FINAL

WATER AND WASTEWATER MASTER PLAN REPORT

Gloucester County, VA

B&V PROJECT NO. 192634

PREPARED FOR

Gloucester County

17 JANUARY 2019

BLACK & VEATCH

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1.0 Introduction

Gloucester County (County) is located in Southeastern Virginia along the Chesapeake Bay. **Figure 1-1** shows the location of the County outlined in red. The County retained Black & Veatch to provide a water and sewer master plan to identify capital improvements required in its water distribution and wastewater collection systems.

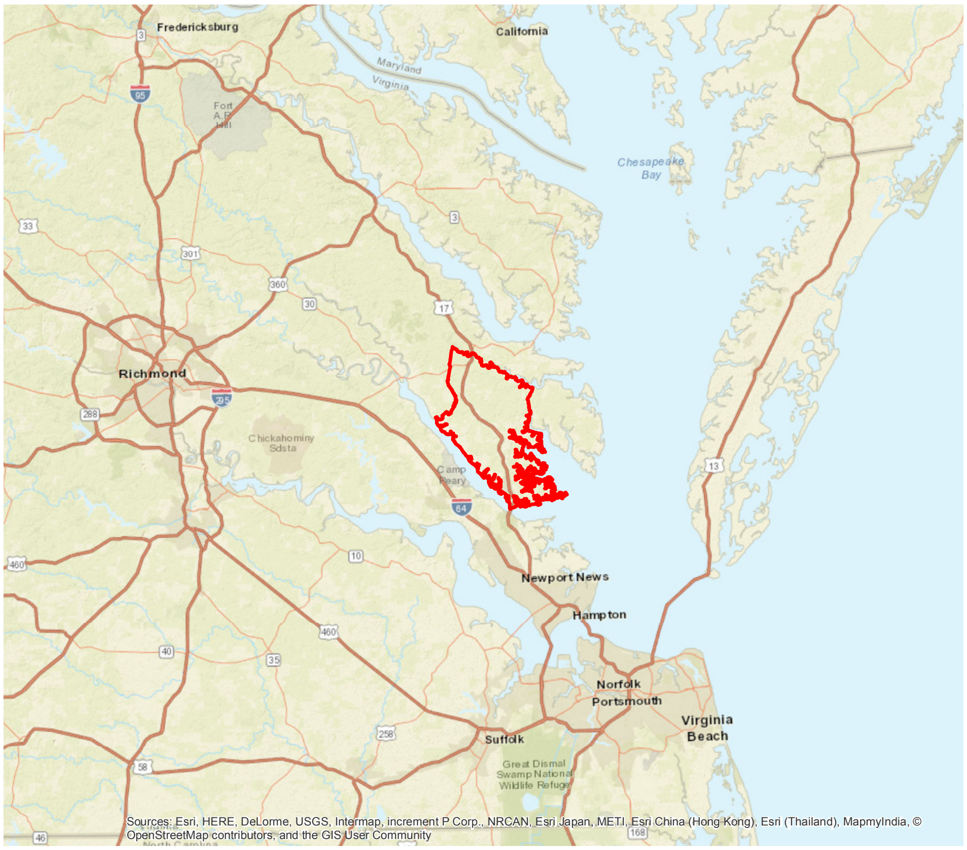


Figure 1-1 Gloucester County Location

The County provides water and wastewater services for its residents. The County owns and operates two drinking water plants. The first plant is a surface water treatment plant that relies on a reservoir as its water source. The other water treatment plant relies on groundwater wells and a reverse osmosis (RO) process. The RO plant typically operates with a 50%/50% blend of the RO and surface water treatment plant to its customers. These plants share a common high service pump station. The County currently owns almost 100 miles of water distribution piping ranging in diameters from 2 inches to 16 inches. **Figure 1-2** shows the location of the water mains (blue) within the County. It should be noted that the water piping is focused on the central and southern portions of the County to serve the customers in the Gloucester Courthouse and Gloucester Point areas as well as customers along Rte. 17.

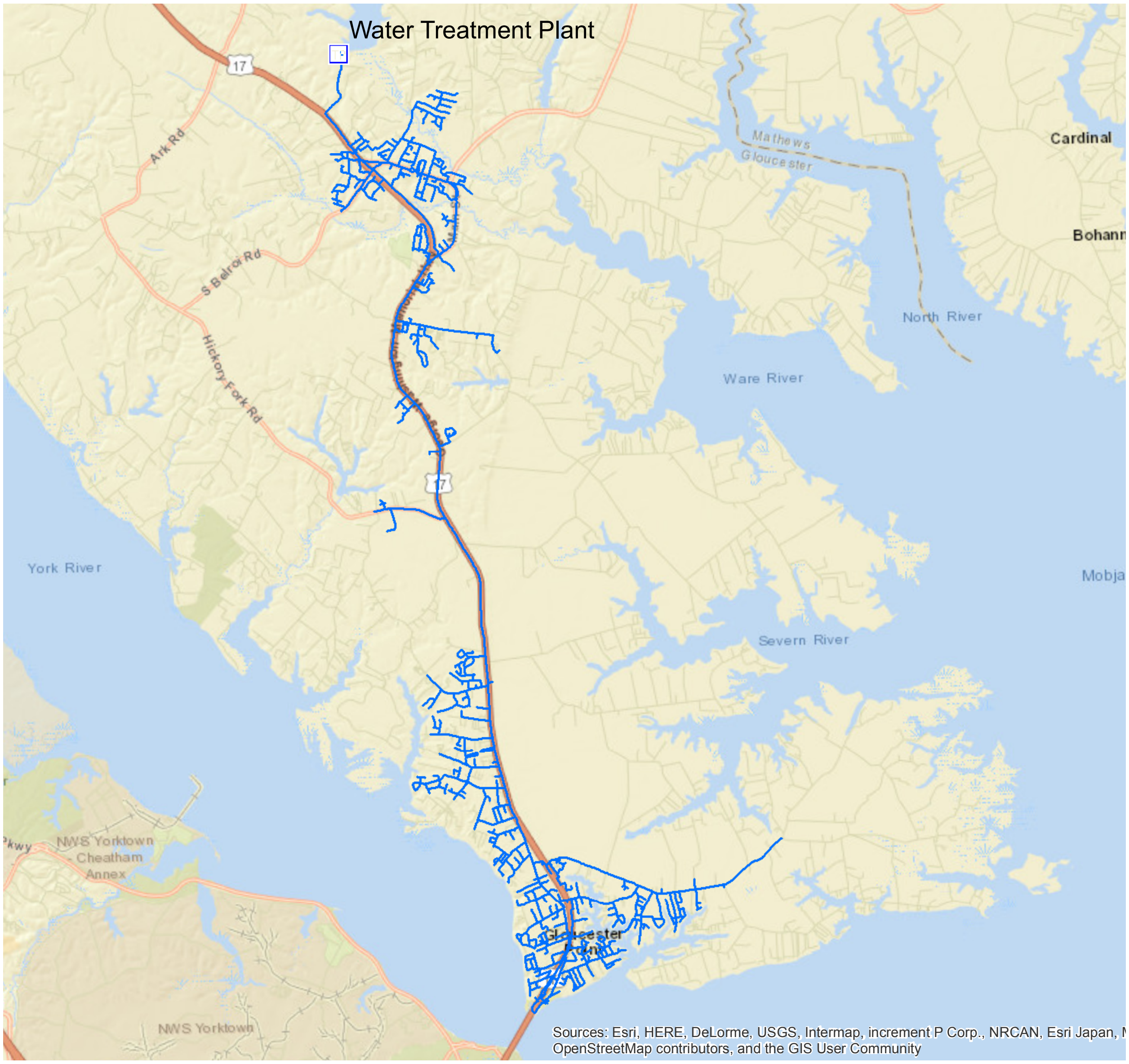


Figure 1-2 Gloucester County Water Distribution System

The County does not own or operate a wastewater treatment plant. Instead, it pumps its wastewater at several of the pump stations directly into a Hampton Roads Sanitation District (HRSD) force main that conveys the wastewater southward along Rte. 17. The force main crosses the York River and eventually transports the wastewater to the York River WWTP. The sewer and force main piping (brown) is shown on **Figure 1-3** below. There is almost 60 miles of gravity sewer and force main piping in the County and 18 pump stations.

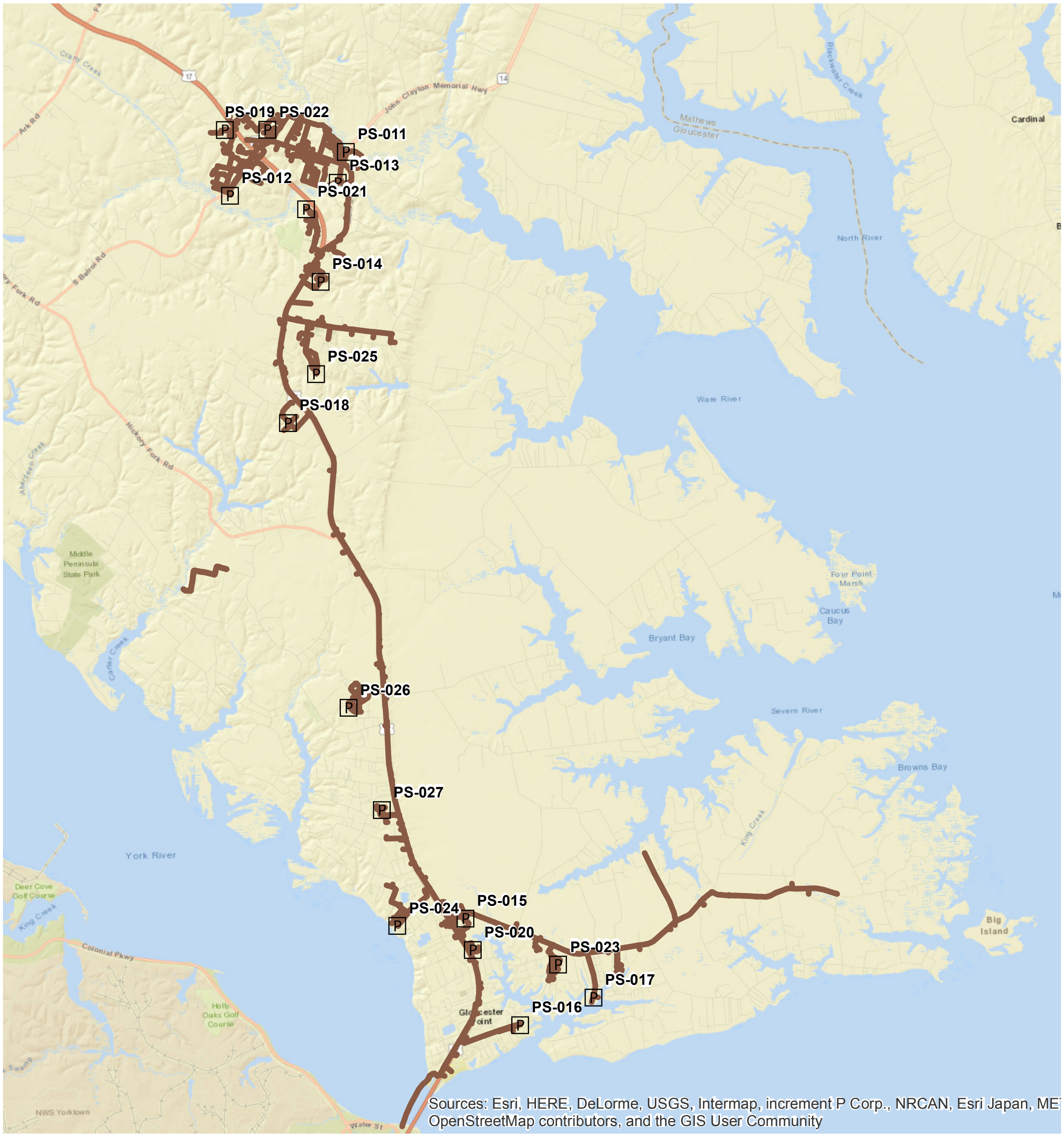


Figure 1-3 Gloucester County Wastewater Collection System

2.0 Water and Sewer Modeling Software Selection

During a workshop with the County on June 16, 2016, a comparison of the various commercially available water distribution and sewer selection software was presented. The comparison included considerations not only for the functionality but also the costs for each package. The County selected to use MIKE URBAN for its wastewater modeling since there was an existing model already developed and the package was already purchased for Gloucester County by HRSD as a part of the larger HRSD consent decree program.

The County selected InfoWater over WaterGEMS based on a lower life cycle cost and was deemed to have the same functionality.

3.0 System Demand and Flow Projections

The future water demand and sewer flow projections are presented below. The projections rely on current and future populations as well as current demand and flow measurements to determine the future forecasts. The procedures and assumptions used for the water demand and sewer flow projections are noted below.

3.1 WATER DEMAND PROJECTIONS

The County is expected to experience growth in its customer base. An understanding of this growth and its resulting impact on its water distribution system is required so that future capital improvements can be quantified. This section documents the methodology used to determine the water demand projections for the County's water distribution system. The resulting projection will be incorporated into the model so that future and current capacity issues can be identified and resolved with capital improvement projects.

3.1.1 Population Projections

The current and future population projections were developed by utilizing the following data sources:

- Hampton Roads Regional Water Supply Plan (RWSP), July 2011
- Hampton Road 2040 Socioeconomic Forecast and Transportation Analysis Zone (TAZ) Allocation, October 2013

The TAZ data tabulates the residential and the non-residential (employment) population spatially over the entire county. The TAZ data was used to determine the total residential population for the base year (37,557 people) and the 2040 planning year total residential population (40,200 people). For the intermediate planning years, the total residential population was interpolated.

A significant portion of the County's population is not connected to the County's public water distribution system. Instead, these households rely on private wells. The RWSP estimated that 41% of the existing population is connected to the County's water distribution system based on an interpolation of Table 4-3 in the RWSP. The base year population served was determined to be 15,211 people.

The future population served was determined by estimating the future residential customer components:

- Future population growth due to new people moving into the County
- Current residents on private well that connect to the County system

These future customer components were added to the current served population to determine the future served population.

It was assumed that 75% of all future population growth would be connected to the County's system, i.e. 75% of all people that move into the County would be connected. This is based on the current developer's trend of building the new construction connected to the County's system instead of relying on private wells. According to the County, the developers in the area prefer to construct the new residential developments that can connect to the municipal water system; therefore, the growth is anticipated to occur along the corridor near the existing water infrastructure. Similarly, the non-residential growth is anticipated to occur near the population centers of Gloucester Courthouse and Gloucester Point, which are currently served by the County. It was also assumed that 10% of the current residents of the County that are not connected to the County water distribution system would switch to the County system by the 2040 planning year. These assumptions were reviewed by the County and confirmed as being reasonable assumptions. The future served population for the future planning years is summarized with the following equation.

2040 residents = 2017 served residents +75% new residents + 10% existing residents not current served

The future populations for the intermediate planning years were determined by interpolating the residential growth and the existing resident conversions. **Table 3-1** and **Figure 3-1** displays the total and served populations for Gloucester County for each planning year.

Table 3-1 Future Total and Served Populations (Water)

PLANNING YEAR	TOTAL POPULATION	POPULATION SERVED
2017	37,557	15,211
2020	37,902	15,761
2025	38,477	16,677
2030	39,051	17,594
2035	39,626	18,511
2040	40,200	19,427

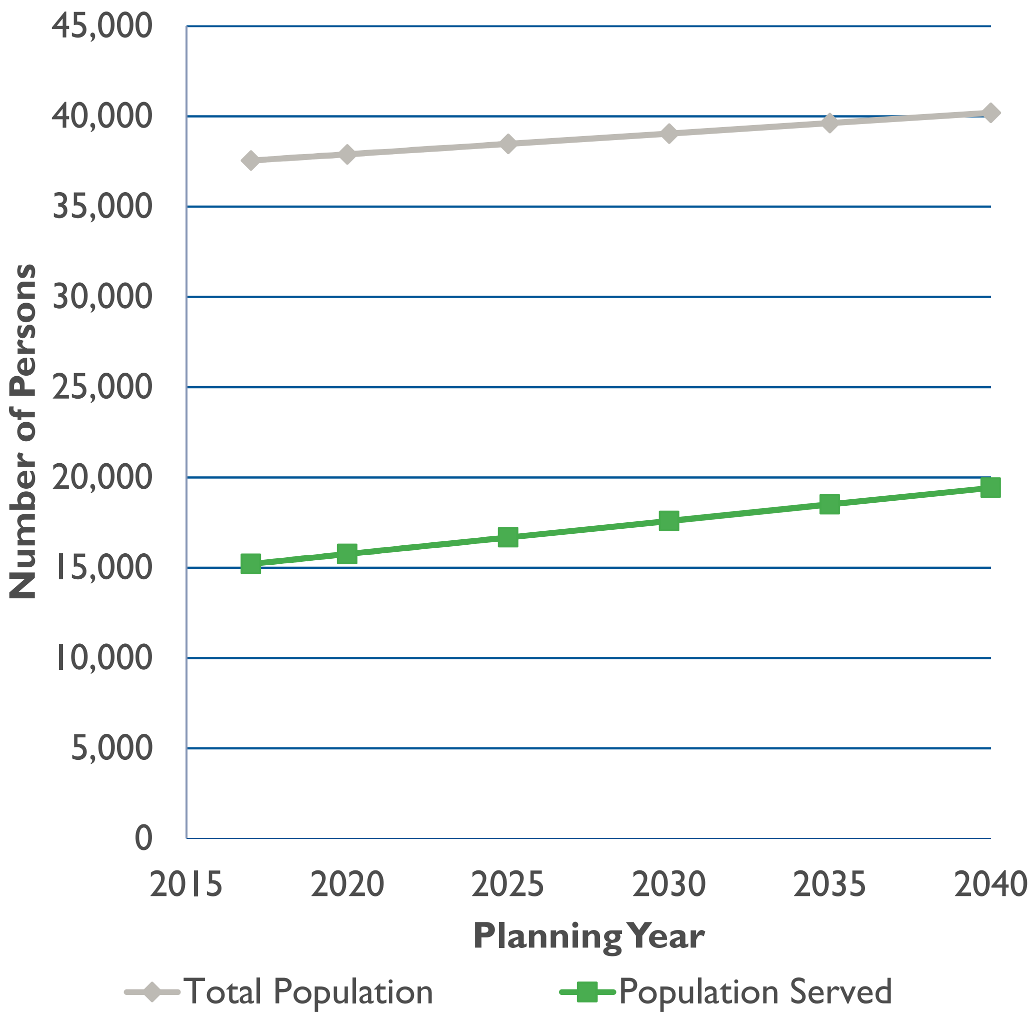


Figure 3-1 Total and Served Population (Water)

3.1.2 Water Demand Projections

The future water demand projections can be determined by utilizing the future population projections. The future growth in customers can be converted into future demand by applying a unit factor to account for each resident's water demand. This growth is then added to the current system's water demand.

The past water production records were reviewed to determine the current water demands. Specifically, water production records from January 2010 through May 2016 were reviewed. The average water production during this period was 1.02 MGD. The County's population during this period has not changed significantly, so this average was used for the base year demand.

The current residential population served was determined to be 15,211 people, so the per capita usage is 67.25 gpdpc. This unit factor would include the demands associated from residential and non-residential uses. It should be noted that the RWSP used 82 gpdpc for its planning purposes. To be consistent with the RWSP, the 82 gpdpc unit factor was used to determine the future flows. Since the current usage is less than this RWSP unit factor, there is an allowance for non-residential water demand. It should also be noted that the per capita water usage has been decreasing in recent years because of water conservation nationwide. A lower future water usage rate was used in the projections to be conservative in the demand projections.

To determine the future water demands, the population growth (future served population minus the current served population) was multiplied by 82 gpdpc. This represents the increase in water demands. The increase in water demands was added to the current water demands to determine the total water demand for each planning year. **Table 3-2** and **Figure 3-2** document the future water demands for the County.

Table 3-2 Water Demand Projections (Water)

PLANNING YEAR	WATER DEMAND (MGD)
2017	1.02
2020	1.07
2025	1.14
2030	1.22
2035	1.29
2040	1.37

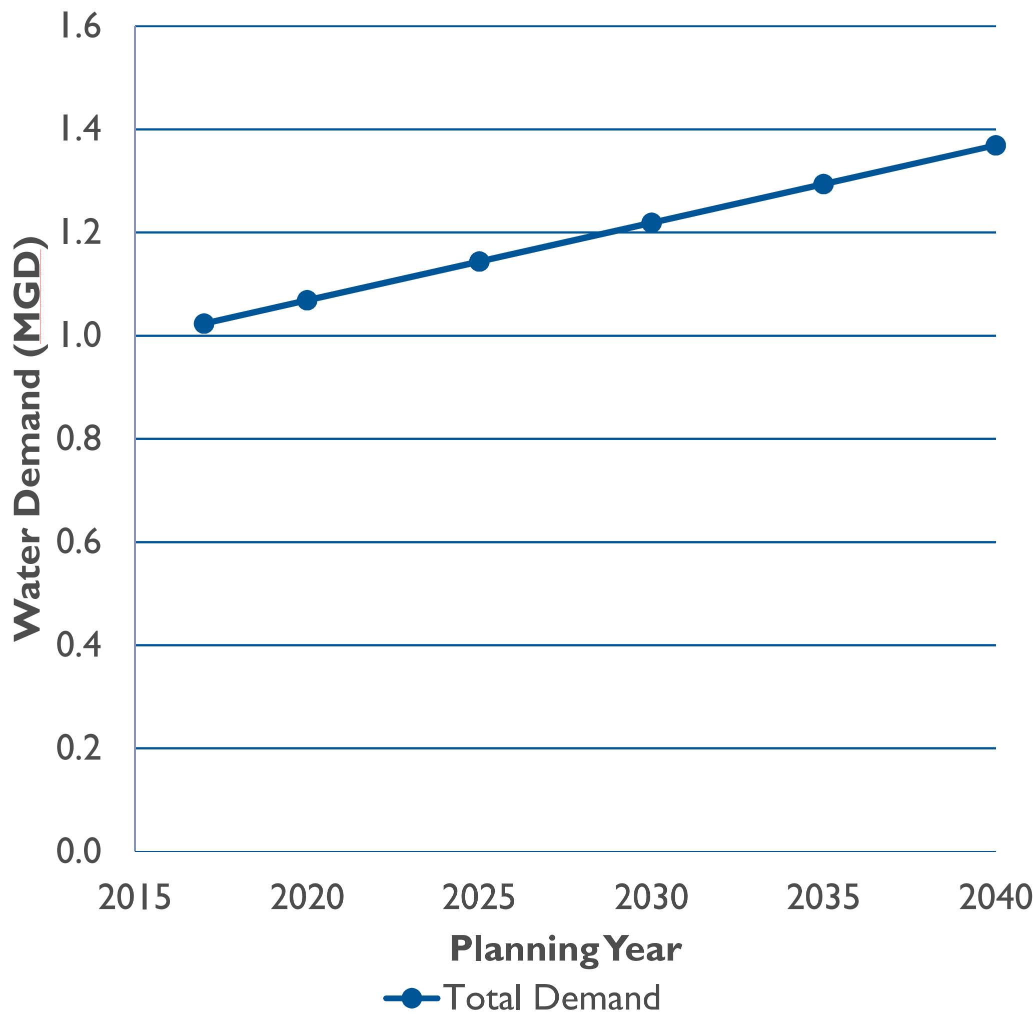


Figure 3-2 Water Demand Projections

3.2 SEWER FLOW PROJECTIONS

This section will document the methodology used to determine the sewer flow projections for the County's wastewater collection system. The sewer flow projections follow a parallel methodology to the water demand projections. The resulting projection will be incorporated into the model so that future and current capacity issues can be identified and resolved with capital improvement projects.

3.2.1 Population Projections

The current and future population projections were developed by utilizing the following data sources:

- Hampton Roads Regional Water Supply Plan (RWSP), July 2011
- Hampton Road 2040 Socioeconomic Forecast and Transportation Analysis Zone (TAZ) Allocation, October 2013

- Gloucester County Comprehensive Plan, February 2016

The total population for the County is documented in the water demand population projections. The total County population will increase from 37,557 to 40,200 people from 2017 to 2040.

The population currently served by the wastewater collection system is not the same as the water distribution system. A significant portion of the County's population is not connected to the County's sewer collection network. Instead, these households rely on private septic tanks or other private treatment and disposal options. To estimate the currently served population, the number of water and sewer customer accounts was collected from the County. The County currently has 4,990 water accounts and 1,450 sewer accounts. Using the current population of 15,211 served by the water system, there is 3.048 people per account. If the 3.048 people per account is indicative of the sewer customers, there are 4,420 people currently served by the sewer system.

The future served sewer population was determined using a similar method as was used for the water served population. The future population served was determined by estimating the following future residential customer components:

- Future population growth due to new people moving into the County
- Current residents on septic or private treatment that connect to the County system

These future customer components were added to the current served population to determine the future served population.

It was assumed that 75% of all future population growth would be connected to the County's system, i.e. 75% of all people that move into the County would be connected. This is based on the current developer's trend of building the new construction connected to the County's system instead of relying on private options. According to the County, the developers in the area prefer to construct the new residential developments that can connect to the municipal water system; therefore, the growth is anticipated to occur along the corridor near the existing water infrastructure. Similarly, the non-residential growth is anticipated to occur near the population centers of Gloucester Courthouse and Gloucester Point, which are currently served by the County.

It was also assumed that 10% of the current residents of the County that are not connected to the County wastewater collection system would switch to the County system by the 2040 planning year. These assumptions were reviewed by the County and confirmed as being reasonable assumptions. The future served population for the future planning years is summarized with the following equation.

2040 residents = 2017 served residents +75% new residents + 10% existing residents not current served

The future populations for the intermediate planning years were determined by interpolating the residential growth and the existing resident conversions. **Table 3-3** and **Figure 3-3** displays the total and served populations for Gloucester County for each planning year.

Table 3-3 Total and Served Population (Wastewater)

PLANNING YEAR	TOTAL POPULATION	POPULATION SERVED
2017	37,557	4,420
2020	37,902	5,111
2025	38,477	6,262
2030	39,051	7,413
2035	39,626	8,564
2040	40,200	9,716

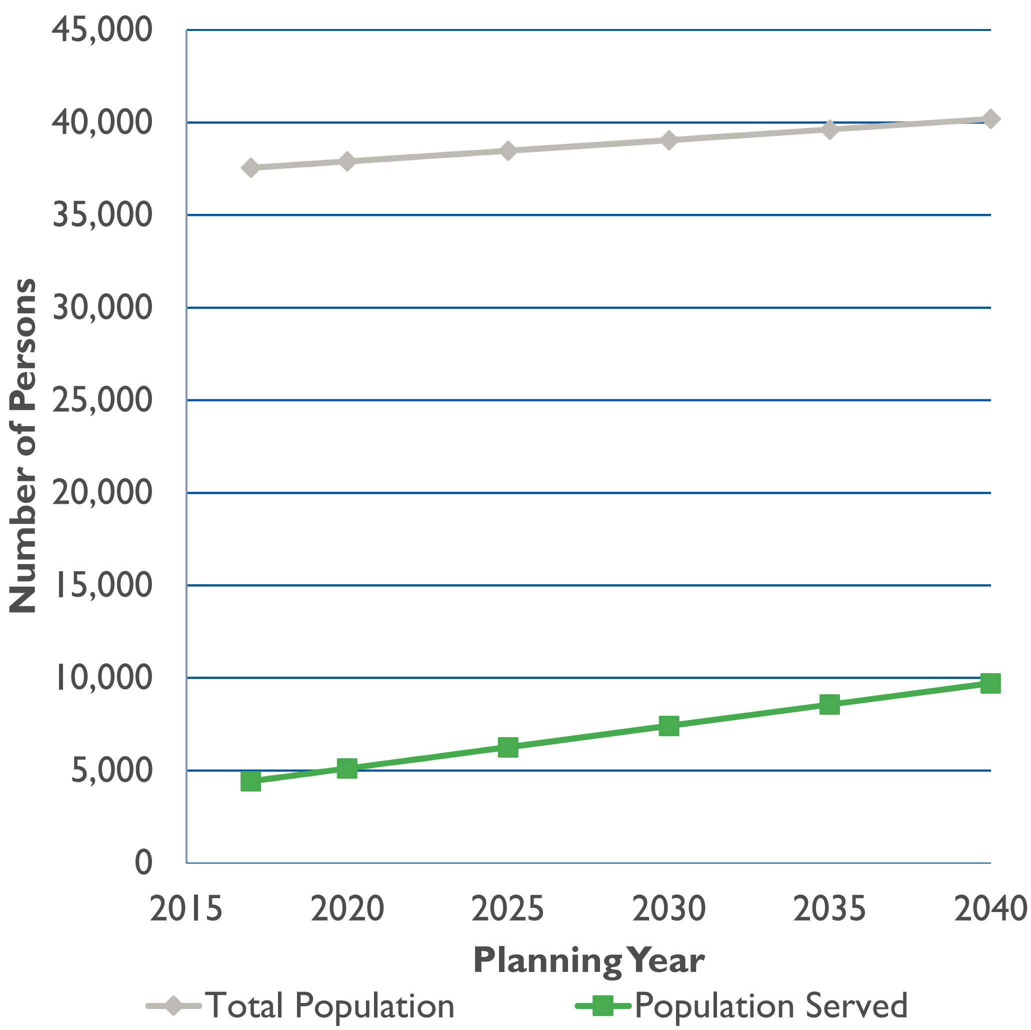


Figure 3-3 Total and Served Population (Wastewater)

3.2.2 Sewer Flow Projections

The future wastewater flow projections can be determined by utilizing the future population projections in a similar manner to the water demand projections. The future growth in customers can be converted into flows by applying a unit factor to account for each resident's sewer flow generation. This growth is then added to the current system's sewer flow.

The County does not have a treatment plant. Instead, it sends it wastewater to HRSD for treatment and disposal. The County pump stations pump into an HRSD force main along Rte. 17. This force main extends southward to convey the flow to the York River WWTP. The County does not currently meter the flows being discharged by the pump stations. HRSD was contacted to obtain flow metering records along the force main. Unfortunately, HRSD said that this force main flow meter is not providing reliable results. Therefore, there was no way to determine accurately the sewer system flows being generated by the County.

It was assumed that the average annual flows coming from the County were 0.5 MGD. This was based on the water billing records indicated that the County is using 0.379 MGD for the customers that are both water and wastewater customers. An allowance for inflow and infiltration (I/I) was added to this water billing amount to yield the 0.5 MGD average annual wastewater flow. This assumption was shared with the County, and they agreed.

The current residential population served was determined to be 4,420 people, so the per capita wastewater generation rate is 113 gpdpc. This unit factor would include the sewer flows associated from residential and non-residential uses. It should be noted that this per capita factor includes an allowance for I/I spread out over the year.

To determine the future wastewater flows, the population growth (future served population minus the current served population) was multiplied by 113 gpdpc. This represents the increase in wastewater flows. The increase in sewer flows was added to the current sewer flows to determine the total sewer flow for each planning year. **Table 3-4** and **Figure 3-4** document the future sewer flows for the County.

Table 3-4 Wastewater Flow Projections

PLANNING YEAR	WASTEWATER FLOW (MGD)
2017	0.500
2020	0.578
2025	0.708
2030	0.839
2035	0.969
2040	1.099

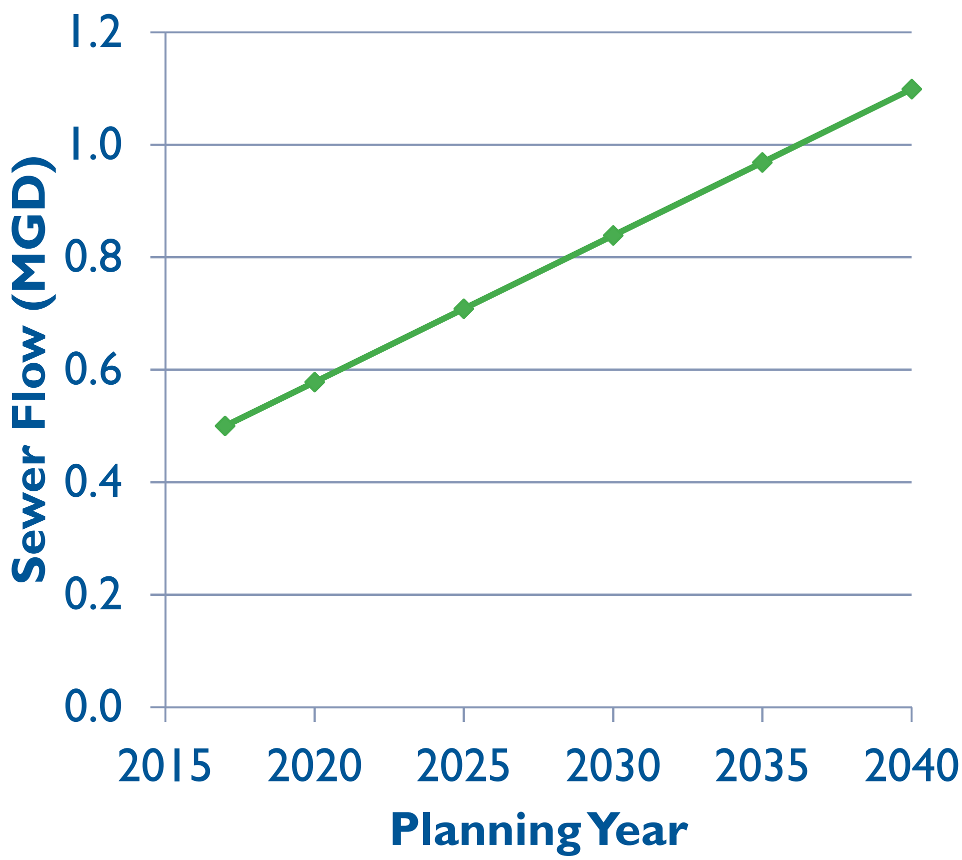


Figure 3-4 Wastewater Flow Projections

4.0 Water Distribution System

4.1 PROJECTED WATER DEMANDS

4.1.1 Demand Diurnal Pattern

Diurnal demand patterns show the demand fluctuations of a distribution system or pressure zone throughout a 24-hour period and are comprised of incremental peaking factors, which average to one over the course of the 24-hour period. The County's typical maximum day demand (MDD) diurnal pattern was calculated by analyzing supervisory controls and data acquisition (SCADA) data in the system one week before and one week after the 2015 MDD of February 23, 2015; February 16 – 28, 2015. The equation used to calculate the diurnal pattern of the system is a mass balance where the flow into the system and flow out of the system was analyzed to calculate the demands. The mass balance equation for Gloucester County is shown below:

$$\boldsymbol{WTP\ Production} \pm \boldsymbol{\Delta Vol\ of\ Courthouse\ Tank} \pm \boldsymbol{\Delta Vol\ of\ 1MG\ Tank} \pm \boldsymbol{\Delta Vol\ of\ Gloucester\ Point\ Tank} = \boldsymbol{Demand}$$

The diurnal patterns for each day and the average pattern for the two week period are shown in **Figure 4-1**.

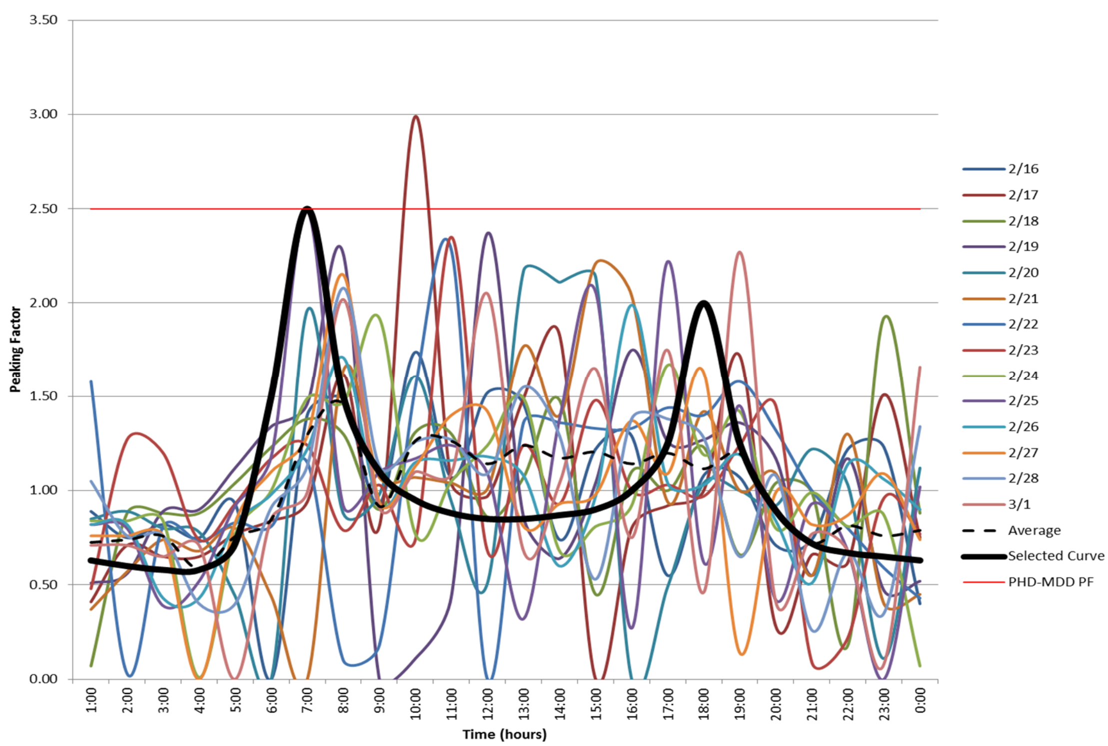


Figure 4-1 Maximum Day Demand Diurnal Pattern

As is typical for systems with demands under 2 million gallons per day (MGD), the diurnal pattern is not very consistent, and the peak hour demand (PHD) can occur at any time, most typically between early morning and the evening. The PHD peaking factor, 2.5 PHD:MDD, for the system was determined from the diurnal pattern. This ignores the largest peak hour of 3.0 on February 17, 2015 which was caused by a forced tank turnover at the Gloucester Point Tank. The diurnal patterns show that peak demands are relatively short in duration, which was reflected in the selected curve patterns.

4.1.2 Demand Peaking Factors

The MDD for 2015 was determined to have occurred on February 23 and was 1.67 MGD based on SCADA data for the high service pump station (HSPS). When compared to the 2017 average day demands (ADD) of 1.02 MGD, the MDD peaking factor (PF) is equal to 1.6.

- MDD:ADD = 1.6
- PHD:MDD = 2.5
- PHD:ADD = 4.0

4.1.3 Projected Demands

Table 4-1 summarizes the ADD, MDD and PHD water system demands for each planning year through 2040.

Table 4-1 Water System Projected Demands

PLANNING YEAR	ADD DEMAND	ADD GROWTH BETWEEN PLANNING YEARS	MDD DEMAND	PHD DEMAND
	(MGD)	(MGD)	(MGD)	(MGD)
2017	1.02	-	1.64	4.09
2020	1.07	0.05	1.71	4.27
2025	1.14	0.075	1.83	4.57
2030	1.22	0.075	1.95	4.87
2035	1.29	0.075	2.07	5.18
2040	1.37	0.075	2.19	5.48

4.2 DEMAND ALLOCATION

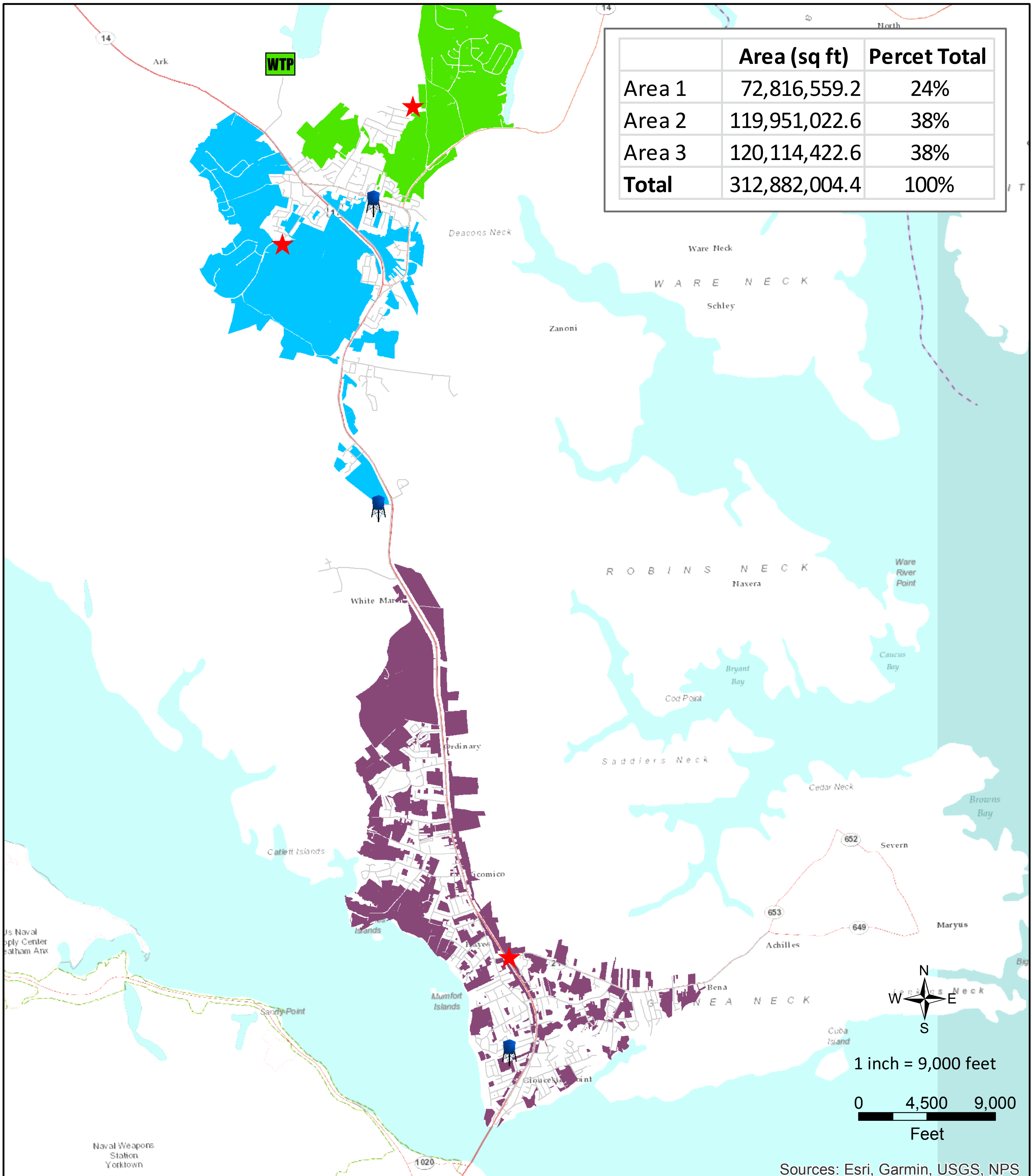
4.2.1 Existing System Demands

The spatial allocation of the demands is important to accurately model and calibrate the existing flows and their impacts on the distribution system. To accomplish this, the 2016 customer billing data was geo-located and distributed across the system based on the nearest model junction. To keep the detailed and accurate allocation of the billing meters throughout the future planning scenarios, the consumption demand allocation for the planning years must build on the base year consumption allocation.

4.2.2 Future System Demands

The actual allocation of future demands is difficult to determine, but strategic placement of those demands will allow the transmission, pumping and storage system to be properly analyzed and ensure sufficient capacity into the future. For this purpose, the projected water demands were applied to the model in three strategic locations as illustrated in **Figure 4-2**.

	Area (sq ft)	Percet Total
Area 1	72,816,559.2	24%
Area 2	119,951,022.6	38%
Area 3	120,114,422.6	38%
Total	**312,882,004.4**	**100%**



Demand Allocation Point

WTP

Tanks

wMain

Future Growth Areas

1

2

3

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GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 4-2

Existing Water System Demand Allocation

4.3 MODEL CALIBRATION

Black & Veatch completed a model calibration process to compare and validate the hydraulic model results with actual system operating data that was collected by the County. The following presents the steps that were followed to complete the calibration process of the County's Hydraulic Model.

4.3.1 Available SCADA Data

The County records and maintains SCADA data at each of the major system facilities within the distribution system including the HSPS and the three storage tanks. The availability of this data allowed Black & Veatch to conduct an EPS model calibration of the distribution system. **Table 4-2** summarizes the available SCADA data. The SCADA data was not provided in a consistent time increment; therefore the data was averaged over each hour.

Table 4-2 Location of SCADA Sensors

FACILITY	FLOW (GPM)	PUMP/VALVE STATUS (ON/OFF)	PUMP SPEED (%)	PRESSURE (PSI)	LEVEL (FT)
High Service Pump Station	Total	Not Available	Not Available	X	
Courthouse Tank	N/A	N/A	N/A	-	X
1-MG Tank	N/A	N/A	N/A	-	X
Gloucester Point Tank	N/A	N/A	N/A	-	X
Clearwell	N/A	N/A	N/A	-	X

4.3.2 Calibration Results

The water distribution hydraulic model was calibrated using a 24-hour extended period simulation (EPS) with 1-hour increments. February 24, 2015 was selected as the calibration day based on the consistency of the available data. It was assumed that the operational pump at the HSPS during calibration was Pump 10 and the variable frequency drive (VFD) speed was varied based on tank level. **Figure 4-3** through **Figure 4-8** illustrate the system demands and calibration results.

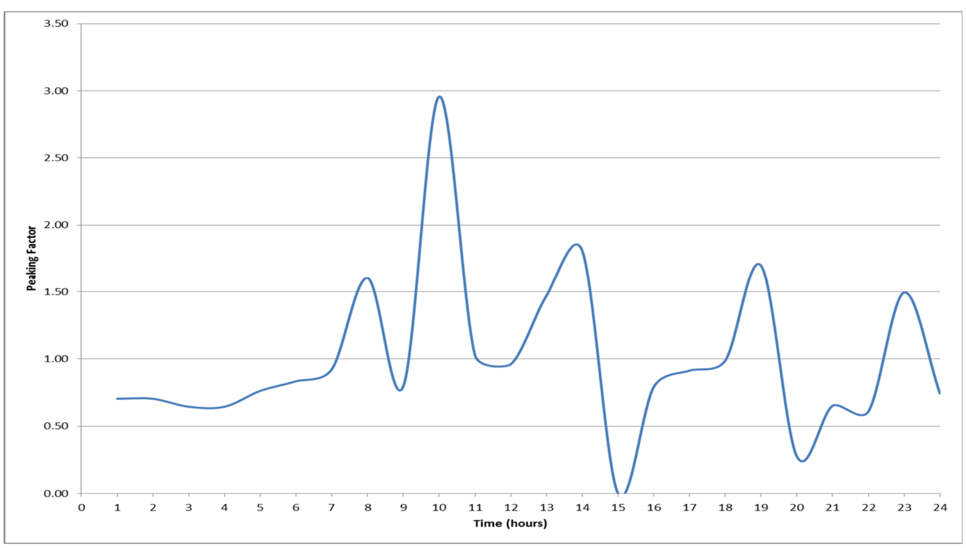


Figure 4-3 Calibration Diurnal Pattern

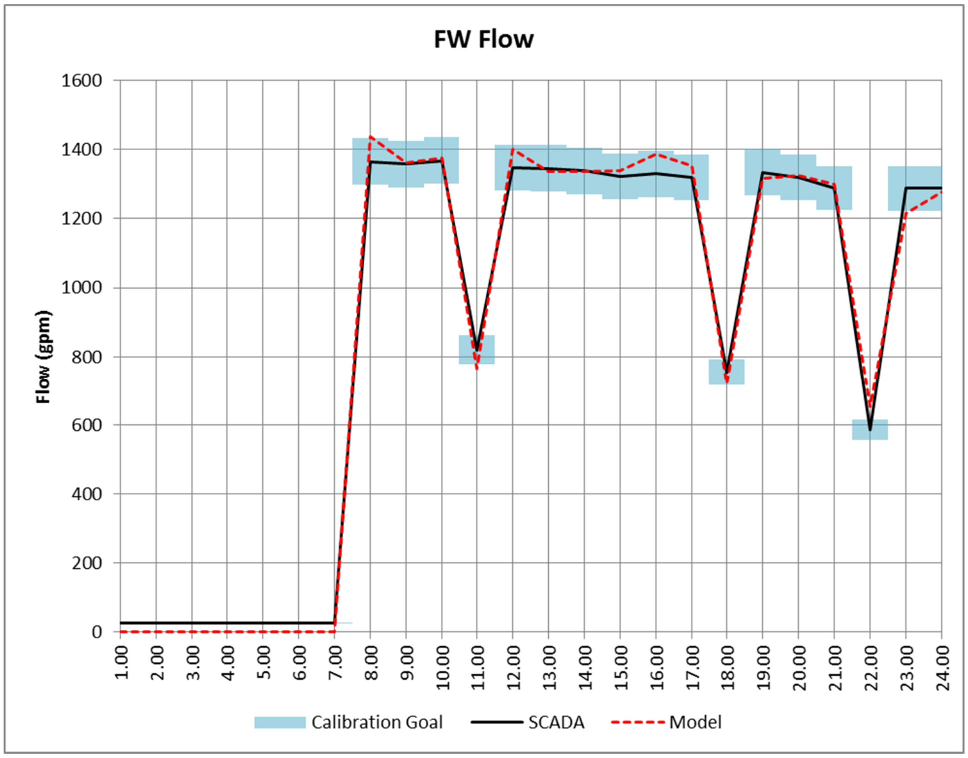


Figure 4-4 **HSPS Flow Calibration Results**

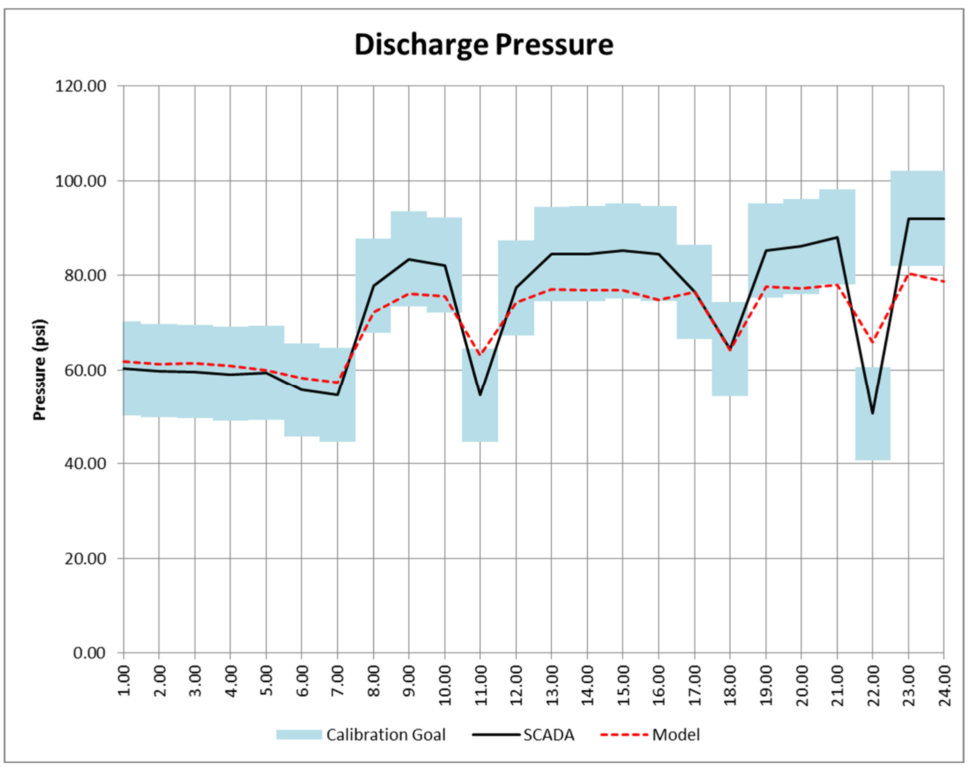


Figure 4-5 **HSPS Discharge Pressure Calibration Results**

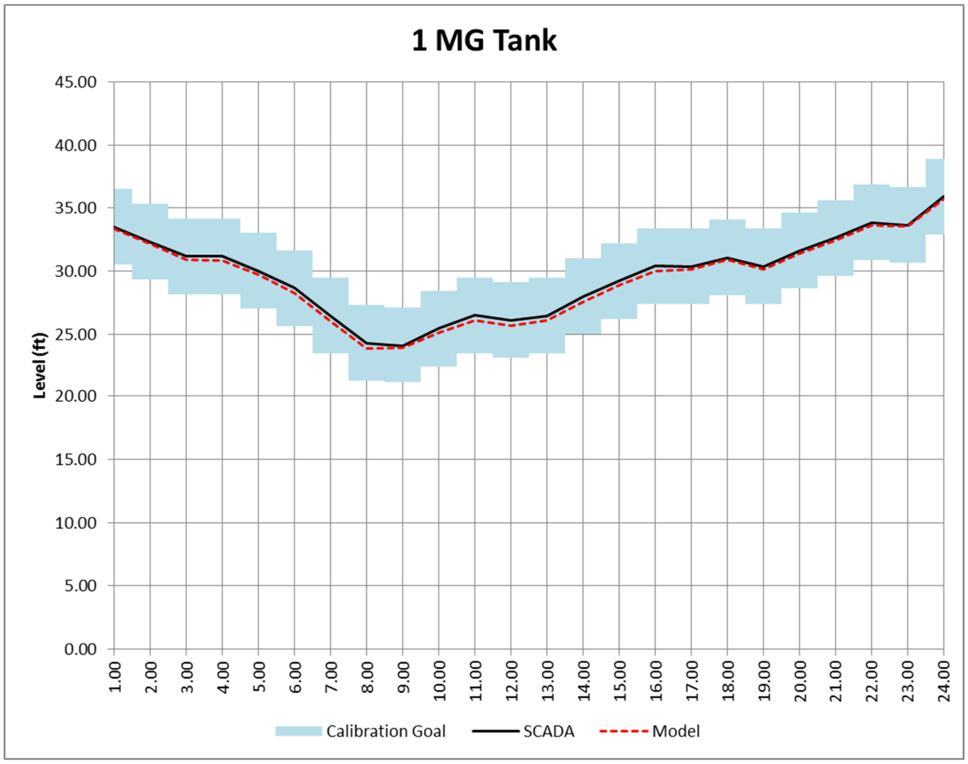


Figure 4-6 1-MG Tank Level Calibration Results

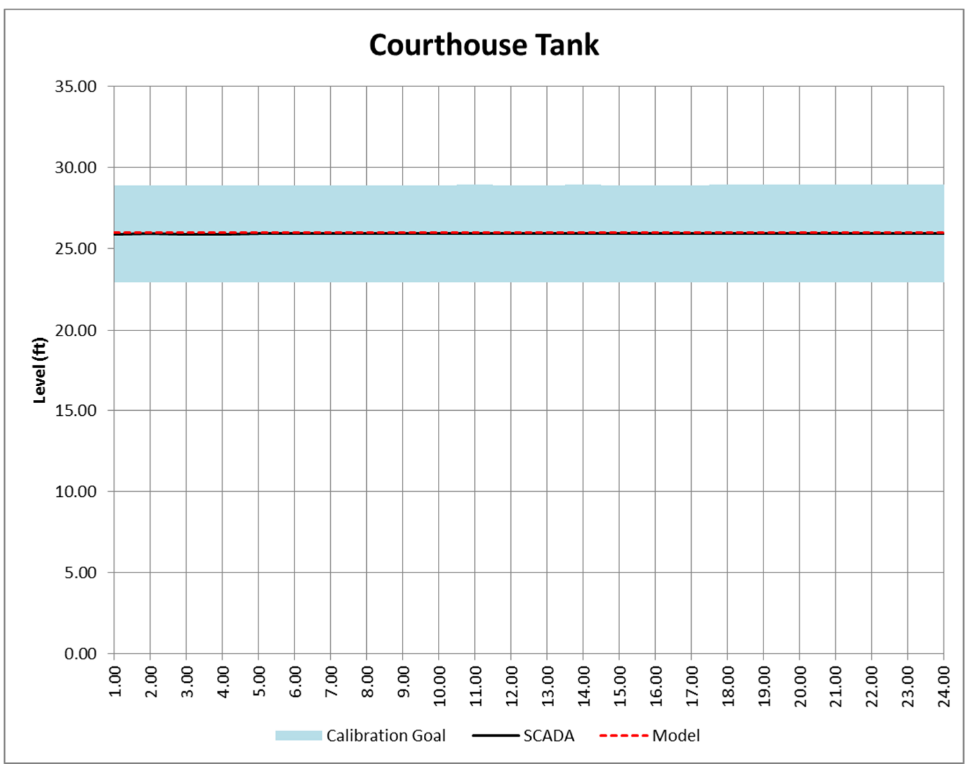


Figure 4-7 Courthouse Tank Level Calibration Results

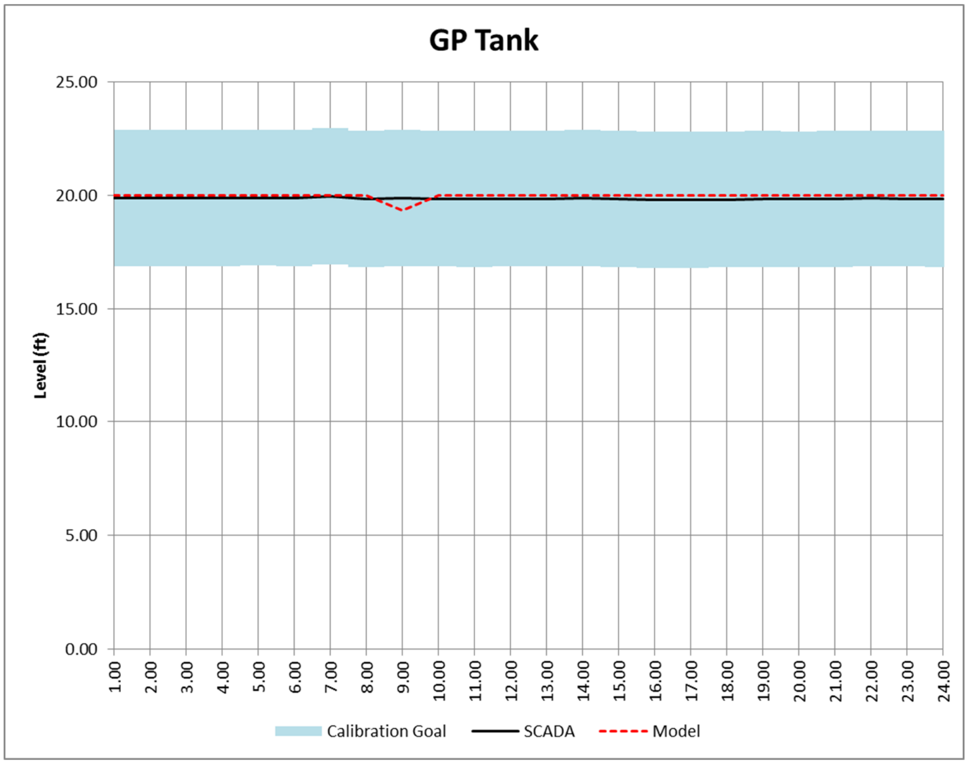


Figure 4-8 Gloucester Point Tank Level Calibration Results

The results of calibration show a very high correlation between the model results and the SCADA data for the tanks levels and acceptable correlation for the HSPS flows and discharge pressures. Based on these results, it is recommended that the hydraulic model be used for the Water Master Plan.

4.4 PERFORMANCE CRITERIA

The performance criteria selection for the Water Master Plan are derived from the State of Virginia regulations 12VAC5-590-690 and 12VAC5-590-1040.

- Minimum Pressures = 20 pounds per square inch (psi) based on greater of PHD or MDD plus fire flow (FF)
- Effective Finished Storage = Greater than 200 gallons per equivalent residential connection (ERC)
  - ERC = 2.53 persons per household, per the 2010 US Census
- Pump Station Firm Capacity = Peak Demand, which is assumed to be MDD+FF
  - Firm Capacity = Capacity when the largest pump is out of service
- Fire Flow = Based on the land-use map
  - Residential = 1,000 gpm for 1 hour for Mixed Density Residential; Suburban High Density & Village Scale Mixed Use
  - Commercial = 2,000 gpm for 2 hours Employment & Light Industrial & Highway Mixed Use

4.5 PUMP STATION CAPACITY ASSESSMENT

The capacity of the HSPS was analyzed using an Excel-based desktop model for each planning year to evaluate the adequacy of the existing facility and to identify any deficiencies in capacity based on the performance criteria. Note that hydraulic limitations were assessed using the hydraulic model and summarized later in this report.

Table 4-3 summarizes the pump station capacity and **Table 4-4** summarizes the system demands and pump station performance criteria for each planning year. The existing HSPS has sufficient capacity to meet the projected demands and a fire flow up to 1,000 gpm through planning year 2040. For the 2,000 gpm requirement, the existing HSPS has sufficient capacity through the 2030 planning year. For the 2035 and 2040 planning years, the firm capacity will be slightly exceeded. Black & Veatch recommends replacing one of the smaller 900 gpm pumps with a larger pump matching the 1,600 gpm pumps already in service. It is recommended that the County monitor the water usage in the future closely to verify when the firm capacity is exceeded triggering the pump replacement.

Table 4-3 HSPS Capacity Summary

PUMP	PUMP NO.	RATED CAPACITY		RATED TDH	MOTOR
(Install Year)		(gpm)	(MGD)	(ft)	(Type)
Pump 7 - High Service Pump Goulds Pumps, 12RJLC, Curve 3118, 4 Stage, 60hp vertical turbine, 1988	7	900	1.3	200	Constant
Pump 8 - High Service Pump Goulds Pumps, 12RJLC, Curve 3118, 4 Stage, 60hp vertical turbine, 1988	8	900	1.3	200	Constant
Pump 9 - High Service Pump Goulds Pumps, 14RJLC, Curve 3124, 2 Stage, 60hp vertical turbine, 1988	9	1,600	2.3	216	Constant
Pump 10 - High Service Pump Afton Pumps, 14RJLC, Curve 40645TR-Vari, 3 Stage, 100hp vertical turbine, 2014	10	1,600	2.3	216	VFD
Total Capacity (gpm / MGD)		5,000	7.2		
Firm Capacity (gpm / MGD)		3,400	4.9		

Table 4-4 HSPS Capacity Analysis

Fire Flow	PERFORMANCE CRITERIA (MGD) MDD + Fire Flow						MEETS CRITERIA (Y/N)					
(gpm / MGD)	2017	2020	2025	2030	2035	2040	2017	2020	2025	2030	2035	2040
1,000 / 1.4	3.1	3.1	3.3	3.4	3.5	3.6	Y	Y	Y	Y	Y	Y
2,000 / 2.9	4.5	4.6	4.7	4.8	5.0	5.1	Y	Y	Y	Y	N	N

4.6 FINISHED WATER STORAGE CAPACITY ASSESSMENT

Similar to the pumping capacity, the capacity of the finished water storage capacity was analyzed using an Excel-based desktop model for each planning year to evaluate the adequacy of the existing facilities and to identify any deficiencies in capacity based on the performance criteria. Note that hydraulic limitations were assessed using the hydraulic model and summarized later in this report.

Table 4-5 Storage Capacity Summary summarizes the storage capacity and **Table 4-6** summarizes the system demands and required storage per the performance criteria for each planning year. The existing storage tanks have sufficient capacity to provide the required storage volume through planning year 2040.

Table 4-5 Storage Capacity Summary

STORAGE FACILITY	EFFECTIVE STORAGE VOLUME (MG)
1 MG Tank	1.0
Courthouse Tank	0.25
Gloucester Point Tank	0.25
Total	1.5

Table 4-6 Storage Capacity Analysis

PLANNING YEAR	SERVED POPULATION	ERC ESTIMATE (2.53 CAPITA/ERC)	MIN. EFFECTIVE WATER STORAGE (200 GAL/ERC)
2017	15,211	6,012	1.2 MG
2020	15,761	6,230	1.2 MG
2025	16,677	6,490	1.3 MG
2030	17,594	6,682	1.3 MG
2035	18,511	6,874	1.4 MG
2040	19,427	7,066	1.4 MG

Even though there is sufficient pumping and storage capacity to meet the State regulations, there is insufficient clearwell storage to allow the pumps to supply flow for the durations required; 1,000 gpm for 1 hour and 2,000 gpm for 2 hours. Black & Veatch recommends that the County have a 0.42 MG finished water clearwell storage to enable the HSPS to supply the appropriate demands during a fire. The existing clearwell is approximately 0.14 MG; therefore, the County is recommended to install an additional 0.30 MG of clearwell storage at the water treatment plant. In fact, the existing storage capacity is not large enough to provide the current maximum day demand plus fire flow for two hours; therefore, the County is recommended to construct this required storage immediately.

2040 MDD+FF = 5.1 MGD
Fire Duration = 2 hours

$$Storage\ Capacity = 5.1\ MGD\ \times {}^{1\ day}/_{24\ hours} \times 2\ hours$$

$$Required\ Storage\ = 0.42\ MG$$

$$Existing\ Storage\ = 0.14\ MG$$

$$Recommended\ Additional\ Storage\ = 0.30\ MG$$

4.7 DISTRIBUTION AND TRANSMISSION CAPACITY ASSESSMENT

4.7.1 Water Main Capacity Assessment

The system capacity analysis shows that the distribution system maintains adequate minimum pressures, does not have excessive maximum pressures, and sustains appropriate maximum velocities throughout the entirety of a 24-hour MDD event, including during PHD conditions. The results show no need for capacity improvements throughout the distribution system through the planning year 2040. This may change within the distribution system based on the actual location of future growth, but the transmission, pumping, and storage infrastructure is sufficient to meet the anticipated demands. Appendix A contains figure maps illustrating the minimum and maximum pressure and the maximum velocity results with the system.

4.7.2 Fire Flow Capacity Assessment

The fire flow capacity assessment, however, resulted in a slightly different outcome. The results of the MDD+FF scenarios show that the transmission main backbone of the system is correctly sized and sufficient to transmit large volumes of water throughout the system. However, the results also show that several areas throughout the distribution system have insufficient capacity to meet the fire flow demands due to insufficient water main capacity.

The minimum water main diameter required to meet 1,000 gpm is 8-inches on a dead-end and 6-inches when supplied from multiple directions. Any water main with a smaller diameter causes too much headloss to maintain the required flow without pressures dropping below 20 psi.

Appendix A contains the figure maps illustrating the available fire flow of the existing system for each planning year through 2040. It is important to note that all of the identified fire flow improvements are needed to meet the performance criteria starting in the base year, 2017.

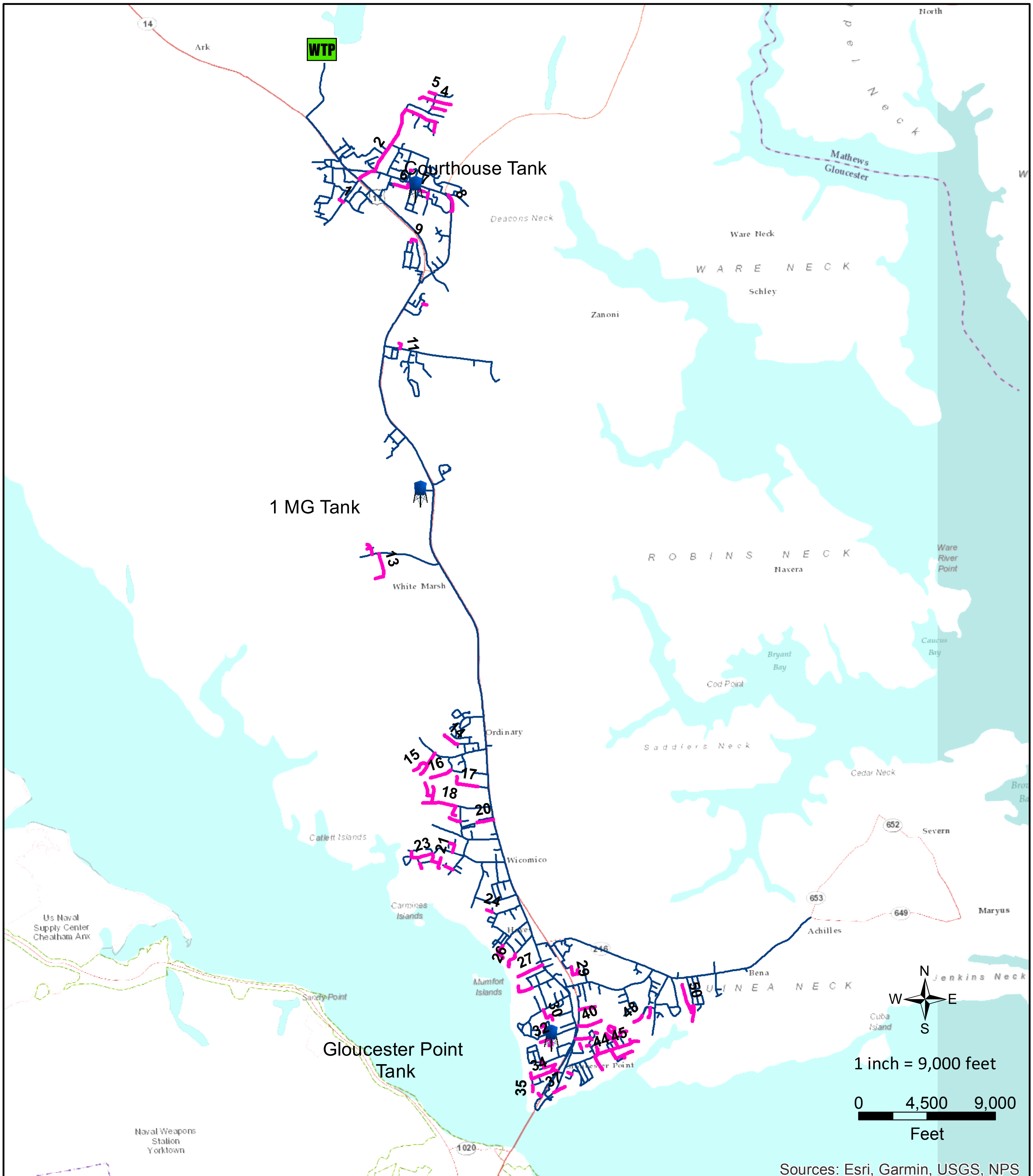
4.8 PROPOSED SYSTEM IMPROVEMENTS

Black & Veatch recommends several improvements to the Gloucester County water distribution system based on the system assessment through planning year 2040. All of the identified improvements are required to provide adequate fire flow supply to customers. Though each improvement is required for the existing system and demands, if funding is limited these improvements could be coordinated with sewer and/or roadway improvements or considered water quality improvements when the original mains are asbestos cement.

Figure 4-9 illustrates the location and prioritization of the recommended water main improvements. Prioritization of the improvements were based on improving public health by replacing asbestos cement pipe and based on how much available fire flow the improvement provided. Replacement of asbestos cement water mains also has the added benefit to the County to reduce the level of effort needed by the operations staff on repair activities if the water main were to be broken or damaged. **Table 4-7** summarizes the prioritized proposed pipeline improvements. The highest priority projects (rank = 1) were the improvements that addressed locations with available fire flows less than 500 gpm. The lowest priority improvement projects (rank = 4) were the ones that addressed available fire flow issues, but the available fire flows were within 10% of the goal. The remaining improvement projects were placed into the second and third priority group. The second priority improvement projects (rank = 2) were the ones that were replacing asbestos cement and where the available fire flow was greater than 500 gpm, but was also had an available fire flow deficiency greater than 10% of the goal. The third priority improvement projects were the ones where the available fire flow was greater than 500 gpm and the fire flow deficiency was greater than 10%, but they were not replacing an existing asbestos cement water main.

The costs were determined by using a unit factor of $10/inch-ft. For example, an 8-inch water main's installation cost would be $80 per foot using this unit factor. This unit cost includes a 30% contingency; however, an additional 15% contingency was added to all asbestos concrete pipe replacement projects to account for additional labor effort, safety precautions, and disposal costs. It is likely that most of the projects can abandon the existing asbestos concrete pipe in place and fill with grout.

It should be noted that the table and figures below do not include the proposed 0.3 MG clearwell or HSPS pump replacement recommended to be installed at the water treatment plant. The clearwell improvement has an opinion of probable planning level cost of 2,100,000 dollars. Additionally, the proposed pump replacement between 2030 and 2035, with a 1,600 gpm pump, has an estimated cost of $250,000. These opinions of planning level cost were prepared without the benefit of a site visit, so assumptions had to be made about the site construction. The tank was assumed to be constructed below grade with a spread footing (since no information on subsurface conditions was available) using cast-in-place concrete with a concrete roof. It is recommended that additional preliminary engineering be conducted to confirm these costs.



WTP

Tanks

Proposed Improvements

wMain

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Figure 4-9

2040 Proposed Water System Improvements

Table 4-7 Prioritized Proposed Fire Flow Improvement Projects

PROJECT	EXISTING DIAMETER	PROPOSED DIAMETER	LENGTH	EXISTING FF	PROPOSED FF	INCREASED FF	EXISTING MATERIAL	% OF GOAL	TOTAL OPCC	RANK
1	6	8	330	31	1,100	1,069	GALVANIZED	3%	$26,400	1
2	6	8 12	2,820 5,845	773	1,404	631	C900 PVC	77%	$927,000	3
3	6	8	930	988	1,207	219	C900 PVC	99%	$927,000	4
4	6	8	2,155	718	1,109	392	C900 PVC	72%	$172,400	3
5	6	8	480	813	1,147	335	C900 PVC	81%	$74,400	3
6	6	6 8	885 435	584	1,240	656	New WM C900 PVC	58%	$172,400	3
7	6	6	715	117	1,756	1639	New WM	11%	$38,400	1
8	6	8	1,265	107	2,203	2095	Unknown	11%	$87,900	1
9	6	8	555	182	2,169	1987	C900 PVC	18%	$44,400	1
10	6	8	250	1,646	2,079	433	Unknown	82%	$52,200	3
11	6	8	475	1,562	2,576	1013	C900 PVC	78%	$101,200	3
12	6	8	1,030	966	1,040	75	C900 PVC	97%	$44,400	4
13	6	8	2,115	733	1,034	301	C900 PVC	73%	$20,000	3
14	6	8	1,100	897	1,188	290	C900 PVC	90%	$38,000	4
15	6	8	2,845	757	1,126	369	C900 PVC	76%	$82,400	3
16	6	8	1,460	860	1,205	345	C900 PVC	86%	$169,200	3
17	6	8	1,865	791	1,334	543	C900 PVC	79%	$88,000	3
18	6	8	5,360	625	1,031	406	C900 PVC	63%	$227,600	3
19	6	8	795	996	1,342	346	C900 PVC	100%	$116,800	4
20	6	8	1,090	1,001	1,636	635	C900 PVC	100%	$149,200	3
21	6	8	905	835	1,080	245	C900 PVC	83%	$428,800	3
22	6	8	545	957	1,158	201	C900 PVC	96%	$63,600	4
23	6	8	3,990	595	1,010	415	C900 PVC	60%	$87,200	3
24	6	8	390	966	1,088	122	C900 PVC	97%	$72,400	4
25	6	8	1,150	992	1,434	442	C900 PVC	99%	$43,600	4
26	6	8	1,125	899	1,252	353	C900 PVC	90%	$319,200	4
27	6	8	1,790	770	1,358	587	DUCTILE IRON	77%	$31,200	3
28	6	8	1,315	878	1,366	488	C900 PVC	88%	$92,000	3
29	6	8	1,185	903	1,182	280	C900 PVC	90%	$90,000	4
30	6	8	1,215	995	1,716	721	C900 PVC	100%	$143,200	3
31	6	8	1,100	135	1,702	1567	ASBESTOS CONCRETE / GALVANIZED	14%	$105,200	1
32	6	8	1,255	79	2,762	2683	GALVANIZED	8%	$94,800	1

33	6	8	2,050	798	1,068	270	ASBESTOS CONCRETE	80%	$97,200	3
34	6	8	2,230	512	1,221	709	ASBESTOS CONCRETE	51%	$101,200	2
35	6	8	420	559	1,162	603	ASBESTOS CONCRETE	56%	$100,400	2
36	6	8	275	630	1,086	456	ASBESTOS CONCRETE	63%	$188,600	2
37	6	8	850	426	1,180	754	ASBESTOS CONCRETE	43%	$205,160	1
38	6	8	310	924	1,071	147	ASBESTOS CONCRETE	92%	$38,640	2
39	6	8	1,120	985	1,394	409	C900 PVC	99%	$25,300	2
40	6	8	1,610	949	1,665	716	ASBESTOS CONCRETE	95%	$78,200	2
41	6	8	1,515	167	1,558	1,391	ASBESTOS CONCRETE / GALVANIZED	17%	$28,520	1
42	6	8	345	641	1,291	651	C900 PVC	64%	$103,040	3
43	6	8	1,045	887	1,322	434	ASBESTOS CONCRETE	89%	$148,120	2
44	6	8	3,705	498	1,109	611	ASBESTOS CONCRETE	50%	$121,200	1
45	6	8	3,550	424	1,134	710	ASBESTOS CONCRETE	42%	$27,600	1
46	6	8	1,705	621	1,057	436	ASBESTOS CONCRETE	62%	$96,140	2
47	6	8	730	432	1,068	636	ASBESTOS CONCRETE	43%	$340,860	1
48	6	8 12	695 45	268	1,061	794	SCH.40 PVC	27%	$326,600	1
49	6	8	725	748	1,345	597	SCH.40 PVC	75%	$156,860	3
50	6	8	3,230	732	1,004	272	C900 PVC	73%	$67,160	3

Table 4-8 Prioritized Proposed Water Main Improvements

RANK	PROJECT TRIGGER	PROJECT #S	OPCC
1	Existing Fire Flow < 500 gpm	1, 7, 8, 9, 31, 32, 37, 41, 44, 45, 47, 48	$1,447,040
2	Public Health / Asbestos Cement	34, 35, 36, 38, 39, 40, 43, 46	$776,600
3	Other	2, 4, 5, 6, 10, 11, 13, 15, 16, 17, 18, 20, 21, 23, 27, 28,30, 33,42, 49, 50	$3,442,660
4	Existing FF is within 10% of Goal	3, 12, 14, 19, 22, 24, 25, 26, 29	$1,715,000

5.0 Wastewater Collection System Master Plan

5.1 BASE YEAR FLOWS

The dry weather flow (DWF) includes contributions from all customers (base sanitary) in the collection system as well as groundwater infiltration (GWI) into the collection system.

The County currently has a collection system model built and calibrated as a part of the regional consent decree (URS 2012). This model was reviewed and utilized for the master planning efforts. The calibrated Mike Urban model included base sanitary flow loadings and diurnal patterns. GWI and wet weather flows were loaded into the model used external time series data (DFS0 files). The dry weather flow loadings in the calibrated model totaled 0.27 MGD. The model was updated to include pump stations 27 and 28. Based on run time data, dry weather flows of 2,300 gpd and 1,990 gpd were added to the model for the PS27 and PS28 areas, respectively. The total dry weather flow, including pump stations 27 and 28, was 0.28 MGD.

The modeled loadings were scaled to match the base year flow of 0.5 MGD. A scalar factor was applied to both the base sanitary flows and the groundwater infiltration.

5.2 FUTURE FLOW ALLOCATION

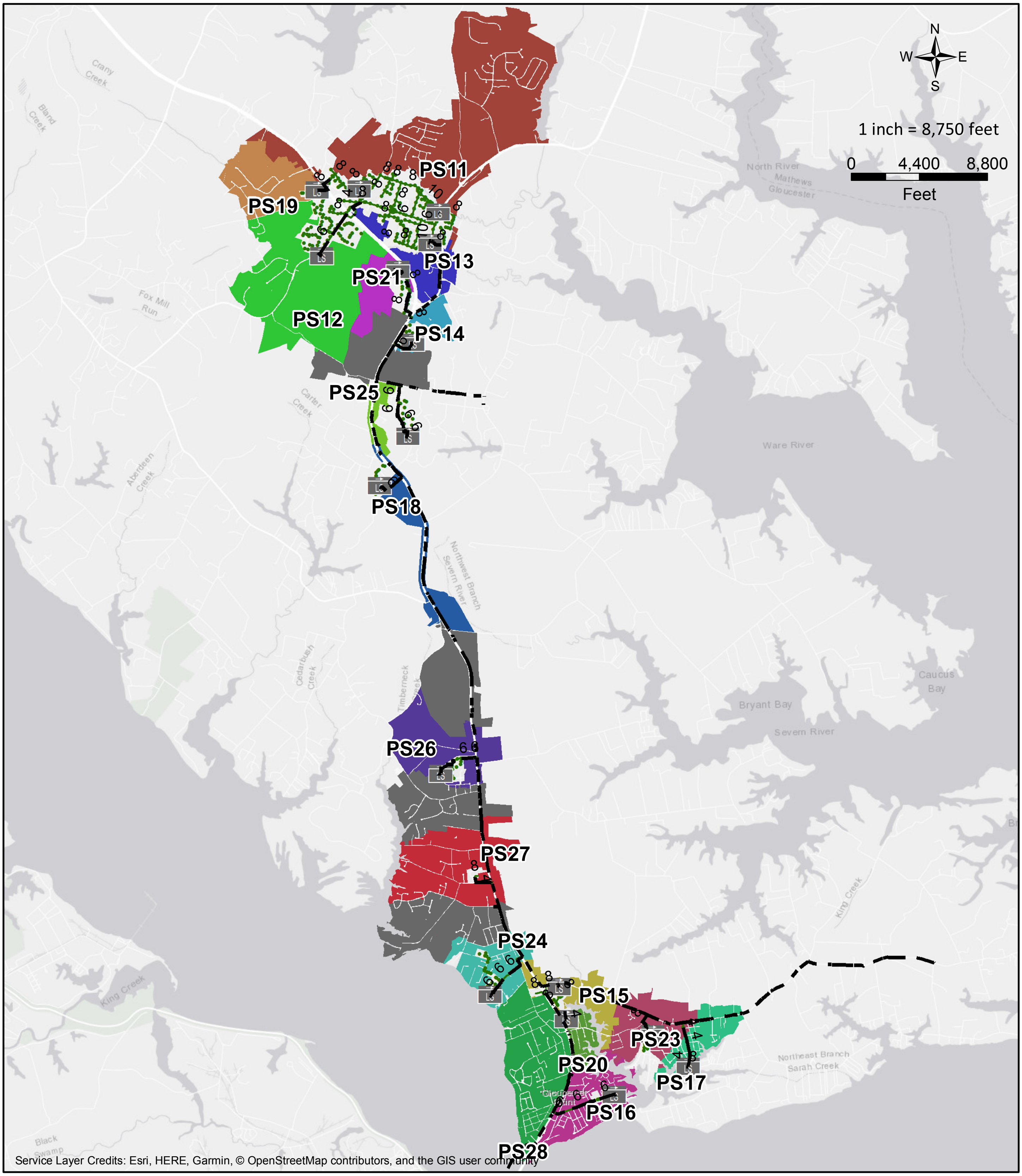
Future flows were added to the base year model to simulate growth across the Gloucester system. Flows were allocated within the existing system as well as to areas outside the existing service area that were designated as system expansion areas.

Flow within the existing service area was expected to grow by 10% by 2040. The 10% increase in flow was allocated across the system based on the allocations of the existing flows. GWI in the existing system was not expected increase, since the flow increase is due to infill rather than system expansion.

The remaining growth in wastewater flows was attributed to system expansion. Future flows from system expansion were allocated throughout the system based on the distribution of buildout flows. Buildout flows were determined based on future land use for the entire service area. Unit rates were used to convert future land use to wastewater flows. The unit rates used to estimate buildout flows are shown in **Table 5-1**. The projected incremental increases in flow from 2017 to 2040 were allocated based on the location of the estimated build out flows. All future infrastructure was sized based on 2040 flows, not the build out flows. The allocation of the future growth areas is shown in **Figure 5-1**.

Table 5-1 Wastewater Unit Rates by Land Use

LAND USE	WASTEWATER PRODUCTION
Employment & Light Industrial	1,500 gpd/acre
Highway Mixed Use	1,500 gpd/acre
Suburban High Density	1,000 gpd/acre
Village Scale Mixed Use	750 gpd/acre
Mixed Density Residential	1,000 gpd/acre



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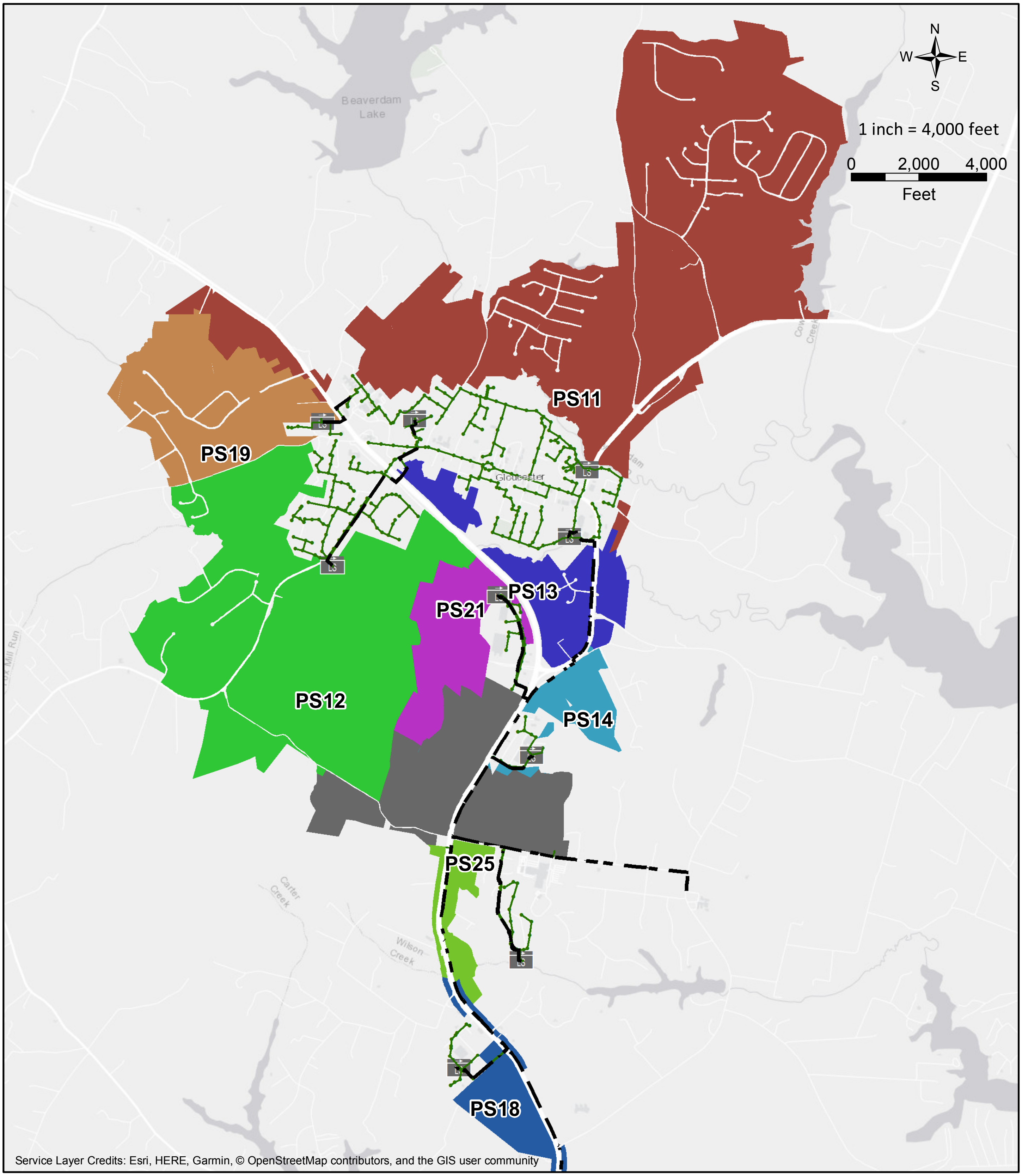
Force Main		PS11		PS17		PS24
PS Locations		PS12		PS18		PS25
Manholes		PS13		PS19		PS26
Pipes		PS14		PS20		PS27
		PS15		PS21		PS28
		PS16		PS23		HRSD FM

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 5-1

Sewer System Analysis Planning Year Flow Allocation by Pump Station



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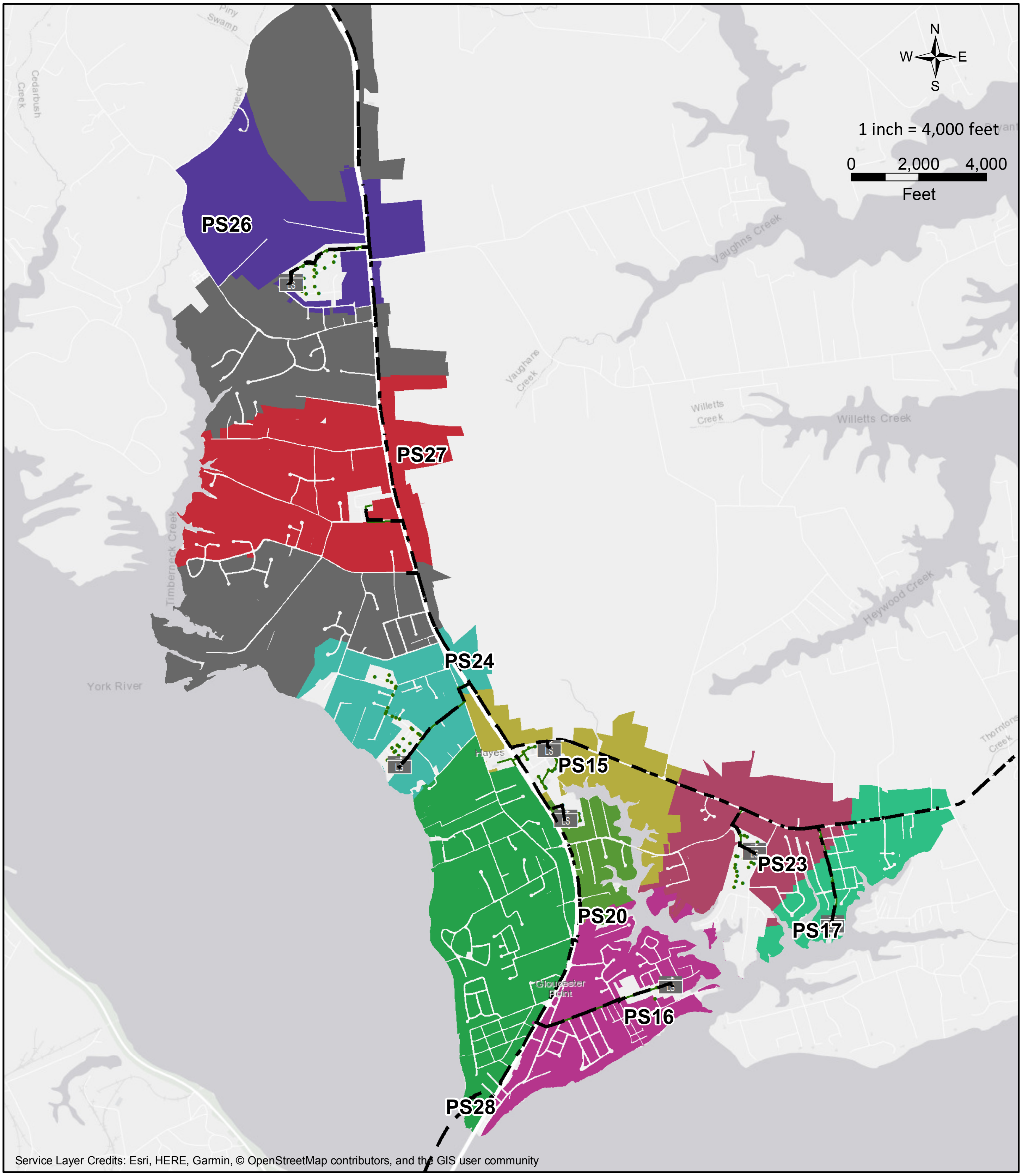
Force Main	PS11	PS17	PS24
PS Locations	PS12	PS18	PS25
Manholes	PS13	PS19	PS26
Pipes	PS14	PS20	PS27
	PS15	PS21	PS28
	PS16	PS23	HRSD FM

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 5-1 N

Sewer System Analysis Planning Year Flow Allocation by Pump Station



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Force Main	PS11	PS17	PS24
PS Locations	PS12	PS18	PS25
Manholes	PS13	PS19	PS26
Pipes	PS14	PS20	PS27
	PS15	PS21	PS28
	PS16	PS23	HRSD FM

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 5-1 S

Sewer System Analysis Planning Year Flow Allocation by Pump Station

5.2.1 Future Wet Weather Flows

In the existing service area, growth is expected to come from redevelopment, so no additional wet weather flows were added to the future year models. In the future expansion areas, both groundwater infiltration and wet weather infiltration were added to the model. Groundwater flows were estimated by assuming a constant GWI/DWF ratio for the entire service area. The average GWI/DWF ratio for the existing system was 13.2% based on the currently allocation of GWI and BSF in the URS hydraulic model. The ratio was applied to all future flows allocated in the system expansion areas to determine the amount of groundwater infiltration.

The wet weather output hydrographs from the 5 year storm model for the existing system were used to develop future wet weather flows. The wet weather hydrographs for each of the pump stations in the existing model were summed together. The average hydrograph was divided by the average base sanitary flow to develop a dimensionless 5 year storm hydrograph. The peak wet weather flows throughout the system were assumed to be proportional to the base sanitary flow. The wet weather flows were allocated to the model using the same methodology as the dry weather flows for the future system expansion.

5.3 PERFORMANCE CRITERIA

Design criteria are used to determine if an improvement is required. The criteria are separated into two groups – trigger and design criteria. Trigger criteria is a set of conditions when exceeded will initiate an improvement. The design criteria are the conditions that the improvements will be designed to convey without exceeding. The criteria are separated to prioritize the capacity investment for the utility.

For Gloucester County, the trigger criteria are summarized below:

- Gravity System – Peak HGL surcharges within 2 feet of the manhole rim during the 5 year design event
- Pump Station – Firm pump station capacity is exceeded during the 5 year design event
- Force Mains – Velocity should be less than 10 ft/s

The design criteria for Gloucester County are summarized below:

- Gravity System – Peak flow stays within the pipe during the 5 year design event in the ultimate planning year (2040)
- Pump Station – Firm pump station capacity is not exceeded during the 5 year design event in the ultimate planning year (2040)
- Force Main – Designed for a velocity of 5 ft/s

5.4 COLLECTION SYSTEM CAPACITY ASSESSMENT

5.4.1 Pump Station Capacity Assessments

By 2040, the projected flows to several pump stations were found to exceed the firm capacity of the station. When the firm capacity was exceeded, the model showed that the second pump in the pump station had to turn on. A second pump came on since the water level in the wet well continued to rise even after the first pump was in operation. The recommended pump station projects are listed in the Proposed Collection System Improvements section. The following 7 stations exceeded their firm capacity by 2040: PS 11, PS 12, PS 13, PS 16, PS 24, PS 27, and PS 28. The firm capacity of each pump station is listed in **Table 5-2**. The firm capacity was determined using the pump curves and the discharge pressures at the HRSD force main received from Gloucester County. **Table 5-2** also shows the recommended upgraded firm capacity for the improved pump stations. The upgraded capacity is based on the 2040 pump station flows. The County may elect to implement a phased approach for these pump station expansions. The initial phase would be to construct the wet well designed for the future 2040 peak wet weather flows, but install smaller capacity pumps that would eventually be replaced with larger capacity pumps. This would defer some capital expenditures for the County.

Table 5-2 Gloucester Pump Stations

PUMP STATION	EXISTING FIRM CAPACITY (GPM)[1]	RECOMMENDED FIRM CAPACITY (2040 FLOWS, GPM)
11	265.7	2400
12	145.0[3]	1090
13	322.9	2280[2]
14	800.1	-
15	800.3	-
16	253.8	730
17	168.0	-
18	1181.3	-
19	320.6	-
20	364.3	-
21	1100.3	-
22	198.6	-
23	896.3	-
24	528.5	1130
25	920.7	-
26	597.3	-
27	167.0[3]	450
28	250.0[3]	440

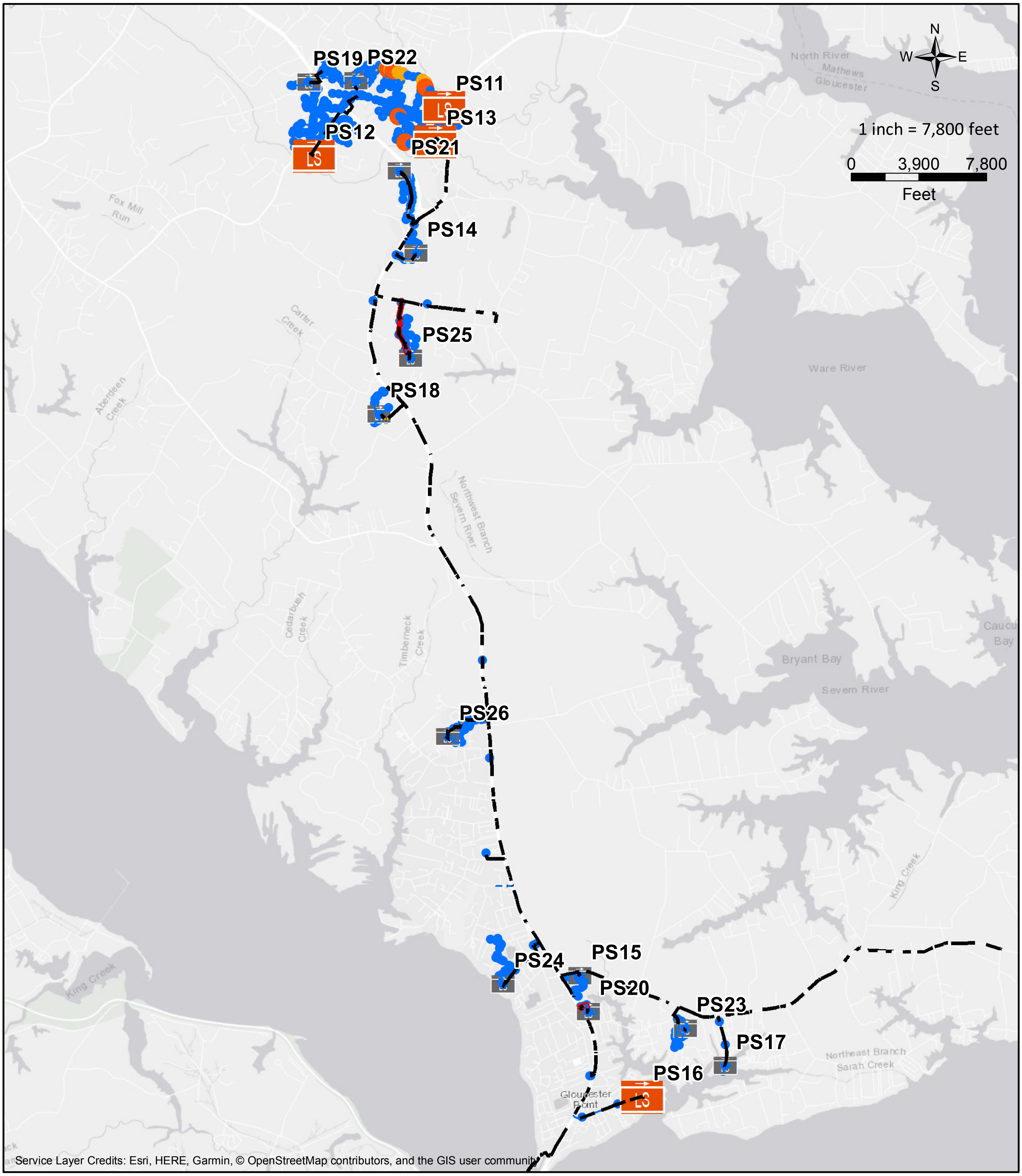
[1]Based on existing system model and pump curves
[2]Assumes PS11 is diverted directly to the HRSD Force Main
[3]Based on design flow

5.4.2 Gravity Sewer Main Capacity Assessment

The system capacity analysis shows that the collection system has capacity restrictions during severe storm events. The results show the need for several capacity improvements through the planning year 2040. While some surcharged depths in the system were caused by backups from capacity limited pump stations, others were caused by capacity restricted sewers. Gravity sewer improvements required to convey the anticipated wastewater flows under the established performance criteria are listed in the following section. Appendix B contains figure maps illustrating the performance results within the system.

Figure 5-2 shows the capacity results for the existing system under a 5 year design storm. The model indicated that four pump stations were beyond their firm capacity. Additionally, the gravity sewer lines upstream of pump stations 11 and 13 were shown to be capacity limited. These areas will be the highest priority projects. After completion of the modeling work, the County shared with us that they recently improved the capacity of Pump Station 12. Its firm capacity following the improvement is 324 gpm as opposed to the 145 gpm that was previously in the model. The results in Figure 5-2 do not reflect this capacity improvement. The peak influent wet weather flow for the 2017 planning year during the 5 year storm is 305 gpm, so there is no capacity issue at this pump station if the improved capacity were used. It should be noted that the peak influent flow for the 2020 planning year does increase to 369 gpm, so this improvement is deferred to the 2020 planning year.

Figure 5-3 shows the results for the unimproved system in 2040 under a 5 year design storm. All additional capacity limited sections shown in the 2040 figure will be addressed by the phased improvements recommended in the following section. The 2040 assessment showed the gravity sewers downstream of PS 19 to be surcharging to within 2 feet of the manhole rim. Since the surcharged sewers run through the Riverside Walter Reed Hospital complex, re-routing of the Pump Station 19 force main is recommended rather than upsizing the gravity sewer. The Force main can be routed to either manhole N090 on the southeastern side of the hospital or slightly farther to manhole M068 located near the intersection of Hwy 17 and Main St. The recommended improvement shows the force main re-routed to manhole N090.



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LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

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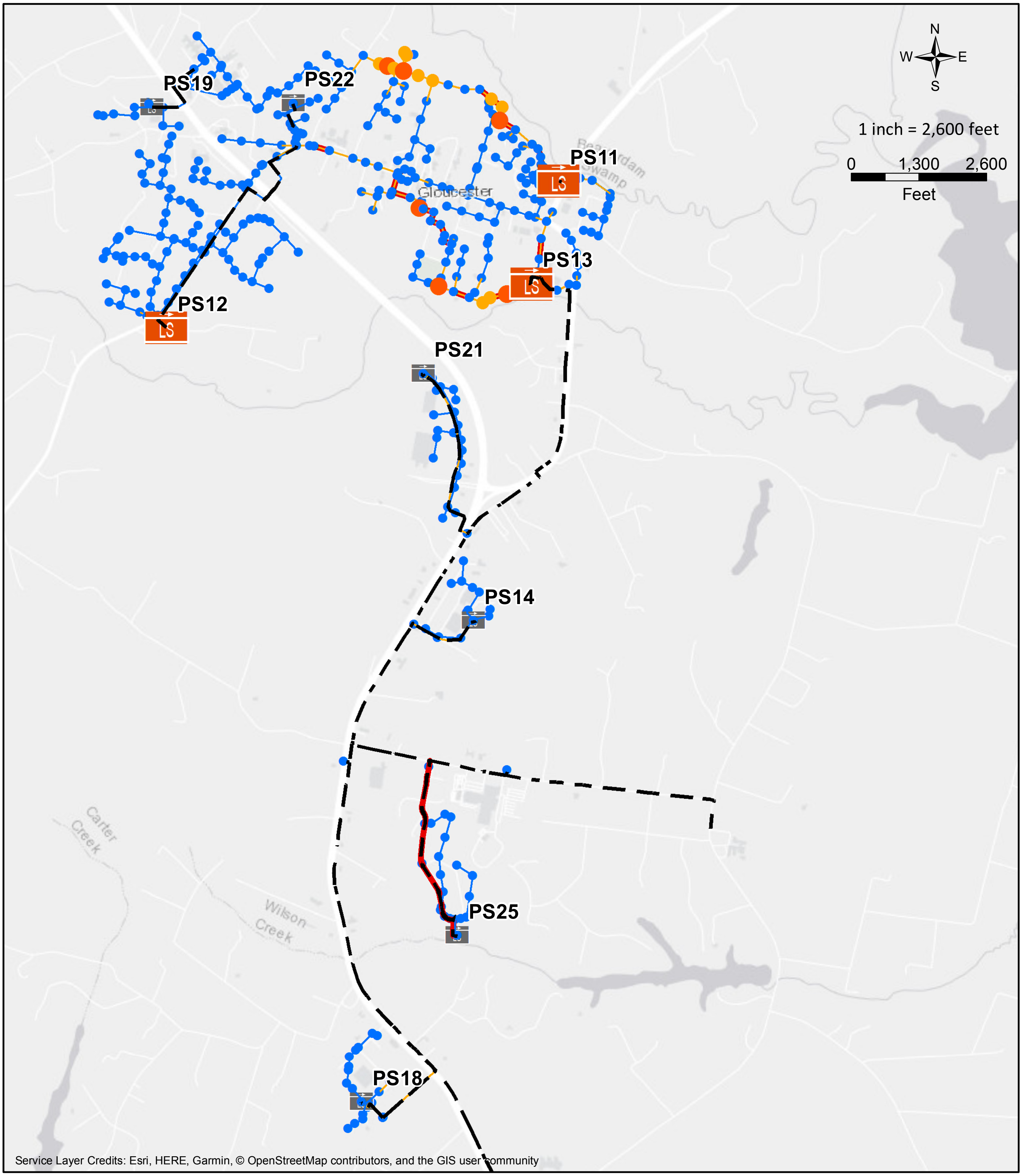
Figure 5-2

Sewer System Analysis
No Improvements
Base Year Flows
5 Year Storm



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LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

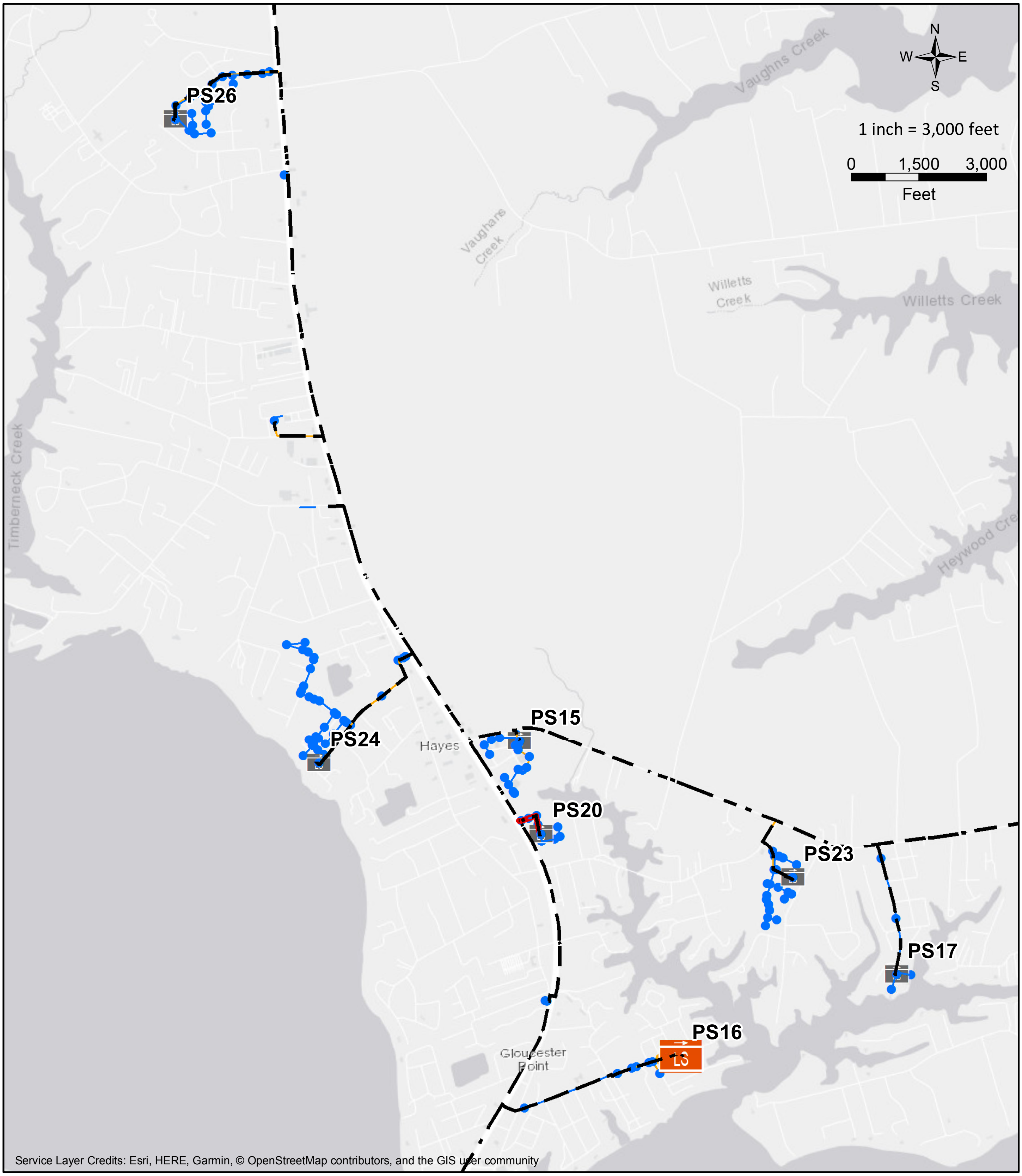
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 5-2 N

Sewer System Analysis
No Improvements
Base Year Flows
5 Year Storm



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LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

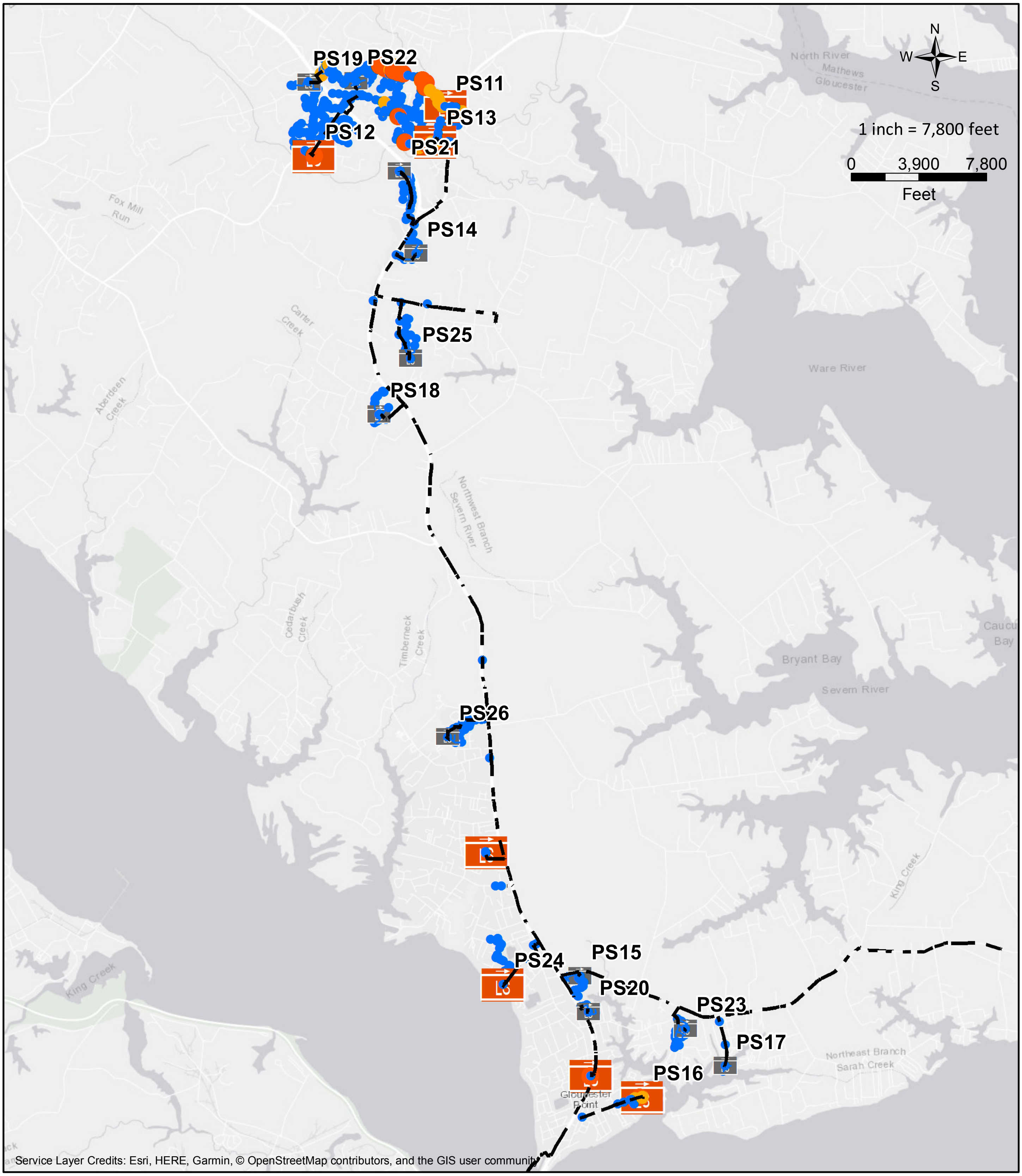
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 5-2 S

Sewer System Analysis
No Improvements
Base Year Flows
5 Year Storm



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LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

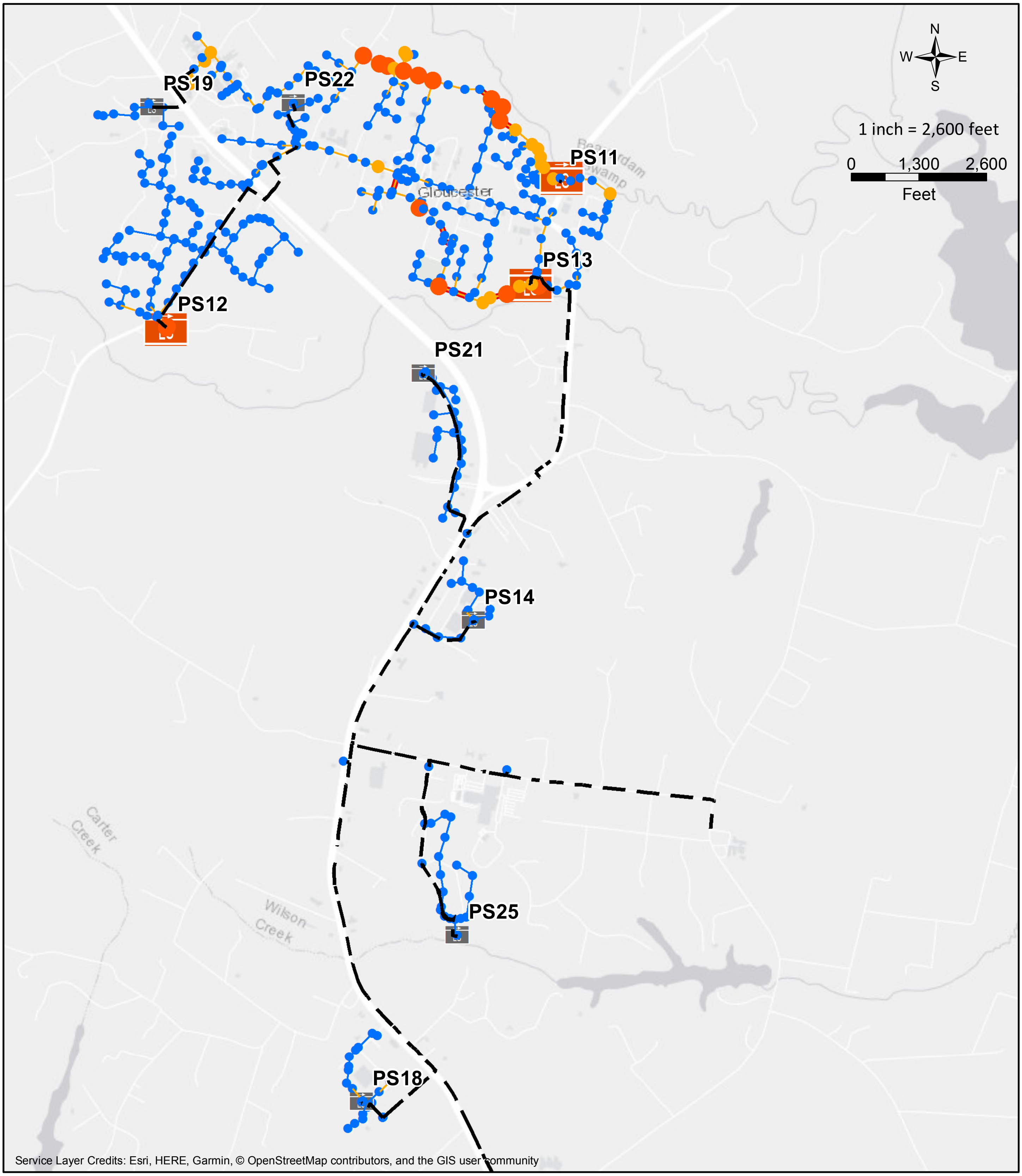
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 5-3

Sewer System Analysis
No Improvements
2040 Planning Year Flows
5 Year Storm



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LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

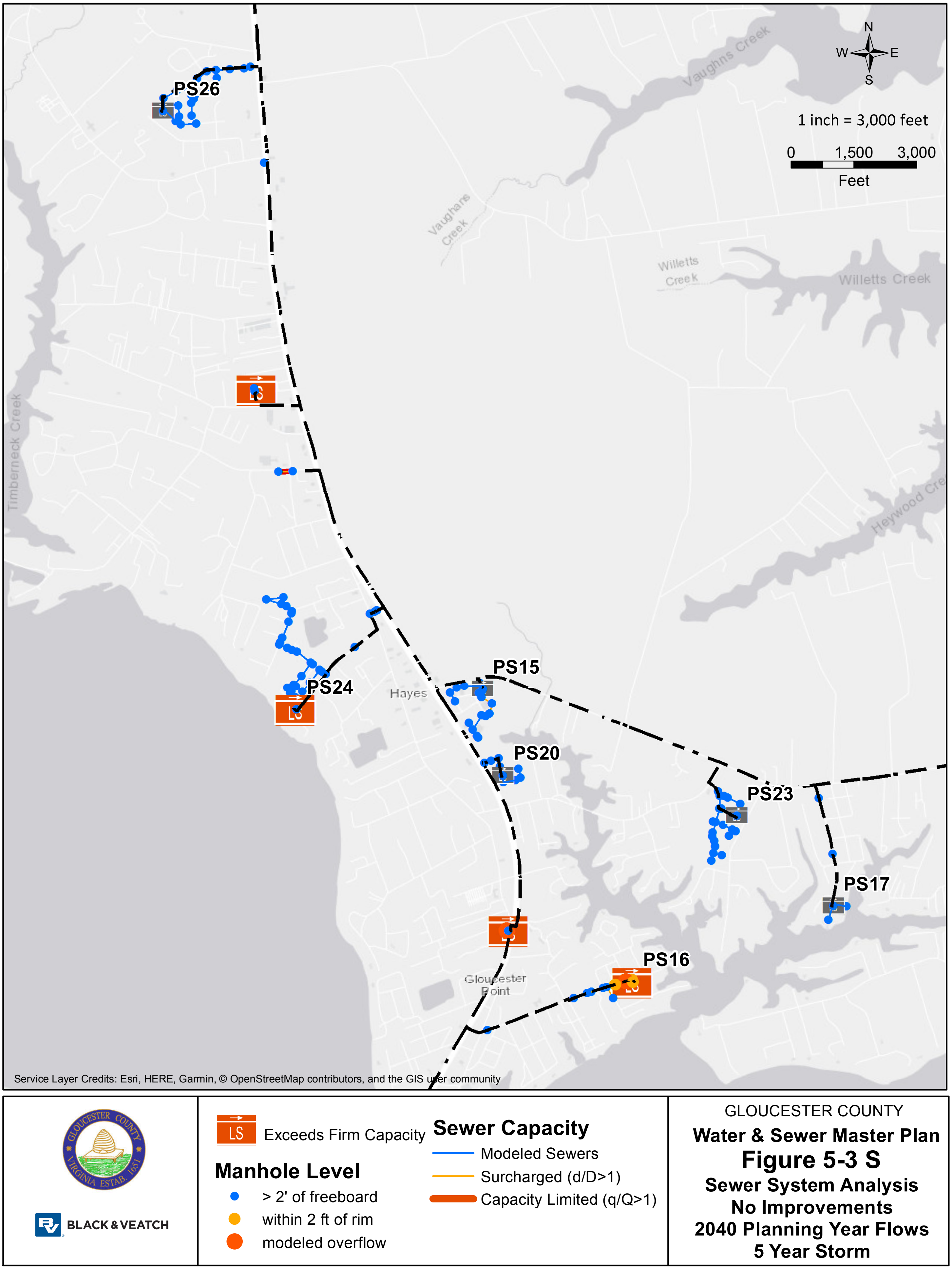
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 5-3 N

Sewer System Analysis
No Improvements
2040 Planning Year Flows
5 Year Storm



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Water & Sewer Master Plan

Figure 5-3 S

Sewer System Analysis
No Improvements
2040 Planning Year Flows
5 Year Storm

5.5 PROPOSED COLLECTION SYSTEM IMPROVEMENTS

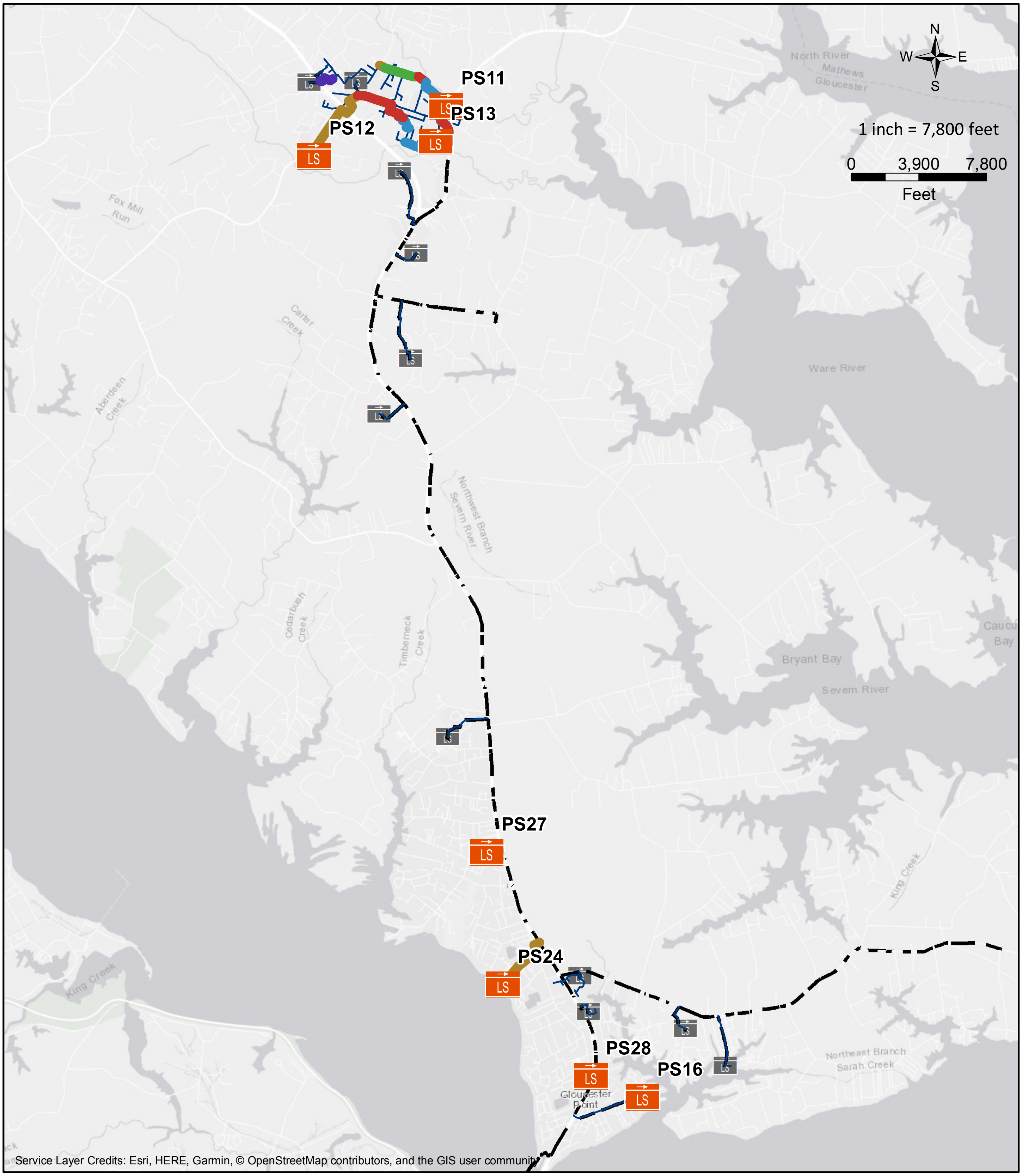
Black & Veatch recommends several improvements to the Gloucester County collection system based on the system assessment through planning year 2040. All of the identified improvements are required to provide adequate capacity for wet weather flows. The improvements were phased based on when the existing flows exceeded the trigger performance criteria.

Figure 5-4 illustrates the location and prioritization of the recommended improvements. Prioritization of the improvements was based on the trigger criteria.

Opinions of Probable cost were estimated for each recommended improvement. Unit cost rates for gravity sewer and sewer force main are shown in **Table 5-3**. Pump Stations were estimated to cost $500,000/MGD of firm capacity. A 30% contingency was added to each construction estimate. **Table 5-4** summarizes the prioritized proposed pump station capacity upgrades. **Table 5-5** summarizes the prioritized proposed gravity sewer improvements. **Table 5-6** summarizes the prioritized proposed force main sewer improvements.

Table 5-3 Sewer Unit Costs

GRAVITY SEWER DIAMETER (IN)	COST / LINEAR FOOT ($)
8	111
10	132
12	153
15	187
18	222
21	260
24	300
27	342
30	386
SEWER FORCE MAIN DIAMETER (IN)	**COST / LINEAR FOOT ($)**
6	100
10	120
15	160



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Improvements

- 6-inch
- 10-inch
- 12-inch
- 15-inch
- 18-inch

- PS Improvements
- PS Locations
- Sewer Main
- Force Main

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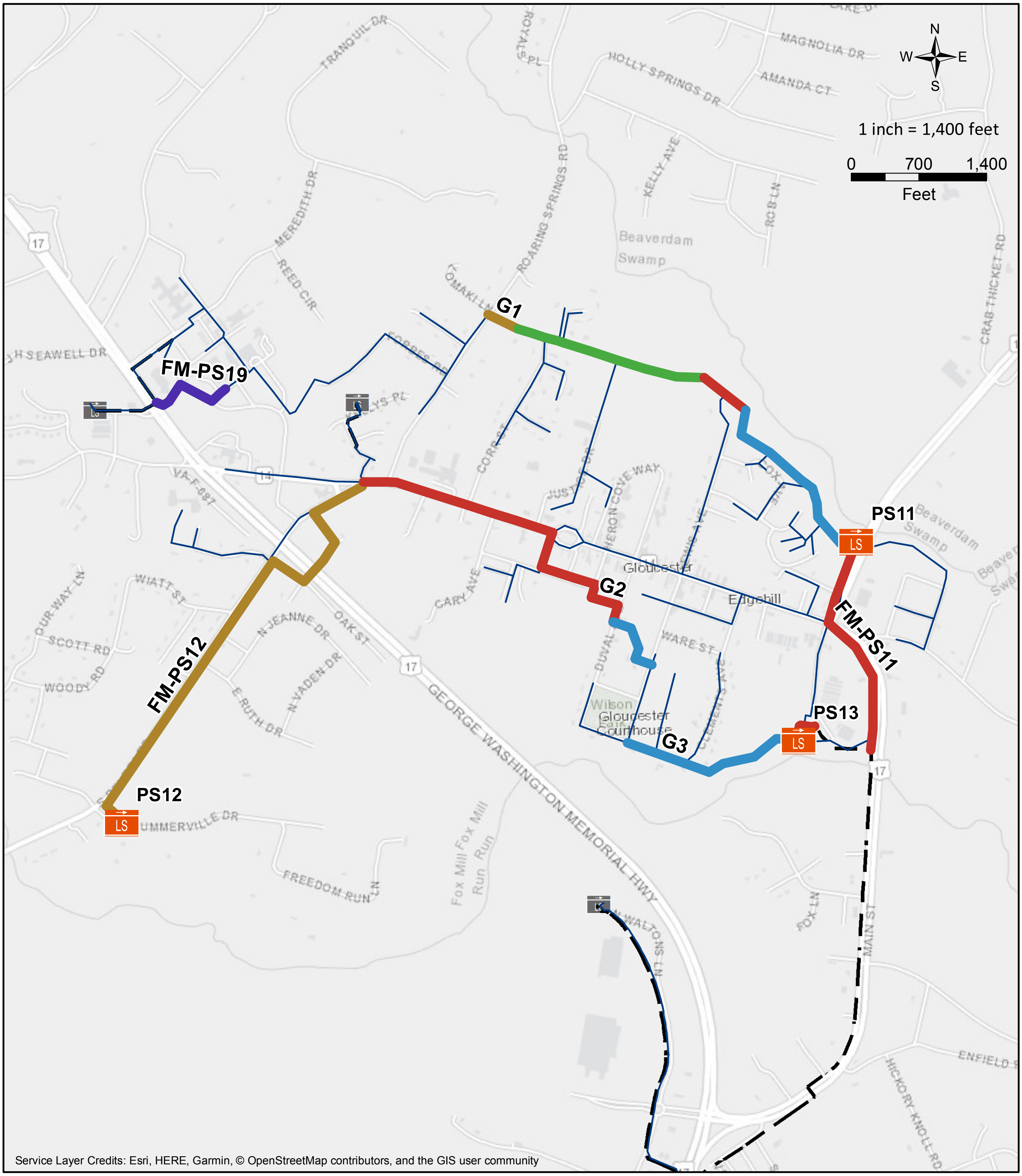
Figure 5-4

Sewer System Analysis Recommended Improvements



Improvements

- 6-inch
- 10-inch
- 12-inch
- 15-inch
- 18-inch
- PS Improvements
- PS Locations
- Sewer Main
- Force Main

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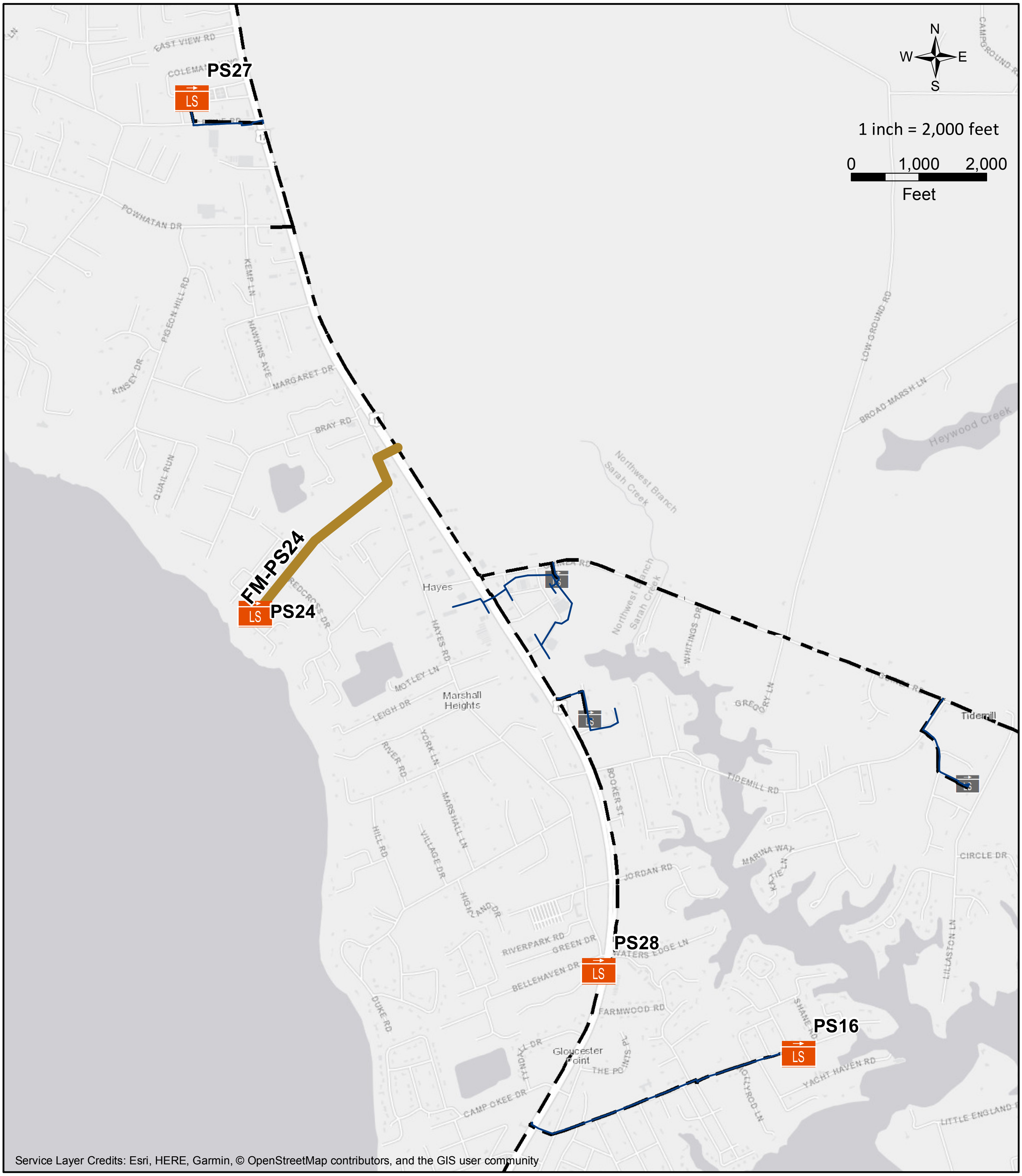
Figure 5-4 N

Sewer System Analysis Recommended Improvements



BLACK & VEATCH

Improvements

- 6-inch
- 10-inch
- 12-inch
- 15-inch
- 18-inch
- PS Improvements
- PS Locations
- Sewer Main
- Force Main

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 5-4 S

Sewer System Analysis Recommended Improvements

Table 5-4 Prioritized Proposed Pump Station Capacity Upgrades

PROJECT	YEAR	RECOMMENDED FIRM CAPACITY (GPM)	PUMP STATION CONSTRUCTION COST
PS11	2017	2400	$2,246,400
PS13	2017	2280	$2,134,080
PS16	2017	730	$683,280
PS12	2020	1090	$1,020,240
PS24	2030	1130	$1,057,680
PS27	2030	450	$421,200
PS28	2040	440	$411,840

Table 5-5 Prioritized Proposed Gravity Sewer Improvements

PROJECT	YEAR	DESCRIPTION	DIAMETER (IN)	LENGTH (FT)	GRAVITY SEWER CONSTRUCTION COST
G1	2017	Upstream of Pump Station 11	10 12 15 18	340 2000 550 1980	$1,160,000
G2	2017	Main Street	15 18	3600 720	$1,080,000
G3	2017	Upstream of PS 13	18	1920	$550,000

Table 5-6 Prioritized Proposed Force Main Improvements

PROJECT	YEAR	RECOMMENDED FIRM CAPACITY (GPM)	NEW FORCE MAIN DIAMETER (IN)	NEW FORCE MAIN LENGTH (FT)	FORCE MAIN COST
FM-PS11	2017	2400	15	2,500[1]	$520,000
FM-PS13	2017	2280	15	185	$38,500
FM-PS24	2030	1130	10	3,540	$552,200
FM-PS12	2020	1090	10	5,190	$810,000
FM-PS19	2030	-	6	1,000	$130,000
[1]Route following Highway 14 and Highway 17 to HRSD Force Main					

Several of the proposed sewer system improvements are/will be addressed within the Facility Maintenance Repair/ Replacement (FMRR) or the Capital Improvement Program (CIP):

- Upgrades of pump station firm capacity; #11, 12 (interim), 13, and 16. These projects will include the force main improvements shown in Figure 5-4 N (including the force main from PS #19).
- Firm capacity upgrades to #24, 27, 28, and addition capacity for 28, including recommended force main upgrades, will likely be done by developers unless the County

decides to extend gravity sewer to serve existing development before developers extend it.

- The CIP will also include the gravity sewer improvements listed in Table 5-5.

6.0 Conclusions and Recommendations

Capital improvement projects were identified for the water and wastewater systems. The water system improvements consisted of almost 79,000 feet of water distribution piping with an opinion of probable planning level cost of 6.6 million dollars along with water treatment plant improvements (a 0.3 MG clearwell & 1,600 gpm high service pump) with an opinion of probable planning level cost of $2.4 million for a total water system opinion of probable planning level cost of 9.0 million dollars.

All the improvements address a capacity issue associated with fire flow requirements in the base year. These improvements were prioritized to focus the ones that address the greatest fire flow issue as well as asbestos cement piping replacements so that the County can invest in the projects that will provide the greatest benefit first.

The wastewater collection system improvements consisted of 7 pump station improvements, 3 gravity sewer improvements, and 5 force main improvements. The opinions of probable planning level costs for the pump station, gravity sewers, and force mains were 8.0, 2.8, and 1.5 million dollars respectively. The total opinion of probable planning level costs for the sewer system improvements is 12.3 million dollars. The improvements were slated for the appropriate planning year when the capacity was required to address a level of service exceedance. No further prioritization was completed since the projects were spread out through multiple planning years.

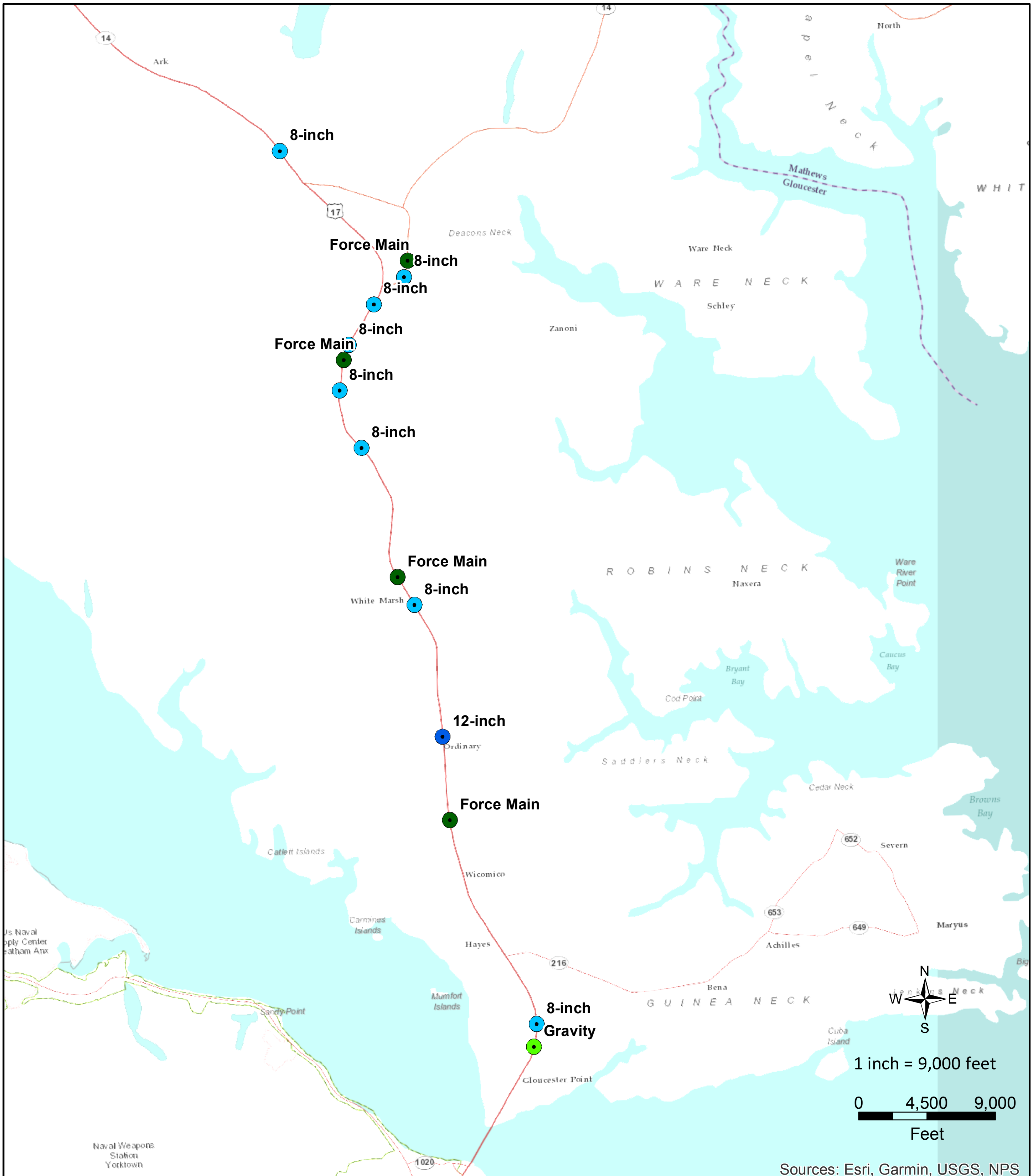
6.1 NON-CAPACITY RELATED IMPROVEMENTS

The scope of the master plan was focused on identifying and addressing capacity related improvements. The County also expressed interest in doing additional improvements to the distribution and collection system to facilitate future growth along Rte. 17 and to address potential flood inundation from storm surges resulting from tropical storms and hurricanes.

6.1.1 Route 17 Connections

The County desires to construct key crossings along Rte. 17 and Main Street to assist with future development. These connection, delineated by the County, were placed to reduce the number of roadway crossings. Developments that are being constructed on the opposite side of the road where the water and wastewater utilities are located will connect to these crossings. The alternative would be for each of these developments to pay for the crossings that would require expensive trenchless construction means since closure or partial closure of Rte. 17 is not feasible.

Figure 6-1 shows the locations of these connections. The wastewater connections (shown as green points) are all stub out connections to the HRSD force main except for the southernmost one where the gravity sewer will be extended across the roadway. This gravity sewer connection is located at Villa Court. Each of the wastewater connections are labeled depending on the type of connection. The water distribution system (shown as blue points) are all 8-inch water main extensions with a fire hydrant with one exception. This exception is a 12-inch water main connection with a hydrant located at Bray’s Point Road. The water distribution system connections are labeled with the size on the figure.



Proposed Wastewater Connections

- Force Main
- Gravity

Proposed Water Connections

- 8-inch
- 12-inch

BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 6-1

Rte. 17 Water/Wastewater Connections

6.1.2 Pump Station Inundation

The County should make plans to reduce the risk posed by tropical events as much as practically possible. Storm inundation mapping provided by the County identified the structures that could be inundated with stormwater. The focus was to identify these pump stations that could be inoperable and/or damaged during these events so that the County can plan to address these risks so that the likelihood of overflows is reduced. Three of the County's pump stations are prone to inundation during a category 1 hurricane storm surge, which are listed below.

- Pump Station 15
- Pump Station 17
- Pump Station 20

No site visit was performed to investigate potential solutions. Pump Stations 15 and 17 are submersible stations located at or near grade elevation, so water tight wet well hatches could be installed with curb to prevent inundation. The control panels are located above grade, so these items are not prone to flooding directly. Pump Station 20 is an above grade building whose finished floor is located three feet above grade elevation. The County should inspect and maintain the pump station so that flood water cannot enter the structure.

Two additional pump stations are prone to flooding during a Category 3 hurricane storm surge:

- Pump Station 11
- Pump Station 13

These stations are less likely to become inundated than the other stations noted previously. The County is recommended to address those station prior to implementing any flood prevention measures at these locations. The County has plans to relocate Pump Station 11 to higher ground, but it may desire to relocate the control panel and generator prior to the rest of the station to reduce the impact of flood inundation. There are no plans to relocate Pump Station 13 now. A more detailed investigation would be required to determine if relocation were possible. Like Pump Station 11, the control panel and generator for Pump Station 13 could be relocated more easily though.

6.1.3 Non-Revenue Water

Distribution system demands are comprised of several different uses and are either consumed by customers, referred to as authorized consumption, which can be billed or unbilled, or fall into the water losses category, which is comprised of apparent losses and real losses. Figure 6-2 Standard AWWA Audit Water BalanceFigure 6-2 below summarizes the standard water balance per the AWWA M36.

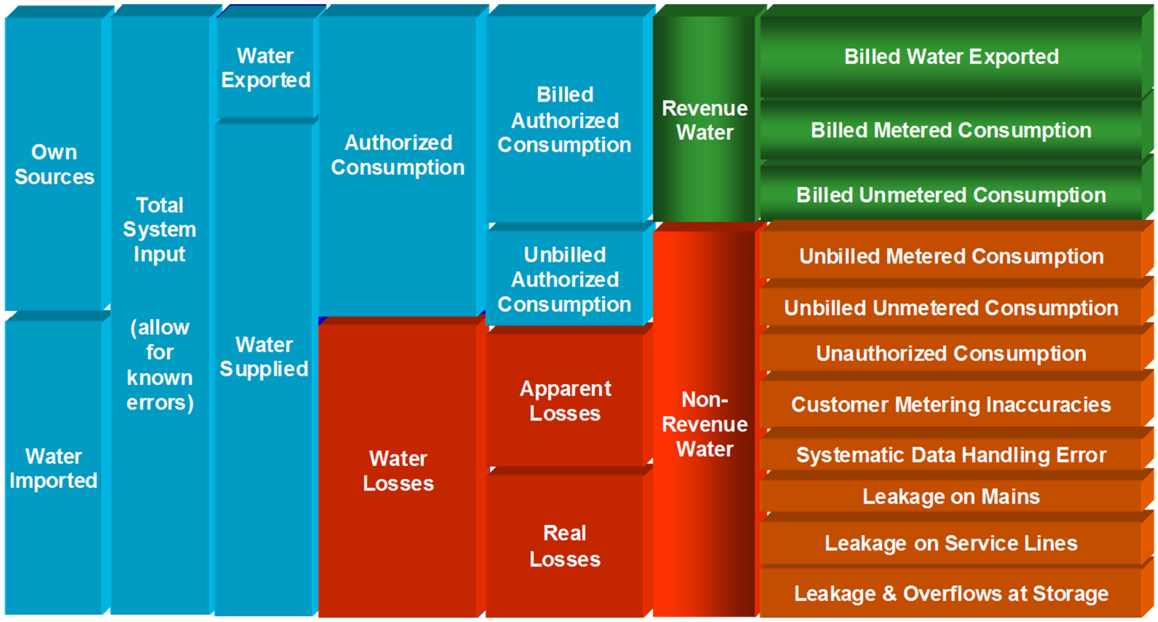


Figure 6-2 Standard AWWA Audit Water Balance

The water balance figure illustrates that the billed authorized consumption contributes to the revenue and sustainability of the water system through the monthly billing cycle. Whereas the unbilled authorized consumption (water quality flushing for both the distribution piping as well as the elevated storage tanks, uses at the treatment plant, County owned facilities, etc.), apparent losses (meter inaccuracies, data errors, etc.) and real losses (main breaks, leakage, etc.) contribute to the non-revenue water (NRW) and are ultimately a burden on the water system.

Water losses (apparent and real) are lost revenue opportunities, which do not achieve their beneficial use potential, and can contribute to a large portion of the NRW in a system. Per AWWA M36, definitions of apparent and real losses are noted below:

- *Apparent losses are the nonphysical losses (meaning no water is actually lost) that occur when water is successfully delivered to a water user, but for various reasons, is not measured or recorded accurately, thereby inducing a degree of error in the amount of actual customer consumption.* They are frequently caused by faulty, improperly sized or badly read water meters and can be corrected by rebuilding or replacing existing mechanical meters.
- *Real losses represent the physical losses of treated, pressurized water from the distribution system and are comprised of breaks and leaks from water mains and customer service connection pipes, joints and fittings.*

There are number of methods to address each type of water loss with widely varying cost implications. As such, Black & Veatch would recommend conducting a Water Loss Audit using the AWWA M36 guidelines and approach before deciding how to reduce the estimated 28% NRW in the County's distribution system in FY18. This will guide the County to the most beneficial improvement options which could include increased water main rehabilitation and replacement (R&R) rates, or to the implementation of automatic meter readers (AMR).

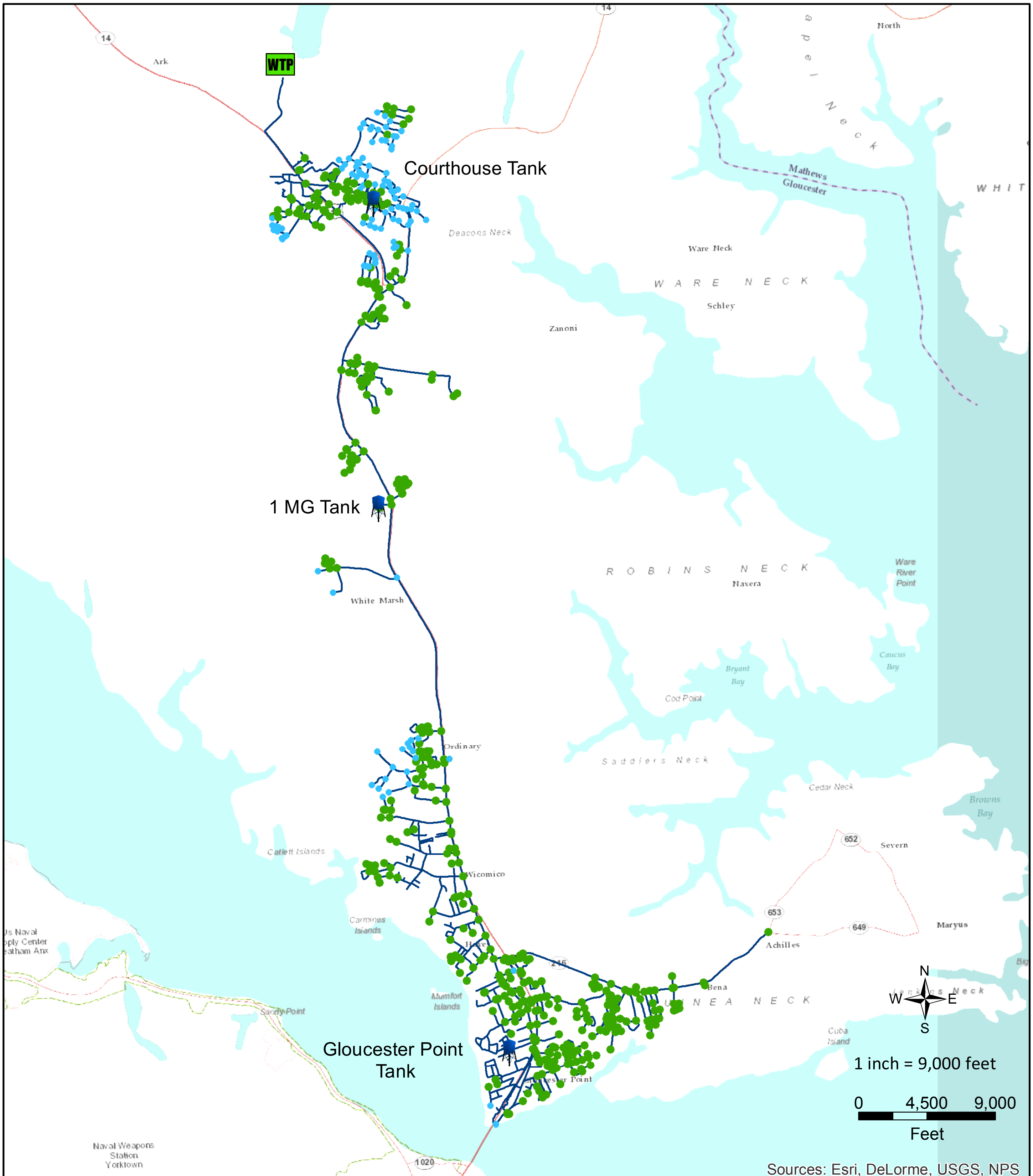
6.2 RECOMMENDATIONS

The County is recommended to verify the existing dry and wet weather wastewater flows at the improvement locations. The sewer model was calibrated using run time data at each of the pump stations (URS 2012). There is a significant amount of uncertainty with this method since the pump will operate at different flow rates due to the varying pressure conditions in the HRSD manifolded force main. With this uncertainty, the County should install flow meter(s) and rain gauge(s) to update the model calibration so that the actual influent peak flows during wet weather events can be recorded and used for the model update.

Since the HRSD flow meter on the manifolded force main is not believed to be recording accurate flows, the County should coordinate with HRSD to get the flow meter running properly. Alternatively, the County could install its own flow meter. This meter can be used to verify the amount of wastewater being sent to HRSD for accurate billing.

The County may desire to replace the remaining asbestos cement water mains in the system that are not related to a capacity improvement. The County has asbestos cement water mains along Hayes Road from Harbor Hills Drive to Bellehaven Road, Bellehaven Road between Gloucester Point Tank and Route 17, Wyncote Avenue between Roaring Springs Road and Lewis Avenue, and Greate Road through the VIMS campus. It should be noted that Wyncote Avenue asbestos cement water main is located in same corridor as the G1 improvement project, so it would reduce disruption to the community and reduce the overall capital expenditures if the water main replacement were done concurrently with the gravity sewer improvement project.

APPENDIX A
WATER HYDRAULIC MODEL RESULTS



BLACK & VEATCH

WTP

Tanks

wMain

MIN_PRESS

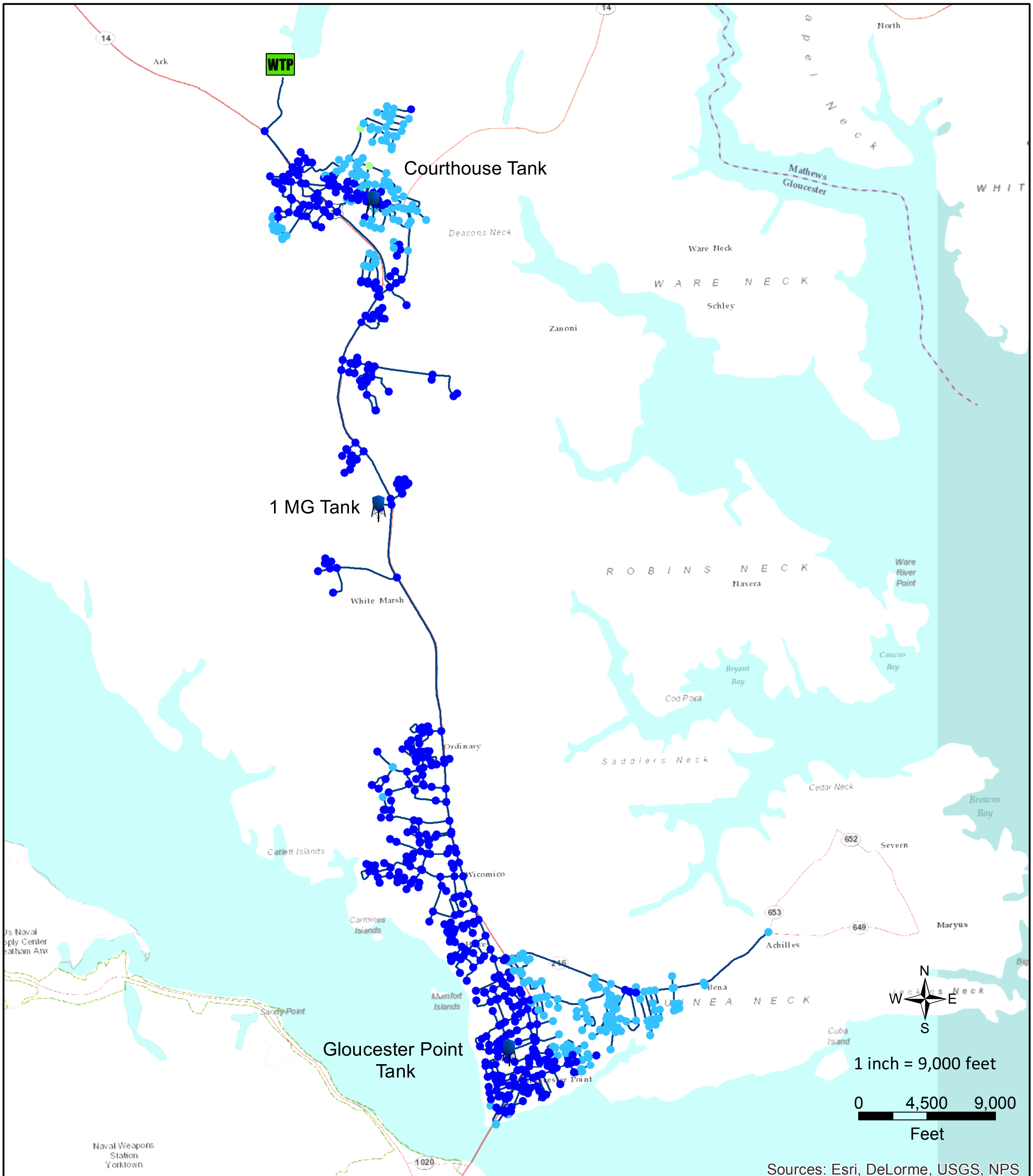
- Less Than 20 psi
- 20 to 40 psi
- 40 to 60 psi
- 60 to 80 psi
- Greater than 80 psi

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 1

Existing Water System Minimum Pressures



BLACK & VEATCH

WTP
Tanks
wMain

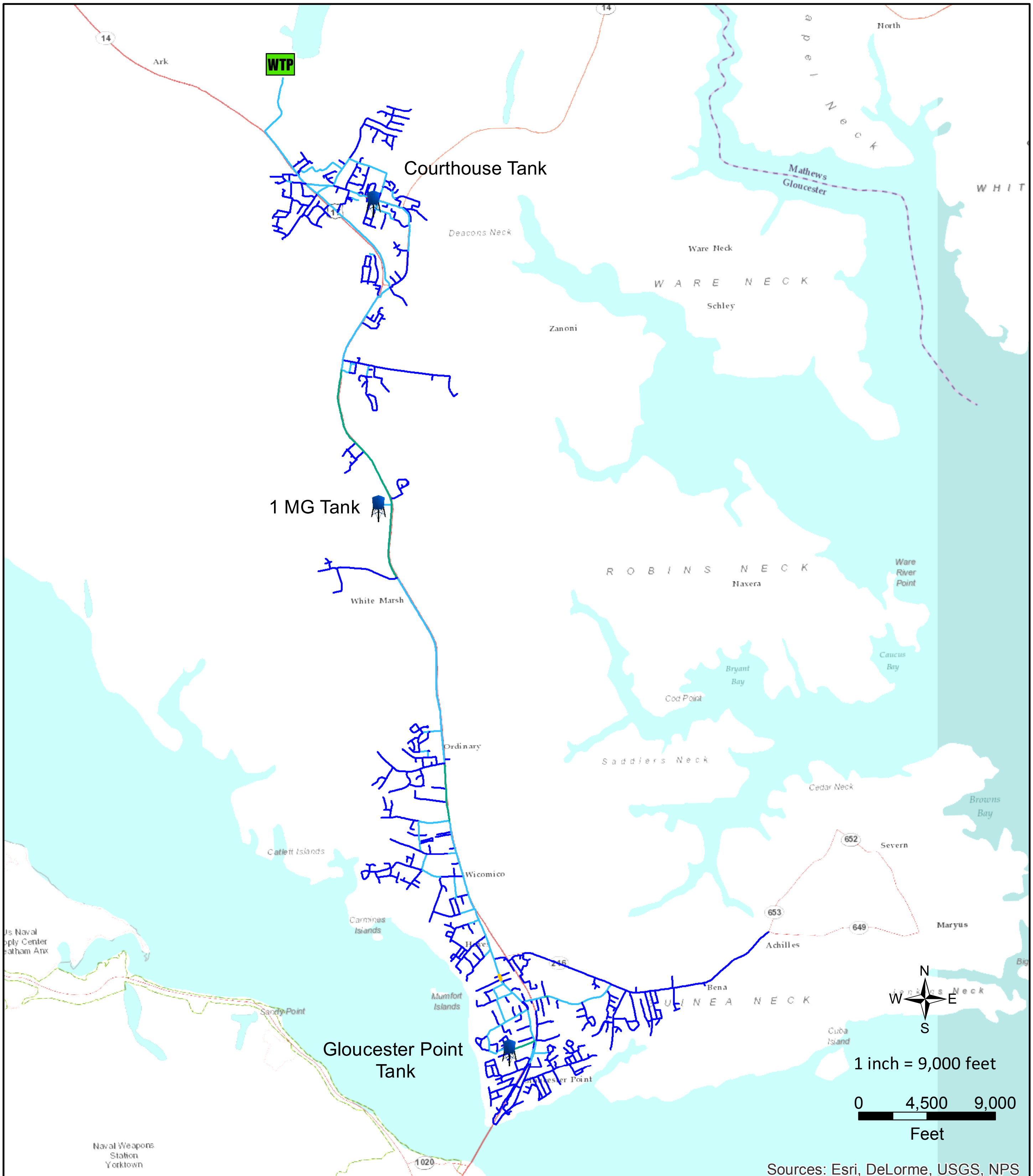
MAX_PRESS
- Less than 80 psi
- 80 - 100 psi
- 100 - 120 psi
- 120 - 140 psi
- Greater than 140 psi

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 2

Existing Water System Maximum Pressures



BLACK & VEATCH

WTP

Tanks

MAX_VELOC

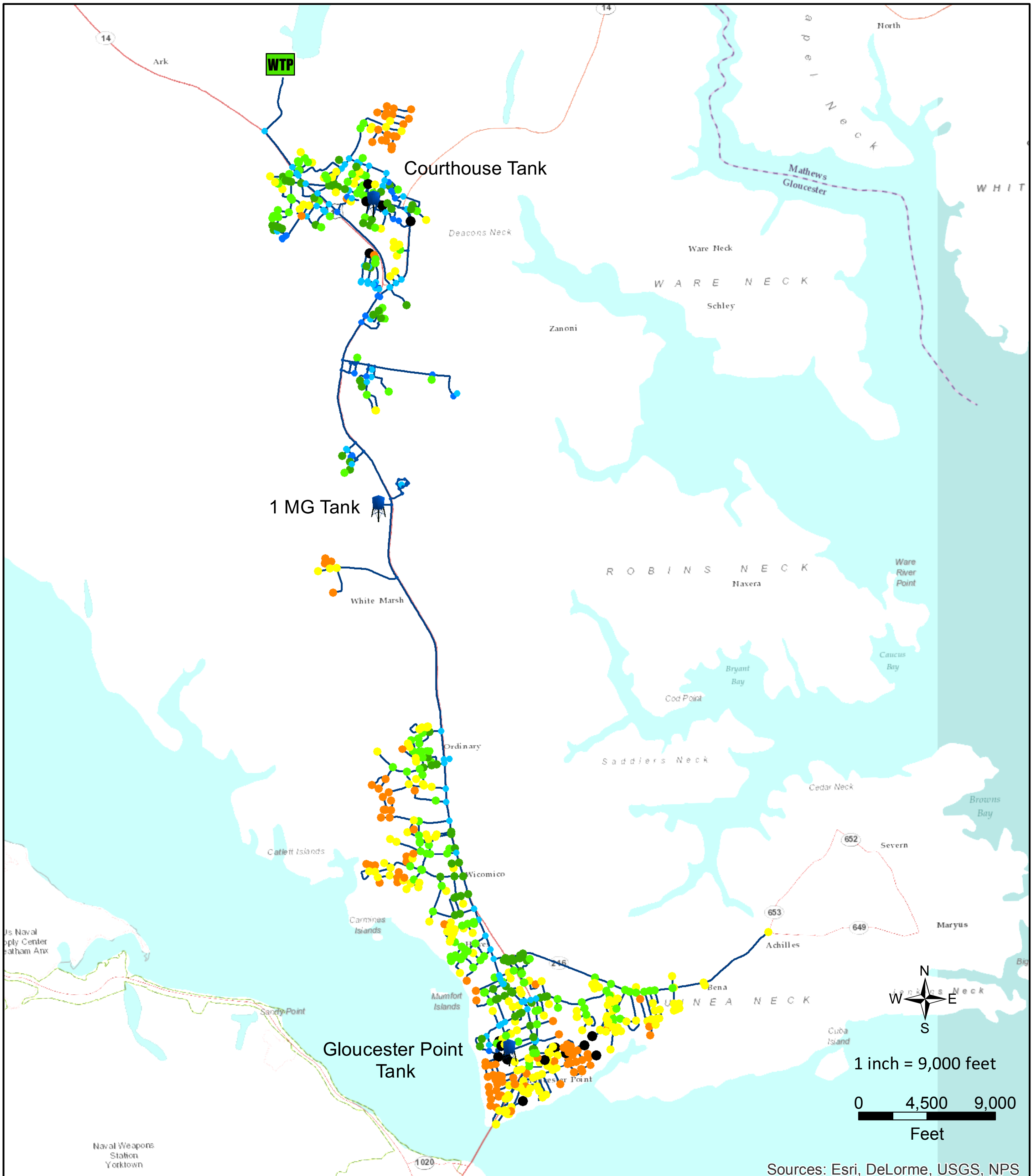
- Less than 1 fps
- 1 - 3 fps
- 3 - 5 fps
- 5 - 7 fps
- Greater than 7 fps

GLOUCESTER COUNTY

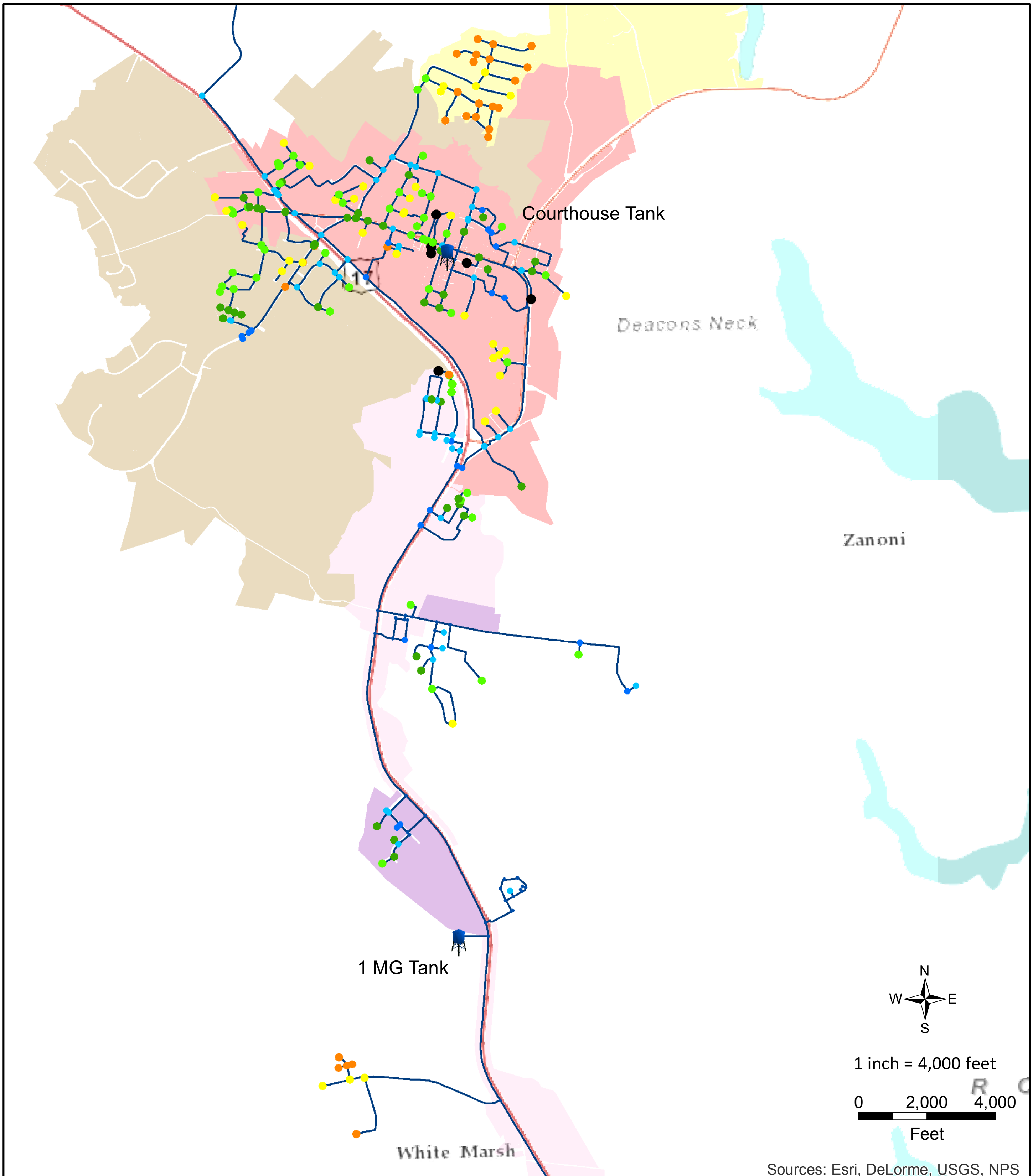
Water & Sewer Master Plan

Figure 3

Existing Water System Maximum Velocity



BLACK & VEATCH	WTP Tanks wMain **AVAIL_FLOW** Less than 500 gpm 500 - 1,000 gpm 1,000 - 1,500 gpm 1,500 - 2,000 gpm 2,000 - 2,500 gpm 2,500 - 3,000 gpm 3,000 - 3,500 gpm Greater than 3,500 gpm	GLOUCESTER COUNTY **Water & Sewer Master Plan** **Figure 4** **Existing Water System Available Fire Flow**



BLACK & VEATCH

WTP

Tanks

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm
- wMain

Future Landuse

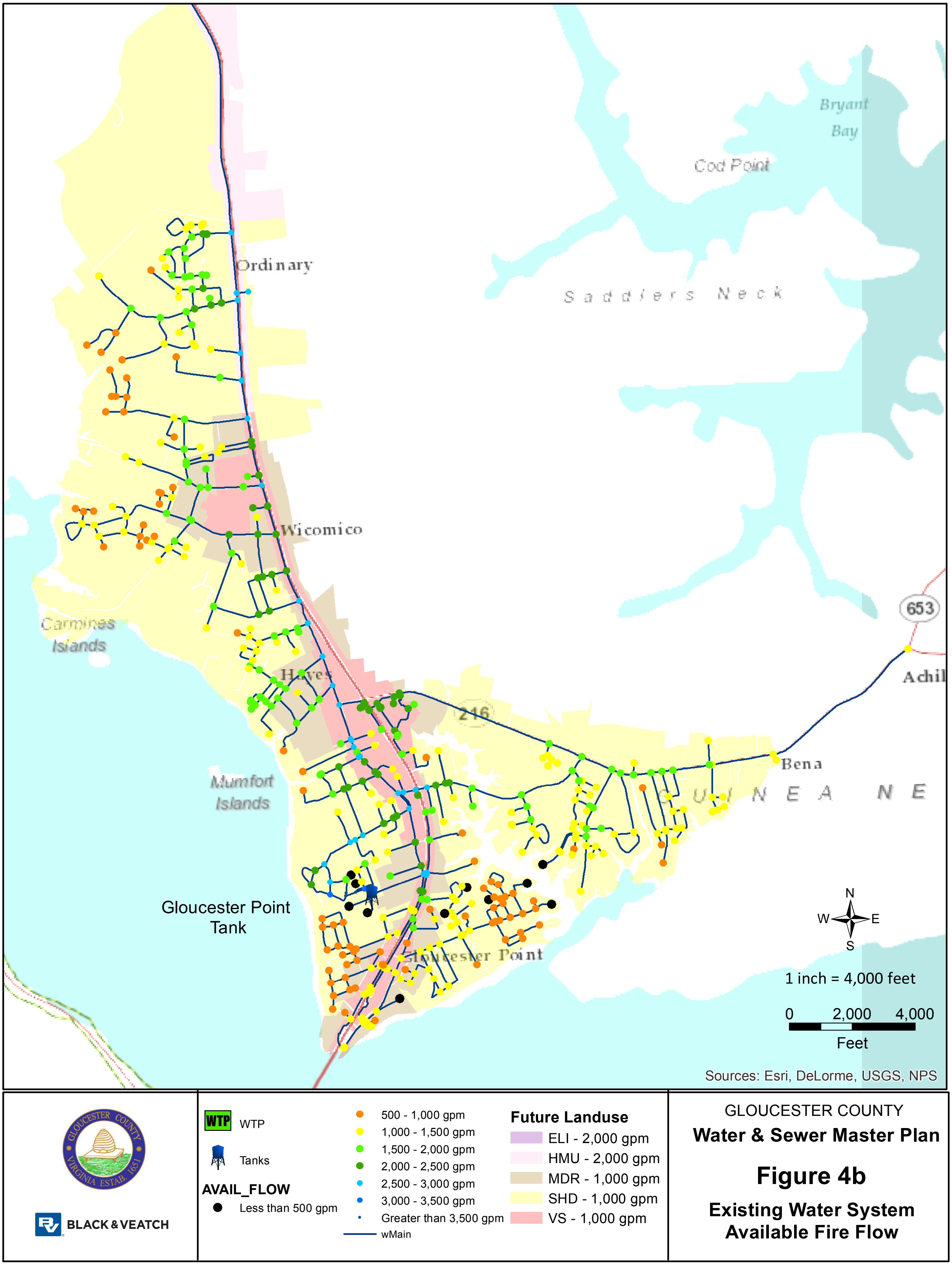
- ELI - 2,000 gpm
- HMU - 2,000 gpm
- MDR - 1,000 gpm
- SHD - 1,000 gpm
- VS - 1,000 gpm

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 4a

Existing Water System Available Fire Flow



BLACK & VEATCH

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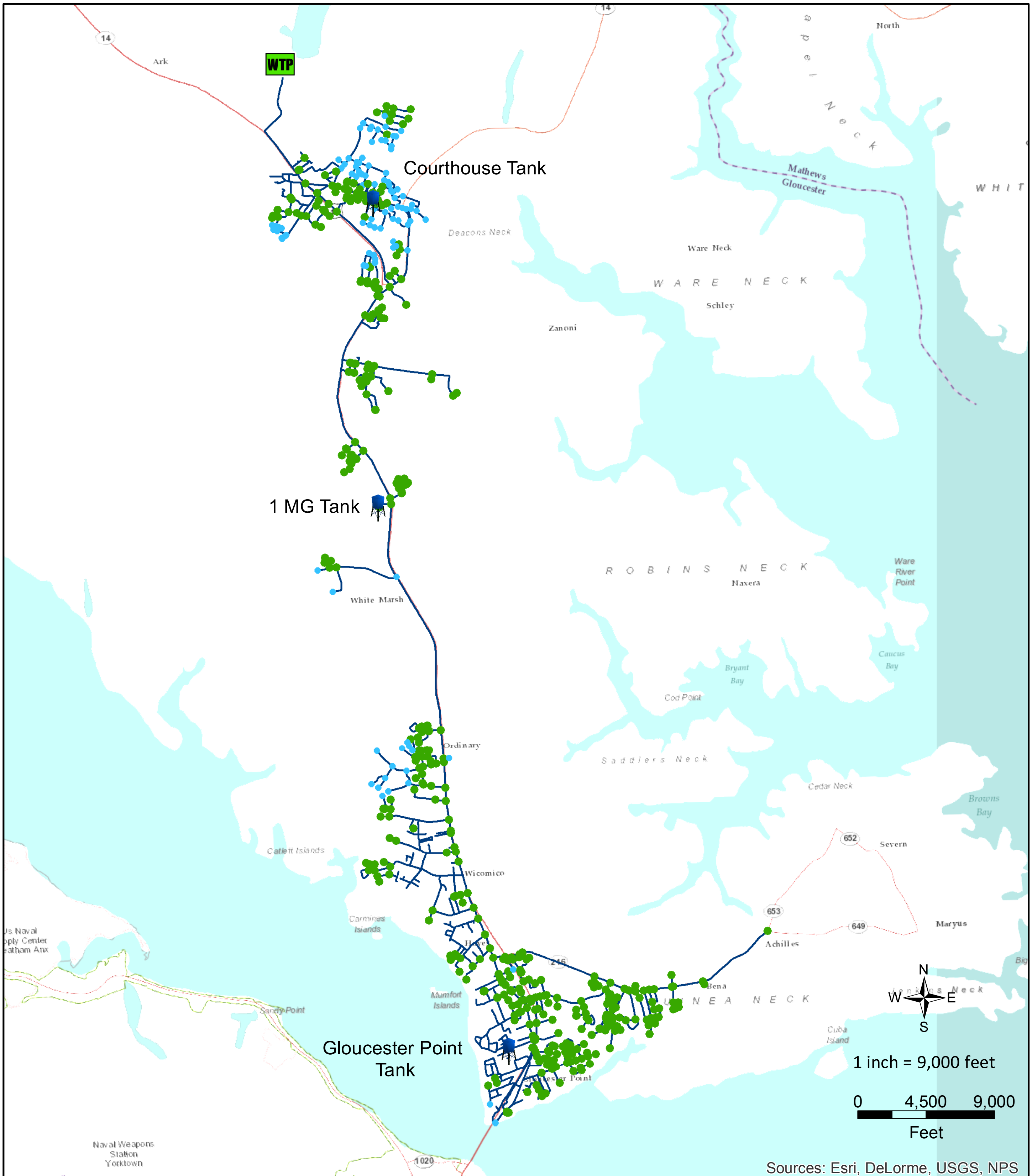
Water & Sewer Master Plan

Figure 4b

Existing Water System Available Fire Flow



BLACK & VEATCH

WTP

Tanks

wMain

MIN_PRESS

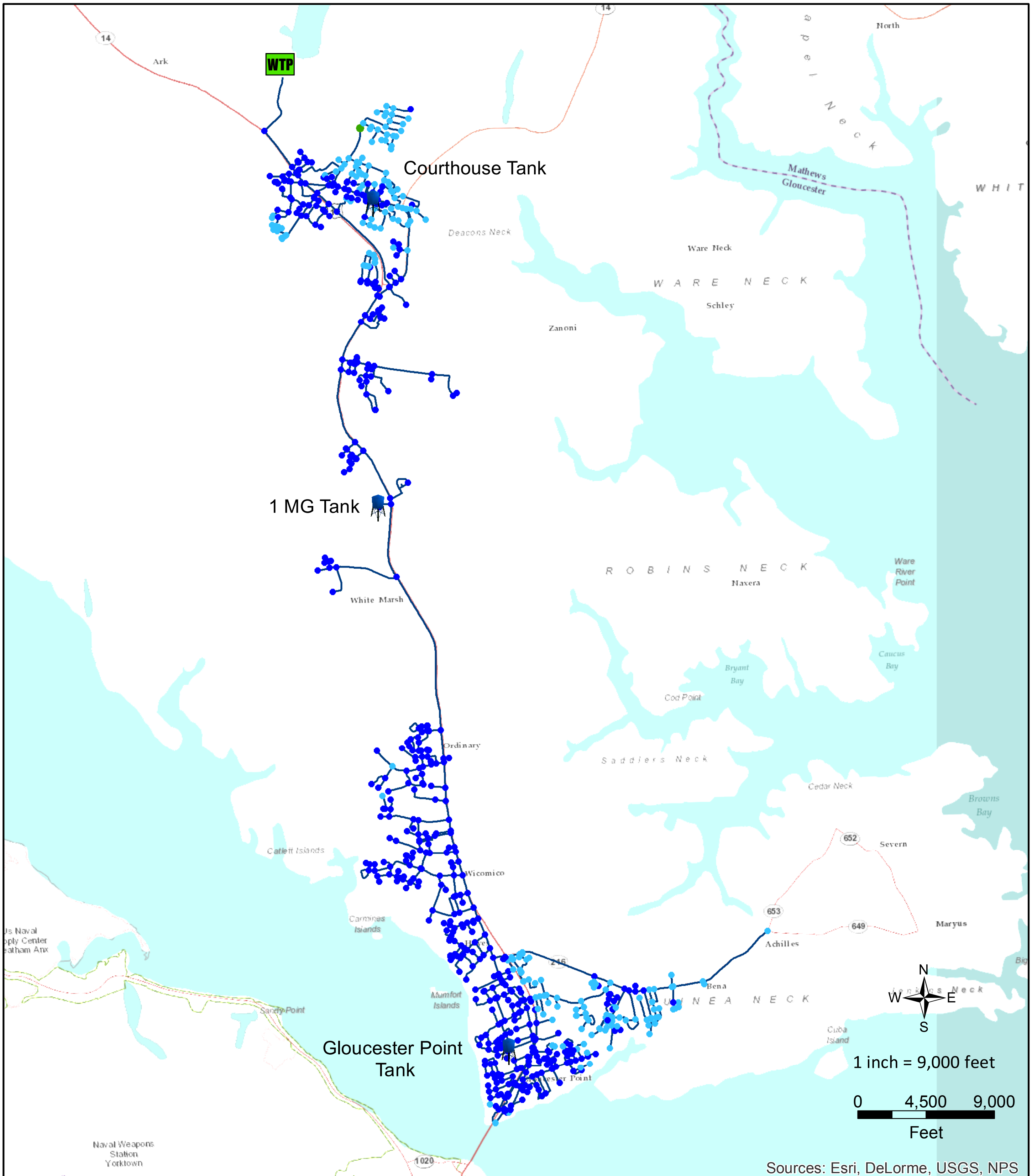
- Less Than 20 psi
- 20 to 40 psi
- 40 to 60 psi
- 60 to 80 psi
- Greater than 80 psi

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 5

2020 Water System Minimum Pressures



BLACK & VEATCH

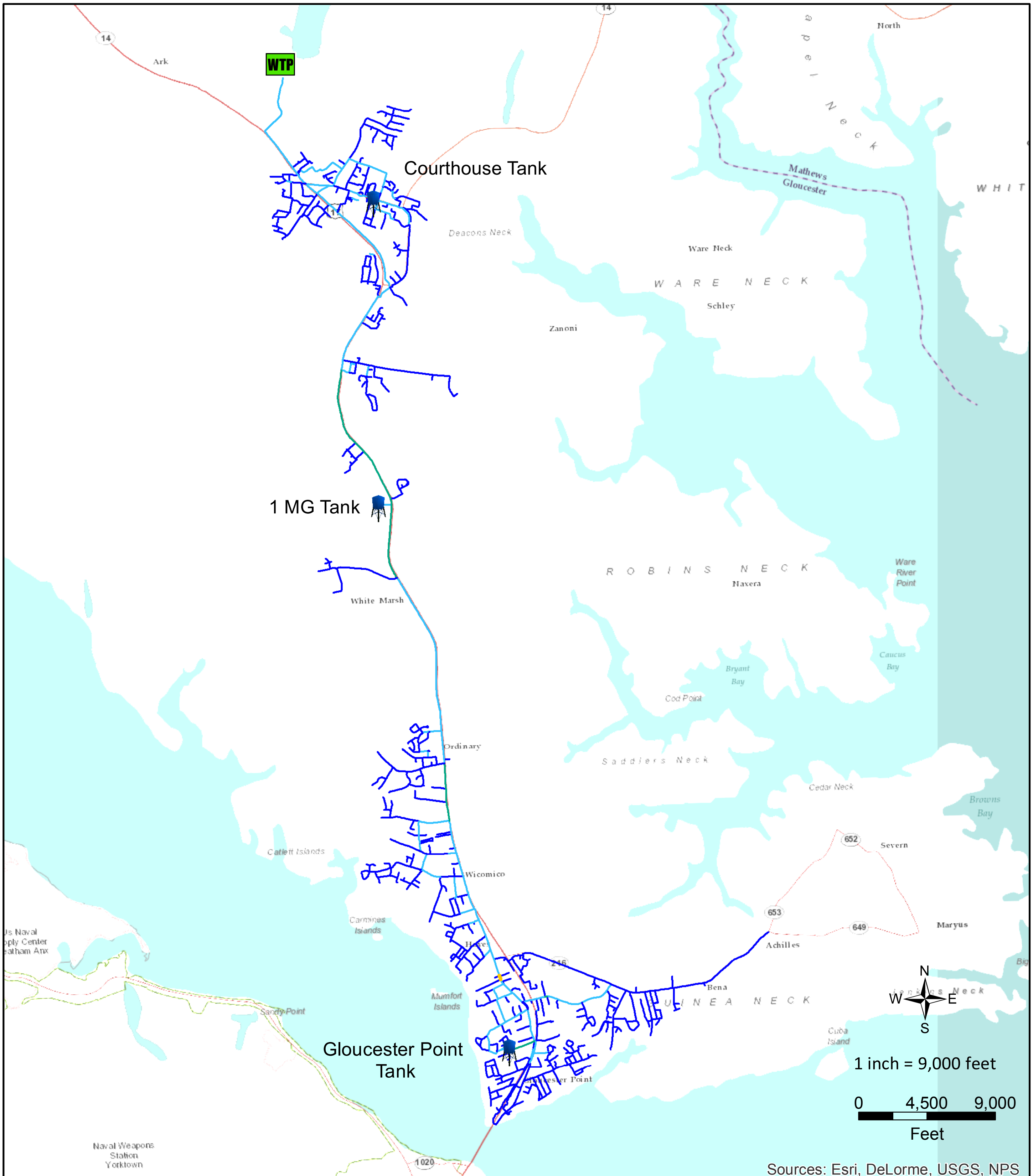
WTP	**MAX_PRESS**	
Tanks		Less than 80 psi
wMain		80 - 100 psi
		100 - 120 psi
		120 - 140 psi
		Greater than 140 psi

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 6

2020 Water System Maximum Pressures



WTP

Tanks

MAX_VELOC

- Less than 1 fps
- 1 - 3 fps
- 3 - 5 fps
- 5 - 7 fps
- Greater than 7 fps

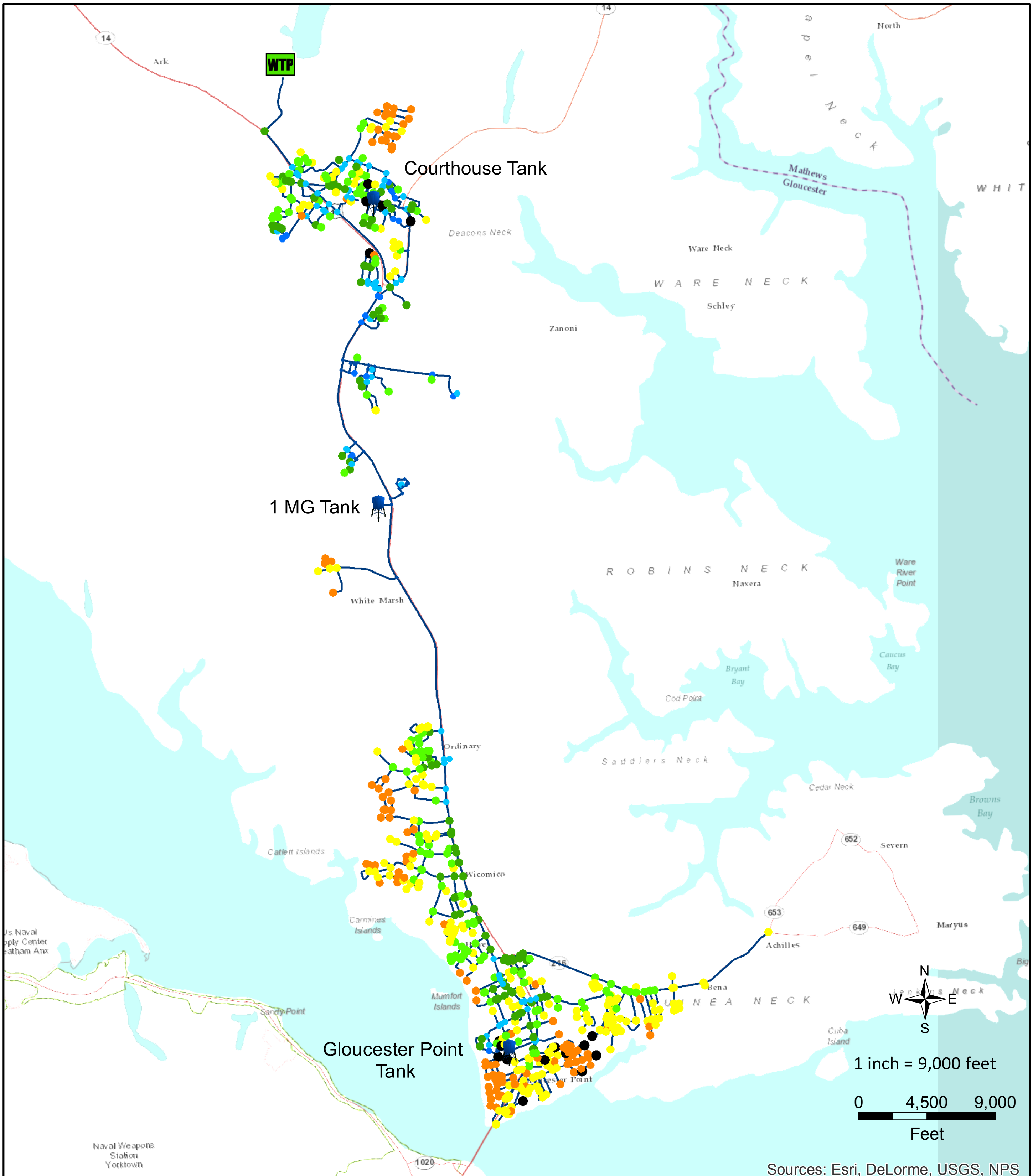
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 7

2020 Water System Maximum Velocity



WTP

Tanks

wMain

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm

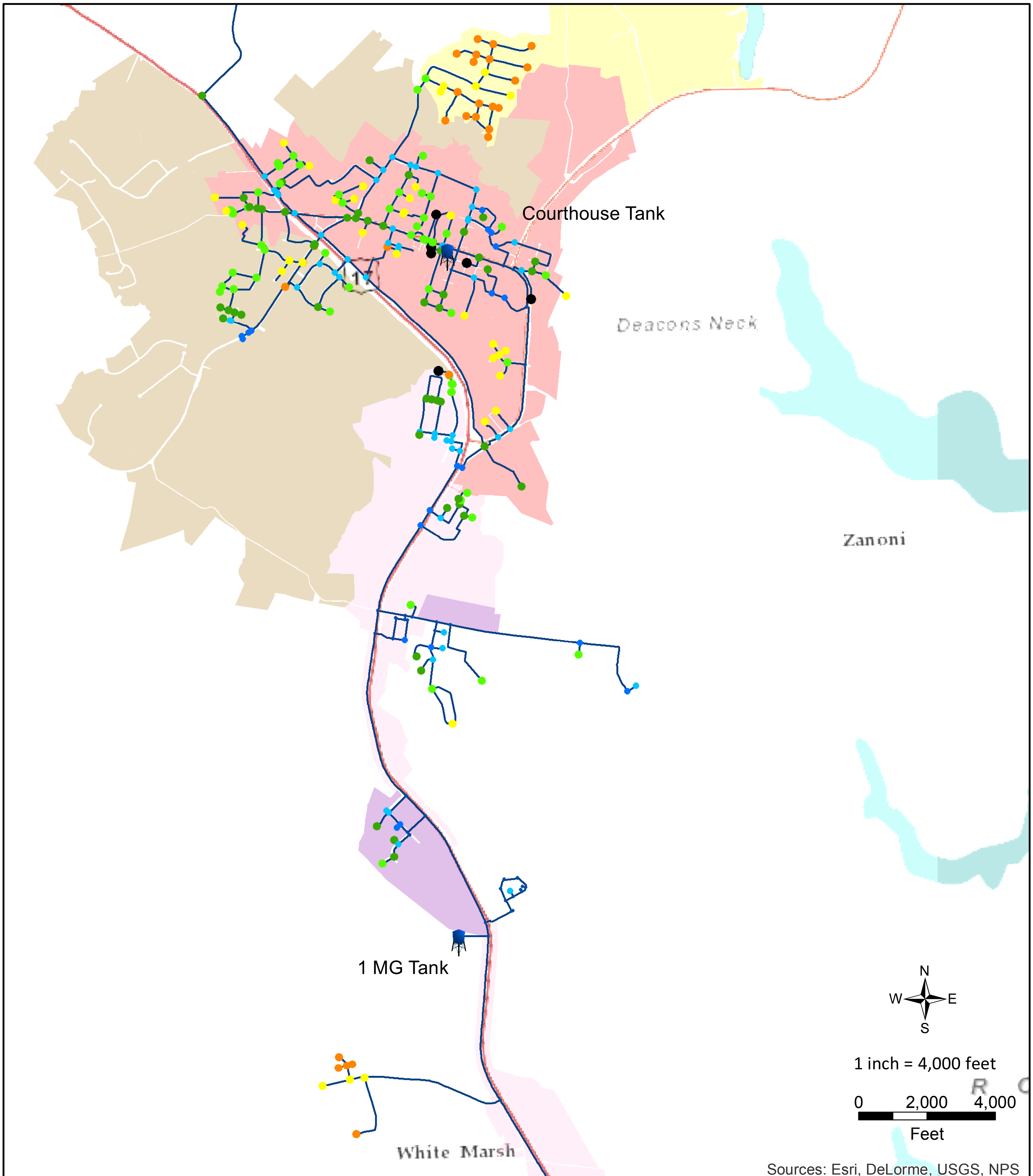
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 8

2020 Water System Available Fire Flow



BLACK & VEATCH

WTP
Tanks

AVAIL_FLOW
- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm
- wMain

Future Landuse
- ELI
- HMU
- MDR
- SHD
- VS

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 8a

2020 Water System Available Fire Flow

BLACK & VEATCH

WTP
Tanks

AVAIL_FLOW
- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm
- wMain

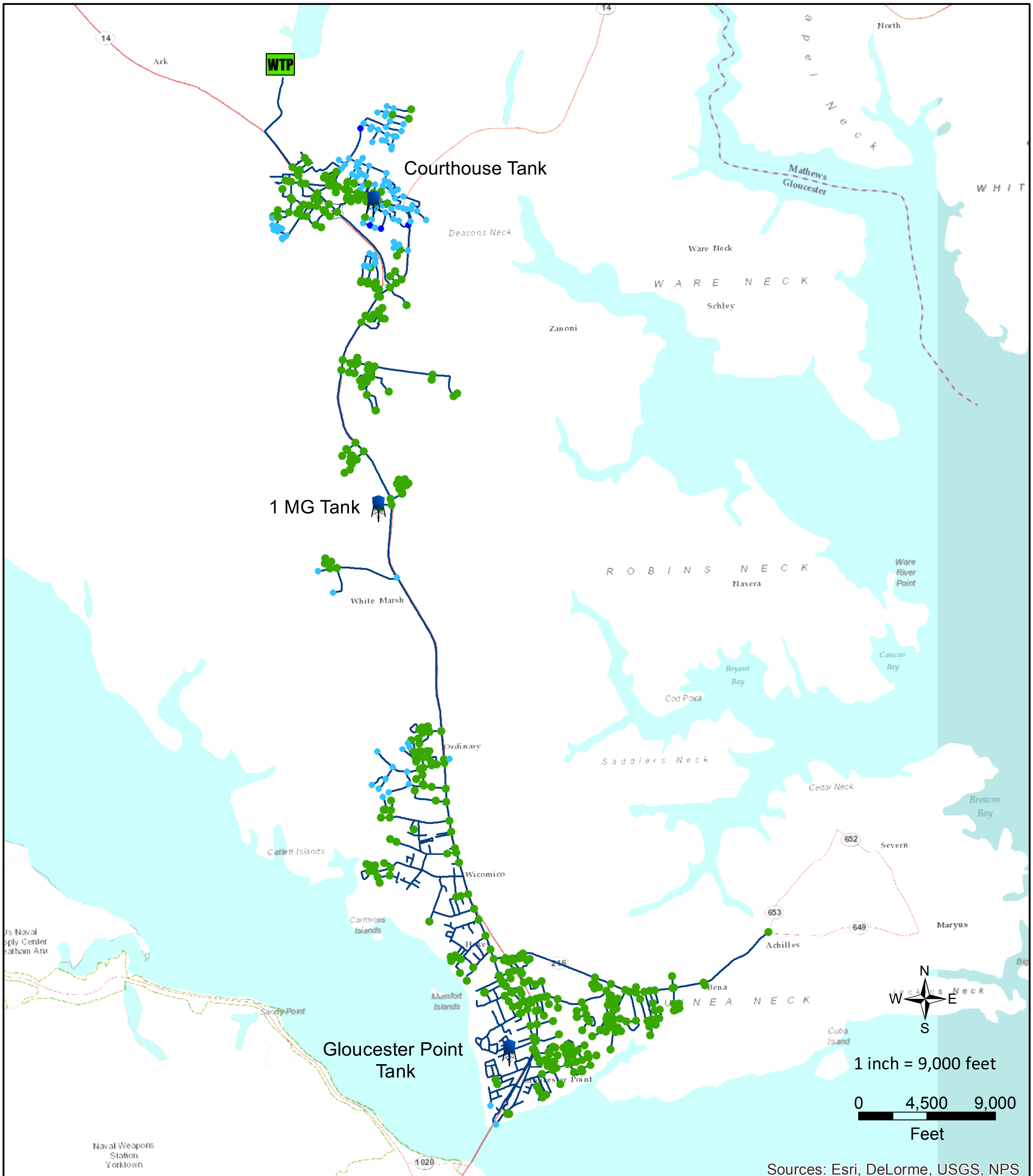
Future Landuse
- ELI
- HMU
- MDR
- SHD
- VS

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 8b

2020 Water System Available Fire Flow



WTP
Tanks
wMain

MIN_PRESS

- Less Than 20 psi
- 20 to 40 psi
- 40 to 60 psi
- 60 to 80 psi
- Greater than 80 psi

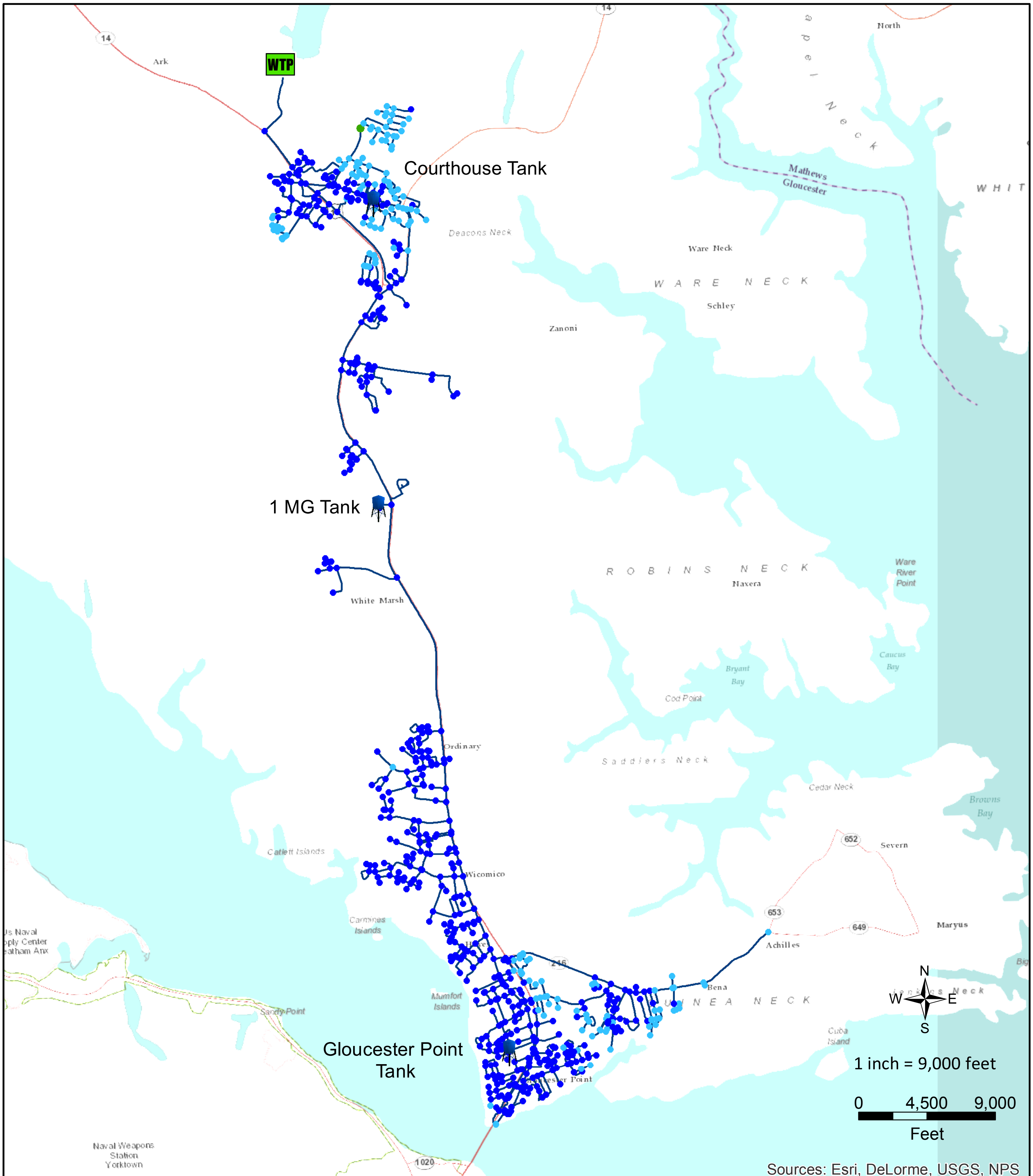
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 9

2025 Water System Minimum Pressures



WTP

Tanks

wMain

MAX_PRESS

- Less than 80 psi
- 80 - 100 psi
- 100 - 120 psi
- 120 - 140 psi
- Greater than 140 psi

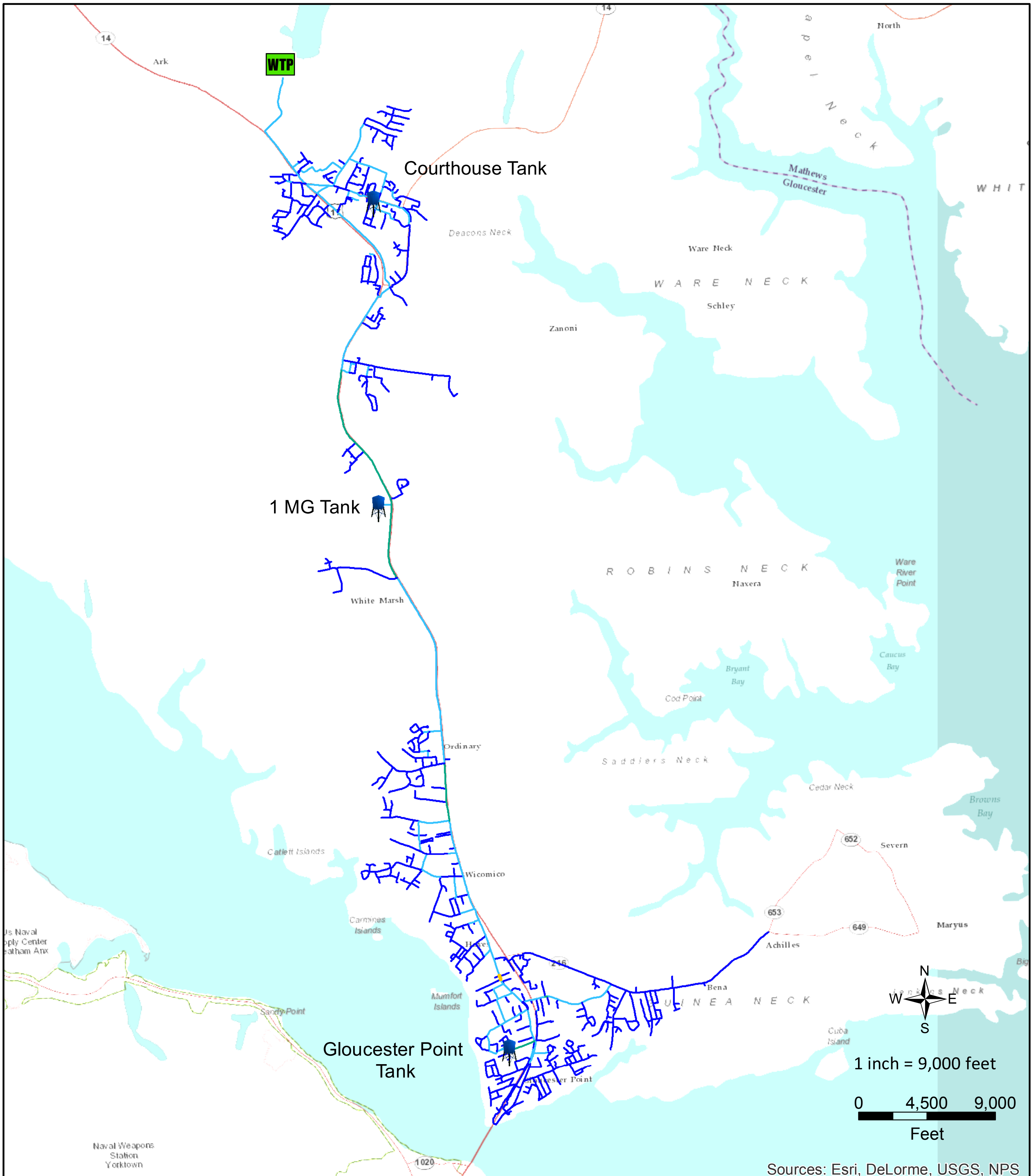
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 10

2025 Water System Maximum Pressures



WTP

Tanks

MAX_VELOC

- Less than 1 fps
- 1 - 3 fps
- 3 - 5 fps
- 5 - 7 fps
- Greater than 7 fps

BLACK & VEATCH

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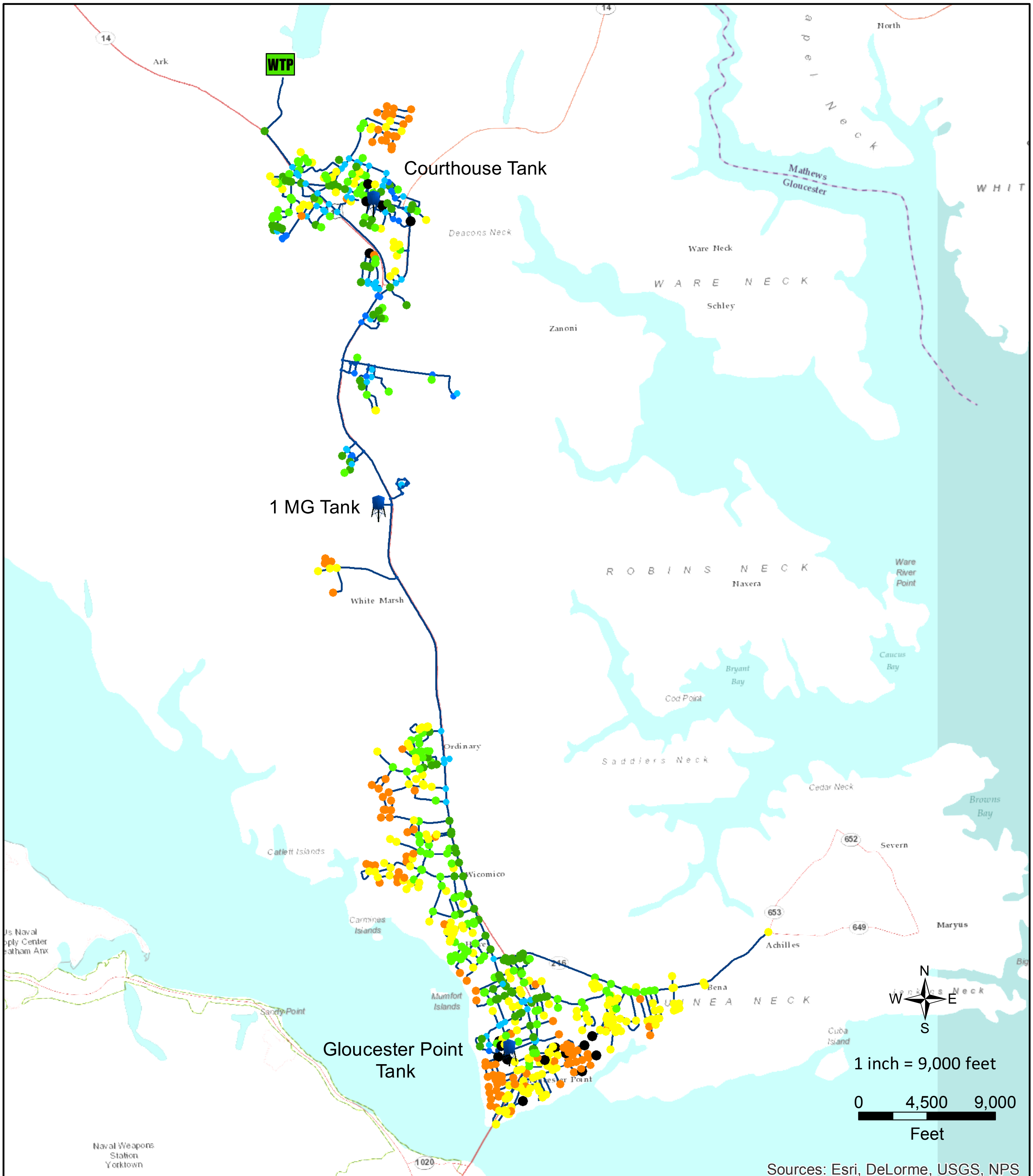
Water & Sewer Master Plan

Figure 11

2025 Water System Maximum Velocity



WTP

Tanks

wMain

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm

BLACK & VEATCH

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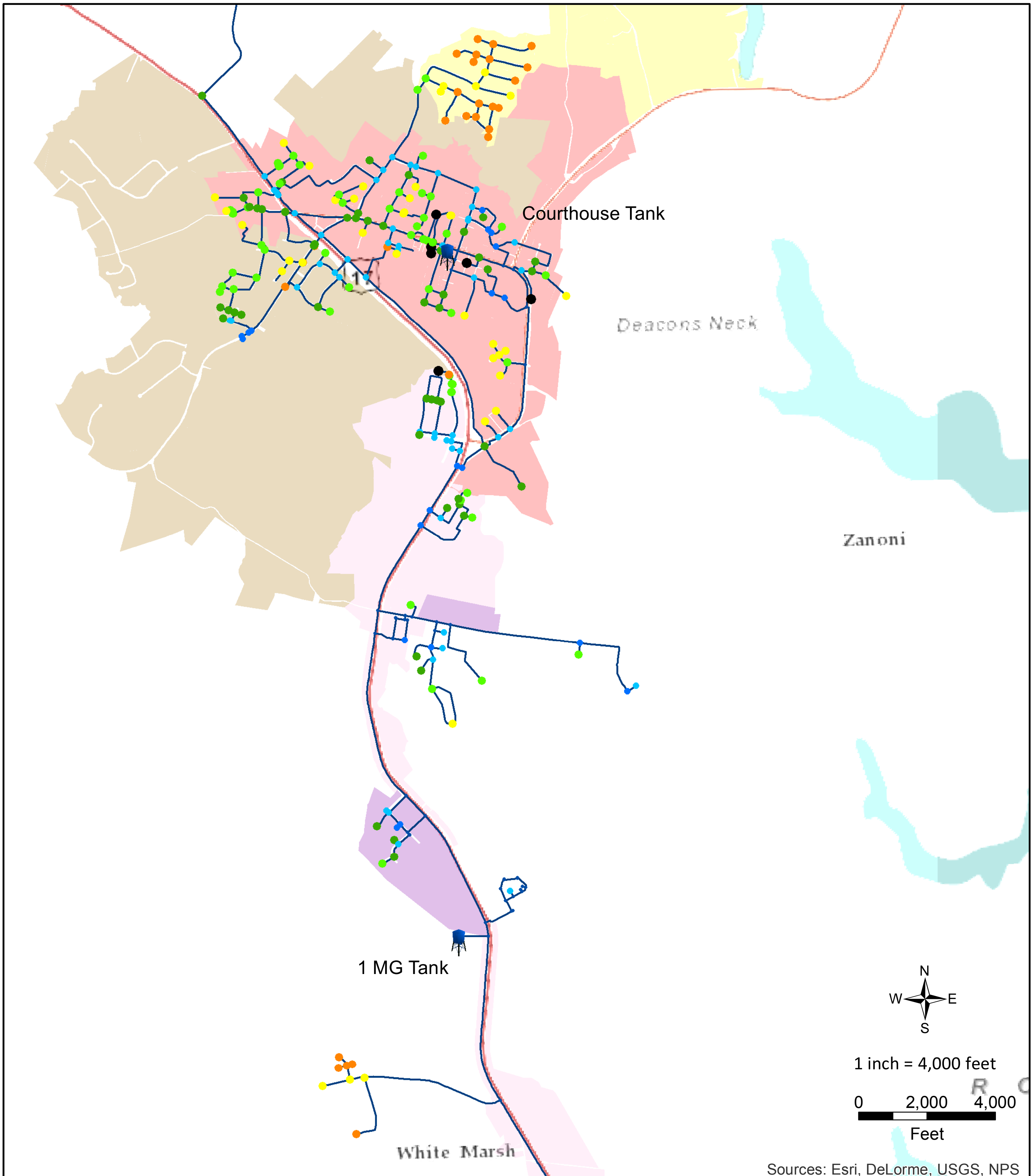
Water & Sewer Master Plan

Figure 12

2025 Water System Available Fire Flow



WTP

Tanks

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm
- wMain

Future Landuse

- ELI
- HMU
- MDR
- SHD
- VS

BLACK & VEATCH

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Water & Sewer Master Plan

Figure 12a

2025 Water System Available Fire Flow

BLACK & VEATCH

WTP

Tanks

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm
- wMain

Future Landuse

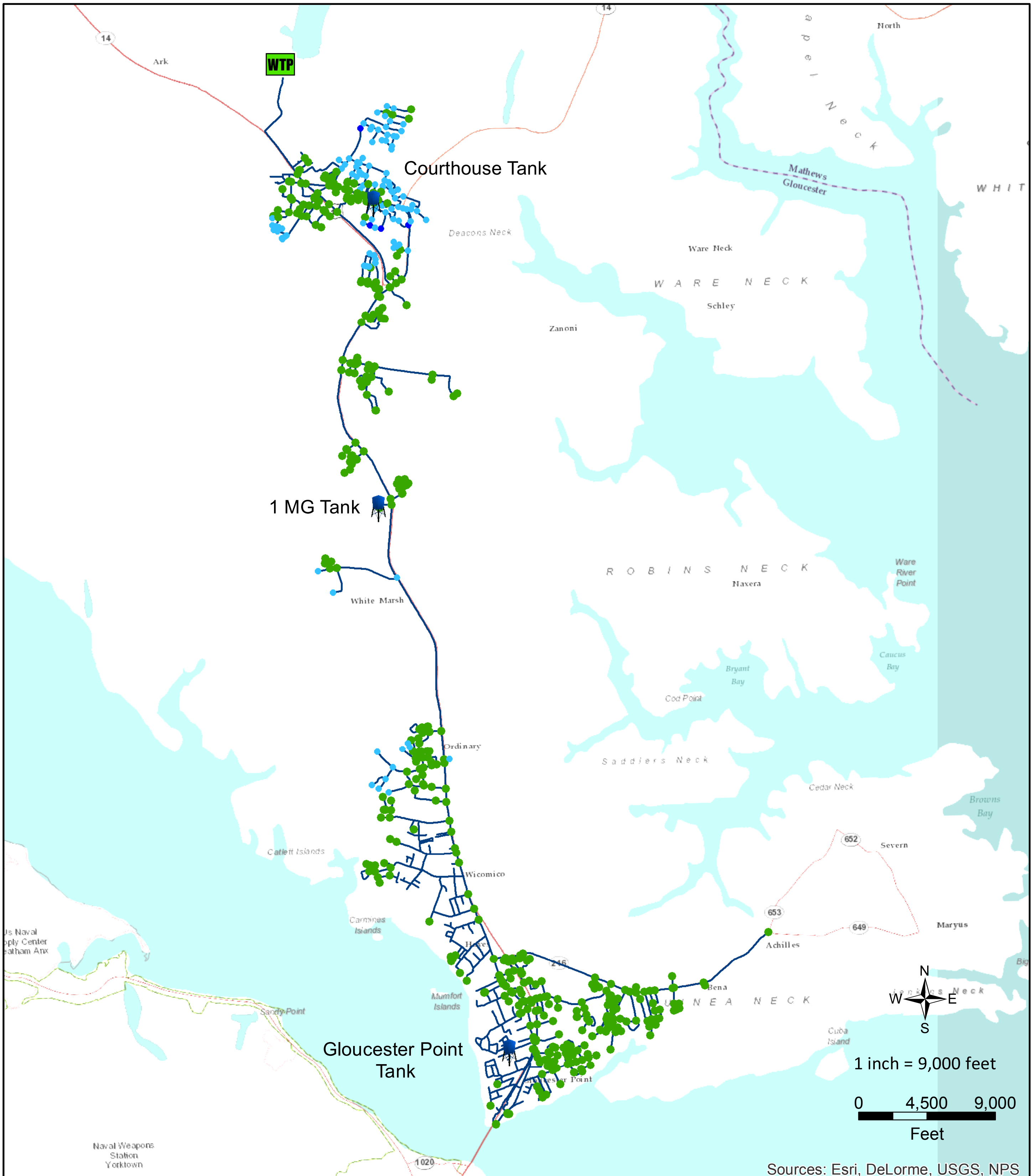
- ELI
- HMU
- MDR
- SHD
- VS

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 12b

2025 Water System Available Fire Flow



WTP

Tanks

wMain

MIN_PRESS

- Less Than 20 psi
- 20 to 40 psi
- 40 to 60 psi
- 60 to 80 psi
- Greater than 80 psi

BLACK & VEATCH

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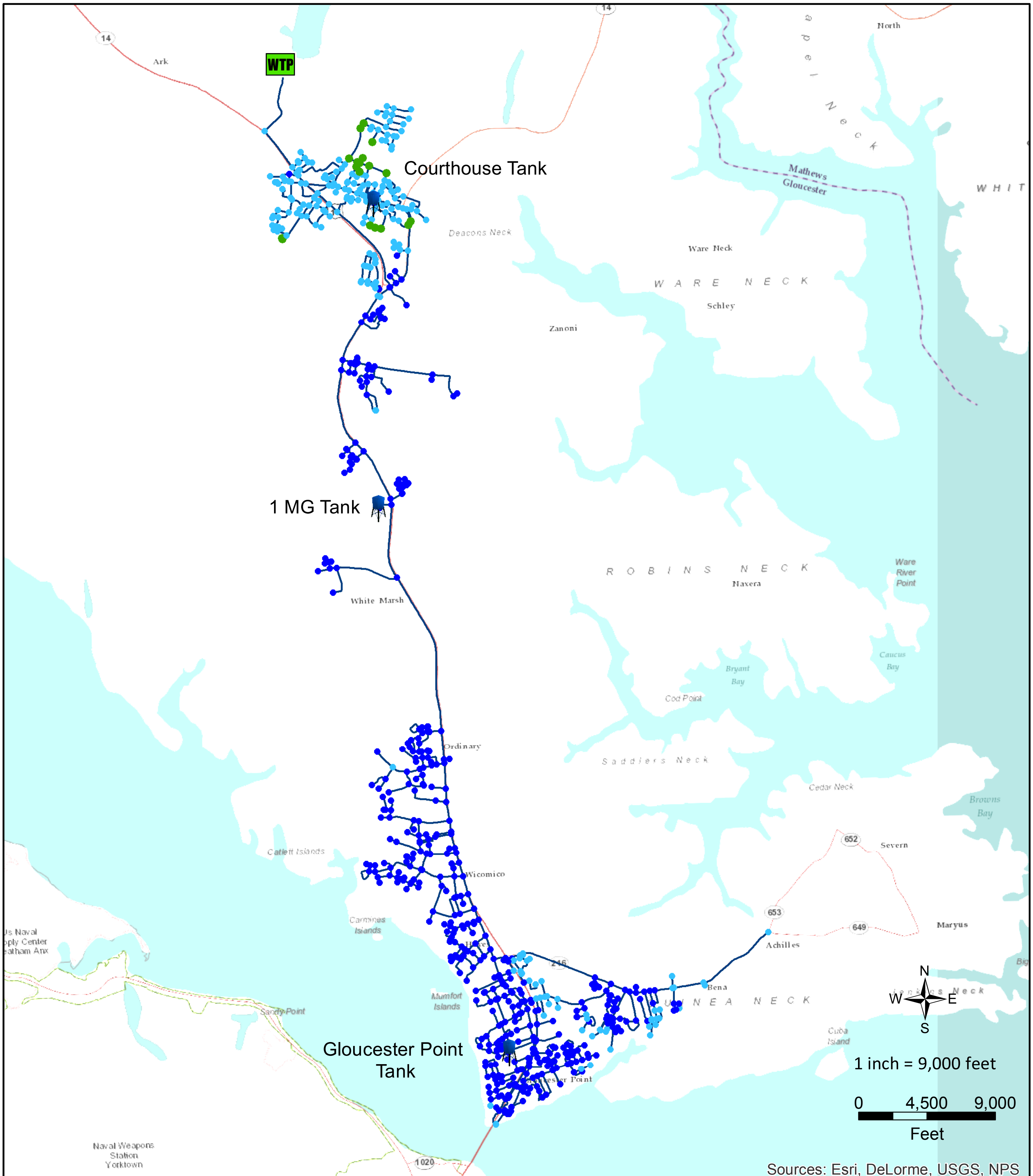
Water & Sewer Master Plan

Figure 13

2030 Water System Minimum Pressures



BLACK & VEATCH

WTP

Tanks

wMain

MAX_PRESS

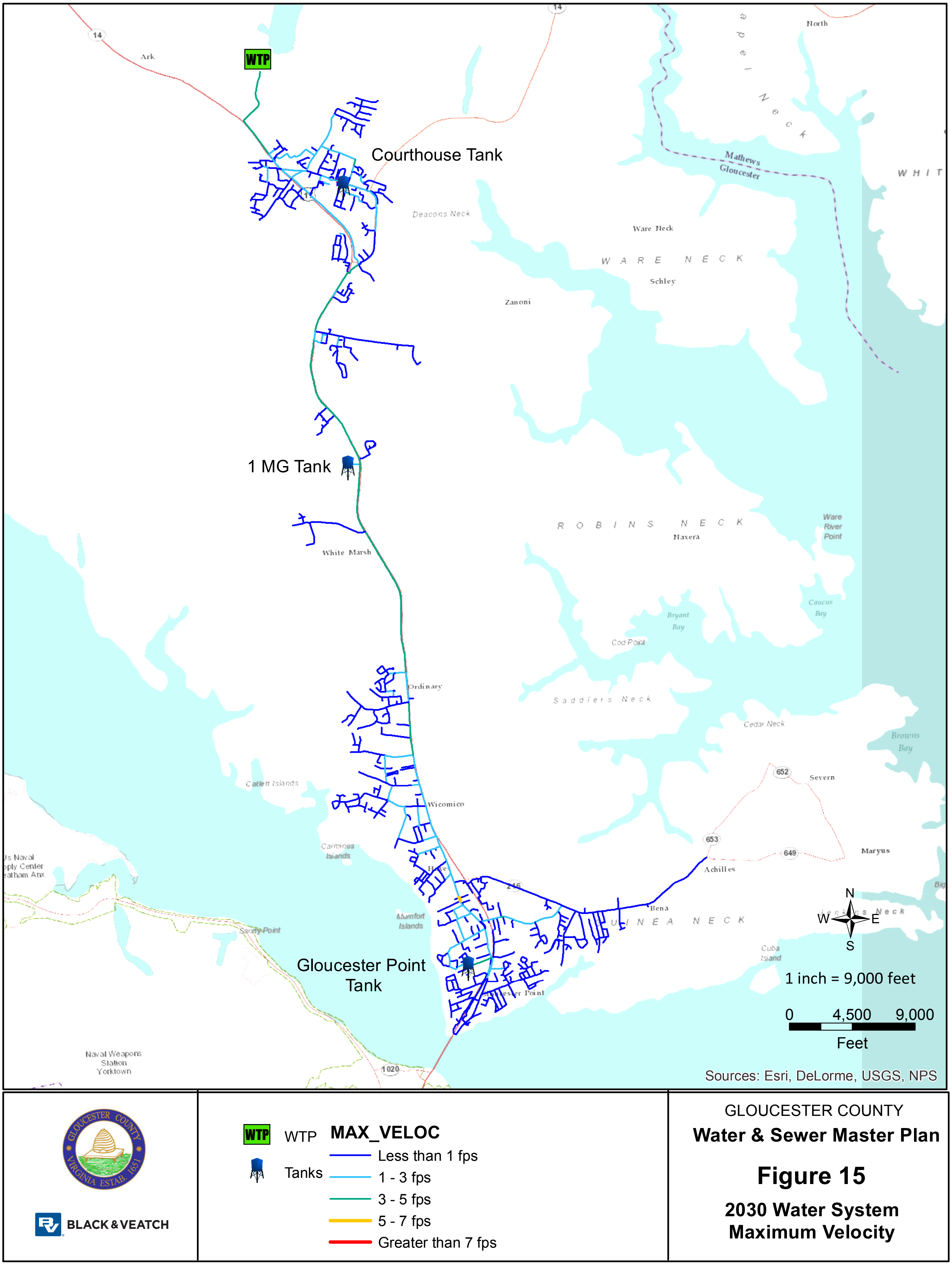
- Less than 80 psi
- 80 - 100 psi
- 100 - 120 psi
- 120 - 140 psi
- Greater than 140 psi

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 14

2030 Water System Maximum Pressures



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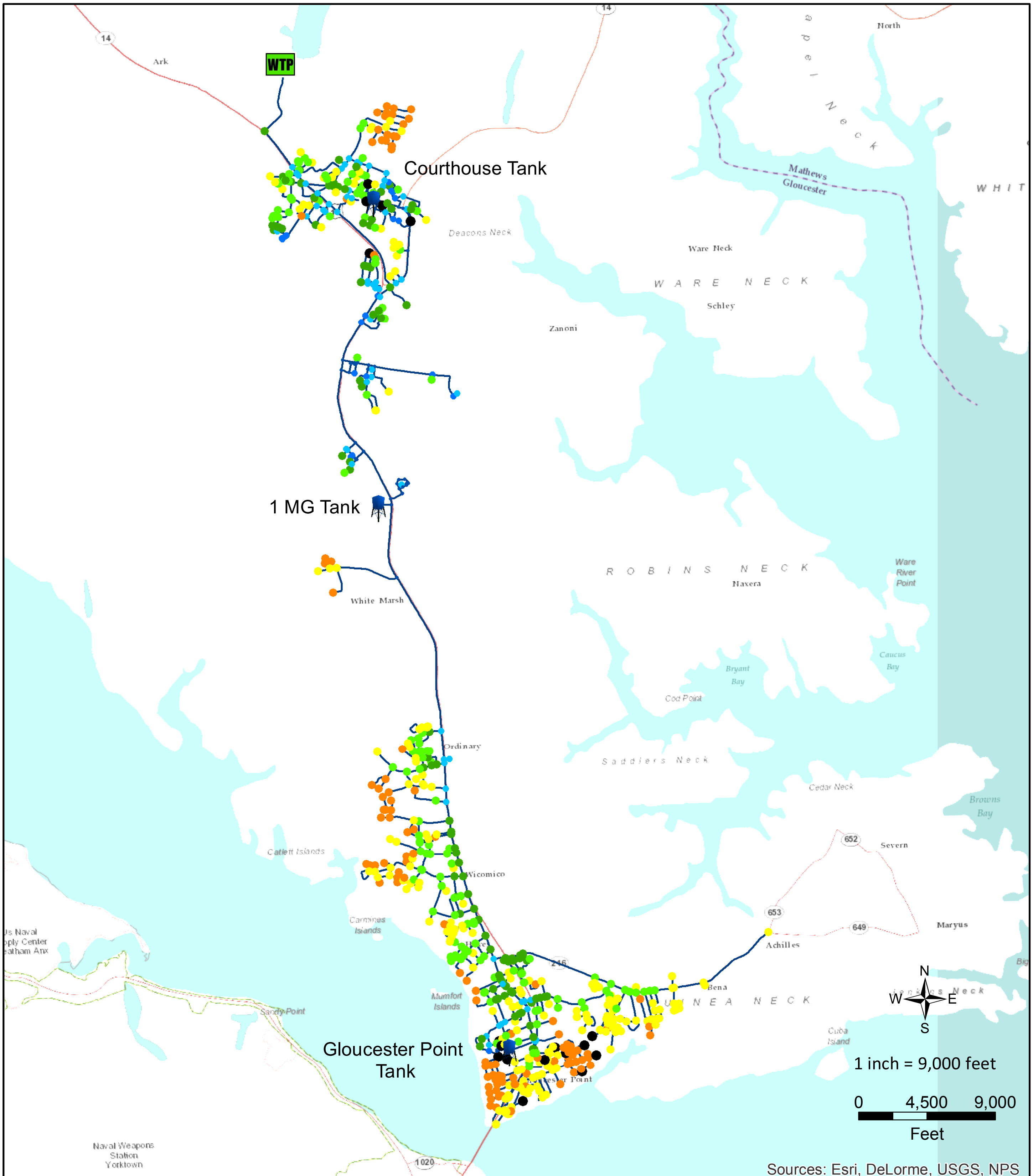
Water & Sewer Master Plan

Figure 15

2030 Water System Maximum Velocity



WTP

Tanks

wMain

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm

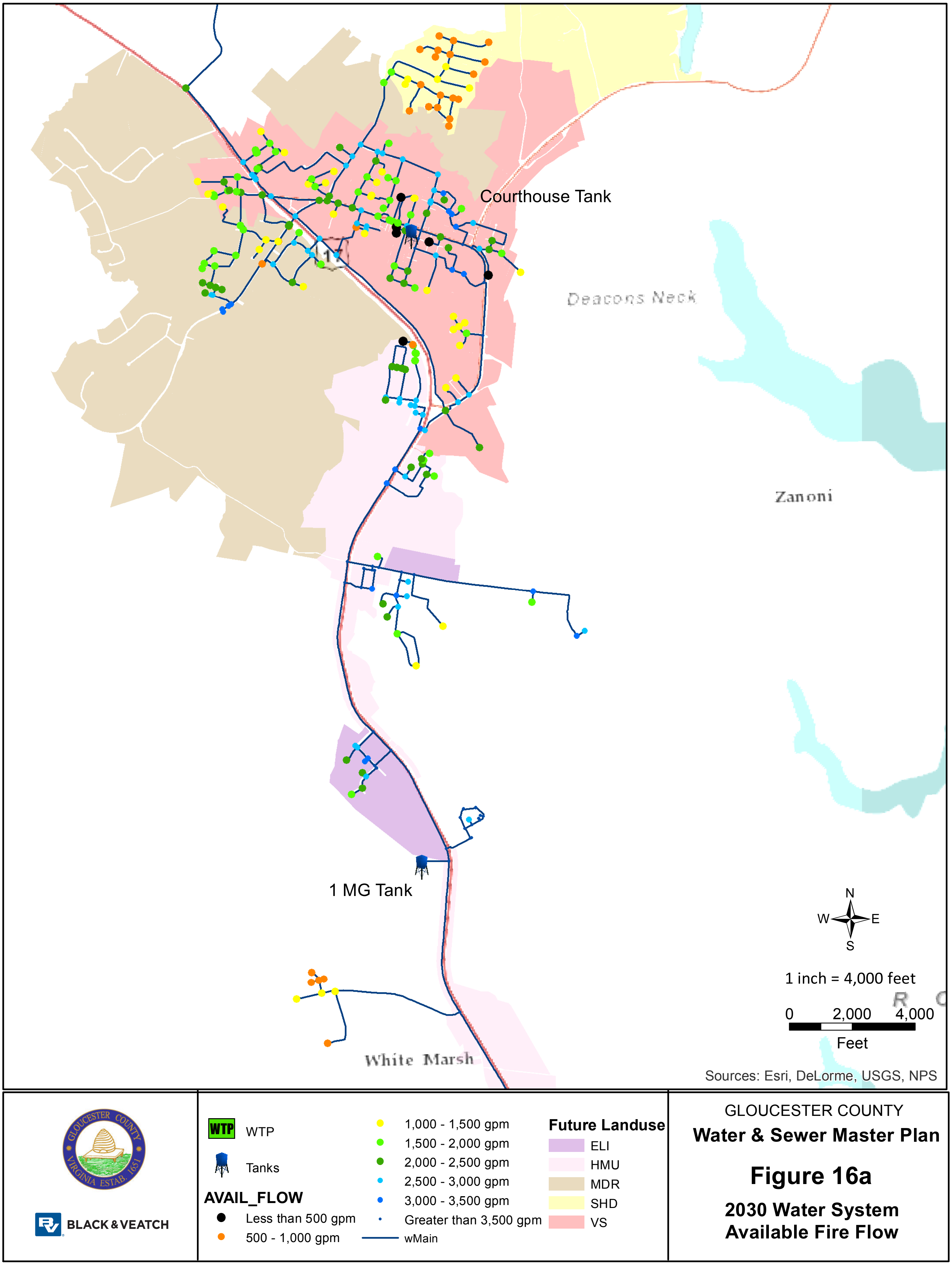
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 16

2030 Water System Available Fire Flow



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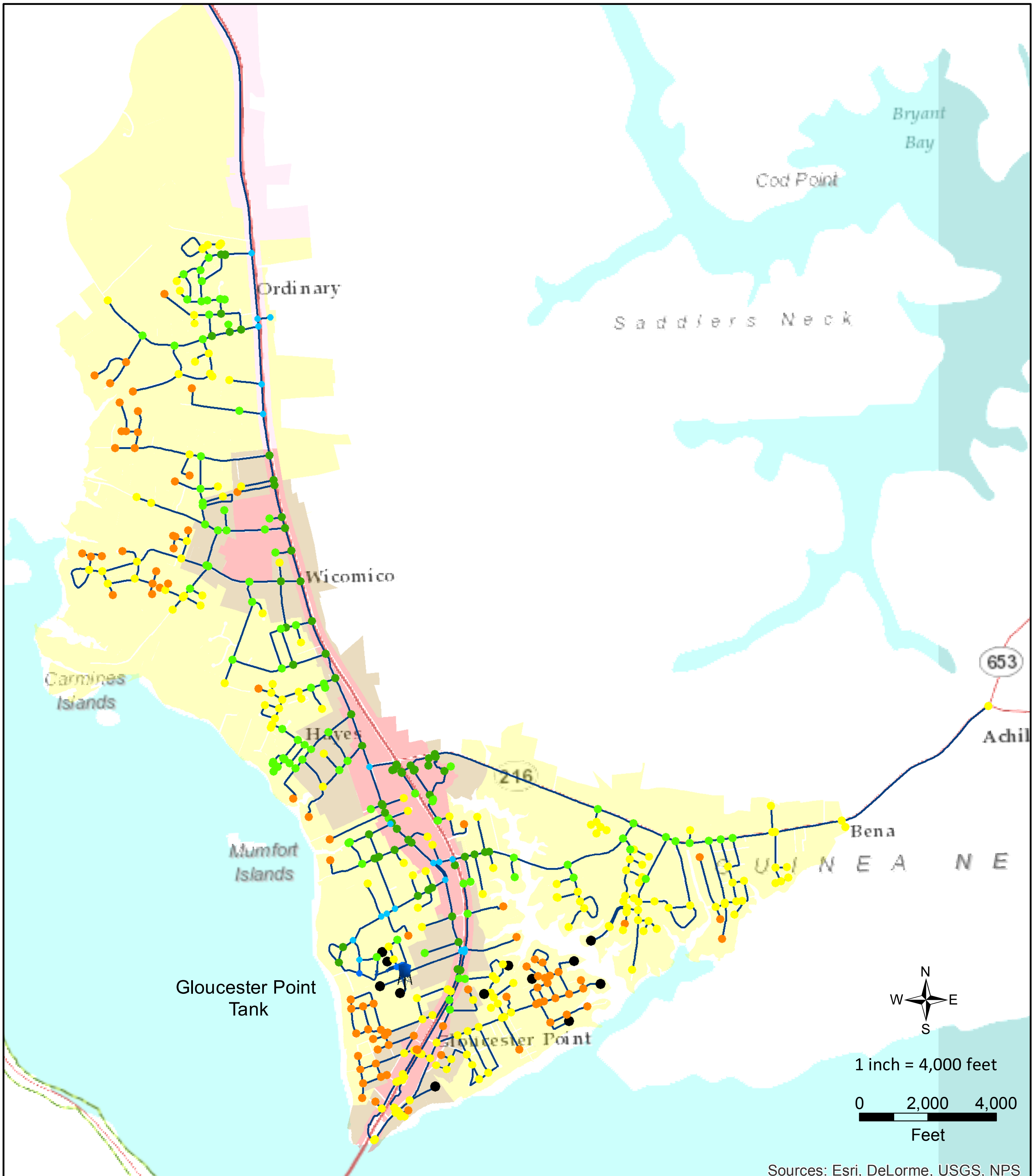
Water & Sewer Master Plan

Figure 16a

2030 Water System Available Fire Flow



WTP WTP

Tanks

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm
- wMain

Future Landuse

- ELI
- HMU
- MDR
- SHD
- VS

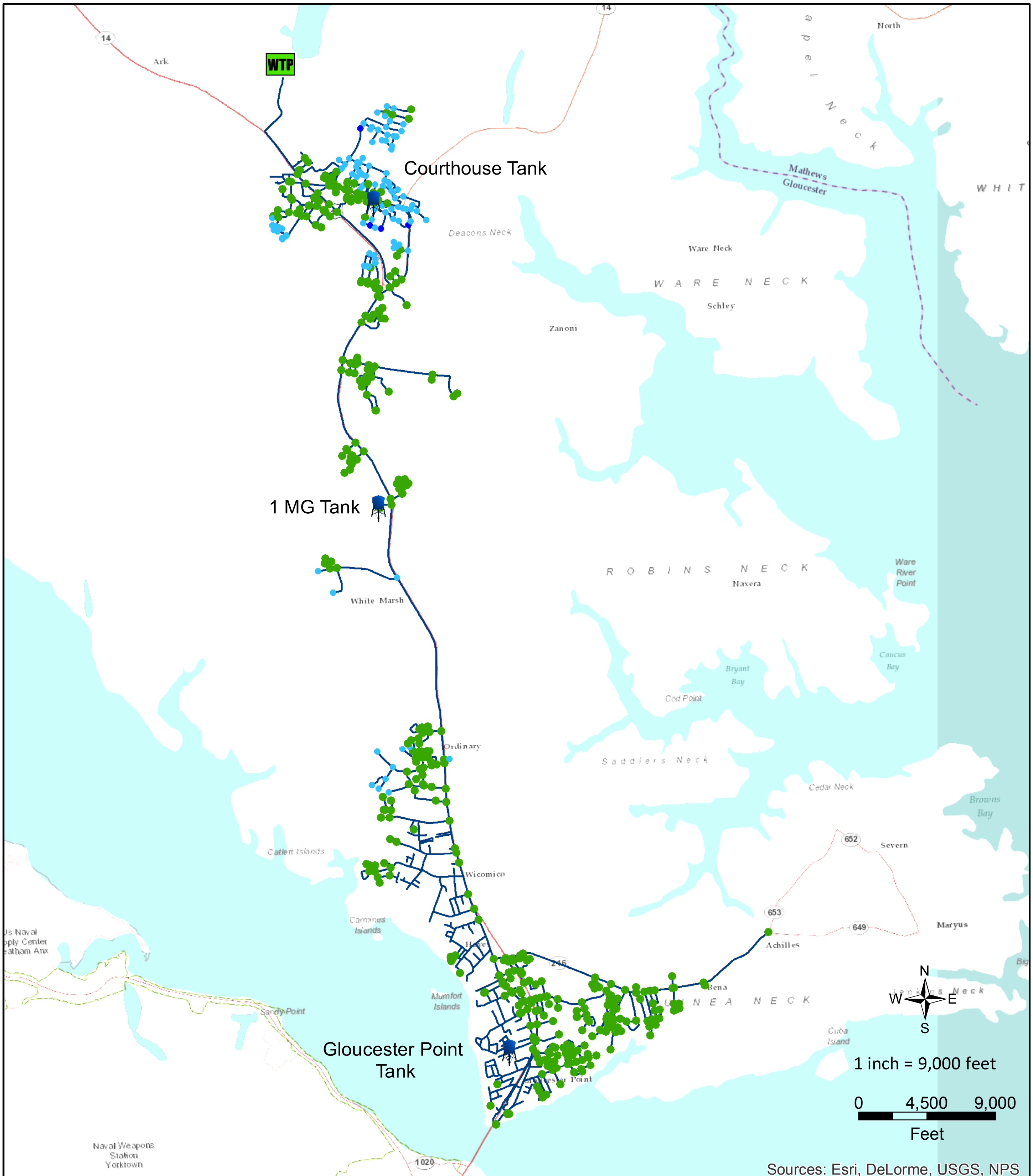
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 16b

2030 Water System Available Fire Flow



WTP

Tanks

wMain

MIN_PRESS

- Less Than 20 psi
- 20 to 40 psi
- 40 to 60 psi
- 60 to 80 psi
- Greater than 80 psi

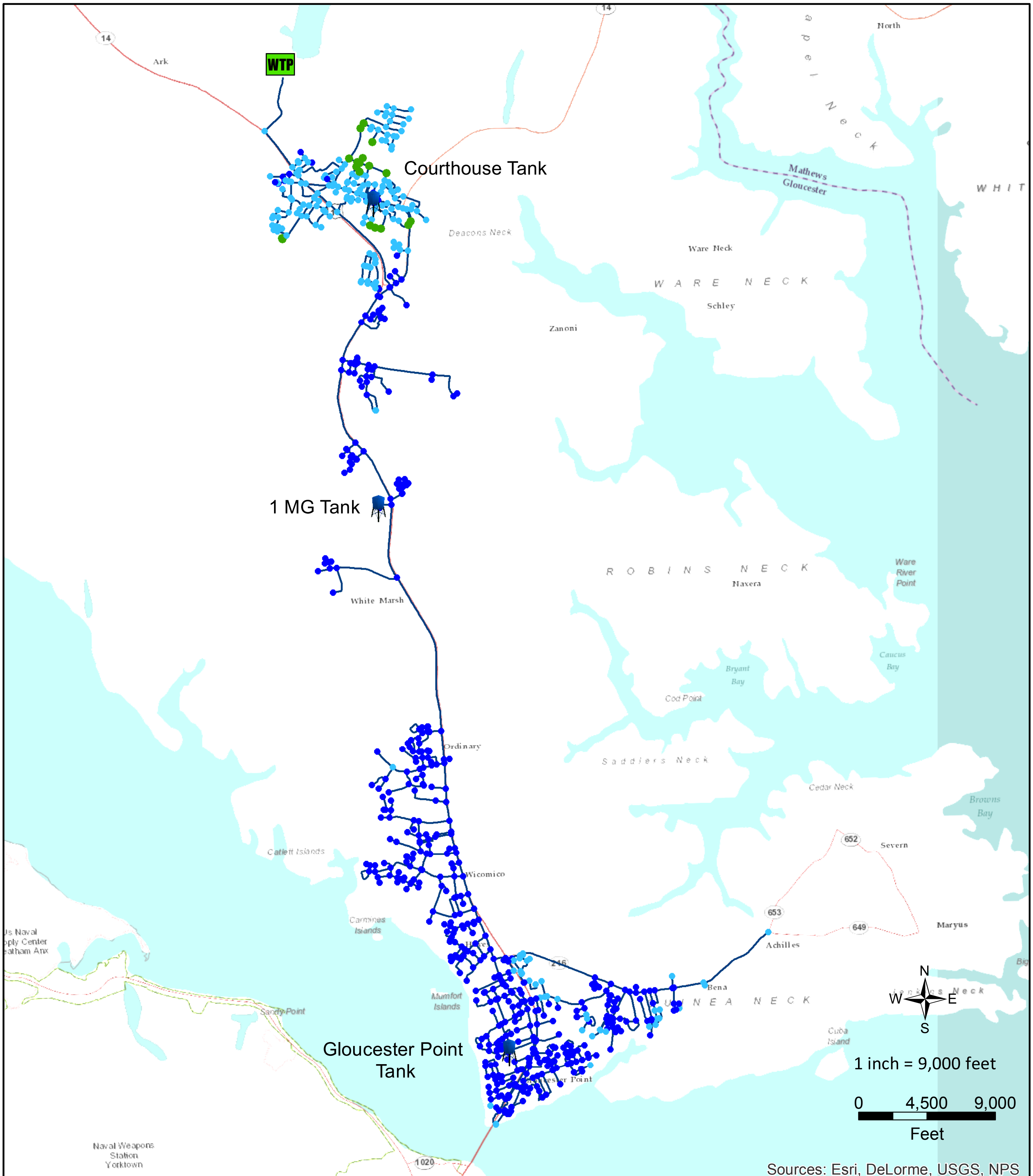
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 17

2035 Water System Minimum Pressures



WTP

Tanks

wMain

MAX_PRESS

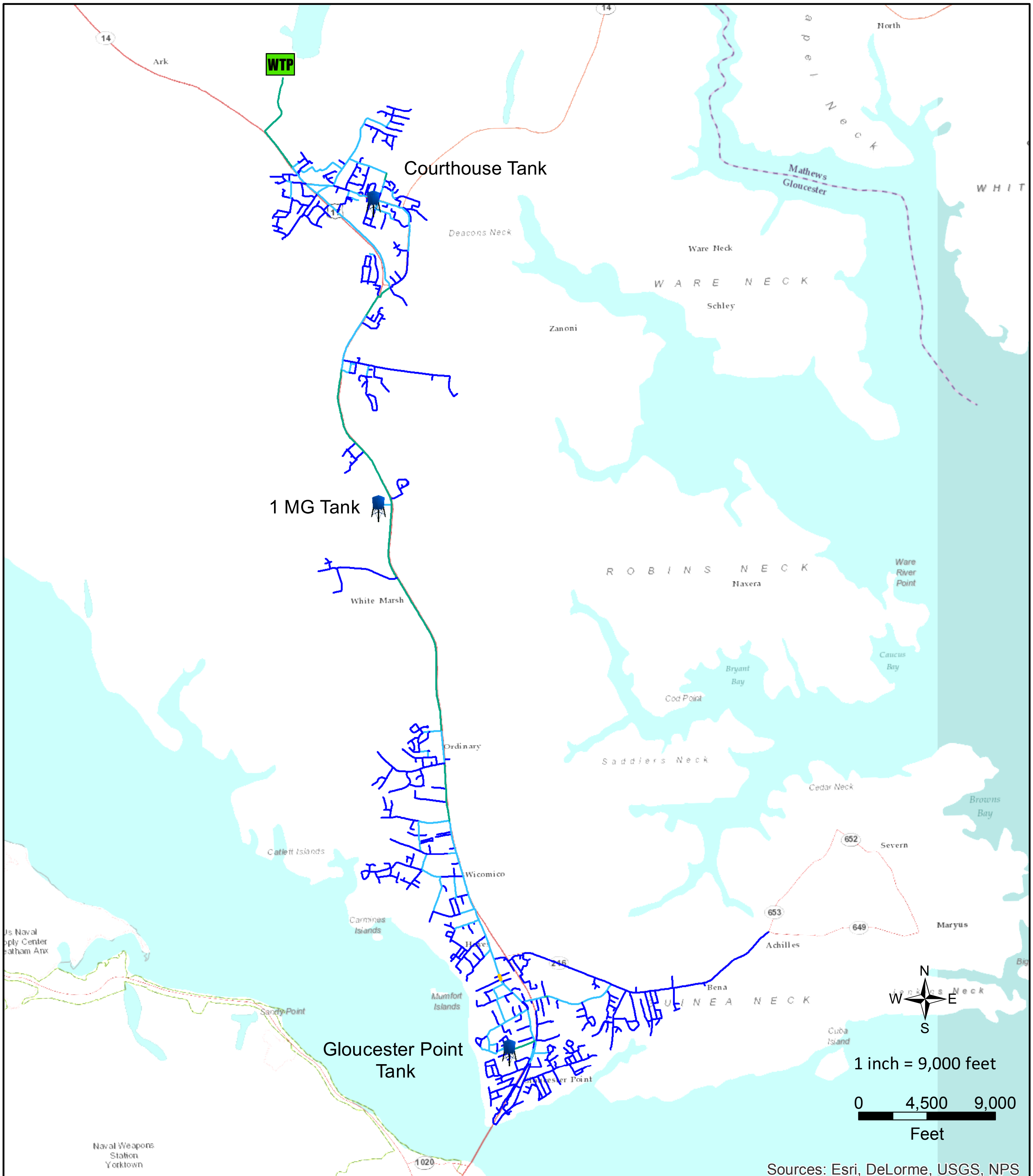
- Less than 80 psi
- 80 - 100 psi
- 100 - 120 psi
- 120 - 140 psi
- Greater than 140 psi

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 18

2035 Water System Maximum Pressures



BLACK & VEATCH

WTP

Tanks

MAX_VELOC

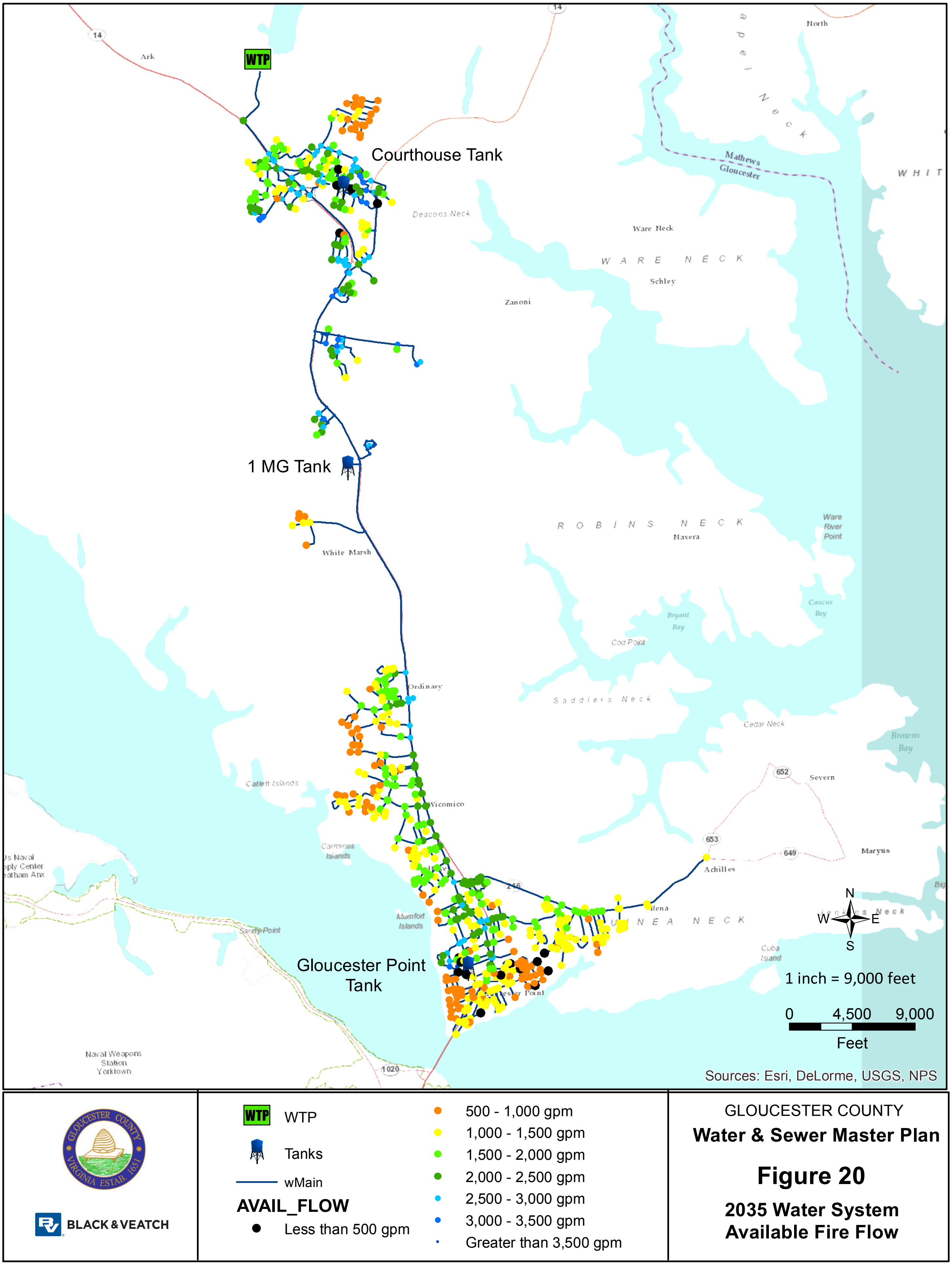
- Less than 1 fps
- 1 - 3 fps
- 3 - 5 fps
- 5 - 7 fps
- Greater than 7 fps

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 19

2035 Water System Maximum Velocity



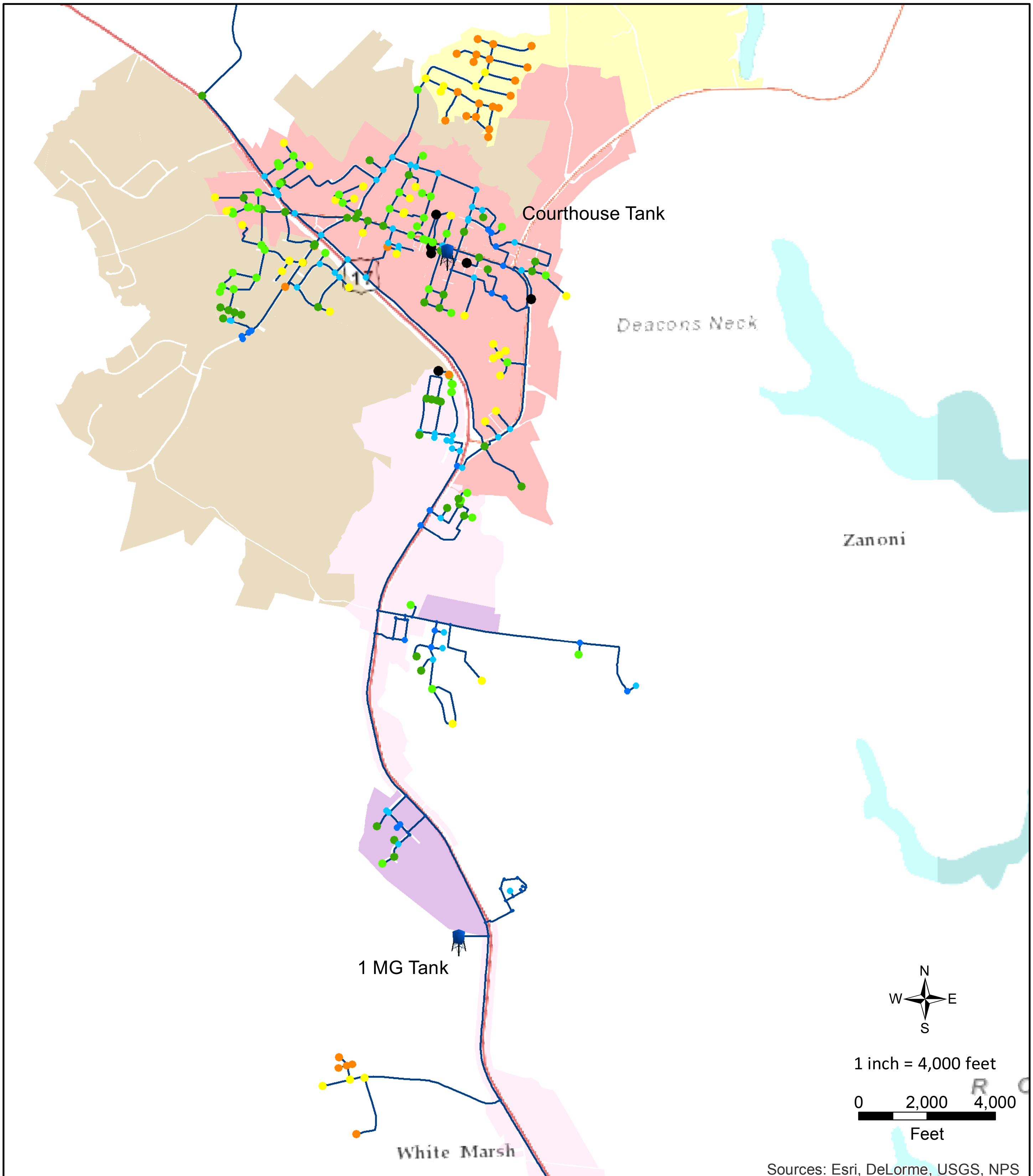
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 20

2035 Water System Available Fire Flow



WTP
Tanks
AVAIL_FLOW
Less than 500 gpm
500 - 1,000 gpm
1,000 - 1,500 gpm
1,500 - 2,000 gpm
2,000 - 2,500 gpm
2,500 - 3,000 gpm
3,000 - 3,500 gpm
Greater than 3,500 gpm
wMain

Future Landuse
ELI
HMU
MDR
SHD
VS

BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 20a

2035 Water System Available Fire Flow

BLACK & VEATCH

WTP

Tanks

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm
- wMain

Future Landuse

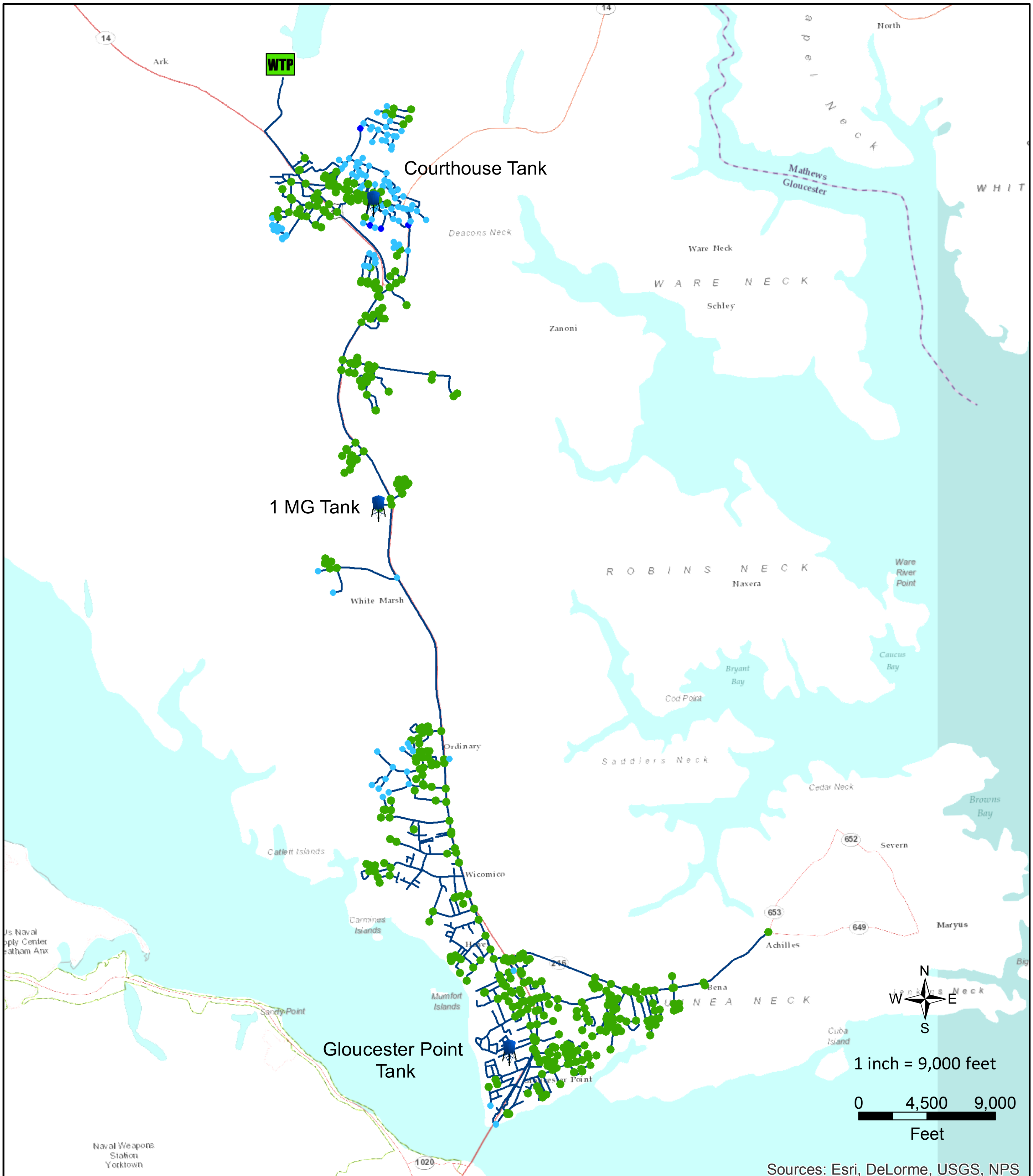
- ELI
- HMU
- MDR
- SHD
- VS

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 20b

2035 Water System Available Fire Flow



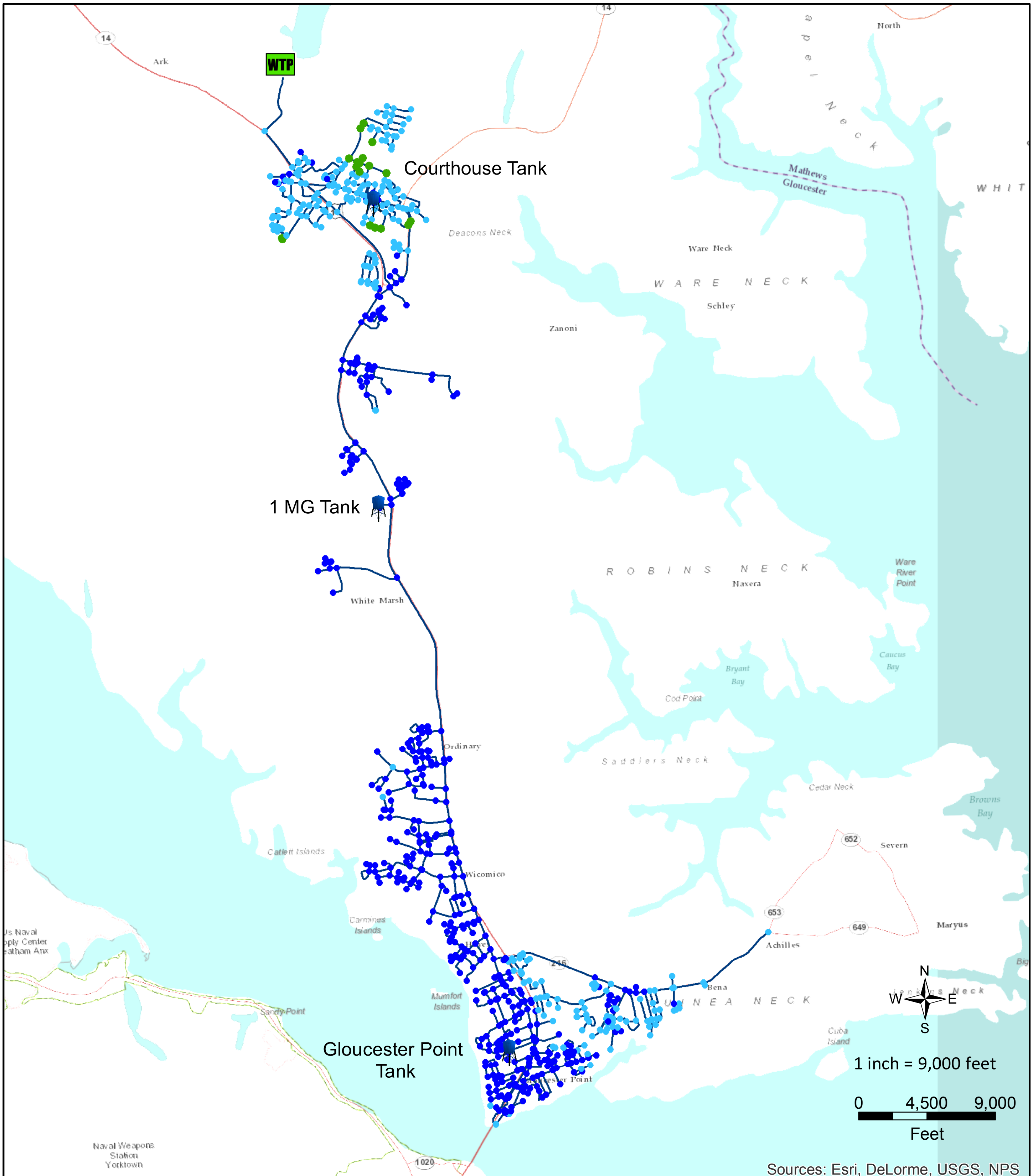
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 21

2040 Water System Minimum Pressures



BLACK & VEATCH

WTP

Tanks

wMain

MAX_PRESS

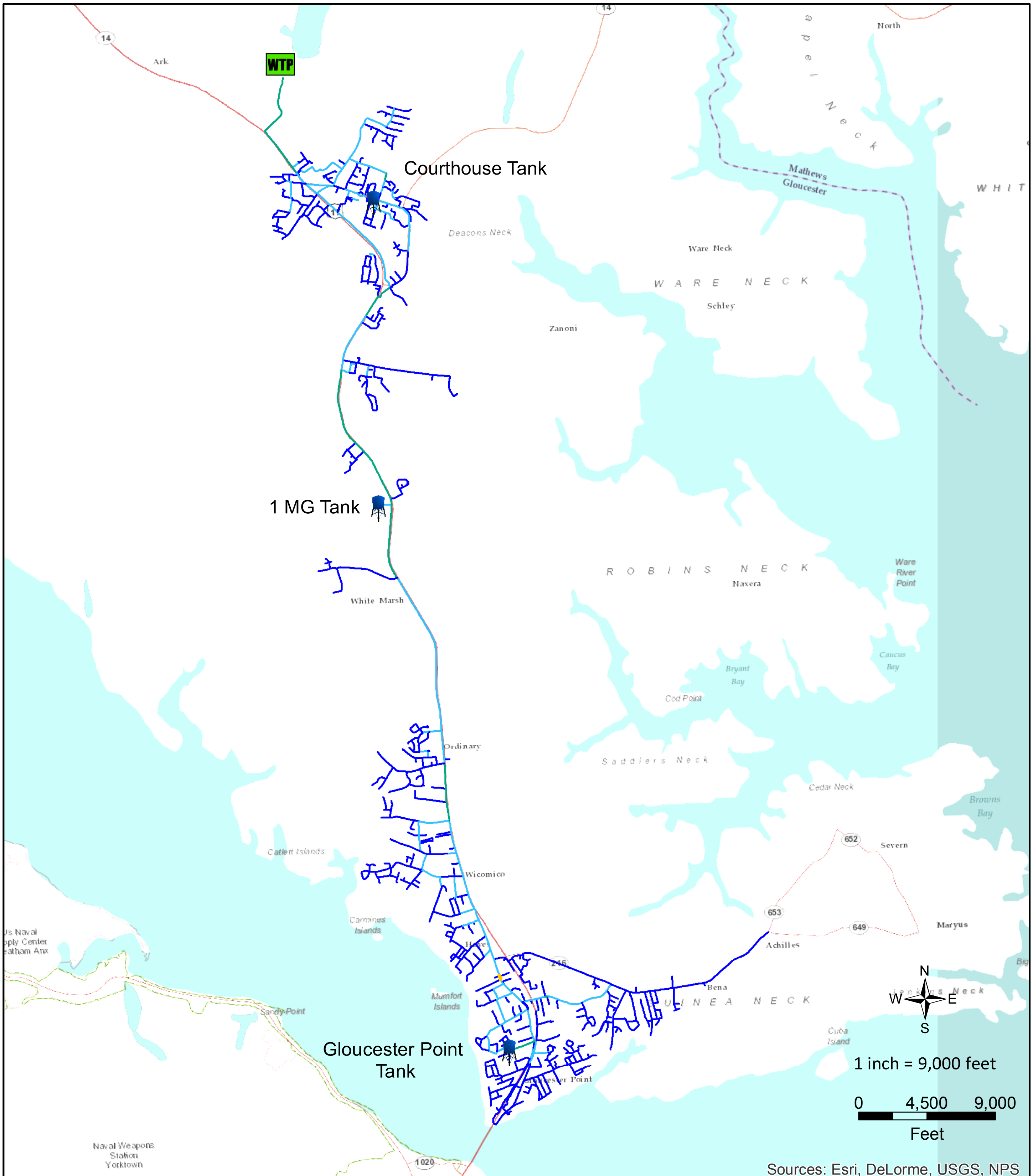
- Less than 80 psi
- 80 - 100 psi
- 100 - 120 psi
- 120 - 140 psi
- Greater than 100 psi

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 22

2040 Water System Maximum Pressures



BLACK & VEATCH

WTP

Tanks

MAX_VELOC

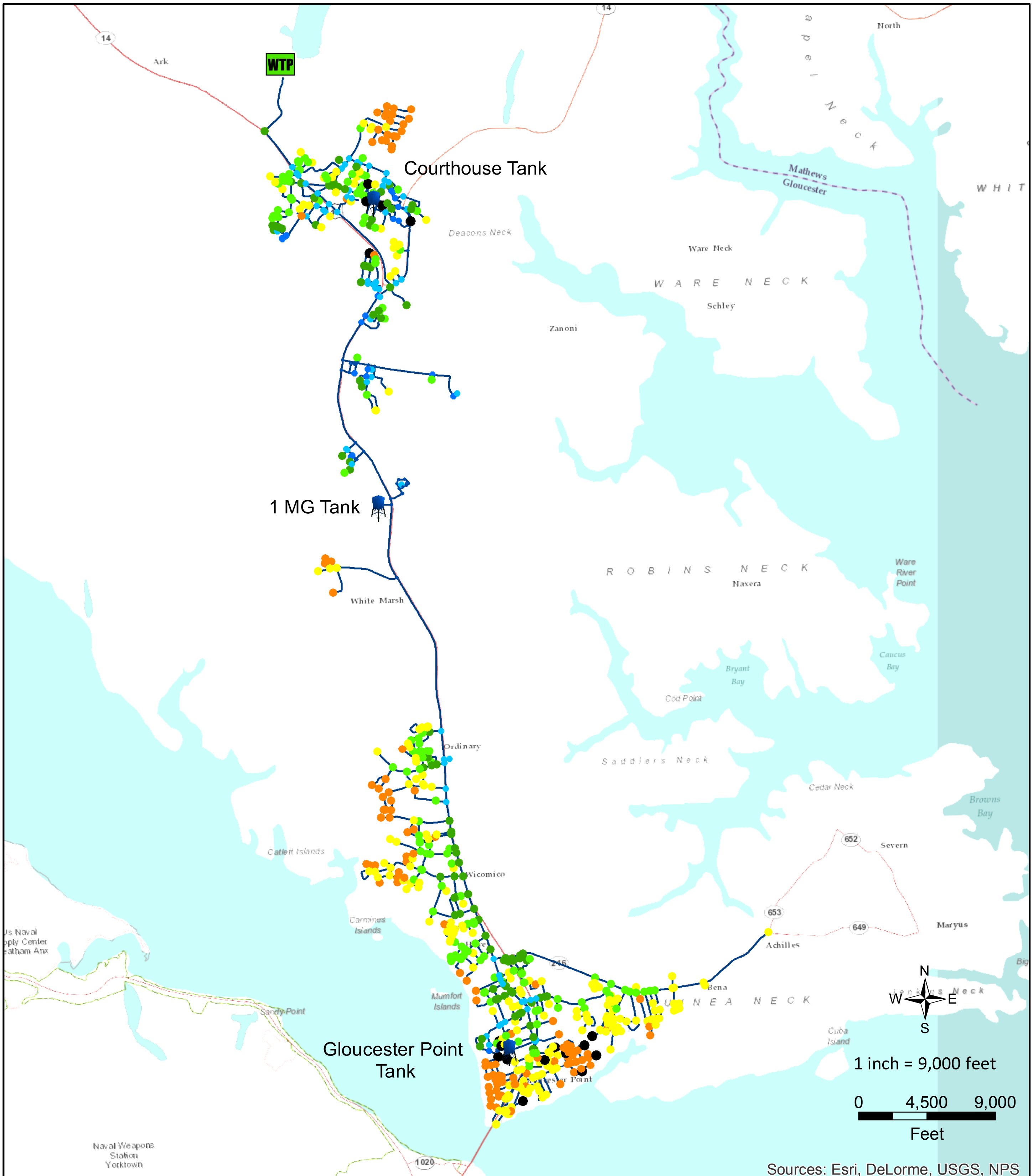
- Less than 1 fps
- 1 - 3 fps
- 3 - 5 fps
- 5 - 7 fps
- Greater than 7 fps

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 23

2040 Water System Maximum Velocity



WTP

Tanks

wMain

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm

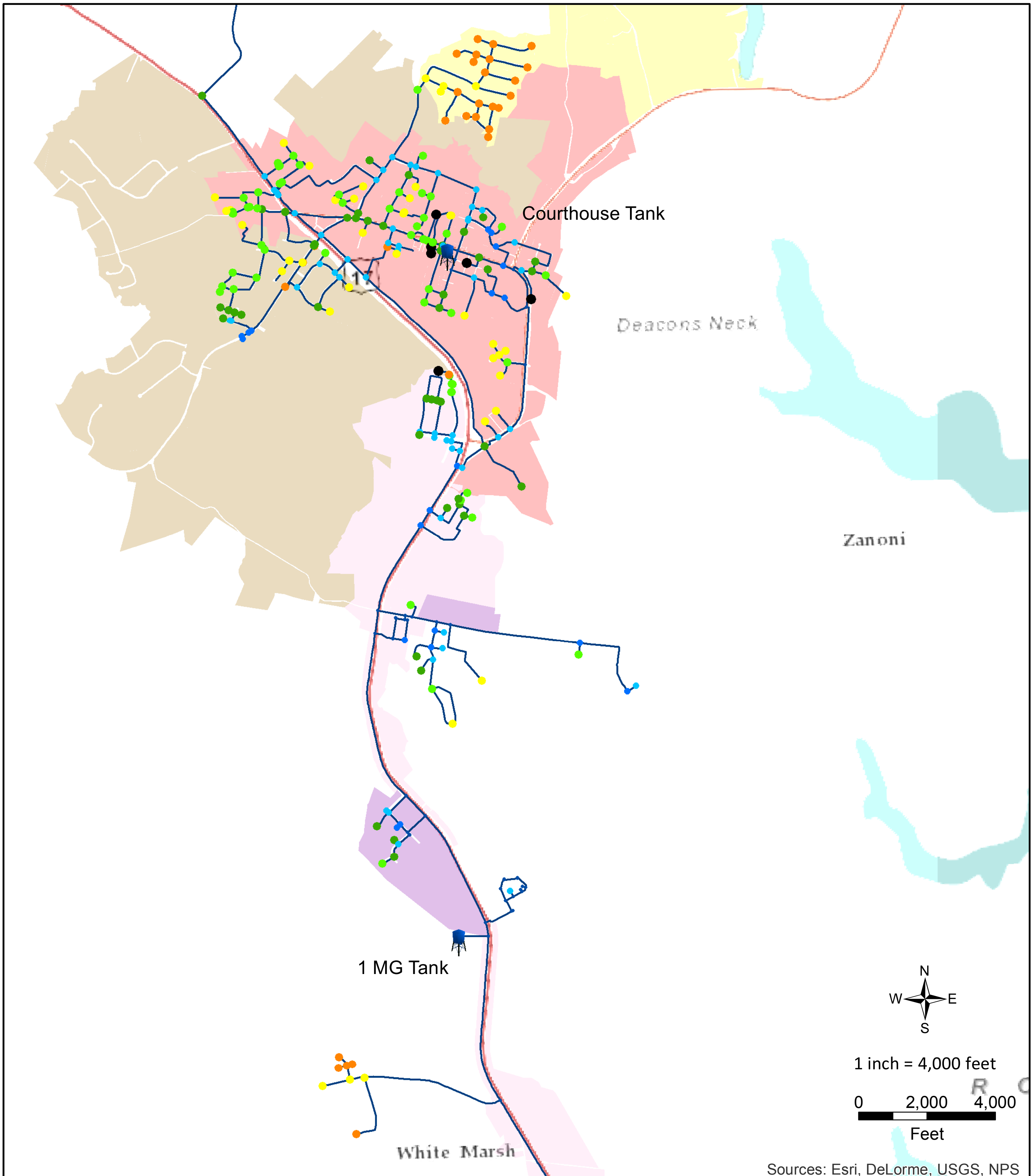
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 24

2040 Water System Available Fire Flow



BLACK & VEATCH

WTP
Tanks
AVAIL_FLOW
Less than 500 gpm
500 - 1,000 gpm
1,000 - 1,500 gpm
1,500 - 2,000 gpm
2,000 - 2,500 gpm
2,500 - 3,000 gpm
3,000 - 3,500 gpm
Greater than 3,500 gpm
wMain

Future Landuse
ELI
HMU
MDR
SHD
VS

GLOUCESTER COUNTY
Water & Sewer Master Plan

Figure 24a

2040 Water System Available Fire Flow

BLACK & VEATCH

WTP

Tanks

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm
- wMain

Future Landuse

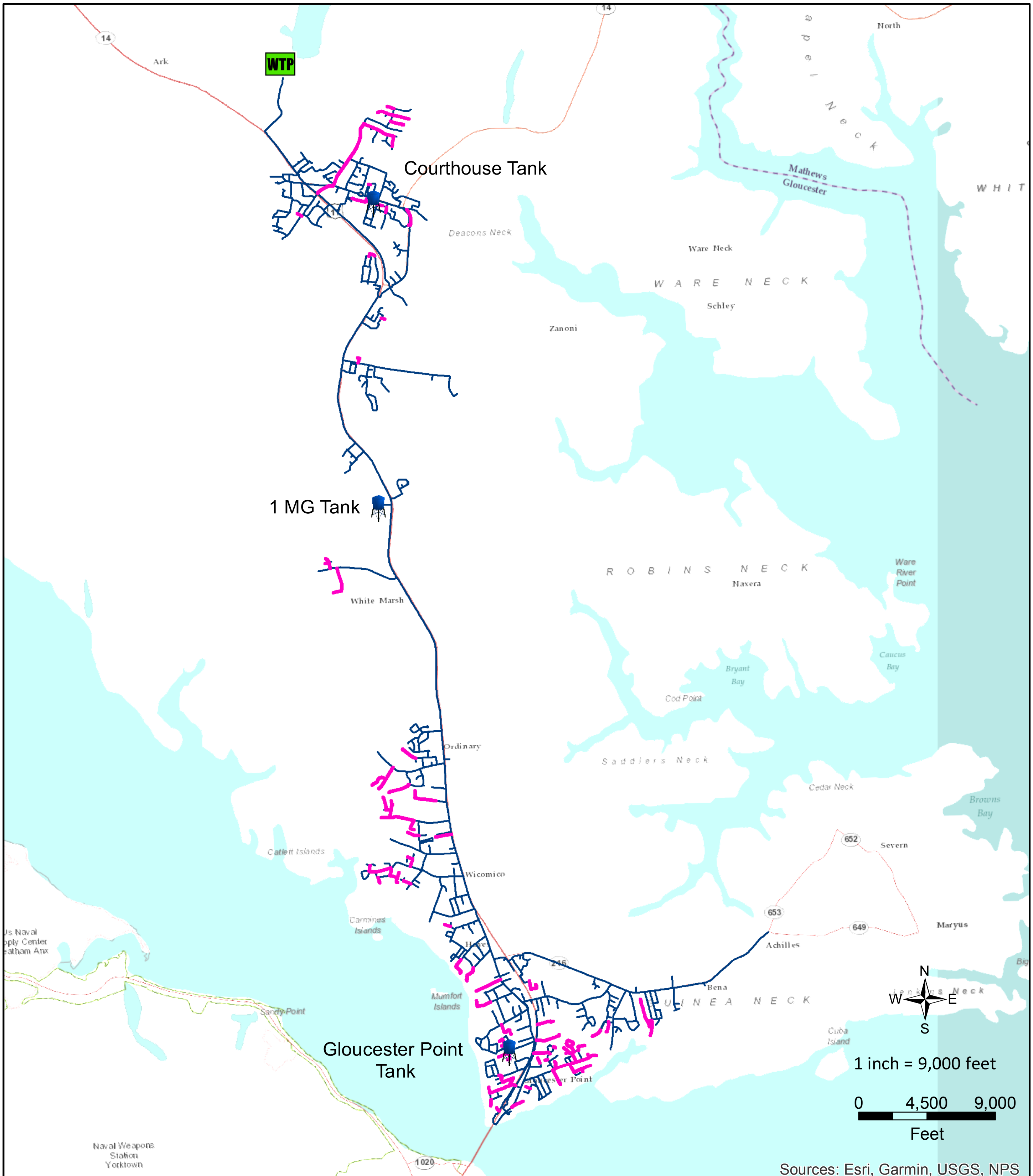
- ELI
- HMU
- MDR
- SHD
- VS

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 24b

2040 Water System Available Fire Flow



BLACK & VEATCH

WTP

Tanks

Proposed Improvements

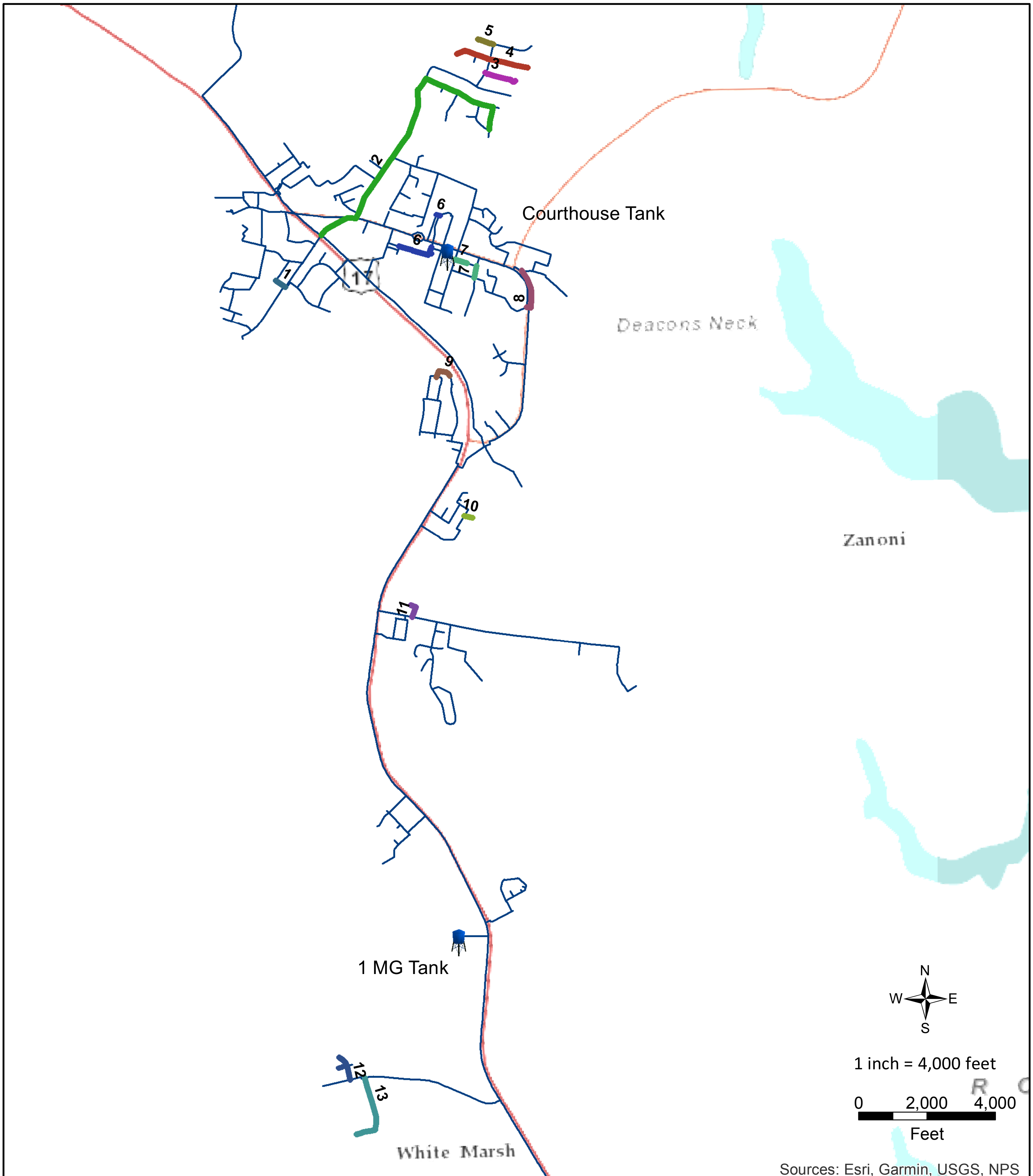
wMain

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 25

2040 Proposed Water System Improvements



WTP
Tanks
wMain
Project_ID
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 25a

2040 Proposed Water System Improvements

WTP

Tanks

wMain

Proposed Improvements

Project_ID

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52

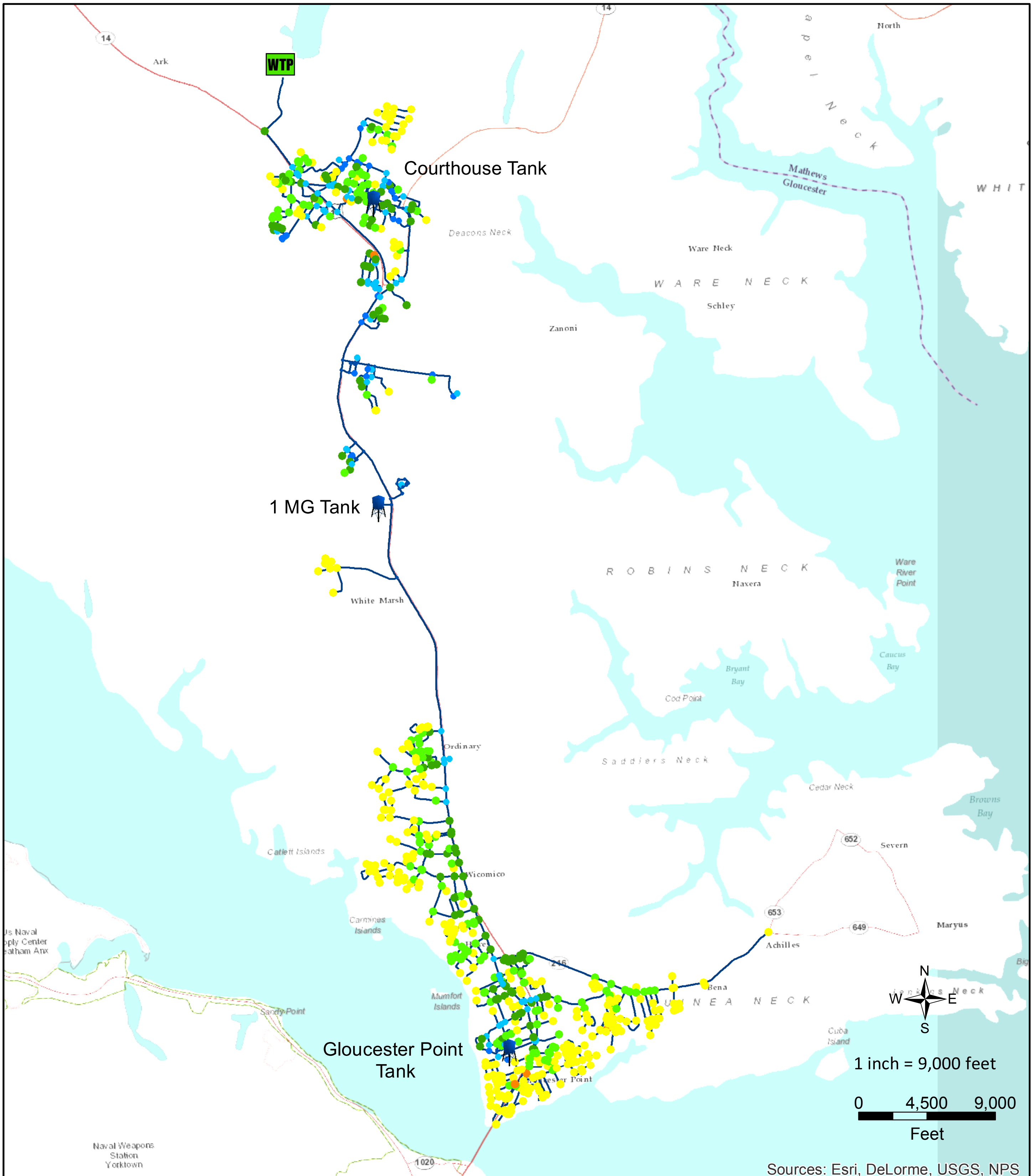
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 25b

2040 Proposed Water System Improvements



WTP

Tanks

wMain

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm

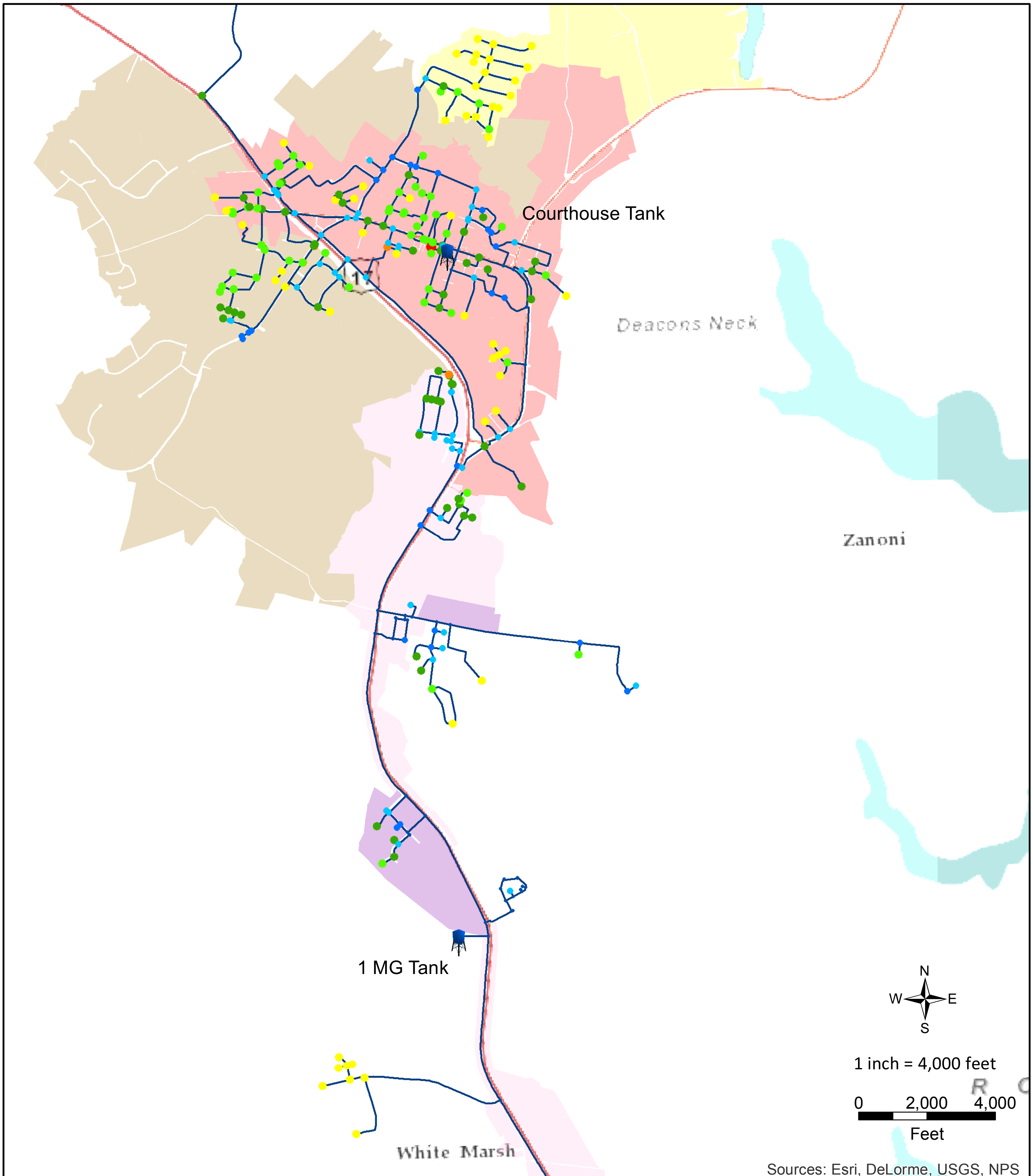
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 26

2040 Proposed Water System Available Fire Flow



BLACK & VEATCH

WTP

Tanks

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm
- wMain

Future Landuse

- ELI
- HMU
- MDR
- SHD
- VS

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure 26a

2040 Proposed Water System Available Fire Flow

BLACK & VEATCH

WTP

Tanks

AVAIL_FLOW

- Less than 500 gpm
- 500 - 1,000 gpm
- 1,000 - 1,500 gpm
- 1,500 - 2,000 gpm
- 2,000 - 2,500 gpm
- 2,500 - 3,000 gpm
- 3,000 - 3,500 gpm
- Greater than 3,500 gpm
- wMain

Future Landuse

- ELI
- HMU
- MDR
- SHD
- VS

GLOUCESTER COUNTY

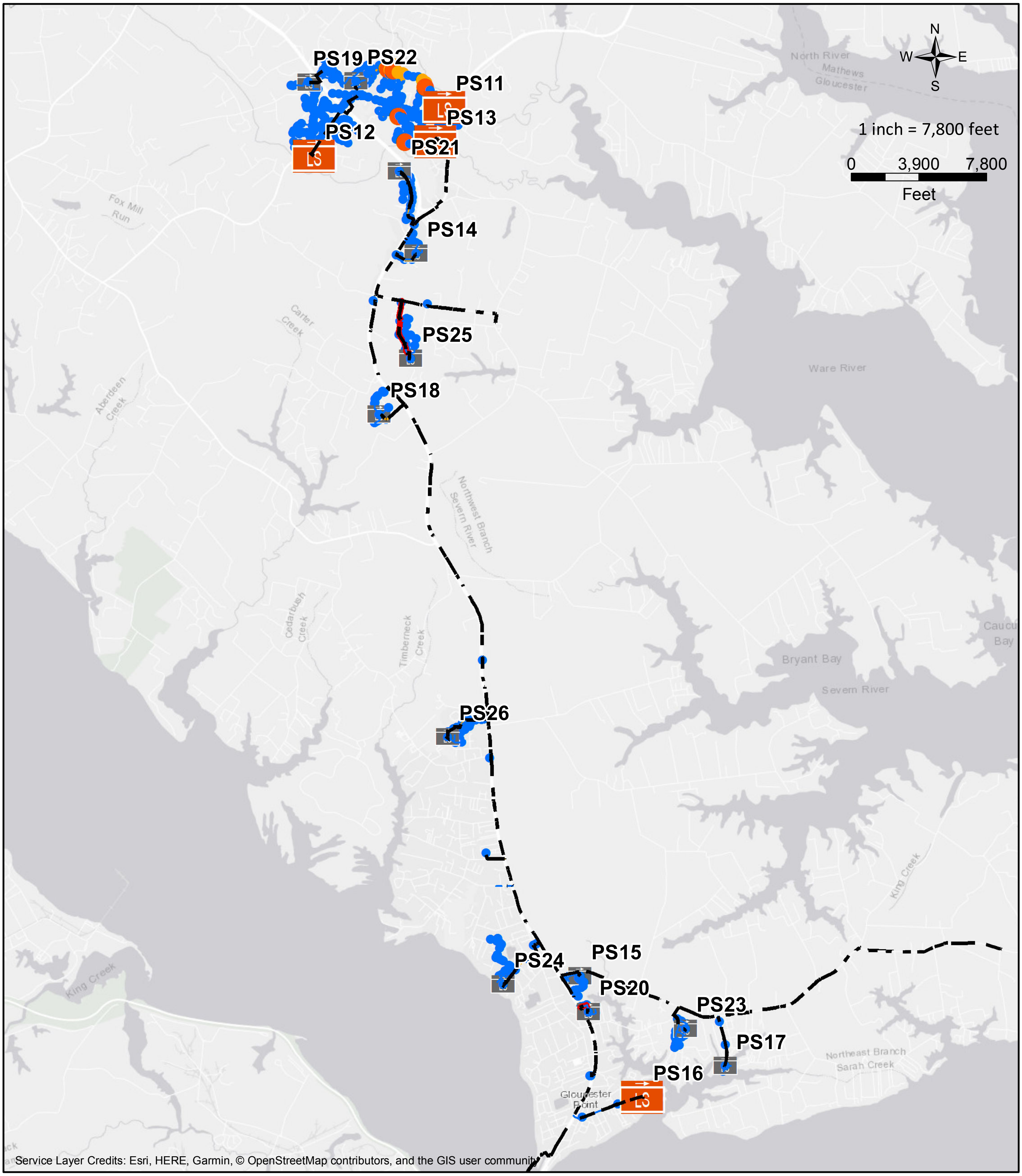
Water & Sewer Master Plan

Figure 26b

2040 Proposed Water System Available Fire Flow

APPENDIX B
WASTEWATER HYDRAULIC MODEL RESULTS

APPENDIX B
SEWER MODEL RESULTS



BLACK & VEATCH

LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

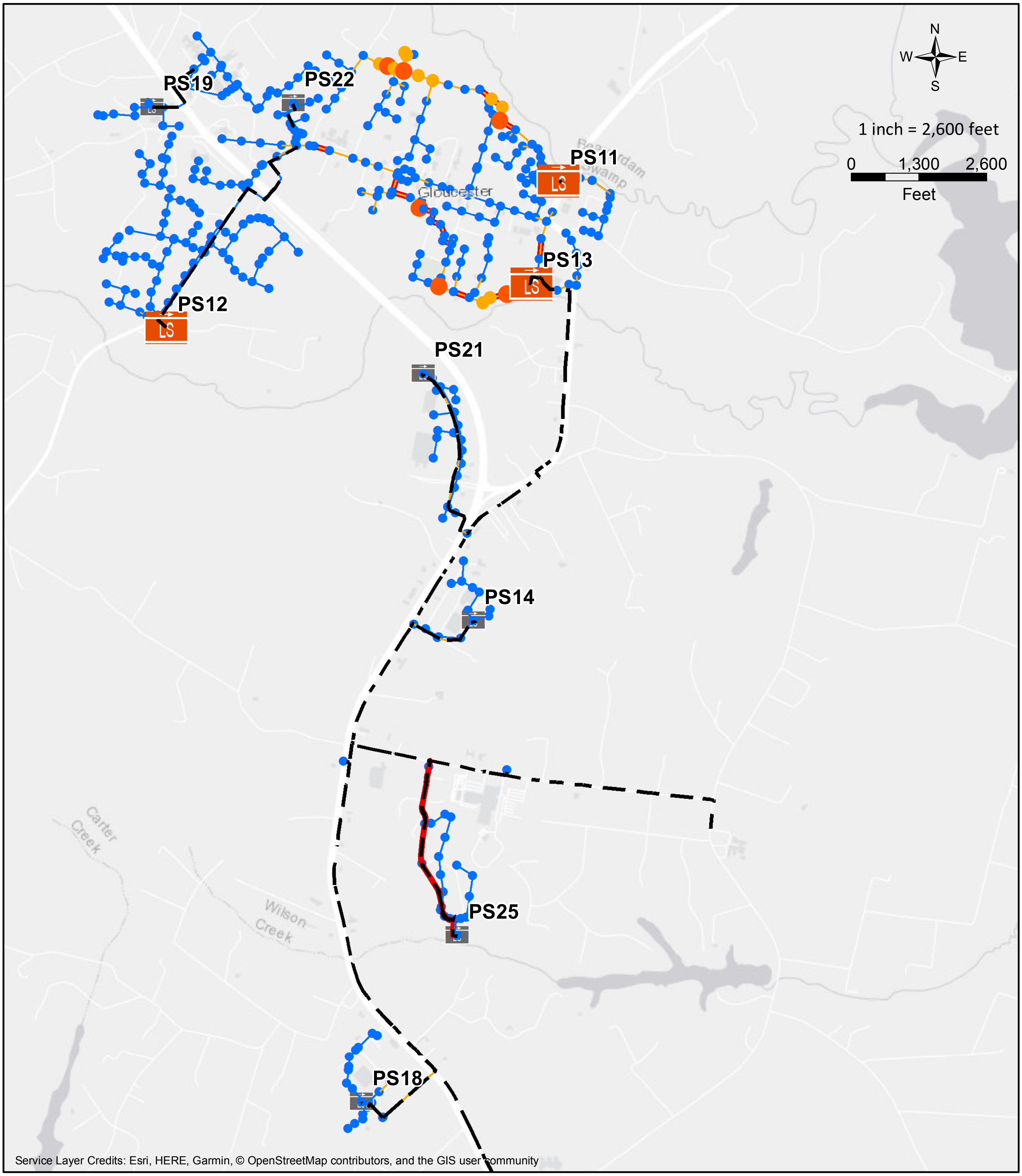
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-1

Sewer System Analysis
No Improvements
Base Year Flows
5 Year Storm



LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

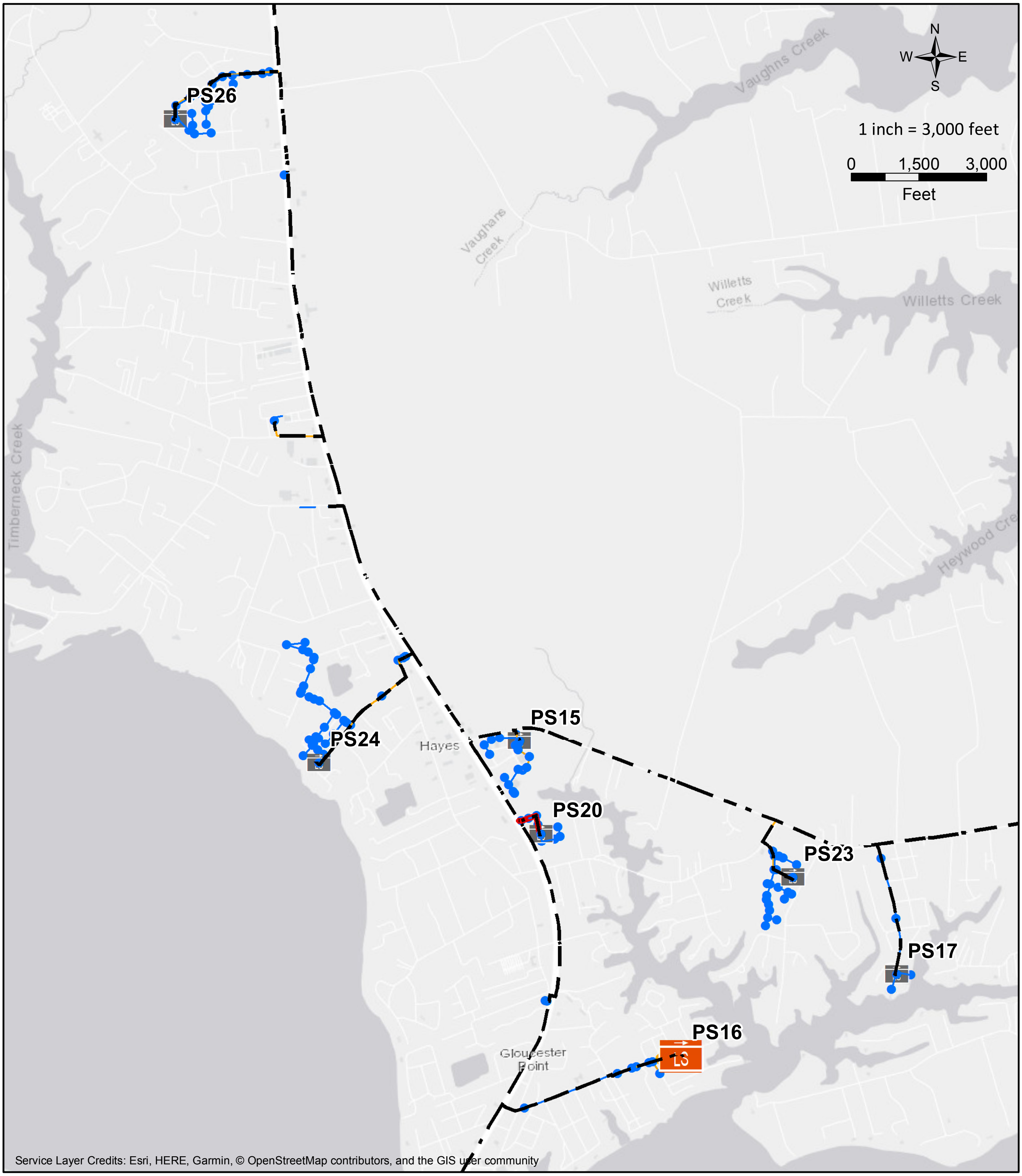
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-1 N

Sewer System Analysis
No Improvements
Base Year Flows
5 Year Storm



BLACK & VEATCH

LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

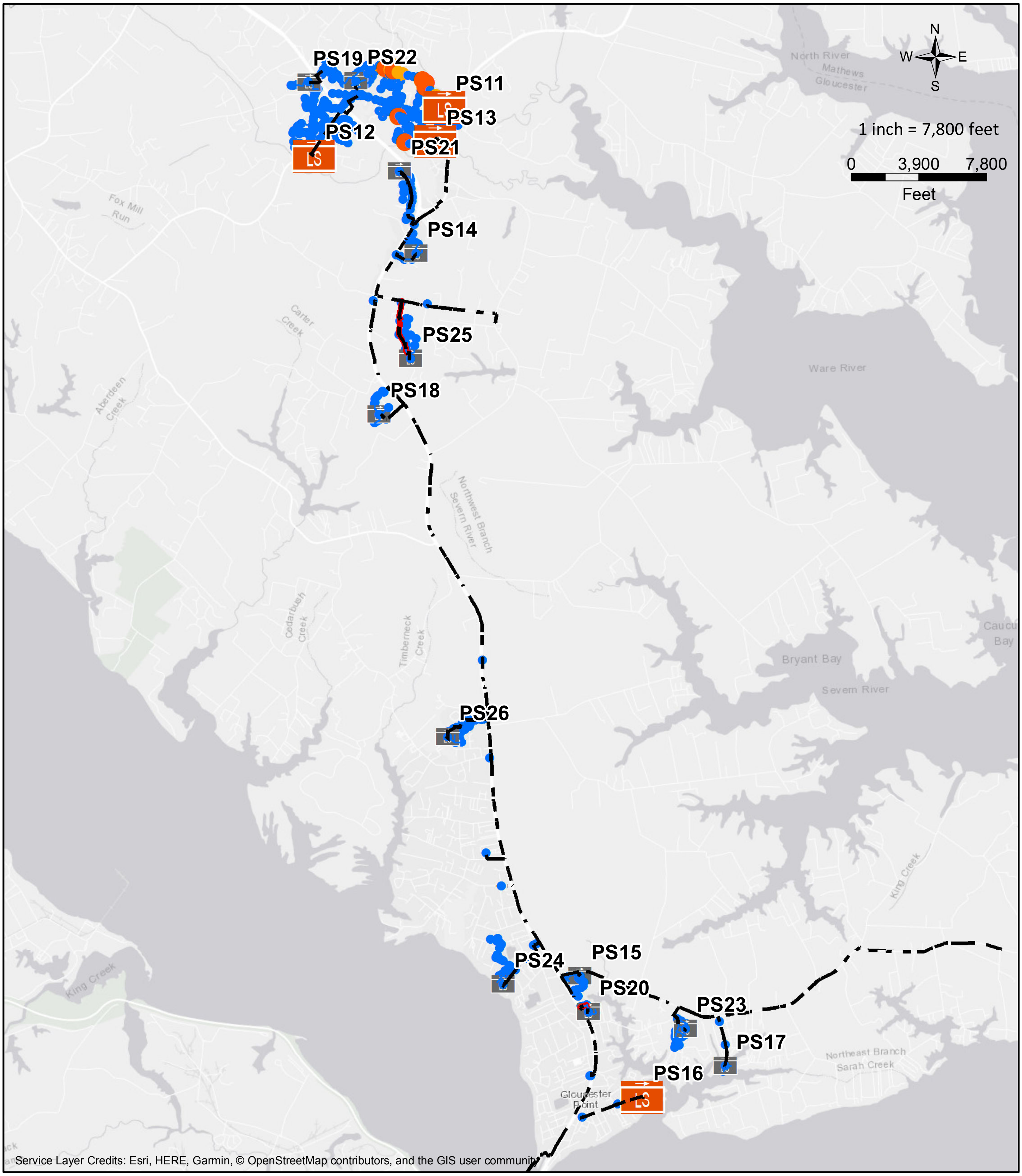
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-1 S

Sewer System Analysis
No Improvements
Base Year Flows
5 Year Storm



BLACK & VEATCH

LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

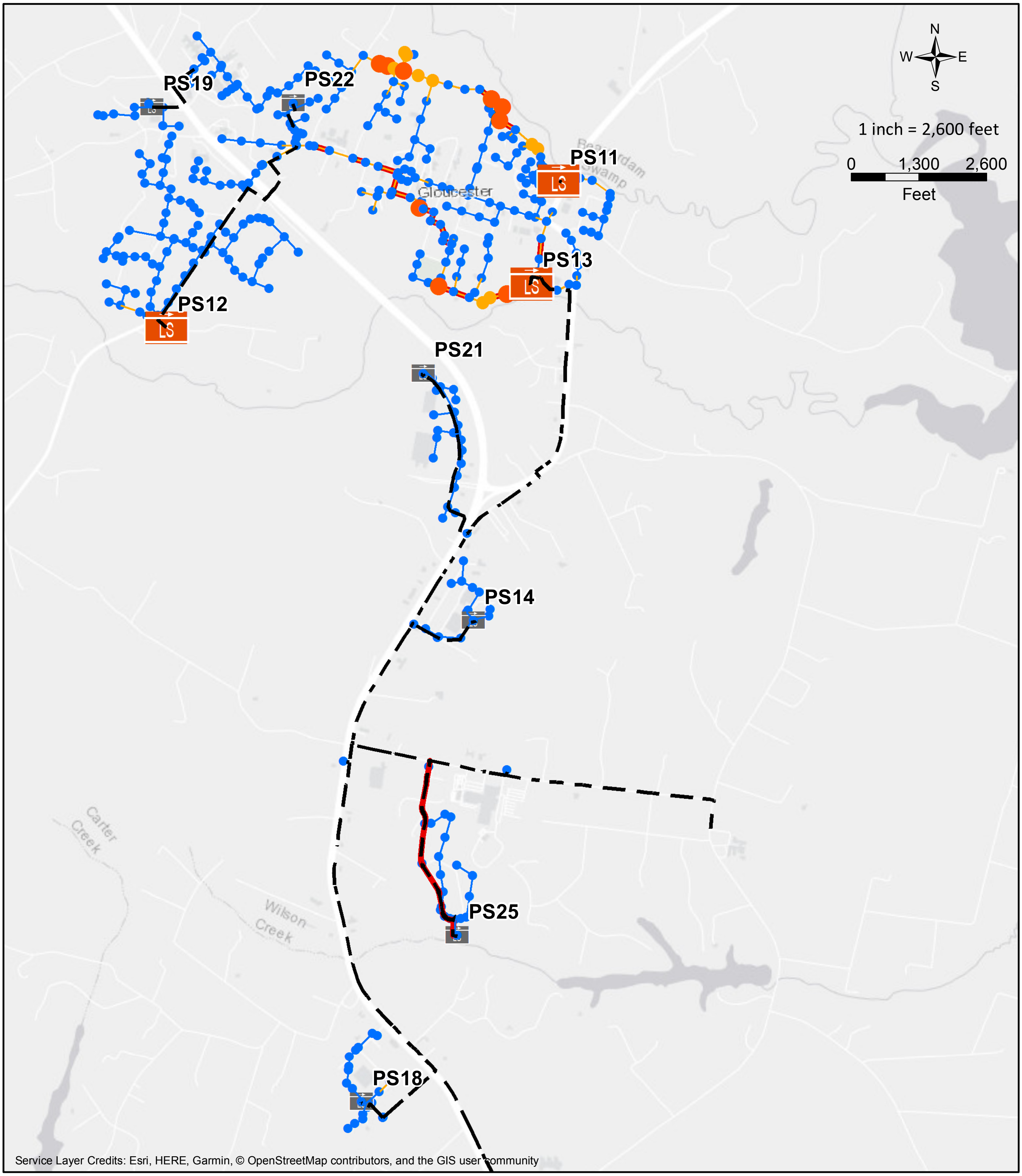
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-2

Sewer System Analysis
No Improvements
2020 Planning Year Flows
5 Year Storm



BLACK & VEATCH

LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

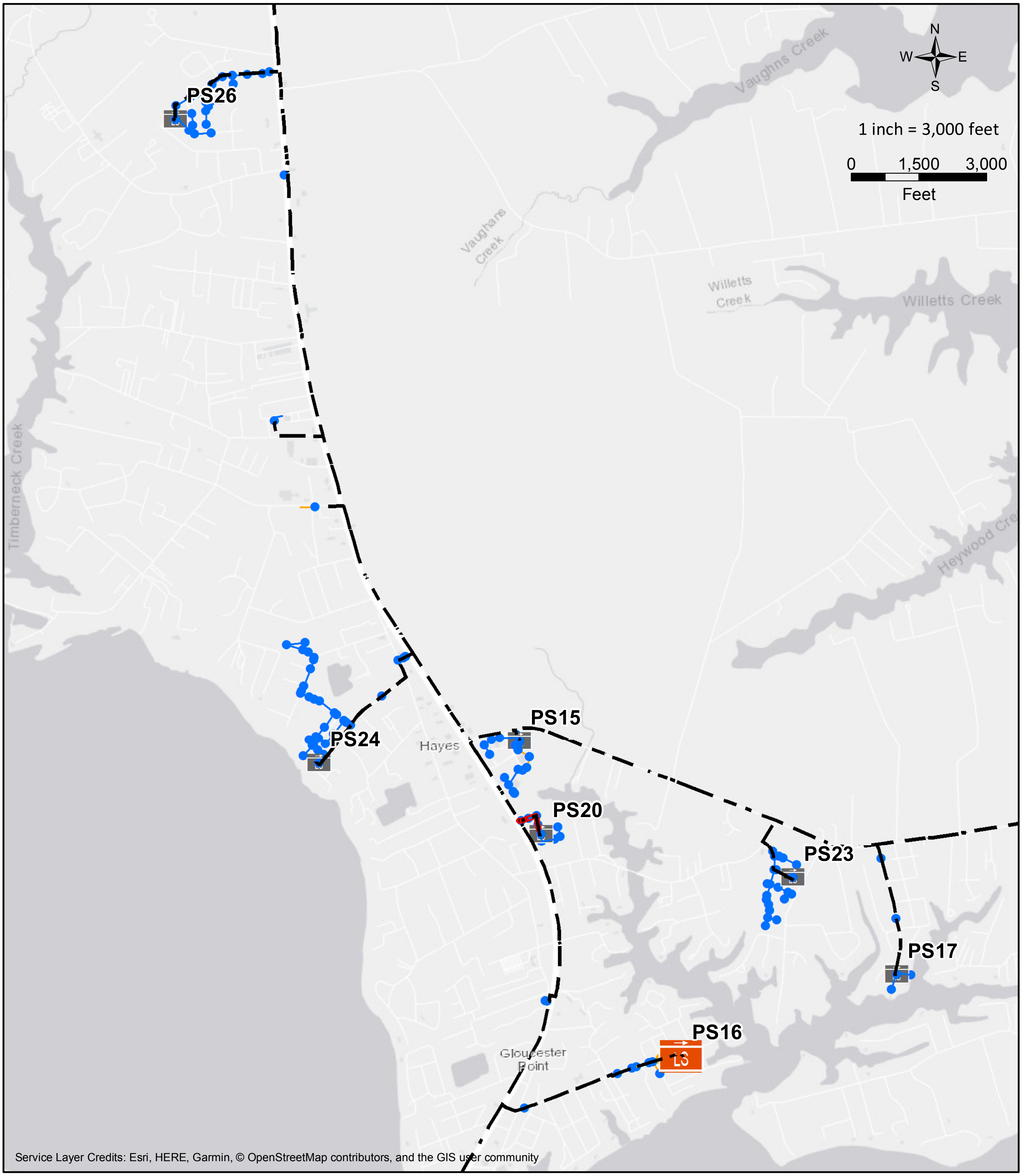
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-2 N

Sewer System Analysis
No Improvements
2020 Planning Year Flows
5 Year Storm



BLACK & VEATCH

LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

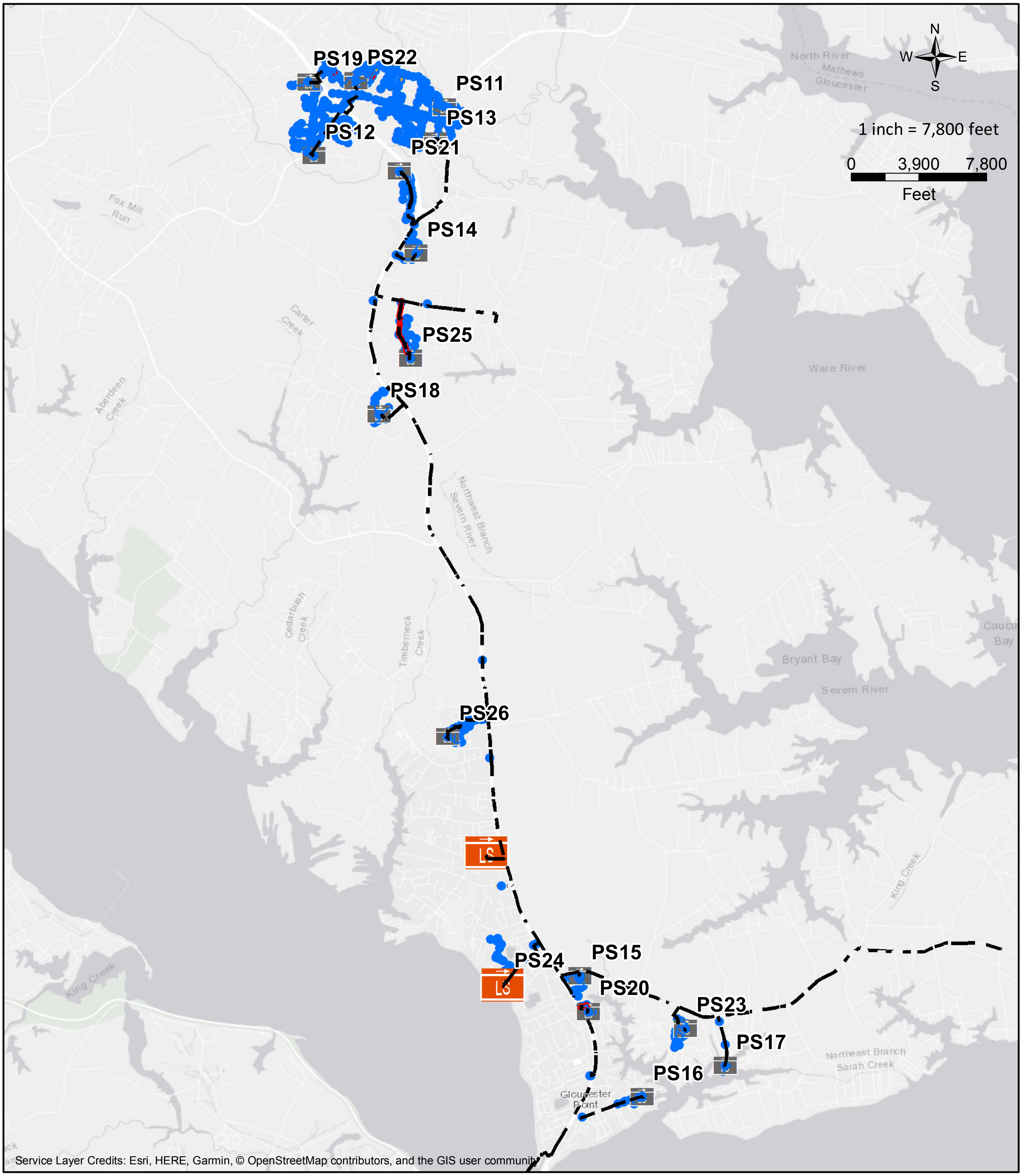
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-2 S

Sewer System Analysis
No Improvements
2020 Planning Year Flows
5 Year Storm



BLACK & VEATCH

LS Exceeds Firm Capacity

Manhole Level
- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

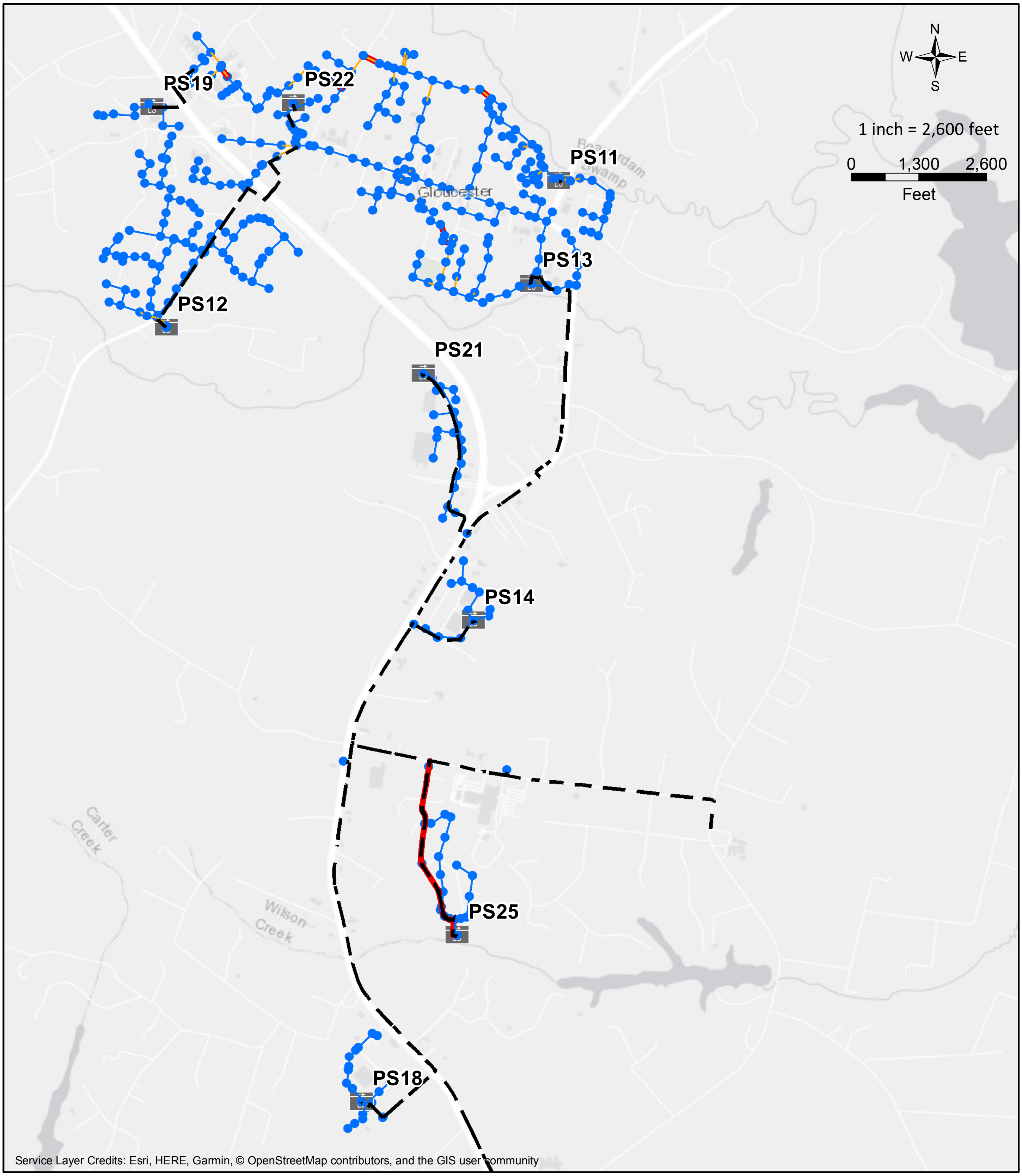
Sewer Capacity
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-3

Sewer System Analysis
2020 Improvements
2030 Planning Year Flows
5 Year Storm



BLACK & VEATCH

LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-3 N

Sewer System Analysis
2020 Improvements
2030 Planning Year Flows
5 Year Storm

BLACK & VEATCH

Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

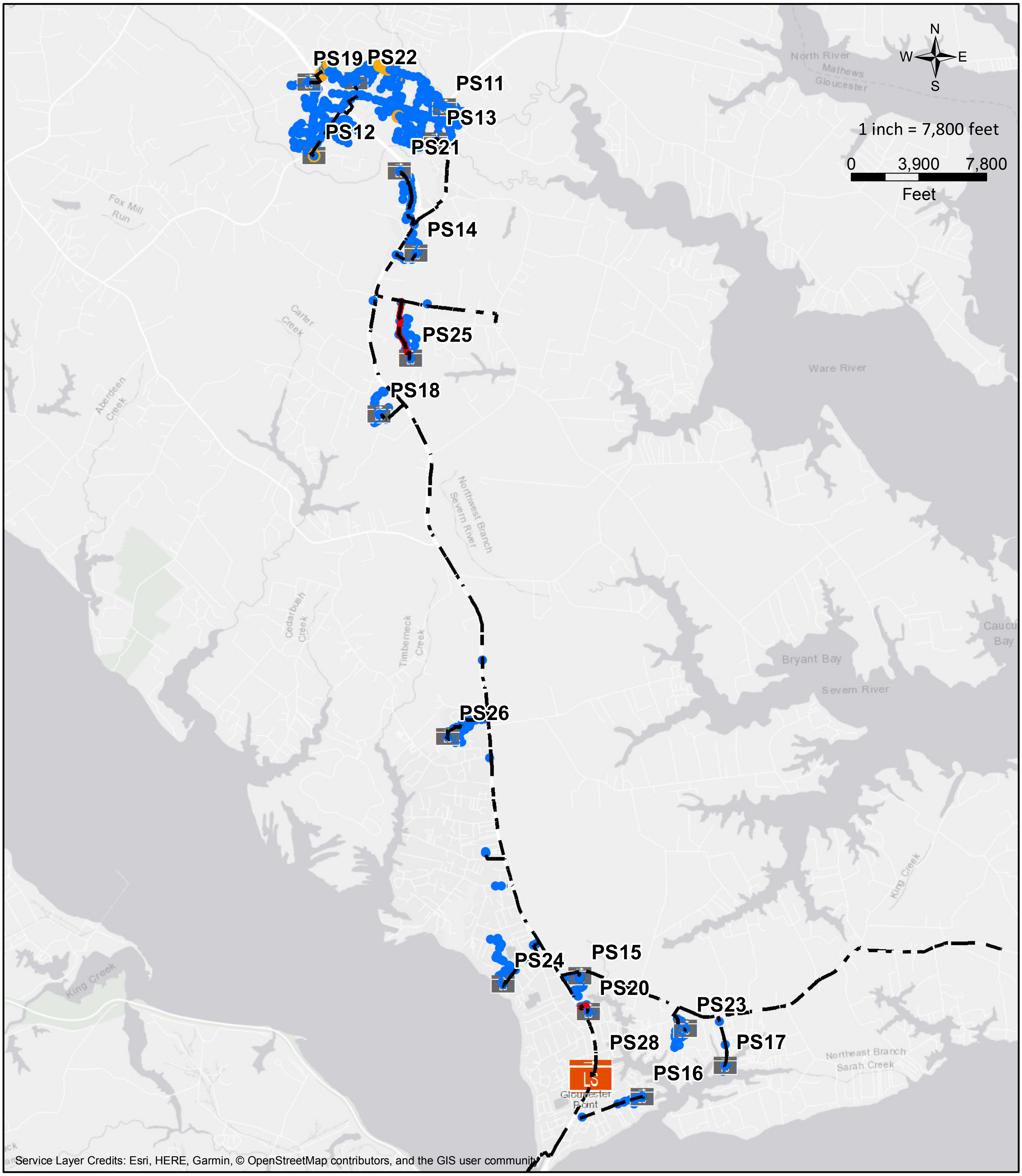
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-3 S

Sewer System Analysis
2020 Improvements
2030 Planning Year Flows
5 Year Storm



LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

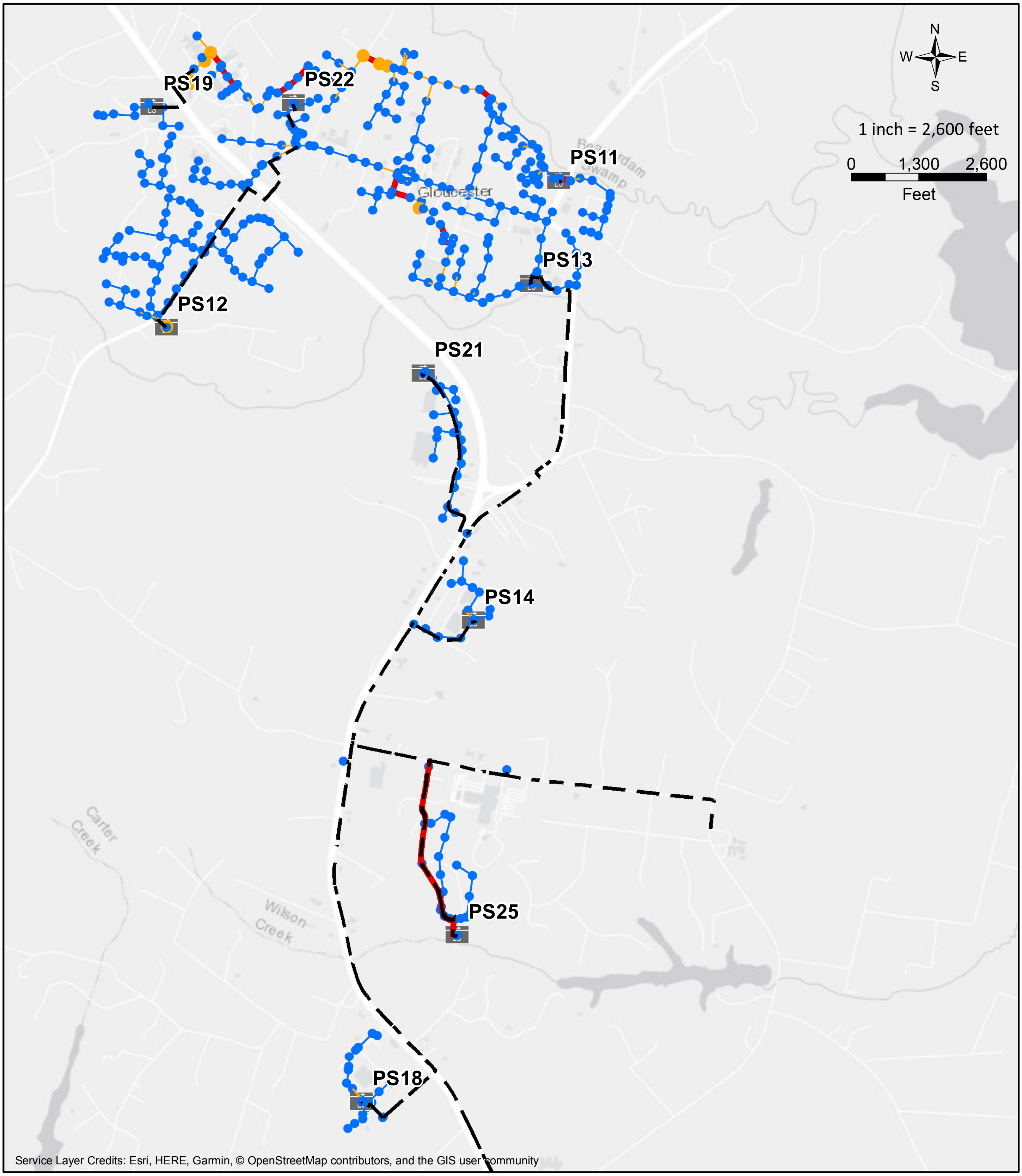
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-4

Sewer System Analysis
2030 Improvements
2040 Planning Year Flows
5 Year Storm



BLACK & VEATCH

Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

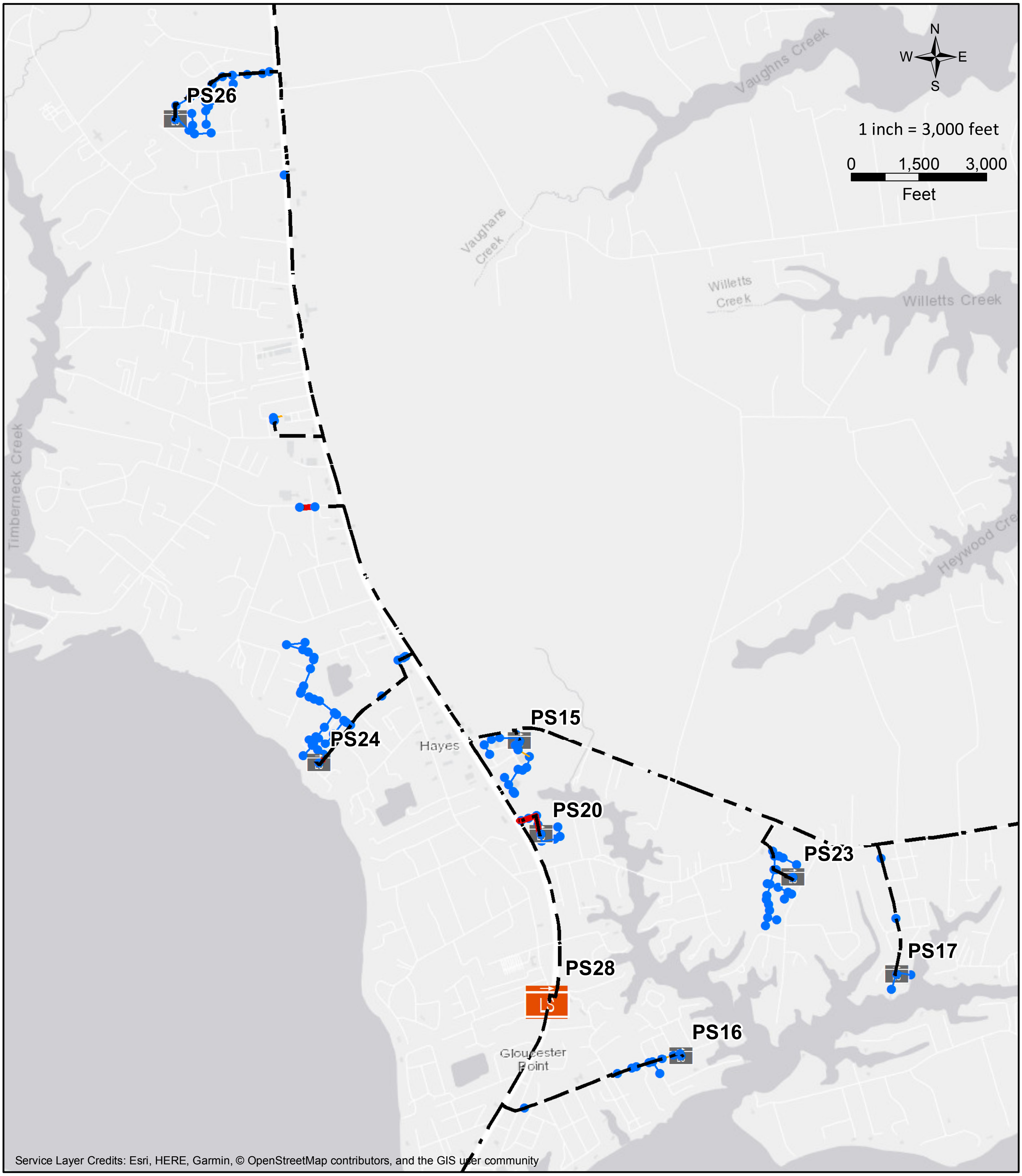
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-4 N

Sewer System Analysis
2030 Improvements
2040 Planning Year Flows
5 Year Storm



LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

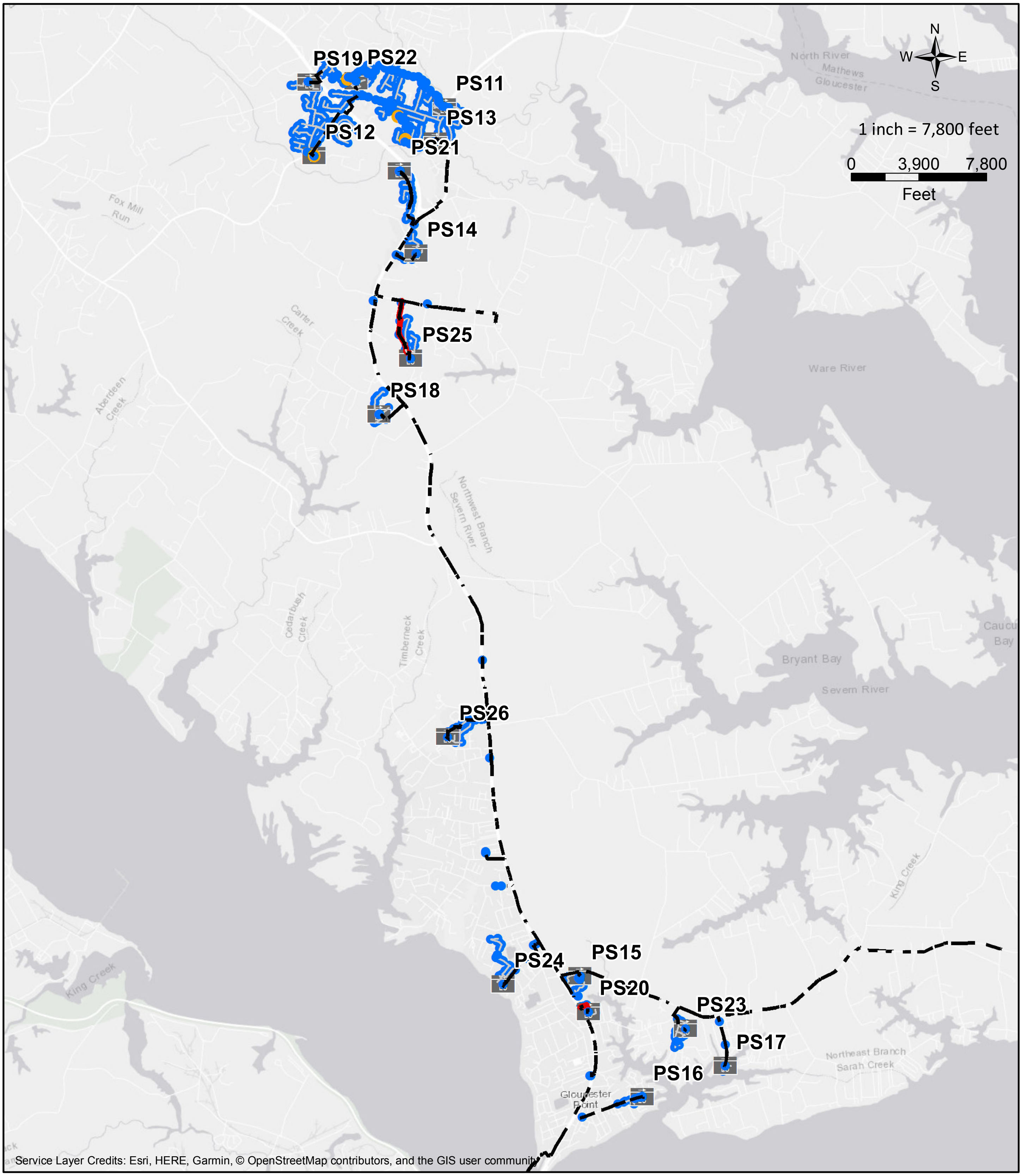
BLACK & VEATCH

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-4 S

Sewer System Analysis
2030 Improvements
2040 Planning Year Flows
5 Year Storm



BLACK & VEATCH

LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

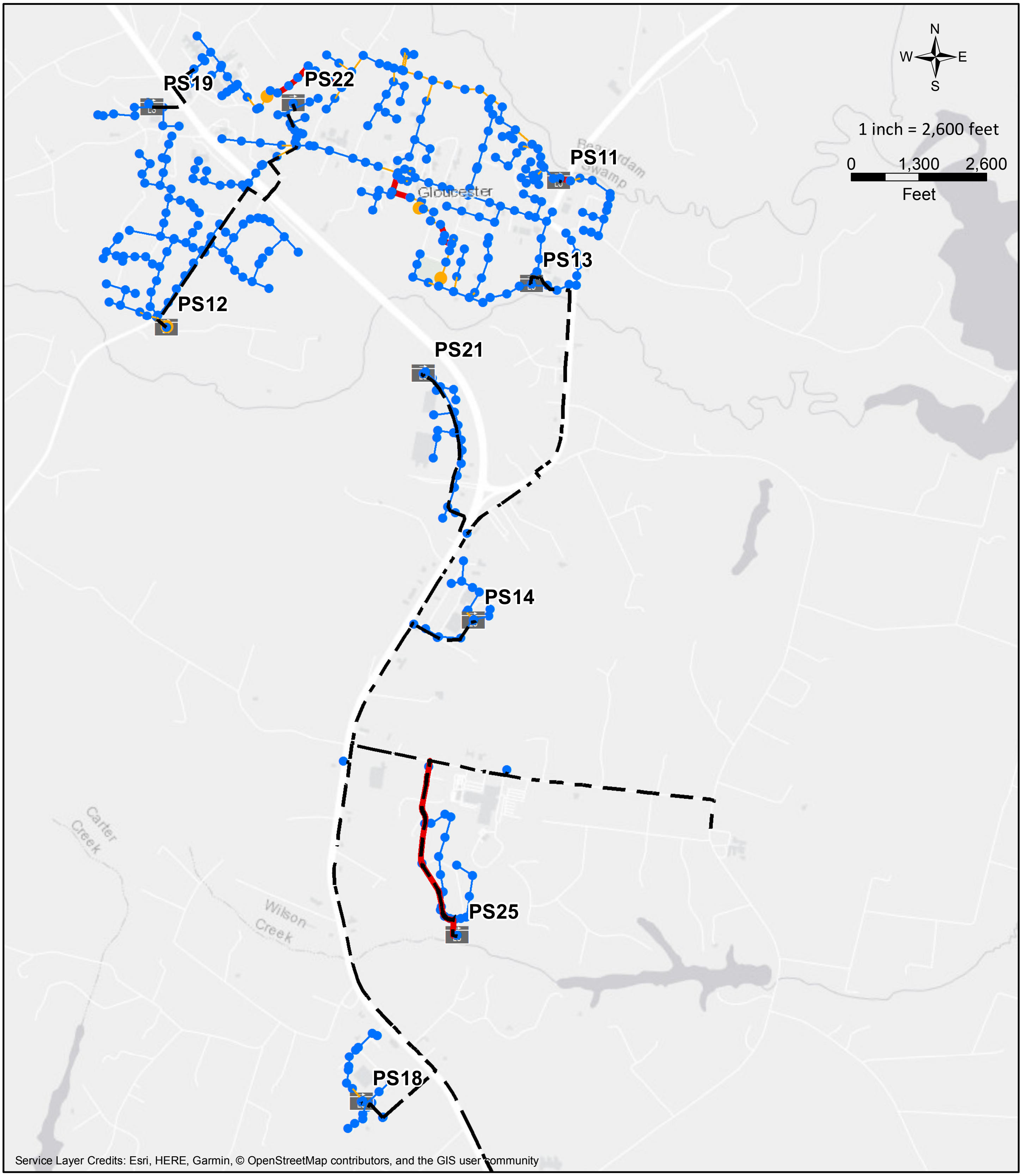
- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-5

Sewer System Analysis
2040 Improvements
2040 Planning Year Flows
5 Year Storm



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BLACK & VEATCH

LS Exceeds Firm Capacity

Sewer Capacity

- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

Manhole Level

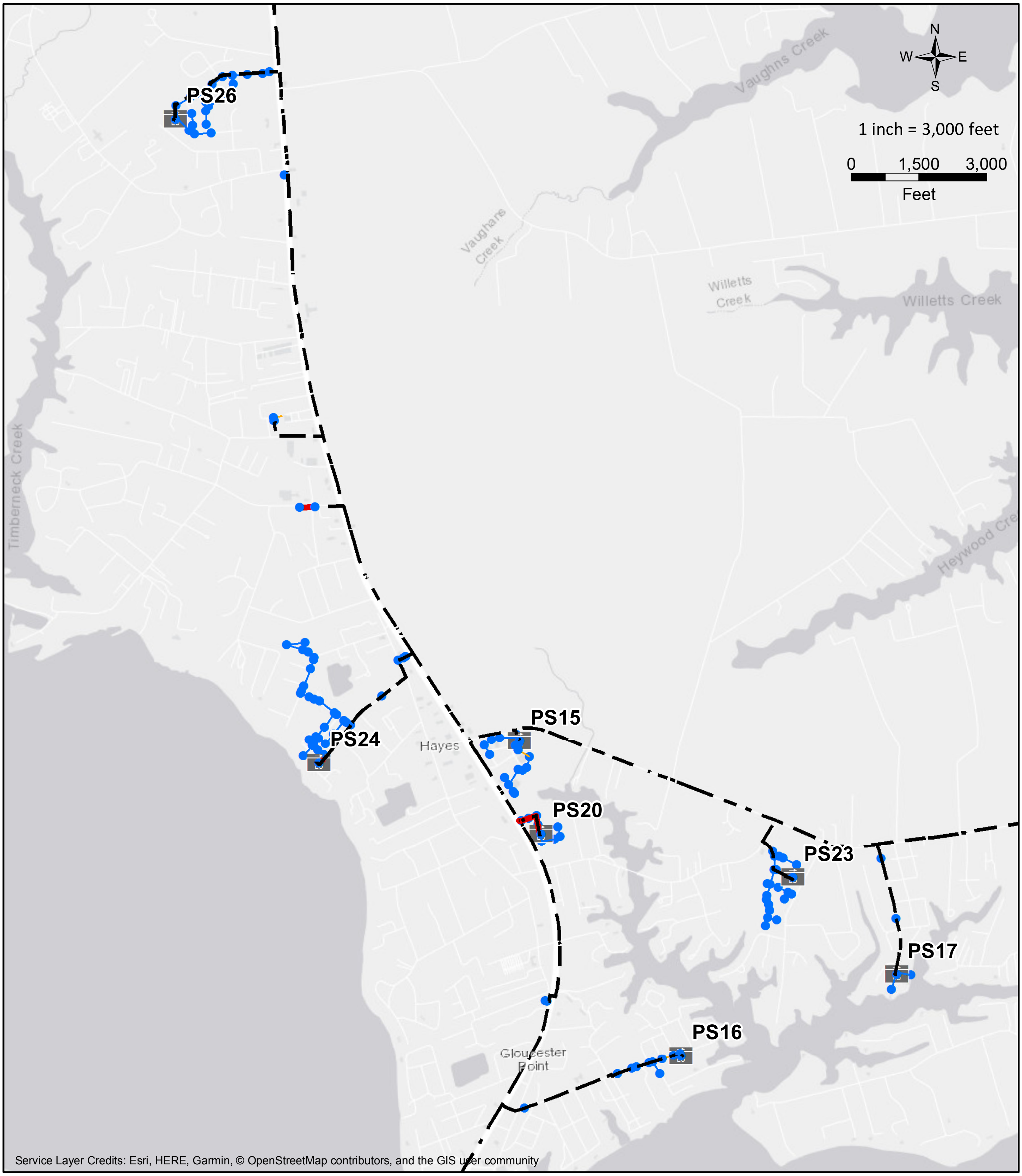
- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-5 N

Sewer System Analysis
2040 Improvements
2040 Planning Year Flows
5 Year Storm



BLACK & VEATCH

LS Exceeds Firm Capacity

Manhole Level

- > 2' of freeboard
- within 2 ft of rim
- modeled overflow

Sewer Capacity

- Modeled Sewers
- Surcharged (d/D>1)
- Capacity Limited (q/Q>1)

GLOUCESTER COUNTY

Water & Sewer Master Plan

Figure B-5 S

Sewer System Analysis
2040 Improvements
2040 Planning Year Flows
5 Year Storm