Report

Long-Term Control Plan
Addendum No. 1

Henderson Water Utility, KY

October 2009

Report for

Henderson Water Utility, Kentucky

Long-Term Control Plan Addendum No. 1

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SPREADSHEET TOOL SUPPLEMENTAL INFORMATION

1.01 INTRODUCTION

Additional information on the methodology and techniques employed to create the Henderson Water Utility (HWU) Combined Sewer Overflow (CSO) spreadsheet tool is provided below. The spreadsheet tool was used to estimate the effectiveness of CSO controls.

1.02 RATIONAL METHOD

To determine the amount of runoff from each CSO drainage basin in the spreadsheet model, the rational method was used. The rational method is as follows:

$Q_p = kCIA$, where:

> Q_p = Peak discharge, cubic feet per second (cfs).
> k = Conversion factor, as needed.
> C = Runoff coefficient or ‘C factor’, dimensionless.
> I = Rainfall intensity, in/hr.
> A = Catchment area, acres.

The rational method provides a peak discharge analysis for a selected storm event based on the storm intensity, catchment area, and an empirical runoff coefficient, or C factor. The rainfall intensity varies based on the frequency and duration of the selected storm event. The runoff coefficient varies based on the abstractive and diffusive properties of the catchment. The spreadsheet model is not a hydrodynamic model; therefore several methods were used to determine C factors for each CSO basin to estimate CSO volumes.

The rational method assumes all rainfall enters the Combined Sewer System (CSS) and combines with the industrial, commercial, and domestic wastewater flow to generate combined wastewater. The rational method is a peak discharge analysis, therefore it will always over predict the actual amount of runoff from a catchment and under predict the CSO reduction based on system improvements, if the C factor is selected appropriately. Factors such as stormwater time of concentration and any other dynamic considerations are not accounted for using the rational method and would reduce the amount of peak flow in a catchment.

1.03 ESTIMATION OF RATIONAL METHOD C FACTORS

C factors used in the rational method for modeling purposes for the HWU Long-Term Control Plan (LTCP) were estimated three different ways: (1) by using the National Land Cover Database 2001 (NLCD01), (2) by using Geographical Information System (GIS) information provided by HWU, and (3) by estimating C factors for the downtown interceptor based on rainfall data and the CSO’s reaction to the rainfall. The following paragraphs describe the methodology and techniques used for the three different methods C factors were estimated.

1.04 C FACTOR ESTIMATION USING THE NCLD01

The first method used to estimate C factors is the NLCD01. In 1993, a consortium of federal agencies called the Multi-Resolution Land Characteristics (MRLC) Consortium pooled their resources to purchase Landsat-5 satellite data for mission applications and to create a NLCD with the circa 1992 data. The Consortium repeated this effort and purchased Landsat-7 data to produce the NLCD01. MRLC Consortium partners include the United States Environmental Protection Agency (USEPA), the National Oceanic Atmospheric Administration (NOAA), the United States Forest Service (USFS), the United States Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), the National Park Service (NPS), the United States Fish and Wildlife Service (USFWS), the Bureau of Land Management (BLM), and the National Resources Conservation Service (NRCS).

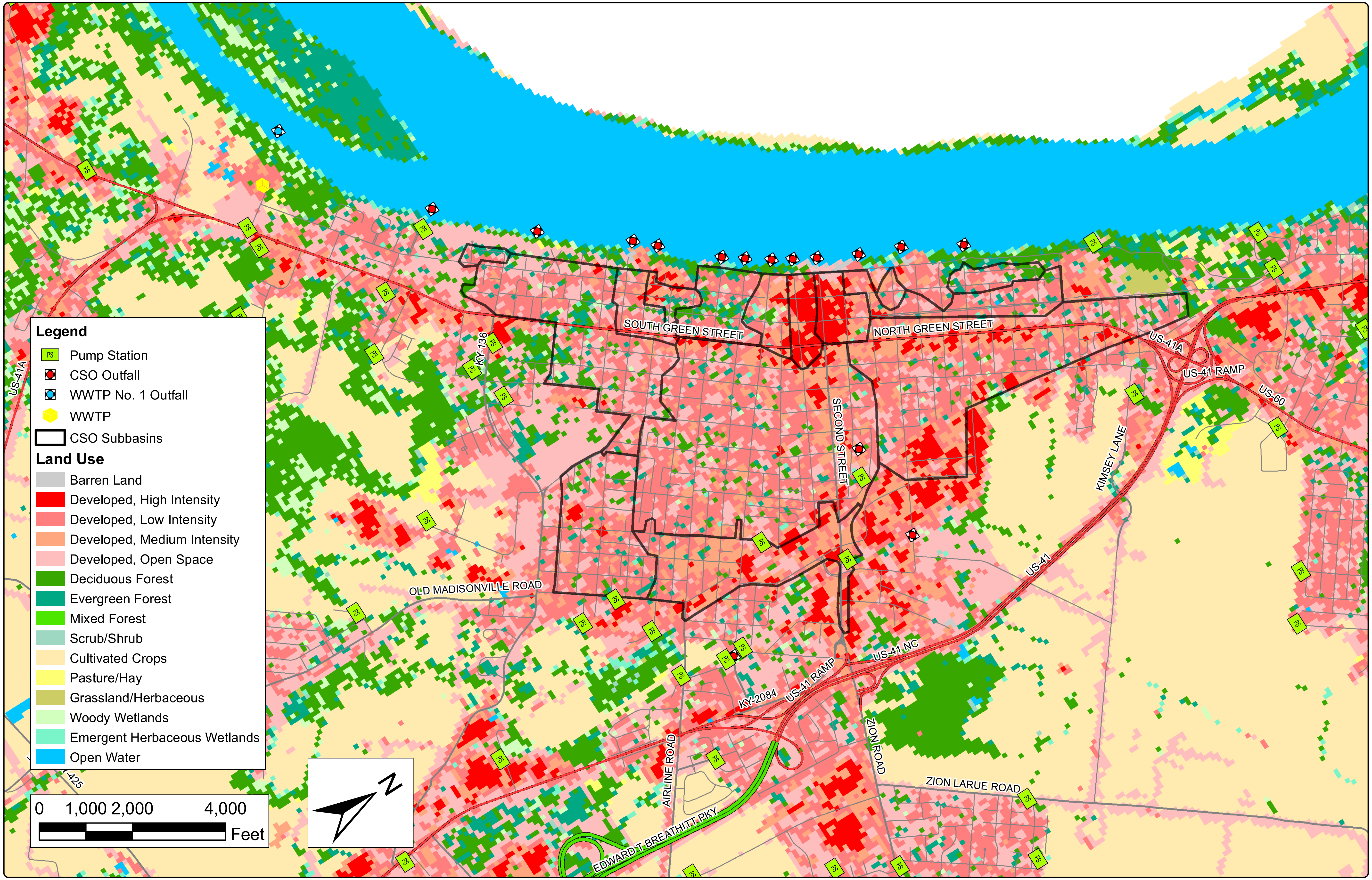
The NLCD01 is available in shapefile format which can be analyzed in ArcMap. The NLCD01 was overlaid on top of the Henderson CSO drainage basins in ArcMap and land use information for each basin was extracted and analyzed. Figure 1.04-1 shows the NLCD01 overlayed on the Henderson Combined Sewer System (CSS). Land uses in the NLCD01 were combined into seven different land use classifications for the purpose of the spreadsheet model. Table 1.04-1 describes the seven land use classifications used for the Henderson CSS.

C factors for each land use were selected by comparing the NLCD01 land use classification and local knowledge of the Henderson CSS to typical C factors used in practice. Table 1.04-2 lists standard ranges of C factors for a variety of land uses that were referenced to select an estimated C factor based on the NLCD01. Estimated C factors used in the model for the NLCD01 analysis are shown in Table 1.04-3.

Land Use Classification	Typical C Factor Range	C Factor Used
Developed, High Intensity	0.70 to 0.95	0.90
Developed, Medium Intensity	0.50 to 0.70	0.65
Developed, Low Intensity	0.30 to 0.50	0.40
Developed, Open Space	0.10 to 0.35	0.25
Forested	0.10 to 0.25	0.20
Wetlands/Woody Wetlands	0.10 to 0.25	0.20
Grassland/Pasture	0.05 to 0.35	0.20

Table 1.04-3 NLCD01 Estimated C Factors

After the NLCD01 land use areas were determined for each CSO basin and estimated C factors were selected for each land use, a composite C factor for each drainage basin was calculated. The composite C factor is calculated as a weighted average according to land use.



NLCD01 LAND USE CHARACTERISTICS

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FIGURE 1.04-1
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TABLE 1.04-1

NLCD01 LAND USE DESCRIPTIONS

Land Use Classification	Land Use Definition
Developed, High Intensity	Includes highly developed areas where people reside or work in high numbers. Examples incglude apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.
Developed, Medium Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover. These areas most commonly include single-family housing units.
Developed, Low Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious areas account for 20 to 49 percent of total cover. These areas most commonly include single-family housing units.
Developed, Open Space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Forested	Areas dominated by various types of forests consisting of trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover.
Wetlands/Woody Wetlands	Areas where the soil or substrate is periodically saturated or covered with water. Areas have varying amounts of vegetative cover.
Grassland/Pasture	Areas dominated by graminoid or herbaceous vegetation, generally greater than 80 percent of total vegetation.

TABLE 1.04-2

TYPICAL C FACTORS FOR 5- TO 10-YR FREQUENCY DESIGN

Description of Area	Runoff Coefficients
Business:	
Downtown Areas	0.70 to .95
Neighborhood Areas	0.50 to 0.70
Residential:	
Single-Family Areas	0.30 to 0.50
Multiunits, detached	0.40 to 0.60
Multiunits, attached	0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment Dwelling Areas	0.50 to 0.70
Industrial:	
Light Areas	0.50 to 0.80
Heavy Areas	0.60 to 0.90
Parks and Cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad Yard Areas	0.20 to 0.40
Unimproved Areas	0.10 to 0.30
Streets:	
Asphaltic	0.70 to 0.95
Concrete	0.80 to 0.95
Brick	0.70 to 0.85
Drives and Walks	0.75 to 0.85
Roofs	0.75 to 0.95
Lawns. Sandy Soil:	
Flat, 2%	0.05 to 0.10
Average, 2-7%	0.10 to 0.15
Steep, 7%	0.15 to 0.20
Lawns, Heavy Soil:	
Flat, 2%	0.13 to 0.17
Average, 2-7%	0.18 to 0.22
Steep, 7%	0.25 to 0.35

Source: *Design and Construction of Sanitary and Storm Sewers.* American Society of Civil Engineers Manual of Engineering Practice, No. 37, 1960.

Tables 1.04-4 and 1.04-5 shows the composite C factor estimates using the NLCD01 for the Canoe Creek drainage basins and downtown interceptor drainage basins, respectively.

Land Use Classification	Estimated C Factor	3rd Street Basin Area (acres)	2nd Street PS Area 1 (acres)	2nd Street PS Area 2 (acres)
Developed, High Intensity	0.9	17.49	16.37	30.93
Developed, Medium Intensity	0.65	77.04	51.97	77.65
Developed, Low Intensity	0.4	206.06	43.70	116.20
Developed, Open Space	0.25	91.44	11.52	50.14
Forested	0.2	29.66	4.50	16.26
Wetlands/Woody Wetlands	0.2	5.06	0.11	2.63
Grassland/Pasture	0.2	0.00	0.00	0.21
Total Area		426.75	128.17	294.02
Composite C Factor		0.42	0.54	0.48

Table 1.04-4 Canoe Creek Basins NLCD01 Analysis

1.05 GIS C FACTOR CALCULATION

The second method to estimate C factors used available GIS shapefiles. Edge of pavement, structures, and CSO drainage basin shapefiles were used to calculate C factors.

The edge of pavement data provided by HWU is a polyline shapefile that consists of six types of pavement: paved road, paved parking, paved drive, unpaved road, unpaved parking, and unpaved drive. Because the edge of pavement shapefile is a polyline and not a polygon, the areas for roads, drives, and parking lots could not directly be calculated. The length of each pavement type was multiplied by an estimated width factor to determine an estimated area.

The structure shapefile consisted of the polygon footprints of homes and buildings in the HWU service area, therefore the area for structures in the CSS could be directly calculated. Henderson is not a highly developed area and single-family housing is the primary land use for the majority of the CSS area.

Therefore, all land use within the CSO drainage basins not accounted for in structures or edge of pavement shapefiles was classified as "Open Space/Lawns," which includes primarily open areas and other green space such as lawns, wetlands, and forested areas.

TABLE 1.04-5

NLCD01 C FACTOR ESTIMATIONS FOR THE DOWNTOWN INTERCEPTOR CSO BASINS

Land Use Classification	Estimated C Factor	CSO 002 Area (acres)	CSO 003 Area (acres)	CSO 004 Area (acres)	CSO 005 Area (acres)	CSO 006 & 007 Area (acres)	CSO 008 Area (acres)	CSO 009 Area (acres)	CSO 010 Area (acres)	CSO 011 Area (acres)	CSO 012 Area (acres)	CSO 013 Area (acres)
Developed, High Intensity	0.9	0.00	0.99	1.28	2.52	0.43	3.76	18.65	17.36	2.09	0.00	0.00
Developed, Medium Intensity	0.65	0.00	8.98	3.86	4.32	1.85	10.75	6.07	8.26	7.79	2.40	0.50
Developed, Low Intensity	0.4	2.88	77.70	12.12	2.76	21.68	7.62	1.05	4.06	31.54	3.54	6.83
Developed, Open Space	0.25	2.41	66.96	10.21	2.31	8.14	3.38	0.31	2.51	10.52	1.35	6.77
Forested	0.2	2.77	30.79	3.02	2.67	15.13	2.35	0.34	0.22	5.48	0.24	6.46
Wetlands/Woody Wetlands	0.2	0.03	4.34	0.06	0.44	2.18	1.86	0.00	0.52	0.42	0.22	0.44
Grassland/Pasture	0.2	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00
Total Area (acres)		8.08	189.76	30.74	15.02	49.41	29.72	26.42	33.28	57.84	7.75	21.00
Composite C Factor		0.29	0.32	0.38	0.49	0.32	0.51	0.81	0.71	0.40	0.44	0.29

Table 1.05-1 summarizes the C factors used for the GIS analysis. Figure 1.05-1 shows the GIS information used for the downtown CSS and Figure 1.05-2 shows the GIS information zoomed in on the CSO 006 and 007 basins.

Land Use Classification	Width Factor	Typical C Factor Range	C Factor Used
Structures	-	07.0 to 0.95	0.95
Road, Paved	8	0.70 to 0.95	0.90
Parking, Paved	10	0.70 to 0.95	0.90
Drive, Paved	6	0.75 to 0.85	0.80
Road, Unpaved	8	0.25 to 0.50	0.45
Parking, Unpaved	10	0.25 to 0.50	0.42
Drive, Unpaved	6	0.25 to 0.50	0.40
Open Space/Lawns	-	0.05 to 0.35	0.20

Table 1.05-1 Edge of Pavement GIS Information

Tables 1.05-2 and 1.05-3 show the GIS C factor estimates for the Canoe Creek drainage basins and downtown interceptor drainage basins, respectively. The Composite C factors for each drainage basin were calculated using a weighted average based on land use.

			3rd Street Basin Area		2nd Street PS Area 1		2nd Street PS Area 2	
Land Use Classification	Estimated C Factor	Width Factor	Length (ft)	Area (acres)	Length (ft)	Area (acres)	Length (ft)	Area (acres)
Structures	0.95	-	-	71.81	-	20.09	-	55.25
Road, Paved	0.90	8	154,788	28.4	42,424	7.8	98,067	18.0
Parking, Paved	0.90	10	33,728	7.7	16,522	3.8	46,476	10.7
Drive, Paved	0.80	6	0	0.0	202	0.0	0	0.0
Road, Unpaved	0.45	8	52,399	9.6	14,500	2.7	25,047	4.6
Parking, Unpaved	0.42	10	5,694	1.3	4,701	1.1	10,496	2.4
Drive, Unpaved	0.40	6	2,400	0.3	160	0.0	1,005	0.1
Open Space/Lawns	0.20	-	-	307.51	-	92.70	-	202.94
Total Area (acres)			-	426.75	-	128.17	-	294.02
Composite C Factor			-	0.39	-	0.39	-	0.42

Table 1.05-2 Canoe Creek Basins GIS Land Use Analysis

1.06 C FACTOR CALIBRATION USING FLOW METERS AND RAIN GAUGES

When possible, C factors were estimated based on linear correlations developed for each CSO drainage basin area using rainfall data collected at the 3rd Street CSO Basin rain gauge and flow data from the Teledyne-ISCO flow modules on each CSO outfall. Flow data is available for seven CSOs on the downtown interceptor, CSO 002, 003, 004, 005, 006, 007, 008, and 009.

Seventeen storm events were selected that caused a CSO in the downtown CSS area. Table 1.06-1 shows a summary of the storm events selected. The storms were selected from the storms that caused a CSO in the downtown interceptor area. They were selected to have a variety of rainfall durations, depths, intensities, and antecedent moisture conditions. The storm events were also selected based on their systemwide impact on the CSS; therefore, small isolated storms that only caused a CSO at one location were not selected for analysis.

DOWNTOWN CSS GIS LAND USE CHARACTERISTICS

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FIGURE 1.05-1
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CSO BASIN 006 & 007
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FIGURE 1.05-2
5454.003

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TABLE 1.05-3

GIS C FACTOR ESTIMATIONS FOR THE DOWNTOWN INTERCEPTOR CSO BASINS

Land Use Classification	Estimated C Factor	Width Factor	CSO 002		CSO 003		CSO 004		CSO 005		CSO 006 & 007		CSO 008	
			Length (ft)	Area (acres)	Length (ft)	Area (acres)	Length (ft)	Area (acres)	Length (ft)	Area (acres)	Length (ft)	Area (acres)	Length (ft)	Area (acres)
Structures	0.95	-	-	1.04	-	26.23	-	4.04	-	2.42	-	8.31	-	5.19
Road, Paved	0.90	8	3,060	0.6	67,411	12.4	10,724	2.0	4,471	0.8	16,335	3.0	10,377	1.9
Parking, Paved	0.90	10	508	0.1	12,474	2.9	4,659	1.1	1,354	0.3	2,665	0.6	5,814	1.3
Drive, Paved	0.80	6	313	0.0	9,579	1.3	364	0.1	18	0.0	732	0.1	353	0.0
Road, Unpaved	0.45	8	0	0.0	18,495	3.4	2,045	0.4	2,704	0.5	3,860	0.7	0	0.0
Parking, Unpaved	0.42	10	0	0.0	612	0.1	695	0.2	36	0.0	0	0.0	0	0.0
Drive, Unpaved	0.40	6	0	0.0	1,217	0.2	751	0.1	0	0.0	0	0.0	0	0.0
Open Space/Lawns	0.20	-	-	6.26	-	143.26	-	22.97	-	10.96	-	36.68	-	21.24
Total Area (acres)			-	8.02	-	189.76	-	30.74	-	15.02	-	49.41	-	29.72
Composite C Factor			-	0.36	-	0.37	-	0.37	-	0.38	-	0.38	-	0.41

Land Use Classification	Estimated C Factor	Width Factor	CSO 009		CSO 010		CSO 011		CSO 012		CSO 013	
			Length (ft)	Area (acres)	Length (ft)	Area (acres)	Length (ft)	Area (acres)	Length (ft)	Area (acres)	Length (ft)	Area (acres)
Structures	0.95	-	-	7.97	-	7.18	-	7.62	-	1.14	-	2.41
Road, Paved	0.90	8	9,154	1.7	10,966	2.0	30,078	5.5	3,401	0.6	7,991	1.5
Parking, Paved	0.90	10	6,875	1.6	9,869	2.3	9,493	2.2	568	0.1	0	0.0
Drive, Paved	0.80	6	171	0.0	313	0.0	2,375	0.3	152	0.0	0	0.0
Road, Unpaved	0.45	8	0	0.0	2,223	0.4	4,843	0.9	407	0.1	0	0.0
Parking, Unpaved	0.42	10	0	0.0	1,426	0.3	492	0.1	0	0.0	0	0.0
Drive, Unpaved	0.40	6	0	0.0	952	0.1	360	0.0	545	0.1	3,266	0.4
Open Space/Lawns	0.20	-	-	15.17	-	20.91	-	41.14	-	5.68	-	16.67
Total Area (acres)			-	26.42	-	33.28	-	57.84	-	7.75	-	21.00
Composite C Factor			-	0.51	-	0.46	-	0.40	-	0.38	-	0.34

TABLE 1.06-1

STORM EVENTS SUMMARY

Count	Event Date	Prior 72-hour Rainfall (inches)	Rainfall Duration (hours)	Total Rainfall (inches)	Average Hourly Intensity (in/hr)	Peak Hourly Intensity (in/hr)
1	9/22/2006	0.00	4	0.66	0.17	0.33
2	10/16/2006	0.00	8	0.62	0.08	0.26
3	10/27/2006	0.00	6	0.83	0.14	0.19
4	11/30/2006	0.12	5	0.45	0.09	0.2
5	1/13/2007	0.23	11	0.52	0.05	0.16
6	4/11/2007	0.02	9	0.78	0.09	0.21
7	10/22/2007	0.00	5	0.32	0.06	0.21
8	11/21/2007	0.00	2	0.73	0.37	0.67
9	12/2/2007	0.00	13	0.82	0.06	0.39
10	1/8/2008	0.09	3	0.32	0.11	0.18
11	1/29/2008	0.00	15	0.17	0.01	0.11
12	2/4/2008	0.18	3	1.8	0.60	1.00
13	3/3/2008	0.00	16	1.82	0.11	0.23
14	3/18/2008	0.37	10	2.03	0.20	0.35
15	4/10/2008	0.04	4	2.01	0.50	0.99
16	5/7/2008	0.00	2	0.28	0.14	0.15
17	5/27/2008	0.78	3	0.78	0.26	0.49

All storm events caused an average of six CSOs and a minimum of three CSOs at the seven metered locations. Three storms caused a CSO at all seven metered CSO locations. These 17 events were compared to the associated duration and peak CSO discharge rates of the CSOs they caused in each drainage basin.

Linear correlations between peak CSO discharge rates and peak rainfall intensities were developed using the first surge of rainfall, if necessary, for the 17 rain events that caused a CSO regardless of antecedent moisture conditions. Some selected rain events had a single, clearly defined surge of rainfall that did not require the selection of a first surge. Figure 1.06-1 is an example of the March 18, 2008 rain event where a first surge of rainfall was selected. For the March 18, 2008 event, the first surge of rainfall was determined to end at 1 P.M. after the first clearly defined storm front passed over the CSS. Figure 1.06-2 is an example of the April 10, 2008 rain event where the rainfall only had one clearly defined surge of rainfall. Appendix A of the LTCP shows graphs of the rainfall events selected and shows where the end of the first rainfall surge was considered for each event.

After each first surge of rainfall was defined from the 17 storm events, each rainfall event was compared against the available flow data for all CSO basins to determine the correlation between peak rainfall intensity and peak CSO discharge. As an example, Figures 1.06-3 and 1.06-4 show selected the rainfall intensities and instantaneous CSO discharge rates used for correlation from CSO 003 for the March 18, 2008 and April 10, 2008 rainfall events, respectively. Rainfall intensity data and CSO flow data were compared to make sure they trended similarly and that the peak rainfall intensities were associated with the correct peak CSO discharge rates. This process was repeated for each selected storm event for each CSO.

The first surge of rainfall was used to decrease the number of variables in the C factor calibration. During the first surge of rainfall, the CSS as a whole will have similar antecedent moisture conditions. This allowed for the C factor to be calibrated for each basin under similar moisture conditions.

C factors were not calibrated based on additional rainfall surges because it is not known how rainfall was distributed throughout the CSS during the rain event, therefore the moisture conditions of each basin will have changed by an unknown amount. Using additional surges of rainfall would also result in calibrating C factors based on unknown dynamic conditions, potentially skewing the C factor.

After the rainfall events were selected and the first surge of rainfall was determined for all the necessary events, linear correlations were plotted for each CSO basin with available overflow data. Figure 1.06-5 shows the linear correlation for CSO 003 and points out the information extracted from the March 18, 2008 and April 10, 2008 events to show how the data was used. Appendix B of the LTCP shows the graphs and linear correlations for each CSO basin with available data. For each correlation, the coefficient of determination was referenced to determine whether the linear correlation was an accurate representation of the CSO basin’s response to rainfall. A coefficient of determination values range from 0 to 1, with a value of 1 indicating a perfect correlation and a value of 0 indicating there is no correlation.

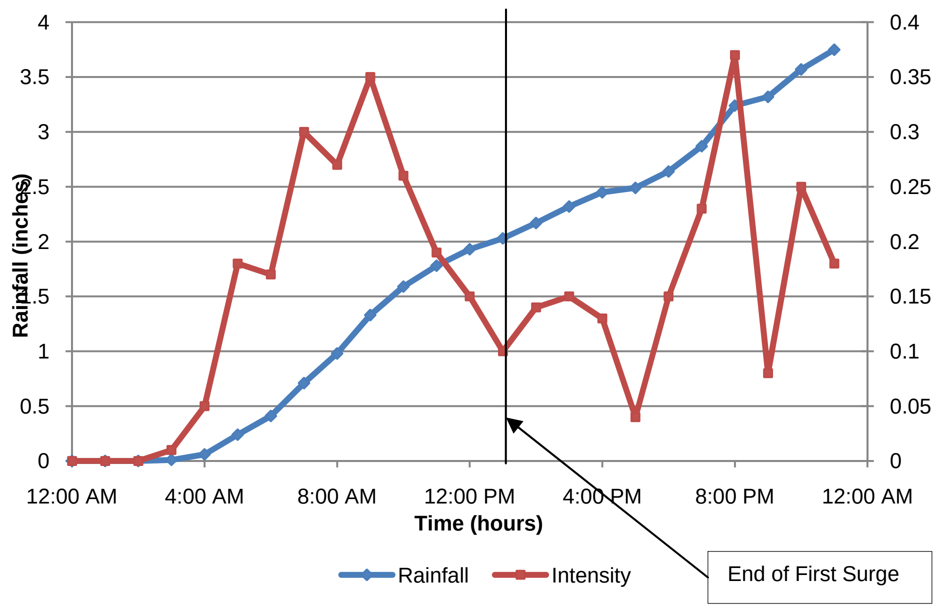


Figure 1.06-1 CSO Event Rainfall Data (March 18, 2008)

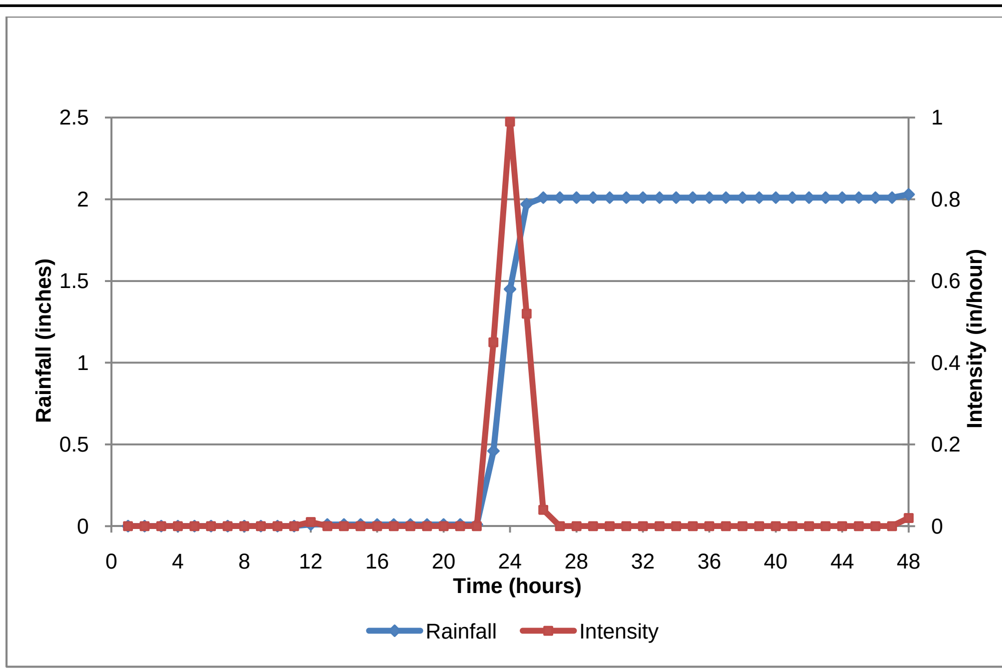


Figure 1.06-2 CSO Event Rainfall Data (April 10, 2008)

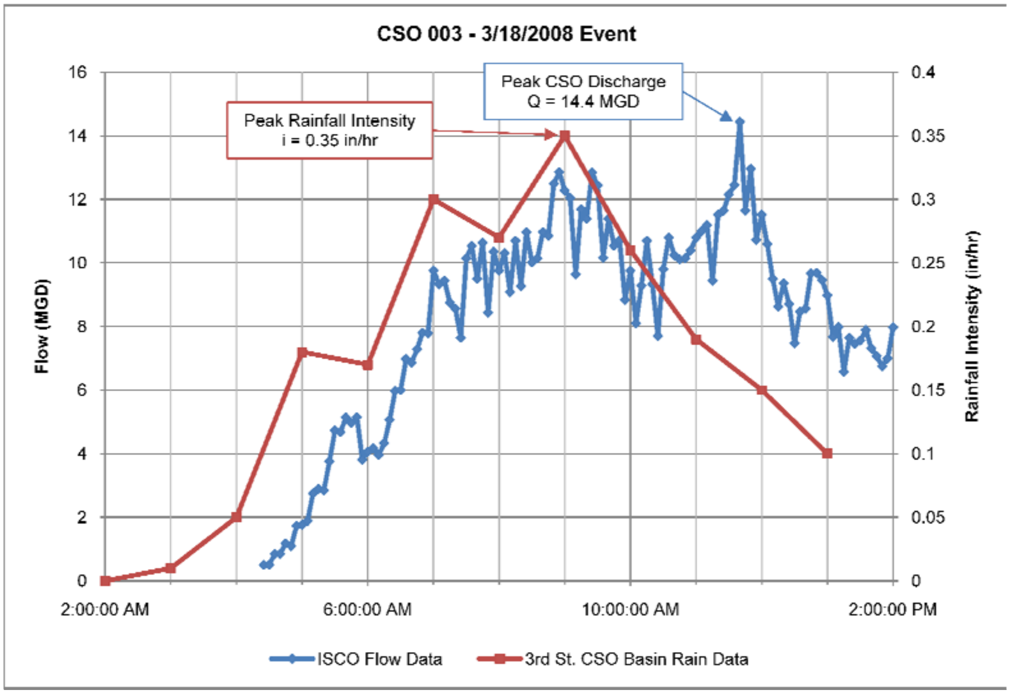


Figure 1.06-3 CSO Event Rainfall and Flow Data Comparison (March 18, 2008)

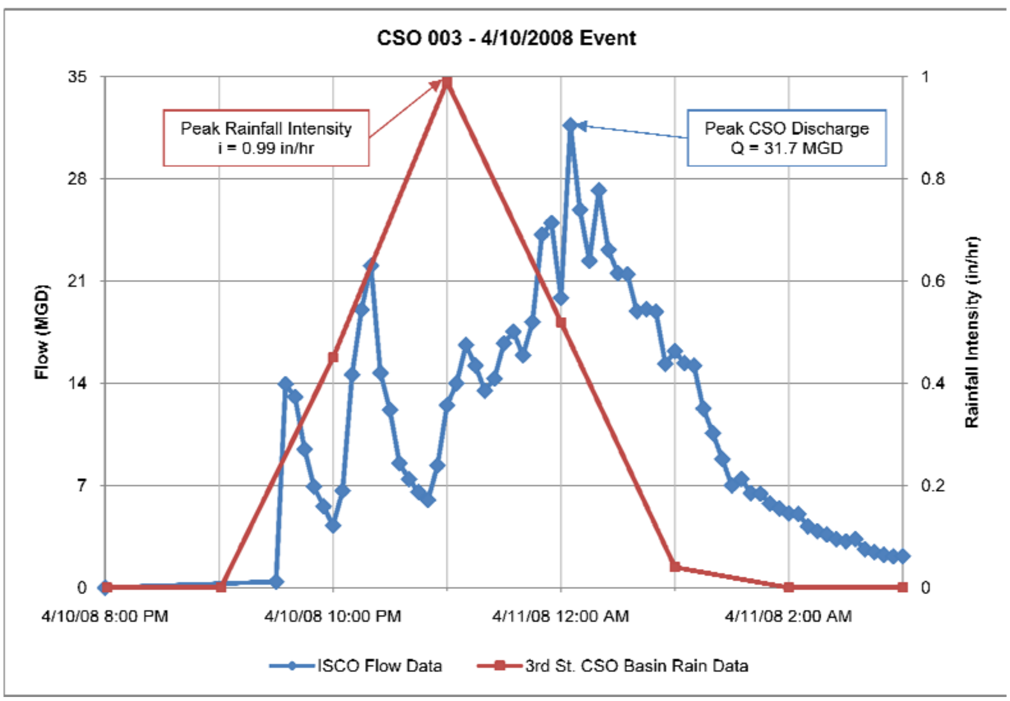


Figure 1.06-4 CSO Event Rainfall and Flow Data Comparison (April 10, 2008)

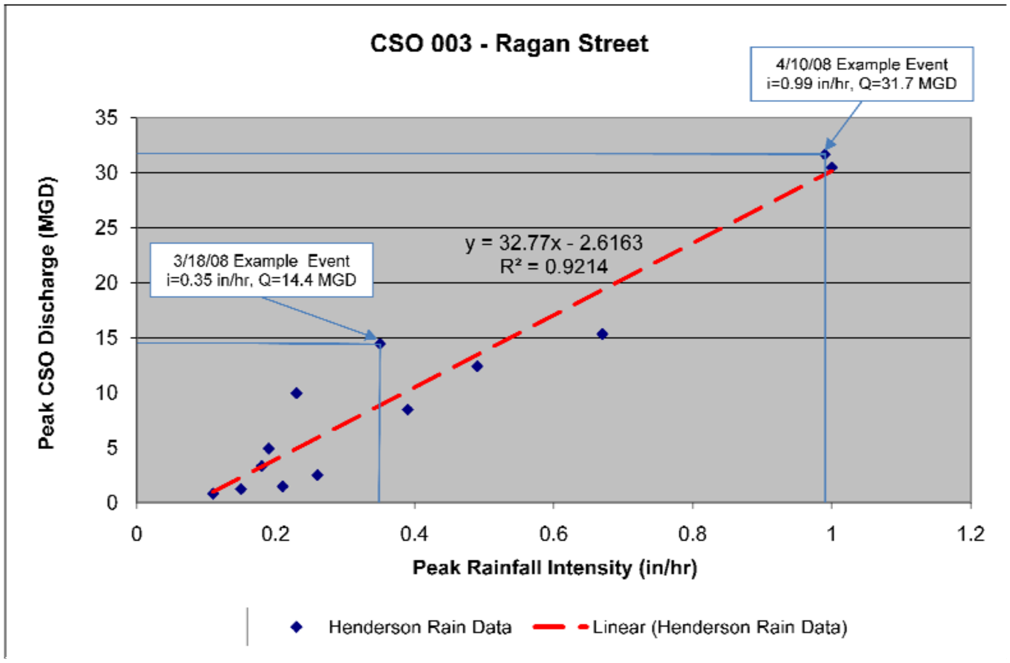


Figure 1.06-5 CSO 003 Peak Intensity and CSO Discharge Correlation

A review of the coefficient of determination values indicated that CSO 002-Janalee Drive Pumping Station and CSO 005-Towles Street did not correlate, with coefficient of determination values of 0.0226 and 0.0424, respectively. Therefore, C factor calibration based on rainfall data and peak CSO discharge rates was not performed for CSO 002 and CSO 005. CSO 003, 004, 007, 008, and 009 all had coefficients of determination greater than 0.9 and as high as 0.9824, indicating a good correlation between rainfall intensity and peak CSO discharge rates.

Once linear correlations were created for each CSO drainage basin, the estimated peak CSO discharge rates of a 3-month 1-hour storm was calculated for each CSO drainage basin using the linear correlations shown in Appendix B of the LTCP.

Table 1.06-2 shows the estimated peak CSO discharge rates for a 3-month, 1-hour storm.

CSO Basin	Peak Discharge Correlation Equation	3-month 1-hour Intensity (in/hr)	Peak CSO Discharge Rate (mgd)
CSO 003	Q_{peak} = 32.77i - 2.6163	0.93	27.86
CSO 004	Q_{peak} = 0.5902i + 0.0049	0.93	0.55
CSO 006 & 007	Q_{peak} = 15.886i - 1.7075	0.93	13.07
CSO 008	Q_{peak} = 10.523i - 0.712	0.93	9.07
CSO 009	Q_{peak} = 16.576i + 0.2852	0.93	15.70

Table 1.06-2 Rainfall Intensity and Combined Sewer Overflow Flow Data Linear Correlations

After each peak CSO discharge rate was calculated, the C factor was determined. This was done by using the rational equation, the known size of the CSO basin, and the know hydraulics of the CSO regulator structures. Table 1.06-3 shows the example calculations to determine the required runoff due to rainfall to achieve the estimated 3-month 1-hour CSO discharge rates based on the linear correlations for CSO Basins CSO 006 and 007 and CSO 008, which are the basins where the calibrated C factor was used for the spreadsheet tool.

CSO Basin	Q_{CSO}[1] (mgd)	Q_{DRY}[2] (mgd)	$Q_{CONTROL}$[3] (mgd)	Required Q_{RUNOFF} to Achieve Q_{CSO} (mgd)
	a	b	c	a + c - b
CSO 006 and 007	13.07	0.055	1.55	14.56
CSO 008	9.07	0.033	0.57	9.61

[1]Estimated peak CSO discharge rate based on linear correlations. Refer to Table 1.06-2.
[2]Estimated dry weather flow rates based on basin area and peak hourly WWTP flows.
[3] Hydraulic capacity of the gravity line at the CSO regulator structure connected to the downtown interceptor.

Table 1.06-3 Rainfall Runoff Estimations

Table 1.06-4 shows the example calculations to determine the C factor using the required runoff rates shown in Table 1.06-3.

CSO Basin	Unseparated Basin Area (acres)	Rainfall Intensity[1] (in/hr)	Q_{RUNOFF}[2] (mgd)	Rational Method Conversion Factor (cfs to mgd)	Rational Method C Factor
	a	b	c	d	c / (a * b * d)
CSO 006 & 007	47.52	0.93	14.56	0.65	0.51
CSO 008	24.13	0.93	9.61	0.65	0.66

[1] Associated rainfall intensity for a 3-month 1-hour storm for Henderson County, KY based on Bulletin-71.
[2] Runoff rate required to achieve the estimated 3-month 1-hour discharge rates based on the linear correlations. Refer to Table 1.06-3.

Table 1.06-4 C Factor Estimations

1.07 C FACTOR SELECTION

Table 1.07-1 summarizes the C factors calculated for all three methods for each CSO basin. The final C factors selected for use in the spreadsheet model were the highest C factor calculated from the three methods. Selecting the highest C factor from the three methods creates the most conservative scenario for modeling purposes and was done in response to comments from Kentucky Division of Water (KDOW) and USEPA.

TABLE 1.07-1

SPREADSHEET TOOL RESULTS USING HIGHEST CALCULATED C-FACTORS

Model	60 Year Data Totals[1]				Annual Average			
	Volume Captured/ Treated[2] (mil gal)	Overflow Volume[3] (mil gal)	Total System Volume[4] (mil gal)	Percent Capture[5]	Volume Captured/ Treated[2] (mil gal)	Overflow Volume[3] (mil gal)	Total System Volume[4] (mil gal)	Percent Capture[5]
1995 SPREADSHEET MODEL								
1995 Spreadsheet Model represents the HWU CSS as it was in 1995 before any separation or improvements were made.								
Downtown Interceptor	20,997	13,875	34,872	60%	349.9	231.3	581.2	60.2%
Canoe Creek	6,818	21,983	28,801	24%	113.6	366.4	480.0	23.7%
Combined System	27,815	35,859	63,673	44%	463.6	597.6	1061.2	43.7%
2008 SPREADSHEET MODEL								
2008 Spreadsheet Model represents the HWU CSS, to the best of our knowledge, as it is today. This includes the construction of the Third St. CSO basin and various separation projects throughout the CSS.								
Downtown Interceptor	20,826	11,485	32,311	64%	347.1	191.4	538.5	64.5%
Canoe Creek	13,517	1,913	15,430	88%	225.3	31.9	257.2	87.6%
Combined System	34,343	13,398	47,741	72%	572.4	223.3	795.7	71.9%
2018 SPREADSHEET MODEL								
2018 Spreadsheet Model represents the HWU CSS as it will be in 2018 assuming their current improvement and separation projects are completed on schedule. This includes the completion of the Canoe Creek interceptor and additional separation in the downtown area.								
Downtown Interceptor	8,299	2,921	11,220	74%	138.3	48.7	187.0	74.0%
Canoe Creek	14,319	19	14,338	100%	238.7	0.3	239.0	99.9%
Combined System	22,619	2,940	25,558	88%	377.0	49.0	426.0	88.5%

[1] Rain data for modeling purposes was obtained from the National Climatic Data Center at the Evansville Airport rain gauge in Evansville, Indiana. Data consists of hourly rainfall totals from July 1948 to June 2008.
[2] Volume of combined sewage stored and/or conveyed to the WWTP during wet weather events.
[3] Volume of combined sewage discharged by permitted CSOs in the CSS.
[4] Sum of the volume captured/treated and overflow volume.
[5] Percent of combined sewage during wet weather events captured and treated. Percent capture equals the volume captured/treated divided by the total system volume.

This changed the percent capture to 89 percent from the original LTCP calculation of 92 percent as shown in Table 1.07-2. These results demonstrate that HWU's robust approach to CSO control comfortably exceeds the compliance threshold of 85 percent even under more conservative assumptions.

CSO Basin	NLCD01 Estimated C Factor	GIS Estimated C Factor	Calibrated C Factor	Final C Factor
CSO 002	0.29	0.36	-	0.36
CSO 003	0.32	0.37	0.26	0.37
CSO 004	0.38	0.37	0.18	0.38
CSO 005	0.49	0.38	-	0.49
CSO 006 & 007	0.32	0.38	0.51	0.51
CSO 008	0.51	0.41	0.66	0.66
CSO 009	0.81	0.51	0.72	0.81
CSO 010	0.71	0.46	-	0.71
CSO 011	0.4	0.4	-	0.4
CSO 012	0.44	0.38	-	0.44
CSO 013	0.29	0.34	-	0.34
3rd Street CSO Basin	0.42	0.39	-	0.42
2nd St. PS Area 1	0.54	0.39	-	0.54
2nd St. PS Area 2	0.48	0.42	-	0.48

Table 1.07-2 Final C Factor Selection

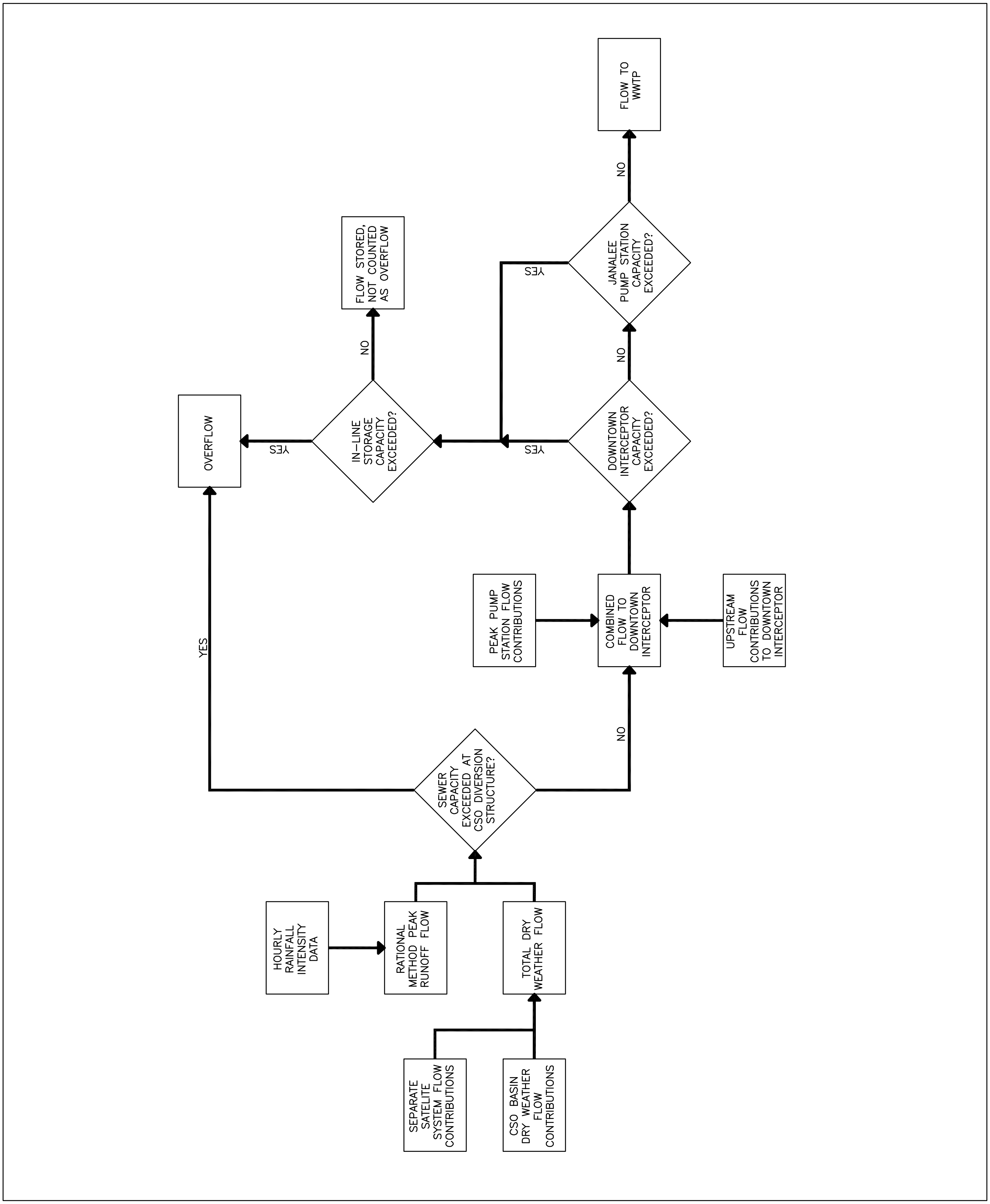
1.08 COMBINED SEWER OVERFLOW VOLUME ESTIMATION

After C-factors were determined for each CSO basin, CSO volumes were calculated for the downtown interceptor area and the Canoe Creek area.

A. Downtown Interceptor Combined Sewer Overflow Volume Estimation

The downtown interceptor spreadsheet model consists of a series of hydraulic capacity checks throughout the system based on the dry and wet weather flow rates to determine the amount of CSO volume. Figure 1.08-1 shows a schematic of the downtown interceptor spreadsheet model.

The first items taken into account are dry and wet weather flows. Dry weather flows from within the basin, separated satellite communities, and pumping stations are summed to determine the total dry weather flows. Wet weather flows are calculated using the rational method based on the CSO basin C factors, CSO basin areas, and hourly intensities from the Evansville Airport rain gage. Wet and dry flows are combined to determine the total flow in the system for each hour with recorded rain data.



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HENDERSON DOWNTOWN INTERCEPTOR
SPREADSHEET MODEL SCHEMATIC

COMBINED SEWER OVERFLOW
LONG TERM CONTROL PLAN
HENDERSON WATER UTILITY
HENDERSON, KENTUCKY

STRAND ASSOCIATES, INC.®
ENGINEERS

FIGURE 1.08-1
5454.003

The rain gauge at the Evansville Airport takes records data in hourly increments, therefore, all flow rates calculated using the rational method are assumed to occur for one hour for purposes of calculating CSO volumes.

The first hydraulic check occurs at the CSO regulator structure. The total flow in the system is compared to the sewer capacity at the CSO regulator structure leading to the downtown interceptor. Flow rates exceeding the sewer capacity are immediately assumed to overflow directly to the Ohio River and flow rates up to the sewer capacity are conveyed to the downtown interceptor.

Flow conveyed to the downtown interceptor goes through two more checks. The first hydraulic check occurs where the flow conveyed from the individual CSO basins enter the downtown interceptor. This check adds the flow from the CSO basin to the existing flow in the downtown interceptor and compares the sum to the hydraulic capacity of the downtown interceptor. If the flow does not exceed the downtown interceptor capacity, it proceeds downstream.

If the flow exceeds the downtown interceptor capacity, the second check occurs. The downtown interceptor is a deep interceptor consisting primarily of 36-inch pipe that runs along the Ohio River, finally discharging into the Janalee Drive Pumping Station. Therefore, the interceptor can provide in-line storage equal to its volume, which is approximately 0.5 mg. Flow exceeding the downtown interceptor capacity, goes into storage until 0.5 mg of combined flow is stored. After the 0.5 mg of storage is full, all additional flow is assumed to surcharge the system and is considered overflow.

The final hydraulic check occurs at the Janalee Drive Pumping Station. The flow in the downtown interceptor flowing into the pumping station is compared to the pumping station capacity of 11.5 mgd. Flow in excess of the pumping station capacity is assumed to overflow into the Ohio River.

For example, assume an hourly rainfall intensity at CSO 005 causes a total flow of 4 mgd within the CSO basin. The 4 mgd is compared against the capacity of the CSO regulators connection to the downtown interceptor, which for CSO 005 is approximately 3.2 mgd. Therefore, for the hour of rainfall that caused 4 mgd of total flow at CSO 005, 0.8 mgd overflowed at the CSO regulator directly into the Ohio River and 3.2 mgd is conveyed to the downtown interceptor. The capacity immediately upstream and downstream of the downtown interceptor where CSO 005 connects to it is approximately 13.7 mgd. Assume that contributions from the upstream CSO basins create a flow in the downtown interceptor of 13 mgd and no storage is currently in use. The 3.2 mgd from CSO 005 added to the existing flow in the downtown interceptor creates a flow of 16.2 mgd, which exceeds the capacity by 2.5 mgd (16.2 mgd to 13.7 mgd). The 2.5 mgd flowing for one hour equals approximately 0.1 mg (2.5 mgd * 1 hour/24 hours per day), which is below the 0.5 mg storage capacity of the downtown interceptor and is therefore stored. For simplicity purposes, assume no additional flows enter the downtown interceptor and 13.7 mgd is conveyed to the Janalee Drive Pumping Station. The flow in the interceptor is compared to the capacity of the Janalee Drive Pumping Station, which is approximately 11.5 mgd. The flow in the downtown interceptor reaching the Janalee Drive Pumping Station exceeds the capacity by 2.2 mgd, therefore, it is assumed 2.2 mgd overflows at the Janalee Drive Pumping Station and 11.5 mgd flows to the wastewater treatment plant (WWTP) for treatment.

Although the spreadsheet model performs these checks for each individual hour of rainfall for the past 60 years, the model also incorporates continuity checks so the 0.5 mg of storage provided by the downtown interceptor is not counted each hour. Storage is filled during consecutive hours of rainfall until it reaches its capacity and further rainfall does not account for any storage. When the spreadsheet model reaches an hour where no rainfall occurs, the storage begins to “recharge” as the system drains. Because the only storage taken into account in the downtown CSS is the downtown interceptor, storage recharges at a rate equal to the Janalee Drive Pumping Station capacity during periods of no rainfall. To be conservative, storage can only recharge during periods of no rainfall, even if flow rates within the downtown interceptor do not exceed the recharge rate due to very low intensity rainfall. This continuity check is performed throughout the 60 years of rainfall data to more accurately simulate the effects of back-to-back storms on the system.

B. Canoe Creek Combined Sewer Overflow Volume Estimation

The Canoe Creek area performs a hydraulic capacity check against the Second Street Pumping Station for the 2008 model and the Canoe Creek Pumping Station (which will replace the Second Street Pumping Station) for the 2018 model to determine overflow volumes. Dry and wet weather flows are calculated using the rational method to determine the total flows within the basin. This total flow is compared to either the capacity of the Second Street Pumping Station for the 2008 analysis or the Canoe Creek Pumping Station for the 2018 analysis.

Combined flow that exceeds the capacity of the pumping stations flows first into the Third Street CSO basin for storage. The storage incorporated into the model for the Third Street CSO basin operates the same way as the downtown interceptor storage, only the CSO basin provides 15 mg of storage and the recharge rate is limited by the capacity of the pumping station within the basin, which is approximately 0.07 mg/hour. As with the downtown interceptor storage, the model has continuity checks to account for how much combined flow has accumulated within the basin for continuous hours of rainfall. The basin only recharges during periods where no rainfall occurs.

C. Average Annual Combined Sewer Overflow Volume Estimation

These series of checks are simulated for the downtown CSS and the Canoe Creek CSS for every hour that rainfall occurred in the past 60 years to determine an estimated CSO volume for the past 60 years. Hourly flow overflow rates, flows conveyed to the WWTP by the Janalee Drive Pumping Station are converted to volumes and added to the storage provided by the downtown interceptor and the Third Street CSO basin determine to total overflow volume, total volume captured/treated, and total system volume, respectively. These totals are then divided by 60 years to estimate the annual averages.

The spreadsheet tool can be used to estimate the incremental increase in percent capture for each of the planned CSO control projects as seen in Table 1.08-1. Because HWU’s approach to CSO control is systematic and each project is interrelated to others, the values presented in the table are for informational purposes only. The overall cumulative results of the entire program and/or series of projects are considered representative projections of the plan's benefits. However, each project’s incremental increase in percent capture may vary from what is presented in the table because of the sequencing of projects. To estimate incremental benefits for each individual project, it was necessary to assume that each project would be completed one at a time without any progress made on other projects. As presented in the LTCP, the planned projects overlap in time and are connected and interrelated to one another. For these reasons, these estimates will vary on an individual project basis.

TABLE 1.08-1

INCREMENTAL BENEFIT TOWARDS PERCENT CAPTURE PER INDIVIDUAL CSO CONTROL PROJECT

Project	Project Completion Date	CSO Area	Pre-CSO Abatement CSS Volumes: CSO Discharge Volume (mg/yr)	Pre-CSO Abatement CSS Volumes: Flow Captured/ Treated (mg/yr)	Pre-CSO Abatement CSS Volumes: Total System Volume (mg/yr)	Pre-CSO Abatement CSS Volumes: Percent Capture[1]	Post-CSO Abatement CSS Volumes: CSO Discharge Volume (mg/yr)	Post-CSO Abatement CSS Volumes: Flow Captured/ Treated (mg/yr)	Post-CSO Abatement CSS Volumes: Total System Volume (mg/yr)	Post-CSO Abatement CSS Volumes: Percent Capture[1]	Percent Capture Increase[1]	Project Notes
CSO Regulator Capacity Increase	Completed as Needed	Downtown	221.4	570.4	791.8	72.0%	217.5	574.3	791.8	72.5%	0.5%	Increases all connections from downtown CSO regulators to the downtown interceptor
Ershig Stormwater Line	First Quarter 2011	Downtown	217.5	574.3	791.8	72.5%	217.5	574.3	791.8	72.5%	0.0%	Alleviates ponding issues and redirects stormwater from contributing to the CSS.
Center and Julia Separation (Phase III)	First Quarter 2012	Canoe Creek	217.5	574.3	791.8	72.5%	195.4	526.1	721.6	72.9%	0.4%	Redirects stormwater flow directly to Canoe Creek allowing for storage capacity in the 3rd Street CSO basin during an overflow event.
Canoe Creek Pumping Station and Interceptor (Phase 2)	End of 2012	Canoe Creek	195.4	526.1	721.6	72.9%	104.2	551.7	655.9	84.1%	11.2%	Includes the completion of the new 12 mgd Canoe Creek Pumping Station and the redirection of flow of numerous separated areas and pumping stations. Also see note on WWTP improvements (headworks) for special notes on percent capture calculations.
Downtown Separation	First Quarter 2013	Downtown	104.2	551.7	655.9	84.1%	51.5	381.1	432.6	88.1%	4.0%	Separation of high percent impervious areas in the downtown CSS.
Canoe Creek Pumping Station and Interceptor (Phase 3)	First Quarter 2014	Canoe Creek	51.5	381.1	432.6	88.1%	49.0	377.0	426.0	88.5%	0.4%	Redirection of a number of pumping stations, including the Atkinson Street pumping station away from the downtown CSS.
WWTP Improvements (Headworks)	Spring 2014	-	49.0	377.0	426.0	88.5%	49.0	377.0	426.0	88.5%	0.0%	All flow transported to the WWTP in the spreadsheet tool is considered treated. WWTP Improvements will increase treatment capacities to match incoming flow rates, which were increased in the spreadsheet tool for the Cano Creek Pumping Station and Interceptor (Phase 2). Therefore, no percent capture increase is shown for this project.
Canoe Creek Pumping Station and Interceptor (Phase 4)	Mid 2016	Canoe Creek	49.0	377.0	426.0	88.5%	49.0	377.0	426.0	88.5%	0.0%	Flow in areas already separated is redirected to new Canoe Creek interceptor, therefore does not result in any increase in capture.

[1] CSO Discharge, Percent Capture, and Percent Capture Increase are calculated from the HWU CSS overflow estimator spreadsheet tool. These values are estimates from the spreadsheet tool based on the current list and schedule of CSO abatement projects. Percent Capture and Percent Capture Increase estimates assume each project will be completed one at a time in consecutive order with no work on any other project to show the estimated changes in percent capture of each project. Projects will not be completed one at a time with no work on any other project and may not be completed in this order. For these reasons, these estimates will vary from percent captures calculated or estimated directly from overflow data. Projects implemented by HWU will not result in these exact percent captures, therefore HWU cannot be held to attaining the percent captures listed in this project tracking summary.

For these reasons, these estimates will vary from percent captures calculated or estimated directly from overflow data and projects implemented by HWU will not result in these exact percent captures. Therefore for these reasons alone, HWU cannot assure that the percent captures listed in this project tracking summary will be accurate. This table is presented as an informational tool only and cannot be relied upon as a guarantee of effectiveness of CSO controls in any way.

1.09 DEFINITIONS

BLM	Bureau of Land Management
cfs	cubic feet per second
col/100 mL	colonies (bacteria) per 100 milliliters
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
HWU	Henderson Water Utility
KDEP	Kentucky Department of Environmental Protection
KDOW	Kentucky Division of Water
LTCP	Long-Term Control Plan
mgd	million gallons per day
mil gal	million gallons
mL	milliliters
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic Atmospheric Administration
NPS	National Park Service
NRCS	National Resources Conservation Service
NWS	National Weather Service
ORSANCO	Ohio River Sanitary Commission
TSS	total suspended solids
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WWTP	Wastewater Treatment Plant

SECTION 2
POSTCONSTRUCTION MONITORING

2.01 INTRODUCTION

The HWU LTCP uses the presumptive approach to evaluate the collection system improvement alternatives. This approach presumes that water quality based requirements of the Clean Water Act (CWA) will be met if no less than 85 percent of the volume of combined sewage collected in the CSS is eliminated or captured during the baseline year 1995 precipitation events on a systemwide annual average basis is eliminated or captured. The primary goal of a postconstruction monitoring plan is to verify the approved LTCP is meeting the 85 percent CSO volume capture/elimination goal.

In addition to meeting the 85 percent capture/elimination goal, guidance recommends a postconstruction compliance monitoring program that evaluates the effectiveness of the CSO controls to protect water quality. HWU currently has a monitoring plan in place and reports CSO discharge volume, duration, and flows. As system improvements are made, HWU will adjust their monitoring plan to monitor the effectiveness of controls. Using Ohio River Sanitary Commission (ORSANCO) data, HWU will establish a baseline of water quality conditions. Based on the baseline assessments, parameters of concern can be identified and tracked during and after LTCP implementation. Results will be reported to KDOW and USEPA and shared with the community during the postconstruction monitoring process.

2.02 RAINFALL MONITORING

HWU currently monitors rainfall at four rain gauges located around the city. In addition to these rain gauges, rainfall data is available through the National Weather Service (NWS) from local airports and USGS monitoring stations.

2.03 CURRENT CSO FLOW MONITORING

Flow monitoring at the CSO discharge locations should continue to accurately determine the volume and flow rate of all discharges. HWU has already installed flow measurement devices at all overflow points except for CSO 016 (Cooper Park Pumping Station), which will be eliminated by the Canoe Creek Pumping Station. These flow monitoring devices are installed in accessible locations, such as in CSO diversion structures so that HWU personnel can access and maintain equipment. In conjunction with the flow meters, the United States Army Corp of Engineers (USACE) collects Ohio River hydraulic data that can be used to correlate the flow and volume in the Ohio River during events.

Flow metering should continue for all discharge points throughout the implementation process to measure the effectiveness of CSO control. Flow to the wastewater treatment plant (WWTP) should also be monitored to determine the amount of wet weather flow from the combined system is captured and treated at the WWTP.

2.04 WASTEWATER TREATMENT PLANT INFLUENT WATER QUALITY MONITORING

HWU currently monitors the WWTP influent water quality. Influent water quality samples collected during wet weather events will be recorded and reported as part of this monitoring program.

2.05 WATER QUALITY MONITORING (OHIO RIVER)

ORSANCO regularly collects water quality information from the Ohio River. HWU plans to utilize this data to evaluate HWU's impact to the water quality in the Ohio River. As a small system, HWU does not have the resources available to collect water quality samples from the Ohio River during or immediately after wet weather events. The use of ORSANCO data will provide a more robust dataset to evaluate the impacts of CSOs to the Ohio River.

2.06 WATER QUALITY MONITORING (CANOE CREEK)

No water quality sampling is planned for Canoe Creek because the LTCP calls for the elimination of all overflows to this water body.

2.07 COMBINED SEWER DISCHARGE EFFLUENT WATER QUALITY MONITORING

HWU will install automatic samplers to take discharge samples at the diversion structures for two overflow events at CSO 002 (Janalee Drive Pumping Station) during the contact recreational season. Analysis done as part of the LTCP indicates that CSO 002 will be the most active CSO remaining in HWU's system. As the most downstream CSO in HWU, discharges from this point include flows from the entire CSS and should produce a representative sample of in-system characteristics. These locations were selected because they are expected to be the most active overflow points after implementation of CSO controls. Flow-weighted grab samples will be tested for TSS, *E. coli,* and fecal coliform. CSO discharge samples will be collected at regular intervals for at least 12 hours after the start of discharge or until discharges cease, whichever occurs first, to assist in defining a pollutograph.

2.08 DATA VALIDATION

Water quality data collected by HWU will be done according to industry-standard procedures. This procedure should require equipment to be maintained and calibrated according to manufacturer's specifications. The laboratory analyses should be performed by a Kentucky-certified laboratory. A quality control and quality assurance plan should be implemented for sample blanks and duplicate samples.

2.09 REPORTING

All collected data will be recorded and reported once a year in conjunction with the Annual Report. The data collected should be compiled and analyzed to assess the progress and effectiveness of the LTCP CSO controls toward meeting the 85 percent capture goal.

Within one year of completing the last scheduled LTCP measure, HWU will submit a final report that will document the final results from the monitoring plan in accordance with the approved plan and determine whether LTCP measures have or are meeting the goals of the CSO policy.

SECTION 3
RAINFALL STATISTICS

3.01 RAINFALL CHARACTERIZATION

Communication with KDOW staff indicated a desire by KDOW to understand the effects of a design storm in the spreadsheet model. To accommodate this request, a 1-year, 24-hour storm was simulated in the spreadsheet model using the precipitation estimates from the Bulletin 71 and the NOAA Atlas 14. The NOAA Atlas 14 was also used because it provides a site specific precipitation estimate for Henderson, where the Bulletin 71 precipitation estimates are split into four larger sections within Kentucky.

The Bulletin 71 1-year, 24-hour storm for Henderson has a rainfall depth of 3.10 inches and the NOAA Atlas 14 1-year, 24-hour storm for Henderson has a rainfall depth of 2.71 inches. Rainfall for each storm was distributed hourly to incorporate it into the spreadsheet model using a third quartile distribution as described in Bulletin 71, which is a typical rainfall distribution for an event of 12.1 to 24 hours in length. Table 3.01-1 shows a summary of the results for each analysis.

Basin	Volume Captured/Treated/Stored (mg)	Overflow Volume (mg)	Total System Volume (mg)	Percent Capture
NOAA Atlas 14 1-year, 24-hour Storm, 2.71 inches of Rainfall				
Downtown Interceptor	8.47	2.38	10.85	78%
Canoe Creek	13.38	0.00	13.38	100%
Total System	21.85	2.38	24.23	90%
Bulletin 71 1-year, 24-hour Storm, 3.10 inches of Rainfall				
Downtown Interceptor	9.05	3.13	12.18	74%
Canoe Creek	14.84	0.00	14.84	100%
Total System	23.89	3.13	27.02	88%

Table 3.01-1 One-year, 24-hour Storm Analysis Summary

As expected, the Bulletin 71 analysis yields slightly less percent capture because the total rainfall depth is greater than the NOAA Atlas 14. HWU's approach to CSO control is based on Criteria ii. of the Presumptive Approach which calls for *"The elimination or the capture for treatment of no less than 85 percent by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis;"*. Both analyses of these significant annual events exceed the 85 percent capture criteria.

From a water quality compliance standpoint, it is anticipated that the residual overflows remaining after implementation of the CSO program will conform to the goals of the CSO policy. As discussed in the LTCP, bacteria is the pollutant of concern for the HWU dischargers to the Ohio River. As discussed with the regulatory agencies, a review of the ORSANCO bacteria data in this segment of the Ohio River generally indicates compliance with the geometric mean standard for bacteria. However, the Kentucky Department of Environmental Protection (KDEP) water quality criteria for bacteria also requires that no more than 20 percent of fecal coliform samples collected over a 30-day period exceed 400 col/100 mL.

An evaluation of Bulletin 71 1-year, 24-hour storm (3.10 inches) indicates that the HWU CSS would discharge approximately 3.13 million gallons to the Ohio River. Applying mixing formulas from the USEPA document titled Combined Sewer Overflows - Guidance for Monitoring and Modeling (EPA 832-B-99-002), it has been estimated that a 3.13 million gallon discharge to the Ohio River over a 24-hour period, with a concentration of 1,000,000 col/100 mL under average river flow conditions, would dilute to levels below the water quality criterion within one hour of the cessation of the discharge.

It should be noted the contact recreation season encompasses approximately 4,320 hours. The bacteria criteria requires that fecal coliform concentrations not exceed 400 col/100 mL in more than 20 percent of collected samples. Based on the evaluation of the 1-year storm, which in terms of CSO compliance is an extreme event, the data appears to demonstrate a very limited duration of water quality impact.

Therefore, following implementation of the HWU LTCP, it seems reasonable to conclude that collective impact of the remaining CSOs would not result in exceedances of existing water quality criteria for bacteria.