APPENDIX E: GRAVITY SYSTEM FLOW MONITORING PLAN

FLOW MONITORING PLAN

Prepared for
Hampton Roads Sanitation District
1436 Air Rail Avenue
Virginia Beach, VA 23455

December 21, 2007
Revised November 2008

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FLOW MONITORING PLAN

EXECUTIVE SUMMARY

Flow monitoring provides sewer flow data under known conditions which can be used for sanitary sewer system hydrologic and hydraulic model calibration, testing, and validation, as well as for Sanitary Sewer Evaluation Study (SSES) and system improvement planning purposes.

The purpose of this Flow Monitoring Plan is to present the program goals/drivers, equipment components, anticipated installation locations, and other relevant components of the flow monitoring program for the wastewater collection system of the Hampton Roads Sanitation District (HRSD). This document has been developed in accordance with the requirements of the Virginia Department of Environmental Quality (DEQ) Special Order by Consent (SOC), effective September 26, 2007.

This plan includes a description of existing flow data, temporary flow metering plan, temporary meter locations, the Master Metering Program (MMP), equipment deployment schedule, rainfall monitoring and quality control procedures to meet the requirements of the SOC and support development of a regional hydraulic model.

The HRSD flow monitoring program shall be comprised of temporary gravity flow meters and pressure-side flow meters. The equipment components meet the requirements of Regional Technical Standards (RTS) contained in Attachment 1 to the Special Order by Consent.

Wastewater flow monitoring program will provide data needed to meet the following objectives:

- Development of inflow and infiltration (I/I) estimates;
- Development of dry weather flow estimates; and
- Development and calibration of a hydraulic model of HRSD's wastewater collection system;

One of the intents of the Flow Monitoring Plan described in the RTS is to identify basins with significant I/I and include such basins in a list for SSES; however, HRSD currently implements an extensive SSES Program for the gravity pipes in the HRSD sewer network. This program includes detailed internal inspection of nearly all pipes at least every 5 years with some sections identified for more frequent inspection. The SSES Plan required to be submitted to the DEQ by December 31, 2008 will document this program. Therefore, this Flow Monitoring Plan will not be used to identify SSES Basins as a specific objective.

To support the development of the Regional Hydraulic Model, HRSD will need to obtain flow data both in the pressurized force main network as well as the gravity sewer interceptors. As required by the EPA Unilateral Administrative Order (UAO), HRSD submitted a Flow, Pressure and Rainfall Monitoring and Reporting System (FPRMRS) Plan in September 2007, with a revision in February 2008, which outlined the location of all flow meters on the force main network, pressure recording sites, and the rainfall gauge network. The majority of these sites are proposed; however, there are several that are already installed and recording data. A more recent revision of a Flow, Pressure, and Rainfall Monitoring (FPRM) Plan was developed in November 2008. This revised FPRM Plan is being provided to the DEQ and is HRSD's submittal to document the force main flow monitoring and rainfall data collection program.

Although HRSD's system is largely comprised of pressurized force mains, there exist a number of gravity interceptors that will need flow monitoring beyond the data collected by the MMP. These sites have been preliminarily identified and are subject to change based on ground-truthing/verification. This process will be

the initial step in the deployment phase. Maps in Section 5 of this Plan identify the proposed approximate location of the temporary gravity flow meters.

This Plan was developed following the outline prescribed in the RTS. Table ES-1 is presented to illustrate the correlation of the required material outlined in the RTS with the Flow Monitoring Plan.

Table ES-1. Correlation of the Flow Monitoring Plan with the Regional Technical Standards

RTS Outline Items	Included	Report Section
TITLE PAGE	X	Title Page
▪ Project/Report Title	X	Title Page
▪ Locality Contact Information	X	Title Page
EXECUTIVE SUMMARY	X	ES
EVALUATION OF EXISTING FLOW DATA FOR COMPLIANCE WITH REGIONAL TECHNICAL STANDARDS	X	1
▪ SCADA Derived Flow Data	X	1
▪ Sanitary Sewer Evaluation Studies	X	1
▪ Flow Surveys	X	1
ASSESSMENT OF FLOW DATA REQUIREMENTS FOR SANITARY SEWER HYDROGRAPH GENERATION/MODELING REQUIREMENTS	X	2
ASSESSMENT OF FLOW DATA REQUIREMENTS FOR SSES BASIN IDENTIFICATION	X	3
IDENTIFICATION OF BASINS/SERVICE AREAS REQUIRING ADDITIONAL FLOW DATA	X	4
FLOW MONITORING SITE SELECTION	X	5
▪ Site Selection Criteria	X	5
▪ Mapping of Flow Monitoring Sites	X	5
EQUIPMENT COMPONENTS	X	6
▪ Equipment types to be used	X	6
▪ Use of SCADA System	X	6
▪ Data acquisition plan	X	6
DEPLOYMENT SCHEDULE	X	7
QA/QC PROCEDURES	X	8

1. EVALUATION OF EXISTING FLOW DATA USING THE REGIONAL TECHNICAL STANDARDS

Flow monitoring data for HRSD is or will be available from the following sources:

- Pressure-side flow monitors from the MMP
- Temporary gravity flow monitors
- SCADA Derived Flow Data
- Sewer system evaluation studies (SSES)

Each of these flow data sources was assessed to determine how it would be used to meet the objectives of the Special Order by Consent.

SCADA Derived Flow Data

HRSD currently has a SCADA system that records some limited information related to wastewater flow and/or pressure at certain locations in the system. The current system records data only during a change in status at the pump station and will not meet the requirements of the Regional Technical Standards (RTS).

Sanitary Sewer Evaluation Studies

Several Sanitary Sewer Evaluation Studies (SSES) have been conducted over the years to identify system deficiencies. These studies typically include a mixture of flow monitoring, physical inspection of the system, and testing to determine the health of the collection system. Unfortunately, flow monitoring associated with the previous studies was not found to meet the criteria established in the RTS, either from a lack of meeting the required minimum rain event or due to a limited duration These studies have not been assumed to provide flow data for the purposes of this Plan.

Flow Surveys

HRSD currently has flow monitors in various locations throughout the collections system. The data from these locations currently does not meet the criteria established in the RTS and will not be useable until system upgrades are completed per the Master Meter Program (MMP).

2. ASSESSMENT OF FLOW DATA REQUIREMENTS FOR SANITARY SEWER HYDROGRAPH GENERATION/MODELING REQUIREMENTS

In general, flow monitoring provides sewer flow data under known conditions which can be used for sanitary sewer system hydrologic and hydraulic model calibration, testing, and validation, as well as for SSES and system improvement planning purposes.

The RTS defines the required duration of flow monitoring, the sampling frequency of each monitor, and the minimum percentage (based on total number of service areas) to be flow monitored. The minimum duration of flow monitoring for hydrologic and hydraulic model calibration and verification, the duration requirements are as follows:

- Sufficient to characterize seasonal variations and capture the peak seasonal sanitary sewer flows.
- Sufficient to record three (3) individual wet-weather flow events of greater than 1 inch of accumulation, including at least one (1) event with at least a 1-year recurrence interval. These events will capture system response under a variety of antecedent rainfall and groundwater conditions.
- Allow sufficient time between rain events for the flow to return to dry weather conditions.

The sampling frequency of each flow monitor is defined in the RTS Section 3.3.4 as follows:

- Record flow at intervals of 15-minutes or less, and
- Record flow at intervals of 5-minutes or less when the percent change in flow is greater than 10 percent in any given 15-minute interval.

In order to ensure that seasonal variation in flow is captured, HRSD intends to deploy temporary flow meters for a minimum period of six (6) months, or until the requirements of the RTS are satisfied.

The data collected during this period will be used to develop and calibrate a Regional Hydraulic Model based on the hydrograph inputs from the Localities.

3. ASSESSMENT OF FLOW DATA REQUIREMENTS FOR SSES BASIN IDENTIFICATION

One of the intents of the Flow Monitoring Plan described in the RTS is to identify basins with significant I/I and include such basins in a list for SSES; however, HRSD currently implements an extensive SSES Program which includes the gravity pipes in the sewer network. This Program includes detailed internal inspection of nearly all pipes at least every 5 years with some sections identified for more frequent inspection. Defects identified are scheduled for repair. The SSES Plan required by the SOC will be submitted to the DEQ by December 31, 2008, which documents this program. Therefore, this Flow Monitoring Plan will not be used to identify SSES Basins as a specific objective.

4. IDENTIFICATION OF BASIN/SERVICE AREAS REQUIRING ADDITIONAL FLOW DATA

HRSD has previously identified sites for flow monitoring the force main network in the FPRM Plan provided in a separate document to the DEQ. Gravity interceptors are currently not monitored and will require the addition of the proposed temporary flow monitoring sites to gather diurnal, dry weather, and peak wet weather wastewater flow rates. Flow monitors have been proposed for certain gravity interceptors to obtain the necessary flow data for modeling.

5. FLOW MONITORING SITE SELECTION

Site Selection Criteria

The following criteria were considered in the development of the flow monitoring program:

- MMP Plan locations
- Locations being monitored through a separate flow monitoring plan
- Size of sewer basin

Initial Deployment

Newly deployed temporary flow meters and the MMP will be used for development and calibration of the Regional Hydraulic Model. The flow meter sites have been selected to maximize the usefulness of data measured by each meter. Basin characterization is not being used in the HRSD flow monitoring program as flow meters are being installed on all major HRSD gravity sewer lines upstream of their respective pump station.

Initial Temporary Open Channel Flow Meters

The initial open channel flow monitoring program will include metering at 27 locations to obtain gravity flow characteristics. These sites have been selected at the downstream end of most gravity sewer interceptors or at the point of a major junction in the gravity system. Gravity sewer flow monitoring within the City of Norfolk is currently being planned and implemented based on a previous Enforcement Action by DEQ dated March 17, 2005.

Subsequent Deployment of the MMP

The locations of the meters planned for the MMP are detailed in the FPRM Plan submitted to the DEQ in November 2008.

Mapping of Flow Monitoring Sites

Figures 5-1 through 5-17 illustrate proposed flow monitoring sites for temporary gravity flow meters. The first and second figures provide an overall site map for the North Shore and the South Shore, and the remaining figures provide a more detailed flow monitor site location. These sites are approximate sites to be further refined in the deployment phase of the Flow Monitoring Program. The location of the force main flow and pressure meters is provided in the FPRM Plan provided to the DEQ.

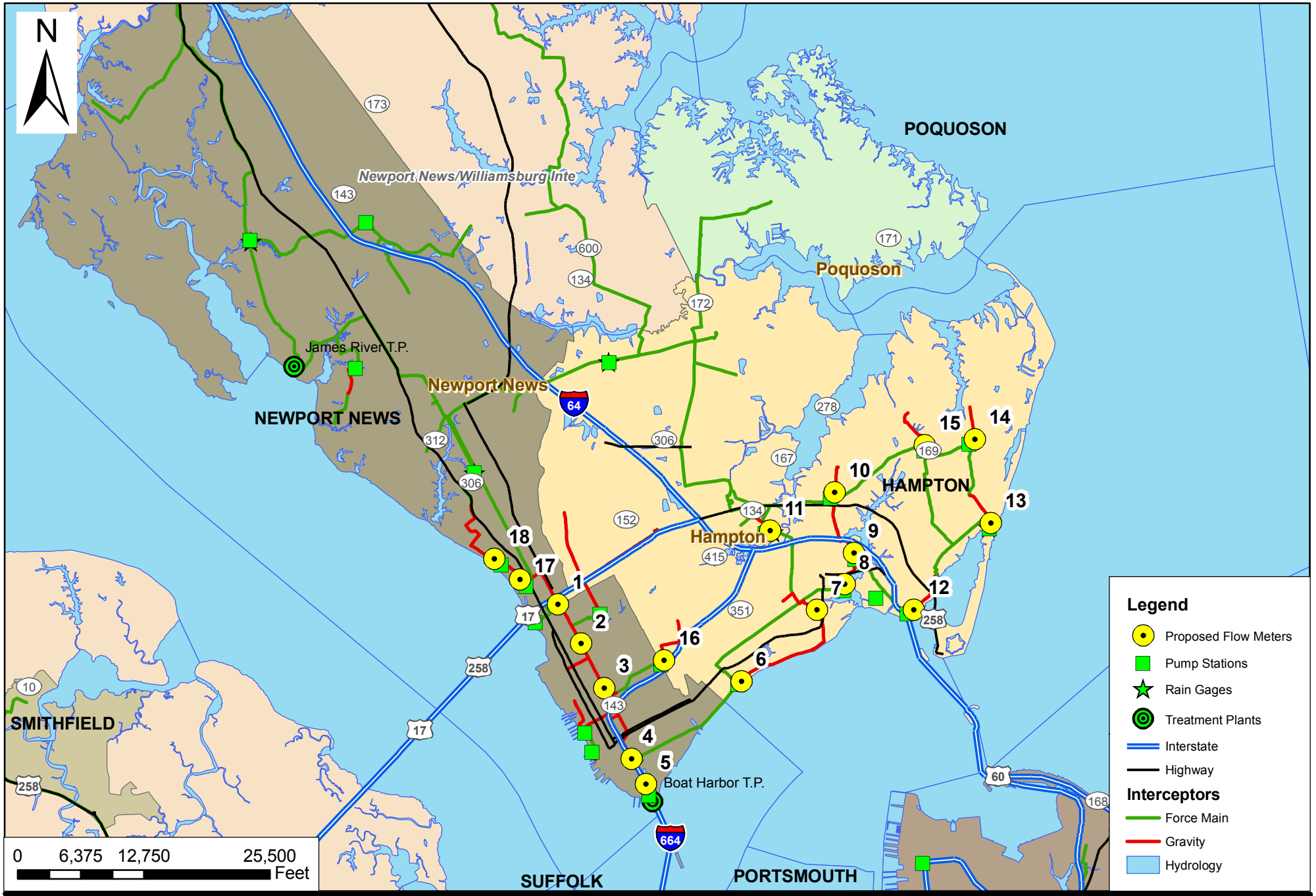

Figure 5-1
North Shore Proposed Gravity Flow Meter Locations

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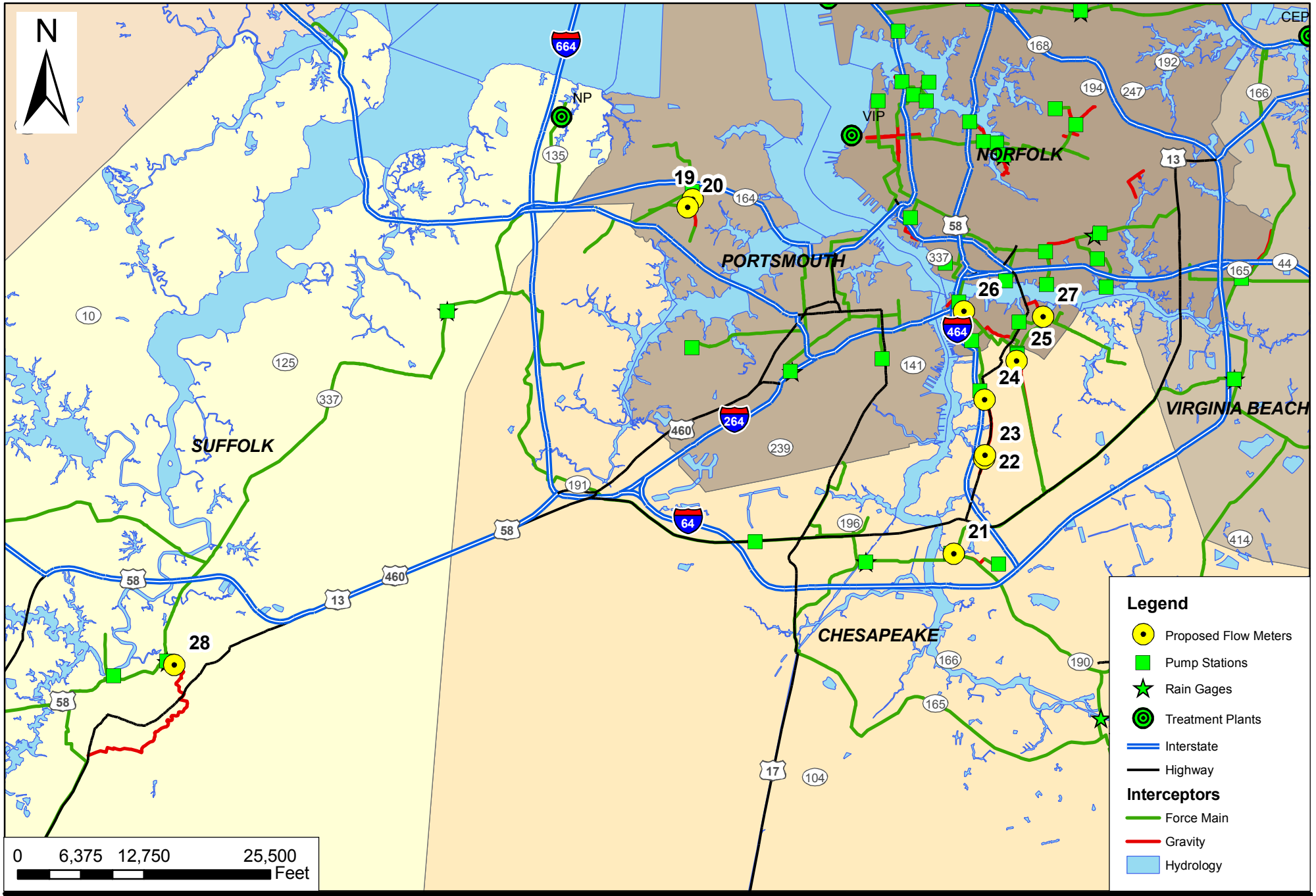

Figure 5-2
South Shore Proposed Gravity Flow Meter Locations

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JUNE 2008

Figure 5-3
Proposed Gravity Flow Meters 1, 2, & 3

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Figure 5-4
Proposed Gravity Flow Meters 4 & 5

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Figure 5-5
Proposed Gravity Flow Meter 6

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Figure 5-6
Proposed Gravity Flow Meters 7, 8, & 9

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JUNE 2008

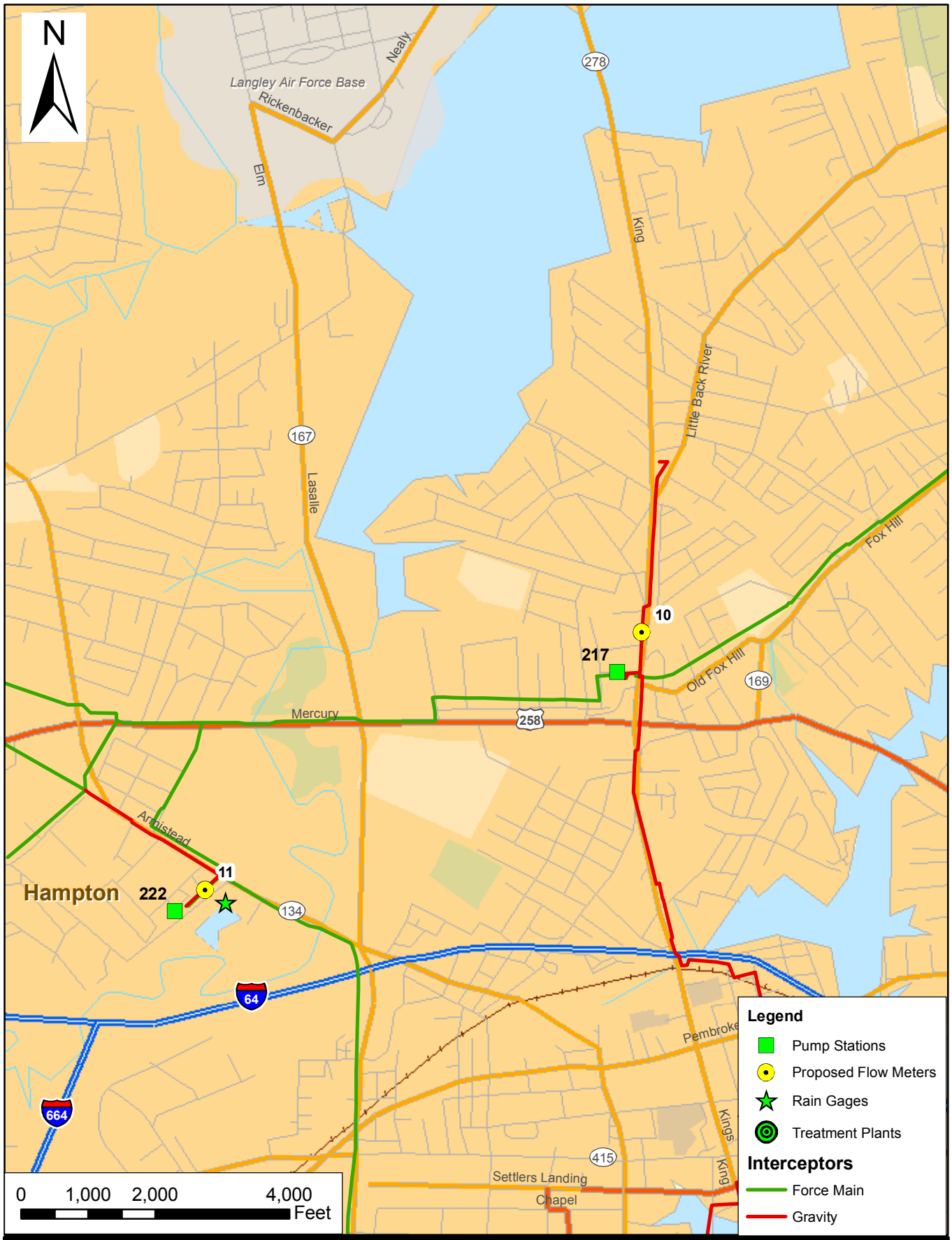

Figure 5-7
Proposed Gravity Flow Meters 10 & 11

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Figure 5-8
Proposed Gravity Flow Meter 12

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Figure 5-9
Proposed Gravity Flow Meters 13, 14, & 15

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Figure 5-10
Proposed Gravity Flow Meter 16

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Figure 5-11
Proposed Gravity Flow Meters 17 & 18

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Figure 5-12
Proposed Gravity Flow Meters 19 & 20

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Figure 5-13
Proposed Gravity Flow Meter 21

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JUNE 2008

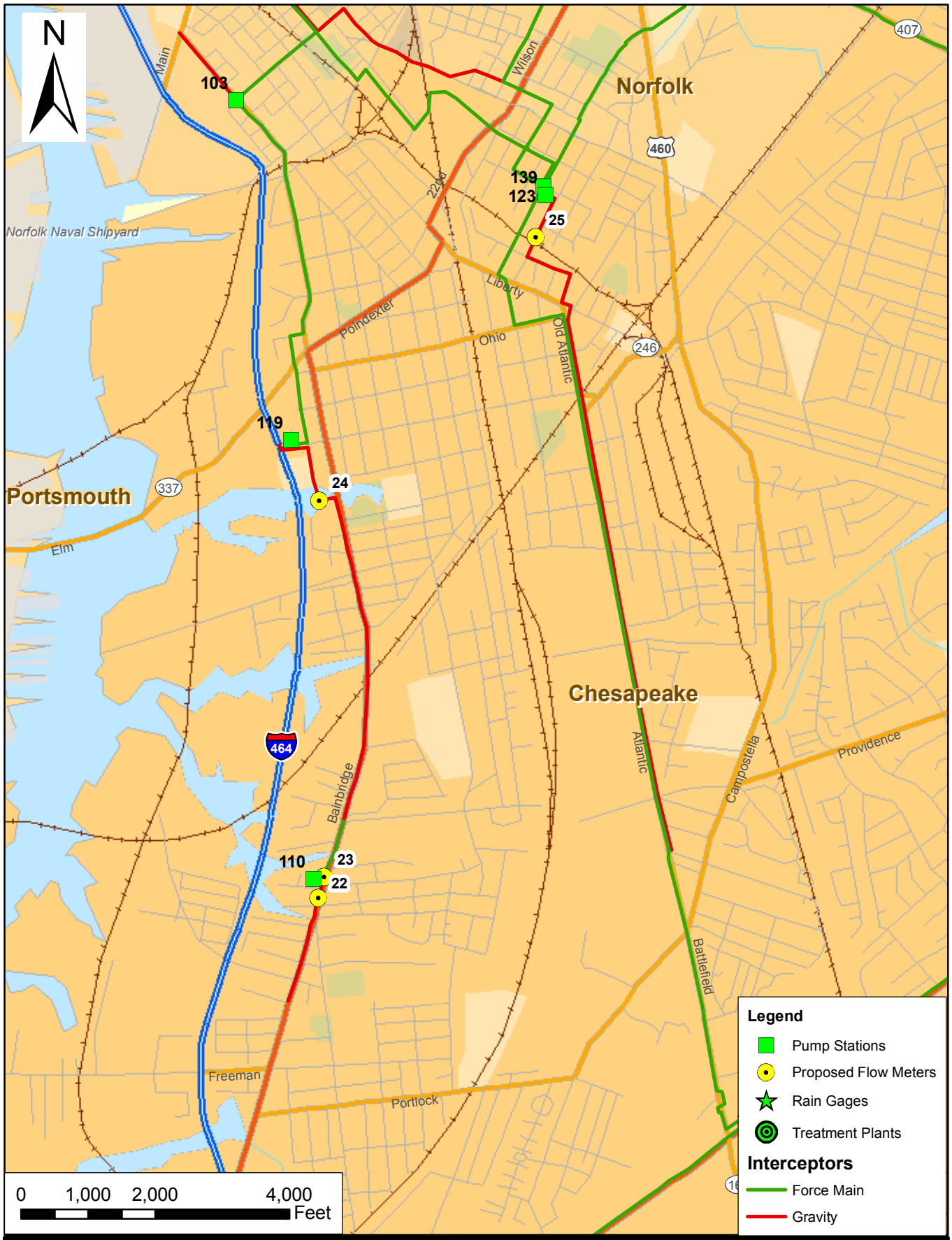

Figure 5-14
Proposed Gravity Flow Meters 22, 23, 24, & 25

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JUNE 2008

Figure 5-15
Proposed Gravity Flow Meter 26

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JUNE 2008

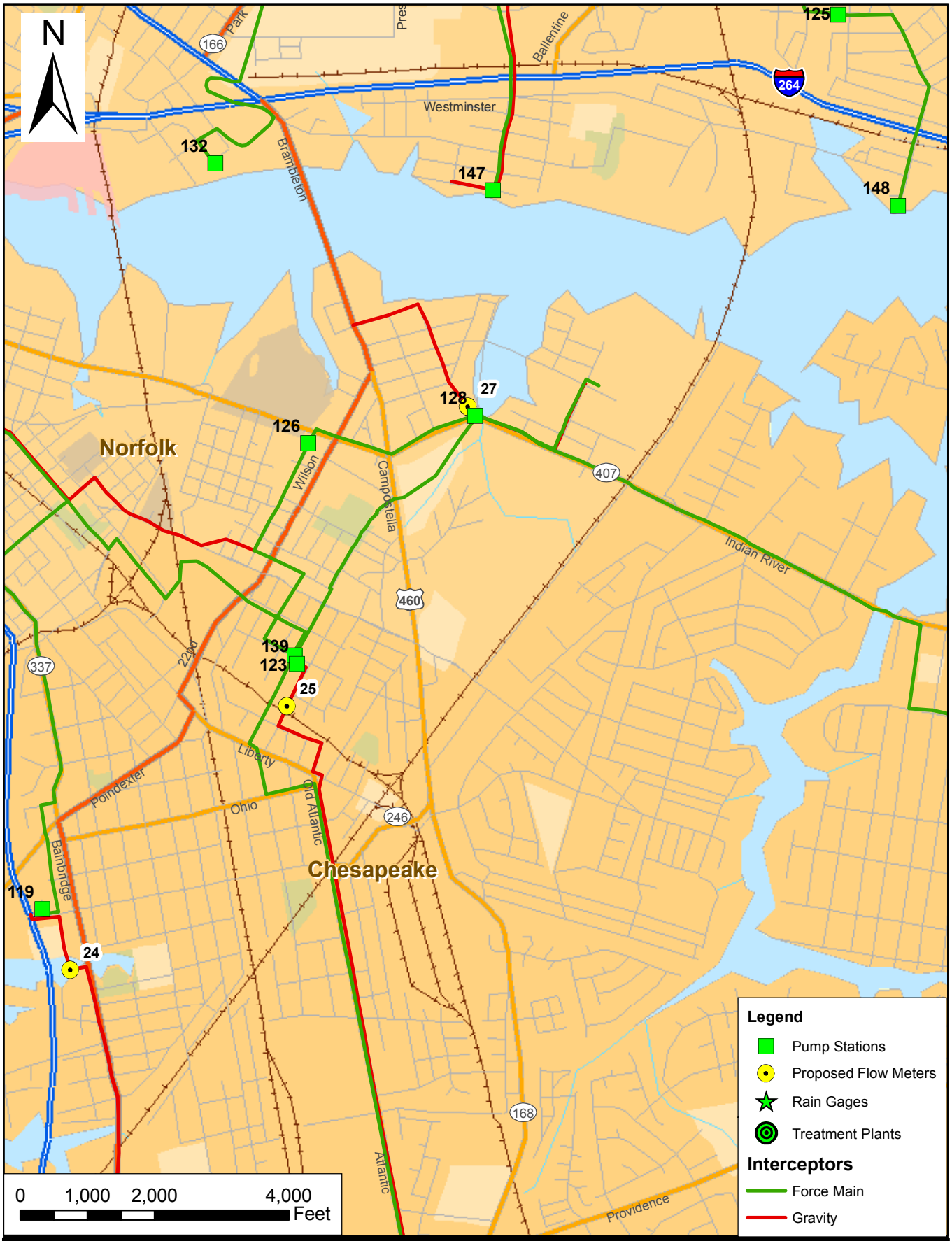

Figure 5-16
Proposed Gravity Flow Meter 27

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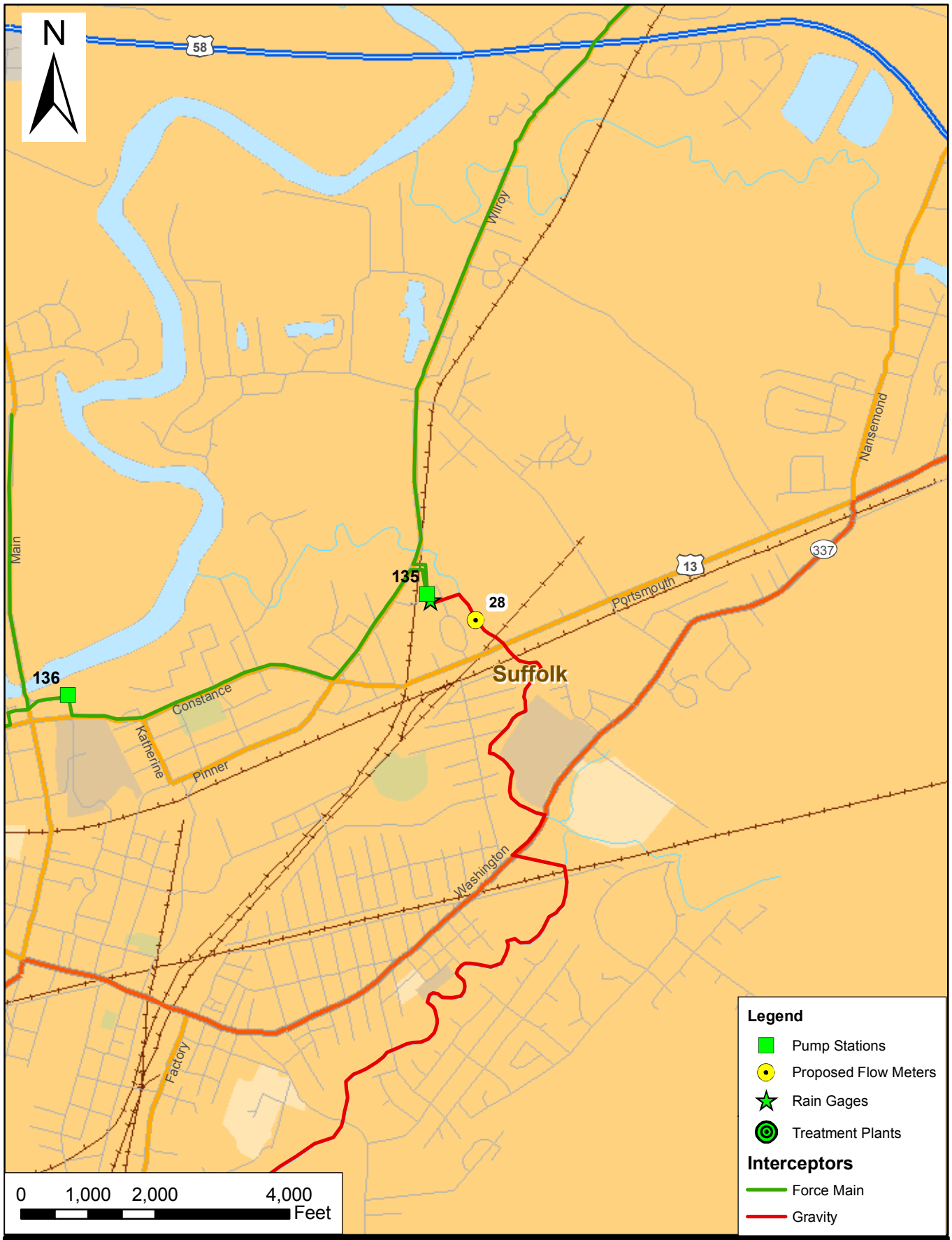

Figure 5-17
Proposed Gravity Flow Meter 28

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6. EQUIPMENT COMPONENTS

Equipment Types to be Used

The flow monitoring program includes both existing and newly deployed equipment including:

- Flow monitors
  - Newly deployed flow monitors
    - Temporary open channel flow meters
    - Pressure-side flow meters from the MMP
- Rain gauges
- Pressure gauges
  - Existing
  - Proposed

Temporary Gravity Flow Meters

Temporary gravity channel flow meters will utilize area-velocity sensors employing either non-submerged, digital Doppler radar velocity sensing technology combined with ultrasonic pulse echo level sensing technology to measure open channel flow, or submerged digital Doppler ultrasonic velocity sensing technology combined with ultrasonic pulse echo level and/or hydrostatic pressure sensing technology to measure open channel flow. These meters will determine flow based on the wetted cross sectional area multiplied by the average velocity of the wastewater flowing past the meter location. The meters will be capable of measuring velocity and levels during open channel, backwater and surcharge flow conditions. When surcharging is encountered, the hydrostatic pressure sensors included in the flow meter will record the surcharge event and level. All gravity flow meters will have a data logger, communication device, and sensing unit. Flow data is captured and recorded at a maximum of 5 minute intervals.

Methodology Strengths and Weaknesses:

Open channel flow meters offer strengths that include:

- Meters meet accuracy requirements in the RTS and use proven technology measuring both velocity and head and calculating flow;
- Meters are portable and can be quickly deployed;
- Meters can measure the flow in varying conditions including surcharged conditions;
- Data can be monitored in near real-time and detect problems or issues with system as they occur; and
- Data is collected at 5-minute intervals and will capture the peak hourly and minimum flow observed at that interval.

Weaknesses of this methodology include:

- The method requires accurate field data and verification for each meter site;

- Submerged pressure and velocity meters require frequent maintenance to prevent fouling and ragging of the sensors;
- This technology cannot be used to monitor flow in vacuum systems or force mains; and
- When the meters are surcharged due to the downstream pumping capacity, the peak flow at the meter cannot be used as a calibration point for the hydrologic model development.

Pressure Pipe Flow Meters

The proposed meters to be used to measure force main flows are detailed in the FPRM Plan provided separately to the DEQ.

Methodology Strengths and Weaknesses:

Pressure pipe flow meters offer strengths that include:

- Meters are accurate and use proven technology for measuring flow in force mains and are not affected by the type of pump used (i.e., VFDs);
- Meters in conjunction with pressure transmitters offer information regarding pump station performance and system hydraulic conditions;
- Meters are can be quickly deployed and integrated into the existing pump station SCADA system;
- Data is collected at 2-minute intervals with the SCADA system and can be monitored in real-time and detect problems or issues with system as they occur; and
- Meters are not typically subject to fouling due to wastewater constituents.

Weaknesses of this methodology include:

- The method requires accurate field data and verification of pipe sizes for each meter site;
- These meters are significantly more expensive that gravity, if installation is included; and
- Meters require wet well level data and geometry to develop peak flow values entering the pump station.

Rain Gauges

Rainfall gauges are being installed as part of the FPRM Plan; however, these gauges will not be operational and collecting data during the initial gravity sewer flow monitoring period. A network of gauges currently exists throughout the Hampton Roads area and additional gauges are being added by the Localities as part of their Flow Monitoring Plans. Any existing gauges which do not meet the RTS will be supplemented by temporary gauges installed by HRSD during the initial flow monitoring period (see Figures 6-1 and 6-2 for locations of temporary and existing rainfall gauges). All gauges will be of continuous recording type, able to store data in 15-minute increments, and will be capable of recording rainfall to 0.1-inch intervals or less.

Pressure Gauges

The proposed gauges to be used to measure system pressures are detailed in the FPRM Plan provided separately to the DEQ.

Use of SCADA System

The SCADA system will be limited to the MMP metering locations as outlined in the FPRM Plan. SCADA will only be collecting actual flow meter data and not volumetric calculated flow data.

Ground Water Data

Ground water level monitoring is performed at 24 sites in HRSD's services area (13 on South Shore and 11 on the North Shore). A portion of this data is collected through the SCADA system and the remainder is manually read at least quarterly. This data will be utilized in conjunction with Localities flow and groundwater data to calibrate the hydrologic portion of the Regional Hydraulic Model.

Data Acquisition Plan

The data acquisition plan can be broken up into 2 data collection regimes. These two regimes include:

- Periodic data collection involving site visits to the flow meter or rain gauge station locations to manually download data to a computer system or other data terminal unit.
- Internet-based data collection where the data is retrieved by a third party and made available to HRSD for retrieval and use.

The metered data will be stored in an open data format that can easily be accessed in an ODBC (open data base connectivity) compliant format. In addition, the data for each meter will be uniquely identified and distinguishable from the data from other meters. All data will be date and time stamped.

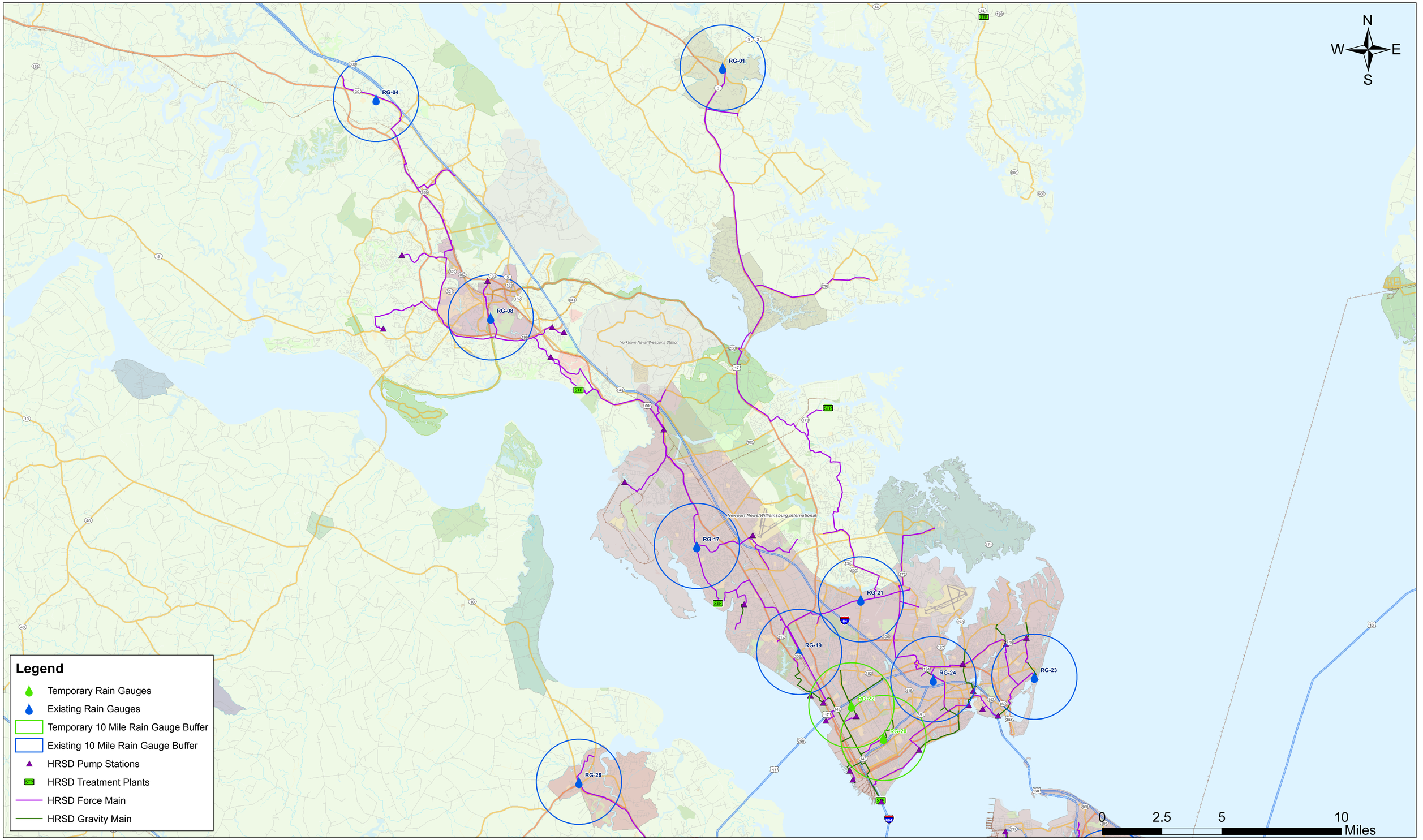

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Figure 6-1 - HRSD Temporary and Existing Rainfall Gauges North Shore

HRSD Rainfall Gauges
North Shore

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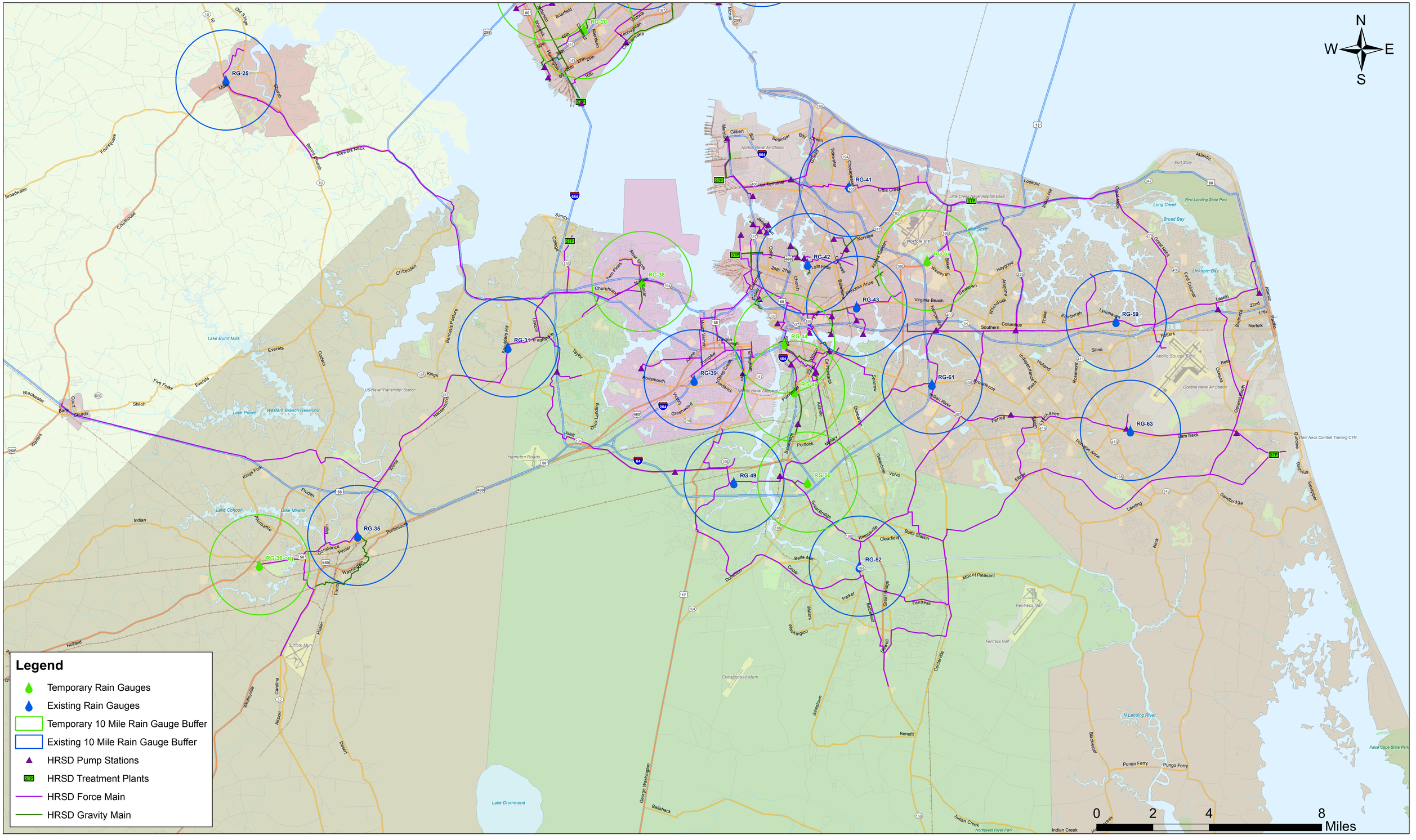

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Figure 6-2 - HRSD Temporary and Existing Rainfall Gauges South Shore

HRSD Rainfall Gauges
South Shore

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7. DEPLOYMENT SCHEDULE

Flow monitoring to meet the SOC requirements is dependent on specific wet weather events. HRSD intends to initially deploy temporary flow meters for between six (6) and twelve (12) months beginning in May 2008, with the duration depending on the data captured. If data gathered is sufficient to meet the requirements of the RTS (including the 1.5-inch rainfall and the 1-year recurrence storm requirements), then flow monitoring may be suspended after 6 months. This first phase will coincide with much of the flow monitoring data being collected by the Localities. The deployment schedule will comply with Sections 3.3, 3.4, and 3.5 of the RTS.

Installation of the pressure-side flow meters in the MMP will continue through 2010. Upon completion of the MMP with all meters collecting data, HRSD may redeploy the temporary gravity flow meters in a second phase (if deemed necessary by HRSD) to collect data that coincides with the MMP meters.

HRSD reserves the right to modify the flow monitoring plan, pending further evaluation of the proposed metering locations. Further evaluation may indicate that some metering is not needed due to overlap between programs, flow redirections, system reconfigurations, and a lack of response to wet weather. HRSD may reassess the monitoring plan following additional investigation. If changes to the Flow Monitoring Plan are anticipated, HRSD will inform DEQ in writing.

8. QA/QC PROCEDURES

General

Based on the RTS, the flow monitoring must meet certain requirements in order to qualify as valid data to assess system performance. The following standards will be maintained directly by HRSD and/or included in field services contracts that involve flow monitoring:

- Flow meters will monitor flow at discrete sample periods and provide average, maximum, and minimum flow, pressure, and depth at least in 5-minute intervals.
- The meters will be operated and maintained in a manner that will provide for a minimum:
  - Seventy-five percent (75%) data reliability for each individual meter during a weekly monitoring period and 90% during qualifying events (data reliability means the percentage of velocity and level data that has been collected and is not obviously incorrect [i.e., flat lines or drift from known calibration levels]).
- The accuracy of all sensors will be field verified and a field calibration program will be implemented to document and maintain the accuracy of the flow data.

The data review process is one of the primary means by which anomalous data is identified and steps are initiated to restore instrumentation performance to an optimal level. The data review will occur frequently enough that any problems can be identified early on. It is anticipated that the data will be reviewed at a minimum on a bi-weekly basis to determine if discrepancies exist from the previous period. Reviewing the data at this interval should be adequate for the needs of the flow monitoring program. If any meter or sensor is noted to have data drift or unexplainable measurements, the device will be checked for calibration, corrected, and/or replaced if discrepancies exist.

The following sections describe the accuracy and QA/QC requirements of each flow monitoring type.

Temporary Gravity Flow Meters

The flow monitoring manufacturer will certify the accuracy of all sensors and HRSD will implement a calibration verification program to document and maintain the accuracy of the flow meters.

HRSD will prepare and submit procedures for performing the field calibration verification. The field calibration verification will demonstrate that the installed sensors are installed and calibrated to factory standard so that the depth and velocity are within the accuracy identified as specified. The field calibration verifications that are not within the required accuracy will be repeated and/or the sensors will be replaced and calibrated within the required accuracy. A minimum of two (2) manual depth and velocity measurements at every site within 24 hours of meter installation will be performed to confirm that the sensors are measuring accurate depths and velocities. Calibration verification will be scheduled on a routine basis as necessary to maintain the accuracy of the flow meters. Verification of calibration will be made in the field monthly at a minimum. Calibration verification information will be documented and will be included in the Meter Site Report.

HRSD will perform field site investigations to determine the adequacy of the proposed flow monitoring locations for equipment installation, operation and proper data collection. Any debris or sediment that would influence the determination of wastewater flows will be removed by the contractors. If during a field site investigation HRSD finds that the sites are not suitable for flow monitoring, HRSD will identify alternative locations. HRSD will specify types of flow meter equipment suitable for each site. A site report will be prepared for each flow meter location prior to a pre-start up meeting.

HRSD Master Metering Program

HRSD will be using several types of flow meters for the MMP. HRSD has outlined specific quality assurance and quality control requirements for this portion of the flow monitoring program in the FPRM Plan.