APPENDIX C

2012 Flow Monitoring Results (Chapter 4 from 2012 Master Plan)

4 FLOW MONITORING

4.1 INTRODUCTION

As part of the hydraulic modeling calibration effort, temporary flow meters were installed to measure dry weather and wet weather flows in the collection system. Monitored flow was recorded every fifteen minutes using the City of West Jordan's Flo-Dar meters. These records of actual collection system flows where then correlated with the flows in the hydraulic model. The City has permanent flow meters to record the discharges to South Valley Water Reclamation Facility (SVWRF) at 7000 South, 7800 South, 8050 South and 9000 South trunklines. These flow meters are located at the east end of the City trunklines and also accumulate flow data every 15 minutes. Additional flow monitors were placed in strategic locations throughout the City to obtain localized flow information. Flow monitoring results at the City's permanent meters and temporary meter locations are discussed below.

4.2 COLLECTION SYSTEM FLOW MONITORING

A total of six temporary flow meters were installed throughout the collection system during 2010 and 2011. These monitors are in addition to the four permanent monitors located at the east end of the City's trunklines. During flow monitoring, pipeline flow (cfs), depth, and velocity data were collected at each flow meter in 15-minute intervals using Flo-Dar® meters. The monitors were left in place for periods over one week in order to capture the differences in weekday and weekend flows. Flow monitoring data was compared to data from the hydraulic model for calibration.

The location of the flow meters divided the collection system into five representative uses or differentiations in trunklines. Appendix B contains graphs of the results of each monitoring station. Table 4.1 presents the location of the flow meters and targeted sewer areas. Flow monitoring occurred during dry weather and is used as the base flow. It should be noted that modeled flow for the 7800 South 4300 West 24-inch trunkline (Appendix B) compared closely to actual monitored flow, and the flow confirms residential daily sewer use of 66 gallons per person per day, as presented in section 2.3.1. This pipe flow does not contain any contributions from groundwater infiltration or rainfall inflow (see section 4.3 for further discussions of inflow and infiltration), which is important for a baseline residential flow for incorporation into the model, and to predict infiltration and inflow rates above the base flow.

4.2.1 Overall Flow Monitoring Results

The average daily flow for the Year 2010 began at 7.8 mgd, increased after the summer to 8.3 mgd, and increased in November to 8.5 mgd. For the Year 2011, the average daily flow ranged from 8.5 mgd on dry weather weeks to 8.7 mgd on wet weather weeks. Weekend flows were typically higher than weekday flows at 9.2 mgd, with peak flows at 12.5 mgd, Thanksgiving Day having the highest flows of the year with a peak instantaneous flow of 15.2 mgd.

Table 4.1. Existing and Buildout Flow Monitoring:
A Comparison of Measured Average and Peak Flows for Residential, Commercial, and Industrial Areas to Modeled Flow.

Meter Location	Primary Land Use and Trunkline Delineation	Average Flow Observed (mgd)	Max Flow & Peaking Factor	Dates	Average Sewer Model Flow (mgd)	Model Max Flow, & Peaking Factor	Model Average Flow Percent Accuracy	Future Average and Max Flow Model Estimates (mgd)
Bagley Park Road and Old Bingham Highway	Industrial Segment prior to Old Bingham Highway	0.12	0.31 PF 2.58	Jan. 26 – Feb 4 2011	0.11	Max 0.21 PF 1.9	92%	Avg. 0.81 Max 2.1
5250 West Old Bingham Highway 18”	Industrial Area with Meat Packing Plant	0.18	0.42 PF 2.33	Jan. 26 – Feb 4 2011	0.19	Max 0.35 PF 1.84	106%	Avg. 0.91 Max 2.5
9000 South 2450 West 15” trunkline	Residential & Fairchild Semiconductor	1.17	1.59 PF 1.36	Aug 11 2010	0.96	Max 1.55 PF 1.61	82%	Avg. 1.97 Max 3.04
7800 South 4300 West 24” trunkline	Residential & Airport Road Light Industrial	1.25	2.22 PF 1.78	Jan 13 – Jan 18 2012	1.3	Max 2.1 PF 1.62	104%	Avg. 5.1 Max 8.2
4100 W. New Bingham Highway 24” trunkline	West side Residential, Industrial, and Light Industrial areas	1.35	1.98 PF 1.47	Jan 13 – Jan 20 2012	1.19	Max 1.89 PF 1.58	88%	Avg. 4.5 Max 7.1
Old Bingham Hwy 7900 S	Mixed Use High Density, Residential, and Light Industrial	0.18	0.31 PF 1.72	8/21/2010	0.35	Max 0.55 PF 1.57	190%	Avg. 1.0 Max 1.62

4.3 INFLOW AND INFILTRATION

4.3.1 Infiltration

Infiltration occurs when existing sewer lines undergo material and joint degradation and deterioration as well as when sewer lines are poorly designed and constructed. (Figure 4.1). Infiltration is groundwater entering the pipes or manholes through cracks, breaks, lids, faulty seals, plant root instructions, improperly aligned or seated joints and manhole walls. Because infiltration is directly influenced by groundwater fluctuations, the volume of infiltration entering a sewer system is generally expected to fluctuate from season to season with typically larger volumes anticipated in the spring and smaller volumes anticipated in the winter. Irrigation canals also raise the height of the groundwater table in the surrounding areas, and contribute to increased infiltration in localized areas down gradient of the canals.

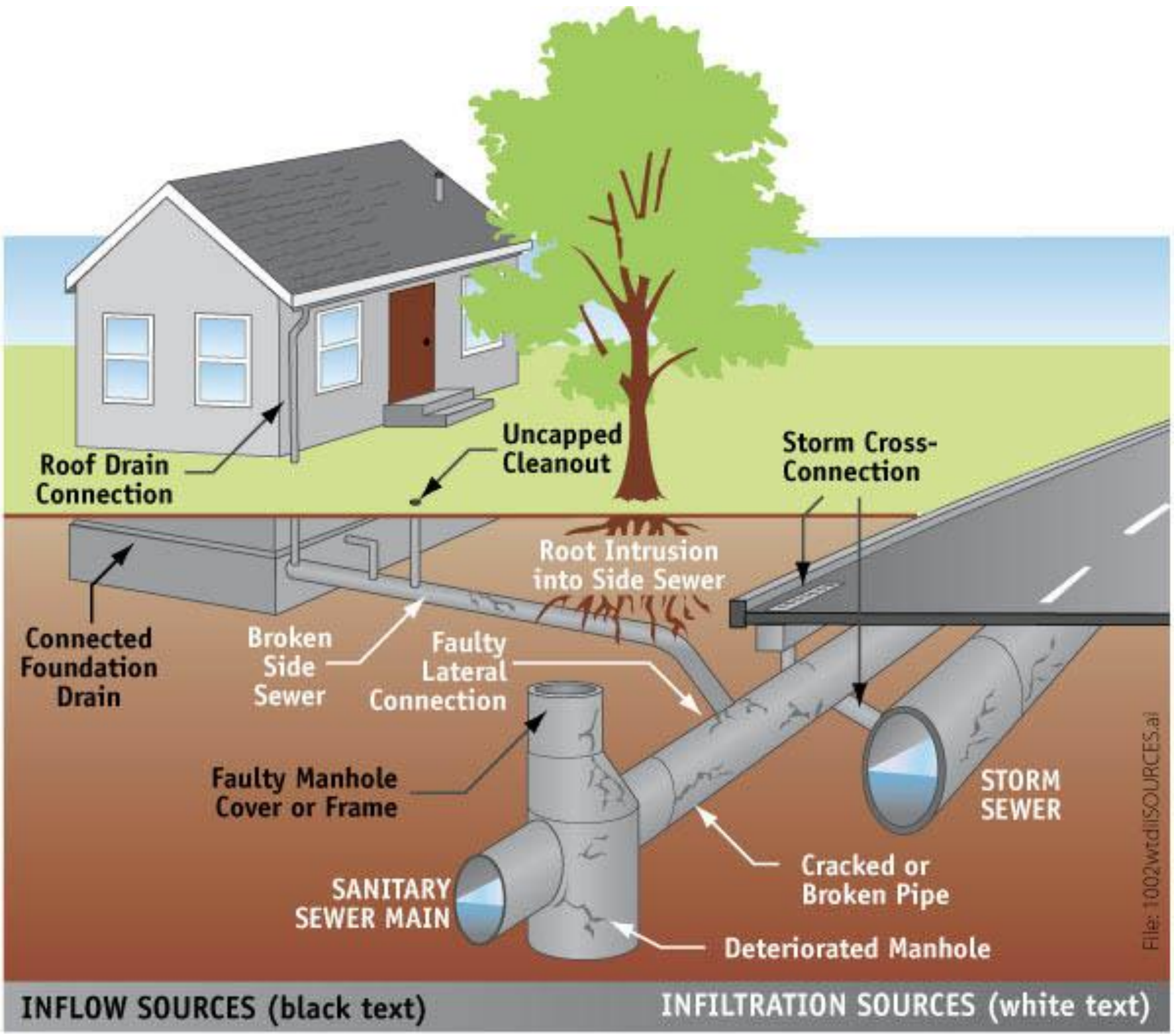

Image Courtesy of King County Website

Figure 4.1: Inflow and Infiltration Sources

4.3.2 Inflow

Inflow is extraneous water discharged into a sewer system from sources such as sump pumps, roof leaders, cellar/foundation drains, surface drains, drains from springs and swampy areas, manhole covers, catch basins, cross-connections from storm drains, cooling water discharges, leaking tide gates, and other inlets. Inflow differs from infiltration in that it is the result of direct connections of extraneous flow sources into the collection system and, generally, is not linked to fluctuations in the groundwater table.

4.3.3 Inflow and Infiltration Effects

Extraneous water from infiltration and inflow (I&I) sources reduces the capacity and capability of sewer systems and treatment facilities to transport and treat domestic and industrial wastewaters. The adverse effects of I&I in the collection system are that they increase both the flow volume and peak flows in the system, causing it to operate at or above its capacity. Because of the additional flow volume, costly pipe size increases may be necessary in the future as the reserved pipe capacity for future growth is used for infiltration and inflow. Excess flows contribute to increased wear of the system and are costly as the City pays a fee for each gallon discharged to the South Valley Water Reclamation Facility for treatment, currently $1.30 per 1000 gallons based on 8.5 mgd, or $4,000,000 annually. Excess I&I water is treated at SVWRF with additional treatment systems that would not be necessary if I&I water were prevented from entering the municipal system. If too much I&I enters the collection system, sanitary sewer overflows may occur.

4.4 INFILTRATION STUDY

Infiltration rates into the sewer system vary in the City based on the groundwater table depth and proximity to irrigation canals. Five major irrigation canals run south to north and either pass through or terminate in the eastern half of the City of West Jordan. The pipelines where low infiltration occurs are generally located west of 4000 West as the groundwater table is deeper and canals are not present. West Jordan also receives groundwater recharge flow from a secondary recharge area located on the east side of the Oquirrh Mountain Range. Due to the slope of the land from west to east, groundwater is conveyed west from the Oquirrh Mountains to the Jordan River, creating higher groundwater levels in the eastern portion of the City. Recent video footage of the 1300 West sewer pipe shows significant flow increases and in some cases pipe submersion due to infiltration from 9400 South to 8600 South. Potholing at 8680 South and 1250 West in May 2011 showed the groundwater elevation at 9 feet below the ground surface, submerging the majority of the sewer system in this area under the groundwater. Wastewater operations personnel reported in 2011 that visual observations of the 1300 West Sewer trunkline show the pipe at capacity for most of the length due to groundwater infiltration.

4.4.1 Historical Infiltration and Inflow Studies and Results

A 1992 infiltration study, *City of West Jordan Sewer System Infiltration Study, CRS, 1992*, concluded that "most infiltration occurring within the City of West Jordan is situated east of

2200 West; with the bulk of infiltration actually occurring east of 1700 West. At several locations throughout the City, existing sanitary sewer lines either pass near or beneath these irrigation canals. During the heavy irrigation season, leakage from these canals completely saturates the surrounding soils." Manholes experiencing infiltration next to the canals were located at 7962 South 3800 West, 6939 South 2200 West, 7269 South 2944 West, 8435 South 2700 West, and 7800 south 3725 West. Infiltration above 120 gallons per minute was observed in manholes in the areas of 1300 West, 1500 West, and Redwood Road. Since this study, the Redwood road trunk line pipe was lined with a continuous pvc liner to reduce infiltration; however, older neighborhood pipes and lateral connections still contribute infiltration water to the trunkline.

The City's 2003 Sanitary Sewer Master Plan, *2003 Sanitary Sewer Model & Capital Facilities Plan, JUB, 2003,* incorporated infiltration into the pipes in Redwood Road and 1300 West at a rate of 412 gallons per acre per day (gpad). The report indicated that during monitoring, the flow meters registered one significant storm event that contributed a relatively small amount of inflow and infiltration to the system. Estimates of inflow were 0 gpad on the West side of the City to 70 gpad on the east side.

4.4.2 Current Infiltration Study and Results

The City conducted an infiltration study out of necessity to bring the sewer model into calibration, as it was observed that the sewer discharge rates from residences were significantly less in the model than what was observed at the trunkline meters for 7000 south and 8050 South. Both inflow and infiltration were observed in the flow monitoring graphs from SVWRF and from the observations of City personnel. Therefore, flow data was collected to quantify infiltration rates.

Infiltration volume is typically measured as the low point of the daily wastewater flow graph, minus the known flows during that time period. In 2010 the City experienced one of the wettest years on record, which saturated the soils and led to increased infiltration. Appendix C shows graphs of West Jordan Sewer Meters for each of the four major trunklines for a dry weather week in August 23, during the years 2009, 2010, 2011, and 2012, with full irrigation canals. These yearly comparisons show that the most infiltration occurred in 2011, after record precipitation in 2010 led to increases in groundwater recharge from the Oquirrh Mountains. The graphs show that 7000 South and 8050 South trunklines are affected the most by higher levels of groundwater; 9000 South has moderate levels of infiltration; and 7800 South is influenced the least from infiltration. Figure 3.1 shows the manholes where infiltration was applied to the model, actual locations where infiltration is present need to be investigated.

Increases in dry weather infiltration were also observed when comparing sewer flows with the irrigation canals full on October 8, 2010 (8.363 mgd) to October 22nd 2010 (7.988 mgd), when the irrigation flows were reduced and the ground was not as saturated (Table 4.2). These results show that the canals likely contribute 375,000 gallons per day in infiltration to the sewer flows.

Table 4.2. Observed Flow Results and Infiltration Rates

Meter	Dry Weather Flow Daily Average Dec 12 2010	Dry Weather Flow Daily Average Dec 26 2010	Wet Weather Flow Daily Average Dec 19 2010	Dry Weather Flow Daily Average Oct 22 2010	Irrigation Season Dry Weather Flow Daily Average Oct 8 2010	Wet Weather Flow Daily Average Oct 30	Dry Weather Flow Daily Average Nov 15 2011	Irrigation Season Dry Weather Flow Daily Average Aug 23 2011	Wet Weather Flow Daily Average Nov 1 2011
7000 South	2.669	2.804	2.719	2.435	2.518	2.612	2.396	2.663	2.525
7800 South	4.193	3.938	4.325	3.624	3.912	4.155	4.017	4.238	4.368
8050 South	0.455	0.45	0.45	0.444	0.476	0.469	0.524	0.744	0.551
9000 South	1.57	1.586	1.596	1.485	1.457	1.565	1.488	1.572	1.39
Total	8.887	8.778	9.090	7.988	8.363	8.801	8.425	9.217	8.834

Note: All flows are in Millions of Gallons per Day

In order to further define the areas contributing infiltration to the 7000 South trunkline, flow monitors were placed in 7000 S from 3200 West to 1450 West, on both pipelines. Appendix C presents the field monitoring graphs along 7000 South in 2012. Differences in the calibrated model flow without infiltration, and based on the number of residences and water meter use records, were compared to field measured flows to calculate the amount of infiltration in each segment of the trunklines in 7000 South, 8050 South and 9000 South, see Table 4.3.

Table 4.3. Calculated Infiltration Assigned to 7000 South, 8050 South, and 9000 South

Location	Modeled Average Dry Weather Flow Without Infiltration (mgd)	Actual Average Dry Weather Flow (mgd)	Assigned Infiltration (gpad)
7000 S west of 3200 W	0.33	0.36	0
7000 S between 3100 W 15” Pipe west of Utah Lake Canal	0.42	0.38	0
7000 S between 3100 W 15” Pipe east of Utah Lake Canal	0.42	0.473	865
7000 S 2637 W 10” Pipe North Side	0.07	0.23	865
7000 S 2637 W 12” Pipe South Side	0.58	1.21	910
7000 S 2300 W 10” Pipe North Side	0.08	0.35	215
7000 S 2300 W 12” Pipe South Side	0.68	1.33	160
7000 S 2160 W 12” Combined Pipe	0.84	1.11	190
7000 S 1550 W 12” Pipe South Side	1.16	1.53	145
7000 S 1400 W 15” Pipe North Side	0.094	0.2	980

8050 S areas east of Redwood Road	0.27	0.75	1030
9000 S areas east of canal at 2300 W	1.42	1.7	635

Gpad = gallons per acre per day. MGD = millions of gallons per day

The results of the infiltration study as represented in Table 4.3 and on the graphs in Appendix C show the highest infiltration areas located east of Redwood Road with an average of 1,005 gallons per acre day (gpad). Areas that contribute infiltration to the 7000 S trunklines are located near the canals from 3100 West to 2637 West with infiltration as high as 910 gpad. Infiltration continues along the 7000 S trunkline from 2637 S to approximately Redwood Road at an average rate of 175 gpad. East of Redwood Road, the infiltration rate is 980 gpad. End of pipe infiltration results show 37% of the 7000 South trunkline flow is from infiltration. In the 8050 South trunkline and areas by the canals on the 7000 S trunkline, the model shows as much as 64% of the flow is attributed to infiltration during 2011, when comparing calculated sewer flows based on water meter records to actual flows. The 9000 South end of the trunkline results show that 16.5% of the flow is from infiltration. The 7800 South trunkline infiltration results were not quantified as part of the study; however, they are projected to be less than 200 gpad based on the amount of commercial areas with shallow sewer pipes that contribute to the trunkline.

4.5 RAINFALL MONITORING

Inflow volume can be quantified by observing peak flow data during storm events and comparing this to monitoring data of the same area during dry weather. The City experienced unusually high precipitation amounts in 2010 with record breaking storm events. Changes in wastewater flows were monitored during storms by using the primary trunkline flow meters located at 7000 South, 7800 South, 8050 South, and 9000 South, see Table 4.4.

Table 4.4. Wet Weather Combined Inflow and Infiltration Monitoring Results.

Area	Rainfall (inches)	Daily Average Flow (MGD) without Rainfall Dec 12-18, 2010	Daily Average Flow (MGD) with Rainfall Dec 19-22, 2010	MGD Difference	Percent Difference
7000 South					
19-Dec	0.59	2.80	2.72	-0.08	0
20-Dec	0.36	2.79	2.75	-0.05	0
21-Dec	0.32	2.74	2.73	-0.01	0
22-Dec	0.63	2.74	2.87	0.13	4.7%
7800 South					
19-Dec	0.59	3.94	4.32	0.39	4.7%
20-Dec	0.36	4.02	4.37	0.35	8.7%
21-Dec	0.32	3.94	4.12	0.19	4.5%
22-Dec	0.63	3.95	4.52	0.58	14.4%
8050 South					
19-Dec	0.59	0.45	0.45	0.00	0
20-Dec	0.36	0.44	0.50	0.05	13.6%
21-Dec	0.32	0.44	0.49	0.05	11.4%
22-Dec	0.63	0.45	0.54	0.09	20%

9000 South					
19-Dec	0.59	1.59	1.60	0.01	0.6%
20-Dec	0.36	1.64	1.67	0.04	1.8%
21-Dec	0.32	1.64	1.61	-0.03	0
22-Dec	0.63	1.56	1.75	0.19	12.2%

Note: A 3.8% flow increase was observed on 7000 South during the October 2010 storm events

Table 4.4 data shows the difference of wet weather flow monitoring for each trunkline as calculated by subtracting monitored dry weather flow from wet weather flow. It was observed that 7000 South does not appear to have significant increases in flow; however, the results actual indicate that saturated soils in the area already contribute significant levels of infiltration and the extra inflow from rainfall is less pronounced. The 7800 South trunkline shows localized flow increases after a storm event. The data for the 8050 South trunkline show significant increases in flow during wet weather, while 9000 South increases are present, but less pronounced.

Dry weather monitoring curves from previous weeks were overlaid with wet weather flows to observe changes in the average flow and determine the amount of inflow proportional to the storm event, (see wet weather flow comparison graphs in Appendix D). Storm events occurred on October 23-26, 2010 with record setting precipitation of 0.84 inches on the 25th, according to the National Weather Service Forecast Office website for the Salt Lake City area, (see Table 4.5). Another series of storms occurred from December 19-22, 2010; and in November 2011.

High inflows (other than on the Christmas holiday) were observed on Wednesday December 22 with 0.63 inches of rainfall. This storm contributed on average an additional 980,000 gallons per day (215 gpad) of total discharge for the City when compared with Wednesday December 29, 2010. The storm on October 23, 2010 measured 0.23 inches of rainfall and contributed on average an additional 130,000 gallons per day (29 gpad) when compared to November 6, 2010, the closest Saturday without rainfall inflow.

Table 4.5. Rainfall Summary and Average Daily Total Flows

Date	Daily Rainfall Volume (inches)	Average Metered Flow (mgd)	Peak Metered Flow (mgd)		Date	Daily Rainfall Volume (inches)	Average Metered Flow (mgd)	Peak Metered Flow (mgd)
Th 10/21/2010	0	8.19	11.2		Tu 12/21/2010	0.32	8.95	10.75
Fr 10/22/2010	0	7.96	10.4		W 12/22/2010	0.63	9.68	11.78
Sa 10/23/2010	0.26	8.58	12.49		Th 12/24/2010	0	9.4	12.3
Su 10/24/2010	0.18	78th Meter Malfunction	78th Meter Malfunction		Fr 12/25/2010	0	9.46	14.64*
M 10/25/2010	0.84	78th Meter Malfunction	78th Meter Malfunction		W 12/29/2011	0	8.7	11.12
Tu 10/26/2010	0.32	78th Meter Malfunction	78th Meter Malfunction		Tu 11/1/2011	0.31	8.84	11.37
W 10/27/2010	0.03	8.65	11.67		Fr 11/4/2011	0.27	8.23	10.03
Th 10/28/2010	0	8.52	11.40		Sa 11/5/2011	0.24	9.15	13.18
Fr 10/29/2010	0	8.45	11.04		Sa 11/12/2011	0.18	8.65	12.66
Sa 10/30/2010	0.29	8.8	12.98		Su 11/13/2011	0.11	9.02	12.92

Su 10/31/2010	0	8.94	12.96		M 11/14/2011	0	8.52	11.6
Sa 11/6/2010	0	8.45	12.50		Fr 11/18/2011	0.30	8.22	10.95
Su 12/19/2010	0.59	9.09	13.17		M 11/21/2011	0.13	8.75	12.47
M 12/20/2010	0.36	9.23	11.54		T 11/22/2011	0	8.58	10.9

Note: All flow results are in million gallons per day (mgd)
*Christmas Day has the 2nd highest peak flow of the year at 14.64 mgd.
Thanksgiving has the highest peak flow at 15.2 mgd.