APPENDIX C
Sewer Flow Generation Forecasting

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Sewer Flow Generation Forecasting

Sewer Flow Generation

In recent years sewer flows across Southern California have been steadily declining. This decline is the result of several factors, chief among them: water conservation due to drought and increased efficiency of interior fixtures. Declines due to drought have historically rebounded at least to some degree once drought conditions subside, while the implementation of increased efficiency in interior use has become a more permanent change with lower sewer flows.

The Master Plan builds on recent updates of the Sewer Hydraulic Model and analysis which use the Fiscal Year (FY) 2013-2014 as a baseline year for sewer flow forecasting. Upon reviewing the data for sewer flow generation for this and historical years before it, FY 13-14 is considered a fairly representative year for future analysis. As is shown below in **Table C-1**, FY 13-14 flow of 0.70 mgd is slightly below the average for both the past five and ten years of average sewer flows. Dramatically reduced sewer flows in FY 14-15 are believed to be largely attributable to the ongoing severe drought conditions and the District's outreach and public response.

Table C-1 Flow Forecasts

Fiscal Year	Fiscal Year Average Flow (MGD)	Calendar Year	Calendar Year Average Flow (MGD)
14-15	0.57	15	0.54
13-14(1)	0.70	14	0.64
12-13	0.78	13	0.76
11-12	0.76	12	0.79
10-11	0.71	11	0.73
09-10	0.70	10	0.70
08-09	0.73	09	0.70
07-08	0.83	08	0.77
06-07	0.78	07	0.81
05-06	0.81	06	0.80
5 Year Average(2)	0.70		0.69
5 Year Average(3)	0.73		0.72
10 Year Average	0.74		0.72

(1) Selected as the Baseline sewer flow generation condition

(2) from FY 10-FY 14 and CY 11- CY 15

(3) from FY 09-FY 13 and CY 10- CY 14

In Chapter 6, **Table 6-4** presents a summary of water sales in comparison to sewer flows. **Table C-2** of this appendix presents the complete analysis of water use versus estimated sewer flow by water pressure zone within the sewer system. Sewer generation rates for existing users were adjusted to account for increased water demands by water meter billing category. The forecasted unit generation rates for residential land uses was derived from an assumed individual sewage generation rate of 65 gpcd and occupancy rates of 2.4 to 3.1 people per dwelling unit. Larger property types and single family homes are assumed to have higher occupancies (compared to high density projects) and sewer generations. The forecasted per connection sewer generation rates are presented in **Table 6-4**, as well as below in **Table C-3**. Where known developments have prepared specific plans forecasting their water demand and sewer generation, those demands and flows were used in forecasting.

Table C-2 CY 2013 Water Sales versus Estimated Sewer Flow by Water Pressure Zone

ESTIMATED SEWER FLOWS

					365		
				Sewer Accounts	Water Sales	Estimated Sewer Flow	Sewer Flow Augmentation
Zone:	**Canonita**				(MGD)	(MGD)	
D	<	1.00	SFR w/ smaller meters	122	0.04	0.02	
D	>=	1.00	SFR w/ larger meters	22	0.02	0.00	
MF	>=	0	Multi-Family Residential	5	0.09	0.07	
C	>=	0	Commercial	1	0.01	0.00	
A	>=	0	Agriculture	1	0.01	0.00	
SC	>=	0	SAWR Commercial	0	0.00	0.00	
SD	>=	0	SAWR Domestic	2	0.04	0.00	
SW	>=	0	TSAWR	1	0.05	0.00	
		TOTAL		**154**	**0.27**	**0.10**	
Zone:	**Canonita**				(GPD)	(GPD)	(GPD)
D	<	1.00	SFR w/ smaller meters	122	300	160	20
D	>=	1.00	SFR w/ larger meters	22	1,098	220	0
MF	>=	0	Multi-Family Residential	5	18,066	75%	0
C	>=	0	Commercial	1	8,358	1,000	0
A	>=	0	Agriculture	1	8,839	500	0
SC	>=	0	SAWR Commercial	0	--	500	0
SD	>=	0	SAWR Domestic	2	21,303	500	0
SW	>=	0	TSAWR	1	54,425	300	0
		TOTAL		**154**	**1,723**	**632**	
Zone:	**Pala Mesa**				(MGD)	(MGD)	
D	<	1.00	SFR w/ smaller meters	861	0.37	0.15	
D	>=	1.00	SFR w/ larger meters	464	0.30	0.09	

Table C-2 CY 2013 Water Sales versus Estimated Sewer Flow by Water Pressure Zone

MF	>=	*0*	*Multi-Family Residential*	3	0.00	0.00	
C	>=	*0*	*Commercial*	7	0.02	0.00	
A	>=	*0*	*Agriculture*	8	0.01	0.00	
SC	>=	*0*	*SAWR Commercial*	1	0.01	0.00	
SD	>=	*0*	*SAWR Domestic*	22	0.05	0.01	
SW	>=	*0*	*TSAWR*	0	0.00	0.00	
		TOTAL		**1,366**	**0.76**	**0.26**	

Zone:	**Pala Mesa**				**(GPD)**	**(GPD)**	**(GPD)**
D	<	*1.00*	*SFR w/ smaller meters*	861	426	180	20
D	>=	*1.00*	*SFR w/ larger meters*	464	640	200	-20
MF	>=	*0*	*Multi-Family Residential*	3	976	75%	0
C	>=	*0*	*Commercial*	7	3,172	500	-500
A	>=	*0*	*Agriculture*	8	1,716	300	-200
SC	>=	*0*	*SAWR Commercial*	1	11,848	600	100
SD	>=	*0*	*SAWR Domestic*	22	2,186	300	-200
SW	>=	*0*	*TSAWR*	0	--	300	0
		TOTAL		**1,366**	**558**	**193**	

Zone:	**Gopher Canyon**				**(MGD)**	**(MGD)**	
D	<	*1.00*	*SFR w/ smaller meters*	44	0.03	0.01	
D	>=	*1.00*	*SFR w/ larger meters*	17	0.01	0.00	
MF	>=	*0*	*Multi-Family Residential*	0	0.00	0.00	
C	>=	*0*	*Commercial*	2	0.00	0.00	
A	>=	*0*	*Agriculture*	5	0.03	0.00	
SC	>=	*0*	*SAWR Commercial*	1	0.00	0.00	
SD	>=	*0*	*SAWR Domestic*	15	0.03	0.00	
SW	>=	*0*	*TSAWR*	0	0.00	0.00	
		TOTAL		**84**	**0.11**	**0.02**	

Zone:	**Gopher Canyon**				**(GPD)**	**(GPD)**	**(GPD)**
D	<	*1.00*	*SFR w/ smaller meters*	44	775	200	40
D	>=	*1.00*	*SFR w/ larger meters*	17	640	220	0
MF	>=	*0*	*Multi-Family Residential*	0	--	75%	0
C	>=	*0*	*Commercial*	2	1,023	500	-500
A	>=	*0*	*Agriculture*	5	6,720	500	0
SC	>=	*0*	*SAWR Commercial*	1	826	200	-300
SD	>=	*0*	*SAWR Domestic*	15	1,782	300	-200
SW	>=	*0*	*TSAWR*	0	--	300	

Table C-2 CY 2013 Water Sales versus Estimated Sewer Flow by Water Pressure Zone

CN	>=	*0*	*Construction*	0	--	0	
		TOTAL		**84**	**1,288**	**247**	

Zone:	**Morro**				(MGD)	(MGD)	
D	<	*1.00*	*SFR w/ smaller meters*	269	0.15	0.05	
D	>=	*1.00*	*SFR w/ larger meters*	244	0.30	0.06	
MF	>=	*0*	*Multi-Family Residential*	26	0.03	0.02	
C	>=	*0*	*Commercial*	33	0.10	0.02	
A	>=	*0*	*Agriculture*	51	0.15	0.02	
SC	>=	*0*	*SAWR Commercial*	4	0.09	0.00	
SD	>=	*0*	*SAWR Domestic*	24	0.14	0.01	
SW	>=	*0*	*TSAWR*	0	0.00	0.00	
		TOTAL		**651**	**0.96**	**0.17**	

Zone:	**Morro**				(GPD)	(GPD)	(GPD)
D	<	*1.00*	*SFR w/ smaller meters*	269	554	180	20
D	>=	*1.00*	*SFR w/ larger meters*	244	1,227	260	40
MF	>=	*0*	*Multi-Family Residential*	26	1,039	75%	0
C	>=	*0*	*Commercial*	33	3,122	500	-500
A	>=	*0*	*Agriculture*	51	2,912	300	-200
SC	>=	*0*	*SAWR Commercial*	4	22,653	700	200
SD	>=	*0*	*SAWR Domestic*	24	5,933	300	-200
SW	>=	*0*	*TSAWR*	0	--	300	
		TOTAL		**651**	**1,475**	**268**	

Zone:	**TOTAL DISTRICT**				(MGD)	(MGD)	
D	<	*1.00*	*SFR w/ smaller meters*	1,296	0.59	0.23	
D	>=	*1.00*	*SFR w/ larger meters*	747	0.63	0.16	
MF	>=	*0*	*Multi-Family Residential*	34	0.12	0.09	
C	>=	*0*	*Commercial*	43	0.14	0.02	
A	>=	*0*	*Agriculture*	65	0.20	0.02	
SC	>=	*0*	*SAWR Commercial*	6	0.10	0.00	
SD	>=	*0*	*SAWR Domestic*	63	0.26	0.02	
SW	>=	*0*	*TSAWR*	1	0.05	0.00	
		TOTAL		**2,255**	**2.10**	**0.555**	

Zone:	**TOTAL DISTRICT**				(GPD)	(GPD)	(GPD)
D	<	*1.00*	*SFR w/ smaller meters*	1,296	453	181	

Table C-2 **CY 2013 Water Sales versus Estimated Sewer Flow by Water Pressure Zone**

D	***>=***	***1.00***	***SFR w/ larger meters***	747	845	221
MF	***>=***	***0***	***Multi-Family Residential***	34	3,538	75%
C	***>=***	***0***	***Commercial***	43	3,154	512
A	***>=***	***0***	***Agriculture***	65	3,149	318
SC	***>=***	***0***	***SAWR Commercial***	6	17,214	600
SD	***>=***	***0***	***SAWR Domestic***	63	4,124	306
SW	***>=***	***0***	***TSAWR***	1	54,425	300

Table C-3 Forecasted per Unit Sewer Generation

Flow Type	**Flow (GPD)**
Single Family, < 1" Meter	160
Single Family, >= 1" Meter	220
Multi-Family	150
Commercial	500
Agriculture	500
SAWR Agriculture	500

Table C-4 includes the projected known developments within the District, their respective location within the water system (by pressure zone) and their projected sewer flows. **Table C-5** shows the SANDAG Series 13 forecast for the water pressure zones that are within the existing sewer service area. The projected quantity of units in each zone was compared to the SANDAG Series 13 projections which forecasted a specific number of housing units in each zone. In comparing the results of the two analysis it was noted that the District projects more units in the sewer area than SANDAG. However, it should also be noted that the assignment of each development to a specific pressure zone is approximate. Portions of an individual developments could be served by multiple water pressure zones and were not analyzed in detail for the summary in **Table C-5**. Since the number of units projected by the District exceeds the number of units projected by SANDAG in the sewer service area, no infill loading was applied for these areas **Table C-6** includes the model junctions that the projected development flows were assigned.

Inflow and Infiltration

The other component of sewer flow is inflow and infiltration. Sewer systems are designed to handle both PDWF and PWWF with varying criteria for each. Typically, PWWF is the governing design condition regardless of design criteria, especially in an area such as the District which is rural and does not have substantial stormwater management infrastructure. Of the data which was available for this study, the multi-day storm occurring from December 18th-23rd, 2010 is the largest storm which was observed within the county. Single day rainfall totals within the District ranged from 4.5 to 6 inches, 2-day rainfall from 6.5 to 8.5 inches and 7-day rainfall totals well over 10 inches throughout the entire District.

Table C-4 Proposed Development	EDUs	SFR Units	MFR Units	Acreage	Development Type	Water Pressure Zone	Projected Sewer Flow (MGD)	Notes
<u>**Upstream of District Office**</u>								
Horse Creek Ridge	751	751		381	Single Family (hi-med dense)	Pala Mesa	0.188	
Horse Creek Ridge Business Center	100			104	Commercial	Pala Mesa	0.025	
Campus Park West	538		283		Mixed	Pala Mesa	0.134	Per Atkins 2013
Pala Mesa Highlands (Beazer)	130	130		85	Single Family (rural)	Pala Mesa	0.026	
Palomar College	100			83.30	Commercial	Canonita	0.042	
Dulan	51	51			Single Family (rural)	Pala Mesa	0.010	
<u>Possible Annexations (all upstream of Office)</u>								
Meadowood (Via VCMWD Service Agreement)	850	355	489	372	Various (potable component)	North	0.280	Per D/W 2009
Warner Ranch								
-- SFR	534	534		210	Single Family (rural)	North	0.107	
-- MFR	246		246		Multi-Family	North	0.037	
Subtotal -- In District	**1,670**	**932**	**283**				**0.425**	
Subtotal -- Possible Annexations	**1,630**	**889**	**735**				**0.424**	
Subtotal -- All	**3,300**	**1,821**	**1,018**				**0.849**	
<u>**Downstream of Office, Upstream of LS#1**</u>								
Vessels	400	392		1,385	Single Family (rural)	South	0.080	
Golf Green Estates	94	94		27	Single Family (hi-med dense)	Morro	0.015	
Leatherbury	85	85		178	Single Family (rural)	Pala Mesa	0.017	
Bonsall Condos	76	76			Single Family (hi-med dense)	South	0.012	
Olive Hill Estates	37	37		45	Single Family (rural)	Morro	0.007	
Lake Vista Estates	15	15			Single Family (rural)	Morro	0.003	
Malabar Ranch	14	14			Single Family (rural)	Morro	0.003	
Silver Holdings	9			4.35	Commercial	Morro	0.002	
Subtotal	**730**	**713**	**0**				**0.140**	
<u>**Downstream of LS#1, Upstream of LS#2**</u>								
Polo Club	156	156		442	Single Family (rural)	South	0.031	
Morris Ranch	89	89		210	Single Family (rural)	Morro	0.018	
Hidden Hills	53	53			Single Family (rural)	Morro	0.011	
Vista Valley Country Club	5			8.75	Commercial	South	0.004	
Subtotal	**303**	**298**	**0**				**0.064**	
Totals -- In District	**2,703**	**1,943**	**283**				**0.628**	
Totals -- Possible Annexations & Agreements	**1,630**	**889**	**735**				**0.424**	
Totals -- All	**4,333**	**2,832**	**1,018**				**1.052**	

Note: Cells marked in yellow had flow values taken from development planning documentations

Table C-5 SANDAG Series 13 Forecast - SEWER SERVICE AREA

Pressure Zone	year	population	total housing units	total households	PPH
CANONITA	**2012**	2,144	961	924	2.23
	2020	2,490	1,086	1,023	2.29
	2035	2,948	1,233	1,208	2.39
	Δ	804	272	284	0.16
	Δ (%)	38%	28%	31%	7%
PALA MESA	**2012**	4,927	2,011	1,945	2.45
	2020	6,781	2,682	2,573	2.53
	2035	7,634	3,020	2,892	2.53
	Δ	2,707	1,009	947	0.08
	Δ (%)	55%	50%	49%	3%
SOUTH	**2012**	2,769	1,228	1,139	2.25
	2020	3,006	1,265	1,172	2.38
	2035	3,395	1,399	1,305	2.43
	Δ	626	171	166	0.17
	Δ (%)	23%	14%	15%	8%
MORRO	**2012**	5,967	2,348	2,235	2.54
	2020	6,939	2,678	2,565	2.59
	2035	8,917	3,396	3,284	2.63
	Δ	2,950	1,048	1,049	0.08
	Δ (%)	49%	45%	47%	3%
TOTAL SEWER DISTRICT	**2012**	**15,807**	**6,548**	**6,243**	**2.37**
	2020	**19,216**	**7,711**	**7,333**	**2.45**
	2035	**22,894**	**9,048**	**8,689**	**2.49**
	Δ	**7,087**	**2,500**	**2,446**	**0.12**
	Δ (%)	**45%**	**38%**	**39%**	**5%**

Table C-6 Development Model Loading

Proposed Development	Sewer Junction	In District Sewer Flow (gpm)	In District Sewer Flow (MGD)	Out of District Sewer Flow (gpm)	Out of District Sewer Flow (MGD)
Horse Creek Ridge	20000	130	0.19	0	0.00
Horse Creek Ridge Business Center	20002	17	0.02	0	0.00
Campus Park West	20004	93	0.13	0	0.00
Pala Mesa Highlands (Beazer)	290	18	0.03	0	0.00
Palomar College	792	29	0.04	0	0.00
Dulan	10006	7	0.01	0	0.00
Meadowood (Via VCMWD Service Agreement)	20004	0	0.00	194	0.28
Warner Ranch	20002	0	0.00	100	0.14
Vessels	500	56	0.08	0	0.00
Golf Green Estates	1034	10	0.02	0	0.00
Leatherbury	711	12	0.02	0	0.00
Bonsall Condos		8	0.01	0	0.00
Olive Hill Estates	1081	5	0.01	0	0.00
Lake Vista Estates	170	2	0.00	0	0.00
Malabar Ranch	624	2	0.00	0	0.00
Silver Holdings	201	2	0.00	0	0.00
Polo Club	410	22	0.03	0	0.00
Morris Ranch	394	12	0.02	0	0.00
Hidden Hills	1001	7	0.01	0	0.00
Vista Valley Country Club	437	3	0.00	0	0.00
Totals -- In District		**436**	**0.63**		
Totals -- Possible Annexations				**194**	**0.42**
Totals -- All		**631**		**1.05**	

According to National Oceanic and Atmospheric Administration (NOAA) data, this storm was between a 10 and 25 year design storm in the 1-3 day periods, with the 7 day rainfall reaching as high as a 50 year storm. This storm event is larger than typical design storm events used in Southern California for sizing wastewater collection systems. The design flow typically selected to design wastewater infrastructure ranges from 2 to 10 year frequency duration storms. **Table 6-6** includes an analysis of weather design storm frequencies. **Appendix C** also includes reference information on sewer design flows presented by the EPA. As noted in **Chapter 6** the December 2010 storm event was assumed as the basis for peak weather flows for the District sewer system. Many other San Diego County sewer agencies have used this storm event in their sewer master planning and peak wet weather hydraulic modeling.

Infiltration is flow into the sewer system from high groundwater common in sewers located in drainage courses or rivers. Historically, the District has experienced known infiltration problems because a large portion of the sewer interceptor system in located within or adjacent to the San Luis Rey River. In addition, the older "Plant B" Interceptor east of I-15 and north of SR 76 (within Horse Ranch Creek) has been known to have infiltration. This sewer interceptor is planned to be relocated out of the drainage course of Horse Ranch Creek.

In 2009 the District conducted and I&I Study (by IEC) to better quantify inflow and infiltration in the system. A copy of their summary report is also include in this **Appendix C**. The report has been used to validate the assumptions on base infiltration used for the existing sewer system. **Table 6-5** estimated base infiltration by considering "return to sewer flows" from water sales data and comparing to District average dry weather flows. Approximately 0.14 mgd was assumed for base infiltration using this methodology or about 20 percent of the total average flow of 0.70 mgd. The I&I Study estimated base infiltration by summing up four subbasin sewer meters and comparing to the Stallions meter for the total District flow. **Figure 3** and **Table 5** from the I&I Study show the field results and estimated base infiltration. It was estimated that 82 gpm of the total flow of 510 gpm was attributed to base infiltration or approximately 16 percent, which correlated well with the return to sewer methodology presented in **Table 6-5**.

RAINBOW MUNICIPAL WATER DISTRICT

2009 SEWER FLOW MONITORING

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REVIEWED BY: SCOTT HUMPHREY, P.E. (C67882)

DATE: MARCH 2010

1.0 Project Summary

The purpose of this report is to present the results of a comprehensive wastewater flow monitoring project conducted by Infrastructure Engineering Corporation (IEC) for the Rainbow Municipal Water District (RMWD). The flow monitoring project was carried out to quantify sanitary sewer flows throughout RMWD. The quantified flows will be used to calibrate RMWD's hydraulic model. The calibrated hydraulic model is a necessary tool for providing a capacity assessment of RMWD's collection system, as mandated for Sanitary Sewer Management Plan (SSMP) compliance. As such, this project represents an important milestone in RMWD's ongoing management of the sewer collection system.

The flow monitoring survey period was 02/24/09 through 04/25/09 for site 1 through site 8, while the survey period for site 9 through site 20 was 03/10/09 to 05/09/09. Site 15 was removed from the study. Results and analysis for each of these sites are presented below.

2.0 Background and Scope

RMWD owns and operates a hydraulic model of its wastewater collection system. This hydraulic model is a tool for capacity analysis of the collection system. In addition to being part of any effective collection system management plan, capacity analysis is a required portion of the Sewer System Management Plan (SSMP) mandated by the State Water Resource Control Boards' *Waste Discharge Requirement 2006-0003*.

The flow monitoring plan was conceived as a means to provide calibration data for the hydraulic model. Because the SSMP requires that the collection system capacity analysis account for peak dry and peak wet flows in the collection system, the flow monitoring plan was developed to divide RMWD's collection system into basins that would provide useful data for both wet weather and dry weather conditions.

Although primarily developed for model calibration purposes, this flow monitoring project provides other valuable information for the management of the wastewater collection system. Through discussion with District Staff, the 19 locations were chosen to maximize the information provided to the District. Results herein confirm existing capacity issues previously identified by RMWD staff, identify areas of high Base Infiltration (BI), and identify areas of high Rainfall Dependant Inflow and Infiltration (RDII). As discussed below, the areas of high BI and RDII can be targeted for more detailed study or rehabilitation in order to preserve system capacity and save money for RMWD in treatment costs.

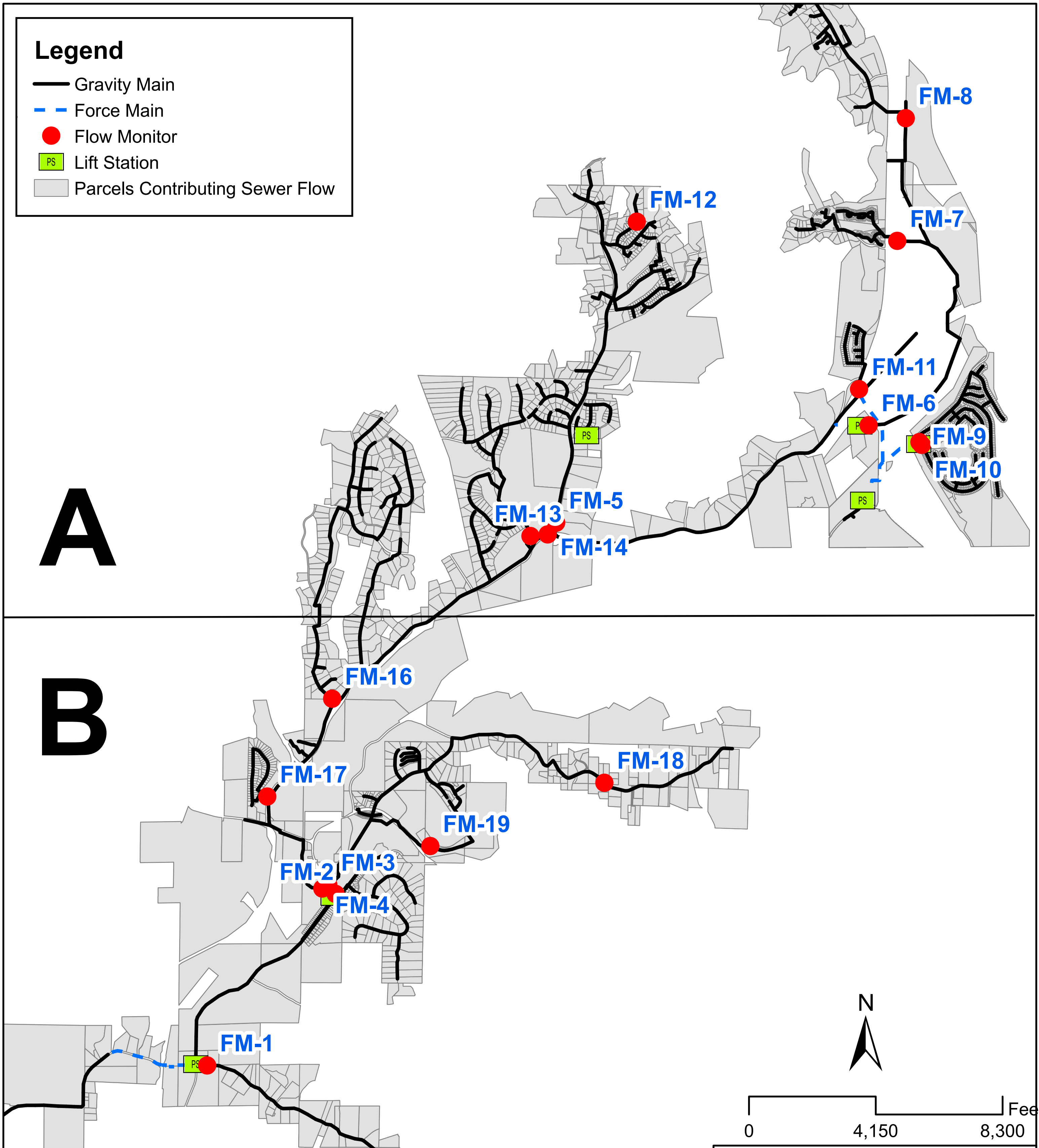
The scope of this study involved the utilization of temporary flow monitors to quantify wet weather wastewater flow at the nineteen (19) designated locations presented in Table 1.

3.0 Location and Data Summary

Area/Velocity flow meters, their identification numbers, location, and metering periods are summarized in Table 1, and illustrated in Figure 1.

Table 1 - Sewer Flow Meter Site Locations

Meter ID	RMWD Manhole No	Existing Diameter (in.)	Installation Date	Removal Date
1	MH5543	8	2/24/2009	4/25/2009
2	MH6053	8	2/24/2009	4/25/2009
3	MH6054	10	2/24/2009	4/25/2009
4	MH5410	12	2/24/2009	4/25/2009
5	MH5721	12	2/24/2009	4/25/2009
6	MH5798	12	2/24/2009	4/25/2009
7	MH5904	8	2/24/2009	4/25/2009
8	MH5965	12	2/24/2009	4/25/2009
9	MH5242	12	3/10/2009	5/9/2009
10	MH6176	8	3/10/2009	5/9/2009
11	MH5826	8	3/10/2009	5/9/2009
12	MH5039	8	3/10/2009	5/9/2009
13	MH6146	8	3/10/2009	5/9/2009
14	MH5719	12	3/10/2009	5/9/2009
16	MH5338	8	3/10/2009	5/9/2009
17	MH5205	8	3/10/2009	5/9/2009
18	MH5569	8	3/10/2009	5/9/2009
19	MH6070	8	3/10/2009	5/9/2009
20	MH5464	8	3/10/2009	5/9/2009



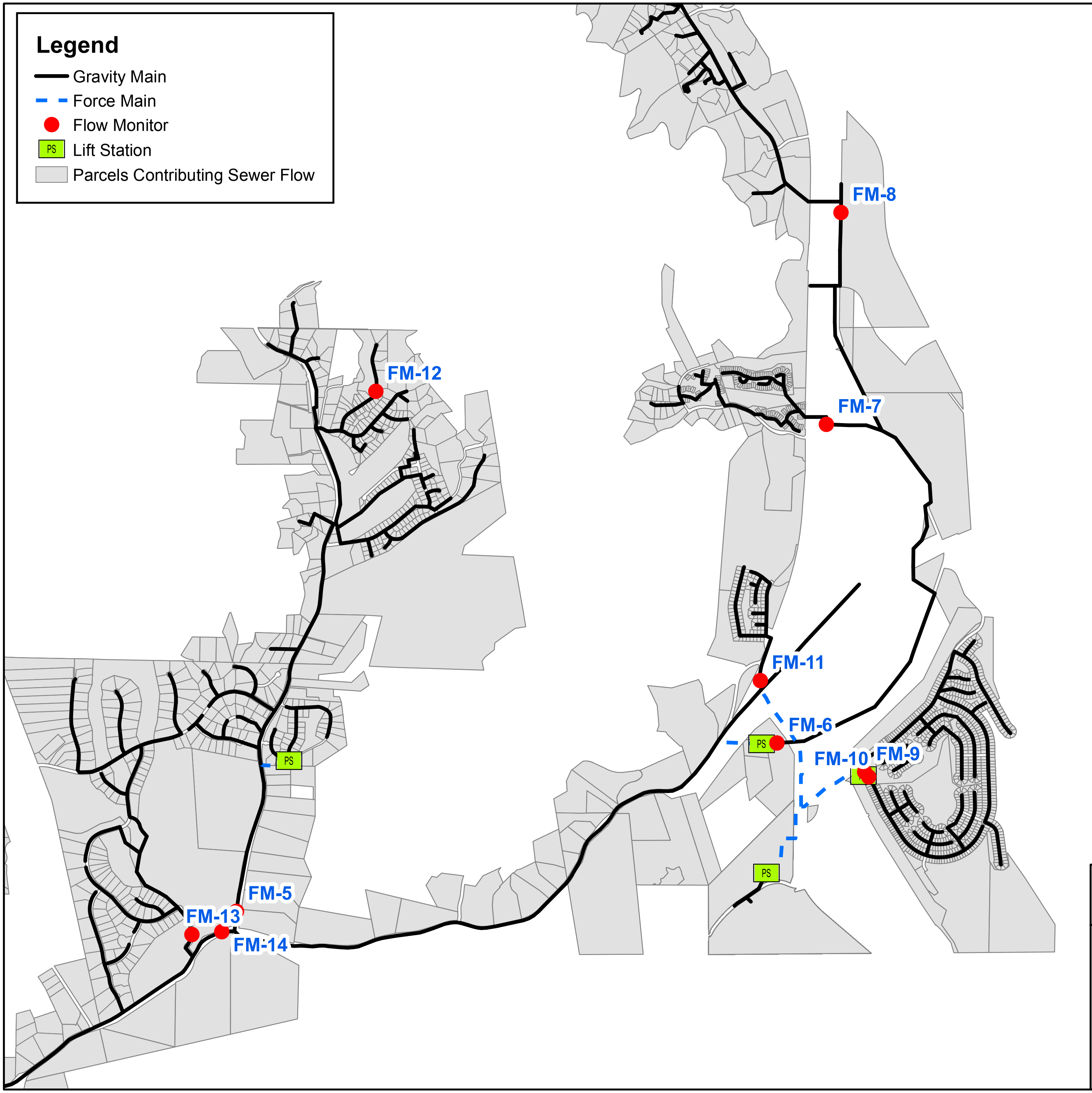
Infrastructure
ENGINEERING CORPORATION

Rainbow Municipal Water District
Flow Monitoring Services

Flow Monitor Locations

March 2010

Figure 1



Infrastructure
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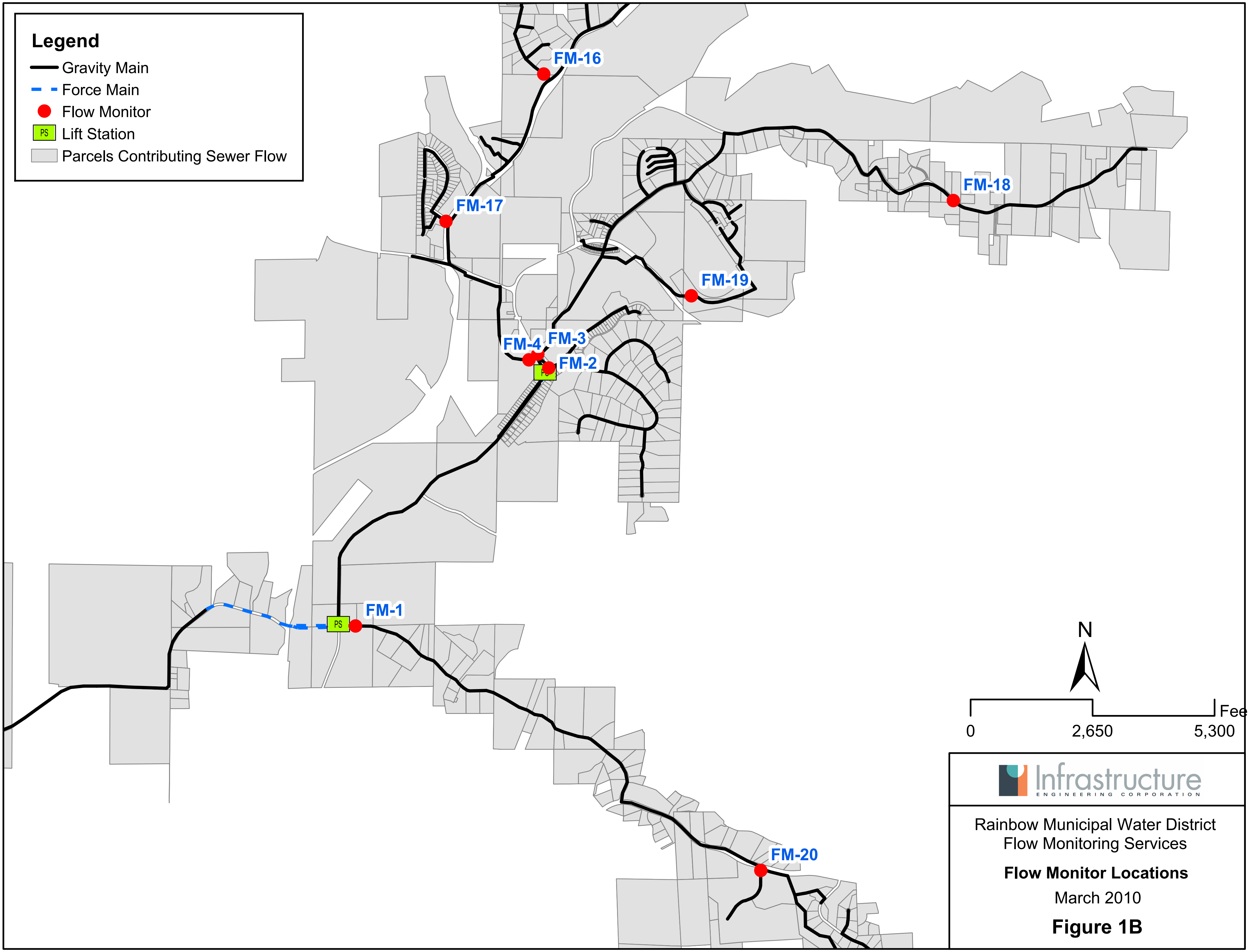
Rainbow Municipal Water District
Flow Monitoring Services

Flow Monitor Locations

March 2010

Figure 1A



Infrastructure
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Rainbow Municipal Water District
Flow Monitoring Services

Flow Monitor Locations

March 2010

Figure 1B

In addition to the flow measurement sites presented, one (1) rain gauge was also installed at the RMWD District Office during the wet season flow monitoring period. This gauge was used to identify the intensity and total rainfall within the metered area. In this way the system's wet weather response is compared to the rainfall event and analyses are performed to identify the most likely types of basin defects. Table 2 shows the rainfall events captured by this rain gauge.

Table 2 - Rain Gauge and Event Summary

Rain Gauge	General Location	February 24, 2009 Rainfall (in.)	March 22, 2009 Rainfall (in.)
RMWD District Office	Fallbrook	0.21	0.20

Table 3 presents a summary of measured flow data. As shown, average and peak dry events have been separated into Weekday (Monday through Friday) and Weekend (Saturday and Sunday) classifications, as all nineteen (19) sites experienced their largest peaks on Weekend days except site 7 and site 19.

Table 3 - Flow Monitoring Measurement Summary Table

Site No.	Location	RMWD Manhole No	Existing Diameter (in.)	Average Flow (gpm)	Average Weekday Flow (gpm)	Average Weekend Flow (gpm)	Peak Dry Weekday Flow (gpm)	Peak Dry Weekend Flow (gpm)	Peak Wet Weather Flow (gpm)	Day of Storm	Maximum d/D
1	Little Gopher Canyon Rd.	MH5543	8	21	21	21	32	35	41	3/22/2009	0.33
2	Old River Rd @ Golf Club Rd.	MH6053	8	30	29	34	45	54	60	2/24/2009	0.31
3	Camino Del Rey on Golf Course	MH6054	10	40	40	41	68	75	108	3/22/2009	0.21
4	Camino Del Rey on Golf Course	MH5410	12	312	307	325	401	471	501	3/22/2009	0.60
5	Gird Rd. @ State Route 76	MH5721	12	71	71	73	100	110	122	2/24/2009	0.20
6	CA-76 @ Old Highway 395	MH5798	12	86	85	90	109	123	129	3/22/2009	0.19
7	15N off Freeway	MH5904	8	6	6	6	9	8	11	2/24/2009	0.15
8	15S Ostrich Farm	MH5965	12	78	75	84	109	129	128	2/24/2009	0.20
9	Lake Circle Dr. s/o Dulin Rd.	MH5242	12	70	68	76	121	130	161	3/22/2009	0.25
10	Lake Circle Dr. s/o Dulin Rd.	MH6176	8	17	17	18	28	29	40	3/22/2009	0.41
11	Via Altamira off S Old Highway 395	MH5826	8	4	3	4	7	9	17	3/22/2009	0.11
12	Laketree Dr. e/o Gird Rd.	MH5039	8	9	9	9	12	12	17	3/22/2009	0.30
13	Flowerwood Ln off Highway 76	MH6146	8	5	5	6	8	9	29	3/22/2009	0.14
14	Highway 76 w/o Gird Rd	MH5719	12	333	326	351	426	498	518	3/22/2009	1.00
16	Sweetgrass Ln. off Highway 76	MH5338	8	4	3	6	6	14	18	3/22/2009	0.14
17	Thoroughbred Ln off Highway 76	MH5205	8	18	18	18	27	30	33	3/22/2009	0.24
18	W Lilac Rd w/o Via Ganelli	MH5569	8	0	0	0	0	0	1	3/22/2009	0.10
19	E/o intersection Camino Del Rey & Golf Club Dr	MH6070	8	16	17	14	40	34	69	3/22/2009	0.40
20	Spa Haven Wy s/o Gopher Canyon Rd	MH5464	8	3	3	3	5	8	46	3/22/2009	0.18

4.0 Summary of Findings

4.1 Average and Peak Flows at 19 sites

Average flow, peak dry flow, and peak wet flow were determined for each of the 19 sites, and are presented in Table 4. The peak dry weather flow, as shown in Table 4, is the weekend peak flow. As is typical of a predominantly residential area with a high commuter population, the peak flows for the sites in this study were most often seen late on a weekend morning. The Peak Dry Flow Factor is the result of dividing the peak dry weather flow for a particular site by the average flow for that site.

Because the wet weather events captured by this study did not always occur during peak times, the peak wet weather flow observed during the study at some sites was less than the peak dry weather flows observed. At such sites, the peak rainfall dependant infiltration/inflow (RDII) flow rate was calculated from the data. This flow rate was added to the peak dry weather flow observed at the site in order to calculate an estimated peak wet weather flow rate. The Peak Wet Flow Factor is the result of dividing the peak wet weather flow by the average flow for a site.

Table 4 - Peak Flow Results Summary Table

Site No.	Location	RMWD Manhole No	Existing Diameter (in.)	Average Flow (gpm)	Peak Dry Weather Flow (gpm)	Peak Dry Weather Flow Factor	Peak Wet Weather Flow* (gpm)	Peak Wet Weather Flow Factor
1	Little Gopher Canyon Rd.	MH5543	8	21	35	1.69	44	2.09
2	Old River Rd @ Golf Club Rd.	MH6053	8	30	54	1.77	70	2.30
3	Camino Del Rey on Golf Course	MH6054	10	40	75	1.87	123	3.06
4	Camino Del Rey on Golf Course	MH5410	12	312	471	1.51	531	1.70
5	Gird Rd. @ State Route 76	MH5721	12	71	110	1.55	135	1.89
6	CA-76 @ Old Highway 395	MH5798	12	86	123	1.43	132	1.53
7	15N off Freeway	MH5904	8	6	9	1.49	12	2.03
8	15S Ostrich Farm	MH5965	12	78	129	1.66	147	1.89
9	Lake Circle Dr. s/o Dulin Rd.	MH5242	12	70	130	1.85	177	2.52
10	Lake Circle Dr. s/o Dulin Rd.	MH6176	8	17	29	1.71	41	2.38
11	Via Altamira off S Old Highway 395	MH5826	8	4	9	2.50	9	2.50
12	Laketree Dr. e/o Gird Rd.	MH5039	8	9	12	1.40	16	1.85
13	Flowerwood Ln off Highway 76	MH6146	8	5	9	1.73	29	5.76
14	Highway 76 w/o Gird Rd	MH5719	12	333	498	1.49	559	1.68
16	Sweetgrass Ln. off Highway 76	MH5338	8	4	14	3.62	25	6.54
17	Thoroughbred Ln off Highway 76	MH5205	8	18	30	1.69	45	2.54
18	W Lilac Rd w/o Via Ganelli	MH5569	8	0	0	2.37	1	4.24
19	E/o intersection Camino Del Rey & Golf Club Dr	MH6070	8	16	40	2.56	39	2.45
20	Spa Haven Wy s/o Gopher Canyon Rd	MH5464	8	3	8	2.89	51	17.38

* Peak wet weather flow is calculated based on adding I/I flow to peak dry weekend flow for each flow monitor site.

4.1.1 Rain Dependent Infiltration/Inflow (RDII)

The RDII response of a sanitary sewer collection system to a wet weather event may vary according to many local factors, including the local rainfall intensity, the location of the water table with relation to the pipes of the system, and the soil saturation at the time of the event. For this reason, predicting the response of a system to a future wet weather event based upon a past event is difficult and imprecise. However, characterizing the response of a system or portion of a system (a basin) to a storm(s) can still be useful. Such characterization can be used to prioritize portions of a system for rehabilitation based upon relative response, can be used to evaluate a system or basin based upon industry standards or peer systems, or can be used to evaluate the effectiveness of rehabilitation based upon “before rehabilitation” and “after rehabilitation” characterization.

Characterization of the wet weather response of a collection system to a wet weather event requires normalization of both the event and the collection system. Normalization of the wet weather event requires describing the response per inches of rain during the event or per rainfall intensity (inches/hour). Event normalization ensures that the characterization is valid over a range of wet weather events, and not simply one particular storm. For instance, the wet weather response of Basin A may be characterized as X gallons of flow entering the system per inch of rainfall measured.

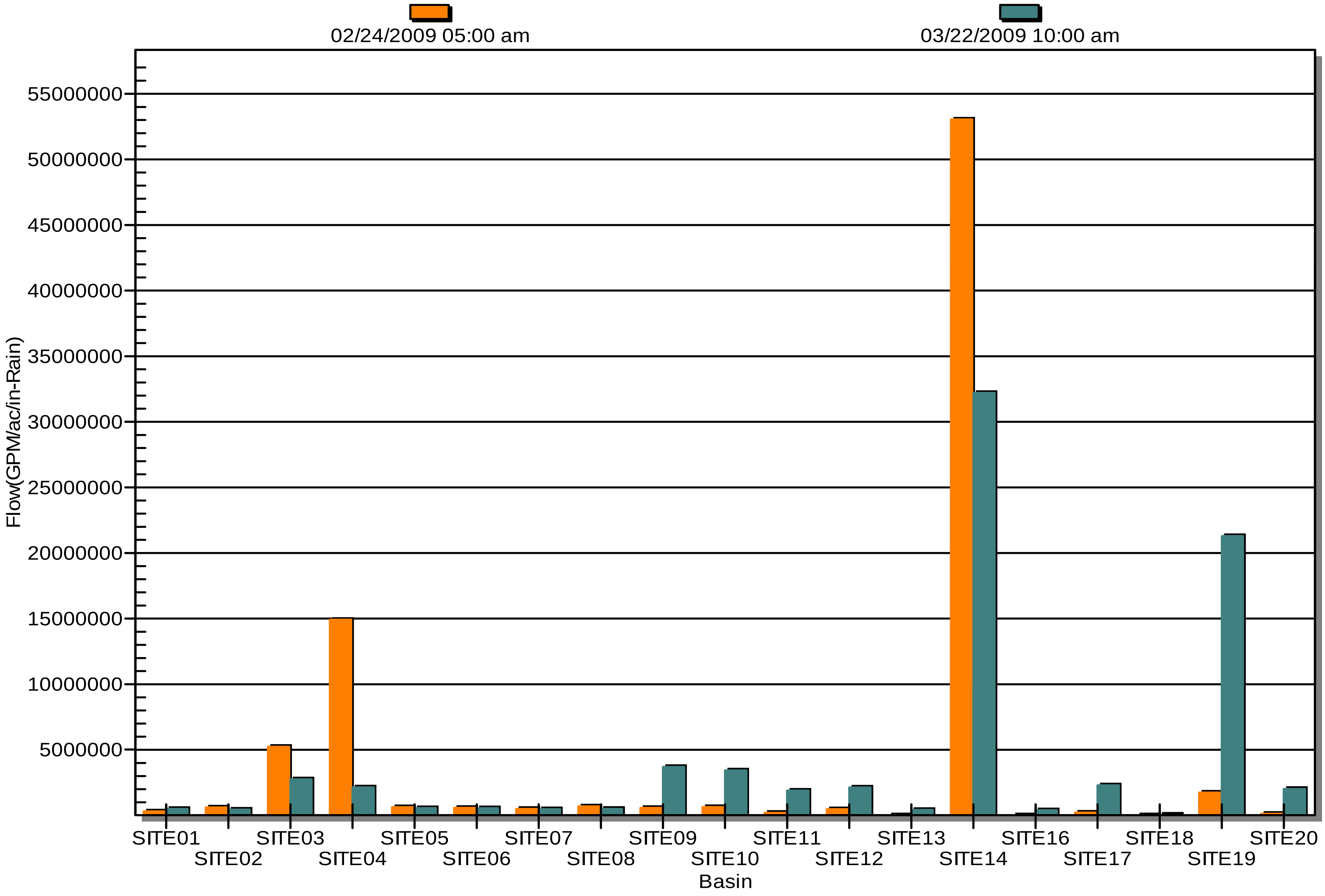
Normalization of the collection system requires expressing the wet weather response in terms of collection system or basin size, most often given in terms of pipe length (feet), pipe footprint (inch diameter-mile), or area served (acres). Because a larger basin presents more opportunity for RDII flows to enter, it is expected that larger basins will see a larger response to a wet weather event in terms of gross RDII flows measured. In order to eliminate the size of the basin as a factor and to more accurately understand the “leakiness” of a basin, the RDII flows are normalized by basin size. For instance, the wet weather response of Basin A may be characterized as X gallons per day of RDII per foot of pipe in the basin.

When the RDII response of a basin is normalized by both the wet weather event and the basin size, a true estimation of the basin’s “leakiness” can be determined. In this case, the wet weather response of Basin A may be characterized as X gallons per day of RDII per foot of pipe per inch of rain, or X gallons per day of RDII per inch-diameter mile per inch of rain. This normalized response of Basin A can be compared to that of other basins in the system, to that of other basins across the region or country, or to that of industry standards in order to evaluate rehabilitation priority and options.

Figure 2 illustrates the District’s normalized RDII response for each flow monitor site of this study, shown as gallons per day of RDII flow per acre per inch of rain. As can be seen in the figure, the majority of the sites in this study show a minimal RDII response to the storms captured in this study. Site 4 and site 14 show a higher RDII response. The response at these sites may indicate the presence of defects in pipes upstream of the site that are susceptible to flow entry.

Figure 2: Rainfall Dependent Inflow/Infiltration

Net I/I Peak Flow for Various Storms



4.1.2 Base Infiltration (BI)

Base infiltration is defined as any water inflow or infiltration into the sanitary sewer system during dry weather days. This includes water entering the sewer system from the ground through defective pipes, pipe joints, connections, or manhole walls. Furthermore, BI includes water on dry weather days entering the sewer that discharged from cellar and foundation drains, cooling-water discharges, and drains from springs and swampy areas.

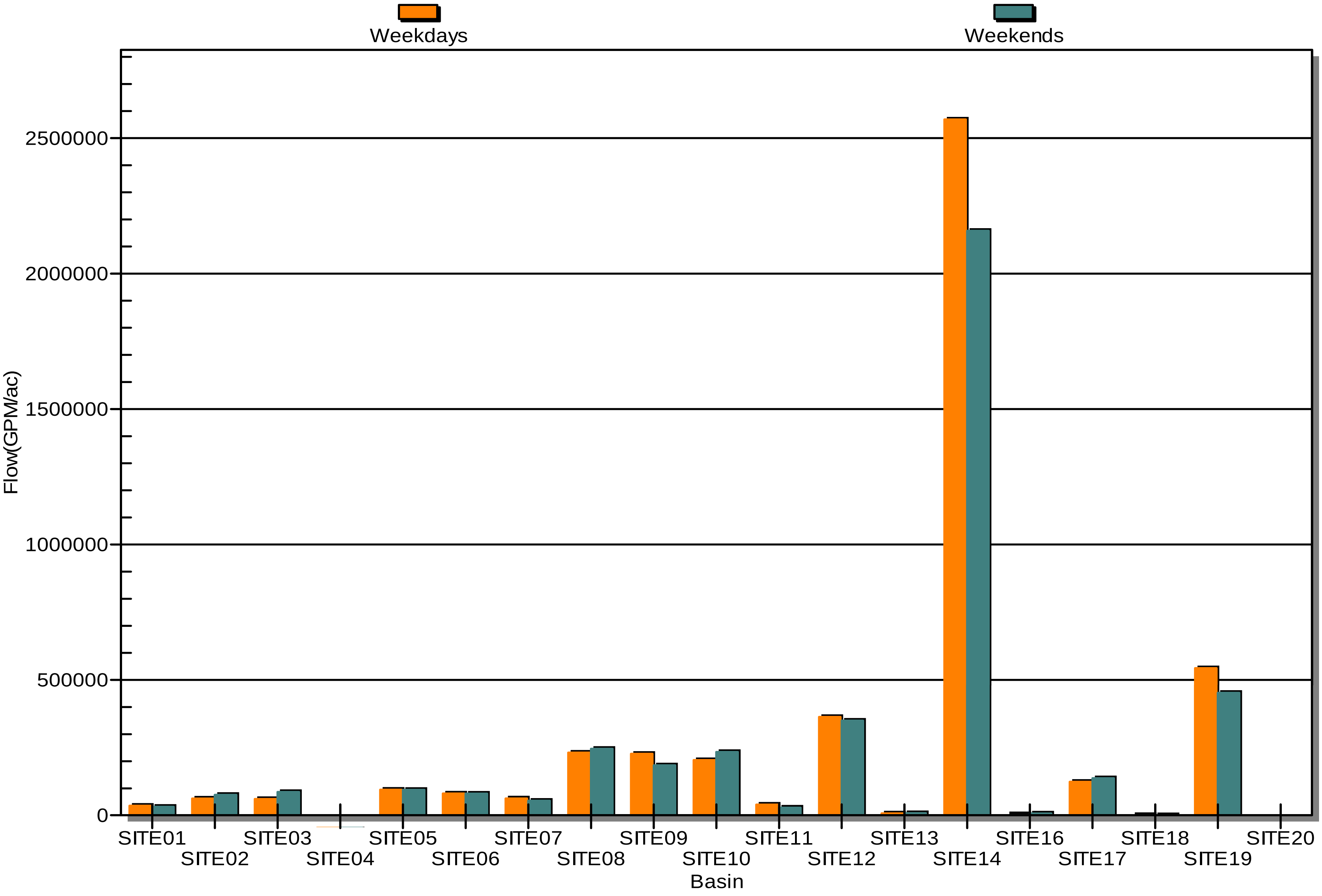
Base infiltration flows can be measured in a sanitary sewer system through sampling temperature and salinity characteristics of flows, and calculating the BI through the effects of the colder, less saline infiltration water on these measurements. Base infiltration flows can also be estimated using statistical models that compare the minimum, average, and peak flows at a particular site in order to estimate the percentage of flow that is BI.

One such statistical model, the Stevens-Schutzbach Equation, was used to estimate BI at the 19 sites in this study. The equation was applied to both typical weekend and typical weekday flows for each site, not because BI is expected to differ based upon day of the week, but because agreement between the two BI estimates provides confidence in results. The BI estimates for each site were normalized by the amount of pipe contributing flow to each site in order to prioritize sites.

The District's normalized base infiltration results are illustrated in Figure 3. As shown, Site 4 and Site 14 shows the highest normalized BI rates, just as they show the highest normalized RDII response. This RDII/BI relationship is typical because the same defects that allow for infiltration during dry periods allow for RDII entry during wet events.

Figure 3: Net Base Infiltration

Dry Day Flow



4.2 Stallion Flow Meter Mass Balance

The District provided IEC with Stallion Flow Meter data for the period observed during this flow monitor study. By performing a mass balance between the total flow seen at the bottom of the flow monitor area (the sum of flow seen at Site 01, Site 02, Site 03, and Site 04) and the flow seen at the Stallion Flow Meter, IEC determined the average unaccounted for difference entering into the Stallion Flow Meter, as shown in Table 5.

Average Difference = Stallion Flow Meter - (Site 1 + Site 2 + Site 3 + Site 4)

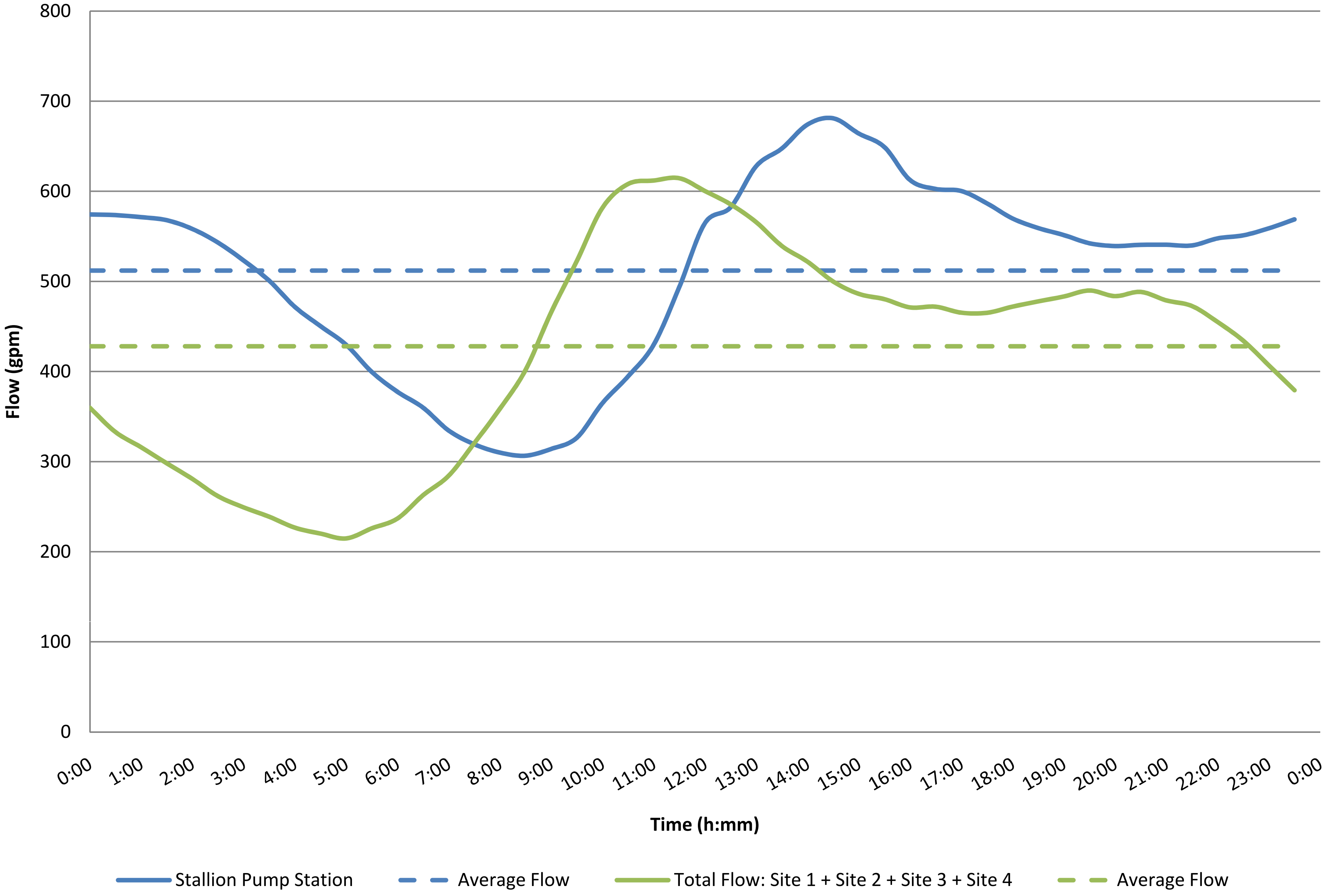
Table 5 - Total Average Difference

Average Stallion Flow Meter (gpm)	Average Observed Flow (gpm)	Average Difference (gpm)
512	420	92

Figure 4 illustrates the total average difference entering into the Stallion Flow Meter. As can be seen in the table and figure, approximately 92 gpm are unaccounted for between the temporary flow monitors and the Stallion Flow Meter. RMWD staff knows of approximately four (4) sanitary connections in the unaccounted for area. It is estimated that these additional connections contribute a maximum of 10 gpm of additional wastewater flow to the average observed flow from Table 5. In summation, the mass balance performed between the temporary flow monitor area and the Stallion Flow Meter indicates significant infiltration in the wastewater conveyance line.

Stallion Flow Meter vs. Total Flow Monitor Flow - Average Flow Mass Balance

Figure 4



4.3 Conclusions and Action Items

The 2009 Flow Monitoring Study for Rainbow Municipal Water District successfully captured dry weather and wet weather data for the wastewater collection system. Although the wet weather events captured during the study were relatively small, portions of the system showed RDII response. The flow monitoring data captured during these events have indicated areas of priority for RMWD.

The following steps can be taken to utilize the results of this study:

- Calibrate the hydraulic model to average dry and peak dry flows. A calibrated hydraulic model is required for existing and future capacity analysis, both of which are required for compliance with the SSMP.
- Use the wet weather data captured in this study to develop a design storm for analysis in wet weather scenarios of the hydraulic model. A wet weather capacity analysis involving a design storm is required for the SSMP.
- Develop land use-based wastewater generation factors for RMWD based upon basin result to help guide assess the wastewater impact of future development. Wastewater generation factors will help RMWD manage the capacity of the collection system into the future.
- Initiate further study and rehabilitation projects into Basin 4 and Basin 14 in order to isolate and remove BI and RDII sources. Removing BI and RDII will lower the risk of sanitary sewer overflows, lower current treatment costs, and free capacity in the system to be sold to future customers.
- Initiate further study and rehabilitation projects into the conveyance pipe leading into Stallion Flow Meter in order to isolate and remove BI

sources. Removing BI will lower the risk of sanitary sewer overflows, lower current treatment costs, and free capacity in the system to be sold to future customers.

- Initiate targeted Inflow and Infiltration (I&I) studies in the system. These studies may include flow monitoring small areas of the system, or prioritizing inspection and condition assessment efforts into areas shown to have noticeable RDII response in this study.

5.0 Equipment and Principles of Operation

5.1 Equipment

Open channel flow for this project was measured with temporary flow meters at twenty-four (24) locations. The flow meters used by IEC use various depth measurement and velocity measurement technologies. Each of the technologies will provide data of high quality when properly applied to specific environmental, hydraulic and physical conditions. The sensors were mounted on an expandable aluminum ring installed in the sewer pipe, normally upstream from the manhole invert. The signal from the sensors was transmitted to the monitor through a communications cable.

IEC carries a variety of flow monitoring products for all pipe capacities and types and are not bound by a specific manufacturer. For this project, IEC utilized the Isco 2150 Area Velocity (AV) flow meter at all sites. The flow meters were programmed to record the measured flow depth and velocity at five-minute intervals.

Data Logging Rain Gauge

For rainfall detection, Onset's Data Logging Rain Gauge RG2 was used. The rain gauge is a self-contained, battery-powered rainfall data collection and recording system. The Data Logging Rain Gauge integrates a HOBO® Event data logger into a tipping-bucket rain gauge. The RG2 automatically records up to 80 inches of rainfall data that can be used to determine rainfall rates, times and duration. A time and date stamp is stored for each 0.01 inch tip event.

2150 Area Velocity Module (AV)

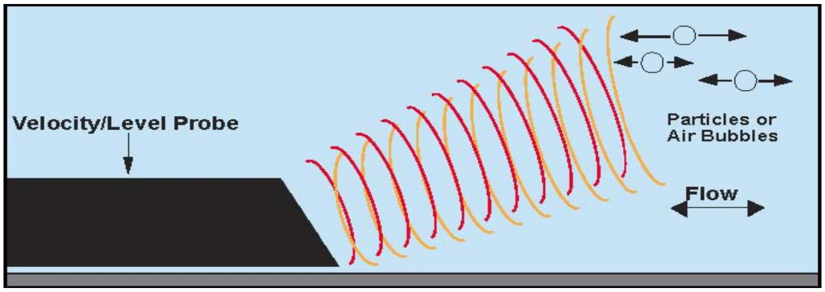
The 2150 Flow Module uses continuous wave Doppler technology to measure mean velocity. IEC typically uses the 2150 area velocity flow meters for pipe sizes ≤30 inches and continuous wave Doppler technology to measure mean velocity. The sensor transmits a continuous ultrasonic wave and measures the frequency shift of returned echoes reflected by air bubbles or particles in the flow. The 500 KHz Doppler is ideal for applications such as sewer flow monitoring, I&I Studies, combined sewer overflow (CSO) monitoring, and storm water runoff monitoring.

5.2 Principles of Operation (2150 AV)

The area velocity method is one method commonly used for automatically measuring open channel flow. A Doppler flow meter (area-velocity meter) operates by emitting into the flow ultrasonic waves of known frequency and duration from a transmitter located in the channel invert. Suspended particles and air bubbles in the flow reflect the emitted waves. The sensor receives and detects the deflected frequencies, and processes them to determine the average velocity.

The area velocity method calculates flow rate by multiplying the area of the flow by its average velocity. This is often referred to as the *continuity equation*, **Q = A * V.** The main advantage of the area velocity method is that it can be used to measure flow under a wide range of conditions such as open channel, surcharged, full pipe, submerged and reverse flow. You don't have to estimate the slope and roughness of the channel, and silt correction allows you to compensate for debris that accumulates on the bottom of the channel.

Figure 6 – Doppler Flow Meter Operations (Courtesy of Teledyne Isco)



6.0 Data and Report Management

Data Management means responsibility for managing the sewer flow data results and making this information available to those that have a stake in the use and management of water and wastewater infrastructure information. This section of the report provides a detailed reporting of the flow meter station information and flow data provided for each metered location.

6.1 Field Investigation Reports

The field investigation reports consist of the temporary flow monitoring Location Information Summary Form. The Location Information Summary Form provides three illustrations of the physical location of each flow monitoring station. Pertinent information relative to pipe details and observations, instrumentation, technician comments, and hydraulic conditions are listed. The Manhole Condition Report Form provides information relative to the manhole, site access, safety and its overall physical condition. All confined space entry permits and site calibration documents are kept on file for reference only.

6.2 Data Summary Sheet

The Data Summary Sheet is provided for a quick overview of the flow monitoring results at each location. It contains the average, minimum, and maximum values for depth of flow, velocity, and flow rate over the duration of the monitoring period.

6.3 Hydrograph Presentation

The Hydrograph is a chart that displays the change of a hydrologic variable over time. A flow data hydrograph illustrating all metered entities is presented in combination with the Data Summary Sheet. A graphical time series presentation of Depth (inches), Average Velocity (ft/s) and Flow Rate (gpm or mgd) is provided for each site. The hydrograph is created using 15-minute averages of the measured data. The stacked axis allows easy visual identification of the location's performance.

6.4 Scattergraphs

Scattergraphs, or X-Y plots of observed average velocities and flow rates versus observed depths, are provided for each site. These plots provide a graphical representation of hydraulic conditions at the sites, and can illustrate the collected data's tendency toward trending to known hydraulic conditions (i.e. Manning's Equation). These graphs are particularly useful for showing a site's hydraulic reaction to conditions such as backwater or surcharge. For this report, there are two different types of scattergraphs, the Flow Rate vs. Depth and the Average Velocity vs. Depth.

6.5 Tabular Data Presentation

Tabular Data time series records of Flow Rate (mgd or gpm), Average Velocity (ft/s) and Depth (inches) are provided as a function of time of day and date. For all monitoring locations, real-time readings are collected every five-minutes for each parameter monitored. Hourly averages are then calculated from these five-minute readings. For example, all discharge measurements recorded from time period 00:00 through 00:59 for any given day are reported as an hourly average on each row of the tabular report.

Hourly averages of the metered data are given for each day of monitoring as well as the average, hourly minimum and maximum and instantaneous minimum and maximum values. At the bottom of each day's column are summary statistics for that day, as follows:

- The *"Mean"* is the average of all instantaneous readings for that day.
- The *"Maximum and Minimum Hourly Means"* are the maximum and minimum hourly averages shown in hours 0 through 24.
- The *"Instantaneous Maximum"* is the greatest single reading data value obtained during the day.
- The *"Instantaneous Minimum"* is the smallest single reading data value obtained during the day.

7.6 Electronic Data Presentation

Final data reports are produced in electronic formats including all data plots and photographs. Flow rate, depth, average velocity and temperature data in 15-minute increments are provided in CSV format. The data are identified by the site number and the manhole identifications.

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Guide for Estimating Infiltration and Inflow

June 2014

Purpose

This Guide is intended to provide background and information for managers of wastewater collection systems on estimating the amount of infiltration and inflow (I&I) entering their collection system and for responding to National Pollutant Discharge Elimination System (NPDES) I&I permit reporting requirements.

This Guide provides methods for analyzing wastewater treatment plant influent flow data to estimate the I&I impact from the collection system as a whole. It will assist municipalities in ascertaining whether they have a significant I&I problem and, if so, what kind of problem they have. Areas (sewersheds) served by pump stations that are capable of recording flow can also be evaluated using these methods.

Background

There are three major components of wastewater flow in a sanitary sewer system, base sanitary (or wastewater) flow, groundwater infiltration and rainfall derived inflow and infiltration, more commonly referred to as inflow. Virtually every sewer system has some infiltration and/or inflow. Historically, small amounts of I&I are expected and tolerated. However, infiltration and inflow may be considered excessive when it is the cause of overflows or bypasses, or the cost to transport and treat exceeds the cost to eliminate it. In cases where the I&I may not be considered "excessive" from a cost-to-eliminate perspective but causes health or environmental risks, corrective actions are required.

Even where a system is not suffering from sanitary sewer overflows (SSOs), systems experiencing surcharging may be good candidates for further I&I investigation, as are systems where significant new growth is expected and existing collection system capacity may be inadequate or marginal for handling new customers.

State Revolving Loan Fund (SRF) applicants are generally required to evaluate the impacts of I&I on their overall system. This evaluation usually begins with an initial screening to determine whether a more complete I&I analysis will be required. The screening compares the sewered population to the treatment plant flow to determine gallons per day per person (gpdpp). The gpdpp is compared to a standard to determine if there is excessive infiltration. The states' standards vary between 100 and 150 gpdpp. The existing EPA guidance, which uses 120 gpdpp, was published in 1985 when 3.5 gallon-per-flush toilets were standard (the Energy Policy Act of 1992 required that toilets installed in new construction use a maximum of 1.6 gallon per flush (low-flow toilets)).

Some guidance documents use the term excessive infiltration/inflow. This can mean quantities of I&I which can be economically eliminated from a sewer system as determined in a cost-effectiveness analysis that compares the costs for correcting the I&I conditions to the total costs for transportation and treatment of the infiltration/inflow. I&I which causes SSOs is considered excessive.

Municipalities will be well served to understand the dimensions and nature of any I&I problems. A clear set of goals is important for keeping an I&I program focused.

The following is a sample of possible goals:

- To reduce ratepayer costs for transporting and treating wastewater by implementing all cost-effective I&I reduction projects within 10 years.
- To minimize liability from water pollution and public health risks by eliminating sanitary sewer overflows in storm events.
- To eliminate sufficient I&I to avoid the capital costs of wastewater treatment plant capacity expansion in anticipation of 10% population growth over the next 20 years.
- To eliminate sufficient I&I to avoid the capital costs of interceptor expansion which will be needed to support the build-out of certain neighborhoods.
- To eliminate enough I&I to offset the environmental and regulatory impact of sewer system expansion and increased water demand over the next 15 years.

In some cases, high levels of infiltration can lower groundwater levels and can cause significant hydrologic impacts to nearby streams. The health of tributary streams is critical to the health of main stem rivers, and reduced flows can impair the fish community by decreasing dissolved oxygen and available habitat, increasing water temperatures, and concentrating pollutant levels.

Finally, just as collection system capacity problems may indicate excessive inflow, the same can be said for treatment plant capacity problems. Your state agency can provide you with treatment plant design standards which can then be compared with your influent flow data. The Ten States Standards for Wastewater Facilities is also a good reference source.

Data Collection

To assess extraneous water entering your system at least a year of influent flow data to the treatment facility should be examined.

For infiltration analysis, flow data collected during the high groundwater periods is used. The Average Dry Weather (ADW) flow can be determined from analyzing a one to two week period during seasonal high water that is not influenced by rainfall. For the northeast, this is usually in the spring when the frost line is receding and the snow is melting. The ADW flow includes the sanitary flow plus infiltration, which can be separated into its individual components.

For inflow analysis, the Average Wet Weather (AWW) flow can be estimated from flow data for a one week period when there has been significant rain. If a single storm event is used to analyze wet weather inflow, it should be an event large enough to cause surface ponding and runoff.

Definitions of terms used in Calculating Inflow and Infiltration

Average Annual Flow - The total annual volume divided by 365 days. This value is approximated by the mean of the twelve monthly average flows.

Average Annual Infiltration - The average of the monthly minimum flows.

Average Annual Inflow - From the average annual flow, subtract the base sanitary flow and average annual infiltration.

Average Dry Weather Flow (ADW) - Flow during a period of extended dry weather (7 to 14 days) and seasonally high groundwater. Flow includes sanitary flow and infiltration, and excludes significant industrial and commercial flows (assumes no inflow during dry weather conditions).

Base Sanitary Flow (BSF) - The portion of wastewater which includes domestic, commercial, institutional, and industrial sewage and specifically excludes infiltration and inflow. (See Estimating Base Flow, below).

Delayed Inflow volume - The portion of total inflow which is generated from indirect connections to the collection system or connections which produce inflow after a significant time delay from the beginning of a storm. Delayed inflow sources include: sump pumps, foundation drains, indirect sewer/drain cross-connections, etc. Rainfall-induced infiltration cannot be distinguished from delayed inflow and is therefore included as part of delayed inflow. Delayed inflow sources have a gradual impact on the collection system and flow decreases gradually upon conclusion of the rainfall event, and after peak inflow caused by direct connections.

Direct Inflow Volume- The portion of total inflow volume which is from direct connections to the collection system such as catch basins, roof leaders, manhole covers, etc. These inflow sources allow stormwater runoff to rapidly impact the collection system.

Dry Weather Flow (DWF) - All flow in a sewer (includes sanitary flow and infiltration) except that caused directly by rainfall. Measured during a period of extended dry weather (7 to 14 days) and seasonally high groundwater.

Groundwater Infiltration (GWI) – Measured during average dry weather flow period (see above). The average of the low nighttime flows (midnight to 6 am) per day for the same time period, minus significant industrial or commercial nighttime flows.

Hydrograph - A graph showing stage (the height of a water surface above an established datum plane), flow, velocity, or other property of water with respect to time.

Infiltration - Water other than sanitary wastewater that enters a sewer system from the ground through defective pipes, pipe joints, connections, or manholes. Infiltration does not include inflow.

Inflow - Water other than sanitary wastewater that enters a sewer system from sources such as roof leaders, cellar/foundation drains, yard drains, area drains, drains from springs and swampy areas, manhole covers, cross connections between storm sewers and sanitary sewers, and catch basins. Inflow does not include infiltration.

Inflow volume - The total volume of inflow from a single storm event including both direct and delayed inflow. Total inflow is the area between the storm event hydrograph and the dry weather hydrograph.

Maximum Daily Flow - The highest flow during a 24 hour period.

Maximum Daily Infiltration - The highest daily flow at seasonal high groundwater after a dry period of three days or more minus the base sanitary flow.

Maximum Weekly Infiltration - The highest 7 day average flow at high groundwater after a dry period of three or more days minus the base sanitary flow.

Maximum Monthly Infiltration - The highest monthly average flow during dry or minimal rain period minus the base sanitary flow.

Maximum Daily Inflow - The highest daily wet weather flow minus the base sanitary flow and the infiltration prior to the rain event.

Maximum Weekly Inflow (includes delayed infiltration) - The highest 7 day average wet weather flow minus the base sanitary flow and the infiltration prior to the rain event.

Maximum Monthly Inflow - The highest monthly flow after subtracting the base sanitary flow and infiltration.

Peak Hourly Dry Weather Flow - The highest one hour flow after a dry period of three or more days.

Peak Hourly Inflow - The highest one hour flow rate during wet weather minus the base sanitary flow and the infiltration prior to the rain event.

Peak Hourly Wet Weather Flow – The highest one hour flow during a significant rain event.

Peak Infiltration- The highest nighttime (midnight to 6 am) flow during high groundwater (usually in early spring).

Peak Instantaneous Wet Weather Flow - The peak flow during a significant rain event day when the ground water is seasonally high.

Peaking Factor - The ratio of peak hourly flow to average daily flow.

Rainfall-Induced Infiltration - The short-term increase in infiltration which is the result of a rain event. Rainfall-induced infiltration is a portion of delayed inflow.

Wet Weather Flow- The highest daily flow during and immediately after a significant storm event. Includes sanitary flow, infiltration and inflow.

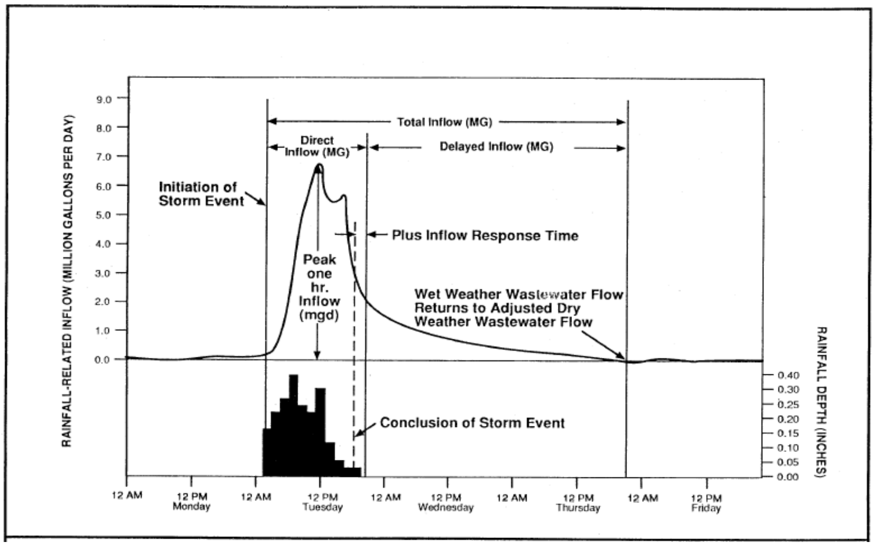

Figure 1: **Hydrograph helps visualize inflow as the response to wet weather flow (from MassDEP 1993)**

Estimating Base Sanitary Flow

The sanitary portion of the wastewater flow can be estimated through two methods, which can be used to 'check' each other - flow meter data and water consumption (if all sewer customers are on metered water).

The first method is to analyze the wastewater flow data at the treatment facility during a dry weather period of 7 to 14 days. It is useful to choose the dry weather period during seasonal high water as you will be able to determine the peak infiltration rate at the same time. From the flow data, calculate the average daily flow for the dry weather period (Average Dry Weather – ADW - flow). The base sanitary flow (BSF) can be estimated by subtracting the groundwater infiltration (GWI) flow from the average daily dry weather wastewater (ADW) flow. (See Estimating Infiltration below).

In the second method, water usage records can be used to estimate the base sanitary flow for the sewered population. The best time to estimate flow using this method would be when outdoor water uses are low and wastewater from a residential area can be assumed to be the same as the billed water use. In the northeast, this would typically be in the winter months prior to landscaping and swimming pool use. Groundwater infiltration can be estimated as the difference between the monitored wastewater flow and the billed water use.

Estimating Infiltration

Groundwater infiltration (GWI) can be estimated from influent flow data collected during a dry weather period at high groundwater. The dry weather period selected should be the same period as for estimating the BSF, however, it is more important to estimate GWI during high seasonal ground water. Dry weather is defined as when it has been at least three days without a rain event. During dry weather, inflow is expected to be zero.

During seasonal high groundwater, which usually occurs after snow melt and soil thaw, infiltration will be at its highest. During this period, the infiltration rate can be quantified by averaging the nighttime flows (midnight to 6 am) over several days, during dry weather conditions. The nighttime flows can be assumed to be mostly groundwater (after subtracting significant industrial or commercial nighttime flows).

In most cases, the GWI rate will approximate the maximum weekly infiltration. The maximum daily infiltration will be higher and maximum monthly infiltration will be lower.

Estimating Inflow

Inflow represents the influence of wet weather on the sewer system and is calculated by subtracting out the sanitary wastewater and infiltration flow during a time that the system has been influence by rain. Flow data during a significant storm event should be compared to the dry weather data immediately preceding the storm when groundwater conditions are similar. The rate and volume of inflow can be estimated by subtracting the base sanitary flow and infiltration flow data from the wet weather flow data.

The peak inflow rate and the total inflow volume can be calculated from the flow records. The peak inflow rate is the largest rate difference, over a one hour period, between the storm event flow data and the dry weather flow prior to the event. The total inflow volume from a storm event can be apportioned into two components: direct inflow and delayed inflow.

Direct inflow is the portion of the inflow which rapidly increases soon after the start of the storm and decreases swiftly upon conclusion of the event. The time it takes for inflow from the nearest sub-basin to reach the treatment facility can be estimated as the time difference between initiation of the storm event and the increase in observed flow. The direct inflow ends at a time after the conclusion of the storm approximately equal to the inflow response time from the furthest sub-basin.

Delayed inflow is the portion of the inflow which decreases gradually upon conclusion of the storm and after the peak inflow caused by direct connections. Delayed inflow is the inflow Beginning at the conclusion of direct inflow and ending at a time when dry weather flow resumes. It is expected that a portion of the delayed inflow includes rainfall-induced infiltration.

In some cases, a second storm will impact the flow data before dry weather flow resumes. When this occurs, the expected delayed inflow can be extrapolated from the flow data collected prior to the second storm.

Estimating Infiltration and Inflow (I&I)

Maximum monthly I&I rate can be estimated by subtracting the BSF from the maximum monthly average flow.

Average annual I&I rate can be estimated by subtracting the BSF rate from average annual flow rate.

Annual I&I volume can be estimated by multiplying the average annual I&I rate by 365 days.

Summary

Sewers and treatment facilities are designed around expected average and maximum flows. Excess storm and groundwater entering the sewer system through I&I robs the system of its valuable capacity, puts a burden on operation and maintenance, and reduces the life expectancy of the treatment facility. Sewer surcharging, back-ups and overflows all require emergency response and contribute to disruption of operations.

Integrating I&I investigation and corrective action into a municipality's normal public works budget can allow an incremental approach to continuous improvement and help defer capacity expansion projects.

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