2.0 Wastewater Flows

2.1 Introduction

This chapter presents the flow and rainfall monitoring program, the monitoring program results, and the projected wastewater flows. Monitoring was performed in the fall of 2001 and the summer of 2002 to gather and analyze rainfall and wastewater flows at temporary flow monitoring locations. The flow metering information was collected to assess current conditions and to help project future flows. All monitoring field work was performed by GMS, Inc.

2.2 Flow Components

For purposes of this report, wastewater production flow (WWP) is defined as the wastewater exclusive of infiltration and inflow. The daily wastewater production flow rate can be approximated using (1) direct measurement of average daily dry weather flow (ADDF) during dry weather/low groundwater conditions or (2) winter month water consumption data. For this project the ADDF was determined for monitoring data during dry weather/low groundwater conditions. The instantaneous wastewater production flow rate varies throughout each day, with the highest rates normally occurring between 8:00 and 11:00 a.m. The ratio of peak 60-minute flow to total average daily flow is defined as the dry weather or diurnal peaking factor. Average annual daily flow (ADF) is the annual flow volume, including I/I, divided by the days per year.

Infiltration is groundwater entering the wastewater collection system and private building lines through defective pipes, pipe joints, and manhole structures below the manhole corbel and chimney. The rate of infiltration depends on the depth of groundwater above the defects, the size of the defects, and the percentage of the collection system submerged. The variation in groundwater levels and the associated infiltration is seasonal and weather-dependent. Low dry weather/groundwater infiltration is infiltration that occurs year-round and is measured during dry weather when previous rainfall is no longer having an effect on flows. High dry weather/groundwater infiltration is the additional infiltration that occurs due to higher groundwater conditions during spring or following rain events.

Inflow is rainfall-related water, which enters the collection system from sources such as private sewer laterals, downspouts, foundation drains, yard and area drains, storm water sump pumps, manholes, defective piping, and cross-connections with storm drains. Inflow is directly influenced by the intensity and duration of a storm event, and therefore is not a fixed quantity. Figure 2-1 illustrates these flow components.

2.3 Flow and Rainfall Monitoring Program

A Flow and Rainfall Monitoring Plan was reviewed and accepted on August 27, 2001 during a meeting between Black & Veatch, FSD, and the District's Engineer, GMS, Inc. Temporary rainfall gauges and open channel flow monitors were installed by GMS, Inc. on September 12, 2001. The monitoring equipment was removed on January 7, 2002. At that time, the monitoring program had observed very few measurable rainfall events and the flow metering equipment had malfunctioned during critical rainfall periods. Subsequently, a second flow and rainfall monitoring program was initiated July 15, 2002 and terminated September 3, 2002. Details of the two programs are presented in the following sections.

2.3.1 Location of Monitoring Stations

Three temporary flow monitors and three temporary rain gauges were used for recording flow and rainfall during each monitoring period. In addition, influent data recorded at the wastewater treatment plant and energy records for the Little Ranches Lift Station were collected. The flow and rain gauge locations are identified on Figure 2-2.

2.3.1.1 Temporary Flow Monitors

During execution of the Flow and Rainfall Monitoring Plan alternative manhole locations were inspected for best monitoring results. Adjustments in the initially proposed monitoring locations were made in consultation with FSD and its Engineer. The temporary flow monitoring locations for both the fall 2002 and the summer 2002 monitoring are summarized in Table 2-1. The monitoring equipment was ISCO Model 4150 Area Velocity Flow Logger, which recorded at 15 minute intervals.

All of the temporary flow monitor sensors were mounted in pipes to record flow entering from the pipe upstream of the designated manhole. The temporary flow monitors were maintained, to collect data for 16 weeks during the first program, and 7 weeks during the second program. Only infrequent and small rain events occurred during this period.

Figure 2-1 Flow Components

Figure 2-2 Flow Meter and Rain Gage Locations

Table 2-1
Temporary Flow Metering Sites

Flow Monitor	Location	Manhole Number	Sewer Size (in)	Meter Type
Fall 2001 Monitoring Program				
SF-003	West side of Santa Fe Avenue	SF-003	18	ISCO 4150
SF-041	West side of Santa Fe Avenue at Comanche Village Drive	SF-041	12	ISCO 4150
JC-002	Link Street and Old Pueblo Road	JC-002	12	ISCO 4150
Summer 2002 Monitoring Program				
SF-005	West side of Santa Fe near FSD Office	SF-005	18	ISCO 4150
RS-002	East side of Santa Fe near FSD Office	RS-002	12	ISCO 4150
JC-003	NE corner of Wilson Rd. @ Old Pueblo Rd.	JC-003	12	ISCO 4150

2.3.1.2 Rainfall Gauges

The location and address of rain gauges are summarized in Table 2-2. The same rain gage locations were used for the first and second monitoring periods. The temporary rain gauge locations are also shown on Figure 2-2. ISCO 675 Logging Rain Gauge equipment was used.

Table 2-2
Rainfall Gauge Locations

Station Number	Location & Address
RG1	10905 Falling Star Road, in the southeast part of the Study Area
RG2	509 Crest Road, in the southwest part of the Study Area
RG3	760 Calle Entrada, in the north-central part of the Study Area

2.3.2 Flow and Rainfall Monitoring Equipment

2.3.2.1 Temporary Flow Monitoring

ISCO Model 4150 Area Velocity Flow Logger, manufactured by ISCO, Inc., were used to measure open channel flow for this project. Each monitoring unit includes a pressure transducer that measures depth of flow and a doppler technology sensor that measures the flow velocity. The ISCO sensors were mounted in the wastewater flow on an expandable aluminum ring installed in the interceptor pipe, normally upstream of the manhole invert. The signal from the sensors was sent through the communication cable to the monitor. The units operate on a battery power supply.

The monitoring units were suspended from brackets mounted in the manhole wall near the top of each manhole and were set to collect and store depth of flow and velocity readings at 15-minute intervals. Data from the monitors was retrieved using a portable laptop computer.

2.3.2.2 Rain Gauge Network

The gauges used for direct rainfall measurements were tipping-bucket type rainfall gauges with electronic recorders. The gauges continuously recorded each 0.01-inch depth of rainfall occurring during the monitoring period. The continuous data record was processed to define each rainfall event and determine the rainfall occurring over 15-minute intervals. The temporary rainfall gauges were serviced and the data retrieved weekly.

2.3.3 Monitoring Methodology

2.3.3.1 Pre-Installation Calibration

Each temporary flow monitor and rainfall gauge was checked for accuracy before installation and inspected at least once a week to check performance. A formal log of each performance check was recorded and filed.

2.3.3.2 Installation Procedures

After completion of the site investigations and monitor pre-installation calibration, the temporary flow monitors and rainfall gauges were installed. An inspection form for each temporary flow and rainfall monitoring site was completed. Each proposed temporary flow monitoring location was inspected for acceptable flow hydraulics as required for accurate flow recording. The site-specific hydraulic considerations that were reviewed before placement of temporary meters included:

?? Uniformly shaped pipe

?? Smooth (laminar) flow away from the influence of flow entries or hydraulic jumps

?? Sufficient elevation differences to counter capacity problems that cause backup conditions

2.3.3.3 Monitoring

During the monitoring, steps were taken to assure the integrity of the collected data. The quality of the field data was analyzed throughout the project. The performance checks performed during regular field visits to each flow monitor are described in the following sections.

2.3.3.3.1 Quality Assurance

The following performance checks were performed during regular field visits to each flow monitor:

?? Download Data - The time, depth, and sensed velocity data accumulated in the monitor's memory were downloaded to a portable laptop computer on each site visit.

?? Measure Power Supply - Power levels were recorded and batteries replaced, when necessary. A battery powers the monitor. A long life battery provided back-up power to the memory, which allows the primary battery to be replaced without loss of data.

?? Confirmation of Monitor Synchronization - The field crew checked the flow monitor's timing against the project master clock to ensure that all readings were taken simultaneously.

?? Documentation of Field Condition - During the field checks, the field crew documented field conditions on daily field logs.

2.3.3.3.2 Flow Monitoring

The following reviews of the flow monitor locations and flow data were performed during the monitoring period:

?? Verified Depth and Velocity of Flow - During the weekly site visits, manual measurements of the depth and velocity of flow in the invert were made from the ground surface. The manual measurements were compared to the monitor readings to check accuracy of the monitors.

?? Measure Deposition Level - The depth of debris or sediment at the sensor was measured by the field crew.

2.3.4 Preliminary Data Analysis and Review

A schematic drawing of the relationship between the monitored areas or subsystems is shown on Figure 2-3.

2.3.4.1 Flow Monitor Profiling and Calibration

Flow monitor profiling and calibration was performed to determine hydraulic conditions at each flow monitoring site. Monitor profiling consists of manually taking a series of flow velocities at different depths in the flow, to compute the actual average velocity, flow rate, and hydraulic gradient. Profiling permits calibrating the monitor to the actual flow rates. Profiling was performed in conjunction with weekly data collection.

This capacity is characteristic of the reach of pipe in the immediate vicinity of the flow monitor. The theoretical design capacity is calculated by Manning's formula for uniform flow conditions using the modeled slope, the nominal pipe size, and the energy gradient. The theoretical design capacity is the average capacity over the length of pipe with the indicated slope. The hydraulic conditions and the calibrated capacities at each temporary meter site during the monitoring period were summarized in Table 2-3.

Table 2-3
Temporary Monitoring Site Descriptions

Monitoring Site	Pipe Diameter (in)	Average Flow Depth(1) (in)	Average Velocity(1) (fps)	Design Parameters Modeled Slope (%)	Design Parameters Pipe Capacity(2) (mgd)
2001 Program					
SF-041	12	1.47	3.99	0.96	2.25
SF-003	18	7.78	1.13	0.50	4.78
JC-002	12	4.28	4.68	1.00	2.32
2002 Program					
SF-005	18	6.72	1.26	0.36	4.08
RS-002	12	2.52	1.27	0.37	1.40
JC-003	12	5.28	2.69	1.00	2.32

(1) Average depth and velocity from calibration site visits.

(2) Capacity based on modeled slope and diameter and full pipe flow.

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Figure 2-3 Temporary Meter Subsystem Schematic

2.3.4.2 Subsystem Areas

Developed area is used in calculating rates of ADDF, infiltration, and inflow as discussed later in this chapter. Residential and ICI acres were determined during the land use analysis presented in Chapter 2. Summing the residential and ICI areas tributary to each flow meter provided the developed area in each monitored subsystem. The current incremental and cumulative developed area information for each temporary flow monitoring area is listed in Table 2-4.

Table 2-4
Developed Areas by Flow Monitor Drainage Area

Flow Monitor	Drainage Area Developed Area (acres)	
	Incremental	Cumulative
2001 Program Sites		
SF-041	207	207
SF-003	726	933
JC-002	367	367
Total	1,300	--
2002 Program Sites		
SF-005	759	759
RS-002	174	174
JC-003	367	367
Total	1,300	--

[1] Developed acres are based on the existing land use GIS map.

2.4 Rainfall Data Analysis

The purpose of the rainfall monitoring was to evaluate observed rainfall events for use in determining the relationship between rainfall and inflow for the FSD system. These values form part of the basis for analyzing existing wastewater collection system capacity and projecting future system requirements.

2.4.1 Design Flow and Probability

Design flow for a sewer is defined as the maximum flow that a specified structure can pass without overload. Since a significant portion of the peak flows in sanitary sewers is inflow resulting from rainfall, the design flow that the sewer must convey is related to the probability of occurrence of a design storm event. Design flow for a selected rainfall event is the sum of three components: (1) peak wastewater production; (2) total infiltration; and (3) inflow. As presented later, inflow is a function of the local intensity-duration-frequency relationship for rainfall. This relationship introduces a probability consideration to the development of the design flow.

A summary of the probability that a storm event having a prescribed recurrence interval will not be equaled or exceeded during a specified period is given in Table 2-5. For example, a design based on a 10-year storm event has a 59 percent chance of not being exceeded during a five-year period.

Table 2-5
Probability of Non-Exceedance (1)

Design Storm (years)	Period (years)							
	1	5	10	20	50	100	200	500
1	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
2	0.50	0.03	0.01	(2)	(2)	(2)	(2)	(2)
5	0.80	0.33	0.12	0.01	(2)	(2)	(2)	(2)
10	0.90	0.59	0.35	0.12	(2)	(2)	(2)	(2)
25	0.96	0.82	0.66	0.44	0.13	0.02	(2)	(2)
50	0.98	0.90	0.82	0.67	0.36	0.13	0.02	(2)
100	0.99	0.95	0.90	0.78	0.61	0.37	0.13	0.01

(1) Example: A 5-year storm event by definition has a 20 % probability of being exceeded in any one year, or 80 % probability of not being exceeded. The probability that no storm event greater than the 5-year storm event not be exceeded during any 10-year period is reduced to 35%.

(2) Values are near 0.

2.4.2 Analysis of Rainfall Data

2.4.2.1 Background

The normal annual average precipitation for the Fountain Sanitation District service area is 15.87 inches. During 2001 and 2002, the state of Colorado has experienced a drought. During the 12-month period of September 2001 through August 2002, Colorado Springs recorded only 6.5 inches precipitation, ranking this period as the driest year in the 110 years of record at the Colorado Springs station. Table 2-6 compares the monthly normal vs. 2001-2002 actual precipitation.

Table 2-6
Historical Monthly Precipitation

Month and Year	Normal Average Precipitation [(1)] (in)	Actual Precipitation (in)	Percent of Normal Precipitation (%)
August 2001	2.93	0.43	15
September 2001	1.18	1.02	86
October 2001	0.84	0.02	2
November 2001	0.48	0.37	77
December 2001	0.31	0.09	29
January 2002	0.30	0.25	83
February 2002	0.33	0.11	33
March 2002	0.84	0.29	35
April 2002	1.32	0.02	2
May 2002	2.22	1.11	50
June 2002	2.13	1.17	55
July 2002	2.98	1.62	54
Total	15.87	6.50	41

(1) Normal average monthly precipitation data is for the Fountain, Colorado station number 053063, with period of record from August 1948 through September 1997.

(2) Year 2001-2002 monthly precipitation is for Colorado Springs, Colorado.

(3) Rainfall information provided by the Western Regional Climate Center, http://www.wrcc.dri.edu.

The rainfall intensity-duration relationships for the Fountain area were developed from Technical Paper 40, “Rainfall Frequency Atlas of the United States”, published by the former U.S. Weather Bureau. The rainfall intensity-duration relationships are presented in Table 2-7 and shown graphically on Figure 2-4.

Table 2-7
Rainfall Depth – Duration – Frequency Relationship, Fountain, CO

Return Period (Years)	Total Rainfall (inches) for Duration Indicated						
	30 Min	60 Min	2 Hrs	3 Hrs	6 Hrs	12 Hrs	24 Hrs
1	1.00	0.70	0.43	0.33	0.20	0.10	0.06
2	1.40	1.00	0.55	0.42	0.23	0.13	0.07
5	2.00	1.40	0.75	0.55	0.29	0.18	0.10
10	2.40	1.60	0.88	0.67	0.37	0.19	0.13
25	2.80	1.90	1.13	0.75	0.44	0.25	0.14
50	3.20	2.20	1.25	0.83	0.50	0.29	0.16
100	3.74	2.50	1.38	0.92	0.56	0.33	0.19

Figure 2-4 Rainfall Intensity – Duration – Frequency Relationship

2.4.2.2 Monitored Rainfall

Rainfall was monitored for the purpose of correlating the peak rain intensities to the peak flow rates in the interceptors. The highest flow for a given storm event is generated when the storm duration has reached the travel time from the farthest point in the system to the flow monitor location. If rainfall does not last as long as the system travel time from the farthest point in the system to the treatment facility, the maximum system inflow for a given rainfall intensity is hindered.

Twenty-one rainfall events of varying total measured rainfall and duration were recorded during the 2001 flow monitoring program. Nine events were recorded during the 2002 flow monitoring period. Unfortunately, none of the observed storms showed either a significant rainfall or resulted in a definable response at the flow monitors. Therefore, detailed analysis of the flow response to rainfall was not possible.

Summaries of the observed daily total rain for the total area tributary to each subsystem are given in Tables 2-8 and 2-9. Table 2-8 lists only the events with 0.10 inches of total rain or more. Each rainfall event was further analyzed to determine the return interval for selected rainfall durations by comparing the recorded data to the rainfall intensity-duration-frequency curves for the Fountain area. As an example, the peak rainfall intensity/duration relationship during selected storm events for monitor JC-03 is given in Table 2-9. At a 60-minute duration, the peak rainfall intensity for the July 26, 2002 storm was only twenty-three percent of a 1-year frequency storm event. The storm data shown on Table 2-9 indicates that while reasonable rain intensities were observed for a short duration, longer duration rainfall was not observed.

Table 2-8
Monitored Rainfall Totals (1)

	Total Rainfall for Each Rain Event by Subsystem (Inches) 2001 Flow and Rainfall Monitoring Program			
Rain Date	**JC-002**	**SF-003**	**SF-041**	**Average**
09/12/2001.1	0.11	0.09	0.18	0.13
09/15/2001.1	0.24	0.11	0.00	0.18
09/17/2001.1	0.66	0.80	0.01	0.49
11/16/2001.1	0.03	0.04	0.08	0.05
11/17/2001.1	0.13	0.17	0.33	0.21
11/29/2001.1	0.31	0.39	0.78	0.49
12/19/2001.1	0.05	0.06	0.12	0.08
12/30/2001.1	0.15	0.19	0.38	0.24
Total Rain 2001 Program	2.10	2.12	2.09	2.10
	Total Rainfall for Each Rain Event by Subsystem (Inches) 2002Flow and Rainfall Monitoring Program			
Rain Date	**JC-003**	**SF-002**	**RS-002**	**Average**
07/16/2002.1	0.11	0.10	0.10	0.10
07/26/2002.1	0.15	0.23	0.00	0.19
07/26/2002.2	0.18	0.13	0.10	0.14
08/09/2002.2	0.16	0.05	0.05	0.09
Total Rain 2002 Program	0.54	0.57	0.27	0.46

(1) Rainfall events with less than 0.10 inch total depth in all subsystems are not shown. The total rainfall depths shown for the 2001 and 2002 program include all rain events regardless of daily depth.

Table 2-9
Monitored Peak Rainfall Intensities vs. Duration for Selected Storms

Date In 2002	Peak Rainfall Intensity (inches/hour) For Duration Indicated					
	30 (min)	60 (min)	120 (min)	180 (min)	240 (min)	600 (min)
Standard 1-Year Storm						
-	1.00	0.70	0.43	0.33	0.20	0.10
Observed Storm Events						
07/26/02	0.180	0.160	0.095	0.060	0.045	0.020
07/26/02	0.175	0.140	0.080	0.055	0.035	0.015
08/09/02	0.180	0.010	0.055	0.035	0.025	0.015

2.5 Flow Data Analysis

The wastewater flow data was reviewed to select the most representative days of data recorded for use in the determination of dry and wet weather flow parameters. Dry weather days were selected to provide the best estimation of base wastewater production. As discussed in the preceding section, analysis of wet weather flow data was not possible due to the limited rainfall during the monitoring period.

2.5.1 Flow Monitoring Data

2.5.1.1 Determination of Average Daily Dry Weather Flow

Daily fluctuations in flows are attributable to variations in domestic, industrial, and commercial wastewater production. ADDF is a flow parameter measured directly by flow monitoring and includes WWP plus the portion of total infiltration that occurs during low groundwater conditions. The ADDF for each monitor was determined using the average flow at the monitor for selected 7-day periods based on data availability. Typically, during this evaluation, dry weather/low groundwater period infiltration is negligible.

A flow balance was performed using the ADDF recorded at each temporary flow monitor site. This process is an accounting procedure for balancing flows recorded throughout the system. At the same time, flows were checked against the developed acres tributary to each meter (to determine the per developed acre use rate (gpad) for each subsystem). In order to provide reasonable values for incremental flows throughout the system, flows at FM2 and FM3 were balanced using cumulative system unit rates at FM1. The subsystem and cumulative ADDF values and rates are shown in Table 2-10. The ADDF per developed acre rates range from 510 gpad to 1009 gpad.

Dry weather peaking factors (the ratio of the cumulative peak 60-minute flow to cumulative average daily flow measured during dry weather/low groundwater conditions) were determined for each monitor. The observed dry weather peaking factors ranged from about 1.3 for monitors closest to the treatment plant to about 1.8 for the most upstream monitor. These factors are typical. In the computer model dry-weather diurnal curves were input for each monitor area to dynamically generate the peaking factors. The shape of each curve was determined from the dry weather flow data. Diurnal curves generally have two peaks, the largest peak occurring in the morning and the second occurring in the evening. The diurnal peaking factors are shown by subsystem in Table 2-10. Diurnal curves for each cumulative area tributary to each monitor are included in the Appendix.

Table 2-10

Subsystem ADDF and Peak Dry Weather Flow Summary

Subsystem	Measured ADDF (mgd)	ADDF Rates			Peak dry weather flow	
		Subsystem ADDF Rate (1) (gpad)	Cumulative ADDF Rate(1) (gpad)	Peaking Factor (Qp/Qa)	Subsystem (mgd)	Cumulative (mgd)
2001 Program						
SF-041	0.156	753	753	1.761	0.272	0.272
SF-003	0.534	770	631	1.493	0.528	0.800
JC-002	0.772	2,104	2,104	1.291	0.998	0.998
Total to WWTF (2)	1.306	--	1,005	--	--	1.798
2002 Program						
SF-005	0.367	483	483	1.377	0.505	0.505
RS-002	0.064	368	368	1.446	0.093	0.093
JC-003	0.595	1,621	1,621	1.305	0.777	0.777
Total to WWTF (2)	1.026	--	789	--	--	1.375

(1) Colorado Centre flows are delivered to the Jimmy Camp Creek trunk sewers and are included in flows monitored at JC-002 or JC-003. For 2002, Colorado Centre delivered 51,601,000 gallons to FSD or an average flow of 0.141 mgd. Colorado Centre flows are excluded from the study area per-acre rates.

(2) The total system flow is the sum of SF-003 and JC-002 for the 2001 program, and the sum of all three meters for the 2002 program. The 2001 program results are somewhat high compared to the average inflow recorded at the treatment plant of 1.15 mgd in September 2001. The 2002 program results compare well with the September 2002 WWTF inflow of 1.14 mgd.

2.5.1.2 Determination of Infiltration

Total infiltration consists of base (dry weather/low groundwater) infiltration and dry weather/high groundwater infiltration. Infiltration during high groundwater periods is measured on days after significant rainfall events. The total flow measured during these infiltration periods includes WWP plus both base and high groundwater infiltration flows. Total infiltration is determined from flow monitoring data by comparing the minimum flow during high groundwater / dry weather periods (e.g., after rain events) with the minimum flow during low groundwater / dry weather periods (e.g., during the same days that were used for determining dry weather flows).

The observed infiltration values by subsystem are shown in Table 2-11 for reference. Due to the dry weather, significant infiltration was not observed. Measurable infiltration rates were only possible from the SF-041 and SF-045 data, and both of those were low. The data did not provide meaningful infiltration estimates for the remaining sites. For reference, the 1988 Master Plan for Lower Fountain Metropolitan Sewage

Disposal District reported that Colorado Springs uses 200 gpd/acre for newly developing basins with low I/I potential, but selected 50 gpd/acre for infiltration based on expected low density development. As shown in Table 2-11, the total infiltration rates that were observed during flow metering were either less than the Colorado Springs design value, or were meaningless due to negative calculated values. Therefore, for projected wastewater flows, a reasonable design infiltration rate of 200 gpd/acre is used for this report.

Table 2-11
ADDF and Total Infiltration Flows

Subsystem	Subsystem Developed Area (acres)	Dry Weather / High Groundwater, Lowest 3-hour Flow (mgd)	Dry Weather /Low Groundwater, Lowest 3-hour Flow (mgd)	Observed Subsystem Total Infiltration (mgd)	Observed Subsystem Infiltration Rate (gpd/acre)
2001 Program					
SF-041	207	0.049	0.030	0.016	77
SF-003	726	0.001	0.263	-0.262	NM (1)
JC-002	367	0.488	0.436	-0.052	NM (1)
2002 Program					
SF-005	759	0.174	0.156	-0.018	NM (1)
RS-002	174	0.048	0.033	0.015	86
JC-003	367	0.345	0.363	-0.018	NM (1)

(1) NM = Values are not meaningful.

2.5.1.3 Determination of Inflow

Inflow for a specific storm event includes all rainfall-induced flow, including direct storm water inflow and rapid infiltration. The total peak flow measured during inflow periods includes wastewater production flow, infiltration, and inflow. Inflow for a particular rainfall event is determined by subtracting the wastewater production and infiltration flow from the measured peak flow.

The magnitude of peak inflow in any system depends on rainfall distribution, intensity, antecedent groundwater conditions, types and locations of inflow sources, and time of concentration of the system to the monitoring point. Due to the dry ground conditions and limited rainfall, no measurable inflow was observed for any of the rainfall events that occurred during flow monitoring. Therefore, no FSD specific inflow parameters could be determined. A system-wide inflow coefficient of 0.003 is assumed to be realistic for the FSD service area. This coefficient is selected based on experience with comparable utilities. The selected inflow coefficient represents a system in good condition and without wet weather overflow problems. This fairly characterizes the current FSD system and should, with current design and construction practices, represent the future system as well.

The inflow coefficient is an attempt to combine all system variables into a single parameter. The time of concentration is the time from initiation of peak rainfall to the time of peak inflow. Generally, the time of concentration increases as the total tributary area increases; and the inflow coefficient is greater for older systems. The average inflow coefficient is used to determine inflow for any selected recurrence interval storm event using the following inflow coefficient method relationship:

$$Q = KiA$$

where: Q = peak inflow (cfs)
K = inflow coefficient
i = rainfall intensity for selected recurrence interval and time of concentration (in/hr)
A = developed area (acres)

An estimate of the current system inflow based on the tributary areas, estimated times of concentration, and the assumed inflow coefficient of 0.003 is given in Table 2-12. Each of the monitoring locations used in both programs is listed. Inflow for a storm with any selected recurrence interval can be determined using these inflow parameters. The 1-year inflow rate provides a basis for use in the calibration of the hydraulic model.

Table 2-12
Summary of Inflow Parameters

Flow Monitoring Location	Area (acres)	Time of Concentration (min)	1-Year Rainfall Intensity (in/hr)	5-Year Rainfall Intensity (in/hr)	1-year Inflow (mgd)	5-year inflow (mgd)
SF-041	207	90	057	1.14	0.23	0.46
RS-002	174	65	0.67	1.34	0.23	0.45
SF-005	759	110	0.49	0.89	0.72	1.31
SF-003	726	95	0.56	1.12	0.78	1.58
JC-002 or JC-003	367	85	0.59	1.14	0.42	0.81
Total System	1,300	130	0.42	0.72	1.06	1.81

2.5.2 Summary of Existing Flows

Having determined the basis for each of the wastewater flow components (ADDF, infiltration, and inflow), it was possible to estimate the total flow for existing conditions at each monitoring location for wet weather events. The results of flow determination for each flow monitor are presented in Table 2-13. The 200 gpd/acre design rate for total infiltration is used in the calculation. The peak dry weather flow (PDF) is the monitored ADDF times the peaking factor observed during flow monitoring. The peak wet weather flow (PWWF) is the PDF plus total infiltration plus the storm inflow. The 1-year storm PWWF is 2.76 mgd at the treatment plant. An equivalent calculation using the 5-year storm inflow shows 3.51 mgd PWWF. Comparison of the 5-year PWWF values in Table 2-13 with the pipe capacities listed in Table 2-3 shows that there is adequate capacity to convey the 5-year storm PWWF at all six monitoring locations.

Table 2-13

Existing System Flow Summary

Flow Monitoring Location	ADDF (mgd)	Peaking Factor	PDF (mgd)	Total Infiltration (mgd)	1-year Inflow (mgd)	1-year PWWF (mgd)	5-year Inflow (mgd)	5-year PWWF (mgd)
SF-041	0.156	1.761	0.27	0.04	0.23	0.54	0.46	0.77
RS-002	0.064	1.446	0.09	0.03	0.23	0.35	0.45	0.57
SF-005	0.367	1.377	0.51	0.15	0.72	1.38	1.31	1.97
SF-003	0.534	1.493	0.80	0.16	0.78	1.74	1.58	2.54
JC-002 or JC-003	0.595	1.305	0.78	0.07	0.42	1.27	0.81	1.66
Total System	1.026	1.4	1.44	0.26	1.06	2.76	1.81	3.51

2.6 Historical WWTP Flows

Monthly WWTP flow records from January 1999 to August 2002 were reviewed to corroborate data acquired during temporary flow monitoring. Table 2-14 presents monthly average influent flows for this time period. There is not a significant variation in flows, either from month to month or between the different years.

Table 2-14
Historical WWTP Monthly Average Flows (mgd)

Month	1999	2000	2001	2002
January	0.98	1.03	1.07	1.12
February	1.00	1.03	1.06	1.09
March	0.97	0.96	1.07	1.10
April	1.02	1.02	1.07	1.08
May	0.98	0.98	1.08	1.09
June	1.03	1.00	1.07	1.03
July	1.00	1.02	1.10	1.10
August	1.15	1.09	1.16	1.14
September	1.07	1.08	1.15	1.22
October	1.03	1.07	1.11	1.15
November	1.05	1.11	1.11	1.15
December	1.04	1.07	1.10	1.13
Average	**1.03**	**1.04**	**1.10**	**1.12**
Minimum Month	0.98	.096	1.06	1.03
Maximum Month	1.15	1.11	1.16	1.22

For comparison, the historical WWTP flows were compared to potable water use. The WMP reports that annual average day water use by the City of Fountain was 1.79 mgd, 2.04mgd, and 2.16 mgd for the years 1999, 2000, and 2001, respectively. For year 2000, the FSD wastewater service population is 86.1 percent of the City's water service population. Assuming that ratio, the annual average day water use by wastewater customers is estimated at 1.54 mgd, 1.76 mgd, and 1.86 mgd for years 1999, 2000, and 2001, respectively. The apparent annual average return ratio of potable water to the wastewater collection system is thus 67 percent, 59 percent, and 59 percent for the three years. These ratios are relatively low and reflect irrigation demands. For year 2000, a comparison of water use reported by the WMP with WWTP flows for the winter months of November through March indicates a winter return ratio of 83 percent. Return ratios nationwide are typically in the range of 80 to 90 percent.

2.6.1 Large User Flows

The historical wastewater production from large water users can be important for both the existing system capacity analysis and the projection of future wastewater flows. Potable water use can be an indicator of wastewater generation, but the percentage of potable water discharged to the wastewater collection system will vary greatly. In Fountain, the four largest users accounted for 0.14 mgd of annual average day water use in 1999 and 0.092 mgd in 2000. Since this total represents less than 10 percent of the total system flow, it was concluded that the large user flows are not significant for the FSD system analysis.