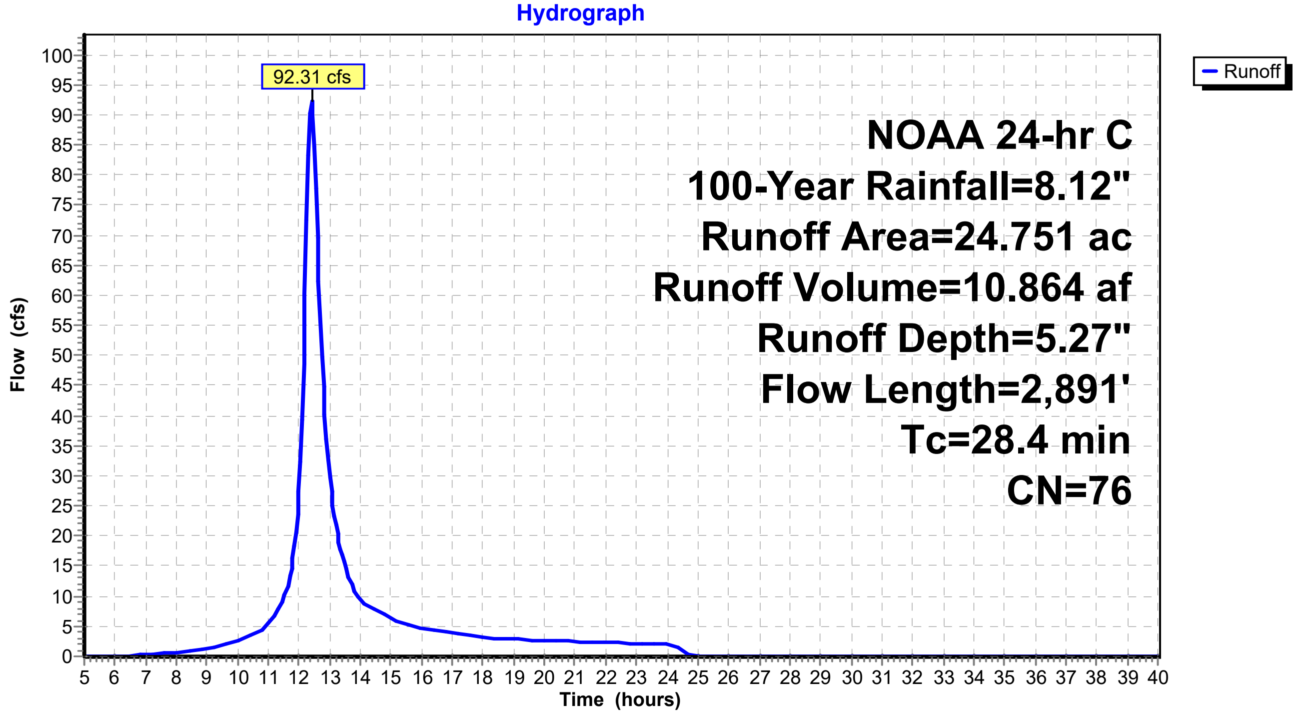
Runoff = 92.31 cfs @ 12.40 hrs, Volume= 10.864 af, Depth= 5.27"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 100-Year Rainfall=8.12"

Area (ac)	CN	Description
0.067	98	Paved parking, HSG B
1.315	98	Paved parking, HSG C
0.035	98	Paved parking, HSG D
0.914	61	>75% Grass cover, Good, HSG B
0.075	74	>75% Grass cover, Good, HSG C
0.647	72	1/3 acre lots, 30% imp, HSG B
8.916	81	1/3 acre lots, 30% imp, HSG C
1.169	86	1/3 acre lots, 30% imp, HSG D
1.536	55	Woods, Good, HSG B
7.587	70	Woods, Good, HSG C
2.490	77	Woods, Good, HSG D
24.751	76	Weighted Average
20.114		81.27% Pervious Area
4.637		18.73% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.8	100	0.0500	0.11		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
5.5	923	0.0300	2.79		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
1.4	322	0.0300	3.85	4.81	**Trap/Vee/Rect Channel Flow, C-D** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
0.6	387	0.0300	10.30	18.19	**Pipe Channel, D-E** 18.0" Round Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.013 Concrete pipe, bends & connections
6.1	1,159	0.0200	3.14	3.93	**Trap/Vee/Rect Channel Flow, E-F (POI)** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
28.4	2,891	Total			

Subcatchment S2: Subarea 2



Summary for Reach R1: DS of Pond

Inflow Area = 10.482 ac, 39.75% Impervious, Inflow Depth > 5.92" for 100-Year event
Inflow = 14.03 cfs @ 12.86 hrs, Volume= 5.174 af
Outflow = 13.96 cfs @ 12.89 hrs, Volume= 5.171 af, Atten= 1%, Lag= 1.8 min

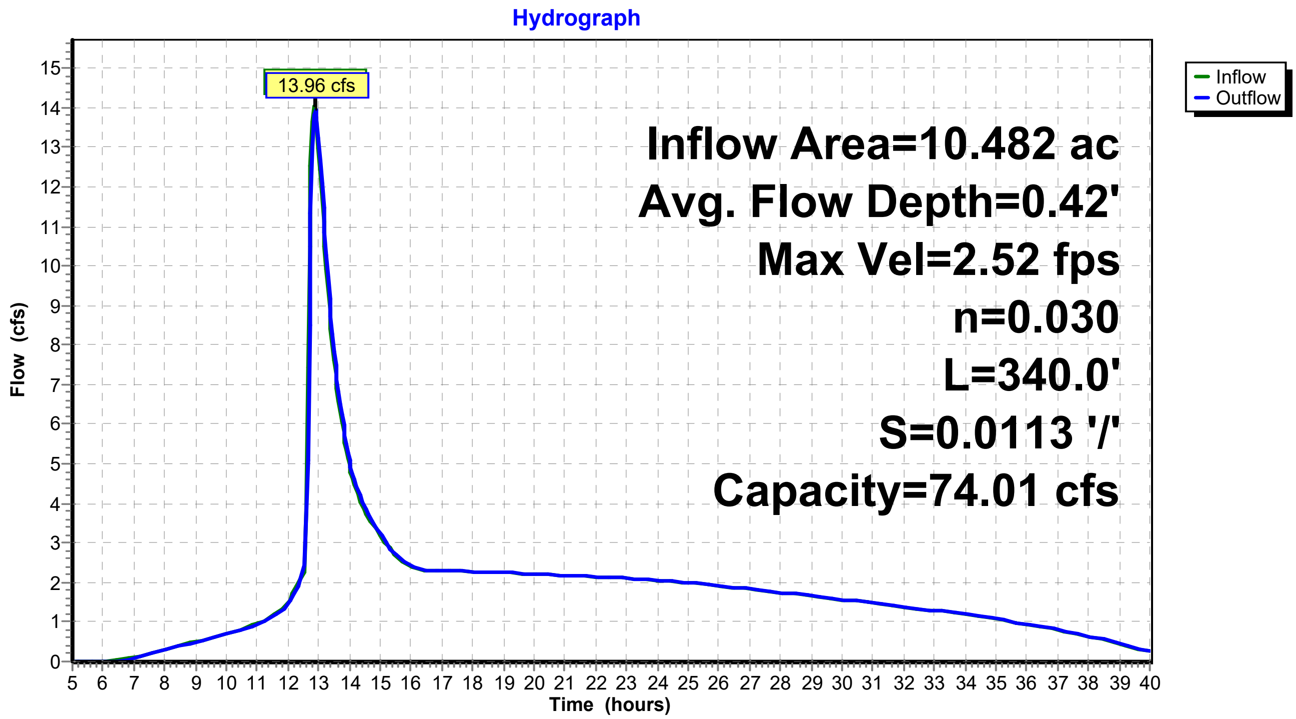
Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.52 fps, Min. Travel Time= 2.2 min
Avg. Velocity = 1.15 fps, Avg. Travel Time= 4.9 min

Peak Storage= 1,881 cf @ 12.89 hrs
Average Depth at Peak Storage= 0.42' , Surface Width= 16.64'
Bank-Full Depth= 1.00' Flow Area= 18.0 sf, Capacity= 74.01 cfs

10.00' x 1.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 8.0 '/' Top Width= 26.00'
Length= 340.0' Slope= 0.0113 '/'
Inlet Invert= 17.85', Outlet Invert= 14.00'

‡

Reach R1: DS of Pond



Summary for Pond P1: Trinity Woods Pond #1

Inflow Area = 10.482 ac, 39.75% Impervious, Inflow Depth > 5.97" for 100-Year event
Inflow = 49.17 cfs @ 12.32 hrs, Volume= 5.218 af
Outflow = 14.03 cfs @ 12.86 hrs, Volume= 5.174 af, Atten= 71%, Lag= 32.9 min
Primary = 14.03 cfs @ 12.86 hrs, Volume= 5.174 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 24.67' @ 12.86 hrs Surf.Area= 23,400 sf Storage= 114,406 cf

Plug-Flow detention time= 440.8 min calculated for 5.167 af (99% of inflow)
Center-of-Mass det. time= 436.3 min (1,251.5 - 815.2)

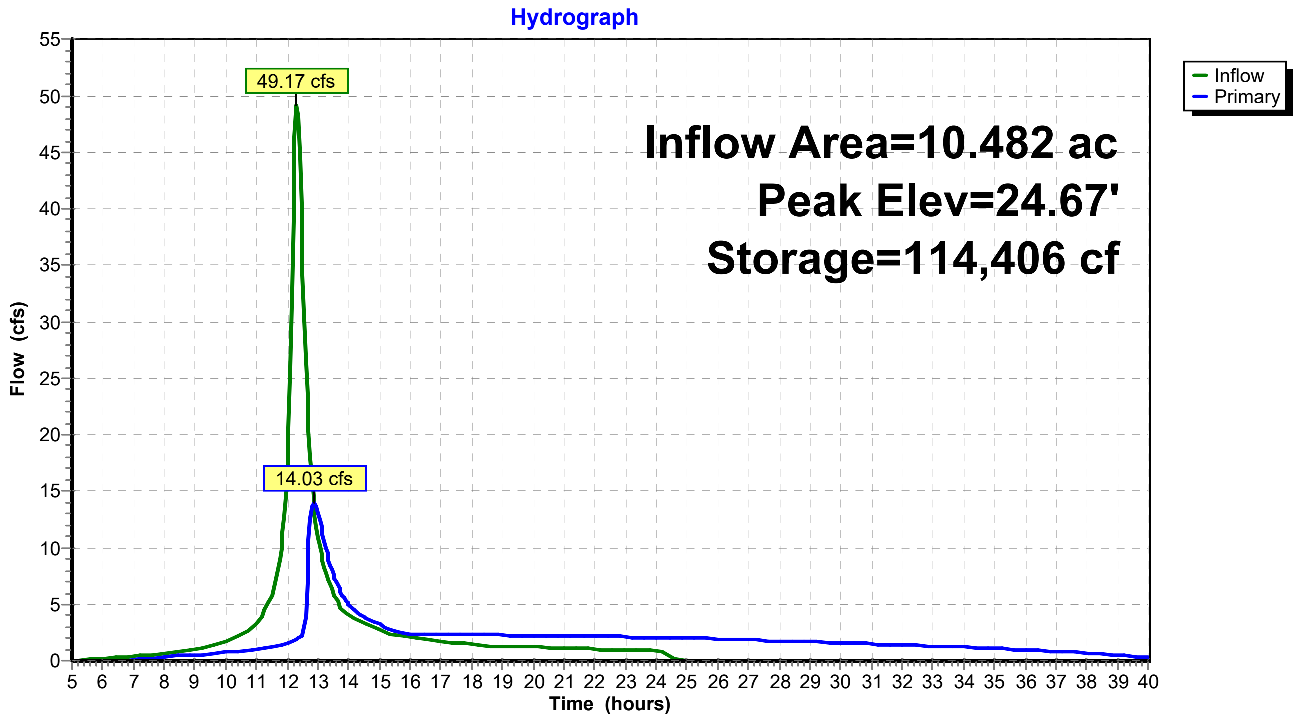
Volume	Invert	Avail.Storage	Storage Description
#1	18.00'	146,776 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
18.00	5,296	0	0
19.00	10,800	8,048	8,048
20.00	15,897	13,349	21,397
21.00	17,900	16,899	38,295
22.00	19,525	18,713	57,008
23.00	21,031	20,278	77,286
24.00	22,435	21,733	99,019
25.00	23,872	23,154	122,172
26.00	25,335	24,604	146,776

Device	Routing	Invert	Outlet Devices
#1	Primary	18.00'	**30.0" Round Culvert** L= 47.0' CMP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 18.00' / 17.85' S= 0.0032 '/' Cc= 0.900 n= 0.024 Corrugated metal, Flow Area= 4.91 sf
#2	Device 1	18.00'	**6.0" Vert. Low Flow Pipe** C= 0.600 Limited to weir flow at low heads
#3	Device 1	24.20'	**42.0" Horiz. Top of Riser** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=13.98 cfs @ 12.86 hrs HW=24.67' TW=18.26' (Dynamic Tailwater)
└─**1=Culvert** (Passes 13.98 cfs of 47.41 cfs potential flow)
  ├─**2=Low Flow Pipe** (Orifice Controls 2.39 cfs @ 12.19 fps)
  └─**3=Top of Riser** (Weir Controls 11.59 cfs @ 2.24 fps)

Pond P1: Trinity Woods Pond #1

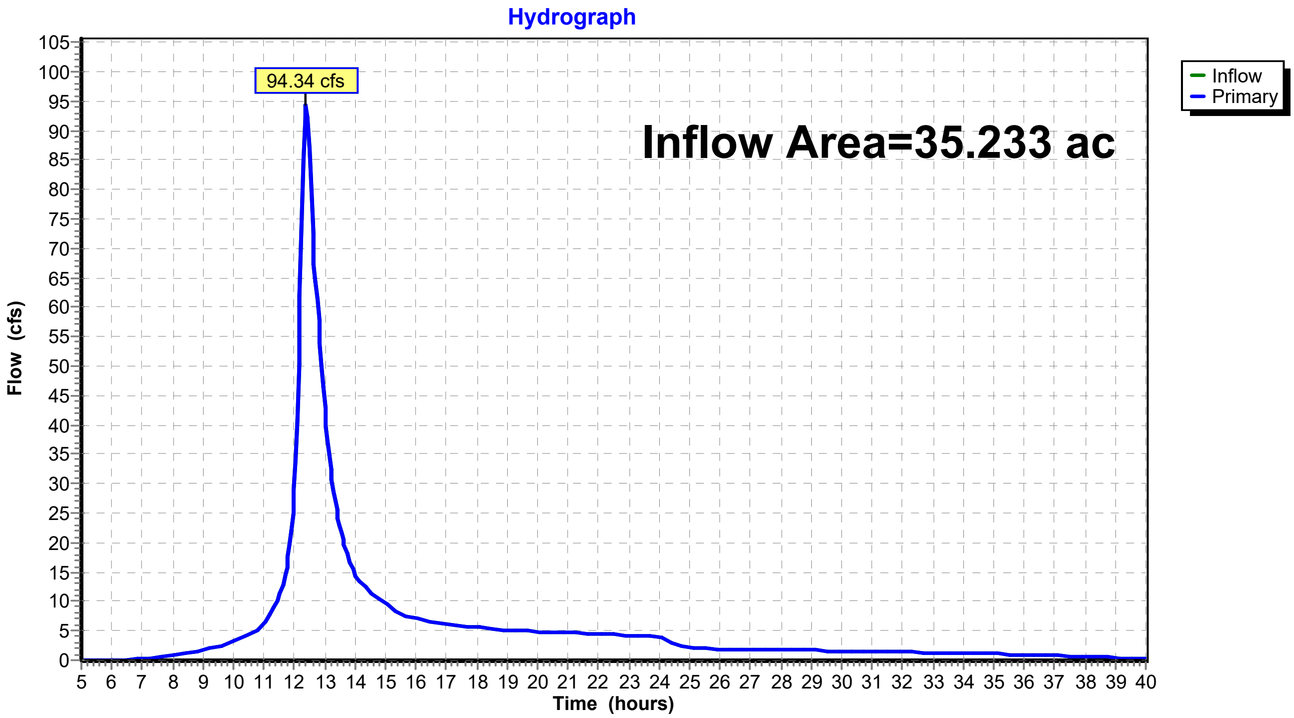


Summary for Link POI-EX: POI #1 - FEMA property, upstream of culvert

Inflow Area =	35.233 ac,	24.99% Impervious,	Inflow Depth > 5.46"	for 100-Year event
Inflow =	94.34 cfs @	12.40 hrs, Volume=	16.035 af	
Primary =	94.34 cfs @	12.40 hrs, Volume=	16.035 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs

Link POI-EX: POI #1 - FEMA property, upstream of culvert



Events for Subcatchment S1: Subarea 1 - Trinity Woods Pond #1

Event	Rainfall (inches)	Runoff (cfs)	Volume (acre-feet)	Depth (inches)
10-Year	4.87	24.90	2.588	2.96
50-Year	7.01	40.85	4.302	4.93
100-Year	**8.12**	**49.17**	**5.218**	**5.97**

Events for Subcatchment S2: Subarea 2

Event	Rainfall (inches)	Runoff (cfs)	Volume (acre-feet)	Depth (inches)
10-Year	4.87	42.65	5.010	2.43
50-Year	7.01	75.03	8.799	4.27
100-Year	**8.12**	**92.31**	**10.864**	**5.27**

Events for Reach R1: DS of Pond

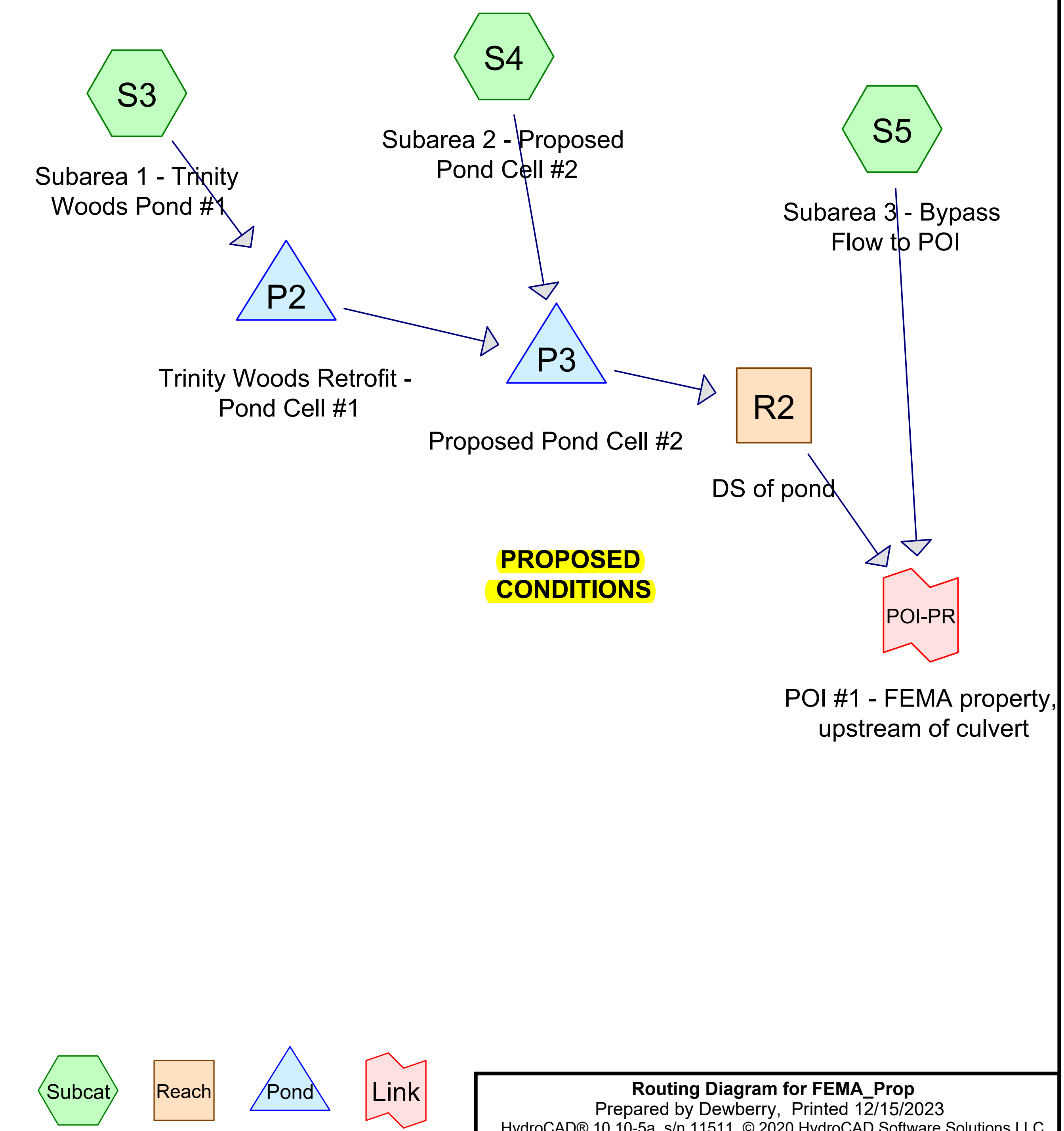
Event	Inflow (cfs)	Outflow (cfs)	Elevation (feet)	Storage (cubic-feet)
10-Year	1.92	1.92	17.98	503
50-Year	5.10	5.09	18.09	951
100-Year	**14.03**	**13.96**	**18.27**	**1,881**

Events for Pond P1: Trinity Woods Pond #1

Event	Inflow (cfs)	Primary (cfs)	Elevation (feet)	Storage (cubic-feet)
10-Year	24.90	1.92	22.37	64,308
50-Year	40.85	5.10	24.38	107,656
100-Year	**49.17**	**14.03**	**24.67**	**114,406**

Events for Link POI-EX: POI #1 - FEMA property, upstream of culvert

Event	Inflow (cfs)	Primary (cfs)	Elevation (feet)
10-Year	44.13	44.13	**0.00**
50-Year	76.90	76.90	0.00
100-Year	**94.34**	**94.34**	0.00



Routing Diagram for FEMA_Prop
Prepared by Dewberry, Printed 12/15/2023
HydroCAD® 10.10-5a s/n 11511 © 2020 HydroCAD Software Solutions LLC

Project Notes

Rainfall events imported from "NRCS-Rain.txt" for 5006 MD Cecil

Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	10-Year	NOAA 24-hr	C	Default	24.00	1	4.87	2
2	50-Year	NOAA 24-hr	C	Default	24.00	1	7.01	2
3	100-Year	NOAA 24-hr	C	Default	24.00	1	8.12	2

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
1.021	72	1/3 acre lots, 30% imp, HSG B (S3, S4, S5)
16.021	81	1/3 acre lots, 30% imp, HSG C (S3, S4, S5)
1.541	86	1/3 acre lots, 30% imp, HSG D (S3, S4, S5)
0.914	61	>75% Grass cover, Good, HSG B (S4, S5)
0.075	74	>75% Grass cover, Good, HSG C (S5)
0.081	98	Paved parking, HSG B (S3, S5)
3.090	98	Paved parking, HSG C (S3, S4, S5)
0.058	98	Paved parking, HSG D (S3, S5)
1.953	55	Woods, Good, HSG B (S3, S4, S5)
7.763	70	Woods, Good, HSG C (S3, S4, S5)
2.716	77	Woods, Good, HSG D (S3, S4, S5)
35.233	**78**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
3.969	HSG B	S3, S4, S5
26.949	HSG C	S3, S4, S5
4.315	HSG D	S3, S4, S5
0.000	Other	
35.233		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	1.021	16.021	1.541	0.000	18.583	1/3 acre lots, 30% imp	S3, S4, S5
0.000	0.914	0.075	0.000	0.000	0.989	>75% Grass cover, Good	S4, S5
0.000	0.081	3.090	0.058	0.000	3.229	Paved parking	S3, S4, S5
0.000	1.953	7.763	2.716	0.000	12.432	Woods, Good	S3, S4, S5
0.000	**3.969**	**26.949**	**4.315**	**0.000**	**35.233**	**TOTAL AREA**	

Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

SubcatchmentS3: Subarea 1 - Trinity Runoff Area=10.482 ac 39.75% Impervious Runoff Depth=2.96"
Flow Length=1,450' Tc=22.1 min CN=82 Runoff=24.90 cfs 2.588 af

SubcatchmentS4: Subarea 2 - Proposed Runoff Area=13.134 ac 17.33% Impervious Runoff Depth=2.34"
Flow Length=1,946' Tc=24.5 min CN=75 Runoff=23.45 cfs 2.566 af

SubcatchmentS5: Subarea 3 - Bypass Runoff Area=11.617 ac 20.32% Impervious Runoff Depth=2.51"
Flow Length=2,891' Tc=28.4 min CN=77 Runoff=20.76 cfs 2.434 af

Reach R2: DS of pond Avg. Flow Depth=0.57' Max Vel=1.58 fps Inflow=14.27 cfs 4.579 af
n=0.030 L=155.0' S=0.0032 '/' Capacity=42.84 cfs Outflow=14.25 cfs 4.578 af

Pond P2: Trinity Woods Retrofit - Pond Cell Peak Elev=21.82' Storage=62,289 cf Inflow=24.90 cfs 2.588 af
Outflow=2.90 cfs 2.411 af

Pond P3: Proposed Pond Cell #2 Peak Elev=17.99' Storage=48,178 cf Inflow=25.57 cfs 4.977 af
Outflow=14.27 cfs 4.579 af

Link POI-PR: POI #1 - FEMA property, upstream of culvert Inflow=27.36 cfs 7.012 af
Primary=27.36 cfs 7.012 af

Total Runoff Area = 35.233 ac Runoff Volume = 7.588 af Average Runoff Depth = 2.58"
75.01% Pervious = 26.429 ac 24.99% Impervious = 8.804 ac

Summary for Subcatchment S3: Subarea 1 - Trinity Woods Pond #1

Segment C-D is average pipe size and average slope.

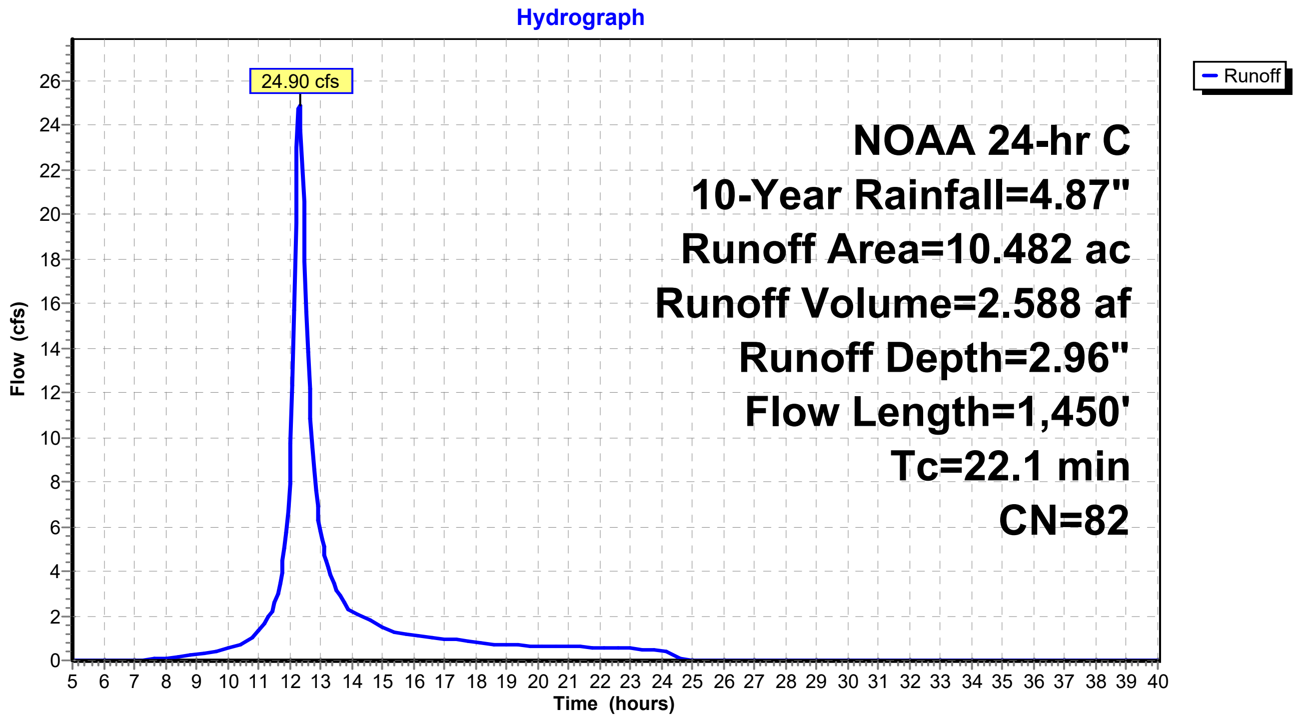
Runoff = 24.90 cfs @ 12.32 hrs, Volume= 2.588 af, Depth= 2.96"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 10-Year Rainfall=4.87"

Area (ac)	CN	Description
0.014	98	Paved parking, HSG B
1.774	98	Paved parking, HSG C
0.023	98	Paved parking, HSG D
0.375	72	1/3 acre lots, 30% imp, HSG B
7.105	81	1/3 acre lots, 30% imp, HSG C
0.372	86	1/3 acre lots, 30% imp, HSG D
0.417	55	Woods, Good, HSG B
0.177	70	Woods, Good, HSG C
0.225	77	Woods, Good, HSG D
10.482	82	Weighted Average
6.315		60.25% Pervious Area
4.167		39.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.2	100	0.1000	0.15		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
0.5	124	0.0600	3.94		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
10.4	1,226	0.0300	1.96	0.02	**Pipe Channel, C-D (outfall to pond)** 1.5" Round Area= 0.0 sf Perim= 0.4' r= 0.03' n= 0.013 Concrete pipe, bends & connections
22.1	1,450	Total			

Subcatchment S3: Subarea 1 - Trinity Woods Pond #1



Summary for Subcatchment S4: Subarea 2 - Proposed Pond Cell #2

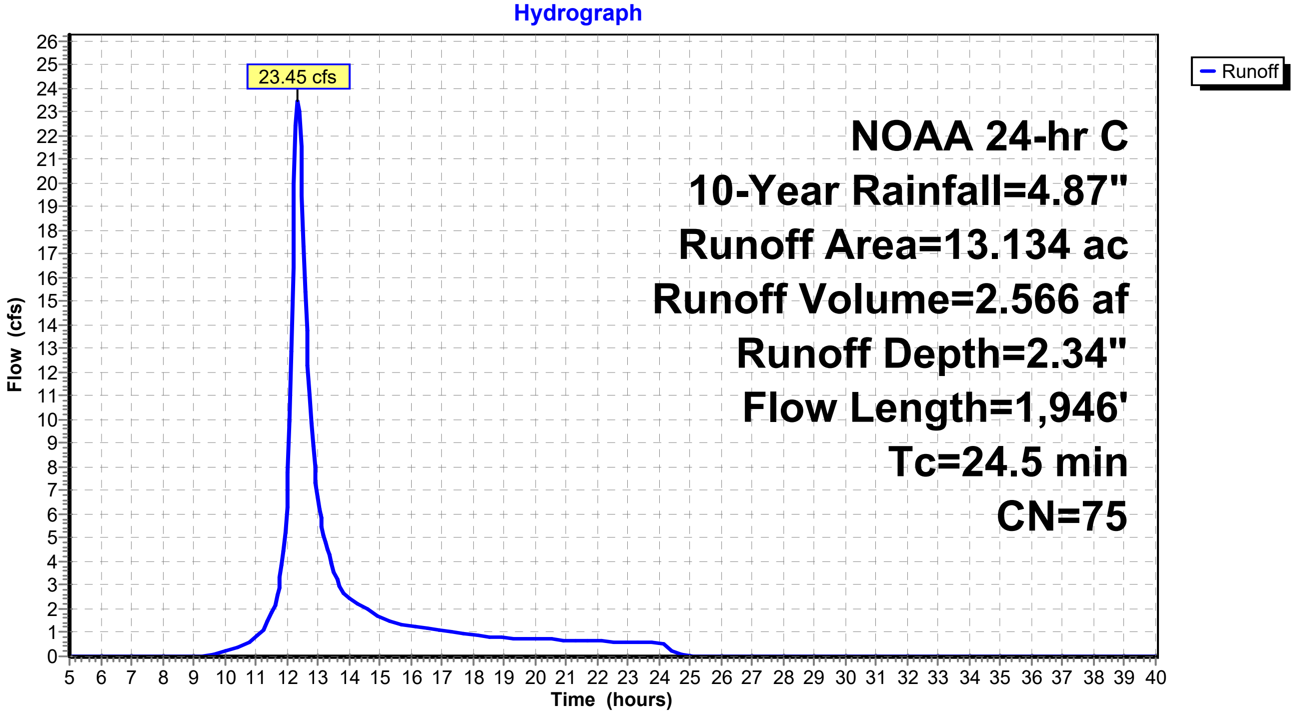
Runoff = 23.45 cfs @ 12.36 hrs, Volume= 2.566 af, Depth= 2.34"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 10-Year Rainfall=4.87"

Area (ac)	CN	Description
0.306	98	Paved parking, HSG C
0.619	61	>75% Grass cover, Good, HSG B
0.524	72	1/3 acre lots, 30% imp, HSG B
5.664	81	1/3 acre lots, 30% imp, HSG C
0.380	86	1/3 acre lots, 30% imp, HSG D
0.639	55	Woods, Good, HSG B
4.577	70	Woods, Good, HSG C
0.425	77	Woods, Good, HSG D
13.134	75	Weighted Average
10.858		82.67% Pervious Area
2.276		17.33% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
16.2	100	0.0400	0.10		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
5.3	1,024	0.0400	3.22		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
0.3	116	0.0300	5.58	9.86	**Pipe Channel, C-D** 18.0" Round Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.024 Corrugated metal
2.5	540	0.0300	3.57	17.83	**Trap/Vee/Rect Channel Flow, D-E (Riprap Channel)** Bot.W=8.00' D=0.50' Z= 4.0 '/' Top.W=12.00' n= 0.040 Earth, cobble bottom, clean sides
0.2	166	0.0400	14.40	45.24	**Pipe Channel, E-F (Outfall to Pond)** 24.0" Round Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Concrete pipe, bends & connections
24.5	1,946	Total			

Subcatchment S4: Subarea 2 - Proposed Pond Cell #2



Summary for Subcatchment S5: Subarea 3 - Bypass Flow to POI

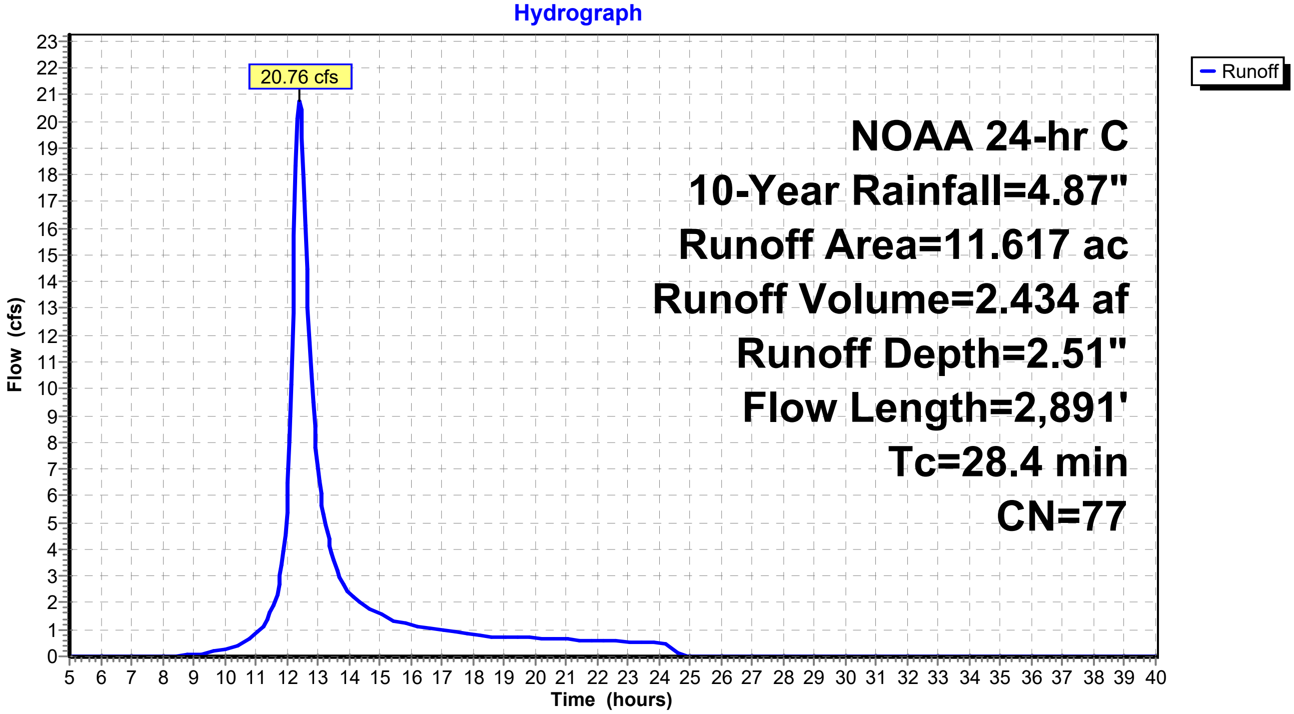
Runoff = 20.76 cfs @ 12.41 hrs, Volume= 2.434 af, Depth= 2.51"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 10-Year Rainfall=4.87"

Area (ac)	CN	Description
0.067	98	Paved parking, HSG B
1.010	98	Paved parking, HSG C
0.035	98	Paved parking, HSG D
0.295	61	>75% Grass cover, Good, HSG B
0.075	74	>75% Grass cover, Good, HSG C
0.122	72	1/3 acre lots, 30% imp, HSG B
3.252	81	1/3 acre lots, 30% imp, HSG C
0.789	86	1/3 acre lots, 30% imp, HSG D
0.897	55	Woods, Good, HSG B
3.009	70	Woods, Good, HSG C
2.066	77	Woods, Good, HSG D
11.617	77	Weighted Average
9.256		79.68% Pervious Area
2.361		20.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.8	100	0.0500	0.11		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
5.5	923	0.0300	2.79		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
1.4	322	0.0300	3.85	4.81	**Trap/Vee/Rect Channel Flow, C-D** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
0.6	387	0.0300	10.30	18.19	**Pipe Channel, D-E** 18.0" Round Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.013 Concrete pipe, bends & connections
6.1	1,159	0.0200	3.14	3.93	**Trap/Vee/Rect Channel Flow, E-F (POI)** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
28.4	2,891	Total			

Subcatchment S5: Subarea 3 - Bypass Flow to POI



Summary for Reach R2: DS of pond

Inflow Area = 23.616 ac, 27.28% Impervious, Inflow Depth > 2.33" for 10-Year event
Inflow = 14.27 cfs @ 12.73 hrs, Volume= 4.579 af
Outflow = 14.25 cfs @ 12.75 hrs, Volume= 4.578 af, Atten= 0%, Lag= 1.4 min

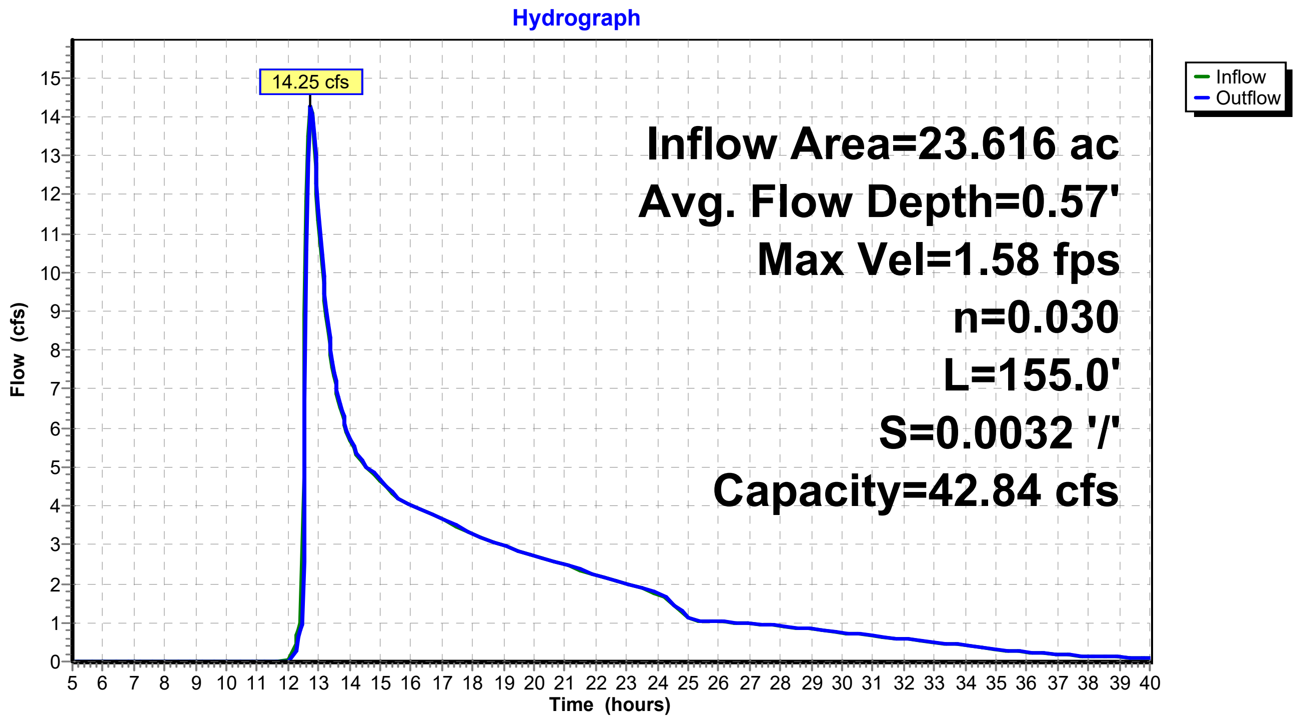
Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.58 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 0.74 fps, Avg. Travel Time= 3.5 min

Peak Storage= 1,401 cf @ 12.75 hrs
Average Depth at Peak Storage= 0.57' , Surface Width= 21.48'
Bank-Full Depth= 1.00' Flow Area= 20.0 sf, Capacity= 42.84 cfs

10.00' x 1.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 10.0 '/' Top Width= 30.00'
Length= 155.0' Slope= 0.0032 '/'
Inlet Invert= 14.50', Outlet Invert= 14.00'

‡

Reach R2: DS of pond



Summary for Pond P2: Trinity Woods Retrofit - Pond Cell #1

Inflow Area = 10.482 ac, 39.75% Impervious, Inflow Depth = 2.96" for 10-Year event
Inflow = 24.90 cfs @ 12.32 hrs, Volume= 2.588 af
Outflow = 2.90 cfs @ 13.62 hrs, Volume= 2.411 af, Atten= 88%, Lag= 77.9 min
Primary = 2.90 cfs @ 13.62 hrs, Volume= 2.411 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 21.82' @ 13.62 hrs Surf.Area= 19,682 sf Storage= 62,289 cf

Plug-Flow detention time= 294.8 min calculated for 2.411 af (93% of inflow)
Center-of-Mass det. time= 258.0 min (1,093.4 - 835.4)

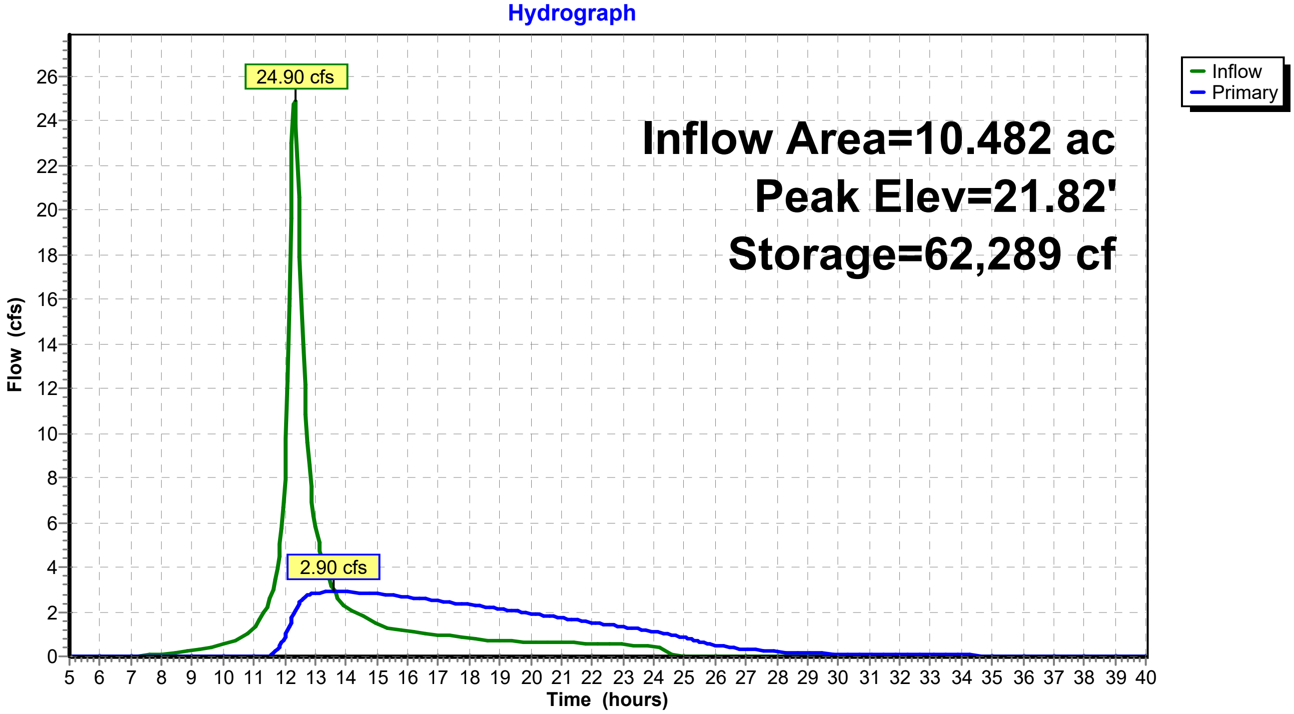
Volume	Invert	Avail.Storage	Storage Description
#1	18.00'	156,703 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
18.00	13,121	0	0
19.00	14,690	13,906	13,906
20.00	16,288	15,489	29,395
21.00	18,353	17,321	46,715
22.00	19,976	19,165	65,880
23.00	21,463	20,720	86,599
24.00	22,833	22,148	108,747
25.00	23,872	23,353	132,100
26.00	25,335	24,604	156,703

Device	Routing	Invert	Outlet Devices
#1	Primary	18.50'	**8.0" Vert. Low Flow Pipe** C= 0.600 Limited to weir flow at low heads
#2	Primary	22.00'	**2.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)
#3	Primary	24.00'	**40.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)

Primary OutFlow Max=2.90 cfs @ 13.62 hrs HW=21.82' TW=17.78' (Dynamic Tailwater)
├─**1=Low Flow Pipe** (Orifice Controls 2.90 cfs @ 8.32 fps)
├─**2=Sharp-Crested Rectangular Weir** (Controls 0.00 cfs)
└─**3=Sharp-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond P2: Trinity Woods Retrofit - Pond Cell #1



Summary for Pond P3: Proposed Pond Cell #2

Inflow Area = 23.616 ac, 27.28% Impervious, Inflow Depth > 2.53" for 10-Year event
Inflow = 25.57 cfs @ 12.37 hrs, Volume= 4.977 af
Outflow = 14.27 cfs @ 12.73 hrs, Volume= 4.579 af, Atten= 44%, Lag= 22.0 min
Primary = 14.27 cfs @ 12.73 hrs, Volume= 4.579 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 17.99' @ 12.73 hrs Surf.Area= 18,662 sf Storage= 48,178 cf
Flood Elev= 20.00' Surf.Area= 22,354 sf Storage= 89,387 cf

Plug-Flow detention time= 203.0 min calculated for 4.573 af (92% of inflow)
Center-of-Mass det. time= 154.6 min (1,126.0 - 971.4)

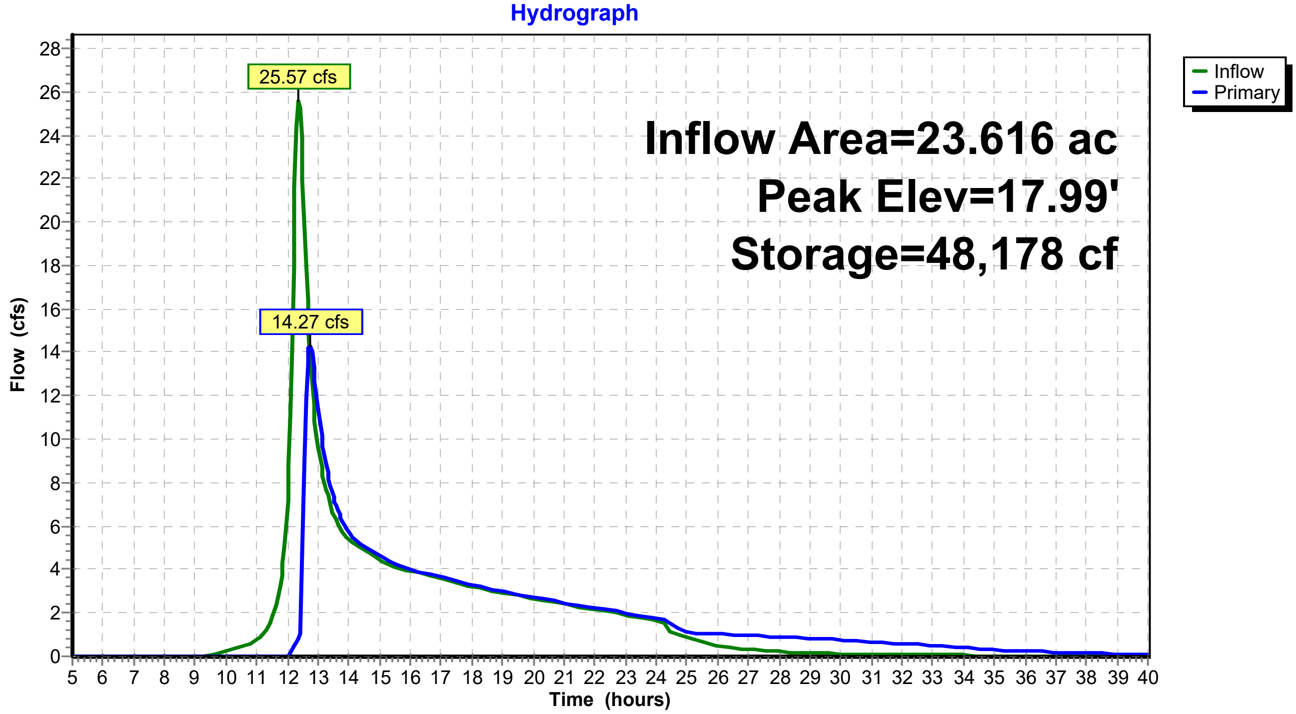
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	89,387 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	13,620	0	0
16.00	15,315	14,468	14,468
17.00	16,900	16,108	30,575
18.00	18,680	17,790	48,365
19.00	20,505	19,593	67,958
20.00	22,354	21,430	89,387

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**30.0" Round Culvert** L= 77.0' RCP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 15.00' / 14.50' S= 0.0065 '/' Cc= 0.900 n= 0.013 Concrete pipe, bends & connections, Flow Area= 4.91 sf
#2	Device 1	16.00'	**6.0" Vert. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Device 1	17.50'	**3.0' long x 0.75' rise Sharp-Crested Rectangular Weir X 4.00** 2 End Contraction(s)

Primary OutFlow Max=14.22 cfs @ 12.73 hrs HW=17.99' TW=15.07' (Dynamic Tailwater)
└─**1=Culvert** (Passes 14.22 cfs of 28.96 cfs potential flow)
 ├─**2=Orifice/Grate** (Orifice Controls 1.25 cfs @ 6.35 fps)
 └─**3=Sharp-Crested Rectangular Weir** (Weir Controls 12.97 cfs @ 2.29 fps)

Pond P3: Proposed Pond Cell #2

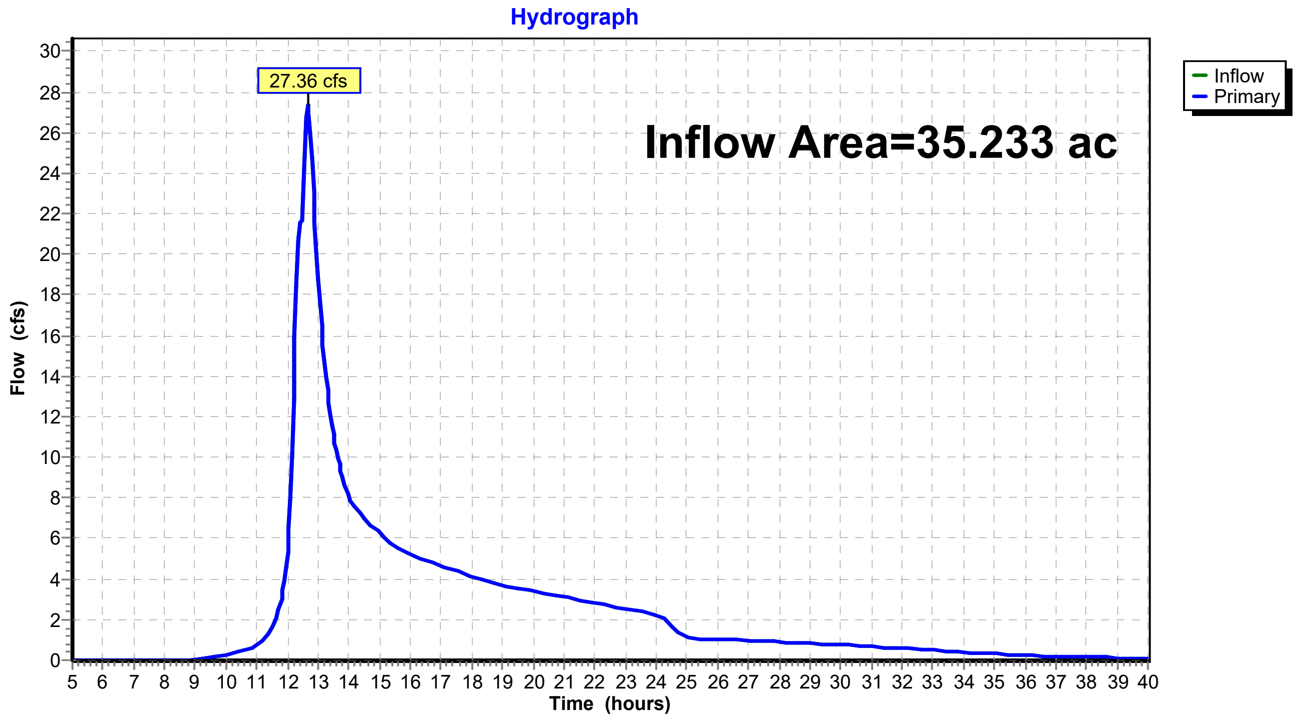


Summary for Link POI-PR: POI #1 - FEMA property, upstream of culvert

Inflow Area = 35.233 ac, 24.99% Impervious, Inflow Depth > 2.39" for 10-Year event
Inflow = 27.36 cfs @ 12.66 hrs, Volume= 7.012 af
Primary = 27.36 cfs @ 12.66 hrs, Volume= 7.012 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs

Link POI-PR: POI #1 - FEMA property, upstream of culvert



Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

SubcatchmentS3: Subarea 1 - Trinity Runoff Area=10.482 ac 39.75% Impervious Runoff Depth=4.93"
Flow Length=1,450' Tc=22.1 min CN=82 Runoff=40.85 cfs 4.302 af

SubcatchmentS4: Subarea 2 - Proposed Runoff Area=13.134 ac 17.33% Impervious Runoff Depth=4.16"
Flow Length=1,946' Tc=24.5 min CN=75 Runoff=41.73 cfs 4.551 af

SubcatchmentS5: Subarea 3 - Bypass Runoff Area=11.617 ac 20.32% Impervious Runoff Depth=4.37"
Flow Length=2,891' Tc=28.4 min CN=77 Runoff=36.07 cfs 4.235 af

Reach R2: DS of pond Avg. Flow Depth=0.90' Max Vel=2.02 fps Inflow=34.81 cfs 8.261 af
n=0.030 L=155.0' S=0.0032 '/' Capacity=42.84 cfs Outflow=34.80 cfs 8.260 af

Pond P2: Trinity Woods Retrofit - Pond Cell Peak Elev=23.21' Storage=91,236 cf Inflow=40.85 cfs 4.302 af
Outflow=11.21 cfs 4.123 af

Pond P3: Proposed Pond Cell #2 Peak Elev=18.73' Storage=62,442 cf Inflow=44.72 cfs 8.674 af
Outflow=34.81 cfs 8.261 af

Link POI-PR: POI #1 - FEMA property, upstream of culvert Inflow=68.46 cfs 12.495 af
Primary=68.46 cfs 12.495 af

Total Runoff Area = 35.233 ac Runoff Volume = 13.089 af Average Runoff Depth = 4.46"
75.01% Pervious = 26.429 ac 24.99% Impervious = 8.804 ac

Summary for Subcatchment S3: Subarea 1 - Trinity Woods Pond #1

Segment C-D is average pipe size and average slope.

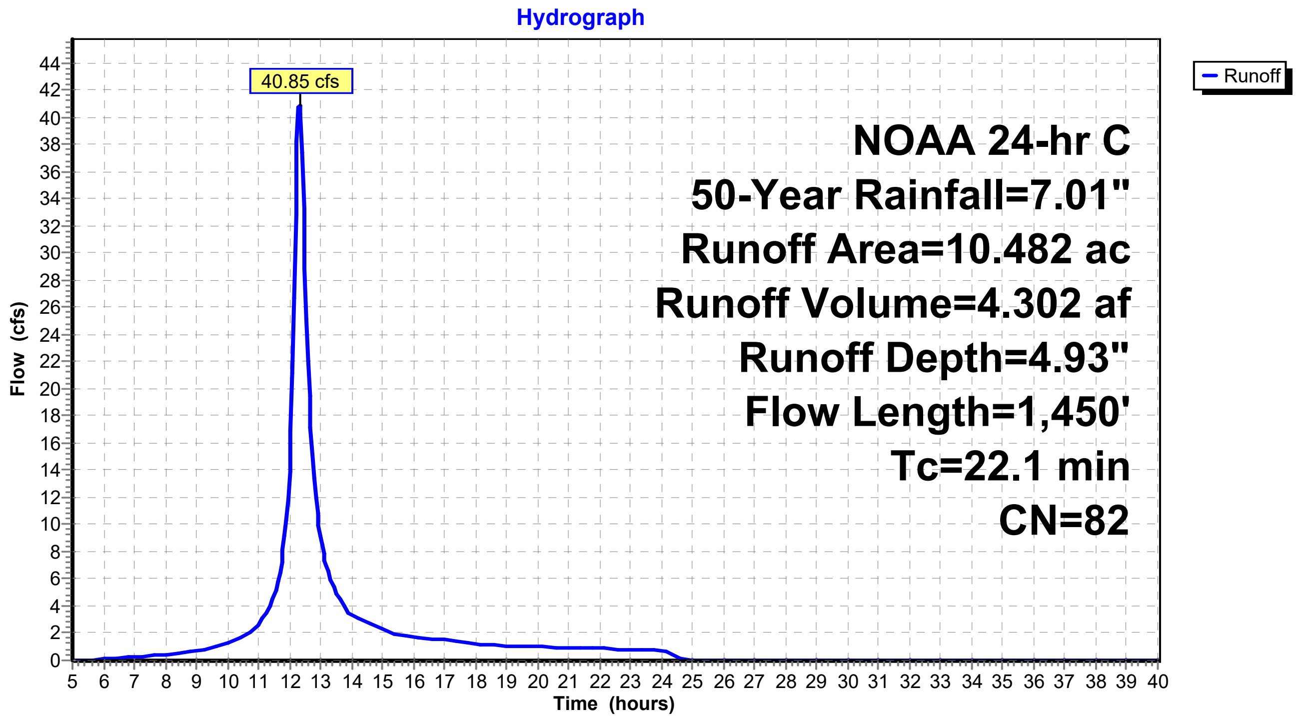
Runoff = 40.85 cfs @ 12.32 hrs, Volume= 4.302 af, Depth= 4.93"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 50-Year Rainfall=7.01"

Area (ac)	CN	Description
0.014	98	Paved parking, HSG B
1.774	98	Paved parking, HSG C
0.023	98	Paved parking, HSG D
0.375	72	1/3 acre lots, 30% imp, HSG B
7.105	81	1/3 acre lots, 30% imp, HSG C
0.372	86	1/3 acre lots, 30% imp, HSG D
0.417	55	Woods, Good, HSG B
0.177	70	Woods, Good, HSG C
0.225	77	Woods, Good, HSG D
10.482	82	Weighted Average
6.315		60.25% Pervious Area
4.167		39.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.2	100	0.1000	0.15		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
0.5	124	0.0600	3.94		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
10.4	1,226	0.0300	1.96	0.02	**Pipe Channel, C-D (outfall to pond)** 1.5" Round Area= 0.0 sf Perim= 0.4' r= 0.03' n= 0.013 Concrete pipe, bends & connections
22.1	1,450	Total			

Subcatchment S3: Subarea 1 - Trinity Woods Pond #1



Summary for Subcatchment S4: Subarea 2 - Proposed Pond Cell #2

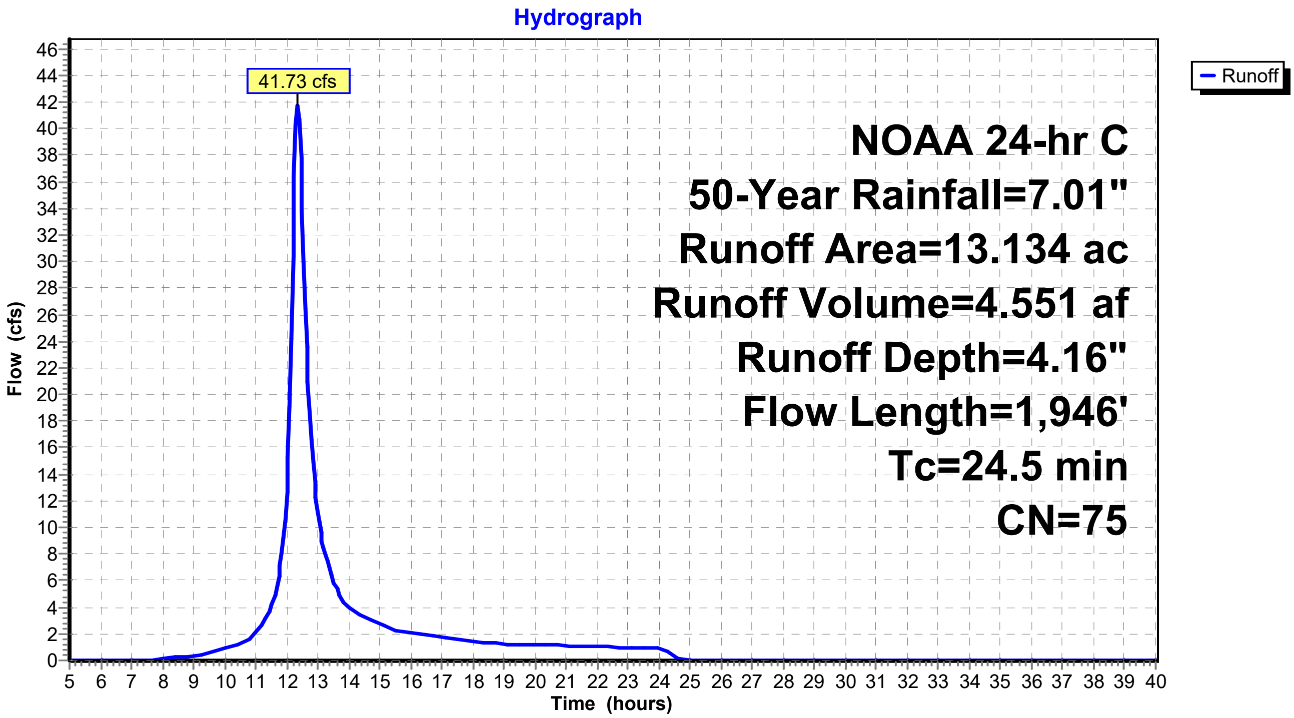
Runoff = 41.73 cfs @ 12.35 hrs, Volume= 4.551 af, Depth= 4.16"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 50-Year Rainfall=7.01"

Area (ac)	CN	Description
0.306	98	Paved parking, HSG C
0.619	61	>75% Grass cover, Good, HSG B
0.524	72	1/3 acre lots, 30% imp, HSG B
5.664	81	1/3 acre lots, 30% imp, HSG C
0.380	86	1/3 acre lots, 30% imp, HSG D
0.639	55	Woods, Good, HSG B
4.577	70	Woods, Good, HSG C
0.425	77	Woods, Good, HSG D
13.134	75	Weighted Average
10.858		82.67% Pervious Area
2.276		17.33% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
16.2	100	0.0400	0.10		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
5.3	1,024	0.0400	3.22		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
0.3	116	0.0300	5.58	9.86	**Pipe Channel, C-D** 18.0" Round Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.024 Corrugated metal
2.5	540	0.0300	3.57	17.83	**Trap/Vee/Rect Channel Flow, D-E (Riprap Channel)** Bot.W=8.00' D=0.50' Z= 4.0 '/' Top.W=12.00' n= 0.040 Earth, cobble bottom, clean sides
0.2	166	0.0400	14.40	45.24	**Pipe Channel, E-F (Outfall to Pond)** 24.0" Round Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Concrete pipe, bends & connections
24.5	1,946	Total			

Subcatchment S4: Subarea 2 - Proposed Pond Cell #2



Summary for Subcatchment S5: Subarea 3 - Bypass Flow to POI

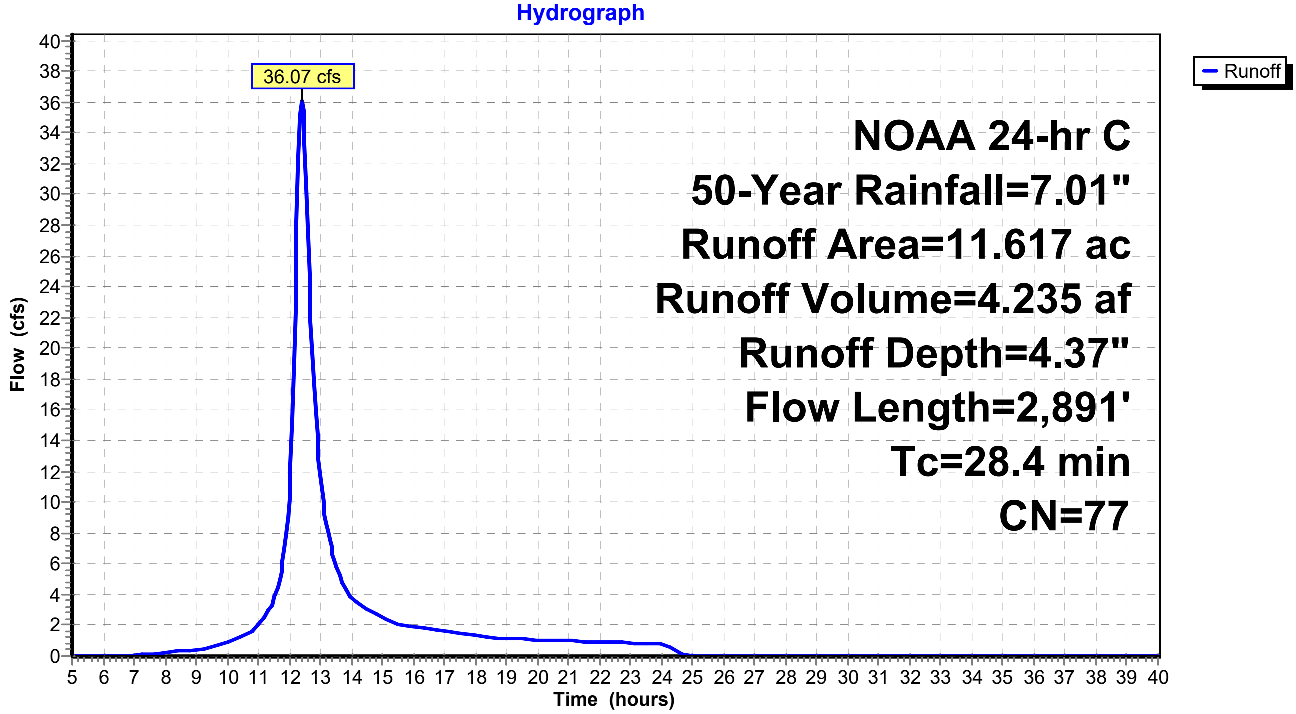
Runoff = 36.07 cfs @ 12.40 hrs, Volume= 4.235 af, Depth= 4.37"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 50-Year Rainfall=7.01"

Area (ac)	CN	Description
0.067	98	Paved parking, HSG B
1.010	98	Paved parking, HSG C
0.035	98	Paved parking, HSG D
0.295	61	>75% Grass cover, Good, HSG B
0.075	74	>75% Grass cover, Good, HSG C
0.122	72	1/3 acre lots, 30% imp, HSG B
3.252	81	1/3 acre lots, 30% imp, HSG C
0.789	86	1/3 acre lots, 30% imp, HSG D
0.897	55	Woods, Good, HSG B
3.009	70	Woods, Good, HSG C
2.066	77	Woods, Good, HSG D
11.617	77	Weighted Average
9.256		79.68% Pervious Area
2.361		20.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.8	100	0.0500	0.11		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
5.5	923	0.0300	2.79		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
1.4	322	0.0300	3.85	4.81	**Trap/Vee/Rect Channel Flow, C-D** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
0.6	387	0.0300	10.30	18.19	**Pipe Channel, D-E** 18.0" Round Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.013 Concrete pipe, bends & connections
6.1	1,159	0.0200	3.14	3.93	**Trap/Vee/Rect Channel Flow, E-F (POI)** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
28.4	2,891	Total			

Subcatchment S5: Subarea 3 - Bypass Flow to POI



Summary for Reach R2: DS of pond

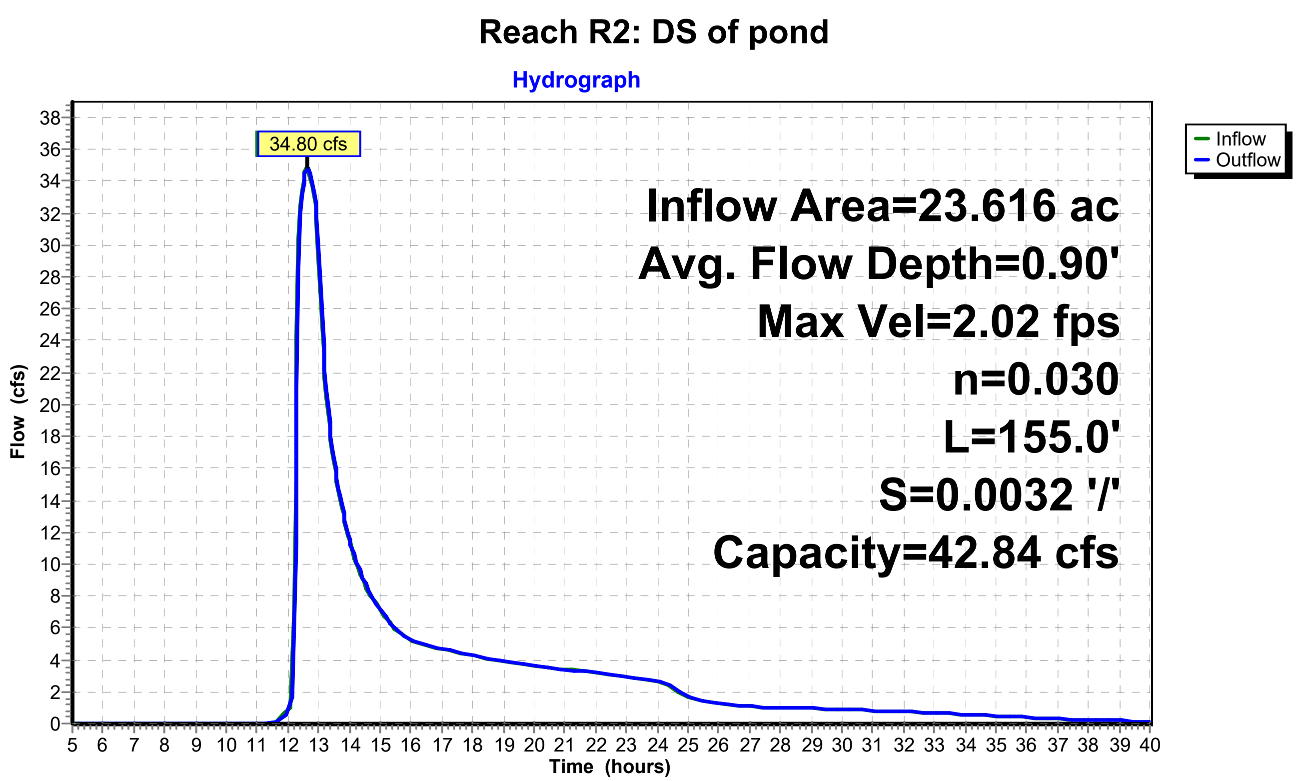
Inflow Area = 23.616 ac, 27.28% Impervious, Inflow Depth > 4.20" for 50-Year event
Inflow = 34.81 cfs @ 12.62 hrs, Volume= 8.261 af
Outflow = 34.80 cfs @ 12.63 hrs, Volume= 8.260 af, Atten= 0%, Lag= 0.9 min

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.02 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 0.84 fps, Avg. Travel Time= 3.1 min

Peak Storage= 2,664 cf @ 12.63 hrs
Average Depth at Peak Storage= 0.90' , Surface Width= 28.06'
Bank-Full Depth= 1.00' Flow Area= 20.0 sf, Capacity= 42.84 cfs

10.00' x 1.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 10.0 '/' Top Width= 30.00'
Length= 155.0' Slope= 0.0032 '/'
Inlet Invert= 14.50', Outlet Invert= 14.00'

‡



Summary for Pond P2: Trinity Woods Retrofit - Pond Cell #1

Inflow Area = 10.482 ac, 39.75% Impervious, Inflow Depth = 4.93" for 50-Year event
Inflow = 40.85 cfs @ 12.32 hrs, Volume= 4.302 af
Outflow = 11.21 cfs @ 12.89 hrs, Volume= 4.123 af, Atten= 73%, Lag= 34.2 min
Primary = 11.21 cfs @ 12.89 hrs, Volume= 4.123 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 23.21' @ 12.89 hrs Surf.Area= 21,757 sf Storage= 91,236 cf

Plug-Flow detention time= 250.5 min calculated for 4.117 af (96% of inflow)
Center-of-Mass det. time= 227.2 min (1,048.0 - 820.7)

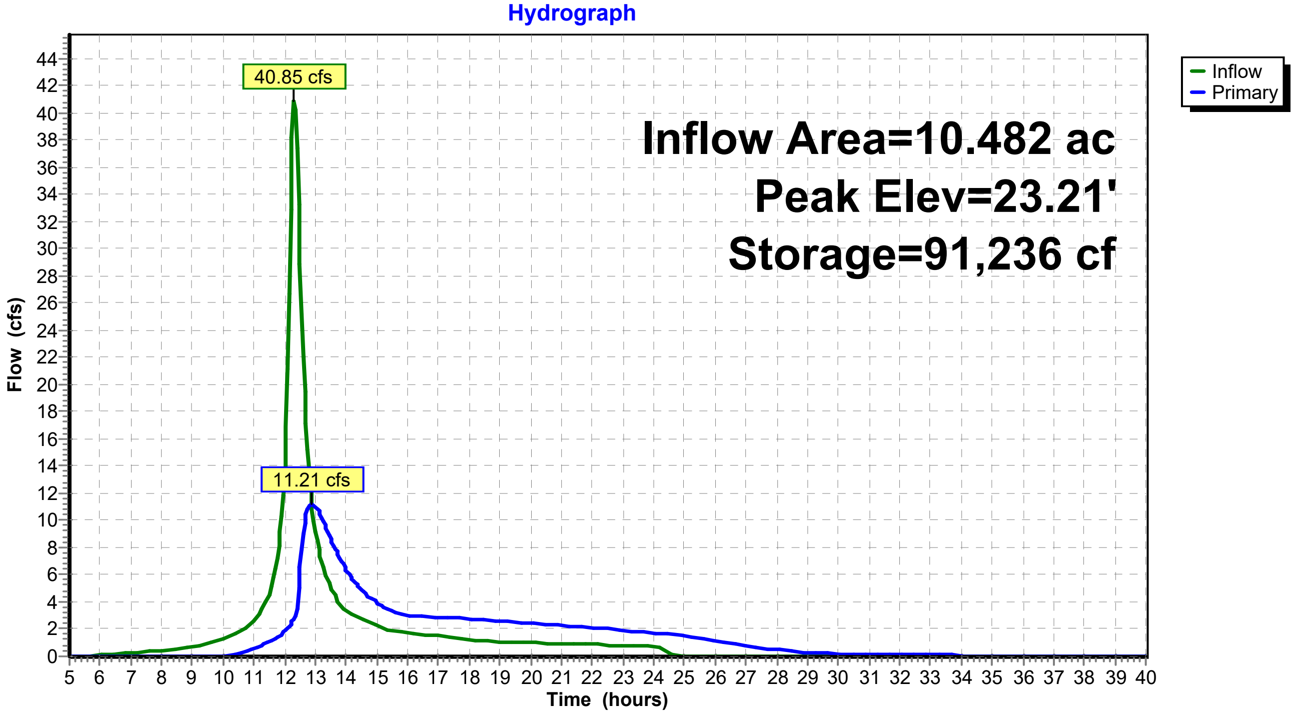
Volume	Invert	Avail.Storage	Storage Description
#1	18.00'	156,703 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
18.00	13,121	0	0
19.00	14,690	13,906	13,906
20.00	16,288	15,489	29,395
21.00	18,353	17,321	46,715
22.00	19,976	19,165	65,880
23.00	21,463	20,720	86,599
24.00	22,833	22,148	108,747
25.00	23,872	23,353	132,100
26.00	25,335	24,604	156,703

Device	Routing	Invert	Outlet Devices
#1	Primary	18.50'	**8.0" Vert. Low Flow Pipe** C= 0.600 Limited to weir flow at low heads
#2	Primary	22.00'	**2.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)
#3	Primary	24.00'	**40.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)

Primary OutFlow Max=11.20 cfs @ 12.89 hrs HW=23.21' TW=18.51' (Dynamic Tailwater)
├─**1=Low Flow Pipe** (Orifice Controls 3.52 cfs @ 10.08 fps)
├─**2=Sharp-Crested Rectangular Weir** (Weir Controls 7.68 cfs @ 3.60 fps)
└─**3=Sharp-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond P2: Trinity Woods Retrofit - Pond Cell #1



Summary for Pond P3: Proposed Pond Cell #2

Inflow Area = 23.616 ac, 27.28% Impervious, Inflow Depth > 4.41" for 50-Year event
Inflow = 44.72 cfs @ 12.36 hrs, Volume= 8.674 af
Outflow = 34.81 cfs @ 12.62 hrs, Volume= 8.261 af, Atten= 22%, Lag= 15.2 min
Primary = 34.81 cfs @ 12.62 hrs, Volume= 8.261 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 18.73' @ 12.62 hrs Surf.Area= 20,008 sf Storage= 62,442 cf
Flood Elev= 20.00' Surf.Area= 22,354 sf Storage= 89,387 cf

Plug-Flow detention time= 131.4 min calculated for 8.261 af (95% of inflow)
Center-of-Mass det. time= 96.9 min (1,035.7 - 938.8)

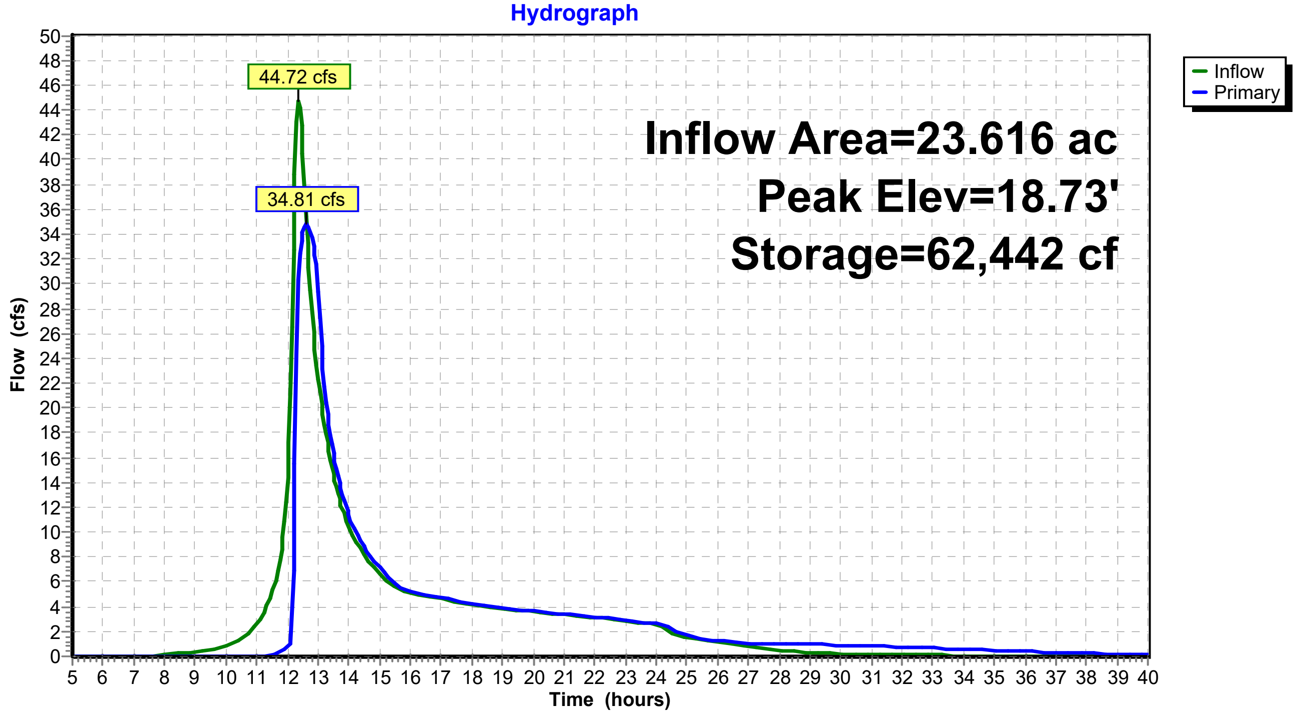
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	89,387 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	13,620	0	0
16.00	15,315	14,468	14,468
17.00	16,900	16,108	30,575
18.00	18,680	17,790	48,365
19.00	20,505	19,593	67,958
20.00	22,354	21,430	89,387

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**30.0" Round Culvert** L= 77.0' RCP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 15.00' / 14.50' S= 0.0065 '/' Cc= 0.900 n= 0.013 Concrete pipe, bends & connections, Flow Area= 4.91 sf
#2	Device 1	16.00'	**6.0" Vert. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Device 1	17.50'	**3.0' long x 0.75' rise Sharp-Crested Rectangular Weir X 4.00** 2 End Contraction(s)

Primary OutFlow Max=34.78 cfs @ 12.62 hrs HW=18.73' TW=15.40' (Dynamic Tailwater)
└─**1=Culvert** (Barrel Controls 34.78 cfs @ 7.09 fps)
  ├─**2=Orifice/Grate** (Passes < 1.49 cfs potential flow)
  └─**3=Sharp-Crested Rectangular Weir** (Passes < 38.35 cfs potential flow)

Pond P3: Proposed Pond Cell #2

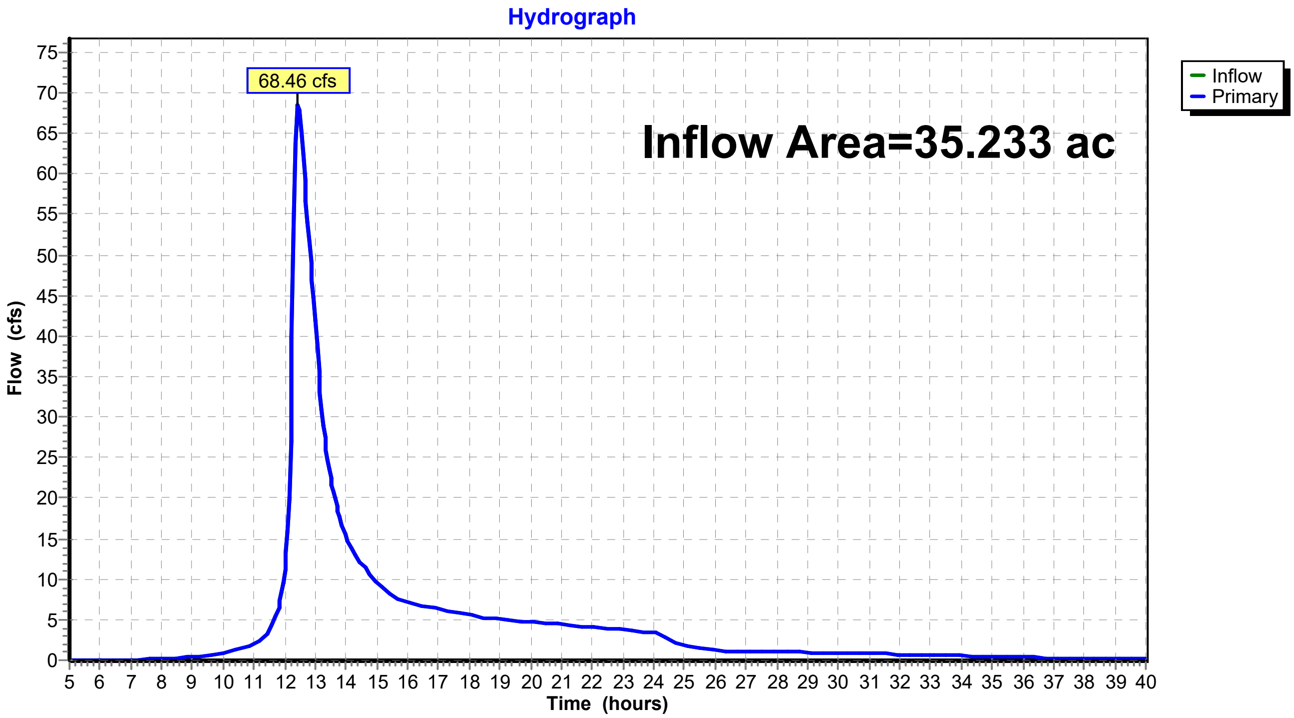


Summary for Link POI-PR: POI #1 - FEMA property, upstream of culvert

Inflow Area = 35.233 ac, 24.99% Impervious, Inflow Depth > 4.26" for 50-Year event
Inflow = 68.46 cfs @ 12.44 hrs, Volume= 12.495 af
Primary = 68.46 cfs @ 12.44 hrs, Volume= 12.495 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs

Link POI-PR: POI #1 - FEMA property, upstream of culvert



Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

SubcatchmentS3: Subarea 1 - Trinity Runoff Area=10.482 ac 39.75% Impervious Runoff Depth>5.97"
Flow Length=1,450' Tc=22.1 min CN=82 Runoff=49.17 cfs 5.218 af

SubcatchmentS4: Subarea 2 - Proposed Runoff Area=13.134 ac 17.33% Impervious Runoff Depth=5.15"
Flow Length=1,946' Tc=24.5 min CN=75 Runoff=51.52 cfs 5.637 af

SubcatchmentS5: Subarea 3 - Bypass Runoff Area=11.617 ac 20.32% Impervious Runoff Depth=5.38"
Flow Length=2,891' Tc=28.4 min CN=77 Runoff=44.21 cfs 5.213 af

Reach R2: DS of pond Avg. Flow Depth=0.99' Max Vel=2.13 fps Inflow=41.74 cfs 10.255 af
n=0.030 L=155.0' S=0.0032 '/' Capacity=42.84 cfs Outflow=41.73 cfs 10.253 af

Pond P2: Trinity Woods Retrofit - Pond Peak Elev=23.80' Storage=104,262 cf Inflow=49.17 cfs 5.218 af
Outflow=16.47 cfs 5.037 af

Pond P3: Proposed Pond Cell #2 Peak Elev=19.48' Storage=78,106 cf Inflow=58.55 cfs 10.673 af
Outflow=41.74 cfs 10.255 af

Link POI-PR: POI #1 - FEMA property, upstream of culvert Inflow=81.23 cfs 15.466 af
Primary=81.23 cfs 15.466 af

Total Runoff Area = 35.233 ac Runoff Volume = 16.067 af Average Runoff Depth = 5.47"
75.01% Pervious = 26.429 ac 24.99% Impervious = 8.804 ac

Summary for Subcatchment S3: Subarea 1 - Trinity Woods Pond #1

Segment C-D is average pipe size and average slope.

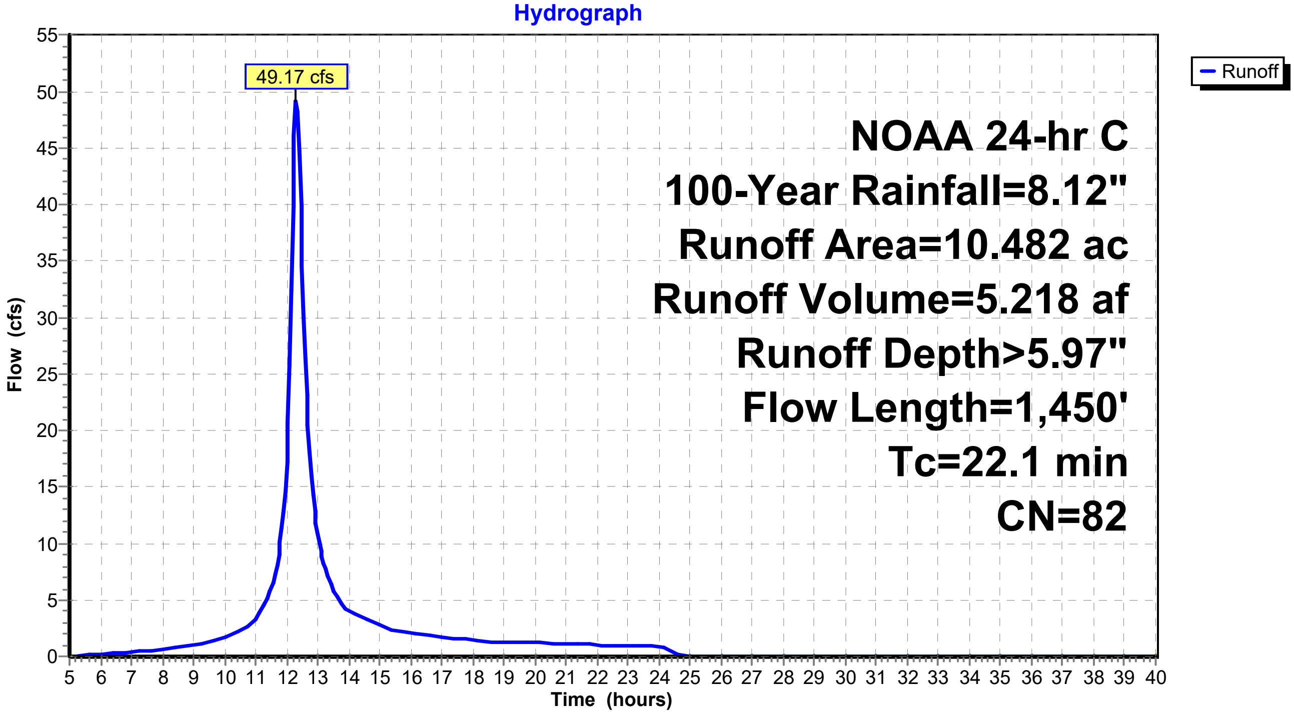
Runoff = 49.17 cfs @ 12.32 hrs, Volume= 5.218 af, Depth> 5.97"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 100-Year Rainfall=8.12"

Area (ac)	CN	Description
0.014	98	Paved parking, HSG B
1.774	98	Paved parking, HSG C
0.023	98	Paved parking, HSG D
0.375	72	1/3 acre lots, 30% imp, HSG B
7.105	81	1/3 acre lots, 30% imp, HSG C
0.372	86	1/3 acre lots, 30% imp, HSG D
0.417	55	Woods, Good, HSG B
0.177	70	Woods, Good, HSG C
0.225	77	Woods, Good, HSG D
10.482	82	Weighted Average
6.315		60.25% Pervious Area
4.167		39.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.2	100	0.1000	0.15		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
0.5	124	0.0600	3.94		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
10.4	1,226	0.0300	1.96	0.02	**Pipe Channel, C-D (outfall to pond)** 1.5" Round Area= 0.0 sf Perim= 0.4' r= 0.03' n= 0.013 Concrete pipe, bends & connections
22.1	1,450	Total			

Subcatchment S3: Subarea 1 - Trinity Woods Pond #1



Summary for Subcatchment S4: Subarea 2 - Proposed Pond Cell #2

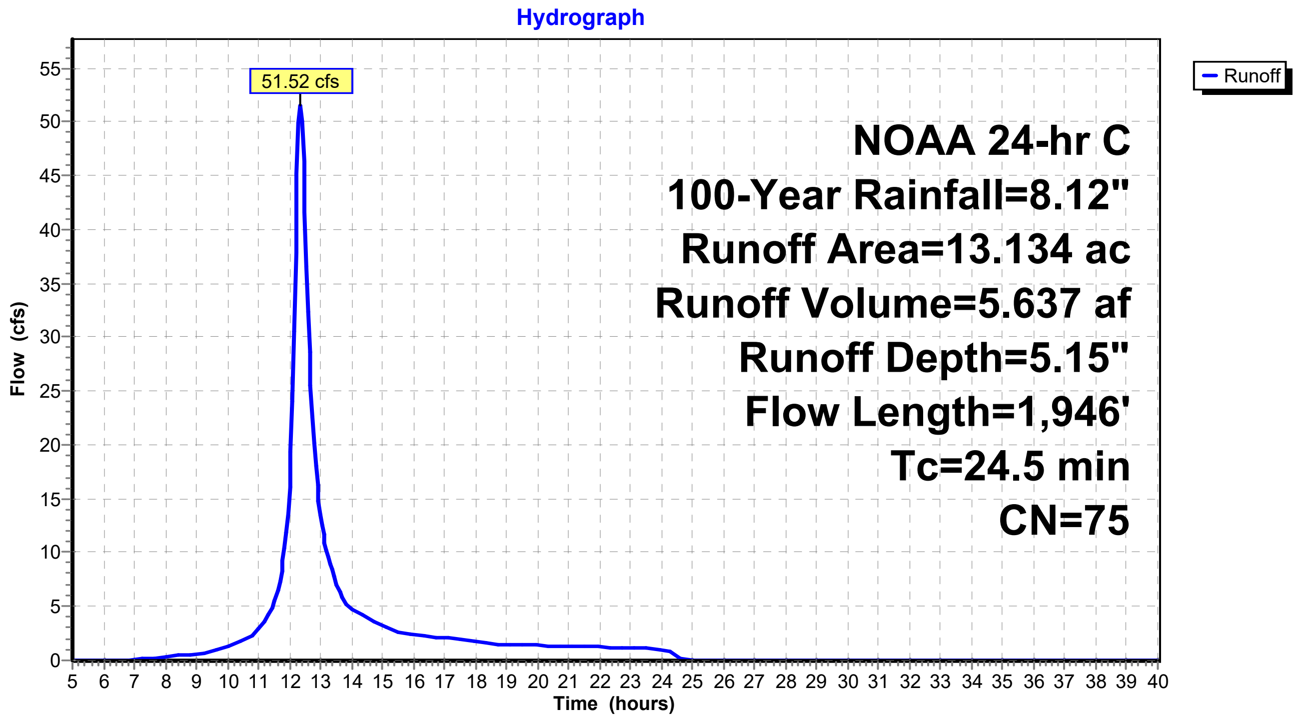
Runoff = 51.52 cfs @ 12.35 hrs, Volume= 5.637 af, Depth= 5.15"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 100-Year Rainfall=8.12"

Area (ac)	CN	Description
0.306	98	Paved parking, HSG C
0.619	61	>75% Grass cover, Good, HSG B
0.524	72	1/3 acre lots, 30% imp, HSG B
5.664	81	1/3 acre lots, 30% imp, HSG C
0.380	86	1/3 acre lots, 30% imp, HSG D
0.639	55	Woods, Good, HSG B
4.577	70	Woods, Good, HSG C
0.425	77	Woods, Good, HSG D
13.134	75	Weighted Average
10.858		82.67% Pervious Area
2.276		17.33% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
16.2	100	0.0400	0.10		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
5.3	1,024	0.0400	3.22		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
0.3	116	0.0300	5.58	9.86	**Pipe Channel, C-D** 18.0" Round Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.024 Corrugated metal
2.5	540	0.0300	3.57	17.83	**Trap/Vee/Rect Channel Flow, D-E (Riprap Channel)** Bot.W=8.00' D=0.50' Z= 4.0 '/' Top.W=12.00' n= 0.040 Earth, cobble bottom, clean sides
0.2	166	0.0400	14.40	45.24	**Pipe Channel, E-F (Outfall to Pond)** 24.0" Round Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Concrete pipe, bends & connections
24.5	1,946	Total			

Subcatchment S4: Subarea 2 - Proposed Pond Cell #2



Summary for Subcatchment S5: Subarea 3 - Bypass Flow to POI

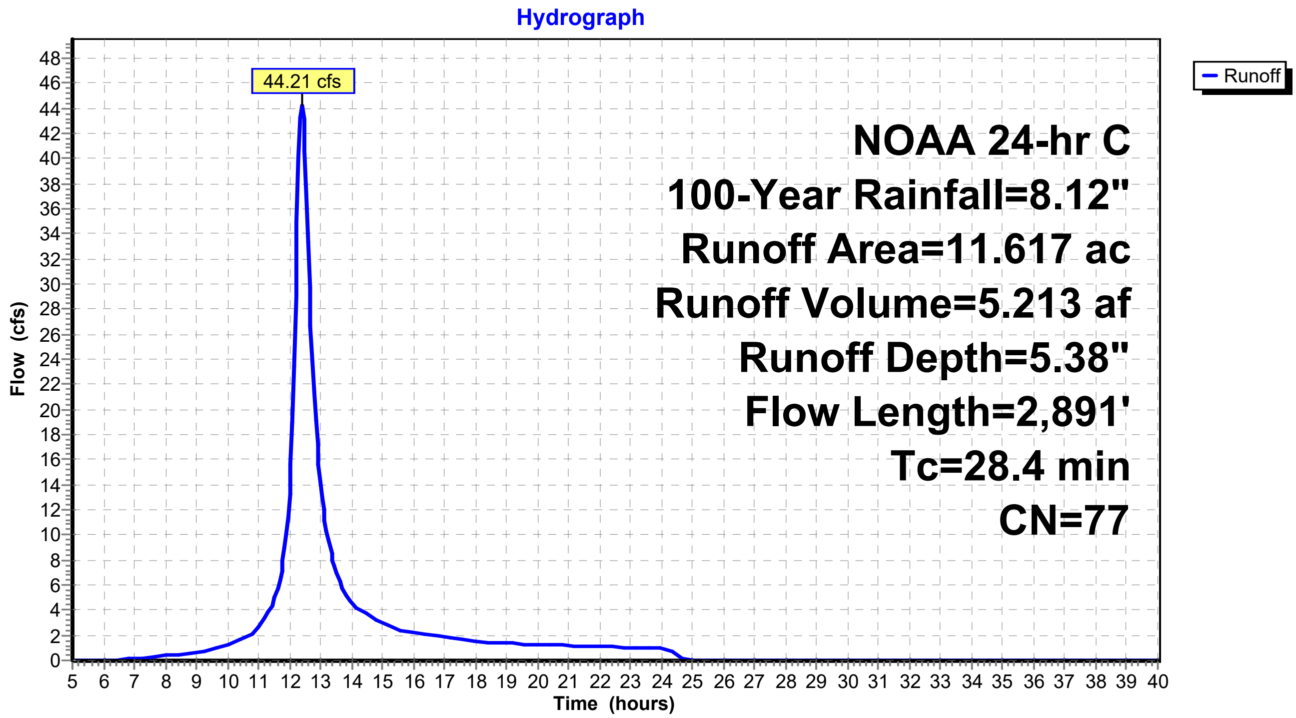
Runoff = 44.21 cfs @ 12.40 hrs, Volume= 5.213 af, Depth= 5.38"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
NOAA 24-hr C 100-Year Rainfall=8.12"

Area (ac)	CN	Description
0.067	98	Paved parking, HSG B
1.010	98	Paved parking, HSG C
0.035	98	Paved parking, HSG D
0.295	61	>75% Grass cover, Good, HSG B
0.075	74	>75% Grass cover, Good, HSG C
0.122	72	1/3 acre lots, 30% imp, HSG B
3.252	81	1/3 acre lots, 30% imp, HSG C
0.789	86	1/3 acre lots, 30% imp, HSG D
0.897	55	Woods, Good, HSG B
3.009	70	Woods, Good, HSG C
2.066	77	Woods, Good, HSG D
11.617	77	Weighted Average
9.256		79.68% Pervious Area
2.361		20.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.8	100	0.0500	0.11		**Sheet Flow, A-B** Woods: Light underbrush n= 0.400 P2= 3.22"
5.5	923	0.0300	2.79		**Shallow Concentrated Flow, B-C** Unpaved Kv= 16.1 fps
1.4	322	0.0300	3.85	4.81	**Trap/Vee/Rect Channel Flow, C-D** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
0.6	387	0.0300	10.30	18.19	**Pipe Channel, D-E** 18.0" Round Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.013 Concrete pipe, bends & connections
6.1	1,159	0.0200	3.14	3.93	**Trap/Vee/Rect Channel Flow, E-F (POI)** Bot.W=1.00' D=0.50' Z= 3.0 '/' Top.W=4.00' n= 0.030 Earth, grassed & winding
28.4	2,891	Total			

Subcatchment S5: Subarea 3 - Bypass Flow to POI



Summary for Reach R2: DS of pond

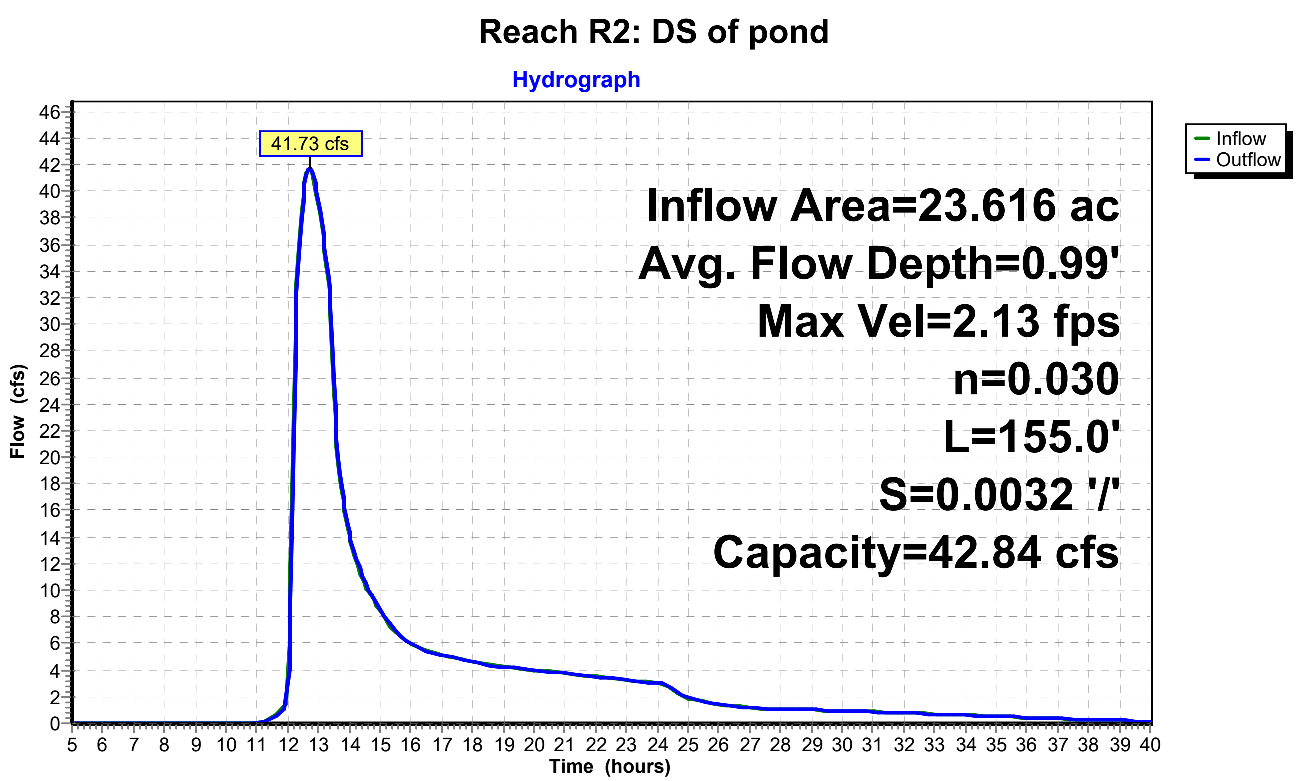
Inflow Area = 23.616 ac, 27.28% Impervious, Inflow Depth > 5.21" for 100-Year event
Inflow = 41.74 cfs @ 12.70 hrs, Volume= 10.255 af
Outflow = 41.73 cfs @ 12.72 hrs, Volume= 10.253 af, Atten= 0%, Lag= 0.9 min

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.13 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 0.87 fps, Avg. Travel Time= 3.0 min

Peak Storage= 3,041 cf @ 12.72 hrs
Average Depth at Peak Storage= 0.99' , Surface Width= 29.75'
Bank-Full Depth= 1.00' Flow Area= 20.0 sf, Capacity= 42.84 cfs

10.00' x 1.00' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 10.0 '/' Top Width= 30.00'
Length= 155.0' Slope= 0.0032 '/'
Inlet Invert= 14.50', Outlet Invert= 14.00'

‡



Summary for Pond P2: Trinity Woods Retrofit - Pond Cell #1

Inflow Area = 10.482 ac, 39.75% Impervious, Inflow Depth > 5.97" for 100-Year event
Inflow = 49.17 cfs @ 12.32 hrs, Volume= 5.218 af
Outflow = 16.47 cfs @ 12.79 hrs, Volume= 5.037 af, Atten= 67%, Lag= 28.7 min
Primary = 16.47 cfs @ 12.79 hrs, Volume= 5.037 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 23.80' @ 12.79 hrs Surf.Area= 22,562 sf Storage= 104,262 cf

Plug-Flow detention time= 228.5 min calculated for 5.036 af (97% of inflow)
Center-of-Mass det. time= 207.9 min (1,023.1 - 815.2)

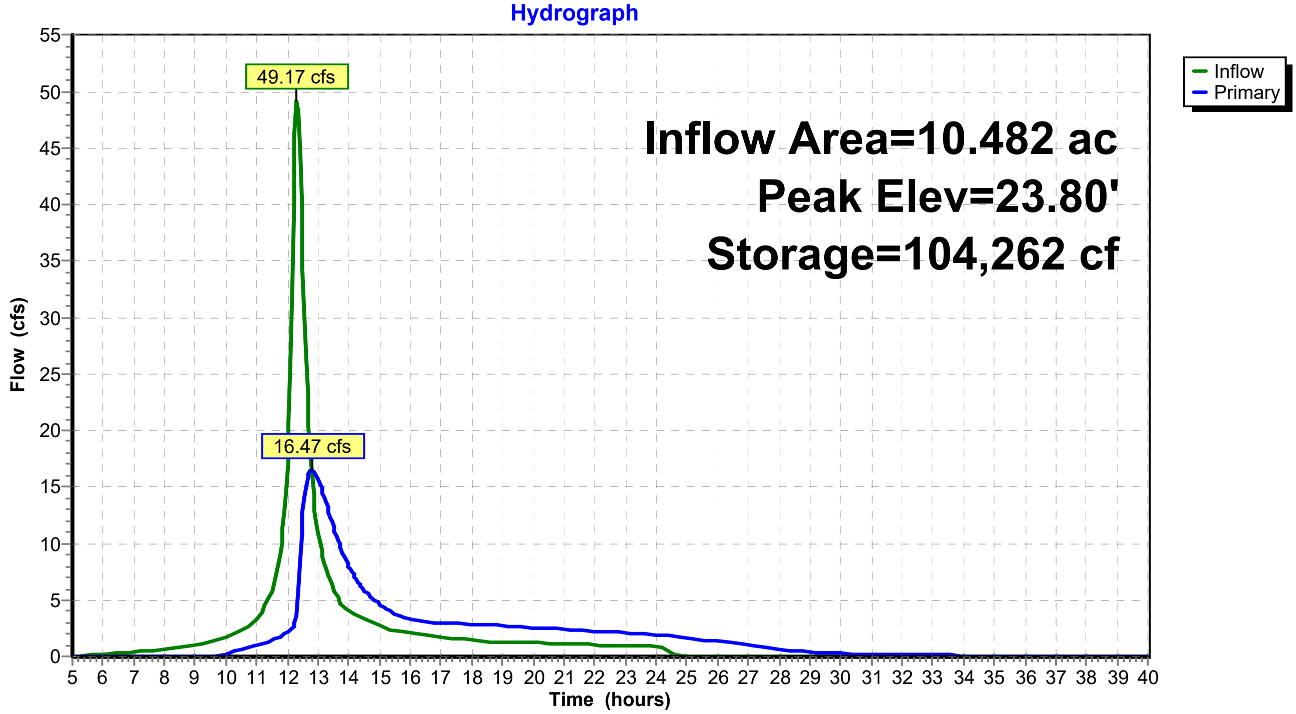
Volume	Invert	Avail.Storage	Storage Description
#1	18.00'	156,703 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
18.00	13,121	0	0
19.00	14,690	13,906	13,906
20.00	16,288	15,489	29,395
21.00	18,353	17,321	46,715
22.00	19,976	19,165	65,880
23.00	21,463	20,720	86,599
24.00	22,833	22,148	108,747
25.00	23,872	23,353	132,100
26.00	25,335	24,604	156,703

Device	Routing	Invert	Outlet Devices
#1	Primary	18.50'	**8.0" Vert. Low Flow Pipe** C= 0.600 Limited to weir flow at low heads
#2	Primary	22.00'	**2.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)
#3	Primary	24.00'	**40.0' long Sharp-Crested Rectangular Weir** 2 End Contraction(s)

Primary OutFlow Max=16.47 cfs @ 12.79 hrs HW=23.80' TW=19.45' (Dynamic Tailwater)
├─**1=Low Flow Pipe** (Orifice Controls 3.51 cfs @ 10.05 fps)
├─**2=Sharp-Crested Rectangular Weir** (Weir Controls 12.97 cfs @ 4.39 fps)
└─**3=Sharp-Crested Rectangular Weir** (Controls 0.00 cfs)

Pond P2: Trinity Woods Retrofit - Pond Cell #1



Summary for Pond P3: Proposed Pond Cell #2

Inflow Area = 23.616 ac, 27.28% Impervious, Inflow Depth > 5.42" for 100-Year event
Inflow = 58.55 cfs @ 12.40 hrs, Volume= 10.673 af
Outflow = 41.74 cfs @ 12.70 hrs, Volume= 10.255 af, Atten= 29%, Lag= 18.2 min
Primary = 41.74 cfs @ 12.70 hrs, Volume= 10.255 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 19.48' @ 12.70 hrs Surf.Area= 21,401 sf Storage= 78,106 cf
Flood Elev= 20.00' Surf.Area= 22,354 sf Storage= 89,387 cf

Plug-Flow detention time= 112.5 min calculated for 10.240 af (96% of inflow)
Center-of-Mass det. time= 83.5 min (1,006.6 - 923.1)

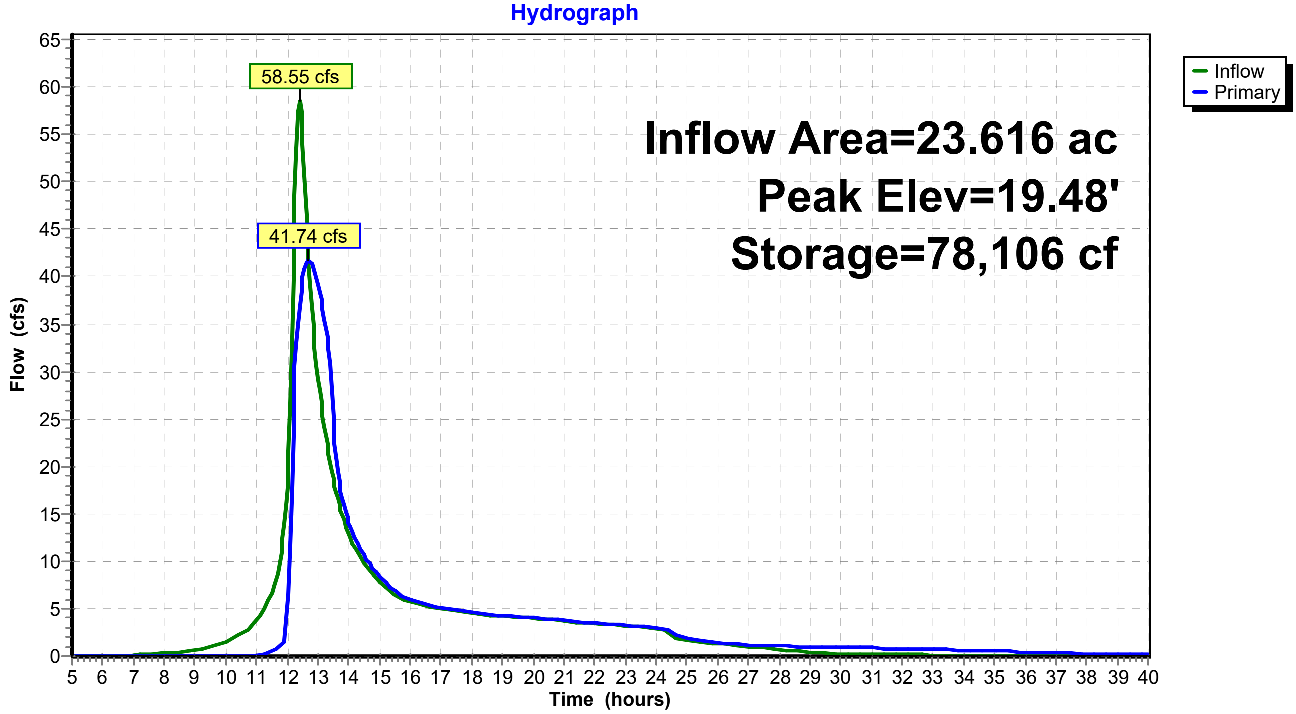
Volume	Invert	Avail.Storage	Storage Description
#1	15.00'	89,387 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
15.00	13,620	0	0
16.00	15,315	14,468	14,468
17.00	16,900	16,108	30,575
18.00	18,680	17,790	48,365
19.00	20,505	19,593	67,958
20.00	22,354	21,430	89,387

Device	Routing	Invert	Outlet Devices
#1	Primary	15.00'	**30.0" Round Culvert** L= 77.0' RCP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 15.00' / 14.50' S= 0.0065 '/' Cc= 0.900 n= 0.013 Concrete pipe, bends & connections, Flow Area= 4.91 sf
#2	Device 1	16.00'	**6.0" Vert. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#3	Device 1	17.50'	**3.0' long x 0.75' rise Sharp-Crested Rectangular Weir X 4.00** 2 End Contraction(s)

Primary OutFlow Max=41.74 cfs @ 12.70 hrs HW=19.48' TW=15.49' (Dynamic Tailwater)
└─**1=Culvert** (Barrel Controls 41.74 cfs @ 8.50 fps)
  ├─**2=Orifice/Grate** (Passes < 1.70 cfs potential flow)
  └─**3=Sharp-Crested Rectangular Weir** (Passes < 53.08 cfs potential flow)

Pond P3: Proposed Pond Cell #2

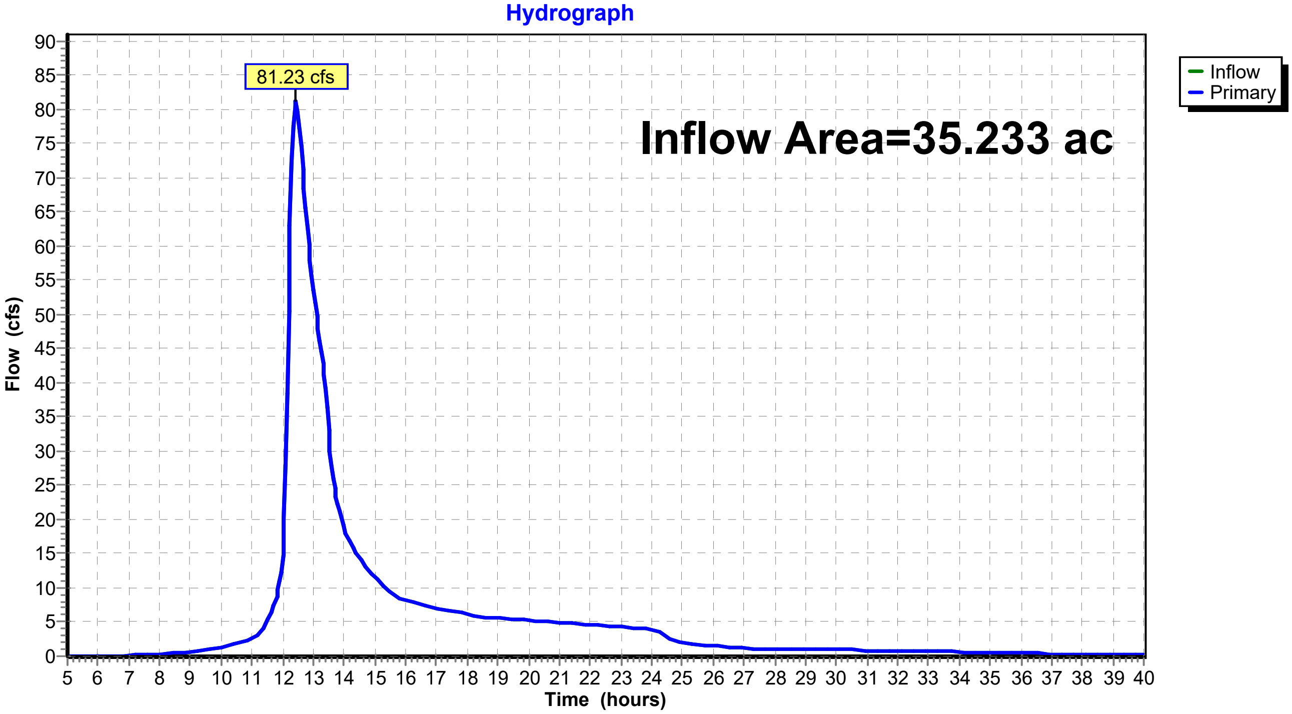


Summary for Link POI-PR: POI #1 - FEMA property, upstream of culvert

Inflow Area = 35.233 ac, 24.99% Impervious, Inflow Depth > 5.27" for 100-Year event
Inflow = 81.23 cfs @ 12.44 hrs, Volume= 15.466 af
Primary = 81.23 cfs @ 12.44 hrs, Volume= 15.466 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs

Link POI-PR: POI #1 - FEMA property, upstream of culvert



Events for Subcatchment S3: Subarea 1 - Trinity Woods Pond #1

Event	Rainfall (inches)	Runoff (cfs)	Volume (acre-feet)	Depth (inches)
10-Year	4.87	24.90	2.588	2.96
50-Year	7.01	40.85	4.302	4.93
100-Year	**8.12**	**49.17**	**5.218**	**5.97**

Events for Subcatchment S4: Subarea 2 - Proposed Pond Cell #2

Event	Rainfall (inches)	Runoff (cfs)	Volume (acre-feet)	Depth (inches)
10-Year	4.87	23.45	2.566	2.34
50-Year	7.01	41.73	4.551	4.16
100-Year	**8.12**	**51.52**	**5.637**	**5.15**

Events for Subcatchment S5: Subarea 3 - Bypass Flow to POI

Event	Rainfall (inches)	Runoff (cfs)	Volume (acre-feet)	Depth (inches)
10-Year	4.87	20.76	2.434	2.51
50-Year	7.01	36.07	4.235	4.37
100-Year	**8.12**	**44.21**	**5.213**	**5.38**

Events for Reach R2: DS of pond

Event	Inflow (cfs)	Outflow (cfs)	Elevation (feet)	Storage (cubic-feet)
10-Year	14.27	14.25	15.07	1,401
50-Year	34.81	34.80	15.40	2,664
100-Year	**41.74**	**41.73**	**15.49**	**3,041**

Events for Pond P2: Trinity Woods Retrofit - Pond Cell #1

Event	Inflow (cfs)	Primary (cfs)	Elevation (feet)	Storage (cubic-feet)
10-Year	24.90	2.90	21.82	62,289
50-Year	40.85	11.21	23.21	91,236
100-Year	**49.17**	**16.47**	**23.80**	**104,262**

Events for Pond P3: Proposed Pond Cell #2

Event	Inflow (cfs)	Primary (cfs)	Elevation (feet)	Storage (cubic-feet)
10-Year	25.57	14.27	17.99	48,178
50-Year	44.72	34.81	18.73	62,442
100-Year	**58.55**	**41.74**	**19.48**	**78,106**

Events for Link POI-PR: POI #1 - FEMA property, upstream of culvert

Event	Inflow (cfs)	Primary (cfs)	Elevation (feet)
10-Year	27.36	27.36	**0.00**
50-Year	68.46	68.46	0.00
100-Year	**81.23**	**81.23**	0.00

Trinity Woods / FEMA Property Concept

CHARLESTOWN WATERSHED MANAGEMENT PLAN - COST ESTIMATE

Date: **12/11/2023**

Item Number	Description	Unit	Total Quantity	Unit Price	Total Cost
Cat. 100	**Preliminary**				
1001	Construction Stakeout	LS	1	$2,500.00	$2,500
1002	Mobilization	LS	1	$15,000.00	$15,000
				Sub-Total	*$17,500*
Cat. 200	**Grading**				
2001	Class 1 Excavation	CY	5000	$50.00	$250,000
2002	Select Borrow	CY	75	$50.00	$3,750
2003	Test Pit Excavation	CY	5	$200.00	$1,000
				Sub-Total	*$254,750*
Cat. 300	**Drainage**				
3001	Erosion & Sediment Control	LS	1	$25,000.00	$25,000
3002	24 Inch RCP	LF	235	$150.00	$35,250
3003	Standard Single Opening Type K Inlet	EA	1	$5,000.00	$5,000
3004	Custom Concrete Box Riser	EA	1	$20,000.00	$20,000
3005	Standard Concrete End Section for 24 Inch Pipe	EA	1	$2,000.00	$2,000
3006	Standard Type C Endwall for 24 Inch Pipes	EA	1	$4,000.00	$4,000
3007	Gabion Baskets for Forebay Weir	CY	36	$250.00	$9,000
3008	Class I Riprap Ditch	SY	500	$150.00	$75,000
3009	Remove Existing Riser	EA	1	$5,000.00	$5,000
3010	Removal of Existing 30 Inch CMP	LF	47	$50.00	$2,350
3011	Clay Backfill for Core Face and Trench	CY	600	$50.00	$30,000
3012	Mix 6 Concrete for Miscellanous Structures (Concrete Weir)	CY	20	$150.00	$3,000
				Sub-Total	*$215,600*
Cat. 700	**Landscaping**				
7001	Tree, Shrub, and Perennial Installation and Establishment	LS	1	$50,000.00	$50,000
7002	Selective Tree Trimming & Brush Removal	LS	1	$25,000.00	$25,000
				Sub-Total	*$75,000*
Sub-total (all categories)					*$562,850*
Contingency (35%)					*$196,998*
Design (30%)					*$227,954*
Total:					**$987,802**

NOTES:

1. Cost assumes all excavation is removed from site and all fill is purchased
2. Quantities are estimated based on limited site information
3. Unit prices include O&P of 15%

Dewberry

APPENDIX C:

AVALON PARK SHORELINE RESTORATION PROJECT

Introduction

The Avalon Park Shoreline Restoration project was identified and selected for concept development by the Town of Charlestown before the start of the Watershed Master Plan. As such, it was not included in the prioritization matrix developed as part of this project. The intent of this project is to stabilize the deteriorated shoreline. The project location currently showcases a timber bulkhead which has failed and is allowing the park to erode into the waterway. This project will create habitat and add public use amenities and access to the water.

Site Name: Avalon Park Shoreline Restoration Project

General Project Information:	
Project Location:	Avalon Park (Water Street/ Louisa Lane Intersection
Northing/Easting:	1603196.70/ 696601.71
PCSWMM Sewershed:	Peddlers Creek Downstream
Prioritization Score:	N/A
Planning Level Cost Estimate:	$621,500

Required Permitting:	
Charlestown SWM Review:	
Erosion & Sediment Control (ESC):	X
Grading Permit:	X
Joint Permit Application (JPA)/ General Waterway Construction Permit:	X
Construction NOI:	X
Chesapeake Bay Critical Area:	X
Forest Resource Ordinance:	
MDE Dam Safety:	

Vicinity map for the Avalon Park Shoreline Restoration Project

Existing Site Conditions

The Avalon Park Shoreline Restoration project is located on a property that used to be a marina located at the intersection of Water Street and Louisa Lane. The property has since been converted into Avalon Park with a gravel parking lot, stage, and beach/kayak launch. The existing timber bulkhead protects the shoreline extending from the mouth of Peddlers Creek to the north towards the North East River to the south creating the park's peninsula (Photo 1 and Photo 2). The last approximately 250 linear feet of bulkhead is failing with the land behind the wooden piers actively eroding (Photo 3 and Photo 4). The wooden bulkhead is gone and only the wooden piers remain in the last 100 feet (Photo 5). The point of the peninsula is armored with rock which wraps around to the south where additional rock sills have been installed. There is an existing sandy beach, that is currently used as a kayak launch, between the end of the failed bulkhead and start of the rock armoring. The remainder of the peninsula is mowed grass and/or naturalized vegetation.

Proposed Conditions

The Avalon Park Shoreline Restoration Project includes removal of the existing, failing bulkhead and piers. The concept proposes to install a walkable rock jetty with woody debris to provide protection for the shoreline from boat and tidal waves. Both sides of the proposed jetty will be planted with native wetland plants to provide habitat. Wooden stairs are proposed to provide access to the new beach and kayak launch area. The remainder of the area will be graded and planted with a variety of native upland plants. A permeable pathway is proposed to improve walkability and provide access to the newly restored area.

Anticipated Site Constraints

This project aims to be environmentally beneficial, however the approvals necessary to permit work within 50 feet of the mean high water (MHW) and below mean low water (MLW) will require additional effort and coordination. This permitting effort may increase the timeline to construction. In addition to the permitting and approval timeline, additional consideration and design effort is required to properly select the plantings for the brackish environment. There are no site access and construction methodology concerns.

Summary of Results

The shoreline stabilization at Avalon Park achieves all major goals including providing additional public amenities, shoreline protection and stabilization, and both aquatic and terrestrial habitat. This project will stabilize approximately 200 feet of shoreline and return it to a vegetated slope. The stabilization will prevent future shoreline erosion and additional material from leeching into the waterway. The offshore structure will be curved with a pedestrian walkway on top and provide protection for the beach while also creating a shallow habitat area on both the exposed and protected side. This project will create approximately 700 square feet of in-water habitat and 2,100 square feet of terrestrial shoreline habitat.

Photo 1: Existing bulkhead looking north towards the mouth of Peddlers Creek

Photo 2: Existing bulkhead looking south towards the North East River and end of peninsula

Photo 3: Failing bulkhead

Photo 4: Erosion behind failing bulkhead

Photo 5: Eroded area where only the wooden piers remain

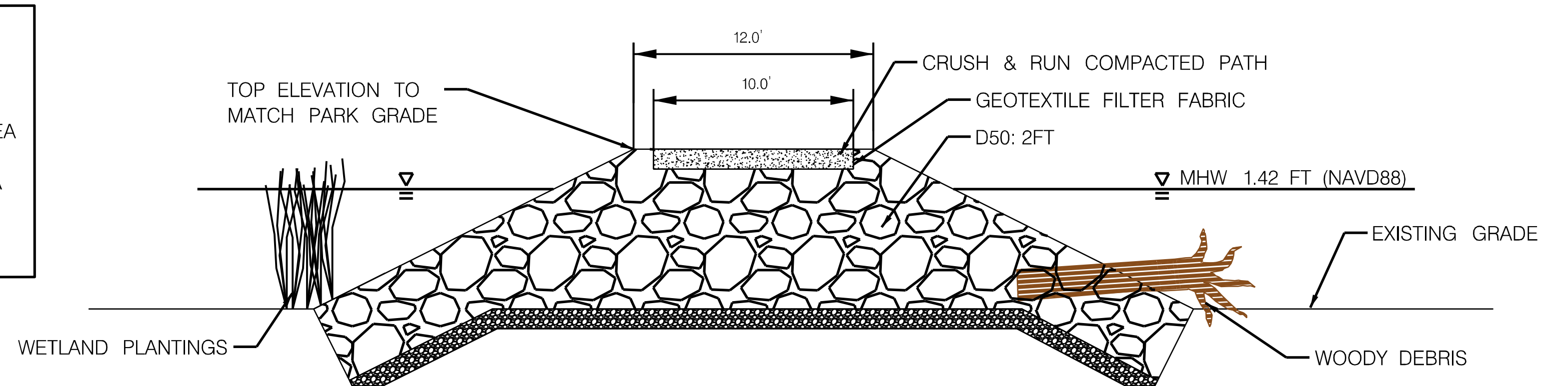
NOTES

1. EXISTING INFORMATION SHOWN ON THIS PLAN ARE BASED ON AVAILABLE GIS DATA AND FIELD OBSERVATION. NO SURVEY HAS BEEN OBTAINED.

2. POTENTIAL SUITABLE PLANTINGS FOR THE GRADED PLANTED UPLAND AREA INCLUDE:
- ASCLEPIAS INCARNATA "SWAMP MILKWEED"
- CAREX STRICTA "TUSSOCK SEDGE"
- CEPHALANTHUS OCCIDENTALIS "BUTTON BUSH"
- ELYMUS VIRGINICUS "EASTERN WILD RYE"
- JUNCUS EFFUSUS "COMMON RUSH"
- PANICUM VIRGATUM "SWITCH GRASS"

3. POTENTIAL SUITABLE PLANTINGS FOR THE SUBMERGED PLANTING AREA INCLUDE:
- IRIS VIRGINICA VAR. SHREVEI "SOUTHERN BLUE FLAG"
- PONTEDERIA CORDATA "PICKLED WEED"
- SCHOENOPLECTUS TABERNAEMONTANI "SOFTSTEM BULRUSH"
- SPARGANIUM AMERICANUM "AMERICAN BUR-REED"
- SPARTINA ALTENIFLORA "SMOOTH CORDGRASS"

	LEGEND
—10—	EXISTING CONTOURS
	WETLAND PLANTING AREA
	UPLAND PLANTING AREA
	PERMEABLE PATH



ROCK JETTY TYPICAL DETAIL
NOT TO SCALE

40' 0 40' 80'
SCALE: 1" = 40'

Dewberry®
Dewberry Engineers
10461 MILL RUN CIRCLE
SUITE #300
OWINGS MILLS, MARYLAND 21117
PHONE: 410.265.9500
FAX: 410.265.8875

BY: aconley -

FOR INFORMATIONAL PURPOSES ONLY.
NOT FOR CONSTRUCTION.

WATERSHED MASTER PLAN
CHARLESTOWN, MD

AVALON PARK

LIVING SHORELINE CONCEPT

SCALE 1" = 40'	ADVERTISED DATE	CONTRACT NO.	
DESIGNED BY TH		COUNTY CECIL COUNTY	
DRAWN BY AC		LOGMILE	
CHECKED BY		HORIZONTAL SCALE	
		VERTICAL SCALE	
DRAWING NO. LD – 01 OF 01		SHEET NO. 1 OF 1	

PROJECT: Avalon Park Shoreline Stabilization - Concept Design

CHARLESTOWN WATERSHED MASTER PLAN - COST ESTIMATE

Date: 12/11/2023

Item No.	Item	Estimated Quantities	Unit	Unit Price	Cost Extension
	GENERAL CONDITIONS				
1	Mobilization / Demobilization	1	LS	$ 85,000.00	$ 85,000.00
2	Temporary Construction Signs	2	EA	$ 450.00	$ 900.00
3	Educational Signage	1	LS	$ 12,000.00	$ 12,000.00
	AVALON PARK SHORELINE STABILIZATION COMPONENTS				
	Rock Jetty				
4	Armor Stone	270	CY	$ 245.00	$ 66,150.00
5	Bedding Stone	100	CY	$ 175.00	$ 17,500.00
6	Excavation & Removal	500	CY	$ 65.00	$ 32,500.00
7	Geotextile Filter Fabric	800	SY	$ 10.00	$ 8,000.00
8	Rootwads	9	EA	$ 2,000.00	$ 18,000.00
9	Wetland Vegetation	650	SF	$ 16.00	$ 10,400.00
	Slope Plantings & Stabilization				
10	Sloped Vegetation	2200	SF	$ 14.00	$ 30,800.00
11	Coir Logs (Final quantity to be determined)	300	LF	$ 8.00	$ 2,400.00
12	Beach Quality Sand	52	CY	$ 125.00	$ 6,500.00
	Upland Improvements				
13	Permeable Walkway	2400	SF	$ 11.00	$ 26,400.00
	EROSION AND SEDIMENT CONTROL				
14	Turbidity Curtains	1	LS	$ 25,000.00	$ 25,000.00
15	Silt Fence	500	LF	$ 5.00	$ 2,500.00
16	Tree Protection	250	LF	$ 5.00	$ 1,250.00
				SUBTOTAL	$ 345,300.00
				CONTINGENCY, 50%	$ 172,650.00
				Engineering Design, 20%	$ 103,590.00
				TOTAL, ROUNDED TO THE NEAREST $100	**$ 621,500.00**

NOTES:

1. Cost assumes all excavation is removed from site and all fill is purchased
2. Quantities are estimated based on limited site information
3. Unit Prices include O&P of 15%

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