Final Report

Wastewater Flow Monitoring and Flow Projections

March 2011

Winston-Salem • Forsyth County
City/County Utilities
Water • Sewer • Solid Waste Disposal

CDM

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March 21, 2011

Mr. Jack Fitzgerald
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Winston-Salem/Forsyth County Utilities
101 North Main Street
Winston-Salem, NC 27101

Subject: Wastewater Flow Monitoring and Flow Projections Final Report

Dear Mr. Fitzgerald:

Per your request, enclosed please find seven (7) copies of the final Wastewater Flow Monitoring and Flow Projections Project report describing the wastewater flow data analysis and wastewater flow projections. Thank you for giving CDM the opportunity to assist the City/County Utility Commission with this important project. If you have any questions or require additional information, please do not hesitate to contact me. We look forward to working with you again in the future.

Sincerely,

Laurin B. Kennedy, P.E., BCEE
Senior Project Manager
Camp Dresser & McKee

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Section 1
Introduction

1.1 Background

The Winston-Salem City/County Utility Commission (CCUC) operates and maintains approximately 1,660 miles of sanitary sewer pipeline ranging from 2-inches in diameter to 66-inches in diameter and over 60 pump stations (**Figure 1-1**). There are three main basins in the CCUC system: Muddy, Elledge, and South Fork. The wastewater flow from the Muddy basin is treated at the Muddy Creek Wastewater Treatment Plant (WWTP). Flow from the Elledge basin is treated at the Elledge WWTP. Flow from the South Fork Basin is transferred to the Elledge WWTP via the South Fork Lift Station. The valving configuration at the South Fork Lift Station allows some flow to bypass the station and be conveyed to the Muddy Creek WWTP.

In 2010, CCUC commissioned CDM to update the population and wastewater flow projections completed in 2008 by HDR (Archie Elledge Wastewater Treatment Plant Flow Projections Memorandum HDR, 2008). Due to the economy and resulting reduced growth within the CCUC's service area, the population and wastewater flow projections developed by HDR are about 12 percent higher for 2009 than the actual 2009 conditions. These flow projections were used as the basis for the 2010 Wastewater Facilities Master Plan prepared by CDM. As a result, the recommended implementation schedule of all capacity-related wastewater improvements in the Wastewater Facilities Master Plan is likely to be sooner than actually needed. The scope of this project includes temporary flow monitoring to establish 2010 dry- weather flows and development of revised wastewater flow projections based on the new flow monitoring data. Also included in this scope of work is an update of the Wastewater Facilities Master Plan to reflect the results of this study. The updated Wastewater Facilities Master Plan will be issued by CDM in February 2011 under a separate cover.

1.2 Project Approach

The following major tasks were conducted as part of this study:

Task 100 - Flow Monitoring and Data Analysis

Task 200 – Wastewater Flow Projections

Task 300 – Update Wastewater Facilities Master Plan

This report contains detailed descriptions of the steps involved in Task 100 and 200, and activities performed as part of Task 300 will be presented in a separate report.

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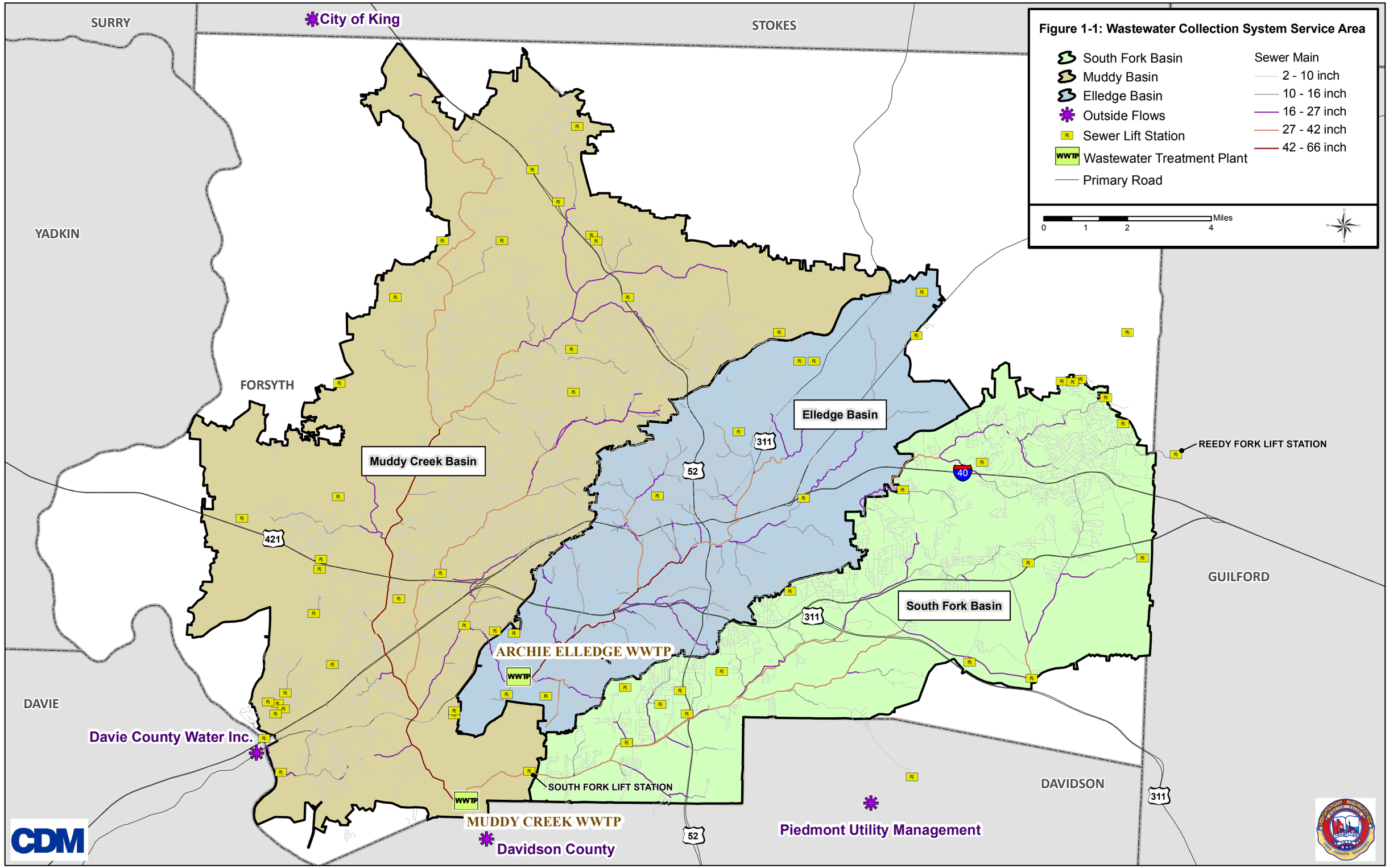
Figure 1-1: Wastewater Collection System Service Area
South Fork Basin
Muddy Basin
Elledge Basin
Outside Flows
Sewer Lift Station
Wastewater Treatment Plant
Primary Road
Sewer Main
2 - 10 inch
10 - 16 inch
16 - 27 inch
27 - 42 inch
42 - 66 inch
Miles
0
1
2
4
City of King
SURRY
STOKES
YADKIN
FORSYTH
GUILFORD
DAVIE
DAVIDSON
Muddy Creek Basin
Elledge Basin
South Fork Basin
REEDY FORK LIFT STATION
ARCHIE ELLEDGE WWTP
MUDDY CREEK WWTP
SOUTH FORK LIFT STATION
Davie County Water Inc.
Davidson County
Piedmont Utility Management
421
52
311
40
CDM

Flow Monitoring and Data Analysis (Task 100):

CDM developed a flow monitoring plan to collect flow and rainfall data within CCUC's sewer collection system. CDM recommended flow monitor locations, duration of flow monitoring, and criteria for completion of the flow monitoring study and hired subconsultant Hydromax for the mobilization, installation, maintenance, and data collection of 27 temporary flow meters and 6 temporary rain gauges. Hydromax monitored temporary meters and rain gauges for up to 60 days, and afterward converted and/or installed 11 permanent flow meters and 3 permanent rain gauges. Because the flow monitoring was performed in the summer months, there was a wide variability in the rainfall recorded. For this reason, radar rainfall data was collected.

Wastewater flow meter data was decomposed into base flow, groundwater infiltration, and rainfall dependent infiltration and inflow (RDI/I) components for the three largest storm events. This decomposition revealed the relative peak RDI/I contributions of various portions of the service area. Wet-weather peaking factors were developed based on the results of flow monitoring analysis.

Wastewater Flow Projections (Tasks 200):

Future wastewater flow projections for the CCUC service area were prepared by CDM using flow monitoring and Transportation Analysis Zone (TAZ) planning data. TAZ data were used to develop population and employee unit flow factors for the service area. Yearly average dry-weather wastewater flow projections were developed for 2010 through 2035. Additionally, annual average, max month, max day and peak hour factors were developed for the Muddy Creek, Elledge, and South Fork Basins. These peaking factors were applied to the yearly average dry-weather flow projections to develop future flow projections from these basins.

Section 2
Evaluation of Wastewater Flows

This section describes the collection and evaluation of flow monitoring data from the CCUC system. The purpose of the flow monitoring was to collect dry weather flow data in order to update the flow projections to the wastewater treatment plants. The flow projection methodology and results are described in Section 3. A secondary goal was to evaluate subbasins relative to their wet weather peaking factors and inflow and infiltration (I/I) contribution. This section includes a description of the planning area (Section 2.1) and data collected (Section 2.2) as well as the results of the rainfall analysis (Section 2.3) and the flow data analysis (Sections 2.4 and 2.5).

2.1 Planning Area Description

The CCUC existing wastewater service area was developed based on the service area boundary provided by City of Winston Salem planning department and identified in the Legacy Development Guide as well as geographic information system (GIS) mapping of the sewer system provided by CCUC. The existing service area includes the city/town centers, urban neighborhoods, and suburban neighborhoods identified in the Legacy Development Guide. In some locations, the sewer service area was extended to include sewered areas as shown in the CCUC GIS data. The existing service area is shown in **Figure 2-1** and is divided into three main basins: Muddy Creek, Elledge, and South Fork.

2.2 Data Collection

2.2.1 Flow Monitoring Data Collection

CDM hired sub-consultant Hydromax USA (Hydromax) to install 27 flow meters (FM 01 - FM 27) and 6 rain gauges (RG 01- RG 06) throughout the collection system (Figure 2-1). Hydromax staff maintained and collected data throughout the 60 day flow monitoring period from August 16, 2010 to October 15, 2010. The meters were pulled starting October 27, 2010 and thus were able to capture flows during the October 27 rain event. The flow meters measured depth and velocity in 5-minute increments, and this data was converted to flow in gallons per minute (gpm).

In addition to data collected by Hydromax, CCUC provided the following historic flow data:

- Effluent flow for the Archie Elledge and Muddy Creek Wastewater Treatment Plants (WWTPs) from November 10, 2005 to October 31, 2010.
- Data for Parshall flumes located upstream of the WWTPs (Figure 2-1). Parshall Flume 28 is located downstream of the South Fork pump station and upstream of the Archie Elledge WWTP. Parshall Flume 29 is located on the Kimmel Branch interceptor upstream of the Archie Elledge WWTP. Parshall Flume 30 is located downstream of the South Fork pump station and upstream of the Muddy Creek WWTP. Data was provided in hourly increments from November 10, 2005 to October 31, 2010 for Parshall flume 28; from November 1, 2005 to October 31, 2010 for Parshall flume 29; and from

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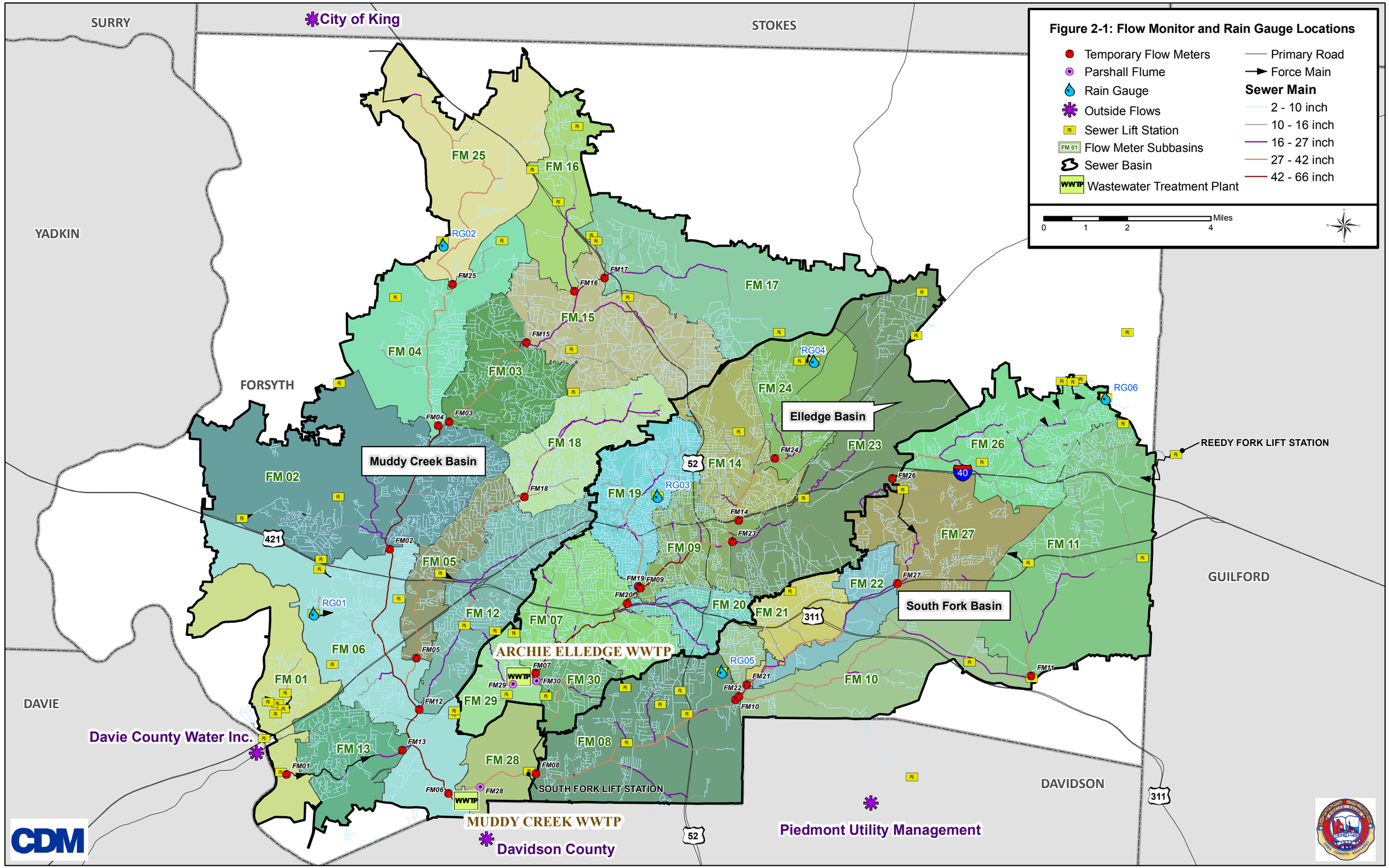
Figure 2-1: Flow Monitor and Rain Gauge Locations
Temporary Flow Meters
Parshall Flume
Rain Gauge
Outside Flows
Sewer Lift Station
Flow Meter Subbasins
Sewer Basin
Wastewater Treatment Plant
Primary Road
Force Main
Sewer Main
2 - 10 inch
10 - 16 inch
16 - 27 inch
27 - 42 inch
42 - 66 inch
Miles
0
1
2
4
SURRY
STOKES
YADKIN
FORSYTH
GUILFORD
DAVIE
DAVIDSON
City of King
Davie County Water Inc.
Davidson County
Piedmont Utility Management
Muddy Creek Basin
Elledge Basin
South Fork Basin
ARCHIE ELLEDGE WWTP
MUDDY CREEK WWTP
SOUTH FORK LIFT STATION
REEDY FORK LIFT STATION
FM 01
FM 02
FM 03
FM 04
FM 05
FM 06
FM 07
FM 08
FM 09
FM 10
FM 11
FM 12
FM 13
FM 14
FM 15
FM 16
FM 17
FM 18
FM 19
FM 20
FM 21
FM 22
FM 23
FM 24
FM 25
FM 26
FM 27
FM 28
FM 29
FM 30
RG01
RG02
RG03
RG04
RG05
RG06
WWTP
421
52
40
311

- November 1, 2005 to December 31, 2008 and from October 20, 2010 to December 31, 2010 for Parshall flume 30.
- Winston-Salem provided flows for four outside areas contributing flow to CCUC's collection system: City of King, Davie County Water, Inc., Davidson County, and Piedmont Utility Management within Davidson County. Data were provided as wastewater flow volume per billing period in cubic feet. Flows were calculated in gpm per billing period and the average flows were calculated for each of the 4 outside contributing areas.

2.2.2 Subbasin Delineation

The upstream area contributing flow to each meter was delineated based on the GIS sewer data provided by CCUC and the existing service area boundary provided by the Planning Department. The service area boundary was extended, if necessary, to include all sewers draining to the flow meter. Modifications were made as necessary in GIS along parcel boundaries. The area draining to each flow meter is called a subbasin. **Table 2-1** lists the flow meters and subbasin area contributing to each meter. Figure 2-1 shows the subbasin area delineation for the Winston Salem CCUC service area. While a description of the connection location for the outside areas was provided, the location of the total contributing area was unknown. Therefore, the areas included in Table 2-1 do not include the acreage from outside flow contributors.

2.2.3 Rainfall Data Collection

Rainfall data was collected by Hydromax in conjunction with flow monitoring data to determine the relationship between rainfall volume and peak flow rates. Six rain gauges were installed in the collection system during the temporary flow monitoring period (Figure 2-1). All rain gauges recorded volumes in increments of 0.01 inches every 5 minutes.

For this analysis, significant storm events are defined as those for which the majority of the gauges recorded total rainfall amounts greater than 0.5 inches. Six significant rainfall events were recorded during the flow monitoring period (**Table 2-2**).

Out of the 6 significant rainfall events recorded during the flow monitoring period, three events were selected for peak flow analysis. The rainfall events were selected based on the size of the storm event and the I/I response in terms of peak flows. The three rainfall events selected were the September 26, 2010, September 30, 2010, and October 27, 2010 events. The two largest storm events were recorded on September 30, 2010 and October 27, 2010, with an average of 3.08 and 3.95 inches, respectively. These two events generally produced the highest peak flows. The next largest event recorded was the September 26, 2010 event with an average of 2.68 inches.

Because the flow monitoring was performed in the summer months, there was a wide variability in the rainfall recorded during each event, especially in the September 30, 2010 and October 27, 2010 events. For example, in the October 27, 2010 event, the rainfall varied from a minimum of 1.17 inches to a maximum of 5.41 inches. For this reason, radar rainfall data was collected as described in the following section.

Table 2-1: Total Upstream Areas

Basin Name	Flow Meter	Manhole ID	Pipe Diameter	Upstream Flow Meters	Subbasin Area (Acres) (1)
Elledge	07	SMH668A	60	09, 19,20	5,100
	09	SMH27547	48	14, 23	2,800
	14	SMH41798	36	24	4,000
	19	SMH27172	42	None	4,000
	20	SMH6956	24	None	1,820
	23	SMH42779	27	None	10,130
	24	SMH14294	30	None	4,010
South Fork	08	SMH50541A	36	10, Davidson County	8,780
	10	SMH7975	36	11, 22, Davidson County	6,990
	11	SMH51424	30	None	11,060
	22	SMH7981	30	27	2,300
	26	SMH15110	30	None	5,890
	27	SMH16167	27	26	5,620
	21	SMH8966	18	None	2,180
Muddy Creek	01	SMH30614	21	Davie County Water Inc.	5,040
	02	SMH54222	54	03, 04	12,860
	03	SMH4807	36	15	4,180
	04	SMH4735	42	25	6,480
	05	SMH1776	36	18	2,700
	06	SMH50582	66	02, 05, 12, 13	9,930
	12	SMH1582	21	None	5,220
	13	SMH50831	24	01	3,400
	15	SMH11133	27	16, 17	6,640
	16	SMH46084	18	None	3,520
	17	SMH49496A	24	None	8,410
	18	SMH22326A	30	None	4,420
	25	SMH12032	36.5	City of King	7,600

(1) Total area within the CCUC boundary and does not include acreage from outside flow contributors

Table 2-2: Summary of Rainfall Events

Rainfall Event		Rainfall Depth (in)						Average (1)
No.	Date	RG01	RG02	RG03	RG04	RG05	RG06	(in)
1	8/17/2010	< 0.5	1.06	0.92	1.87	1.15	1.87	1.37
2	8/18/2010	0.92	0	0.79	0	1.64	0	1.12
3	9/26/2010	3.83	3.14	2.35	2.38	1.97	2.4	2.68
4	9/30/2010	0	1.44	2.14	4.15	2.59	5.08	3.08
5	10/14/2010	0.51	0.51	0.67	0.62	0.64	0.87	0.64
6	10/27/2010	5.41	5.33	4.74	4.05	1.17	2.99	3.95

(1) The average rainfall is the average for all gauges which reported greater than 0.5-inches

2.2.4 Radar Rainfall Collection and Analysis

Peak flow analysis requires that the rainfall pattern be accurately captured so that the response to rainfall can be accurately characterized. Due to the potential for high spatial variation in rainfall recorded from ground-based rain gauges, more precise rainfall data was desired for this analysis. To gain more precise rainfall data, radar rainfall data was utilized. Vieux, Inc. was selected to provide radar rainfall data for select storm events in 2010 during the temporary flow monitoring period. Data from the 6 temporary rain gauges plus additional data from two National Weather Service (NWS) rain gauges and 4-four United States Geological Survey (USGS) rain gauges were used to determine the rainfall spatial and temporal distributions for a grid of 1-km^2 areas called pixels.

The storm events selected for further wet-weather analysis using radar rainfall included the September 26, 2010 and the September 30, 2010 rain events. The October 27, 2010 event fell just outside the temporary flow monitoring period and thus was not selected. **Figures 2-2 and 2-3** shows the radar rainfall pixels overlain on the delineated subbasins for the September 26, 2010 and the September 30, 2010 storm events. The subbasins and pixels were "intersected" to find the area common to both. The rainfall pattern for each pixel was then weighted based on the common area, and a unique rainfall pattern was formed for every subbasin. This process gives a specific rainfall pattern for each subbasin. The rainfall for each subbasin was then analyzed to determine the return period as described in Section 2.3

2.3 Rainfall Intensity-Duration-Frequency Analysis

A rainfall intensity-duration-frequency (IDF) analysis was performed on historical rainfall records for the Winston-Salem CCUC service area to determine the probability that a storm of a given size or larger will occur in any given year. This analysis was used to determine the return period for the storm events. One of the criteria used in this analysis for defining separate events was a minimum of 24 hours with no rain between the separate events. **Table 2-3** shows the rainfall event depth (in inches) for a range of return periods. The return period of a storm is related to the probability that a storm of a given size or larger will occur in any given year. For example, an event with a 2-year return period has a 50 percent chance of occurring in any given year. From the frequency analysis, a 2-year, 24-hour duration storm event is approximately 3.42 inches; while a 10-year, 24-hour duration storm is approximately 4.96 inches.

For the September 26, 2010 and September 30, 2010 storm events, an IDF analysis was performed for the subbasin rainfall. Based on this IDF analysis, the September 26, 2010 event is less than a 1-year event for all subbasins (**Figure 2-4**). As noted in Figure 2-2, the rainfall for this event was relatively consistent across Winston-Salem. Conversely, the September 30, 2010 event was highly variable with subbasin rainfall ranging from a less than 1-year event up to a 10-year event based on total rainfall as shown in **Figure 2-5**.

An IDF analysis was performed on the rainfall data collected by the temporary rain gauges for the October 27, 2010 storm event (**Figure 2-6**). This event ranged from a 1 year event to a 10-year event based on total rainfall.

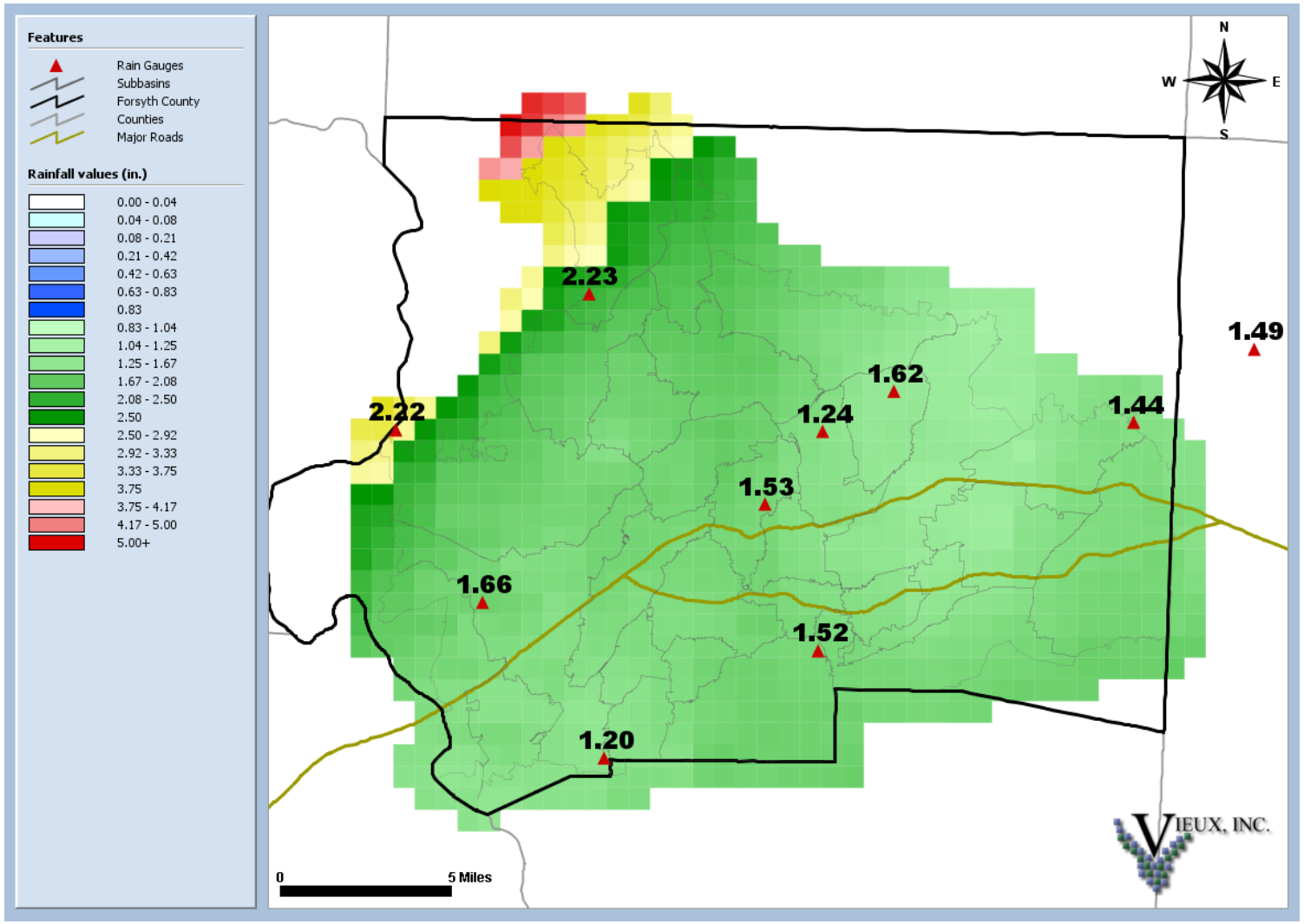

Figure 2-2: Radar Rainfall Data for September 26, 2010 Event

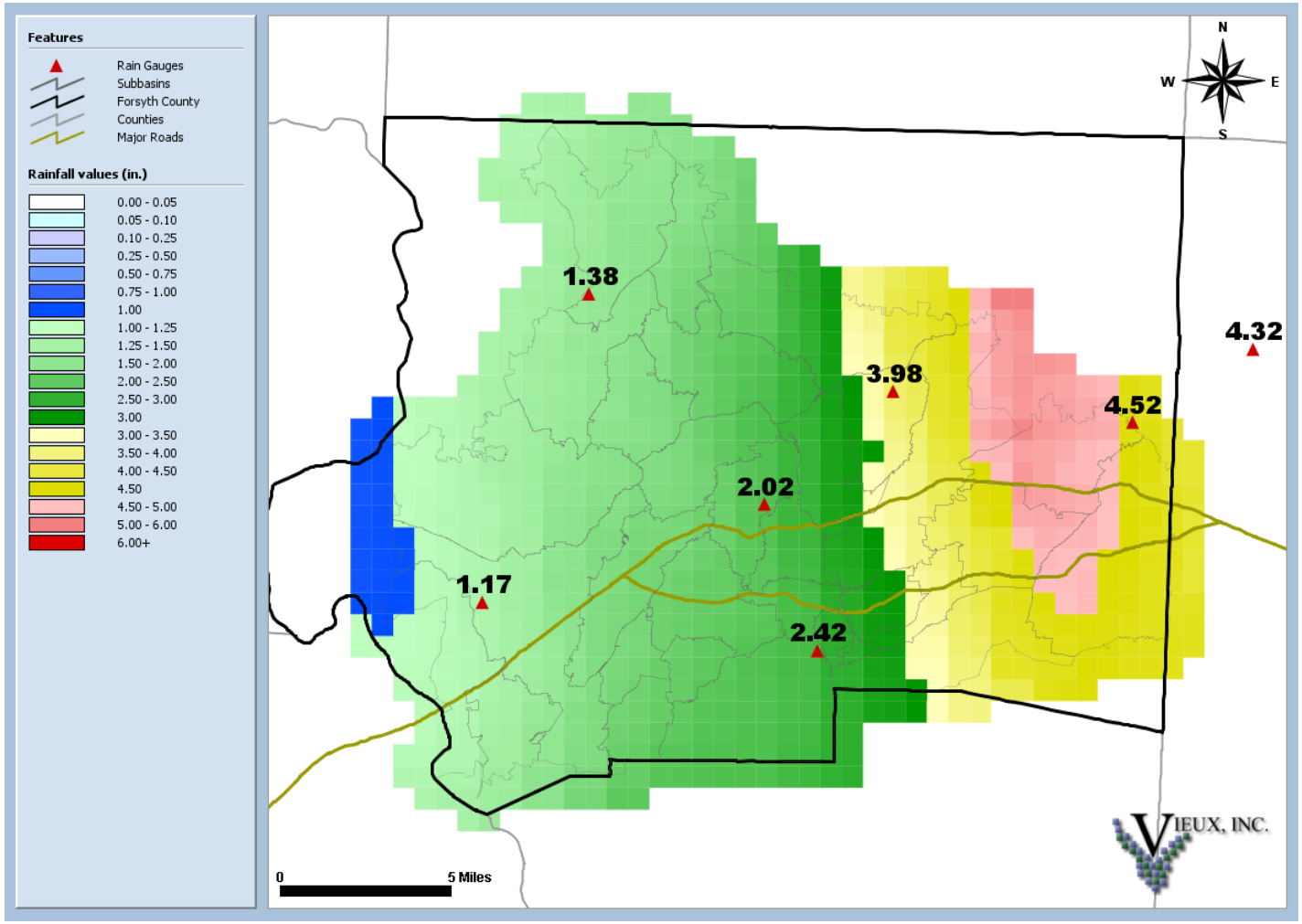

Figure 2-3: Radar Rainfall data for September 30, 2010 Storm Event

Table 2-3: Intensity-Duration-Frequency Analysis

All Seasons							
DESIGN STORM DEPTHS (inches)							
DURATION	1 year	2 year	5 year	10 year	25 year	50 year	100 year
1 Hour	1.27	1.54	1.92	2.19	2.52	2.76	3
2 Hour	1.5	1.82	2.28	2.62	3.06	3.4	3.73
3 Hour	1.61	1.95	2.45	2.82	3.31	3.68	4.05
6 Hour	1.97	2.38	2.99	3.45	4.08	4.58	5.08
12 Hour	2.35	2.85	3.58	4.16	4.97	5.61	6.29
24 Hour	2.83	3.42	4.28	4.96	5.89	6.63	7.4

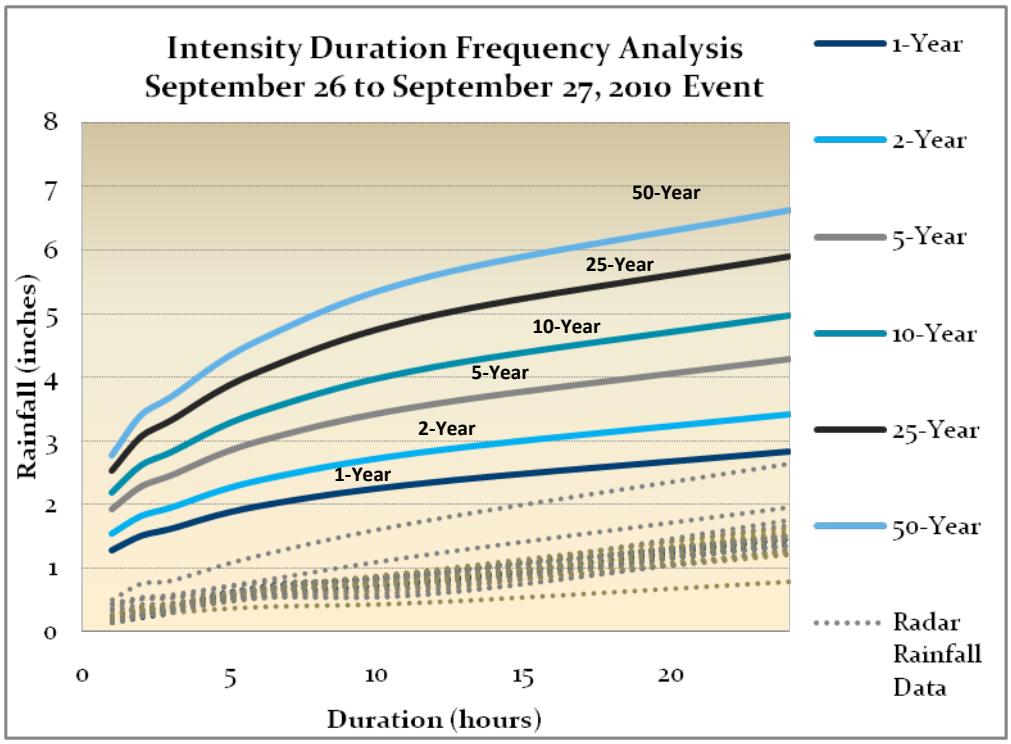

Figure 2-4: Intensity Duration Frequency Analysis for September 26 to 27, 2010 Event

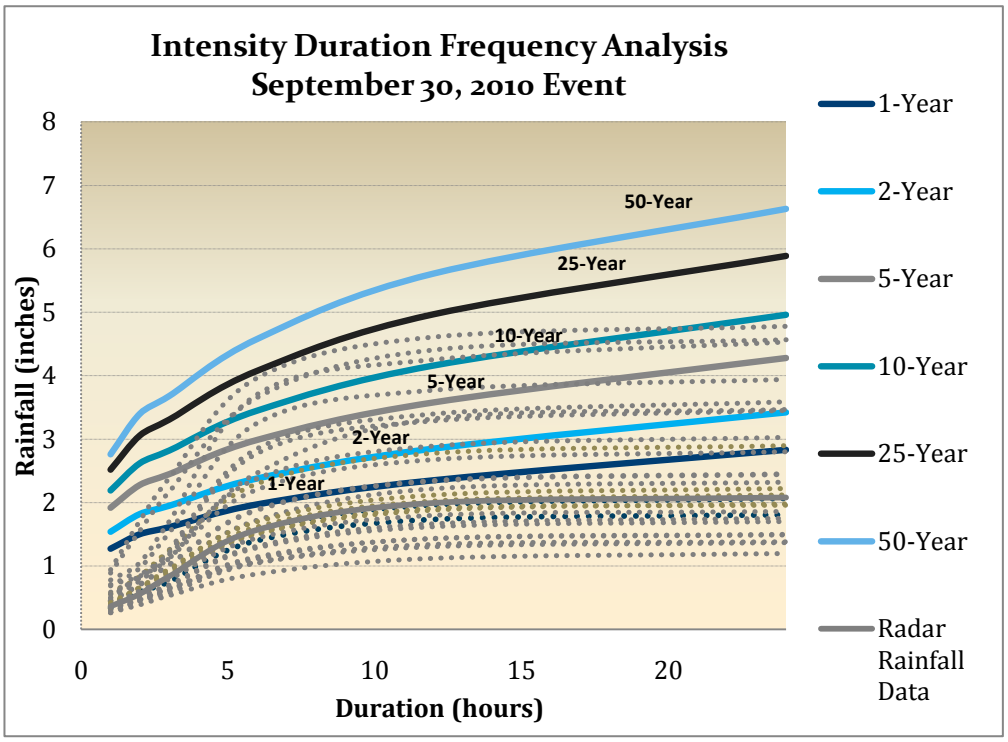

Figure 2-5: Intensity Duration Frequency Analysis for September 30, 2010 Event

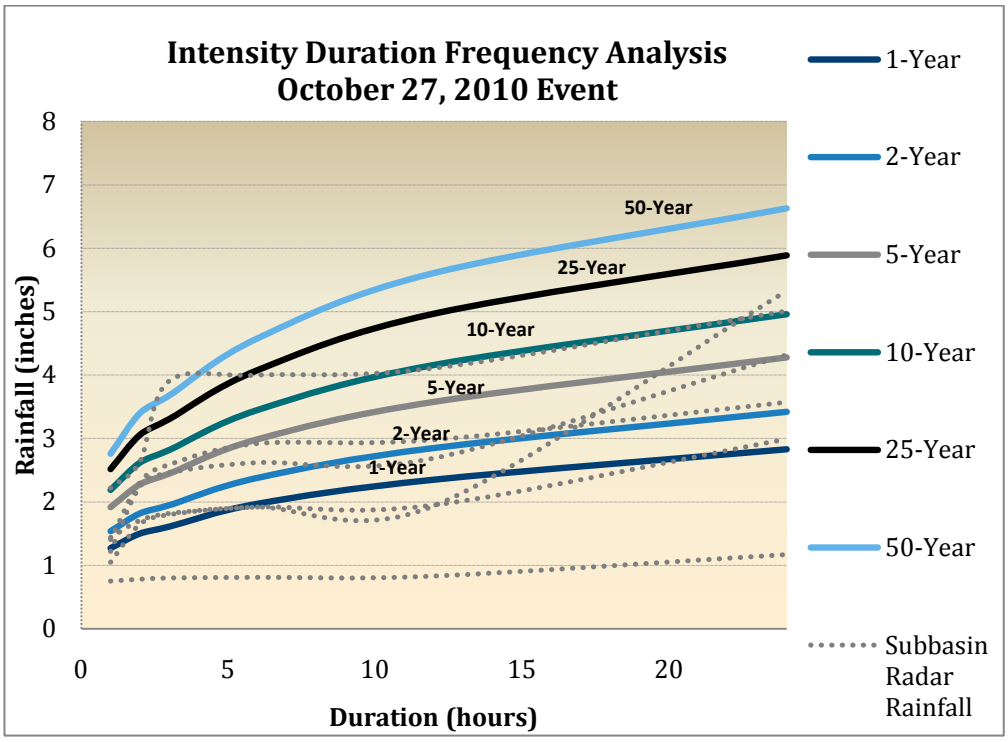

Figure 2-6: Intensity Duration Frequency Analysis for October 27, 2010 Event

2.4 Wastewater Flow Components

In general, wastewater flows can be divided into three components: base wastewater flow (BWWF), groundwater infiltration (GWI), and rainfall dependent infiltration and inflow (RDI/I). The wet-weather component (i.e., RDI/I) is of particular importance because it is the increased portion of flow that occurs during a rainfall event. Consequently, hydrograph decomposition was performed on the CCUC flow data to determine the portion of the flow hydrograph attributed to RDI/I. Results of the hydrograph decomposition were utilized to evaluate existing conditions within the basins. The three components of the hydrograph are described in the following sections.

2.4.1 Base Wastewater Flow

BWWF is domestic wastewater from residential, commercial, and institutional (i.e., schools, churches, hospitals, etc.) sources, as well as industrial wastewater sources. It is affected by the population and land uses in an area and varies throughout the day in response to personal habits and business operations.

2.4.2 Groundwater Infiltration

GWI is defined as groundwater entering the collection system through defective pipes, pipe joints, and manhole walls. The magnitude of GWI depends on the depth of the groundwater table above the pipelines, the percentage of the system that is submerged, and the physical condition of the sewer system. The variation in groundwater levels in the study area, and the amount of GWI, is seasonal in nature. While GWI is also affected by rainfall, it responds gradually and is not directly related to any individual rainfall event. It is evidenced by a general increase in wastewater flow that persists for periods of many days or weeks. From a practical standpoint, it is often not possible to differentiate infiltration of groundwater (saturated zone) from infiltration due to long-term drainage of unsaturated soils. The term GWI is used in this report to describe both types of flow.

2.4.3 Rainfall Dependent Infiltration/Inflow

RDI/I refers to stormwater that enters the sanitary sewer system in direct response to the intensity and duration of rainfall events. RDI/I can be further broken down into stormwater inflow (SWI) and rainfall-dependent infiltration (RDI), based upon the pathways through which the flow enters the sewers or manholes. SWI reaches the collection system by direct connections rather than by first percolating through the soil. SWI sources may include roof downspouts illegally connected to the sanitary sewers, yard and area drains, holes in manhole covers, cross-connections with storm drains, or catch basins. RDI includes all other rainfall-dependent flow that enters the collection system, including stormwater that enters defective pipes, pipe joints, and manhole walls after percolating through the soil.

2.5 Data Analysis

2.5.1 Decomposition of Flow Monitoring Data

These three components (BWWF, GWI, and RDI/I) make up a total flow hydrograph that shows the quantities of wastewater over a period of time. Hydrograph decomposition is a method of estimating the different components of flow and was used to analyze flow monitoring data to estimate the quantities of BWWF, GWI, and RDI/I flow. Environmental Protection Agency (EPA) approved analysis software (Sanitary Sewer Overflow Analysis and Planning Toolbox, or SSOAP), which CDM developed in conjunction with EPA, was used to assist in separating measured wastewater flows into base flow (including GWI) and RDI/I components (Computer Tools for Sanitary Sewer System Capacity Analysis and Planning, October 2007). The computer program develops an average base flow hydrograph for a typical weekday and weekend from the recorded data for average dry-weather conditions.

The RDI/I component was determined for each of the three selected storm events. The RDI/I component was determined by subtracting the typical base flow hydrograph from the wet-weather hydrograph. This method of hydrograph decomposition is an important step in analyzing and simulating wet-weather flows in the sewer system. **Figure 2-7** presents an example of hydrograph decomposition for flow meter FM 07 during the September 30, 2010 storm event. Flow meter 7 is located upstream of the Elledge WWTP and captures the majority of the flow from the Elledge Basin. The average weekday dry-weather flow (BWWF + GWI) for FM 07 is 6,900 gpm. The peak hour flow rate during the event is 18,370 gpm. The difference between the dry-weather hydrograph and the total wet-weather hydrograph gives the volume of rainfall that entered the collection system from subbasin FM 07 during the September 30, 2010 event. A total of 8,600,000 gallons of stormwater (RDI/I) entered the collection system upstream of monitor FM 07 during this event. The peaking factor is calculated as the peak hour flow divided by the ADWF. The peaking factor for this event is 2.66.

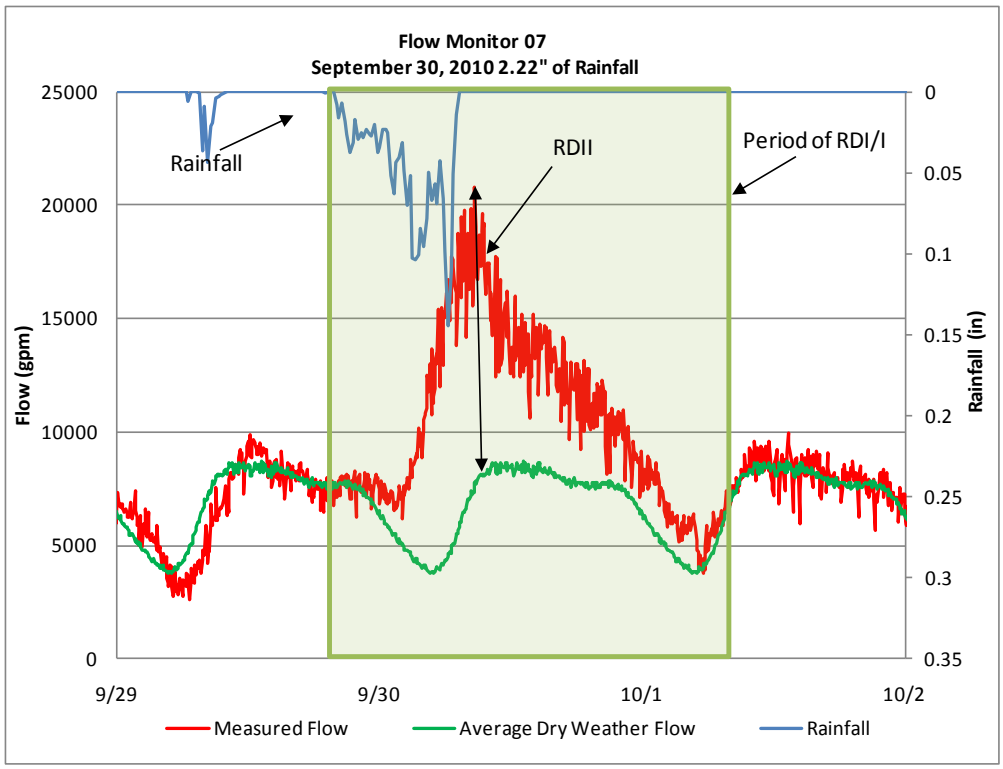

Figure 2-7: Hydrograph Decomposition for FM 07 during the September 30, 2010 Storm Event

Prior to analysis, the flow data recorded during each of the three selected rainfall events was reviewed for quality. The QA/QC process included review of the following:

- Velocity & Scatter Plots. Data was reviewed for consistency in velocity (i.e. no unexplained drops or rises in velocity). Velocity data was also reviewed with respect to corresponding changes in level data and the velocity vs. level scatter plot compared with an ideal Manning curve.
- Level. The level/depth data was reviewed for consistency. Sites with very low levels, corresponding to low flows, were examined for data quality.
- Flow Pattern and RDI/I Response to Rainfall. The RDI/I response to rainfall was reviewed for consistency with respect to intensity and duration of the rainfall.

In general, most of the flow meters appear to have provided usable data. A few monitors, FM 04, FM 06, FM 07, FM 10 and FM 15 had issues with debris interference; however, this was corrected by Hydromax personnel through the application of an offset, specific to each meter. Flow meter FM 23 had 6-inches of silt accumulation in a 27-inch diameter pipe, thus data was corrected by Hydromax personnel through an offset.

2.5.2 Dry-Weather Wastewater Flows

Existing dry-weather flows were estimated using the base flow hydrograph for typical dry-weather days (i.e., days during which there was no recorded rainfall or RDI/I from the decomposition of flow monitoring data. The ADWF includes both the BWWF and GWI flow components. The ADWF was estimated as dry-weather flows during the 2010 flow monitoring period. Separate averages were calculated for weekday and weekend flows. A summary of average weekday and weekend flow at each monitor is presented in **Table 2-4**.

For most meters the difference between average weekday and weekend dry-weather flows was under 10 percent. Two meters in the Elledge Basin, FM 19 and FM 20 had differences greater than 10 percent (16 percent and 18 percent, respectively) and 1 meter in the Muddy Creek Basin had exactly a 10 percent difference in weekday and weekend flows.

A comparison of the temporary flow meter data and the WWTP effluent data is presented in **Table 2-5**. During the flow monitoring period from August through October 2010, the effluent ADWF for the Muddy and Elledge WWTPs was 13.2 mgd and 16.6 mgd for a total of 29.8 mgd. The ADWF for each effluent meter was calculated by removing days which rainfall occurred and days where there was infiltration and inflow following a rainfall event. The total flow to the Muddy Creek WWTP based on data from temporary flow meter FM 06 and the flow coming from the South Fork Basin was 12.8 mgd. This is within 3 percent of the ADWF measured by the Muddy Creek effluent meter. The total flow to the Elledge WWTP based on data from temporary flow meter FM 07, Kimel flume 29, South Fork flume 30, and estimated flows from subbasin 30 is 17.5 mgd, which is 5 percent higher than the recorded effluent flow from the WWTP for the same period.

Groundwater Infiltration

GWI is commonly assumed to be between 50 percent and 80 percent of the average nighttime minimum flows. For this study, GWI is estimated to be 50 percent of the minimum nightime flow. On average, in this study GWI is 27 percent of the average dry weather flow. GWI flows are presented in Table 2-4.

2.5.3 Wet-Weather Wastewater Flows

For the Muddy Basin the wet-weather peaking factors were all less than 2.5 during the September 26, 2010 event (**Table 2-6**). The highest peaking factors were recorded during the October 27 event. Seven of the 13 meters in the Muddy Basin (FM 01, 05, 06, 12, 16, 17, and 18) recorded a maximum peaking factor greater than 4, and one of these meters recorded a maximum peaking factor greater than 10. From the IDF analysis of the rainfall for this event, RG1 and RG2 in the Muddy Basin recorded a total rainfall equal to a 10 year event. The peak 1-hour rain for RG1 was a 10 year event, and the 3-hour peak rain for RG1 was greater than a 50 year event.

For the Elledge Basin the wet-weather peaking factors were all less than 2 during the September 26, 2010 event (**Table 2-7**). The highest peaking factors were recorded during the September 30 and October 27 events. Four of the 7 meters in the Elledge Basin (FM 09, 14, 23, and 24) recorded a maximum peaking factor greater than 4, and 2 of these meters recorded a maximum peaking factor greater than 8. Radar rainfall for the September 30, 2010 event showed a large variation in rainfall patterns across the service

area with subbasin rainfall ranging from less than a 2-year storm to a 25-year storm. From the radar rainfall analysis, most of the rainfall that fell over the Elledge Basin during the September 30, 2010 event was between a 1-year and 5-year storm event. IDF analysis of the October 27, 2010 event showed the rain gauges in the Elledge Basin captured a 2 to 5 year event.

Table 2-4: Estimated Contribution of Groundwater Infiltration by Flow Meter

Basin Name	Flow Meter	Average Minimum Nightime Flow (GPM)	Estimated GWI (GPM)
Elledge	07	3760	1880
	09	1450	730
	14	630	320
	19	1240	620
	20	740	370
	23	660	330
	24	170	90
South Fork	08	2800	1410
	10	1620	810
	11	210	110
	21	140	70
	22	1190	600
	26	530	260
	27	610	300
Muddy Creek	01	90	50
	02	3010	1510
	03	1300	650
	04	890	440
	05	1100	550
	06	5230	2600
	12	520	260
	13	120	60
	15	1230	620
	16	60	30
	17	140	70
	18	920	460
	25	580	290

Table 2-5: Summary of ADWF to the WWTP[1]

Muddy and Elledge WWTP Effluent Meters	
Muddy Creek Effluent Meter ADWF (mgd)	13.2
Elledge Effluent Meter ADWF (mgd)	16.6
Total to Muddy and Elledge WWTP (mgd)	29.8
Average Dry Weather Flow to Muddy Creek WWTP Based on Influent Flow Data	
Meter 6 (mgd)	12.1
South Fork (Flume 28) (mgd)	0.70
Total to Muddy Creek WWTP (mgd)	12.8
Percent Difference Between Monitored and Effluent Flows	-3%
Average Dry Weather Flow to Archie Elledge WWTP Based on Influent Flow Data	
Meter 7 (mgd)	9.94
Kimel Flume (FM 29) (mgd)	1.67
South Fork PS (FM 30) (mgd)	5.89
Total to Elledge WWTP (mgd)	17.5
Percent Difference Between Monitored and Effluent Flows	57%

[1] Average dry weather flow calculated from August through October 2010

The peak 1-hour wet-weather flows measured during the 3 selected events are presented in Tables 2-6, 2-7, and 2-8. The peak wet-weather ratio is calculated by dividing the peak flows by the average dry-weather flow. For the subbasin size metered, a peak wet-weather flow of more than 4 times the average is an indicator of excessive I/I in the system.

For the South Fork Basin the wet-weather peaking factors for all but one meter were less than 2 during the September 26, 2010 event (**Table 2-8**). The highest peaking factors were recorded during the September 30 event. Six of the 7 meters in the South Fork Basin (FM 10, 11, 21, 22, 26, and 27) recorded a maximum peaking factor greater than 4, and 2 of these meters (FM 11 and 21) recorded a maximum peaking factor greater than 9. From the radar rainfall analysis, the rainfall that fell over the South Fork Basin during the September 30, 2010 event ranged from less than 1-year to a 10-year storm event.

Figure 2-8 color codes the subbasins by the maximum recorded peaking factor. Subbasins with a maximum peaking factor greater than 4 are red and those with a maximum factor less than 4 are green. Peak factors are not calculated for subbasins downstream of flumes.

2.5.4 System Surcharge

Excessive peaking factors may lead to system surcharging. Peak depths recorded during the three analyzed storm events were analyzed to determine if surcharging was observed. Surcharging occurs when the peak level observed in the manhole is above the crown of the pipe. Twelve of the 27 flow meters surcharged during one or more of the 3 storm events analyzed: FM 05, FM 06, FM 08, FM 10, FM 12, FM 15, FM 16, FM 17, FM 18, FM 21, FM 22, and FM 26 (**Table 2-9**). Of the meters that surcharged; all but two flow meters had peaking factors greater than 4. FM 08 and FM 15 did not have excessive peaking factors, yet were noted to be substantially full upon installation. FM 08 was at 46 percent capacity upon installation and FM 15 was at 62 percent capacity upon installation, which likely contributed to wet-weather surcharging at these 2 meters.

Table 2-6: Peak Hour Flows and Peaking Factors for Meters in the Muddy Basin

Flow Meter	Upstream Meter(s)	Peak-Hour Wet Weather Flow (gpm)			ADWF (gpm)	Ratio of Peak Wet Weather Flow to ADWF			Max
		9/26/10	9/30/2010	10/27/2010		9/26/10	9/30/2010	10/27/2010	
01	Davie County Water Inc.	410	590	770	190	2.16	3.11	4.05*	4.05*
02	3, 4	7,760	9,500	15,140	4,640	1.67	2.05	3.26	3.26
03	15	3,410	5,750	9,170	2,300	1.48	2.50	3.99	3.99
04	25	1,970	2,220	3,150	1,120	1.76	1.98	2.81	2.81
05	18	2,930	5,580	11,500	1,870	1.57	2.98	6.15*	6.15*
06	2, 5, 12, 13	11,300	18,120	35,000	8,380	1.35	2.16	4.18*	4.18*
12	None	1,200	1,990	3,800	920	1.30	2.16	4.13*	4.13*
13	1	1,730	2,470	N/A[1]	780	2.22	3.17	N/A[2]	3.17
15	16, 17	3,110	5,050	6,410	2,220	1.40	2.27	2.89	2.89
16	None	380	580	1,100	160	2.38	3.63	6.89*	6.89*
17	None	480	1,500	2,960	270	1.78	5.56*	10.96*	10.96*
18	None	2,450	4,160	8,460	1,540	1.59	2.70	5.49*	5.49*
25	City of King	1,850	1,980	2,490	860	2.15	2.30	2.90	2.90

(1) Peak wet weather flow is unknown for event

(2) Ratio could not be calculated because peak wet weather weather flow is unknown for event

Highlighted values indicate the maximum peak flows of the 3 events analyzed

* denotes peaking factors greater than 4

Table 2-7: Peak Hour Flows and Peaking Factors for Meters in the Elledge Basin

Flow Meter	Upstream Meter(s)	Peak-Hour Wet Weather Flow (gpm)			ADWF (gpm)	Ratio of Peak Wet Weather Flow to ADWF			Max
		9/26/10	9/30/10	10/27/10		9/26/10	9/30/10	10/27/10	
07	09, 19, 20	11,920	18,370	25,020	6,900	1.73	2.66	3.62	3.62
09	14, 23	3,540	10,240	9,850	2,470	1.43	4.15*	3.99	4.15*
14	24	1,590	5,970	8,470	1,050	1.51	5.69*	8.07*	8.07*
19	None	3,028	6,100	8,650	2,260	1.34	2.70	3.83	3.83
20	None	1,730	3,770	2,790	1,110	1.56	3.40	2.51	3.40
23	None	1,420	4,180	2,650	920	1.54	4.54*	2.88	4.54*
24	None	570	2,980	4,320	320	1.78	9.31*	13.50*	13.50*

Highlighted values indicate the maximum peak flows of the 3 events analyzed.
* denotes peaking factors greater than 4.

Table 2-8: Peak Hour Flows and Peaking Factors for Meters in the South Fork Basin

Flow Meter	Upstream Meter(s)	Peak-Hour Wet Weather Flow (gpm)			ADWF (gpm)	Ratio of Peak Wet Weather Flow to ADWF			Max
		9/26/2010	9/30/2010	10/27/2010		9/26/2010	9/30/2010	10/27/2010	
08	10	5,320	9,500	7,460	3,750	1.42	2.53	1.99	2.53
10	11, 22	4,980	13,930	7,710	2,880	1.73	4.84*	2.68	4.84
11	None	940	3,940	940	430	2.19	9.16*	2.19	9.16
21	None	420	3,310	740	260	1.62	12.73*	2.85	12.73
22	27	3,700	9,060	7,530	2,170	1.71	4.18*	3.47	4.18
26	None	1,810	5,580	4,370	1,070	1.69	5.21*	4.08*	5.21
27	26	2,750	7,950	5,440	1,500	1.83	5.30*	3.63	5.30

Highlighted values indicate the maximum peak flows of the 3 events analyzed
* denotes peaking factors greater than 4

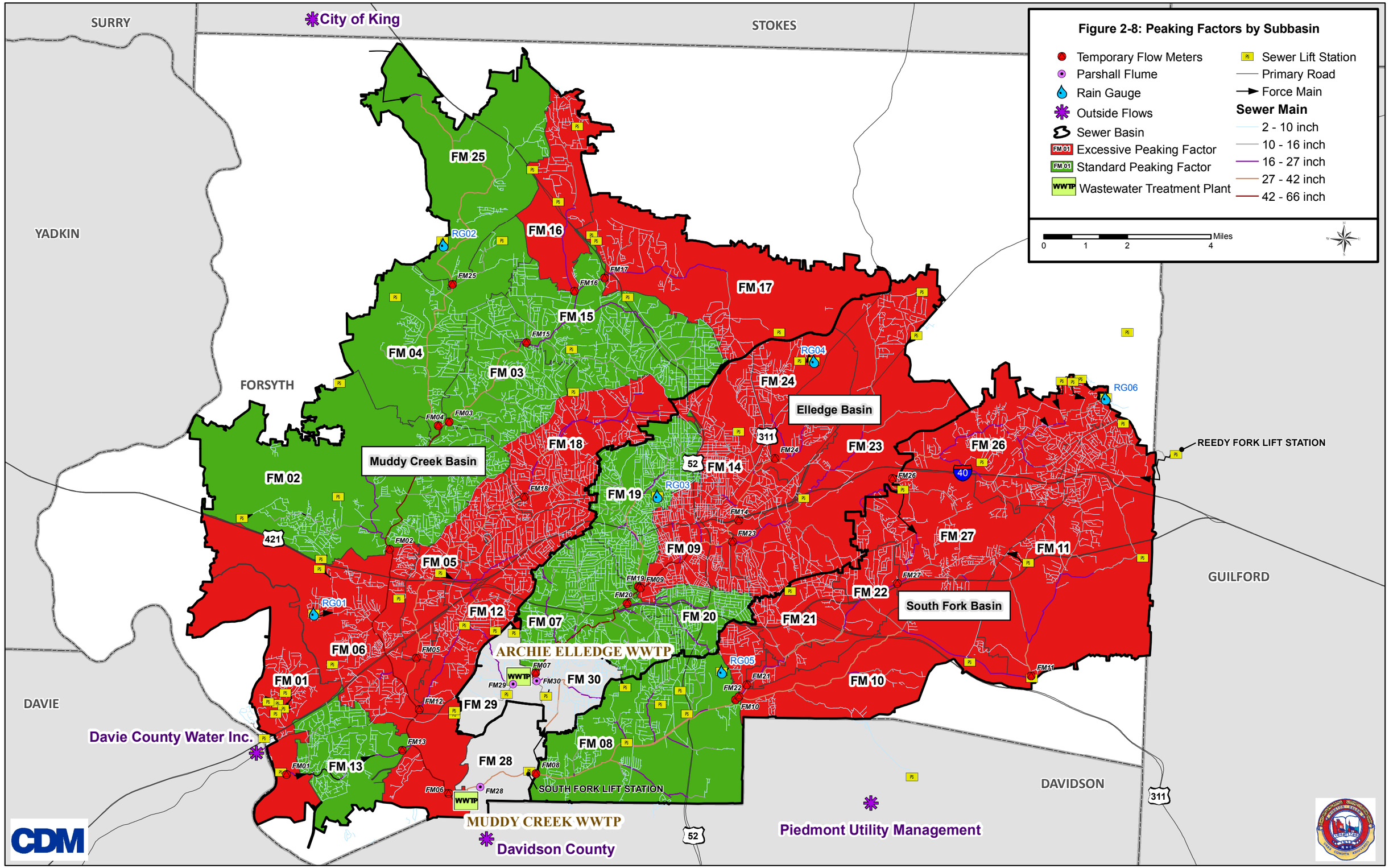
Figure 2-8: Peaking Factors by Subbasin
Temporary Flow Meters
Parshall Flume
Rain Gauge
Outside Flows
Sewer Basin
Excessive Peaking Factor
Standard Peaking Factor
Wastewater Treatment Plant
Sewer Lift Station
Primary Road
Force Main
Sewer Main
2 - 10 inch
10 - 16 inch
16 - 27 inch
27 - 42 inch
42 - 66 inch
Miles
0
1
2
4
SURRY
STOKES
YADKIN
FORSYTH
DAVIE
GUILFORD
DAVIDSON
City of King
Davie County Water Inc.
Davidson County
Piedmont Utility Management
Muddy Creek Basin
Elledge Basin
South Fork Basin
ARCHIE ELLEDGE WWTP
MUDDY CREEK WWTP
SOUTH FORK LIFT STATION
REEDY FORK LIFT STATION
FM 01
FM 02
FM 03
FM 04
FM 05
FM 06
FM 07
FM 08
FM 09
FM 10
FM 11
FM 12
FM 13
FM 14
FM 15
FM 16
FM 17
FM 18
FM 19
FM 20
FM 21
FM 22
FM 23
FM 24
FM 25
FM 26
FM 27
FM 28
FM 29
FM 30
RG01
RG02
RG03
RG04
RG05
RG06
421
52
311
40

Table 2-9: System Surcharge

Flow Meter	Diameter (inches)	Peak level by Event (inches)			Surcharge by Event (feet)		
		9/26/2010	9/30/2010	10/27/2010	9/26/2010	9/30/2010	10/27/2010
1	21	5.1	5.9	7.5	0	0	0
2	54	18.1	20.8	30.6	0	0	0
3	36	12.2	15.5	22.0	0	0	0
4	42	10.3	11.2	13.2	0	0	0
5	36	12.1	17.4	93.8	0	0	4.8 *
6	66	19.0	28.3	217.1	0	0	12.6 *
7	60	36.7	48.5	93.6	0	0	0
8	36	22.1	90.6	27.8	0	4.6	0
9	48	13.5	26.9	32.5	0	0	0
10	36	17.8	143.8	24.6	0	9.0 *	0
11	30	7.7	14.6	8.0	0	0	0
12	21	8.0	14.0	102.5	0	0	6.8 *
13	24	10.9	11.0	10.9	0	0	0
14	36	8.4	16.6	24.8	0	0	0
15	27	18.4	25.8	119.1	0	0	7.7
16	18	5.4	59.6	97.7	0	3.5	6.6
17	24	5.6	14.2	108.9	0	0	7.1 *
18	30	10.0	12.7	103.6	0	0	6.1 *
19	42	12.2	16.6	21.3	0	0	0
20	24	6.6	12.2	9.7	0	0	0
21	18	5.8	77.0	7.6	0	4.9 *	0
22	30	16.0	129.5	23.6	0	8.3 *	0
23	27	13.3	24.6	20.2	0	0	0
24	30	5.7	13.1	18.8	0	0	0
25	36	9.1	9.0	9.9	0	0	0
26	30	9.3	93.0	23.5	0	5.2 *	0
27	27	14.7	22.2	19.5	0	0	0

* denotes surcharge within 3 ft of manhole rim
Highlighted values indicate system surcharge

Section 3
Wastewater Flow Projections

The purpose of this section is to describe how wastewater flows were projected for 2010 through 2035 for the Winston-Salem/Forsyth County Utility Commission (CCUC) wastewater service area. This section also describes the development of the average annual, maximum month, maximum day, and maximum hourly flow peaking factors. These factors are applied to the projected average dry-weather flow from the Muddy, Elledge, and South Fork Basins in order to estimate future peak flows. Section 3.1 describes the methodology and results of the future average dry-weather flow projections. Section 3.2 describes the development of the peaking factors. Section 3.3 describes the application of these factors to the future flows and resulting estimated peak flow for the Muddy, Elledge, and South Fork Basins.

3.1 Future Dry-Weather Flow Calculation for CCUC's Wastewater Service Area

Future dry-weather wastewater flows were calculated for the three main basins in the existing CCUC service area (Muddy, Elledge, and South Fork), outside areas that contribute flows to the CCUC system, and future service areas (FSAs) identified in the Legacy Development Guide (**Figure 3-1).** The outside areas include portions of Davie County, Davidson County, City of King, and Piedmont Utilities contributing flow to the CCUC wastewater collection system. Future service areas were identified in the Growth Management Plan chapter in the Legacy Development Guide. These areas do not currently have sewer, but are identified as FSAs because of their potential to be served efficiently by sewer and other facilities and services in the future and/or their proximity to towns, major roads, and other public investments. The Growth Management Plan calls for them to eventually become urban, and development that does occur will be encouraged to install public sewerage. The data sources used to develop the flow factors and population projections include:

- Projected residential and employee populations obtained from the Traffic Analysis Zone (TAZ) data provided by the City of Winston-Salem Transportation Department
- Recorded wastewater flows at temporary monitoring stations within the collection system
- Muddy Creek and Archie Elledge WWTP effluent data
- Parshall flume data for two flumes downstream of the South Fork Basin and for the Kimel branch upstream of the Archie Elledge WWTP
- Recorded flows from outside municipalities
- Future flow allocations for outside areas and timing of the allocations provided by CCUC

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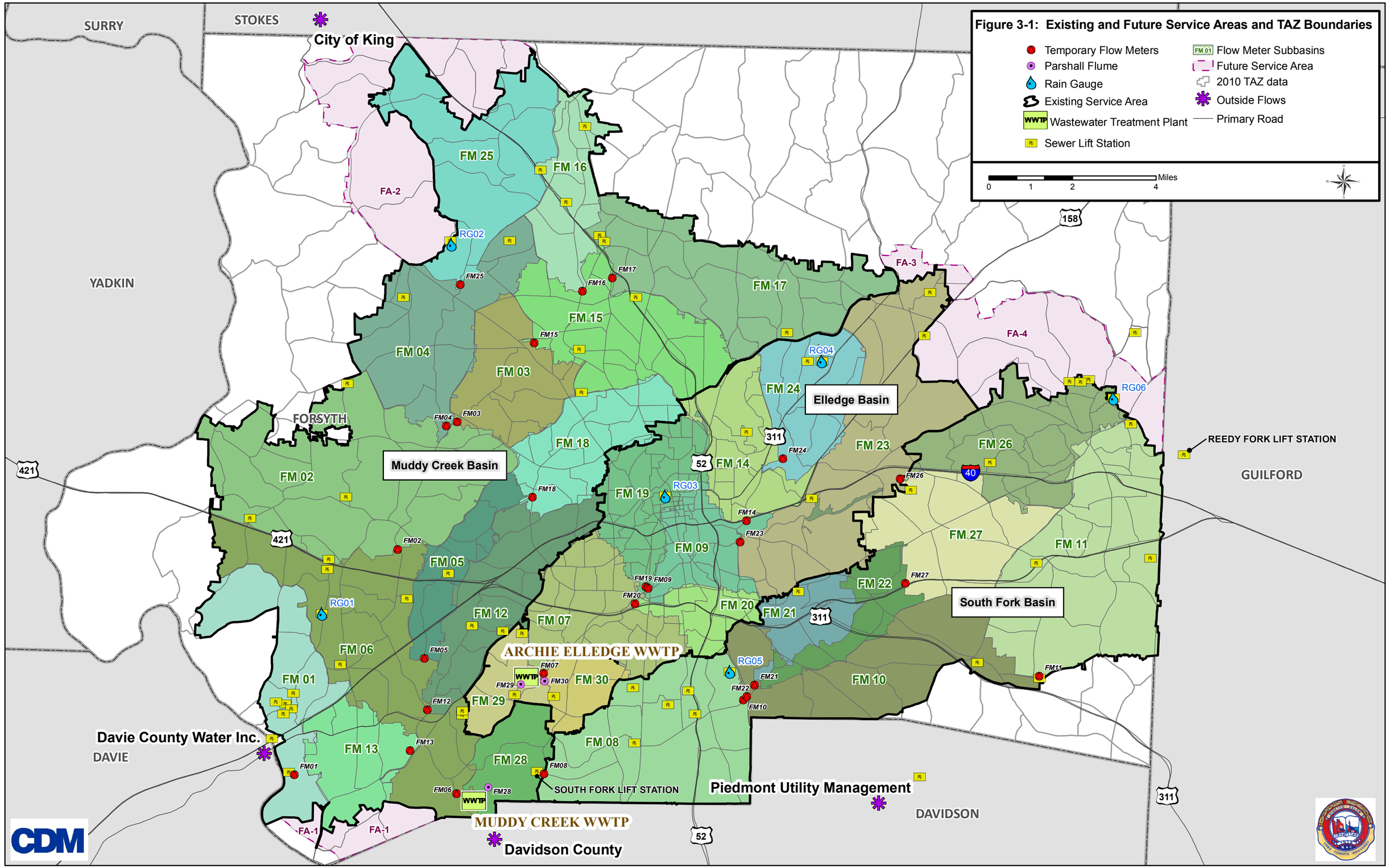
Figure 3-1: Existing and Future Service Areas and TAZ Boundaries
Temporary Flow Meters
Parshall Flume
Rain Gauge
Existing Service Area
Wastewater Treatment Plant
Sewer Lift Station
Flow Meter Subbasins
Future Service Area
2010 TAZ data
Outside Flows
Primary Road
Miles
0
1
2
4
SURRY
STOKES
City of King
YADKIN
FORSYTH
GUILFORD
DAVIE
DAVIDSON
Davie County Water Inc.
Piedmont Utility Management
Davidson County
Muddy Creek Basin
Elledge Basin
South Fork Basin
ARCHIE ELLEDGE WWTP
MUDDY CREEK WWTP
SOUTH FORK LIFT STATION
REEDY FORK LIFT STATION
FM 01
FM 02
FM 03
FM 04
FM 05
FM 06
FM 07
FM 08
FM 09
FM 10
FM 11
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FM 21
FM 22
FM 23
FM 24
FM 25
FM 26
FM 27
FM 28
FM 29
FM 30
FA-1
FA-2
FA-3
FA-4
RG01
RG02
RG03
RG04
RG05
RG06
421
158
311
52
40
CDM

Future flows within the Muddy, Elledge, and the South Fork Basins were calculated based on population and employee projections as described in Section 3.1.1. Future flows for outside areas were calculated using an assumed percent annual increase in flow as described in Section 3.1.2. Projected flows for future service areas were based on population and employee projections as described in Section 3.1.3. The total average dry-weather flow from the basins, outside areas, and future service areas is summarized in Section 3.1.3.

3.1.1 Muddy, Elledge, and South Fork Basins

Average dry-weather flow for the Muddy, Elledge, and South Fork Basins were calculated using estimated per capita wastewater factors multiplied by projected populations as described in the three step process outlined below.

Step 1: Calculate the population and employee flow factors

The first step in the process was to develop representative per capita wastewater flow factors for the existing CCUC wastewater service area. **Table 3-1** shows the development of the per capita flow factors. The table contains the estimated population, service employees, industrial employees, office employees, and highway retail employees within the service area for the year 2010. Base flows within the service area were calculated using a factor of 50 gallons per capita per day (GPCD) for residential population and 35 gallons per capita per day (GPCD) for employee population. These factors are similar to those CDM has used for other municipalities in North Carolina. The total 2010 base flow for the CCUC service area is calculated as 21.9 mgd. Groundwater infiltration (GWI) was added to the base flow to obtain the average dry-weather flow (ADWF). GWI is estimated as 40 percent of the base flow based on analysis of the temporary meters installed in the CCUC collection system. The ADWF is calculated as the base flow (21.9 mgd) plus the GWI (8.8 mgd) for a total of 30.7 mgd.

Average dryweather flow from outside areas (Davie County, Davidson County, City of King, and Piedmont Utilities) contributing flow to the CCUC wastewater service area was calculated as described in Section 2. Adding the outside flow of 0.78 mgd to the average dry-weather flow of 30.7 mgd gives a total calculated dry-weather flow of 31.5 mgd.

To check on the reasonableness of the flow factors, the total wastewater flows calculated from the per capita rates are compared to recorded 2010 wastewater treatment plant effluent average dry-weather flow. The 2010 average dry-weather flow recorded at the Muddy and Elledge WWTP is 31.2 mgd. The flows calculated using the TAZ data and the flow factors are within 1 percent of the measured ADWF at the WWTPs. The closeness of the calculated and measured wastewater flows validates the approach used and provides some confidence that the per capita rates can be used to reasonably calculate future flows as described in Step 2.

Step 2: Calculate the population and employees for the Muddy, Elledge, and South Fork Basins

Residential and employee populations were obtained from the TAZ data for the years 2010, 2015, 2025, and 2035. The TAZ areas were intersected with the Muddy, Elledge, and South Fork Basin boundaries in GIS to obtain the population and employee estimates per basin. Where a TAZ zone overlapped basin boundaries, the populations were allocated to each basin based on the proportion of each zone by area in each basin. The population and employee projections for each basin and for each planning period are contained in **Tables 3-2** and **3-3**.

Table 3-1: Calculation of Per Capita Wastewater Flow Factors

	CCUC Service Area	Flows Within the Service Area		
		2010 Population [1]	Factor (gpcd)	Flow (mgd)
	Population	302,599	50	15.1
	Service Employees	61,846	35	2.2
	Industrial Employees	44,776	35	1.6
(2)	Office Employees	72,137	35	2.5
	Highway Retail Employees	15,709	35	0.5
	Students	-	-	-
	Total Base Flow			21.9
(3)	GWI			8.8
(4)	Total ADWF			30.7

(5)	Outside Areas	Flows From Outside Areas
	City of King	0.44
	Davie County Water Inc.	0.24
	Davidson County	0.06
	Piedmont Utility Management	0.04
	Total ADWF From Outside Areas	0.78

(6)	Total Calculated ADWF to Muddy and Elledge WWTPs	31.5

	Muddy Creek Effluent Meter 2010 ADWF	14.2
	Elledge Effluent Meter 2010 ADWF	17.0
	Total Measured ADWF from Effluent Meters	31.2

(7)	Percent Difference	0.9%

(1) Based on the 2010 TAZ data.

(2) Includes retail, office, school, and university employees

(3) GWI Estimated as 40% of the base flow based on analysis of Winston Salem temporary meters.

(4) Total ADWF = Total Base Flow + GWI

(5) Based on monthly billing meter readings and thus include I/I.

(6) Total Calculated ADWF to Muddy and Elledge WWTPs = Total ADWF + Total ADWF from Outside Areas

(7) Percent difference between the calculated total ADWF to Muddy and Elledge WWTPs and total measured ADWF from the WWTP effluent meters.

Table 3-2: Residential Population Projections

Year	Projected Residential Populations			
	Muddy	Elledge	South Fork	Total
2010	145,388	94,193	63,018	302,599
2015	156,147	98,914	69,625	324,686
2025	179,443	106,526	84,147	370,116
2035	208,668	115,583	102,606	426,857

Table 3-3: Employee Population Projections

Year	Projected Employee Populations			
	Muddy	Elledge	South Fork	Total
2010	81,828	88,149	24,491	194,468
2015	88,494	95,454	27,767	211,715
2025	105,450	114,538	34,752	254,740
2035	120,590	133,180	42,827	296,597

1) Employee population is the sum of all employee categories identified in the TAZ: highway retail, industrial, retail, service, office, school, and university

Step 3: Calculate the dry-weather wastewater flow for each basin

The future dry-weather wastewater flows generated in the Muddy, Elledge, and South Fork Basins are presented in **Table 3-4**. The three left-most columns contain the 2010 base flow, GWI, and total ADWF for each basin. The ADWF and GWI are based on the flow monitoring data analysis presented in Section 2. Base flow is calculated as ADWF minus GWI.

The wastewater flow projection increases are developed beginning with 2015. The TAZ 2015 population projections are totaled for each basin. The base wastewater flow increase for each tributary area is calculated by multiplying the population increase times the respective per capita flow factors and then summing residential and employee flows. Because the flow factors (50 GPCD and 35 GPED) calibrated so well for the service area, these values were used in future projections for all tributary areas. The future flow projections include an estimated GWI increase of 10 percent of the base flow, which represents the GWI entering newly installed sewer. The projected wastewater flow increase is summed for each planning year (2015, 2025, and 2035) at the bottom of Table 3-4. The increases in flow for the entire service area between 2010-2015, 2015-2025, and 2025-2035 are 2.24 mgd, 4.16 mgd, and 4.73 mgd, respectively. This corresponds to an annual increase in flow of 2.01 percent, 1.69 percent, and 1.64 percent.

3.1.2 Outside Areas

Flows from outside areas (Davie County, Davidson County, City of King, and Reedy Fork) are conveyed to the CCUC wastewater collection system. 2010 flows from the outside areas were obtained from billing meters. CCUC provided the maximum future flow allocation and the timing of the flow increases as follows:

- Davie County – Assume gradual escalation from 2010 billing flow to an allocated annual average flow of 550,000 gpd over the next five years. Assume a 5 mgd increase in average annual flow in 2030.
- Davidson County (including Piedmont Utilities) – Assume a gradual escalation from 2010 billing flow to an allocated annual average flow of 1,500,000 gpd over the next 30 years.

Table 3-4: Wastewater Flow Increases Generated Within the Muddy, Elledge, and South Fork Basins

										2010-2015 Flow Increase			2015-2025 Flow Increase			2025-2035 Flow Increase		
	2010 Base Flow	2010 Estimated GWI	2010 Measured ADWF	Category [1]	Factor	2010	2015	2025	2035	Base Flow	GWI	ADWF	Base Flow	GWI	ADWF	Base Flow	GWI	ADWF
	MGD	MGD	MGD		GPCD	CAPITA	CAPITA	CAPITA	CAPITA	MGD	MGD	MGD	MGD	MGD	MGD	MGD	MGD	MGD
MUDDY CREEK BASIN																		
[2]	8.34	3.78	12.11	Employees	35	81,465	88,494	105,450	120,590	0.25			0.59			0.53		
				Population	50	140,802	156,147	179,443	208,668	0.77			1.16			1.46		
										1.01	**0.10**	**1.11**	**1.7583**	**0.176**	**1.93**	**1.9912**	**0.199**	**2.19**
ARCHIE ELLEDGE BASIN																		
[3]	8.6	3.4	11.9	Employees	35	88,149	95,454	114,538	133,180	0.26			0.67			0.65		
				Population	50	94,193	98,914	106,526	115,583	0.24			0.38			0.45		
										0.49	**0.05**	**0.54**	**1.05**	**0.105**	**1.15**	**1.11**	**0.111**	**1.22**
SOUTH FORK BASIN																		
[4]	3.4	2.0	5.4	Employees	35	24,465	27,767	34,752	42,827	0.12			0.24			0.28		
				Population	50	61,339	69,625	84,147	102,606	0.41			0.73			0.92		
										0.53	**0.05**	**0.58**	**0.97**	**0.097**	**1.07**	**1.21**	**0.121**	**1.33**
INCREASE IN FLOWS										**2.03**	**0.20**	**2.24**	**3.78**	**0.38**	**4.16**	**4.30**	**0.43**	**4.73**
PERCENT ANNUAL INCREASE IN BASE FLOWS										**2.01%**			**1.69%**			**1.64%**		

(1) Employees include include industrial, service, office, school, university, retail, and highway retail.

(2) 2010 flow generated in the Muddy Creek basin includes the ADWF measured by meter 6 plus the estimated flow from subbasin 28. Subbasin 28 was not measured directly and thus 2010 flows are estimated based on 2010 population and employee numbers.

(3) 2010 flow generated in the Archie Elledge basin includes the ADWF measured by meter 7 plus the estimated flow from subbasins 29 and 30. Subbasins 29 and 30 were not measured directly and thus 2010 flows are estimated based on 2010 population and employee numbers.

(4) 2010 flow generated in the South Fork basin includes the ADWF measured by meter 8.

- City of King – Assume a gradual escalation from 2010 billing flow to an allocated average annual flow of 970,000 gpd over the next 20 years.
- Reedy Fork Pump Station – The pump station will be redirected to the South Fork Basin in 2013. Assume a gradual escalation from the 2013 peak day flow of 1.2 mgd to a peak day flow of 5.2 mgd by 2043.

A summary of the yearly average annual flow is provided in **Table 3-5**. The total increase in average annual flow totalled for all outside areas in between 2010-2015, 2015-2025, and 2025 to 2035 is 1.21 mgd, 1.21 mgd, and 6.09 mgd, respectively.

Table 3-5: Average Annual Flow for Outside Areas (mgd)

Year	Davie County	Davidson County	City of King	Reedy Fork Pump Station	Total
2010	0.24	0.11	0.47	0	0.82
2011	0.30	0.16	0.50	0	0.96
2012	0.37	0.20	0.52	0	1.09
2013	0.43	0.25	0.55	0.45	1.67
2014	0.49	0.30	0.57	0.50	1.85
2015	0.55	0.34	0.60	0.55	2.04
2016	0.55	0.39	0.62	0.60	2.16
2017	0.55	0.43	0.65	0.65	2.28
2018	0.55	0.48	0.67	0.70	2.40
2019	0.55	0.53	0.70	0.75	2.52
2020	0.55	0.57	0.72	0.80	2.64
2021	0.55	0.62	0.75	0.85	2.76
2022	0.55	0.67	0.77	0.90	2.89
2023	0.55	0.71	0.80	0.95	3.01
2024	0.55	0.76	0.82	1.00	3.13
2025	0.55	0.81	0.85	1.05	3.25
2026	0.55	0.85	0.87	1.10	3.37
2027	0.55	0.90	0.90	1.15	3.49
2028	0.55	0.94	0.92	1.20	3.61
2029	0.55	0.99	0.95	1.25	3.73
2030	5.55	1.04	0.97	1.30	8.86
2031	5.55	1.08	0.97	1.35	8.95
2032	5.55	1.13	0.97	1.40	9.05
2033	5.55	1.18	0.97	1.45	9.14
2034	5.55	1.22	0.97	1.50	9.24
2035	5.55	1.27	0.97	1.55	9.34

1) For Reedy Fork Pump Station, peak day flows were converted to average annual flows using a factor of 2.67. Development of the peak day factor is discussed in more detail in Section 3.2.3.

3.1.3 Future Service Areas

Future service areas (FSAs) were identified in the Growth Management Plan chapter in the Legacy Development Guide. Figure 3-1 contains the four future service areas labeled as FSAs 1-4. FSAs 1 and 2 contribute flow to Muddy Basin, FSA 3 contributes flow to Archie Elledge Basin, and FSA 4 contributes flow to the South Fork Basin.

As in the previous section, flow factors of 50 GPCD for residents, 35 GPCD for employees, and GWI of 10 percent of the base flow increase were used to calculate future flows. Also as in the previous section, the FSA boundaries were overlaid with the TAZ data, and flow factors were applied to the TAZ population projections. For this study, it is assumed that 25 percent of the wastewater flow generated within the FSA will be sewered by 2015, 75 percent will be sewered by 2025, and 100 percent will be sewered by 2035.

Average dry-weather flow projections for the FSAs are given for each planning period in **Table 3-6**. The total increase in flows between 2010 and 2035 is 1.34 mgd. South Fork Basin sees the highest increase in flow due to future service areas (0.82 mgd).

3.1.4 Summary of Dry-Weather Flows

Table 3-7 presents the total predicted ADWF including outside areas and future service areas going to the Muddy, Elledge, and South Fork Basins. It is assumed that all necessary improvements are made upstream in order to convey the flows. In 2035, Muddy, Elledge, and South Fork Basins contain 48, 30, and 22 percent of the total ADWF, respectively.

Table 3-7: Projected ADWF by Basin (mgd)

	2010	2015	2025	2035
MUDDY CREEK BASIN				
Muddy	11.42	12.53	14.46	16.65
Davie County Water Inc.	0.21	0.47	0.47	4.70
City of King	0.40	0.50	0.72	0.82
Davidson County	0.09	0.29	0.68	1.07
FSA 1	0.00	0.02	0.08	0.14
FSA 2	0.00	0.06	0.21	0.33
Total	**12.11**	**13.87**	**16.62**	**23.73**
ARCHIE ELLEDGE BASIN				
Elledge	11.95	12.49	13.64	14.86
FSA 3	0.00	0.01	0.03	0.05
Total	**11.95**	**12.49**	**13.67**	**14.90**
SOUTH FORK BASIN				
South Fork	5.40	5.98	7.05	8.37
Reedy Fork Pump Station	0.00	0.48	0.92	1.36
FSA 4	0.00	0.14	0.50	0.82
Total	**5.40**	**6.60**	**8.46**	**10.55**

1) Average annual flow for the outside areas in the Muddy Basin was converted to average dry weather flow using a factor of 1.18. Average annual flow for the outside area in the South Fork Basin was converted to average dry weather flow using a factor of 1.14. Development of these factors is discussed in more detail in Section 3.2.1.

Table 3-6: Future Service Area Projections

							2010 Flow			2015 Flow			2025 Flow			2035 Flow		
	Category	Factor	2010	2015	2025	2035	Base Flow	GWI	ADWF	Base Flow	GWI	ADWF	Base Flow	GWI	ADWF	Base Flow	GWI	ADWF
		GPCD								MGD	MGD	MGD	MGD	MGD	MGD	MGD	MGD	MGD
MUDDY CREEK BASIN																		
FSA 1	Service	35	187	188	213	238	0.01			0.01			0.01			0.01		
	Industrial	35	70	74	83	94	0.00			0.00			0.00			0.00		
	Office	35	8	8	35	35	0.00			0.00			0.00			0.00		
	Highway retail	35	15	16	15	16	0.00			0.00			0.00			0.00		
	Population	50	1211	1332	1745	2321	0.06			0.07			0.09			0.12		
							0.0704	**0.0070**	**0.08**	**0.0766**	**0.0077**	**0.08**	**0.0994**	**0.010**	**0.11**	**0.1295**	**0.013**	**0.14**
FSA 2	Service	35	54	61	96	137	0.00			0.00			0.00			0.00		
	Industrial	35	339	360	483	616	0.01			0.01			0.02			0.02		
	Office	35	171	250	272	289	0.01			0.01			0.01			0.01		
	Highway retail	35	48	56	64	76	0.00			0.00			0.00			0.00		
	Population	50	3,688	3,951	4,503	5,190	0.18			0.20			0.23			0.26		
							0.21	**0.02**	**0.23**	**0.22**	**0.02**	**0.25**	**0.26**	**0.026**	**0.28**	**0.30**	**0.030**	**0.33**
Total Flow							**0.28**	**0.03**	**0.30**	**0.30**	**0.03**	**0.33**	**0.36**	**0.036**	**0.39**	**0.43**	**0.043**	**0.47**
Percent Sewered							0%	0%	0%	25%	25%	25%	75%	75%	75%	100%	100%	100%
Total Sewered Flow							**0.00**	**0.00**	**0.00**	**0.07**	**0.01**	**0.082**	**0.27**	**0.027**	**0.29**	**0.43**	**0.043**	**0.470894**
ARCHIE ELLEDGE BASIN																		
FSA 3	Service	35	15	16	25	34	0.00			0.00			0.00			0.00		
	Industrial	35	14	15	18	21	0.00			0.00			0.00			0.00		
	Office	35	72	72	72	78	0.00			0.00			0.00			0.00		
	Highway retail	35	3	3	3	3	0.00			0.00			0.00			0.00		
	Population	50	498	538	623	730	0.02			0.03			0.03			0.04		
							0.03	**0.00**	**0.03**	**0.03**	**0.003**	**0.03**	**0.04**	**0.004**	**0.04**	**0.04**	**0.004**	**0.05**
Total							**0.03**	**0.00**	**0.03**	**0.03**	**0.00**	**0.03**	**0.04**	**0.004**	**0.04**	**0.04**	**0.004**	**0.05**
Percent Sewered							0%	0%	0%	25%	25%	25%	75%	75%	75%	100%	100%	100%
Total Sewered							**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.01**	**0.03**	**0.003**	**0.03**	**0.04**	**0.004**	**0.05**
SOUTH FORK BASIN																		
FSA 4	Service	35	142	159	253	356	0.00			0.01			0.01			0.01		
	Industrial	35	525	563	634	698	0.02			0.02			0.02			0.02		
	Office	35	267	318	392	458	0.01			0.01			0.01			0.02		
	Highway retail	35	3	1	1	3	0.00			0.00			0.00			0.00		
	Population	50	8,409	9,108	11,137	13,861	0.42			0.46			0.56			0.69		
							0.45	**0.05**	**0.50**	**0.49**	**0.049**	**0.54**	**0.60**	**0.060**	**0.66**	**0.75**	**0.075**	**0.82**
Total							**0.45**	**0.05**	**0.50**	**0.49**	**0.05**	**0.54**	**0.60**	**0.060**	**0.66**	**0.75**	**0.075**	**0.82**
Percent Sewered							0%	0%	0%	25%	25%	25%	75%	75%	75%	100%	100%	100%
Total Sewered							**0.00**	**0.00**	**0.00**	**0.12**	**0.01**	**0.14**	**0.45**	**0.045**	**0.50**	**0.75**	**0.075**	**0.82**
TOTAL FLOW							0.76	0.08	0.83	0.82	0.08	0.90	0.99	0.10	1.09	1.22	0.12	1.34
TOTAL SEWERED FLOW							0.00	0.00	0.00	0.21	0.02	0.23	0.75	0.07	0.82	1.22	0.12	1.34

3.2 Development of Peaking Factors

Average annual, maximum month, maximum day, and maximum hour peaking factors were developed for the Muddy, Elledge, and South Fork Basins. The peaking factors were developed based on analysis of effluent meter flow data. Maximum hour comparisons observed in the effluent flow were compared to data recorded during the temporary flow monitoring period. Development of the peaking factors is described in Sections 3.2.1 through Section 3.2.4. A peaking factor summary is provided in Section 3.2.6 and a peaking factor analysis for the South Fork Basin is provided in Section 3.2.5.

3.2.1 Average Annual Flow Peaking Factor

Future flows for the Muddy, Elledge, and South Fork Basins are based on average dry weather flow. An annual average peaking factor was developed to convert the average dry weather flows to average annual flows. The average annual flow peaking factor is calculated as the ratio of the average annual flow to the average dry-weather flow. To calculate this factor, the average annual flow for 2006, 2007, 2008, 2009, and 2010 was calculated for the Muddy Creek WWTP effluent meter and the Archie Elledge WWTP effluent meter. The average annual flow is calculated as an average of the non-erroneous flows recorded by the effluent meters. The average dry-weather flow was also calculated for 2006-2010 for each effluent meter. Since the ADWF developed for the projections is based on data collected from August–October, the ADWF for 2006-2010 is also based on data from August–October. This was done in order to accurately project the

ADWF recorded during the low groundwater season to an average annual flow. The ADWF was calculated using SSOAP (Section 2) by removing days on which rain occurred and on days which flows were elevated due to preceding rainfall. **Table 3-8** presents the average annual flows, average dry-weather flows, and average annual peaking factors for 2006-2010. The maximum average annual factors for the Muddy and Elledge Basins were 1.18 and 1.14 and both occurred in 2010.

Table 3-8: Average Annual Flow Peaking Factor

	Average Annual Flow (mgd)	Average Dry Weather Flow (mgd)	Average Annual Peaking Factor
MUDDY CREEK WWTP			
2006	15.10	14.08	1.07
2007	14.46	13.64	1.06
2008	14.36	13.21	1.09
2009	14.89	13.00	1.15
2010	15.58	13.20	1.18
ARCHIE ELLEDGE WWTP			
2006	18.00	18.90	0.95
2007	18.14	17.61	1.03
2008	17.17	16.54	1.04
2009	17.92	16.32	1.10
2010	18.52	16.3	1.14

3.2.2 Maximum Month Flow Peaking Factor

The maximum day peaking factor is calculated as the ratio of the maximum month to the average annual flow. To calculate this factor, the three highest maximum month readings were determined for the Muddy Creek WWTP effluent meter and the Archie Elledge WWTP effluent meter. The average annual flow was calculated as described in Section 3.2.1. **Table 3-9** presents the maximum month flows, average annual flows, and maximum month peaking factors for the Muddy and Elledge Basins. The highest maximum month peaking factor for the Muddy and Elledge Basins was 1.26 and 1.22, respectively.

Table 3-9: Maximum Month Peaking Factor

	Max Month Flow (mgd)			Average Annual Flow (mgd)	Ratio of Max Month Flow to Average Annual Flow		
MUDDY CREEK WWTP	**December 2009**		**February 2010**		**December 2009**	**January 2010**	**February 2010**
2009	17.9	-	-	14.89	1.20	-	-
2010	-	17.7	19.6	15.58	-	1.14	1.26
	Max Month Flow (mgd)			**Average Annual Flow (mgd)**	**Ratio of Max Month Flow to Average Annual Flow**		
ARCHIE ELLEDGE WWTP	**November 2009**		**March 2010**		**November 2009**	**February 2010**	**March 2010**
2009	21.9	-	-	17.9	1.22	-	-
2010	-	21.5	20.4	18.5	-	1.16	1.10

3.2.3 Maximum Day Flow Peaking Factor

The maximum day peaking factor is calculated as the ratio of the maximum day flow to the average annual flow. To calculate this factor, the three highest maximum day readings were determined for the Muddy Creek WWTP effluent meter and the Archie Elledge WWTP effluent meter. The average annual flow was calculated as described in Section 3.2.1. **Table 3-10** presents the maximum day flows, average annual flows, and maximum day peaking factors for the Muddy and Elledge Basins. The highest maximum day peaking factor for the Muddy and Elledge Basins was 3.01 and 2.67, respectively.

Table 3-10: Maximum Day Peaking Factor

	Max Day Flow			Average Annual Flow mgd)	Ratio of Max Day Flow to Average Annual Flow		
MUDDY CREEK WWTP	**2/6/2010**	**3/29/2010**	**10/28/2010**		**2/6/2010**	**3/29/2010**	**10/28/2010**
2010	46.6	41.6	46.9	15.58	2.99	2.67	3.01
	Max Day Flow			**Average Annual Flow mgd)**	**Ratio of Max Day Flow to Average Annual Flow**		
ARCHIE ELLEDGE WWTP	**11/12/2009**	**3/29/2010**	**2/6/2010**		**11/12/2009**	**3/29/2010**	**2/6/2010**
2009	47.9	-	-	17.9	2.67	-	-
2010	-	47.51	46.4	18.5	-	2.57	2.51

3.2.4 Maximum Hour Flow Peaking Factor

The maximum hour peaking factor is calculated as the ratio of the maximum hour flow to the average annual flow. To calculate this factor, the three highest maximum hour readings were determined for the Muddy Creek WWTP effluent meter and the Archie Elledge WWTP effluent meter. The average annual flow was calculated as described in Section 3.2.1. **Table 3-11** presents the maximum hour flows, average annual flows, and maximum hour peaking factors for the Muddy and Elledge Basins. The highest maximum day peaking factor for the Muddy and Elledge Basins was 3.53 and 3.27, respectively.

Table 3-11: Maximum Hour Peaking Factor

	Max Hour Flow			Average Annual Flow (mgd)	Ratio of Max Hour Flow to Average Annual Flow		
MUDDY CREEK WWTP	**12/25/2009 (22:00)**	**1/25/2009 (5:00)**	**2/5/2010 (21:00)**		**12/25/2009 (22:00)**	**1/25/2009 (5:00)**	**2/5/2010 (21:00)**
2009	52.63	-	-	14.89	3.53	-	-
2010	-	53.80	54.69	15.58	-	3.45	3.51
	Max Hour Flow			**Average Annual Flow (mgd)**	**Ratio of Max Hour Flow to Average Annual Flow**		
ARCHIE ELLEDGE WWTP	**1/25/2010 (6:00)**	**2/5/2010 (19:00)**	**2/6/2010 (6:00)**		**1/25/2010 (6:00)**	**2/5/2010 (19:00)**	**2/6/2010 (6:00)**
2010	60.4	60.2	60.5	18.5	3.26	3.25	3.27

As a comparison, the maximum hour flows recorded by the effluent meter during the three largest events in the temporary flow monitoring period are shown in **Table 3-12**. The largest peaking factor for both the Muddy and Elledge WWTPs occurred on October 27, 2010 where the peaking factor was 3.34 and 3.24, respectively. These peaking factors are slightly less than the maximum calculated peaking factors of 3.51 and 3.27.

Table 3-12: Maximum Hour Peaking Factor Recorded During Temporary Flow Monitoring Period

	Max Hour Flow			Average Annual Flow (mgd)	Ratio of Max Hour Flow to Average Annual Flow		
MUDDY CREEK WWTP	**9/26/2010 (22:00)**	**9/30/2010 (10:00)**	**10/27/2010 (5:00)**		**9/26/2010 (22:00)**	**9/30/2010 (10:00)**	**10/27/2010 (5:00)**
2010	19.50	30.35	51.99	15.58	1.25	1.95	3.34
	Max Hour Flow			**Average Annual Flow (mgd)**	**Ratio of Max Hour Flow to Average Annual Flow**		
ARCHIE ELLEDGE WWTP	**9/27/2010 (14:00)**	**9/30/2010 (8:00)**	**10/27/2010 (18:00)**		**9/27/2010 (14:00)**	**9/30/2010 (8:00)**	**10/27/2010 (18:00)**
2010	23.3	50.9	60.0	18.5	1.26	2.75	3.24

Based on the analysis of temporary meters presented in Section 2, the peaking factor for FM 06 immediately upstream of the Muddy WWTP during this event was 4.18 (Table 2-5). Meter 6 also recorded 12.6 feet of surcharge during this event (Table 2-9). Surcharge is defined as the water depth above the pipe crown. Based on the higher upstream peaking factor, it appears that the flows generated in the Muddy Basin are higher than those conveyed through the WWTP or the peak attenuates as it goes through the

plant. The high level of surcharge suggests that there is a restriction downstream of the meter that is backing up flow in the collection system. If any conveyance improvements are made to correct this restriction, it is possible that the maximum hour flows to the Muddy WWTP could increase.

The peaking factor for FM 07 immediately upstream of the Elledge WWTP during the October 27, 2010 event was 3.62 (Table 2-5). Flow meters 9, 19, and 2 upstream of meter 7 had peaking factors of 3.99, 3.83, and 2.51, respectively. Based on the high upstream peaking factors, it appears that the flows generated in the Elledge Basin are higher than those conveyed through the WWTP or the peak attenuates as it goes through the plant. Meter 7 recorded 7.8 feet of surcharge during this event (Table 2-9). The high level of surcharge suggests that there is a restriction downstream of the meter that is backing up flow in the collection system. Similar to the Muddy Creek WWTP, upstream conveyance improvements or upgrades to the influent pump station could increase the maximum hour flows seen at the WWTP.

The peaking factor for meter 8 immediately upstream of the South Fork pump station during this event was 1.99, and there was no surcharge recorded.

3.2.5 Peaking Factor Development for the South Fork Basin

Flows from the South Fork Basin are directed to the Archie Elledge WWTP via the South Fork pump station. Due to issues with the valve operation at the pump station, not all of the dry- and wet-weather flows from the South Fork Basin are diverted to the South Fork pump station. Rather, a portion of the flow bypasses the pump station and is conveyed by gravity sewer to the Muddy Creek WWTP.

Data from two parshall flumes downstream of the South Fork pump station was analyzed to develop peaking factors for the South Fork Basin. Parshall flume 28 is located in the most downstream portion of the South Fork Basin and upstream of the Muddy Creek WWTP. This flume captures flow that bypasses the South Fork pump station, as well as flow from Muddy Creek subbasin 28. Parshall flume 30 is located downstream of the discharge from the South Fork pump station and upstream of the Archie Elledge WWTP. This flume captures flow that is pumped from the South Fork pump station, as well as flow from subbasin 30.

Data for Parshall Flume 28 was provided from November 10, 2005 through October 31, 2010. Approximately 53 percent of the data recorded from November 10, 2005 through April 5, 2007 was marked “erroneous”, and therefore data during this time period could not be analyzed with a high degree of confidence.

Data for Parshall Flume 30 was provided from November 1, 2005 through December 31, 2008 and from October 20, 2010 through December 31, 2010. A gap exists in the data provided since SCADA communication from the flume was down due to construction activities at the WWTP due to a cut in the fiber optic cable, which transmitted data from the flume to the SCADA system. From November 2005 through October 2010, 2 percent of the data was marked “erroneous”.

The data for flumes 28 and 30 was added in order to obtain the total flow from the South Fork Basin. The time period for which data from both flumes was available and of reasonable quality was from April 6, 2007 through December 31, 2008 and from October 10, 2010 through October 31, 2010.

The first factor evaluated was the maximum hour factor. The storm events that produced the highest maximum hour factors in the Muddy and Elledge WWTPs effluent data occurred December 2009 through March 2010; during which time the flow from flume 30 was unavailable. The only date for which data was available for both flume 28 and flume 30 was October 27, 2010. This event was also captured by temporary meter FM 08 located upstream of the South Fork pump station. Parshall flume 28 recorded a peak flow of 33.3 mgd and Parshall flume 30 recorded a peak flow of 9.5 mgd. Much of the data recorded by Flume 28

was marked as erroneous before and after the peak flow reading so the 33.3 mgd reading is suspect. Temporary meter FM 08, which is located just upstream of the South Fork pump station recorded a peak 1 hour flow of 10.7 mgd. Therefore it is assumed that the flows recorded by the flume 28 are in error since they exceed the total flow recorded by FM 08.

The next three days with the highest maximum hour flow are April 5, 2008 , May, 9, 2008, and August 27, 2008. Similar to the October 27, 2010 event, the readings from flume 28 ranged from 31.1 mgd to 33.1 mgd and in two of the events were preceded by "erroneous" readings. Based on this, data from flume 28 could not be analyzed with a high degree of confidence. To obtain a better understanding of the peak flows from the South Fork Basin, flow from flume 30 was analyzed. This was considered a reasonable approach for development of the peaking factors since CCUC staff confirmed that the flume did capture most of the flow from South Fork Basin.

The peak events recorded by FM 30 from 2005 to 2010 during which data was available are listed in **Table 3-13**. The table contains the maximum hour flow from the event and the average annual flow. Maximum hour factors are calculated as the maximum hour flow divided by the average annual flow. The peaking factor for flume 30 was 3.37, which is very close to the maximum hour factor for the Elledge Basin of 3.27.

Table 3-13: Maximum Hour Factor for South Fork Basin

	Maximum Hour Flow (mgd)	Average Annual Flow (mgd)	Maximum Hour Factor
11/19/2006	19.67	5.84	3.37
1/3/2007	19.76	6.85	2.88
3/19/2007	19.68	6.85	2.87

The three highest maximum day readings recorded by flume 29 from 2005 to 2010 during which data was available are listed in **Table 3-14**. The table contains the maximum day flow and the average annual flow. Maximum day factors are calculated as the maximum month flow divided by the average annual flow. The highest maximum day factor for flume 29 was 2.53, which is lower than the maximum day factor for the Elledge Basin of 2.67.

Table 3-14: Maximum Day Factor for South Fork Basin

	Maximum Day Flow (mgd)	Average Annual Flow (mgd)	Maximum Day Factor
1/4/2007	15.99	6.85	2.33
3/19/2007	15.40	6.85	2.25
11/19/2006	14.77	5.84	2.53

The three highest maximum month readings recorded by flume 29 from 2005 to 2010 during which data was available are listed in **Table 3-15**. The table contains the maximum month flow and the average annual flow. Maximum month factors are calculated as the maximum month flow divided by the average annual flow. The highest maximum month factor for flume 29 was 1.26, which is close to the maximum month factor for the Elledge Basin of 1.22.

Table 3-15: Maximum Month Factor for South Fork Basin

	Maximum Month Flow (mgd)	Average Annual Flow (mgd)	Maximum Month Factor
Sept 2006	7.37	5.84	1.26
March 2007	7.29	6.85	1.06
June 2007	7.21	6.85	1.05

The average dry-weather flows from August to October for 2006 and 2007 were higher than the average annual flow, resulting in an average annual factor less than 1.0. Due to the lack of 2010 data, it was assumed that the average annual factor was the same as was calculated for the Elledge Basin.

In summary, both the maximum hour and the maximum month factors for the South Fork Basin are higher than those calculated for the Elledge Basin, and are therefore applied to the South Fork Basin projections. The maximum day factor for the South Fork Basin was lower than was calculated for the Elledge Basin. Due to the limited data set available for flume 30, it was decided that a more conservative approach would be to apply the higher maximum day factor developed for the Elledge Basin to the South Fork Basin. Likewise, the average annual factor calculated for the Elledge Basin was applied to the South Fork Basin.

3.2.6 Peaking Factory Summary

A summary of the average annual, maximum month, maximum day, and maximum hour peaking factors developed for the Muddy, Elledge, and South Fork Basins is shown in **Table 3-16**.

Table 3-16: Peaking Factor Summary

	Average Annual	Max Month	Max Day	Max Hour
Elledge	1.14	1.22	2.67	3.27
Muddy	1.18	1.26	3.01	3.53
South Fork	1.14	1.26	2.67	3.37

The peaking factors presented in the Archie Elledge Wastewater Treatment Plant Wastewater Flow Projections Memorandum (HDR, April 2008) are presented in **Table 3-17**. The factors developed through this analysis were higher than those in the previous study with the exception of the maximum hour factor for the Elledge Basin.

Table 3-17: Previous Peaking Factors Developed
Archie Elledge Wastewater Treatment Plant Wastewater Flow Projections Memorandum

	Max Month	Max Day	Max Hour
Elledge	1.10	2.12	3.62
Muddy	1.14	1.96	2.81

3.3 Development of Yearly Flows

The projected average dry-weather flows developed in Section 3.1 were combined with the peaking factor developed in Section 3.2 to produce yearly projected peak flows for the Muddy, Elledge, and South Fork Basins. These flows are shown in **Table 3-18**. Flows predicted in years between 2010, 2015, 2025, and 2035 are projected by linear interpolation.

Table 3-18: Projected Yearly Flows by Basin

	Average Dry Weather Flow (mgd)				Average Annual Flow (mgd)				Max Month Flow (mgd)				Max Day Flow (mgd)				Max Hour Flow (mgd)			
	Muddy	Elledge	South Fork	Total	Muddy	Elledge	South Fork	Total	Muddy	Elledge	South Fork	Total	Muddy	Elledge	South Fork	Total	Muddy	Elledge	South Fork	Total
2010	**12.11**	**11.95**	**5.40**	**29.46**	**14.31**	**13.58**	**6.13**	**34.02**	**18.00**	**16.59**	**7.73**	**42.32**	**43.04**	**36.26**	**16.38**	**95.67**	**50.56**	**44.35**	**20.67**	**115.58**
2011	12.47	12.06	5.54	30.06	14.72	13.70	6.30	34.73	18.52	16.75	7.93	43.20	44.29	36.59	16.81	97.69	52.03	44.76	21.22	118.01
2012	12.82	12.17	5.68	30.67	15.14	13.83	6.46	35.43	19.05	16.90	8.14	44.09	45.54	36.92	17.25	99.71	53.50	45.17	21.77	120.44
2013	13.17	12.28	6.22	31.67	15.56	13.95	7.07	36.58	19.57	17.05	8.91	45.53	46.79	37.26	18.88	102.92	54.97	45.57	23.83	124.37
2014	13.52	12.38	6.41	32.31	15.97	14.08	7.28	37.33	20.09	17.20	9.18	46.48	48.03	37.59	19.45	105.08	56.44	45.98	24.55	126.97
2015	**13.87**	**12.49**	**6.60**	**32.96**	**16.39**	**14.20**	**7.50**	**38.09**	**20.62**	**17.36**	**9.45**	**47.42**	**49.28**	**37.92**	**20.02**	**107.23**	**57.90**	**46.39**	**25.27**	**129.56**
2016	14.15	12.61	6.78	33.54	16.71	14.34	7.71	38.76	21.02	17.52	9.71	48.26	50.26	38.28	20.59	109.13	59.05	46.83	25.98	131.86
2017	14.42	12.73	6.97	34.12	17.04	14.47	7.92	39.43	21.43	17.68	9.98	49.10	51.24	38.64	21.15	111.03	60.20	47.26	26.70	134.16
2018	14.70	12.85	7.16	34.70	17.36	14.60	8.13	40.10	21.84	17.85	10.25	49.94	52.21	38.99	21.72	112.93	61.35	47.70	27.41	136.46
2019	14.97	12.96	7.34	35.28	17.69	14.74	8.35	40.77	22.25	18.01	10.52	50.78	53.19	39.35	22.29	114.83	62.49	48.13	28.13	138.76
2020	15.25	13.08	7.53	35.86	18.01	14.87	8.56	41.44	22.66	18.17	10.78	51.61	54.17	39.71	22.85	116.73	63.64	48.57	28.84	141.05
2021	15.52	13.20	7.72	36.44	18.33	15.00	8.77	42.11	23.07	18.33	11.05	52.45	55.15	40.06	23.42	118.63	64.79	49.01	29.56	143.35
2022	15.80	13.32	7.90	37.02	18.66	15.14	8.98	42.78	23.48	18.50	11.32	53.29	56.12	40.42	23.99	120.53	65.94	49.44	30.27	145.65
2023	16.07	13.43	8.09	37.60	18.98	15.27	9.20	43.45	23.88	18.66	11.59	54.13	57.10	40.78	24.55	122.43	67.08	49.88	30.99	147.95
2024	16.35	13.55	8.28	38.18	19.31	15.41	9.41	44.12	24.29	18.82	11.85	54.97	58.08	41.13	25.12	124.33	68.23	50.31	31.70	150.25
2025	**16.62**	**13.67**	**8.46**	**38.75**	**19.63**	**15.54**	**9.62**	**44.79**	**24.70**	**18.99**	**12.12**	**55.81**	**59.05**	**41.49**	**25.68**	**126.23**	**69.38**	**50.75**	**32.42**	**152.55**
2026	16.92	13.79	8.67	39.38	19.98	15.68	9.86	45.52	25.14	19.16	12.42	56.72	60.11	41.86	26.32	128.29	70.62	51.21	33.22	155.05
2027	17.22	13.92	8.88	40.01	20.34	15.82	10.09	46.25	25.58	19.33	12.72	57.63	61.16	42.24	26.95	130.35	71.86	51.66	34.02	157.54
2028	17.51	14.04	9.09	40.64	20.69	15.96	10.33	46.98	26.03	19.50	13.02	58.55	62.22	42.61	27.59	132.42	73.10	52.12	34.82	160.04
2029	17.81	14.16	9.30	41.27	21.04	16.10	10.57	47.71	26.47	19.67	13.32	59.46	63.27	42.98	28.22	134.48	74.34	52.58	35.62	162.54
2030	22.35	14.28	9.51	46.14	26.39	16.24	10.81	53.44	33.21	19.84	13.62	66.67	79.38	43.36	28.85	151.59	93.26	53.04	36.42	182.72
2031	22.62	14.41	9.72	46.75	26.72	16.38	11.04	54.14	33.62	20.01	13.92	67.55	80.36	43.73	29.49	153.58	94.42	53.49	37.22	185.13
2032	22.90	14.53	9.92	47.35	27.05	16.52	11.28	54.85	34.03	20.19	14.22	68.43	81.34	44.11	30.12	155.57	95.57	53.95	38.02	187.54
2033	23.17	14.65	10.13	47.96	27.37	16.66	11.52	55.55	34.44	20.36	14.51	69.31	82.32	44.48	30.76	157.56	96.72	54.41	38.82	189.95
2034	23.45	14.78	10.34	48.57	27.70	16.80	11.76	56.25	34.85	20.53	14.81	70.19	83.30	44.85	31.39	159.55	97.87	54.87	39.62	192.36
2035	**23.73**	**14.90**	**10.55**	**49.18**	**28.02**	**16.94**	**11.99**	**56.96**	**35.26**	**20.70**	**15.11**	**71.07**	**84.28**	**45.23**	**32.02**	**161.54**	**99.02**	**55.32**	**40.42**	**194.77**

Section 4
Conclusions and Recommendations

The scope of this project included temporary flow monitoring to establish 2010 dry- weather flows and development of wastewater flow projections based on the new 2010 flow monitoring data. CDM developed a flow monitoring plan to collect flow and rainfall data within CCUC's sewer collection system. Twenty-seven temporary flow meters and 6 temporary rain gauges were installed in the collection system for 60 days. After the temporary flow monitoring period, 11 meters and 3 rain gauges were converted to permanent installations. CDM decomposed the wastewater flow meter data into base flow, groundwater infiltration, and rainfall dependent infiltration and inflow (RDI/I) components for the three largest storm events. This decomposition revealed the relative peak RDI/I contributions of various portions of the service area. Wet-weather peaking factors were developed based on the results of flow monitoring analysis.

Future dry-weather wastewater flows were calculated for the three main basins in the existing CCUC service area (Muddy, Elledge, and South Fork), outside areas that contribute flows to the CCUC system, and future service areas (FSAs) identified in the Legacy Development Guide**.** The outside areas include portions of Davie County, Davidson County, City of King, and Piedmont Utilities within Davidson County contributing flow to the CCUC wastewater collection system. Future service areas were identified in the Growth Management Plan chapter in the Legacy Development Guide. These areas do not currently have sewer, but are identified as FSAs because of their potential to be served efficiently by sewer. The Growth Management Plan calls for them to eventually become urban, and development that does occur will be encouraged to install public sewerage.

Future wastewater flow projections for the CCUC service area were prepared by CDM using flow monitoring and Traffic Analysis Zone (TAZ) planning data and flow projections for outside areas provided by CCUC. Yearly average dry-weather wastewater flow projections were developed for 2010 through 2035. Additionally, annual average, max month, max day and max hour factors were developed for the Muddy Creek, Elledge, and South Fork Basins. These peaking factors were applied to the yearly average dry-weather flow projections to develop future flow projections from these basins.

4.1 Summary of Major Conclusions

The following is a summary of the major conclusions of this study.

- The flow monitoring and radar rainfall data collected during the flow monitoring period was of good quality and compared well to the data captured by CCUC's effluent meters. Six significant storm events (three storm events were greater than 2.5-inches on average) were recorded during the flow monitoring period and the three largest events were selected for further analysis.

- The peak wet-weather ratio is calculated by dividing the peak flows by the average dry-weather flow. For the subbasin size metered a peak wet-weather flow of more than 4 times the average is an indicator of excessive I/I in the system. Seventeen of the 27 meters (seven meters in Muddy Basin, four meters in Elledge Basin, and six in South Fork Basin) recorded a maximum peaking factor greater than 4.
- Peak depths recorded during the three analyzed storm events were analyzed to determine if surcharging was observed. Surcharging occurs when the peak level observed in the manhole is above the crown of the pipe. Twelve of the 27 flow meters surcharged during one or more of the 3 storm events analyzed. Of the meters that surcharged; all but two flow meters had peaking factors greater than 4. Nine meters surcharged within three feet of the manhole rim.
- Total average annual flow from the Muddy, Elledge, and South Fork Basins is projected to increase from 34.0 mgd in 2011 to 57.0 in 2035. This includes a 5 mgd projected increase in flow from Davie County in 2030.
- Average annual, maximum month, maximum day, and maximum hour peaking factors were developed for the Muddy, Elledge, and South Fork Basins (**Table 4-1**). The peaking factors were developed based on analysis of effluent meter flow data. The factors developed through this analysis were higher than those in the Elledge Wastewater Treatment Plant Wastewater Flow Projections Memorandum (HDR, April 2008) study with the exception of the maximum hour factor for the Elledge Basin. The peaking factors were applied to projected average dry weather flows for each basin. A summary of the projected average annual, max month, max day, and max hour factors are presented **Table 4-2**.

Table 4-1: Peaking Factor Summary

	Average Annual	Max Month	Max Day	Max Hour
Elledge	1.14	1.22	2.67	3.27
Muddy	1.18	1.26	3.01	3.53
South Fork	1.14	1.26	2.67	3.37

4.2 Additional Recommendations and Next Steps

Additional recommendations are listed below:

- Analysis of the flow data indicts potentially higher peaking factors in the temporary flow monitors. Surcharge level data indicates that water is backing up in the collection system during larger storm events. It is possible that improvements made to the collection system could increase the peak flows seen at the WWTP. CDM recommends further analysis to predict design storm flows to the WWTP for different storm events. The design storm flows (2-year, 5-year, 10-year) can be based on a level of service chosen by CCUC.
- High peak flows were observed in all three basins during the monitored rain events. CDM recommends additional prioritization of areas within the Muddy, Elledge, and South Fork Basins to initiate Sewer System Evaluation Survey (SSES) activities. The prioritization can be based on the condition of sewer (probability of failure) and the criticality of the sewer (consequence of failure).

Table 4-2: Flow Projections Summary

	Average Annual (mgd)	Max Month (mgd)	Max Day (mgd)	Max Hour (mgd)
	2010			
Muddy	14.31	18.00	43.04	50.56
Elledge	13.58	16.59	36.26	44.35
South Fork	6.13	7.73	16.38	20.67
Total	34.02	42.32	95.67	115.58
	2015			
Muddy	16.39	20.62	49.28	57.9
Elledge	14.20	17.36	37.92	46.39
South Fork	7.50	9.45	20.02	25.27
Total	38.09	47.42	107.23	129.56
	2025			
Muddy	19.63	24.70	59.05	69.38
Elledge	15.54	18.99	41.49	50.75
South Fork	9.62	12.12	25.68	32.42
Total	44.79	55.81	126.23	152.55
	2035			
Muddy	28.02	35.26	84.28	99.02
Elledge	16.94	20.7	45.23	55.32
South Fork	11.99	15.11	32.02	40.42
Total	56.96	71.07	161.54	194.77

- One of the assumptions made in this study is that the peaking factors will be maintained through the planning period (2010-2035). Therefore, the amount of sewer rehabilitation must keep up with the rate of sewer decay. CDM recommends rehabilitation of 1 to 2 percent of the collection system per year. In addition to comprehensive rehabilitation for I/I reduction, consideration should be given to structural and maintenance issues.
- CDM recommends that CCUC continue the permanent flow monitoring program. There are several benefits to collection of this flow data. One benefit is that the data can be used in future capacity study updates to determine historical levels of I/I. Furthermore, upon completion of sub-basin rehabilitation, the flow monitors can be used to document I/I reduction. The flow monitoring data can also be used to calibrate a hydraulic model of the collection system.
- Because unforeseen events affecting projected growth and expansion may occur, it is recommended that the flow projections be updated periodically, at least every five years, to ensure that the system improvements and associated funding are kept in pace with growth and development patterns.
- The Capital Improvements Plan implementation schedule contained in the 2010 Wastewater Facilities Master Plan is being updated based on the results of this study. These updates will be included in the Wastewater Facilities Master Plan update issued by CDM in February 2011 under a separate cover.

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