



**Long Term Control Plan
Update**

Combined Sewer System Characterization

**City of Alexandria
Department of Transportation and Environmental Services**

FINAL – September 2014



GREELEY AND HANSEN

Combined Sewer System Characterization

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Combined Sewer System Characterization

Executive Summary

Executive Summary

The City of Alexandria's sewer system covers approximate 15.4 square miles and consists of both a separate sewer system and a 544 acre combined sewer system (CSS). During wet weather, flows in the CSS discharge to the surrounding waterbodies through four outfalls that serve three subareas within the CSS (Outfall 003 and Outfall 004 serve the same subarea):

- Pendleton Street CSO (Outfall 001);
- Royal Street CSO (Outfall 002);
- Duke Street CSO (Outfall 003); and
- Hooffs Run CSO (Outfall 004).

The regulator structures at each of these outfalls are configured and function differently. The Outfall 001 regulator consists of a side weir which, when overtopped, discharges into Oronoco Bay during wet weather events. The Outfall 002 regulator consists of a gate that closes when flows in the nearby Potomac Interceptor becomes surcharged. When this gate is closed, all flow from this CSS subarea is discharged into tidal Hunting Creek. The Outfall 003 regulator consists of an orifice in the bottom of the combined sewer. When flows become larger than what can be conveyed through the orifice, it continues to the outfall pipe and is discharged into Hooffs Run. A project is now under construction (Summer 2014) to improve the Outfall 003 regulator to provide for easier maintenance. The Outfall 004 regulator consists of a weir and a slightly elevated overflow pipe in series. When flow becomes so large that it overtops the weir and the water surface is high enough to reach the invert of the overflow pipe, it is discharged into Hooffs Run downstream of Outfall 003.

The information contained in this technical memorandum will be utilized in evaluating combined sewer overflow (CSO) control alternatives for the City of Alexandria's Long Term Control Plan Update (LTCPU). In particular, the existing CSO controls will be evaluated relative to the City's overall strategy. The LTCPU will only evaluate CSO controls at Outfall 002, Outfall 003, and Outfall 004 as required by the Hunting Creek TMDL. Outfall 001 is not part of the Hunting Creek TMDL and therefore will not be evaluated as part of this effort.

Combined Sewer System Characterization

Section 1

Section 1 Introduction

1.1 Sewer System Overview

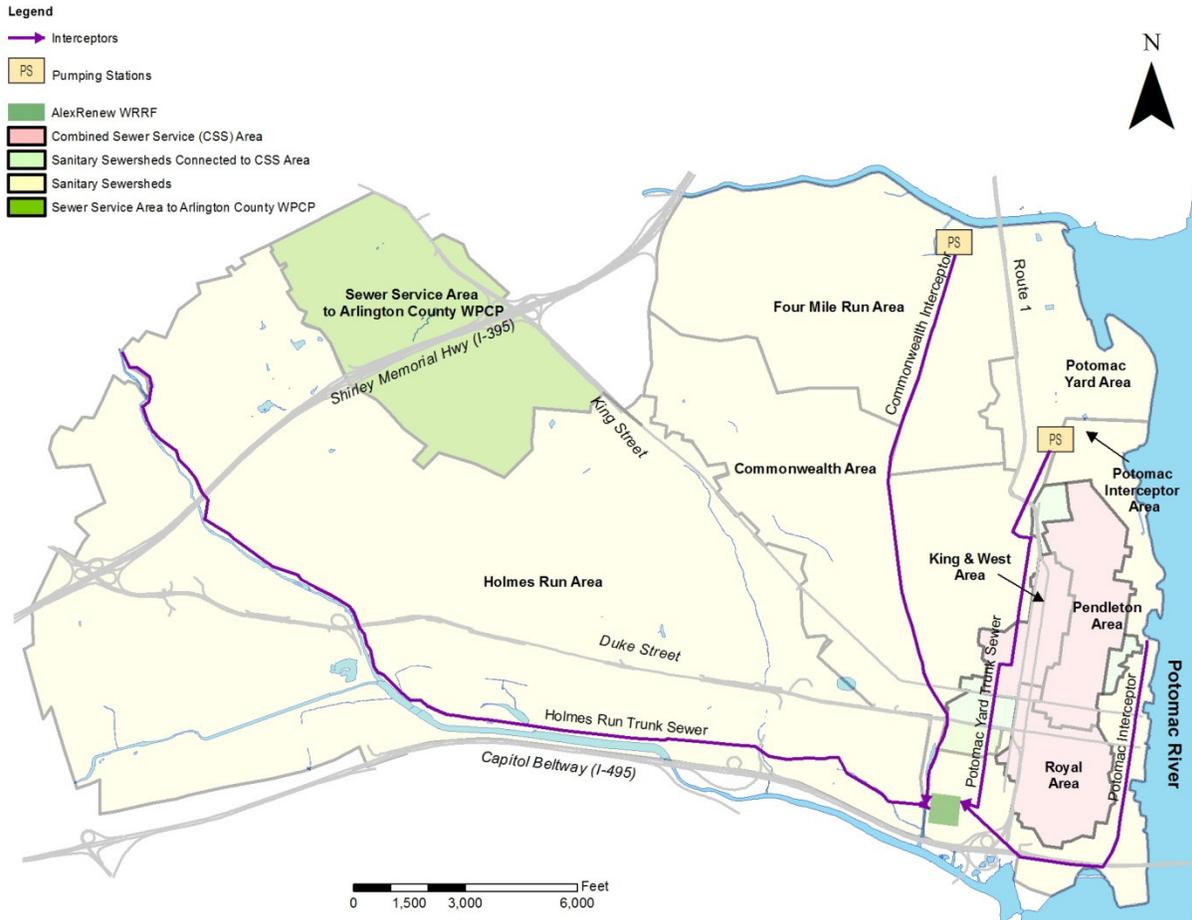
The City's wastewater collection system covers approximately 15.4 square miles. Wastewater treatment services are provided by Alexandria Renew Enterprises (AlexRenew) and Arlington County. Approximately 1.2 square miles (7.8 %) is serviced by the Arlington County Water Pollution Control Plant (WPCP). The rest of the City is served by the AlexRenew Water Resources Recovery Facility (WRRF); AlexRenew also accepts flows from Fairfax County.

There are four AlexRenew operated interceptors in the City including the Holmes Run Trunk Sewer, the Commonwealth Interceptor, the Potomac Interceptor, and the Potomac Yard Trunk Sewer. The Holmes Run Trunk Sewer is a joint use interceptor shared by the City and Fairfax County. The dry weather flows from the four interceptors, which are operated by AlexRenew terminate at the WRRF. An overview of the system and the interceptor sewers and sewersheds they serve can be seen in Figure 1-1.

Combined Sewer System Characterization

Section 1

**Figure 1-1
 Sewer System Overview**



1.2 Combined Sewer System (CSS)

The City of Alexandria owns and operates a combined sewer system (CSS) comprising approximately 540 acres that is generally located in the Old Town area east of U.S. Route 1. During dry weather, sanitary wastes collected in the CSS are conveyed to the WRRF, owned and operated by AlexRenew. During periods of rainfall, the capacity of the CSS may be exceeded and excess flow, which is a mixture of stormwater and sanitary wastes, is discharged directly to Hunting Creek, Hooffs Run, or Oronoco Bay through the City’s four permitted combined sewer overflow (CSO) outfall structures. The following CSO outfalls are regulated under the City’s Virginia Pollutant Discharge Elimination System (VPDES) Permit No. VA0087068:

Combined Sewer System Characterization

Section 1

**Table 1-1
 CSO Outfalls**

| Permitted Outfall Number | Description |
|--------------------------|----------------------|
| 001 | Pendleton Street CSO |
| 002 | Royal Street CSO |
| 003 | Duke Street CSO |
| 004 | Hooffs Run CSO |

The location of the CSS and the outfalls are shown in Figure 1-2 on the following page.

1.2.1 Combined Sewer System Sewersheds

The CSS is divided into three separate combined sewer subareas based on the conveyance of combined sewer flow to the outfalls. These subareas are shown in Figure 1-2. A brief description of each subarea is provided below:

- King and West Area – This area encompasses approximately 120 acres and is served by two CSO structures (CSO-003 and CSO-004). The CSO-003 is a diversion structure located on West Street near the intersection with King Street. During dry weather and wet weather, flows are diverted from a large combined sewer to a smaller parallel 21-inch sewer. Once the level in the larger combined sewer rises and overtops a weir, these flows are directed into the Peyton Street combined sewer and discharge through Outfall 003 into Hooffs Run under Duke Street. The CSO-004 structure is called the Duke Street Siphon Chamber and consists of two siphons and a weir between the primary and secondary siphons, which are connected to the Commonwealth Interceptor. If combined sewage overtops this weir it flows into the secondary siphon. Depending on the depth of flow over the weir, flow may also be directed to the CSO-004 outfall in Hooffs Run.
- Royal Area – This area encompasses approximately 194 acres. Combined sewage enters two large trunk sewers that flow south along Royal Street to a diversion structure. Sanitary flow is directed to the Potomac Interceptor through a float/gate regulator structure. During dry weather the gate is fully open and the dry weather flows are conveyed to the WRRF. During wet weather when flows in the Potomac Interceptor are surcharged, the float is activated and closes the gate so that flow from the Royal Area cannot enter the interceptor. Combined sewage then crests the weir at the diversion structure is directed to Outfall 002.
- Pendleton Area – This area encompasses approximately 230 acres. Combined sewage enters a large combined trunk sewer that runs east along Pendleton Street to a diversion weir located at the intersection of Pendleton and Union Streets. During dry weather, sanitary flow is directed into the Potomac Interceptor that flows to the AlexRenew WRRF. During wet weather events, combined sewage will continue to enter the Potomac Interceptor. Once the depth of sewage reaches the weir height, combined sewage is discharged to Outfall 001.

Combined Sewer System Characterization

Section 1

Figure 1-2
CSS Overview



Combined Sewer System Characterization

Section 2

Section 2 Geologic Conditions

Several geotechnical investigations have taken place within the CSS area, specifically the Wythe Street Tunneling Project, the Payne and Fayette Sewer Separation Project, and the Jefferson-Houston Geotechnical Exploration. In addition, published literature was researched regarding the geology for the CSS area. According to the *Geologic Map of Virginia* (1993), the area is located in the Coastal Plain Physiographic Province. The CSS area is underlain by unconsolidated sand, silt, clay, and gravel strata deposited by ancient oceans and freshwater rivers. The CSS is located in the Low Coastal Plain, occupying the low, flat and wet portions of the Hybla Valley, Mason Neck, and Gunston Cove. These areas typically have high water tables and thick subsoil clay layers with overall drainage to the southeast. Please refer to the above referenced publication for a more detailed description of the geologic unit.

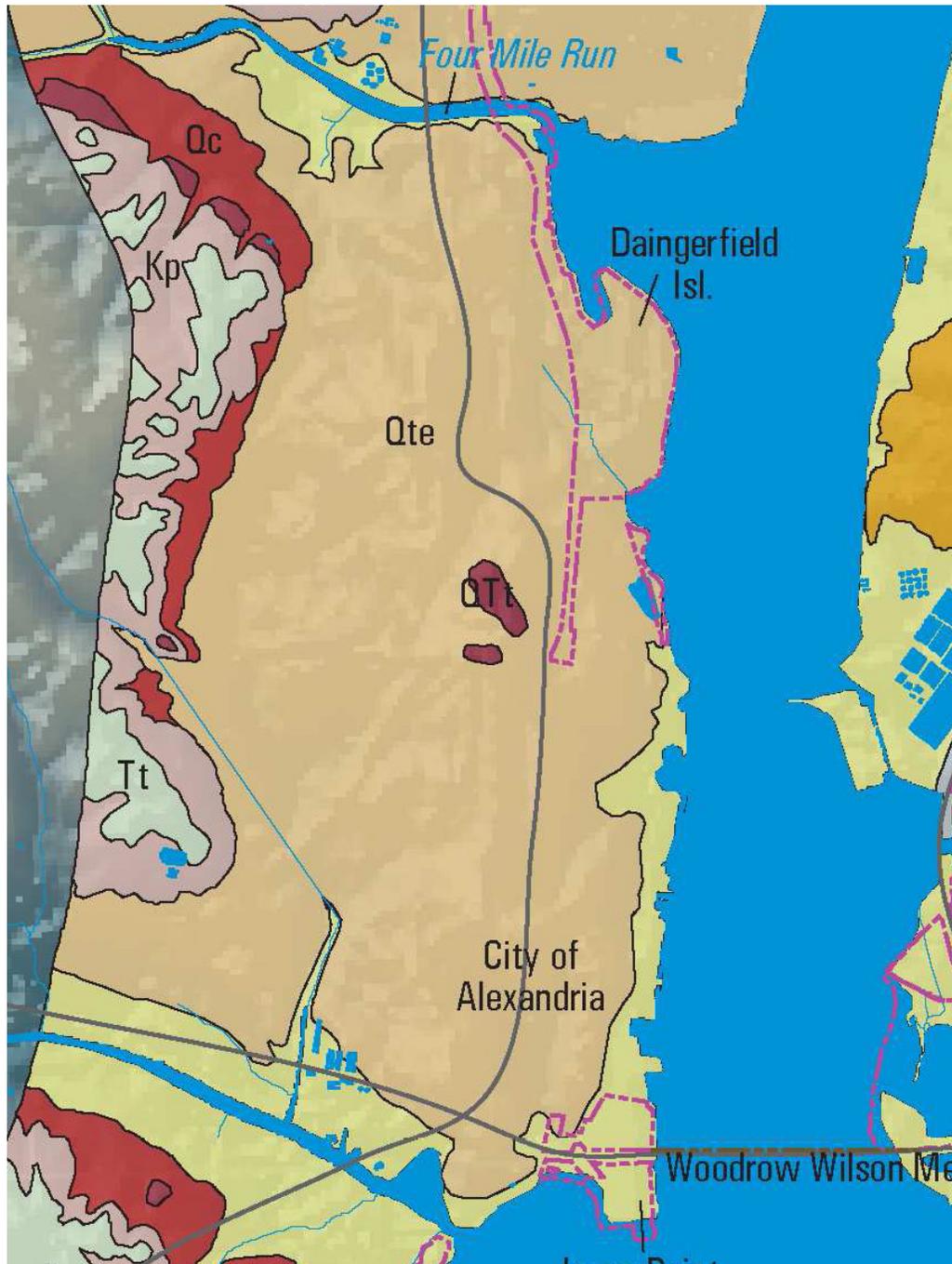
According to the Natural Resources Conservation Service (NRCS) Online Soil Survey the site consists of Urban land Grist-Mill (98). Urban land Grist-Mill is described as a mixture of impervious man-made materials that comprise Urban Land and the development disturbed Grist Mill soil. It is found in very densely developed, low elevation areas of the Coastal Plain. Most of the soil areas are covered with impervious paving and rooftop but there are many areas of graded and compacted soils. The permeability is highly reduced due to the existing impervious surfaces with majority of precipitation converting to runoff. It is classified as a Class IVB soil type. More specifically Figure 2-1 shows the predominate soil type in the CSS area, with type Qte (low-level fluvial and estuarine deposits (Pleistocene)) being the most abundant.

Based on the boring logs from the three projects above, silty lean clay composes the top 3-4 feet of cover throughout the CSS. Below that is a layer of silty sand, this layer extends to a depth of at least 20 feet. None of the boring logs went to a depth greater than 20 feet. In nearly all cases groundwater was encountered at a depth of 10-18 feet.

Combined Sewer System Characterization

Section 2

Figure 2-1
Soil Types in Alexandria



Combined Sewer System Characterization

Section 3

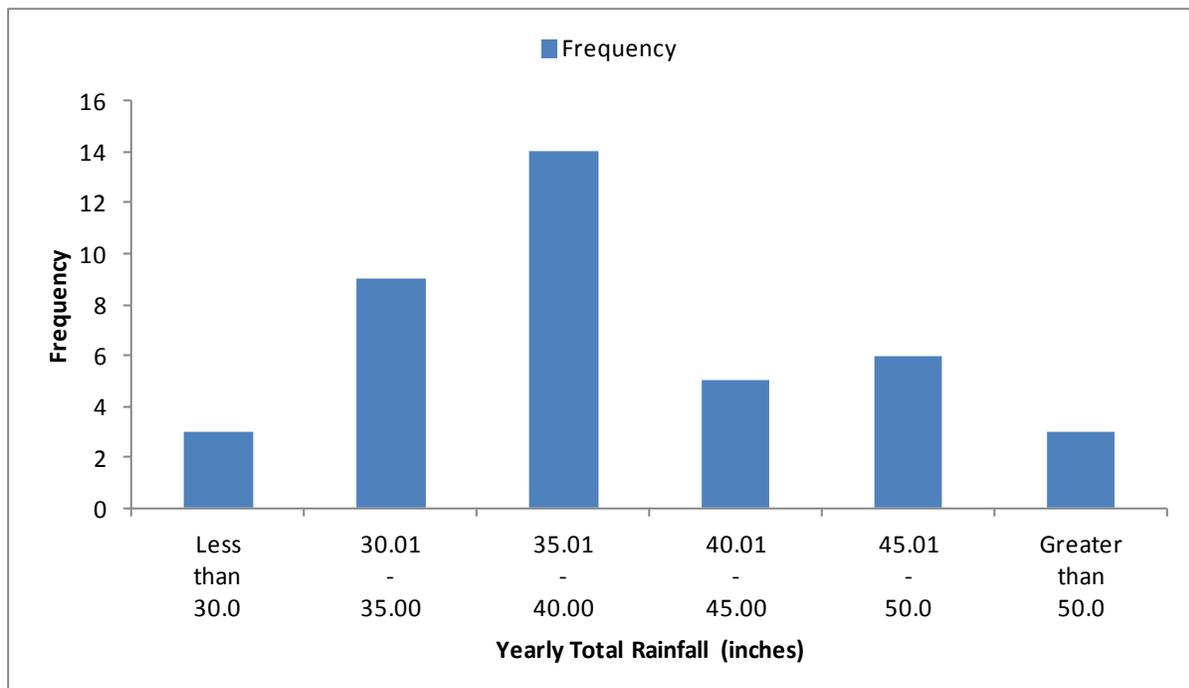
Section 3 Meteorological Conditions

The meteorological conditions for the City of Alexandria consist of many characteristics such as temperature, pressure, and precipitation. Most important to Hunting Creek is the amount and type of precipitation. The precipitation conditions directly impact the volume of combined sewer overflow (CSO), which directly impacts the bacterial loads in Hunting Creek. This section will characterize the precipitation that the City of Alexandria receives during a typical calendar year.

Climate, in a very simple term, can be defined as the “average weather” over a period of time ranging from several months to thousands of years. For the purpose of this report, the characterization was performed by evaluating the last 40 years (1974 – 2013) of hourly precipitation data from Ronald Reagan National Airport.

During this time period, the total rainfall was approximately 1,555 inches. Average yearly rainfall ranged from 28.74 inches per year to 58.30 inches per year; throughout the 40 years, the average yearly rainfall was 38.88 inches. The distribution of the yearly total rainfall can be seen in Figure 3-1. The distribution is positively skewed which indicates that majority of the yearly total rainfall values are on the lower end of the range.

Figure 3-1
Histogram of Yearly Total Rainfall



Combined Sewer System Characterization

Section 3

It is also important to look at the individual precipitation events, specifically the larger events, and the way in which each event occurred over time. Typically, the five to ten largest events in a year produce a majority of the CSO volume. One way to determine the typical 10 largest events is to average the largest events per year across all 40 years, followed by averaging the second largest event per year across all 40 years, and so on. Table 3-1 shows the results of this analysis for the ten largest storms on average.

Table 3-1
Ten Largest Storms for an Average Year

| Rank | Depth of Rainfall (inches) |
|------|----------------------------|
| 1 | 3.23 |
| 2 | 2.23 |
| 3 | 1.90 |
| 4 | 1.70 |
| 5 | 1.53 |
| 6 | 1.38 |
| 7 | 1.32 |
| 8 | 1.22 |
| 9 | 1.15 |
| 10 | 1.09 |

In addition to volume it is also important to evaluate the intensity. Intensity is important because the higher the intensity, the more likely the sewer system will not be able to convey the amount of flow entering the sewer system and it could yield surcharging of the sewers or even localized flooding. The calculations to determine the ten largest peak intensities in an average year were performed in the same manner as the calculations for the ten largest volumes in an average year. Table 3-2 presents the ten largest peak intensities averaged over all 40 years examined.

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Table 3-2
Ten Largest Peak Intensities for an Average Year

| Rank | Peak Intensity of Event (in/hr) |
|------|---------------------------------|
| 1 | 1.16 |
| 2 | 0.89 |
| 3 | 0.74 |
| 4 | 0.66 |
| 5 | 0.58 |
| 6 | 0.54 |
| 7 | 0.50 |
| 8 | 0.47 |
| 9 | 0.43 |
| 10 | 0.41 |

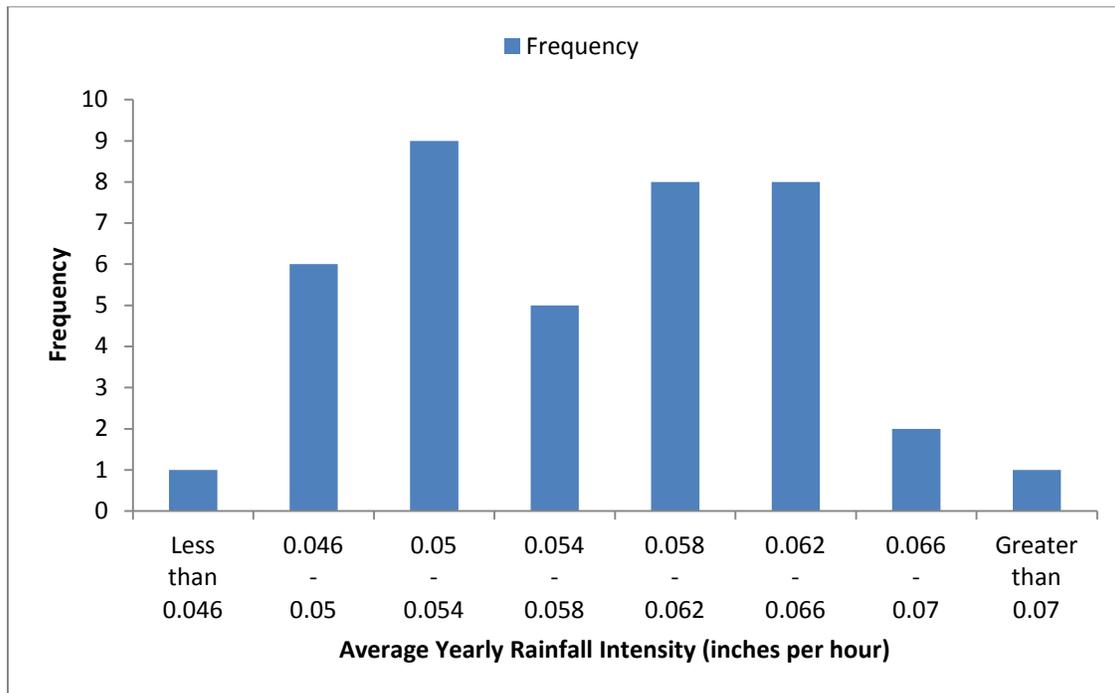
It is important to note that the ten largest volume events do not typically correspond to the ten largest peak intensity events.

The average rainfall intensity for an individual calendar year ranged from 0.039 inches per hour to 0.081 inches per hour; throughout the 40 years, the average annual rainfall intensity was 0.057 inches per hour. The distribution of the average rainfall intensity can be seen in Figure 3-2. The distribution is fairly normal which indicates that majority of the average yearly rainfall values are relatively close to the average yearly rainfall intensity.

Combined Sewer System Characterization

Section 3

Figure 3-2
Histogram of Average Yearly Rainfall Intensity



Further in-depth analysis of rainfall data will be presented in another technical memo titled *Typical Year Selection*. This technical memo will also recommend an actual year of precipitation in which CSO controls will be evaluated against.

Combined Sewer System Characterization

Section 4

Section 4 Population Estimates

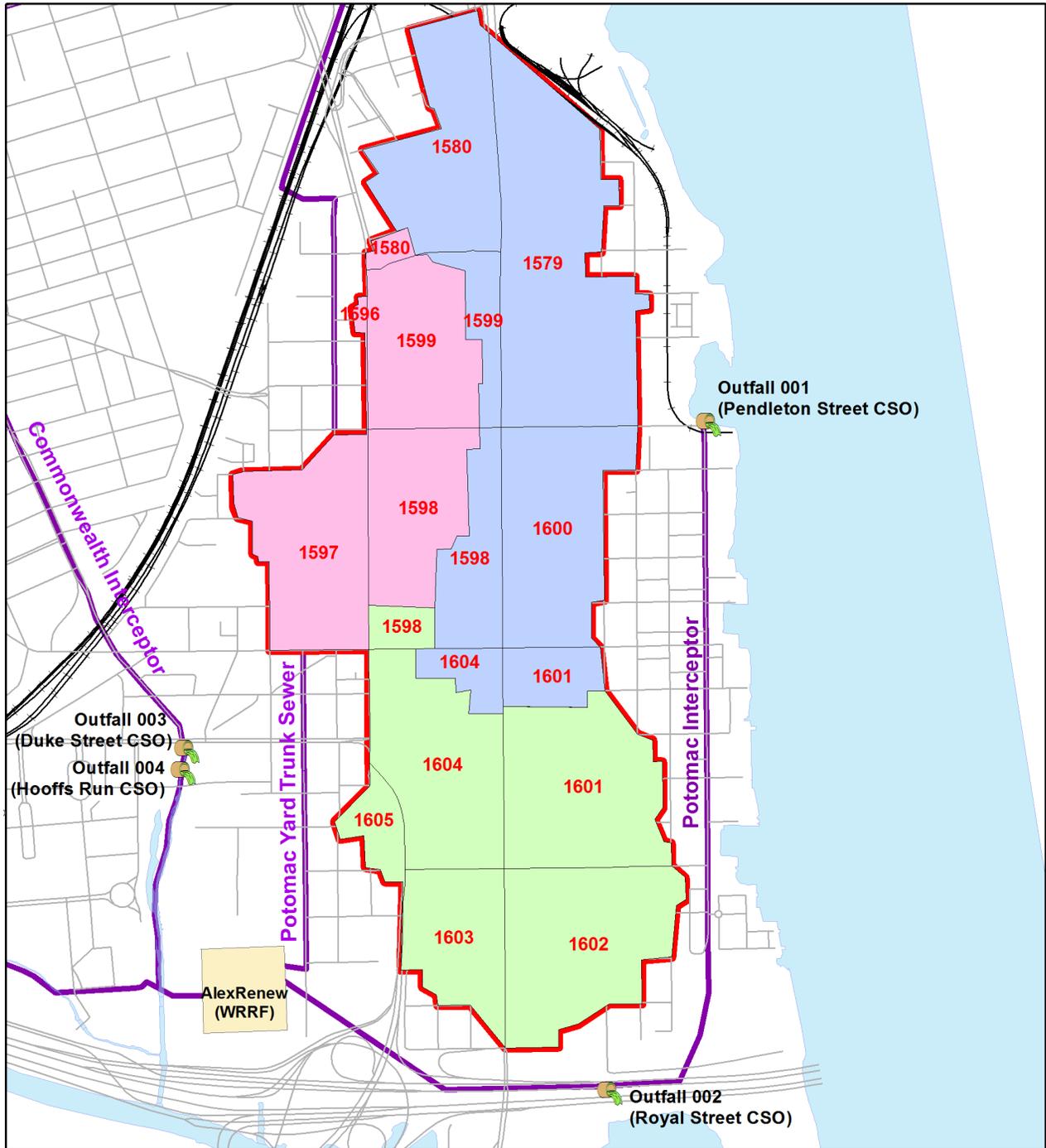
According to the most recent official Census 2010 estimates, there are approximately 140,000 people living in the City of Alexandria with an area of approximately 15.4 square miles. The current 2013 population estimate is 148,892¹. The CSS is approximately 540 acres (5.48%); however the US Census data does not include enough detail to determine the number of people living within and served by the CSS. To more accurately determine the number of people living within the CSS, Traffic Analysis Zone (TAZ) data was used. Traffic Analysis Zones are small geographic zones that forecast population and employment typically used in transportation planning but can be adapted for other uses. The TAZ data used for this estimate came from the Metropolitan Washington Council of Governments (MWCOG) which is an independent nonprofit association that brings area leaders together to address major regional issues in the District of Columbia, suburban Maryland, and Northern Virginia. MWCOG publishes many studies, reports, and other types of data related to planning in and around the DC metropolitan area. The location TAZ data is shown in Figure 4-1.

¹ 2013 population estimate from US Census (<http://quickfacts.census.gov/qfd/states/51/51510.html>)

Combined Sewer System Characterization

Section 4

Figure 4-1
TAZ Data Location



Combined Sewer System Characterization

Section 4

Based on this data the population for each of the CSS areas is estimated in Table 4-1 below:

**Table 4-1
 2013 Population Estimates**

| CSS Subshed | Households | Persons | Employees |
|------------------------------------|-------------------|----------------|------------------|
| Pendleton (CSO-001) | 2,195 | 3,897 | 7,464 |
| Royal (CSO-002) | 1,850 | 3,328 | 4,295 |
| King & West (CSO-003 & CSO-004) | 1,189 | 2,624 | 2,819 |
| Total | 5,234 | 9,849 | 14,578 |

The data shows that there are more employees located in the CSS than there are residents. This is evident from the number of businesses and associations that are located within the CSS. These businesses and associations are an important economic driver for the City. When evaluating CSO control alternatives it is important to keep in mind the impact that a particular control will have on both residents and businesses alike.

Using TAZ data, population estimates were also derived for year 2040, as shown in Table 4-2 below.

**Table 4-2
 2040 Population Estimates**

| CSS Subshed | Households | Persons | Employees |
|------------------------------------|-------------------|----------------|------------------|
| Pendleton (CSO-001) | 2,794 | 5,114 | 7,750 |
| Royal (CSO-002) | 2,030 | 3,698 | 4,401 |
| King & West (CSO-003 & CSO-004) | 1,603 | 3,466 | 3,120 |
| Total | 6,427 | 12,278 | 15,271 |

Combined Sewer System Characterization

Section 5

Section 5 Land Use

In order to assess the type, level, and cost of CSO control alternatives, particularly green infrastructure, it is important to understand the land cover and ownership. Using GIS data for the City of Alexandria, the land cover was broken down into several categories:

- Roads and alleys;
- Sidewalks;
- Driveways;
- Parking Lots;
- Buildings; and
- Pervious Cover (green space).

In addition it was important to consider whether the land was owned by the City or if it was privately owned. Determining the amount of City-owned land is necessary because implementing CSO controls or green infrastructure on City land will be easier to implement than if it is on private land.

The table below shows the breakdown of land use. It should be noted that the public areas reported in Table 5-2 are included in Table 5-1 below.

**Table 5-1
 Land Use Summary**

| Land Use | Pendleton Area acres (%) | Royal Area acres (%) | King and West Area acres (%) | Total CSS Area acres (%) |
|---------------------------------|-----------------------------|-------------------------|---------------------------------|-----------------------------|
| Roads and Alleys | 56.3 (24%) | 44.6 (23%) | 26.7 (22%) | 127.6 (23%) |
| Sidewalks | 22.5 (10%) | 19.4 (10%) | 10.2 (9%) | 52.1 (10%) |
| Driveways | 3.1 (1%) | 2.5 (1%) | 2.7 (2%) | 8.3 (2%) |
| Parking Lots | 26.6 (12%) | 17.3 (9%) | 8.7 (7%) | 52.6 (10%) |
| Buildings | 64.9 (28%) | 48.2 (25%) | 32.3 (27%) | 145.4 (27%) |
| Pervious Cover (green space) | 56.9 (25%) | 62.3 (32%) | 38.8 (33%) | 158.0 (29%) |
| Total | 230.3 | 194.3 | 119.4 | 544 |

This table shows that the CSS area is approximately 71% impervious, although it varies within each subshed (Pendleton area = 75%, Royal area = 68%, and King and West area = 67%). It is important to note that a majority of the roads, alleys, and sidewalks in the table above are City-owned and are not shown in Table 5-2 for simplicity.

Combined Sewer System Characterization

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Table 5-2
Land Use Summary for City-owned Parcels

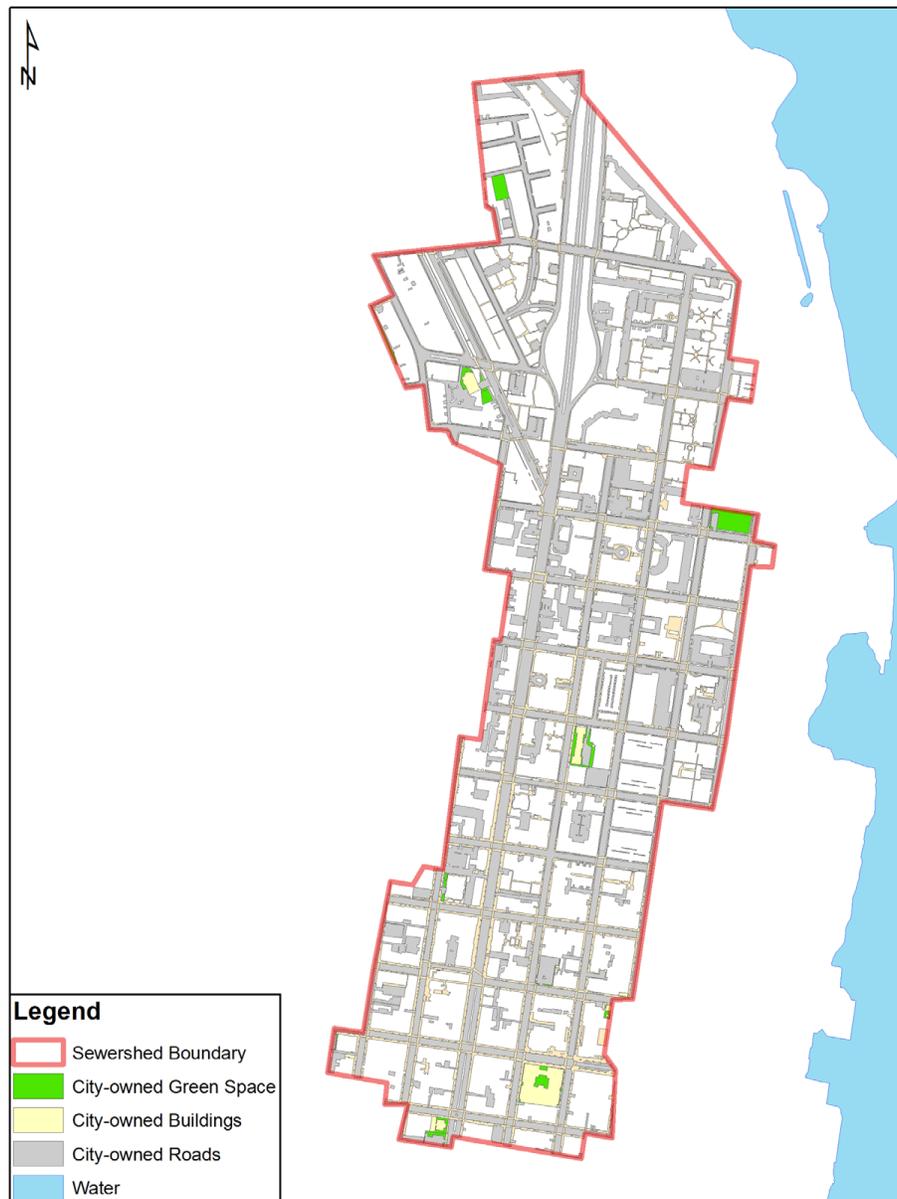
| Land Use | Pendleton Area acres (%) | Royal Area acres (%) | King and West Area acres (%) | Total CSS Area acres (%) |
|---------------------------------|-----------------------------|-------------------------|---------------------------------|-----------------------------|
| Driveways | 0.1 (1%) | 0.0 (0%) | 0.0 (0%) | 0.1 (1%) |
| Parking Lots | 1.3 (23%) | 1.0 (28%) | 0.4 (13%) | 2.7 (21%) |
| Buildings | 2.3 (41%) | 0.6 (17%) | 1.0 (33%) | 3.9 (32%) |
| Pervious Cover (green space) | 2.0 (35%) | 2.0 (55%) | 1.6 (54%) | 5.6 (46%) |
| Total | 5.6 | 3.6 | 3.0 | 12.2 |

Combined Sewer System Characterization

Section 5

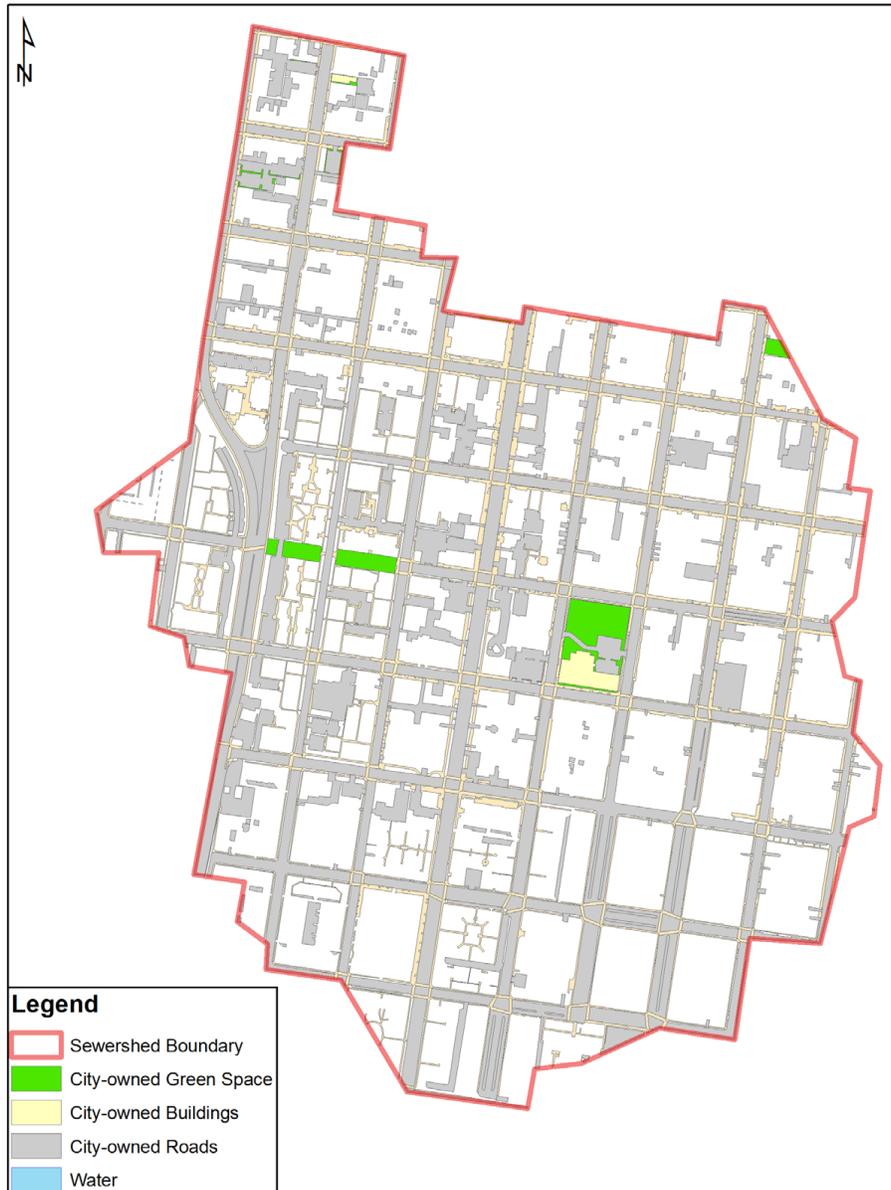
Figure 5-1 through Figure 5-3 shows the location of green space within the CSS area. Privately-owned green space is shown in blue while City-owned green space is shown in green.

Figure 5-1
Green Space in the Pendleton Area



Combined Sewer System Characterization

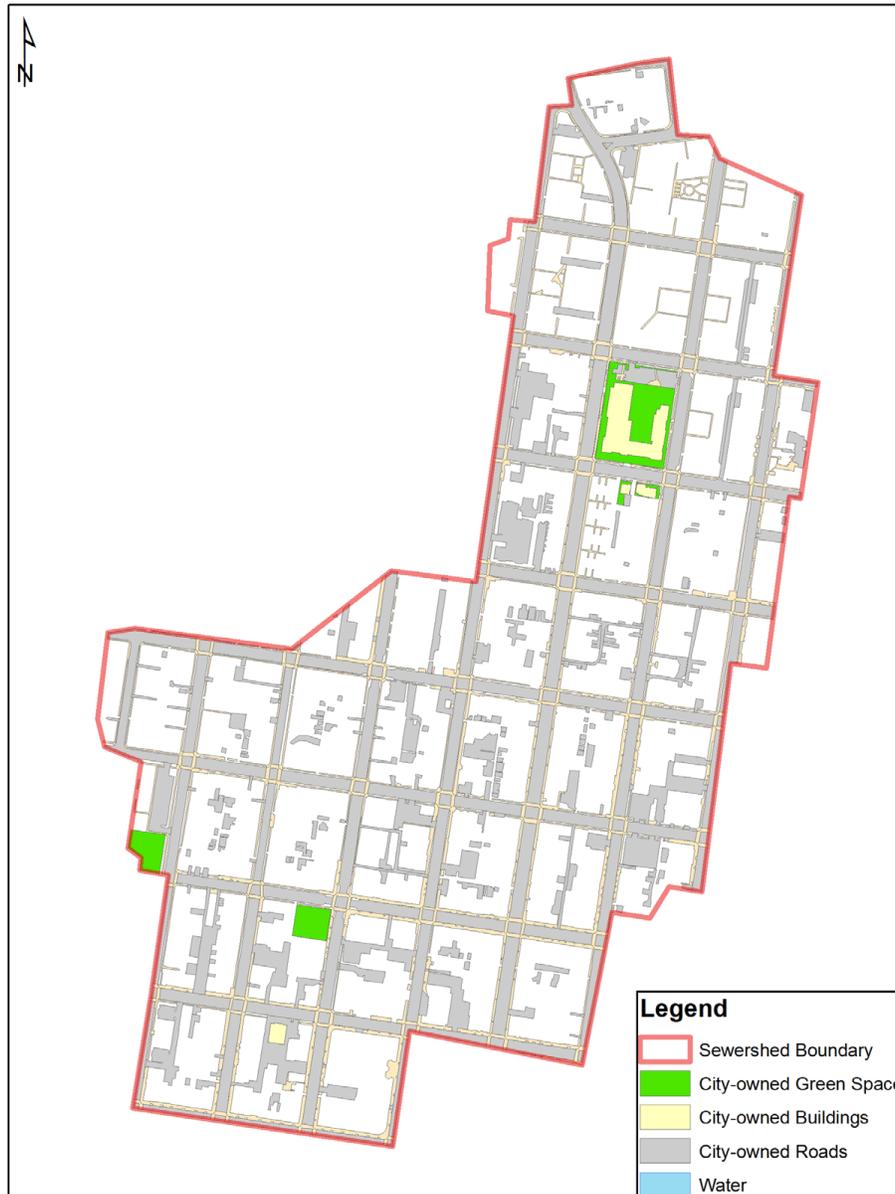
Figure 5-2
Green Space in the Royal Area



Combined Sewer System Characterization

Section 5

Figure 5-3
Green Space in the King and West Area



Combined Sewer System Characterization

Section 6

Section 6 City Initiatives

6.1 Eco-City Charter

The City of Alexandria has several initiatives aimed at improving water quality around the region. One of the major initiatives is the Eco-City Charter. This charter sets forth goals and principles to guide Alexandria toward environmental sustainability. It focuses on land use and open space, water resources, air quality, transportation, energy, building green, solid waste, environment and health, emerging threats, and implementation. In addition to the charter, the City also worked developed an *Environmental Action Plan 2030* (EAP 2030). This document serves as a road map for City leaders and residents to implement the Eco-City Charter. The EAP 2030 outlines 48 goals, 50 targets, and 353 actions for the next 20 years to lead the City towards environmental sustainability.

The water resources goals for the EAP 2030 focus on four main areas to improve receiving water quality:

- Stormwater runoff;
- The stormwater and sanitary sewer systems;
- Water conservation; and
- The combined sewer system.

While all of these areas will help to improve water quality, this Long Term Control Plan Update (LTCPU) focuses on the combined sewer system. The goal for the combined sewer system in the EAP 2030 is:

“Eliminate the harmful impact of the combined sewer systems in the long-term, and minimize them in the short term.”

With the following actions to be taken:

Short-Term Actions (2009-2011)

- Continue to comply with Virginia Pollutant Discharge Elimination Permit (VPDES) for CSO discharges.
- Continue to be proactive in enhancing efforts to continue to implement the Area Reduction Plan.

Mid-Term & Long-Term Actions (2012-2030)

- As development occurs in areas served by combined sewers, require developers of new buildings to build separate sanitary sewer and stormwater infrastructure as a condition of development approval.
- Study the effectiveness of overflow storage, low-impact development, and sewer separation to achieve federal CSO requirements and incorporate any of these methods into the City’s CSO eliminations strategy determined to be cost-effective.
- Study funding options for the City’s CSO elimination strategy, including State revolving funds.
- Optimize waterfront development opportunities and address the need for adaptation to global climate change.

Combined Sewer System Characterization

Section 6

6.2 Area Reduction Plan

In 2005, the City developed an Area Reduction Plan (ARP); in 2013 the ARP received a minor update to clarify language. The ARP is a plan for separating the entire combined sewer system over time and as redevelopment takes place within the CSS. While it is cost prohibitive and extremely disruptive to the Old Town area to separate the entire system at once, separation over time is an effective means to reduce the size of the combined sewer system and meet the waste load allocations in the Hunting Creek TMDL. The City has taken the initiative to implement the ARP as a requirement of redevelopment projects within the CSS. Developers who want to redevelop areas within the CSS are required to separate the sewers that serve their area, separate an equivalent area somewhere else within the CSS if separation of that specific area is deemed infeasible due to the lack of nearby separated sewers, or contribute monies to fund City-led sewer separation projects, including the Payne and Fayette sewer separation project currently in design. This program has successfully separated close to 14 acres from the combined sewer system since it was implemented, including City-led sewer separation projects. Areas separated are shown on Figure 6-1.

The LTCPU may consider the progressive reduction in sanitary flows over time within the CSS due to the ARP.

Combined Sewer System Characterization

Section 6

6.3 Other City Initiatives

The City has also been proactive in looking for other ways to further reduce the impact of combined sewer system on the surrounding water bodies. One initiative the City has implemented to reducing the volume of combined sewer overflows is to reduce the amount of stormwater entering the system. This is being accomplished through the City's rain barrel and water harvesting program. The City has implemented a program in which residents of the City can attend "*Build Your Own Rain Barrel Workshops*". The City has been successful in handing out rain barrels to its residents and helping to reduce stormwater flows within the combined sewer system. The City is also working to implement stricter water use standards for all new construction. The City is looking at ways to require new development or redevelopment to install low flow appliances or gray water infrastructure where applicable.

Combined Sewer System Characterization

Section 7

Section 7 Combined Sewer Infrastructure

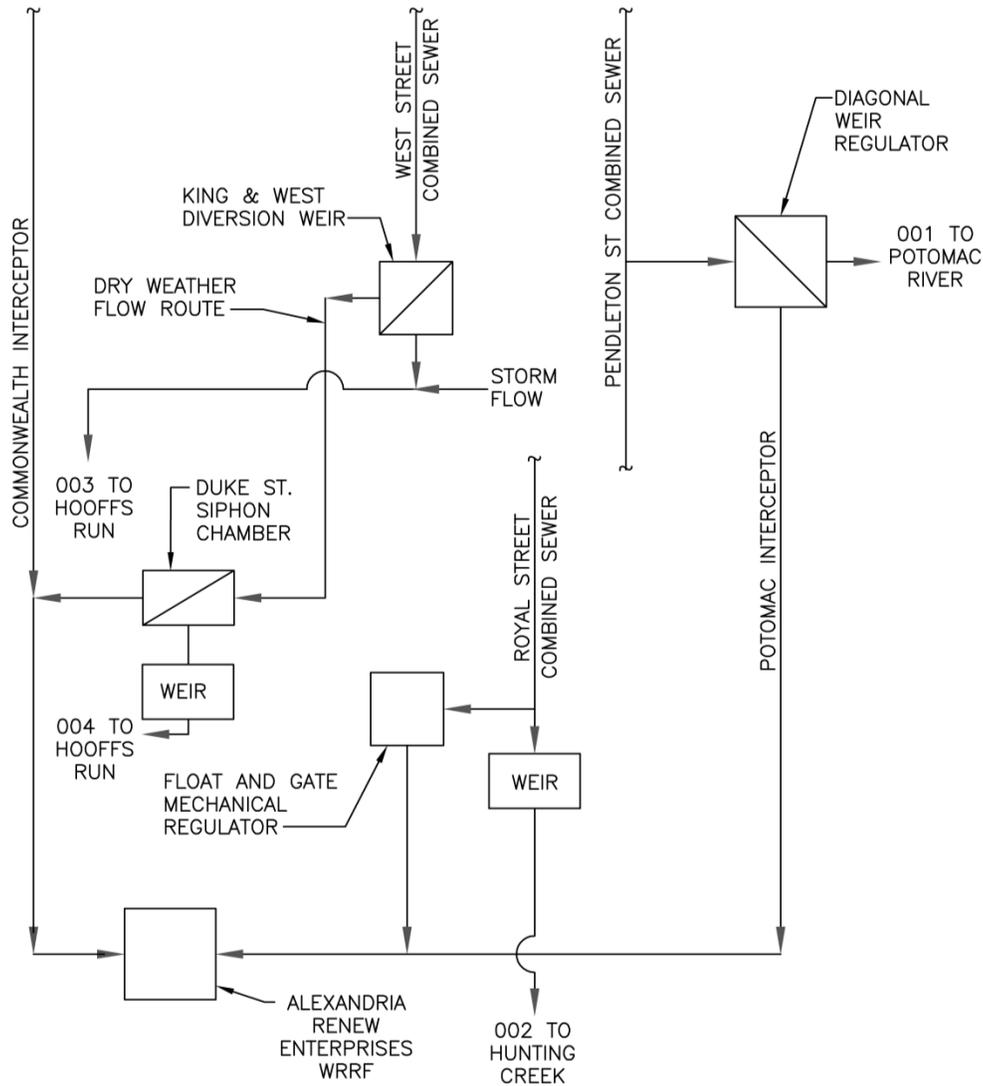
The CSS infrastructure has been constructed, extended, updated, and reduced over the last 200 years. Initially constructed to alleviate the City's issue with sewage in the streets, combined sewers were gradually constructed and expanded as the City's population grew. The original sewers simply discharged directly into the surrounding waterbodies until a wastewater treatment plant was built in the 1950's. With the treatment and its corresponding interceptor sewers built, new sewers were then separated so that stormwater (which can be up to 90% of the flows during wet weather events) would be discharged directly to the surrounding waterbodies while the sanitary sewage would be conveyed to the plant.

When the new interceptors and treatment plant were constructed it was necessary to modify the outfalls in the Old Town area to convey sanitary sewage to the plant while still allowing the system to relieve itself during wet weather events. As described in Section 1, the CSS has four permitted outfalls. A schematic of the combined sewer system is shown in Figure 7-1 and will be described in greater detail in the following subsections.

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**Figure 7-1
 Combined Sewer System Schematic Diagram**



Additionally, each sewershed is made up of a different length of combined, sanitary and storm pipes, with smaller diameter sanitary and storm sewers connected to larger diameter combined sewers that convey flow to the regulators. A breakdown of the length of combined, sanitary, and storm sewers in each of the sewersheds is shown in Table 7-1.

Combined Sewer System Characterization

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**Table 7-1
 Length of Sewers in Each Sewershed**

| Sewershed | Combined Sewers (miles) | Sanitary Sewers (miles) | Storm Sewers (miles) |
|--|------------------------------------|------------------------------------|---------------------------------|
| Pendleton (CSO-001) | 3.83 | 7.35 | 5.49 |
| Royal (CSO-002) | 3.10 | 7.71 | 2.94 |
| King and West (CSO-003 and CSO-004) | 3.02 | 3.11 | 1.40 |

The diameter of combined sewers range from 8 inches to 72 inches; the diameter of sanitary sewers range from 4 inches to 30 inches; and the diameter of storm sewers range from 4 inches to 60 inches.

Combined Sewer System Characterization

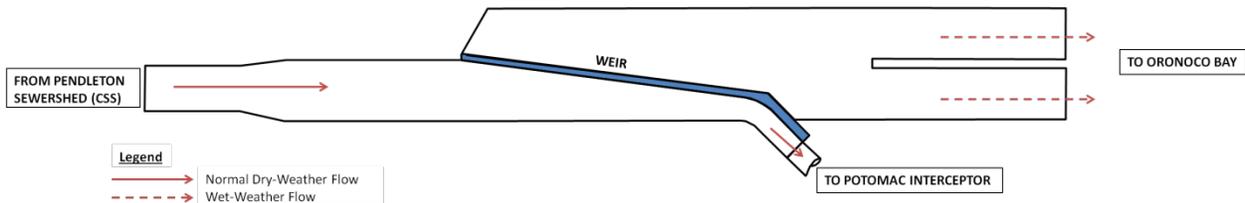
Section 7

7.1 Pendleton Street CSO (Outfall-001)

The Pendleton Street CSO regulates flows originating in the Pendleton Area of the CSS. The regulator structure at this CSO consists of a 40-foot long weir along the side of a 9-foot by 6-foot box culvert. This is a static weir with an elevation set just above the crown of the outgoing pipe. This allows the maximum amount of flow to be conveyed to the WRRF while reducing the potential for basement backups. During dry weather, flows from the Pendleton Area enter the structure, continue along the invert of the culvert below the top of the weir, and enter the 30-inch diameter Potomac Interceptor where they are conveyed to the treatment plant.

During wet weather, the flows entering the regulator are too high to be conveyed into the 30-inch Potomac Interceptor. When this happens, the flow begins to back up and the water level rises in the structure. Once the water level is high enough, it will overtop the 40-foot side weir and continue out the Pendleton Street tide gates where it discharges into Oronoco Bay.

Figure 7-2
Pendleton Street Diversion Structure



Although reductions at CSO-001 are not included as part of the Hunting Creek TMDL, combined sewer improvements in the Pendleton Area may be considered as part of the LTCPU and part of an overall strategy for reducing CSO impacts.

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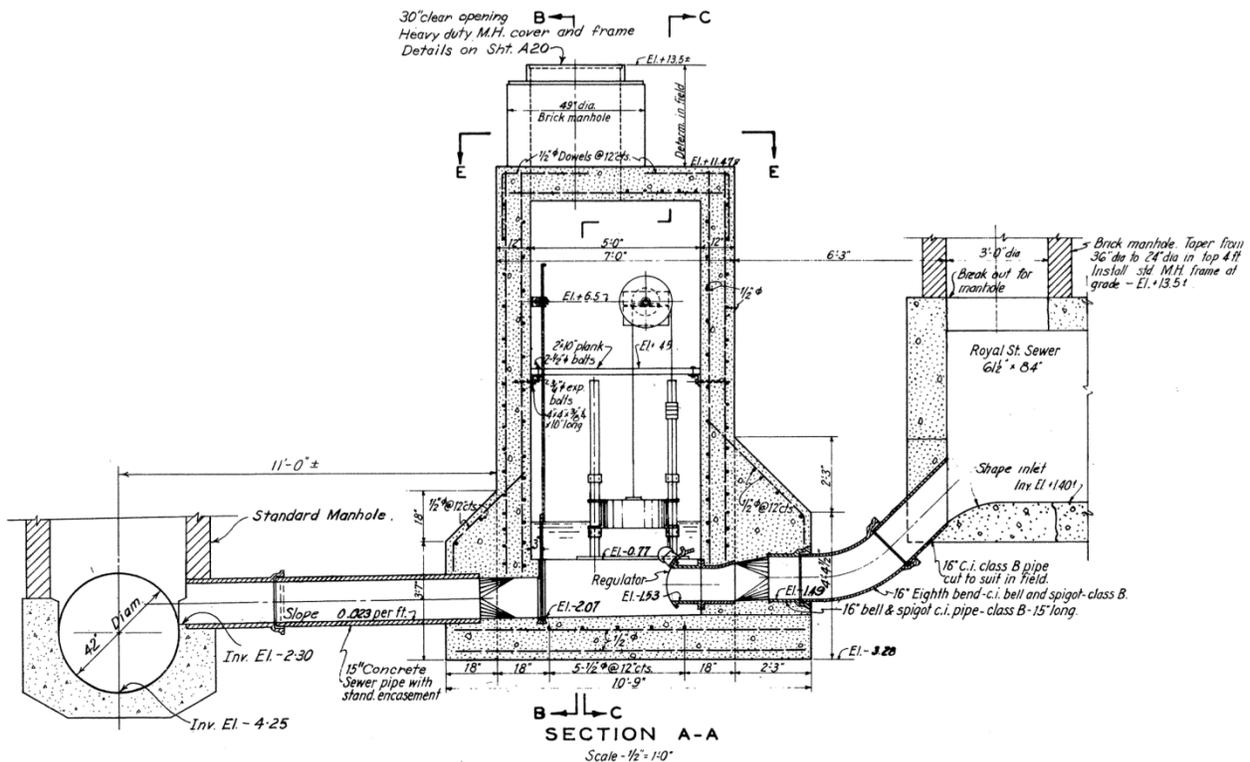
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7.2 Royal Street CSO (Outfall 002)

The Royal Street CSO has a regulator which consists of a weir and a float- activated gate. This regulator is located underneath the Woodrow Wilson Bridge. During dry weather, flow travels down the Royal Street combined sewer, which is a 61.5-inch x 84-inch box culvert. The flow then encounters a 6-inch transverse weir where it is diverted to the Potomac Interceptor which feeds into the AlexRenew treatment plant. During wet weather events, when the water level in the box culvert exceeds the elevation of the weir, flow overtops the weir and continues to the overflow in tidal Hunting Creek.

Before flow can enter the Potomac Interceptor, it must pass through a float and gate mechanical regulator; this regulator functions based on the water level in the Potomac Interceptor. In Figure 7-3 the Potomac Interceptor is on the left side; during dry weather all the flow from the Royal Street Trunk Sewer is able to enter the Potomac Interceptor. However, during wet weather the water level in the Potomac Interceptor rises and begins to backup into the Royal Street mechanical regulator structure. As the water level in this structure rises, it raises a float. This float is connected to a gate via a pulley; so as the float rises the gate closes prohibiting combined flow from the Royal Street Trunk Sewer from entering the Potomac Interceptor. While the gate is closed, all of the flow in the Royal Street Trunk Sewer goes out the Royal Street CSO (Outfall 002).

Figure 7-3
 Royal Street Mechanical Regulator



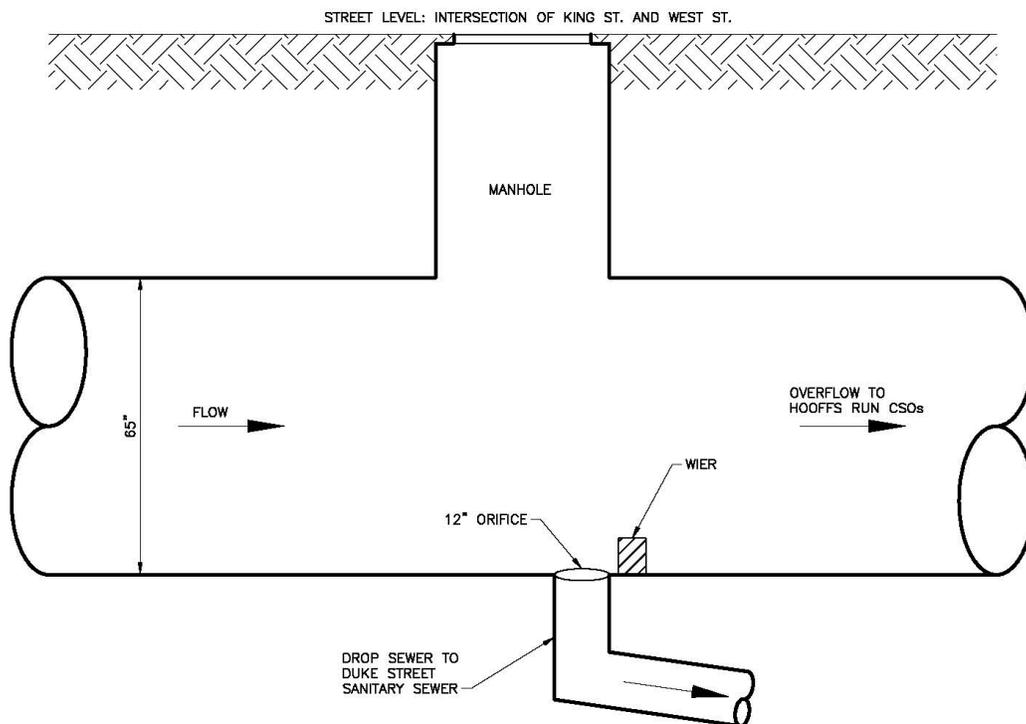
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7.3 Duke Street CSO (CSO-003)

The Duke Street CSO regulator is located at the intersection of King Street and West Street. This regulator consists of a 6-inch weir and an orifice as shown in Figure 7-4. During dry weather flow travels down the combined sewer until it encounters a 12-inch orifice in the bottom of the pipe. Flow continues down this drop sewer and to the Duke Street siphons and the AlexRenew treatment plant. The weir on the downstream side of the orifice helps to ensure that dry weather flow is diverted into the orifice and to the plant. During wet weather flow becomes elevated and is at such a high flow rate that it is unable to be sent to the plant. In this case, flow proceeds over the weir and continues to the CSO-003 outfall on Hooffs Run.

Figure 7-4
King & West Diversion Structure



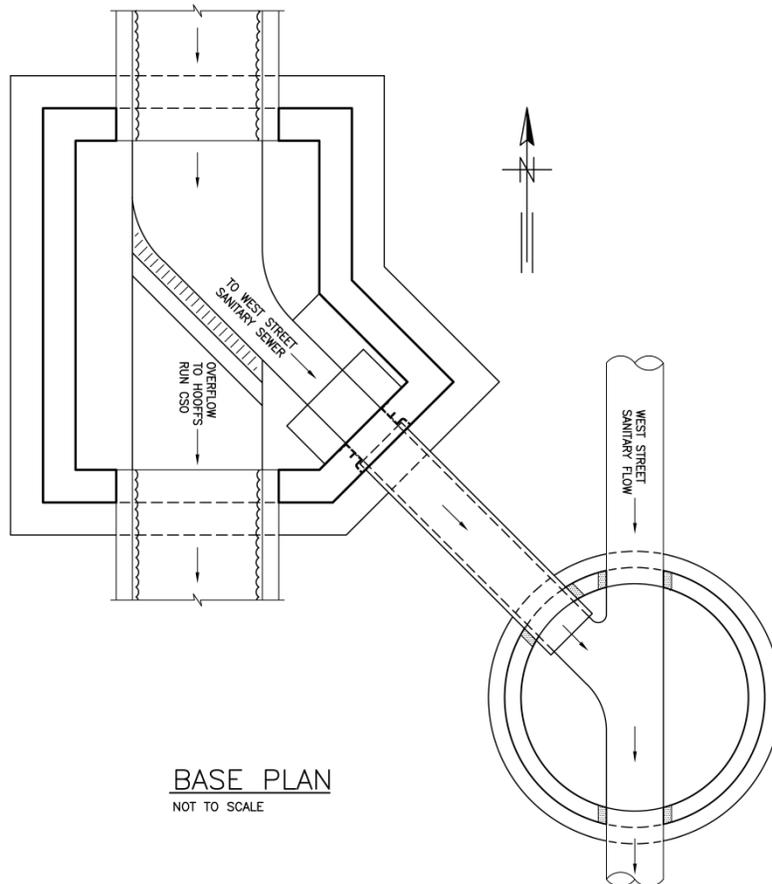
As of Summer 2014, a new diversion structure at King West Streets has been under construction. This new structure is being built to improve maintenance access, reduce the risk of dry weather overflows, and to utilize more storage in the system during wet weather events. The new structure will be similar in that it will still have a weir; however, rather than dry weather flows going through an orifice in the bottom of the pipe, the weir will divert flows to an orifice in the side of the pipe as shown in Figure 7-5. This new orifice has been sized to convey the same amount of dry weather flow so as to not increase the risk of basement backups; however the new weir will be higher than the old one, allowing for more storage within the system. Flow that is diverted through the new side orifice will continue to the Duke Street

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sanitary sewer as it is in the existing King & West diversion structure. This information was summarized in a Preliminary Engineering Report sent to VDEQ December 2013 and is intended to meet the requirements of Section E.8.e (Outfall Improvements).

Figure 7-5
King & West New Diversion Structure



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7.4 Hooffs Run CSO (CSO-004)

The Hooffs Run CSO is located downstream of the King & West diversion structure as shown in Figure 7-1. All flows that are diverted into the West Street combined sewer are conveyed to the Duke Street siphon chamber. As shown in Figure 7-6, this figure consists of two siphons, a weir, and an elevated overflow pipe. As flow enters the structure it encounters the first weir and is diverted in to the 14-inch siphon. This siphon conveys dry weather flow to the Commonwealth Interceptor and is then conveyed to the AlexRenew WRRF. During wet weather conditions, if the flow entering the diversion structure greater than the capacity of the 14-inch siphon, then it will over top the weir where flow is then diverted to the a second 21-inch siphon that conveys flow to the Commonwealth Interceptor and then to the plant, and/or to the elevated 27-inch outfall pipe that discharges out the Hooffs Run CSO.

Figure 7-6
Hooffs Run Diversion Structure

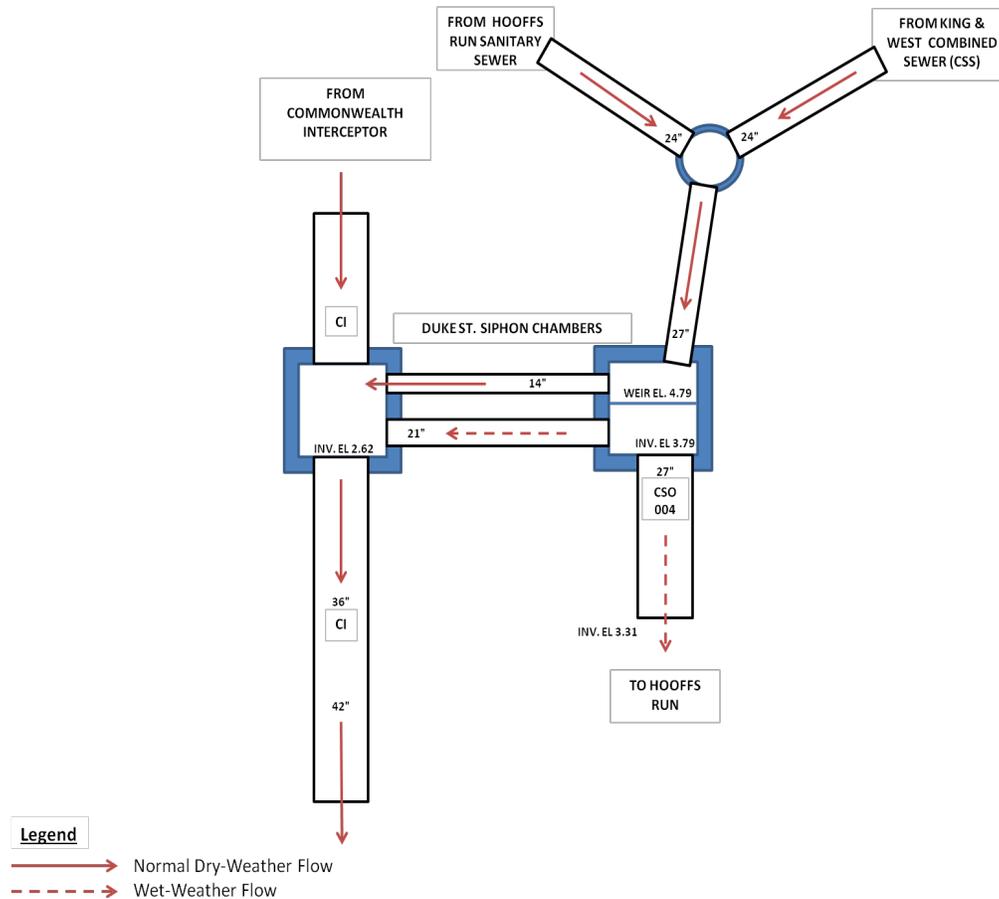
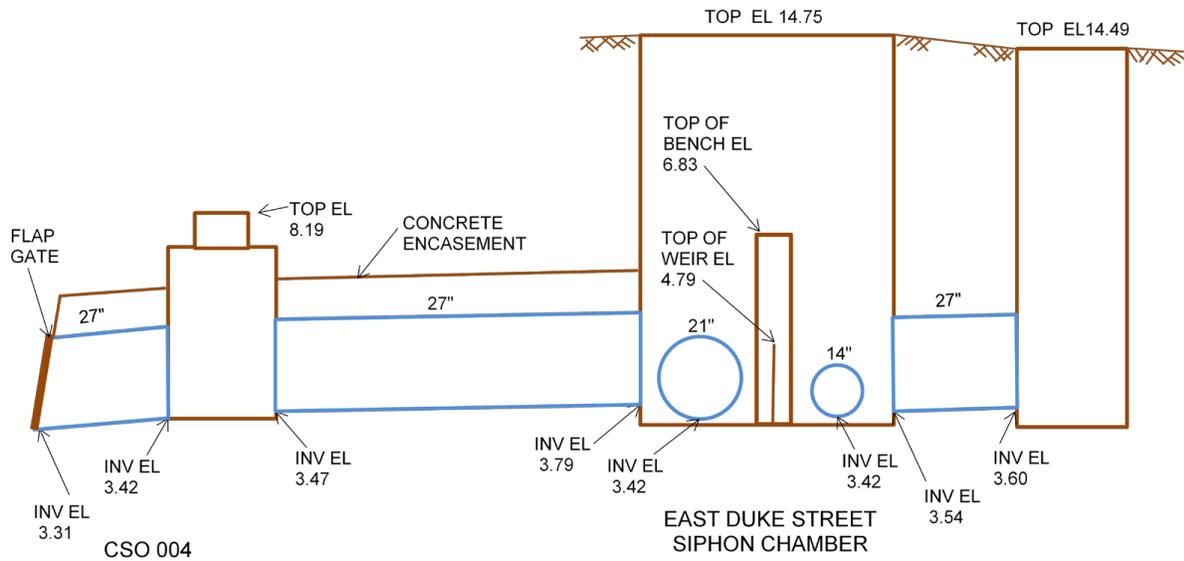


Figure 7-7 shows a profile of the CSO-004 regulator and the elevated overflow pipe more clearly.

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Figure 7-7
Hooffs Run Diversion Structure Profile



DATUM: NGVD 29

The current CSS Permit requires the City to “...further evaluate alternatives being considered for improvements...at Outfall 004...and implement its proposed improvements at ...Outfall 004 on or before 23 February 2016.” The City is currently investigating outfall improvements to meet permit requirements and reduce CSO impacts at this outfall.

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Section 8 Current Flow Estimates

8.1 Sanitary Flows

Sanitary flows were estimated using TAZ data. The TAZ data subdivided each sewer service area into smaller areas, each of which had TAZ data for the number of employees and the number of households. For each employee, it was estimated that 20 gallons per day of wastewater is contributed to the sanitary flow and that 184 gallons per day is contributed for each household.

For each proposed sanitary sewer or for those where flow was being altered from the existing condition, the collection area for that pipe was determined and compared to the TAZ areas. This proportion was utilized to ascertain the percentage of the population that contributed to the sanitary flow of each pipe. This percentage was then multiplied by the flow estimated from the TAZ data.

**Table 8-1
 Existing Estimated Sanitary Flows**

| CSS Subshed | Households Sanitary Flows (gpd) | Employees Sanitary Flows (gpd) | Total Sanitary Flows (gpd) |
|---------------------------------|---------------------------------|--------------------------------|----------------------------|
| Pendleton (CSO-001) | 401,685 | 149,280 | 550,965 |
| Royal (CSO-002) | 338,550 | 85,900 | 424,450 |
| King & West (CSO-003 & CSO-004) | 217,587 | 56,380 | 273,967 |
| Total | 957,822 | 291,560 | 1,249,382 |

8.2 Existing CSO Regulator Capacity

The hydraulic capacity in the combined sewersheds was set equal to the full pipe capacities of the pipes directly upstream of the different combined sewer overflow (CSO) regulator structures. Manning's Equation was used to estimate pipe capacity:

$$Q = \frac{k}{n} * A * R^{\frac{2}{3}} * S^{\frac{1}{2}}$$

Where: *Q* is the volumetric flow rate in cubic feet per second (cfs)

k is a conversion factor of 1.4859 ft^{1/3} per second

n is the roughness coefficient

A is the cross sectional area of flow in square feet (sf)

R is the hydraulic radius in feet (ft)

S is the slope of the pipe in ft per ft

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Hydraulic radius can be expressed as

$$R = \frac{A}{P}$$

Where: *A* is the cross sectional area of flow in *sf*
P is the wetter perimeter in *ft*

The assumptions used for the calculations as well as the resulting hydraulic capacity can be found in Table 8-2.

Table 8-2
Full Pipe Capacity Estimates Upstream of CSO Regulator Structures

| Outfall | Pipe Shape | Width (ft) | Height (ft) | Diameter (ft) | Roughness Coefficient | Slope (%) | Hydraulic Capacity (MGD) |
|---------|-------------|------------|-------------|---------------|-----------------------|-----------|--------------------------|
| CSO 001 | Rectangular | 5.83 | 6.00 | - | 0.014 | 0.120 | 108.0 |
| CSO 002 | Rectangular | 7.00 | 5.13 | - | 0.014 | 0.500 | 225.9 |
| CSO 003 | Circular | - | - | 4.28 | 0.013 | 1.000 | 111.4 |
| CSO 004 | Circular | - | - | 2.25 | 0.012 | 0.545 | 16.0 |

Once the full pipe capacities were obtained, the combined sewersheds were given the flow rates of the pipes that are located within it. The Pendleton combined sewershed is assumed to have a hydraulic capacity equal to the pipe capacity of the pipe upstream of the CSO 001 regulator structure. The Royal combined sewershed is assumed to have a hydraulic capacity equal to the pipe capacity of the pipe upstream of the CSO 002 regulator structure. The King and West combined sewershed is assumed to have a hydraulic capacity equal to the sum of the pipe capacities of the pipes upstream of the CSO 003 and CSO 004 regulator structures. These hydraulic capacities were assumed to be constant from 2015 to 2040.

It is important to note that these hydraulic capacities are not the flow rates that are delivered to the AlexRenew WRRF; these are the flow rates that could be delivered to each regulator structure, so some of that flow will continue to the AlexRenew WRRF while the rest of it will be discharged as CSO. It is important to understand the flows entering each regulator structure, so that in designing future CSO controls, the same amount of flow will be able to be conveyed without backing up into homeowners' basements.

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