St. Michaels San Domingo Creek and West Side Stormwater and Harbor Infrastructure Assessment and Flood Mitigation Study

DRAFT FOR REVIEW

Submittal Date: October 24, 2023

Prepared By:

BayLand Consultants & Designers, Inc.
7455 New Ridge Road, Suite T
Hanover, Maryland 21076
410.694.9401 • baylandinc.com

Prepared For:

Town of St. Michaels
Edgar M. Bosley, Jr. Building
300 Mill Street, PO Box 206
St. Michaels, Maryland 21663

EXECUTIVE SUMMARY

The Town of St. Michaels has approximately 2 miles of shoreline along the Miles River to the east and 0.7 miles of shoreline along San Domingo Creek, a tributary of Broad Creek along the western town limits. The elevation of St. Michaels ranges from zero to eight feet above mean sea level, resulting in low lying areas being exposed to both coastal and stormwater flooding. Impacts of climate change such as Sea Level Rise (SLR) and increase rainfall frequency and duration will continue to threaten vulnerable areas within the Town of St. Michaels.

This Flood Mitigation Study assesses the area of the Town of St. Michaels along San Domingo Creek and infrastructure west of South Talbot Street between West Marengo Street and Canton Street. The study includes a description of the existing conditions within the study boundary that includes topography, shoreline features and a description of the observed stormwater drainage system. A flooding analysis that examines both coastal and stormwater flooding was performed for both current conditions and utilizing 1.7 feet of SLR and increased storm intensity in 2050. Based on this flooding assessment, six areas vulnerable to future flooding were identified. A vulnerability assessment was conducted for each area and, in coordination with the Town of St. Michaels Climate Change and Sea Level Rise (CC/SLR) Committee, the six areas were prioritized for project implementation, shown in the table below.

Table i – Prioritization of Assessment Areas

Priority	Assessment Area Description
1	Grace Street
2	Back Creek Park
3	West Chestnut Street @ Tilden Street
4	Canton Street @ Glory Avenue
5	St. Michaels Nature Trail
6	Thompson Street

After prioritizing the areas for project implementation, risk management strategies were developed to mitigate the risk of flooding. These strategies were compared in an alternatives analysis that examined each alternatives' feasibility, effectiveness, social and environmental impacts, and costs. A preferred alternative was developed for risk management of the six assessment areas.

Finally, the preferred alternatives were developed into implementable projects which aim at providing multi-faceted benefits to the assessment areas. An Implementation Plan was developed that prioritized the projects based on the vulnerability of the areas that would be protected by the projects. The Implementation Plan was divided into Immediate Implementation, Short-Term Implementation, and Long-Term Implementation (Monitoring). Planning level implementation costs for each project were also developed. The Implementation Plan is provided in the subsequent table.

Table ii – St. Michaels West Side Implementation Plan		
Project	**Description**	**Cost***
Immediate Implementation – Action to Recognize Benefits in 0 – 10 years		
1	Back Creek Park Living Shoreline	$204,000
2	Tide Gate Assessment and Preliminary Design	$20,000
3	Tide Gate Implementation	$2,424,000
	Total Immediate Implementation Cost	**$2,648,000.00**
Short-Term Implementation – Action to Recognize Benefits in 10 – 20 years		
4	Grace Street Culvert Improvements	$84,000
5	W. Chestnut & Tilden Street Retention Area Pipe Outfall Improvements	$81,000
6	Stormwater Infrastructure Replacement along St. Michaels Nature Trail	$199,200
7	Raise Boating Infrastructure at Back Creek Park	$708,000
	Total Short-Term Implementation Cost	**$1,072,200.00**
Long-Term Implementation – Action to Recognize Benefits in 20+ years		
8	Monitor Flood Risk for Assessment Areas	TBD
9	Nourish Living Shorelines along Back Creek Park	TBD
	Total Long-Term Implementation Cost	**TBD**

**planning level cost estimates based on 2023 dollars*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

1. INTRODUCTION

The Town of St. Michaels (Figure 1), located in Western Talbot County, MD, is home to approximately 1,055 residents. The Town is nationally known as a tourist destination and has been named one of the Top 10 Best Small Coastal Towns in America by USA Today. In addition to its harbor area and historic homes, some dating back to the mid 1600s, St. Michaels has considerable cultural significance as a historic maritime town on the Chesapeake Bay.

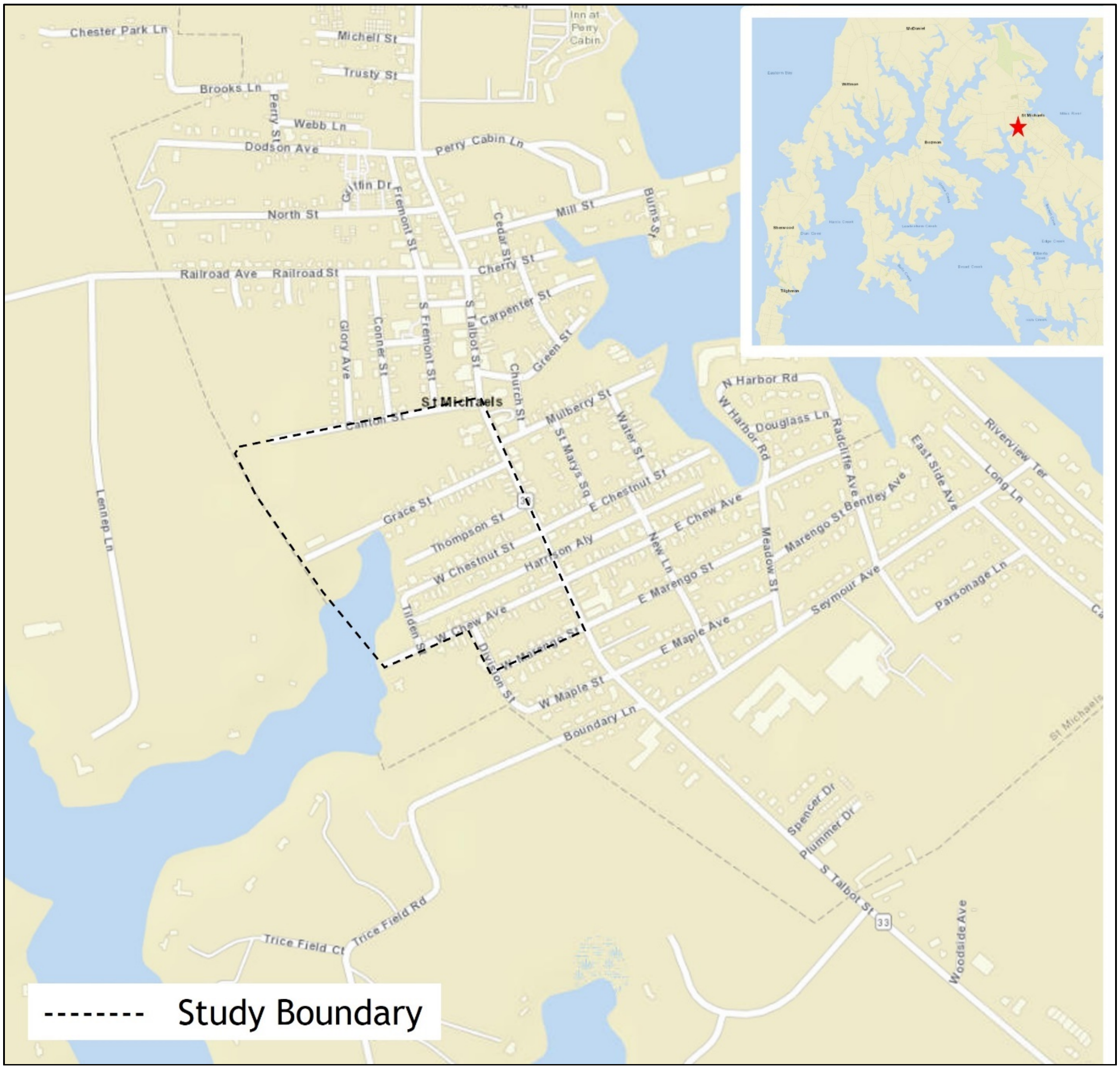


Figure 1 - The Town of St. Michaels Vicinity Map

The Town of St. Michaels has approximately 2 miles of shoreline along the Miles River to the east and 0.7 miles of shoreline along San Domingo Creek, a tributary of Broad Creek along the western town limits. The elevation of St. Michaels ranges from zero to eight feet above mean sea level, resulting in low lying areas being exposed to both coastal and stormwater flooding. Impacts of climate change such as sea level rise and increase rainfall frequency and duration will continue to threaten vulnerable areas within the Town of St. Michaels. Flooding experienced at St. Michaels west end are presented in Photo 1 and Photo 2.

Photo 1- Flooding at 124 Grace St.

Photo 2 - Flooding at Grace Street Culvert

The Town of St. Michaels created the Climate Change/Sea Level Rise Commission (CC/SLRC) to prepare the Town for the increased risk of flooding by 2050. The St. Michaels San Domingo Creek and West Side Flood Mitigation Study is part of the Community Resilience Partnership initiative undertaken with the Chesapeake and Coastal Service to provide input into the decision-making process for future capital project and updates to the Town's floodplain ordinances and mitigation plans.

In December 2022, BayLand Consultants and Designers, Inc. (BayLand) was selected to assess the west side of St. Michaels' vulnerability to flooding due to coastal and stormwater sources. As part of this work, BayLand examined the shoreline and stormwater infrastructure and modeled multiple flood scenarios to determine the likelihood and intensity of flooding for 2050 conditions. This study presented the areas that are identified as vulnerable to flood risk and prioritizes them for risk management measures. Next, the study presents flood risk mitigation strategies to manage the risk and compares them in an Alternatives Analysis. Decision matrices for different alternatives are presented for each assessment area. Finally, projects were developed from the preferred alternatives and input into an Implementation Plan that provides timeframes for implementation as well as planning level cost estimates.

2. EXISTING CONDITIONS

Data specific to the Town of St. Michaels was collected from Town archives, State LiDAR, County GIS and as-built data, and the Maryland Environmental Resources and Land Information Network (MERLIN). This data was used to supplement field collected data in order to gain a better understanding of how flood events are impacting the area. The data collected was compiled into a basemap that served as the basis for assessing the flooding vulnerability and in the creation of flood mitigation strategies. A summary of this data is provided in the following sections.

2.1. Topography

Detailed topographic data for the City of St. Michaels was obtained from a DEM produced by the United States Geological Survey (USGS) and the National Resource Conservation Service (NRCS)[1]. The DEM was processed in 2015 and utilized Light Detection and Ranging (LiDAR) data flown for Talbot County in 2004. The elevations of the study area are shown in Figure 2.

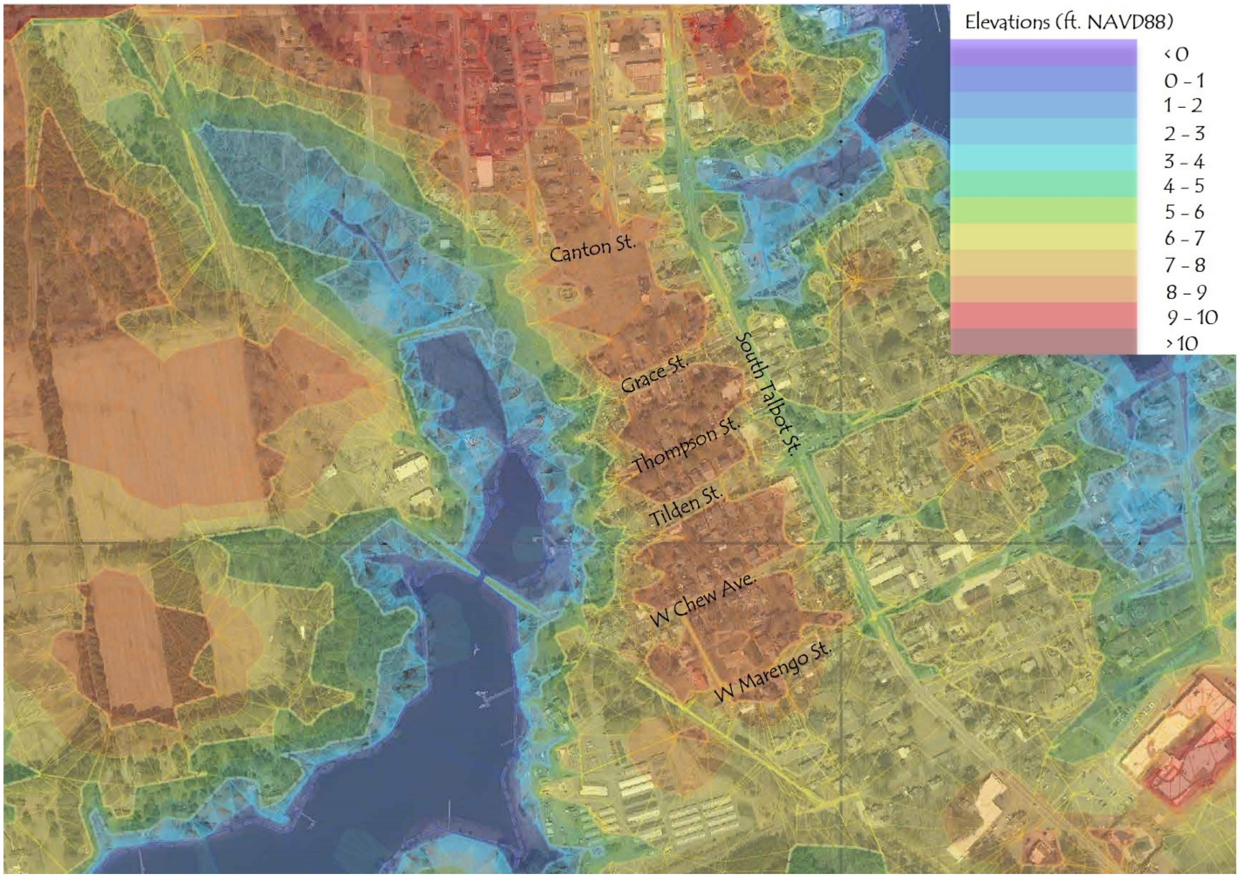


Figure 2 - LiDAR Elevations along West Side of St. Michaels

[1] https://imap.maryland.gov/pages/lidar-inventory

Elevations shown in Figure 2 reference feet above the North American Vertical Datum of 1988 (NAVD88), which is approximated as less than 0.1 feet higher than Mean Sea Level (MSL). Therefore, elevations shown in Figure 2 match closely with known Town elevations referenced to feet above MSL.

The majority of residential properties west of South Talbot Street are located at elevations of +8 feet above NAVD88 or above. Lower elevations are experienced closer to the shoreline and along South Talbot Street, where average elevations range from +3 to +5 feet above NAVD88.

2.2. Shoreline Features

The shoreline along the west side of St. Michaels features various shoreline protection structures such as a living shoreline, bulkheads, revetment and natural banks, shown in Figure 3.

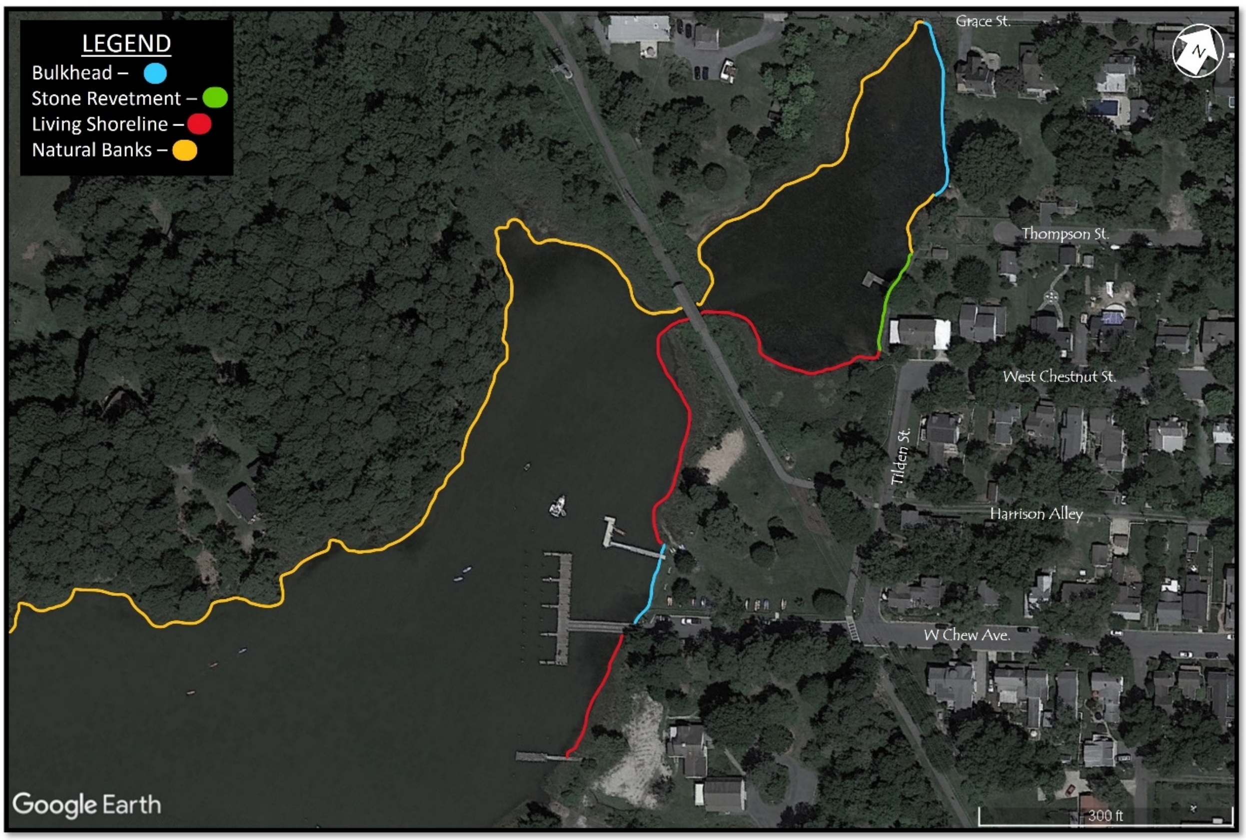


Figure 3 - Shoreline Features

The south-western shoreline of the Town of St. Michaels consists of natural banks south of the Back Creek Park boating infrastructure. The southern shoreline of Back Creek Park consists of a dilapidated bulkhead (Photo 3) that is past its service life and is leaning seaward. A living shoreline made up of a stone sill and marsh planting is located just north of the bulkhead and stretches along the remaining extents of Back Creek Park

(Photo 4). The shoreline north of living shoreline to the Grace Street culvert consists of revetment, bulkhead and natural banks on private property (Photo 5 and Photo 6).

Photo 3 - Bulkhead at Back Creek Park

Photo 4 - Living Shoreline at Back Creek Park

Photo 5 - Revetment and Natural Banks along Private Properties

Photo 6 - Bulkhead along Private Property

2.3. Drainage System

A field assessment was conducted to identify components of the West Side's drainage system. Both hard and soft stormwater infrastructure was mapped and structures requiring topographic survey for critical elevations (i.e. top of grate/manhole rim, pipe size/inverts; swale, curb, road elevation, etc.) were identified. The assessment also documented drainage characteristics, identified surface visible infrastructure deterioration and failure, and documented suitable locations for new infrastructure, green infrastructure best management practices (BMP), and other solutions to provide flood relief.

The assessment identified two main connected stormwater systems. First, a stormwater system running along the St. Michaels Nature Trail that outlets flow into a retention facility along the shoreline. Second, a small stormwater system along Canton St. that outlets flow into a swale. The systems both flow towards tidal waters to the west of St. Michaels and feature rain gardens and swales in addition to stormwater drainage pipes. (Figure 4)

Figure 4 - Stormwater Management Features

Photo 7 - Best Management Practice (BMP) along West Chestnut

Photo 8 - Swale along Canton Street


Photo 9 - BMP at Tilden Street End


Photo 10 - Outfall Pipe near W. Chestnut Street BMP


Photo 11 – Bridge at St. Michaels Nature Trail


Photo 12 - Grace Street Culvert

3. FLOODING ANALYSIS

For the purpose of this analysis, flooding was divided into two categories:

1. Flooding due to High Water Levels – when the coastal water level rises higher than the adjacent land, water will inundate the area. For this study, increases in water level due to sea level rise (SLR) and storm surge were evaluated.

    a. SLR – flooding that occurs due to an increase in still water level (water level not including waves) as a result of climate change. With an increase in still water level, areas that have previously not flooded or only flooded during higher-than-usual water levels will become inundated more frequently.
    b. Storm Surge – flooding that occurs due to an increased water level during a storm event. Storm events, such as hurricanes, bring low pressure and high winds that raise the water level along the shoreline, resulting in coastal flooding of areas below the storm surge level.

2. Heavy Rainfall (Stormwater) Flooding– flooding that occurs during a period of intense rainfall. This flood event is not associated with coastal water levels. It results from a high intensity rain storm or 'flash flood' that dumps a large amount of precipitation in a short enough period of time to prevent proper runoff. It can also occur due to prolonged rainfall that has overwhelmed the drainage system. This type of flooding is anticipated to increase in frequency with SLR as a higher static coastal water level may not allow the outfalls to discharge the stormwater, resulting in backwatering of the system. The intensity and frequency of rainfall events is also expected to increase due to factors associated with climate change, which can overwhelm existing storm drain systems from the increased runoff volume.

3.1. Water Levels

Tide datums, or the average daily water levels experienced during the tidal epoch period between 1983 and 2001, are available from the National Oceanic and Atmospheric Administration (NOAA)-operated Tide Station 8571892 in Cambridge, MD[2] and shown in Table 1.

Table 1 – Tidal Datums at Station 8571892 Cambridge, MD

Datum	Water Elevation (ft NAVD88)
Mean Higher High Water (MHHW)	+0.93
Mean High Water (MHW)	+0.72
North American Datum of 1988 (NAVD88)	**0.00**
Mean Sea Level (MSL)	-0.09
Mean Low Water (MLW)	-0.90
Mean Lower Low Water (MLLW)	-1.11

The close correlation between the North American Datum of 1988 (NAVD88) and Mean Sea Level (MSL) should be noted. Therefore, elevations presented in this study referencing NAVD88 can be approximated as elevations above MSL.

3.1.1. Sea Level Rise (SLR)

SLR is the increase of average water levels. It is divided into two categories based on contributing factors:

1. Global Sea Level Rise – increase in the global sea level based on the thermal expansion of water (the size of water molecules increases as it warms up) and ice melt from the glaciers and continental ice masses adding a significant amount of freshwater into the world's oceans.

[2] https://www.tidesandcurrents.noaa.gov/datums.html?id=8571892

2. Relative Sea Level Rise – increase in the local sea level along a specific coast that includes global SLR and land subsidence (sinking of land), tectonic plate movements, and other local factors.

Based on water level measurements taken between 1943 and 2022 at the NOAA Tide Station 8571892 at Cambridge, MD, sea levels in the lower Chesapeake Bay have risen approximately 1.02 feet in 80 years (~0.15 inch/year).

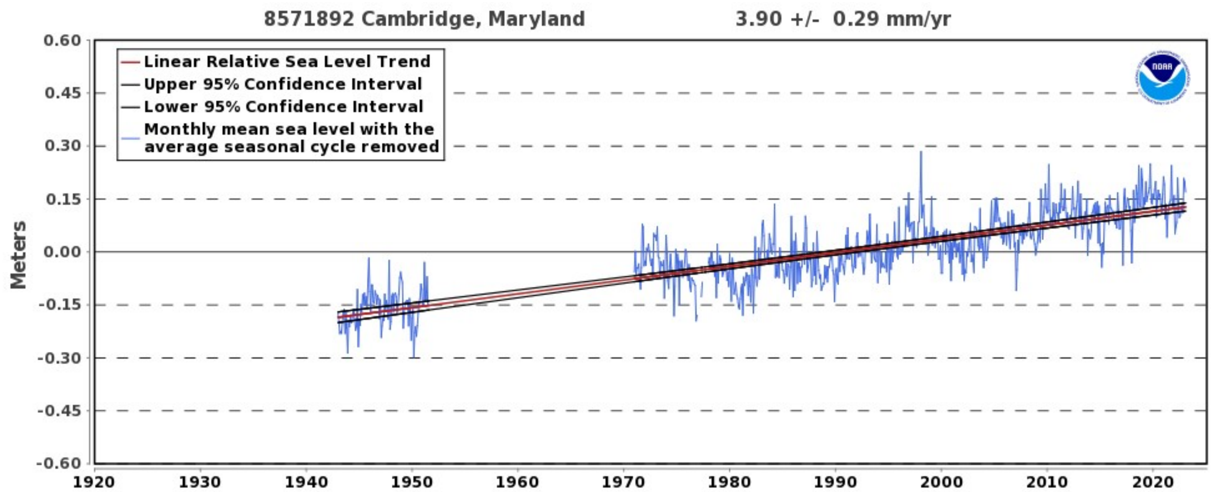


Figure 5 - SLR Trend at NOAA Tide Station 8571892 in Cambridge, MD

Recent evidence indicates the rate of SLR has increased and will likely do so for the coming decades. To determine which SLR projection should be used for analysis, planning and design of areas vulnerable to SLR, the University of Maryland Center for Environmental Science (UMCES) has developed the *Sea-Level Rise Projections for Maryland 2018* which provides likely ranges, central estimates and the 5% and 1% probability estimates for SLR relative to the water levels experienced in 2000. Additionally, representatives of the Maryland DNR and Maryland Sea Grant Extension are developing guidance on how to utilize the SLR projections based on an area's risk tolerance to impacts. The values presented in Table 2 present the SLR projections for Cambridge, Maryland assuming greenhouse gas emissions are stabilized by 2050 (RCP 4.5). These projections are intended for use when conducting studies or developing designs for areas or assets subject to the impacts for SLR and will be applied to the St. Michaels West Side assessment areas discussed in subsequent paragraphs of this study.

Table 2 – Recommended SLR Projections*			
Year	**High Tolerance for Risk**	**Medium Tolerance for Risk**	**Low Tolerance for Risk**
2030	0.9 ft	1.1 ft	1.3 ft
2040	1.2 ft	1.5 ft	1.8 ft
2050	1.7 ft	2.0 ft	2.4 ft
2060	1.9 ft	2.3 ft	2.9 ft

Table 2 – Recommended SLR Projections*			
2070	2.3 ft	2.8 ft	3.5 ft
2080	2.7 ft	3.3 ft	4.2 ft
2090	3.1 ft	3.8 ft	5.0 ft
2100	3.5 ft	4.3 ft	5.7 ft

** Based on projections at Cambridge per design year and risk tolerance for RCP 4.5 – Stabilized Emissions*

For the purposes of this study, the 'High Tolerance for Risk' project for 2050 will be used to assess the vulnerability of each assessment area and guide the development of the risk management strategies. Applying this projection of 1.7 feet of SLR over the existing tidal datums will result in the following 2050 estimated tidal datums at the Cambridge Station:

Table 3 – Current and 2050 Tidal Datums at Station 8571892 Cambridge, MD		
Datum	**2000 Water Elevation (ft NAVD88)**	**2050 Water Elevation (ft NAVD88)**
Mean Higher High Water (MHHW)	+0.93	+2.63
Mean High Water (MHW)	+0.72	+2.42
North American Datum of 1988 (NAVD88)	**0.00**	**+1.70**
Mean Sea Level (MSL)	-0.09	+1.61
Mean Low Water (MLW)	-0.90	+0.80
Mean Lower Low Water (MLLW)	-1.11	+0.58

3.1.2. Storm Surge

Storm surge is the abnormal rise of water, over and above the astronomical tides, generated by a low-pressure weather system. As a result of these events, water levels can increase by several feet. High winds and waves and extreme rainfall often accompany these elevated water levels and cause significant flooding to coastal areas.

Extreme water levels based on storm surge return-period, or likely intervals between storm events, were obtained for the tide station at Cambridge Station. The SLR estimate of 1.7 feet was added to the estimated storm surge elevations to project 2050 elevations, presented in Table 4.

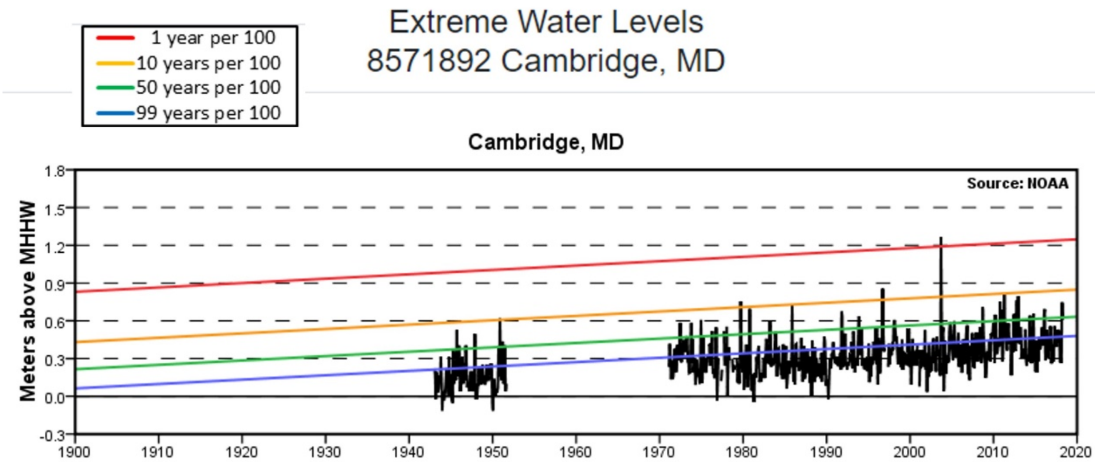


Figure 6 - Extreme Water Levels data for Cambridge Station[3]

Table 4 – Storm Surge Elevations Estimates at Cambridge, MD			
Return Period (yr)	**Annual Chance of Occurrence (%)**	**2000 Storm Surge Elevation (ft NAVD88)**	**2050 Storm Surge Elevation (ft NAVD88)**
1 – year (99 events per 100 years)	99%	+2.4	+4.1
2 – year (50 events per 100 years)	50%	+2.9	+4.6
10 – year (10 events per 100 years)	10%	+3.4	+5.1
100 – year (1 event per 100 years)	1%	+4.9	+6.6

3.1.3. High Tide and Storm Surge Flood Mapping

For each of the assessment areas, discussed in Section 4, flood maps were developed to estimate the extent of flooding in 2050. To represent the 2050 daily flood extents, the MHW elevation of +2.4 feet NAVD88 was mapped for assessment area. These areas are expected to experience inundation every day. Additionally, to map the flood extents for storm surge events, the 2050 10-year return period storm elevation of +5.1 feet NAVD88 was overlain on the existing topography. The areas shown as inundated during this event have an approximate 10% annual chance of being flooded due to storm surge.

3.2. Hydrologic and Hydraulic Analysis

A hydraulic and hydrologic analysis, discussed in the subsequent sections, was performed at study points to determine flow patterns and flood extents resulting from rainfall events.

3.2.1. Hydrologic Analysis

The United States Department of Agriculture (USDA) NRCS Technical Release 55 (TR-55) computer program was used to compute runoff curve number (RCN) for the select study points. The RCN is based on the latest Talbot County GIS planimetric data and

[3] https://www.tidesandcurrents.noaa.gov/est/est_station.shtml?stnid=8571892

USDA Web Soil Survey data. The RCN is determined from the percentages of Open Space, Impervious, and Woods within a drainage area. Soils are classified according to their runoff potential using NRCS Hydrologic Soil Classification, which characterizes the soils and their potential to generate runoff.

These categories range from Hydrologic Soil Group (HSG) A (low runoff, high infiltration) to HSG D (high runoff, low infiltration). The soils in the area are primarily HSG D soils, resulting in high amounts of runoff and low infiltration (Table 5). The corresponding RCN values were applied to the drainage areas of each study point. The full hydrologic analysis is located in Appendix A.

Table 5 – Soil Summary

HSG	Runoff Rate	Infiltration Rate	Percent of Drainage Area
A	Very Low	Very High	0%
B	Low	High	0%
C	High	Low	0%
D	Very High	Very Low	100%

Peak discharges for the 10-, and 100-yr storms in 2050 were computed using the NRCS TR-20 computer program. NOAA Atlas 14 Intensity-Duration-Frequency (IDF) precipitation estimates were used with a 24-hour distribution curve to develop runoff parameters The Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) NOAA and RAND Corporation climate projections was then utilized to determine the change factors to the NOAA Atlas 14 IDF data for projected storm events in 2050 due to climate change. Change factors were based on high emissions future Representative Concentration Pathway (RCP) 8.5. and 90^{th} percentile uncertainty range to be consistent with high tide and storm surge flooding analysis.

See Appendix A for full hydrologic analysis and peak discharges to select study points.

3.2.2. Hydraulic Analysis

A conceptual-level hydraulic analysis of the storm drain system was performed using the Storm Water Management Model (SWMM) version 5.2, developed by the Environmental Protection Agency (EPA). The pipe, inlet, and manhole data were taken from the critical elevations obtained during field investigations. Where additional data was necessary for the model, interpolations were assumed based on nearby survey data. Flood duration and proliferation of outfall conditions for storm events were determined based on storm surge and 2050 SLR projections discussed in Section 3. Table 6 lists the special conditions and equivalent return periods analyzed for the SWMM scenarios.

Models were developed for existing and proposed conditions for all storm scenarios to demonstrate system behavior based on water levels obtained from the SLR analysis.

Data from the SLR analysis was used to establish anticipated semidiurnal tidal cycles for 2050. These cycles were utilized for the tailwater conditions at the system outfall locations to San Domingo Creek. The peak discharges developed in Section 3.2.1 and Mean Higher High Water (MHHW) were synchronized to provide more conservative results.

The full hydraulic analysis is located in Appendix B.

Table 6 – Hydraulic Analysis: Analyzed Storm Scenarios

Storm Event	Tailwater Elevation (ft NAVD88)
10-yr	2000 Tidal Cycle
10-yr	2050 Tidal Cycle
100-yr	2000 Tidal Cycle
100-yr	2050 Tidal Cycle

4. ASSESSMENT AREAS

Input from community officials, business owners, and residents and the results of the flooding assessment highlighted six areas of particular concern to the community. These areas currently experience flooding or are most susceptible to flooding with future conditions. The areas examined in detail in this assessment are presented in Table 7.

Table 7 – Assessment Areas

ID	Street Intersection
1	Canton Street near Glory Avenue
2	Grace Street
3	Thompson St.
4	Tilden St. / W. Chestnut St.
5	Back Creek Park
6	St. Michaels Nature Trail

4.1. Canton Street near Glory Avenue

Canton Street is a narrow, residential road with elevations ranging from approximately +4 to +8 feet NAVD88. The southern side of the road borders the St. Luke's Cemetery and property owned by Choptank Electric Cooperative. The easternmost 750 feet of road is paved (Photo 13), ending at the intersection with Glory Avenue. West of Glory Avenue, the unpaved portion (Photo 14) of road leads to homes and the headwaters of

San Domingo Creek (Photo 15). Swales with pipes beneath driveways were observed along the southern edge of the road (Photo 16).

Photo 13 - Canton Street (looking West)

Photo 14 - Unpaved Area of Canton Street (looking East)

Photo 15 - Headwaters of San Domingo Creek near Canton St.

Photo 16 - Outfall along Swale at Canton St.

4.1.1. 2050 High Tide and Storm Surge Flooding

Flooding at Canton Street near the intersection with Glory Avenue was assessed for the 2050 MHW event and the 2050 10-year return period storm surge event, as described in Section 3.1. The results of the flood analysis show that flooding is not anticipated daily in 2050, though water levels are anticipated to cross Canton Street around the headwaters of San Domingo Creek. For the 10-year return period storm surge level in 2050, flooding occurs on the road and neighboring properties.

No homes along Canton Street and Glory Avenue are anticipated to experience flooding during the 2050 MHW. Areas within St. Luke's cemetery would experience 1 foot or less of flooding for the 10-year return period storm surge event. Up to 2 feet of flooding could be experienced at the Choptank Electric Cooperative property and 1 – 2 properties along Glory Avenue. An additional 1 or 2 properties along Glory Avenue could experience flooding of 1 foot or less for the modeled storm surge scenario.

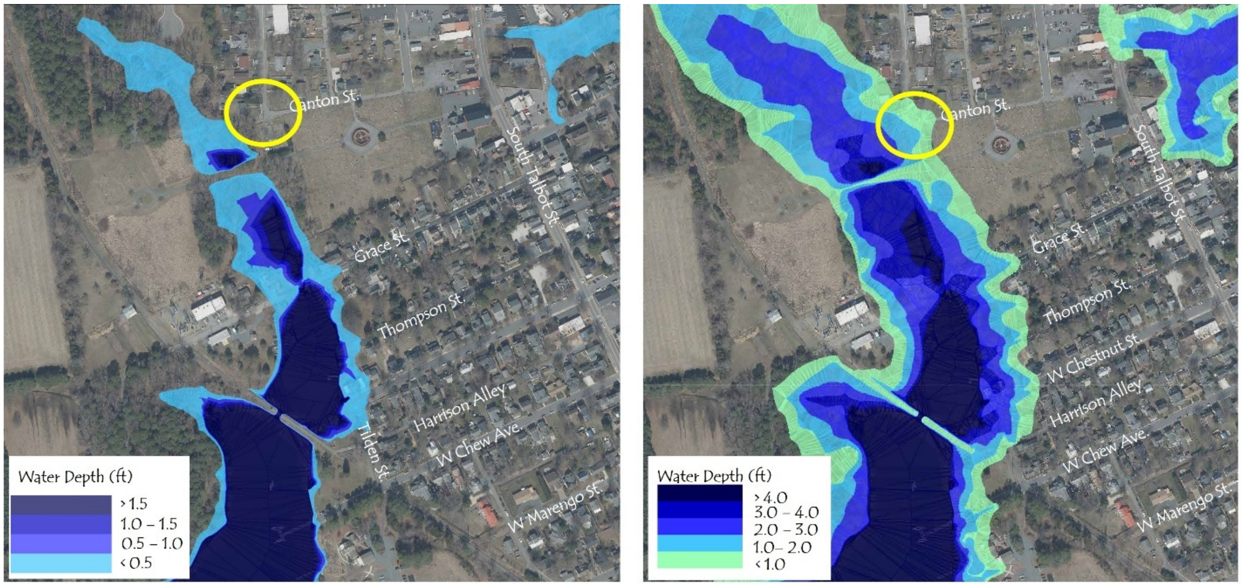


Figure 7 - 2050 High Tide and Storm Surge Flooding at Canton Street

4.1.2. 2050 Stormwater Flooding

The duration of stormwater flooding was evaluated for the 10-year and 100-year return period rainfall event with current and future conditions. The result of the flood duration modeling for Canton Street at Glory Avenue is shown in Figure 8 and indicate that the 2050 10-year return period rainfall event will not result in flooding while the 2050 100-year return period rainfall event will result in flooding that is likely to drain in less than 1 hour.

4.1.1. Flood Impacts at Canton Street near Glory Avenue

Damage from these flood scenarios could include impacts to the road infrastructure including the pavement, storm drains, electric poles and other utilities that would require repairs. Erosion of flow paths was also observed along the shoulder of the road. Storm surge flooding in 2050 could impact homes and the Choptank Electric Cooperative property with up to 2 feet of flooding.

Figure 8 - 2050 Stormwater Flooding duration at Canton St. and Glory Avenue

4.2. Grace Street

Grace St. is a residential road with elevations ranging from +2.5 feet NAVD88 near the culvert and humps to +7.5 feet NAVD88 moving east before ending at approximately +6.5 feet at the intersection with S. Talbot Street (Photo 17 and Photo 18). Residences along this road are generally 1 – 2 feet higher than the road elevations. This road has sidewalks and curbs on both sides of the street with no stormwater management features, indicating stormwater likely sheetflows along the road toward the shoreline or the drainage infrastructure on S. Talbot Street. Grace Street bridges over San Domingo Creek with an approximate 8.5-foot culvert allowing flow between the north and south side of the road (Photo 19 and Photo 20). The top of the culvert was surveyed to be approximately +1.5 feet NAVD88 with the toe at approximately -2 feet NAVD88 at the center of the structure. Located approximately 60 feet from the Grace Street Culvert is a County-owned sanitary-sewer pump station. On the west side of the Grace Street Culvert is a utility sub-station and two residences that are only accessible via Grace Street.

Photo 17 - Grace Street (looking East)

Photo 18 - Grace Street at Culvert (looking East)

Photo 19 - Grace Street Culvert (looking SE)

Photo 20 - Grace Street Culvert (looking NE)

4.2.1. 2050 High Tide and Storm Surge Flooding

Flooding along Grace Street was assessed for the 2050 MHW event and the 2050 10-year return period storm surge event, as described in Section 3.1. The results of the flood analysis show that flooding could occur daily near the Grace Street culvert with flooding of less than 0.5 feet impacting approximately 4 properties and the pump station. The storm surge analysis of the 10-year return period storm could impact approximately 10 properties, some with as much as 3 – 4 feet of flooding. The County pump station will experience approximately 3 feet of flooding. Access to and from the utility sub-station and the residences located on Grace Street west of the culvert would be restricted due to flooding of the road.

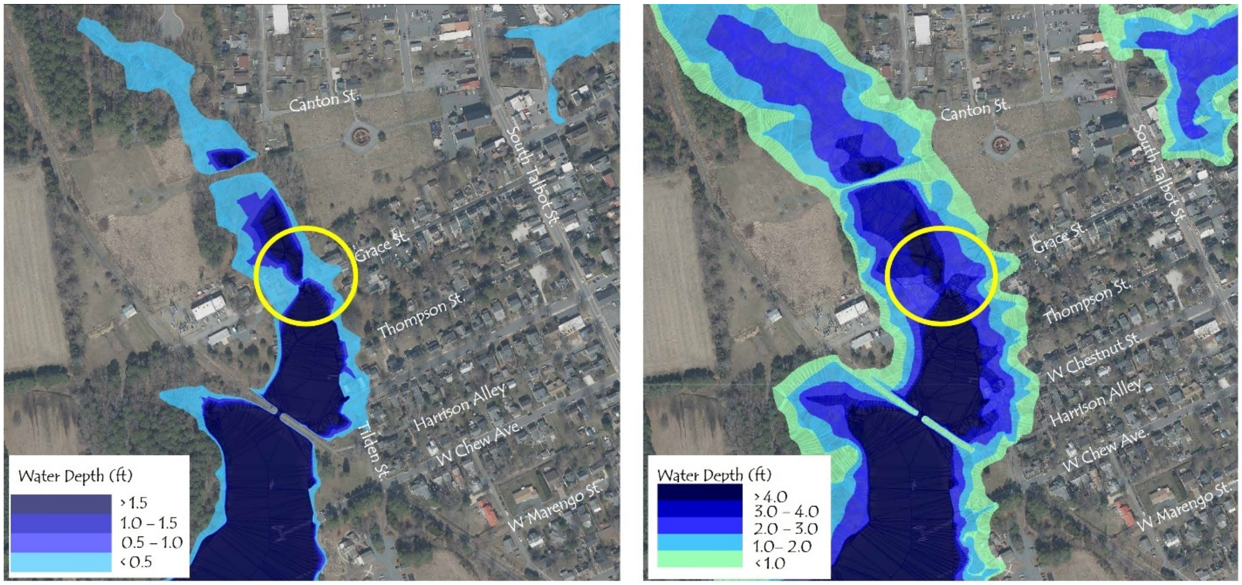


Figure 9 - 2050 High Tide and Storm Surge Flooding at Grace Street

4.2.2. 2050 Stormwater Flooding

An analysis of the culvert located along Grace Street indicated that, given the large drainage area, the culvert is undersized to pass the 2050 10-year rainfall event. Therefore, flooding is likely for all extreme rainfall events greater than the 10-year event in 2050.

4.2.3. Flood Impacts at Grace Street

Damage from these flooding scenarios could include impacts to the road infrastructure including the pavement, storm drains, electric poles and other utilities that would require repairs. Erosion of flow paths was also observed along the shoulder of the road. Multiple homes are threatened by flooding for the daily high tide and storm surge events in 2050. The County sanitary-sewer pump station will be flooded daily in 2050.

4.3. Thompson Street

Thompson Street is a residential road with elevations ranging from +2.5 to +8 feet NAVD88 (Photo 21 and Photo 22). Similarly to other streets within the west end, the residential properties along the road are at higher elevations than the road. A swale runs along the southern edge of the road (Photo 23) and ends at a retention pond (Photo 24).

4.3.1. 2050 High Tide and Storm Surge Flooding

Flooding along Thompson Street was assessed for the 2050 MHW event and the 2050 10-year return period storm surge event, as described in Section 3.1. The results, shown in Figure 10, show that flooding of the retention pond could occur daily with as much as 1 foot of flooding. The shed located just south of the retention pond would also be inundated with less than 1 foot of water for the 2050 daily high tide. The storm surge analysis of the 2050 10-year return period storm could impact approximately two properties with homes on West Chestnut Street. The homes along Thompson Street appear to be outside the limit of the 2050 10-year storm surge flood extents.


Photo 21 - Thompson Street near Shoreline (looking East)


Photo 22 - Thompson Street (looking West)


Photo 23 - Grassy Swale along Southern Road Edge


Photo 24 - Retention Pond at Thompson Street

4.3.1. 2050 Stormwater Flooding

The duration of stormwater flooding was evaluated for the 10–year and 100–year return period rainfall event with current and future conditions. The results of the flood duration modeling for Thompson Street indicate that stormwater flooding is not likely to occur for either rainfall event for current or 2050 conditions.

4.3.2. Flood Impacts at Thompson Street

Damage from these flood scenarios could include impacts to the road infrastructure including pavement, curbs, storm drains and other utilities that could require repairs. A shed is anticipated to experience flooding daily during high water events in 2050 and two homes are likely to experience flood damage as well during the 2050 10-year storm surge event. Other damage at the retention pond is anticipated to be temporary as this form of green infrastructure typically ‘bounces back’ after flood events with little or temporary damage.

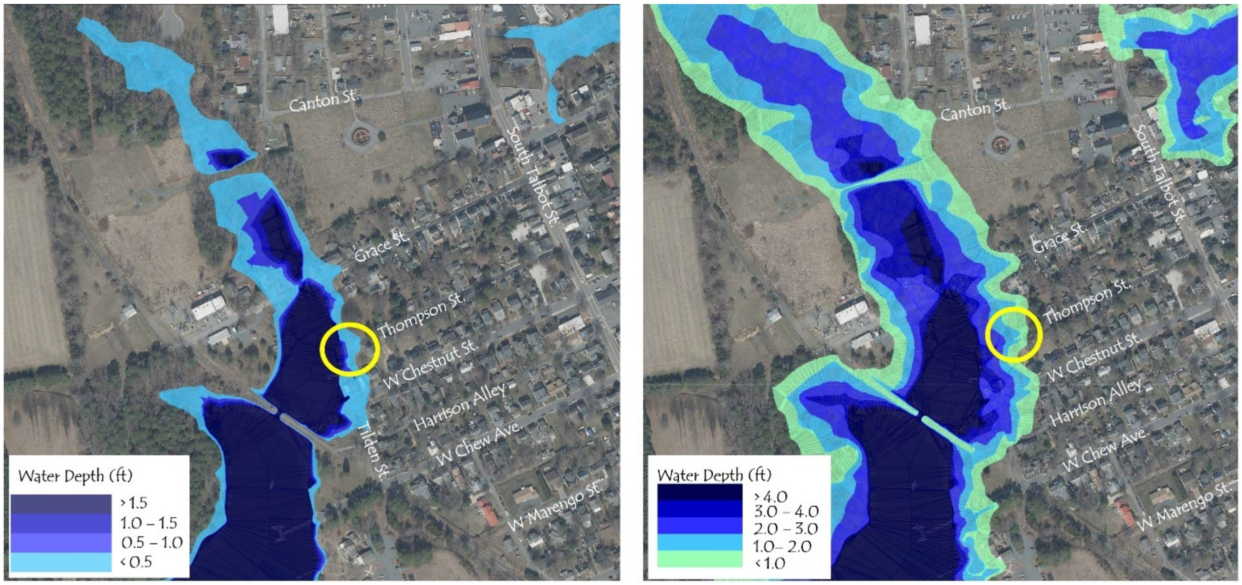


Figure 10 - 2050 High Tide and Storm Surge Flooding at Thompson Street

4.4. West Chestnut Street at Tilden Street

West Chestnut Street (Photo 25) is a residential road that begins at the intersection with S. Talbot Street and ends at the intersection with Tilden Street (Photo 26), near Back Creek Park and the shoreline of San Domingo Creek. The lowest elevations of the road occur at the intersection of West Chestnut St. and Tilden St., with road elevations averaging +2 feet NAVD88. A retention pond is located on the west side of the road intersection (Photo 27). A 24-inch RCP pipe with an invert elevation of approximately -1.4 feet NAVD88 outfalls through the marsh area into San Domingo Creek (Photo 28). A grassy swale was located on the east side of Tilden Street (Photo 29).

The homes on the southern edge of West Chestnut St. are generally 0.5 to 1 foot higher than the road elevation. On the northern edge of West Chestnut St., the homes are generally at the same elevation of the road. From the lowest road elevations of approximately +2 feet NAVD88, elevations of both West Chestnut St. and Tilden St. increase to approximately +6 feet NAVD88 moving east or south from their intersection. No stormwater infrastructure was located along West Chestnut St, so it is assumed that stormwater sheetflows down the road to the retention pond and drains through the outfall pipe.

Photo 25 - West Chestnut Street (looking West)

Photo 26 - Tilden St. (looking South)

Photo 27 - Retention Pond at Intersection of W. Chestnut and Tilden Streets

Photo 28 - Outfall Pipe from Retention Pond at W. Chestnut St. and Tilden St.

Photo 29 - Grassy Swale along Tilden Street

4.4.1. 2050 High Tide and Storm Surge Flooding

Flooding at the intersection of West Chestnut St. and Tilden St. was assessed for 2050 MHW and the 2050 10-year return period storm surge event, as described in Section 3.1. The results, shown in Figure 11, show that flooding in this area is anticipated daily in 2050. Approximately 2 homes will experience flooding of less than 0.5 feet for the 2050 daily high tides. The retention pond would be inundated by more than 1 foot daily. The storm surge analysis of the 2050 10-year return period storm could impact approximately 5 properties with homes on West Chestnut St. Two homes would experience flooding of less than 1 foot for this storm condition. Two additional homes would experience approximately 2 – 3 feet of flooding while one home could have between 3 and 4 feet of flooding for the 2050 10-year return period storm.

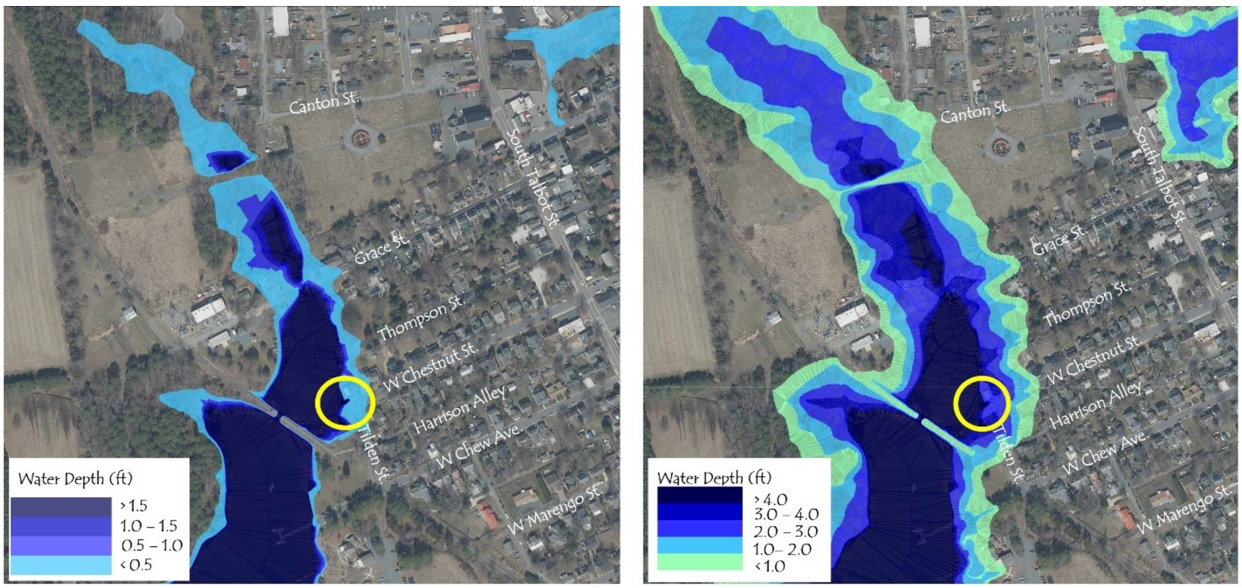


Figure 11 - 2050 High Tide and Storm Surge Flooding at West Chestnut St. and Tilden Ave.

4.4.2. 2050 Stormwater Flooding

The duration of stormwater flooding was evaluated for the 10–year and 100–year return period rainfall event with current and future conditions. The results of the flood duration modeling for the retention pond located at West Chestnut St. and Tilden St. is shown in Figure 12.

The results of the modeling show that the higher tailwater elevations at the outfall pipe will prevent drainage of the outfall pipe and result in a significant increase in flood duration at this location for 2050 conditions.

4.4.1. Flood Impacts at W. Chestnut and Tilden St.

Damage from these flood scenarios could include impacts to the road infrastructure including pavement, curbs, storm drains and other utilities that could require repairs. Multiple homes are likely to experience flood damage as well. Two homes may be considered uninhabitable without adjustments due to the frequent flooding. Other damage at the retention pond is anticipated to be temporary as these assets typically ‘bounce back’ after flood events.

Figure 12 - 2050 Stormwater Flooding Duration at West Chestnut St. and Tilden St.

4.5. Back Creek Park

Back Creek Park is an open space recreational area located west of Tilden Street at the end of West Chew Avenue. The park consists of lawn and tree areas with benches (Photo 30 and Photo 31) that slope down to a bulkhead and living shoreline. The living shoreline consists of small stone sills protecting an area of marsh plantings and other shoreline vegetation (Photo 32). A bulkhead in a failed condition runs the remaining length of shoreline along San Domingo Creek (Photo 33). Boating and water access infrastructure, including kayak racks and piers for docking and launching are also present along the shoreline within the Park (Photo 34 and Photo 35).

Photo 30 - Benches at Back Creek Park

Photo 31 - Lawn Area

Photo 32 - Living Shoreline Area

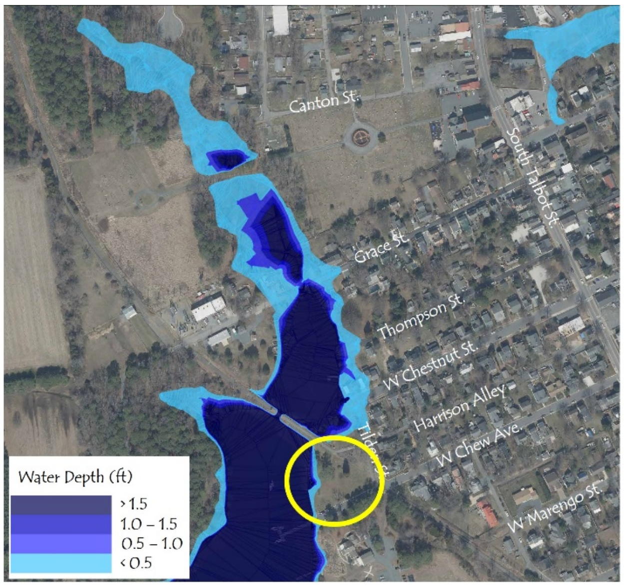
Photo 33 - Failed Bulkhead along Back Creek Park

Photo 34 - Pier and Floating Dock Infrastructure

Photo 35 - Fixed Pier for Docking along San Domingo Creek

4.5.1. 2050 High Tide and Storm Surge Flooding

Flooding at Back Creek Park was assessed for 2050 MHW and the 2050 10-year return period storm surge event, as described in Section 3.1. The results, shown in Figure 13, show that flooding of the living shoreline marsh area is anticipated daily in 2050 with approximately 1.5 feet of water. The storm surge analysis of the 2050 10-year return period surge could result in approximately 3 – 4 feet of flooding within the Park.



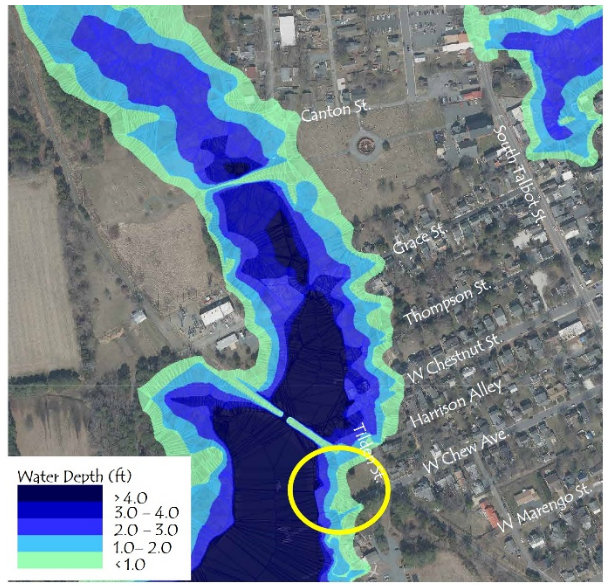


Figure 13 - 2050 High Tide and Storm Surge Flooding at Back Creek Park

4.5.2. 2050 Stormwater Flooding

The duration of stormwater flooding was evaluated for the 10 – year and 100 – year return period rainfall event for current and future conditions. The results of the flood duration modeling for Back Creek Park indicate that stormwater flooding is not likely to occur for either rainfall event today or in 2050.

4.5.3. Flood Impacts to Back Creek Park

Damage from these flood scenarios could include impacts to the park infrastructure including piers, pavement, benches and kayak launch that would require repairs. Erosion may be experienced at the living shoreline and lawn area. Other damage at the living shoreline and lawn area is anticipated to be temporary as these assets typically ‘bounce back’ after flood events.

4.6. St. Michaels Nature Trail

St. Michaels Nature Trail starts about 0.6 miles south of the area of study near the St. Michaels Volunteer Fire Department and continues outside of town limits. The trail runs through Back Creek Park and across a covered bridge structure (Photo 36) across San Domingo Creek. Elevations of the path are lowest across San Domingo Creek at approximately +4 feet NAVD88. East of the bridge crossing, the trail elevations increase to approximately +6 feet NAVD88. Swales and a storm drain pipe run along the trail and outfall into San Domingo Creek.

Photo 36 – St. Michaels Nature Trail Bridge over San Domingo Creek

Photo 37 - Bridge Structure along Trail

Photo 38 - Swale along St. Michaels Nature Trail near Boundary Lane

Photo 39 - Swales leading to St. Michaels Trail

4.6.1. 2050 High Tide and Storm Surge Flooding

Flooding along the St. Michaels Nature Trail was assessed for 2050 MHW and the 2050 10-year return period storm surge event, as described in Section 3.1. The results, shown in Figure 14, show that flooding of the trail is not anticipated during the 2050 MHW. The storm surge analysis of the 2050 10-year return period storm could result in approximately 1 – 2 feet of flooding along the lowest lying area of the trail.

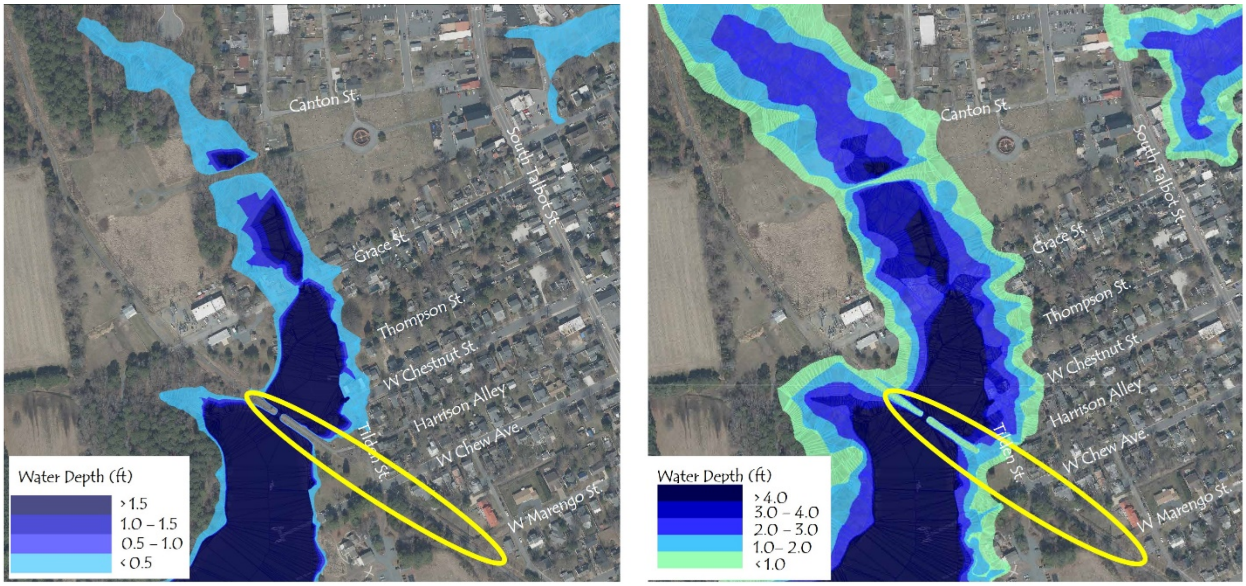


Figure 14 - 2050 High Tide and Storm Surge Flooding at St. Michael's Nature Trail

4.6.2. 2050 Stormwater Flooding

The duration of stormwater flooding was evaluated for the 10–year and 100–year return period rainfall event with current and future conditions. The results of the flood duration modeling for the St. Michaels Nature Trail indicate that stormwater flooding for the 2050 10-year event will result in less than 30 minutes of flooding while the 100-year rainfall event is likely to result in more than 1 hour of flooding in the portion of trail near West Marengo St. The portion of trail where flooding is anticipated is shown in Figure 15.

4.6.1. Flood Impacts to St. Michaels Nature Trail

Damage from these flood scenarios could include impacts to the trail infrastructure including pavement, storm drain infrastructure and other utilities that could require repairs. Erosion of the existing swales and lawn area may also result from flood events. However, minimal infrastructure is anticipated to be impacted by flooding in this area.

Figure 15 - 2050 Stormwater Flooding Duration at St. Michaels Nature Trail

5. VULNERABILITY ANALYSIS

The vulnerability of each assessment area can be determined by examining the three components of vulnerability:

1. ***Exposure*** – how exposed is each area to a hazard such as flooding?
2. ***Sensitivity*** – is the area sensitive to the consequences of a hazard such as flooding?
3. ***Adaptive Capacity*** – can the area be easily adapted to the conditions posed by a hazard such as flooding?

For the purposes of this study, the assessment areas examined are already known to experience flooding. However, the source of flooding can be due to a rainfall event or coastal flooding. Exposure for each assessment area is defined for both types of flooding. The following guidelines were used to determine the 'exposure' rating for each area:

- **Very High** – Likely to flood in 2050 from:
  - High tide event and/or
  - 10-year rainfall event
- **High** – Likely to flood in 2050 from:
  - 10-year storm surge event (but not high tide event) and/or

  - o Rainfall event > 10-year rainfall event
- ❖ **Medium** – Likely to flood in 2050 from:
  - o Storm surge event > 10-year storm surge and/or
  - o 100-year rainfall event
- ❖ **Low** – Unlikely to flood until past 2050.

Sensitivity to flooding was determined by examining the assets within the assessment area. The following classifications were used for ‘sensitivity’ to flooding:

- ❖ **Very High** – Area contains critical infrastructure such as hospitals or exit routes and/or flooding could result in significant damage to property.
- ❖ **High** – Area consists of residential properties only and/or flooding could result in some damage to property;
- ❖ **Medium** – Area consists of assets where flooding could result in minimal long-term damage to property, such as pavement or lawn area;
- ❖ **Low** – Area consists of assets where flooding could result in no long-term damage to property, such as marshes area.

Finally, the adaptive capacity of each assessment area was examined to determine the vulnerability. The ‘adaptive capacity’ of the assessment areas was determined using the following guidelines:

- ❖ **High** – Area can naturally adapt or rebound after flooding, such as a marsh or lawn area;
- ❖ **Medium** – Minor modifications are required to adapt an assessment area to mitigate the risk of flooding, such as conversion of open space to a raingarden or retention area.
- ❖ **Low** – Major construction is required to adapt an assessment area to mitigate the risk of flooding, such as storm drain upgrades or barrier construction.

These metrics were assessed and combined to determine the vulnerability of each area as shown by the diagram in Figure 16. The results of the vulnerability analysis of each assessment area are presented in Table 8.

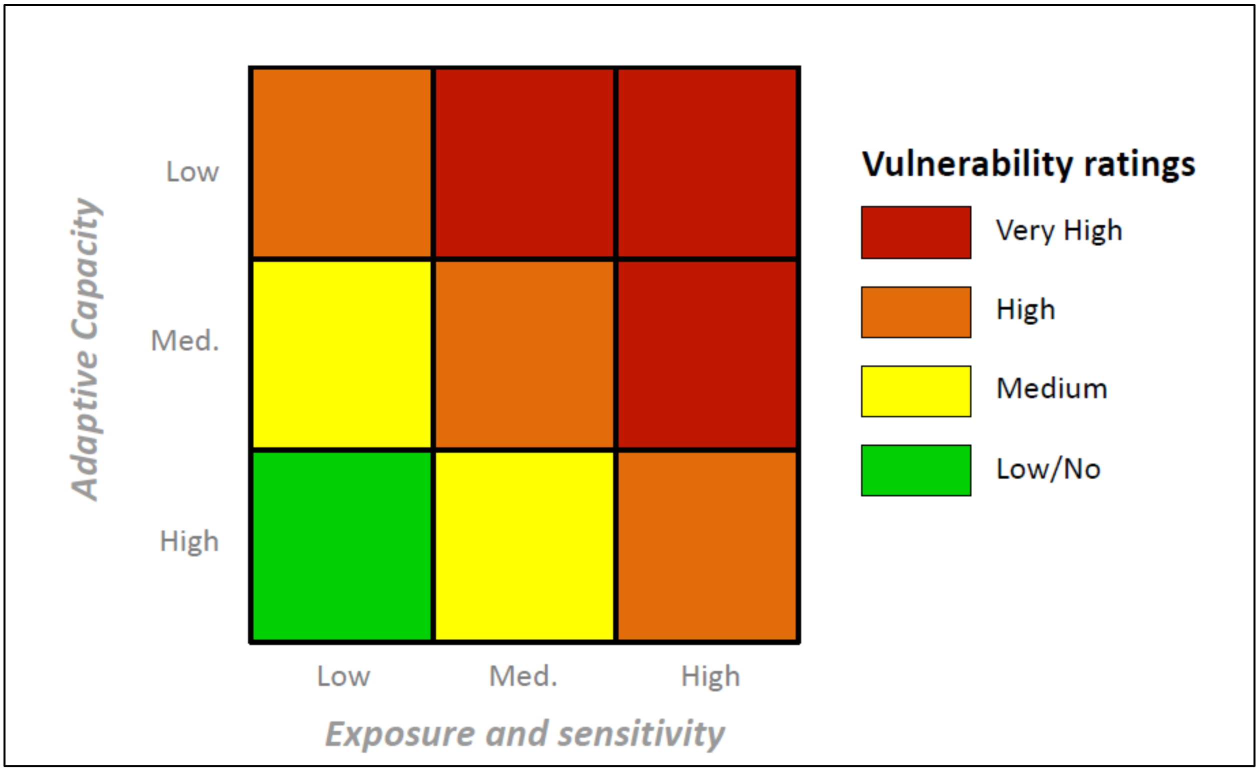


Figure 16 - Determination of Vulnerability Ratings

Table 8 – Assessment Area Vulnerability to Flooding					
Assessment Area	**Exposure**	**Sensitivity**	**Notes**	**Adaptive Capacity**	**Vulnerability Rating**
Canton Street @ Glory Avenue	• High Tide & Storm Surge – High • Rainfall – High	Very High	• No infrastructure flooded during 2050 High Tide; • Flooding of up to 5 homes & utilities for 2050 10-year surge; • Area flooded due to 2050 100-year rainfall.	Low – major construction project needed to remediate flooding	Very High
Grace Street	• High Tide & Storm Surge – Very High • Rainfall – High	Very High	• Approximately 10 properties and pump station at risk of flooding from High Tide and Storm Surge • Area flooded for events > than 2050 10-year rainfall	Low – major construction project needed to remediate flooding	Very High
Thompson Street	• High Tide & Storm Surge – High • Rainfall – Low	High	• No infrastructure flooded during 2050 High Tide; • Flooding of up to 2 homes for 2050 10-year surge; • Area flooded due to 2050 10-year rainfall.	Low – major construction project needed to remediate flooding	High
West Chestnut @	• High Tide &	Very High	• Approximately 5	Low – major	Very High

Table 8 – Assessment Area Vulnerability to Flooding

Tilden Street	Storm Surge – Very High • Rainfall – Very High		properties at risk of flooding from High Tide and Storm Surge • Area flooded for 2050 10-year rainfall	construction project needed to remediate flooding	
Back Creek Park	• High Tide & Storm Surge – Very High • Rainfall – Low	Medium	• Marina Infrastructure and parking lot only infrastructure at risk of flooding for 2050 High Tide and 10-year Storm Surge • No stormwater flooding anticipated until past 2050	Medium – Major construction only required for pier and parking lot	High
St. Michaels Nature Trail	• High Tide & Storm Surge – High • Rainfall – Very High	Medium	• Only pavement and drainage swales anticipated to flood in 2050	Medium – Maintenance likely to provide improvements	High

6. ASSESSMENT AREA PRIORITIZATION

Based on the results of the Vulnerability Analysis and discussion with the CC/SLR committee on areas to prioritize for project implementation, the following prioritization table was developed to rank the assessment areas in order of priority for flood management.

Table 9 – Prioritization of Assessment Areas

Priority	Assessment Area Description
1	Grace Street
2	Back Creek Park
3	West Chestnut Street @ Tilden Street
4	Canton Street @ Glory Avenue
5	St. Michaels Nature Trail
6	Thompson Street

7. MITIGATION STRATEGIES

Mitigation strategies for combatting the threat of compound flooding along the San Domingo Creek area were developed for the areas shown in Table 9.

7.1. Coastal Flooding Mitigation Strategies

Coastal floodwaters threaten to flood areas along the San Domingo Creek shoreline. Various strategies to inhibit the propagation of coastal floodwaters inland can be used alone or in conjunction with one another to mitigate the risk of flooding during high tide or storm surge events. These strategies are presented in the following sections.

7.1.1. Earthen Berm with Living Shoreline

For areas along the natural shoreline where additional habitat could be implemented, an earthen berm can be constructed with a living shoreline on the seaward edge. The living shoreline would provide additional elevation and a wider buffer for the flooding as well as environmental benefits.

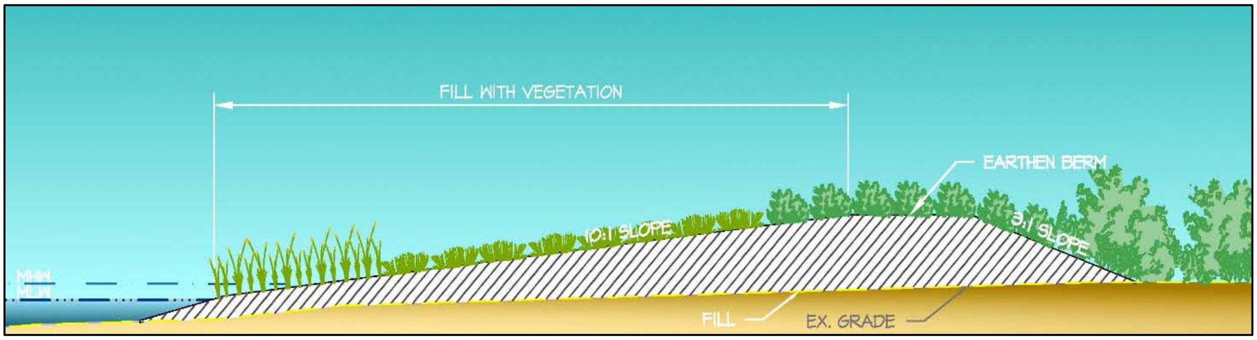


Figure 17 - Earthen Berm with Living Shoreline

This alternative is appropriate where habitat improvement is desired and there is a sufficient amount of space to allow a larger footprint. This alternative has the advantage of providing an opportunity for environmentally focused grants to fund all or a portion of construction as it utilizes green infrastructure to provide flood protection from elevated water levels in San Domingo Creek. A disadvantage of this alternative is the large footprint and encroachment into tidal waters, which may not be acceptable to residents and the community and/or the regulatory agencies. The alternative also requires a significant amount of fill to be bought and transported to the site to construct the berm, resulting in high construction costs. Stormwater management through the use of pumps or redirection of flow would also be required for areas when drainage would be blocked by the elevated structure.

7.1.2. Upland Conversion to Berm and Living Shoreline

If the large encroachment and significant fill of the previous mitigation strategy are impractical for implementation, an alternative to this would be to replace existing hard shoreline protection structures such as bulkheads or revetments with earthen berm and living shoreline option by excavating a portion of the uplands to construct the footprint. This alternative balances the upland footprint and the tidal encroachment. The excavation also provides the material for earthen berm, negating the need to buy and transport fill from offsite. This alternative is often preferred by regulatory agencies as it converts a hard structure to green infrastructure, creates additional habitat and balances impacts to both upland and tidal resource. A cross section of this alternative is provided in Figure 18.

The advantages of this alternative include utilizing green infrastructure and the replacement of hard structures, which is more appealing to funding and regulatory agencies. Utilizing the excavated material on site will also result in significant cost savings. Disadvantages include the footprint size, which may still be too large for use on private property or community areas and the implementation of stormwater management measures to prevent blockage of stormwater flow.

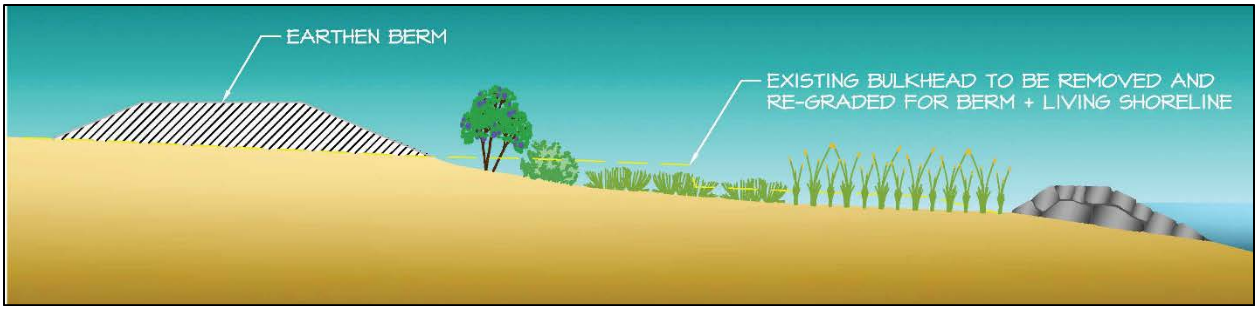


Figure 18 - Replacement of Bulkhead with Berm & Living Shoreline

7.1.3. Seawalls and Bulkheads

For shorelines adjacent to developed areas, marina infrastructure or private properties that require a minimum footprint or encroachment to protect against flooding from SLR and storm surge, a seawall or bulkhead can be implemented. The wall can take multiple forms depending on the site and geotechnical conditions. Options for structural protection include timber or vinyl sheeting bulkheads or concrete seawalls on foundations or piles. This alternative has the advantage of having a minimal footprint and less disturbed area, as shown in Figure 19. However, this alternative does not provide any environmental benefits or habitat uplift. Marsh vegetation can be added to this design to include some habitat improvements, as shown in Figure 19. Stormwater management for diverting or pumping the stormwater blocked by the structure will also be required.

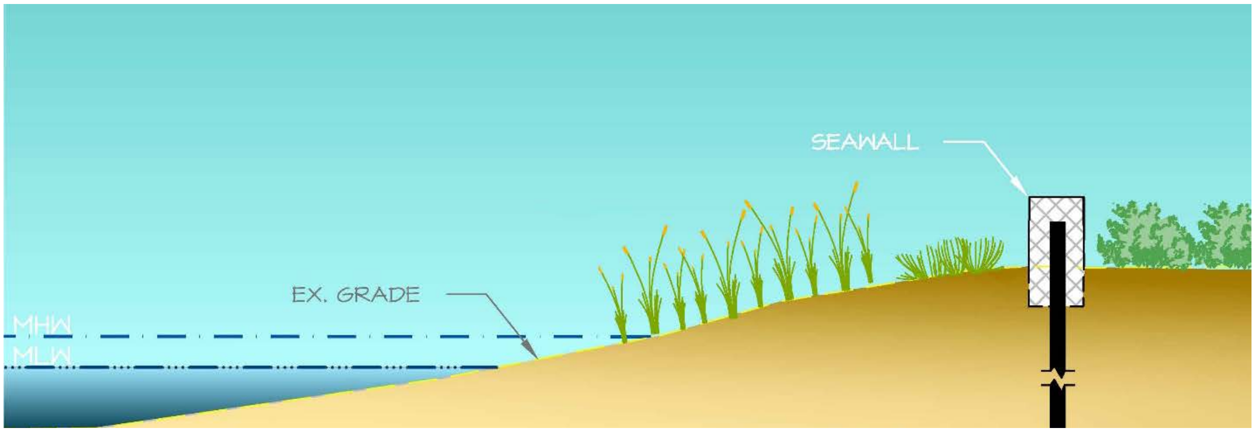


Figure 19 - Sheet Wall with Concrete Cap and Marsh Vegetation

7.1.4. Impermeable Rock Berm

An impermeable rock berm, shown in Figure 20, is also a strategy for preventing flooding while reducing the footprint of the protection structure. An impermeable liner is placed along the seaward edge of the rock structure to prevent flooding through the voids. Similarly to the seawall or bulkhead, it utilizes hard infrastructure and does not provide environmental benefits. However, the added width of the berm adds additional protection from flooding and could serve as a walking path or waterfront viewing area with benches for the community. This design is also easier to adjust for higher water levels and will likely require less maintenance than the earthen berms or seawalls. Disadvantages of this alternative include difficulty in obtaining grant funding for hard structures and the permitting challenges likely to occur. Stormwater management will also need to be included so as not to block flows after rainfall events.

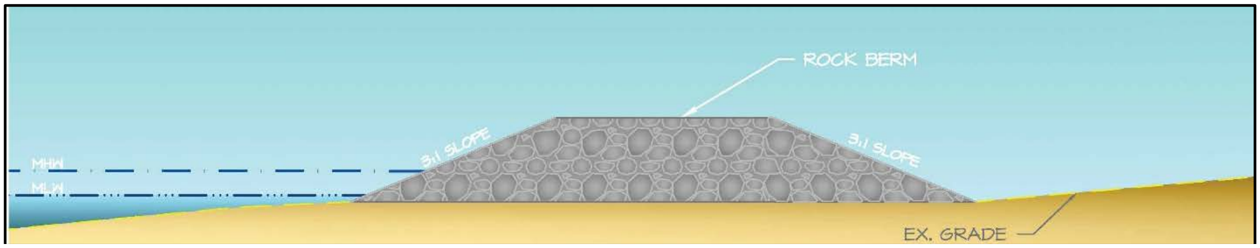


Figure 20 - Impermeable Rock Berm

7.1.5. Tide Gate

The final mitigation strategy considered to prevent against coastal flooding are tide gates that could be installed to prevent high water elevations from flowing along the length of San Domingo Creek. Tide gates are designed to be installed within channels to restrict flow in one direction during storm events while allowing flow to continue in both directions during normal tide levels. The self-regulating tide gate, shown in Photo 40 and Figure 21, is designed to remain open during periods of normal tides. This allows flow to pass through the gate as needed. However, during large storm surge or unusually high tide events, the pressure of the water would close the tide gate to prevent the tide from flowing into adjacent areas where it may lead to flooding of homes.

Advantages of this mitigation strategy is the minimal impact to the existing shoreline. As these structures are typically installed downstream of the area they are protecting, the shoreline, vegetation and areas immediately adjacent to the shoreline are not impacted and require little to no improvements. Additionally, installation of a tide gate can reduce the flood risk for many areas upstream of the gate location along San Domingo Creek. Finally, no adjustments to the existing stormwater drainage system will be required as a result of this alternative. Disadvantages of this alternative include grant funding limitations as it does not include environmental uplift. Maintenance and operations may also be required depending on the product chosen. It is also likely this alternative will have a high initial construction cost.

Photo 40 - Self-Regulated Tide Gate (source: Golden Harvest, Inc)

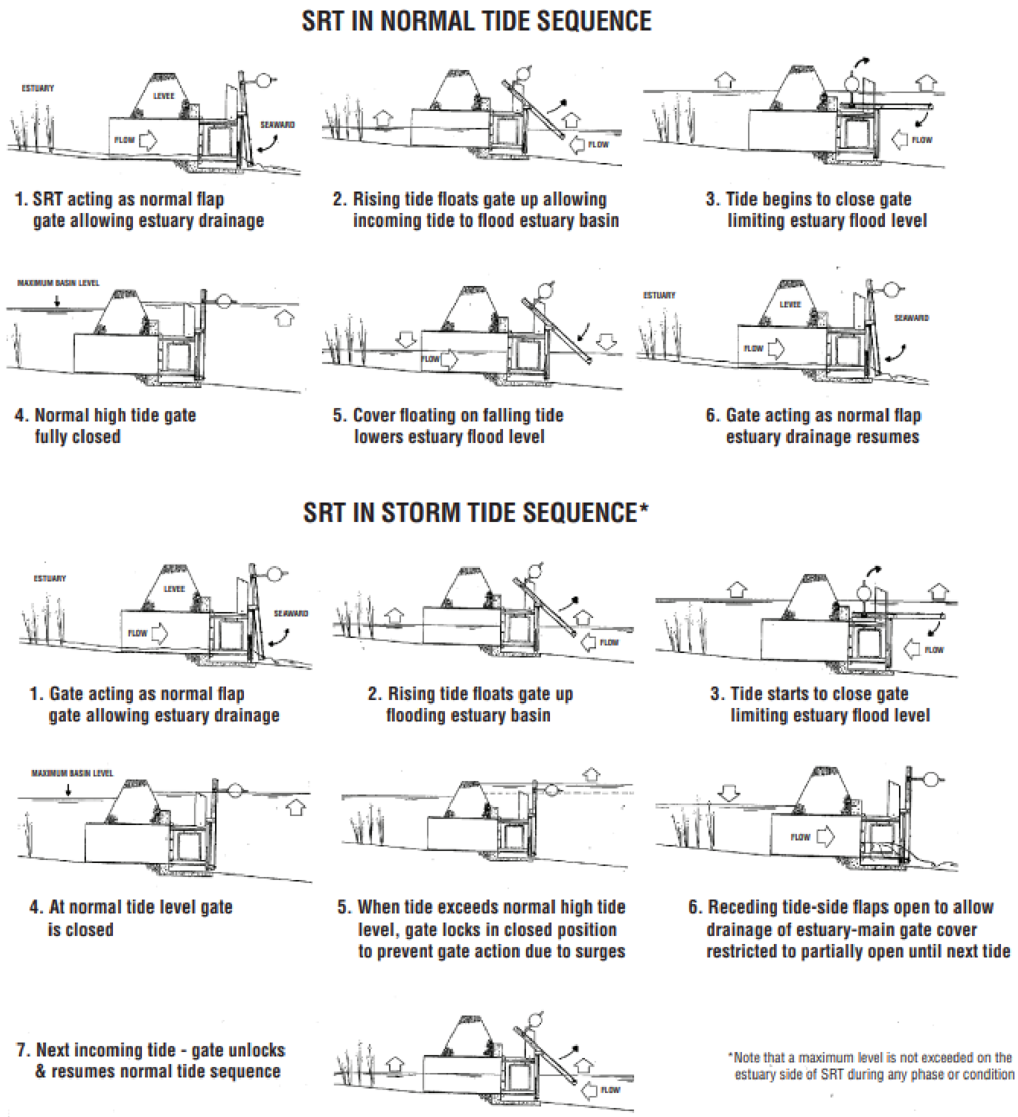


Figure 21 - Diagram of Self-Regulating Tide Gate (source: Waterman Valve[4])

[4] https://watermanusa.com/wp-content/uploads/2020/12/Waterman_SRT_TideGate_SpecSheet.pdf

7.2. Stormwater Flooding Mitigation Strategies

Stormwater runoff is collected by branches of the storm drain system and concentrated into several main branches before being discharged. Various strategies to increase the capacity of the system can be used in conjunction with one another to attenuate flooding and are presented in the following sections.

7.2.1. Storm Drain Infrastructure Improvements

Drainage infrastructure improvements will reduce the extents of stormwater flooding in areas with undersized infrastructure or localized areas lacking storm drain infrastructure. Upgrading the pipe sizes or installing additional pipes in parallel and increasing inlet capacity increases the system's ability to collect and convey runoff and decreases the duration and frequency of storm flooding.

Increasing pipe sizes is limited by the existing topography, storm drain system elevations and other underground infrastructure, but can be used to mitigate flooding at the upper reaches of the system by efficiently conveying the flow to outlets. This approach can be used widely to mitigate flooding in areas where above ground practices are not feasible. The design must consider the increased flow being routed to the central storm drain conduits to ensure they do not become inundated.

Photo 41 - Pipe Replacement

7.2.2. Pumping Station

Installation of pumping stations will alleviate flooding from rainfall events. Though pumping stations will not prevent flooding during the storm event, they help dewater larger flooded areas in a timely manner.

Photo 42 - Pumping Station

7.2.3. Underground Storage Vault

For areas with little existing underground infrastructure, underground storage vaults can be used to increase storage capacity within the system and allow the area more time to discharge flow before areas become inundated with flooding. Periods of high intensity rainfall can quickly inundate an area before it has time to discharge through gravity flow or pumping. The additional capacity provided by an underground storage vault attenuates the peak flow and provides more time for the system to discharge flow before flooding occurs at inlets.

7.2.4. Green Infrastructure

Green infrastructure concepts can be used to restore and mimic natural runoff patterns. These practices include bioretention facilities, vegetated swales, and riffle-pool conveyance. The facilities intercept runoff that would otherwise enter the storm drain system and allow for it to infiltrate. The size and location of the practices impact their effectiveness at mitigating runoff, but they can be used to lower overall inflow to the system and decrease peak flow rates.

Photo 43 - Biotention Facility

Photo 44 - Vegetated Swale

Photo 45 - Riffle-Pool Conveyance System

Photo 46 - Submerged Gravel Wetland

8. ALTERNATIVES ANALYSIS FOR RISK MANAGEMENT

Risk management strategies refer to concepts or ideas for handling the risk determined during the Vulnerability Assessment. Options should follow the four T's of risk management, shown in Figure 22.

Figure 22 - The 4 T's of Risk Management

The four types of Risk Management Strategies (RMS) are defined as follows:

- Tolerate – also referred to as Risk Acceptance where the risk is either ignored or accepted.
- Terminate – also referred to as Risk Avoidance where the risk is avoided altogether.
- Transfer – Risk Transfer occurs when a separate entity is given the responsibility for managing the risk, such as the purchase of insurance.
- Treat – also referred to as Risk Mitigation or Risk Reduction. This option will aim at lessening the risk or the impacts should the risk be realized.

Considering the four T's can help a community assess the options available to them for risk management. For the flood mitigation strategies described in Section 7, the RMS alternatives developed will consider flood protection using the 2050 projected flooding from both coastal and rainfall events.

In order to evaluate each RMS alternative against each other, a decision matrix was utilized with a ranking system applied toward each criterion. The criteria were ranked from 0 to 5 depending on how well the alternative met the criteria. The ranking of the criteria utilized is as follows:

- Feasibility – How easily can the alternative be implemented (0 – not at all; 5 – very easily);
- Effectiveness – How well does the alternative reduce the risk from flooding (0 – not at all; 5 – very well);

- Socio-economic Impacts – How beneficial to the community is the implementation of the alternatives for protecting against flooding (0 – not beneficial; 5 – very beneficial);
- Environmental Impacts – How significant are the environmental impacts of the alternative (0 – significant impacts; 5 – few impacts);
- Cost – How expensive will constructing the alternative be (0 – expensive relative to other alternatives; 5 – not expensive relative to other alternatives).
- Grant Friendly – How likely is the project able to receive grant funding (0 – not likely; 5 – likely).

The following sections describe the analysis performed and the preferred alternative for each assessment area as ranked in the Prioritization Table.

8.1. Grace Street

With both residential and County property at risk of increased flooding risk by 2050, Grace Street was ranked as the highest priority area for protection. Flooding can occur from multiple sources and does not drain efficiently. Both homes and County infrastructure are at risk of flooding due to high tide and storm surge events. The culvert at Grace Street also does not provide adequate drainage during the 2050 10-year return period storm event.

8.1.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 at Grace Street.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Daily flooding of 0.5 feet by 2050 impacting approximately 4 properties and the County-owned sanitary-sewer pump station;
    - Extreme storm surge events likely to flood up to 10 homes.
    - Flooding for all extreme rainfall events greater than the 10-year event in 2050 due to undersized culvert;
    - Road over culvert will be flooded daily with up to 1 foot of water by 2050.
  - Impacts
    - Four properties likely lost due to too frequent flooding.
    - Loss of County owned pump station.
    - Road likely impassable multiple times a month resulting in blocked access to electric sub-station and residences on the west side of the culvert.
    - Frequent and extensive repairs to road and infrastructure likely.
- Terminate – Risk Avoidance
  - Projects:

        - Relocate pump station, electric sub-station, homes and remaining infrastructure outside of 2050 flood area.
    - Results:
        - Area will continue to flood as shown in the Section 4.2 analysis but with no damage to homes and infrastructure.
    - Impacts:
        - Approximately 10+homes to be acquired and converted to open space;
        - County pump station to be relocated and infrastructure re-routed;
        - Passage along Grace Street to be discontinued. New access to homes and electric sub-station required.
- <u>Transfer</u> – Risk Transfer
    - Project:
        - Purchase of Flood Insurance
    - Results:
        - Area will continue to flood as shown in the Section 4.2 analysis.
    - Impacts:
        - This option likely not viable for approximately 5 homes as flooding will be too frequent.
        - Pump station would not be operational as flooding will be too frequent.
        - Road would continue to be impassable daily.
        - Likely increase in insurance premiums due to increased flood risk.
- <u>Treat</u> – Risk Mitigation
    - Projects:
        - Coastal Flood Mitigation Alternative 1 – Tide Gate at St. Michaels Nature Trail.
        - Coastal Flood Mitigation Alternative 2 – Construct berm or seawall
        - Stormwater Flood Mitigation Project: Upsize culvert to drain larger storm events.
    - Results:
        - Risk of flooding to be prevented for the daily high tide;
        - Risk of flooding to be reduced for large storm surge events;
        - Risk of flooding to be reduced for large rainfall events.
    - Impacts:
        - Coastal Flood Mitigation Alternative 1:
            - No anticipated impacts as high tide and storm surge events will not pass the tide gate at the St. Michaels Nature Trail Bridge
        - Coastal Flood Mitigation Alternative 2:
            - Significant land disturbance anticipated to accommodate structure footprint;
            - Possible land acquisition required;
            - Likely impacts to vegetation and water bottom;
        - Stormwater Flood Mitigation Project
            - No anticipated long-term impacts.

The decision matrix to determine the optimal RMS alternative is presented in Table 10.

Table 10 – Decision Matrix for Managing Flood Risk at Grace Street

Options	Feasibility	Effective-ness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	0	5	1	11
RMS 2 – Terminate Risk	2	5	1	5	2	15
RMS 3 – Transfer Risk	1	1	0	5	2	9
RMS 4 – Treat Risk (Alt 1)	4	4	4	3	2	17
RMS 4 – Treat Risk (Alt 2)	1	4	2	1	1	9

8.1.2. Preferred Alternative

The preferred alternative for managing the risk of flooding at Grace Street is RMS 4 – Risk Reduction Alternative 1 using a tide gate at the St. Michaels Nature Trail Bridge and increasing the size of the culvert under Grace Street. This alternative would entail raising the elevation of the bridge and installing a tide gate, as discussed in Section 7.1.5, as well as improving the existing culvert with a larger structure.

8.2. Back Creek Park

The bulkhead along Back Creek Park is in a failed condition. Elevations along the shoreline are low and unlikely to provide adequate flood protection for the park and boating infrastructure in 2050. The park area and marina infrastructure is anticipated to experience frequent flooding. No flooding due to 2050 extreme rainfall events is anticipated at this location.

8.2.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 at Back Creek Park.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - Daily flooding in 2050 will overtop bulkhead and piers
    - Storm surge events in 2050 to impact park, boating infrastructure and natural areas.
  - Impacts:
    - Upland area likely to naturally transition to marsh area.
    - Flooding from storm surge events may result in damage to park infrastructure such as piers, pavement, bulkhead, benches and kayak launch;
    - Natural areas such as marsh and lawn area anticipated to only experience temporary impacts after storm surge events.
    - Periodic repairs due to flood damage anticipated.

- Terminate – Risk Avoidance
    - Projects:
        - Relocate boating infrastructure.
        - Relocate road area and all park infrastructure outside of floodplain.
        - Replace bulkhead with living shoreline that can tolerate frequent flooding.
    - Results:
        - Area will continue to flood as shown in the Section 4.5 analysis but with no damage to infrastructure.
        - Living shoreline and lawn area will flood periodically but not likely to experience permanent damage.
        - Park will no longer contain amenities such as piers, kayak launch and racks, benches.
    - Impacts:
        - Boating infrastructure and other recreation no longer available at this location.
        - Existing park use likely to change due to lack of amenities.
- Transfer – Risk Transfer
    - Project:
        - Purchase of Flood Insurance
    - Results:
        - Area will continue to flood as shown in the Section 4.5 analysis.
    - Impacts:
        - Insurance premiums anticipated to increase with more frequent flooding.
- Treat – Risk Mitigation
    - Projects:
        - Coastal Flood Mitigation Alternative 1 – Improve bulkhead and raise elevation.
        - Coastal Flood Mitigation Alternative 2 – Replace bulkhead with living shoreline and use fill to elevate upland area.
        - Replace or raise boating infrastructure to accommodate higher water levels.
    - Results:
        - Risk of flooding to be prevented for the daily high tide;
        - Risk of flooding to be reduced for large storm surge events;
    - Impacts:
        - Coastal Flood Mitigation Alternative 1:
            - Regrading of park likely required to ensure bulkhead ties into high ground.
            - Stormwater management from rainfall events will likely need to be diverted around raised bulkhead;
            - Pier-land interface over bulkhead will need to be raised to pass over higher bulkhead.
        - Coastal Flood Mitigation Alternative 2:
            - Loss of some upland area for living shoreline construction.

      - Road adjustments at the end of W. Chew may be needed.
  - Pier Raising:
      - Likely require regrading of road to tie-into the higher pier elevations.

The decision matrix to determine the optimal RMS alternative is presented in Table 11.

Table 11 – Decision Matrix for Managing Flood Risk at Back Creek Park

Options	Feasibility	Effective-ness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	1	5	5	16
RMS 2 – Terminate Risk	0	5	0	4	0	9
RMS 3 – Transfer Risk	0	0	1	5	3	9
RMS 4 – Treat Risk (Alt 1)	5	3	3	2	4	17
RMS 4 – Treat Risk (Alt 2)	5	4	3	3	3	18

8.2.1. Preferred Alternative

The preferred alternative for managing the risk of flooding at Back Creek Park is RMS 4 – Risk Reduction Alternative 2 that includes replacing the bulkhead with a living shoreline and raising the boating infrastructure. This alternative would entail converting a portion of the upland area directly behind the existing bulkhead to a living shoreline and using the excavated material to raise the elevation of other areas of Back Creek Park, as shown in Section 7.1.2.

For this alternative, it is likely that approximately the first 50 feet along the existing bulkhead would be excavated and sloped. The piers would require raising as well to ensure they remain above future water elevations.

8.3. West Chestnut and Tilden Rd.

The area near West Chestnut St. and Tilden St. will experience flooding from both coastal and stormwater flooding in 2050. The 2050 daily high tide will flood approximately 2 homes and the retention pond. The 2050 10-year storm surge threatens an additional 3 homes. Drainage of the 2050 extreme rainfalls through the retention pond will also be impacted.

8.3.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 at West Chestnut St. and Tilden St.

- Tolerate – Risk Acceptance
    - Projects: None
    - Results:

        - Daily flooding in 2050 will flood up to two homes and road infrastructure.
        - The 10-year return period storm surge in 2050 will flood up to 5 homes.
        - Stormwater from rainfall events in 2050 will be unable to adequately drain due to backwatering of the pipe at the retention area.
    - Impacts
        - Likely loss of two homes due to frequent flooding.
        - Frequent and extensive repairs to property and infrastructure anticipated.
- <u>Terminate</u> – Risk Avoidance
    - Projects:
        - Relocate homes outside of the flood extents.
        - Relocate Tilden St and portion of St. Michael's nature trail.
        - Pump station for stormwater.
    - Results:
        - Area will continue to flood as shown in the Section 4.4 analysis but with no damage to infrastructure.
    - Impacts:
        - Approximately 5+ homes to be acquired and converted to open space;
        - Passage along Tilden Street and St. Michael's Nature Trail to be discontinued; area to be converted to open space.
- <u>Transfer</u> – Risk Transfer
    - Project:
        - Purchase of Flood Insurance
    - Results:
        - Area will continue to flood as shown in the Section 4.4 analysis.
    - Impacts:
        - Likely not viable for 1 - 2 homes that are anticipated to flood daily.
        - Likely increase in insurance premiums due to increased flood risk.
- <u>Treat</u> – Risk Mitigation
    - Projects:
        - Coastal Flood Mitigation Alternative 1 – Tide Gate at St. Michaels Nature Trail.
        - Coastal Flood Mitigation Alternative 2 – Construct berm or seawall
        - Stormwater Flood Mitigation Project: Raise pipe outfall and install tide valve.
    - Results:
        - Risk of flooding to be prevented for the daily high tide.
        - Risk of flooding to be reduced for large storm surge events.
        - Risk of flooding due to stormwater reduced for extreme rainfall events in 2050.
    - Impacts:
        - Coastal Flood Mitigation Alternative 1:

  - No anticipated impacts as high tide and storm surge events will not pass the tide gate at the St. Michaels Nature Trail Bridge
- Coastal Flood Mitigation Alternative 2:
  - Significant land disturbance anticipated to accommodate structure footprint;
  - Possible land acquisition required;
  - Likely impacts to vegetation and water bottom;
- Stormwater Flood Mitigation Project
  - Regrading likely needed at retention area.

The decision matrix to determine the optimal RMS alternative is presented in Table 12.

Table 12 – Decision Matrix for Managing Flood Risk at W. Chestnut & Tilden St.

Options	Feasibility	Effective-ness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	2	5	5	17
RMS 2 – Terminate Risk	1	5	2	4	1	13
RMS 3 – Transfer Risk	3	3	3	5	4	18
RMS 4 – Treat Risk (Alt 1)	4	5	5	3	2	19
RMS 4 – Treat Risk (Alt 2)	1	4	2	1	1	9

8.3.2. Preferred Alternative

The preferred alternative for managing the risk of flooding at Grace Street is RMS 4 – Risk Reduction Alternative 1 using a tide gate at the St. Michaels Nature Trail Bridge and installation of a new pipe with tide valve. This alternative would entail raising the elevation of the bridge and installing a tide gate as discussed in Section 7.1.5 and raising the pipe invert elevations and installing a tide valve to prevent backwatering.

8.4. Canton St. near Glory St.

Flooding along Canton St. near Glory St. is anticipated to occur for extreme storm surge and rainfall events in 2050. Daily high tides will not flood properties and infrastructure. The 2050 10-year storm surge was shown to flood up to two homes and the Choptank Electric Cooperative station. The 10-year rainfall event in 2050 did not result in flooding, however, larger storms such as the 100-year rainfall event in 2050 were shown to result in flooding that lasted up to one hour.

8.4.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 at Canton St. and Glory St.

- Tolerate – Risk Acceptance

- Projects: None
- Results:
  - Flooding to only occur during extreme storm surge events in 2050.
  - Flooding to only occur during extreme rainfall events greater than the 10-year return period event in 2050.
- Impacts
  - Periodic repairs after extreme storm events anticipated.

❖ Terminate – Risk Avoidance
- Projects:
  - Relocate homes along Glory St. outside of the flood extents and convert to open space.
  - Relocate Choptank Electric Cooperative station and convert to open space.
- Results:
  - Area will continue to flood as shown in the Section 4.1 analysis but with no damage to infrastructure.
- Impacts:
  - Approximately 2+ homes and electric station parcel to be acquired and converted to open space;
  - Canton Road to end at Glory Street.

❖ Transfer – Risk Transfer
- Project:
  - Purchase of Flood Insurance
- Results:
  - Area will continue to flood as shown in the Section 4.1 analysis.
- Impacts:
  - Likely increase in insurance premiums due to increased flood risk.

❖ Treat – Risk Mitigation
- Projects:
  - Coastal Flood Mitigation Alternative 1 – Tide Gate at St. Michaels Nature Trail.
  - Coastal Flood Mitigation Alternative 2 – Elevate Canton Street
  - Stormwater Flood Mitigation Project: Increase pipe size.
- Results:
  - Risk of flooding to be prevented for the daily high tide.
  - Risk of flooding to be reduced for extreme storm surge events.
  - Risk of flooding is prevented for 100-yr stormwater events in 2050.
- Impacts:
  - Coastal Flood Mitigation Alternative 1:
    - No anticipated impacts as high tide and storm surge events will not pass the tide gate at the St. Michaels Nature Trail Bridge
  - Coastal Flood Mitigation Alternative 2:
    - Road proposed to be raised a minimum of 4 feet, resulting in significant land disturbance anticipated to accommodate increased footprint;

        - Possible land acquisition required;
        - Likely impacts to vegetation and possibly forested area.
    - Stormwater Flood Mitigation Project
        - Impacts on the existing roadway and underground utilities.

The decision matrix to determine the optimal RMS alternative is presented in Table 13.

Table 13 – Decision Matrix for Managing Flood Risk at Canton St. near Glory St.

Options	Feasibility	Effective-ness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	2	3	5	5	20
RMS 2 – Terminate Risk	1	5	1	5	2	14
RMS 3 – Transfer Risk	5	3	5	5	3	21
RMS 4 – Treat Risk (Alt 1)	4	5	5	3	2	19
RMS 4 – Treat Risk (Alt 2)	4	4	3	2	3	16

8.4.2. Preferred Alternative

The preferred alternative for managing the flood risk along Canton Street near Glory Street is the purchase of flood insurance. Because the homes and infrastructure impacted is not extensive and are only anticipated to flood during extreme storm surge and rainfall events, it is recommended that risk be managed through the purchase of damage insurance in lieu of constructing a flood mitigation project. These areas should be monitored and reassessed periodically to determine if further action is necessary.

8.5. St. Michaels Nature Trail

Flooding along St. Michaels Nature Trail is only anticipated to occur during extreme storm surge and rainfall events in 2050. The 2050 10-year storm surge event will result in approximately 560 feet of the trail over San Domingo Creek experiencing 1 – 2 feet of flooding. Additionally, the 10-year rainfall event in 2050 will result in approximately 30 minutes of flooding along the trail near West. Marengo St.

8.5.1. Alternatives Analysis

The following alternatives were evaluated to manage the risk of flooding in 2050 along the St. Michaels Nature Trail.

- Tolerate – Risk Acceptance
    - Projects: None
    - Results:
        - Flooding to only occur during extreme storm surge events in 2050.
        - Flooding to only occur during extreme rainfall events in 2050.
    - Impacts:
        - Periodic repairs to bridge structure and trail anticipated.

- Terminate – Risk Avoidance
  - Projects:
    - Relocate trail outside of flood extents.
  - Results:
    - Area will continue to flood as shown in the Section 4.6 analysis but with no damage to infrastructure.
  - Impacts:
    - Existing trail would require re-routing to avoid area near San Domingo Creek
- Transfer – Risk Transfer
  - Project:
    - Purchase of Flood Insurance
  - Results:
    - Area will continue to flood as shown in the Section 4.6 analysis.
  - Impacts:
    - Likely increase in insurance premiums due to increased flood risk.
- Treat – Risk Mitigation
  - Projects:
    - Coastal Flood Mitigation – Elevate Bridge and Path over San Domingo Creek.
    - Stormwater Flood Mitigation Project: Increase pipe sizes along the existing swale.
  - Results:
    - Risk of flooding to be reduced for extreme storm surge events.
    - Risk of flooding due to stormwater prevented for 100-yr storm events in 2050.
  - Impacts:
    - Coastal Flood Mitigation:
      - Grade change along path leading to the bridge structure anticipated.
    - Stormwater Flood Mitigation Project
      - Regrading of the swale may be required;
      - Impacts on the existing roadway and underground utilities may occur.

The decision matrix to determine the optimal RMS alternative is presented in Table 14.

Table 14 – Decision Matrix for Managing Flood Risk at St. Michaels Nature Trail

Options	Feasibility	Effective-ness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	2	3	5	5	20
RMS 2 – Terminate Risk	1	5	1	3	1	11
RMS 3 – Transfer Risk	3	2	3	5	4	17
RMS 4 – Treat Risk (Alt 1)	4	4	5	3	4	20

8.5.2. Preferred Alternative
For St. Michaels Nature Trail, the decision matrix indicates that RMS 1 – Risk Acceptance and RMS 4 – Risk Reduction are both viable options. For this particular area, the 'no project' alternative would result in infrequent flooding without significant damages, making the option to repair as necessary after flood events an acceptable option. Additionally, implementing a risk reduction measure such as raising the bridge structure and elevating the path would also be a feasible option, especially if done in conjunction with installation of the tide gate.

8.6. Thompson Street

The flood analysis along Thompson Street shows that flooding during the 2050 daily high tide could impact the retention pond and one property parcel. The 2050 10-year return period storm surge could impact up to two homes on Thompson Street. No stormwater impacts to infrastructure were modeled at this location.

8.6.1. Alternatives Analysis
The following alternatives were evaluated to manage the risk of flooding in 2050 at Thompson Street.

- Tolerate – Risk Acceptance
  - Projects: None
  - Results:
    - 2050 daily high tide to flood retention pond and property parcel.
    - 2050 10-year return period storm surge events to flood up to 2 homes.
  - Impacts
    - Possible loss of sheds or other accessory structures due to too frequent flooding.
    - Periodic repairs to road and retention pond likely needed.
- Terminate – Risk Avoidance
  - Projects:
    - Relocate homes and road infrastructure outside of flood extents and convert to open space.
  - Results:
    - Area will continue to flood as shown in the Section 4.3 analysis but with no damage to infrastructure.
  - Impacts:
    - Approximately 2+ homes to be acquired and converted to open space.
    - Road end to be converted to open space.
    - Retention pond to be inundated regularly and converted to natural marsh.
- Transfer – Risk Transfer
  - Project:
    - Purchase of Flood Insurance.

- Results:
  - Area will continue to flood as shown in the Section 4.3 analysis.
- Impacts:
  - Road will continue to flood and may require periodic repairs.
  - Likely increase in insurance premiums due to increase flood risk.

❖ Treat – Risk Mitigation
- Projects:
  - Coastal Flood Mitigation Alternative 1 – Tide Gate at St. Michaels Nature Trail.
  - Coastal Flood Mitigation Alternative 2 – Construct berm or seawall
- Results:
  - Risk of flooding to be prevented for the daily high tide;
  - Risk of flooding to be reduced for large storm surge events;
- Impacts:
  - Coastal Flood Mitigation Alternative 1:
    - No anticipated impacts as high tide and storm surge events will not pass the tide gate at the St. Michaels Nature Trail Bridge
  - Coastal Flood Mitigation Alternative 2:
    - Significant land disturbance anticipated to accommodate structure footprint;
    - Possible land acquisition required;
    - Likely impacts to vegetation, retention pond and water bottom.

The decision matrix to determine the optimal RMS alternative is presented in Table 15.

Table 15 – Decision Matrix for Managing Flood Risk at Thompson Street

Options	Feasibility	Effective-ness	Socio-economic Impacts	Environmental Impacts	Cost	Total
RMS 1 – Tolerate Risk	5	0	4	4	4	17
RMS 2 – Terminate Risk	1	5	1	4	1	12
RMS 3 – Transfer Risk	5	1	3	5	4	18
RMS 4 – Treat Risk (Alt 1)	4	5	5	5	2	21
RMS 4 – Treat Risk (Alt 2)	3	3	3	1	3	13

8.6.2. Preferred Alternative

The preferred alternative for managing the risk of flooding at Thompson Street is RMS 4 – Risk Reduction Alternative 1 using a tide gate at the St. Michaels Nature Trail Bridge. This alternative would entail raising the elevation of the bridge and installing a tide gate as discussed in Section 7.1.5.

9. IMPLEMENTATION PLAN

Once the preferred alternatives for risk management were selected, projects were developed and prioritized in the Implementation Plan. The Implementation Plan is meant to focus efforts on the assessment areas most in need and/or projects that will have the greatest benefits. Projects were developed that could address multiple flooding sources (coastal and stormwater) or several priority areas by combining the preferred alternatives of the various assessment areas.

Based on the Vulnerability Assessment and applying the preferred alternatives, the Implementation Plan was divided into three categories, as defined below:

- Immediate Implementation – Action to recognize benefits in 0 – 10 years
- Short-Term Implementation – Action to recognize benefits in 10 – 20 years
- Long-Term Implementation – Action to recognize benefits in +20 years

In addition to implementation timeframes, cost estimates are provided for each project. The cost estimates presented are based on 2023 construction and do not account for future inflation.

The projects developed and prioritized are discussed in subsequent paragraphs.

9.1. Immediate Implementation

Projects defined for 'Immediate Implementation' target assessment areas ranked highly in the Prioritization Table presented in Table 9. Work should begin immediately to secure funding for engineering, permitting and design so that construction can be underway in the near future. Though the projects are shown as individual efforts in the sections below, it is recommended that those in close proximity to each other should be combined to limit disturbance and take advantage of other cost efficiencies.

The projects proposed for Immediate Implementation are presented in the following sections.

9.1.1. Back Creek Park Living Shoreline

Given the failed condition of the bulkhead, it is recommended that the flood mitigation project at Back Creek Park be initiated soon. The project recommends removing the top portion of bulkhead and grading the areas behind it back to create a marsh similar to the living shoreline directly adjacent to the bulkhead. The material excavated would be used to construct an elevated berm behind the marsh to an approximate +5 feet NAVD88 elevation. This berm would tie into higher ground to the north and south and act as a barrier to high tides and storm surges. The cost for implementation of this project is presented in Table 16.

Table 16 – Back Creek Park Living Shoreline Planning Level Costs				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	$50,000	$50,000
Bulkhead Removal, Replacement with Living Shoreline and Berm	LF	120	$1,000	$120,000
			Subtotal	$170,000
			20% Contingency	$34,000
			Total Cost	**$204,000**

9.1.2. Tide Gate at St. Michaels Nature Trail Bridge

Another project recommended for immediate implementation would be the tide gate at the St. Michaels Nature Trail bridge. Implementation of this project could prevent coastal flooding for areas located upstream of the bridge structure which would reduce the flood risk for most of the assessment areas. For this project, the elevation of the bridge and pathway leading to the bridge is proposed to be raised to a minimum elevation of +5 feet NAVD88. This will prevent storm surge from overtopping the structure and bridge during flood events less than the 10-year return period flood in 2050.

A self-regulating tide gate would be installed that closes itself once a threshold elevation is reached. This would prevent tidal waters from entering the upstream areas of San Domingo Creek, keeping the shoreline areas north of the tide gate safe from high water events. As the water level recedes, the tide gate will open again and allow flow to continue as normal.

Given the large cost of project implementation, initiation of this project should start with conducting a feasibility assessment and preliminary design. This effort would include performing a detailed natural resource assessment and existing conditions analysis, modeling to determine flow patterns, development of a 10% concept design and meeting with environmental regulators to discuss the impacts of implementing the tide gate. A cost estimate for this effort is presented in Table 17.

Table 17 – Tide Gate Preliminary Design Costs				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Assessment & Preliminary Design	-	-	$20,000	$20,000
			Total Cost	**$20,000**

After the completion of the Assessment and Preliminary Design, the Town will be in a position to pursue grant funding to design and construct the project. The cost to complete the design and construction is presented in Table 18.

Table 18 – Tide Gate Implementation Planning Level Costs				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	$180,000	$180,000
Installation of Tide Gate	EA	1	$1,000,000	$1,000,000
Elevation of Bridge and Pathway	LF	560	$1,500	$840,000
			Subtotal	$2,020,000
			20% Contingency	$404,000
			Total Cost	**$2,424,000**

9.2. Short-Term Implementation

The Short-Term Implementation Plan includes projects that address areas not of immediate concern but will experience more significant and frequent impacts in the near future. Engineering, design and permitting is recommended to begin in approximately 10 – 20 years so as to allow for complete project implementation by 2045. The proposed projects are discussed in the following paragraphs.

9.2.1. Grace Street Culvert Improvements

To prevent stormwater flooding along Grace Street, the existing culvert would be increased to an approximate 8'x5' structure to pass the 2050 10-year return period stormwater event. The planning level implementation cost for this project is presented in Table 19.

Table 19 – Grace Street Culvert Improvements Planning Level Costs				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	$20,000	$20,000
Improvements to the Grace St. Culvert	EA	1	$50,000	$50,000
			Subtotal	$70,000
			20% Contingency	$14,000
			Total Cost	**$84,000**

9.2.2. W. Chestnut & Tilden Street Retention Area Pipe Outfall Improvements

The next project recommended for Short-Term Implementation is improvements to the outfall at the W. Chestnut and Tilden St. Retention Area. Currently, the pipe outfalls at a low elevation and backwatering can lead to tidal waters entering upland areas through the pipe. The project proposes to raise the elevation of the outfall pipe and install a tide valve to prevent backwatering. The planning level cost estimate to implement this work is presented in Table 20.

Table 20 – W. Chestnut & Tilden St. Retention & Outfall Planning Level Costs				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	$20,000	$20,000
Pipe Replacement	LF	25	$100	$2,500
Install Tide Valve	EA	1	$45,000	$45,000
			Subtotal	$67,500
			20% Contingency	$13,500
			Total Cost	**$81,000**

9.2.3. Stormwater Infrastructure Replacement along St. Michaels Nature Trail

The third project recommended for Short-Term Implementation is improvements to the stormwater infrastructure along the St. Michaels Nature Trail. This project involves replacing 1060 feet of pipe with a larger pipe diameter. The project would also include replacing 7 inlets that connect to the pipe. The project may also require the regrading of the existing swale. The planning level estimate to implement this project is presented in Table 21.

Table 21 – St. Michaels Nature Trail Pipe Replacement Planning Level Costs				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	$25,000	$25,000
Pipe Replacement	LF	1,060	$100	$106,000
Inlet Replacement	EA	7	$5,000	$35,000
			Subtotal	$166,000
			20% Contingency	$33,200
			Total Cost	**$199,200**

9.2.4. Raising Boating Infrastructure at Back Creek Park

The current elevation of the boating infrastructure was surveyed to be just below +3 feet NAVD88. This infrastructure is likely to be frequently inundated during higher tides in the coming years. Therefore, it is recommended that the infrastructure be raised to prevent flooding of the piers in the short term. The cost to raise the existing infrastructure is presented in Table 22.

Table 22 – Raise Boating Infrastructure Planning Level Costs				
Description	**Unit Size**	**Estimate Quantity**	**Unit Cost**	**Capital Cost**
Design & Permitting	-	-	$50,000	$50,000
Elevation of Pier Infrastructure	SF	4000	$100	$400,000
Raise Road Infrastructure to Match Pier	SF	1750	$80	$140,000
			Subtotal	$590,000
			20% Contingency	$118,000
			Total Cost	**$708,000**

9.3. Long-Term Implementation

Long-term implementation refers to monitoring of existing areas to determine how future conditions impact the area. The timeframe also includes some strategies that should be commenced, if necessary, in the next 20 years so that project benefits can be recognized by 2050. The proposed projects are discussed in the following paragraphs.

9.3.1. Monitor Flood Risk

For areas such as Canton Street, the preferred risk management alternative was to purchase insurance and/or perform repairs as needed after storm events. This area should be re-assessed in the future to determine if additional action is required.

9.3.2. Nourishment of Living Shorelines

The existing living shoreline along Back Creek Park will continue to be impacted by sea level rise. Therefore, it is recommended that sediment nourishment and structure improvements be conducted as necessary to ensure the living shoreline continues to function as intended in future conditions.

9.4. Total Implementation Plan Costs

An estimate for the Implementation Plan Costs is provided in Table 23.

Table 23 – Planning-Level Implementation Plan Costs		
Project	**Description**	**Cost**
Immediate Implementation		
1	Back Creek Park Living Shoreline	$204,000
2	Tide Gate Assessment and Preliminary Design	$20,000
3	Tide Gate Implementation	$2,424,000
	Total Immediate Implementation Cost	**$2,648,000.00**
Short-Term Implementation		
4	Grace Street Culvert Improvements	$84,000
5	W. Chestnut & Tilden Street Retention Area Pipe Outfall	$81,000

Table 23 – Planning-Level Implementation Plan Costs		
	Improvements	
6	Stormwater Infrastructure Replacement along St. Michaels Nature Trail	$199,200
7	Raise Boating Infrastructure at Back Creek Park	$708,000
	Total Short-Term Implementation Cost	**$1,072,200.00**
Long-Term Implementation		
8	Monitor Flood Risk for Assessment Areas	TBD
9	Nourish Living Shorelines along Back Creek Park	TBD
	Total Long-Term Implementation Cost	**TBD**

Appendix A

Hydrologic Analysis

Hydrologic Soil Group—Talbot County, Maryland
(St Michaels Soils)

Map Scale: 1:9,650 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0, 100, 200, 400, 600

Feet: 0, 450, 900, 1800, 2700

Map projection: Web Mercator   Corner coordinates: WGS84   Edge tics: UTM Zone 18N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:12,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Talbot County, Maryland
Survey Area Data: Version 19, Sep 14, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Apr 1, 2021—Oct 1, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
CsA	Crosiadore silt loam, 0 to 2 percent slopes	C/D	70.8	18.5%
CsB	Crosiadore silt loam, 2 to 5 percent slopes	C/D	56.5	14.7%
EmA	Elkton silt loam, 0 to 2 percent slopes	C/D	74.8	19.5%
Ho	Honga peat, very frequently flooded, tidal	C/D	2.0	0.5%
MtcB	Mattapex silt loam, 2 to 5 percent slopes, Mid-Atlantic Coastal Plain	C	11.1	2.9%
OtA	Othello silt loams, 0 to 2 percent slopes, Mid-Atlantic Coastal Plain	C/D	68.0	17.7%
SuA	Sunken mucky silt loam, 0 to 2 percent slopes, occasionally flooded, tidal	C/D	4.5	1.2%
UoB	Udorthents, loamy, 0 to 5 percent slopes	C	0.1	0.0%
W	Water		78.8	20.6%
WdcA	Woodstown sandy loam, 0 to 2 percent slopes, Mid-Atlantic Coastal Plain	C	6.5	1.7%
WdcB	Woodstown sandy loam, 2 to 5 percent slopes, Mid-Atlantic Coastal Plain	C	5.2	1.3%
Zk	Zekiah silt loam, frequently flooded	C/D	4.7	1.2%
Totals for Area of Interest			**383.0**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

DRAINAGE AREA	**S1**				
TOTAL DA	3048.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	3048.00	3048.00
IMPERVIOUS	0.00	0.00	0.00	0.00	0.00
1/8 ACRE LOT	0.00	0.00	0.00	0.00	0.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	3048.00	3048.00

DRAINAGE AREA	**J2**				
TOTAL DA	32381.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.00	0.00
IMPERVIOUS	0.00	0.00	0.00	16376.00	16376.00
1/8 ACRE LOT	0.00	0.00	0.00	16005.00	16005.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	32381.00	32381.00

DRAINAGE AREA	**J3**				
TOTAL DA	1117.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	285.00	285.00
IMPERVIOUS	0.00	0.00	0.00	832.00	832.00
1/8 ACRE LOT	0.00	0.00	0.00	0.00	0.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	1117.00	1117.00

DRAINAGE AREA	**J4**				
TOTAL DA	10298.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.00	0.00
IMPERVIOUS	0.00	0.00	0.00	5779.00	5779.00
1/8 ACRE LOT	0.00	0.00	0.00	4519.00	4519.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	10298.00	10298.00

DRAINAGE AREA	**J5**				
TOTAL DA	40348.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.00	0.00
IMPERVIOUS	0.00	0.00	0.00	22049.00	22049.00
1/8 ACRE LOT	0.00	0.00	0.00	18299.00	18299.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	40348.00	40348.00

DRAINAGE AREA	**J11**				
TOTAL DA	5623.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	1160.00	1160.00
IMPERVIOUS	0.00	0.00	0.00	4463.00	4463.00
1/8 ACRE LOT	0.00	0.00	0.00	0.00	0.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	5623.00	5623.00

DRAINAGE AREA	**J12**				
TOTAL DA	24485.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	19660.00	19660.00
IMPERVIOUS	0.00	0.00	0.00	4825.00	4825.00
1/8 ACRE LOT	0.00	0.00	0.00	0.00	0.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	24485.00	24485.00

DRAINAGE AREA	**S2**				
TOTAL DA	267465.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.00	0.00
IMPERVIOUS	0.00	0.00	0.00	96018.00	96018.00
1/8 ACRE LOT	0.00	0.00	0.00	171447.00	171447.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	267465.00	267465.00

DRAINAGE AREA	**J13**				
TOTAL DA	23994.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.00	0.00
IMPERVIOUS	0.00	0.00	0.00	13708.00	13708.00
1/8 ACRE LOT	0.00	0.00	0.00	10286.00	10286.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	23994.00	23994.00

DRAINAGE AREA	**J14**				
TOTAL DA	50655.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.00	0.00
IMPERVIOUS	0.00	0.00	0.00	21957.00	21957.00
1/8 ACRE LOT	0.00	0.00	0.00	28698.00	28698.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	50655.00	50655.00

DRAINAGE AREA	**J15**				
TOTAL DA	10957.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	9845.00	9845.00
IMPERVIOUS	0.00	0.00	0.00	1112.00	1112.00
1/8 ACRE LOT	0.00	0.00	0.00	0.00	0.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	10957.00	10957.00

DRAINAGE AREA	**J16**				
TOTAL DA	9272.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	6350.00	6350.00
IMPERVIOUS	0.00	0.00	0.00	2922.00	2922.00
1/8 ACRE LOT	0.00	0.00	0.00	0.00	0.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	9272.00	9272.00

DRAINAGE AREA	J17				
TOTAL DA	8874.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.00	0.00
IMPERVIOUS	0.00	0.00	0.00	4221.00	4221.00
1/8 ACRE LOT	0.00	0.00	0.00	4653.00	4653.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	8874.00	8874.00

DRAINAGE AREA	J18				
TOTAL DA	39238.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.00	0.00
IMPERVIOUS	0.00	0.00	0.00	14075.00	14075.00
1/8 ACRE LOT	0.00	0.00	0.00	25163.00	25163.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	39238.00	39238.00

DRAINAGE AREA	S3				
TOTAL DA	17551.00				
	HYDROLOGIC SOIL GROUP				Total
LAND USE	A	B	C	D	
OPEN SPACE	0.00	0.00	0.00	0.00	0.00
IMPERVIOUS	0.00	0.00	0.00	7478.00	7478.00
1/8 ACRE LOT	0.00	0.00	0.00	10073.00	10073.00
WOODS	0.00	0.00	0.00	0.00	0.00

SOIL AREAS	A	B	C	D	TOTAL
	0.00	0.00	0.00	17551.00	17551.00

NOAA Atlas 14, Volume 2, Version 3
Location name: Saint Michaels, Maryland, USA*
Latitude: 38.7817°, Longitude: -76.2256°
Elevation: 2.84 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.354 (0.320-0.391)	0.423 (0.383-0.467)	0.504 (0.455-0.556)	0.562 (0.507-0.621)	0.636 (0.570-0.703)	0.690 (0.616-0.764)	0.745 (0.661-0.826)	0.796 (0.702-0.887)	0.860 (0.750-0.965)	0.910 (0.788-1.03)
10-min	0.565 (0.511-0.624)	0.677 (0.612-0.747)	0.807 (0.729-0.891)	0.899 (0.811-0.993)	1.01 (0.908-1.12)	1.10 (0.981-1.22)	1.18 (1.05-1.31)	1.26 (1.11-1.41)	1.36 (1.19-1.53)	1.43 (1.24-1.62)
15-min	0.706 (0.639-0.780)	0.851 (0.770-0.939)	1.02 (0.922-1.13)	1.14 (1.03-1.26)	1.29 (1.15-1.42)	1.39 (1.24-1.54)	1.50 (1.33-1.66)	1.59 (1.40-1.77)	1.71 (1.49-1.92)	1.80 (1.56-2.03)
30-min	0.968 (0.876-1.07)	1.18 (1.06-1.30)	1.45 (1.31-1.60)	1.65 (1.49-1.82)	1.90 (1.71-2.10)	2.10 (1.87-2.32)	2.29 (2.03-2.54)	2.48 (2.19-2.76)	2.73 (2.38-3.06)	2.91 (2.52-3.29)
60-min	1.21 (1.09-1.33)	1.48 (1.33-1.63)	1.86 (1.68-2.05)	2.15 (1.94-2.37)	2.53 (2.27-2.80)	2.84 (2.54-3.15)	3.16 (2.80-3.50)	3.47 (3.06-3.87)	3.91 (3.41-4.39)	4.25 (3.68-4.81)
2-hr	1.45 (1.31-1.60)	1.76 (1.60-1.95)	2.23 (2.02-2.46)	2.59 (2.34-2.86)	3.10 (2.78-3.42)	3.51 (3.13-3.88)	3.94 (3.49-4.36)	4.39 (3.86-4.88)	5.02 (4.36-5.62)	5.54 (4.76-6.23)
3-hr	1.57 (1.43-1.74)	1.92 (1.74-2.12)	2.43 (2.20-2.69)	2.84 (2.56-3.13)	3.42 (3.06-3.77)	3.89 (3.46-4.30)	4.40 (3.88-4.86)	4.93 (4.31-5.48)	5.70 (4.90-6.37)	6.33 (5.38-7.12)
6-hr	1.96 (1.78-2.17)	2.38 (2.16-2.63)	3.00 (2.72-3.32)	3.52 (3.17-3.89)	4.28 (3.82-4.72)	4.92 (4.36-5.45)	5.63 (4.93-6.24)	6.39 (5.53-7.11)	7.51 (6.39-8.44)	8.46 (7.09-9.58)
12-hr	2.36 (2.13-2.66)	2.87 (2.57-3.22)	3.65 (3.26-4.10)	4.32 (3.84-4.85)	5.34 (4.70-5.99)	6.23 (5.43-7.00)	7.23 (6.22-8.15)	8.35 (7.07-9.45)	10.1 (8.33-11.5)	11.5 (9.38-13.2)
24-hr	2.72 (2.47-3.04)	3.32 (3.01-3.70)	4.31 (3.90-4.80)	5.17 (4.66-5.74)	6.48 (5.81-7.17)	7.63 (6.78-8.41)	8.93 (7.87-9.81)	10.4 (9.07-11.4)	12.6 (10.9-13.8)	14.6 (12.4-15.9)
2-day	3.14 (2.84-3.48)	3.82 (3.46-4.24)	4.96 (4.49-5.51)	5.94 (5.36-6.58)	7.42 (6.65-8.19)	8.72 (7.76-9.60)	10.2 (8.98-11.2)	11.8 (10.3-12.9)	14.3 (12.3-15.6)	16.4 (14.0-18.0)
3-day	3.32 (3.02-3.68)	4.03 (3.68-4.48)	5.22 (4.75-5.78)	6.23 (5.64-6.89)	7.75 (6.98-8.55)	9.06 (8.11-9.98)	10.5 (9.36-11.6)	12.2 (10.7-13.4)	14.6 (12.7-16.1)	16.8 (14.4-18.4)
4-day	3.50 (3.20-3.88)	4.25 (3.89-4.71)	5.48 (5.00-6.06)	6.52 (5.93-7.20)	8.07 (7.30-8.90)	9.41 (8.46-10.4)	10.9 (9.73-12.0)	12.6 (11.1-13.8)	15.0 (13.1-16.5)	17.1 (14.8-18.8)
7-day	4.07 (3.74-4.46)	4.91 (4.51-5.39)	6.22 (5.71-6.82)	7.33 (6.71-8.03)	8.97 (8.16-9.80)	10.4 (9.39-11.3)	11.9 (10.7-13.0)	13.6 (12.1-14.8)	16.1 (14.2-17.6)	18.3 (15.9-19.9)
10-day	4.61 (4.28-5.01)	5.54 (5.14-6.02)	6.90 (6.38-7.50)	8.03 (7.42-8.72)	9.67 (8.89-10.5)	11.0 (10.1-11.9)	12.5 (11.4-13.5)	14.1 (12.7-15.2)	16.4 (14.7-17.8)	18.5 (16.4-20.0)
20-day	6.18 (5.76-6.65)	7.35 (6.85-7.92)	8.90 (8.28-9.57)	10.1 (9.43-10.9)	11.9 (11.0-12.8)	13.3 (12.3-14.3)	14.8 (13.6-15.9)	16.3 (14.9-17.5)	18.4 (16.7-19.8)	20.1 (18.1-21.6)
30-day	7.66 (7.16-8.19)	9.08 (8.49-9.72)	10.8 (10.1-11.6)	12.2 (11.4-13.0)	14.1 (13.1-15.0)	15.6 (14.5-16.6)	17.1 (15.8-18.2)	18.6 (17.2-19.9)	20.7 (19.0-22.2)	22.4 (20.4-23.9)
45-day	9.64 (9.07-10.2)	11.4 (10.7-12.1)	13.3 (12.6-14.1)	14.8 (14.0-15.7)	16.8 (15.8-17.8)	18.3 (17.1-19.4)	19.7 (18.5-20.9)	21.2 (19.8-22.4)	23.0 (21.4-24.4)	24.4 (22.6-25.9)
60-day	11.5 (10.9-12.2)	13.6 (12.8-14.3)	15.7 (14.8-16.6)	17.3 (16.3-18.3)	19.3 (18.2-20.4)	20.8 (19.6-22.0)	22.2 (20.9-23.5)	23.6 (22.1-24.9)	25.3 (23.6-26.7)	26.5 (24.7-28.1)

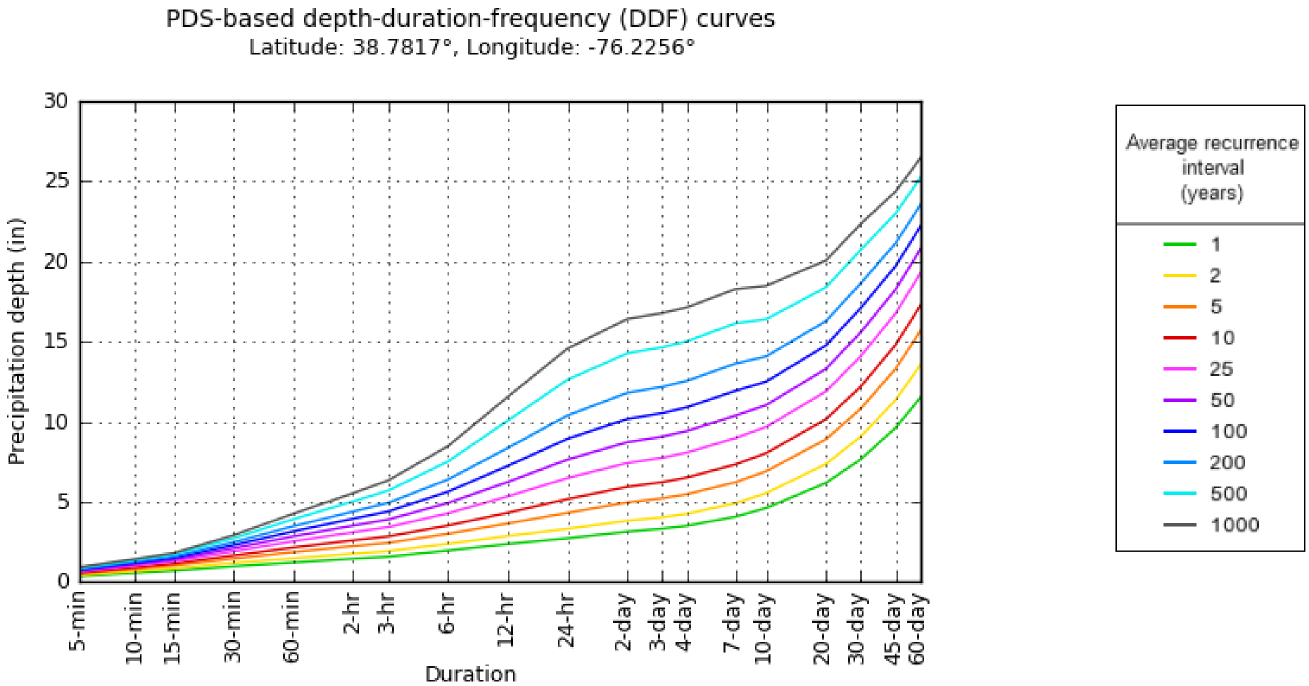
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

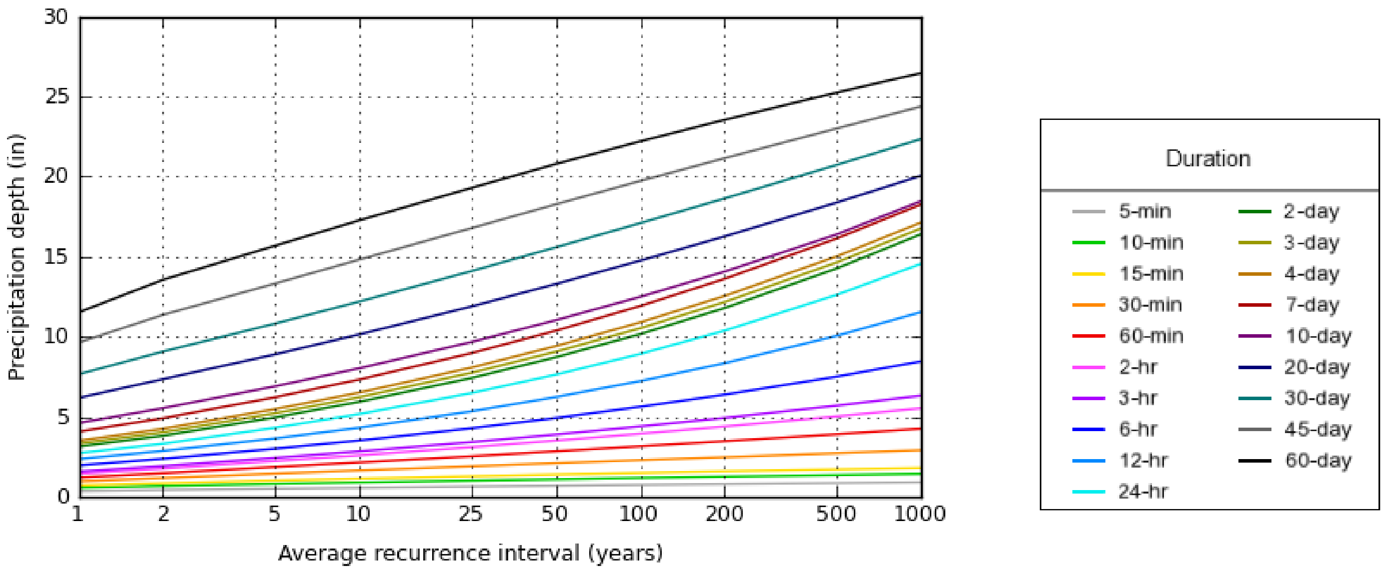
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Back to Top

PF graphical



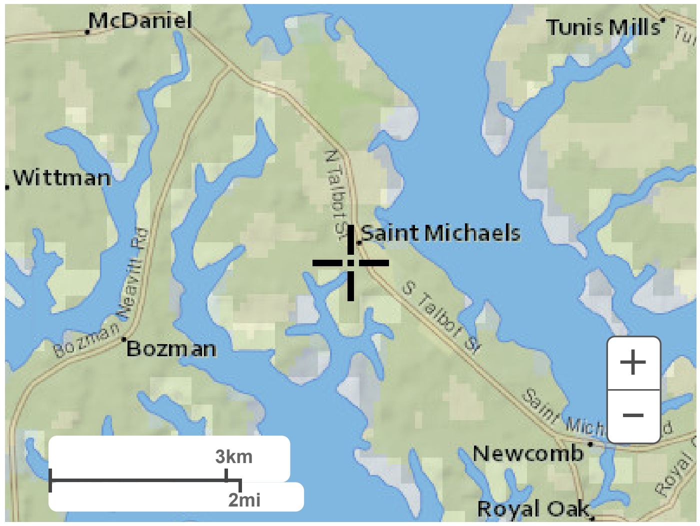


NOAA Atlas 14, Volume 2, Version 3 Created (GMT): Fri Feb 17 21:19:35 2023

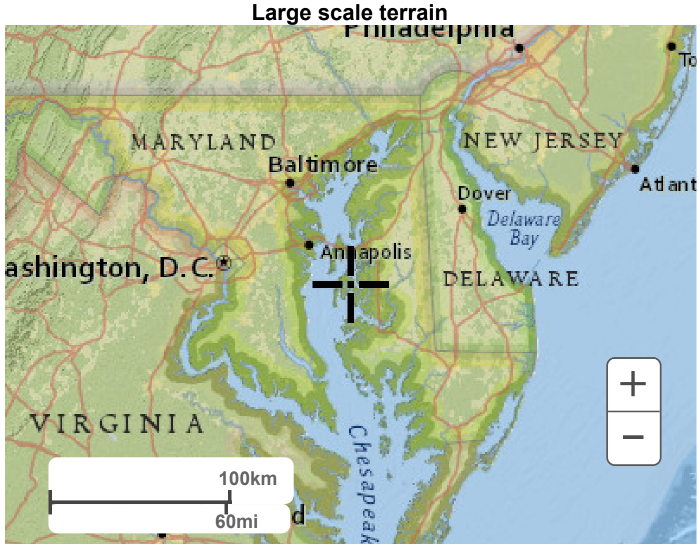
Back to Top

Maps & aerials

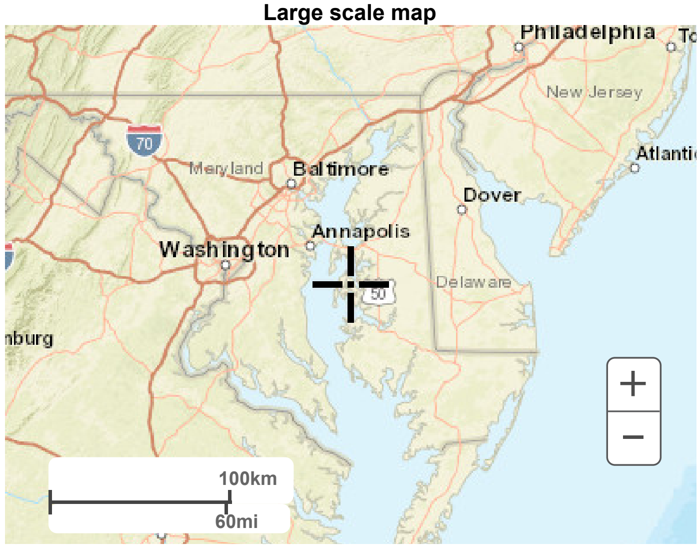
Small scale terrain



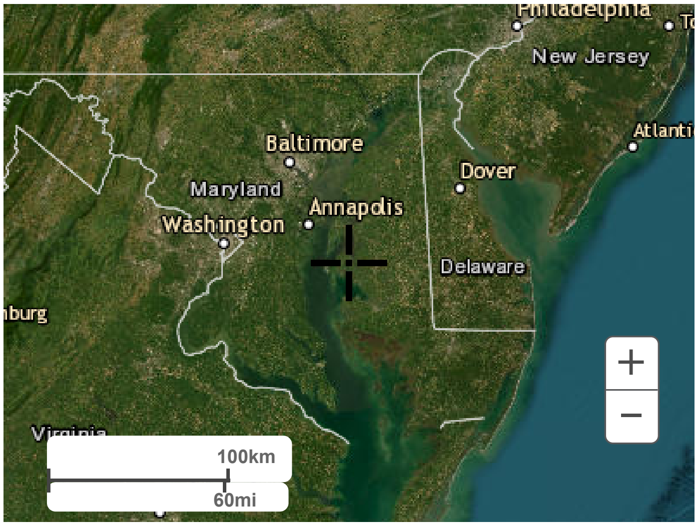
Large scale terrain



Large scale map



Large scale aerial



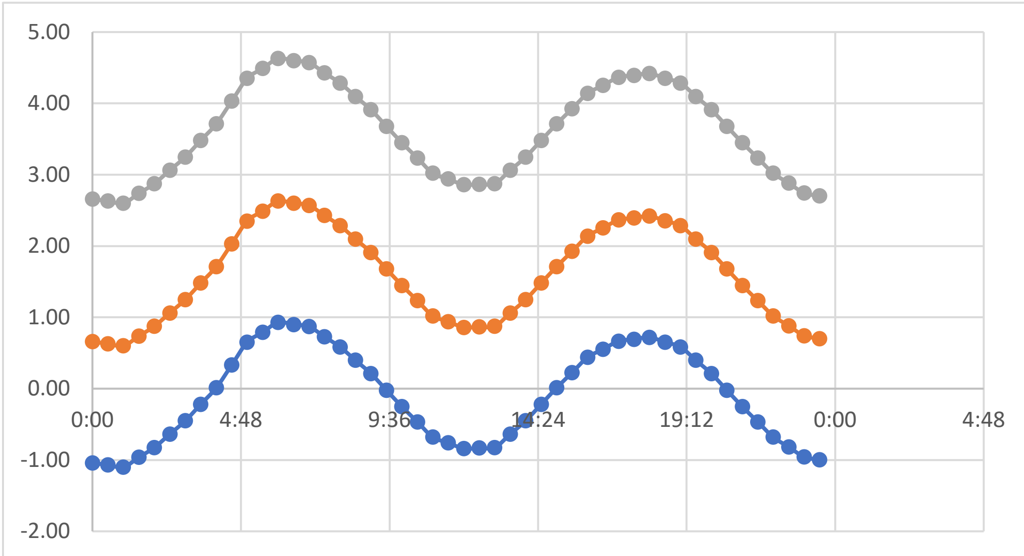
Back to Top

US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

Time	Typical	2050 SLR	2050 SLR + 2' Surge
0:00	-1.04	0.66	2.66
0:30	-1.07	0.63	2.63
1:00	-1.10	0.60	2.60
1:30	-0.96	0.74	2.74
2:00	-0.82	0.88	2.88
2:30	-0.64	1.06	3.06
3:00	-0.45	1.25	3.25
3:30	-0.22	1.48	3.48
4:00	0.01	1.71	3.71
4:30	0.33	2.03	4.03
5:00	0.65	2.35	4.35
5:30	0.79	2.49	4.49
6:00	0.93	2.63	4.63
6:30	0.90	2.60	4.60
7:00	0.87	2.57	4.57
7:30	0.73	2.43	4.43
8:00	0.58	2.28	4.28
8:30	0.40	2.10	4.10
9:00	0.21	1.91	3.91
9:30	-0.02	1.68	3.68
10:00	-0.25	1.45	3.45
10:30	-0.47	1.23	3.23
11:00	-0.68	1.02	3.02
11:30	-0.76	0.94	2.94
12:00	-0.84	0.86	2.86
12:30	-0.83	0.87	2.87
13:00	-0.82	0.88	2.88
13:30	-0.64	1.06	3.06
14:00	-0.45	1.25	3.25
14:30	-0.22	1.48	3.48
15:00	0.01	1.71	3.71
15:30	0.23	1.93	3.93
16:00	0.44	2.14	4.14
16:30	0.55	2.25	4.25
17:00	0.67	2.37	4.37
17:30	0.69	2.39	4.39
18:00	0.72	2.42	4.42
18:30	0.65	2.35	4.35
19:00	0.58	2.28	4.28
19:30	0.40	2.10	4.10
20:00	0.21	1.91	3.91
20:30	-0.02	1.68	3.68
21:00	-0.25	1.45	3.45
21:30	-0.47	1.23	3.23
22:00	-0.68	1.02	3.02
22:30	-0.82	0.88	2.88

23:00	-0.96	0.74	2.74
23:30	-1.00	0.70	2.70
	-1.04		2



5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
0:00
4:48
9:36
14:24
19:12
0:00
4:48

Appendix B

Hydraulic Analysis

Existing Subcatchments		
Subcatchment	Receiving Node	Drainage Area (AC)
DA1	S1	0.07
DA2	J2	0.74
DA3	J3	0.03
DA4	J4	0.24
DA5	J5	0.93
DA6	J11	0.13
DA7	J12	0.56
DA8	S2	6.14
DA10	J14	1.16
DA11	J15	0.25
DA12	J16	0.21
DA13	J17	0.20
DA14	J18	0.90
DA15	S3	0.40

2050 90th Percentile Node Flooding Summary						
Node	Hours Flooded					
	EX 1-yr	EX 10-yr	EX 100-yr	PR 1-yr	PR 10-yr	PR 100-yr
J2	0.2	0.2	0.2	-	-	-
J14	-	-	0.8	-	-	-
S1	15.8	15.8	15.8	3.8	5.2	5.2
S2	-	0.3	1.0	-	-	-

Existing 2050 1-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J2	0.2	15:52
S1	15.8	18:01

Existing 2050 10-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J2	0.2	15:52
S1	15.8	18:24
S2	0.3	13:00

Existing 2050 100-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
J2	0.2	15:52
J14	0.8	13:00
S1	15.8	19:30
S2	1.0	12:58

Proposed 2050 1-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
S1	3.8	13:00

Proposed 2050 10-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
S1	5.2	13:00

Proposed 2050 100-YR 90th Percentile Flooding Summary		
Node	Hours Flooded	Hour of Maximum Flooding
S1	5.2	13:00