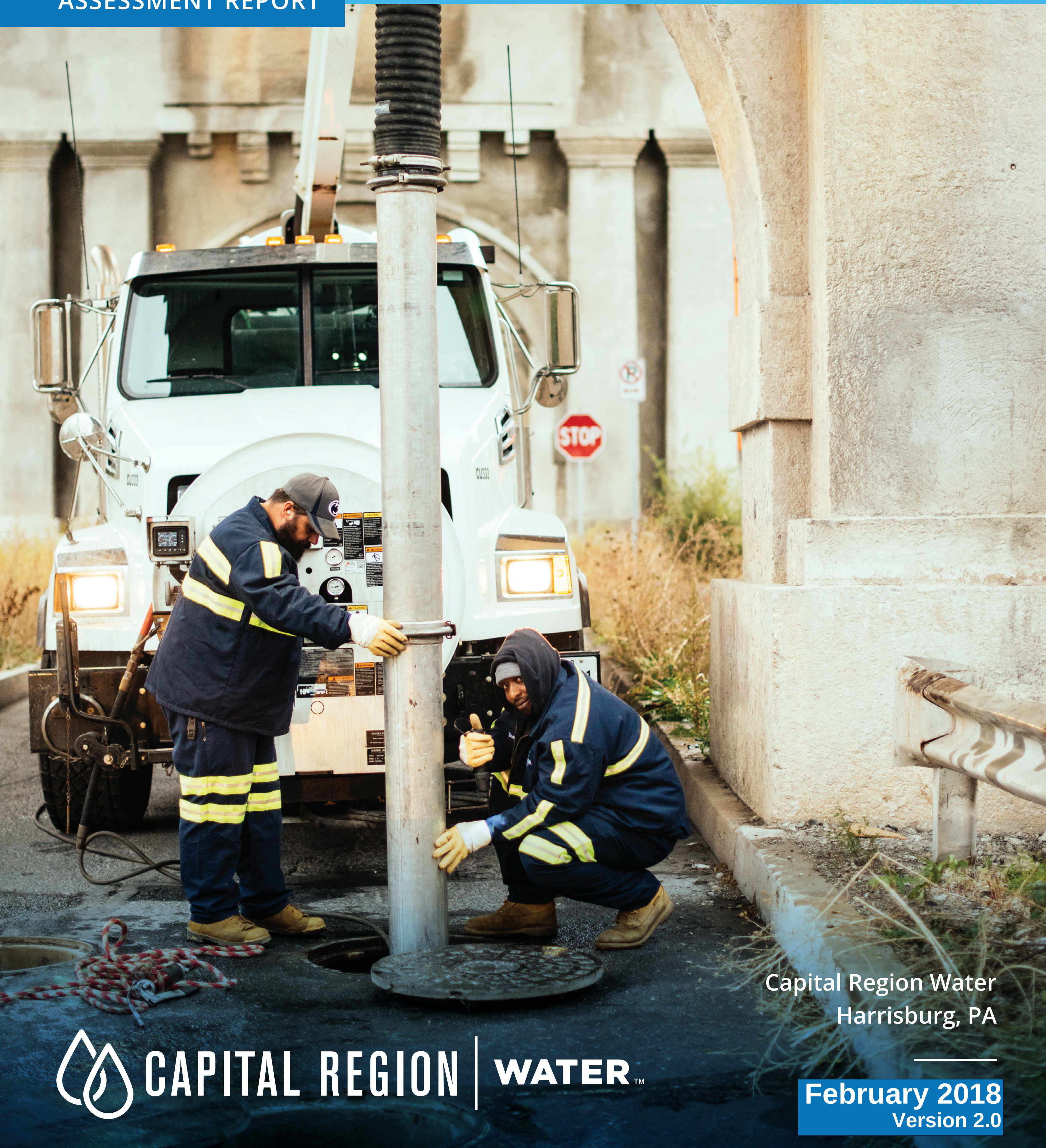
SEPARATE SANITARY SEWER CAPACITY

ASSESSMENT REPORT



Capital Region Water
Harrisburg, PA

CAPITAL REGION | WATER™

February 2018
Version 2.0

Introduction

Capital Region Water (CRW) is required to perform a Separate Sanitary Sewer System Capacity Assessment under Paragraph V(F)(30)(a) of the partial Consent Decree lodged February 10, 2015:

a. *CRW shall submit a Capacity Assessment Plan to Plaintiffs for review and comment pursuant to Section VI (Review and Approval of Deliverables) within 12 months of the Date of Lodging. The Capacity Assessment Plan shall describe how CRW will carry out an engineering assessment that satisfies the requirements described below in Paragraph 30(b), and shall include a schedule for the completion of that assessment, and the development of a report that summarized the result of that assessment, by April 1, 2017.*

On February 10, 2016, CRW submitted the Separate Sanitary Sewer Capacity Plan. The Plan was subsequently approved by the regulatory agencies.

Paragraph V(F)(30(b) requires CRW to address the following assessment activities in the Plan:

i. *CRW shall carry out an assessment of the capacity of the Separate Sanitary Sewer System according to the Capacity Assessment Plan prepared under Paragraph 30(a). The assessment will identify locations within the Separate Sanitary Sewer System that have experienced SSOs and are forecast through hydraulic modeling to experience SSOs during the specific storm events listed below. CRW's assessment shall include:*

   1. *The Spring Creek and Asylum Run Interceptors;*
   2. *All pump stations and force mains;*
   3. *All sanitary gravity sewers upstream of the interceptors eighteen (18) inches in diameter or greater; and*
   4. *An additional ten (10) percent of the sanitary gravity sewers for model continuity and/or that hydraulically impact known chronic SSOs;*

ii. *This assessment shall consider the capacity of the Separate Sanitary Sewer System under current conditions, during the following events:*

   1. *Typical peak dry weather conditions;*
   2. *2 Year, 24-Hour Storm event;*
   3. *5-Year, 24-Hour Storm event;*
   4. *10-Year, 24-Hour Storm event.*

iii. *The assessment shall identify locations expected to experience SSOs, during the conditions specified in Paragraph 30(b)(ii), above.*

iv. *The assessment shall consider the current actual firm capacity of CRW's pump stations, and the ability of those pump stations to pump the flows forecast for typical peak dry weather flow rates and the peak flow rates associated with the rainfall events specified in Paragraph 30(b)(ii), above.*

v. In support of this assessment, CRW shall:

1. Complete inspections of the interior of the Spring Creek and Asylum Run Interceptors as required by Paragraph 11(a)(iii);

2. Conduct sufficient flow monitoring in addition to the monitoring defined in Section 14, as defined in the Capacity Assessment Plan, to allow adequate development, calibration, and validation of all such portions of the Separate Sanitary Sewer System listed in Paragraph 30(b)(i) included in the H&H Model developed pursuant to the IFMMPP.

Paragraph V(F)(30)(c) of the partial Consent Decree defines what the Capacity Assessment Report should include:

i. *At the completion of Capacity Assessment, CRW shall submit a Capacity Assessment Report, consistent with the schedule in the approved Capacity Assessment Plan required by Paragraph 30(b), which presents and summarizes the results of the implementation of the Capacity Assessment Plan. The Capacity Assessment Report shall demonstrate that the assessment has been carried out in accordance with the approved Capacity Assessment Plan, shall describe the analyses carried out, and shall identify, using both narrative and appropriate sewer maps, the lengths of sewer and locations within the designated portions of the Separate Sanitary Sewer System that have actually experienced SSOs, and those that through modeling conditions experience Surcharge Conditions or SSOs during each flow condition specified in Paragraph 30(b)(ii).*

ii. By April 1, 2017, CRW shall also submit as part of the Capacity Assessment Report a description of remedial measures necessary to address all of the actual and predicted capacity constraints identified by the Capacity Assessment, estimates of the capital costs of each such remedial measure, and a priority-based schedule for completion of the remedial work necessary to address identified capacity constraints in the Separate Sanitary Sewer System.

This report is CRW's Capacity Assessment Report, in fulfillment of Paragraph V(F)(30)(c).

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Section 1

Delineate Separate Sanitary Sewers and Catchment Areas

Task 1 of the approved *Separate Sanitary Sewer Capacity Assessment Plan* (SSS-CAP) required CRW to delineate separate sanitary sewers and catchment areas within the CRW service area. CRW's separate sanitary sewer system (S4) consists of the following components:

- The Spring Creek Interceptor (within the City).
- The Asylum Run Interceptor (within the City).
- City Island Pump Stations, and their associated force mains.
- Separate sanitary sewers (within the City) connected directly to CRW interceptors, which generally collect runoff from the areas marked "separate".

Two of CRW's interceptors – Asylum Run and Spring Creek –receive flow only from separate sanitary sewers, with the majority of this flow contributed by sewer systems operated by suburban municipalities outside the City of Harrisburg. The remaining interceptors receive flow from both combined sewers and separate sanitary sewers. CRW completed an inspection of its entire interceptor system in 2015, and has recently completed an interceptor cleaning program which began in 2016. In addition, interceptor repairs were identified (including repairs to the Asylum Run and Spring Creek Interceptors) and have been scheduled under paragraph V(G)(31)(a) of the partial Consent Decree.

In 2015 and 2016, CRW completed an extensive inspection of the collection system (rapid assessment), which consisted of a pole camera inspection of each manhole and connecting pipe segments. This data was used to determine connectivity, physical attributes, maintenance needs, and structural integrity of CRW's collection system. The inspections were used to update CRW's GIS mapping to reflect the actual field conditions and to delineate the various combined sewershed areas and separate catchment areas.

Figure 1-1 shows the combined sewershed and separate sanitary catchment delineations resulting from the rapid assessment program. Using the updated GIS information, sewershed and catchment boundaries were delineated by outlining the individual property parcels which can be assumed to connect to the separate sanitary sewers. Individual lateral connections are not included in CRW's GIS because the asset management program is still being developed. In most cases, this process provided a high degree of confidence in the sewershed and catchment boundaries. However, there are areas within the City, particularly the industrial/commercial properties located along Paxton Creek, where the inspections led to the assumption that these properties connect directly to the interceptor. While the connections from a few industrial/commercial properties (i.e. scrap yards, warehouse facilities, etc.) along the Paxton Creek Interceptor are not mapped in CRW's GIS, these properties are confidently assumed to be direct lateral connections to the interceptor. In general, this would not represent a significant proportion of sanitary flow.

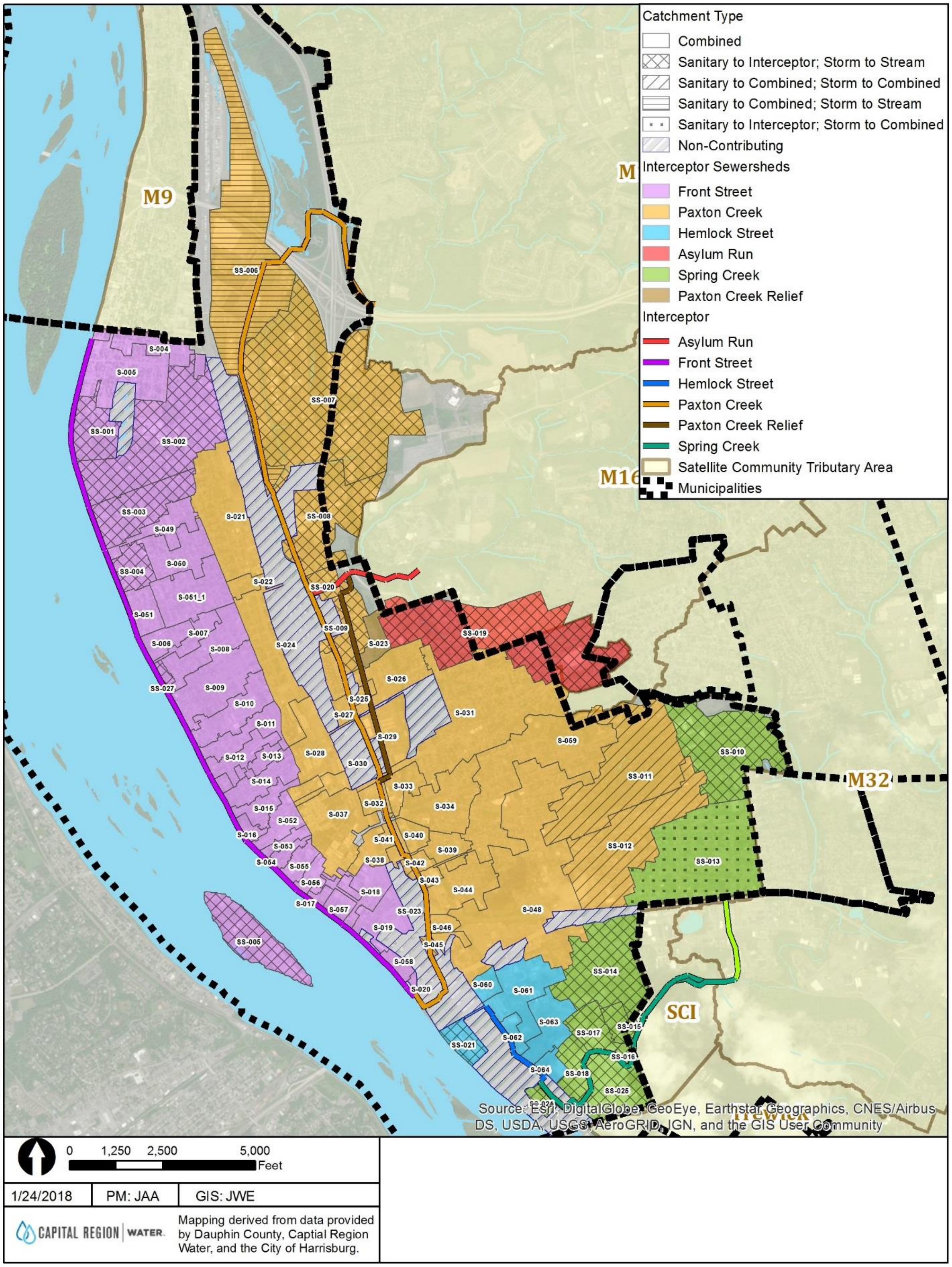

Figure 1-1: Separate Sanitary Catchment Area Delineations

Therefore, the referenced uncertainties, do not impact the delineated catchment boundaries used for the H&H model and are limited to the specific configurations of some private sewers on private properties. Since the Report was completed, the data from the interceptor cleaning project has been analyzed, and lateral locations along the Paxton Creek Interceptor have been identified. Under this assumption, these areas would only include private sanitary connections to the interceptor. Major separate sanitary catchment areas were chosen for wastewater flow monitoring, which is described in **Section 3**.

CRW used this information to define that areas served by its combined sewer system (CSS) and its separate sanitary sewer system (S4), as defined in **Table 1-1** and summarized as follows.

- CRW's CSS includes approximately 60 percent of the area draining to CRW's collection system, consisting of combined sewers that collect both stormwater and wastewater and separate sanitary and/or storm sewers that drain into these combined sewers. CRW's CSS includes sub-catchments in which sanitary and storm systems are separated before the sanitary sewers (and in some cases the storm sewers) discharge to a combined sewer.

- The remaining 40 percent of CRW's collection system lies within CRW's S4, as defined by the partial CD. Storm sewers from a small portion of this area are ultimate collected by combined sewers and will be evaluated as part of the CSO LTCP.

- CRW's conveyance system also transports wastewater from approximately 34.6 square miles from separate sanitary catchment areas outside the City of Harrisburg.

Table 1-1. Catchment Area Types and Tributary Area Statistics

Interceptor Sewershed	Combined Sewer System		Separate Sewer System					Non-Contributing Area (ac)	Separate Sanitary Outside City* (ac)
	[1] Combined Sewer Catchments (ac)	[2] Sanitary / Storm to Combined (ac)	[3] Sanitary to Combined; Storm to River		Sanitary to Interceptor				
					[4] Storm to Combined (ac)	[5] Storm to River			
			CRW MS4 (ac)	Other MS4 (ac)		CRW MS4 (ac)	Other MS4 (ac)		
Front Street	723	0	0	0	0	366	0	-	1
Paxton Creek	1,223	301	184	55	0	66	262	-	211
Hemlock Street	124	0	0	0	0	19	0	-	0
Paxton Creek Relief	16	0	0	0	0	0	0	-	0
Asylum Run	0	0	0	0	0	58	34	-	137
Spring Creek	0	0	0	0	169	367	0	-	5
Total	**2,086**	**301**	**184**	**55**	**169**	**876**	**295**	**561**	**354**
Percent of City	**46%**	**7%**	**4%**	**1%**	**4%**	**19%**	**7%**	**12%**	**-**
Percent of Contributing Area	**53%**	**8%**	**5%**	**1%**	**4%**	**22%**	**7%**	**-**	**-**

The rapid assessment data was also used to extend the hydrologic and hydraulic (H&H) model into the separate sanitary sewer system, as required under the partial CD. The model was extended into the major trunk sewers of the S4, defined as all 18-inch (and larger) separate sanitary sewers, plus an additional 10 percent of the separate sanitary collection sewers serving each delineated separate catchment area. Typically, the model was extended along the trunk sewers of each separate sanitary catchment to about the centroid of each area, or major branching point. The separate sanitary pipes included in the H&H model are shown in **Figure 1-1**. The separate sanitary pipe lengths and the corresponding major trunk sewers represented in the H&H model for each separate sanitary catchment area are provided in **Table 1-2** to demonstrate compliance with PCD requirements. The third column was provided to differentiate between separate sanitary sewers in the CRW GIS database and those owned and operated by CRW. These statistics are different in two catchments where the sewers serve a single property owner and are not owned or operated by CRW.

Table 1-2: Major Trunk Sewers Included in the H&H Model

Catchment	Lengths (Linear Feet)							
	Total Separate Sanitary Sewer	Total CRW Separate Sanitary Sewer	Modeled Separate Sanitary Sewer					
			Total Modeled Pipe	Percent Modeled	Pipes >= 18"		Additional Pipes (< 18")	
SS-001	2,282	2,282	333	14.60%	0	0.00%	333	14.60%
SS-002	17,766	17,766	2,482	14.00%	2,482	14.00%	0	0.00%
SS-003	11,683	11,683	3,018	25.80%	1,122	9.60%	1,896	16.20%
SS-004	4,113	4,113	833	20.20%	0	0.00%	833	20.20%
SS-005	3,386	0	0	0.00%	0	0.00%	0	0.00%
SS-006	13,495	13,495	6,712	49.70%	1,698	12.60%	5,014	37.20%
SS-007	3,033	3,033	3,033	100.00%	154	5.10%	2,879	94.90%
SS-008	4,543	4,543	1,183	26.00%	99	2.20%	1,085	23.90%
SS-009	3,355	3,355	568	16.90%	0	0.00%	568	16.90%
SS-010	17,340	17,340	0	0.00%	0	0.00%	0	0.00%
SS-013	34,059	34,059	5,600	16.40%	3,739	11.00%	1,861	5.50%
SS-014	19,241	19,241	1,487	7.70%	315	1.60%	1,172	6.10%
SS-015	2,327	2,327	203	8.70%	0	0.00%	203	8.70%
SS-016	1,563	1,563	69	4.40%	0	0.00%	69	4.40%
SS-017	2,772	2,772	604	21.80%	0	0.00%	604	21.80%
SS-018	5,542	5,542	2,144	38.70%	0	0.00%	2,144	38.70%
SS-019	18,650	18,650	4,060	21.80%	4,060	21.80%	0	0.00%
SS-020	1,456	1,456	0	0.00%	0	0.00%	0	0.00%
SS-025	1,100	0	0	0.00%	0	0.00%	0	0.00%
SS-027	957	957	340	35.50%	0	0.00%	340	35.50%
TOTAL	**168,662**	**164,176**	**32,670**	**19.90%**	**13,669**	**8.30%**	**19,001**	**11.60%**

Note: Statistics for proportions of modeled sewer were quantified August 2017 (may not reflect future GIS data as it continues to be updated).

According to the partial Consent Decree, CRW is required to use the H&H model to assess the Spring Creek and Asylum Run Interceptors, separate sanitary pump stations and force mains, and the major trunk sewers within the S4 that provide model continuity and/or represent hydraulic impacts to known chronic SSOs during typical peak dry weather and wet weather conditions through the 10-year, 24-hour design storm event. For each separate sanitary catchment area, the H&H model was extended to include the sewer pipe conveying the catchment flow to the CRW interceptor system.

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Section 2

Identify Historical SSO Locations

Task 2 of the approved *Separate Sanitary Sewer Capacity Assessment Plan* (SSS-CAP) required CRW to identify historical sanitary sewer overflow (SSO) locations.

Since taking ownership of the City of Harrisburg's collection system in 2014, CRW is unaware of any chronic SSO locations due to hydraulic limitations, including basement backups attributable to CRW system capacity constraints. CRW did not receive from the City, and is not aware of City records, of any SSO-related complaints. All former City employees responsible for O&M of the CRW collection system either transferred to CRW employment or are no longer employed by the City. All known operational City records were also transferred to CRW. O&M staff who transferred from the City to CRW are not aware of any historical SSOs, and the operational records transferred to CRW do not contain any information about historical SSOs. Since then, available records do not reveal any SSO-related complaints in the separate sanitary sewer systems assessed. CRW continues to collect anecdotal information and customer complaints, and generally there have been a limited number of customer complaints regarding SSOs. These complaints were limited to isolated situations resulting from operation and maintenance issues, not hydraulic capacity issues.

During significant storm events, it has been brought to CRW's attention that a few manholes along Spring Creek may exhibit flooding. However, given the significant change in elevation from the interceptor to the adjacent and upstream contributing properties, these surcharged manholes should not be causing basement backups to neighboring structures or those upstream along the collection system. The manhole covers for these structures were subsequently bolted down. The Spring Creek Interceptor is inspected after significant storm events for evidence of wastewater releases. No evidence of manhole releases has been observed since the manhole covers have been bolted down.

CRW submits a summary of collection system SSOs in the annual Chapter 94 Municipal Wasteload Management Report. A few SSOs are reported each year, but these were attributed to O&M issues (i.e. grease blockages), rather than hydraulic limitations. **Table 2-1** lists the SSOs reported during 2015 and 2016.

Table 2-1: Summary of Sanitary Sewer Overflows

Date	Location	Issue	Duration (Hours)	Volume (Gallons)
1/14/15	2977 Heather Place	Blockage, Basement Backup	unknown	unknown
1/15/15	372 Wyatt Street	Blockage, Basement Backup	unknown	unknown
2/1/15	2817 Watson Street	Blockage, Basement Backup	unknown	unknown
4/10/15	1463 S. 13th Street	Blockage, Basement Backup	unknown	unknown
6/26/15	2541 N. 4th Street	Blockage, Basement Backup	unknown	unknown
7/14/15	2235 Adrian Street	Blockage, Manhole Surcharge	0.5	10

Date	Location	Issue	Duration (Hours)	Volume (Gallons)
10/9/15, 10/13/15	Unnamed tributary to Asylum Run (from Calder St. & Reily St.)	Blockage, Manhole Surcharge	unknown	unknown
12/20/15	Unnamed tributary to Asylum Run (from Reily St.)	Blockage, Manhole Surcharge	unknown	unknown
12/28/15	1527 S. 12th Street	Blockage, Basement Backup	unknown	unknown
3/28/16	1433 S. 14^{th} Street	Blockage (grease); basement backup	2	unknown
9/22/16	25th & Market Street	Blockage (grease/rags); manhole overflow	unknown	unknown

Section 3

Collect and Evaluate Monitoring Data

This section presents the findings of Task 3 of the approved *Separate Sanitary Sewer Capacity Assessment Plan* (SSS-CAP), which committed CRW to collect, evaluate and analyze monitoring data to quantify and characterize base wastewater flow (BWF), ground water infiltration (GWI), and rainfall dependent infiltration and inflow (RDII) generated within CRW's separate sanitary catchment areas and those entering the CRW separate sanitary conveyance system from suburban community collection systems. The resulting BWF, GWI and RDII characteristics and quantities were used with design storm rainfall data to develop design storm hydrographs that were routed through the hydrologic and hydraulic (H&H) model of the existing separate sanitary sewer collection and conveyance systems to evaluate their hydraulic capacity during peak dry weather and wet weather conditions. The results from these analyses allowed CRW to assess the potential for excessive hydraulic surcharge conditions or SSO discharges to occur.

3.1 Collect and Evaluate Available Monitoring Data

CRW developed and successfully implemented a comprehensive wastewater flow monitoring plan to collect data that is sufficient to quantify and characterize wastewater flow from CRW's separate sanitary sewer collection systems and from suburban community collection systems discharging to CRW's separate sanitary conveyance system under dry and wet weather conditions. CRW also collected high resolution, spatially distributed precipitation data over the service area. The collected wastewater and precipitation monitoring data are sufficient to quantify and characterize dry and wet weather wastewater flows within CRW's separate sanitary sewer system.

3.1.1 Suburban Community Flow Meters

CRW established a network of four flow monitoring sites at points of connection (POC) between CRW interceptor sewers and the collection system trunk sewers of the suburban customer communities. Two of these meters, sites M32 and M167, monitored suburban customer community flows into CRW's two separate sanitary sewer interceptors, Spring Creek and Asylum Run, respectively. The other two sites, M9 and M13, monitored suburban community flow to the combined interceptors. The data facilitated quantifying and characterizing dry and wet weather flow conveyed to and along the CRW system, and calibrating and validating the H&H model. Area-velocity meters with redundant depth measurement sensors were installed during August 2014 and continuously monitored calculated wastewater flow in 5-minute increments. Over 24 months of data were collected and utilized for the analyses, which permitted the model to account for seasonal variability of ground water conditions and the RDII response of the separate sanitary collection systems. The first 12 months of data were used to calibrate the model, as presented in the April 2016 H&H Model report. The more recent 12 months were used to check and verify that the suburban community flows into CRW's separate sanitary sewer interceptors were consistent with the calibrated model.

- Site M32 quantified wastewater depth and flow along a 34-inch diameter trunk sewer that conveys flow from Paxtang and Penbrook Boroughs, and Lower Paxton, Swatara and Susquehanna Townships to the CRW Spring Creek Interceptor. The tributary catchment area is approximately 6,700 acres.

- Site M167 continuously monitored wastewater depth and flow along a 24-inch diameter trunk sewer that conveys flow from Lower Paxton Township, Penbrook Borough, and Susquehanna Township to the CRW Asylum Run Interceptor. The tributary catchment area is approximately 2,300 acres.

The locations of these monitoring sites are provided in **Figure 3-1**.

3.1.2 CRW Separate Sanitary Trunk Sewer Meters

CRW successfully monitored 7 critical or key separate sanitary catchments within their collection system. Two of these seven meters, SSMH-2413 and SSMH 3023, monitor flow from separate sanitary catchment areas that discharge into a downstream CRW combined sewer, are ultimately controlled at the CSO-048 regulator structure, and discharge to the Paxton Creek Interceptor. These separate sanitary areas and the downstream combined areas are shown in Figure 1-1 (previously provided in Section 1.) They are thus considered to be part of CRW's combined sewer system, and are not included in the bullet list below. However, these catchment areas were further evaluated and analyzed, the characterization results were integrated into the updated H&H model and are presented in the CSS System Characterization Report. The remaining five meters provided the necessary data to successfully quantify and characterize CRW's separate sanitary system wastewater flow contributing to CRW's separate sanitary sewer conveyance system. The monitors collected and recorded redundantly monitored wastewater depth, monitored velocity, and calculated flow in 5-minute time-step increments. Over 12 months of data were collected and utilized for the analyses, which permitted the model to account for seasonal variability of ground water and the response of the separate sanitary collection systems to wet weather.

- Site SSMH-0254 quantified wastewater depth and flow along a 15-inch diameter trunk sewer that contributes flow from the Industrial Road catchment area to the Paxton Creek Interceptor. The tributary catchment area is 240 acres.

- Site SSMH-2079 monitored wastewater depth and flow along a 14-inch diameter trunk sewer that conveys flow from the South 19th Street catchment area to the Spring Creek Interceptor. The tributary catchment area is 105 acres.

- Site SSMH-2825 continuously monitored wastewater depth and flow along an 18-inch diameter trunk sewer that conveys flow from the Front and Shamokin catchment area to the Front Street Interceptor. The tributary catchment area is 166 acres.

- Site SSMH-3208 monitored wastewater depth and flow along a 24-inch diameter trunk sewer that conveys flow from the Arsenal Boulevard catchment area to the Asylum Run Interceptor. The tributary catchment area is 229 acres.

- Site M15A quantified wastewater depth and flow along an 18-inch diameter trunk sewer that conveys flow from the South 26th Street catchment area to the Spring Creek Interceptor. The tributary catchment area is 169 acres.

The locations of these separate sanitary trunk sewer monitoring sites are provided in **Figure 3-2**.

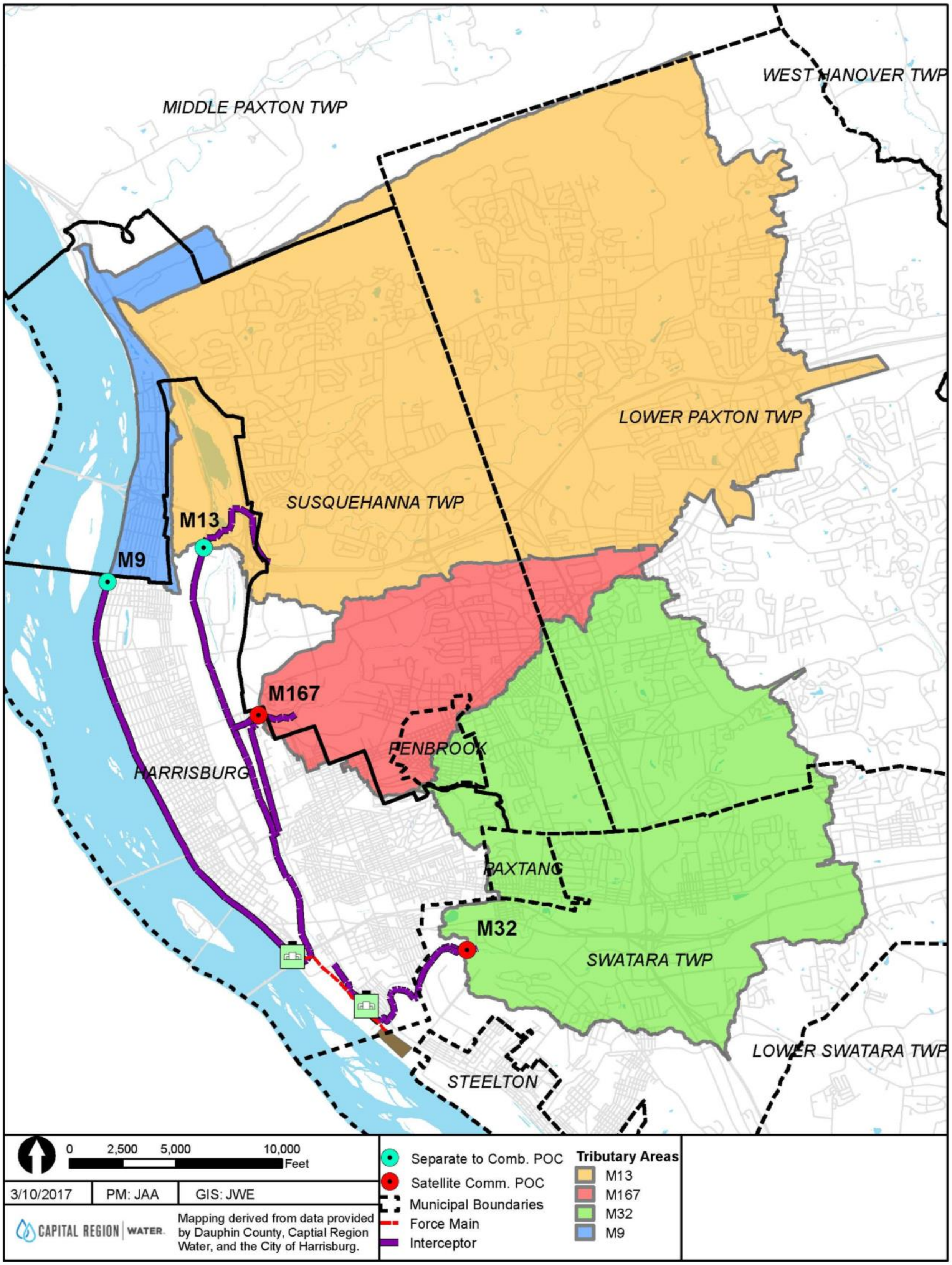

Figure 3-1: Location of Suburban Community Monitoring Sites

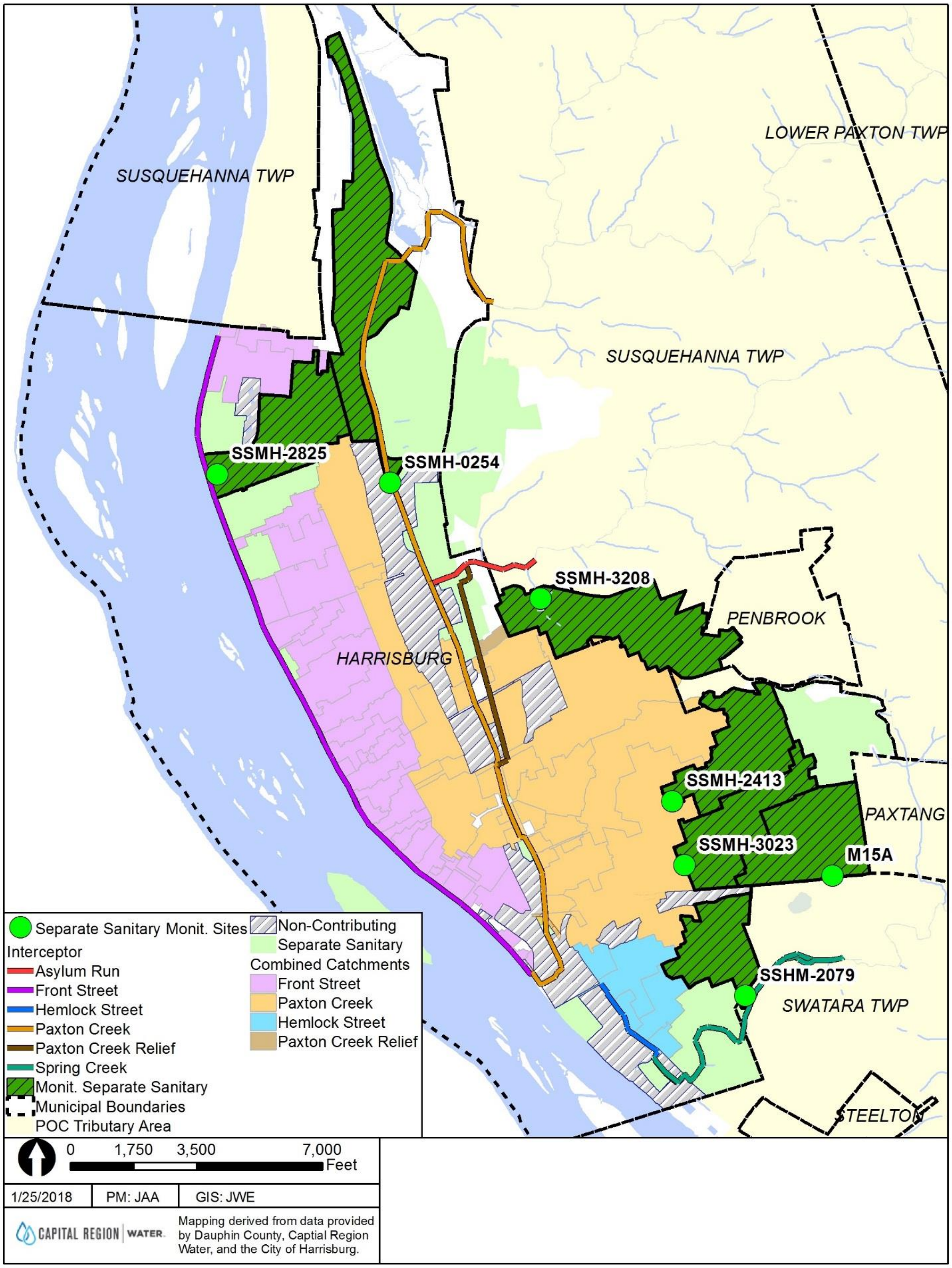

Figure 3-2: Location of CRW Separate Sanitary Catchment Monitoring Sites

3.1.3 Precipitation Monitoring

CRW successfully developed and implemented a precipitation gauge network consisting of 8 tipping bucket rain gauges located throughout the service area. The gauge network recorded rainfall depths in 5-minute time-step intervals with a minimum recorded depth of 0.01 inches. All the gauges are heated to allow for accurate measurement of frozen precipitation events during winter. Hourly rainfall data were also collected from the two National Weather Service gauges located at the Capital City Airport and at the Harrisburg International Airport. The network of heated CRW gauges was installed in August and September 2014 and will continue to collect data through the duration of the development and implementation of the CRW LTCP. The gauge locations are provided in **Figure 3-3**.

Like any rain gauge network, the CRW system cannot quantify and characterize precipitation volumes and patterns that occur between the gauge locations. To characterize the spatial variability of rainfall within a single event over the CRW service area, gauge adjusted radar rainfall (GARR) data were obtained and used along with the gauge network data. In August 2014, CRW contracted with a firm specializing in providing radar rainfall data, and monthly data submissions commenced in September. GARR precipitation data were provided in 5-minute intervals within a high-resolution pixel grid comprised of 1-km by 1-km cells. A total of 586 pixel cells defined precipitation patterns over the CRW service area, including the separate sanitary sewer collection systems serving the suburban communities. The required radar data were produced by the National Weather Service (NWS) Next Generation Radar (NEXRAD) system and were obtained from the KCCX radar site located near State College, Pennsylvania, approximately 100 km from the City of Harrisburg. In the production of GARR, radar rainfall was bias corrected through comparison with rain gauge accumulations. The high-resolution, spatially distributed GARR data over the entire CRW service area were used to characterize the response of separate sanitary sewer collection systems to wet weather, support the April 2016 calibration of the H/H models, and provide rainfall data for future historical system performance evaluations required in semi-annual CD progress reports.

3.2 Quality Assurance Measures

CRW successfully implemented the quality assurance and quality control (QA/QC) measures necessary to confirm that the network of flow monitoring equipment provided representative, accurate and reliable data, and that data quality is sufficient for use in the SSS-CAP. These QA/QC measures were applied to all monitored flow data, including the data used in support of calibrating the H&H model. QA refers to programmatic efforts to ensure the validity of the reported analytical data. QA programs increase the confidence in the validity of the monitoring data. QC, a subset of quality assurance, refers to the application of procedures designed to obtain prescribed standards of performance in monitoring. The QA/QC Plan was organized into two main categories: protocols directing activities and procedures in the field, and protocols directing data verification in the office.

3.2.1 Protocols and Standards for Field Activities

Comprehensive protocols and standards for field activities were required elements to execute the flow monitoring program to maximize the collection of high quality data. Proposed suburban community and CRW separate sanitary catchment meter sites were pre-screened, and field verification investigations were conducted to ensure conditions were conducive to accurate and reliable flow monitoring. An effective inspection and assessment process ensured proper selection of monitoring sites and equipment. The physical and hydraulic characteristics of each site were matched with technology selection and sensor placement that maximized the quality of collected data. All meter installations conformed to the flow monitoring equipment manufacturer's specifications.

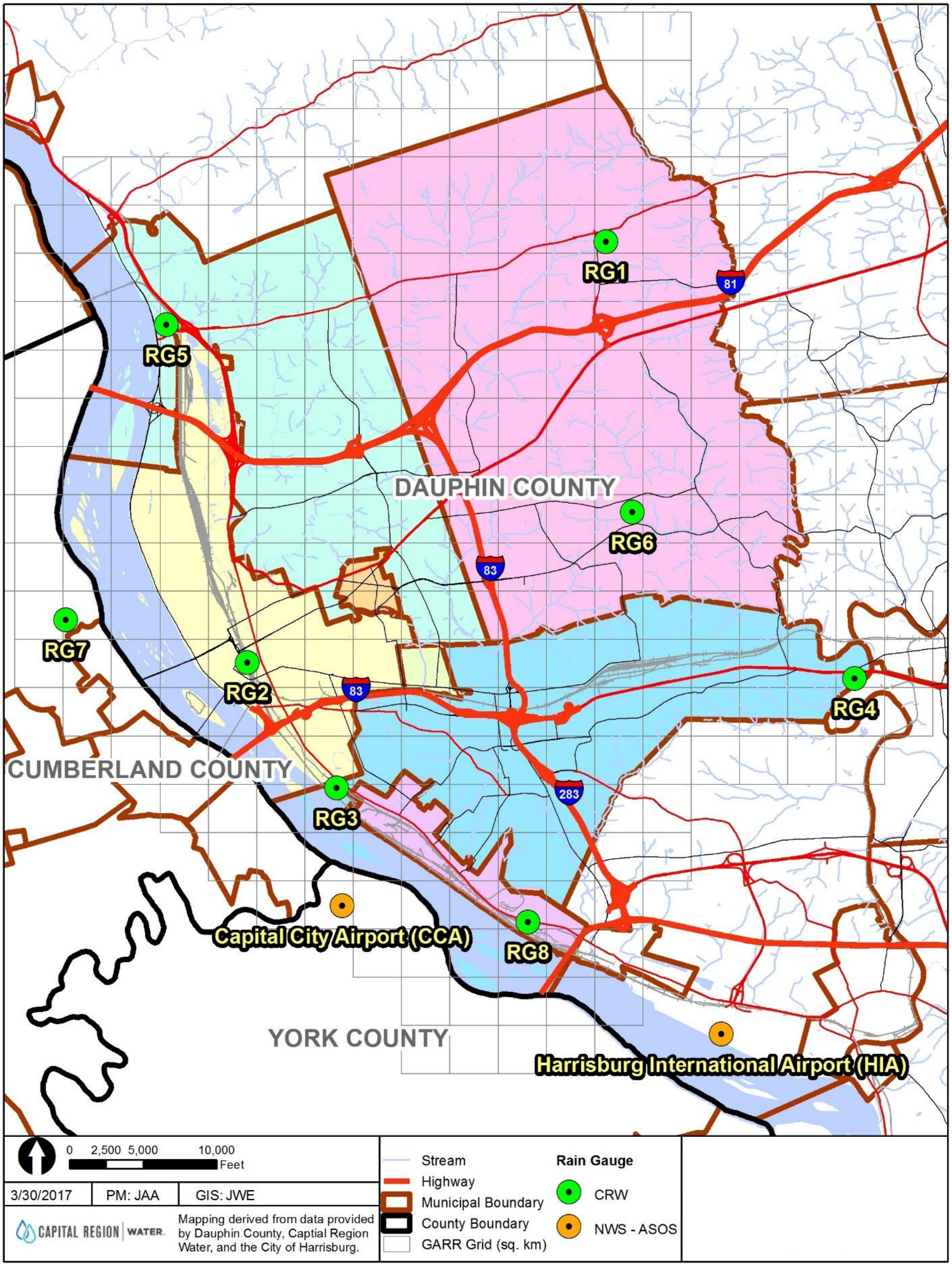

Figure 3-3: Location of Precipitation Monitoring Sites

Qualified field technicians routinely interrogated the data, maintained the monitoring equipment, performed as-needed sensor calibrations, and documented field procedures and observations. These routine field visits consisted of the field technician obtaining physical measured levels and velocities, comparing these measurements to the real-time metered readings and calibrating and/or cleaning the sensors when needed. These field measurements and activities were documented in field logs and were used by the data analysts in the QA/QC process, to ensure the quality of the collected data.

3.2.2 Protocols and Standards for Office Activities

The second category of activities within the QA/QC process was data verification in the office. A data QA/QC system was implemented to provide a comprehensive review of the collected data, the identification of data gaps, and the conversion of raw flow data into final quality-reviewed data sets. Monthly time-series and scatter plots of the monitored data were produced to assist in the data review process and verify the reliability and accuracy of the collected flow monitoring data.

Time-series plots were used to flag any inconsistencies in the monitored diurnal cycles that could not be attributed to precipitation or seasonal changes in groundwater levels, and to flag inconsistencies due to equipment failures. **Figure 3-4** illustrates an example time-series plot of data used in the QA/QC process. These plots have the depth and flow plotted on the primary y-axis, the velocities plotted on the secondary y-axis, and the precipitation data plotted in a separate smaller graph above this data. Field measured calibration points were superimposed over the monitored data to ensure the equipment was properly calibrated.

Redundant level sensors were utilized, and their monitored depths were compared to one another to verify that they were internally consistent, adding confidence to the accuracy of the monitored levels. The monitored levels were confirmed by comparing them to independent field measurements. If the field measured readings were within an acceptable range of the monitored data recorded at the time of the field visit, the data was considered to be reliable. When the redundant levels were not tracking one another, the field logs were used to confirm which level was more reliable by comparing which one was closest and within the acceptable range of the field measured readings at that time.

Precipitation data, obtained from the nearest rain gage was added to the time-series plots. This aided in confirming that increases in level, velocity, and corresponding flow rates throughout the monitoring period were attributed to precipitation events and not errant data.

Scatter plots were also generated for each month of data collected displaying flow and/or velocity on the vertical axis versus monitored depth on the horizontal axis. Field measured calibration points were superimposed over the monitored data to ensure the equipment was properly calibrated. Scatter plots were used to review the quality of the data collected and verify that the equipment was properly calibrated. A depth-flow relationship with a consistent envelope curve and a minimal degree of scatter in the data typically is indicative that the equipment was functioning properly and the data was reasonably reliable. **Figure 3-5** provides an example scatter plot of data used in the QA/QC process.

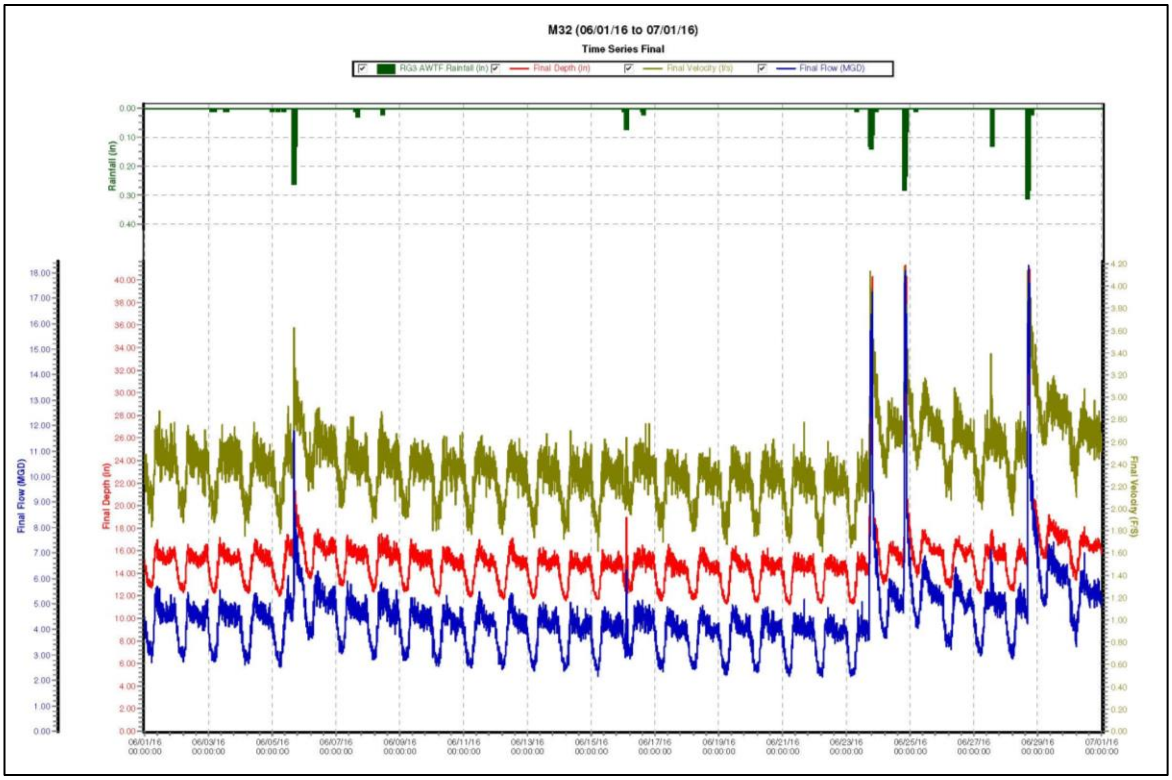

Figure 3-4: Example time-series plot for monitored data from Site M32

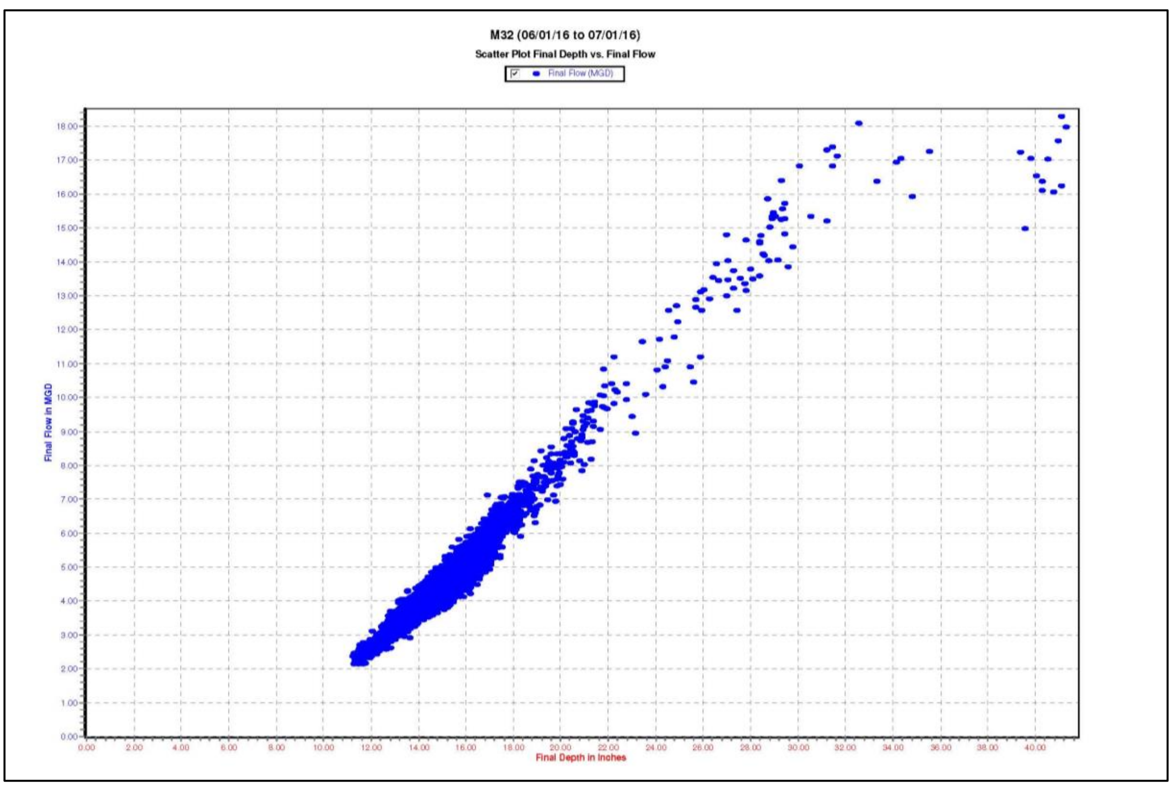

Figure 3-5: Example scatter plot for monitored data from Site M32

Two general categories of data errors were identified through the QA/QC process: short-term errors and long-term errors. Short-term errors were generally caused by temporary hydraulic conditions or intermittent sensor fouling lasting for a brief duration. Since these brief periods of errant data were surrounded by reliable data points, both depth and velocity errors could usually be corrected by interpolating between adjacent points. Long-term errors, on the other hand, were caused by ongoing hydraulic conditions, extended sensor fouling, improper equipment calibration and/or equipment failures and could last from several hours to several days in extreme cases. Errant data identified through the review process was either flagged as unusable in subsequent analyses, or corrected using approved techniques such as a rating curve (established depth-flow relationship developed based on reasonably reliable monitored data) or interpolation between adjacent reliable data points as mentioned above. A DVD containing a complete set of the time-series and scatter-plots for all the monitored catchment areas was submitted to PA-DEP and US-EPA.

3.3 Data Analysis

The suburban community POC monitoring data and the CRW major separate sanitary sewer monitoring data were collected and analyzed to quantify and characterize sanitary inflows to CRW's separate sanitary sewer conveyance system under dry and wet weather conditions. Peak flows were quantified during dry weather and for a range of storm volumes, intensities and durations. The monitoring data allowed the assessment of the existing capacity of the CRW separate sanitary collection systems to safely convey these peak flows. The results of the flow monitoring analyses were applied to and combined with the corresponding results from the H&H model simulations and analyses to assess the potential for surcharge conditions or SSO discharges to occur.

3.3.1 Dry Weather Flow Analysis

For each of the monitoring sites and corresponding tributary catchment areas, dry weather periods were identified and corresponding monitored flows were analyzed to characterize typical dry weather hydrology. The total base weekday and weekend wastewater flow (BWF) and ground water infiltration (GWI) tributary to each of the monitoring sites was quantified from the monitored dataset, as illustrated in **Figure 3-6** and **Figure 3-7**.

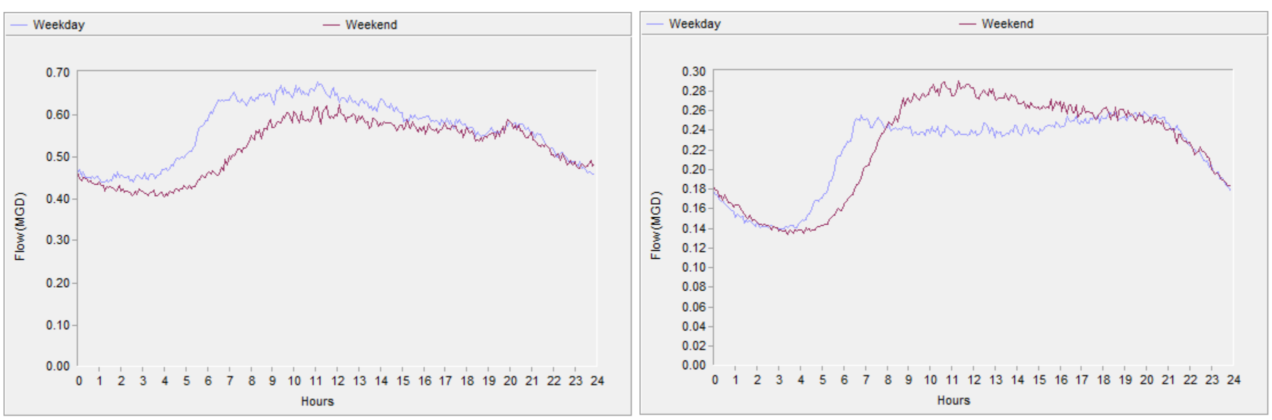

Figure 3-6: Average weekday and weekend dry weather hydrographs for the monitored Site SSMH-3208 and M15A catchment areas

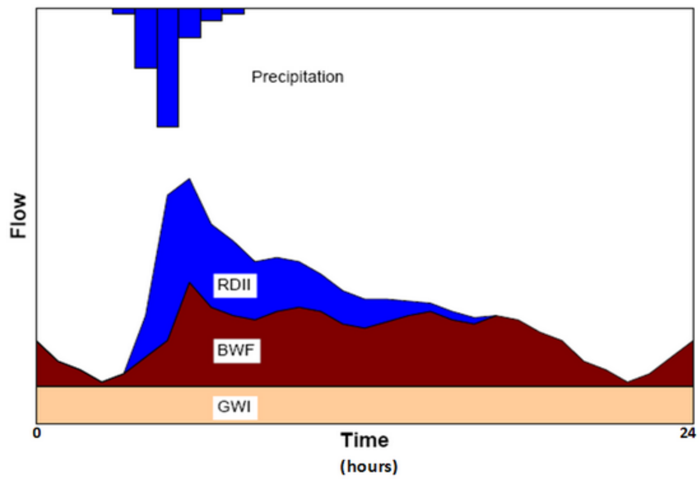

Figure 3-7: Typical flow characterization in a separate sanitary sewer system, including the BWF, GWI and RDII components

The flow quantification analyses were conducted using the Environmental Protection Agency (EPA) Sanitary Sewer Overflow Analysis Program (SSOAP). Peak dry weather flows were quantified for each monitoring site, based upon the available monitoring data. The quantified BWF and GWI together comprise the dry weather flow that was generated within the monitored sanitary sewer system. The quantified BWF represents the monitored residential, commercial, institutional and industrial flow that was discharged to the sanitary sewer system for collection and treatment. BWF normally varies with water use patterns throughout a 24-hour period with higher flows occurring during morning hours and lower flows during the night. The quantified GWI represents the monitored infiltration of ground water that entered the collection system through leaking pipes, pipe joints, and manhole walls. GWI varies throughout the year, often trending higher in winter and spring as groundwater table levels and soil moisture levels rise, and subsiding in summer after an extended dry weather period.

For the capacity assessment, the quantified peak dry weather flows and the corresponding monitored wastewater depths within the sewer pipes, based upon the available monitoring data, were used to characterize dry weather hydraulics and associated separate sanitary sewer capacities. The portion of the available hydraulic capacity used by the monitored peak dry weather flows were determined, as well as the remaining reserve capacity available to protect against surcharge conditions and potential basement backups and SSO discharges. The analysis results were integrated into the H&H model to provide seasonally varied dry weather flow patterns.

3.3.2 Wet Weather Flow Analyses

For each monitoring site, monitored storm flows were analyzed to characterize wet weather hydrology within separate sanitary sewer systems. The total rainfall dependent infiltration and inflow (RDII) generated within each monitored catchment area were quantified using the SSOAP program, as illustrated in **Figure 3-7**. The quantified inflow was the water that entered the sanitary sewer system directly via leaky manhole lids and frames, roof drain connections, sump pumps, foundation drains, and cross connections. Rainfall-dependent infiltration refers to rainfall runoff that filters through the soil before entering a sanitary sewer system through damaged pipe sections, leaky joints, etc. These defects can occur in both the public right-of-way portions of the sewer system or in individual service laterals on private property. Infiltration typically extends beyond the end of rainfall and takes some time to recede to zero after an event.

To support the capacity assessment, two categories of wet weather analyses were conducted on the monitoring data collected at each site. The SSOAP program was used to quantify the RDII associated with each successfully monitored storm and develop a series of input values for use by the H&H models. Peak depths and flows monitored during significant storm events were analyzed to characterize wet weather hydraulics and determine the available level of protection in the CRW collection system against hydraulic surcharge conditions and potential SSO discharges.

The SSOAP toolbox program was used to analyze the monitored precipitation and flow data, quantify the RDII generated by each of the monitored catchment areas, and develop an understanding of the RDII hydrological characteristics. The total flow for each monitored storm was deconstructed into the characteristic components of BWF, GWI and RDII. During the SSOAP analysis, the analyst implemented GWI adjustments to account for seasonal availability, identified the start and end times of the individual RDII events, and produced statistics detailing each event's RDII volume, rainfall volume, and the deconstructed components of the total monitored flow. Scatter plots of the monitored flow and velocity versus the monitored depth were prepared and used to determine if the trunk sewer was free flowing or under the influence of back water interferences from any downstream hydraulic restrictions. The calculated volume of RDII for each monitored storm was divided by the corresponding volume of rainfall over the catchment area and expressed as a percentage or R-value.

This R-value represents the fraction of monitored rainfall that fell over the tributary catchment area that entered the sanitary sewer system. Low values typically indicate a tight sewer system with minimal extraneous flow. On the contrary, high values indicate high quantities of extraneous flow. The analyst subsequently used the SSOAP program to distribute the calculated RDII volumes and develop a series of three triangular unit hydrographs to represent the fast, medium and slow responses of the catchment collection systems to each of the monitored storms, as depicted in **Figure 3-8**. These hydrographs represent the magnitude and timing of the RDII hydrology of the monitored separate sanitary catchment areas. Selected individual storm hydrographs were averaged together on a monthly basis to represent seasonal variability. These monthly unit hydrographs were used as input into the H&H model for monitored areas, and extrapolated values were derived for unmonitored areas. For each storm within each separate sanitary catchment area, the model applied the appropriate monthly-average unit hydrographs to the monitored rainfall so that the model-simulated sewer system responses correlated well to the monitored RDII flow.

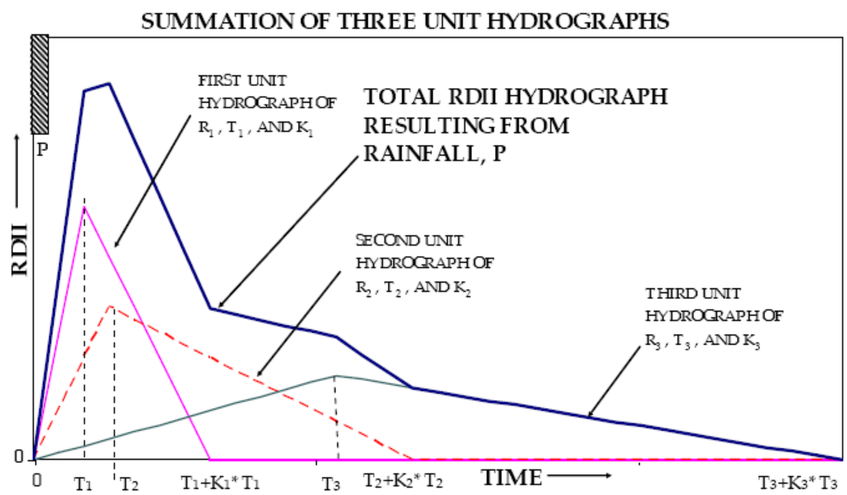

Figure 3-8. Unit hydrograph parameters derived from SSOAP Toolbox to build design RDII response hydrographs

Representative analysis results are illustrated in **Figure 3-9** and **Figure 3-10**. The short-term (R1) RDII responses, medium-term (R2), and long-term (R3) responses are depicted for the monitored SSMH-2079 and SSMH-0254 catchment areas. The analysis results revealed that the SSMH-2079 catchment area demonstrated significant seasonal variability, and total RDII flows during the winter and early spring seasons are more than twice those experienced during the summer and fall. Conversely, the SSMH-0254 catchment area demonstrated minimal seasonal variability where RDII flows were consistent throughout the year, except for an observed 20% reduction during the fall season. Both catchment areas had relatively low total R-values, indicative of a "tight" collection system, despite the differences in the seasonality of the RDII responses.

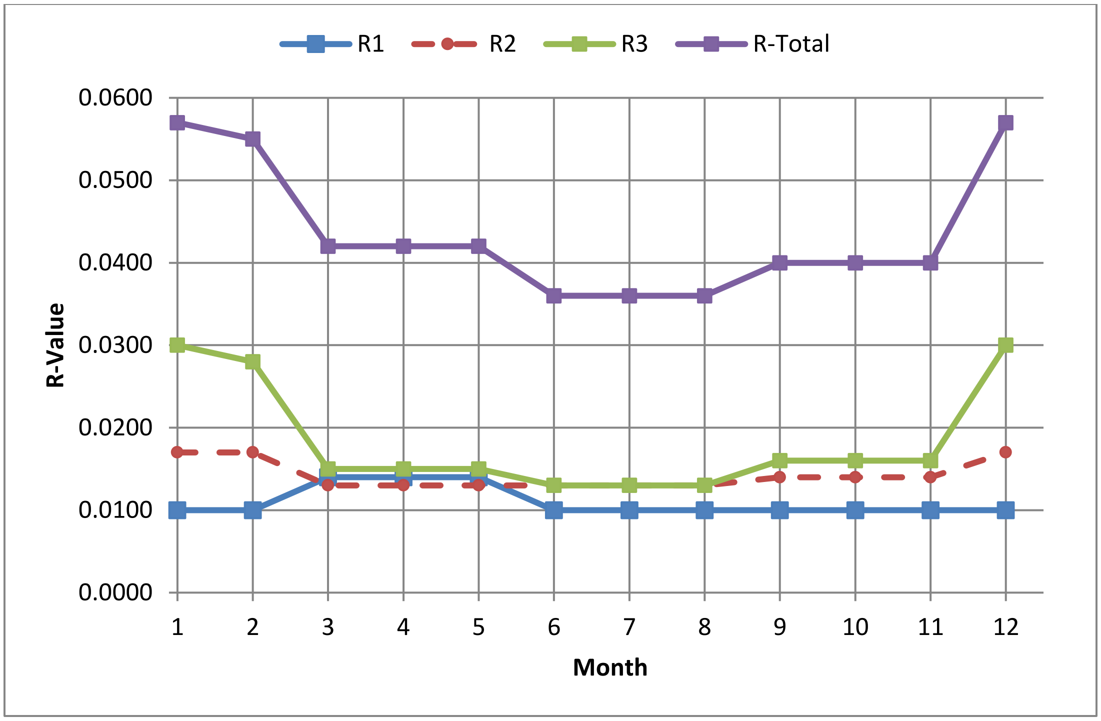

Figure 3-9: Monthly varied R values with significant seasonal variation as observed at catchment area SSMH-2079 (S. 19th St.) to the Spring Creek Interceptor

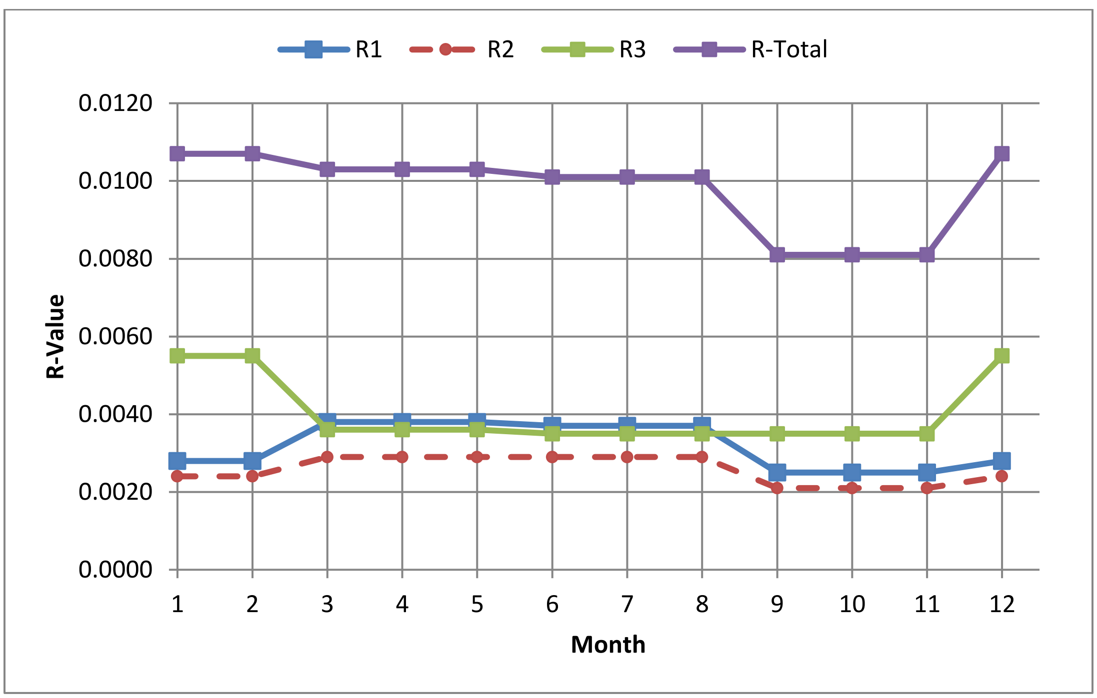

Figure 3-10: Monthly varied R values with minimal seasonal variation as observed at catchment area SSMH- 0254 (Industrial Road) to the Paxton Creek Interceptor

Individual RDII analysis results for each of the monitored separate sanitary catchment areas are provided in **Table 3-1**. The short-term (R1), medium-term (R2), and long-term (R3) RDII responses, along with the total RDII response are provided. Also included is the GWI ratio, which reflects the magnitude of observed GWI component of the monitored average daily dry weather flow. The reported GWI ratios were developed using the SSOAP Toolbox methodology and are the fractions of the monitored average daily dry weather flow attributed to GWI. They reflect the average minimum nighttime flow observed in the diurnal patterns of the dry weather flow.

Table 3-1: Summary RDII Analysis Results for Separate Sanitary Catchment Areas

Monitoring Site	R1	R2	R3	Total R	GWI Ratio
SSMH-0254	0.0033	0.0026	0.0040	0.0099	0.93
SSMH-2079	0.0095	0.0137	.0187	0.0419	0.63
SSMH-2825	0.0117	0.0070	0.0055	0.0242	0.72
SSMH-3208	0.0105	0.0098	0.0130	0.0333	0.78
SSMH-M15A	0.0144	0.0118	0.0115	0.0376	0.64
POC M32	0.0024	0.0024	0.0088	0.0137	0.69
POC M167	0.0044	0.0044	0.0148	0.0237	0.79

An evaluation and assessment were conducted of the suburban community flows conveyed to the Spring Creek and Asylum Run Interceptors. The total R-values associated with the two POC monitoring sites indicate that respectively approximately 1.4 percent and 2.4 percent of the rainfall falling over the separate sanitary catchment areas infiltrates or inflows into the sewer collection system. To provide an overall context from which to interpret the results of the individual site analyses, a cumulative distribution function (CDF) analysis was prepared for approximately 4,200 individual storm events that were monitored and analyzed from other major cities in Pennsylvania. The total R-vales for each storm were placed in order, from the lowest value to the highest, irrespective of the catchment area over which the storm occurred. The resulting CDF plot, provided in **Figure 3-11**, was color-coded to facilitate interpretation of the results. The figure was obtained from the Philadelphia Water *Department's Sewer System Evaluation Study*. That was submitted to US-EPA and PA-DEP on June 1, 2015. Individual storm events with very high monitored total R-values (above 0.18) were color coded red. Catchment areas with moderately high values (0.060 to 0.099) were color coded yellow. Storms with average (0.020 to 0.059) and low (less than 0.020) total R-values were color coded green and blue, respectively. The median or 50th percentile value over all the analyzed storm events was 0.035. A clear inflection point or knee-of-the curve along the CDF line, can be observed at the 0.10 total R-value.

The average total R-value for the M32 suburban community POC monitoring site was in the blue range. This would indicate low RDII volumes were being discharged into the Spring Creek Interceptor. The average total R-value for the M167 site was in the green range indicating average RDII quantities were being conveyed to the Asylum Run Interceptor. The total R-values would normally be indicative of a reasonably "tight" system, however, we know from anecdotal reports from the suburban communities that upstream SSOs occur, affecting these findings. It is assumed that SSO discharges in the upstream municipal collection systems only occur during storms with large rainfall volumes. The observed average annual R-values would reflect RDII conditions along the sewer collection systems for all magnitudes of storm events. This would tend to indicate that the SSO discharges are the result of conveyance limitations and not overall leakiness of the collection system.

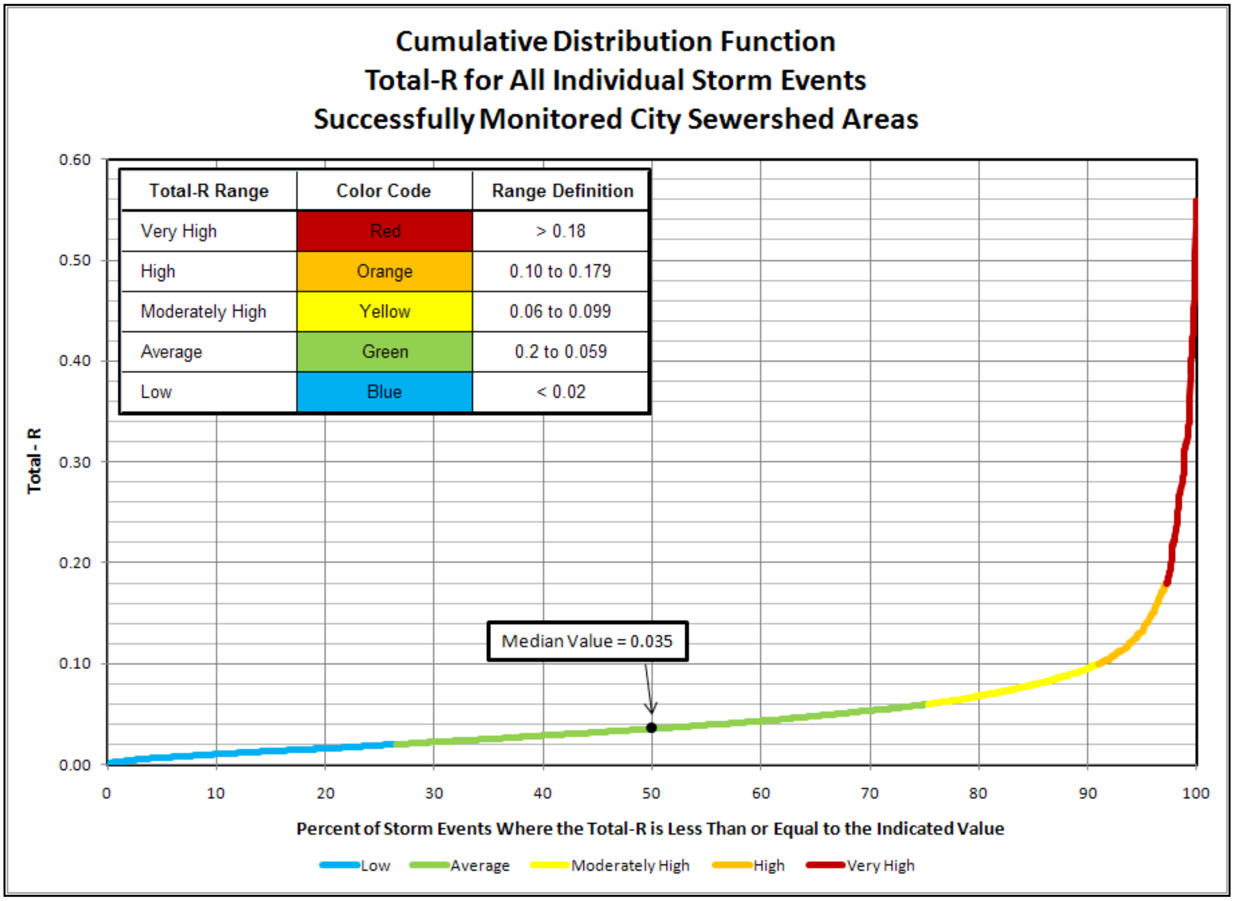

Figure 3-11: CDF Curve for 4,200 Individual Storm Total R-Values

For separate sanitary catchment areas within the CRW collection system, the average total R-value for the SSMH-0254 monitoring site was in the blue range, indicating low RDII volumes were observed. The average total R-values for the other four CRW sites were in the green range indicating RDII values in the average range were observed. These assessment results indicate that a comprehensive RDII reduction program would not be considered to be cost-effective for CRW, since the existing sewer collection systems are relatively tight.

The ground water infiltration (GWI) ratios presented in **Table 3-1** signify the extent of dry weather infiltration into the separate sanitary sewer systems the same way the R-values indicate RDII flows during wet weather. Most of the GWI ratios observed from the suburban community POC monitoring sites and from the CRW sites are within a typical range. However, the high GWI ratio monitored at SSMH-0254 may indicate that the Industrial Road trunk sewer could be experiencing an excessive quantity of GWI flow. There may be sources of round-the-clock base wastewater flow from commercial or industrial facilities that contribute to the high GWI ratio. However, the trunk sewer is located adjacent to Paxton Creek and Wildwood Lake. The Industrial Road trunk sewer may be a potential candidate for an infiltration investigation and assessment to discern if GWI flow could be cost-effectively removed.

The GWI ratio associated with the CRW SSMH-3208 catchment area (tributary to the Asylum Run Interceptor) and the GWI ratio associated with the M167 suburban community POC area (also tributary to the Asylum Run interceptor) are moderately high. The trunk sewers serving these catchment areas may also be potential candidates for an infiltration investigation and assessment to discern if GWI flow could be cost-effectively removed.

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Section 4

Develop Synthetic Design Storm Rainfall

Task 4 of the approved *Separate Sanitary Sewer Capacity Assessment Plan* (SSS-CAP) and Paragraph V(F)30b of the Partial Consent Decree require CRW to conduct the capacity assessment under current conditions during the 2-year, 5-year, and 10-year, 24-hour storm events. CRW obtained and utilized rainfall intensity-duration-frequency statistics for Harrisburg published in NOAA Atlas 14 to define 24-hour rainfall volumes for the recurrence interval events. Design rainfall hyetographs were developed by fitting these volumes to the SCS-Type II distribution, which embeds the intensity of storms with durations less than 24 hours, properly converting precipitation statistics to runoff statistics across drainage areas of varying size, slope, and storage characteristics. This distribution properly estimates peak flows from drainage catchments over a range of times of concentration shorter than 24-hours. Monitored summer season base flows and rainfall dependent infiltration and inflow (RDII) responses of the separate sanitary sewer systems, were applied to the synthetic design storms for the required 2-year, 5-year, and 10-year recurrence interval analyses.

4.1 Collect NOAA Atlas 14 Data

CRW obtained point precipitation frequency estimates from the Atlas 14, Volume 2 data provided by the National Oceanographic and Atmospheric Administration (NOAA) for the Harrisburg Capital City rain gauge site. The precipitation volumes presented in the atlas were based upon statistical analyses conducted on the historical record from the Capital City Airport gauge. The rainfall depths for a range of intensity durations ranging from 5 minutes to 24 hours is provided in **Table 4-1**. The SSS-CAP and the Partial Consent Decree require the use of the 24-hour design storm values.

Table 4-1: Point Precipitation Frequency Estimates (Inches) for Harrisburg, PA

Duration	Average Recurrence Interval (years)			
	1	2	5	10
5 Minutes	0.32	0.38	0.45	0.50
10 Minutes	0.51	0.61	0.72	0.80
15 Minutes	0.64	0.77	0.91	1.01
30 Minutes	0.87	1.06	1.29	1.46
60 Minutes	1.09	1.32	1.65	1.90
2 Hours	1.26	1.53	1.94	2.26
3 Hours	1.38	1.67	2.12	2.48
6 hours	1.70	2.06	2.60	3.04
12 Hours	2.08	2.50	3.17	3.74
24 Hours	2.40	2.90	3.67	4.36

4.2 Apply an SCS Type-II Distribution

In addition to the 24-hour design rainfall depths, there also is a need to establish a temporal distribution for the design storm rainfall volume. A Soil Conservation Service (SCS) Type II distribution was required by the SSS-CAP and the Partial Consent Decree, and was applied to the Atlas 14 design storm depths. The distribution is considered a stacked distribution, where approximations of the 5-minute, 10-minute, 15 minute, 30-minute, 1-hour, 2-hour, 6-hour, and 12-hour storm volumes are superimposed symmetrically around the twelfth hour of the synthetic storm. This temporal distribution is widely understood and accepted by water resources professionals and include frequency duration volumes and peak intensities applicable to a wide range of sewershed areas and times of concentration.

Hyetographs, or graphical bar-chart representations, of the resulting design storm rainfall distributions are provided in **Figure 4-1** through **Figure 4-3**.

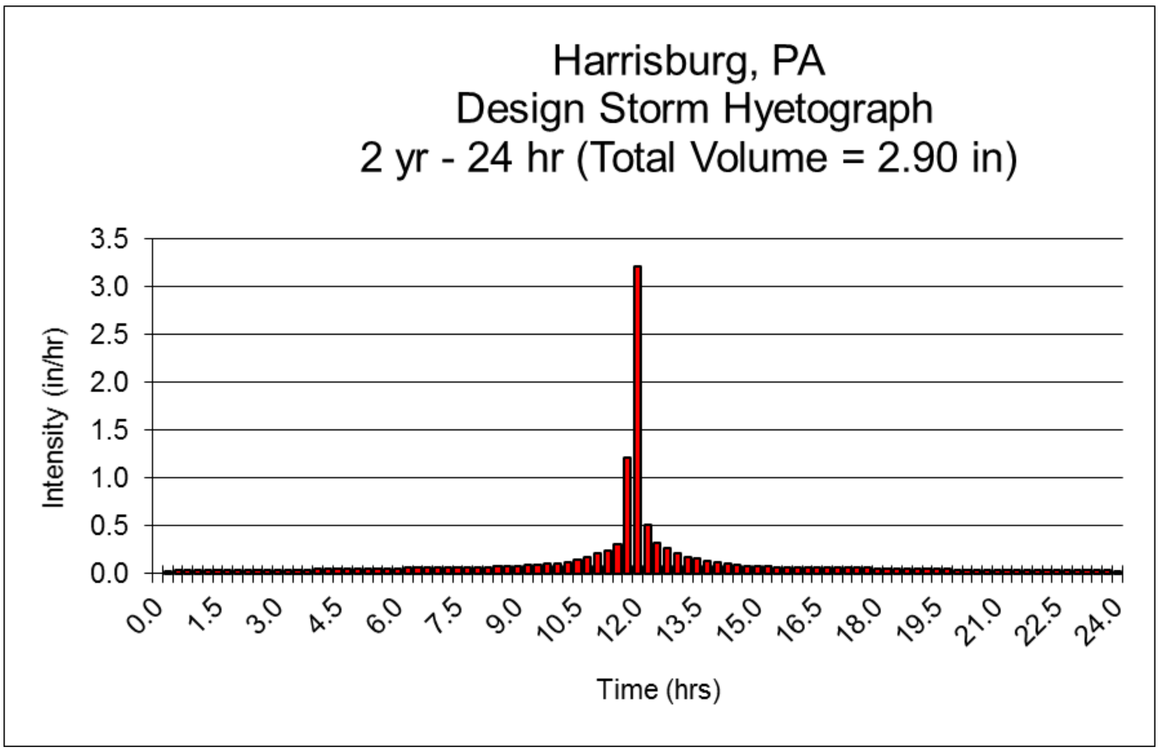

Figure 4-1: Hyetograph for a 2-year, 24-hour synthetic design storm

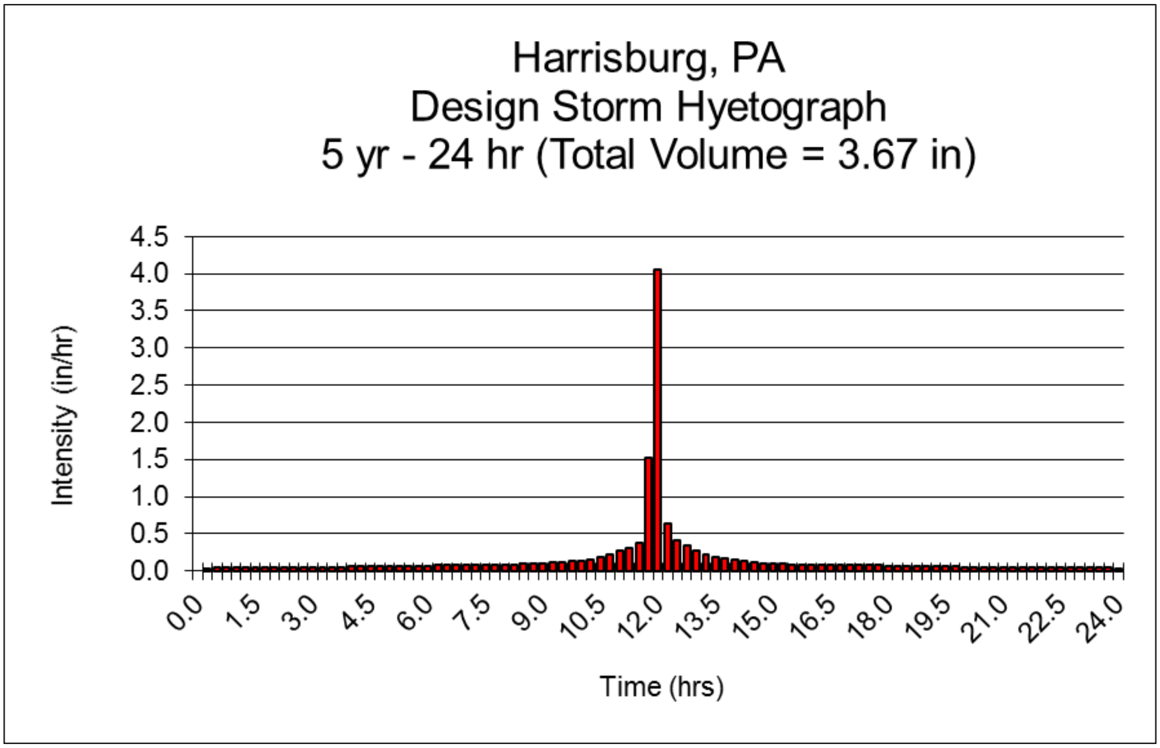

Figure 4-2: Hyetograph for a 5-year, 24-hour synthetic design storm

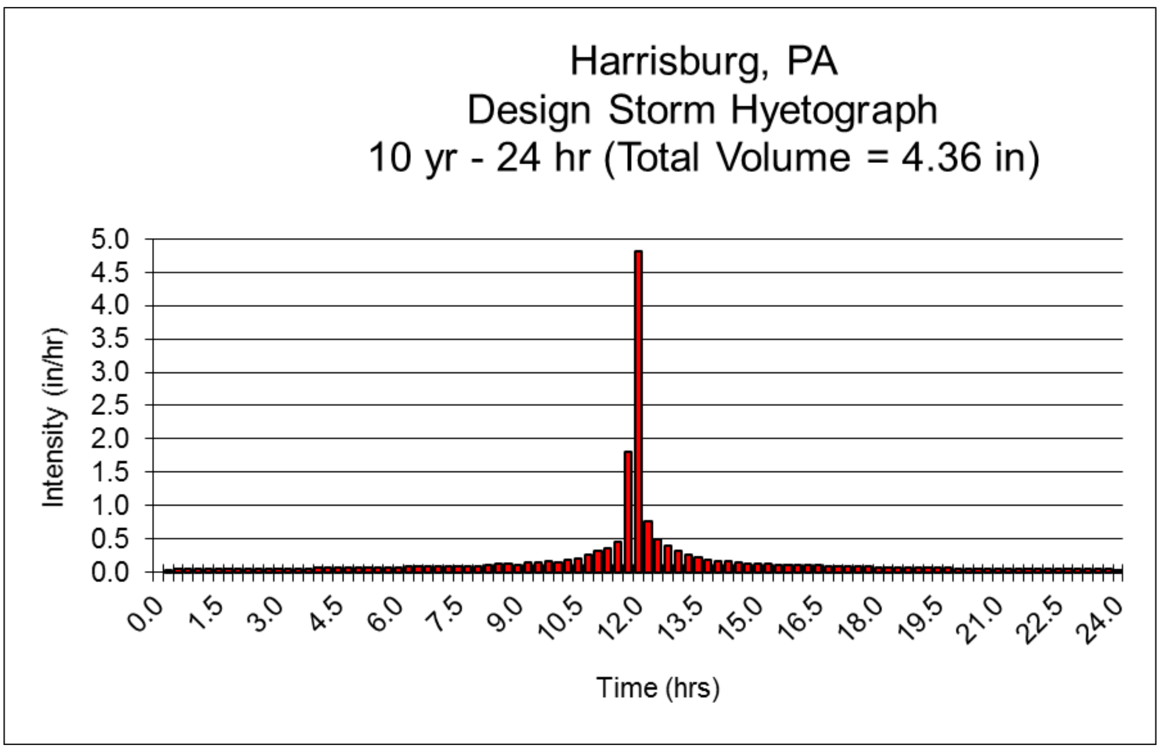

Figure 4-3: Hyetograph for a 10-year, 24-hour synthetic design storm

4.3 Seasonal Analysis Results

The CRW H&H model successfully represents the seasonal variability of ground water infiltration (GWI) and the monthly variability of the rainfall dependent infiltration and inflow (RDII) response of separate sanitary sewer systems to wet weather. Therefore, it was important to determine what GWI conditions and what RDII values to use for the synthetic design storm simulations.

NOAA Atlas 14 includes figures that show the results of analyses they conducted for monthly precipitation exceedance values for the 60-minute and 24-hour duration storms. A copy of these figures is provided in **Figure 4-4** and **Figure 4-5**. The results indicate that 60-minute duration design storms, typically associated with intense thunderstorm activity, are most likely to occur during the months of July and August. The 24-hour duration design storms, typically associated with large frontal systems, are most likely to occur during the months of August and September. The analysis figures indicate it would be unlikely that these design storms would occur during the winter season or during times of high seasonal ground water that occur during the months of February, March and April. Therefore, the CRW rainfall analyses deliberately avoided invoking joint probability issues by not applying NOAA-based design storms to spring-season base flows or R-values. Artificially imposing these design storms on spring-time hydrologic conditions would artificially increase the recurrence intervals. The CRW analyses matched the design storms to the seasonal hydraulic conditions that would most likely be encountered. Based on the NOAA seasonal analysis results for the Harrisburg region, GWI values and RDII values for the month of August were selected for the model simulations because they are appropriate for both the short-duration and long-duration aspects of the synthetic design storms.

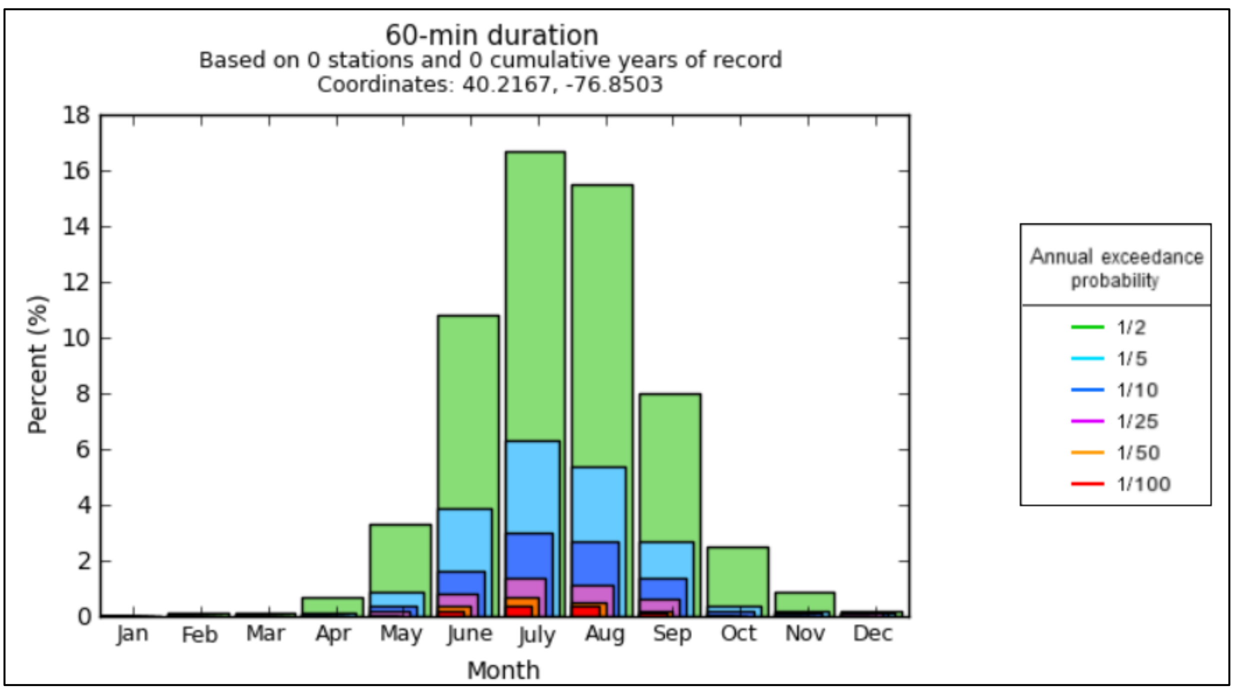

Figure 4-4: Monthly storm probability for 60-minute rain durations from NOAA Atlas 14

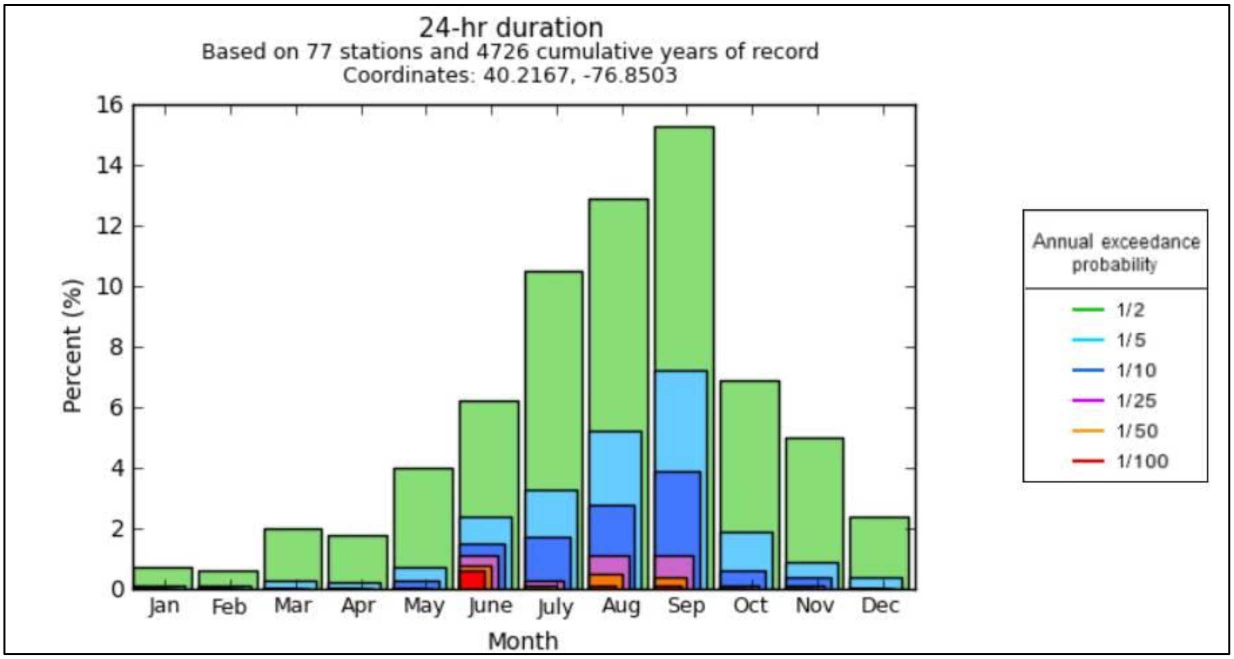

Figure 4-5: Monthly storm probability for 24-hour rain durations from NOAA Atlas 14

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Section 5

Perform Hydraulic Capacity Evaluation

5.1 Introduction

Task 5 of the approved Separate Sanitary Sewer Capacity Assessment Plan (SSS-CAP) committed CRW to apply the calibrated hydrologic and hydraulic (H&H) model of its conveyance and collection systems and the synthetic design storm rainfalls, developed under Tasks 1 through 4, to estimate peak wastewater flows and water surface elevations within the existing separate sanitary sewer system during the following hydraulic flow scenarios:

- Typical peak dry weather flow conditions
- 2-year, 24-hour design storm event
- 5-year 24-hour design storm event
- 10-year 24-hour design storm event

The objective of this evaluation was to define the projected probability and locations of potential SSO discharges, including water in basements, within the CRW separate sanitary sewer system. The model simulations produced a series of hydraulic profiles along each of the modeled interceptor sewers and separate sanitary trunk sewers. The water surface elevations from each of the hydraulic profiles were applied to the Geographic Information System (GIS) database of the CRW collection system to produce a series of color-coded maps, found in Appendix A. A series of 7 GIS maps, lettered A through G, provides the required coverage of the CRW system for each design flow scenario. A map series was generated to illustrate the hydraulic profile information under peak dry weather flow and each of the synthetic design storm flow recurrence intervals.

5.2 Overall Hydraulic Capacity Evaluation

The successfully implemented wastewater flow monitoring plan collected flow data that was subsequently analyzed to quantify and characterize wastewater flow under dry weather and wet weather flow scenarios from separate sanitary sewer collection/conveyance systems within the City of Harrisburg and from suburban community collection systems. Weekday and weekend hydrographs, such as those previous depicted in **Figure 3-6**, were developed for each of the delineated separate sanitary catchment areas and routed through the hydraulic model. The hydraulic capacity evaluation under each flow scenario is summarized in **Tables 5-1** and **5-2**.

Table 5-1: Summary of Hydraulic Conditions along Separate Sanitary Sewer Pipes

Scenario	Sewer Length (linear ft.) at Percent of Full Pipe Depth of:				Total
	0% to 30%	30% to 60%	60% to 90%	>= 90%	
Peak Dry Weather Flow	38,284	8,035	759	69	47,147
2-Year Design Storm	2,706	15,126	11,888	17,426	47,147
5-Year Design Storm	2,101	10,772	10,432	23,842	47,147
10-Year Design Storm	1,616	7,419	8,594	29,517	47,147

Table 5-2: Summary of Hydraulic Conditions at Separate Sanitary Sewer Manholes

Scenario	Number of Manholes with Peak Depth Below Rim Elevation of:					Potential for Water in Basement
	> 8 ft.	6 to 8 ft.	4 to 6 ft.	0 to 4 ft.	< 0 ft.	
Peak Dry Weather Flow	144	43	15	0	0	0 structures
2-Year Design Storm	119	17	11	47	8	18 structures
5-Year Design Storm	109	24	13	47	9	24 structures
10-Year Design Storm	86	20	19	67	10	49 structures

5.2.1 Peak Dry Weather Flow Conditions

Model simulations confirmed that there are no hydraulic limitations anywhere within the CRW separate sanitary trunk sewer system that would cause SSO discharges or basement backups under peak dry weather flow conditions. There were no surcharge conditions observed along any of the modeled separate sanitary sewers. None of the pump station capacities were exceeded by peak dry weather flow from separate sanitary sewer systems. **Table 5-1** indicates that 81 percent of the separate sanitary trunk sewer pipe lengths conveyed the peak dry weather flow at a depth less than 30 percent of the diameter of the pipe. More than 98 percent of the separate sanitary trunk sewer pipes conveyed the peak dry weather flow at a depth below 60 percent of the diameter of the pipe, indicating the CRW separate sanitary sewer collection system has adequate capacity to convey peak dry weather flow. **Table 5-2** indicates that the computed hydraulic grade line profiles at 93 percent of the separate sanitary trunk sewer manholes had at least 6 to 8 feet of freeboard below the manhole rim elevations. The 15 manholes with 4 to 6 feet of freeboard below the manhole rims are all located along the Spring Creek Interceptor. The reduced freeboard depth at some of the manholes is because the manhole depths from rim to invert are relatively shallow and not because of an excessive surcharge problem. The sloping topography along the sides of the sewer route and the elevations of adjacent homes and businesses, located at the top of slope embankments, are sufficiently high to preclude any basement backups.

5.2.2 Systemwide Hydraulic Conditions During the 2-year Design Storm

Table **5-1** indicates that during the 2-year design storm, 63 percent of the separate sanitary trunk sewer pipe lengths conveyed the peak flow under less than full pipe conditions and 37 percent of the pipe lengths were flowing full or under surcharge conditions. **Table 5-2** shows that 136 sewer manholes, or 67 percent of manhole structures had greater than 6 feet of freeboard below the manhole rim and had a minimal potential to cause sewage backups into basements. There were 55 manholes with freeboard depths less than 4 feet below the manhole rims. All buildings affected by these surcharge conditions were identified and assessed. Field reconnaissance indicates that only 18 structures adjacent to these manholes have basements potentially subject to backwater flooding, as described in the following sections. Sewer surcharging is projected to exceed the rim elevation at 6 manholes along the Spring Creek Interceptor. Additionally, the model results show sewer surcharging exceeding the rim elevation for one manhole along the Industrial Road trunk sewer. This does not occur for the modeled 5-year and 10-year design storm events, so this is likely attributable to model variability. Additionally, the model results show sewer surcharging exceeding the rim elevation at the most-upstream modeled manhole on Nineteenth Street for the 2- to 10-year design events, but this is likely attributed to how the upstream flow contribution is loaded here.

5.2.3 Systemwide Hydraulic Conditions During the 5-year Design Storm

Table 5-1 indicates that during the peak 5-year design storm, 49 percent of the separate sanitary trunk sewer pipe lengths conveyed the peak flow under less than full pipe conditions and 51 percent of the pipes were flowing full or under surcharge conditions. **Table 5-2** shows that 133 sewer manholes, or 66 percent of manhole structures had greater than 6 feet of freeboard below the manhole rim and had a minimal potential to cause sewage backups into basements. There were 56 manholes with freeboard depths less than 4 feet below the manhole rims. All buildings affected by these surcharge conditions were identified and assessed. Field reconnaissance indicates that only 24 structures adjacent to these manholes have basements potentially subject to backwater flooding, as described in the following sections. Sewer surcharging is projected to exceed the rim elevation at 8 manholes along the Spring Creek Interceptor.

5.2.4 Systemwide Hydraulic Conditions During the 10-year Design Storm

Table 5-1 indicates that during the 10-year design storm, 37 percent of the separate sanitary trunk sewer pipe lengths conveyed the peak flow under less than full pipe conditions and 63 percent of the pipes were flowing full or under surcharge conditions. **Table 5-2** shows that 106 sewer manholes, or 52 percent of manhole structures had greater than 6 to 8 feet of freeboard below the manhole rim and had a minimal potential to cause sewage backups into basements. There were 77 manholes with freeboard depths less than 4 feet below the manhole rims. All buildings affected by these surcharge conditions were identified and assessed. Field reconnaissance indicates that only 49 structures adjacent to these manholes have basements potentially subject to backwater flooding, as described in the following sections. Sewer surcharging is projected to exceed the rim elevation at 9 manholes along the Spring Creek Interceptor.

5.2.5 Hydraulic Conditions at Points of Connection to Suburban Systems

Suburban communities draining to CRW's system have long-standing I/I control programs under terms of their permits with DEP. CRW is not a party to these programs, but is aware of them. There is no evidence that capacity issues within the suburban systems are caused by CRW's system. Scatter plots of the monitoring data collected at the 4 major points of connection between the suburban community and CRW systems show no evidence of significant backwater interferences. There is a strong indication that suburban community flows into CRW's portion of the Spring Creek interceptor have overwhelmed the available capacity, causing surcharging.

Future interjurisdictional coordination is necessary to coordinate between actions taken/anticipated by these communities, measures available to CRW, and equitable ways to implement necessary improvements. This would be best accomplished as part of LTCP development since there is a relationship between the actions taken by all parties.

The collected monitoring data shows no evidence that overflow volumes in suburban collection systems would significantly skew the results of the RDII analyses. If the overflow volumes had significant impacts, we would expect R-values to be consistently higher for smaller storms (with no upstream SSO activity) than for larger storms (assuming pre-relieving upstream). This was not observed in the analysis results.

Scatter plots of the monitoring data collected at the 4 major points of connection between the suburban community and CRW systems show no evidence of significant backwater interferences." This provides confidence that surcharging can be attributed to upstream flow contributions rather that backwater caused by CRW's contributions. In any event, CRW will be collaborating with its upstream customers to develop an appropriate, interjurisdictional solution to hydraulic capacity deficiencies in the Spring Creek interceptor.

5.2.6 Identification of Potential SSOs

Sanitary Trunk Sewers Discharging to the Front Street Interceptor

Catchment SS-001. The single separate sanitary trunk sewer segment along Manor Street flows full during the 5- to 10-year design storms. During the 10-year design storm, surcharge elevation at 1 manhole exceeds 6 feet below the rim. Field reconnaissance indicates that 4 structures have basements that may be subject to backups at these surcharge elevations. CRW has not received reports of basement backups along Manor Street.

Catchment SS-002. Separate sanitary trunk sewers along Seneca Street exhibit hydraulic capacity limits during the 2- to 10-year design storms. While CRW has not received reports of basement backups along Shamokin / Division Streets, hydraulic capacity evaluations reveal potential risks of basement backups:

- Four of the eleven separate sanitary trunk sewer segment along Shamokin /Division Streets flow full during the 2-year design storms.
- Nine of the eleven separate sanitary trunk sewer segment along Shamokin /Division Streets flow full during the 2-year design storms.
- All separate sanitary trunk sewer segment along Shamokin /Division Streets flow full during the 2-year design storms, with surcharge elevations at 11 manholes exceeding 6 feet below the rim. Field reconnaissance indicates that 17 structures have basements that may be subject to backups at these surcharge elevations.

Catchment SS-003. Separate sanitary trunk sewers along Radnor and Third Streets flow full during the 5- to 10-year design storms. During the 5-year design storm, surcharge elevation at 1 manhole (intersection of Third and Wiconisco) exceeds 6 feet below the rim. Field reconnaissance indicates that 4 structures have basements that may be subject to backups at these surcharge elevations. CRW has not received reports of basement backups at this location.

Catchment SS-004. Separate sanitary trunk sewers along Seneca Street exhibit hydraulic capacity limits during the 2- to 10-year design storms, but no manholes exhibit surcharge elevations exceeding 6 feet below the rim.

Spring Creek Pump Station, Interceptor, and Tributary Sanitary Trunk Sewers

CRW owns and operates the Spring Creek Interceptor from approximately the location of Meter M32 to the Spring Creek Pump Station. CRW also operates the Spring Creek Pump Station, which receives separate sanitary sewage from the Spring Creek Interceptor and combined sewage from the Hemlock Interceptor (and consequently, the Spring Creek Pump Station should be considered to be part of CRW's combined sewer system). CRW also operates the separate sanitary collection system serving eight catchments within the City of Harrisburg – SS-013, SS-014, SS-015, SS-016, SS-017, SS-018, SS-024, and SS-025. The majority of the Spring Creek interceptor and the remaining sewers discharging to the Spring Creek interceptor are owned and operated by other jurisdictions. It is important to note that 90 percent of the dry and wet weather wastewater flow to the Spring Creek interceptor originates from outside the CRW service area. These flows are contributed by Paxtang and Penbrook Boroughs, and Lower Paxton and Swatara Townships. Thus, hydraulic conditions within the Spring Creek interceptor and pump station are interjurisdictional in nature and cannot be resolved by CRW alone.

Spring Creek Pump Station

The H&H model indicated that peak flows during the 2-year design storm exceeds the hydraulic capacity of the Spring Creek Pump Station. However, CRW has not detected any pump station overflows based upon its daily inspections. The Spring Creek Pump Station is scheduled for a major rehabilitation, to be performed once the CSO LTCP recommends a final alternative for CSO control and the effects of the recommended control levels are known.

Spring Creek Interceptor

The portion of the Spring Creek Interceptor owned and operated by CRW is surcharged throughout its entire length during peak flow conditions of the 2-year design storm. Along this reach, the sewer pipe slopes, and the corresponding flow velocities, decrease along the creek bed and the interceptor can no longer convey all the wastewater flow under gravity flow conditions. Most of the interceptor manholes have less than 4 feet of freeboard below the rim elevations. CRW has sealed many of the manholes along its section of the Spring Creek interceptor to withstand pressure flow conditions and reduce the risk of SSOs. CRW field investigations have provided a reasonably complete understanding of which Spring Creek Interceptor manholes are and are not sealed. Not all the manholes with the potential to overflow during the largest storms are currently sealed. Model analyses indicated that sealing all the low-elevation manholes would result in an unacceptable and potentially unsafe operation of the interceptor. The magnitude of the resulting increases in the HGL along the interceptor would be unacceptable and would surcharge some municipal collection sewer reaches and potentially increase the possibility for basement backups.

Six manholes exhibit hydraulic grade line profiles above the manhole rims during the 2-year and 5-year design storms, increasing to 8 and 9 manholes during the 5-year and 10-year design storm, respectively. HGL elevations exceeding the rim elevations indicate a heightened risk of SSOs unless these manholes are sealed and allowed to flow under pressure. While evidence of SSOs exist along Spring Creek, there are no adjacent buildings near these manholes, located along a deep valley, so no basement backup would occur. Windshield surveys of commercial buildings along Amity Street, adjacent to two of the surcharging manholes, indicated they likely did not have basements.

CRW Separate Sanitary Trunk Sewers

Catchment SS-013. CRW sanitary trunk sewers serving this catchment discharge into Swatara Township sanitary trunk sewer near the intersection of Woodlawn and Elder, where it crosses I-83. Surcharge elevations are projected to reach 6 feet or less below the rim elevation during the 10-year design storm in 4 manholes at the discharge point from this catchment. Many of the buildings adjacent to the surcharged manholes are commercial buildings built upon slab foundations, where basement backups would not occur. However, field reconnaissance indicates that 4 structures along Elder Street have basements that may be subject to backups at these surcharge elevations.

Catchment SS-014. There was one manhole along Nineteenth Street where modeled surcharge depths rose to less than 4 feet from the rim of the manhole during the 2-year design storm. Windshield surveys confirmed the adjacent homes had basements. Homes along the uphill sire of the street are high enough to avoid basement flooding. However, there are 6 homes along the downhill side of the street that potentially could be subjected to basement backups during the 5-year design storm. As stated above, surcharging at the most-upstream modeled manhole on Nineteenth Street is likely attributed to how the upstream flow contribution is loaded here.

Catchment SS-016. The model indicates that the manhole for the sewer serving the Ivey Lane apartment complex had a freeboard depth less than 4 feet from the manhole rim during the 2-year design storm. Completed windshield surveys confirmed the apartments had basements. There were no known basement backups in these buildings, but the model predicted a potential for possible basement backups within 12 apartment buildings during a 2-year design storm, with basement backups potential in 2 additional apartments during the 5-year design storm.

Asylum Run Interceptor and Tributary Sanitary Trunk Sewers

The Arsenal Boulevard trunk sewer was flowing 30 to 60 percent full during 2- to 10-year design storms, indicating adequate capacity to convey tributary flows to the Asylum Run Interceptor. The H&H model indicates that the Asylum Run Interceptor flows full during the 2-year to 10-year design storms, with HGL elevations more than 8 feet below the rim elevations of most manholes. Therefore, there is no evidence of known or predicted SSOs or basement backups associated with the hydraulic capacities of the Asylum Run sewer pipes during a 2- to 10-year design storm.

Sanitary Trunk Sewers Discharging to the Paxton Creek Relief Interceptor

The H&H model runs showed that none of the manholes along Cameron Street experienced a peak water surface elevation less than 4 feet from the manhole rim during the 2- to 10-year design storms. The wastewater from the commercial/industrial facilities within the SS-009 catchment area is conveyed to the Paxton Creek Relief Interceptor. These facilities are built on slab foundations and do not appear to have basements, so sewer backups would not occur.

Sanitary Trunk Sewers Discharging to the Paxton Creek Interceptor

For the Industrial Road separate sanitary trunk sewer in SS-006, one of the twelve separate sanitary manholes exhibit surcharge elevations exceeding 6 feet below the rim for the 2-year design storm, increasing to 9 manholes for the 10-year design storm (as stated above, surcharge elevation exceeding the rim at one manhole during the 2-year design storm is attributable to model variability). Completed windshield surveys indicate that the structures within the catchment areas are commercial and industrial facilities constructed on slab foundations, so backups would not occur. Separate sanitary trunk sewers within SS-007 flow full during the 2- to 10-year design storms, but there are no manholes with surcharge elevations exceeding 6 feet below the rim. Separate sanitary trunk sewers within SS-008 flow less than full during the 2- to 10-year design storms.

5.3 Evaluate Possible Remedial Measures

The CRW Separate Sanitary Sewer Capacity Assessment Plan commits the authority to submit with the assessment report, "… *a description of remedial measures necessary to address all of the actual and predicted capacity constraints identified by the Capacity Assessment*…" This section of the report describes the recommended remedial measures to mitigate the discovered capacity constraints. It also discusses alternatives for addressing capacity constraints along the Spring Creek Interceptor, where a final remedial measure recommendation must be developed in coordination with CRW's CSO LTCP and incorporate multi-jurisdictional use of the interceptor outside CRW's direct control.

5.3.1 Capacity Constraints along the Spring Creek Interceptor

The H&H model simulations and capacity assessment analyses identified capacity constraints along the Spring Creek Interceptor, starting in sections of the interceptor operated by Swatara Township and proceeding through the lower reaches operated by CRW. Peak dry weather flows were safely conveyed to the Spring Creek Pump Station, but sewer surcharging is projected to exceed the rim elevation at 6 to 9 manholes along the Spring Creek Interceptor during the 2- to 10-year design storms..

Additional model simulations were conducted with all manholes sealed and downstream CSO controls to discern if that could be a temporary short-term solution to limit the frequency of SSO discharges. The model runs verified that bolting down the manhole covers may be a viable option for peak flows approaching the 2-year design storm (coupled with backflow protection on Ivey Lane), but would require additional improvements during the 5- to 10-year design storm to prevent the hydraulic grade line elevation along the interceptor from increasing to the point where the interceptor significantly surcharges the tributary residential collector sewers connected to it.

Alternatives beyond sealing manholes and allowing limited pressurization of the interceptor require coordination with CRW's CSO LTCP (due April 1, 2018) and/or exploring controls on wet weather flows generated within the suburban communities contributing 90 percent of the dry and wet weather flow conveyed to the interceptor. Initial evaluation of these alternatives has begun, but must be coordinated with associated long-term CSO control options and/or wet weather flow management programs in the contributing jurisdictions, as described in the following sections.

Alternatives Requiring Interjurisdictional Coordination

The analysis results from the completed flow monitoring studies do not indicate excessive rainfall-dependent infiltration and inflow (RDII) is reaching CRW's portion of the Spring Creek interceptor. The completed flow analyses, for wastewater quantities monitored at the M32 monitoring site, indicate that for the Spring Creek basin, the annual average RDII quantities, or total R-value, as was explained in report Section 3.3.2, was 0.014. Less than 1.4 percent of the rainfall over the tributary sewershed area was found to reach CRW's portion of the interceptor under existing conditions. **Figure 3-11** demonstrated that this level of RDII would be classified as being in the "low" range, and rehabilitation measures directed at further reducing the RDII quantity would not be successful or cost-effective.

Wet weather flow conditions in these tributary systems, are currently being evaluated by the contributing jurisdictions, however, and it is unclear at this time whether it is cost-effective to reduce existing wet weather peak flows generated within the contributing jurisdictions, or if these jurisdictions may need additional conveyance and treatment capacity. As a result, the solution to this condition cannot be decided or implemented as an early action project. The problem is complex and multi-jurisdictional between CRW, Paxtang and Penbrook Boroughs, and Lower Paxton, Susquehanna, and Swatara Townships. Several alternative solutions would need to be developed and assessed, including the construction of additional conveyance capacity and off-line peak flow reduction storage facilities. CRW has begun discussions with the upstream suburban communities, and an optimal solution will be developed and assessed, as part of the development of CRW's Long Term Control Plan (LTCP).

Alternatives Associated with CRW's CSO LTCP

Similarly, the model analysis results indicated that the existing Spring Creek Pump Station does not have adequate capacity to convey peak design storm flows to the Advanced Wastewater Treatment Facility (AWTF). Hydraulic modeling indicates, however, that increased pumping capacity at the Spring Creek pump station is able to lower the hydraulic grade line within CRW's portion of the Spring Creek interceptor, reducing the potential risk and frequency of SSOs, particularly if the interceptor can be sealed and allowed to flow under pressure (see **Figure 5-1**). However, CRW does not recommend pressurizing the interceptor at this time, as it is scheduled for structural repairs, and could not withstand pressurization in the near-term. Further decreases in the HGL can be achieved under CSO control options for the Hemlock Interceptor involving flow reduction through green infrastructure, storage/post-storm pump-back, and/or satellite treatment. A major upgrade to the Spring Creek pump station is required to address outdated equipment and controls, and potential reconfiguration and/or expansion of the pump station will be evaluated as part of the CSO LTCP.

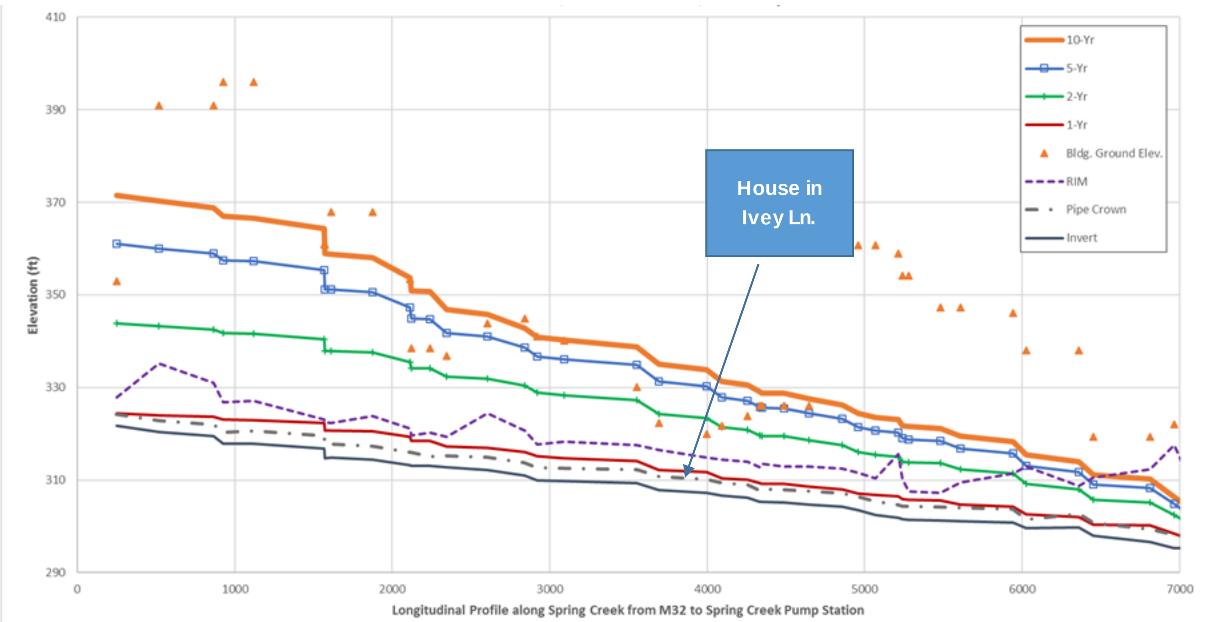

Figure 5-1: Max Water Surface Elevation along Spring Creek Interceptor Under 1-, 2-, 5-, and 10-year Design Storms

Early Action Recommendations for the Spring Creek Interceptor

CRW will investigate the possibility of bolting down additional manhole covers to seal the individual manholes and allow surcharged wastewater flows to leave the manhole as SSO discharges into Spring Creek. CRW will also coordinate with Swatara Township to define a practical limit to sewer surcharging and establish a specific manhole to serve as a temporary relief point until long-term controls can be established.

5.3.2 Asylum Run Improvements

The Asylum Run tributary trunk sewer rehabilitation and replacement project involves the following:

- Installation of a new 24” gravity sewer with an alternate alignment, totaling approximately 1,150 LF, to facilitate abandonment of the existing 24” gravity sewer located in the stream and/or beneath steep slopes,
- CIPP lining of approximately 2,300 LF of 20”-24” VCP, including stream stabilization in key areas,
- Elimination of one of two stream crossing by re-routing the gravity sewer,
- Replacement of a 10” existing gravity sewer stream crossing, including new manholes, and
- Manhole stabilization and rehabilitation.

5.3.3 Capacity Constraints along CRW Separate Sanitary Trunk Sewers

The H&H model simulations and capacity assessment analyses identified localized capacity constraints within CRW's separate sanitary trunk sewer system that can be addressed as an early action in advance of the CSO LTCP.

Separate Sanitary Trunk Sewers Discharging to the Spring Creek Interceptor. The completed model analyses indicate that the capacity constraints along the Spring Creek interceptor could result in potential basement flooding within the apartment buildings within the Ivey Lane complex during design storm events. Capacity constraints along the Nineteenth Street sewer could result in potential basement backups within homes located on the down-hill side of the street during design storm events. Until a long-term solution is implemented, CRW will conduct detailed surveys to accurately determine the basement floor elevations for each of the apartment building within the Ivey Lane Apartment complex and along Nineteenth Street. These floor elevations would be used to set accurate target goals for the LTCP development process and help determine an optimal solution for the interceptor capacity restrictions. No basement backups have been reported from the residents living in these structures. However, if any the surveyed basement elevations were found to be below the computed hydraulic grade line elevations associated with the 2-year design storm, backflow prevention valves would be installed along the service laterals of these apartments.

***Separate Sanitary Trunk Sewers Discharging to the Front Street Interceptor*:** The completed analyses indicate that capacity constraints along Manor, Shamokin, Diversion, Third, and Wiconisco Streets, located within the delineated SS-001, SS-002, and SS-03 catchments, could result in potential basement backups within several the homes along the streets during synthetic design storm events. CRW will conduct detailed surveys to accurately determine the basement floor elevations for each of the residential homes identified as being potentially at risk for basement flooding during design storm flow conditions. No basement flooding has been reported from any of the residents living in these homes. However, if any the surveyed basement elevations were found to be below the computed hydraulic grade line elevations associated with the 2-year design storm, backflow prevention valves would be installed along the service laterals of these homes.

***Separate Sanitary Trunk Sewers Discharging to the Paxton Creek Interceptor*:** The completed analyses indicated that there were potential capacity constraints along the Industrial Road trunk sewer, with none projected to cause an SSO during the 2-year to 10-year design storms (with the exception of one manhole attributed to manhole variability, as stated above). Most of the commercial industrial facilities within the tributary sewershed area are directly connected to the trunk sewer and were built upon slab foundations. While no basement backups have been reported, the model showed that the freeboard within the trunk sewer manholes was less than 4 feet from the rim elevations.

The completed flow analyses for the data collected from the SSMH-0254 metering site along Industrial Road indicated that ground water infiltration (GWI) quantities were excessive and consuming much of the available capacity within the trunk sewer. The completed rapid assessment surveys indicated there were multiple points along the sewer with observed infiltration flows. As an early action project, CRW has recently completed a detailed CCTV inspection along the Industrial Road trunk sewer, and is reviewing the data. If the investigations were to demonstrate that observed infiltration flows could be cost-effectively removed, effectively increasing the available wet weather capacity, a sewer lining project may be implemented.