

No Two Wet Weather Events are Alike: Wastewater Flow Monitoring in Round Rock, Texas

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Abstract

In 2005, the City of Round Rock with GSWW, Inc. initiated a project to monitor portions of their wastewater collection system to identify levels of inflow and infiltration in the system. As proactive managers of the collection system, the city had recently completed inspections in areas of the system, managed current and future growth through the application of hydraulic modeling and rehabilitation of identified system deficiencies. The City of Round Rock is a member of the Brushy Creek Regional Wastewater System, and conveys its wastewater flows through a regional interceptor system where it is treated at the regional plant. Inflow and infiltration entering the Round Rock system not only affects the Round Rock collection system but also the Brushy Creek Regional Wastewater system and the other members of the regional authority. Therefore, monitoring of system wastewater flows was utilized to gage the effectiveness of their system efforts and to demonstrate responsibility and support in minimizing extraneous flows into the regional system and the environment.

Through flow monitoring analysis of more than 12 months of flow data, the City of Round Rock was able to determine more than simple dry and wet weather flows and resultant inflow & infiltration rates. GSWW, Inc.'s application of tools for evaluating the quality of flow monitoring data revealed characteristics of the collection system not evident from plans/profiles or site investigations. Throughout the flow monitoring period, collected data from each monitored site was analyzed by GSWW engineering staff. Field calibrations were performed at regular intervals for each monitored site to confirm sensed measurements (measurements taken by the flow meter sensor) and to develop points along the flow profile. Both the collected flow meter data and field calibration information were used in flow data analysis. Continuous evaluation of the reliability and accuracy of the collected data is essential to ensuring quality data analysis. Tools used by GSWW in this process include: 1) Time Series data; 2) Flow Hydrographs; 3) Scatter Plots and data variability calculations; and 4) Field Information (Calibration Data, Atmospheric Conditions, Observations, Pictures and Videos.). Using these tools and applying open channel hydraulic engineering principles, flow data quality is determined, system analysis is performed and existing hydraulic conditions are revealed.

Multiple rain events of varying degrees of intensity were experienced by the area during the monitoring period. Two rainfall events were measured in the study area in May 2005 and May 2006 were selected for wet weather analysis. The storm pattern experienced by the study area for each rain event generally resulted in highly variable precipitation levels over the entire study area, as demonstrated by extensive rainfall gage coverage. Wet weather analysis performed for the May 2005 rainfall event revealed that rainfall induced inflow and infiltration was evident in several areas of the system despite the dry conditions preceding this event. An average of 1.9

inches of rainfall was measured by the rainfall gages during the May 2005 event. However, the dry ground conditions preceding this event minimized the infiltration experienced by the area. The absence of saturated ground conditions preceding the event prevented it from being classified as a significant rain event (one or more inches of rainfall in a 24-hour period) for inflow and infiltration analysis purposes. In contrast to the May 2005 analysis period, small rainfall events occurred prior to the May 2006 analysis period. However, because an average of 0.75 inches of rainfall was recorded throughout the area during the May 8 – 9, 2006 event, this event could not be classified as a significant rain event either.

Comparing the two system responses to wet weather analysis and applying the data quality tools, it was revealed that predicting how a system will respond to a rainfall event based upon previous system measurements and analysis is not always accurate. Areas that responded to the May 2005 event demonstrated evidence of inflow through the flow analysis as well as evidence of lingering infiltration. Flow monitoring sites that did not respond to the May 2005 event, did respond to the May 2006 event, with evidence of infiltration (water migration). Taking this data analysis and comparing the geographic locations of each monitored area, the age of the system and the amount of rehabilitation/repair performed in each area, a system response to wet weather becomes increasingly more predictable than with just flow data alone. Flow monitoring, like other system evaluation techniques, is one of the, but not the only, tool that should be applied in collection system evaluation.

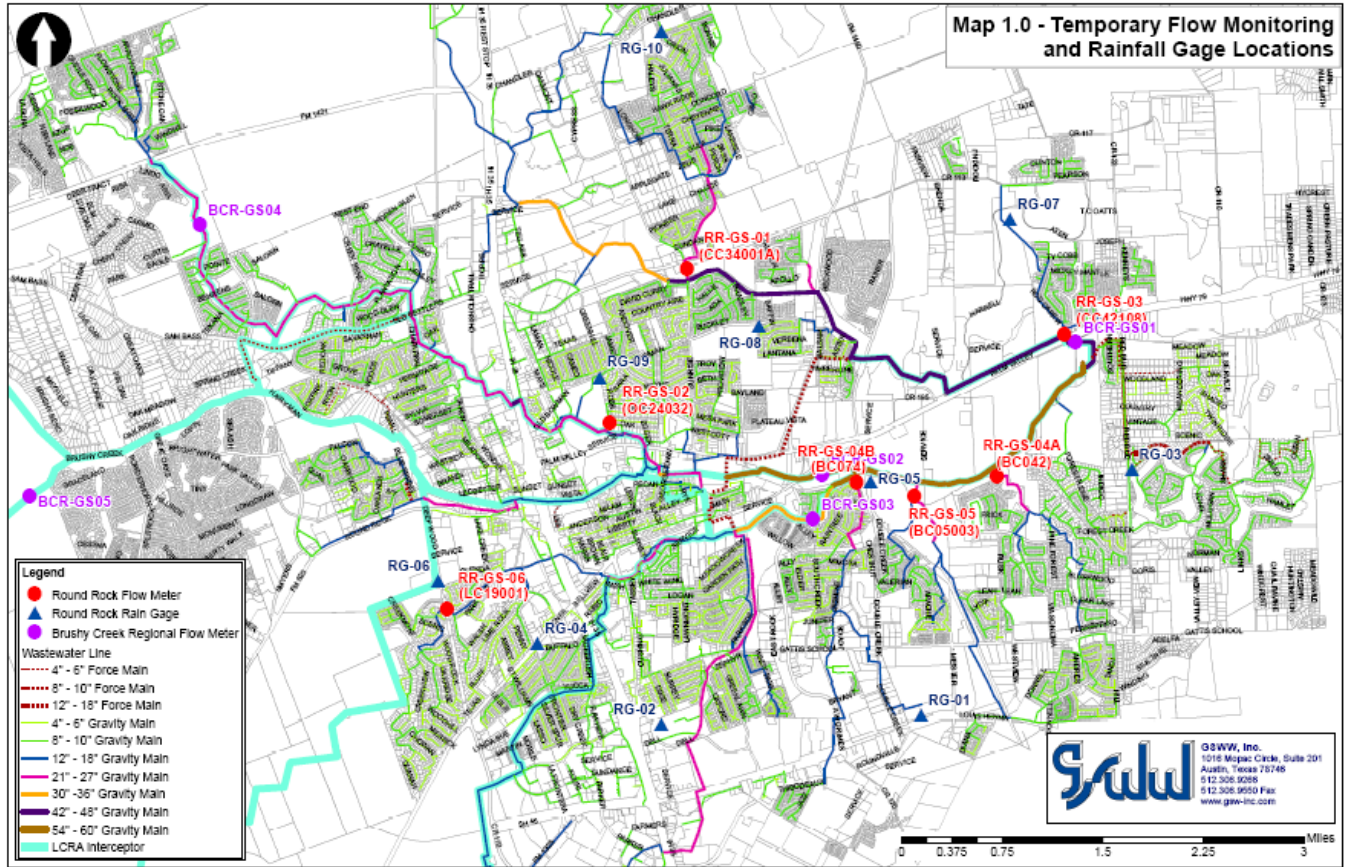
Keywords

Wastewater Collection Systems, Inflow and Infiltration, Flow Monitoring, Rain Induced Inflow and Infiltration

Background

The City of Round Rock selected GSWW, Inc. to perform a Flow Monitoring Study of selected sites within the City of Round Rock's collection system. The project required the investigation of proposed flow monitoring sites, equipment selection, procurement and installation, monitoring of flows and training of City Staff. GSWW was responsible for installation, maintenance of wastewater monitoring equipment and to provide an engineering evaluation of the collected flow data for six (6) monitoring points throughout the wastewater collection.

The monitoring sites were determined through a joint planning effort of GSWW engineering staff and City Staff, the requirements of the City's ongoing hydraulic modeling efforts, and on a map study of the existing wastewater collection system. A total of six gravity-monitoring sites and ten rain gage locations were monitored during the study as depicted in Map 1.0 on the following page. The flow monitoring was performed during two time periods to take advantage of weather patterns; February 14, 2005 through January 15, 2006 and May 1st through May 28, 2006.



Map 1.0 Temporary Flow Monitoring and Rainfall Gage Locations.

Monitoring Sites and Equipment

Site investigations were conducted prior to installation of equipment to determine suitability for monitoring. A total of six (6) gravity-monitoring sites were identified for initial field investigation. Each gravity site was evaluated using the following criteria:

1. Manhole depth and pipe size
2. Condition of manhole and pipe invert
3. Access for equipment installation and servicing
4. Existing hydraulic conditions such as turbulence and backwater effects
5. Evidence of debris and surcharge potential
6. Depth of flow and velocity
7. Type of flow (residential or commercial)
8. Hazardous atmospheric conditions
9. Access to the site and traffic considerations
10. System continuity and monitoring feasibility

A total of six (6) gravity-monitoring sites and ten (10) rain gage locations were selected as monitoring sites. These sites were operated and maintained throughout the 12 month flow-monitoring period. The flow monitoring locations operated and maintained during this project are presented in Table 1.0.

Table 1.0 - Flow Monitoring Equipment Locations			
Gaging Station	Manhole Number	Address/Location	Pipe Dimensions (in.)
RR-01	CC34001A	2400 Sunrise Rd.	27.00
RR-02	CC24032	500 W. Oak Dr.	8.00
RR-03	CC42108	Hwy 79, W. of Ryan's Crossing	17.25
RR-4A	BC04001A	Hwy 79, N. of Brushy Creek	20.50
RR-4B	BC-074	2717 Vinwood	24.00
RR-05	BC05003	Round Rock Ranch, Brushy Creek	20.50
RR-06	LC19001	500 Deepwood Drive	12.00

Temporary flow monitoring and rain gage equipment was installed and operational on or before February 14, 2005 for the first monitoring period and May 1, 2006 for the second monitoring period. Each temporary meter was calibrated prior to installation and all flow monitoring equipment was calibrated at regular intervals during the monitoring period. The calibration process consists of the comparison of physical wastewater flow measurements and sensed measurements. The physical measurements are obtained with a portable velocity meter to determine velocity and a ruler to obtain level readings. If the sensed and physical measurements do not agree, the flow meter is serviced and reevaluated or replaced. For example, should the flow monitor indicate a lower velocity than the velocity measured by the portable velocity meter, this condition would prompt an evaluation and resolution of the condition responsible for the difference in the readings. A typical cause of this condition is debris accumulation on the meter probe. In this case, the probe would be cleaned using a brush and the physical and sensed monitor readings would be reevaluated for consistency.

Multiple calibration points were obtained at each metering site during the monitoring period to cover the widest range of flow conditions. Calibrations are performed at various times throughout the day to gather data for the site flow profile. This practice allows for calibration of the meter under various flow conditions. The raw flow data is also collected during calibration. The data is downloaded into a laptop computer and visually checked for anomalies, before leaving the site. The raw data is then transferred to the engineering office for analysis by the project engineer.

Rainfall data is used in wet weather analysis in determining rain induced infiltration and inflow (RDII). Tipping bucket rain gages (where one "tip" equals 0.01 inch of precipitation) were maintained at a total of ten sites for the flow monitoring study. Data was collected from each rain gage site during the flow meter site visits.

Flow Meter Equipment

Selecting the appropriate technology for the flow monitoring application is essential to achieving accurate and reliable data. GSWW was able to utilize one type of flow monitoring technology for the project: Continuous Wave Doppler (ISCO Model 2150). The ISCO 2150 Area Velocity module utilizes a submerged area-velocity sensor (Doppler velocity and pressure-transducer

depth). The published specifications for the ISCO 2150 list a level measurement range of 0.4 inches to 10 feet, level accuracy of +/- 0.012 ft/ft, a velocity range of -5 to 20 feet/second and a velocity accuracy of +/- 2% of reading. Data is retrieved onsite from the unit through an RS232 communication port. The meter is powered by a 12 volt DC battery. The City of Round Rock purchased the flow monitoring equipment installed at the conclusion of the project.

Rainfall Data

Multiple rain events of varying degrees of intensity were experienced by the area during the monitoring period of February 14, 2005 through January 15, 2006 and May 1, 2006 through May 28, 2006. Figure 1.0 displays the rainfall events experienced during the monitoring period.

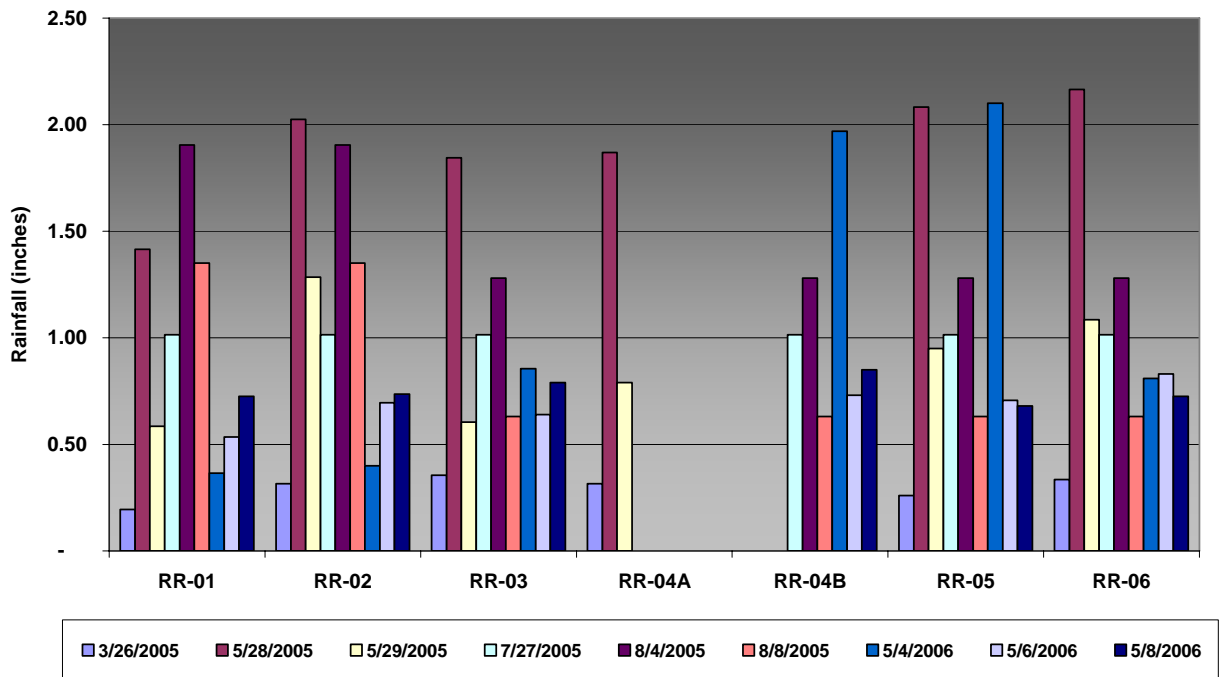


Figure 1.0¹ – Rainfall Events by Flow Monitored Basin, Average Rainfall Gage Data

¹RR-04A was moved to RR-04B on July 12, 2005.

A *significant rain event* can be described as one or more inches of rainfall in a 24-hour period. For an appropriate wet weather analysis of the flow data, it is desirable that a significant rain event occurs following several smaller rain events. This situation will generally cause the ground to become saturated in the study area. Ground saturation, prior to a significant rainfall event, will allow infiltration into the collection system to occur, rather than have the rainfall absorbed by the dry soil. Rainfall events on dry ground typically result in runoff and inflow, as there is typically not enough time for the ground to absorb the water and allow rainwater to infiltrate into the wastewater system. The observed system responses replicate the precipitation pattern with quick rises in level and a return to a typical diurnal pattern for this type of event. This type of response to precipitation is identified as inflow in analysis.

The storm pattern experienced by the study area generally resulted in highly variable precipitation levels over the entire study area. This condition caused a variable resultant system response. Flow analysis periods were preferentially chosen based on 1) availability of good “accurate” data; 2) non-surge wet weather site conditions; and 3) continuity with other sites wet and dry weather periods to ensure applicable flow comparisons. Based on this criterion, both the May 28 – 29, 2005 and May 8 – 9, 2006 events were used in the wet weather analysis performed for with Gaging Station 4A included in the May 28 - 29, 2005 analysis and Gaging Station 4B included in the May 8 - 9, 2006 analysis.

Table 2.0 describes the rain events observed in the study area during the monitoring period of February 11, 2005 through January 15, 2006 and May 1, 2006 through May 28, 2006 in tabular format based on the average rainfall gage for each flow monitoring basin.

Table 2.0 ¹ Rainfall Gage Analysis												
Date	3/26/2005	5/28/2005	5/29/2005	7/27/2005	8/4/2005	8/8/2005	5/4/2006	5/6/2006	5/8/2006	GAGE		
GAGING STATION	Rain Gage	Rain Gage	Rain Gage	Rain Gage	Rain Gage	Rain Gage	Rain Gage	Rain Gage	Rain Gage	MAX	AVERAGE	Total
RR-01	0.20	1.42	0.59	1.02	1.91	1.35	0.37	0.54	0.73	1.91	1.03	6.59
RR-02	0.32	2.03	1.29	1.02	1.91	1.35	0.40	0.70	0.74	2.03	1.07	7.39
RR-03	0.36	1.85	0.61	1.02	1.28	0.63	0.86	0.64	0.79	1.85	0.88	6.27
RR-04A	0.32	1.87	0.79	N/A	N/A	N/A	N/A	N/A	N/A	1.87	0.99	2.98
RR-04B	N/A	N/A	N/A	1.02	1.28	0.63	1.97	0.73	0.85	1.97	1.13	5.63
RR-05	0.26	2.08	0.95	1.02	1.28	0.63	2.10	0.71	0.68	2.10	1.15	7.82
RR-06	0.34	2.17	1.09	1.02	1.28	0.63	0.81	0.83	0.73	2.17	0.91	6.73
AVERAGE	0.30	1.90	0.88	1.02	1.49	0.87	1.08	0.69	0.75	1.98	1.02	6.20
MAX	0.36	2.17	1.29	1.02	1.91	1.35	2.10	0.83	0.85	2.17	1.15	7.82

¹RR-04A was moved to RR-04B on July 12, 2005.

Flow Monitoring Data

Dry and wet weather periods were selected from the collected data to perform wet and dry weather analysis for each monitoring location. Tables 3.0 through 6.0, present dry and wet weather flow parameters and inflow/infiltration measured at each flow monitoring site for both selected analysis periods.

Table 3.0 Measured Wastewater Flows – May 28 – 29, 2005 Event

Gaging Station No.	Dry Weather¹ Average Daily Flow (mgd)	Dry Weather¹ Peak Flow Rate (mgd)	Wet Weather¹ Daily Maximum Flow (mgd)	Wet Weather¹ Peak Flow Rate (mgd)	Peak¹ Flow Ratio
RR-01	0.70	0.87	1.23	1.51	2.17
RR-02	0.06	0.07	0.07	0.12	2.13
RR-03	0.17	0.23	0.20	0.31	1.82
RR-04A ²	0.32	0.44	0.42	0.63	1.96
RR-05	1.02	1.28	1.44	1.88	1.85
RR-06	0.21	0.30	0.21	0.34	1.66
Average	0.41	0.53	0.60	0.80	1.93
Maximum	1.02	1.28	1.44	1.88	2.17

¹ Dry and wet weather flows are representative of the selected analysis time periods.

² RR-04A was moved to RR-04B on July 12, 2005.

Table 4.0 Inflow and Infiltration – May 28 – 29, 2005 Event

Gaging Station No.	Peak I/I¹ (mgd)	Length of Sewer Main (linear feet)	Sewered Area (acre)	I/I (GPD) per acre	I/I (GPD) per LF of sewer main
RR-01	0.81	98,056	1,030	790	8.29
RR-02	0.06	13,444	94	678	4.74
RR-03	0.14	46,704	811	174	3.02
RR-04A ²	0.31	62,028	571	541	4.99
RR-05	0.86	89,938	786	1,099	9.61
RR-06	0.14	49,649	417	329	2.76
Average	0.39	59,970	618	602	5.57
Maximum	0.86	98,056	1,030	1,099	9.61

¹ Peak I/I is representative of the selected wet and dry weather analysis time periods.

² RR-04A was moved to RR-04B on July 12, 2005.

Table 5.0 Measured Wastewater Flows – May 8 – 9, 2006 Event

Gaging Station No.	Dry Weather¹ Average Daily Flow (mgd)	Dry Weather¹ Peak Flow Rate (mgd)	Wet Weather¹ Daily Maximum Flow (mgd)	Wet Weather¹ Peak Flow Rate (mgd)	Peak¹ Flow Ratio
RR-01	0.28	0.33	0.37	0.71	2.49
RR-02	0.04	0.06	0.05	0.07	1.99
RR-03	0.15	0.23	0.18	0.30	2.04
RR-04B ²	0.22	0.24	0.26	0.33	1.55
RR-05	0.56	0.79	0.63	0.71	1.27
RR-06	0.19	0.32	0.20	0.35	1.82
Average	0.24	0.33	0.28	0.41	1.86
Maximum	0.56	0.79	0.63	0.71	2.49

¹ Dry and wet weather flows are representative of the selected analysis time periods.

² RR-04A was moved to RR-04B on July 12, 2005.

Table 6.0 Inflow and Infiltration – May 8 – 9, 2006 Event

Gaging Station No.	Peak I/I¹ (mgd)	Length of Sewer Main (linear feet)	Sewered Area (acre)	I/I (GPD) per acre	I/I (GPD) per LF of sewer main
RR-01	0.43	98,056	1,030	413	4.33
RR-02	0.04	13,444	94	391	2.73
RR-03	0.15	46,704	811	191	3.31
RR-04B ²	0.12	68,312	865	137	1.73
RR-05	0.15	89,938	786	194	1.69
RR-06	0.16	49,649	417	374	3.14
Average	0.17	61,017	667	283	2.83
Maximum	0.43	98,056	1,030	413	4.33

¹ Peak I/I is representative of the selected analysis wet and dry weather time periods.

² RR-04A was moved to RR-04B on July 12, 2005.

Figure 2.0 Wet Weather Flow Hydrograph Comparison for 2005 and 2006 Events demonstrates the differences in system response to each event.

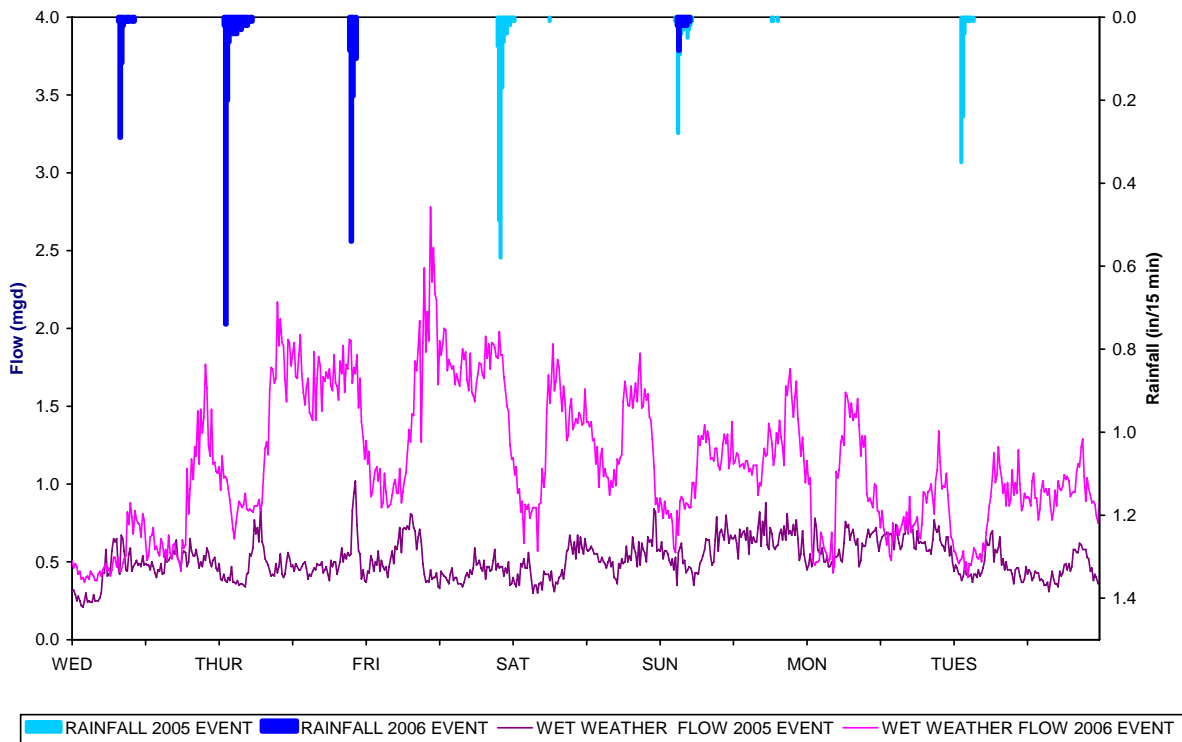


Figure 2.0 Wet Weather Flow Hydrograph Comparisons for 2005 and 2006 Events

While the rainfall for the 2006 event accumulates over several days, the system flow incrementally rises during the rainfall event and more than 24 hours after. This system response supports evidence of inflow and lingering infiltration in the system; the result of antecedent ground conditions followed by additional rainfall. The trail down (return to pre-weather diurnal) for the 2006 event occurs several days after the conclusion of the measured precipitation.

In contrast, the majority of the rainfall for the 2005 event occurs very rapidly over a 4 hour period. The system responds with a spike in the diurnal (daily) trend, followed by a gradual increase in system flow that returns to the typical diurnal trend quickly. This system response demonstrates evidence of system inflow with some lingering infiltration caused by short rainfall duration, resulting initially in run-off and gradually infiltrating into the ground and system appurtenances.

Flow Monitoring Data Analysis

Throughout the flow monitoring period, collected data from each gaging station was processed and analyzed by GSWW engineering staff. Field calibrations are performed at regular intervals for each monitored site to confirm sensed measurements (measurements taken by the flow meter sensor) and to develop points along the flow profile. Collected data and field calibration information are used together in flow data analysis.

Continuous evaluation of the reliability and accuracy of the collected data is essential to ensuring quality data analysis. Four tools are used in this process: 1) Time Series Depth and Velocity Graphs; 2) Flow Hydrographs; 3) Scatter Plots of Velocity vs. Level; and 4) Field Information (Calibration Data, Pictures, etc.). Using these tools and applying open channel hydraulic engineering principles, flow data quality is determined and system analysis is performed.

A demonstration of the flow data analysis for Gaging Station RR-06 is as follows:

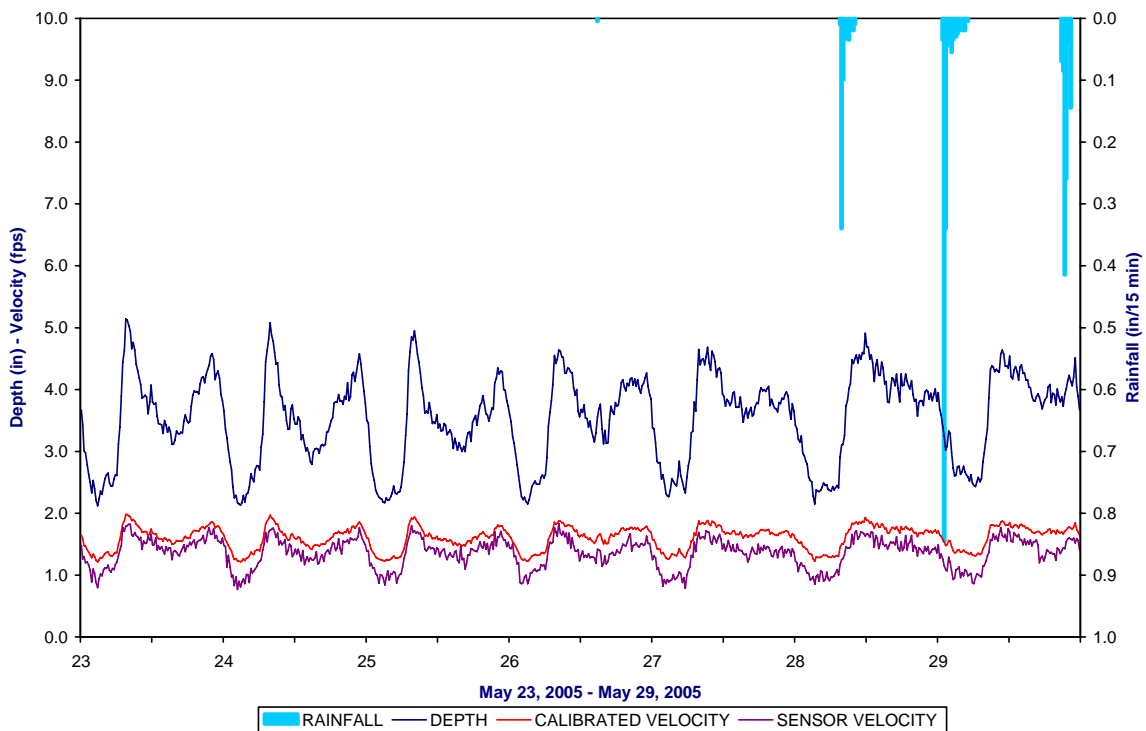


Figure 3.0 Time Series Depth and Velocity Data Graph

By plotting the depth and velocity points, the diurnal trend (daily flow pattern) can be evaluated. We are evaluating the data for a regular and repeatable diurnal pattern and for an elevated system response during and immediately after rainfall events. The portion of the collection system monitored by this gaging station responded to wet weather as demonstrated by the elevated valleys in the time series graph. With this site, calibrated data and sensor data graphs are tracking, indicating a close correlation between measured data and velocity calibration points.

Figure 4.0 displays the hydrograph (Flow vs. Time) and rainfall during the period of May 23, 2005 through May 29, 2006 for this site.

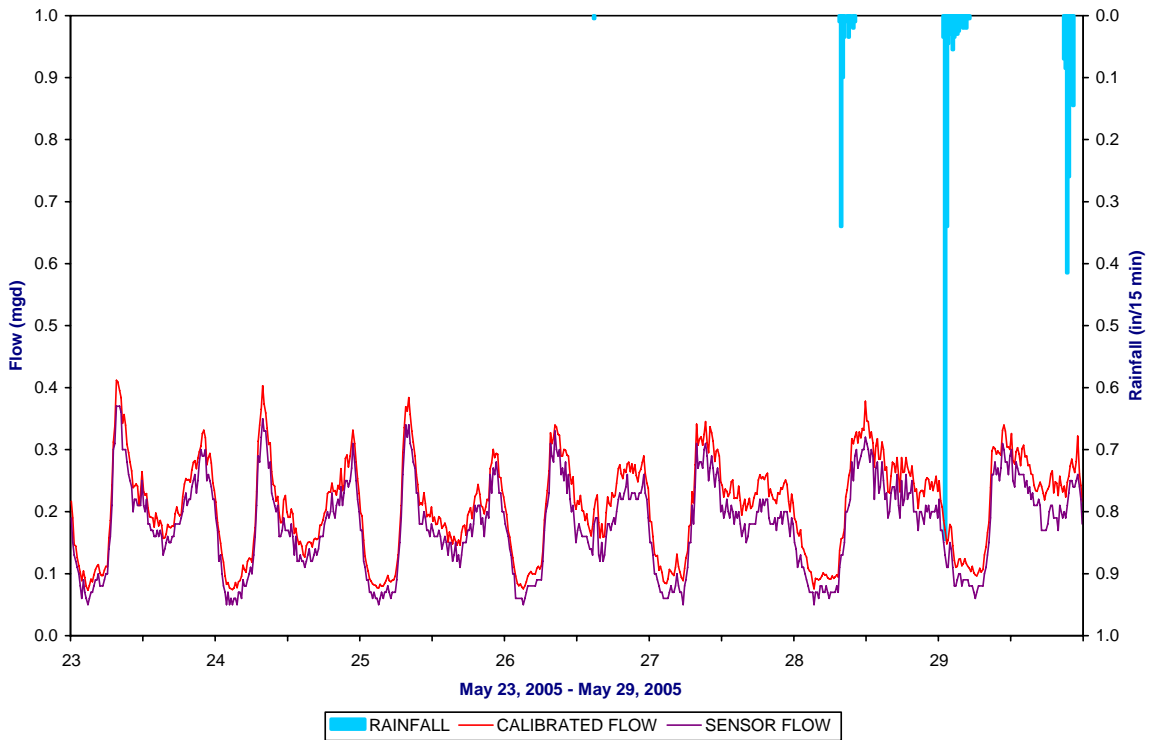


Figure 4.0 Flow Hydrograph

Sensor flow is calculated using the Continuity Equation:

Continuity Equation: $Q = V \times A$ Equation 1.0

Where:

Q= Flow V= Velocity A= Flow Area

Flow data is graphed to evaluate the diurnal trend and wet weather response. Problems with the flow meter equipment, such as equipment malfunction or debris on the velocity sensors can be seen at this stage in the analysis. This graph shows the immediate response the site experiences during a rainfall event.

Figure 5.0 on the next page is a scatter plot, which is a graphical representation of velocity vs. level, of all data collected during the 12-month monitoring period for this site.

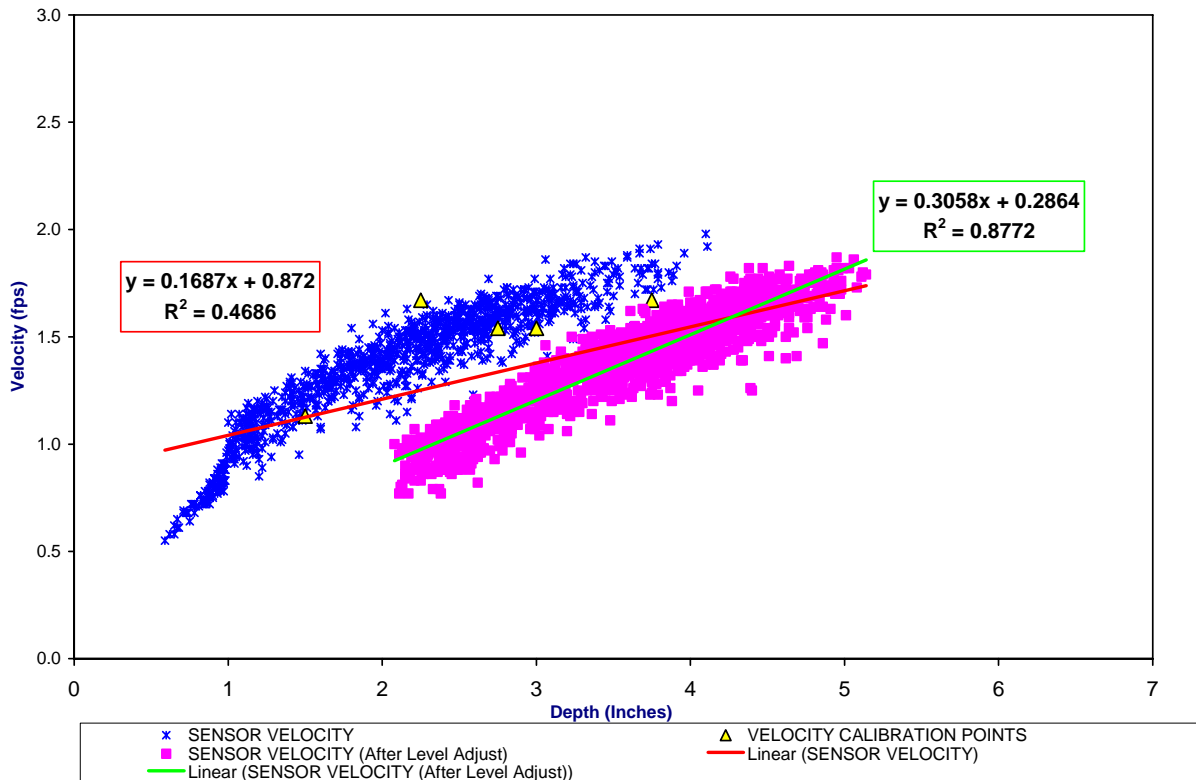


Figure 5.0 Scatter Plot

Velocity vs. depth is plotted continuously throughout the monitoring period. Shape and correlation of depth and velocity is the concept applied in scatter plot analysis. Plotting the actual field calibration points against the scatter plot and performing regression analysis (“best-fit” line) for the data demonstrates how the site is performing.

The collected data for Gaging Station RR-6 is plotted to display correlation of data before and after a sensor adjustment was performed during a field site visit. The plot of data after the sensor adjustment demonstrates free-flow hydraulics with a shape that follows Manning’s curve. The linear regression shows symmetry in the points. The derived equation for the plot after sensor adjustment shows that y (Velocity) relates to x (Depth) by a factor of $0.3058x + 0.2864$. The calculated R^2 value demonstrates the variation between y (Velocity) and x (Depth) data and the best-fit line. For Gaging Station RR-06, the R^2 value of 0.88, 88% of the variability in velocity can be explained by the variability in depth.

Hydraulic Coefficient Curves, Figure 6.0 on the next page, are another tool used to evaluate calibration data collected in the field.

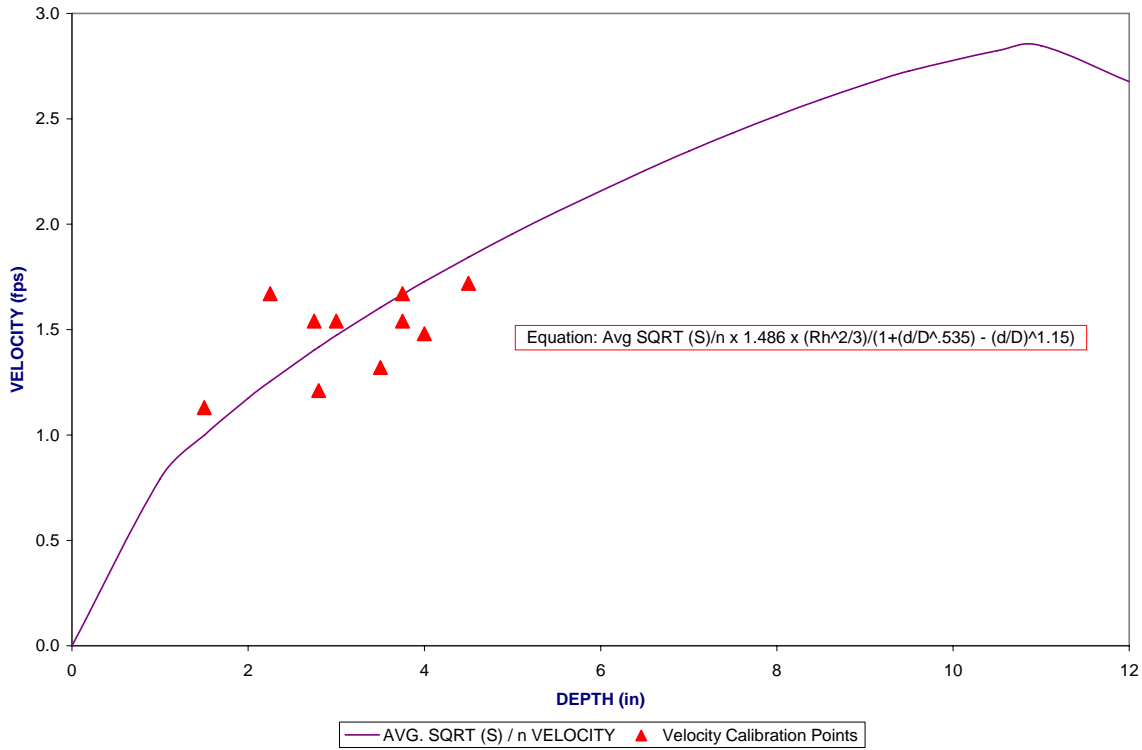


Figure 6.0 Hydraulic Coefficient Curve

The calibration data (measured level and velocity) that is collected during site visits is used to calculate a calibrated velocity and calibrated flow for the monitored sites. Velocity calibration data is collected throughout the monitoring period to verify the sensed (meter) velocity measurements and to provide a visual representation of the flow profile for the monitored site. Using the measured velocity values at different depths of flow, an average velocity (Avg. SQRT (S)/n) can be calculated. Applying Manning’s equation and the calculated average velocity, a calibrated velocity can be derived for any depth of flow.

Manning’s Equation: $Q = 1.49/n A R_h^{2/3} S^{1/2}$ **Equation 2.0**

Where:

Q = Flow n = Manning’s Roughness A= Flow Area R_h = Hydraulic Radius S= Pipe Slope

Applying the derived Avg SQRT (S)/n value, the equation becomes:

Velocity = Avg SQRT (S)/n x 1.486 x $(R_h^{2/3}) / (1 + (d/D)^{.535} - (d/D)^{1.15})$ **Equation 3.0**

Where:

R_h = Flow Area/ Wetted Perimeter d= Depth of Flow D= Pipe Diameter

Equation 3.0 is used to develop the hydraulic coefficient curve presented in Figure 6.0. The relationship between the velocity calibration points and the calculated curve further demonstrates

the hydraulic flow regime of the site with points on either side of the curve. It is realistic to expect measured velocity points (calibration points) to be higher or lower than the calculated values. This is the result of open channel hydraulics in a closed conduit. While the flow is acted upon by gravity, the force of friction as the flow moves through the pipe and the various appurtenances (manholes, junctions, bends, etc.) affect the hydraulics, changing from laminar (smooth) to sometimes transitional and turbulent flow regimes. The force of friction is compounded by the viscosity and solid content of sewage. Therefore, a field calibration is necessary to demonstrate the flow profile throughout the depth of flow.

Data analysis is typically performed using sensor flow data, and applying calibrated flow data as an accuracy check. The relationship between sensor and calibrated data is evaluated in selecting dry and wet weather periods to ensure that the measured system response is accurate.

Another tool is used to determine the precision of field calibrations taken. While a precision instrument is used to collect calibration data, the field crews who collect field measurements may introduce human error. This is typical for any system of measurement devices. Figure 7.0 is a graphical representation of the relationship between the calibrations performed at different times of day throughout the monitoring period. The size of the point represents the level measurement.

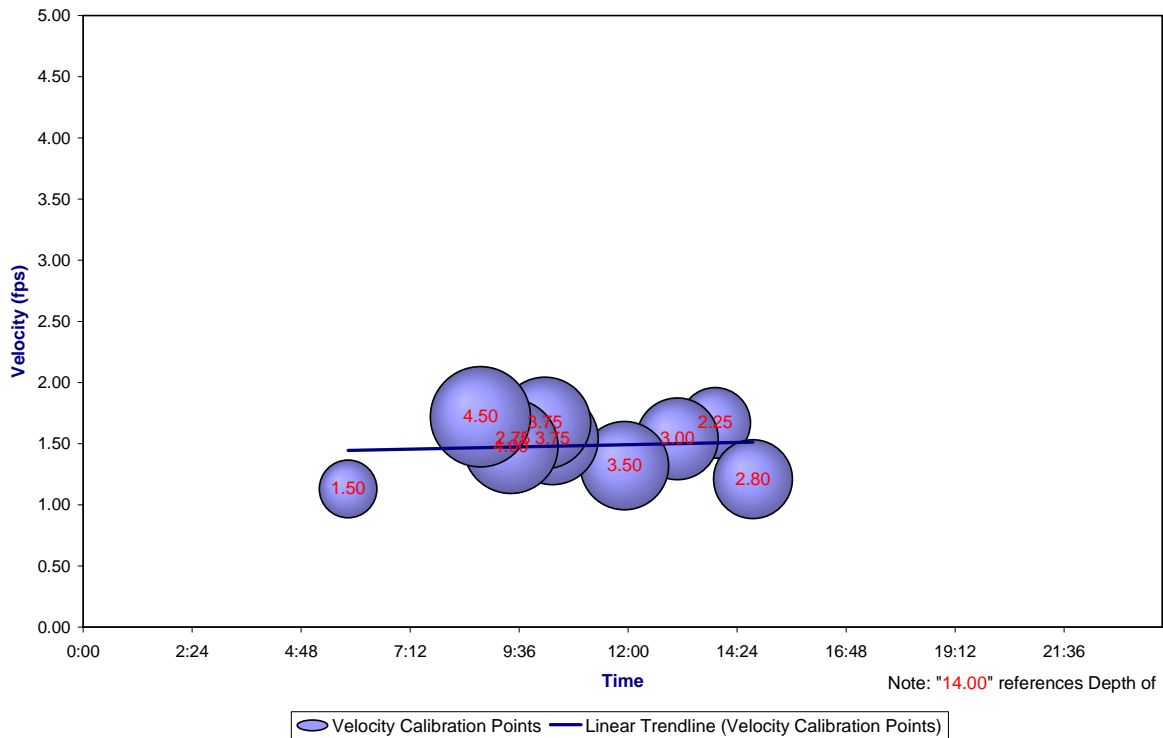


Figure 7.0 Calibration Data vs. Time

This graph demonstrates how each calibration performed correlates with other calibration data collected during a similar time and depth of flow. The multiple calibrations performed during the same time period graphically represent repeatability of the field measurements taken. The

calibration point of 1.50 inches was taken during early morning calibrations to represent night flow conditions.

Flow Monitoring and Rainfall Data Analysis Conclusions

May 28 – 29, 2005 Event

Wet weather analysis performed for the May 28-29, 2005 rainfall event concludes that rain induced inflow and infiltration is evident in several areas of the system despite the dry conditions preceding this event. While an average of 1.9 inches of rainfall was measured by the rainfall gages on May 28, 2006, the dry ground conditions preceding this event minimized the infiltration experienced by the area. The absence of saturated ground conditions preceding this event prevent it from being classified as a significant rain event for inflow and infiltration analysis purposes.

Gaging Station RR-01 experienced the highest peaking factor of 2.17 for this event. RR-01 linear footage represents 27% of the study area footage. The peaking factor for RR-01 is the result of inflow and lingering infiltration.

Figure 8.0 graphically demonstrates the percent footage contributed to each Gaging Station.

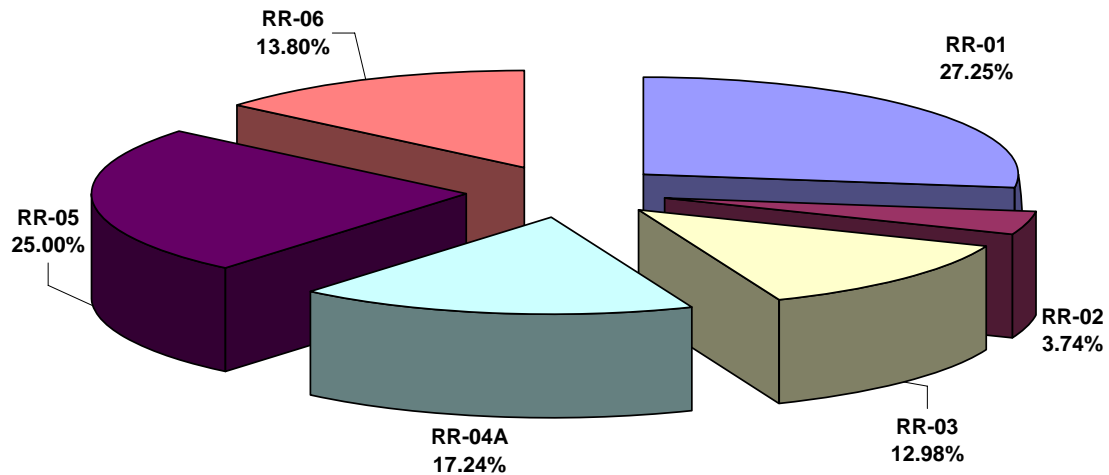


Figure 8.0- Percent Metered Basin Footage, including Gaging Station RR-04A

Gaging Station RR-06 experienced the lowest peaking factor, 1.66 for this event. The rainfall amounts recorded by the rainfall gages varied widely throughout the study area. Wastewater main footage is a factor in inflow and infiltration contribution. Figure 9.0 presents the average I/I (GPM) per linear feet of sewer main, in descending order for each Gaging Station.

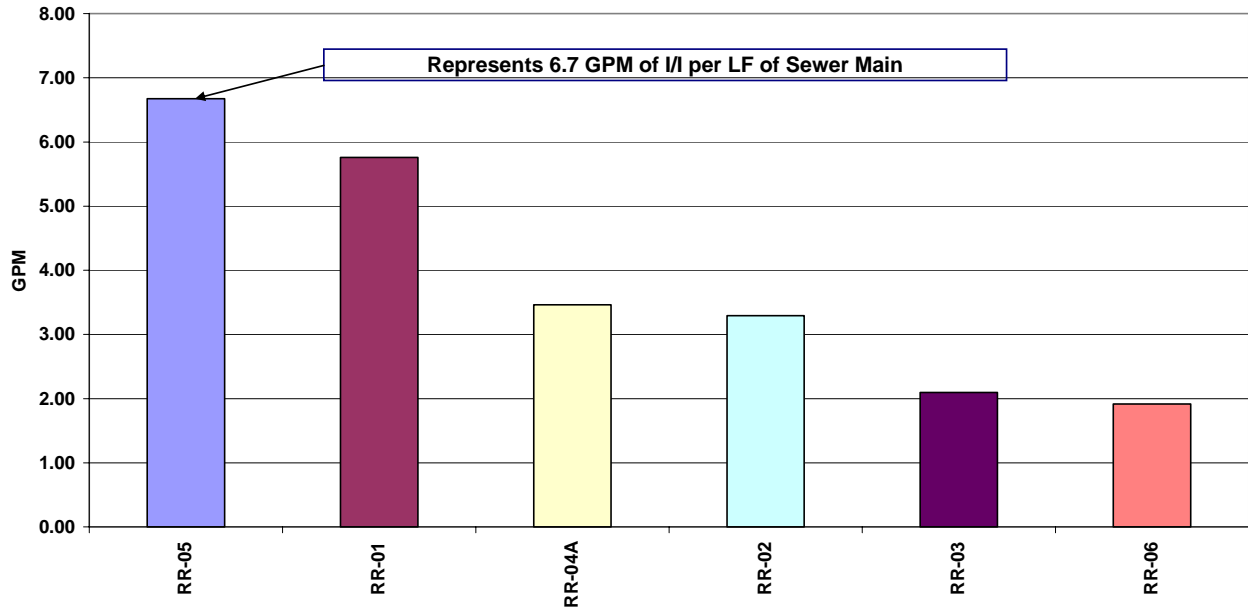


Figure 9.0 – Gaging Station Ranking according to I/I per LF of Sewer Main, May 28 - 29, 2005 Event

For the May 28 – 29, 2005 event, Gaging Station RR-05 ranks the highest, with 6.7 GPM of I/I per linear feet of sewer main, accounting for 25% of the study area footage.

May 8 – 9, 2006 Event

Wet weather analysis performed for the May 8-9, 2006 rainfall event concludes that rain induced inflow and infiltration is evident in a few areas of the system. Unlike the May 28 – 29, 2005, small rainfall events occurred prior to the May 8 -9, 2006 event. However, because only an average of 0.75 inches of rainfall was recorded throughout the area during the May 8 – 9, 2006 event, this event cannot be classified as a significant rain event either.

Gaging Station RR-01 again experienced the highest peaking factor of 2.40 for this event. RR-01 linear footage represents 27% of the study area footage. The peaking factor for RR-01 for this event is the result of inflow and lingering infiltration. Figure 10.0 graphically demonstrates the percent footage contributed to each Gaging Station, discretely.

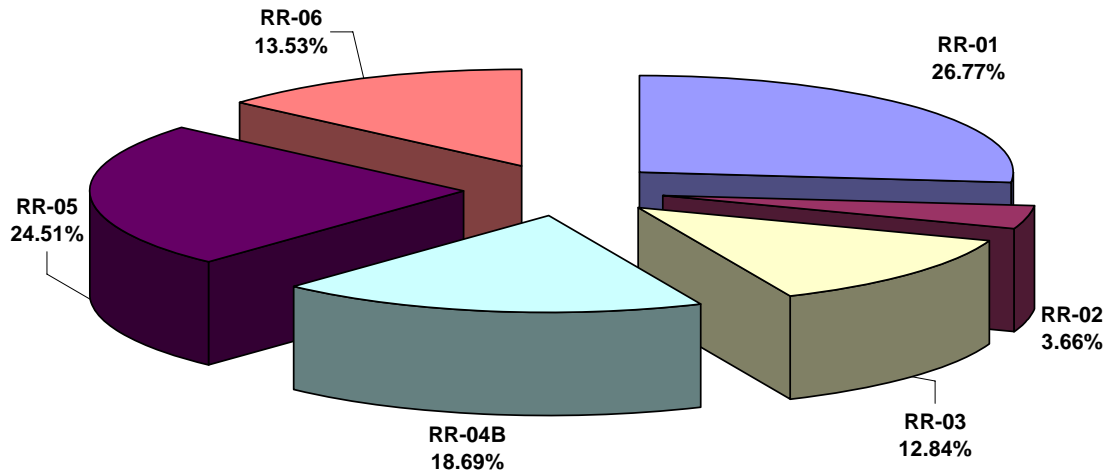


Figure 10.0- Percent Metered Basin Footage, including Gaging Station RR-04B

The lowest peaking factor of 1.27 was measured at RR-05 during the May 8 – 9, 2006 rain event. As discussed earlier, the May 28 – 29, 2005 and May 8-9, 2006 both events were selected for wet weather analysis.

Wastewater main footage is a factor in inflow and infiltration contribution. Figure 11.0 presents the average I/I (GPM) per linear feet of sewer main, in descending order for each Gaging Station for the May 8-9, 2006 event.

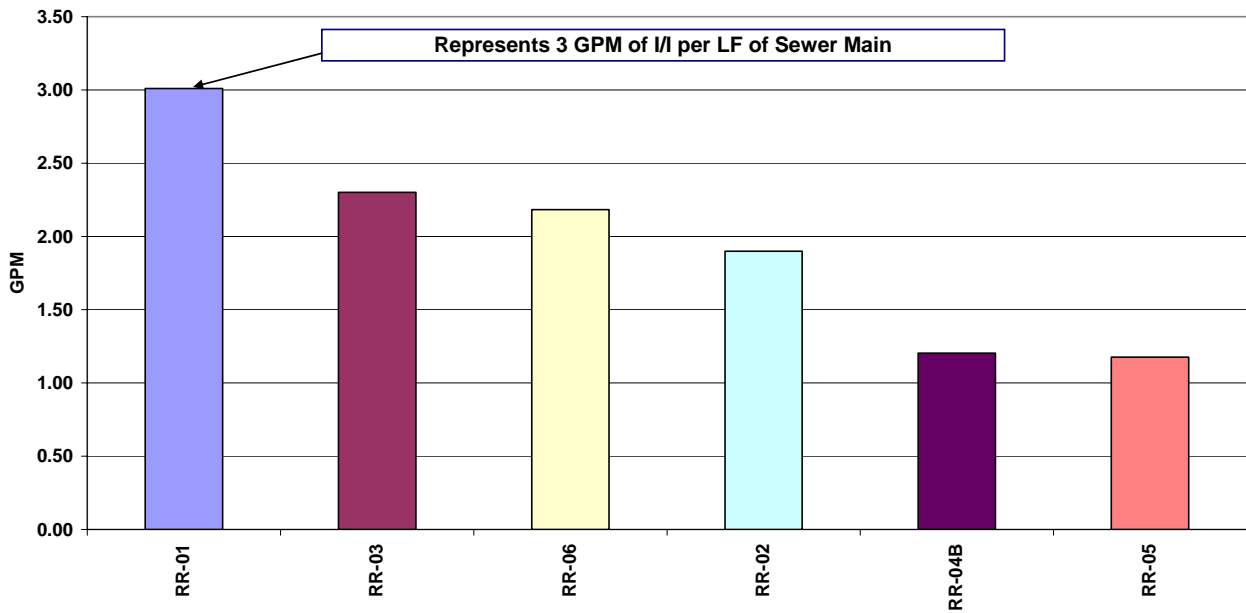


Figure 11.0 – Gaging Station Ranking according to I/I per LF of Sewer Main, May 8-9, 2006 Event

Gaging Station RR-01 ranks the highest, with 3 GPM of I/I per 1000 LF of sewer main, accounting for the largest percentage of the study area footage (27%). It is recommended that the collection system be monitored during additional rainfall events to perform future inflow and infiltration analysis of the collection system during a significant rain event. Figures 12.0 and 13.0 provide a graphical representation of the I/I percent of the total sewer area I&I, per gaging station, for the monitoring period.

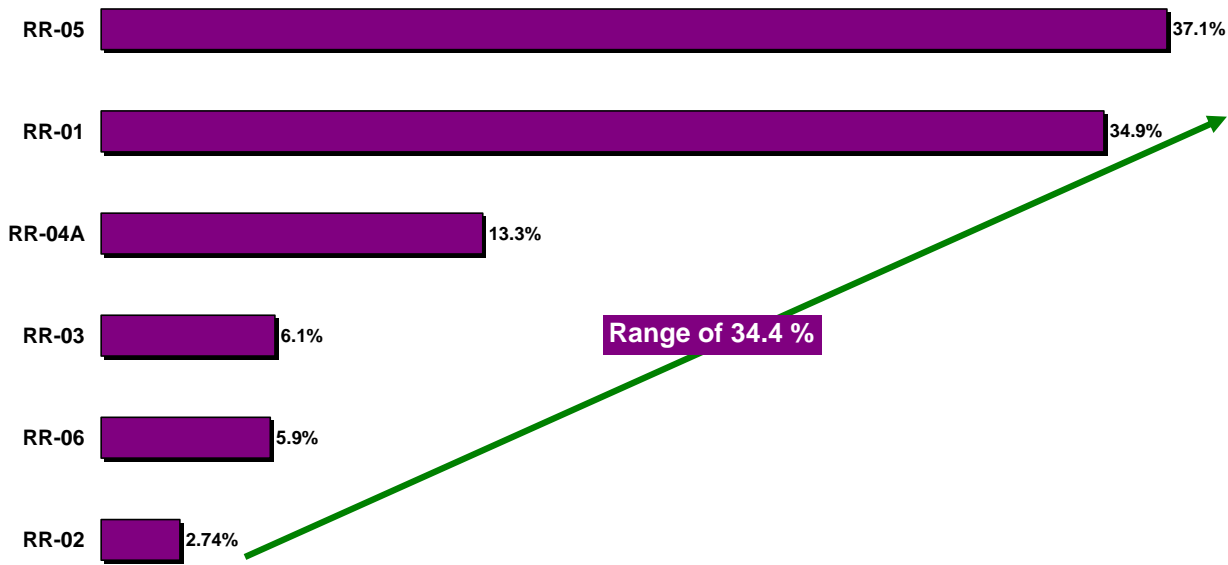


Figure 12.0 I/I Percent Contribution per Gaging Station – May 28 – 29, 2005 Event

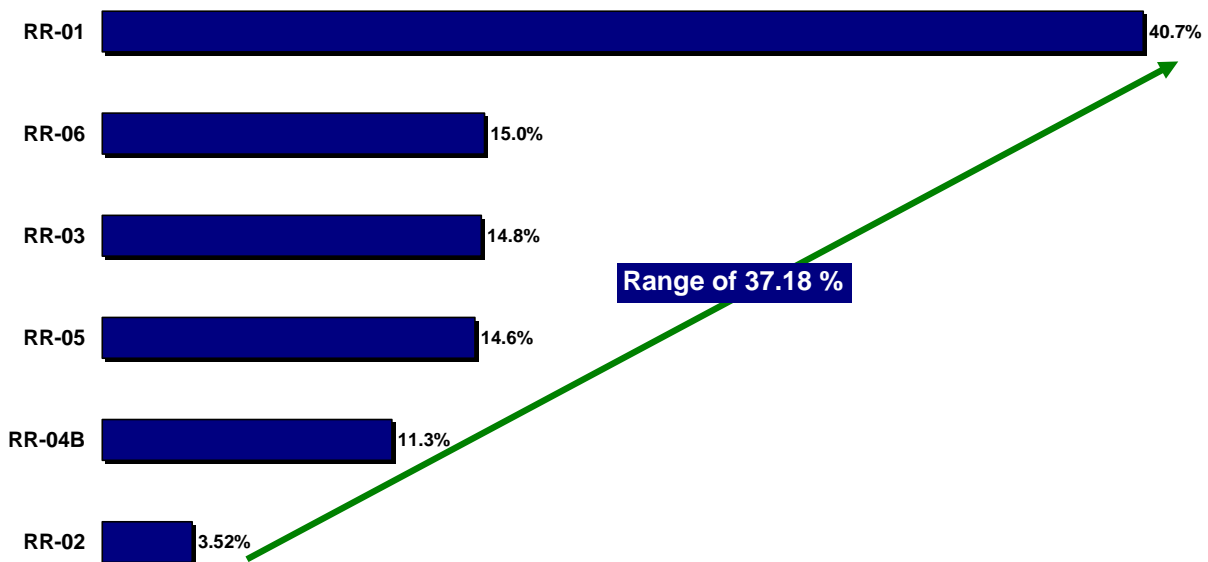


Figure 13.0 I/I Percent Contribution per Gaging Station – May 8 – 9, 2006 Event

Figures 12.0 and 13.0 demonstrate Gaging Stations RR-01 response to both an inflow (May 28 – 29, 2005) and an inflow/infiltration (May 8 – 9, 2006) event. Inflow and Infiltration sources may exist in the basin contributing to Gaging Station RR-01. Gaging Station RR-05 responds to the May 28 -29, 2005 event, which supports the analysis theory that inflow sources may be present in the basin.

Figure 14.0 Measured Peak Flow Ratio – May 28 - 29, 2005 Wet Weather Event and Figure 15.0 Measured Peak Flow Ratio – May 8 – 9, 2006 Wet Weather Event displays the peaking factors for each monitored basin overlaid on the Round Rock sewershed map. This spatial representation of wet weather analysis serves as visual means for portraying the system flows as a sewer area for both selected periods.

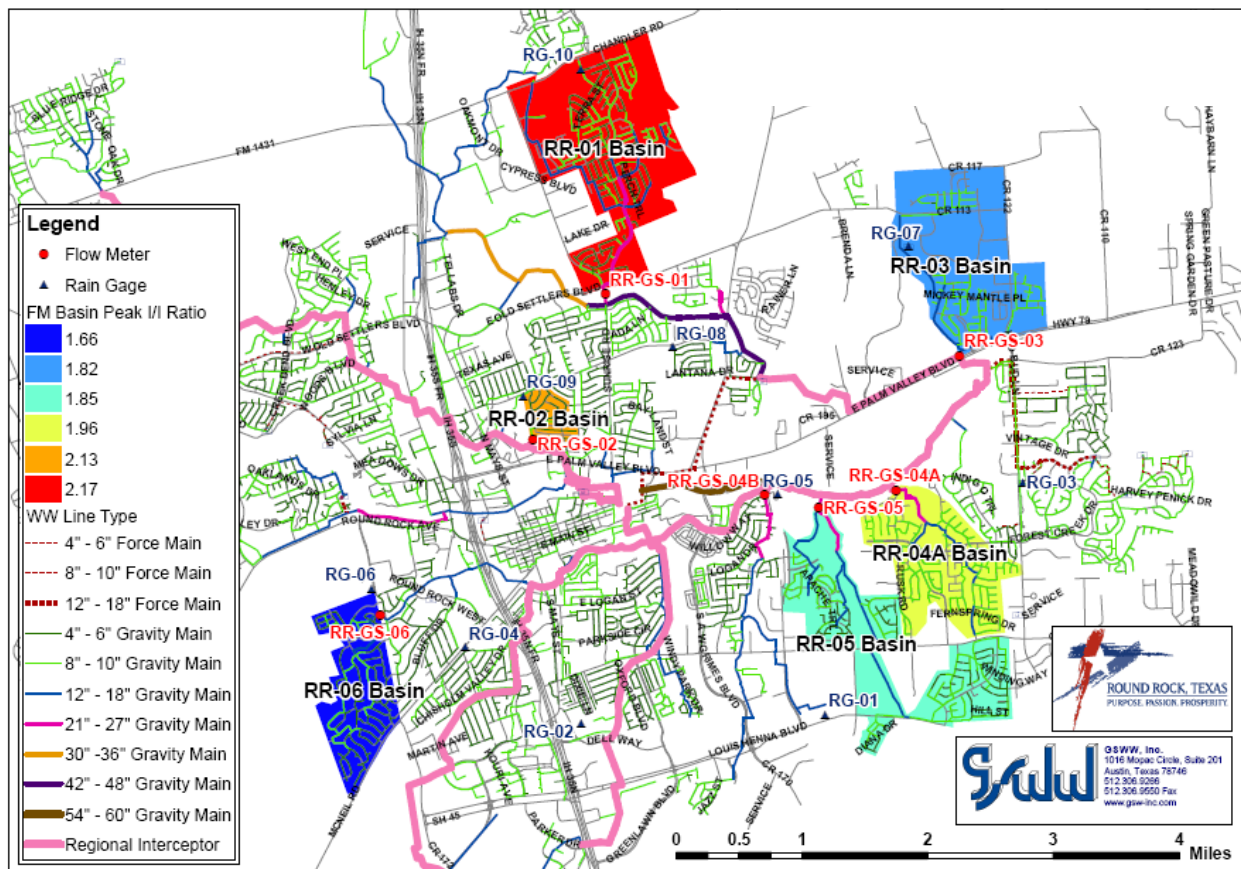


Figure 14.0 Measured Peak Flow Ratio – May 28 - 29, 2005 Wet Weather Event

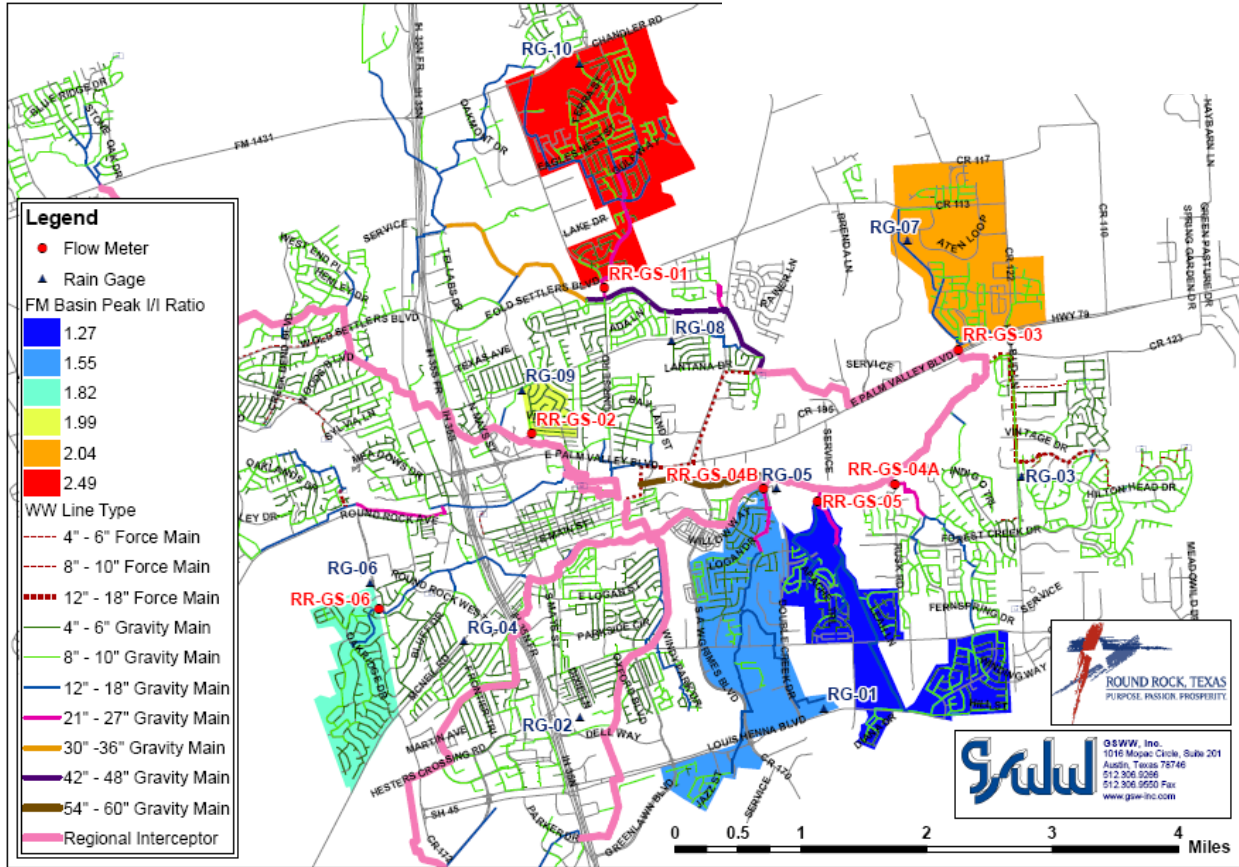


Figure 15.0 Measured Peak Flow Ratio – May 8 – 9, 2006 Wet Weather Event