WATERSHED MASTER PLAN

Township of Upper

Prepared by:
Dr. Stewart C. Farrell, Kevin Pretti, and Matthew Deibert
Stockton University Coastal Research Center
30 Wilson Avenue Port Republic, NJ 08241
October 1, 2021

Table of Contents

List of Figures

List of Tables

Introduction:

The Township of Upper was one of the original 104 townships incorporated by the New Jersey legislature on February 21, 1798. It was formed as a precinct in April 1723. Portions of the original tract of land have been extracted to form: Dennis Township (March 1827); Ocean City (March 1884); Sea Isle City March and (April 1905). The name originated in 1723 when Cape May County was split into three townships initially, named Lower, Middle and Upper.

The township has a total area of 68.68 square miles (43,785 acres) including 62.03 square miles (39,699 acres) of land and 6.66 square miles (4,262 acres) of water area. The township occupies the northern third of Cape May County including the barrier island community known as Strathmere (Ludlam Island). Bordering communities in Cape May County include Dennis Township, Ocean City, and Woodbine. It also borders Corbin City, Egg Harbor Township, Estell Manor, and Somers Point in Atlantic County plus Maurice River Township in Cumberland County. The Township either borders or contains several water bodies including the Tuckahoe River, Great Egg Harbor and the Atlantic Ocean in Strathmere.

The 2010 census counted 12,373 people, 4,566 households in the township. Township of Upper is governed under the Township form of municipal government, one of 141 NJ municipalities using this form. The Township committee has 5 members elected directly by voters to serve three-year terms on a staggered basis. The mayor is selected by the committee annually at its reorganization meeting in January. Township of Upper is in the 2nd Congressional District and is part of the New Jersey 1st legislative district.

There are three pre-K through 8th grade schools and all 9th through 12th grade students attend the Ocean City High School. There are two County-wide schools; the Cape May County Technical High School and the Cape May County Special Services School District for students with special needs.

The township has 140.68 miles of roadways. The municipality maintains 74.84 miles, Cape May County maintains 36.95 miles, the NJ Dept. of Transportation maintains 19.37 miles, and New Jersey Turnpike Authority (Garden State Parkway) are under supervision of 9.07 miles. Public transportation is conducted by NJ Transit with three inter-city bus routes through the township three times daily.

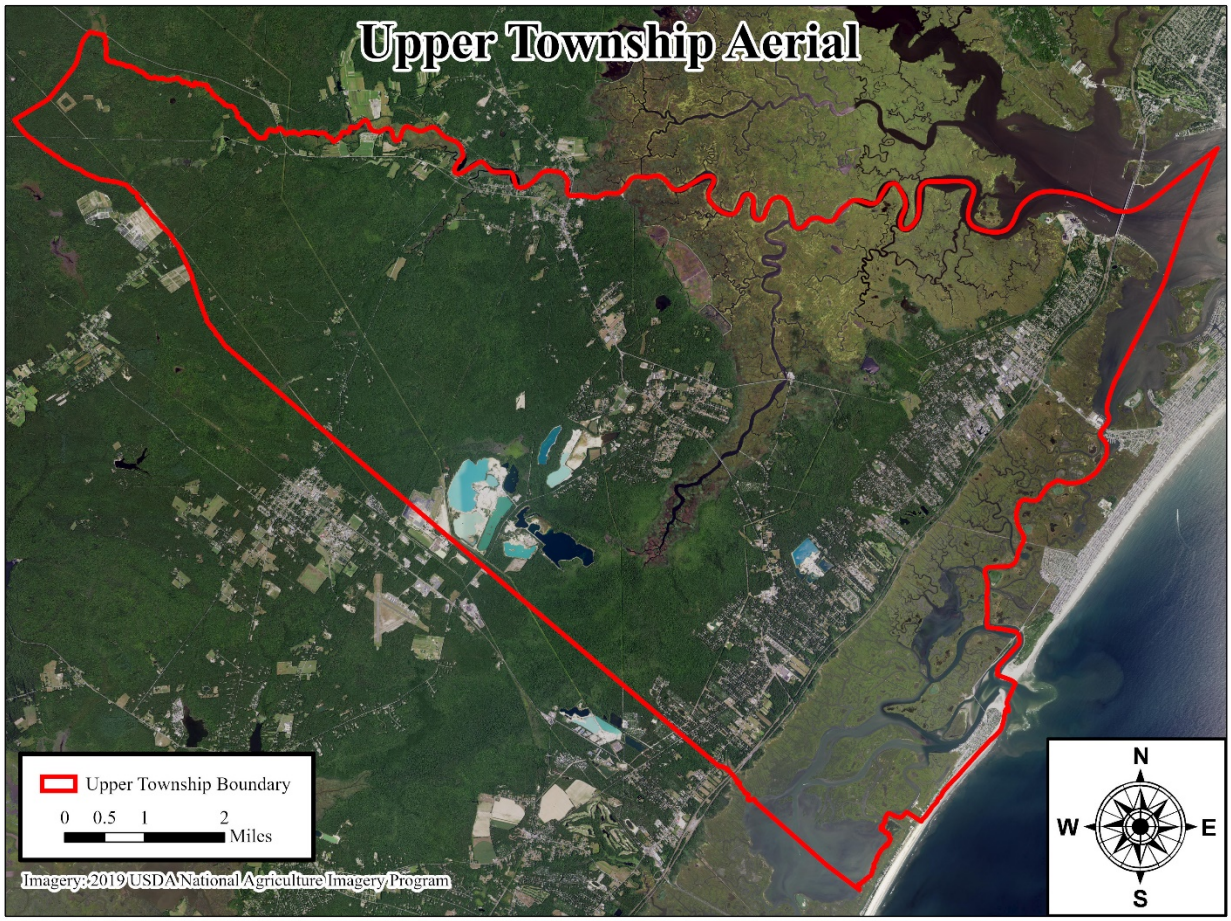


Figure 1. Aerial photograph of northern Cape May County, NJ with the extents of the Township of Upper outlined in red.

Climate:

The Township of Upper in Cape May County has a humid subtropical climate with moderately humid, hot summers, and cool winters with periodic snowfall. The yearly precipitation averaging 3.5 inches per month. There are abundant marginal water bodies to moderate extreme temperature changes. The township also contains widespread forested regions which contain fresh to brackish water wetlands associated with the Great Egg Harbor. The Tuckahoe River partitions Cape May County from Atlantic County and its tributary, Cedar Swamp Creek, divides the township into a western and eastern portion.

Table 1. Climate summary for West Cape May, NJ.

Climate data for The Township of Upper, NJ (1981-2010 Averages)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °F (°C)	42.3 (5.7)	44.3 (6.8)	51.4 (10.8)	60.8 (16.0)	70.4 (21.3)	79.4 (26.3)	84.5 (29.2)	83.4 (28.6)	77.8 (25.4)	67.1 (19.5)	56.8 (13.8)	46.8 (8.2)	63.7 (17.6)
Daily mean °F (°C)	35.1 (1.7)	36.8 (2.7)	43.3 (6.3)	52.3 (11.3)	61.5 (16.4)	71 (22)	76.1 (24.5)	75.1 (23.9)	69.2 (20.7)	58.5 (14.7)	49.0 (9.4)	39.4 (4.1)	55.6 (13.1)
Average low °F (°C)	27.9 (−2.3)	29.2 (−1.6)	35.2 (1.8)	43.8 (6.6)	52.7 (11.5)	62.5 (16.9)	67.7 (19.8)	66.8 (19.3)	60.7 (15.9)	49.9 (9.9)	41.1 (5.1)	31.9 (−0.1)	47.4 (8.6)
Average precipitation inches (mm)	3.32 (84)	2.82 (72)	4.26 (108)	3.53 (90)	3.53 (90)	3.37 (86)	3.70 (94)	3.62 (92)	3.27 (83)	3.70 (94)	3.29 (84)	3.47 (88)	41.88 (1,064)

Source: NWS

Climate data for Cape May County, NJ Ocean Water Temperature (4 NW Cape May)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily mean °F (°C)	42 (6)	40 (4)	45 (7)	52 (11)	59 (15)	68 (20)	73 (23)	76 (24)	72 (22)	61 (16)	52 (11)	42 (6)	57 (14)

Source: NOAA

(The climate data provided by NOAA detail the average climatic conditions for the Township of Upper, NJ between 1981 and 2010.)

Table 2. FEMA Precipitation frequency estimates in inches for the Township of Upper.

Average recurrence interval (Years)						
Hours	1	5	10	25	50	100
1	1.23	1.85	2.16	2.54	2.87	3.19
3	1.73	2.62	3.1	3.7	4.24	4.78
6	2.11	3.17	3.76	4.54	5.25	5.98
12	2.49	3.75	4.5	5.53	6.48	7.5
24	2.73	4.32	5.18	6.49	7.65	8.94
48	3.09	4.89	5.87	7.33	8.61	10
72	3.24	5.08	6.08	7.55	8.84	10.3
120	x	x	6.65	x	9.81	11.47

Land Use and Zoning in the Township of Upper:

Forest and wetlands comprise 76.9 percent of the township land area whereas water areas account for 9.6% of the total municipal area. Large tracts of salt marsh exist along the south bank of the Tuckahoe River that grade into freshwater wetlands and then into uplands forest. These areas are sparsely populated, but the communities of Tuckahoe and Petersburg are nestled

development within the larger natural areas. Agriculture and sand/gravel mining operate in this part of the township in the open space areas.
The Cedar Swamp Creek runs south from the Tuckahoe River within the salt marsh region dividing the forests from the higher ground associated with US Route 9 and the Garden State Parkway. Urban development comprises 13.2% of the Township land area. The tidal marsh bordering the Cedar Swamp Creek diminishes to the south, finally converting into freshwater swamp land that continues south out of Township of Upper. This wetland continues south as the Dennis Creek finally reaching the salt water of Delaware Bay in Middle Township exiting as Dennis Creek into the bay in the Dennis Creek Wildlife Management Area.

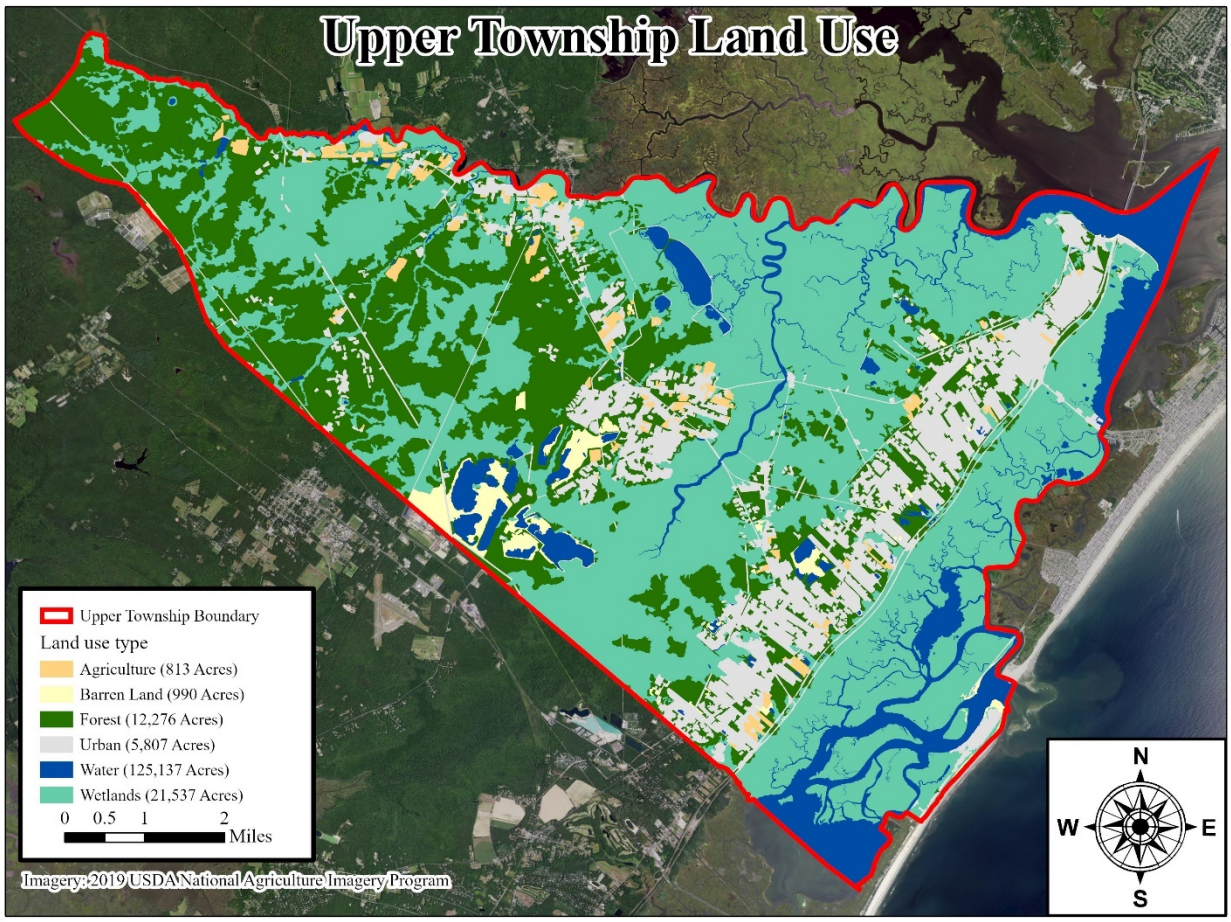


Figure 2. Land use distribution for the Township of Upper, Cape May County, NJ. The US Route 9 corridor is very evident along with the small core municipalities to the northwest. Wetlands and forest comprise the majority of the Township.

Development is much denser along US Route 9 with local names such as Beesley's Point, Marmora, and Palermo making up the distance from the Great Egg Harbor Garden State Parkway bridge to Middle Township. Development has moved west toward the wetlands associated with Cedar Swamp Creek and up to the western edge of the Garden State Parkway. The Garden State Parkway was built in the 1950's after being a pre-WW II concept with a Cape May County pilot segment built pre-war. This roadway essentially prevented the development of the mainland salt marsh lagoon margin in Cape May County by occupying the eastern edge of the county mainland uplands. Only a few homes exist east of the parkway on the mainland

marsh edge at Beesley's Point. The township does include the northern third of Ludlam Island as the community of Strathmere. This community was developed as a coastal barrier for second homes and has a tourist-centered business district. Sea Isle City occupies the remainder of Ludlam Island.

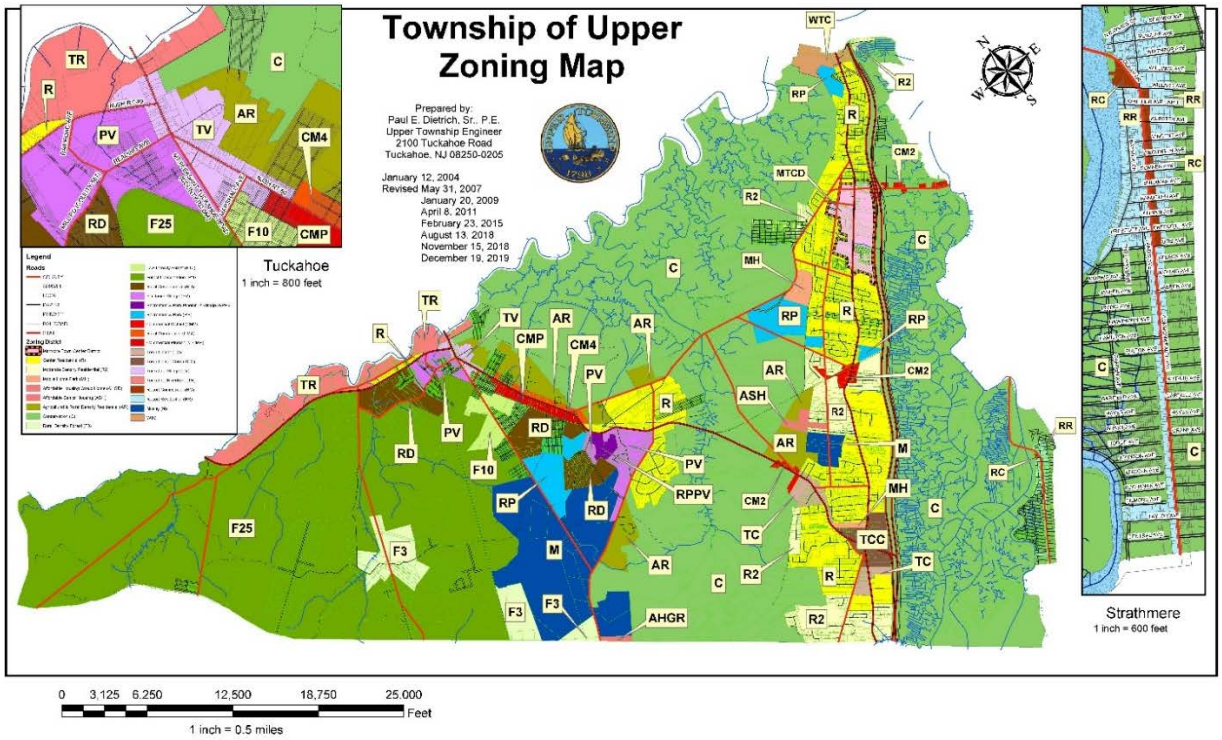


Figure 3. Zoning map for the Township of Upper adopted January 2004 and repeatedly amended most recently as of December 2019. Since the legend for zones is too small to read at this scale it is presented in Figure 4.

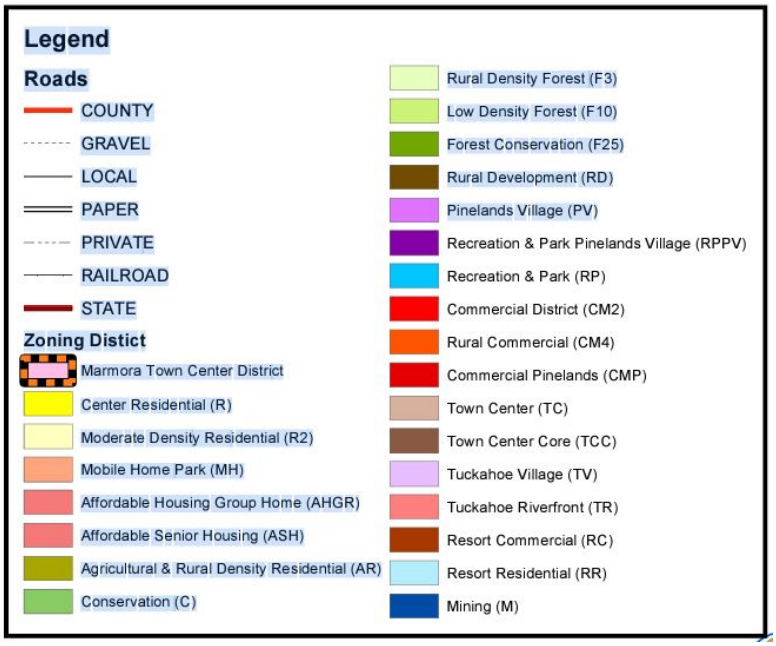


Figure 4. Zoning map legend showing the variety of Residential areas, agricultural and conservation zones in the Township of Upper.

The Township of Upper has a relatively complex zoning plan established to encompass both a coastal barrier island community as well as southern New Jersey rural agriculture and sand mining quarries. The zoning map displays the special nexus between the major travel roadways into Cape May County and the residential zone density pattern associated with US Route 9. Strathmere is shown to the right margin as a Resort Residential, Resort Commercial and Conservation zone for the dunes, beaches, and salt marshes. The entire western third of the Township is zoned Forest Conservation (F25).

Figures 5 and 6 below show the array of individual zoning district parameters, with this report focused on minimum lot area, lot coverage percentages, and impervious lot coverage. The coastal community of Strathmere has the smallest lot size of 4,000 square feet (0.92 acre) with a 45% impervious lot coverage, ranging upwards within the Agricultural and Rural Residential zone to 120,000 square feet (2.75 acres) with just 5% impervious lot coverage. The Strathmere elevation data and proximity to coastal storms make this sub-community of special focus in evaluation of the watershed impacts from both rainfall events and tidal flooding exacerbated by rising sea level. The interior regions of Township of Upper are both much higher in elevation and far less developed.

ZONING

20 Attachment 3

Township of Upper

SCHEDULE C - Revised March 9, 2020

AREA AND YARD REQUIREMENTS FOR ZONE DISTRICTS

[Ord. #002-2013; Ord. #004-2015 § 3; Ord. No. 011-2018; amended 5-26-2020 by Ord. No. 005-2020]

		Principal Building												Accessory Building			
	Zoning District	Minimum Lot Area	Minimum Lot Frontage	Minimum Lot Width	Minimum Lot Depth	Minimum Yards (feet)			Height[3]	Maximum Building Coverage	Maximum Impervious Lot Coverage	Tree Preservation	Landscape Buffer[11]	Minimum Yard (feet)		Distance to Other Building	Maximum Building Coverage
		(square feet)	(feet)	(feet)	(feet)	Front	Side (one/both)	Rear	(feet)			(11)	(feet)	Side (one/both)	Rear	(feet)	
Residential Zones																	
AR	Agriculture and Rural Density Residential	120,000	200	200	300	80	50/100	100	35	3%	5%	70%	40	25/50	50	20	1.0%
	House of worship and cemeteries	120,000	200	200	200	50	50/50	50	55	5%	10%	50%	25	15/30	15	15	2.5%
	9-hole golf courses	50 acres	600	600	1,000	200	200/400	200	35	1%	10%	35%	20	50/100	50	20	0.1%
	18-hole golf courses	200 acres	600	600	1,000	200	200/400	200	35	1%	10%	35%	20	50/100	50	20	0.1%
R	Center Residential	40,000	140	140	175	50	25/50	50	35	10%	30%	35%	10	15/30	15	15	5.0%
	House of worship and cemeteries	60,000	200	200	200	50	50/50	50	55	10%	30%	35%	10	15/30	15	15	5.0%
R2	Moderate Density Residential	40,000	140	140	175	50	25/50	50	35	8%	20%	35%	10	15/30	15	15	4.0%
	House of worship and cemeteries	60,000	200	200	200	50	50/50	50	55	10%	30%	35%	10	15/30	15	15	5.0%
	9-hole golf courses	50 acres	600	600	1,000	200	200/400	200	35	1%	10%	35%	20	50/100	50	20	0.1%
	18-hole golf courses	200 acres	600	600	1,000	200	200/400	200	35	1%	10%	35%	20	50/100	50	20	0.1%
RR	Resort Residential	4,000	40	40	100	15	[14]	30	35	27%	45%	0%	0	6/6	10	10	2.5%
	Houses of worship	6,000	50	50	100	15	8/8	30	55	20%	50%	0%	0	8/8	10	10	5.0%
TR	Tuckahoe Riverfront	2 acres	150	150	250	50	35/70	50	35	3%	5%	50%	25	35/70	50	20	1.5%
MH	Mobile Home	20 acres	200	200	400	75	7/150	75	35	35%	70%	25%	50	15/30	50	15	5.0%
AHGR	Affordable Housing Group Home	5 acres	200	200	400	100	60/120	60	45	30%	40%	25%	35	15/30	50	15	5.0%
C	Conservation	10 acres	400	400	400	(4) 200	50/50	70	35	1.5%	3%	70%	25	40/40	40	20	0.5%
PV	Pinelands Village	1 acre	120	120	150	(2) 70	25/50	50	35	6%	10%	50%	10	15/30	15	15	5.0%
RD	Rural Development	3.75 acres	150	150	300	200[4]	30/60	70	35	5%	10%	50%	10	30/30	30	15	2.0%
	House of worship and cemeteries	60,000	200	200	200	50	50/50	50	55	5%	10%	50%	25	15/30	15	15	2.0%
	9-hole golf courses	50 acres	600	600	1,000	200	200/400	200	35	1%	10%	35%	20	50/100	50	20	0.1%
	18-hole golf courses	200 acres	600	600	1,000	200	200/400	200	35	1%	10%	35%	20	50/100	50	20	0.1%
F3	Rural Density Forest	3.2 acres	(5) 150	150	325	200[4]	50/100	75	35	3%	5%	70%	25	30/60	30	15	1.0%
F10	Low Density Forest	10 acres	(6) 175	175	350	200[4]	50/100	100	35	2%	4%	70%	25	30/60	30	15	0.5%
F25	Forest Conservation	25 acres	(7) 200	200	350	200[4]	50/100	100	35	0.5%	3%	70%	25	50/100	50	20	0.5%
RP	Recreation and Park	3.75 acres	150	150	300	200	50/100	75	35	5%	10%	70%	25	30/60	30	15	2.0%
	9-hole golf courses	50 acres	600	600	1,000	200	200/400	200	35	1%	10%	35%	20	50/100	50	20	0.1%
	18-hole golf courses	200 acres	600	600	1,000	200	200/400	200	35	1%	10%	35%	20	50/100	50	20	0.1%
RPPV	Recreation and Park Pinelands Village	3.75 acres	150	150	300	200	50/100	75	35	5%	10%	70%	25	30/60	30	15	2.0%
	9-hole golf courses	50 acres	600	600	1,000	200	200/400	200	35	1%	10%	35%	20	50/100	50	20	0.1%
	18-hole golf courses	200 acres	600	600	1,000	200	200/400	200	35	1%	10%	35%	20	50/100	50	20	0.1%
Mixed Use Zones																	

Figure 5. Page one of two showing all lot specification details for the range of zoning districts for the Township of Upper, NJ. Many districts require multiple acres for developemetn making the Township generally able to manage stormwater using natural soil infiltration combined with stream runoff.

		Principal Building												Accessory Building			
	Zoning District	Minimum Lot Area	Minimum Lot Frontage	Minimum Lot Width	Minimum Lot Depth	Minimum Yards (feet)			Height[1]	Maximum Building Coverage	Maximum Impervious Lot Coverage	Tree Preservation	Landscape Buffer[11]	Minimum Yard (feet)		Distance to Other Building	Maximum Building Coverage
		(square feet)	(feet)	(feet)	(feet)	Front	Side (one/both)	Rear	(feet)			(11)	(feet)	Side (one/both)	Rear	(feet)	
MTCD	Marmora Town Center District[12]	40,000 < 10 acres	250	250	300	0	5/10[12]	50	5[13] stories	45%	70%	15%	15	10/20	10	10	5.0%
		10 acres and over	300	300	600	0	5/10[12]	50	5[13] stories	45%	70%	15%	25	10/20	10	10	5.0%
TCC	Town Center Core[10]	40,000-<5 acre	100	100	200	50	25/50[9]	50[9]	45	35%	60%	15%	10	10/20	25	25	5.0%
		5 acres-<10 acre	250	250	300	50	25/50[9]	50[9]	45	25%	70%	15%	15	10/20	25	25	5.0%
		10 acres and over	300	300	600	100	50/100[9]	50[9]	45	20%	70%	25%	25	10/20	25	25	5.0%
TC	Town Center[10]	40,000-5 acres	125	125	200	50	25/50[9]	50[9]	45	30%	50%	15%	10	10/20	25	25	5.0%
		5 acres-<10 acre	250	250	300	50	25/50[9]	50[9]	45	20%	60%	15%	15	10/20	25	25	5.0%
		10 acres and over	300	300	600	100	50/100[9]	50[9]	45	15%	60%	25%	25	10/20	25	25	5.0%
WTC	Waterfront Town Center[10]	40,000- <5 acres	100	100	200	50	25/50[9]	50[9]	45[13]	35%	60%	15%	10	10/20	25	25	5.0%
—	—	5 acres-<10 acre	250	250	300	50	25/50[9]	50[9]	45[13]	25%	70%	15%	15	10/20	25	25	5.0%
—	—	10 acres and over	300	300	600	100	50/100[9]	50[9]	45[13]	20%	70%	25%	25	10/20	25	25	5.0%
TV	Tuckahoe Village	15,000	50	50	100	10	10/10	25	35	50%	70%	25%	10	6/12	6	10	5.0%
Commercial Zones																	
RC	Resort Commercial	6,000	50	50	100	15	8/16	30	35	30%	60%	0%	5	8/16	10	10	5.0%
CM2	Commercial	40,000- <5 acres	150	150	200	50	25/50[9]	50[9]	35	20%	30%	50%	15	15/30	25	25	5.0%
		5 acres-<10 acres	250	250	300	100	25/50[9]	50[9]	35	15%	35%	50%	20	15/30	25	25	5.0%
		10 acres and over	300	300	600	100	50/100[9]	100[9]	35	15%	35%	50%	25	15/30	25	25	1.0%
CM4	Rural Density Commercial	2 acres	200	200	250	100	50/100	50	35	5.0%	15%	70%	15	15/30	25	25	1.0%
CMP	Commercial Pinelands	3.2 acres	200	200	250	100	50/100	50	35	5.0%	15%	70%	15	15/30	25	25	1.0%

Schedule C Notes

1. No building shall exceed maximum specified height, except that churches shall not exceed 55 feet in height and except further as allowed in Subsection 20-6.3.
2. May be reduced to the average setback of the five closest principal buildings.
3. (Reserved)
4. May be reduced to 100 feet in agricultural areas or where environmental limitations require reduction.
5. The lot frontage requirements may be reduced to 50 feet for 3.2-acre flag lot.
6. The lot frontage requirements may be reduced to 50 feet for a 10-acre flag lot.
7. The lot frontage requirements may be reduced to 50 feet for a 25-acre flag lot.
8. (Reserved)
9. An additional side and rear setback of 25 feet shall be provided when the adjacent property is in a residential district.
10. See additional WTC, MTCD, TC and TCC front yard and side yard setback and height standards in Subsection 20-4.7a.
11. Tree preservation and landscape buffer shall not be required for properties with existing structures that existed prior to October 15, 2007.
12. See additional front yard and side yard setback and height standards in Subsection 20-4.20a.
13. Except for buildings attached to a hotel use, there shall be no maximum limit on stories or height.
14. Side yard setbacks shall be provided in accordance with Subsection 20-4.5b2(a).

Figure 6. Page two of two showing the details on The Township of Upper's zoning district lot dimension allowances required. Town core districts are specific to the mainland central development regions such as Tuckahoe and Petersburg.

Land use percentages are:

Residential (mainland & resort)	13.1%
Commercial	0.6%
Conservation (Forest & Marshland)	76.1%
Mining	1.2%
Agricultural	1.6%
Water Areas	8.3%

The Township of Upper consists of two markedly different geographic and hydrographic sections: a larger mainland section of Cape May County with extensive open space in permanent conservation status separated by tidal marshes and open lagoons from the other area, Strathmere on Ludlam Island. Strathmere occupies the northern third of Ludlam Island; the 6th barrier island moving south along the New Jersey coastline. This island is the narrowest and has the lowest in total elevation of the land above mean high tide among the NJ barrier islands. Strathmere' s development is concentrated at the northern segment next to Corson's Inlet, one of only three unstructured tidal inlets in NJ. Development density declines south along the barrier with a very narrow island segment that includes southernmost Strathmere in Township of Upper and northernmost Sea Isle City, the southern Ludlam Island community.

For this watershed management plan, the two elements of Township of Upper, the mainland body and the barrier island, will be evaluated separately with final conclusions applied across the entire municipality of The Township of Upper (its formal name).

THE TOWNSHIP OF UPPER, CAPE MAY COUNTY MAINLAND PORTION:

The Township of Upper occupies the northern segment of Cape May County starting at the Great Egg Inlet and its tidal estuaries (The Tuckahoe River). The mainland segment extends from the lagoons and tidal marshes landward of the NJ barrier island to the Cumberland County boundary with a northern boundary with Atlantic County. Development is concentrated along the old US Route 9 highway corridor augmented mid-20th Century with the Garden State Parkway. Further to the west are several town cores of development such as Tuckahoe, Petersburg and Steelmanville.

THE TOWNSHIP OF UPPER, STRATHMERE on LUDLAM ISLAND

The Ludlam Island segment of The Township of Upper is called Strathmere and represents a typical NJ barrier island sub-section as a separate community for watershed management purposes. Entirely surrounded by tide water with the Atlantic Ocean to the southeast and tidal lagoons and salt marshes to the north and northwest, Strathmere shares Ludlam Island with Sea Isle City to its south. The State of NJ introduced beach management to Strathmere in 1984 with its first large scale beach restoration using Corson's Inlet ebb shoal sand supplies. The State returned to enhance where erosion had occurred in 2001 and in 2009. In 2015-6 the Philadelphia District Corps of Engineers undertook the Corson's Inlet to Townsends Inlet Shore Protection Project where by the entire oceanfront beach was enhanced to current conditions in both Strathmere and Sea Isle City. The Corps obtained sand supplies from authorized offshore borrow sites, not Corson's Inlet. Normal maintenance work followed in 2020. The design dune elevation is 14.8 feet NAVD 1988 with a 100 to 300-foot wide dry beach berm seaward of the dune toe (USACOE project fact sheet https://www.nap.usace.army.mil/Missions/Factsheets/Fact-Sheet-Article-View/Article/490784/new-jersey-shore-protection-great-egg-harbor-inlet-to-townsends-inlet-nj/ Dwight Pakan, manager). Sequential surveys of the beach in Strathmere show that the region south of Corson's Inlet appears quite stable with inlet induced channel migrations the main cause of periodic shoreline erosion. Prior to the federal project any moderate to major northeast storm frequently over-washed the dunes then present crossing the only shore-parallel highway and depositing beach sand into the marshes to the west. Cape May County added a 10-foot diameter geo-textile core to the dunes in Sea Isle City along 2,400 feet of the highway in 1995 which has held up quite well. No breaching has occurred since the federal project was completed in either community.

The bayshore along tidal channels has been protected with individual owner bulkheads with municipal oversight with the ordinance requirements imposed of 8.0 feet NAVD 1988 top elevation on replacement of aging structures. There are segments of the bayshore in Strathmere remaining undeveloped and without any bulkhead in place making tidal flooding from the bayside relatively easy during any elevated tidal stage. Bulkheads stop at the end of Bayview Drive about 500 feet southwest of W. Prescott Road at the bayshore. The southern 5,300 feet of Strathmere development has no bayshore bulkheads. All the homes except for those on South Bayshore Drive are over 1,500 feet from Whale Creek, the main tidal channel landward of Strathmere. The South Bayshore Drive development consists of one marina and six homes with bayshore bulkheads, but no protection from tidal flooding from the sides immediately adjacent to the development. The wide expanse of marshes and transitional vegetation above mean high tide elevations between the tidal channel and development does mitigate storm generated waves on a flooded bay but does nothing to mitigate tidal flooding driven by storm surge.

From Putnam Ave to Jasper Avenue along Commonwealth Avenue (main north/south roadway) is the only seasonal recreational vehicle park on the New Jersey coastline at the beach. This facility is entirely evacuated during the non-tourism months every year and has seen multiple sessions of oceanic over-wash since the 1970's. However, cleanup after the storms has consisted of scraping up the accumulated sand deposition and returning it to the beach.

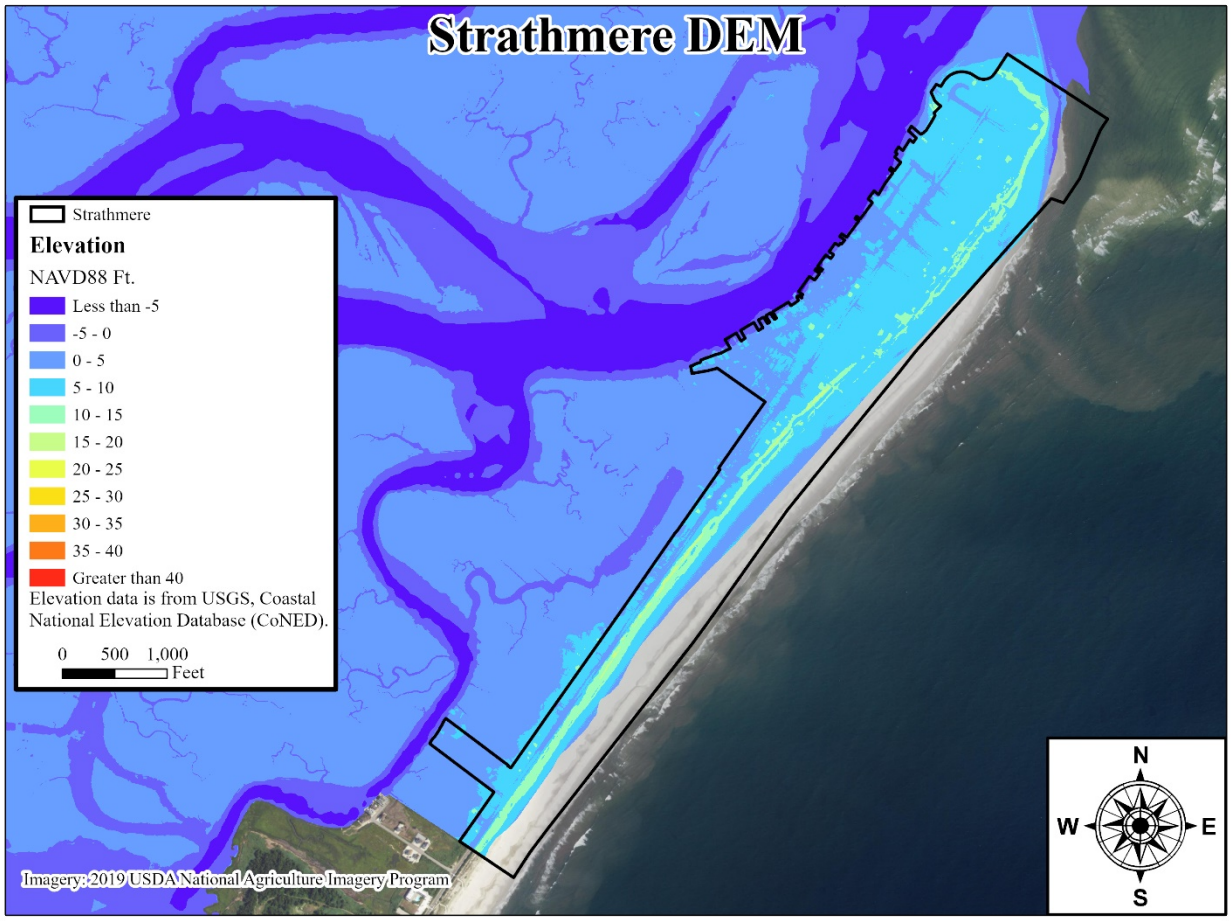


Figure 7. **The elevations of Strathmere derived from a DEM. The dune ridge is the main area above 10 feet NAVD 88 in elevation. The development lies between 5 and 10 feet in elevation.**

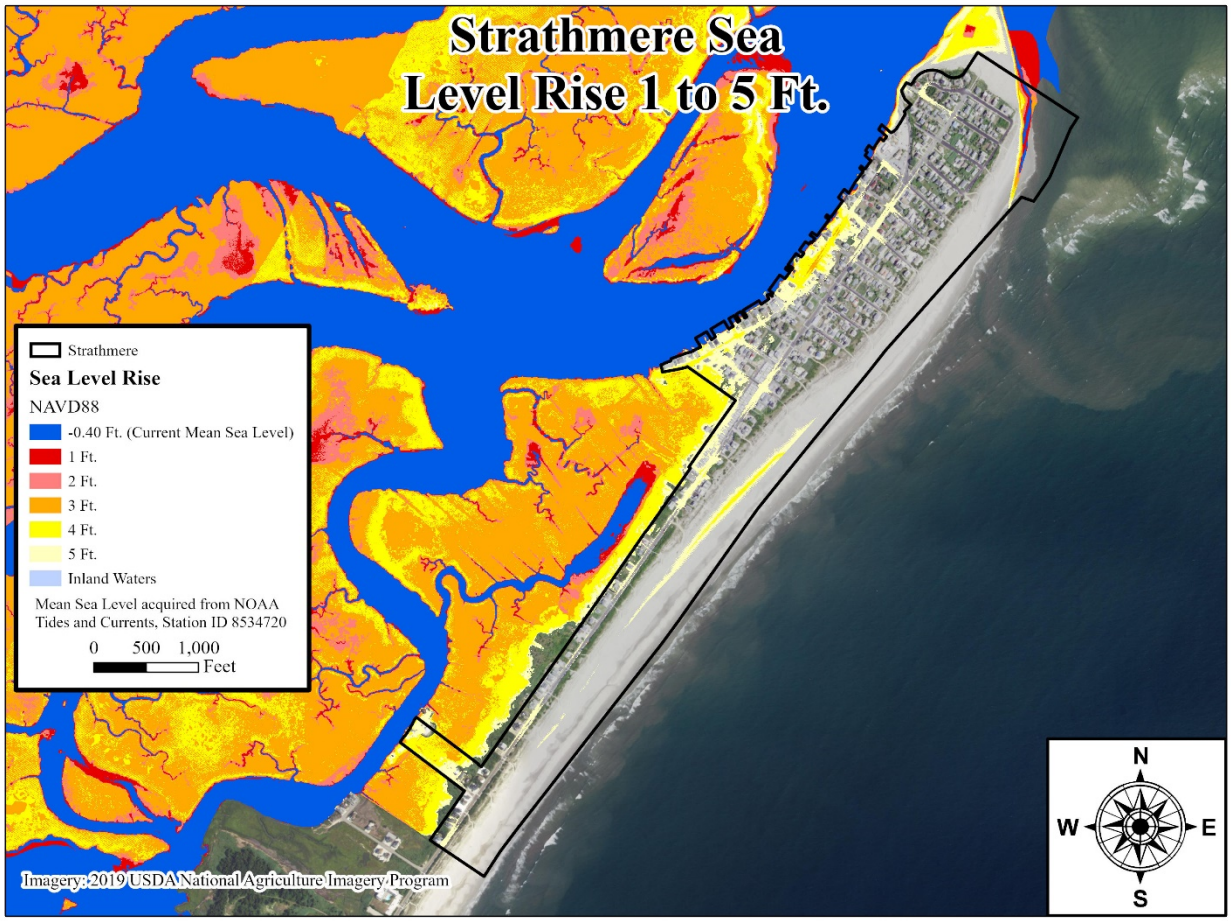


Figure 8. **Sea level rise based on 1 foot intervals for Strathmere. Four to five feet of sea level rise invades the developed area.**

Of the 17 roads located in Strathmere, only Bayview Drive, Taylor Avenue, and Prescott Avenue are significantly affected. Impacts begin at 3 Ft. of sea level rise and the road becomes nearly covered with 4 Ft. of sea level rise for Bayview Drive. Taylor Aveue becomes significantly flooded under 4 Ft. of sea level rise with additional flooding occurring with 5 Ft. of sea level rise. Prescott Avenue does not become impacted until the 5 Ft. interval. The evacation route for Strathmere only has a small section that could potentially face flooding under this scenario.

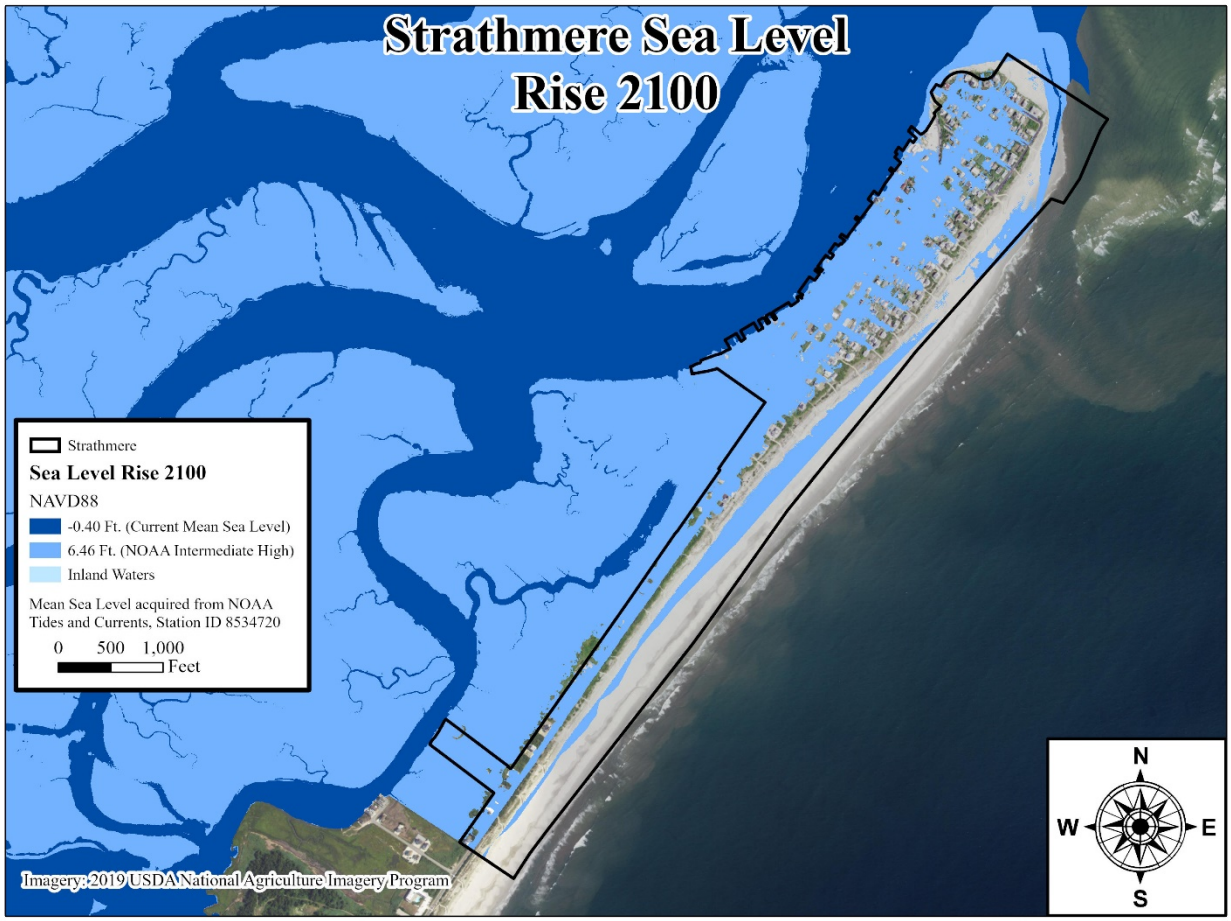


Figure 9. **Sea level rise for Strathmere based on NOAA's 2100 intermediate high projections. This level of water surface rise is disasterous to the beach community.**

Under the NOAA 2100 intermediate high projection, all of the 17 roads in Strathmere are all partially under water at mean sea level. Only Seaview Avenue has a significant portion above the future water line. Additionally, the evacation routes serving Strathmere will be almost completely under water. This currently poses issues for evacautions during tropical storms or hurricane-generated storm surge flooding. Evacuation currently is to the north through Ocean City where low lying roadways inhibit traffic flow and to the south through Sea Isle City on Commonwealth Avenue where flooding impacts the highway today with water levels starting at 2.5 feet above mean high water.

The Township of Upper, Route 9 Corridor

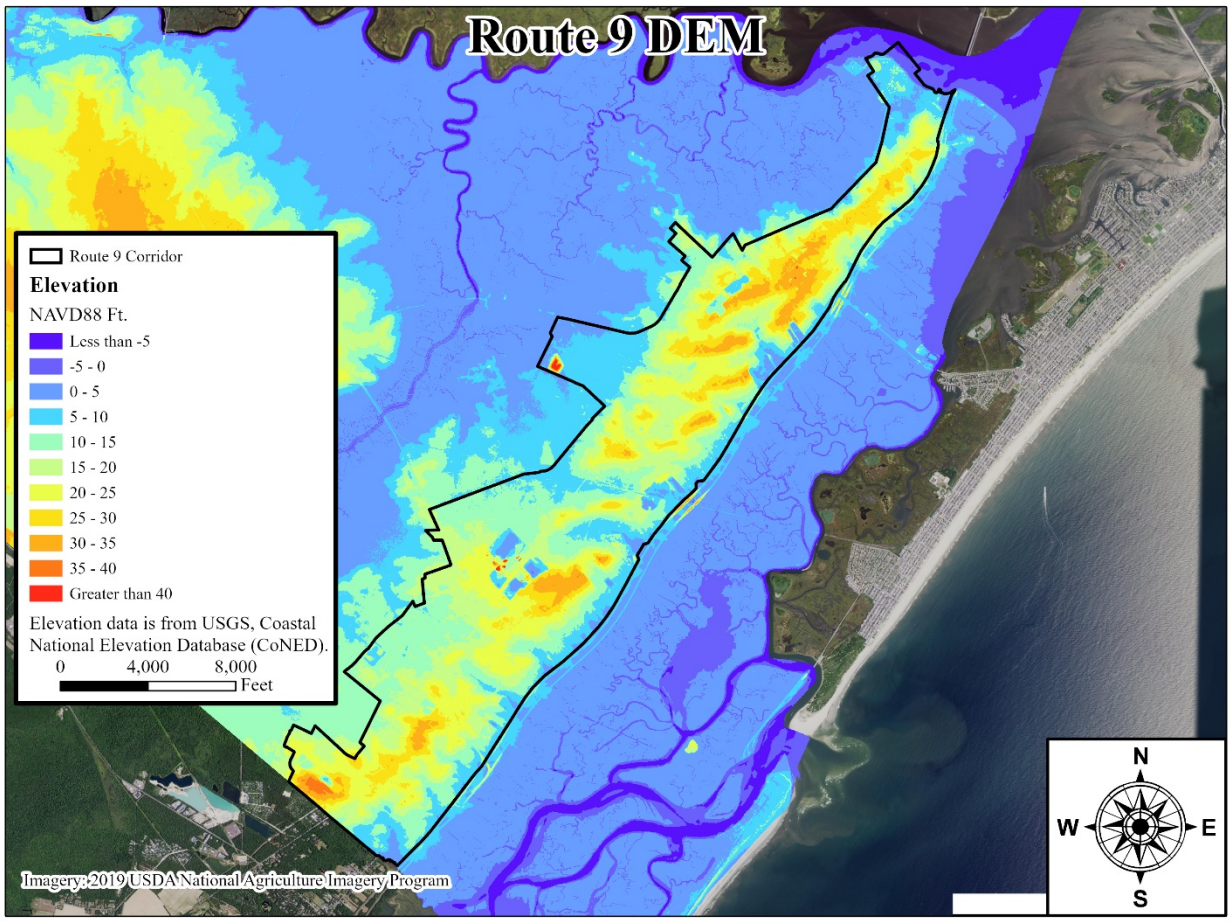


Figure 10. **Shows the DEM for the Route 9 Corridor section of Township of Upper. Elevation averages exceed 10.0 feet NAVD 1988.**

The majority of this area is higher than 5 Ft. NAVD88. There is a high point ridge that passes through the center of the study region. Additionally, Figures 8 and 9 show sea level rise projections for this area. Only Harbor Road faces any issue from either projection of sea level rise. Impacts occur at the 5 Ft. interval and the NOAA Intermediate high projection. Impacts are minimal for the 5 Ft. interval whereas the NOAA intermediate high projection covers much more of the road.

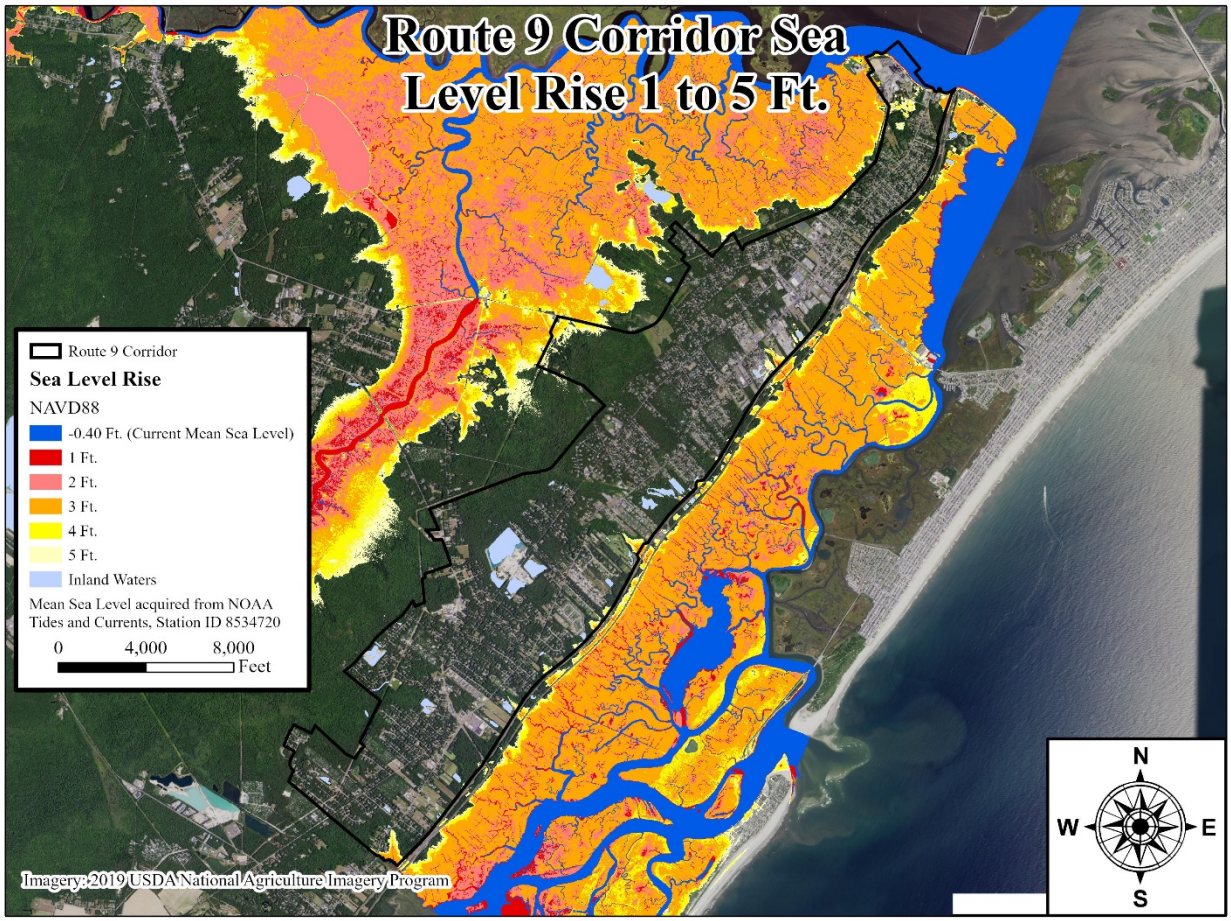


Figure 11. The impacts of sea level rise, 1 to 5 ft., for the Route 9 Corridor. Edge impacts are seen.

This mainland segment is surrounded on three sides by tidal waters and salt marsh wetlands. These grade up-slope into transitional plants and then into the forest. As sea level rises the water line creeps inland touching development near, at and around Beesley's Point at the northern end of the basin. Minimal development exists along the Atlantic Ocean side of the region because the Garden State Parkway precludes property access to points east of the highway.

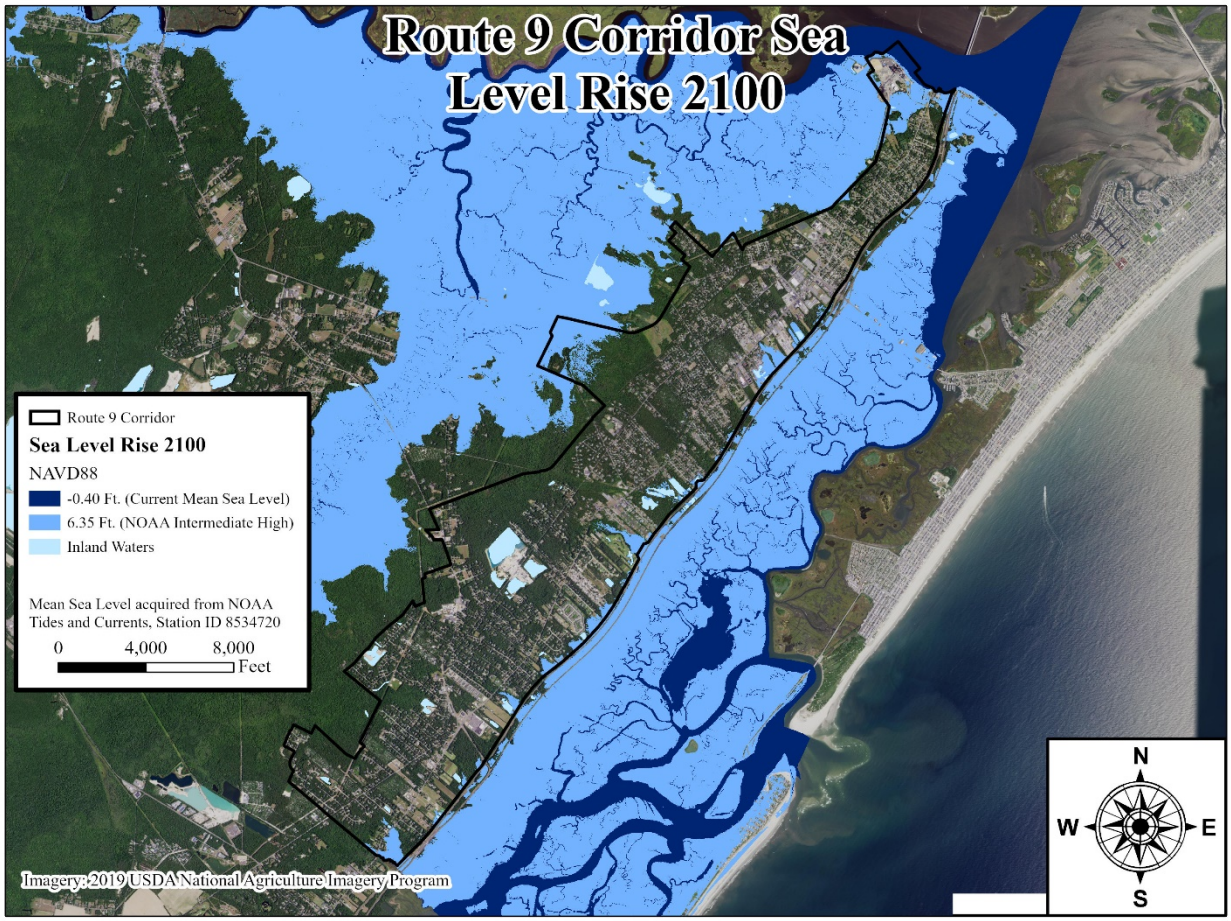


Figure 12. The impacts of the NOAA Intermediate High Projection for the Route 9 Corridor. The NOAA 2100 intermediate high water level rise affects the Beesley's Point area in the north and creeps up each small stream valley towards developed lands.

The 6.35-foot NOAA intermediate high prediction for 2100-year sea level rise inundates the Beesley's Point area covering about 30% of that area. This scenario adversely impacts the utility of the Garden State Parkway by either closing the roadway or forcing the authority to raise 28 miles of dual highway by a minimum of 3.0 feet vertically. That would also force the replacement of all roadway bridges that overpass the highway as well. Flooding begins to impact the development closest to the Garden State Parkway particularly adjacent to small freshwater creeks draining southeast from this region under the parkway.

The Township of Upper, Petersburg

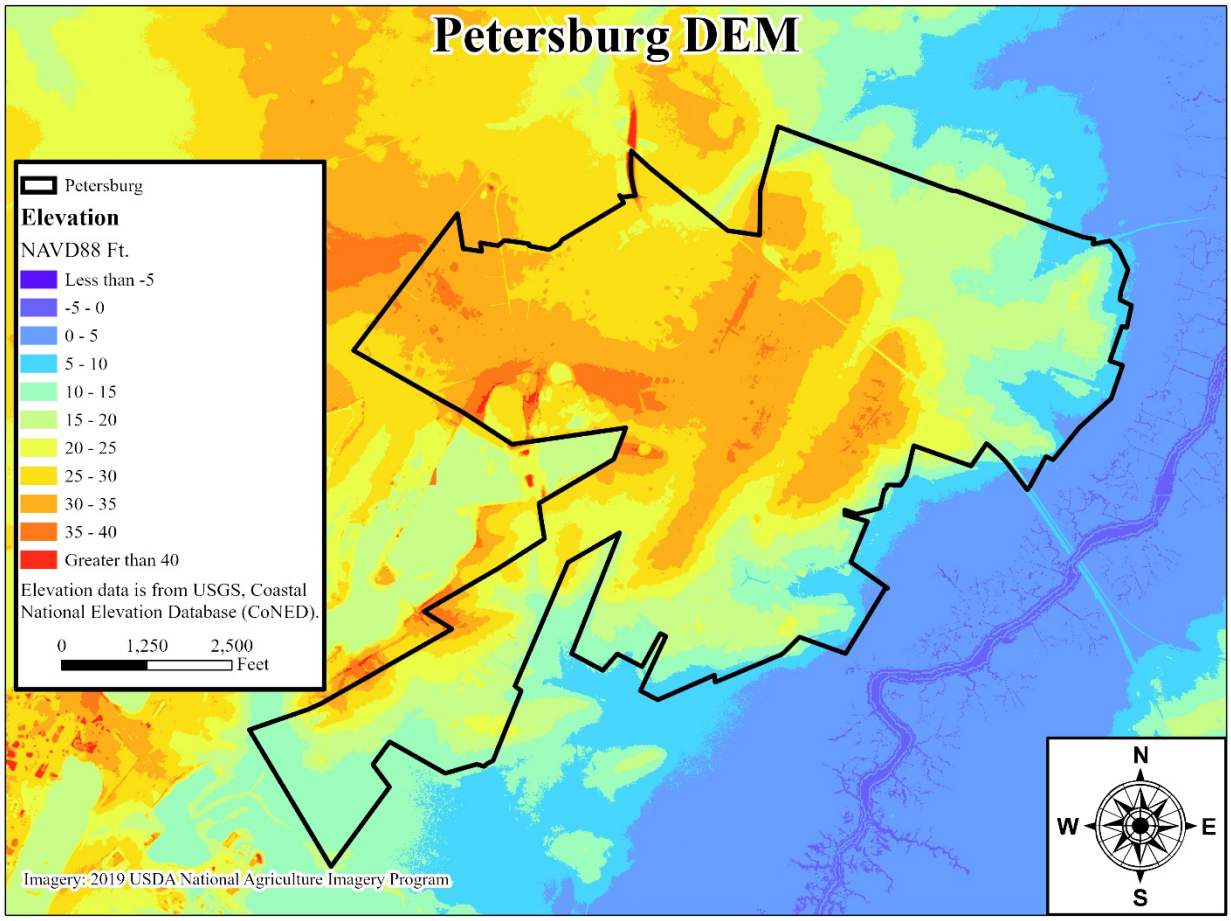


Figure 13. Petersburg Elevation derived from the CoNED DEM. Average land elevations exceed 10.0 feet NAVD 1988.

Petersburg is in the central portion of the town. The developed areas are above 5 Ft. in elevation. The area is characteristic of higher elevations and presents little concern for sea level rise. However, under the 5 Ft. interval and the NOAA intermediate high projection shown in Figure 14 and 15, the water will now be in the backyard of several homes. These homes are located on the eastern end of Meadowlark Road, Killdeer Hill Road, Upper Bridge Road, and Frances Drive South. While sea level will not cover these areas, the area will flood more easily.

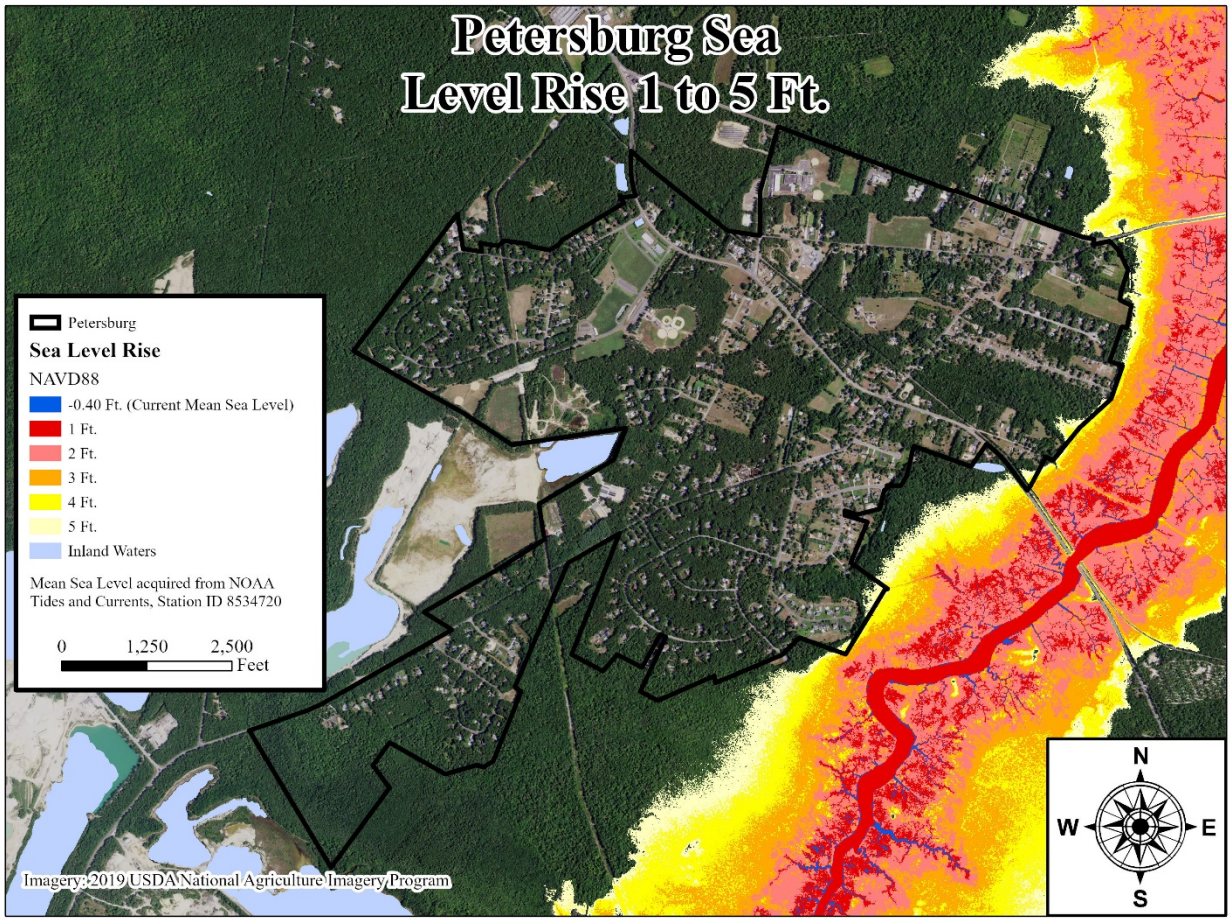


Figure 14. The impacts of sea level rise, from 1 to 5 ft., for the Petersburg core town. Cedar Creek marsh land edge areas are marginally affected at a +5.0-foot water level rise.

Sea level rise values under 4.0 feet do not materially impact this core community. The 5.0-foot and above elevation increase does have development edge effects along Cedar Creek to the southeast.

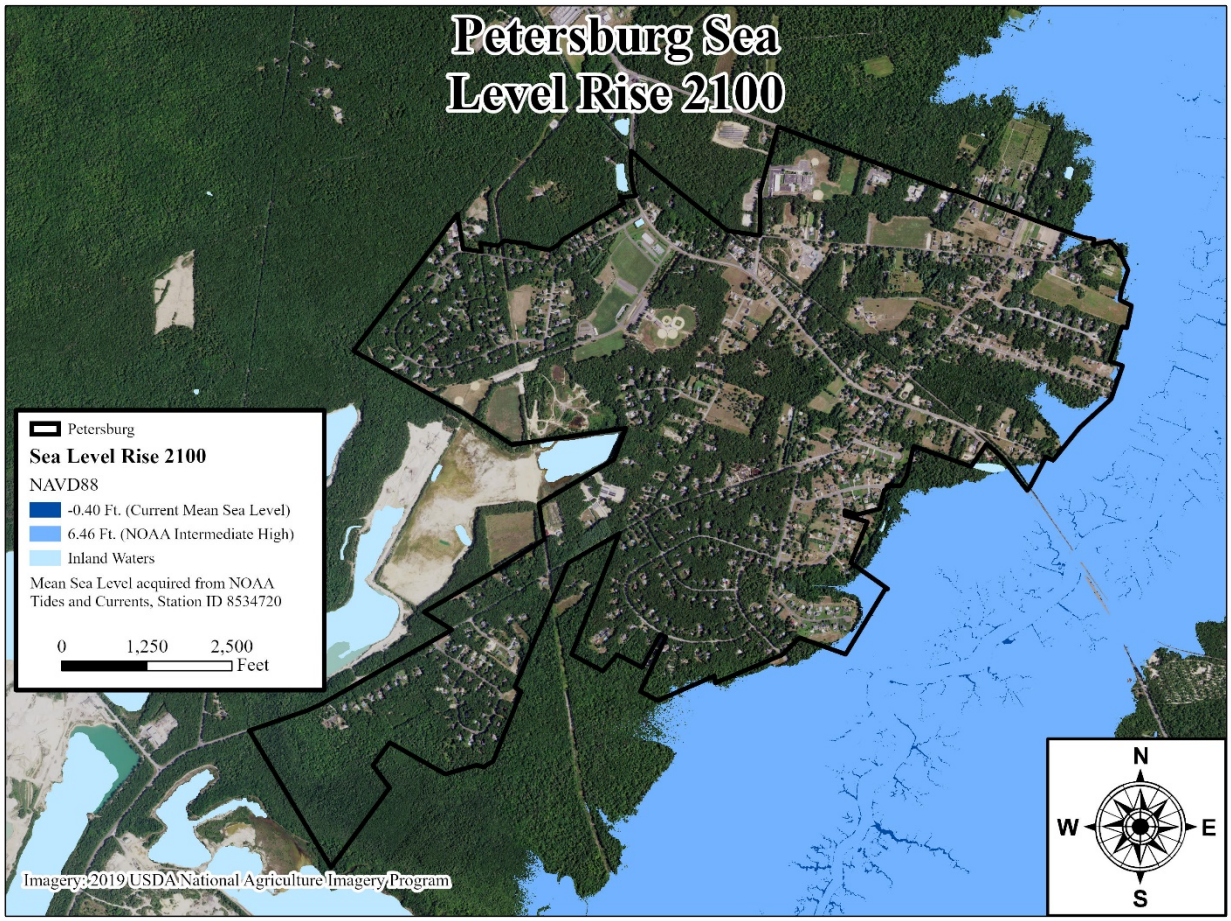


Figure 15. Sea level rise for the Petersburg according to NOAA Intermediate High projections. Marginal developed lots are impacted by this 6.46-foot sea level increase by 2100.

The 6.46-foot, year 2100 NOAA predicted sea level rise further inundates the southeastern margin of this community. Overall impacts are fairly limited but will need to be addressed by relocation or property raising. Bulkheads might also be a solution in some cases.

The Township of Upper, Tackahoe

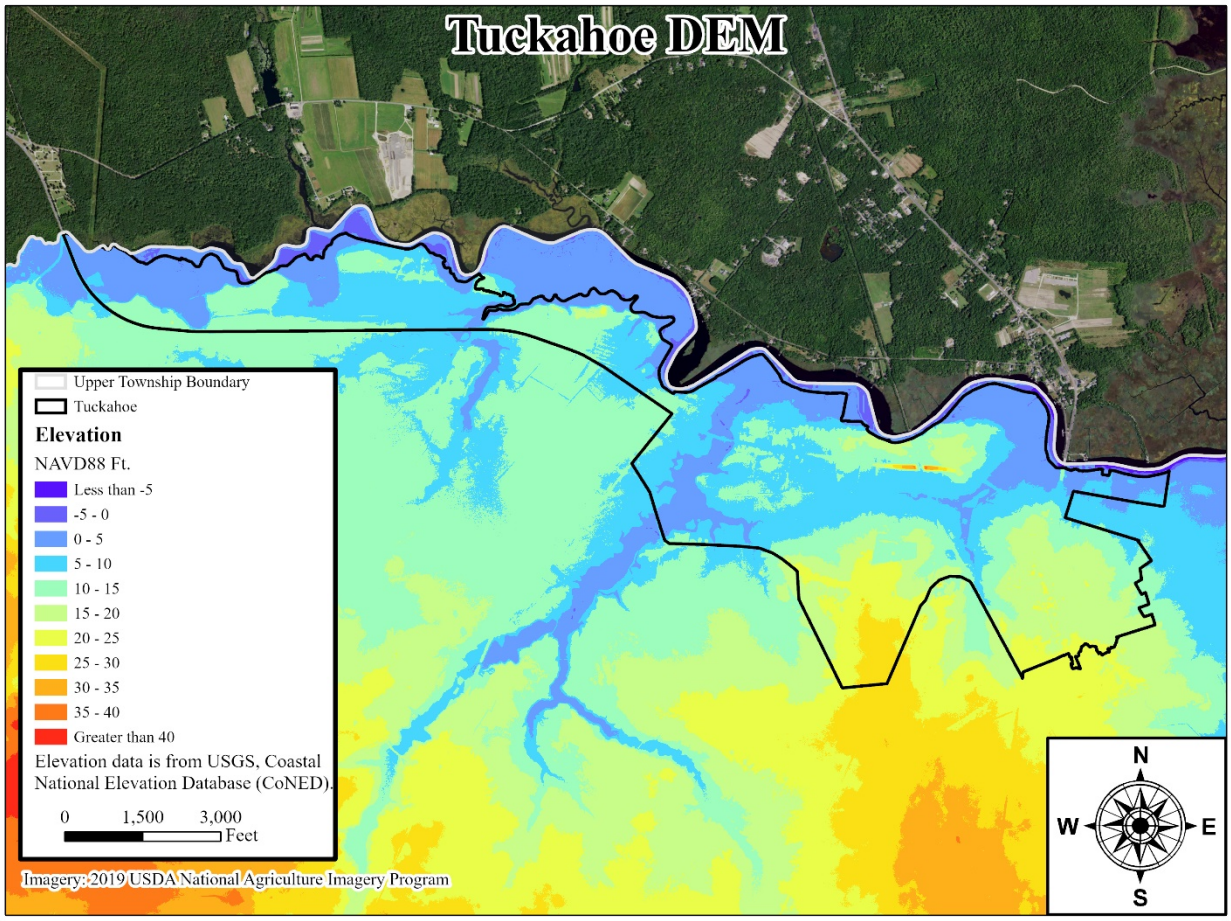


Figure 16. The elevation for the community of Tuckahoe. Large marginal river banks lie between 5 and 10 feet elevations.

Tuckahoe lies on the bank of the Tuckahoe River. Therefore, portions of Tuckahoe are lower in elevation as they are in the direct flood plain of the river and its surrounding streams. There are also high elevation areas that are 25+ Ft. Development in this area is concentrated in the 10-15 Ft. elevations, protecting most of the residential areas. Some development occurs in lower areas and these will be the flood prone areas. Figures 17 and 18 show the areas covered under sea level rise scenarios. These will push the river front closer to development and may cause increases flooding in these areas.

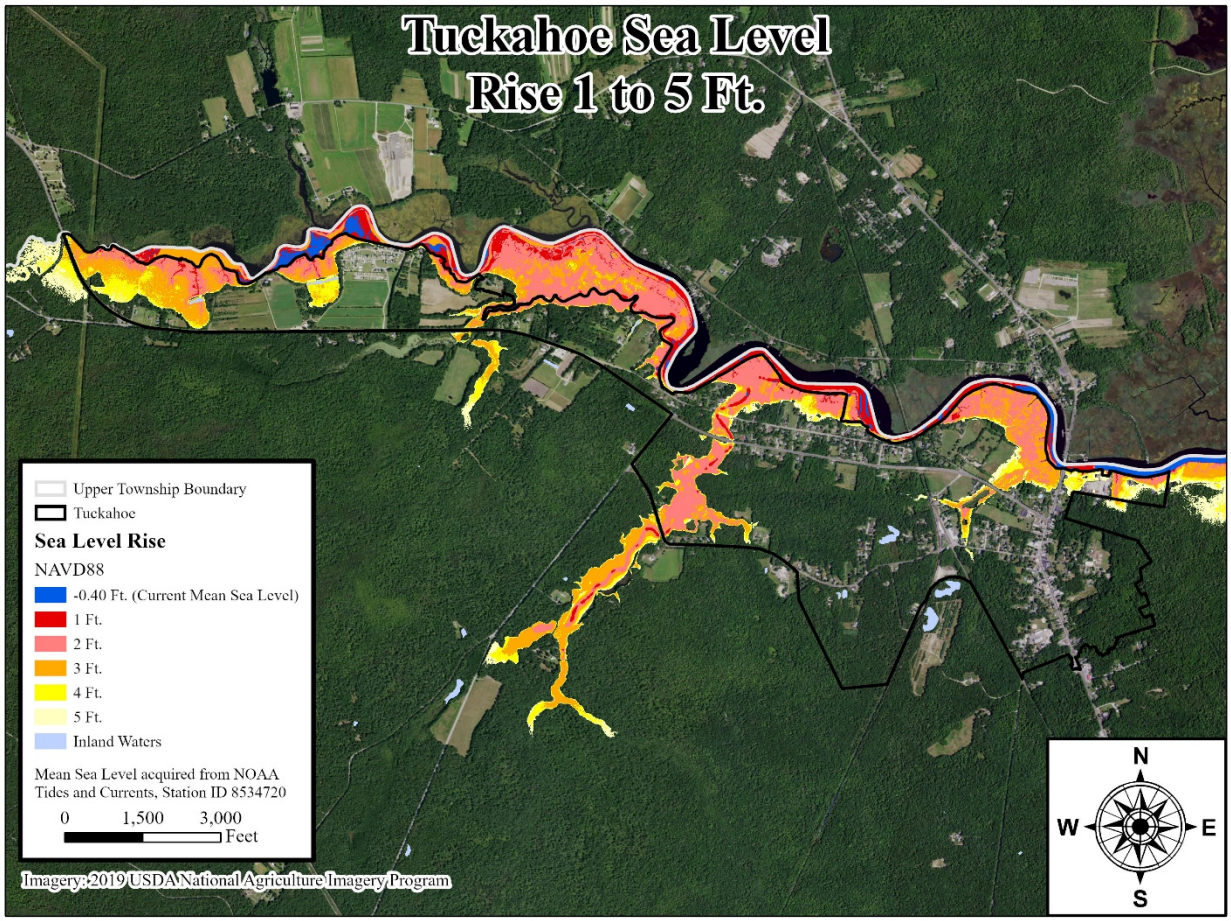


Figure 17. Sea level rise from 1 to 5 ft. for Tuckahoe. Water moves up tributary channels and across the floodplain.

Sea level rise under 4.0 feet has minimal impact except for properties immediately adjacent to the Tuckahoe River banks. The impact on these properties will depend on the river bank slope from the water's edge to the structures and any residual flood freeboard remaining.

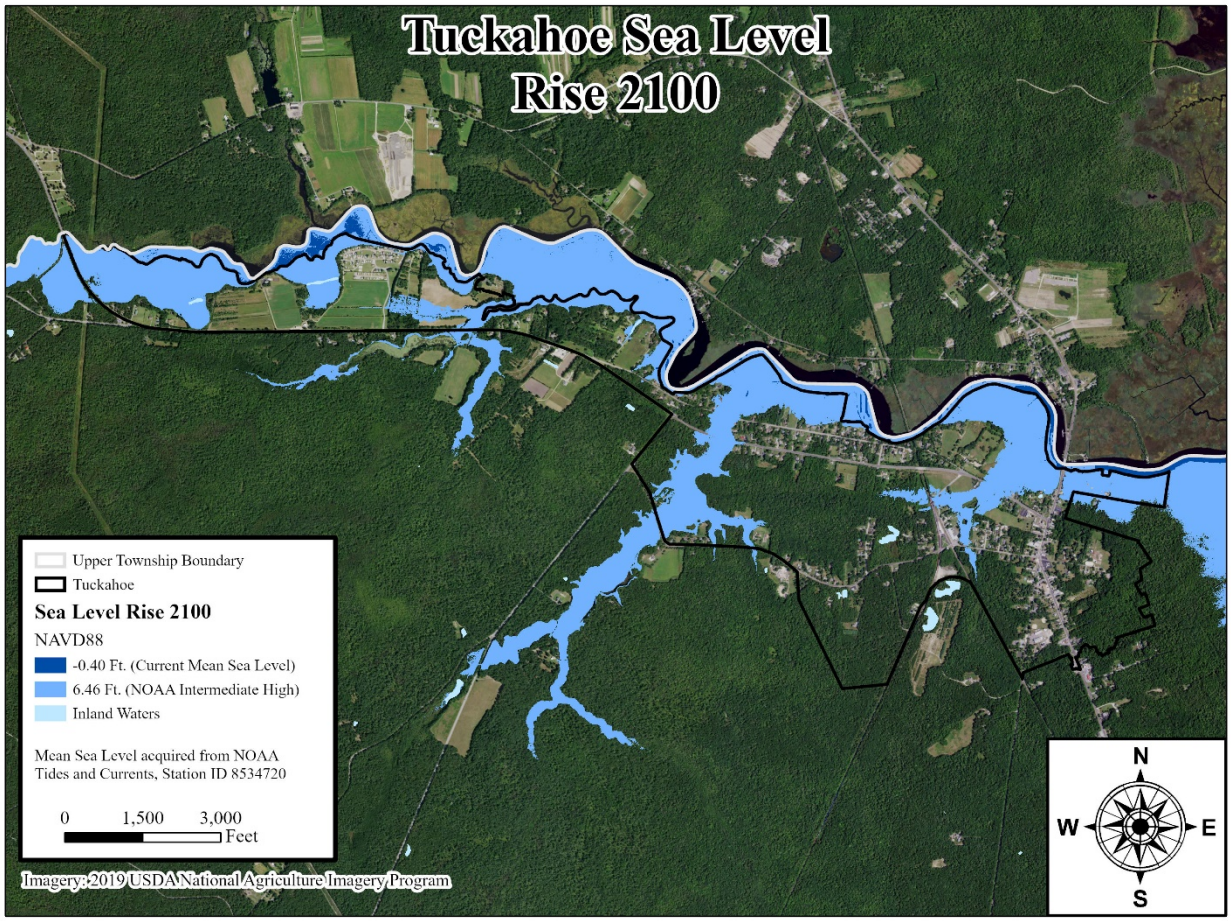


Figure 18. NOAA Intermediate High mean sea level for the community of Tuckahoe. Impacts are seen right adjacent to the river margins.

The 6.46-foot sea level rise moves further inland up minor river tributaries and does cause considerable river bank flooding. Some properties will need to be relocation, raised up or bulkheaded to remain in place by 2100 if this sceaniro unfolds as anticipated.

The Township of Upper CRS Activity 452a – Prerequisites

(1) The community must have adopted a watershed master plan for one or more of the watersheds that drain into the community, and the plan must identify the natural drainage system and constructed channels.
(2) The community must have adopted regulatory standards that are based on the plan and that receive credit under SMR in Section 452.a.
(3) The plan's regulatory standards must manage future peak flows so that they do not increase over present values.
(4) The plan's regulatory standards must require management of runoff from all storms up to and including the 25-year event.
(5) For any plan that is more than five years old, the community must evaluate the plan to ensure that it remains applicable to current conditions.
(6) WMP1 credit must be received in order to receive credit for any of the other items.

Impact Adjustment Ratio:

The Township of Upper is located on the Atlantic Ocean in Cape May County and extends into the county mainland with a northern boundary along the Great Egg Harbor Estuary and Tuckahoe River. Access to the Atlantic Ocean is by means of Great Egg Inlet or Corson's Inlet between Strathmere and Ocean City. This Watershed Management Plan determines quantity and frequency of runoff from precipitation events and with impacts from tidal influences for the entirety of the municipality.

The Watershed Master Plan (WMP) covers the entirety of the Township of Upper (43,785 acres). There are small streams running through the Township, all of which originate within the Township and discharge into tide water. There are no developed communities upstream or downstream of the Township. The Township is part of the rest of the watershed (WMA-16 - 214,097 acres). The area falling within the Special Flood Hazard Area is 19,710 acres out of 43,785 acres total land mass (44.8%). The Flood Insurance Study for Cape May County, NJ dated October 5, 2017 include the following Flood Insurance Rate Maps adopted by the Township (§18-3.2 a).

{34009C0017F, 34009C0028F, 34009C0029F, 34009C0036F, 34009C0037F, 34009C0039F, 34009C0041F, 34009C0042F, 34009C0043F, 34009C0044F, 34009C0061F, 34009C0062F, 34009C0063F, 34009C0064F, 34009C0066F, 34009C0067F, 34009C0068F, 34009C0069F, 34009C0086F, 34009C0088F, 34009C0131F, 34009C0132F, 34009C0134F, 34009C0151F, 34009C0152F, 34009C0153F, 34009C0154F, 34009C0156F, 34009C0157F, 34009C0158F, 34009C0159F, 34009C0162F, 34009C0166}

The Township land mass acts as its own sub-watershed where runoff does not flow into other communities but into the Tuckahoe River or the Atlantic Ocean and actions taken by the community do not impact other communities. The municipal boundaries are along tidal water to the east, north and drainage to the south toward Delaware Bay is via Dennis Creek which is a freshwater wetland that transitions into a salt marsh in the Township of Middle. Therefore, because Watershed Master Plan encompasses the entirety of The Township of Upper's sub-watershed, the impact adjustment ratio is determined to be 1.0. Likewise, the Strathmere segment of the Township lies entirely on a barrier island surrounded by tide water with no drainage into or incoming from other communities. Its impact adjustment ratio is also 1.0.

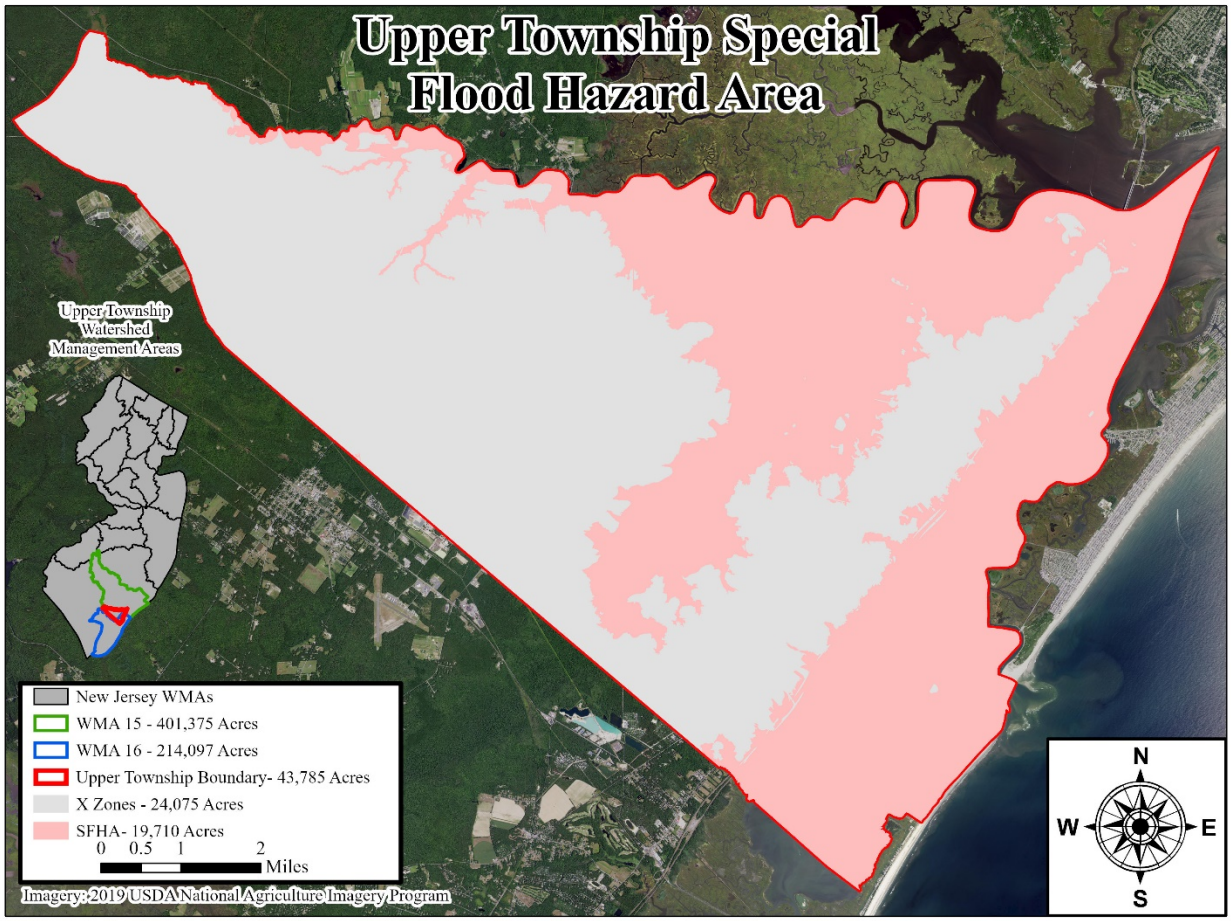


Figure 19. FEMA Special Flood Hazard Areas for The Township of Upper, NJ. The western mainland lies at elevations above the SFHA and the majority of the SFHA indicated is fresh or salt water wetlands. Only development on Strathmere, Ludlam Island and on the shores of Great Egg Harbor or the Tuckahoe River are affected by flood hazards up to the 100-year event. There is a coastal VE zone on Strathmere.

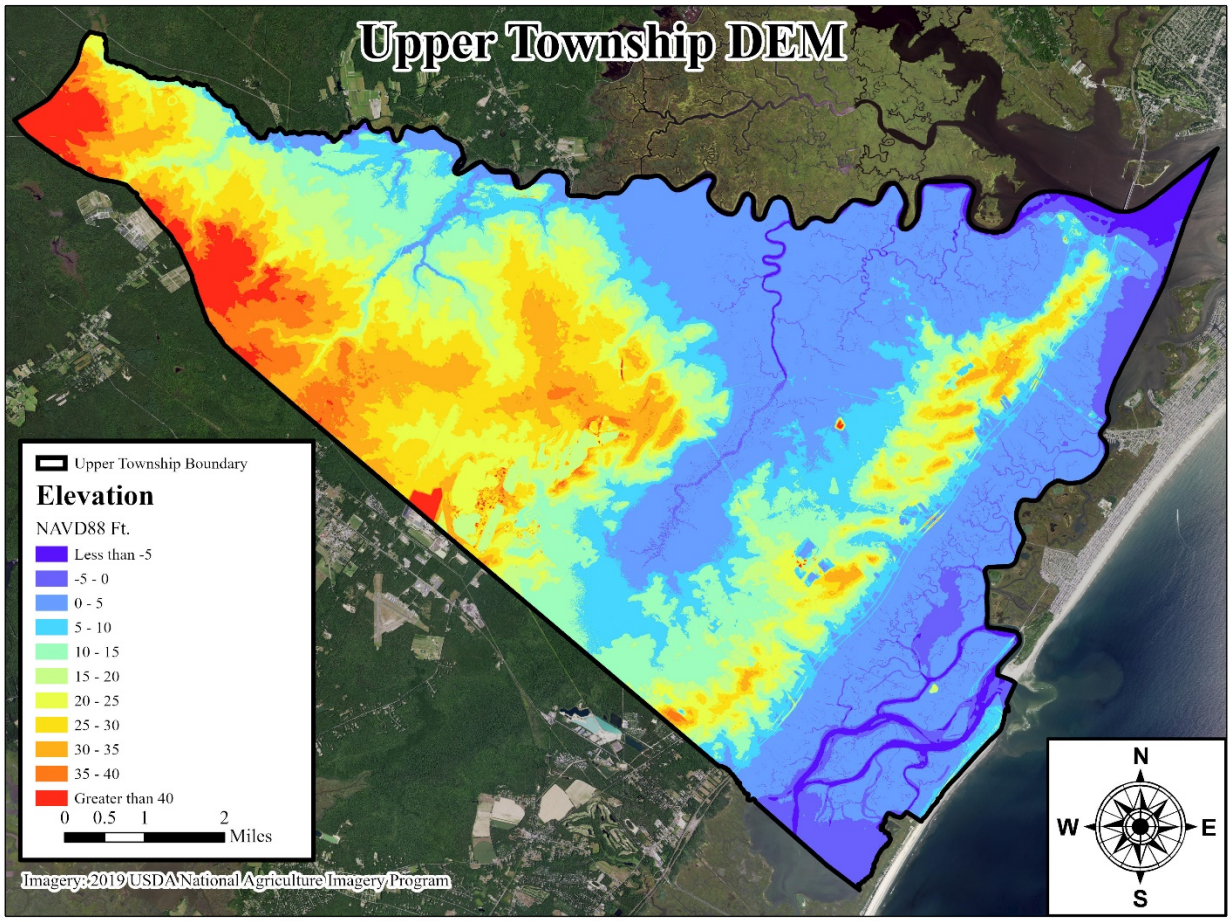


Figure 20. Digital Elevation Map for The Township of Upper, NJ. Here the wetlands stand out as vast blue areas which are devoid of development. The western 60% of the Township is very rural with the Route 9 corridor the concentration of residential and commercial properties. Strathmere lies at the coast to the extreme southeast on the Atlantic Ocean.

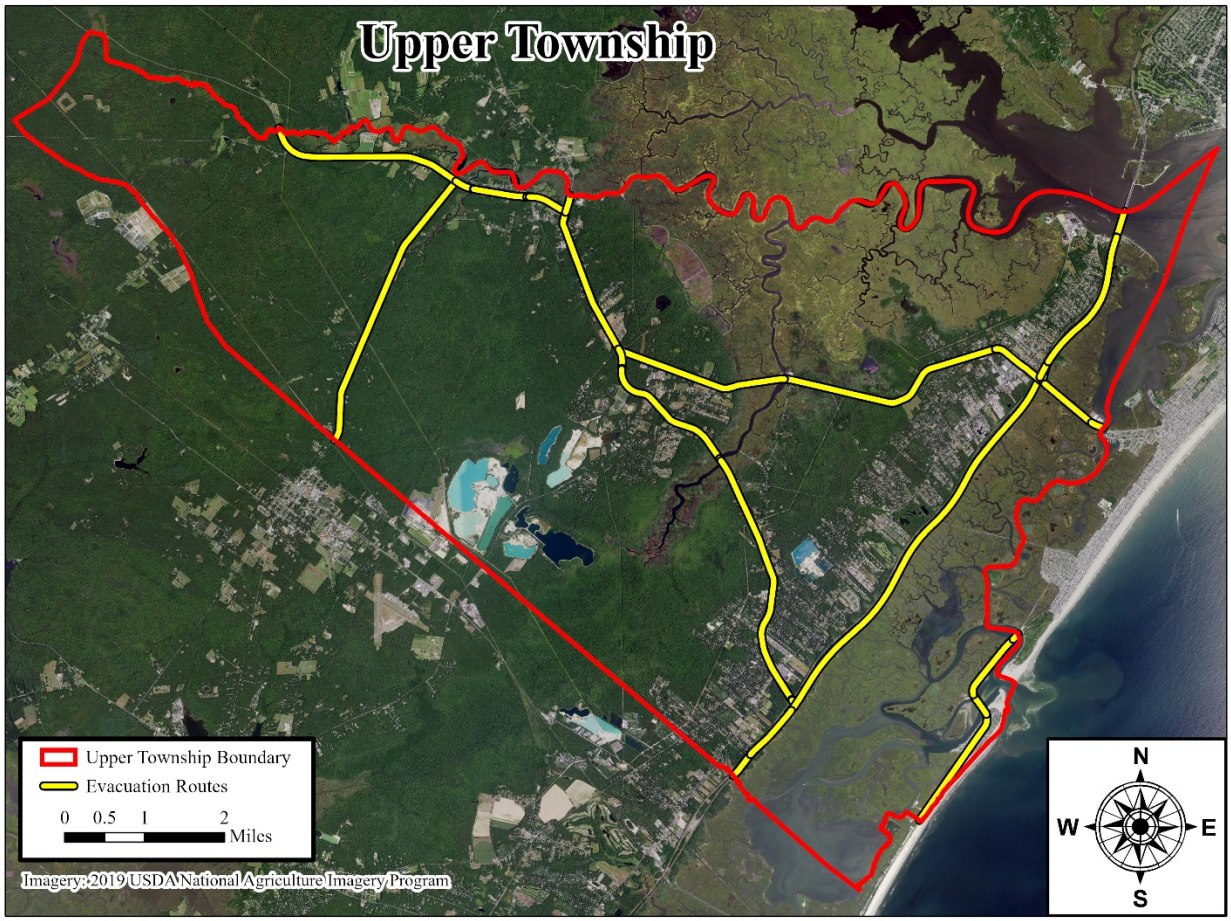


Figure 21. The Upper Township coastal evacuation routes.

Evacuation to the west is the safest pathway out of storm treats. The Garden State Parkway is fine for surge levels under 4.0 feet depending on wind velocities when crossing the bridge over the Great Egg Harbor Estuary into Atlantic County. Exits from Strathmere are problematic due to low roadway elevations and exposure going into Ocean City from storm waves entering Corson's Inlet where the road is at salt marsh surface elevations adjacent to open ocean wave attack. The exit south through Sea Isle City also floods readily in storms.

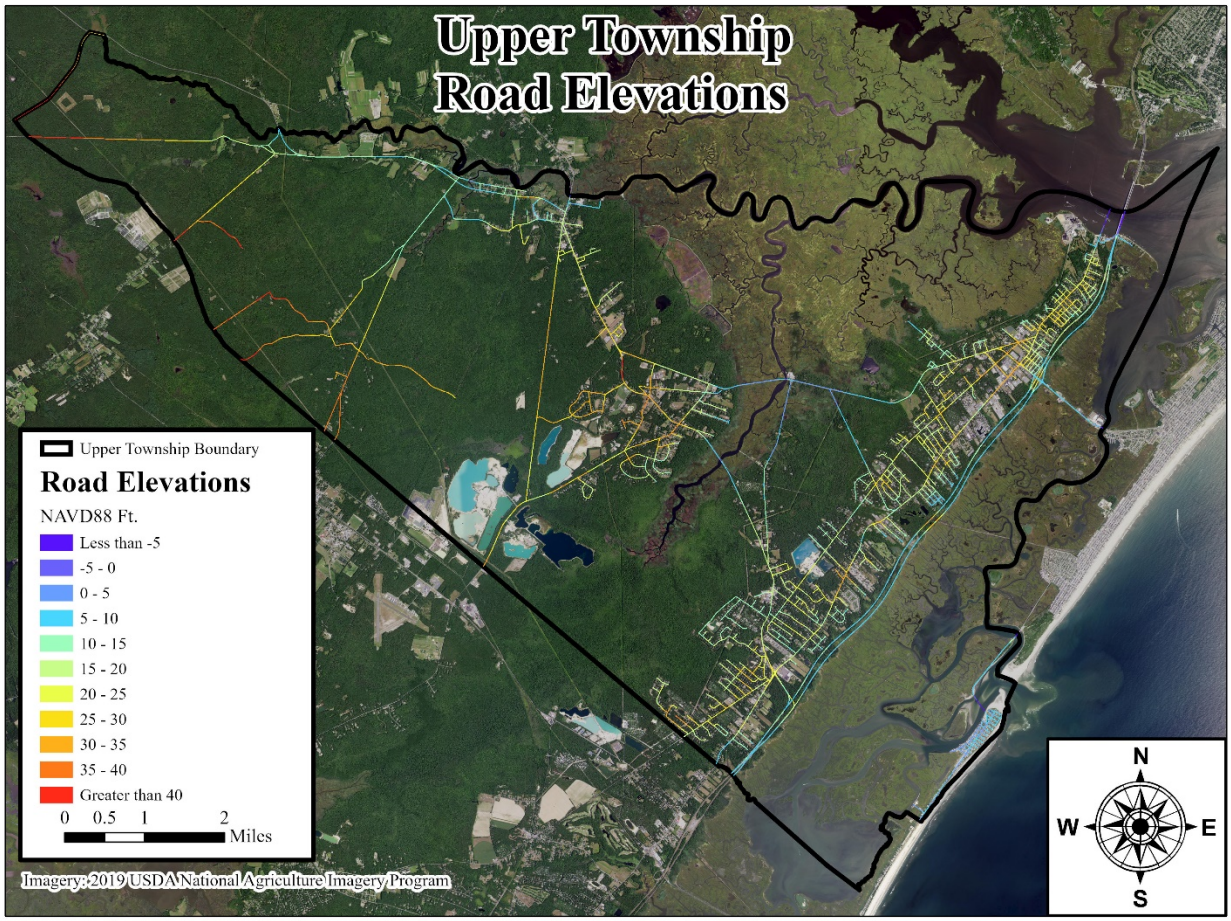


Figure 22. Road elevations determined by the CoNED DEM. Lower lying roads are close to wetlands whereas high road elevations are typical of the more forested upland regions.

Parts of The Township of Upper reach elevations over 40 feet and large portions of the western parts of the township exceed 15-foot elevations making them essentially immune from the sea level rise projected to occur by the year 2100. The lowest regions are uninhabited or not developed in any meaningful way and will remain so in perpetuity. Figure 21 shows the evacuation routes present in the township. Generally, the roads are high in elevation as shown in figure 21. However, the evacuation route in Strathmere and via the Garden State Parkway are lower in elevation than the other evacuation routes. The soils map shows the relationship across the county for the deposits under lying the real estate.

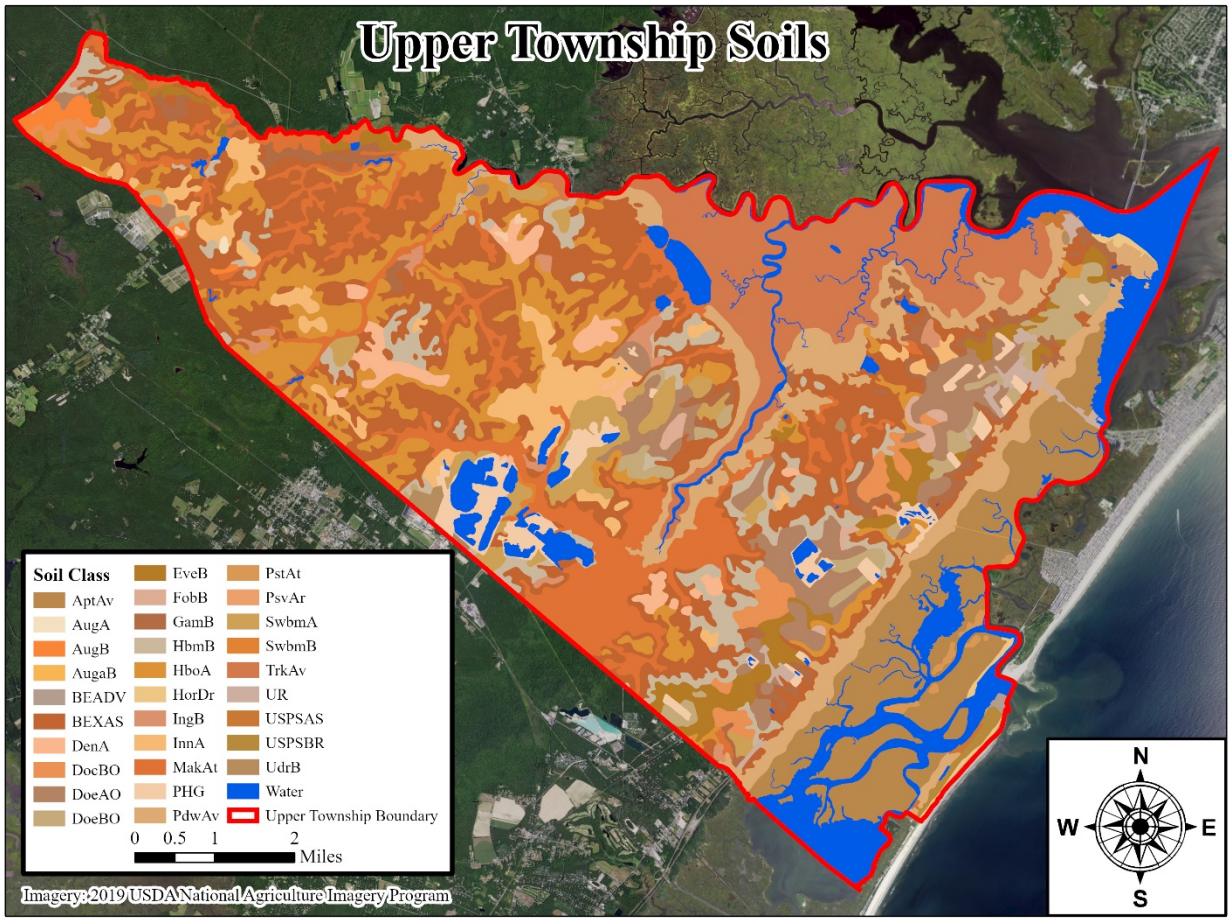


Figure 23. Soils map for The Township of Upper, NJ. There is substantial variation among the municipal soils found in Township of Upper most of which are highly permeable except for the major wetland zones.

The permeability of the Upper Township soils is dominated by sandy soils. Major sand mining sites exist in the large western segment southwest of Tuckahoe and west of Petersburg. Infiltration of rainfall remains consistent with these soil types allowing drainage to occur during all but the most intense cloudburst rain storms. As a result, the vast majority of stormwater drainage occurs on land or via small tributary creeks of ephemeral nature the majority of the time.

Map Unit Symbol	Soil Series	HSG	Total Area (Acres)
AptAv	Appoquinimink-Transquaking-Mispillion complex, 0 to 1 percent slopes, very frequently flooded	B/D	3684.4
AugA	Aura sandy loam, 0 to 2 percent slopes, Northern Coastal	B	13.2
AugaB	Aura sandy loam, 2 to 5 percent slopes, Northern Tidewater	B	0.7
AugB	Aura sandy loam, 2 to 5 percent slopes, Northern Coastal	B	209.8
BEADV	Beaches, 0 to 15 percent slopes, very frequently flooded	A/D	50.6
BEXAS	Berryland and Mullica soils, 0 to 2 percent slopes,	A/D	8344.3
DenA	Dennisville sandy loam, 0 to 2 percent slopes	A	652.3
DocBO	Downer loamy sand, 0 to 5 percent slopes, Northern	A	551.7
DoeAO	Downer sandy loam, 0 to 2 percent slopes, Northern	A	1779.1
DoeBO	Downer sandy loam, 2 to 5 percent slopes, Northern	A	870.5
EveB	Evesboro sand, 0 to 5 percent slopes	A	1075.6
FobB	Fort Mott sand, 0 to 5 percent slopes	A	185.6
GamB	Galloway loamy sand, 0 to 5 percent slopes	A/D	994.6
HbmB	Hammonton loamy sand, 0 to 5 percent slopes	B	1770.9
HboA	Hammonton sandy loam, 0 to 2 percent slopes	B	4362.7
HorDr	Hooksan sand, 2 to 15 percent slopes, rarely flooded	A	109.6
IngB	Ingleside loamy sand, 0 to 5 percent slopes	A	263.4
InnA	Ingleside sandy loam, 0 to 2 percent slopes	A	1453.3
MakAt	Manahawkin muck, 0 to 2 percent slopes, frequently flooded	A/D	3712.1
PdwAv	Pawcatuck-Transquaking complex, 0 to 1 percent slopes,	D	2948.3
PHG	Pits, sand and gravel	Unrated	902.5
PstAt	Psammaquents, sulfidic substratum, 0 to 2 percent slopes,	A/D	108.5
PsvAr	Psamments, wet substratum, 0 to 2 percent slopes, rarely	A	15.6
SwbmA	Swainton sandy loam, 0 to 2 percent slopes	A	932.5
SwbmB	Swainton sandy loam, 2 to 5 percent slopes	A	24.7
TrkAv	Transquaking mucky peat, 0 to 1 percent slopes, very	A/D	3810.5
UdrB	Udorthents, refuse substratum, 0 to 8 percent slopes	B	95.6
UR	Urban land	D	271
USPSAS	Urban land-Psamments, sulfidic substratum complex, 0 to 2 percent slopes, occasionally flooded	D	74.7
USPSBR	Urban land-Psamments, wet substratum complex, 0 to 2 percent slopes, rarely flooded	D	105.4
WATER	Water	N/A	975.4
WATERs	Water, saline	N/A	3411.4

Figure 24. Definition of each soil symbol on the previous map.

Watershed Master Plan (WMP)

General Ordinances of the Township of Upper adopted July 1976 and last updated as of August 9, 2021 (Chap. 19), as Ord. No. 013-2021. These Township codes are accessible at https://ecode360.com/35460787 .

WMP1

(1) A copy of the ordinance adopting a watershed management plan affecting the community that identifies the natural drainage system and constructed channels.

(2) A copy of the ordinance adopting regulatory standards based on the plan

(3) The regulatory standards must require future peak flows to be no more than current peak flows

(4) The standards must address at least the 25-year event

(5) If more than five years old the community must determine if the plan is still current and provide documentation.

(6) WMP1 credit is required in order to receive credit for any additional items.

Ord. No. § 19-7.7, 1 (b)1 (a through (j): Storm water management promotes a scope and purpose:

(a) *"To reduce flood damage, including damage to life and property;*
(b) *To minimize any increase in stormwater runoff from new development;*
(c) *To reduce soil erosion from any development or construction project;*
(d) *To assure the adequacy of existing and proposed culverts and bridges, and other instream structures;*
(e) *To maintain groundwater recharge;*
(f) *To minimize any increase in nonpoint pollution;*
(g) *To maintain the integrity of stream channels for their biological functions, as well as for drainage;*
(h) *To restore, protect, maintain and enhance the quality of the streams and water resources of Upper Township and the ecological character and quality of the Pinelands Area;*
(i) *To minimize pollutants in stormwater runoff from new and existing development in order to restore, protect, enhance and maintain the chemical, physical and biological integrity of the surface and groundwaters of Upper Township, to protect public health and to enhance the domestic, municipal, recreational, industrial and other uses of water; and*
(j) *To protect public safety through the proper design and operation of stormwater management basins"*

WMP2

The plan and the community's regulations manage the runoff from all storms up to and including the 100-year event. These must include the 10-year storm, a storm larger than the 10-year, but less than the 100-year and the 100-year storm.

Ordinance Section 19-7.7n

n. Stormwater Runoff Quantity and Rate Standards.

1. There shall be no direct discharge of stormwater runoff from any point or nonpoint source to any wetland, wetlands transition area or surface waterbody. In addition, stormwater runoff shall not be directed in such a way as to increase the volume and/or rate of discharge into any surface waterbody from that which existed prior to development of the site. To the maximum extent practical, there shall be no direct discharge of stormwater runoff onto farm fields so as to protect farm crops from damage due to flooding, erosion and long-term saturation of cultivated crops and cropland.

2. For all major developments, the total runoff volume generated from the net increase in impervious surfaces by a ten-year, twenty-four-hour storm shall be retained and infiltrated on site.

3. In addition, the design engineer, using the assumptions and factors for stormwater runoff and groundwater recharge calculations contained in Subsection 19-7.7j through l, shall either:

(a) Demonstrate through hydrologic and hydraulic analysis that the post-developed stormwater runoff hydrographs from the project site for the two-, ten-, and 100-year storms do not exceed, at any point in time, the site's predeveloped runoff hydrographs for the same storms;

(b) Demonstrate through hydrologic and hydraulic analysis that under post-developed site conditions:

(1) There is no increase in predeveloped stormwater runoff rates from the project site for the two- ten-, and 100-year storms; and

(2) Any increased stormwater runoff volume or change in stormwater runoff timing for the two-, ten- and 100-year storms will not increase flood damage at or downstream of the project site. When performing this analysis for pre-developed site conditions, all off-site development levels shall reflect existing conditions. When performing this analysis for post-developed site conditions, all off-site development levels shall reflect full development in accordance with current zoning and land use ordinances;

or

(c) Demonstrate that the peak post-developed stormwater runoff rates from the project site for the two-, ten-, and 100-year storms are 50%, 75% and 80%), respectively, of the site's peak pre-developed stormwater runoff rates for the same storms. Peak outflow rates from on-site stormwater measures for these storms shall be adjusted where necessary to account for the discharge of increased stormwater runoff rates and/or volumes from project site areas not controlled by the on-site measures. These percentages do not have to be applied to those portions of the project site that are not proposed for development at the time of application, provided that such areas are:

(1) Protected from future development by imposition of a conservation easement, deed restriction, or other acceptable legal measures; or

(2) Would be subject to review under these standards if they are proposed for any degree of development in the future.

4. In tidal flood hazard areas, a stormwater runoff quantity analysis in accordance with paragraphs (a), (b), and (c) above shall only be applied if the increased volume of stormwater runoff could increase flood damages below the point of discharge.

5. The standards for stormwater runoff quantity and rate required by this subsection shall be met using the methods, calculations and assumptions provided in Subsection 19-7.7j through l.

Since the Township of Upper has tracts of open land greater than 1.0 acres, any application for a major development or a new agricultural development shall be submitted to the Cape May County Soil Conservation District for review and approval. The water quality design storm is one and one-quarter (1.25) inches of rainfall in two hours (N.J.A.C. 7:14A).

WMP3

The plan manages peak flows and volumes to not increase over the existing values.

Section Code § 19-7.7 n1. & n3(c);

n1. *There shall be no direct discharge of stormwater runoff from any point or nonpoint source to any wetland, wetlands transition area or surface waterbody. In addition, stormwater runoff shall not be directed in such a way as to increase the volume and/or rate of discharge into any surface waterbody from that which existed prior to development of the site. To the maximum extent practical, there shall be no direct discharge of stormwater runoff onto farm fields so as to protect farm crops from damage due to flooding, erosion and long-term saturation of cultivated crops and cropland.*

n3(c) *Demonstrate that the peak post-developed stormwater runoff rates from the project site for the two-, ten-, and 100-year storms are 50%, 75% and 80%), respectively, of the site's peak pre-developed stormwater runoff rates for the same storms. Peak outflow rates from on-site stormwater measures for these storms shall be adjusted where necessary to account for the discharge of increased stormwater runoff rates and/or volumes from project site areas not controlled by the on-site measures. These percentages do not have to be applied to those portions of the project site that are not proposed for development at the time of application, provided that such areas are:*
(1) *Protected from future development by imposition of a conservation easement, deed restriction, or other acceptable legal measures; or*
(2) *Would be subject to review under these standards if they are proposed for any degree of development in the future.*

WMP4

The plan manages runoff from all storms up to and including the 100-year event, but is not specific as to the 5-day storm regulation.

Section Code § 19-7.7 (o) 2;

> ***[1]*** *Demonstrate through hydrologic and hydraulic analysis that for stormwater leaving the site, postconstruction runoff hydrographs for the two-, ten- and one-hundred-year storm events do not exceed, at any point in time, the preconstruction runoff hydrographs for the same storm events;*
> ***[2]*** *The design engineer shall assess the hydraulic impact on the groundwater table and design the project site and all site groundwater recharge measures so as to avoid adverse hydraulic impacts. Adverse hydraulic impacts include, but are not limited to: raising the groundwater table so as to cause surface ponding; flooding of basements and other subsurface structures and areas; preventing a stormwater infiltration basin from completely draining via infiltration within 72 hours of a design storm event; and interference with the proper operation of subsurface sewage disposal systems and other surface and subsurface facilities in the vicinity of the groundwater recharge measure.*
> ***[3]*** *In tidal flood hazard areas, stormwater runoff quantity analysis in accordance with [1], [2] and [3] above shall only be applied if the increased volume of stormwater runoff could increase flood damages below the point of discharge.*

Point precipitation frequency estimates for the Township of Upper (Latitude 38° 56.197'N Longitude 74°54.649'W) for a 10-year recurrence interval for a: 1-hr event – 1.84" to 2.28", 3-hr event – 2.50" to 3.20", and a 12-hr event – 3.72" to 4.76" (NOAA 2014).

Northeasters are the most likely long-duration rain event that will impact Cape May County coastal communities. These systems often travel slowly and pass through in two to five days. The model uses the 120-hour (5-day) event as the locally appropriate "worst-case" runoff event as it replicates the duration of multiple northeaster events that have inundated barrier islands in the past. Not only are there heavy rains during a northeaster, but tidal stacking often occurs as well. This means that any gravity-driven drainage system without pumping stations are unable to flush out its system and, therefore, are completely inundated leading to widespread roadway flooding. See the "Historic Flooding and Rain Events" section in this plan for more historical rainfall events. The maximum rainfall event for this part of New Jersey occurred August 20th and 21st in 1997 when 13.52" of rain fell over a 48-hour period. It rained 7.57" at the Atlantic City International Airport on the 20th and 5.95" on the 21st. While this was in the terms of the US Weather Service a "Training Event" where multiple individual thunder storm cells track along the same path across Atlantic and Cape May Counties, it did set the record locally for the

most water added to the ground over a short time period. Northeast events and hurricanes have yet to achieve double digit rainfall accumulations along the NJ coastline.

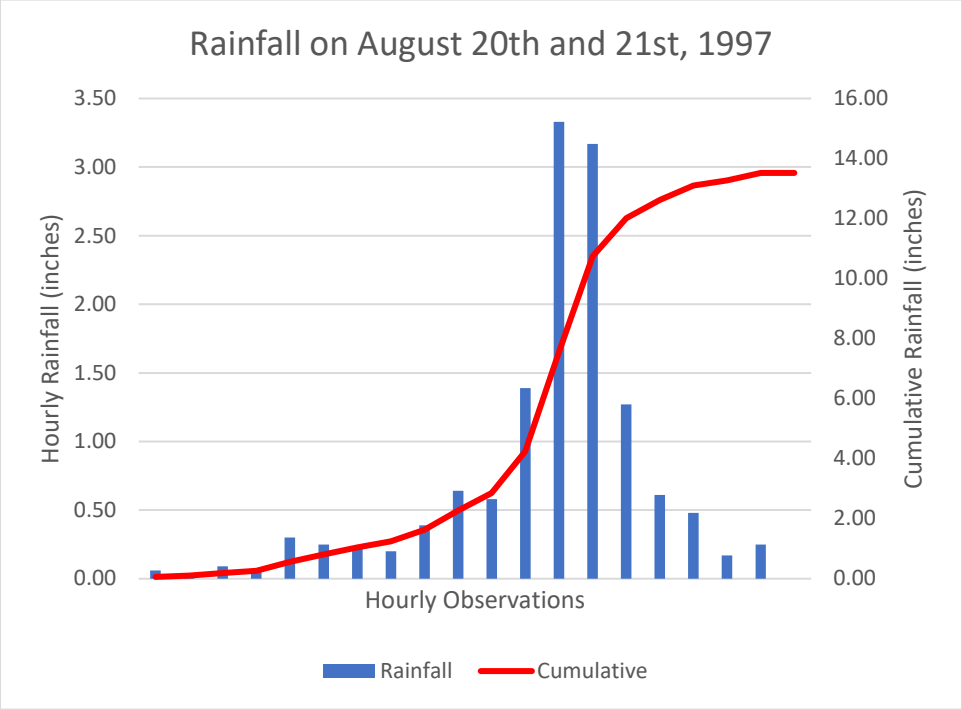
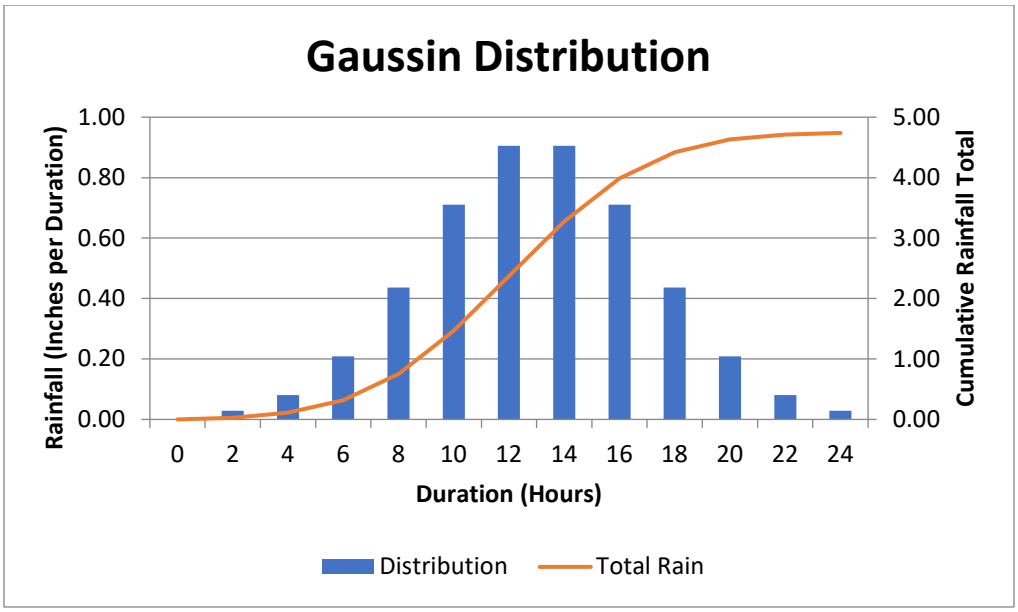
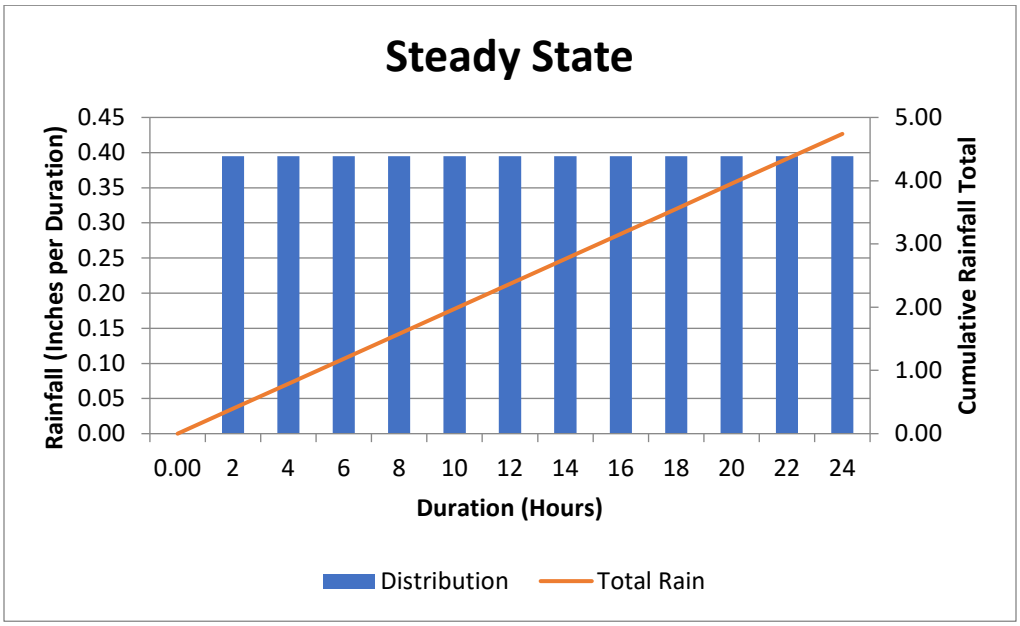


Figure 25. Historical Rainfall Data from KACY (Weather Underground)

Stormwater Model

Rainfall that is not absorbed into the ground during storm events is deemed runoff. Unmanaged stormwater can pose significant negative ecological impacts. It can collect pollutants that can be discharged into drinking sources. It will also produce erosion of streambanks and other areas within the defined system. Development increases the runoff in comparison to the natural land. Additionally, if a stormwater system cannot handle the rainfall, it will produce flooding. The water that falls over the basin is modeled under three distributions: the Gaussian, Steady State, and Deluge. Gaussian distribution is a mathematical distribution where 68% of the rainfall is distributed one standard deviation unit from the mean value, and 98% is distributed 2 standard deviation units either side of the mean. The Steady State is when the rain starts and continues to the end of the event at a constant rate. The Deluge Distribution is when most of the rainfall will fall in ¼ of the storm event.


Gaussin Distribution
Rainfall (Inches per Duration)
1.00
0.80
0.60
0.40
0.20
0.00
Cumulative Rainfall Total
5.00
4.00
3.00
2.00
1.00
0.00
0 2 4 6 8 10 12 14 16 18 20 22 24
Duration (Hours)
Distribution
Total Rain


Steady State
Rainfall (Inches per Duration)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Cumulative Rainfall Total
5.00
4.00
3.00
2.00
1.00
0.00
0.00 2 4 6 8 10 12 14 16 18 20 22 24
Duration (Hours)
Distribution
Total Rain

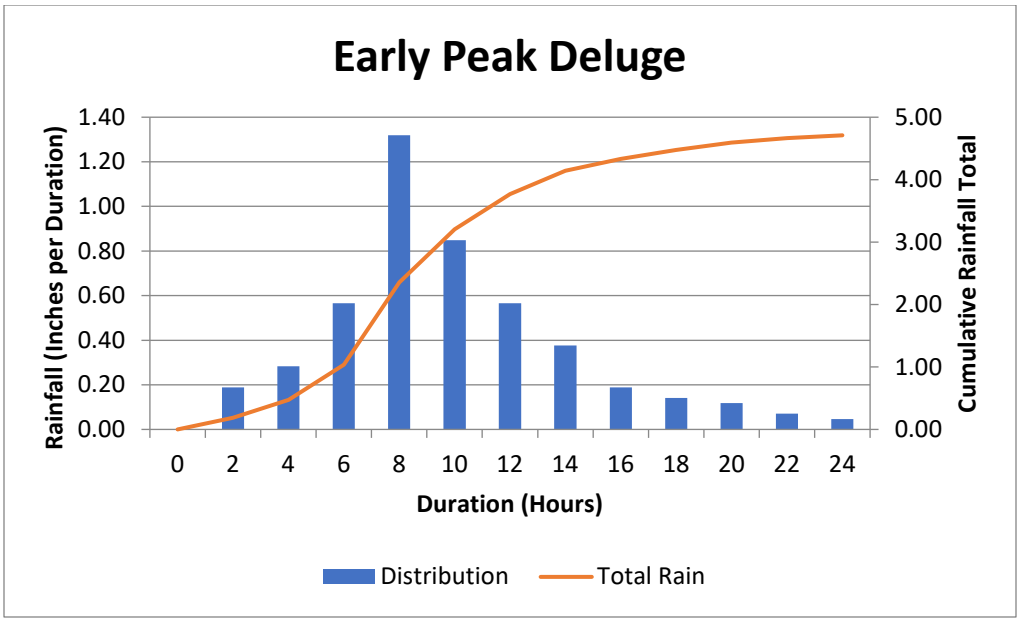


Figure 26. Hyetographs that were used to determine rainfall distributions.

To evaluate the Township of Upper, Esri's ArcGIS Pro program is used to delineate subbasins to better illustrate problem areas. This makes use of the basin tool within the program. For this particular town, a notable of area is zoned as conservation. As such, these areas were removed from the modeling due to the commitment to keeping the area natural. A summary of the basins outputted is found below.

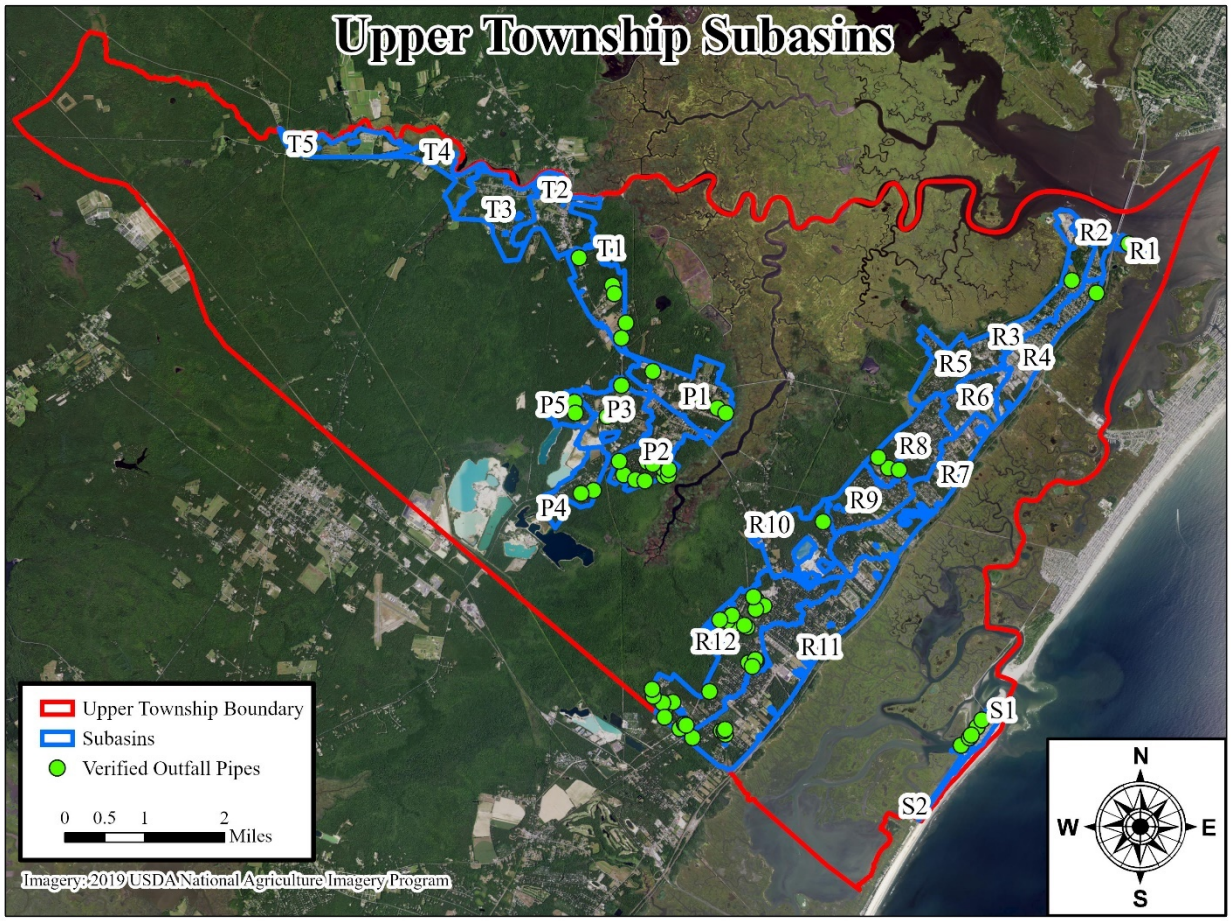


Figure 27. Generated subbasins for the Township of Upper. In total, there are 22 subbasins that will be evaluated.

The model utilizes and adds the discharge rate and the infiltration rate of different soil groups to determine the gallons of water that the basin can handle within each interval. Residual water is the remaining water that is not discharged or infiltrated by the basin. Any residual water must be infiltrated along with any new rainfall. Residual water is used to determine the flood depth at each time interval. Flood depth assumes that the basin is completely flat. This is the height of water that will blanket the basin. However, it is rare for the environment to be completely flat. This will lead to high elevation areas within the basins to be better protected against flooding and low-lying areas to be exposed. This model does not account for elevation differences in this manner. The model also does not account for the use of green infrastructure to absorb residual water.

The stormwater model will evaluate the success of the implemented stormwater system. If successful, the amount of water not infiltrated into the ground, or runoff, or handled by the stormwater system should be zero during the entire storm event. What the stormwater system can handle is defined by the outfall pipe discharge rates. Outfall pipe discharges are calculated using the Hazen-Williams equation shown below. The input units are inches, and the output units are gallons per minute. The Hazen-Williams can be utilized for both gravity-fed and pressurized conduit systems. As the slope is unknown for these pipes, it is assumed that the constructed slope is 0.001. The EPA stormwater model utilizes a similar method when outfall pipe slopes are unknown.

$$Q = 0.28 \times C \times D^{2.63} \times s^{0.54}$$

Where Q is water discharged in gallons per minute, C is a pipe coefficient, D is pipe diameter in inches, and S is slope.

The stormwater system is aided by the natural infiltration of local soils. Infiltration rates are based on defined limits by the Hydrologic Soil Groups (HSG) assigned to each soil type by the National Resources Conservation Service (NRCS). The lower limit of each soil group is used to determine the infiltration rate and are shown in Table 5. The HSG are broken down into 7 categories: A, B, C, D, A/D, B/D, and C/D. Web Soil Survey defines each category as such:

"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."

Table 3. **Soil infiltration rate ranges and values utilized in the model.**

Soil Infiltration Rates		
Soil Group	Infiltration Rate Range (in/hr)	Modeled Infiltration Rate (in/hr)
HSG A	>0.30	0.3
HSG B	0.15-0.30	0.15
HSG C	0.05-0.15	0.05
HSG D	<0.05	0
Not Rated	0	0
Impervious Surface	0	0

Impervious surfaces are defined as surfaces that allow little infiltration or are impermeable. Impervious surfaces are shown in Figure 14. Any area that is considered impervious surface has an infiltration rate of zero. Building roofs and roadways comprise the bulk of the impervious surfaces.

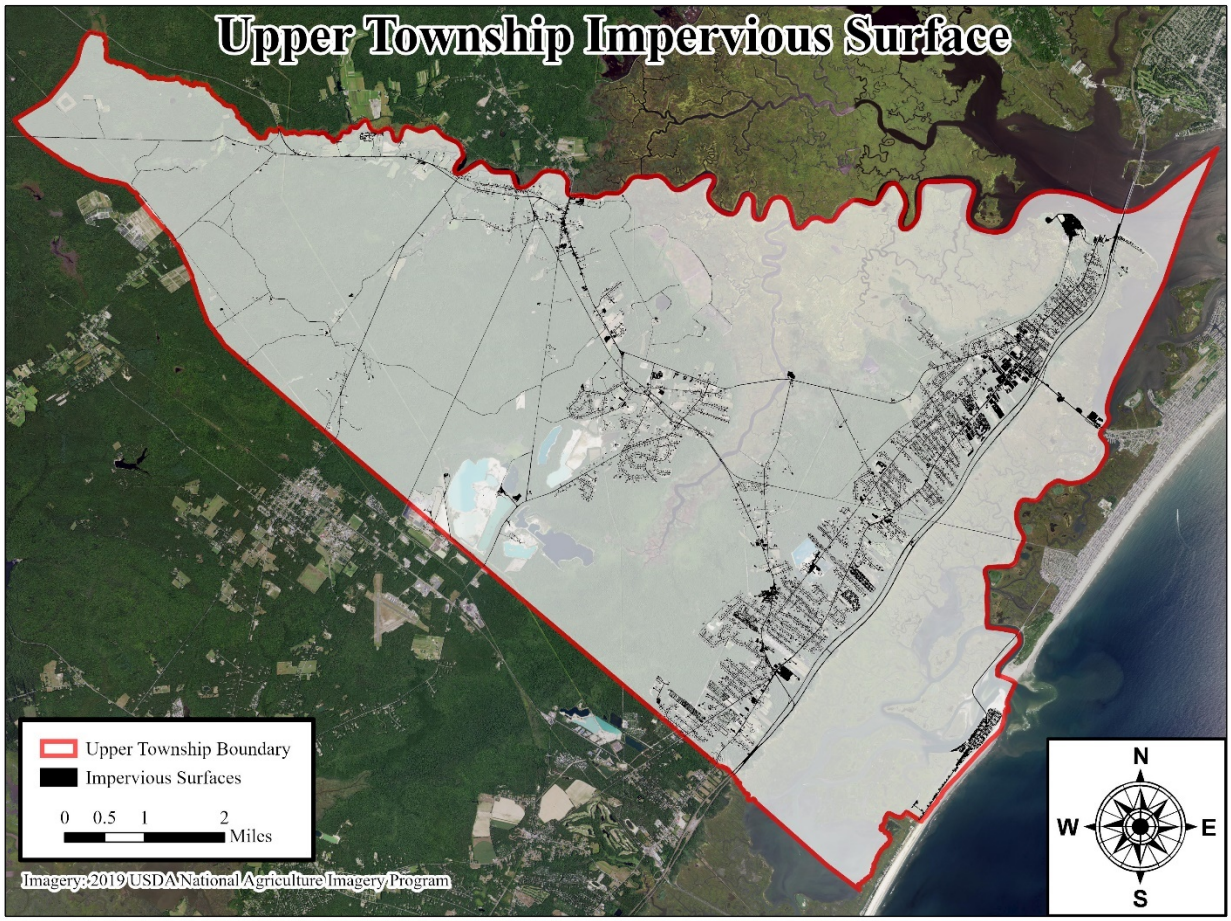


Figure 28. The impervious cover map shows heavy development in four sectors: Strathmere, along Route 9, Petersburg, and Tuckahoe.

This model excludes areas designated as wetlands as defined by NJDEP Land Use as shown in Figure 17. Furthermore, areas deemed as 'open space' are shown in Figure 18 and are also excluded. While rainfall and flooding can potentially occur at these sites, it is more important to model urban and developed areas rather than natural areas, such as wetlands, or open spaces.

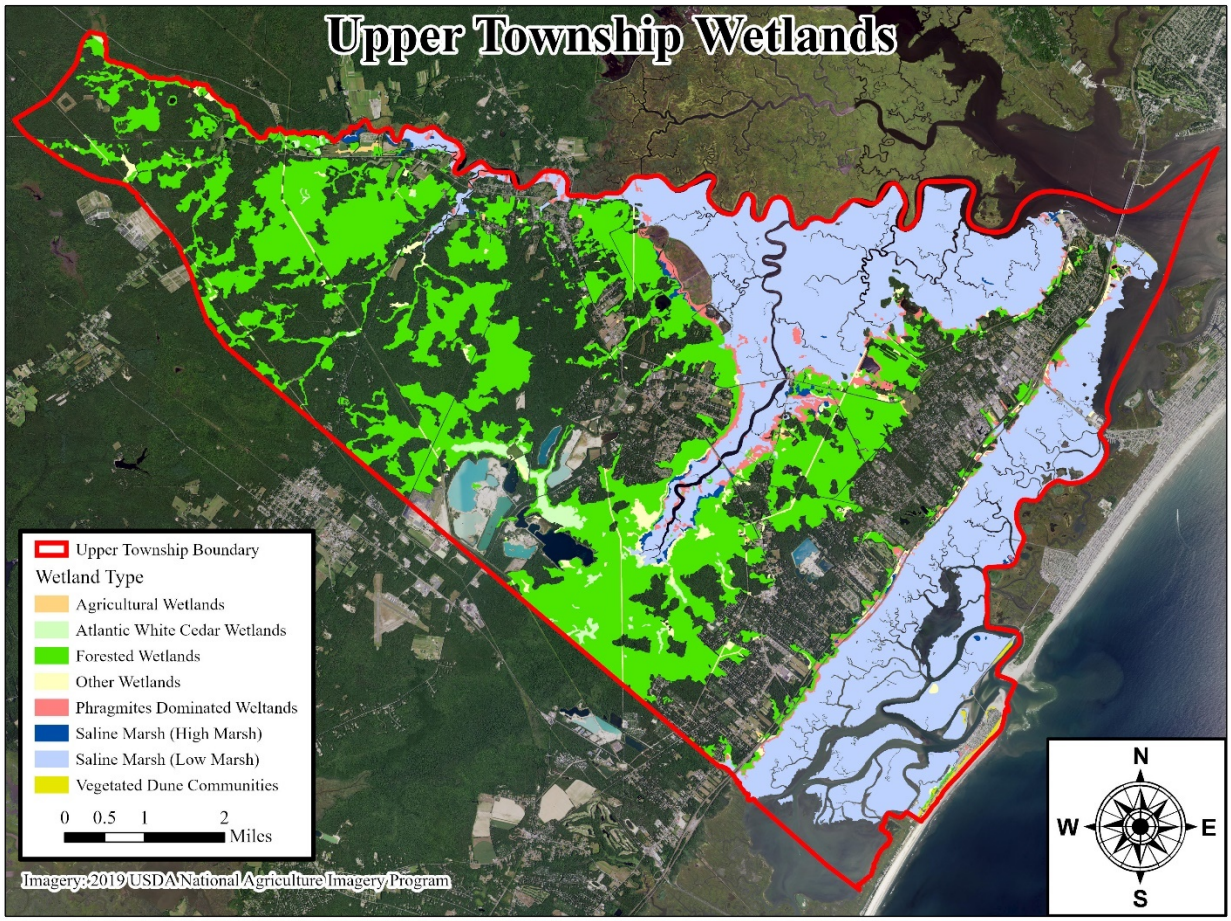


Figure 29. The wetlands classified by NJDEP within Upper Township. Saline tidal marsh and forested wetlands are shown in separate colors with minor subsets included (Phragmites marshes).

Tidal and freshwater wetlands dominate much of The Township of Upper. The tidal marsh land lies along the bayshore of Ludlam Island and Ocean City while the Tuckahoe River margins extend inland and south behind the Route 9 upland corridor essentially dividing mainland Upper Township into eastern and western provinces. All existing wetlands are preserved through either the NJ Wetlands Act of 1970 or the Freshwater Wetlands Act of 1987 under NJAC 7:7A et cet.

Cape May County has also become a significant force in land management since the County Farmland and Open Space Preservation program was instituted by voter referendum in Nov. 1989. Voters agreed to provide 1 cent per $100 of assessed valuation of all county properties as a fund to purchase both farmland future development rights and outright purchase of open space lands in cooperation with the municipal government for the parcel involved. Currently this fund amounts to $1.3 million per year and is allocated through voluntary offerings from property owners at their monthly commission meetings. Following review of lot drawings, setting priorities on acquisitions, the property is either deed restricted to continue as farmland in perpetuity with minor alterations to the farming practices allowed, but no subdivision or enhanced development. Open space purchase is done in concert with the municipal government to acquire property outright for preservation.

Upper Township presently has set aside 221.51 acres as preserved farmland and 150.02 acres of open space (total = 371.53 acres Ernst & O'Connor 2012). Since 2012 the township has added 60.27 acres to this total.

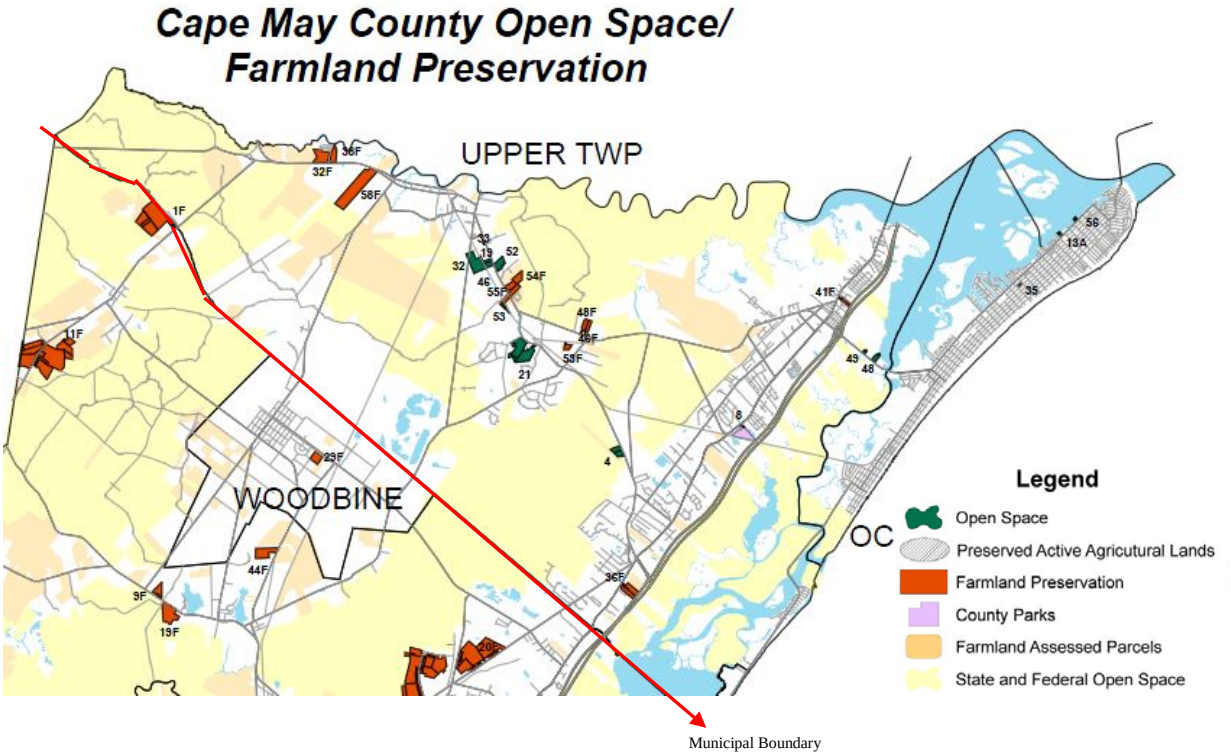


Figure 30. Cape May County Preserved Farmland Map for The Township of Upper showing preserved farmland parcels (281.78 acres); preserved open space parcels (150.02 acres) and the far larger areas of state and federal open space conserved plus the existing farmland assessed parcels. This county-wide program has resulted in the reduction of development potential on over 4,000 acres of Cape May County's mainland since its inception in 1989. Open spaces are likewise purchased under a grant program administered by the county. In 2021 grants up to $2.5 million are available for municipalities to partner with the county in program priority parcel purchases.

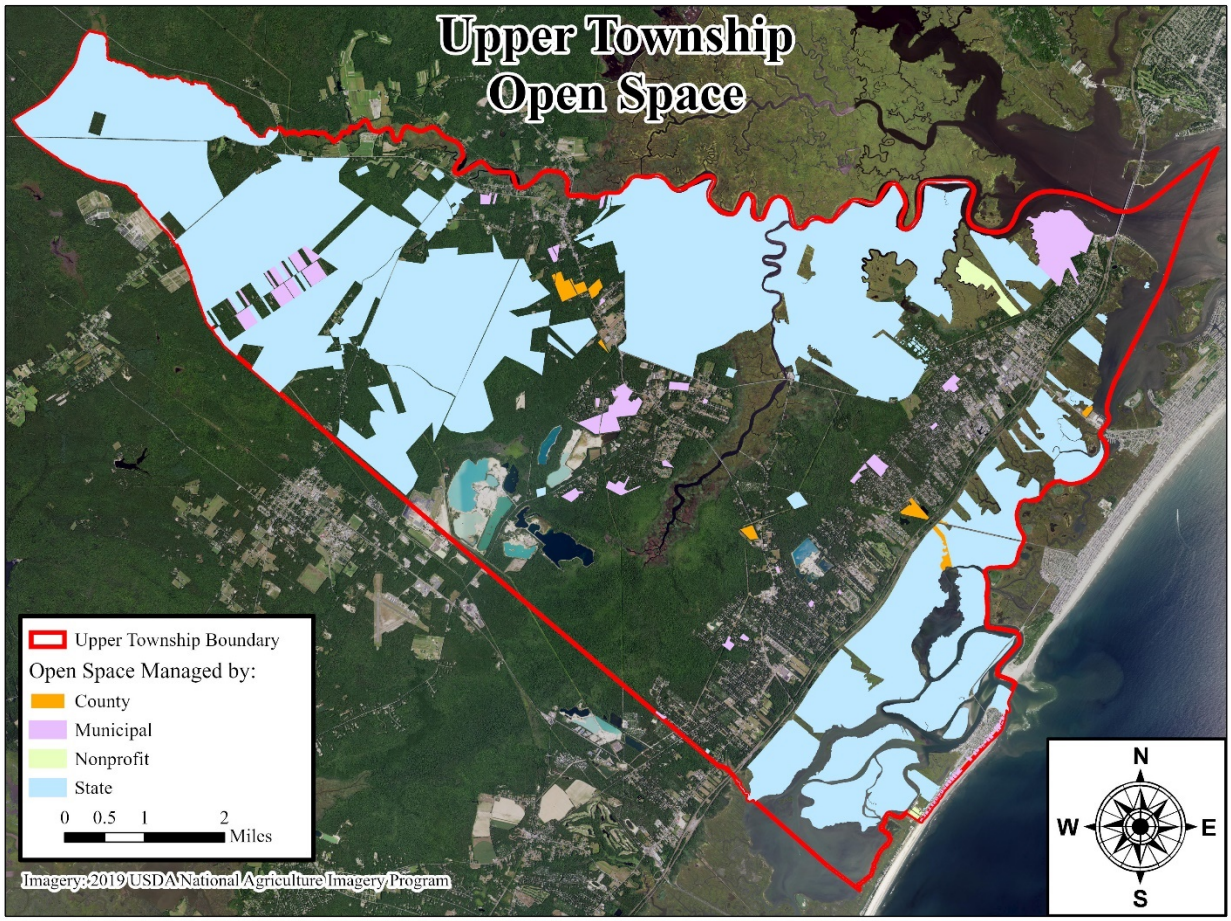


Figure 30. The Township of Upper contains a large quantity of open space dominated by state-owned lands.

Due to the size of the township, in depth discussion was broken down into five sections: Mainland portion, Strathmere, Route 9 Corridor, Petersburg, and Tuckahoe. All except the Mainland portion are modeled in the flood model. Most of the mainland, outside of the other core towns, is scarcely developed or listed as preserved for conservation. A discussion of Strathmere is separate from the Route 9 Corridor, Petersburg, and Tuckahoe areas. Strathmere is a coastal community whereas the other areas pertain to a mainland, largely rural community. Therefore, the recommendations for each of these types of communities is going to vary. The future conditions Strathmere are also done differently than the mainland areas. Future conditions for Strathmere are reliant on the elevation of the outfall pipes. If the outfall pipes are submerged, they will not be effective. Submersion will likely take place for coastal towns via sea level rise. Alternatively, mainland sections will be evaluated by the allowable impervious coverage defined by the zoning districts. The maximum allowable impervious coverage is what the future development in each basin could look like. Developable land is defined by areas that are not preserved as open space and/or wetlands.

Strathmere Corridor Flood Models

Basin S1 Flood Model

Table 4. Summary of the stormwater model for Basin S1 under three rainfall distributions.

Basin S1, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	3,733,269	2.06	3,733,269	2.06
	24	5.18	0.99	5,643,882	3.12	6,131,251	3.39
	72	6.08	1.16	817,887	0.45	3,286,267	1.82
10	120	6.65	1.27	-	0.00	1,183,986	0.65
	1	2.87	0.55	5,018,176	2.77	5,018,176	2.77
	24	7.65	1.46	10,011,101	5.53	10,395,660	5.74
	72	8.84	1.69	5,435,902	3.00	7,527,447	4.16
50	120	9.81	1.87	873,127	0.48	5,079,737	2.81
	1	3.19	0.61	5,597,289	3.09	5,597,289	3.09
	24	8.94	1.71	12,291,956	6.79	12,622,820	6.97
	72	10.30	1.97	7,901,078	4.37	9,815,596	5.42
100	120	11.47	2.19	3,542,076	1.96	7,424,222	4.10

Basin S1, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	3,733,269	2.06	3,733,269	2.06
	24	5.18	0.99	5,156,513	2.85	5,156,513	2.85
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	5,018,176	2.77	5,018,176	2.77
	24	7.65	1.46	9,626,543	5.32	9,626,543	5.32
	72	8.84	1.69	3,344,358	1.85	3,344,358	1.85
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	5,597,289	3.09	5,597,289	3.09
	24	8.94	1.71	11,961,093	6.61	11,961,093	6.61
	72	10.30	1.97	5,986,561	3.31	5,986,561	3.31
100	120	11.47	2.19	-	0.00	-	0.00

Basin S1, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	3,733,269	2.06	3,733,269	2.06
	24	5.18	0.99	5,156,513	2.85	5,812,522	3.21
	72	6.08	1.16	-	0.00	3,484,324	1.93
10	120	6.65	1.27	-	0.00	2,025,191	1.12
	1	2.87	0.55	5,018,176	2.77	5,018,176	2.77
	24	7.65	1.46	9,626,543	5.32	9,988,792	5.52
	72	8.84	1.69	3,853,498	2.13	7,206,089	3.98
50	120	9.81	1.87	-	0.00	5,399,344	2.98
	1	3.19	0.61	5,597,289	3.09	5,597,289	3.09
	24	8.94	1.71	11,961,093	6.61	12,259,598	6.77
	72	10.30	1.97	6,295,423	3.48	9,330,950	5.16
100	120	11.47	2.19	-	0.00	7,494,733	4.14

Basin S1 is located in the northern section of Strathmere. The basin is exclusively impervious cover over urban land with little wetlands present. Most of the soils for the basins are rated as HSG D which does not allow any infiltration. Subsequently, only 10 $ft.^3$ of water per minute is handled by the natural infiltration system. The rest of the rainfall that occurs over the basin must be processed by the stormwater system. There are outfalls that can only handle 381 $ft.^3$ of water per minute. These are back bay outfalls with none discharging into the open coastline. Combined, the basin handles 392 $ft.^3$ of water per minute; any other rainfall in the basin becomes runoff.

This basin is not designed to prevent flooding. Some of the water will runoff out of the basin to the adjacent wetlands and waterways. Nevertheless, the basin produced significant flooding during 31 storm events. Significant flooding occurs when the flood depth is greater than one inch in maximum depth. The 1-hour and 24-hour storm events had maximum flood depths that were close in value to the total rainfall. This means that very little of the rainfall was processed at all and instead accumulated in the basin. Additionally, the storm types that had the greatest flood depths are the 24- and 72-hour storm events. Management should be directed to mitigating flooding from these storms. Even if the water runoffs to the nearby natural areas, the basin will face flooding during each storm event.

Basin S2 Flood Model

Table 5. Summary of storms for Basin S2 under three rainfall distributions.

Basin S2, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	1,627,068	2.15	1,627,068	2.15
	24	5.18	0.99	3,697,567	4.88	3,697,567	4.88
	72	6.08	1.16	3,954,439	5.22	3,983,568	5.26
10	120	6.65	1.27	3,980,046	5.25	4,053,303	5.35
	1	2.87	0.55	2,165,001	2.86	2,165,001	2.86
	24	7.65	1.46	5,568,968	7.35	5,568,968	7.35
	72	8.84	1.69	6,033,013	7.96	6,049,595	7.98
50	120	9.81	1.87	6,348,262	8.38	6,398,273	8.44
	1	3.19	0.61	2,407,450	3.18	2,407,450	3.18
	24	8.94	1.71	6,546,340	8.64	6,546,340	8.64
	72	10.30	1.97	7,132,548	9.41	7,142,493	9.43
100	120	11.47	2.19	7,593,950	10.02	7,636,443	10.08

Basin S2, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	1,627,068	2.15	1,627,068	2.15
	24	5.18	0.99	3,697,567	4.88	3,697,567	4.88
	72	6.08	1.16	-	0.00	3,925,310	5.18
10	120	6.65	1.27	-	0.00	3,906,789	5.16
	1	2.87	0.55	2,165,001	2.86	2,165,001	2.86
	24	7.65	1.46	5,568,968	7.35	5,568,968	7.35
	72	8.84	1.69	6,016,431	7.94	6,016,431	7.94
50	120	9.81	1.87	1,742,395	2.30	6,298,250	8.31
	1	3.19	0.61	2,407,450	3.18	2,407,450	3.18
	24	8.94	1.71	6,546,340	8.64	6,546,340	8.64
	72	10.30	1.97	7,122,603	9.40	7,122,603	9.40
100	120	11.47	2.19	7,551,458	9.97	7,551,458	9.97

Basin S2, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	1,627,068	2.15	1,627,068	2.15
	24	5.18	0.99	3,697,567	4.88	3,697,567	4.88
	72	6.08	1.16	3,925,310	5.18	3,936,013	5.20
10	120	6.65	1.27	3,906,789	5.16	3,969,962	5.24
	1	2.87	0.55	2,165,001	2.86	2,165,001	2.86
	24	7.65	1.46	5,568,968	7.35	5,568,968	7.35
	72	8.84	1.69	6,016,431	7.94	6,016,431	7.94
50	120	9.81	1.87	6,298,250	8.31	6,318,527	8.34
	1	3.19	0.61	2,407,450	3.18	2,407,450	3.18
	24	8.94	1.71	6,546,340	8.64	6,546,340	8.64
	72	10.30	1.97	7,122,603	9.40	7,122,603	9.40
100	120	11.47	2.19	1,984,844	2.62	7,559,203	9.98

Basin S2 is located in the southern section of Strathmere. The basin is predominantly impervious cover over urban land with little wetlands and forest area present. Most of the soils for the basins are rated as HSG D which does not allow any infiltration. Some of HSG A is present as well. Due to the limited amount of soils characterized as HSG A, the basin processes 106 $ft.^3$ of water per minute. The basin does not contain any outfall pipes which means the basin is exclusively reliant on the natural infiltration of the soils. Any other rainfall in the basin that does not get infiltrated becomes runoff or floods the basin.

This basin is not designed to prevent flooding. While water will runoff to nearby natural areas, model shows that the basin produced significant flooding during each of the 36 storm events. The 1-hour and 24-hour storm events had maximum flood depths that were close in value to the total rainfall. This means that very little of the rainfall was processed at all and instead accumulated in the basin. The 120-hour storm event produced more than 3/4 a foot of residual water over the basin during several of the 100-year storm events. Consequently, the flooding in this basin is severe and actions must be taken to address this level of flooding.

Discussion on Current Management of Stormwater in Strathmere up to and including the 100-year storm

Both basins face high levels of flooding as shown by the results of the model. There are two driving factors for the flooding within Strathmere. First, the high level of development has reduced the natural drainage of the soils to be an almost non-factor. The high level of development has placed a greater burden has placed a greater burden on the stormwater system. However, the second problem arises because the stormwater system was not designed to handle this adjusted burden. The modeling shows both basins can both use upgrades to their infrastructure. Basin S2 needs particular attention as the flood levels were higher for this area and there were no identifiable outfall pipes. The implementation of outfall pipes is key to handling the stormwater here.

Additionally, a place to hold the rainwater during each event will likely be key. This could come in the form of green infrastructure such as rain barrels or extensive utilization of infiltration into the sandy soils closest to the oceanfront. Discharging all rainwater directly into the back bay would compound flooding issues and provide no enhanced solution. The use of storage systems with a variety of scales will reduce excessive flooding. The rainwater, post-treatment, can be used as a supply for municipal landscape irrigation or be discharged out to the ocean front. These recommendations are applicable to both basins, but particular action should be taken in Basin S2.

Discussion on the Impacts of the Stormwater System by Sea Level Rise according to NOAA Projections

The impacts of sea level rise are of particular concern for the Strathmere community. The rising sea level will restrict the efficiency of any outfall pipes that become partially or entirely submerged due to their lower elevations. An outfall pipe will be rendered useless when they are completely submerged. For Basin S1, the outfalls present are rendered useless before the new expected local mean sea level of 6.46 ft. NAVD88 in 2100. In order to address this concern, pump stations and reconstructed outfall pipes to higher elevations will be essential for the community to handle new levels of flooding. This should be in combination with expanding storage areas as this will prevent flooding from the back bays. As there are no outfall pipes that perform any discharge at the projected sea level, no modeling was run for these basins.

Route 9 Corridor Flood Models

Basin R1 Flood Model

Basin R1, Current Conditions

Table 6. Summary of Basin R1 current storm events under three rainfall distributions.

Basin R1, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	690,965	1.91	694,204	1.92
	24	5.18	0.99	55,242	0.15	518,633	1.43
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	946,786	2.61	948,481	2.62
	24	7.65	1.46	872,854	2.41	1,258,518	3.47
	72	8.84	1.69	-	0.00	81,158	0.22
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	1,062,085	2.93	1,063,084	2.93
	24	8.94	1.71	1,309,131	3.61	1,663,466	4.59
	72	10.30	1.97	-	0.00	283,323	0.78
100	120	11.47	2.19	-	0.00	-	0.00

Basin R1, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	687,726	1.90	687,726	1.90
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	945,091	2.61	945,091	2.61
	24	7.65	1.46	487,190	1.34	487,190	1.34
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	1,061,086	2.93	1,061,086	2.93
	24	8.94	1.71	954,796	2.63	954,796	2.63
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R1, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	687,726	1.90	687,833	1.90
	24	5.18	0.99	-	0.00	552,431	1.52
	72	6.08	1.16	-	0.00	45,639	0.13
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	945,091	2.61	945,091	2.61
	24	7.65	1.46	590,859	1.63	1,210,525	3.34
	72	8.84	1.69	-	0.00	331,099	0.91
50	120	9.81	1.87	-	0.00	43,388	0.12
	1	3.19	0.61	1,061,086	2.93	1,061,086	2.93
	24	8.94	1.71	1,015,657	2.80	1,579,209	4.36
	72	10.30	1.97	-	0.00	574,544	1.59
100	120	11.47	2.19	-	0.00	211,269	0.58

Basin R1 is located on the Great Egg Harbor Bay to the east of the Garden State Parkway. It is the smallest basin studied for Township of Upper. The basin is primarly urban land with impervious cover but also contains forests, wetlands, and barren land. The soils in the basin are almost completely HSG A leading to good natural infiltration. The soils can infiltrate 175 $ft.^3$ of water per minute. The outfall pipe in the basin can handle 37 $ft.^3$ of water per minute. Combined, 212 $ft.^3$ of water per minute can be handled by the basin's natural infiltration and the outfall pipe drainage.

The basin adequately handles most storm events. Of the 36 modeled storm events, 18 produced significant flooding. There were two other storms did not have flooding present at the end of the storm. The majority of these 8 storm events occur during the 72-hour and 120-hour storm events. The greatest flood depths occurred during the 1-hour and 24-hour storm events. Since minimal flooding occurred during the longer storm events, the shorter events produce greater concern for the basin and can handle the longer storm events.

Basin R1, Future Development Conditions

Basin R1 will allow a maximum of 20% impervious coverage under future conditions. As it stands, the basin is at 19% impervious lot coverage. Due to the similarity between current and future conditions, the basin will perform nearly identical in the future to how it performs now. Therefore, the model was not run.

Basin R2 Flood Model

Basin R2, Current Conditions

Table 7. Summary of Basin R2 current storm events under three rainfall distributions.

Basin R2, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	3,518,840	1.96	3,526,581	1.96
	24	5.18	0.99	1,984,345	1.10	3,595,381	2.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	4,787,736	2.66	4,787,818	2.66
	24	7.65	1.46	6,127,775	3.41	7,441,266	4.14
	72	8.84	1.69	-	0.00	1,899,565	1.06
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	5,363,004	2.98	5,363,004	2.98
	24	8.94	1.71	8,291,752	4.61	9,449,845	5.26
	72	10.30	1.97	-	0.00	3,689,836	2.05
100	120	11.47	2.19	-	0.00	424,599	0.24

Basin R2, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	3,511,099	1.95	3,511,099	1.95
	24	5.18	0.99	373,308	0.21	373,308	0.21
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	4,787,655	2.66	4,787,655	2.66
	24	7.65	1.46	4,814,284	2.68	4,814,284	2.68
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	5,363,004	2.98	5,363,004	2.98
	24	8.94	1.71	7,133,659	3.97	7,133,659	3.97
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R2, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	3,511,099	1.95	3,511,099	1.95
	24	5.18	0.99	931,988	0.52	3,539,436	1.97
	72	6.08	1.16	-	0.00	825,818	0.46
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	4,787,655	2.66	4,787,655	2.66
	24	7.65	1.46	5,009,119	2.79	7,083,651	3.94
	72	8.84	1.69	-	0.00	2,841,171	1.58
50	120	9.81	1.87	-	0.00	1,214,279	0.68
	1	3.19	0.61	5,363,004	2.98	5,363,004	2.98
	24	8.94	1.71	7,235,720	4.02	9,031,926	5.02
	72	10.30	1.97	-	0.00	4,048,684	2.25
100	120	11.47	2.19	-	0.00	2,046,987	1.14

Basin R2 is located on the Great Egg Harbor Bay to the west of the Garden State Parkway. It contains a variety of urban land with impervious cover, forest, and wetlands. The soils are predominantly classified as HSG A leading to a good infiltration rate. However, there are no outfalls in this basin. The basin, therefore, is reliant upon natural soil infiltration rates to prevent flooding. In total, the soils can infiltrate up to 830 $ft.^3$ of water per minute.

In total, there were 26 storms that produced flooding. Of these 26, four were insignificant because the maximum flooding depth was less than one inch. Additionally, four basins had flooding greater than one inch, but they did not last the entire storm event. Greatest flood depths occurred during the shorter storms, and these also had flooding that lasted at least as long as the storm event. Subsequently, the basin does not handle the shorter storms as well as it does the longer storm events.

Basin R2, Future Development Conditions

Table 8. Summary of Basin R2 future development conditions under three rainfall distributions.

Basin R2, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	3,601,126	2.00	3,601,386	2.00
	24	5.18	0.99	3,600,146	2.00	4,672,582	2.60
	72	6.08	1.16	-	0.00	783,007	0.44
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	4,877,422	2.71	4,877,422	2.71
	24	7.65	1.46	7,783,291	4.33	8,597,898	4.78
	72	8.84	1.69	-	0.00	4,053,966	2.25
50	120	9.81	1.87	-	0.00	1,083,881	0.60
	1	3.19	0.61	5,452,771	3.03	5,452,771	3.03
	24	8.94	1.71	10,049,321	5.59	10,810,583	6.01
	72	10.30	1.97	2,010,326	1.12	5,858,865	3.26
100	120	11.47	2.19	-	0.00	2,749,479	1.53

Basin R2, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	3,600,866	2.00	3,600,866	2.00
	24	5.18	0.99	2,527,709	1.41	2,527,709	1.41
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	4,877,422	2.71	4,877,422	2.71
	24	7.65	1.46	6,968,685	3.88	6,968,685	3.88
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	5,452,771	3.03	5,452,771	3.03
	24	8.94	1.71	9,288,060	5.17	9,288,060	5.17
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R2, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	3,600,866	2.00	3,600,866	2.00
	24	5.18	0.99	2,727,322	1.52	4,437,104	2.47
	72	6.08	1.16	-	0.00	1,635,674	0.91
10	120	6.65	1.27	-	0.00	522,914	0.29
	1	2.87	0.55	4,877,422	2.71	4,877,422	2.71
	24	7.65	1.46	6,983,986	3.88	8,160,851	4.54
	72	8.84	1.69	-	0.00	4,340,059	2.41
50	120	9.81	1.87	-	0.00	2,459,841	1.37
	1	3.19	0.61	5,452,771	3.03	5,452,771	3.03
	24	8.94	1.71	9,288,060	5.17	10,264,073	5.71
	72	10.30	1.97	-	0.00	6,177,580	3.44
100	120	11.47	2.19	-	0.00	3,827,861	2.13

Basin R2 zoning allows for a 46% impervious coverage on average for the entire basin. As it stands, the basin is currently a little over 29% impervious coverage. Subsequently, there will be a 17% increase in impervious coverage in the future. This will add 11 acres of impervious coverage. The increase in impervious coverage will decrease the soil infiltration by 200 $ft.^3$ of water per minute, placing a greater strain on the stormwater system. Under this scenario, the maximum residual water is now 10,810,583 gallons of water, a greater than 1,000,000-gallon increase over current conditions. Additionally, the flood maximum flood depth will increase from 5.26 inches to 6.01 inches. The basin will see three new storm events produce significant flooding with one more storm producing flooding until the end of the storm event.

Basin R3 Flood Model

Basin R3, Current Conditions

Table 9. Summary of Basin R3 storm events under current conditions and three storm distributions.

Basin R3, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	10,638,061	1.95	10,665,743	1.95
	24	5.18	0.99	5,122,075	0.94	10,314,524	1.89
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	14,490,734	2.65	14,495,160	2.66
	24	7.65	1.46	17,702,520	3.24	21,991,550	4.03
	72	8.84	1.69	-	0.00	4,563,707	0.84
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	16,233,204	2.97	16,233,204	2.97
	24	8.94	1.71	24,272,873	4.45	28,090,078	5.15
	72	10.30	1.97	-	0.00	9,999,397	1.83
100	120	11.47	2.19	-	0.00	285,993	0.05

Basin R3, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	10,610,379	1.94	10,610,379	1.94
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	14,486,307	2.65	14,486,307	2.65
	24	7.65	1.46	13,413,489	2.46	13,413,489	2.46
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	16,233,204	2.97	16,233,204	2.97
	24	8.94	1.71	20,455,669	3.75	20,455,669	3.75
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R3, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	10,610,379	1.94	10,610,379	1.94
	24	5.18	0.99	1,826,548	0.33	10,345,105	1.90
	72	6.08	1.16	-	0.00	2,206,425	0.40
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	14,486,307	2.65	14,486,307	2.65
	24	7.65	1.46	14,105,375	2.58	20,905,744	3.83
	72	8.84	1.69	-	0.00	8,024,560	1.47
50	120	9.81	1.87	-	0.00	3,185,247	0.58
	1	3.19	0.61	16,233,204	2.97	16,233,204	2.97
	24	8.94	1.71	20,865,867	3.82	26,821,175	4.91
	72	10.30	1.97	-	0.00	11,690,861	2.14
100	120	11.47	2.19	-	0.00	5,713,548	1.05

Basin R3 is located to the west of Garden State Parkway. It is made up of predominantly urban land with impervious cover with areas of minimal forest and wetlands. The soils are mostly HSG A with HSG B and HSG D present as well. These soils infiltrate 2,249 ft.^{3} of water per minute. The natural infiltration is augmented by outfall discharge of 383 ft.^{3} of water per minute. Combined, the basin can handle 2,694 ft.^{3} of water per minute.

In total, there were 25 storms that produced flooding. Four of these storms did not produce significant flooding because they did not they do not have flood depths greater than 1 inch. No flooding event lasted the entire storm event for each of the 72- and 120-hour storm events. These storms also did not produce greater than one inch of flooding during the 10-year storm events. Therefore, the basin handles these storm lengths well. Alternatively, the basin does not handle the shorter storm lengths of 1- and 24-hour. These flood events lasted the entire storm and produced flooding greater than one inch in all scenarios except the 10-year, 24-hour storm event. Due to significant flooding during the shorter duration storms, the basin could improve to handle the shorter duration storm events.

Basin R3, Future Development Conditions

Basin R3 currently has 37% of its area developed via impervious coverage. However, the basin only allows for an average development of 31%. Since the basin has already surpassed its development limit, future conditions are not modeled.

Basin R4 Flood Model

Basin R4, Current Conditions

Table 10. Summary of three storm distributions for Basin R4 under current conditions.

Basin R4, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,770,839	2.01	17,770,839	2.01
	24	5.18	0.99	19,174,958	2.17	23,946,118	2.71
	72	6.08	1.16	-	0.00	5,276,563	0.60
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	24,041,487	2.72	24,041,487	2.72
	24	7.65	1.46	39,888,852	4.52	43,559,118	4.93
	72	8.84	1.69	2,969,352	0.34	21,901,020	2.48
50	120	9.81	1.87	-	0.00	6,980,269	0.79
	1	3.19	0.61	26,867,694	3.04	26,867,694	3.04
	24	8.94	1.71	51,019,958	5.78	54,428,181	6.16
	72	10.30	1.97	14,346,434	1.62	31,760,614	3.60
100	120	11.47	2.19	-	0.00	16,818,024	1.90

Basin R4, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,770,839	2.01	17,770,839	2.01
	24	5.18	0.99	14,403,799	1.63	14,403,799	1.63
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	24,041,487	2.72	24,041,487	2.72
	24	7.65	1.46	36,218,586	4.10	36,218,586	4.10
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	26,867,694	3.04	26,867,694	3.04
	24	8.94	1.71	47,611,734	5.39	47,611,734	5.39
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R4, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,770,839	2.01	17,770,839	2.01
	24	5.18	0.99	15,185,949	1.72	22,756,638	2.58
	72	6.08	1.16	-	0.00	9,028,336	1.02
10	120	6.65	1.27	-	0.00	3,396,671	0.38
	1	2.87	0.55	24,041,487	2.72	24,041,487	2.72
	24	7.65	1.46	36,218,586	4.10	41,261,942	4.67
	72	8.84	1.69	-	0.00	23,306,352	2.64
50	120	9.81	1.87	-	0.00	13,739,206	1.56
	1	3.19	0.61	26,867,694	3.04	26,867,694	3.04
	24	8.94	1.71	47,611,734	5.39	51,743,638	5.86
	72	10.30	1.97	3,508,114	0.40	32,332,551	3.66
100	120	11.47	2.19	-	0.00	20,459,142	2.32

Basin R4 is located in the upper portion of the Route 9 corridor. The basin is dominated by urban land with impervious cover. There are some forests and wetlands in the southern portion of the basin. The HSG A is the domineering soil group present with some HSG D present in smaller quantities. 2,848 $ft.^3$ of water per minute are percolated for this basin. Outfalls discharge an additional 62 $ft.^3$ of water per minute. In total, 2,910 $ft.^3$ of water per minute are handled between the soil infiltration and outfall discharge.

The basin does not handle short or long storm events particularly well. There were 29 storm events that produced flooding and 26 of these had flood depths greater than one inch. 21 storms lasted at least as long as the storm duration. The 1-hour and 24-hour storm events produce flooding greater than one inch and lasted the entire duration of the storm event. The longer storm durations, 72- and 120-hour storm lengths, have eight maximum flood depths greater than one inch. Only three of these eight storms lasted the entire storm length. Therefore, the longer storm durations are handled better by the basin but do produce some struggle. The high level of development will lead to house and street flooding and their subsequent damages. Improvements can be made to improve the basin's stormwater system so that reduced flooding occurs and damage is limited during all short storm events and some longer events.

Basin R4, Future Development Conditions

Table 11. Summary of future development conditions for Basin R4 under three rainfall distributions.

Basin R4, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	18,097,586	2.05	18,097,586	2.05
	24	5.18	0.99	25,110,736	2.84	27,975,756	3.17
	72	6.08	1.16	-	0.00	13,118,480	1.49
10	120	6.65	1.27	-	0.00	2,866,154	0.32
	1	2.87	0.55	24,368,233	2.76	24,368,233	2.76
	24	7.65	1.46	46,423,783	5.26	48,787,063	5.52
	72	8.84	1.69	19,960,113	2.26	32,356,792	3.66
50	120	9.81	1.87	-	0.00	19,924,851	2.26
	1	3.19	0.61	27,194,440	3.08	27,194,440	3.08
	24	8.94	1.71	57,554,889	6.52	59,656,126	6.75
	72	10.30	1.97	31,990,748	3.62	43,523,490	4.93
100	120	11.47	2.19	6,815,958	0.77	29,887,886	3.38

Basin R4, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	18,097,586	2.05	18,097,586	2.05
	24	5.18	0.99	22,245,716	2.52	22,245,716	2.52
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	24,368,233	2.76	24,368,233	2.76
	24	7.65	1.46	44,060,503	4.99	44,060,503	4.99
	72	8.84	1.69	7,563,435	0.86	7,563,435	0.86
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	27,194,440	3.08	27,194,440	3.08
	24	8.94	1.71	55,453,651	6.28	55,453,651	6.28
	72	10.30	1.97	20,458,005	2.32	20,458,005	2.32
100	120	11.47	2.19	-	0.00	-	0.00

Basin R4, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	18,097,586	2.05	18,097,586	2.05
	24	5.18	0.99	22,374,373	2.53	26,677,596	3.02
	72	6.08	1.16	-	0.00	14,085,043	1.59
10	120	6.65	1.27	-	0.00	7,450,678	0.84
	1	2.87	0.55	24,368,233	2.76	24,368,233	2.76
	24	7.65	1.46	44,060,503	4.99	46,558,181	5.27
	72	8.84	1.69	11,507,794	1.30	31,518,309	3.57
50	120	9.81	1.87	-	0.00	21,484,606	2.43
	1	3.19	0.61	27,194,440	3.08	27,194,440	3.08
	24	8.94	1.71	55,453,651	6.28	57,396,974	6.50
	72	10.30	1.97	23,112,907	2.62	41,576,074	4.71
100	120	11.47	2.19	-	0.00	31,710,595	3.59

Basin R4 has current conditions of 32% area of impervious cover. Based on the zoning restrictions, the basin can develop an extra 14% of its area which equates to 45 acres of impervious coverage added to the basin. The added impervious coverage reduces the soil infiltration from 2,848 $ft.^3$ of water per minute to 2,120 $ft.^3$ of water per minute, a significant decrease. At the maximum, there will be an additional 5,000,000+ gallons of residual water and 0.6 inches of flood depth over current conditions. Furthermore, there will be three new storms with significant flooding whereas four more will have flooding at the end of the event. The reduction of soil infiltration has added a burden on the stormwater system.

Basin R5 Flood Model

Basin R5, Current Conditions

Table 12. Summary of current conditions for Basin R5 under three rainfall distributions.

Basin R5, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	16,981,071	1.94	17,030,531	1.95
	24	5.18	0.99	7,096,152	0.81	15,781,198	1.81
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	23,151,343	2.65	23,163,558	2.65
	24	7.65	1.46	27,244,442	3.12	34,482,612	3.94
	72	8.84	1.69	-	0.00	6,085,231	0.70
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	25,936,882	2.97	25,936,882	2.97
	24	8.94	1.71	37,767,233	4.32	44,249,747	5.06
	72	10.30	1.97	-	0.00	14,538,411	1.66
100	120	11.47	2.19	-	0.00	-	0.00

Basin R5, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	16,931,610	1.94	16,931,610	1.94
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	23,139,128	2.65	23,139,128	2.65
	24	7.65	1.46	20,006,272	2.29	20,006,272	2.29
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	25,936,882	2.97	25,936,882	2.97
	24	8.94	1.71	31,284,719	3.58	31,284,719	3.58
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R5, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	16,931,610	1.94	16,931,610	1.94
	24	5.18	0.99	1,695,165	0.19	16,076,206	1.84
	72	6.08	1.16	-	0.00	3,164,667	0.36
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	23,139,128	2.65	23,139,128	2.65
	24	7.65	1.46	21,237,381	2.43	32,743,632	3.75
	72	8.84	1.69	-	0.00	12,113,692	1.39
50	120	9.81	1.87	-	0.00	4,486,275	0.51
	1	3.19	0.61	25,936,882	2.97	25,936,882	2.97
	24	8.94	1.71	32,064,690	3.67	42,217,528	4.83
	72	10.30	1.97	-	0.00	17,985,479	2.06
100	120	11.47	2.19	-	0.00	8,535,491	0.98

Basin R5 is located in the upper portion of the route 9 corridor and borders natural land. The basin itself contains urban land with impervious cover but also has a significant portion of natural land in it as well. The natural land in the basin is the reason the basin is dominated by HSG A. This allows for great infiltration of 4,352 $ft.^3$ of water per minute. However, there are no outfalls located within this basin, making Basin R5 completely reliant on natural soil infiltration to handle storm events.

Despite relying on only natural soil infiltration, the basin performs adequately. Only 20 storms produce flooding that is greater than one inch in maximum depth. These only occur during the 1-, 24-, and 72-hour storm events. Therefore, the 120-hour storm event does not cause any significant flooding for the basin. The 72-hour storm is less concerning than the 1- and 24-hour storm events as the flood depths are smaller and the flooding is not present at the end of the storm event. Outside of the 10-year, 24-hour, the 1- and 24-hour storm events were not handled well as they had significant flood depths and flooding was present at the end of each storm. Overall, water will likely concentrate in one of the lakes present in the basin or low-lying areas. The development is concentrated on higher elevations and may alleviate the flooding concerns for the basin. The water will also likely flow out of the basin into the nearby wetlands. The model does still show flooding during short storm lengths, so actions can be taken to improve these conditions.

Basin R5, Future Development Conditions

Table 13. Summary of future development conditions for Basin R5 under three rainfal distributions.

Basin R5, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,333,159	1.98	17,350,611	1.98
	24	5.18	0.99	14,009,881	1.60	20,390,351	2.33
	72	6.08	1.16	-	0.00	1,476,483	0.17
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	23,523,224	2.69	23,523,224	2.69
	24	7.65	1.46	34,158,171	3.91	39,091,764	4.47
	72	8.84	1.69	-	0.00	15,051,155	1.72
50	120	9.81	1.87	-	0.00	1,385,515	0.16
	1	3.19	0.61	26,320,978	3.01	26,320,978	3.01
	24	8.94	1.71	44,981,832	5.14	49,460,639	5.66
	72	10.30	1.97	415,863	0.05	23,756,717	2.72
100	120	11.47	2.19	-	0.00	6,909,802	0.79

Basin R5, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,315,706	1.98	17,315,706	1.98
	24	5.18	0.99	7,629,412	0.87	7,629,412	0.87
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	23,523,224	2.69	23,523,224	2.69
	24	7.65	1.46	29,224,578	3.34	29,224,578	3.34
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	26,320,978	3.01	26,320,978	3.01
	24	8.94	1.71	40,503,024	4.63	40,503,024	4.63
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R5, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,315,706	1.98	17,315,706	1.98
	24	5.18	0.99	9,377,086	1.07	19,633,797	2.25
	72	6.08	1.16	-	0.00	5,622,755	0.64
10	120	6.65	1.27	-	0.00	600,235	0.07
	1	2.87	0.55	23,523,224	2.69	23,523,224	2.69
	24	7.65	1.46	29,687,495	3.40	37,352,785	4.27
	72	8.84	1.69	-	0.00	16,722,845	1.91
50	120	9.81	1.87	-	0.00	8,327,236	0.95
	1	3.19	0.61	26,320,978	3.01	26,320,978	3.01
	24	8.94	1.71	40,514,804	4.63	46,826,681	5.36
	72	10.30	1.97	-	0.00	25,377,666	2.90
100	120	11.47	2.19	-	0.00	14,728,689	1.68

Basin R5 will allow for a maximum of 31% impervious coverage. As it stands now, the basin is covered by 16% impervious coverage. In the future, an additional 48 acres of impervious coverage can be added to the basin. These acres will reduce the soil infiltration from 4,352 $ft.^3$ of water per minute to 3,496 $ft.^3$ of water per minute. This will exacerbate the issue of no identifiable stormwater system within the basin. The residual water added as a result of development will be in excess of 5,000,000 gallons with an additional 0.6 inches of water. There will also be two new storms that produce significant flooding and two new storms that have flooding at the end of the event.

Basin R6 Flood Model

Basin R6, Current Conditions

Table 14. Summary of current conditions for Basin R6 under three rainfall distributions.

Basin R6, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	12,882,499	1.97	12,902,300	1.97
	24	5.18	0.99	9,013,487	1.38	14,269,360	2.18
	72	6.08	1.16	-	0.00	130,949	0.02
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	17,502,914	2.68	17,502,914	2.68
	24	7.65	1.46	24,074,647	3.68	28,248,958	4.32
	72	8.84	1.69	-	0.00	9,305,482	1.42
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	19,594,279	3.00	19,594,279	3.00
	24	8.94	1.71	32,003,378	4.90	35,675,605	5.46
	72	10.30	1.97	-	0.00	15,813,026	2.42
100	120	11.47	2.19	-	0.00	3,543,943	0.54

Basin R6, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	12,862,698	1.97	12,862,698	1.97
	24	5.18	0.99	3,757,614	0.57	3,757,614	0.57
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	17,502,914	2.68	17,502,914	2.68
	24	7.65	1.46	19,900,337	3.04	19,900,337	3.04
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	19,594,279	3.00	19,594,279	3.00
	24	8.94	1.71	28,331,152	4.33	28,331,152	4.33
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R6, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	12,862,698	1.97	12,862,698	1.97
	24	5.18	0.99	5,388,276	0.82	13,865,948	2.12
	72	6.08	1.16	-	0.00	3,601,972	0.55
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	17,502,914	2.68	17,502,914	2.68
	24	7.65	1.46	20,408,499	3.12	26,949,044	4.12
	72	8.84	1.69	-	0.00	11,527,842	1.76
50	120	9.81	1.87	-	0.00	5,414,118	0.83
	1	3.19	0.61	19,594,279	3.00	19,594,279	3.00
	24	8.94	1.71	28,502,081	4.36	34,030,928	5.21
	72	10.30	1.97	-	0.00	17,024,710	2.60
100	120	11.47	2.19	-	0.00	9,388,682	1.44

Basin R6 is located in the upper middle portion of the Route 9 corridor. It contains concentrated areas of development surrounded by forests and has some wetlands in the southern portion. It is surrounded by high elevations on all sides and contains lower elevations in the middle of the basin. The basin contains mostly HSG A with some HSG D present as well. This allows for better infiltration in the basin, but it is limited by a significant area of impervious cover. The soil infiltration is 2,564 $ft.^3$ of water per minute. The outfalls discharge 230 $ft.^3$ of water per minute which total 2,794 $ft.^3$ of water per minute that the basin can handle.

Within this basin, 27 storms produce some level of flooding. 18 of these have flooding present at the end of the storm and 22 have a depth greater than 1 inch of water. The 18 storms that have flooding present at the end of the storm occur during the 1-hour and 24-hour storm events. This is a significant source of flood issues for the basin. The steady-state 10-year, 24-hour storm event does not produce significant flood depths. The four storm events that have flood depths greater than one inch but do not have flooding present at the end of the storm event occur during the longer 50- and 100-year storm events. These storms are still important to manage despite not having water present at the end of the event. The water that accumulates in these basins will flow towards the middle of the basin and out into a body of wetlands. The length of time it takes for the water to move to this point is undetermined, however. Overall, the basin does not handle the modeled storm events and should be improved to prevent flooding.

Basin R6, Future Development Conditions

Figure 31. Summary of future development conditions for Basin R6 under three rainfall distributions.

Basin R6, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,358,101	2.04	13,358,101	2.04
	24	5.18	0.99	17,930,743	2.74	20,214,197	3.09
	72	6.08	1.16	-	0.00	8,893,226	1.36
10	120	6.65	1.27	-	0.00	1,442,328	0.22
	1	2.87	0.55	17,998,317	2.75	17,998,317	2.75
	24	7.65	1.46	33,674,535	5.15	35,559,058	5.44
	72	8.84	1.69	12,938,070	1.98	22,722,225	3.48
50	120	9.81	1.87	-	0.00	13,386,995	2.05
	1	3.19	0.61	20,089,682	3.07	20,089,682	3.07
	24	8.94	1.71	41,911,441	6.41	43,602,055	6.67
	72	10.30	1.97	21,840,619	3.34	30,985,470	4.74
100	120	11.47	2.19	2,329,351	0.36	20,759,540	3.18

Basin R6, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,358,101	2.04	13,358,101	2.04
	24	5.18	0.99	15,647,289	2.39	15,647,289	2.39
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	17,998,317	2.75	17,998,317	2.75
	24	7.65	1.46	31,790,012	4.86	31,790,012	4.86
	72	8.84	1.69	3,153,915	0.48	3,153,915	0.48
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	20,089,682	3.07	20,089,682	3.07
	24	8.94	1.71	40,220,827	6.15	40,220,827	6.15
	72	10.30	1.97	12,695,768	1.94	12,695,768	1.94
100	120	11.47	2.19	-	0.00	-	0.00

Basin R6, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,358,101	2.04	13,358,101	2.04
	24	5.18	0.99	15,810,354	2.42	19,333,994	2.96
	72	6.08	1.16	-	0.00	9,608,473	1.47
10	120	6.65	1.27	-	0.00	4,834,830	0.74
	1	2.87	0.55	17,998,317	2.75	17,998,317	2.75
	24	7.65	1.46	31,790,012	4.86	33,859,170	5.18
	72	8.84	1.69	6,479,860	0.99	22,305,335	3.41
50	120	9.81	1.87	-	0.00	14,541,198	2.22
	1	3.19	0.61	20,089,682	3.07	20,089,682	3.07
	24	8.94	1.71	40,220,827	6.15	41,851,122	6.40
	72	10.30	1.97	15,067,527	2.31	29,747,980	4.55
100	120	11.47	2.19	-	0.00	22,108,327	3.38

Basin R6 currently contains 63 acres of impervious surface which accounts for 26% of the developable land within the basin. Zoning restrictions will allow for an increase to 53% impervious surface, or an additional 66 acres. Future development could lead to an additional 8,000,000 gallons of water. This will increase flood depths by 1.2 inches at maximum. The increase in residual water in the basin are from a reduction over 1,100 $ft.^3$ of water per minute being removed from soil infiltration. Not only does the maximum residual water increase, the number of storms that produce significant flooding increases. There will be seven new storms that produce flooding over one inch and there will also be seven more storms that have residual water at the end of the event.

Basin R7 Flood Model

Basin R7, Current Conditions

Figure 32. Summary of current conditions for Basin R7 under three rainfall distributions.

Basin R7, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	28,471,303	1.96	28,529,259	1.96
	24	5.18	0.99	17,012,893	1.17	29,696,424	2.04
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	38,723,882	2.67	38,723,882	2.67
	24	7.65	1.46	50,478,712	3.48	60,759,018	4.18
	72	8.84	1.69	-	0.00	16,656,696	1.15
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	43,370,884	2.99	43,370,884	2.99
	24	8.94	1.71	67,956,812	4.68	76,981,991	5.30
	72	10.30	1.97	-	0.00	31,116,423	2.14
100	120	11.47	2.19	-	0.00	4,524,591	0.31

Basin R7, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	28,413,347	1.96	28,413,347	1.96
	24	5.18	0.99	4,329,362	0.30	4,329,362	0.30
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	38,723,882	2.67	38,723,882	2.67
	24	7.65	1.46	40,198,407	2.77	40,198,407	2.77
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	43,370,884	2.99	43,370,884	2.99
	24	8.94	1.71	58,931,633	4.06	58,931,633	4.06
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R7, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	28,413,347	1.96	28,413,347	1.96
	24	5.18	0.99	8,622,691	0.59	29,135,048	2.01
	72	6.08	1.16	-	0.00	6,998,555	0.48
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	38,723,882	2.67	38,723,882	2.67
	24	7.65	1.46	41,662,543	2.87	57,870,615	3.99
	72	8.84	1.69	-	0.00	23,604,786	1.63
50	120	9.81	1.87	-	0.00	10,355,126	0.71
	1	3.19	0.61	43,370,884	2.99	43,370,884	2.99
	24	8.94	1.71	59,646,441	4.11	73,606,525	5.07
	72	10.30	1.97	-	0.00	33,808,780	2.33
100	120	11.47	2.19	-	0.00	17,511,572	1.21

Basin R7 is in the mideastern section of the Route 9 corridor and border the Garden State Parkway. The basin has urban land with impervious cover that is separated by forested land. The low-lying areas of the basin are mostly wetlands or lakes. The basin's soils consist of primarily HSG A with HSG B and D present as well. Since the basin does not have outfall pipes within it, the basin relies on the 6,581 $ft.^3$ of water per minute to handle the storm events.

The storm events produce flooding 26 times. There are 18 storms that have flooding present at the end of the storm event and 22 are greater than one inch at the flood depth's maximum. Flood events with greater than one inch and had flood present at the end of the storm event only occurred during the shorter storms. The 10-year storm event produces flooding greater than one inch for the 1- and 24-hour storm events. The 50-year storm events produced flooding greater than one inch for all storms except the 120-hour storm length. The 72-hour storm did not have flooding present at the end of the event. Therefore, the impacts of this storm are only felt during the actual rain event. The 100-year storm did produce flooding for all storm events, but flooding was not present at the end of the 72-hour and 100-hour storm events.

Basin R7, Future Development Conditions

Table 15. Summary of Basin R7's future development conditions under three rainfall distributions.

Basin R7, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	28,947,890	1.99	28,962,520	1.99
	24	5.18	0.99	26,371,341	1.82	35,935,389	2.47
	72	6.08	1.16	-	0.00	4,519,914	0.31
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	39,243,796	2.70	39,243,796	2.70
	24	7.65	1.46	59,857,221	4.12	67,038,105	4.62
	72	8.84	1.69	-	0.00	29,134,626	2.01
50	120	9.81	1.87	-	0.00	5,747,160	0.40
	1	3.19	0.61	43,890,798	3.02	43,890,798	3.02
	24	8.94	1.71	78,159,583	5.38	84,909,602	5.85
	72	10.30	1.97	8,960,788	0.62	43,594,354	3.00
100	120	11.47	2.19	-	0.00	16,192,753	1.12

Basin R7, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	28,933,260	1.99	28,933,260	1.99
	24	5.18	0.99	16,807,292	1.16	16,807,292	1.16
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	39,243,796	2.70	39,243,796	2.70
	24	7.65	1.46	52,676,338	3.63	52,676,338	3.63
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	43,890,798	3.02	43,890,798	3.02
	24	8.94	1.71	71,409,564	4.92	71,409,564	4.92
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R7, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	28,933,260	1.99	28,933,260	1.99
	24	5.18	0.99	19,020,966	1.31	34,334,186	2.36
	72	6.08	1.16	-	0.00	11,406,771	0.79
10	120	6.65	1.27	-	0.00	2,719,903	0.19
	1	2.87	0.55	39,243,796	2.70	39,243,796	2.70
	24	7.65	1.46	53,100,646	3.66	64,109,581	4.41
	72	8.84	1.69	-	0.00	31,445,348	2.17
50	120	9.81	1.87	-	0.00	16,860,568	1.16
	1	3.19	0.61	43,890,798	3.02	43,890,798	3.02
	24	8.94	1.71	71,409,564	4.92	80,495,532	5.54
	72	10.30	1.97	-	0.00	46,286,710	3.19
100	120	11.47	2.19	-	0.00	27,909,848	1.92

Basin R7 currently has 94 acres of impervious coverage. This accounts for 17% of the total developable land within the basin, but an additional 13% of impervious cover can be added to the basin. In the future, a total of 163 acres can be developed with impervious coverage according to zoning restrictions. Consequently, this will prevent over 1,100 $ft.^3$ of water per minute from being drained via soil infiltration. As a result of depletion of soil infiltration, there will be an increase of 8,000,000 gallons of residual water and half an inch more of water blanketing the entirety of the basin. There will also be three new storms with significant flooding and one new storm with residual water at the end of the event. As the basin relies on soil infiltration at the moment, any future development that decreases highly drainable soils should be strongly evaluated.

Basin R8 Flood Model

Basin R8, Current Conditions

Table 16. Summary of the current conditions in Basin R8 under three rainfall distributions.

Basin R8, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	19,716,368	1.93	19,783,792	1.94
	24	5.18	0.99	6,191,378	0.61	17,027,350	1.67
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	26,919,260	2.64	26,943,206	2.64
	24	7.65	1.46	29,711,566	2.91	38,858,522	3.81
	72	8.84	1.69	-	0.00	5,708,723	0.56
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	30,165,634	2.96	30,169,985	2.96
	24	8.94	1.71	41,995,390	4.11	50,260,227	4.92
	72	10.30	1.97	-	0.00	14,181,681	1.39
100	120	11.47	2.19	-	0.00	-	0.00

Basin R8, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	19,648,943	1.93	19,648,943	1.93
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	26,895,314	2.64	26,895,314	2.64
	24	7.65	1.46	20,564,611	2.01	20,564,611	2.01
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	30,161,284	2.96	30,161,284	2.96
	24	8.94	1.71	33,730,552	3.30	33,730,552	3.30
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R8, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	19,648,943	1.93	19,648,943	1.93
	24	5.18	0.99	-	0.00	17,836,694	1.75
	72	6.08	1.16	-	0.00	2,996,839	0.29
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	26,895,314	2.64	26,895,314	2.64
	24	7.65	1.46	22,342,316	2.19	36,936,599	3.62
	72	8.84	1.69	-	0.00	12,746,072	1.25
50	120	9.81	1.87	-	0.00	4,074,658	0.40
	1	3.19	0.61	30,161,284	2.96	30,161,284	2.96
	24	8.94	1.71	34,873,538	3.42	47,887,908	4.69
	72	10.30	1.97	-	0.00	19,600,526	1.92
100	120	11.47	2.19	-	0.00	8,801,527	0.86

Basin R8 is located in the midwestern portion of the Route 9 corridor. The basin consists of two sections of development that are divided in the middle by forests. Overall, the basin is higher in elevation. The soils in the basin are dominated by HSG A with HSG B present as well. This allows for all soils to infiltrate rainwater. The soils can infiltrate 4,848 $ft.^3$ of water per minute. The outfalls also add 491 $ft.^3$ of water per minute of discharge that helps the basin handle water. Therefore, the basin can handle 5,339 $ft.^3$ of water per minute.

The number of storm events that result in flooding is 24. Four of these events are less than one inch of rainfall whereas eight do not have flooding at the end of the event. The 10-year storm only has flooding last during the 1-hour and one 24-hour storm event. No 72- or 120-hour storm event had flooding at the end of the storm event. Only the 72-hour storm event had flood depths greater than one inch. The 120-hour storms do not have these. Therefore, the longer storm durations do pose some potential issues, but they are minimal. The shorter storm events pose concern for the basin. These storms produce flooding that is present at the end of the storm and are greater than one inch. Management should be directed toward the shorter storm events.

Basin R8, Future Development Conditions

Table 17. Summary of future development conditions for Basin R8 under three rainfall distributions.

Basin R8, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	20,043,336	1.96	20,081,036	1.97
	24	5.18	0.99	12,611,849	1.24	21,307,664	2.09
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	27,252,007	2.67	27,252,007	2.67
	24	7.65	1.46	36,132,037	3.54	43,138,836	4.23
	72	8.84	1.69	-	0.00	12,579,835	1.23
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	30,517,977	2.99	30,517,977	2.99
	24	8.94	1.71	48,415,860	4.74	54,540,541	5.34
	72	10.30	1.97	-	0.00	22,742,309	2.23
100	120	11.47	2.19	-	0.00	3,907,692	0.38

Basin R8, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	20,005,636	1.96	20,005,636	1.96
	24	5.18	0.99	3,916,034	0.38	3,916,034	0.38
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	27,252,007	2.67	27,252,007	2.67
	24	7.65	1.46	29,125,239	2.85	29,125,239	2.85
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	30,517,977	2.99	30,517,977	2.99
	24	8.94	1.71	42,291,180	4.14	42,291,180	4.14
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R8, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	20,005,636	1.96	20,005,636	1.96
	24	5.18	0.99	6,787,887	0.67	20,840,347	2.04
	72	6.08	1.16	-	0.00	5,136,996	0.50
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	27,252,007	2.67	27,252,007	2.67
	24	7.65	1.46	30,081,476	2.95	41,108,831	4.03
	72	8.84	1.69	-	0.00	17,026,386	1.67
50	120	9.81	1.87	-	0.00	7,641,587	0.75
	1	3.19	0.61	30,517,977	2.99	30,517,977	2.99
	24	8.94	1.71	42,720,780	4.19	52,168,222	5.11
	72	10.30	1.97	-	0.00	24,634,530	2.41
100	120	11.47	2.19	-	0.00	13,035,102	1.28

Basin R8 currently has 63 acres of impervious cover, accounting for 17% of the total developable areas of the basin. Another 12% of the basin, or 45 acres, can be developed into impervious coverage. The additional development would lead to approximately a maximum of 4,000,000 gallons of additional residual water. Flood depths increase about 0.4 inches at maximum. Additionally, there will be two new storms with significant flooding and two new storms with residual water leftover at the end of the storm. The basin will drain approximately 800 $ft.^3$ less of water per minute over current conditions, but the presence of outfall pipes minimizes this impact.

Basin R9 Flood Model

Basin R9, Current Conditions

Table 18. Summary of Basin R9's current conditions under three rainfall distributions.

Basin R9, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	14,112,185	1.89	14,193,150	1.90
	24	5.18	0.99	-	0.00	9,356,692	1.25
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	19,394,391	2.59	19,443,472	2.60
	24	7.65	1.46	14,980,572	2.00	23,957,867	3.20
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	21,775,104	2.91	21,809,814	2.91
	24	8.94	1.71	23,988,854	3.21	32,319,252	4.32
	72	10.30	1.97	-	0.00	3,821,955	0.51
100	120	11.47	2.19	-	0.00	-	0.00

Basin R9, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	14,031,220	1.87	14,031,220	1.87
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	19,345,311	2.58	19,345,311	2.58
	24	7.65	1.46	6,003,277	0.80	6,003,277	0.80
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	21,740,394	2.90	21,740,394	2.90
	24	8.94	1.71	15,658,456	2.09	15,658,456	2.09
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R9, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	14,031,220	1.87	14,047,518	1.88
	24	5.18	0.99	-	0.00	10,054,559	1.34
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	19,345,311	2.58	19,345,311	2.58
	24	7.65	1.46	8,819,895	1.18	23,304,908	3.11
	72	8.84	1.69	-	0.00	5,712,423	0.76
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	21,740,394	2.90	21,740,394	2.90
	24	8.94	1.71	17,509,556	2.34	30,835,947	4.12
	72	10.30	1.97	-	0.00	9,835,110	1.31
100	120	11.47	2.19	-	0.00	2,672,190	0.36

Basin R9 is the mideastern portion of the Route 9 corridor. Its boundary is defined by a ridge of higher elevations with low lying elevations in the center of the basin. It contains natural areas concentrated in the middle of basin and development along the ridge line. It does have an outfall system, so it does not rely exclusively on the soil infiltration to handle any of the flood waters. The basin contains mostly HSG A. The HSG B is present as well. The basin handles 4,758 $ft.^3$ of water per minute with 3,646 $ft.^3$ of water per minute infiltrating into the soil and the rest exiting through outfall discharge pipes.

In total, 15 of the 36 storms do not present flooding issues for the basin. There are an additional four storms that do not flood more than one inch at maximum. Two other storms do not have flooding present at the end of the event. Storms that are producing flooding greater than an inch and have flooding at the end of the storm event occur during the 1-hour and 24-hour storm events. The 10 year, 24-hour storm event does not produce flooding at the end of the event. Any flooding that occurs during the 120-hour storm events are insignificant. Additionally, only the 100-year storm event produces concerns for flooding for the 72-hour storm event. Therefore, these longer duration storms do not pose significant concern within this basin. Since the basin does see flooding during the shorter duration storms, it is important to adjust for these rainfall events.

Basin R9, Future Development Conditions

Table 19. Summary of future development conditions for Basin R9 under three rainfall distributions.

Basin R9, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	14,281,540	1.91	14,347,109	1.92
	24	5.18	0.99	1,392,471	0.19	10,834,697	1.45
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	19,563,746	2.61	19,597,431	2.62
	24	7.65	1.46	18,306,084	2.45	26,174,875	3.50
	72	8.84	1.69	-	0.00	1,864,632	0.25
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	21,944,459	2.93	21,963,773	2.93
	24	8.94	1.71	27,314,365	3.65	34,536,260	4.61
	72	10.30	1.97	-	0.00	6,038,962	0.81
100	120	11.47	2.19	-	0.00	-	0.00

Basin R9, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	14,215,971	1.90	14,215,971	1.90
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	19,530,062	2.61	19,530,062	2.61
	24	7.65	1.46	10,437,292	1.39	10,437,292	1.39
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	21,925,145	2.93	21,925,145	2.93
	24	8.94	1.71	20,092,471	2.68	20,092,471	2.68
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R9, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	14,215,971	1.90	14,216,873	1.90
	24	5.18	0.99	-	0.00	11,532,564	1.54
	72	6.08	1.16	-	0.00	1,036,801	0.14
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	19,530,062	2.61	19,530,062	2.61
	24	7.65	1.46	12,514,907	1.67	25,152,414	3.36
	72	8.84	1.69	-	0.00	7,025,437	0.94
50	120	9.81	1.87	-	0.00	1,053,270	0.14
	1	3.19	0.61	21,925,145	2.93	21,925,145	2.93
	24	8.94	1.71	21,317,646	2.85	32,796,531	4.38
	72	10.30	1.97	-	0.00	12,052,118	1.61
100	120	11.47	2.19	-	0.00	4,519,696	0.60

Basin R9 currently has 40 acres of impervious coverage. Under future conditions, the basin can be 23% developed in qualifying areas. This would lead to an additional 24 acres in the basin of impervious coverage. The additional acres have a minor impact on the basin. A little over 2,000,000 gallons of water will be added as runoff under the maximum condition whereas there is less than a 0.3-inch increase in flood depth. The basin has a high outfall discharge of 1,113 $ft.^3$ of water per minute and the soil infiltration only decreases 400 $ft.^3$ of water per minute under these new conditions. Therefore, the basin will perform only marginally worse than current conditions. This is further supported by only one new storm producing significant flooding as well as one new storm with residual water.

Basin R10 Flood Model

Basin R10, Current Conditions

Table 20. Summary of current conditions for Basin R10 udner three rainfall distributions.

Basin R10, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	15,428,417	1.94	15,477,471	1.94
	24	5.18	0.99	5,604,096	0.70	13,804,656	1.73
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	21,050,457	2.64	21,065,575	2.64
	24	7.65	1.46	23,962,198	3.01	30,844,439	3.87
	72	8.84	1.69	-	0.00	4,970,182	0.62
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	23,584,510	2.96	23,584,510	2.96
	24	8.94	1.71	33,550,033	4.21	39,743,758	4.99
	72	10.30	1.97	-	0.00	12,097,919	1.52
100	120	11.47	2.19	-	0.00	-	0.00

Basin R10, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	15,379,363	1.93	15,379,363	1.93
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	21,035,338	2.64	21,035,338	2.64
	24	7.65	1.46	17,079,957	2.14	17,079,957	2.14
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	23,584,510	2.96	23,584,510	2.96
	24	8.94	1.71	27,356,308	3.43	27,356,308	3.43
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R10, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	15,379,363	1.93	15,379,363	1.93
	24	5.18	0.99	587,260	0.07	14,264,911	1.79
	72	6.08	1.16	-	0.00	2,596,298	0.33
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	21,035,338	2.64	21,035,338	2.64
	24	7.65	1.46	18,297,411	2.30	29,259,969	3.67
	72	8.84	1.69	-	0.00	10,463,010	1.31
50	120	9.81	1.87	-	0.00	3,609,023	0.45
	1	3.19	0.61	23,584,510	2.96	23,584,510	2.96
	24	8.94	1.71	28,162,707	3.54	37,892,103	4.76
	72	10.30	1.97	-	0.00	15,813,085	1.99
100	120	11.47	2.19	-	0.00	7,298,463	0.92

Basin R10 is located in the lower mid-eastern section of the Route 9 corridor. It has low levels of development and consists mostly of natural land that is either wetland or forested. The basin also contains several water bodies. Surrounding these artificial lakes are mining operations The elevation change in the basin is gradual and stays relatively similar throughout. There are several high points that are likely results of the mining operation. The soils in the basin consist of HSG A and B. Together, they infiltrate 3,842 $ft.^3$ of water per minute. The outfalls discharge 230 $ft.^3$ of water per minute. The basin can handle 4,072 $ft.^3$ of water per minute between the soil infiltration and outfall discharges.

Basin R10 handles the longer storm events well and has trouble with shorter storm events. The basin produces flooding during 24 storm events, but four of these storms do not have flooding greater than an inch and do not have flooding at the end of the event. Two of these events occur during the 120-hour storm events. These are the only times a 120-hour storm produces any flooding, but since it is not a substantial flood depth, these storms provide no concern for the basin. An additional three do not have flooding at the end of the event but still flood greater than inch. These occur during the 50- and 100-year, 72-hour storm events. These do provide some concern as they are greater than one inch of flood depth at maximum, but they are not too concerning as the flooding is not present at the end of the event. The shorter storms produced flooding and typically had some level of flooding at the end of the event. Management of these storms is critical to ensure that the basin limits the flooding events.

Basin R10, Future Development Conditions

Table 21. Summary of future development conditions for Basin R10 under three rainfall distributions.

Basin R10, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	15,693,136	1.97	15,718,125	1.97
	24	5.18	0.99	10,802,215	1.36	17,270,069	2.17
	72	6.08	1.16	-	0.00	36,709	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	21,324,123	2.68	21,324,123	2.68
	24	7.65	1.46	29,160,317	3.66	34,309,851	4.31
	72	8.84	1.69	-	0.00	11,096,677	1.39
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	23,873,295	3.00	23,873,295	3.00
	24	8.94	1.71	38,804,191	4.87	43,321,250	5.44
	72	10.30	1.97	-	0.00	19,028,745	2.39
100	120	11.47	2.19	-	0.00	4,114,883	0.52

Basin R10, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	15,668,147	1.97	15,668,147	1.97
	24	5.18	0.99	4,334,360	0.54	4,334,360	0.54
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	21,324,123	2.68	21,324,123	2.68
	24	7.65	1.46	24,010,783	3.01	24,010,783	3.01
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	23,873,295	3.00	23,873,295	3.00
	24	8.94	1.71	34,287,133	4.30	34,287,133	4.30
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R10, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	15,668,147	1.97	15,668,147	1.97
	24	5.18	0.99	6,362,948	0.80	16,798,833	2.11
	72	6.08	1.16	-	0.00	4,329,005	0.54
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	21,324,123	2.68	21,324,123	2.68
	24	7.65	1.46	24,650,667	3.09	32,725,381	4.11
	72	8.84	1.69	-	0.00	13,928,423	1.75
50	120	9.81	1.87	-	0.00	6,496,867	0.82
	1	3.19	0.61	23,873,295	3.00	23,873,295	3.00
	24	8.94	1.71	34,515,964	4.33	41,357,516	5.19
	72	10.30	1.97	-	0.00	20,505,671	2.57
100	120	11.47	2.19	-	0.00	11,239,058	1.41

Basin R10 currently has 40 acres of impervious coverage. This is roughly 14% of the developable area of the basin. Future development will allow 27% of development which is an additional 40 acres of impervious coverage. This development will add a little under 4,000,000 gallons of water and 0.5 inches of flooding across the entire basin. Overall, there will be two new storms with significant flooding and one new storm with some residual water left at the end of the event. The basin has very little outfall drainage, so the removal of 700 $ft.^3$ of water per minute with new development increases the impact.

Basin R11 Flood Model

Basin R11, Current Conditions

Table 22. Summary of three rainfall distributions for Basin R11 under courrent conditions.

Basin R11, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	52,588,736	1.91	52,816,674	1.92
	24	5.18	0.99	7,582,351	0.28	41,023,502	1.49
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	71,987,027	2.62	72,097,872	2.62
	24	7.65	1.46	70,004,219	2.55	97,975,696	3.56
	72	8.84	1.69	-	0.00	8,699,141	0.32
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	80,729,919	2.94	80,787,990	2.94
	24	8.94	1.71	103,086,092	3.75	128,681,914	4.68
	72	10.30	1.97	-	0.00	24,842,714	0.90
100	120	11.47	2.19	-	0.00	-	0.00

Basin R11, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	52,360,799	1.90	52,360,799	1.90
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	71,876,182	2.61	71,876,182	2.61
	24	7.65	1.46	42,032,743	1.53	42,032,743	1.53
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	80,671,847	2.93	80,671,847	2.93
	24	8.94	1.71	77,490,269	2.82	77,490,269	2.82
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R11, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	52,360,799	1.90	52,360,799	1.90
	24	5.18	0.99	-	0.00	43,586,339	1.59
	72	6.08	1.16	-	0.00	4,733,282	0.17
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	71,876,182	2.61	71,876,182	2.61
	24	7.65	1.46	49,045,377	1.78	93,912,244	3.42
	72	8.84	1.69	-	0.00	27,651,601	1.01
50	120	9.81	1.87	-	0.00	5,410,928	0.20
	1	3.19	0.61	80,671,847	2.93	80,671,847	2.93
	24	8.94	1.71	81,680,999	2.97	122,292,962	4.45
	72	10.30	1.97	-	0.00	46,111,504	1.68
100	120	11.47	2.19	-	0.00	18,140,975	0.66

Basin R11 is a skinny section of the Route 9 corridor that borders the Garden State Parkway. It is highly developed with urban land covered with impervious cover, but it does contain forested land and wetlands as well. Additionally, it has several lakes present as well. The basin does not contain many outfalls that have identifiable diameters. Those that could have those defined are concentrated in the south of the basin. These outfalls discharge 2,681 $ft.^3$ of water per minute. The soils present are predominantly HSG A. These infiltrate 12,937 $ft.^3$ of water per minute. Together, the basin can handle 15,618 $ft.^3$ of water per minute.

There are 24 storms that cause flooding for the basin. There are five flood events that do not have flooding greater than one inch. An additional four had no flooding present at the end of the storm but did have flooding present at some point of the storm event. The storm events that produced flooding but did not last until the end of the event were typically the 72-hour storm events. Not all 72-hour storm events produced flooding greater than one inch, either. The 120-hour storm events did not produce significant flooding of concern throughout the entire modeling process. Therefore, these long duration storm events are not to be focused on. Alternatively, the short duration storm event do produce flooding that lasts the length of the storms. Adjustments should be made to address these storm types as these are the ones that produce issues.

Basin R11, Future Development Conditions

Table 23. Summary table of rainfall events for Basin R11 under future development conditions.

Basin R11, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	54,089,550	1.97	54,181,050	1.97
	24	5.18	0.99	36,131,932	1.31	58,828,634	2.14
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	73,513,433	2.67	73,513,433	2.67
	24	7.65	1.46	99,474,742	3.62	117,622,711	4.28
	72	8.84	1.69	-	0.00	36,767,931	1.34
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	82,309,099	2.99	82,309,099	2.99
	24	8.94	1.71	132,623,302	4.83	148,462,305	5.40
	72	10.30	1.97	-	0.00	64,136,744	2.33
100	120	11.47	2.19	-	0.00	12,931,288	0.47

Basin R11, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	53,998,050	1.96	53,998,050	1.96
	24	5.18	0.99	13,435,229	0.49	13,435,229	0.49
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	73,513,433	2.67	73,513,433	2.67
	24	7.65	1.46	81,326,773	2.96	81,326,773	2.96
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	82,309,099	2.99	82,309,099	2.99
	24	8.94	1.71	116,784,299	4.25	116,784,299	4.25
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R11, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	53,998,050	1.96	53,998,050	1.96
	24	5.18	0.99	20,688,014	0.75	57,329,352	2.09
	72	6.08	1.16	-	0.00	14,556,789	0.53
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	73,513,433	2.67	73,513,433	2.67
	24	7.65	1.46	83,661,301	3.04	112,155,655	4.08
	72	8.84	1.69	-	0.00	47,298,616	1.72
50	120	9.81	1.87	-	0.00	21,783,440	0.79
	1	3.19	0.61	82,309,099	2.99	82,309,099	2.99
	24	8.94	1.71	117,700,527	4.28	141,939,977	5.16
	72	10.30	1.97	-	0.00	69,232,732	2.52
100	120	11.47	2.19	-	0.00	37,512,544	1.36

The basin currently has 13% of its developable land covered by impervious cover. Under future development, a maximum of 35% can be developed, which if done, will add 223 acres of impervious coverage. The new impervious cover will result in a substantial increase of residual water. Nearly 20,000,000 gallons of water, will now be added to this basin, creating a new total of 148,462,305 gallons for the entire basin. An increase of 0.7 inches flood depth across the entire basin will also be added. The new development will also create three new significant flooding events as well as two new events with water remaining when the storm event ends.

Basin R12 Flood Model

Basin R12, Current Conditions

Table 24. Summary of rainfall events for Basin R12 under current conditions.

Basin R12, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	43,430,623	1.86	43,739,348	1.87
	24	5.18	0.99	-	0.00	23,826,359	1.02
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	59,917,393	2.56	60,126,600	2.57
	24	7.65	1.46	34,657,488	1.48	66,710,575	2.86
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	67,348,050	2.88	67,512,403	2.89
	24	8.94	1.71	62,774,048	2.69	92,808,046	3.97
	72	10.30	1.97	-	0.00	3,862,563	0.17
100	120	11.47	2.19	-	0.00	-	0.00

Basin R12, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	43,121,899	1.85	43,121,899	1.85
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	59,708,186	2.56	59,708,186	2.56
	24	7.65	1.46	2,604,401	0.11	2,604,401	0.11
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	67,183,696	2.88	67,183,696	2.88
	24	8.94	1.71	32,740,050	1.40	32,740,050	1.40
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R12, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	43,121,899	1.85	43,228,785	1.85
	24	5.18	0.99	-	0.00	26,313,347	1.13
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	59,708,186	2.56	59,708,186	2.56
	24	7.65	1.46	14,084,428	0.60	66,395,649	2.84
	72	8.84	1.69	-	0.00	13,796,317	0.59
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	67,183,696	2.88	67,183,696	2.88
	24	8.94	1.71	41,206,512	1.76	89,522,783	3.83
	72	10.30	1.97	-	0.00	23,346,281	1.00
100	120	11.47	2.19	-	0.00	1,618,342	0.07

Basin R12 is located at the southern end of the Route 9 corridor. It has plentiful development, but it also has a considerable amount of forests and wetlands within its boundaries. To its immediate western border, there is almost exclusively wetlands and forested areas. The basin contains mostly HSG A, with some HSG B and very little HSG D. They infiltrate 10,305 $ft.^3$ of water per minute. This infiltration is aided by the plentiful outfall pipes that are present in the basin. They discharge 6,043 $ft.^3$ of water per minute. Together, the basin collectively drains 16,349 $ft.^3$ of water per minute.

The basin has 21 total storms that produce some level of flooding. Only 15 of these have flooding at the end of the event and 16 have flood depths greater than one inch. The longer duration storm events again do not pose significant for this basin. Only the 100-year, 72-hour storm prevents any significant level of flooding and it is exactly one inch. The 120-year storm does not produce anything more than negligible flooding. The shorter storm events flood the basin and do cause concerns. Typically, the 24-hour storm prevents the most issues for this basin.

Basin R12, Future Development Conditions

Basin R12, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	44,164,649	1.89	44,406,644	1.90
	24	5.18	0.99	-	0.00	30,232,400	1.29
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	60,651,419	2.60	60,793,896	2.60
	24	7.65	1.46	49,071,082	2.10	76,319,637	3.27
	72	8.84	1.69	-	0.00	442,746	0.02
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	68,082,075	2.91	68,179,699	2.92
	24	8.94	1.71	77,187,642	3.30	102,417,109	4.38
	72	10.30	1.97	-	0.00	13,471,625	0.58
100	120	11.47	2.19	-	0.00	-	0.00

Basin R12, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	43,922,654	1.88	43,922,654	1.88
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	60,508,941	2.59	60,508,941	2.59
	24	7.65	1.46	21,822,527	0.93	21,822,527	0.93
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	67,984,451	2.91	67,984,451	2.91
	24	8.94	1.71	51,958,175	2.22	51,958,175	2.22
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin R12, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	43,922,654	1.88	43,962,810	1.88
	24	5.18	0.99	-	0.00	32,410,577	1.39
	72	6.08	1.16	-	0.00	547,492	0.02
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	60,508,941	2.59	60,508,941	2.59
	24	7.65	1.46	30,099,532	1.29	74,024,530	3.17
	72	8.84	1.69	-	0.00	18,600,848	0.80
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	67,984,451	2.91	67,984,451	2.91
	24	8.94	1.71	57,221,616	2.45	97,530,336	4.17
	72	10.30	1.97	-	0.00	32,239,827	1.38
100	120	11.47	2.19	-	0.00	9,625,895	0.41

Basin R12 currently has 140 acres of impervious surface, but future conditions permit an additional 109 acres of impervious surface to be added. This will reduce the soil infiltration from 10,305 $ft.^3$ of water per minute to 8,521 $ft.^3$ of water per minute. This basin does have substantial outfall discharge which will lessen the impacts of development. Over 9,000,000 gallons of water will be added as residual water which will increase the flood depth 0.4 inches. Despite the new impervious coverage and substantial volume added, there will only be one new significant flooding for this basin.

Petersburg Flood Models

Basin P1 Flood Model

Basin P1, Current Conditions

Table 25. Summary of Basin P1's current conditions under three rainfall events.

Basin P1, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	19,323,225	1.88	19,438,722	1.89
	24	5.18	0.99	-	0.00	12,424,940	1.21
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	26,573,881	2.59	26,645,612	2.59
	24	7.65	1.46	19,621,364	1.91	32,258,050	3.14
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	29,841,783	2.90	29,893,788	2.91
	24	8.94	1.71	31,986,644	3.11	43,735,363	4.26
	72	10.30	1.97	-	0.00	4,618,351	0.45
100	120	11.47	2.19	-	0.00	-	0.00

Basin P1, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	19,207,727	1.87	19,207,727	1.87
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	26,502,151	2.58	26,502,151	2.58
	24	7.65	1.46	6,984,677	0.68	6,984,677	0.68
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	29,789,778	2.90	29,789,778	2.90
	24	8.94	1.71	20,237,925	1.97	20,237,925	1.97
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P1, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	19,207,727	1.87	19,234,459	1.87
	24	5.18	0.99	-	0.00	13,382,873	1.30
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	26,502,151	2.58	26,502,151	2.58
	24	7.65	1.46	11,060,221	1.08	31,466,407	3.06
	72	8.84	1.69	-	0.00	7,527,256	0.73
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	29,789,778	2.90	29,789,778	2.90
	24	8.94	1.71	22,988,143	2.24	41,803,941	4.07
	72	10.30	1.97	-	0.00	12,872,350	1.25
100	120	11.47	2.19	-	0.00	3,144,765	0.31

Basin P1 is located in the center part of Upper Township. It is lightly developed with areas of wetlands, forest, and barren land. It contains either HSG A or B, allowing for good soil infiltration. The soils infiltrate 5,520 ft.^{3} of water per minute whereas the outfalls discharge 1,127 ft.^{3} of water per minute. In total, the basin can handle 6,648 ft.^{3} of water per minute.

There were a total of 21 modeled storm events that produced flooding. Four of these produced insignificant flooding as they only had under an inch of flooding at maximum and no flooding at the end of the event. Two other storms did not have flooding at the end of the event. The storms that did not have flooding at the end of the event were 72-hour and 120-hour storm events. These events also did not produce sizable flood depths outside the 100-year, 72-hour storm event. Overall, these long duration storm events are handled by the basin due to lack of significant flood depths.

Basin P1, Future Development Conditions

Table 26. Summary of rainfall events for Basin P's future maximum development.

Basin P1, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	19,718,883	1.92	19,798,411	1.93
	24	5.18	0.99	3,922,646	0.38	15,877,952	1.55
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	26,969,539	2.63	27,005,301	2.63
	24	7.65	1.46	27,390,641	2.67	37,437,568	3.64
	72	8.84	1.69	-	0.00	4,067,946	0.40
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	30,237,441	2.94	30,253,477	2.94
	24	8.94	1.71	39,755,921	3.87	48,914,881	4.76
	72	10.30	1.97	-	0.00	10,918,457	1.06
100	120	11.47	2.19	-	0.00	-	0.00

Basin P1, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	19,639,354	1.91	19,639,354	1.91
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	26,933,777	2.62	26,933,777	2.62
	24	7.65	1.46	17,343,714	1.69	17,343,714	1.69
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	30,221,404	2.94	30,221,404	2.94
	24	8.94	1.71	30,596,961	2.98	30,596,961	2.98
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P1, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	19,639,354	1.91	19,639,354	1.91
	24	5.18	0.99	-	0.00	16,835,885	1.64
	72	6.08	1.16	-	0.00	2,177,396	0.21
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	26,933,777	2.62	26,933,777	2.62
	24	7.65	1.46	19,692,751	1.92	35,782,673	3.48
	72	8.84	1.69	-	0.00	11,151,961	1.09
50	120	9.81	1.87	-	0.00	2,702,817	0.26
	1	3.19	0.61	30,221,404	2.94	30,221,404	2.94
	24	8.94	1.71	32,027,298	3.12	46,526,830	4.53
	72	10.30	1.97	-	0.00	18,051,868	1.76
100	120	11.47	2.19	-	0.00	7,461,031	0.73

The basin will allow for a 24% coverage of impervious cover under future conditions. Current conditions show 35 acres of development, which equates to 9% impervious coverage. Future development conditions will lead to an increase of approximately 5,000,000 gallons of water in the basin, translating to exactly 0.5 inches in flood depth. The additional water is from a 1, 000 $ft.^3$ of water per minute reduction in soil drainage. The development will cause three new storms to produce significant flooding and one new storm with residual water at the end of the event.

Basin P2 Flood Model

Basin P2, Current Conditions

Table 27. Summary of rainfall events for Basin P2 as currently developed.

Basin P2, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,760,572	1.80	17,944,687	1.82
	24	5.18	0.99	-	0.00	4,915,268	0.50
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	24,726,797	2.51	24,868,863	2.52
	24	7.65	1.46	3,593,467	0.36	21,543,041	2.18
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	27,866,504	2.82	27,989,618	2.84
	24	8.94	1.71	14,931,770	1.51	31,486,302	3.19
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P2, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,576,457	1.78	17,576,457	1.78
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	24,584,731	2.49	24,584,731	2.49
	24	7.65	1.46	-	0.00	-	0.00
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	27,743,390	2.81	27,743,390	2.81
	24	8.94	1.71	-	0.00	-	0.00
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P2, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,576,457	1.78	17,675,288	1.79
	24	5.18	0.99	-	0.00	8,542,198	0.87
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	24,584,731	2.49	24,613,480	2.49
	24	7.65	1.46	-	0.00	22,902,252	2.32
	72	8.84	1.69	-	0.00	1,965,278	0.20
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	27,743,390	2.81	27,743,390	2.81
	24	8.94	1.71	4,530,700	0.46	31,815,592	3.22
	72	10.30	1.97	-	0.00	6,000,465	0.61
100	120	11.47	2.19	-	0.00	-	0.00

Basin P2 is located in the center of Upper Township and the southern portion of Petersburg. The basin contains mostly urban land with impervious cover and natural area. There is predominantly HSG A within the area. Additionally, there are several outfalls within the basin. These outfalls can handle 3,314 $ft.^3$ of water per minute. The soils infiltrate 5,029 $ft.^3$ of water per minute. This combines to remove 8,340 $ft.^3$ of water per minute from the basin.

The basin only significantly floods for 13 of the 36 storms. There is an additional storm that does not have flooding present at the end of the event. Four storm events produce flooding, but they are insignificant as the flooding does not surpass one inch at maximum. No significant flooding occurred for storm events lasting 72 and 120 hours. This proves that the basin can manage long duration storms. The 24-hour storm did not begin flooding until the 50-year storm. The shortest storm duration of 1-hour flooded in each distribution. Management for this basin should be focused on these short storms.

Basin P2, Future Development Conditions

Table 28. Summary of rainfall events for Basin P2 under future development conditions.

Basin P2, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	18,123,816	1.84	18,274,909	1.85
	24	5.18	0.99	-	0.00	8,085,394	0.82
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	25,090,041	2.54	25,199,084	2.55
	24	7.65	1.46	10,184,344	1.03	25,214,416	2.55
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	28,229,748	2.86	28,319,839	2.87
	24	8.94	1.71	22,064,555	2.24	36,241,492	3.67
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P2, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,972,723	1.82	17,972,723	1.82
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	24,980,997	2.53	24,980,997	2.53
	24	7.65	1.46	-	0.00	-	0.00
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	28,139,656	2.85	28,139,656	2.85
	24	8.94	1.71	7,887,617	0.80	7,887,617	0.80
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P2, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	17,972,723	1.82	18,038,532	1.83
	24	5.18	0.99	-	0.00	10,127,262	1.03
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	24,980,997	2.53	24,980,997	2.53
	24	7.65	1.46	996,007	0.10	26,072,378	2.64
	72	8.84	1.69	-	0.00	4,342,873	0.44
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	28,139,656	2.85	28,139,656	2.85
	24	8.94	1.71	12,456,017	1.26	35,348,870	3.58
	72	10.30	1.97	-	0.00	8,378,060	0.85
100	120	11.47	2.19	-	0.00	-	0.00

Basin P2 currently has 42 acres of impervious coverage on developable area, or 12% of impervious coverage. 14% more, for a total of 52 acres, can be further developed within this basin. This development will reduce soil infiltration by 900 $ft.^3$ of water per minute, resulting in an increase of approximately 4,500,000 gallons of water. This will translate to a 0.45 increase in water depth across the basin as well. Despite the strong influence of outfalls in this basin, substantial water is added into the basin at maximum. However, only one more storm will have significant flooding and two new storms with flooding at the end of the event.

Basin P3 Flood Model

Basin P3, Current Conditions

Table 29. Summary of rainfall events for Basin P3 under current conditions

Basin P3, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	10,733,226	1.90	10,789,144	1.91
	24	5.18	0.99	-	0.00	7,588,775	1.34
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	14,728,758	2.60	14,760,557	2.61
	24	7.65	1.46	12,481,812	2.20	18,888,923	3.34
	72	8.84	1.69	-	0.00	500,330	0.09
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	16,529,560	2.92	16,550,490	2.92
	24	8.94	1.71	19,295,797	3.41	25,213,586	4.45
	72	10.30	1.97	-	0.00	3,657,849	0.65
100	120	11.47	2.19	-	0.00	-	0.00

Basin P3, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	10,677,309	1.89	10,677,309	1.89
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	14,696,958	2.60	14,696,958	2.60
	24	7.65	1.46	6,074,702	1.07	6,074,702	1.07
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	16,508,631	2.92	16,508,631	2.92
	24	8.94	1.71	13,378,008	2.36	13,378,008	2.36
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P3, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	10,677,309	1.89	10,684,311	1.89
	24	5.18	0.99	-	0.00	8,116,651	1.43
	72	6.08	1.16	-	0.00	329,199	0.06
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	14,696,958	2.60	14,696,958	2.60
	24	7.65	1.46	7,949,605	1.40	18,267,204	3.23
	72	8.84	1.69	-	0.00	4,704,389	0.83
50	120	9.81	1.87	-	0.00	38,289	0.01
	1	3.19	0.61	16,508,631	2.92	16,508,631	2.92
	24	8.94	1.71	14,522,581	2.57	23,963,783	4.23
	72	10.30	1.97	-	0.00	8,206,280	1.45
100	120	11.47	2.19	-	0.00	2,660,340	0.47

Basin P3 is located in Petersburg. The basin is high in elevation with a ridge running through the middle of the basin. There is some development, but there is also plentiful natural land as well. The soil types are generally classified as HSG A with HSG B present in small numbers. These soils will infiltrate 3,165 ft.^{3} of water per minute in total. The outfalls will discharge 292 ft.^{3} of water per minute. This amounts to 3,457 ft.^{3} of water per minute that will be handled by the basin.

The basin produces some level of residual water for 24 storm events, but it only has significant flooding for 18 storm events. An additional three storms do not have residual flooding at the end of the storm event. These storms are still significant but pose less of an issue than storms that have residual water at its end. The typical storm lengths that pose significant flooding are the 1- and 24-hour storms. Management should be directed at handling these events. Management for the longer storm durations is not as important. The 72-hour storm is only a concern during the 100-year storm interval. The 120-hour storm does not produce any level of flooding.

Basin P3, Future Development Conditions

Basin P3 has an allowable development percentage of 10%. The basin has passed this threshold and therefore future development conditions have been achieved and future development will only involve footprint replacement. Therefore, the model was not run.

Basin P4 Flood Model

Basin P4, Current Conditions

Table 30. Summary of current conditions for Basin P4 under three rainfall distributions.

Basin P4, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	7,818,977	1.88	7,865,641	1.89
	24	5.18	0.99	-	0.00	5,033,577	1.21
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	10,752,618	2.59	10,781,574	2.59
	24	7.65	1.46	7,953,279	1.91	13,061,324	3.14
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	12,074,823	2.90	12,095,797	2.91
	24	8.94	1.71	12,956,314	3.12	17,705,084	4.26
	72	10.30	1.97	-	0.00	1,878,206	0.45
100	120	11.47	2.19	-	0.00	-	0.00

Basin P4, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	7,772,314	1.87	7,772,314	1.87
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	10,723,662	2.58	10,723,662	2.58
	24	7.65	1.46	2,845,234	0.68	2,845,234	0.68
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	12,053,848	2.90	12,053,848	2.90
	24	8.94	1.71	8,207,544	1.97	8,207,544	1.97
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P4, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	7,772,314	1.87	7,783,062	1.87
	24	5.18	0.99	-	0.00	5,421,160	1.30
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	10,723,662	2.58	10,723,662	2.58
	24	7.65	1.46	4,491,012	1.08	12,739,422	3.06
	72	8.84	1.69	-	0.00	3,050,356	0.73
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	12,053,848	2.90	12,053,848	2.90
	24	8.94	1.71	9,317,090	2.24	16,922,023	4.07
	72	10.30	1.97	-	0.00	5,217,802	1.26
100	120	11.47	2.19	-	0.00	1,280,387	0.31

Basin P4 is located in the southern end of the Petersburg area. It contains some development that is surrounded by natural area. The development is concentrated in higher elevations with the lower elevation being consistent natural areas. The HSG A is the dominant soil condition for the basin. HSG B also exists in the basin. The soils infiltrate 2,329 $ft.^3$ of water per minute where as the outfalls discharge 359 $ft.^3$ of water per minute. This results in 2,688 $ft.^3$ of water per minute that the basin can handle.

There are 17 significant storm events that produce flooding at depths greater than one inch. Six other storms produce flooding less than one inch and these are insignificant storm events. These low flood depths occur only during the 72- and 120-hour storm events. The significant flooding depths only occur during shorter storm durations and the 100-year, 72-hour storm event. Therefore, it is more important to focus on mitigating the effects from the shorter storm events. The storm event that produces the greatest level of flooding occurs during the Gaussian 100-year, 24-hour storm event. Management of this storm should completely eliminate flooding for the basin.

Basin P4, Future Development Conditions

Basin P4 has an allowable development percentage of 6%. The basin has passed this threshold and therefore future development will be in the form of structure replacement not expansion. Therefore, the model was not run.

Basin P5 Flood Model

Basin P5, Current Conditions

Table 31. Summary of current conditions for Basin P5 under three rainfall distributions.

Basin P5, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	5,679,237	1.80	5,739,389	1.81
	24	5.18	0.99	-	0.00	1,465,122	0.46
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	7,911,752	2.50	7,958,427	2.52
	24	7.65	1.46	931,408	0.29	6,793,940	2.15
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	8,917,955	2.82	8,958,557	2.83
	24	8.94	1.71	4,537,545	1.43	9,925,472	3.14
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P5, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	5,619,085	1.78	5,619,085	1.78
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	7,865,076	2.49	7,865,076	2.49
	24	7.65	1.46	-	0.00	-	0.00
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	8,877,353	2.81	8,877,353	2.81
	24	8.94	1.71	-	0.00	-	0.00
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P5, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	5,619,085	1.78	5,651,906	1.79
	24	5.18	0.99	-	0.00	2,682,524	0.85
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	7,865,076	2.49	7,875,436	2.49
	24	7.65	1.46	-	0.00	7,229,536	2.29
	72	8.84	1.69	-	0.00	547,245	0.17
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	8,877,353	2.81	8,877,591	2.81
	24	8.94	1.71	1,176,716	0.37	10,086,056	3.19
	72	10.30	1.97	-	0.00	1,840,430	0.58
100	120	11.47	2.19	-	0.00	-	0.00

The Basin P5 is located in the Petersburg. The elevation is high, and the development is concentrated in higher elevation areas. There is substantial natural area to the left of the urban development. The basin only contains soils that are classified as HSG A. There are also two outfalls located within the basin. The basin can handle 2,704 ft.^{3} of water per minute. The soils remove 1,938 ft.^{3} of water per minute from the basin while the outfalls remove 766 ft.^{3} of water per minute.

Basin P5 produces significant flooding for 13 storm events. A storm event did not have flooding present at the end of the event. Four storm events produced flooding, but the depths were too minimal to be significant. Only the 1-hour storm produced flooding during all storm intervals. The 24-storm interval produced significant flooding during the 50- and 100-storm events. The 72- and 120-hour storm lengths do not produce significant flooding during any storm interval. Consequently, the basin manages longer storms well and management needs to be focused on the shorter storm lengths. These are the only ones that produce flooding. The residual water in the basin may also concentrate in the lower lying natural areas.

Basin P5, Future Development Conditions

Table 32. Summary of rainfall events for Basin P5 under future development conditions.

Basin P5, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	5,716,758	1.81	5,773,499	1.83
	24	5.18	0.99	-	0.00	1,792,576	0.57
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	7,949,272	2.51	7,992,537	2.53
	24	7.65	1.46	1,586,316	0.50	7,121,394	2.25
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	8,955,476	2.83	8,992,667	2.84
	24	8.94	1.71	5,274,317	1.67	10,416,653	3.29
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P5, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	5,660,017	1.79	5,660,017	1.79
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	7,906,008	2.50	7,906,008	2.50
	24	7.65	1.46	-	0.00	-	0.00
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	8,918,285	2.82	8,918,285	2.82
	24	8.94	1.71	131,981	0.04	131,981	0.04
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin P5, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	5,660,017	1.79	5,689,426	1.80
	24	5.18	0.99	-	0.00	2,846,251	0.90
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	7,906,008	2.50	7,912,957	2.50
	24	7.65	1.46	-	0.00	7,556,990	2.39
	72	8.84	1.69	-	0.00	792,836	0.25
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	8,918,285	2.82	8,918,285	2.82
	24	8.94	1.71	1,995,351	0.63	10,413,510	3.29
	72	10.30	1.97	-	0.00	2,086,020	0.66
100	120	11.47	2.19	-	0.00	-	0.00

Basin P5 currently has 6 acres of impervious cover and can add 5 acres under future conditions. The additional acres provide nearly no impact on the drainage system. The soil infiltration only decreases 90 $ft.^3$ of water per minute whereas only 400,000 gallons of residual water are added. The flood depth only increases a tenth of an inch. These minimal changes show that future development will not greatly affect the basin. Additionally, this basin sees no new significant flooding events with development and only one storm will have flooding at the end of the event.

Tuckahoe Flood Models

Basin T1 Flood Model

Basin T1, Current Conditions

Table 33. Summary of rainfall events under the current conditions of Basin T1.

Basin T1, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,544,973	1.94	13,588,483	1.94
	24	5.18	0.99	4,828,886	0.69	12,061,798	1.72
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	18,482,417	2.64	18,496,124	2.64
	24	7.65	1.46	20,951,522	2.99	27,026,645	3.86
	72	8.84	1.69	-	0.00	4,303,097	0.62
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	20,707,744	2.96	20,708,018	2.96
	24	8.94	1.71	29,371,847	4.20	34,842,295	4.98
	72	10.30	1.97	-	0.00	10,501,024	1.50
100	120	11.47	2.19	-	0.00	-	0.00

Basin T1, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,501,462	1.93	13,501,462	1.93
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	18,468,710	2.64	18,468,710	2.64
	24	7.65	1.46	14,876,399	2.13	14,876,399	2.13
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	20,707,469	2.96	20,707,469	2.96
	24	8.94	1.71	23,901,398	3.42	23,901,398	3.42
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin T1, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,501,462	1.93	13,501,462	1.93
	24	5.18	0.99	412,640	0.06	12,486,628	1.78
	72	6.08	1.16	-	0.00	2,249,214	0.32
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	18,468,710	2.64	18,468,710	2.64
	24	7.65	1.46	15,965,022	2.28	25,644,225	3.67
	72	8.84	1.69	-	0.00	9,127,064	1.30
50	120	9.81	1.87	-	0.00	3,117,997	0.45
	1	3.19	0.61	20,707,469	2.96	20,707,469	2.96
	24	8.94	1.71	24,619,913	3.52	33,216,116	4.75
	72	10.30	1.97	-	0.00	13,825,660	1.98
100	120	11.47	2.19	-	0.00	6,358,175	0.91

Basin T1 is directly above the Petersburg area of Upper Township. The basin contains higher elevations to the left and lower elevations to its right. The basin has low levels of development with more natural areas in the form of wetlands and forests. The basin contains several outfall pipes that discharge 499 $ft.^3$ of water per minute. Soils are classified as either HSG A or B and are present in nearly identical areas. The soils can infiltrate a total 3,587 $ft.^3$ of water per minute.

The basin produces flooding for 24 total storm events, but only 20 of these are significant. The 1-hour and 24-hour storm events are most concerning for the basin. Both produce flooding during all storm lengths and intervals. The 72-hour storm event produces flooding during the 50- and 100-year storm intervals. This means that the stormwater system must be upgraded to mitigate impacts from the 1-, 24-, and 72-hour storms. The 120-hour storm does not produce any significant issues. The residual water from the storms that produce significant flooding will likely move into the more natural areas that are to the right of the basin.

Basin T1, Future Development Conditions

Table 34. Summary of rainfall events under the future development conditions of Basin T1.

Basin T1, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,598,687	1.94	13,637,315	1.95
	24	5.18	0.99	5,883,645	0.84	12,764,970	1.82
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	18,536,131	2.65	18,544,955	2.65
	24	7.65	1.46	22,006,281	3.15	27,729,818	3.96
	72	8.84	1.69	-	0.00	5,006,270	0.72
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	20,766,067	2.97	20,766,067	2.97
	24	8.94	1.71	30,426,605	4.35	35,545,467	5.08
	72	10.30	1.97	-	0.00	11,907,369	1.70
100	120	11.47	2.19	-	0.00	-	0.00

Basin T1, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,560,060	1.94	13,560,060	1.94
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	18,527,307	2.65	18,527,307	2.65
	24	7.65	1.46	16,282,745	2.33	16,282,745	2.33
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	20,766,067	2.97	20,766,067	2.97
	24	8.94	1.71	25,307,744	3.62	25,307,744	3.62
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin T1, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,560,060	1.94	13,560,060	1.94
	24	5.18	0.99	1,584,595	0.23	12,955,410	1.85
	72	6.08	1.16	-	0.00	2,600,801	0.37
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	18,527,307	2.65	18,527,307	2.65
	24	7.65	1.46	17,245,064	2.46	26,338,289	3.76
	72	8.84	1.69	-	0.00	9,830,236	1.41
50	120	9.81	1.87	-	0.00	3,703,975	0.53
	1	3.19	0.61	20,766,067	2.97	20,766,067	2.97
	24	8.94	1.71	25,909,063	3.70	33,919,288	4.85
	72	10.30	1.97	-	0.00	14,528,833	2.08
100	120	11.47	2.19	-	0.00	6,944,152	0.99

Basin T1 has 7% of the potential 11% developed within its basin. If the basin is built out, it will add an additional 10 acres of impervious cover to the developable land. These increases will have very minimal impact on the basin as a whole. The soil infiltration reduces 130 $ft.^3$ of water per minute with new development. The residual water added is 800,000 gallons of water at maximum, but this increase is only a tenth of an inch across the entire basin. Subsequently, the basin performs similarly to pre-development. The number of storms that produce significant flooding does not change under the future conditions.

Basin T2 Flood Model

Basin T2, Current Conditions

Table 35. Summary of rainfall events for Basin T2 under current development conditions.

Basin T2, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,411,976	1.99	13,421,099	1.99
	24	5.18	0.99	11,737,989	1.74	16,345,490	2.42
	72	6.08	1.16	-	0.00	1,762,414	0.26
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	18,189,008	2.70	18,189,008	2.70
	24	7.65	1.46	27,272,836	4.05	30,764,759	4.56
	72	8.84	1.69	-	0.00	12,852,841	1.91
50	120	9.81	1.87	-	0.00	2,108,281	0.31
	1	3.19	0.61	20,346,148	3.02	20,346,148	3.02
	24	8.94	1.71	35,722,157	5.30	38,967,429	5.78
	72	10.30	1.97	2,816,673	0.42	19,565,053	2.90
100	120	11.47	2.19	-	0.00	6,397,576	0.95

Basin T2, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,402,854	1.99	13,402,854	1.99
	24	5.18	0.99	7,130,488	1.06	7,130,488	1.06
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	18,189,008	2.70	18,189,008	2.70
	24	7.65	1.46	23,780,913	3.53	23,780,913	3.53
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	20,346,148	3.02	20,346,148	3.02
	24	8.94	1.71	32,476,885	4.82	32,476,885	4.82
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin T2, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,402,854	1.99	13,402,854	1.99
	24	5.18	0.99	8,269,987	1.23	15,658,167	2.32
	72	6.08	1.16	-	0.00	4,959,296	0.74
10	120	6.65	1.27	-	0.00	982,803	0.15
	1	2.87	0.55	18,189,008	2.70	18,189,008	2.70
	24	7.65	1.46	24,033,833	3.57	29,423,961	4.36
	72	8.84	1.69	-	0.00	13,925,479	2.07
50	120	9.81	1.87	-	0.00	7,267,129	1.08
	1	3.19	0.61	20,346,148	3.02	20,346,148	3.02
	24	8.94	1.71	32,476,885	4.82	36,918,416	5.48
	72	10.30	1.97	-	0.00	20,814,846	3.09
100	120	11.47	2.19	-	0.00	12,396,209	1.84

Basin T2 is located on the bank of the Tuckahoe river and is the most developed of the basins in Tuckahoe. The basin still contains substantial natural area that is mostly wetlands. There are no confirmed outfalls within the basin causing it to rely completely on the natural infiltration of the soils. The soils are classified as HSG B mostly, but HSG A also has a substantial level in the basin. HSG D exists in very small quantities. In total, the basin can handle 2,580 $ft.^3$ of water per minute.

There are 29 storms that produced flooding events. Five of these were insignificant because they did not have flooding greater than an inch. Another five storms did not have flooding present at the end of the storm event, but they are still important to note for management purposes. These storms that do not have flooding present at the end of the event are the 72- and 120-hour storm events. These storm lengths do not pose flooding issues under the 10-year storm interval. The 1- and 24-hour storm intervals produce flooding concerns for all storm intervals and distributions. Management should be concentrated on these storm events, but the other storm events must be addressed as well.

Basin T2, Future Development Conditions

Table 36. Summary of rainfall events for Basin T2's potential future development.

Basin T2, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,524,742	2.01	13,524,742	2.01
	24	5.18	0.99	13,931,979	2.07	17,808,151	2.64
	72	6.08	1.16	-	0.00	3,225,074	0.48
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	18,310,897	2.72	18,310,897	2.72
	24	7.65	1.46	29,663,960	4.40	32,621,686	4.84
	72	8.84	1.69	390,232	0.06	15,778,162	2.34
50	120	9.81	1.87	-	0.00	4,546,048	0.67
	1	3.19	0.61	20,468,037	3.04	20,468,037	3.04
	24	8.94	1.71	38,159,924	5.66	40,917,643	6.07
	72	10.30	1.97	8,839,421	1.31	22,834,587	3.39
100	120	11.47	2.19	-	0.00	11,273,110	1.67

Basin T2, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,524,742	2.01	13,524,742	2.01
	24	5.18	0.99	10,055,808	1.49	10,055,808	1.49
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	18,310,897	2.72	18,310,897	2.72
	24	7.65	1.46	26,706,234	3.96	26,706,234	3.96
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	20,468,037	3.04	20,468,037	3.04
	24	8.94	1.71	35,402,205	5.25	35,402,205	5.25
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin T2, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	13,524,742	2.01	13,524,742	2.01
	24	5.18	0.99	10,730,968	1.59	16,900,264	2.51
	72	6.08	1.16	-	0.00	6,421,956	0.95
10	120	6.65	1.27	-	0.00	2,201,687	0.33
	1	2.87	0.55	18,310,897	2.72	18,310,897	2.72
	24	7.65	1.46	26,715,377	3.96	30,886,622	4.58
	72	8.84	1.69	-	0.00	16,850,800	2.50
50	120	9.81	1.87	-	0.00	9,704,896	1.44
	1	3.19	0.61	20,468,037	3.04	20,468,037	3.04
	24	8.94	1.71	35,402,205	5.25	38,868,629	5.77
	72	10.30	1.97	332,409	0.05	23,740,166	3.52
100	120	11.47	2.19	-	0.00	14,833,976	2.20

Basin T2 can increase the area of impervious cover from 14% to 22%, adding a total of 21 new acres of impervious development. The future maximum residual water will increase about 2,000,000 gallons with a 0.3-inch increase over the basin. The basin infiltration is reduced by nearly 300 $ft.^3$ per minute of water. The difference in performance is minimal at first, but it does add a significant amount of residual water. There will be one new significant flooding event with two new storms that have flooding at the end of the event with increased development.

Basin T3 Flood Model

Basin T3, Current Conditions

Table 37. Summary of current conditions for Basin T3 under three rainfall distributions.

Basin T3, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	12,213,438	1.97	12,233,006	1.97
	24	5.18	0.99	8,382,407	1.35	13,425,149	2.17
	72	6.08	1.16	-	0.00	11,582	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	16,596,192	2.68	16,596,192	2.68
	24	7.65	1.46	22,671,416	3.66	26,688,046	4.30
	72	8.84	1.69	-	0.00	8,603,106	1.39
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	18,580,338	3.00	18,580,338	3.00
	24	8.94	1.71	30,174,883	4.87	33,696,394	5.43
	72	10.30	1.97	-	0.00	14,777,022	2.38
100	120	11.47	2.19	-	0.00	3,174,498	0.51

Basin T3, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	12,193,870	1.97	12,193,870	1.97
	24	5.18	0.99	3,339,664	0.54	3,339,664	0.54
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	16,596,192	2.68	16,596,192	2.68
	24	7.65	1.46	18,654,786	3.01	18,654,786	3.01
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	18,580,338	3.00	18,580,338	3.00
	24	8.94	1.71	26,653,373	4.30	26,653,373	4.30
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin T3, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	12,193,870	1.97	12,193,870	1.97
	24	5.18	0.99	4,924,277	0.79	13,061,195	2.11
	72	6.08	1.16	-	0.00	3,360,981	0.54
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	16,596,192	2.68	16,596,192	2.68
	24	7.65	1.46	19,155,671	3.09	25,454,775	4.11
	72	8.84	1.69	-	0.00	10,824,183	1.75
50	120	9.81	1.87	-	0.00	5,042,671	0.81
	1	3.19	0.61	18,580,338	3.00	18,580,338	3.00
	24	8.94	1.71	26,834,314	4.33	32,173,588	5.19
	72	10.30	1.97	-	0.00	15,926,586	2.57
100	120	11.47	2.19	-	0.00	8,719,591	1.41

Basin T3 is located on the Tuckahoe river front. It is a mostly natural basin with ample wetlands, but there is substantial development right along the edge of the river. The development is generally in the higher elevation areas. There are no confirmed outfalls in the basin. Therefore, the basin relies on the soil infiltration to address stormwater runoff and flooding. There are more HSG B than HSG A, but they are similar in area. The HSG D has a small area within the basin too. These soils can handle 2,672 $ft.^3$ of water per minute.

Basin T3 produces flooding in 27 of the 36 storm events. There are five of these do not flood greater than one inch, making them insignificant. The model generates significant flooding for the 1- and 24-hour storm lengths. The 120-hour storm interval only proposes issues for the 100-year storm interval whereas the 72-hour storm floods during all but the 10-year storm interval. The greatest flooding occurred during the 100-year, 24-hour storm event. As this is the worst modeled flooding, managing this storm should alleviate all other storm flooding. While the water in this basin may flow to the river, the river level may rise due to the input of stormwater. This may compound flooding for this basin's development.

Basin T3, Future Development Conditions

Table 38. Summary of rainfall events for Basin T3's potential future development.

Basin T3, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	12,263,279	1.98	12,278,316	1.98
	24	5.18	0.99	9,361,107	1.51	14,077,616	2.27
	72	6.08	1.16	-	0.00	664,049	0.11
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	16,650,564	2.69	16,650,564	2.69
	24	7.65	1.46	23,650,116	3.81	27,340,513	4.41
	72	8.84	1.69	-	0.00	9,908,039	1.60
50	120	9.81	1.87	-	0.00	344,162	0.06
	1	3.19	0.61	18,634,710	3.01	18,634,710	3.01
	24	8.94	1.71	31,262,328	5.04	34,566,350	5.57
	72	10.30	1.97	-	0.00	16,081,956	2.59
100	120	11.47	2.19	-	0.00	4,261,943	0.69

Basin T3, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	12,248,242	1.98	12,248,242	1.98
	24	5.18	0.99	4,644,598	0.75	4,644,598	0.75
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	16,650,564	2.69	16,650,564	2.69
	24	7.65	1.46	19,959,720	3.22	19,959,720	3.22
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	18,634,710	3.01	18,634,710	3.01
	24	8.94	1.71	27,958,306	4.51	27,958,306	4.51
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin T3, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	12,248,242	1.98	12,248,242	1.98
	24	5.18	0.99	6,011,722	0.97	13,604,918	2.19
	72	6.08	1.16	-	0.00	3,687,215	0.59
10	120	6.65	1.27	-	0.00	106,465	0.02
	1	2.87	0.55	16,650,564	2.69	16,650,564	2.69
	24	7.65	1.46	20,351,861	3.28	26,107,242	4.21
	72	8.84	1.69	-	0.00	11,476,650	1.85
50	120	9.81	1.87	-	0.00	5,586,393	0.90
	1	3.19	0.61	18,634,710	3.01	18,634,710	3.01
	24	8.94	1.71	28,030,504	4.52	32,826,055	5.29
	72	10.30	1.97	-	0.00	17,231,520	2.78
100	120	11.47	2.19	-	0.00	9,807,036	1.58

Basin T3, according to zoning restrictions, can add 9 acres of impervious coverage to its developable area. The basin currently has 7% impervious coverage but can increase it to 11%. The increase in impervious coverage produces minimal impacts on the basin. There is an approximate 900,000-gallon increase in the residual water whereas the flood depth only increases 0.14 inches. The basin is nearly identical in performance to the current conditions. This is further shown with no new storms producing significant flooding or having flooding at the end of the event.

Basin T4 Flood Model

Basin T4, Current Conditions

Table 39. Summary of rainfall events under the current conditions of Basin T4.

Basin T4, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	4,833,060	2.03	4,833,060	2.03
	24	5.18	0.99	5,789,521	2.43	6,874,253	2.88
	72	6.08	1.16	-	0.00	2,239,934	0.94
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	6,526,479	2.74	6,526,479	2.74
	24	7.65	1.46	11,451,324	4.80	12,306,669	5.16
	72	8.84	1.69	2,459,080	1.03	6,783,947	2.84
50	120	9.81	1.87	-	0.00	3,209,510	1.35
	1	3.19	0.61	7,289,710	3.06	7,289,710	3.06
	24	8.94	1.71	14,457,334	6.06	15,241,913	6.39
	72	10.30	1.97	5,708,012	2.39	9,799,569	4.11
100	120	11.47	2.19	-	0.00	5,900,077	2.47

Basin T4, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	4,833,060	2.03	4,833,060	2.03
	24	5.18	0.99	4,704,789	1.97	4,704,789	1.97
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	6,526,479	2.74	6,526,479	2.74
	24	7.65	1.46	10,595,980	4.44	10,595,980	4.44
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	7,289,710	3.06	7,289,710	3.06
	24	8.94	1.71	13,672,755	5.73	13,672,755	5.73
	72	10.30	1.97	1,616,456	0.68	1,616,456	0.68
100	120	11.47	2.19	-	0.00	-	0.00

Basin T4, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	4,833,060	2.03	4,833,060	2.03
	24	5.18	0.99	4,848,098	2.03	6,553,028	2.75
	72	6.08	1.16	-	0.00	2,845,633	1.19
10	120	6.65	1.27	-	0.00	1,256,860	0.53
	1	2.87	0.55	6,526,479	2.74	6,526,479	2.74
	24	7.65	1.46	10,595,980	4.44	11,686,305	4.90
	72	8.84	1.69	-	0.00	7,108,967	2.98
50	120	9.81	1.87	-	0.00	4,389,484	1.84
	1	3.19	0.61	7,289,710	3.06	7,289,710	3.06
	24	8.94	1.71	13,672,755	5.73	14,519,121	6.09
	72	10.30	1.97	2,984,814	1.25	9,599,353	4.02
100	120	11.47	2.19	-	0.00	6,392,309	2.68

Basin T4 is located along the Tuckahoe river front. It is sparsely developed and contains mostly forests or wetlands. The basin is lower in elevation than the other Tuckahoe basins discussed to this point. There are no confirmed outfalls in this basin. The soils are HSG B mostly but do contain classifications with HSG B and D. They drain 710 $ft.^3$ of water per minute.

Basin T4 produces flooding during 30 of the 36 storm events with 27 being significant. Five do not last to the end of the storm, but they do produce significant flood depths and are still important. All storm lengths produce significant flooding during all storm intervals except the 10-year, 120-hour storm event. The flood depths for the 24 and 72-hour storms are greater than the 1-hour storm event for the 50- and 100-year storm intervals. This makes management of the 24- and 72-hour storms more important than the 1-hour storm events. The basin can utilize an upgraded stormwater system to mitigate the flood impacts it sees.

Basin T4, Future Development Conditions

Basin T4 has an allowable development percentage of 6%. The basin has passed this threshold at 7 %. Subsequently, future development conditions have already been evaluated and the model was not run.

Basin T5 Flood Model

Basin T5, Current Conditions

Table 40. Summary of rainfall events under the current conditions of Basin T5

Basin T5, Gaussian							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	6,751,958	1.91	6,782,445	1.92
	24	5.18	0.99	751,336	0.21	5,165,077	1.46
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	9,247,272	2.62	9,262,697	2.62
	24	7.65	1.46	8,753,018	2.48	12,435,160	3.52
	72	8.84	1.69	-	0.00	951,001	0.27
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	10,371,920	2.93	10,380,557	2.94
	24	8.94	1.71	13,008,530	3.68	16,385,077	4.63
	72	10.30	1.97	-	0.00	2,922,955	0.83
100	120	11.47	2.19	-	0.00	-	0.00

Basin T5, Steady State							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	6,721,470	1.90	6,721,470	1.90
	24	5.18	0.99	-	0.00	-	0.00
	72	6.08	1.16	-	0.00	-	0.00
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	9,231,846	2.61	9,231,846	2.61
	24	7.65	1.46	5,070,876	1.43	5,070,876	1.43
	72	8.84	1.69	-	0.00	-	0.00
50	120	9.81	1.87	-	0.00	-	0.00
	1	3.19	0.61	10,363,283	2.93	10,363,283	2.93
	24	8.94	1.71	9,631,982	2.72	9,631,982	2.72
	72	10.30	1.97	-	0.00	-	0.00
100	120	11.47	2.19	-	0.00	-	0.00

Basin T5, Deluge							
Storm Interval (Years)	Storm Length (Hours)	Total Rainfall (In.)	Maximum Rainfall per Time Interval (In.)	Residual Water at the End of Rain Event (Gallons)	Flood Depth at the End of Rain Event (In.)	Maximum Residual Water (Gallons)	Maximum Flood Depth (In.)
	1	2.16	0.41	6,721,470	1.90	6,721,470	1.90
	24	5.18	0.99	-	0.00	5,494,749	1.55
	72	6.08	1.16	-	0.00	524,860	0.15
10	120	6.65	1.27	-	0.00	-	0.00
	1	2.87	0.55	9,231,846	2.61	9,231,846	2.61
	24	7.65	1.46	6,028,958	1.71	11,940,457	3.38
	72	8.84	1.69	-	0.00	3,388,966	0.96
50	120	9.81	1.87	-	0.00	556,023	0.16
	1	3.19	0.61	10,363,283	2.93	10,363,283	2.93
	24	8.94	1.71	10,199,063	2.88	15,563,230	4.40
	72	10.30	1.97	-	0.00	5,763,570	1.63
100	120	11.47	2.19	-	0.00	2,193,562	0.62

Basin T5 is located on the Tuckahoe River where it begins to open up. It is sparsely developed except for a small development along the river front. It is dominated by wetlands and barren land. Development is focused in the higher elevation areas whereas the wetlands are lower in elevation. The soil classifications are exclusively HSG A. These soils will infiltrate 2,040 $ft.^3$ of water per minute. There are no confirmed

Basin T5 produces some level of flooding for 24 storm events. Six of these do not present flooding issues as they do not surpass flood depths over the whole basin greater than one inch. The 1-and 24-hour storm flooded during all storm intervals. The 72-hour storm event only flooded during the 100-year storm interval. The data shows that improvments must be made to the stormwater system to address the 1-hour and 24-hour storm events. The longer duration storms do not present issues. Additional flooding may occur along the river front as the river's water level rises with stormwater inputs. It will be important to prepare for this rise.

Basin T5, Future Development Conditions

Basin T5 has an allowable development percentage of 5%. The basin has passed this threshold as it is currently 6.5%. Therefore, future development conditions have already been evaluated and the model was not run.

Discussion on Current Mangagment of Stormwater up to and including the 100-year storm event

To determine priority for adjusting for the potential flooding in each basin, the basins must be compared. The total maximum residual water is important to evaluate to determine what basin is contributing the most runoff and flooding to the township. These are most often going to be the largest basins as they will have more area and more runoff subsequently.

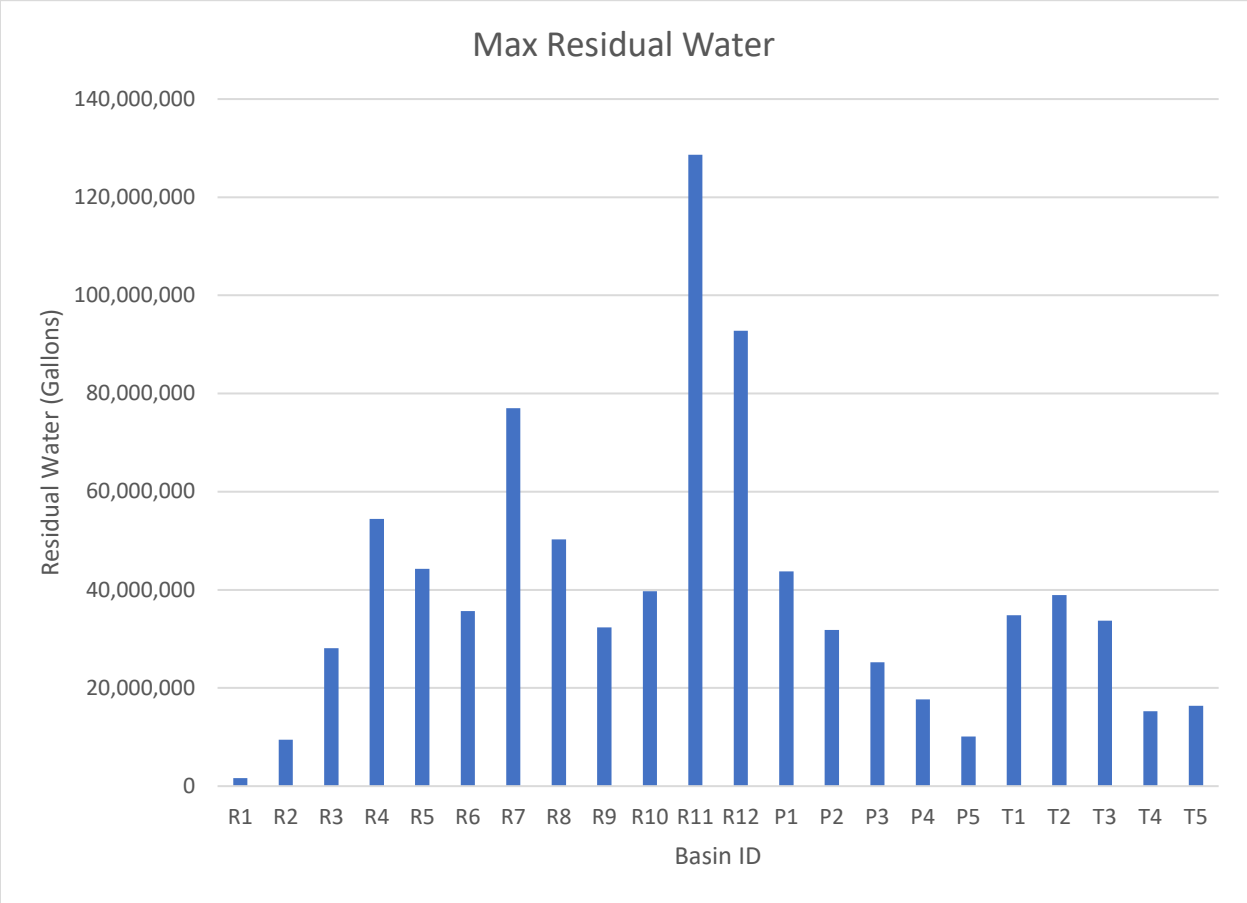


Figure 33. The Route 9 corridor has the basins with the most residual water. Of these, R11 and R12 produce substantially more than any other basin. To reduce total residual water for the township, these basins must have adjustments. Basins R4 and R7 are also important to focus on.

It is also important to consider the size of the basin when determining the priority basins. This number is generated from dividing the maximum residual water by the area of the basin. Basins T4, R4, and T2 are the basins with the greatest level of concern. These areas will have the greatest risk for property damage and overall flooding. Conversely, Basins R12, P2, and P5 are the three least concerning basins as they have the lowest flood depths. All other basins perform relatively similar to one another.

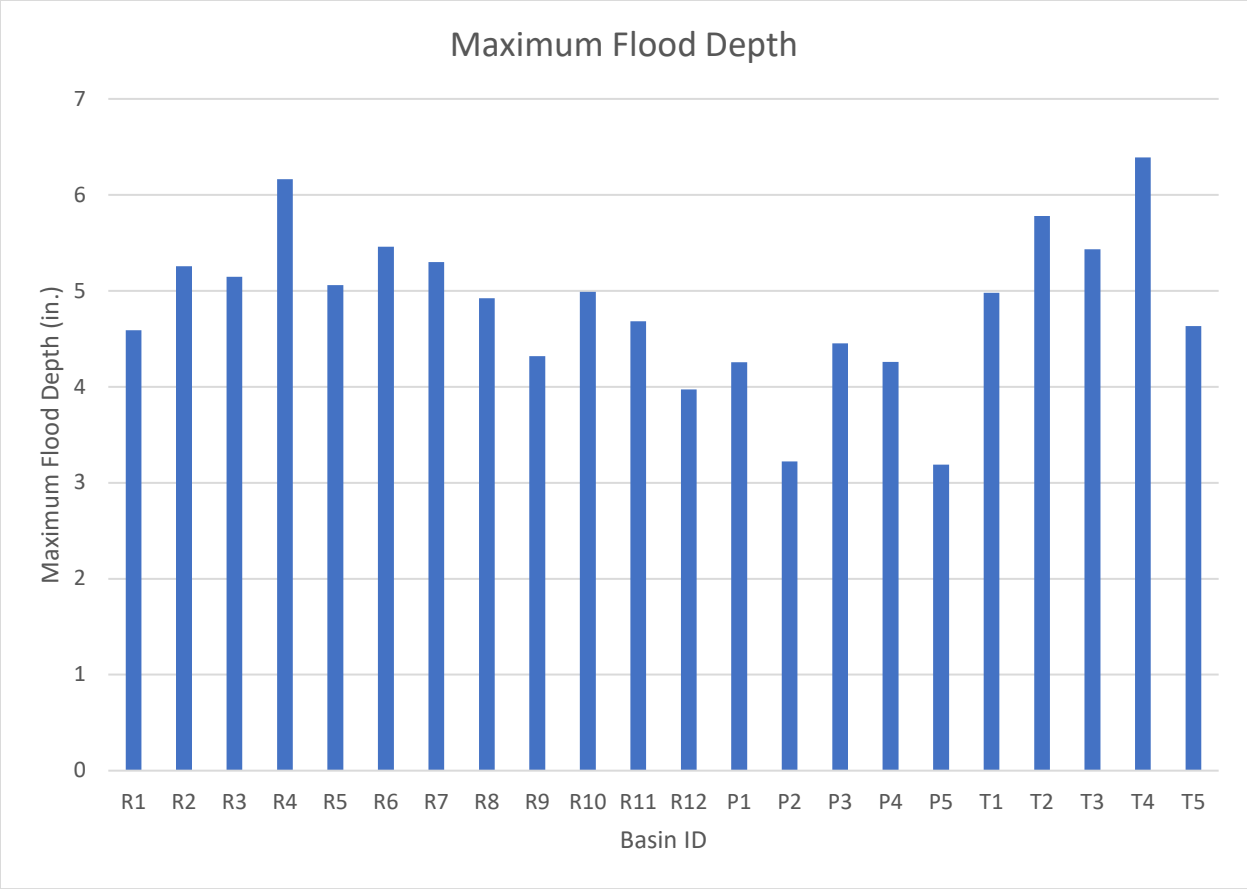


Figure 34. Summary of the flood depths for the individual basins. These flood depths are the maximum that occur during any storm interval and distribution.

To confirm the modeling results, a more detailed flood study should be conducted. Flooding may concentrate within select areas of each basin due to their unique elevations. Low-lying areas may face more significant flooding than the maximum flood depth while the higher elevations may face no flooding. The water may also move quickly into the surrounding waterways and wetlands that causes a reduced flooding impact. Conversely, water in these areas may increase the water level of the sea, bays, or rivers. The impacts or a rising water level may compound issues and should be studied as well.

Several actions can be taken to curb flooding within priority basins. The easiest way to address the stormwater concerns is to improve existing and add additional stormwater infrastructure such as outfalls. Several outfalls were under mean sea level, buried, or did not have existing data. Before any additions are undertaken, Upper Township must complete a more thorough review of its inlets, outfalls, and pipes to quantify the issues. The inclusion of all municipal drainage infrastructure would improve the accuracy of the modeling, but the information was not accessible.

Grey infrastructure is not the only way Upper Township can improve its stormwater system. Green infrastructure, which is not calculated in this model, can be used to reduce flooding as well. This may come in the form of rain barrels, rain gardens, and permeable pavement that allows for additional water to be infiltrated. To properly model any new green infrastructure, GIS layers or volumetric figures must be produced to determine the size and effectiveness of these practices.

Discussion on the Future Development Impacts of the Stormwater System

The graph below demonstrates that the greatest increase of maximum residual water is within Basin R11. Development will, therefore, affect the total water the most for this basin. To minimize volumetric increases due to future development, this basin should either be developed last. Alternatively, adding to the stormwater system will allow for substantially more development to take place if done properly. Particular attention should also be paid to Basins R4, R7, and R12 as they have large increases of water volume with development.

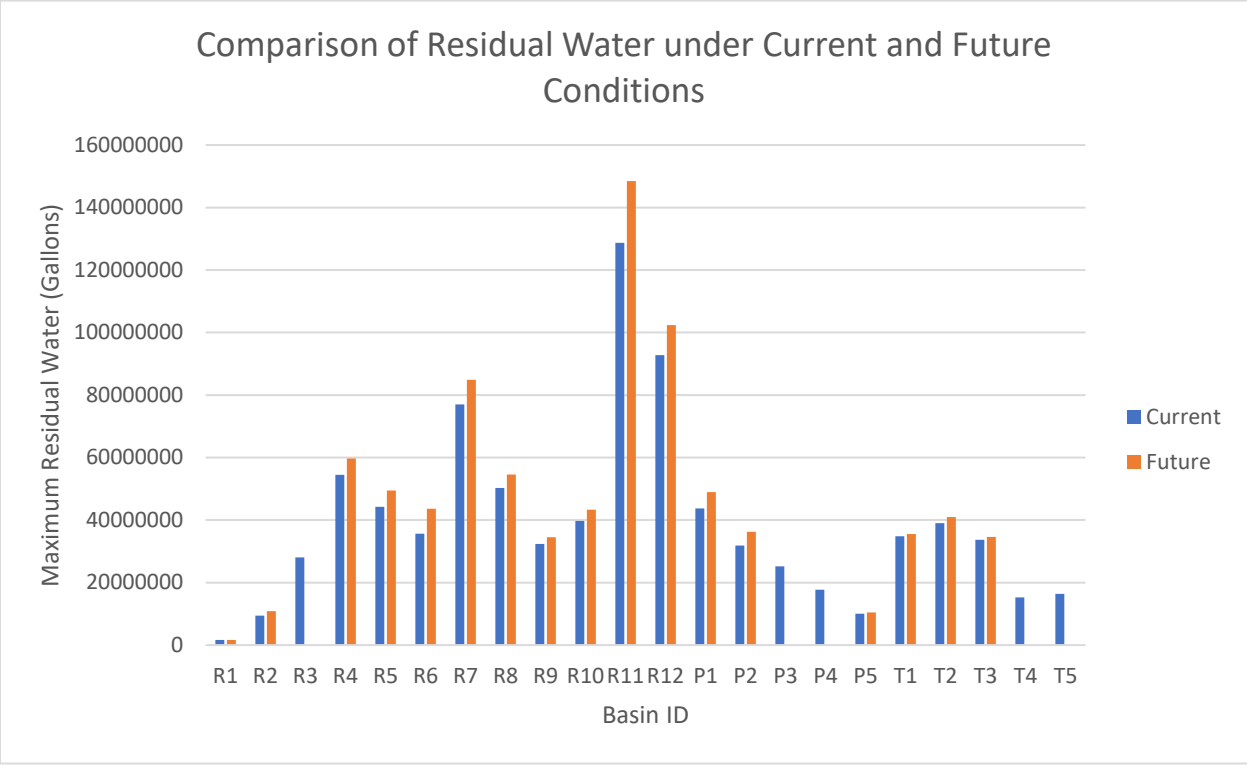


Figure 35. The maximum residual water for all storm events for both current and future conditions are shown.

To compare the basins via impact by area, the flood depths are compared. Basin R6 sees the most substantial rise in flood depth. The impacts will be greater felt for this area as the water per area is greatest. Conversely, Basin P5, T1, and T3 see almost no change in their flood depths. Therefore, the flood depth is not going to change with new development.

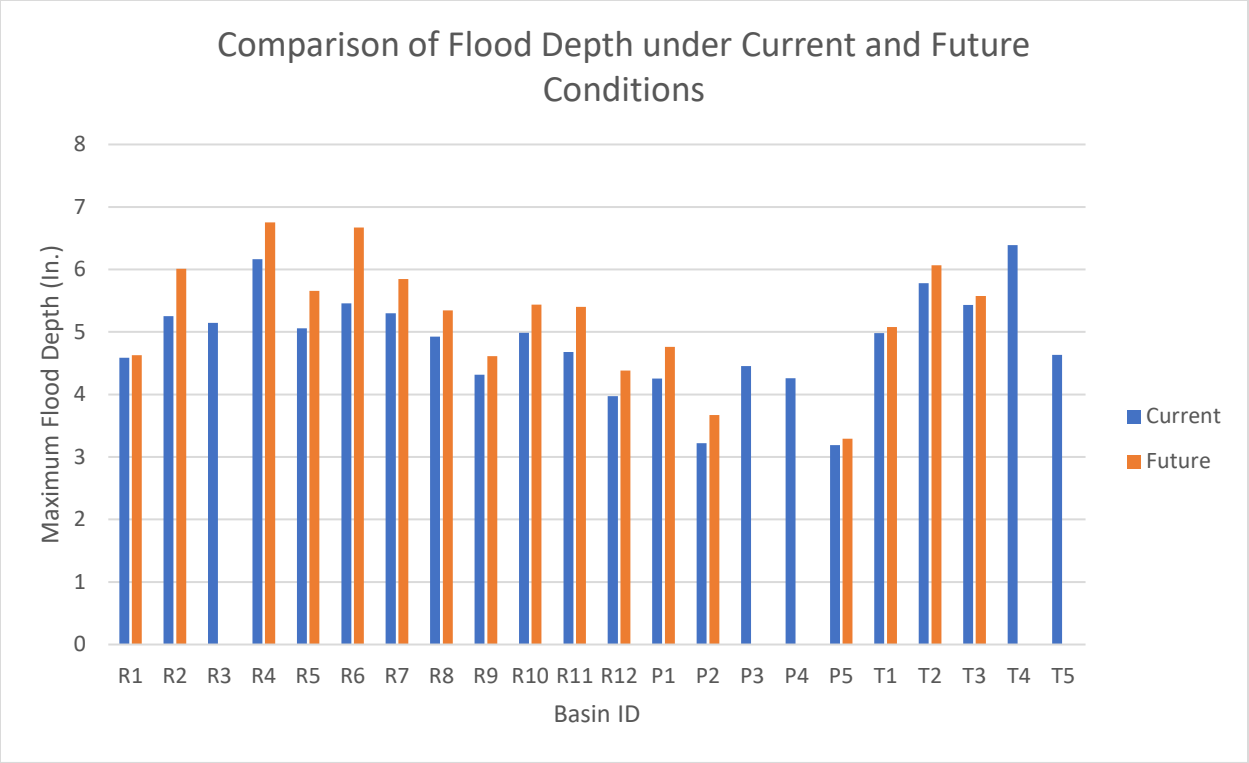


Figure 34. The maximum flood depth for all storm events for both current and future conditions are shown.

To mitigate impacts of new development, stormwater systems should be updated and added to. Supplementing gray infrastructure with green infrastructure, such as rain barrels, rain gardens, or permeable pavement would be ideal. However, before any development in any of the basins takes place, it is advised that the stormwater systems are updated to handle the storms discussed in this report. Careful detail should then be taken to ensure that development does not surpass what the stormwater system can manage. For future FEMA CRS documentation, updating the outfall data to include slope, outfall diameter, and pipe material will give a better picture of stormwater system. This in turn will likely reduce the impacts of the storm events. Additionally, any green infrastructure data will also aid modeling purposes.

WMP5

The plan identifies existing natural open space to be preserved from development so that natural storage of runoff is maintained.

Page 39-41 in the WMP identify the location of wetlands and natural open space area. N.J.A.C. 7:7A Freshwater Wetlands Protection Act Rules regulate and prevent disturbance of the freshwater wetlands and prohibits development which provide natural attenuation, retention and detention of runoff.

WMP6

The plan prohibits development, alteration, or modification of existing natural channels.

Section Code 19-7.7 (m) 1 states:

Nonstructural Stormwater Management Strategies.
1. *To the maximum extent practicable, the performance standards in Subsection* ***19-7.7m*** *through* ***q*** *for major development shall be met by incorporating the nine nonstructural strategies identified in Subchapter 5 of the NJ Stormwater Management Rules (N.J.A.C. 7:8-5), and set forth in Subsection* ***19-7.7i4(a)****, into the design. The applicant shall identify within the Land Use Planning and Source Control Plan required by Subsection 19-7.7i4 how each of the nine nonstructural measures will be incorporated into the design of the project to the maximum extent practicable*

From N.J.A.C. 7:9B-1.4, Upper Township has adopted the following as § 19-7.7e {54} et cetera; "Special Water Resource Protection Areas" The adopted language below shows that the City is compliant with the WMP-6 standards.

Special water resource protection areas shall be established along all waters designated Category One at N.J.A.C. 7:9B, and perennial or intermittent streams that drain into or upstream of the Category One waters as shown on the USGS Quadrangle Maps or in the County Soil Surveys, within the associated HUC14 drainage area. These areas shall be established for the protection of water quality, aesthetic value, exceptional ecological significance,

exceptional recreational significance, exceptional water supply significance, and exceptional fisheries significance of those established Category One waters. These areas shall be designated and protected as follows:
(a) *The applicant shall preserve and maintain a special water resource protection area in accordance with one of the following:*
[1] *A 300-foot special water resource protection area shall be provided on each side of the waterway, measured perpendicular to the waterway from the top of the bank outwards or from the centerline of the waterway where the bank is not defined, consisting of existing vegetation or vegetation allowed to follow natural succession is provided.*
[2] *Encroachment within the designated special water resource protection area under paragraph (a) above shall only be allowed where previous development or disturbance has occurred (for example, active agricultural use, parking area or maintained lawn area). The encroachment shall only be allowed where applicant demonstrates that the functional value and overall condition of the special water resource protection area will be maintained to the maximum extent practicable. In no case shall the remaining special water resource protection area be reduced to less than one hundred fifty (150') feet as measured perpendicular to the top of bank of the waterway or centerline of the waterway where the bank is undefined. All encroachments proposed under this paragraph shall be subject to review and approval by the Department.*
(b) *All stormwater shall be discharged outside of and flow through the special water resource protection area and shall comply with the Standard for Off-Site Stability in the "Standards for Soil Erosion and Sediment Control in New Jersey," established under the Soil Erosion and Sediment Control Act, N.J.S.A. 4:24-39 et seq.*
(c) *If stormwater discharged outside of and flowing through the special water resource protection area cannot comply with the Standard For Off-Site Stability in the "Standards for Soil Erosion and Sediment Control in New Jersey," established under the Soil Erosion and Sediment Control Act, N.J.S.A. 4:24-39 et seq., then the stabilization measures in accordance with the requirements of the above standards may be placed within the special water resource protection area, provided that:*

[1] *Stabilization measures shall not be placed within 150 feet of the Category One waterway;*
[2] *Stormwater associated with discharges allowed by this section shall achieve a 95% TSS post-construction removal rate;*

WMP7

The plan requires channel improvement projects use natural approaches rather than hard techniques.

Section Code 19-7.7 does not address this issue;

WMP8

The following are excerpts of “Funding Stormwater Programs” by the United States Environmental Protection Agency in 2009. This document can be used as a guide for the implementation of a dedicated funding source in the future for stormwater infrastructure improvement projects.
Types of Stormwater Utilities

1. Equivalent Residential Unit
    a. Bills an amount proportional to the impervious area on a parcel, regardless of the parcel’s total area
    b. Based on the effect of a typical single-family residential home’s impervious area footprint
2. Intensity of Development
    a. Based on the percentage of impervious area relative to an entire parcel’s size
    b. Suggested monthly rates per 1,000 square feet
        i. Vacant/Undeveloped (0%) $0.08
        ii. Light development (1% to 20%) $0.12

iii. Moderate development (21% to 40%) $0.16
iv. Heavy development (41% to 70%) $0.24
v. Very heavy development (71% to 100%) $0.32

3. Equivalent Hydraulic Area
    a. Based on stormwater runoff stormwater runoff generated by their impervious and pervious areas
    b. Parcels are billed based on individual measurements of pervious and impervious areas

Recommendations for the Township of Upper

There are several steps that the Township of Upper can take to mitigate the flooding it experiences. As previously discussed, new outfalls, elevating current outfalls, installing pumping stations, and implementing green infrastructure can all reduce the flood experience.

The Cape May County mainland portions of Upper Township readily reach elevations higher than the NOAA predictions for intermediate high values for sea level rise by year 2100. The anticipated water rise will impact marginal and mostly individual home owner properties most of which could be defended with bulkheads or ground elevation raises to reach a safe condition. Some may require purchase and abandonment but due to low density development near the potential flood prone areas this action is most likely affordable if necessary. Any further mainland development should also be carefully considered to not exacerbate residual water in any of the mainland sites.

To address sea level rise in the Strathmere community, some roads and homes may need to be elevated fairly soon. However, the financial feasibility of raising homes to above future sea levels (2100) should be analyzed critically. House elevation can be costly and may not always be the best course of action. The existing bulkhead arrays, the low ground elevation along the bayshore, and the expense associated with regional levee protection may dictate gradual retreat. If the 2100 intermediate high value for sea level in 2100 does occur, Strathmere will require either total elevation except for the dunes or a major levee array around the community and a massive rainwater pumping system.

Finally, to acquire CRS points for WMP8, the Township of Upper can propose an approved funding mechanism for stormwater infrastructure and this plan's implementation in the future.

References

Alliance for the Chesapeake Bay. 2017. https://www.allianceforthebay.org/our-work/key-programfocuses/reducing-stormwater-runoff/

Alliance for the Chesapeake Bay. (n.d.) Impervious. http://www.stormwater.allianceforthebay.org/glossary-of-terms/impervious

Ernst, B., O'Connor, B., 2012, Cape May County Open Space and Farmland Preservation Map. http://www.capemaycountynj.gov/DocumentCenter/Home/View/843

FEMA. 2017. National Flood Insurance Program Community Rating System Coordinator's Manual. OMB No. 1660-0022. 641 p. https://www.fema.gov/media-library-data/1493905477815-d794671adeed5beab6a6304d8ba0b207/633300_2017_CRS_Coordinators_Manual_508.pdf

New Jersey Office of GIS. (2021). NJGIN Open Data. https://njogis-newjersey.opendata.arcgis.com/

NOAA. (n.d.) Tides and Currents. Cape May, NJ - Station ID: 8534720. https://tidesandcurrents.noaa.gov/stationhome.html?id=8534720

NOAA Hydrometeorological Design Studies Center. (2017, April 21) NOAA atlas 14-point precipitation frequency estimates: ks. Station Name: Atlantic City Marina https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html

Oregon Water Resources Department. (n.d.). Calculation Instructions. https://www.oregon.gov/owrd/programs/WaterRights/COBU/Documents/calculations.pdf

PECivilExam. (n.d.). WR-Formula-Properties-and-Definitions.pdf. https://www.pecivilexam.com/Study_Documents/WR-ENV-Materials-Online/WR-Formula-Properties-and-Definitions.pdf

PennState Extension. (2021, April 8). Stormwater basics. https://extension.psu.edu/stormwater-basics

PennState Extension. (2018, April 19). Why does my community flood more than it used to? https://extension.psu.edu/why-does-my-community-flood-more-than-it-used-to

PennState Extension. (2018, April 19). Why should I care about stormwater? https://extension.psu.edu/why-should-i-care-about-stormwater

Township of Upper administrative ordinance codes. https://ecode360.com/35460787

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at the following link: http://websoilsurvey.sc.egov.usda.gov/.

USEPA. (2015, September). Storm water management model user's manual version 5.1.

USEPA. (2021, February 1). Urbanization and storm water runoff. https://www.epa.gov/sourcewaterprotection/urbanization-and-storm-water-runoff

USEPA. (2021, July 29). What is green infrastructure? https://www.epa.gov/green-infrastructure/what-green-infrastructure