FInal REPORT

Dublin San Ramon Services District

Water, wastewater, recycled water

2017 Wastewater Collection System Master Plan

WEST YOST ASSOCIATES

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FINAL REPORT | December 2019

2017 Wastewater Collection System Master Plan

Prepared for

Dublin San Ramon Services District

Project No. 406-21-17-56

Project Manager: Jon M. Wells, PE	1/10/2020 Date
QA/QC Review: Jeffrey D. Pelz, PE	1/10/2020 Date

WEST YOST ASSOCIATES

Concord

1001 Galaxy Way, Suite 310
Concord, CA 95420
(925) 949-5800

Davis

2020 Research Park Drive, Suite 100
Davis, CA 95618
(530) 756-5905

Eugene

1650 W 11th Ave. Suite 1-A
Eugene, OR 97402
(541) 431-1280

Irvine

6 Venture, Suite 290
Irvine, CA 92618
(949) 517-9060

Phoenix

4505 E Chandler Boulevard, Suite 230
Phoenix, AZ 85048
(602) 337-6110

Pleasanton

6800 Koll Center Parkway, Suite 150
Pleasanton, CA 94566
(925) 426-2580

Portland

5 Centerpointe Drive, Suite 130
Lake Oswego, OR 97035
(503) 451-4500

Sacramento

8950 Cal Center Drive, Bldg. 1, Suite 363
Sacramento, CA 95826
(916) 306-2250

Santa Rosa

2235 Mercury Way, Suite 105
Santa Rosa, CA 95407
(707) 543-8506

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ABS	Acrylonitrile Butadiene Styrene
AC	Asbestos Cement
ADWF	Average Dry Weather Flows
BWF	Base Wastewater Flow
Camp Parks	Parks Reserve Forces Training Area
CCTV	Closed Circuit Television
CIP	Capital Improvement Program
CIPP	Cured-in-place Pipe
CIWQS	California Integrated Water Quality System
CSMP	Collection System Master Plan
D	Diameter
d	Depth of Flow
DIP	Ductile Iron Pipe
District	Dublin San Ramon Services District
DOF	California Department of Finance
DU	Dwelling Unit
EPA	United States Environmental Protection Agency
fps	Feet Per Second
GIS	Geographical Information System
GIS ID	GIS Identifiers
gpd	Gallons Per Day
gpm	Gallons Per Minute
gpm	Gallons per Minute
GWI	Groundwater Infiltration
H2OMap Sewer	H2OMap Sewer Pro Software
HDD	Horizontal Directional Drilling
I&I	Infiltration and Inflow
LAVWMA	Livermore-Amador Valley Water Management Agency
mgd	Million Gallons Per Day
NASSCO	National Association of Sewer Service Companies
NOAA	National Oceanic and Atmospheric Administration
PACP	Pipeline Assessment Certification7-8 Program
Parks RFT	Parks reserve Forces Training Area
PCL	Private Sewer Line
PDWF	Peak Dry Weather Flow
PSLs	Private Sewer Laterals
PVC	Polyvinyl Chloride
PWWF	Peak Wet Weather Flow

q	Pipe Under Design Conditions
Q	Full Pipe Capacity
RDII	Rainfall-Dependent Inflow and Infiltration
SCADA	Supervisory Control and Data Acquisition
SSOAP	Sanitary Sewer Overflow Analysis and Planning
SSOs	Sanitary Sewer Overflows
SWRCB	State Water Resources Control Board
TM	Technical Memorandum
VCP	Vitrified Clay Pipe
West Yost	West Yost Associates
WR	Weighted Rating
WWTP	DSRSD Wastewater Treatment and Biosolids Facility

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EXECUTIVE SUMMARY

ES.1 OVERVIEW AND NEED FOR COLLECTION SYSTEM MASTER PLAN UPDATE

The Dublin San Ramon Services District (District) wastewater service area includes the City of Dublin in Alameda County and the southern portion of the City of San Ramon in Contra Costa County. The existing wastewater service area encompasses approximately 13,340 acres, or 20.85 square miles. Within the wastewater service area there are currently 207 miles of gravity mains, one permanent lift station, and one temporary lift station. The permanent lift station has 26 feet of force main.

While the District is continually planning and designing collection system improvements to ensure a safe and reliable system, a comprehensive review of the City's collection system facilities has not been completed since 2005. With changes in customer's water use in response to recent drought conditions, and corresponding changes in wastewater flows, and several new development projects proposed throughout the District's wastewater service area, there is a need for an updated Collection System Master Plan (CSMP) to evaluate the collection system's ability to meet existing and projected future flows and identify improvements needed to address system deficiencies.

The City's existing collection system and sewer service area can be seen on Figure ES-1.

ES.2 COLLECTION SYSTEM MASTER PLAN GOALS AND OBJECTIVES

The objective of this CSMP is to guide the District's remaining capital improvement projects and establish appropriate Capacity Reserve Fees to fund these projects while recognizing the District's mission of providing wastewater service in a safe, efficient, and environmentally responsible manner. The Capacity Reserve Fees are being calculated as part of the CSMP project, but as will be seen in the CSMP report outline provided below, the Capacity Reserve Fees are not included in the CSMP document itself. Rather, the Capacity Reserve Fees will be described in a separate, stand-alone document that is based on and directly aligned with the findings and conclusions of the CSMP.

Further objectives of the CSMP are to develop solutions and policies for the long-term management of the collection system, including Inflow & Infiltration (I&I) management and Private Sewer Lateral (PSL) policies. Specific objectives are listed in Table ES-1 with references to specific chapters and appendices of this CSMP.

Table ES-1. Collection System Master Plan Objectives	
Collection System Master Plan Objective	Report Location
Evaluate and review available information on the existing wastewater collection system that defines its current capabilities	**Chapter 2** Existing System Description
Establish existing wastewater flow factors, peaking factors and Rainfall Dependent Inflow and Infiltration factors so that Average Dry Weather Flow, Peak Dry Weather Flow, and Peak Wet Weather Flow values for existing and for buildout conditions can be developed.	**Chapter 3** Existing and Future Design Flows Refer to Appendix A for information on the temporary flow monitoring program that was the basis for the design flow development
Confirm the Districts standard collection system performance criteria and re-evaluate and better define specific collection system performance criteria that establish the foundation of the District's wastewater collection system planning	**Chapter 4** Collection System Design and Performance Criteria
Update and validate the City's existing wastewater collection system hydraulic model to accurately reflect the existing collection system configuration and have a 1:1 correlation with the District's wastewater system Geographic Information System (GIS), and to be used as a planning tool to evaluate the need for future collection system improvements	**Chapter 5** Hydraulic Model Update Refer to Appendix B for information on the update and validation of the District's wastewater collection system hydraulic model
Use the updated hydraulic model of the District's collection system to analyze and identify improvements that provide appropriate capacity for the existing system and future system at buildout design flows	**Chapter 6** Capacity Evaluation
Recommend future programs and actions to manage the long-term condition and performance of the District's collection system.	**Chapter 7** Long Term Management Strategies Refer to Appendix C for information on the District's potential strategies for managing Private Sewer Laterals
Develop a plan that identifies and prioritizes required wastewater collection system improvements to meet estimated existing and buildout flows	**Chapter 8** Prioritized Capital Improvement Program Refer to Appendix D for details on the background information used to develop the costs for the capital improvement program

ES.3 EXISTING AND FUTURE DESIGN FLOWS

In this CSMP, the capacity of the District's collection system is evaluated versus design wastewater flow requirements under existing and future conditions. As is typical, the design flow for the City's collection system is defined to be the Peak Wet Weather Flow (PWWF) for existing and future conditions in the collection system. PWWF is developed using Average Dry Weather Flow (ADWF), Peak Dry Weather Flow (PDWF), and Rainfall Dependent Infiltration and Inflow (RDII) components.

A summary of the projected design flows for existing and future conditions developed in this CSMP are summarized in Table ES-2, and are described below.

Table ES-2. PWWF Summary for District Collection System

Year	ADWF, mgd	PDWF, mgd	RDII, mgd	PWWF, mgd
Calibrated Existing	6.63	9.95	8.90	18.85
Rebounded Existing	7.16	10.75	8.90	19.65
2020 Projected	7.58	11.36	9.33	20.69
2025 Projected	8.24	12.35	9.75	22.10
2035 Projected	9.72	14.57	10.46	25.03

Between the years 2013 to 2016, California experienced a severe three-year drought. This drought significantly impacted water demand patterns and sanitary sewer generation patterns throughout the state, and has made it difficult to establish a true "baseline" water demand or wastewater flow for this time period. This difficulty in establishing a baseline complicates the development of reliable future projections.

A baseline ADWF independent of drought impacts was calculated for this CSMP projected by applying a Return-to-Sewer ratio to average day water demands. This non-drought baseline for existing flows is identified as the existing rebounded ADWF. Future ADWF projections were developed using the baseline existing rebounded ADWF projections as a starting point. Projected flows from reasonably foreseeable development projects, as identified by planning staff for the Cities of Dublin and San Ramon, were added to the existing rebounded ADWF projections, in addition to projected flows from other vacant areas.

Historical PDWF was determined based on daily hydrographs for flows entering the District's WWTP, as well as from flow monitoring data. A dry weather peaking factor of 1.50 was observed, and since the dry weather peaking factor is not expected to vary significantly in the future, that same factor was used to project future PDWF. Detailed information on the flow monitoring program can be found in Appendix A.

Existing wet weather flows were evaluated using the R-T-K Method. The R-T-K factors are utilized in the hydraulic model to generate hydrographs from each tributary area to represent peak wet weather flows during and immediately after rainfall events. The R-T-K Method utilizes a series of three triangular hydrographs that represent short-term, medium-term, and long-term rainfall response. The R-T-K factors used in the CSMP were estimated via EPA Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox. The 2017 flow monitoring data and the storm in early April 2017 served as the basis for the PWWF calibration. The R-T-K factors for each flow monitoring basin were used for both existing and future conditions.

A complete description of the development of the ADWF, PDWF and PWWF for the City's collection system is described in Chapter 3.

ES.4 DESIGN AND PERFORMANCE CRITERIA

This CSMP utilizes existing rebounded and future design flows described above to evaluate the capacity requirements of the City's collection system. Design flow factors and the performance criteria by which the collection system performance is evaluated is described in Chapter 4. The performance criteria address the gravity mains, lift stations, and force mains. Where the performance evaluation identifies recommended improvements, these improvements shall be designed with the goal of being in accordance with the District's current facility planning guidelines, standard specifications and details, and development plan check and procedures manual.

ES.5 HYDRAULIC MODEL UPDATE

The hydraulic model developed for the 2005 Master Plan was a skeletonized model that contained only the trunk gravity mains from the District's collection system. Small diameter gravity mains were excluded from the hydraulic model. For this CSMP, the District desired a more comprehensive evaluation of collection system capacity, including the small diameter gravity mains that predominate the collection system. Further, the District desired that a clear link be developed between individual parcel flows and their connection to the collection system. Such a link requires that all gravity mains, regardless of diameter, be included in the hydraulic model. Therefore, as part of this CSMP, the hydraulic model has been updated to include a network that contains all collection system gravity mains.

As described in Chapter 5, a gap analysis was performed to identify gaps in the existing GIS information (such as invert elevations) that were needed for the purposes of modeling. For these gaps, modeling assumptions were made and documented in Appendix B. It is a recommendation of this CSMP that in the future the City perform field verification of the higher priority gap analysis findings to improve the accuracy of the model.

ES.6 HYDRAULIC MODEL CAPACITY ANALYSIS

The design flows developed as described in Chapter 3 were used in the model updated as described in Chapter 5 to evaluate the capacity of the District's wastewater collection system. The results of this evaluation are presented in Chapter 6. The hydraulic model was used to evaluate the capacity of the collection system under Rebounded Existing, 2020, 2025, and 2035 flow conditions. For each flow condition, the hydraulic model identified the gravity mains that violated the capacity performance criteria. In addition, the hydraulic model routed flows to the collection system lift stations so that the capacity of the lift stations could be assessed.

The preliminary hydraulic results provided by the model were reviewed and vetted to refine the preliminary results. The result of this review is list of areas that have identified as capacity deficient, and a lit of areas for which further information should be gathered to confirm the hydraulics of the collection system. Because the District was worked proactively throughout the years to identify and implement the capacity required for growth and development within the collection system service area, the capacity deficiencies identified in Chapter 6 are relatively small in scope and extent.

ES.7 LONG TERM MANAGEMENT ANALYSIS

Chapter 7 of the CSMP evaluates the collection system from a long-term perspective that includes both capacity and condition of the collection system assets. The District is one of the many agencies in California that is facing challenges in the operation and management of the collection system that goes beyond providing capacity for new growth and development. Deferred maintenance that took place as resources were focused on new growth has resulted in a need for focus on the condition of collection system assets. Aging infrastructure requires a different management strategy than younger systems; one which addresses system condition, performance, and current maintenance issues. A long-term management plan provides proactive utility management strategies which will allow the District to sustainably manage the wastewater collection system both now and into the future.

The District is currently experiencing the transition from owning and operating a younger growth-driven collection system to owning and operating an older, maintenance-focused collection system. As discussed previously, the District's wastewater service area is approximately 84 percent developed – 99 percent within the City of San Ramon and 74.5 percent within the City of Dublin. Much of this development in these two cities has occurred over the past 10 years, during which the population in the Cities of San Ramon and Dublin increased by almost 50 percent.

The District has identified management of Private Sewer Laterals (PSLs) and management of I&I as two high priority focus areas for this CSMP. Strategies include evaluation of PSL policy and identification of areas of emphasis for reduction of I&I. Details of potential PSL policies can be found in Appendix C. Chapter 7 provides background on the potential focus areas and an evaluation of each based on the District's current and long-term needs. This chapter concludes with long-term management strategy recommendations including integration of the hydraulic capacity evaluation results found in Chapter 6.

ES.8 RECOMMENDED COLLECTION SYSTEM IMPROVEMENTS

Recommended improvements were developed for existing and buildout conditions as part of the Sewer Master Plan.

ES.8.1 Existing and Buildout Collection System Evaluations

The District's collection system was evaluated to assess the system's ability to meet the recommended collection system planning and design criteria under existing rebounded and buildout flow conditions and to identify needed improvements. The findings and recommendations of these evaluations are summarized below.

Chapter 8 provides details of the recommended CIP projects that were identified in Chapter 6 and Chapter 7. These CIP projects have been prioritized based on the development timeline that drives the need for the project as well as the risk posed by the deficiency being corrected or each project. The recommended collection system CIP projects are described below and shown on Figure ES-2.

The recommended collection system improvements for existing rebounded design flows are as follows:

- Upsize 2,413 feet of 8-inch to 12-inch gravity main starting on Vomac Road from Shannon Ave and continuing east on Landale Ave, Donohue Drive, and Irving Way to Ironwood Drive (Project No. EX-CIP-P01). The 8-inch gravity main in Donohue Drive between Gardella Drive and Hillrose Drive should be blocked to prevent splitting flow from the gravity main in Hillrose Drive to the gravity main in Donohue Drive. This blockage would prevent an extension of the required improvement project further to the southeast, which is located in easement area.
- Upsize 1,048 feet of 10-inch gravity main to 12-inch gravity main in Dublin Boulevard between Clark Avenue and Sierra Court. The siphons proximate to these gravity mains are not included as part of the project. (Project No. EX-CIP-P02).
- Upsize 1,262 feet of 36-inch and 39-inch gravity main to 42-inch gravity main in Village Parkway south of Dublin Boulevard (Project No. 2023-CIP-P01). These gravity mains are recently lined but are still recommend for upsizing due to hydraulic deficiency.

The recommended collection system improvements for future design flows are as follows:

- Upsize 731 feet of 18-inch gravity main to 21-inch gravity main in Dublin Boulevard between Amador Plaza Road and Village Parkway in 2020 (Project No. 2023-CIP-P02). The recommended future system improvements should be implemented when flows approach those projected for 2020.
- Construction of 1,300 feet of 15-inch gravity mains in Croak Rd from N. Terracina Dr to Dublin Blvd (Project No. 2025-CIP-P01). Future development that is planned within the District's wastewater service area will require an extension of the collection system to serve currently undeveloped and unserved areas. These 15-inch gravity mains represent the trunk lines that will be constructed by the District; smaller diameter gravity mains will be the responsibility of the developers.
- Construction of a parallel relief gravity main for the existing 42-inch trunk from Stoneridge Drive downstream to the WWTP influent line (to the point where it becomes 48-inch pipe and turns west into the WWTP) in 2025. This project includes difficult construction because of easement alignments (Project No. 2035-CIP-P01). The recommended future system improvements should be implemented when flows approach those projected for 2035.

In addition to the improvements to the District's collection system described above, future development that is planned within the District's wastewater service area will require an extension of the collection system to serve currently undeveloped and unserved areas. Although this extension of infrastructure will be funded entirely by the future developer(s) and therefore is not included in the CIP improvements, a preliminary layout and sizing plan for this infrastructure was developed in the hydraulic model to aid in the orderly extension of the collection system in the future.

The preliminary layout of the future infrastructure is based upon the likely future orientation of roads but is subject to change as development plan changes. The estimated slopes of the proposed gravity mains were estimated based upon the topography of the area to be developed. The proposed infrastructure is shown on Figure ES-2.

ES.8.2 Opinion of Probable Project Costs

Chapter 8 of this CSMP provides a summary of recommended collection system improvements, along with an opinion of probable project costs for the recommended collection system improvements to support the Districts existing and future wastewater flows.

A complete description of the assumptions used in the development of the opinion of probable construction cost is provided in Appendix D. The probable construction costs are included for each project in Table ES-3.

Table ES-3. Summary of Recommended Capital Improvement Projects and Estimated Cost

CIP ID	Improvement Type	Was this a project in the 2005 SMP?	Estimated Conceptual Construction Cost, dollars	Estimated Conceptual Total Project Cost, dollars
EX-CIP-P01	Gravity Main Upsize	Yes	832,000	1,410,000
EX-CIP-P02	Gravity Main Upsize	Yes	398,000	675,000
2023-CIP-P01	Gravity Main Upsize	No	1,676,000	2,832,000
2023-CIP-P02	Gravity Main Upsize	No	485,000	820,000
2025-CIP-P01	New Construction	Yes	776,000	1,311,500
2035-CIP-P01	New Construction	Yes	3,991,000	6,745,000
		Total	8,158,000	13,793,500

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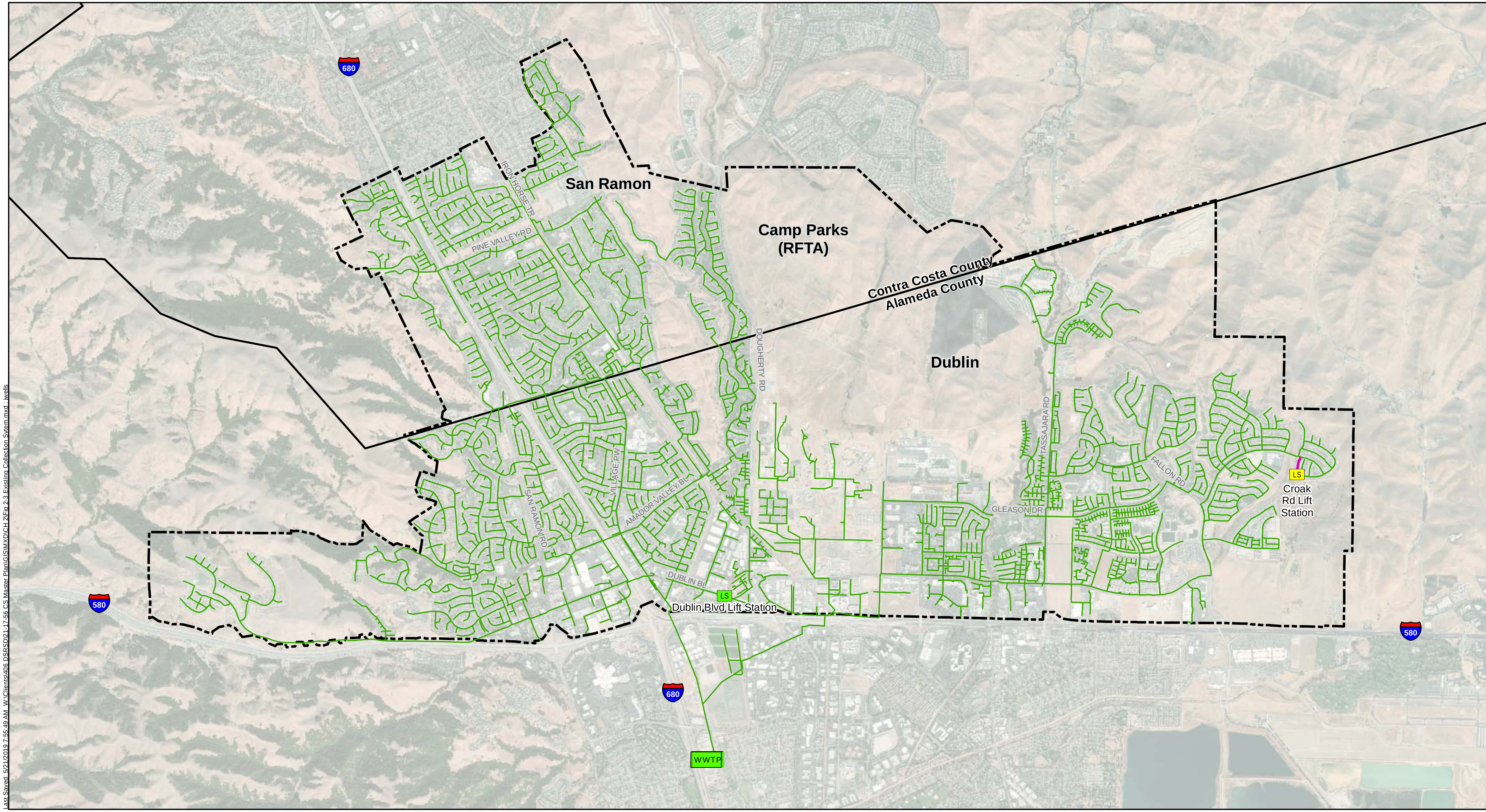

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Symbology

- WWTP
- Permanent Lift Station
- Temporary Lift Station
- Gravity Main
- Temporary Force Main
- Wastewater Collection Service Boundary

N

0 1,600 3,200

Scale in Feet

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Figure ES-1

Existing Collection System

Dublin San Ramon Services District
Collection System Master Plan

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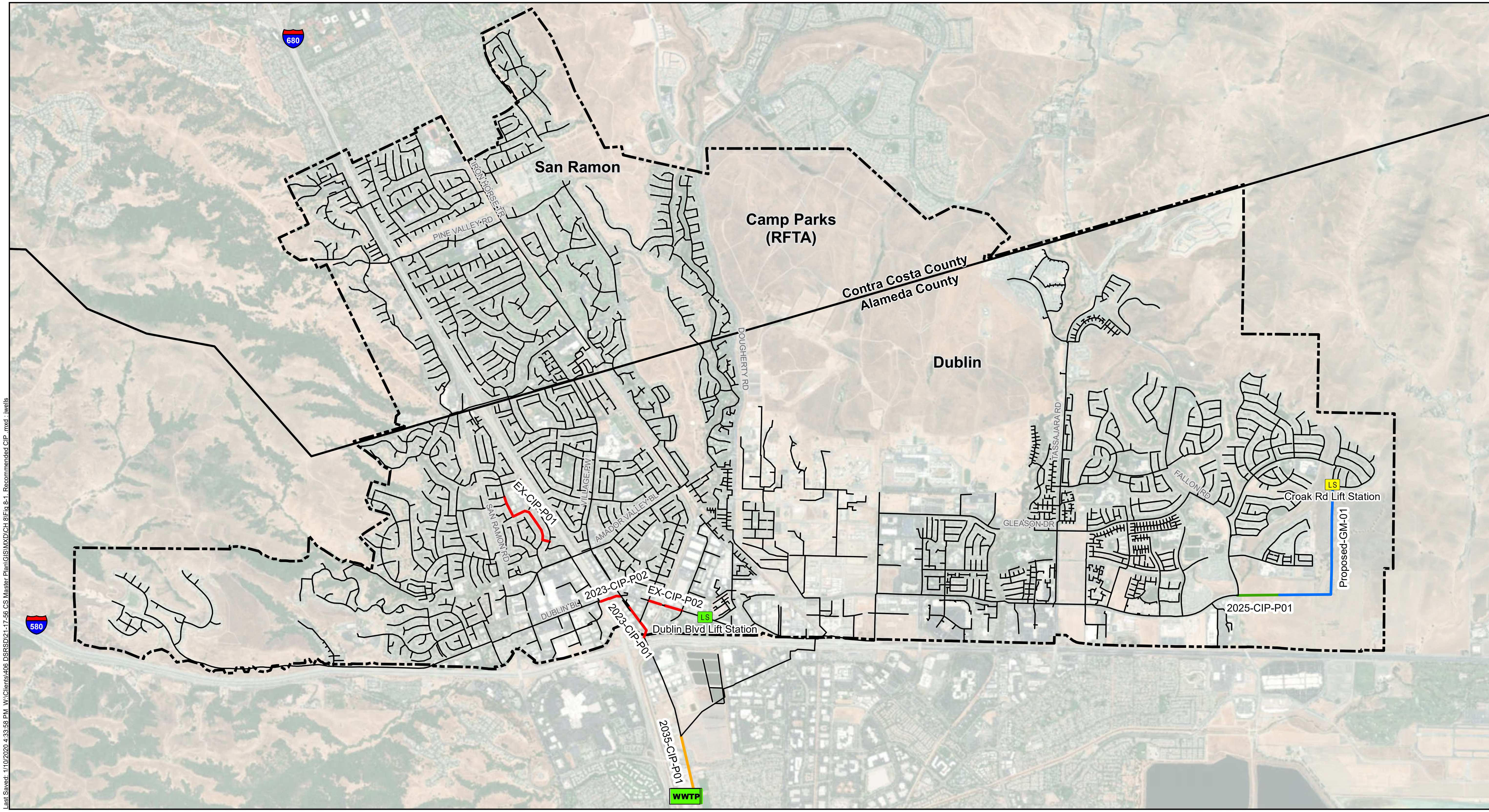

Symbology

WWTP WWTP

LS Permanent Lift Station

LS Temporary Lift Station

Gravity Main

Parallel Existing Gravity Main

Replace Existing Gravity Main

New Gravity Main (Developer Funded)

New Gravity Main (District Project)

Wastewater Collection Service Boundary

N

0 1,600 3,200

Scale in Feet

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Figure ES-2

Recommended CIP Projects

Dublin San Ramon Services District
Collection System Master Plan

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CHAPTER 1
Introduction

1.1 OVERVIEW AND NEED FOR COLLECTION SYSTEM MASTER PLAN

The Dublin San Ramon Services District (District) wastewater service area includes the City of Dublin in Alameda County and the southern portion of the City of San Ramon in Contra Costa County. The existing wastewater service area encompasses approximately 13,340 acres, or 20.85 square miles. Within the wastewater service area there are currently 207 miles of gravity mains, one permanent lift station, and one temporary lift station. The permanent lift station has 26 feet of force main.

While the District is continually planning and designing collection system improvements to ensure a safe and reliable system, a comprehensive review of the City's collection system facilities has not been completed since 2005. With changes in customer's water use in response to recent drought conditions, and corresponding changes in wastewater flows, and several new development projects proposed throughout the District's wastewater service area, there is a need for an updated Collection System Master Plan (CSMP) to evaluate the collection system's ability to meet existing and projected future flows and identify improvements needed to address system deficiencies.

1.2 CSMP OBJECTIVES AND TASKS

The objective of this CSMP is to guide the District's remaining capital improvement projects and establish appropriate Capacity Reserve Fees to fund these projects while recognizing the District's mission of providing wastewater service in a safe, efficient, and environmentally responsible manner. The Capacity Reserve Fees are being calculated as part of the CSMP project, but as will be seen in the CSMP report outline provided below, the Capacity Reserve Fees are not included in the CSMP document itself. Rather, the Capacity Reserve Fees will be described in a separate, stand-alone document that is based on and directly aligned with the findings and conclusions of the CSMP.

Further objectives of the CSMP are to develop solutions and policies for the long-term management of the collection system, including Inflow & Infiltration (I&I) management and Private Sewer Lateral (PSL) policies. To accomplish these objectives, ten primary tasks were conducted. These tasks are outlined below:

- Task 1. Data Collection and Review
- Task 2. Review of District Standards and Guidelines for the Wastewater Collection System
- Task 3. Development of Wastewater Collection System Flows
- Task 4. Update of the Existing Wastewater Hydraulic Model
- Task 5. Wastewater Collection System Capacity Analysis
- Task 6. Develop Long-Term Collection System Management Strategy
- Task 7. Develop Capital Improvement Plan
- Task 8. Prepare Capacity Reserve Fees

- Task 9. Master Plan Report and Project Completion
- Task 10. Project Management and QA/QC

With the completion of these tasks, this resulting CSMP provides a comprehensive road map for the District for future planning for its collection system.

1.3 AUTHORIZATION

The District authorized West Yost Associates (West Yost) to prepare this CSMP in July 2017.

1.4 REPORT ORGANIZATION

This CSMP is organized into the following chapters:

- Executive Summary
- Chapter 1. Introduction
- Chapter 2. Existing System Description
- Chapter 3. Existing and Future Design Flows
- Chapter 4. Design Flow and Performance Criteria
- Chapter 5. Hydraulic Model Update
- Chapter 6. Hydraulic Model Capacity Evaluation
- Chapter 7. Long Term Management
- Chapter 8. Prioritized Capital Improvement Program

The following appendices to this CSMP contain additional technical information, assumptions and calculations:

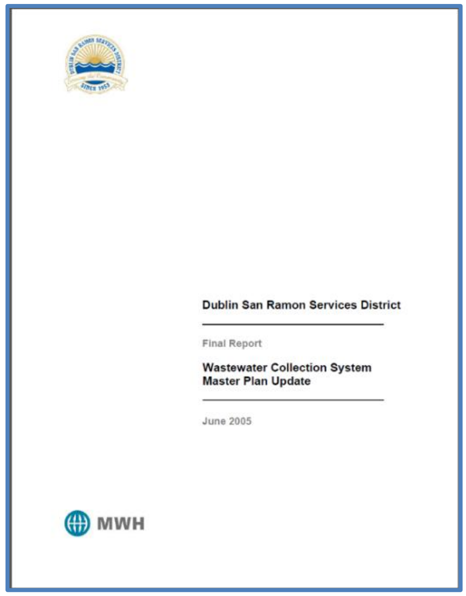
- Appendix A: 2017 Flow Monitoring Study Technical Memorandum
- Appendix B: Collection System Hydraulic Model Modeler's Notebook
- Appendix C: Private Sewer Lateral Technical Memorandum
- Appendix D: Cost Estimating Assumptions

As stated above, the Capacity Reserve Fee Study that results from Task 8 of this effort will be issued as a separate report to the CSMP; however, the basis for the assumptions in the Connection Fee Study will be directly aligned with the findings and recommendations from the CSMP.

1.5 RELATED PLANS AND REPORTS

The following documents contain topics related to those in the CSMP, and were referenced during development of the CSMP.

1.5.1 2005 Wastewater Collection System Master Plan Update


Dublin San Ramon Services District
Final Report
Wastewater Collection System Master Plan Update
June 2005
MWH

The District's last collection system master plan was completed in 2005[1]. At that time, the District's average dry weather flow (ADWF) was 6.00 million gallons per day (mgd), and was projected to increase to 9.60 mgd at buildout of the District's wastewater service area. This compares to a current (2017) ADWF of 6.63 mgd, now projected to increase to 9.77 mgd at buildout of the wastewater service area.

It is interesting to note that the 2017 ADWF is only 10 percent more than the 2005 ADWF despite significant development in the wastewater service area during the intervening time. It also interesting to note that the current projected buildout ADWF is just slightly more than what was projected in the 2005 Wastewater Collection System Master Plan Update. These values are the result of many changes which have occurred both within the District's wastewater service area and throughout California since the 2005 Wastewater Collection System Master Plan Update was completed.

Drought conditions have impacted water resources throughout the state from 2007 to 2009, and again from 2012 to 2016. All but two years of the last decade have been dry in California. The most recent prior drought in Water Years 2007 to 2009 was followed by the current five years of drought (Water Years 2012 to 2016), and four of those years set a record for the driest four consecutive water years in California history since record-keeping began. These dry conditions prompted unprecedented State mandates for water conservation and efficient water use. And although much of the water conservation was due to reduced outdoor water use, indoor water use was also significantly reduced resulting in corresponding reductions in wastewater flows.

As described in Chapter 3, unit wastewater generation factors have been reviewed and updated for this CSMP to account for changes in sewer generation for different land uses based on recent water consumption and sewer flow data. These changes include an assumed demand rebound to account for increases in water use as the District's water customers return to some of their pre-drought water use habits, which will result in a rebound in wastewater generation as well. In many instances, the resulting revised unit sewer generation factors are lower than those used in the 2005

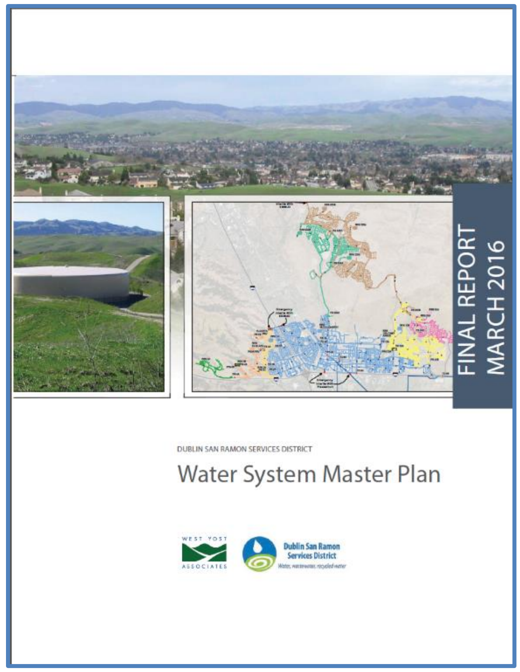
[1] Dublin San Ramon Services District Wastewater Collection System Master Plan Update, prepared MWH, June 2005.

Wastewater Collection System Master Plan Update contributing to the slightly lower wastewater flow projections in this CSMP.

Many collection system improvements have been implemented since the completion of the 2005 Wastewater Collection System Master Plan Update; however, with many changes in planned new development projects within the wastewater service area, and reduced ADWF projected at buildout, there is a need to re-evaluate the District collection system’s ability to meet existing and projected future flow conditions and identify improvements needed to address system deficiencies.

1.5.2 2016 Water System Master Plan Update

The District’s Water System Master Plan was updated in 2016[2]. While the District’s wastewater service area and water service area do not exactly coincide, there are significant areas of geographic overlap. In these areas, water demand projections and sewer flow projections will be closely related. In addition to the geographic overlap, the hydraulic modeling software used to evaluate the water distribution system is similar, particularly in how future demands are integrated, to the hydraulic modeling software used to model the wastewater collection system. Because of these geographic and technological similarities, the flow projections for the CSMP were developed using identical methods to those used to develop demand projections for the Water System Master Plan Update.



Both plans contain a detailed table of future developments that include the location, type of development (residential, commercial/industrial, or mixed use), projected water demand or sewer flow, and projected year of development. The data contained in these tables is loaded in the water distribution system hydraulic model or wastewater collection system hydraulic model in similar ways. The result of this transparency and alignment between the water distribution system hydraulic model and wastewater collection system hydraulic model is that as development plans change or are refined in the future, the impacts to both water and wastewater infrastructure can be easily identified.

1.5.3 2017 Wastewater Treatment and Biosolids Facilities Master Plan

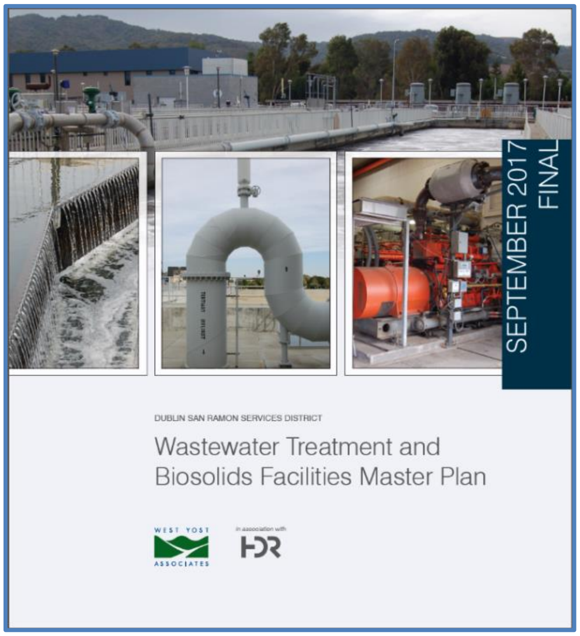
The District updated its Wastewater Treatment and Biosolids Facilities Master Plan in 2017[3]. This Wastewater Treatment Plant and Biosolids Facilities Master Plan provides a 20-year vision for the

[2] Dublin San Ramon Services District Water System Master Plan, prepared West Yost Associates, March 2016.

[3] Dublin San Ramon Services District Wastewater Treatment and Biosolids Facilities Master Plan, prepared West Yost Associates in association with HDR, September 2017.

District's Wastewater Treatment Plant that considers planned District growth, anticipated and potential regulatory changes, and new opportunities for wastewater resources recovery.

The District's Wastewater Treatment Plant (WWTP) receives flow from both the DSRSD wastewater collection system that is the focus of this CSMP and the City of Pleasanton's wastewater collection system. Therefore, flow projections for the Wastewater Treatment Plant and Biosolids Facilities Master Plan, which span the same planning horizon as the CSMP (present – 2035), contain dry weather and wet weather contributions from both collection systems. Dry weather flow projections for the Wastewater Treatment Plant and Biosolids Facilities Master Plan were developed based upon population growth projections for the District collection system service area and City of Pleasanton collection system service area. Being based purely on population growth projections, these flow projections do not fully capture all of the non-residential development and re-development that are captured in the specific development projects utilized in the CSMP flow projections, and they are predictably lower. ADWF at the WWTP is projected to increase from 9.7 mgd to 12.3 mgd, an increase (2.6 mgd) that is less than the increase projected for the District collection system study area alone in the CSMP (3.14 mgd). Given that the City of Pleasanton is relatively built-out, it is not expected that this relatively small difference in dry weather flow projections will impact infrastructure needs either in the collection system or at the WWTP. However, flows in the District collection system and at the WWTP should be tracked going forward, and projections adjusted as necessary



Wet weather flow projections for the Wastewater Treatment Plant and Biosolids Facilities Master Plan are based upon measured influent at the WWTP during storms dating back to 2004. The effective wet weather peaking factor (ratio of peak wet weather flow to ADWF) developed for the Wastewater Treatment Plant and Biosolids Facilities Master Plan is 3.8. This compares to the effective peaking factor of 2.9 developed for the CSMP. It is not unexpected that the District's collection system, which is newer and presumably more resistant to infiltration of wet weather flows, would have a lower wet weather peaking factor than the combined factor that is created with the addition of flows from the older City of Pleasanton collection system.

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CHAPTER 2
Existing System Description

The purpose of this chapter is to describe the District's existing wastewater collection service area, collection system, and treatment infrastructure. The District's collection system infrastructure has been evaluated as part of this CSMP.

2.1 WASTEWATER COLLECTION SERVICE AREA

The District's wastewater collection system serves the entire District. The wastewater collection service area, its population, and its land use are described below.

2.1.1 Service Area Description

The District's wastewater collection service area includes the City of Dublin in Alameda County and the southern portion of the City of San Ramon in Contra Costa County (the northern portion of San Ramon and Dougherty Valley are located in the Central Contra Costa Sanitary District wastewater service area.). In addition to these areas, the service area includes Parks Reserve Forces Training Area (Parks RFTA, or Camp Parks). The flow from the wastewater collection service area is conveyed to the DSRSD WWTP, which is located in the City of Pleasanton. Pleasanton has a separate wastewater collection system that delivers wastewater to the District's WWTP. This CSMP does not address Pleasanton's collection system but does include the large sewer mains that carry the flow from the DSRSD service area to the WWTP. Wastewater effluent is discharged to the Livermore Amador Valley Water Management Agency (LAVWMA) effluent disposal facilities for conveyance and discharge to San Francisco Bay.

The existing wastewater collection service area encompasses approximately 13,340 acres, or 20.85 square miles. This area includes open space and right-of-way areas that are not relevant to wastewater generation and are not considered in the land use descriptions provided later in this chapter. The wastewater collection service area is shown on Figure 2-1. It should be noted that the District's wastewater collection service area is different than both the wastewater treatment service area and the water service area. Only the wastewater collection service area is represented throughout the CSMP.

2.1.2 Historical Population

DSRSD's wastewater collection service area serves a highly desirable area due to its close proximity to major employment centers in the East San Francisco Bay Area. The 2017 City of Dublin and San Ramon populations are 59,686 and 80,550 people, respectively, based on 2017 DSRSD Comprehensive Annual Financial Report data for each city. Historical populations for the City of Dublin and the City of San Ramon are presented in Table 2-1. As shown in Table 2-1, the population of the City of Dublin increased by approximately 50 percent from 2005 to 2016; the City of San Ramon population increased by approximately 45 percent during the same time period. The population values presented for the City of San Ramon represent the entire population of the City, not only the portion provided wastewater service by DSRSD. These population values are presented to provide context for the recent growth seen in the geographic area that contains DSRSD.

Table 2-1. Historical Population (2005-2017)		
Year	City of Dublin	City of San Ramon[a]
2005[b]	38,147	53,923
2006[b]	39,868	60,134
2007[c]	41,309	64,173
2008[c]	44,321	66,642
2009[c]	45,104	69,428
2010[c]	46,036	72,148
2011[c]	46,207	73,111
2012[c]	46,730	74,753
2013[c]	49,932	76,429
2014[c]	53,462	77,270
2015[c]	55,844	78,561
2016[c]	57,349	78,363
2017[d]	59,686	80,550

(a) These population values represent the population of the entire City of San Ramon.
(b) Source: 2014 DSRSD Comprehensive Annual Financial Reports for the two cities.
(c) Source: 2016 DSRSD Comprehensive Annual Financial Reports for the two cities.
(d) Source: 2017 DSRSD Comprehensive Annual Financial Reports for the two cities.

2.1.3 Wastewater Collection Service Area Land Use

The City of Dublin and the City of San Ramon provided Geographical Information System (GIS) General Plan land use maps for West Yost to review and develop an existing land use database for the District's wastewater collection service area. For the CSMP, it is important to identify those parcels that are currently active and generating wastewater flows from those that are currently vacant but which may generate flow in the future. Active parcels (those with existing development) were distinguished from vacant parcels throughout the wastewater collection service area through the following process:

1. Active parcels within the District's potable water service area were previously identified as part of the District's 2016 Water Master Plan using water billing data in conjunction with the review of aerial photography. These results were used as a baseline and were updated using the 2017 City of Dublin General Plan Land Use map. Additionally, water billing information was reviewed to identify water accounts that became active since the development of the 2016 Water Master Plan, capturing recent development in the water service area. Given the drought conditions experienced in 2014-2016, the 2013 water billing data used for the 2016 Water Master Plan is considered suitably representative of current conditions.

2. For those parcels within the wastewater collection service area but not within the water service area, West Yost identified the active parcels using the City of San Ramon General Plan Land Use map in conjunction with review of aerial photography and the results were confirmed by City of San Ramon planning staff.

The existing land use map for the wastewater collection service area that results from the process described above is presented on Figure 2-2. The total areas categorized by General Plan Land Use designation for the currently developed parcels within the District's wastewater collection service area are summarized in Table 2-2.

As shown in Table 2-2, the current wastewater collection service area is approximately 79 percent developed. The District's wastewater collection service area is approximately 99 percent developed in the City of San Ramon and approximately 74.5 percent developed in the City of Dublin. It should be noted that these estimates for percent developed do not include the open space areas or rights-of-way, which include roads, railroads and other transportation areas. Such areas have no potential for development and are excluded from the calculations and total acreage.

2.2 EXISTING COLLECTION SYSTEM

The District's wastewater infrastructure includes the wastewater collection system and the WWTP. The collection system conveys wastewater primarily by gravity to the WWTP, which is located south of the District's wastewater collection service area on Johnson Drive, in the City of Pleasanton. Generally, wastewater flows by gravity from the northwest to the south and from the east to the west and then to the south within the wastewater collection service area. The collection system consists of approximately 207 miles of gravity mains, 26 feet of force main, one permanent lift station, and one temporary lift station. An overview of the District's collection system is shown on Figure 2-3. The gravity mains, force mains, and lift stations that comprise the collection system are described in more detail in the sections below.

2.2.1 Existing Gravity Mains

The existing gravity mains in the collection system, which range in size from 4-inch to 48-inch diameter, are summarized by diameter in Table 2-3. As noted in the table, approximately 82 percent of the gravity mains are 8-inch diameter or smaller, approximately 7 percent are 10-inch diameter, and approximately 11 percent are larger than 10-inch diameter. The gravity main diameters are shown on Figure 2-4.

Table 2-2. Wastewater Service Area Existing Land Use[a]

General Plan Land Use	City of Dublin Acreage[b]	City of San Ramon Acreage[c]	Total Acreage
Public / Semi-Public / Open Space			
Parks / Public Recreation	401	205	606
Public Lands	1,409		1,409
Public / Semi-Public	430	153	583
Subtotal	2,240	358	2,598
Commercial / Industrial			
General Commercial	323		323
Retail / Office	38	4	42
Retail / Office and Automotive	39		39
General Commercial / Campus Office	13		13
Campus Office	89		89
Business Park / Industrial	119		119
Business Park / Industrial and Outdoor Storage	57		57
Mixed Use	15	25	40
Mixed Use 2 / Campus Office	11		11
Medium/High-Density Residential and Retail Office	11		11
Subtotal	715	29	744
City of Dublin Residential			
Rural Residential / Agriculture (1 du per 100 Gross Residential Acres)	8		8
Estate Residential (0.01 - 0.8 du/acre)	24		24
Low-Density Single Family (0.5 - 3.8 du/acre)	44		44
Single Family Residential (0.9 - 6.0 du/acre)	1,373		1,373
Medium-Density Residential (6.1 - 14.0 du/acre)	363		363
Medium/High-Density Residential (14.1 - 25.0 du/acre)	119		119
High-Density Residential (>25.1 du/acre)	50		50
Subtotal	1,982		1,982
City of San Ramon Residential			
Low-Density Single Family (0.2 - 3.0 du/acre)		110	110
Low/Medium-Density Single Family (3.0 - 6.0 du/acre)		913	913
Medium-Density Single Family (6.0 - 14.0 du/acre)		24	24
High-Density Multiple Family (14.0 - 30.0 du/acre)		49	49
Very High-Density Multiple Family (30.0 - 50.0 du/acre)		25	25
Subtotal		1,121	1,121
Vacant Parcels[d]			
Vacant Parcels	1,690	16	1,706
Subtotal	1,690	16	1,706
Total	6,627	1,524	8,151
Percent of Total Vacant	25.5%	1.0%	20.9%

(a) Does not include no land use, stream corridor and undeveloped open space acreage.

(b) Developed based on data received from the City of Dublin on 08/27/2014.

(c) Developed based on data received from the City of San Ramon on 09/13/2017.

(d) Does not include Parks RFTA and Dublin Crossing Specific Plan areas as these areas are not currently vacant and are considered redevelopment projects (conversion of current Public Lands).

Table 2-3. District Existing Gravity Mains by Diameter

Diameter, inches	Length, feet	Length, miles	Percentage
4	194	0.04	0.02
6	24,843	4.71	2.27
8	878,289	166.34	80.21
10	73,061	13.84	6.67
12	39,578	7.50	3.61
15	19,714	3.73	1.80
18	7,671	1.45	0.70
21	1,878	0.36	0.17
24	12,931	2.45	1.18
27	4,739	0.90	0.43
30	3,759	0.71	0.34
33	2,053	0.39	0.19
36	17,542	3.32	1.60
39	3,565	0.68	0.33
42	4,801	0.91	0.44
48	306	0.06	0.03
Total	**1,094,924**	**207.37**	**100%**

Source: District Geographical Information system (GIS) updated in September 2017.

The existing collection system gravity main material is summarized in Table 2-4. Approximately 50 percent of the existing collection system gravity mains are constructed of polyvinyl chloride (PVC), and about 46 percent are constructed of vitrified clay pipe (VCP). Other materials, which in aggregate compose less than 15 percent of the entire collection system, include reinforced concrete, acrylonitrile butadiene styrene (ABS), asbestos cement, ductile iron, reinforced concrete lined with polyvinyl chloride, alloy stainless steel, cast iron pipe, steel, and concrete. The existing gravity main materials in the collection system are presented on Figure 2-5.

Table 2-4. District Existing Gravity Mains by Pipeline Material

Material	Length, ft	Length, miles	Percentage
Polyvinyl Chloride (PVC)	537,635	101.82	49.10
Vitrified Clay Pipe (VCP)	505,897	95.81	46.20
Reinforced Concrete	28,785	5.45	2.63
Acrylonitrile Butadiene Styrene (ABS)	10,497	1.99	0.96
Asbestos cement (AC)	5,118	0.97	0.47
Ductile Iron Pipe (DIP)	3,780	0.72	0.35
Concrete	1,144	0.21	0.10
Reinforced Concrete Lined with Polyvinyl Chloride	764	0.14	0.07
Alloy Stainless Steel	737	0.14	0.07
Cast Iron Pipe	420	0.08	0.04
Steel	147	0.03	0.01
Total	**1,094,924**	**207.37**	**100.00%**

Source: District GIS updated in September 2017.

2.2.2 Existing Lift Stations

The District's collection system has one permanent lift station located in Dublin Boulevard. The Dublin Boulevard Lift Station raises the elevation of the tributary wastewater flow by approximately 17 feet so it can continue to flow by gravity to the DSRSD WWTP. The station has two submersible pumps in a 6-foot diameter wet well located under the sidewalk. The District has replaced and relocated this wastewater lift station as part of the Dublin Boulevard Widening Project. The District began construction of this project in August 2017 and completed it in February 2019. The current lift station has a rated firm capacity of approximately 300 gallons per minute (gpm).

In addition to the Dublin Boulevard Lift Station, the District owns and operates one temporary lift station, the Croak Road Lift Station. The Croak Road Lift Station, located at the northeast corner of Terracina Drive and Croak Road, serves a newly developed tributary area that cannot be served by gravity using the existing collection system. As development in the area continues, gravity mains will be installed that serve this tributary area, and the Croak Road Lift Station will no longer be required. The existing capacity of each lift station is provided in Table 2-5.

Table 2-5. District Existing Lift Station Capacity

Lift Station Name	Pump Number	Pump Capacity, gpm	Design Head, ft	Firm Capacity, gpm
Dublin Blvd Lift Station	1 2	300 300	24	300
Croak Rd Lift Station (Temporary Lift Station)	1 2	80 80	55	80

2.2.3 Existing Force Main

The existing collection system includes approximately 26 feet of 6-inch force main. This force main discharges wastewater from the Dublin Boulevard Lift Station into the 10-inch gravity main in Dublin Boulevard.

2.2.4 Wastewater Treatment and Disposal

The WWTP is located approximately one mile south of the District's wastewater collection service area. The wastewater treatment facilities have a capacity of approximately 17.0 mgd, and the current average dry weather flow is approximately 9.7 mgd. The WWTP includes primary, secondary, and tertiary treatment processes using microfiltration or sand filtration and ultraviolet disinfection. The District also has a recycled water program that provides treated effluent for irrigation purposes in Dublin and Dougherty Valley, as well as to the City of Pleasanton. The District's wastewater treatment and disposal infrastructure is not evaluated as part of this CSMP.

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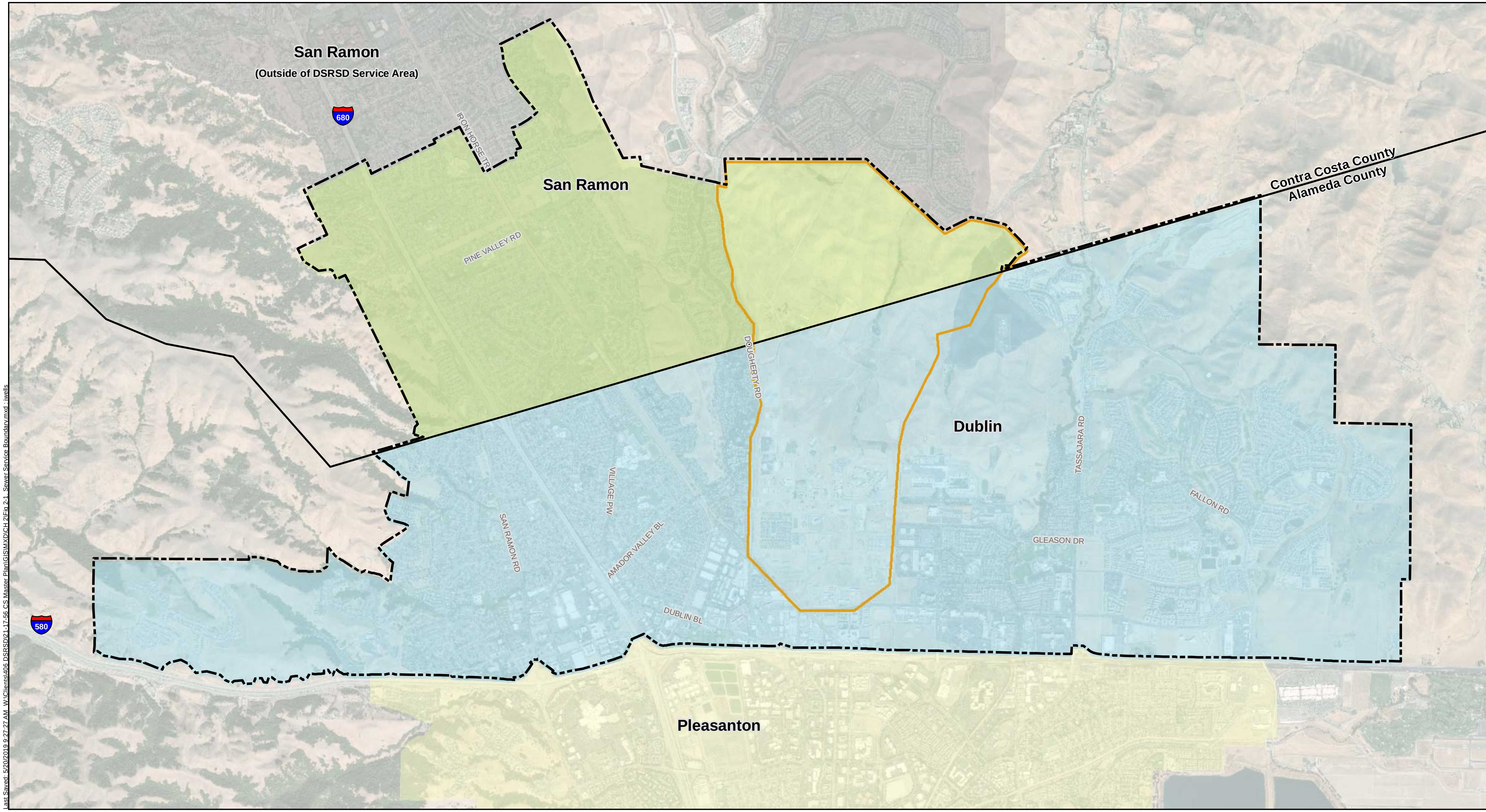

Symbology

- Wastewater Only Service Area
- Water and Wastewater Service Area
- Wastewater Treatment Under Contract
- Camp Parks
- Wastewater Collection Service Boundary

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 2-1

Wastewater Collection Service Boundary

Dublin San Ramon Services District
Collection System Master Plan

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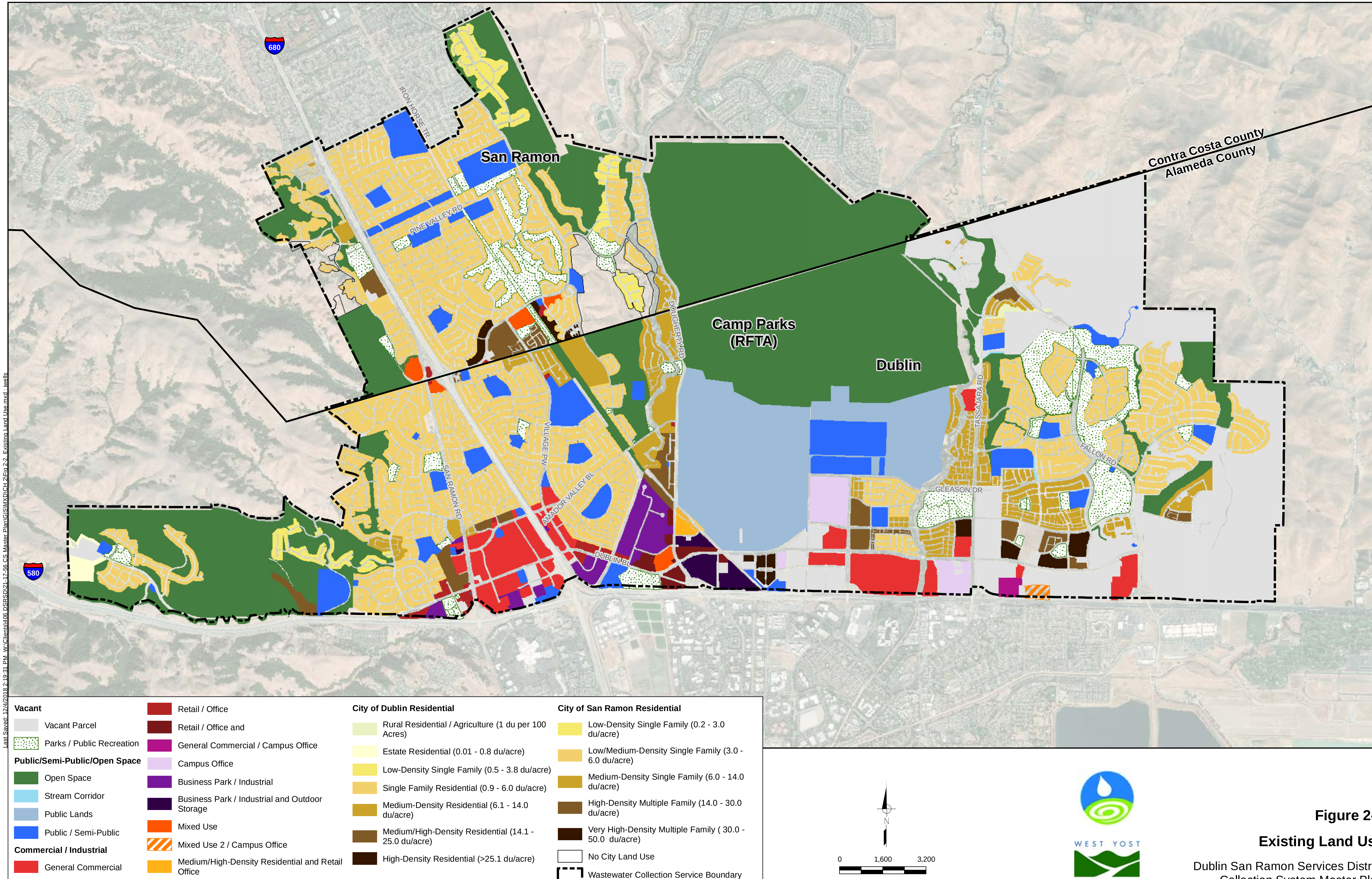

WEST YOST ASSOCIATES

Figure 2-2

Existing Land Use

Dublin San Ramon Services District
Collection System Master Plan

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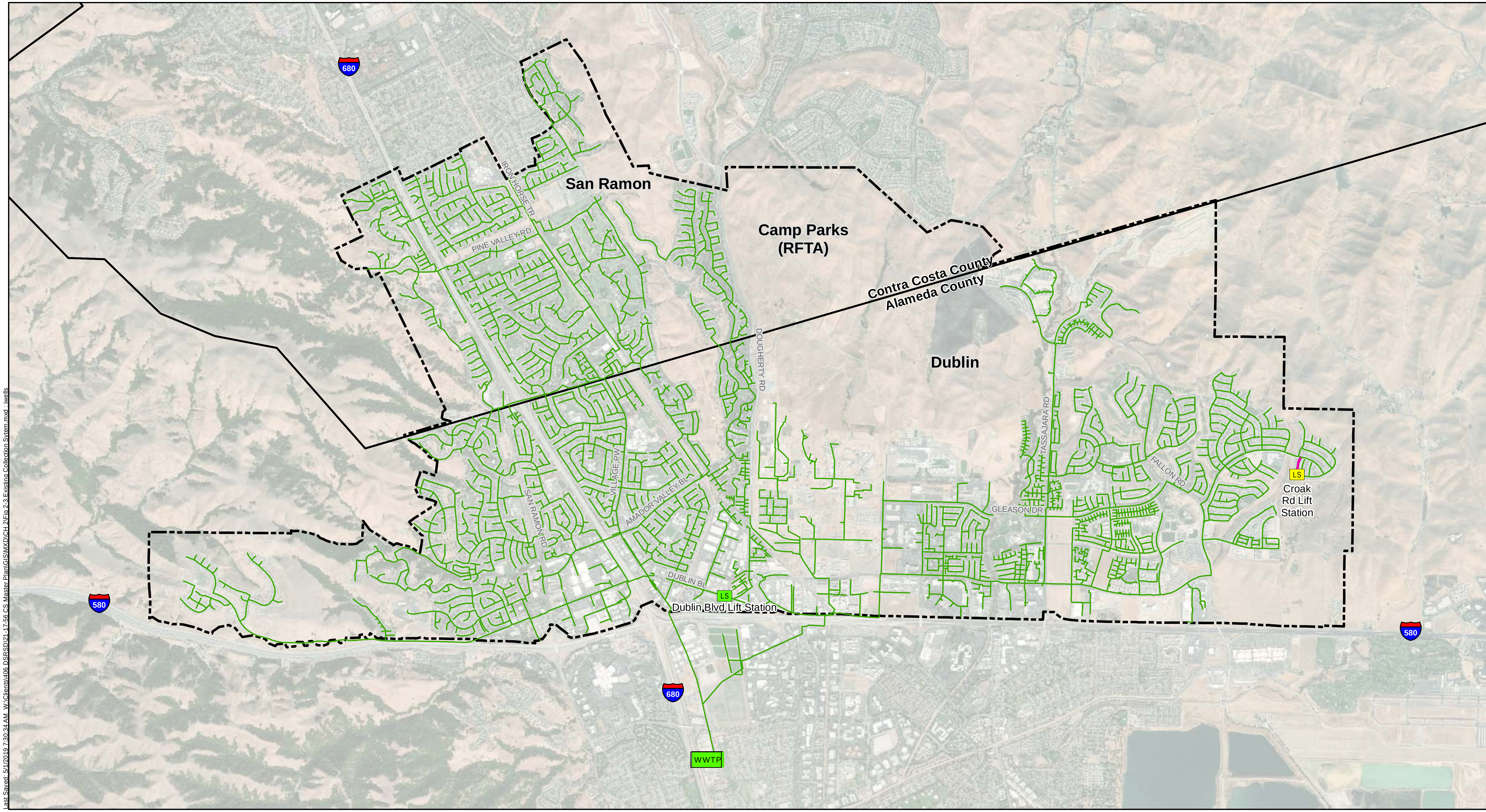

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Symbology

- WWTP — WWTP
- LS — Permanent Lift Station
- LS — Temporary Lift Station
- Gravity Main
- Temporary Force Main
- Wastewater Collection Service Boundary

N

0 1,600 3,200
Scale in Feet

WEST YOST ASSOCIATES

Figure 2-3

Existing Collection System

Dublin San Ramon Services District
Collection System Master Plan

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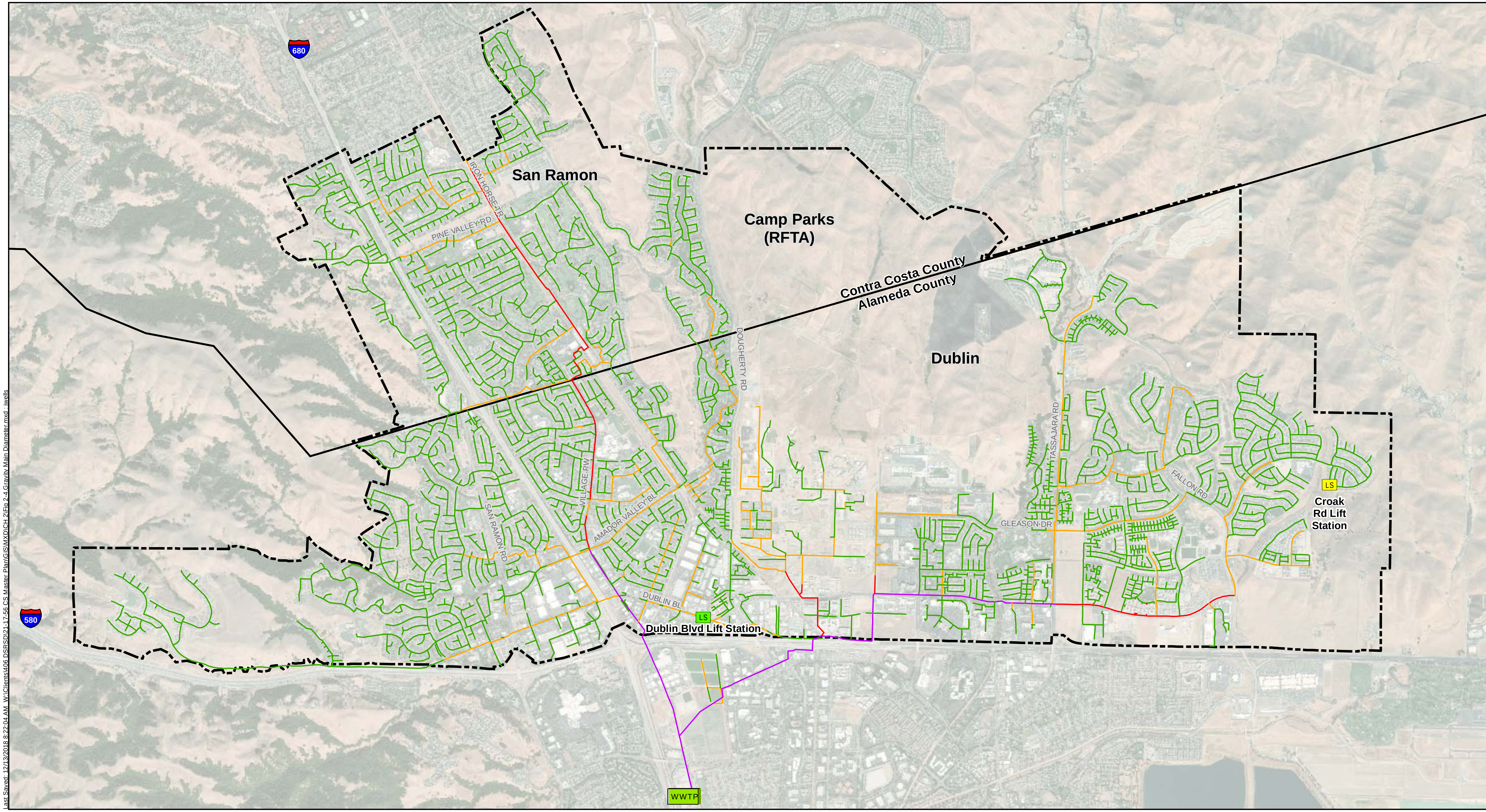

Symbology

WWTP WWTP

LS Permanent Lift Station

LS Temporary Lift Station

Gravity Main - Diameter

- 4-inch - 8-inch
- 10-inch - 18-inch
- 21-inch - 33-inch
- 36-inch - 60-inch
- Wastewater Collection Service Boundary

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 2-4

Gravity Main Diameter

Dublin San Ramon Service District
Collection System Master Plan

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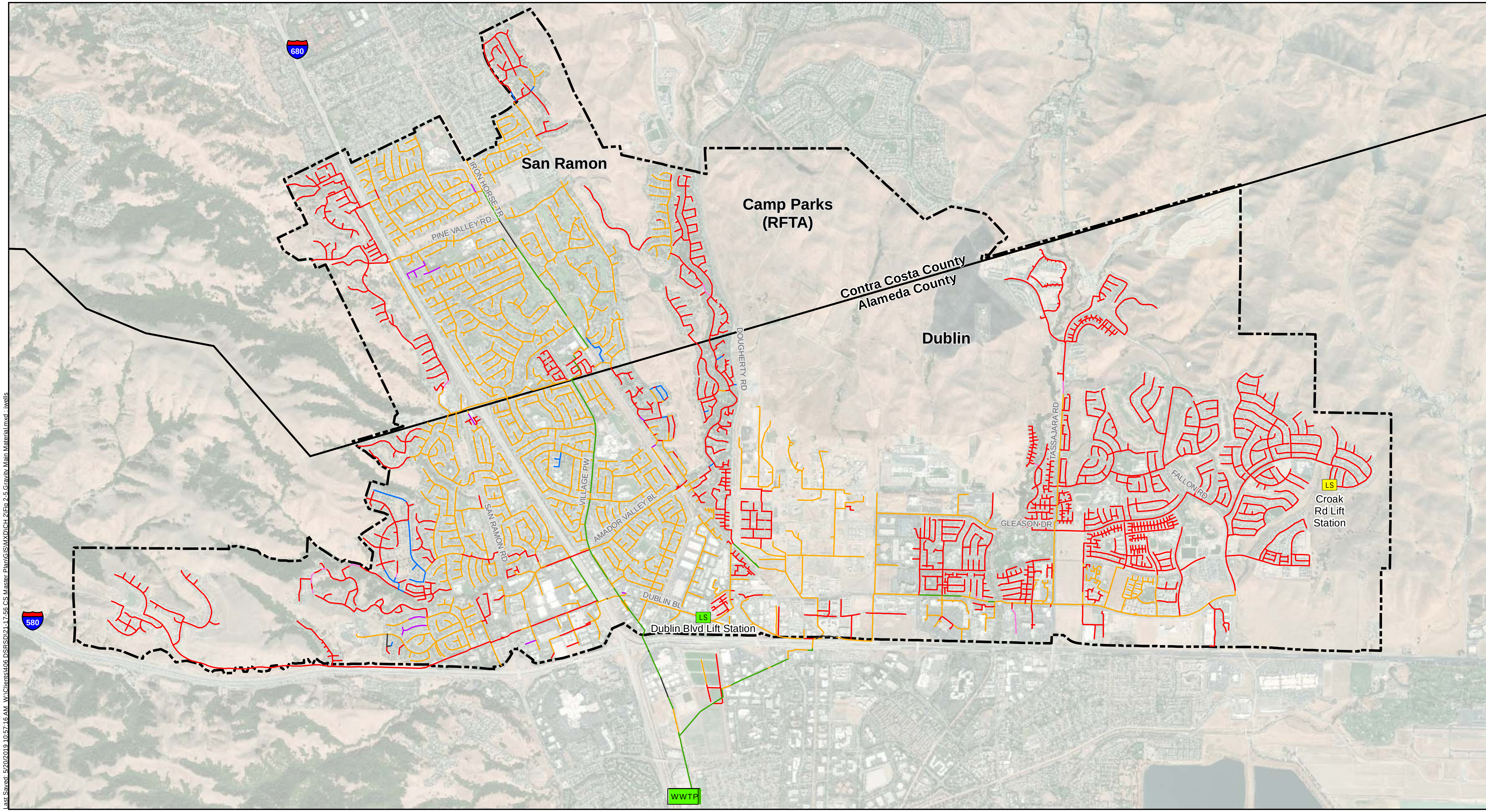

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Symbology

WWTP WWTP

LS Permanent Lift Station

LS Temporary Lift Station

Gravity Main - Material

Polyvinyl Chloride (PVC)

Vitrified Clay Pipe (VCP)

Reinforced Concrete

Acrylonitrile Butadiene Styrene (ABS)

Asbestos cement (AC)

Ductile Iron Pipe (DIP)

Others

Wastewater Collection Service Boundary

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 2-5

Gravity Main Material

Dublin San Ramon Services District
Collection System Master Plan

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CHAPTER 3
Existing and Future Design Flows

Chapter 2 described the existing wastewater collection service area and wastewater collection system for the District. The purpose of Chapter 3 is to describe the development of existing and projected future design flows generated within the wastewater collection service area. Recent drought conditions in California have impacted water consumption and wastewater generation trends throughout the state, complicating the projection of design flows. For this CSMP, the District invested significant effort in a flow monitoring program to quantify existing flows. Furthermore, future design flows were projected using factors that account for the drought and its aftermath, and that can be adjusted as that aftermath becomes more defined. The result of these efforts are existing and future design flows that represent the best current information for the wastewater collection service area but that are flexible as that information potentially changes. In future chapters, these design flows will be used to evaluate the hydraulic capacity of the District's collection system. The major topics addressed in Chapter 3 include:

- Wastewater Flow Component Overview
- 2017 Flow Monitoring Study
- ADWF Development
- Peak Flow Development

3.1 WASTEWATER FLOW COMPONENT OVERVIEW

Wastewater collection systems typically convey both sanitary flow, which is the intended use of the collection system, and external flows that enter the collection system infrastructure. A realistic evaluation of the hydraulic capacity of a collection system requires that design flow conditions, including both sanitary flows and external flows, be established for the collection system. The detailed flow components relevant to the development of design flows for the District's collection system, and therefore required for the hydraulic evaluation of the collection system include:

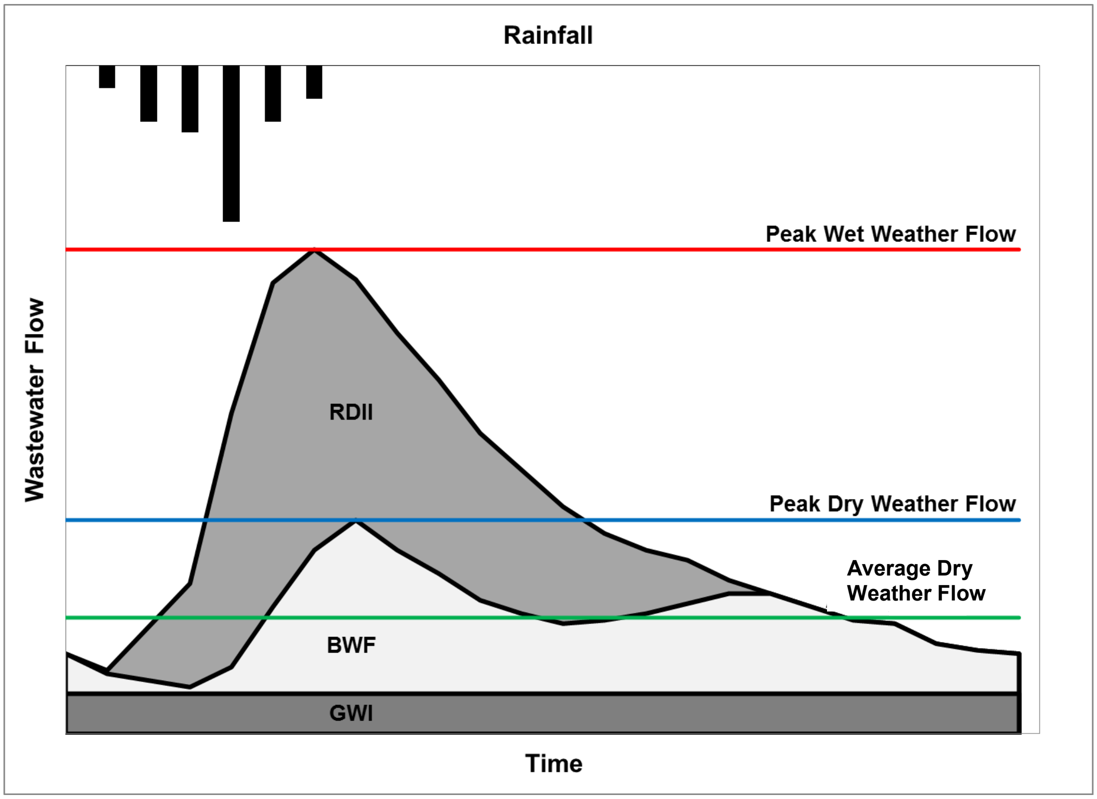
- Average Dry Weather Flow (ADWF)
- Peak Dry Weather Flow (PDWF)
- Peak Wet Weather Flow (PWWF)

The wastewater flow components described in this section are depicted conceptually on Figure 3-1.

3.1.1 Average Dry Weather Flow

ADWF is generally accepted to include two components: base wastewater flow (BWF) and groundwater infiltration (GWI). BWF represents the sanitary flow contributions from residential, commercial, institutional, and industrial dischargers to the collection system. GWI refers to groundwater that infiltrates into the collection system via defects in wastewater pipes and manholes. GWI tends to increase following rainfall events, and generally tends to be highest in winter and springtime, and in low-lying areas. In some collection systems, GWI is low enough compared to BWF that it can assumed to negligible. As described in more detail below, GWI values vary across the District and are not assumed to negligible in certain areas.

Figure 3-1. Wastewater Components for Typical PWWF Conditions



3.1.2 Peak Dry Weather Flow

While GWI tends to remain relatively constant over any given day, BWF varies throughout the day, but typically follows predictable diurnal patterns depending on the type of land use. For example, residential dischargers tend to produce higher flows in the morning hours and in the evening hours, while commercial dischargers tend to have fairly steady discharge during business hours, but very low discharge outside of business hours. Industrial dischargers have flow patterns that depend upon their individual processes.

PDWF is the defined as the diurnal flow peak within the collection system during baseline dry weather conditions. PDWF is typically 1.2 to 3.0 times the ADWF, depending on the mixture of discharger types and the size and layout of the collection system.

3.1.3 Peak Wet Weather Flow

PWWF is composed of PDWF and rainfall-dependent inflow and infiltration (RDII). RDII consists of stormwater inflow and infiltration that enter the system in direct response to rainfall events, either through direct connections such as holes in manhole covers or illicitly-connected roof leaders or area drains, or through defects in wastewater pipes, manholes, and service laterals. RDII is typically characterized by short-term peak flows that recede relatively quickly after a given rainfall ends. The magnitude of RDII flows are related to the intensity and duration of the rainfall, but are also related to the degree of soil saturation arising from earlier (antecedent) rainfall conditions.

3.2 2017 FLOW MONITORING STUDY

The District understood the importance of quantifying the flow elements described above as part of this CSMP effort, and invested significant effort in gathering flow data for the collection system. The primary means of gathering this data was a temporary flow monitoring study undertaken during the late winter of 2017. The 2017 Flow Monitoring Study provided the data used to perform an assessment of dry and wet weather flow conditions from the 2016/2017 wet season in the District's collection system. Key elements of that study discussed in this section include:

- Flow Monitoring Locations
- Rainfall Results
- Flow Monitoring Results
- Comparison of Collection System and Wastewater Treatment Plant Results

3.2.1 Flow Monitoring Locations

A total of 15 flow monitoring locations and two rainfall gauging sites were monitored during the period of data collection. Monitoring was performed over a period of approximately two and half months from March 15, 2017 to May 26, 2017. The geographic configuration of the flow monitoring locations and the rainfall gauging sites are depicted on Figure 3-2 and summarized in Table 3-1.

Table 3-1. Summary of Flow Monitoring Locations

Site	Manhole	Pipe Diameter, in	Location	Tributary Area/Reason for Location
1	U20D1-40	12	Dublin Boulevard east of Amador Plaza Road	Areas along Dublin Blvd west of I-680/ Capture potential high flows reported by staff.
2	T20C1-13	8	Dublin Boulevard west of Brigadoon Way; upstream of Site 1	New development areas at the western end of Dublin Blvd (upstream of Site 1)/ Determine if high flows reported at Site 1 are coming from these new developments.
3	W20C1-24	24	Between 3rd Street and Fernandez Ave	Camp Parks (except the southeastern corner), plus areas along Dougherty Road/ Capture majority of Camp Parks.
4	W19C1-3	15	Fernandez Avenue	Southeast portion of Camp Parks plus FCI/ Capture remainder of Camp Parks.
5	V19D2-57	12	North of Powers Street and Cornwell Avenue; upstream of Site 3	The northern portion of Camp Parks from 8th Street northward/ Isolate potential high RDII areas identified by District staff.
6	Y20C2-7	15	Fallon Road just north of Dublin Boulevard	New development areas in eastern Dublin east of Fallon Road/ Isolate potential areas of high RDII identified by District staff.
7	X20A4-16	18	Tassajara Road north of Dublin Blvd	New development areas in the eastern portion of the service area, primarily north of Gleason Drive/ Isolate potential areas of high RDII identified by District staff.
8	T16D3-1	15	Bernard Avenue	The northwestern portion of the service area in southern San Ramon/ Repeat monitoring of high RDII area from previous master plan.
9	V18A1-2	10	Iron Horse Trail near Craydon Court	Areas east of Coyote Creek adjacent to Alcosta Blvd/ Repeat monitoring of high RDII area from previous master plan.
10	U19C4-18	8	Donahue Drive	Areas of northwest Dublin west of I-680/ Repeat monitoring of high RDII area from previous master plan.
11	U19A2-12	8	Vomac Road east of San Ramon Road	Areas of northwest Dublin west of San Ramon Blvd (upstream of Site 10) / Split basin to isolate RDII in area of high RDII area from previous master plan.
12	U19D1-4	33	Village Pkwy north of Amador Valley Blvd	Areas of Dublin and southern San Ramon east of and adjacent to I-680 (downstream of Sites 8 and 9)/ Complete flow capture from southern central area of the collection system.
13	U20D2-1	36	Village Pkwy south of Dublin Blvd	The majority of western and central Dublin and southern San Ramon (downstream of Sites 1, 2, 8, 9, 10, 11, and 12)/ Complete flow capture from southern central area of the collection system.
14	V20A1-38	15	Clark Avenue south of Dublin Blvd (site 14 from 2005 MP)	South-central Dublin between I-680, I-580, and Amador Valley Blvd/ Repeat monitoring from previous master plan.
15	W20C1-11	36	Arnold Road south of Martinelli Way	All of eastern Dublin east of Arnold Road/ Complete flow capture from eastern portion of the collection system.

The flow monitoring locations were chosen through a collaboration of West Yost and District staff and were chosen to satisfy the following goals:

- Capture both wet and dry weather flow from as much of the collection system as possible
- Confirm flow conditions at District-identified areas of concern
- Isolate older areas of the collection system with potential for high RDII and GWI flows
- Repeat previous monitoring locations to provide continuity of data

The results of the flow monitoring conducted at these locations is discussed below.

3.2.2 Rainfall Results

A critical goal of the flow monitoring program was to quantify the wet weather flows within the District's collection system. For this goal to be achieved, wet weather events had to occur during the flow monitoring period. Fortunately for the achievement of the District's goal, wet weather events did indeed take place. The following two temporary rain gauges were established within the District service area to quantify and categorize wet weather events for the collection system monitoring program:

- RG-1: Located in the southwestern corner of the service area near Schaeffer Ranch Park
- RG-2: Located in the southeastern corner of the service area near Fallon Road and Dublin Boulevard (adjacent to Flow Monitoring Site 6)

In addition, long-term rainfall gauges are maintained at nearby locations in Dublin, San Ramon, and Pleasanton. The data from these gauges have been used in this analysis to assess longer-term rainfall trends, but these data are generally only available as daily totals, and therefore have limited utility for an analysis of this kind. In addition, rainfall return period information for District service area was obtained from the National Oceanic and Atmospheric Administration (NOAA).

According to the temporary rain gauges deployed for this study, the two most significant rainfall events of the monitoring period occurred on March 21–22, 2017 and April 6–7, 2017. According to NOAA return period information, neither event achieved a 1-year return period, with the exception of the peak 6-hour rainfall during the April 6–7 event at RG-2, during which a 2-year return period was achieved. In general, rainfall events with a return of 5 years or less are used to establish design flows in wastewater collection systems (the return frequency of the design storm used to establish design flows in the District's collection system is discussed in Chapter 4). In summary, the 2017 Flow Monitoring Study captured measurable rainfall events. However, the events captured were relatively small, and did not approach the magnitude typically used to establish design flows in a wastewater collection system.

Th rainfall events described above were relatively small, but they both occurred after significant antecedent rainfall, especially season-to-date rainfall. Based on daily rainfall data from long-term rain gauges in Dublin, San Ramon, and Pleasanton, between 23 and 31 inches of season-to-date rainfall occurred prior to the March 21–22 event. High antecedent rainfall tends to result in elevated groundwater levels and soil saturation surrounding the collection system. These conditions make the collection system sensitive to further rainfall, because none of this further rainfall can be absorbed by the soil. Because of the high antecedent rainfall conditions, the response of the District's collection system to the relatively small rainfall events captured during the 2017 Flow Monitoring Study can be scaled to estimate the response to larger events for design purposes. The process by which this scaling is detailed further in the sections below.

3.2.3 Flow Monitoring Results

The 2017 Flow Monitoring Study produced directly measured results at the 15 locations described above. The directly measured site results are combined with characteristics such as the size of the tributary basin for each site to produce flow monitoring basin results. Both the site results and the basin results are discussed below.

3.2.3.1 Flow Monitoring Site Results

The flow monitoring results at the 15 sites described above are summarized in Table 3-2. All flows are shown in units of millions of gallons per day (mgd). The peaking factors shown in the table are determined by dividing the peak measured flow by the calculated ADWF over the entire monitoring period. The direct site results as shown in Table 3-2 directly measure the collection system performance at the flow monitoring sites. One important measurement of collection system performance is the ratio of the measured flow (q) to the maximum capacity flow (Q), or q/Q ratio. A second important measurement of collection system performance is the ratio of measured flow depth (d) to the gravity main diameter (D), or d/D ratio. Both performance measurements are provided in Table 3-2 at each of the flow monitoring sites. As can be seen in Table 3-2, only Site 10 experiences elevated q/Q and d/D values during the temporary flow monitoring period. As will be discussed below, the basin tributary to Site 10 contributes significant amounts of GWI and RDII that are responsible for the elevated flow values.

It should be noted that Site 2 and Site 6 were chosen for the 2017 Flow Monitoring Study because District staff was concerned about reports that flow was particularly deep at these locations, and in danger of surcharging. The results of the 2017 Flow Monitoring Study indicate that the flow is not particularly deep, and that the flow is well within the capacity of the gravity mains at these locations. In the case of Site 2, these results indicate that maintenance activity that removed tree branches and similar debris was successful in returning the flow depth to typical conditions.

3.2.3.2 Flow Monitoring Basin Results – BSF and GWI

The directly measured flow monitoring results described above were integrated with tributary basin information to characterize the wastewater flow generation characteristics of the individual areas tributary to each of the 15 flow monitoring sites. Values for BSF generation per basin were quantified as part of this process, but BSF generation is most usefully characterized by land use. BSF generation factors by land use are discussed in more detail below. Because GWI generation

Table 3-2. Flow Monitoring Site Results Summary

Site	Manhole	Nominal Diameter, in	ADWF, mgd	Peak Day Flow, mgd	Date of Peak Day Flow	Peak Hour Flow, mgd	Time of Peak Flow	Peaking Factor	Full-Pipe Capacity[(a)], mgd	Maximum q/Q	Maximum d/D
1	U20D1-40	12	0.357	0.41	5/17/2017	0.62	5/17/2017 7:45	1.7	1.03	0.60	0.41
2	T20C1-13	8	0.081	0.091	5/14/2017	0.18	5/15/2017 7:15	2.2	0.46	0.40	0.40
3	W20C1-24	24	0.104	0.25	3/22/2017	0.49	3/22/2017 7:05	4.7	4.64	0.11	0.15
4	W19C1-3	15	0.245	0.31	3/22/2017	0.44	3/22/2017 6:10	1.8	1.62	0.27	0.40
5	V19D2-57	12	0.011	0.049	3/23/2017	0.11	5/1/2017 6:50	10.0	1.03	0.11	0.20
6	Y20C2-7	15	0.452	0.51	5/21/2017	0.98	5/15/2017 7:15	2.2	1.62	0.60	0.33
7	X20A4-16	18	0.704	0.74	5/16/2017	1.26	5/17/2017 7:40	1.8	2.36	0.53	0.28
8	T16D3-1	15	0.308	0.66	3/22/2017	0.87	3/22/2017 7:20	2.8	1.62	0.54	0.65
9	V18A1-2	10	0.140	0.24	5/11/2017	0.65	3/22/2017 7:35	4.6	1.02	0.60	0.59
10	U19C4-18	8	0.123	0.23	4/9/2017	0.41	4/8/2017 9:35	3.3	0.46	0.89	1.00
11	U19A2-12	8	0.086	0.12	5/20/2017	0.21	4/16/2017 9:50	2.4	0.46	0.46	0.43
12	U19D1-4	33	2.060	3.44	3/22/2017	4.50	3/22/2017 8:05	2.2	10.84	0.42	0.51
13	U20D2-1	36	3.031	4.39	3/22/2017	5.88	3/22/2017 8:15	1.9	13.67	0.43	0.57
14	V20A1-38	15	0.463	0.58	3/22/2017	0.82	3/22/2017 8:00	1.8	1.62	0.51	0.54
15	W20C1-11	36	2.178	2.35	4/23/2017	4.01	4/14/2017 8:20	1.8	13.67	0.29	0.44

(a) Minimum Standard Slope

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rates and RDII rates are geographically based (dependent on soil types, groundwater tables, and surface permeability, for instance), it is useful to characterize each flow monitoring basin by GWI rate and RDII rate.

As discussed above, GWI generally increases after prolonged periods of rainfall. Since the wastewater service area experienced significant rainfall events prior to the flow monitoring period, it is expected that GWI entering the collection system would be near their maximum levels. The magnitude of GWI depends on the porosity of the collection system as well as on the depth of the groundwater table with respect to the collection system. Therefore, GWI is highly dependent on location and topography, and is highly variable throughout the District's wastewater collection service area.

Short of flow monitoring studies that measure and quantify wastewater salinity (such studies require more expensive equipment than typical flow monitoring studies and are generally cost prohibitive), GWI cannot be directly measured in a collection system. GWI is typically estimated using statistical methods that compare the ratios of flow characteristics such as maximum flow, minimum flow, and average flow. These statistical methods have replaced older and less sophisticated estimates that assumed a certain percentage of night time flow was GWI. In this CSMP, GWI was evaluated using three established methods: The Minimum Flow Factor Method, the Stevens-Schutzbach Equation, and the Wastewater Production Method. Because the Wastewater Production Method was developed for larger flow basins, and because the Wastewater Production Method estimated higher values for GWI than the other two methods, which were consistent with each other, it was determined that GWI values calculated by Minimum Flow Factor Method and Stevens-Schutzbach Equation provided the most reliable estimates for GWI for this CSMP.

GWI estimates generated using the two methods selected as described above were compared to preliminary dry weather flow calibration values and further refined. The refined GWI values were subtracted from the calculated ADWF values to produce BWF values for each basin. Table 3-3 presents the GWI and BWF component per flow monitoring basin. As indicated in the table, flow monitoring basins 6, 8, 11 and 14 are identified to have higher values of GWI compared to other basins across the collection system. These basins will be discussed further in summaries presented below.

Table 3-3. ADWF Components per Flow Monitoring Basin					
Basin	Area, Acres[a]	Net BWF, mgd	Net GWI, mgd	Net ADWF, mgd	Net GWI Generation, gpad
1	303.90	0.276	-	0.276	-
2	96.24	0.079	0.002	0.081	17
3	125.13	0.093	-	0.093	-
4	354.48	0.245	-	0.245	-
5	121.85	0.011	-	0.011	-
6	244.35	0.312	0.140	0.452	573
7	416.70	0.514	0.190	0.704	456
8	216.66	0.194	0.114	0.308	527
9	103.41	0.119	0.021	0.140	203
11	83.10	0.056	0.030	0.086	361
12	1212.64	1.531	0.081	1.612	66
13 and 10	897.66	0.528	-	0.528	-
14	293.48	0.269	0.195	0.463	663
15	889.43	0.869	0.153	1.022	172
Total[b]	**5358.61**	**5.096**	**0.925**	**6.021**	**173**

(a) Includes current active parcels with wastewater service.
(b) These total values represent the values captured in the flow monitoring program. They are slightly lower than total values calculated for the entire wastewater service area because a small portion of the wastewater service area was not captured during flow monitoring.

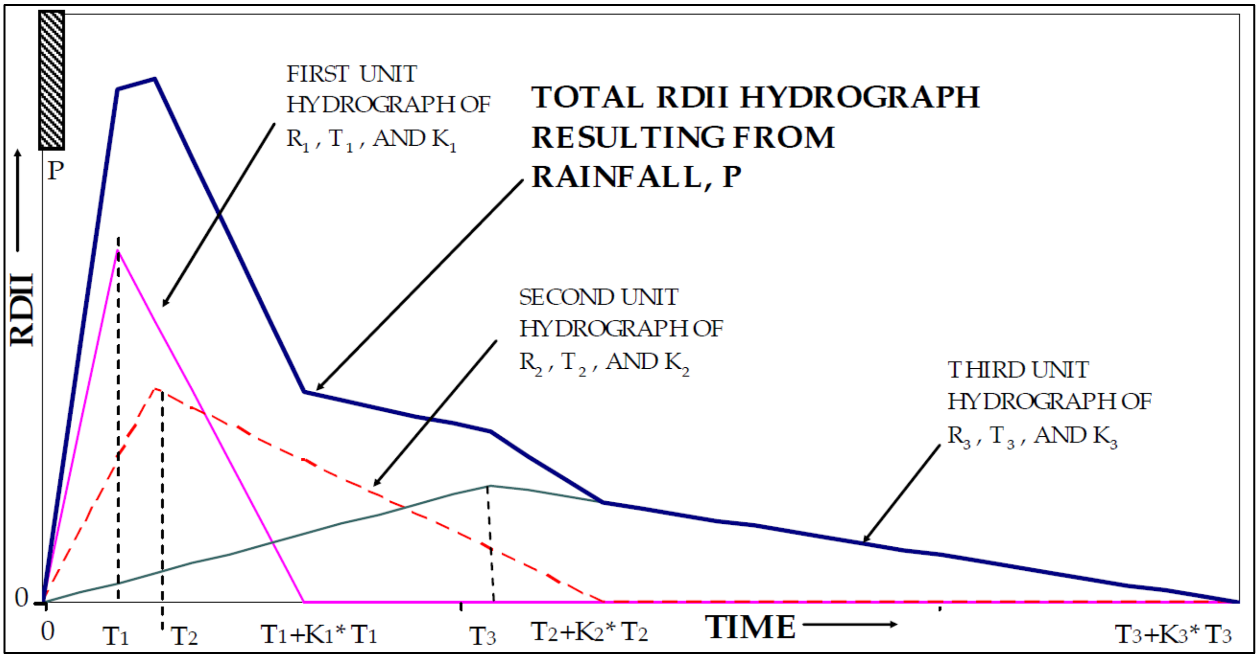
3.2.3.3 Flow Monitoring Basin Results – RDII

Wet weather flow data from the 2017 Flow Monitoring Study was evaluated using the R-T-K Method. R-T-K factors are utilized to quantify the amount of RDII that enters the collection system for each flow monitoring basin, as well as the timing of the RDII entry with respect to the rainfall that generates the RDII. The R-T-K Method utilizes a series of three triangular hydrographs that represent short-term, medium-term, and long-term rainfall response for each flow monitoring basin. The individual R-T-K factors are defined as follows:

- **R-factor**: The percentage of rainfall that enters the collection system in the form of RDII
- **T-factor**: The time from the storm onset to the runoff peak
- **K-factor**: A constant used in defining the ratio of the “time to recession” to the “time to peak” of the hydrograph

A graphical depiction of the components of the R-T-K hydrograph is provided courtesy of the Environmental Protection Agency (EPA) Office of Research and Development, and is presented on Figure 3-3.

Figure 3-3. Components of R-T-K Hydrograph



R-Factor values were calculated for each flow monitoring basin using the data from the 2017 Flow Monitoring Study in combination with the acreage calculated for each basin. Total R (total percentage of rainfall that falls on a flow monitoring basin that enters the collection system) was calculated for each basin; in addition, the R1, R2, and R3 components of the total R (the portion of R that is composed of short-term, medium-term, and long-term response, respectively) were broken out for each flow monitoring basin.

The R-T-K factors used in the CSMP were estimated via EPA Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox during wet weather calibration of the hydraulic model. The April 6 to April 7 storm was chosen for calibration because it produced larger flow responses in the collection system. During calibration, the R-T-K factors were adjusted until the volume of RDII measured, the peak flow measured, and the timing of the peak flow was replicated within 10% accuracy at each flow monitoring location. The resulting R-Factor values are presented in Table 3-4.

Table 3-4. R-Factor by Flow Monitoring Basin

Basin	**Total R**	R1	R2	R3
1	**1.20%**	0.10%	0.10%	1.00%
2	**0.24%**	0.16%	0.04%	0.04%
3	**2.80%**	0.30%	0.50%	2.00%
4	**0.48%**	0.10%	0.10%	0.28%
5	**0.64%**	0.21%	0.21%	0.22%
6	**0.16%**	0.16%	0.00%	0.00%
7	**1.40%**	1.00%	0.40%	0.00%
8	**6.00%**	0.50%	0.50%	5.00%
9	**2.90%**	0.40%	0.50%	2.00%
10	**5.00%**	1.00%	2.00%	2.00%
11	**1.15%**	0.30%	0.25%	0.60%
12	**1.80%**	0.25%	0.55%	1.00%
13	**0.62%**	0.12%	0.20%	0.30%
14	**1.75%**	0.10%	0.90%	0.75%
15	**0.40%**	0.17%	0.13%	0.10%

As can be seen in Table 3-4, the majority of the flow monitoring basins in the collection system recorded a total R value of approximately one percent or less, which is typical of "tight" collection systems with low amounts of RDII entry. Flow monitoring basins 3, 8, 9, and 10 have higher values that indicate higher rates of RDII entry. Additionally, flow monitoring basin 7, although it has a relatively low R value of 1.4%, has a higher value than would be expected for such a new portion of the collection system. It is expected that the value for flow monitoring basin 7 should be similar to that calculated for flow monitoring basin 6. The basins with higher values are discussed below in the basin summaries.

3.2.3.4 Flow Monitoring Results Basin Summaries

Overall, the results of the of the 2017 Flow Monitoring Study indicate that the District's collection system is well-maintained and operating normally. The BWF values (discussed in detail in the ADWF Development section below) are typical for the land uses within the District, and consistent with what the District has determined in past studies. The GWI and RDII values described above are in general low and indicative of a collection system with relatively few of the defects that allow GWI and RDII to enter the collection system. However, as discussed above, several of the flow monitoring basins in the collection system have either high GWI values, RDII values, or both. These basins, and the potential causes and impacts of the high values, are summarized below.

Flow Monitoring Basin 3. Flow monitoring basin 3 comprises the southwest corner of Camp Parks RFTA. This basin does not appear to have significant GWI entry, but it has moderate RDII entry (2.8% R-Factor). This value is not surprising, because the local collection gravity mains and laterals in this area are owned and operated by the Camp Parks RFTA, and have been known by the District to be in relatively poor condition.

Flow Monitoring Basin 6. Flow monitoring basin 6 is the eastern-most basin in the District's collection system, and encompasses the new development areas of East Dublin. The total R-Factor value for this basin is very low, as would be expected for newly developed areas with a new portion of the collection system. However, flow monitoring basin 6 has a relatively high GWI value. This value is confirmed by both the GWI estimation methods as well as a review of water billing data for the area, which does not indicate higher-than-average water consumption and BWF generation. Because the GWI analysis and the water billing analysis both indicate high GWI values in this basin, it is suspected that an elevated groundwater table resulting from the high seasonal rainfall is contributing to the GWI. This suspicion can be confirmed with flow monitoring during dry conditions.

Flow Monitoring Basin 7. Flow monitoring basin 7 is also found in East Dublin, and it also contains significant recent development. This basin is found directly west of flow monitoring basin 6, described above. Similar to flow monitoring basin 6, this basin has relatively high GWI entry. The reason for this high value is presumably the same as that for flow monitoring basin 6. In contrast to flow monitoring basin 6, flow monitoring basin 7 has a moderate, rather than low, RDII entry rate. As can be seen in Table 3-4, the majority of the RDII in flow monitoring basin 7 is entering as short-term response RDII (often called inflow). Inflow typically indicates direct surface connections to the collection system, which would be unusual in an area with such recent development. Discussion with District operations staff indicated that they were aware of areas under construction at the time of the 2017 Flow Monitoring Study that potentially drained significant areas of land directly into the collection system. Such areas would be expected to stop draining in this manner upon completion of construction. This situation can be confirmed with wet weather flow monitoring after construction has ceased in the basin.

Flow Monitoring Basin 8. Flow monitoring basin 8 is in the northwest corner of the collection system. It includes one of the oldest portions of the collection system in the City of San Ramon. This basin was isolated in the 2017 Flow Monitoring Study because it had been identified as a high RDII basin in previous studies. As expected, flow monitoring basin 8 had high values for both GWI and RDII. The majority of the RDII entering the collection system in the basin was long-term response, indicating that precipitation is traveling through the ground and entering the collection system through underground defects, rather than through direct connections with the surface.

Flow Monitoring Basin 9. Flow monitoring basin 9 is in the center of the collection system, in the City of San Ramon. This basin was isolated in the 2017 Flow Monitoring Study because it had been identified as a high RDII basin in previous studies. As expected, flow monitoring basin 9 had moderately high values for both GWI and RDII. The majority of the RDII entering the collection system in the basin was long-term response, indicating that precipitation is traveling through the ground and entering the collection system through underground defects, rather than through direct connections with the surface.

Flow Monitoring Basin 10. Flow monitoring basin 10 contains the older portions of the City of Dublin. This basin was isolated in the 2017 Flow Monitoring Study because it had been identified as a high RDII basin in previous studies. The previous basin was split to isolate potential RDII flow, with flow monitoring basin 10 comprising the lower half of the previous basin, and flow monitoring basin 11 comprising the upper half. Flow monitoring basin 10 had low values of GWI, but high values for RDII.

Flow Monitoring Basin 11. Flow monitoring basin 11 contains the older portions of the City of Dublin. This basin was isolated in the 2017 Flow Monitoring Study because it had been identified as a high RDII basin in previous studies. The previous basin was split to isolate potential RDII flow, with flow monitoring basin 10 comprising the lower half of the previous basin, and flow monitoring basin 11 comprising the upper half. Flow monitoring basin 11 had high values for GWI.

Flow Monitoring Basin 14. Flow monitoring basin 14 contains a portion of the collection system in central Dublin, directly north of the WWTP. The basin has high GWI values but low RDII values. The GWI values are likely the result of high groundwater tables during the 2017 Flow Monitoring Study.

3.2.3.5 Flow Monitoring Results Conclusions

The 2017 Flow Monitoring Study accomplished its primary goals in providing comprehensive dry weather and wet weather data for the flows in the District's collection system. The study measured an ADWF of 6.02 mgd for the portion of the District's collection system upstream of the meters. As will be discussed below in more detail, the area encompassed by flow monitoring is slightly smaller than the full collection system service area of the District, so the collection system service area ADWF is higher. The results from the 2017 Flow Monitoring Study correspond well to the results reported in the 2005 Wastewater Collection System Master Plan Update, with expected differences for growth and drought impacts (discussed more fully below).

The results from this study also correspond well to the District staff's understanding of the collection system. As described above, areas of the collection system that had previously been identified with GWI or RDII problems were for the most part confirmed. Older areas of the collection system were generally found to have higher GWI and RDII values. The 2017 Flow Monitoring Study is considered to be a strong foundation for understanding and quantifying existing flows and for projecting future flows as part of this CSMP. The development of existing and future design flows for the collection system service area is described in the following sections.

3.3 ADWF DEVELOPMENT

The development of existing and future ADWF as a basis for collection system planning is discussed in the sections below.

3.3.1 Existing (2017) ADWF

The 2017 Flow Monitoring Study established a BWF value of 5.10 mgd for the monitored area, in addition to GWI of 0.93 mgd. These values result in 6.02 mgd of ADWF for the monitored area. There is a small portion of the District's collection system service area that is un-monitored but that contributes flow to the collection system. This area contains the Commerce Circle area (technically part of the City of Pleasanton), as well as the facultative sludge lagoons, both of which discharge flow to the collection system. Water billing records and discussions with District staff were used to establish the ADWF for this un-monitored area as 0.61 mgd, including discharges from the lagoons. With this flow, the ADWF for the entire District collection system service area (monitored plus un-monitored) was established to be 6.63 mgd for existing (2017) conditions.

3.3.2 Rebounded Existing ADWF

The existing (2017) ADWF for the collection system was established based upon the 2017 Flow Monitoring Study. Although that study captured significant wet weather events as described above, it occurred at the tail end of five years of significant drought (Water Years 2012 to 2017). Water consumption, and the BWF generation that is directly tied to water consumption, was at this point significantly impacted by the drought and by the mandatory water consumption reductions necessitated by the drought. The impacts of drought on water consumption and BWF generation are known to be impermanent and to reduce as the drought condition recede. It is therefore inappropriate to base future ADWF values on existing values that reflect drought impact.

The concept of Rebounded Existing ADWF has been introduced to account for the "rebound" of ADWF values to non-drought values as part of the demand projection process. The Rebounded Existing ADWF is an estimate of what the ADWF in the collection system would have been in 2017 if drought conditions were not present. To establish the Rebounded Existing ADWF, water bills within the District from 2013 to 2017 were examined. A summary of these bills is presented in Table 3-5.

Table 3-5. Potable Water Consumption for Continuously Active Accounts, 2013–2017[a]

Year	Annual Average Water Consumption, mgd	Percentage Decrease in Annual Average Water Consumption Compared to 2013	Winter Water Consumption, mgd[b]	Percentage Decrease in Winter Water Consumption Compared to 2013
2013[b]	8.17	-	4.37	-
2015	5.47	33%	3.78	13%
2016	5.87	28%	3.94	10%
2017	6.46	21%	3.83	12%

(a) Source: 2013 consumption SUMMARY (rev 093014).xls received from District; ConsumptionData_12082017.xlsx received from District in December 2017; the results represent the water consumption of District water accounts active continuously between 2013 and 2017. The values reflect a per meter comparison in water usage trends over the given years.
(b) Winter water consumption results are based on demand data from January and February when irrigation activities are expected to be at a minimum.
(c) For potable water and wastewater master planning, 2013 is considered to be the baseline consumption year because it reflects pre-drought conditions.

It is important to note that the water bills summarized in this table represent a sample of accounts that are continuously active during the time period, and therefore the values in the table do not reflect growth in the number of accounts during this time. As can be seen, total consumption for these accounts decreases 33% between 2013 and 2015. Consumption rebounds to show a 21% decrease between 2013 and 2017. Because outdoor water use does not typically end up in the wastewater collection system, winter water consumption, which is composed mainly of indoor use, tracks more closely with BWF generation. As can be seen in Table 3-5, winter water consumption falls by 13% between 2013 and 2015 before rebounding to a 10% reduction in 2016 and a 12% reduction in 2017. The rebound values seen in Table 3-5 are typical for what has been seen across California during this time period.

Historical influent flow data from 2013 to 2017 at the WWTP were examined to provide comparison to the water demand values described above. As shown in Table 3-6, ADWF decreased by 9 percent from 2013 to 2015, presumably due to increased conservation efforts in response to the ongoing drought. By 2017, the ADWF had retuned to 99 percent of the 2013 ADWF. Some of that rebound is due to growth in the service area of the WWTP, and some is due to a reduced degree of water conservation practices.

Table 3-6. Historical ADWF at WWTP[(a)]

Year	ADWF[(b)], mgd	Percentage of Change from 2013
2013[(c)]	10.16	-
2015	9.27	-9%
2016	9.75	-4%
2017	10.01	-1%

(a) Source: CIWQS.waterboards.ca.gov
(b) Includes City of Pleasanton Wastewater Flow. ADWF is defined as flow measured at the WWTP during dry months.
(c) For potable water and wastewater master planning, 2013 is considered to be the baseline consumption year because it reflects drought conditions before government-mandated demand reduction.

As shown in Table 3-6, the measured ADWF at the District WWTP in 2013 was 10.16 mgd. An apparent drop-off and subsequent rebound occurred in those flows; however, the numbers are complicated by population growth within the WWTP service area. Because only a portion of San Ramon is served by the WWTP, the contributing population of San Ramon was estimated as follows:

- Based on the District's GIS database, there are estimated to be 18,739 DU in the City of Dublin in 2017. According to the DOF, the 2017 population of Dublin was 59,686 residents. The result is an estimated 3.19 residents/DU for Dublin.
- Based on the District's GIS database, there are estimated to be 7,524 DU in the portion of San Ramon served by the District. Applying an assumed rate of occupancy of 3.19 residents/DU, as just established for the City of Dublin (the occupancy rates probably vary slightly between the two cities, but the estimate is suitable for this calculation), the estimated 2017 population of areas of San Ramon served by the

District is 23,965 residents. Because the San Ramon portion of the service area has essentially been built out for several years, it is assumed that this population figure has not changed since 2013.

- Apply the calculated rate of growth for the District service area to the 2013 ADWF value to determine what the 2017 ADWF would be if a full rebound had occurred. This approach assumes that groundwater infiltration in 2013 was occurring at a similar rate as occurred in 2017.

Given the approach just described, Table 3-7 shows the population growth from 2013 to 2017 of the three cities that contribute to the WWTP. As indicated in the table, the population of the WWTP service area is estimated to have increased by 9.46 percent from 2013 to 2017. Therefore, if wastewater flows had fully rebounded from 2013 to 2017, we would expect to see a flow increase of 9.46 percent in the ADWF estimates.

Table 3-7. Estimated Population Growth within the District WWTP Service Area

Entity	2013 Population, residents[(a)]	2017 Population, residents[(a)]	Growth Rate, percent
Dublin	50,197	59,686	18.90
San Ramon[(b)]	23,965	23,965	0
Pleasanton	71,618	75,916	6.00
Total – Three Cities	145,780	159,567	9.46

(a) Population estimates taken from DOF at www.dof.ca.gov/Forecasting/Demographics/Estimates/E-5/.
(b) Represents only the portion of San Ramon that contributes to the WWTP, which is assumed not to have changed since 2013.

Given that the measured ADWF in 2013 was 10.16 mgd, a full rebound implies that flows in 2017 would have been 11.12 mgd. Instead, the actual measured ADWF for 2017 was 10.01 mgd, which is 90.0 percent of the fully-rebounded value. That result agrees with the assumed 90 percent rebound discussed above in the subsection on water demand rebound. Therefore, the water consumption and wastewater treatment plant influent data both support the conclusion that wastewater generation on a per capita basis in 2017 is approximately 90% of that in 2013.

The development of Rebounded Existing ADWF assumes that wastewater generation values will not continue at 2017 values as California's drought recedes, because many of the water conservation drivers are voluntary actions that will be discontinued. However, the wastewater generation factors will not return to the 2013 (pre-drought) values either. Some of the water conservation drivers are actually infrastructure and fixtures (for example, low-flow showers and toilets) that will not allow values to return entirely to pre-drought values. Therefore, reasonable wastewater generation factors for the future will be between the pre-drought values and the values measured in 2017. Rebounded Existing ADWF, along with its relationship to both pre-drought values and 2017 measured values, is easiest understood in terms of wastewater generation factors. Wastewater generation factors for these three situations are presented in Table 3-8.

Table 3.8. Base Wastewater Flow Generation Factors

General Plan Land Use	Land Use Code	Unit of Land Use Designation	Previous Master Plan Base Wastewater Flow Factor, gpd/unit	Existing (2017) Base Wastewater Flow Factor, gpd/unit	**Rebounded Existing Base Wastewater Flow Factor, gpd/unit**
Public / Semi-Public / Open Space					
Parks / Public Recreation	P	acres	-	-	**-**
Public Lands	PL	acres	200	180	**200**
Public / Semi-Public	PSP	acres	200	180	**200**
Commercial / Industrial					
General Commercial	GC	acres	900	600	**700**
Retail / Office	RO	acres	900	700	**800**
Retail / Office and Automotive	ROA	acres	900	700	**800**
General Commercial / Campus Office	GCCO	acres	900	700	**800**
Campus Office	CO	acres	900	800	**900**
Business Park / Industrial	BPI	acres	900	800	**900**
Business Park / Industrial and Outdoor Storage	BPIOS	acres	900	800	**900**
Mixed Use	MU	acres	900	700	**800**
Mixed Use 2 / Campus Office	MU2CO	acres	900	700	**800**
Medium/High-Density Residential and Retail Office	MHRRO	acres	900	700	**800**
City of Dublin Residential					
Rural Residential / Agriculture (1 du per 100 Gross Residential Acres)	RRA	dwelling units	220	190	**210**
Estate Residential (0.01 - 0.8 du/acre)	ER	dwelling units	220	190	**210**
Low-Density Single Family (0.5 - 3.8 du/acre)	LDSF	dwelling units	220	190	**210**
Single Family Residential (0.9 - 6.0 du/acre)	SFR	dwelling units	220	190	**210**
Medium-Density Residential (6.1 - 14.0 du/acre)	MDR	dwelling units	190	160	**180**
Medium/High-Density Residential (14.1 - 25.0 du/acre)	MHDR	dwelling units	140	120	**130**
High-Density Residential (>25.1 du/acre)	HDR	dwelling units	140	120	**130**
City of San Ramon Residential					
Low-Density Single Family (0.2 - 3.0 du/acre)	SFL	dwelling units	220	190	**210**
Low/Medium-Density Single Family (3.0 - 6.0 du/acre)	SFLM	dwelling units	220	190	**210**
Medium-Density Single Family (6.0 - 14.0 du/acre)	SFM	dwelling units	190	160	**180**
High-Density Multiple Family (14.0 - 30.0 du/acre)	MFH	dwelling units	140	120	**130**
Very High-Density Multiple Family (30.0 - 50.0 du/acre)	MFVH	dwelling units	140	120	**130**
Other					
RFTA (Camp Parks)	Multiple	-	-	-	**-**[(a)]

Note:
[(a)] Flows for RFTA development are documented in the RFTA Infrastructure Evaluation Report, December 2013, Table 2.1.

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The generation factors presented in Table 3-8 are based upon acres for non-residential land uses and dwelling units for residential land uses. The pre-drought values were calculated from flow monitoring data collected as part of the 2005 Wastewater Collection System Master Plan Update. The Existing (2017) values were calculated from the 2017 Flow Monitoring Study. The Rebounded Existing values were calibrated between the pre-drought and Existing (2017) values such that 90% of the conservation-impacted wastewater generation is expected to rebound across the entire collection system service area. This rebound value is consistent with historical precedent. The Gold Coast area of Australia experienced a severe drought between June 2002 and January 2004. Demands decreased significantly during the drought as a result of water restrictions, but after the drought ended, the conserved water rebounded 90 percent. The BWF and ADWF values in this CSMP are based upon the Rebounded Existing generation factors presented in Table 3-8.

3.3.3 Return-to-Wastewater Ratio

The Return-to-Wastewater ratio is defined as the portion of potable water use that ultimately enters the wastewater collection system, and is generally calculated on an annual average basis. For this analysis, the Return-to-Wastewater ratio was determined by comparing the BWF of each land use type within the City of Dublin to 2017 water meter records for the same geographical areas. The results of this analysis are shown in Table 3-9. The Return-to-Wastewater ratio varies by usage type, with public land use typically having relatively low ratios, and commercial and industrial users typically having higher ratios. The values shown in Table 3-9 are typical for similar collection systems.

Table 3-9. Return-to-Wastewater Ratio Summary[(a)]

General Plan Land Use	Return to Wastewater Ratio
Public / Semi-Public	32%
Commercial / Industrial	75%
Residential	85%

(a) Source: ConsumptionData_12082017.xlsx received from District received in December 2017 and filtered for City of Dublin consumption data.

3.3.4 Projected ADWF

In this CSMP, BWF values are calculated on a parcel basis, using land use information and Existing Rebounded Base Wastewater Generation Factors. Land use information is discussed in Chapter 2 and Existing Rebounded Base Wastewater Generation Factors are described in the sections above. GWI is projected to be constant for all time periods of wastewater flow projections. It should be noted that because the BWF and GWI have been developed separately as part of this CSMP, flow projections can be easily modified in the future should new data show that conditions have changed. For example, should future flow monitoring indicate that GWI values have decreased, the GWI value can be easily removed from the flow projections. Furthermore, because this CSMP invested in performing the rebound analysis described above, BWF projections can be modified efficiently if future data shows that pre-drought generation factors are returning, or if future data shows that no rebound is occurring and Existing (2017) values should be used instead.

Future development projects were comprehensively identified as part of the District's 2016 Water Master Plan. Because it is helpful to the District that the development projections for the water distribution system and wastewater collection system align as much as possible, future development projections for the CSMP began with the projections from the 2016 Water Master Plan.

A review of aerial photography was performed in conjunction with the analysis of water billing data described above to identify completed development projects since the 2016 Water Master Plan. Additionally, the development project descriptions were updated through conversation with City of Dublin and City of San Ramon planning staff, and from information on the City of Dublin website. All future development projects identified for the CSMP, with their associated time frame and BWF are presented in Table 3-10 and depicted on Figure 3-4. BWF values for future development projects were calculated using the Rebounded Existing wastewater flow factors summarized above.

The 2020 and 2025 ADWF projections are based on existing rebounded wastewater flows plus projected flows from all future development projects that are expected to be completed by 2020 and 2025, respectively. For the buildout development condition, it is assumed that all planned development projects will be completed and all undeveloped parcels will be developed, consistent with their General Plan land use designations. The future ADWF projections and their associated dwelling unit equivalents are summarized in Table 3-11. As can be seen in this table, projected future ADWF values are built systematically from existing values, with BWF and GWI values separated so that they are transparent, and so that they can be adjusted as data changes. GWI values increase throughout the projection period because more contributing acreage is added to the service area every time period.

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Table 3-10. BWF Projections for Future Development											
Site No.	Name	Description	Estimated Start	Estimated End	Planning Area	Flow Monitoring Basin	Land Use Designation	Unit of Land Use Designation	Total Dwelling Units	Total Area, acres	Projected BWF, gpd(a)	Net Increase from Existing BWF, gpd
1	Parks RFTA[(b)]	Parks Reserve Forces Training Area	2015	2025	Camp Parks	3,4,5	Multiple (Source: Parks RFTA Infrastructure Evaluation Report, December 2013)	Dwelling Unit Equivalents	1,433		300,930	300,930
2	Boulevard	Dublin Crossing	2016	2027	Camp Parks	15	Residential Medium High Density	Dwelling Units	1,122		145,860	133,116
2	Boulevard	Dublin Crossing	2016	2027	Camp Parks	15	Residential High Density	Dwelling Units	630		81,900	59,244
2	Boulevard	Dublin Crossing	2016	2027	Camp Parks	15	Elementary School	acres		12	2,400	-
3	Dublin Retail LLC	Downtown Dublin Specific Plan - Retail District	2015	2035	Central Dublin	1	Commercial Retail	acres		1.19	833	833
3	Dublin Place SDR	Downtown Dublin Specific Plan - Retail District	2016	2035	Central Dublin	1	Commercial Retail	acres		0.39	273	63
3	Avesta Senior Care Facility	Downtown Dublin Specific Plan - Retail District	2017	2035	Central Dublin	1	Senior Care Facility	Dwelling Units	80		7,200	6,500
3	The Perch at Downtown Dublin	Downtown Dublin Specific Plan - Retail District	2017	2018	Central Dublin	1	Medium High Density	Dwelling Units	60		7,800	7,800
4	Saint Patrick Way SDR	Downtown Dublin Zoning District - Transit - Oriented District	2015	2035	Central Dublin	1	Residential Very High Density	Dwelling Units	499		64,870	58,899
4	Aster	Downtown Dublin Zoning District - Transit - Oriented District	2015	2017	Central Dublin	1	Residential Medium Density	Dwelling Units	313		56,340	56,340
5	Randeri SDR Pre-App	Downtown Dublin - Village Parkway District	2015	2035	Central Dublin	13	Commercial Retail	acres		0.25	175	175
6	Heritage Park	Dublin Village Historic Area Specific Plan	2015	2017	Central Dublin	1	Single Family Residential	Dwelling Units	25		5,250	5,250
7	Valley Christian Center	Master Plan	2018	2025	Central Dublin	1	Public Semi Public	acres		2	400	400
8	Central Dublin-Infill 1	Business Park, Industrial, Outdoor Storage	2030	2035	Central Dublin	14	Industrial Business Park	acres		2.7	2,430	2,430
9	Schaefer Ranch GPA	Single Family	2017	2019	Western Dublin	2	Residential Rural	Dwelling Units	18		3,780	3,780
10	UDR. Dublin Station (A-3)	Apartments	2026	2028	Eastern Dublin	14	Residential High Density	Dwelling Units	220		28,600	28,600
11	Tribeca	Townhome	2016	2017	Eastern Dublin	14	Residential Medium High Density	Dwelling Units	52		6,760	6,760
12	Zeiss Innovation Center	Office - Research & Development	2018	2020	Eastern Dublin	15	Campus Office	acres		11.4	10,260	10,260
13	Ikea	Commercial	2015	2020	Eastern Dublin	15	Commercial Retail	acres		27.5	19,250	19,250
14	East County Hall of Justice	Alameda County Courtrooms	2014	2017	Eastern Dublin	15	Public Semi Public	acres		22	4,400	4,400
15	Gateway Medical Center Phase 2	Medical Offices	2016	2023	Eastern Dublin	15	Commercial Office	acres		3	2,700	2,700
16	At Dublin	Commercial - Residential - Public	2020	2030	Eastern Dublin	15	General Commercial	acres		23.2	16,240	16,240
16	At Dublin	Commercial - Residential - Public	2020	2030	Eastern Dublin	15	Residential Medium Density	Dwelling Units	180		32,400	32,400
16	At Dublin	Commercial - Residential - Public	2020	2030	Eastern Dublin	15	Residential Medium High Density	Dwelling Units	200		26,000	26,000
16	At Dublin	Commercial - Residential - Public	2020	2030	Eastern Dublin	15	Mixed Use	acres		16.0	12,800	12,800
17	Grafton Plaza	Mixed Use-Townhomes	2017	2022	Eastern Dublin	15	Residential Medium High Density	Dwelling Units	115		14,950	14,950
17	Grafton Plaza	Mixed Use-Commercial	2020	2024	Eastern Dublin	15	Commercial Retail	acres		3.68	2,576	2,576
17	Grafton Plaza	Aloft Hotel	2015	2018	Eastern Dublin	15	Residential Medium High Density	acres		2	260	260
18	Fallon Gateway	Retail Commercial Center	2016	2018	Eastern Dublin	15	Commercial Retail	acres		5	3,500	3,500
19	Kaiser	Medical Offices	Unknown	2018	Eastern Dublin	15	Medical Campus	acres		15.0	13,500	13,500
19	Kaiser	Hospital	Unknown	2035	Eastern Dublin	15	Medical Campus	acres		27.1	24,390	24,390
19	Kaiser	Commercial	Unknown	2020	Eastern Dublin	15	Medical Campus/Commercial	acres		15.9	12,720	12,720
20	Irongate - Lennar Homes	Medium Density Residential	2015	2019	Eastern Dublin	15	Residential Medium Density	Dwelling Units	203		36,540	36,540
20	Irongate - Lennar Homes	Townhomes	2015	2019	Eastern Dublin	15	Residential Medium High Density	Dwelling Units	107		13,910	13,910
21	Jordan Ranch - Capri (N3)	Alley Loaded Homes	2014	2017	Eastern Dublin	6	Residential Medium Density	Dwelling Units	18		3,240	3,240
21	Jordan Ranch - Trio (N4)	Townhomes	2014	2017	Eastern Dublin	6	Residential Medium High Density	Dwelling Units	11		1,430	1,430
22	Jordan Ranch - Neighborhood 6 (Kingswood)	Townhomes and Flats	2017	2017	Eastern Dublin	6	Residential Medium High Density	Dwelling Units	109		14,170	14,170
23	Wanmei	Medium Density Residential	2030	2035	Eastern Dublin	7	Residential Medium Density	Dwelling Units	19		3,420	3,420
24	Enclave at Tassajara Highlands	Single Family	2015	2018	Eastern Dublin	7	Residential Medium Density	Dwelling Units	48		8,640	8,640
25	Wallis Ranch	Mixed Residential	2015	2021	Eastern Dublin	7	Residential Medium Density	Dwelling Units	494		88,920	88,920
25	Wallis Ranch	Mixed Residential	2015	2022	Eastern Dublin	7	Residential Medium High Density	Dwelling Units	185		24,050	24,050
25	Wallis Ranch	Low Density Residential	2015	2020	Eastern Dublin	7	Single Family Residential	Dwelling Units	92		19,320	19,320
26	Tassajara Hills	Single Family Residential	2015	2024	Eastern Dublin	7	Low Density Residential	Dwelling Units	370		77,700	77,700
27	Grafton Station Area A	Commercial	2020	Unknown	Eastern Dublin	15	Commercial Retail	acres		4.5	3,150	3,150
28	Fallon Village - Croak	Rural Residential - Ag	2022	Unknown	Eastern Dublin	6	Residential Rural	acres	2		347	347
28	Fallon Village - Croak	Residential	2022	Unknown	Eastern Dublin	6	Single Family Residential	Dwelling Units	469		98,490	98,490
28	Fallon Village - Croak	Residential	2022	Unknown	Eastern Dublin	6	Residential Medium Density	Dwelling Units	104		18,720	18,720
29	Fallon Village - Chen	Medium High Density Residential	2028	Unknown	Eastern Dublin	6	Residential Medium High Density	Dwelling Units	130		16,900	16,900
29	Fallon Village - Chen	Commercial	2028	Unknown	Eastern Dublin	6	Commercial Retail	acres		72.1	50,470	50,470
29	Fallon Village - Chen	General Commercial/Campus Office	2028	Unknown	Eastern Dublin	6	General Commercial/Campus Office	acres		18.5	14,800	14,800
30	Fallon Village - Anderson	Medium High Density Residential	2027	Unknown	Eastern Dublin	6	Residential Medium High Density	Dwelling Units	108		14,040	14,040
30	Fallon Village - Anderson	General Commercial/Campus Office	2027	Unknown	Eastern Dublin	6	Commercial Retail	acres		34.2	23,940	23,940

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Table 3-10. BWF Projections for Future Development

Site No.	Name	Description	Estimated Start	Estimated End	Planning Area	Flow Monitoring Basin	Land Use Designation	Unit of Land Use Designation	Total Dwelling Units	Total Area, acres	Projected BWF, gpd(a)	Net Increase from Existing BWF, gpd
31	Fallon Village - Righetti	Medium Density Residential	2025	Unknown	Eastern Dublin	6	Residential Medium Density	Dwelling Units	96		17,280	17,280
31	Fallon Village - Righetti	General Commercial/Campus Office	2025	Unknown	Eastern Dublin	6	General Commercial/Campus Office	acres		18.5	14,800	14,800
32	Fallon Village - Righetti	Industrial Park	2025	Unknown	Eastern Dublin	6	Industrial Business Park	acres		21.5	19,350	19,350
33	Fallon Village - Monte Vista	Industrial	2028	Unknown	Eastern Dublin	6	Industrial Business Park	acres		9.3	8,370	8,370
34	Fallon Village - Branaugh	Medium Density Residential	2027	Unknown	Eastern Dublin	6	Residential Medium Density	Dwelling Units	97		17,460	17,460
34	Fallon Village - Branaugh	Industrial Park	2027	Unknown	Eastern Dublin	6	Industrial Business Park	acres		30.5	27,450	27,450
35	EBJ Partners L.P.	Commercial	2030	2035	Eastern Dublin	6	Commercial Retail	acres		1.1	770	770
36	Pleasanton Ranch Investments	Commercial	2030	2035	Eastern Dublin	6	Commercial Retail	acres		0.4	280	280
37	Dublin Station - Site D-1	Campus Office	2030	2035	Eastern Dublin	15	Campus Office	acres	195		175,500	175,500
38	Dublin Station - Site D-2	Campus Office	2030	2035	Eastern Dublin	15	Campus Office	acres		12.2	10,980	10,980
39	Dublin Station - Site E-2	Campus Office	2030	2035	Eastern Dublin	15	Campus Office	acres		7.4	6,660	6,660
40	East Dublin	Commercial	2030	2035	Eastern Dublin	15	Commercial Retail	acres		13.8	11,040	11,040
41	Dublin Ranch	Rural Residential	2030	2035	Eastern Dublin	6	Residential Rural	Dwelling Units		79.4	16,674	16,674
42	Dublin Ranch	Rural Residential	2030	2035	Eastern Dublin	7	Residential Rural	Dwelling Units		49.8	10,458	10,458
43	Jordan Ranch - Parcel H (Quartz)	Duets	2017	2019	Eastern Dublin	6	Residential Medium Density	Dwelling Units	45		8,100	8,100
44	Jordan-Elementary School	Elementary School	2015	2018	Eastern Dublin	6	Elementary School	acres		3	600	600
45	Jordan Ranch - Slate (N5)	Single Family	2017	2018	Eastern Dublin	6	Residential Medium Density	Dwelling Units	56		10,080	10,080
46	Jordan Ranch - Onyx (N7)	Single Family	2017	2020	Eastern Dublin	6	Residential Medium Density	Dwelling Units	105		18,900	18,900
47	Jordan - Semi - Public	Semi - Public	2020	2022	Eastern Dublin	6	Public_Semi_Public	acres		2.1	420	420
48	Jordan - Residential 3	Low Density Residential	2020	2022	Eastern Dublin	6	D Residential_Low Density	Dwelling Units	8		1,680	1,680
49	Fallon Enterprises - Residential 1	Rural Residential - Ag	2030	2035	Eastern Dublin	6	Residential Rural	Dwelling Units		36	7,560	7,560
50	Fallon Enterprises - Residential 2	Rural Residential - Ag	2030	2035	Eastern Dublin	6	Rural Residential/Agriculture	Dwelling Units		23.6	4,956	4,956
51	Braddock & Logan - Residential 1	Rural Residential - Ag	2030	2035	Eastern Dublin	6	Residential Rural	Dwelling Units		71.4	14,994	14,994
52	Dublin Ranch - Commercial 1	General Commercial	2030	2035	Eastern Dublin	15	Commercial Retail	acres		2.1	1,470	1,470
53	Grafton Station Area E	Commercial	2030	2035	Eastern Dublin	15	Commercial Retail	acres		2.1	1,470	1,470
54	Promenade	Village Commercial	Unknown	Unknown	Eastern Dublin	15	Residential Medium Density	acres		23	4,140	4,140
55	Dublin Ranch North (Redgewick)	Estate Residential	2018	2019	Eastern Dublin	7	Residential Rural	Dwelling Units	4		840	840
56	The Laborer's Property	Hillside Residential GP Designation	Unknown	Unknown	San Ramon	12	Single Family	Dwelling Units	21		4,410	4,410
57	Bay Church and Valley Vista Properties	Residential Units for Church Personnel	Unknown	Unknown	San Ramon	12	Single Family	Dwelling Units	4		840	840
58	Aspenwood Apartments	Senior Care Facilities	Unknown	Unknown	San Ramon	12	Senior Care Facilities		95		8,550	8,550
								Total	8,142	727	1,870,026	1,825,345

(a) Based on Rebounded Existing Base Wastewater Flow Factors, Table 3-8.
(b) Source: Park RFTA Infrastructure Evaluation, Table 2-1.

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Table 3-11. Projected ADWF for District Collection System

Area Description	Flow Description	Calibrated Existing, mgd	Rebounded Existing, mgd[a]	2020 Projected mgd	2025 Projected, mgd	2035 Projected mgd
Existing Developed Areas	Base Wastewater Flow[b]	5.70	6.23	6.23	6.23	6.23
	Groundwater Infiltration	0.93	0.93	0.93	0.93	0.93
Future Development	Base Wastewater Flow	-	-	0.28	0.79	1.83
	Groundwater Infiltration	-	-	0.13	0.28	0.73
	Total	**6.63**	**7.16**	**7.58**	**8.24**	**9.72**
	Dwelling Unit Equivalents[c]	**30,014**	**29,686**	**31,017**	**33,467**	**38,378**

(a) Rebounded Existing values are based upon Existing Rebounded wastewater generation factors in Table 3-8.
(b) Includes entire wastewater service area, including portions not captured by flow monitoring and also outside of wastewater service area, including commerce circle and facultative sludge lagoon.
(c) One dwelling unit equivalent is assumed to produce to 190 gallons per day of BWF for measured existing conditions and 210 gpd of BWF in the rebounded and future projected conditions.

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3.4 PEAK FLOW DEVELOPMENT

The development of projected peak flows based upon the projected ADWF values is described in the sections below.

3.4.1 Existing and Projected PDWF

Daily hydrographs (diurnal patterns) were composited from all flow captured in the 2017 Flow Monitoring Study during the non-precipitation days. The dry weather peaking factor (PDWF/ADWF) is calculated to be 1.50, which is approximately equal to the dry weather peaking factor at the WWTP, as reported in the September 2017 Dublin San Ramon Services District Wastewater Treatment Plant Master Plan.

The dry weather peaking factor is not expected to vary significantly in the future, and therefore a value of 1.50 was retained for future projections. The projected collection system PDWF values for the future timeframes evaluated in this CSMP are presented in Table 3-12.

Table 3-12. PDWF Summary for District Collection System

Year	ADWF, mgd	PDWF, mgd	Dry Weather Peak Factor
Calibrated Existing[(a)]	6.63	9.95	1.5
Rebounded Existing	7.16	10.75	1.5
2020 Projected	7.58	11.36	1.5
2025 Projected	8.24	12.35	1.5
2035 Projected	9.72	14.57	1.5

(a) PDWF values and factors were measured both with flow monitoring data and the influent stream to the WWTP. Measured values were found to be consistent and similar for both methods.

3.4.2 Existing and Projected PWWF

As described above, existing wet weather flows were evaluated using the R-T-K Method. The R-T-K factors used in the CSMP were estimated via EPA Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox. The 2017 Flow Monitoring Study and the storm in early April 2017 served as the basis for the PWWF calibration. The R-T-K factors for each flow monitoring basin are shown in Table 3-13. The specific attributes of some of the basins that contribute to the values seen in Table 3-13 were previously discussed with the results of the 2017 Flow Monitoring Study. In particular, it should be noted that the calibrated R-T-K values for flow monitoring basin 7 indicated a very rapid and intense inflow into the basin. District operations and maintenance staff indicated that a particular construction project that was active during the 2017 Flow Monitoring Study was potentially draining into the collection system during precipitation events. Because this draining would not be expected to continue after the construction project is complete, wet weather flow projections were calculated using the R-T-K factors for flow monitoring basin 6, which would be expected to accurately represent flow monitoring basin 7 because of similarities in age and gravity main materials, to represent flow monitoring basin 7 in the future projections.

Table 3-13. Calibrated RTK Values for PWWF

Basin	Total R	R1	R2	R3	T1, hours	T2, hours	T3, hours	K1	K2	K3
1	1.20%	0.10%	0.10%	1.00%	1.00	4.00	12.00	1.00	2.00	5.00
2	0.24%	0.16%	0.04%	0.04%	1.00	4.00	12.00	1.00	2.00	5.00
3	2.80%	0.30%	0.50%	2.00%	2.00	4.00	12.00	1.00	1.00	6.00
4	0.48%	0.10%	0.10%	0.28%	1.00	3.00	10.00	1.00	2.00	2.00
5	0.64%	0.21%	0.21%	0.22%	1.00	4.00	12.00	1.00	2.00	5.00
6	0.16%	0.16%	0.00%	0.00%	1.00	4.00	6.00	0.75	2.00	2.00
7	1.40%	1.00%	0.40%	0.00%	1.00	2.00	6.00	1.00	2.00	2.00
8	6.00%	0.50%	0.50%	5.00%	1.00	2.00	12.00	1.00	2.00	5.00
9	2.90%	0.40%	0.50%	2.00%	2.00	4.00	12.00	1.00	2.00	2.00
10	5.00%	1.00%	2.00%	2.00%	2.00	4.00	12.00	1.00	2.00	2.00
11	1.15%	0.30%	0.25%	0.60%	1.00	4.00	10.00	1.00	2.00	2.00
12	1.80%	0.25%	0.55%	1.00%	2.00	4.00	12.00	1.00	2.00	2.00
13	0.62%	0.12%	0.20%	0.30%	1.00	4.00	12.00	1.00	2.00	2.00
14	1.75%	0.10%	0.90%	0.75%	1.00	4.00	10.00	1.00	2.00	4.00
15	0.40%	0.17%	0.13%	0.10%	1.00	4.00	12.00	1.00	2.00	2.00

The R-T-K values shown above were calculated from an actual storm and the collection system response to that storm captured by the 2017 Flow Monitoring Study. Projected PWWF design flows are calculated by applying the calibrated R-T-K values to a design storm. The design storm selected for this CSMP is detailed in Chapter 4. The RDII and PWWF factors that result from this design storm are shown in Table 3-14. For each future development project identified in Table 3-10, the R-T-K parameters for the associated flow monitoring basin are applied to generate future RDII for the development.

Table 3-14. PWWF Summary for District Collection System

Year	ADWF, mgd	PDWF, mgd	RDII, mgd	PWWF, mgd
Calibrated Existing	6.63	9.95	8.90	18.85
Rebounded Existing	7.16	10.75	8.90	19.65
2020 Projected	7.58	11.36	9.33	20.69
2025 Projected	8.24	12.35	9.75	22.10
2035 Projected	9.72	14.57	10.46	25.03

3.5 FLOW PROJECTION COMPARISON

It is important to understand the flow projections in this CSMP in context of other recent flow projections. The 2005 Wastewater Collection System Master Plan developed flow projections for the District's collection service area based upon flow monitoring conducted for that plan. ADWF, PDWF, and PWWF values were developed for existing and buildout conditions. These projections can be seen in Table 3-15. The buildout projections are very similar to the buildout projections developed for this CSMP, which were independently developed from data collected in the 2017 Flow Monitoring Study. The fact that two separate flow monitoring studies conducted more than 12 years apart arrived at such similar values provides a high level of confidence in the understanding of the collection system that produced these values. The consistency of the PWWF projections is also a testament to the effort the District has invested in maintaining the integrity of the collection system over the past 12 years.

Table 3-15. Wastewater Flow Projection Comparison

Year	ADWF, mgd	Diurnal Peaking Factor	PDWF, mgd	PWWF Factor	PWWF, mgd
2005 Wastewater Collection System Master Plan Update					
Existing (2005)	6.0	1.50	9.0	2.87	17.2
Buildout (2020)	9.6	1.48	14.2	2.59	24.9
Conservative Buildout (2020)	8.5	1.45	12.3	2.71	23.0
2017 CSMP					
Existing (2017)	6.6	1.50	9.9	2.74	18.2
Rebounded Existing	7.2	1.50	10.7	2.65	19.0
2035 (Build-out)	9.8	1.50	14.7	2.50	24.4
September 2017 Dublin San Ramon Services District Wastewater Treatment Plant Master Plan (Includes City of Pleasanton Flows)					
Existing	9.7	1.58	-	3.77	36.6
2035 (Build-out)	12.3	1.58	-	3.80	46.7

As can be seen in Table 3-15, the September 2017 Dublin San Ramon Services District Wastewater Treatment Plant Master Plan developed flow projections for the District's treatment service area. The treatment service area incorporates the collection service area plus the City of Pleasanton. The ADWF values from this plan appear to be low when compared to the values of this CSMP, considering that they must include ADWF from the City of Pleasanton. This potential discrepancy was evaluated by District staff, and District staff are currently evaluating the effectiveness of the influent flow meters at the WWTP upon which the September 2017 Dublin San Ramon Services District Wastewater Treatment Plant Master Plan values are based. This evaluation may bring the flow values seen at the WWTP into better alignment with the values of both the 2005 Wastewater Collection System Master Plan Update and this CSMP.

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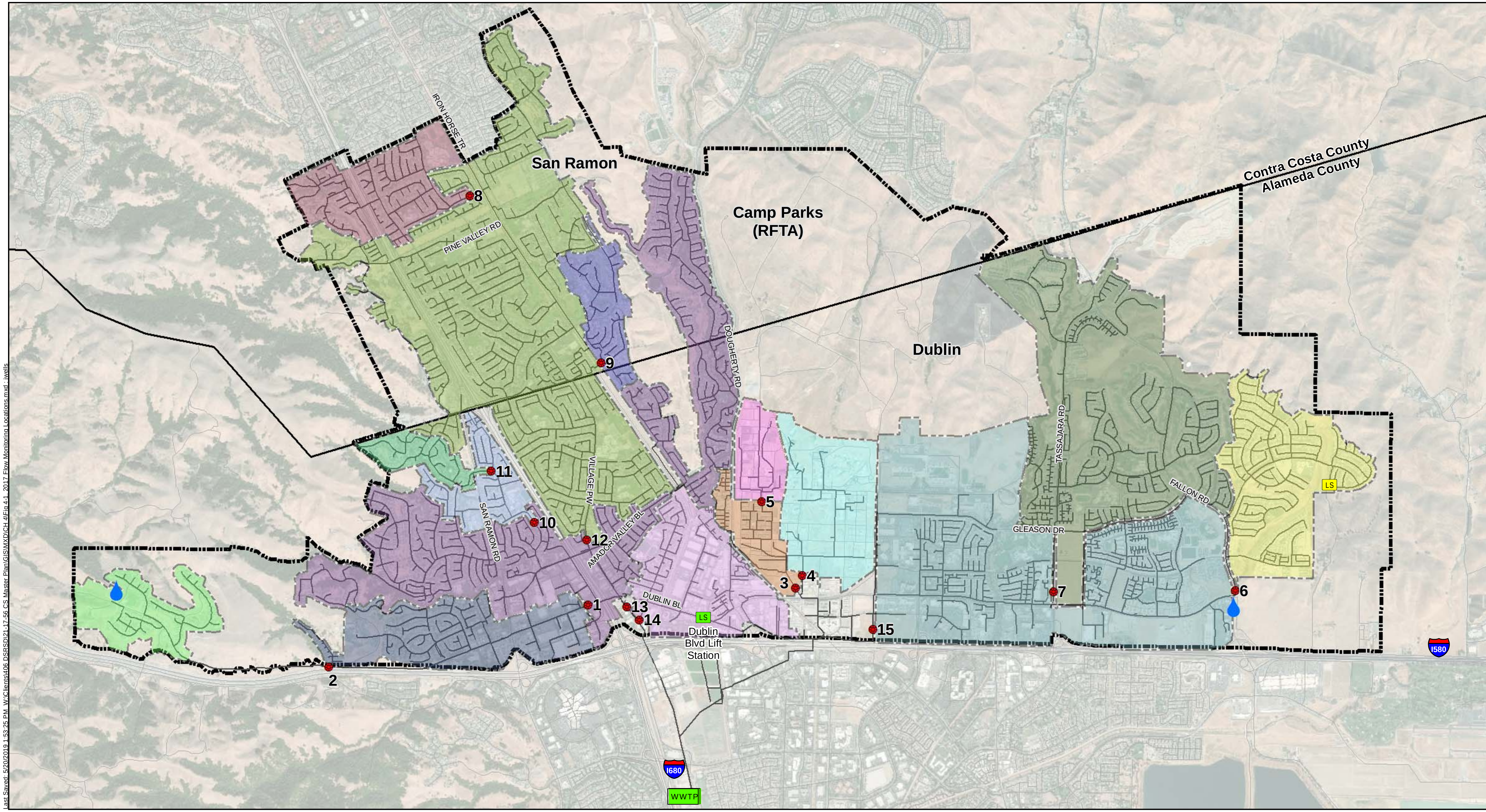

Symbology

- WWTP — WWTP
- LS — Permanent Lift Station
- LS — Temporary Lift Station
- Flow Meter Location
- Rainfall Gauge
- Gravity Main

2017 Flow Monitoring Shed

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

Wastewater Collection Service Boundary

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 3-2

2017 Flow Metering and Rainfall Gauge Locations

Dublin San Ramon Services District
Collection System Master Plan

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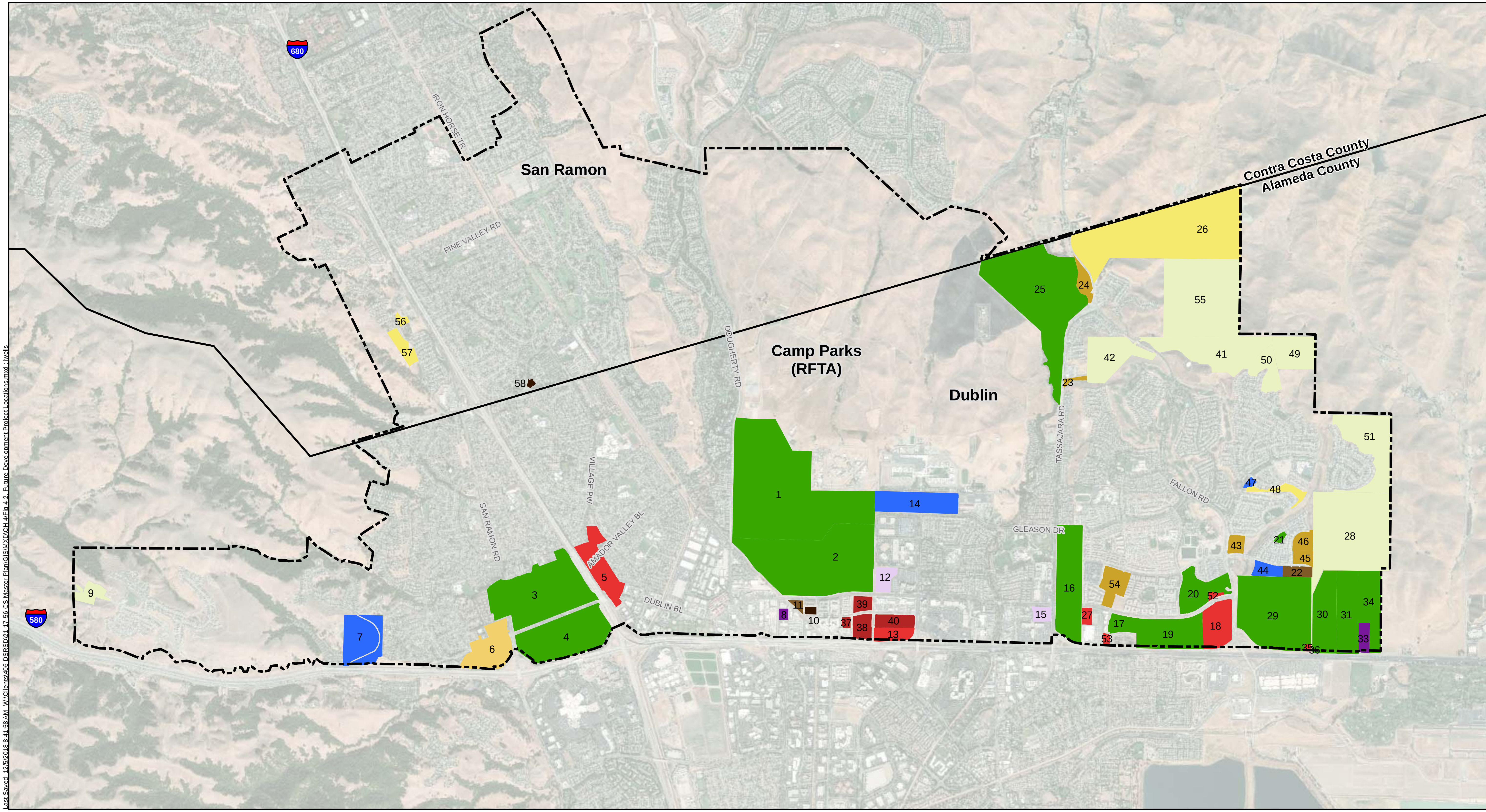

Wastewater Collection Service Boundary

Multiple Land Uses

See Table 4.8 for Details

Public/Semi-Public/Open Space

Public / Semi-Public

Commercial / Industrial

General Commercial

Retail / Office

Campus Office

Business Park / Industrial

City of Dublin Residential

Rural Residential / Agriculture (1 du per 100 Acres)

Low-Density Single Family (0.5 - 3.8 du/acre)

Single Family Residential (0.9 - 6.0 du/acre)

Medium-Density Residential (6.1 - 14.0 du/acre)

Medium/High-Density Residential (14.1 - 25.0 du/acre)

High-Density Residential (>25.1 du/acre)

City of San Ramon Residential

Low-Density Single Family (0.2 - 3.0 du/acre)

Very High-Density Multiple Family (30.0 - 50.0 du/acre)

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 3-4

Future Development Project Locations

Dublin San Ramon Services District
Collection System Master Plan

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CHAPTER 4
Design Flow and Performance Criteria

Chapter 2 of the CSMP describes the infrastructure in the District's collection system, and Chapter 3 describes the existing and future flows which the collection system must convey. This chapter defines the performance criteria that are used to evaluate the ability of the collection system to convey these flows. This chapter also includes a description of the design storm that is used to generate the wet weather flows that were detailed in Chapter 3.

4.1 PERFORMANCE CRITERIA

The capacity of the District's collection system is evaluated for the CSMP based on the performance criteria defined in this section. The criteria are primarily taken from the District's Standard Procedures, Specifications and Drawings for Wastewater Utilities (District Standards) and from the 2005 Collection System Master Plan. The criteria are supplemented with other commonly-used criteria as needed and as specified below. The following performance criteria are discussed in this section:

- Gravity Main Performance Criteria
- Lift Station and Force Main Performance Criteria

4.1.1 Gravity Main Performance Criteria

Conceptually speaking, gravity main performance criteria concern the determination of how full a gravity main will be at a given flow (what is the capacity of the gravity main), and determination of how full a gravity main may be before it is identified to have insufficient capacity (how much capacity in the gravity main can be taken by design flows before the gravity main is identified as insufficient). The following gravity main capacity topics are discussed below:

- Flow Capacity
- Maximum Allowable Flow
- Design Velocities and Minimum Slopes

4.1.1.1 Flow Capacity

In evaluating flow and capacity in gravity mains, two equations are used. With the following two equations, the depth of flow can be determined in a gravity main for any given flow, and the full flow capacity (flow at which the depth of flow equals the gravity main diameter) of the gravity main can be determined:

Continuity Equation: $Q = V*A$

where:

Q = peak flow, cubic feet per second (fps)
V = flow velocity, fps
A = cross-sectional area of pipe, square feet

Manning's Equation: $V = (1.486*R^{2/3}*S^{1/2})/n$

where:

V	=	flow velocity, fps
n	=	Manning's coefficient of friction (unitless)
R	=	hydraulic radius (cross-sectional area of flow divided by wetted perimeter), feet
S	=	slope of pipe, feet per foot

Manning's "n" is a pipe friction-related coefficient that varies with pipe material, age, and other factors. For collection system gravity mains, the Manning's coefficient typically ranges between 0.011 and 0.017, with 0.013 being a typical value used for collection system master planning. A value of 0.013 is the default value used in this CSMP for the majority of gravity mains, including all gravity mains composed of VCP, and older gravity mains composed of HDPE or PVC. This value is consistent with the recommendations provided in the District Standards. For gravity mains less than five years old that are composed of HDPE or PVC, or for gravity mains that were lined less than five years ago, a Manning's "n" value of 0.012 may be used for hydraulic evaluation.

4.1.1.2 Maximum Allowable Flow

The maximum allowable flow performance criterion concerns how much of a given gravity main's total capacity may be taken by the design flow in that gravity main before the gravity main is identified as having insufficient capacity. The maximum allowable flow in a gravity main is typically expressed in one of two ways. The first way is as a function of depth of flow (d) at design flow conditions as a ratio of the gravity main diameter (D). For instance, a d/D ratio of 0.50 for a 12-inch diameter gravity main indicates that this main is flowing at a depth of 6-inches under design flow conditions. Typically, d/D performance criteria are established between 0.50 and 1.00 depending on gravity main size. Smaller diameter gravity mains typically have lower d/D criteria values because the small diameter leaves less freeboard and therefore less contingency at a given design flow.

The second manner of expressing the maximum allowable flow in a gravity main is the ratio of the maximum flow in the pipe under design conditions (q) to the full pipe capacity (Q). Although d/D ratios have a maximum of 1.00 (the depth of flow cannot physically be greater than the gravity main diameter), the q/Q ratio can exceed 1.00. In such a case, the design flow exceeds the maximum full pipe capacity, and surcharge conditions are created. It should be noted that for circular gravity mains (which includes all of the District's existing gravity mains), a d/D ratio of 0.50 is equal to a q/Q ratio of 0.50. For other ranges of flow, the d/D ratio and q/Q ratio for a given flow will be similar but not identical.

Although the 2005 Wastewater Collection System Master Plan Update defines performance criteria in terms of d/D ratios, the actual hydraulic analysis in that document uses q/Q ratios (gravity mains were said to be deficient with q/Q > 1.00, and were prioritized with q/Q > 1.20). The construction standards provided by the District to developers for new construction use d/D ratios. For this CSMP, q/Q ratios are used to express maximum allowable flow in gravity mains for the following reasons:

1. The q/Q ratios used in the 2005 Wastewater Collection System Master Plan Update were appropriate and effective, and using consistent criteria allows collection system performance to be tracked over time.

2. The q/Q ratio evaluates each gravity main on its own capacity, without influence from downstream capacity restrictions and backwater conditions that can impact d/D ratios.

3. The q/Q ratio allows for classification of flows above q/Q = 1.00, which is useful for prioritizing gravity mains with insufficient capacity.

The use of q/Q ratios for performance criteria in this CSMP does not preclude the District from continuing to use d/D ratios for design and construction criteria with developers. The performance criteria for the CSMP are concerned with long-term management of capacity in the collection system, while the design and construction standards are concerned with constructing appropriate infrastructure for much more detailed and well-defined portions of the collection system.

Determination of the specific q/Q ratios that are to be used as performance criteria is a both a policy decision and an engineering decision that balances the risk of a potential overflow caused by insufficient capacity versus the cost required to meet a particular q/Q ratio throughout the collection system. For this CSMP, it was determined that a maximum q/Q ratio of 1.00 in gravity mains provided the appropriate balance of risk versus cost. As described above, this criterion is consistent with the 2005 Wastewater Collection System Master Plan Update, and it is a widely used value for collection systems across California, particularly those collection systems that are performing well with very few capacity issues. Major and minor capacity deficiencies are prioritized by a cutoff value of q/Q = 1.20.

Once a gravity main has been determined to have insufficient capacity, the gravity main performance criteria for this CSMP recommend that the capacity improvement project indicated be designed to a q/Q ratio of 0.75. Once a project is required, designing the project to q/Q = 0.75 rather than q/Q = 1.00 provides significant risk reduction at a small marginal cost. The maximum allowable q/Q ratios for design flow conditions as described above are summarized in Table 4-1.

Table 4-1. q/Q Ratios for Design Flow Conditions

Gravity Main Description	Design Flow Maximum q/Q Ratio
Existing Gravity Main – Major Capacity Deficiency	q/Q > 1.20
Existing Gravity Main – Minor Capacity Deficiency	q/Q > 1.00 and q/Q ≤ 1.20
Existing Gravity Main – No Deficiency	q/Q ≤ 1.00
New Gravity Main Design	q/Q < 0.75

4.1.1.3 Design Velocities and Minimum Slopes

To effectively operate, gravity mains must have sufficient capacity for peak design flows, but also must operate effectively during typical daily flows. To minimize the settlement of wastewater solids in the pipe during typical daily flows, District Standards require gravity main velocities equal to or greater than 2 fps for all gravity mains when flowing half full to ensure adequate flushing of solids. The maximum velocity for gravity mains shall normally be 8 to 10 fps. Table 4-2 lists the recommended minimum slopes for maintaining velocities greater than 2 fps when the gravity main is flowing half full.

Table 4-2. Gravity Main Minimum Slopes

Gravity Main Diameter	Minimum Slope, feet/feet
6-inch	0.0049
8-inch	0.0033
10-inch	0.0025
12-inch	0.0019
15-inch	0.0014
18-inch	0.0011
21-inch	0.0009

Source: District Standards

4.1.2 Lift Station and Force Main Criteria

Key lift station and force main criteria discussed in this section include:

- Lift Station Hydraulic Capacity
- Force Mains

4.1.2.1 Lift Station Hydraulic Capacity

Per District Standards, lift stations are not normally allowed, but may be considered under extraordinary circumstances if specifically approved by the District Engineer during the preliminary design stages. For this CSMP, the hydraulic criteria for lift stations is that they should have sufficient capacity to pump the peak design flow with the largest pump out of service (firm capacity). Standby power is not required by the District Standards, but should be considered as standard on all new lift stations and all lift station rehabilitation projects.

4.1.2.2 Force Mains

The District Standards do not include specific hydraulic criteria for force mains. Nevertheless, force mains are typically sized such that the velocity in the force main will exceed 3 fps under normal operating condition so that the force main will remain free of settled debris. Similarly, force mains are typically sized such that the maximum velocity in the force main will not exceed 8 fps under peak conditions. This maximum velocity prevents excessive wear and tear on the force main, and limits excessive energy expenditures due to the high friction losses that result from higher flow velocities.

For the CSMP, the force main design criteria of a minimum velocity of 3 fps under normal operating conditions and a maximum velocity of 8 fps under peak operating conditions are applied. The Hazen-Williams formula is used to calculate force main velocities, as follows:

Velocity Equation: $V = 1.32*C*R^{0.63}*S^{0.54}$

where:

- V = flow velocity, fps
- C = Hazen-Williams coefficient (unitless)
- R = hydraulic radius (defined as D/4, where D is the pipe diameter), feet
- S = slope of the energy gradient (defined as the friction loss divided by the pipe length), feet per foot

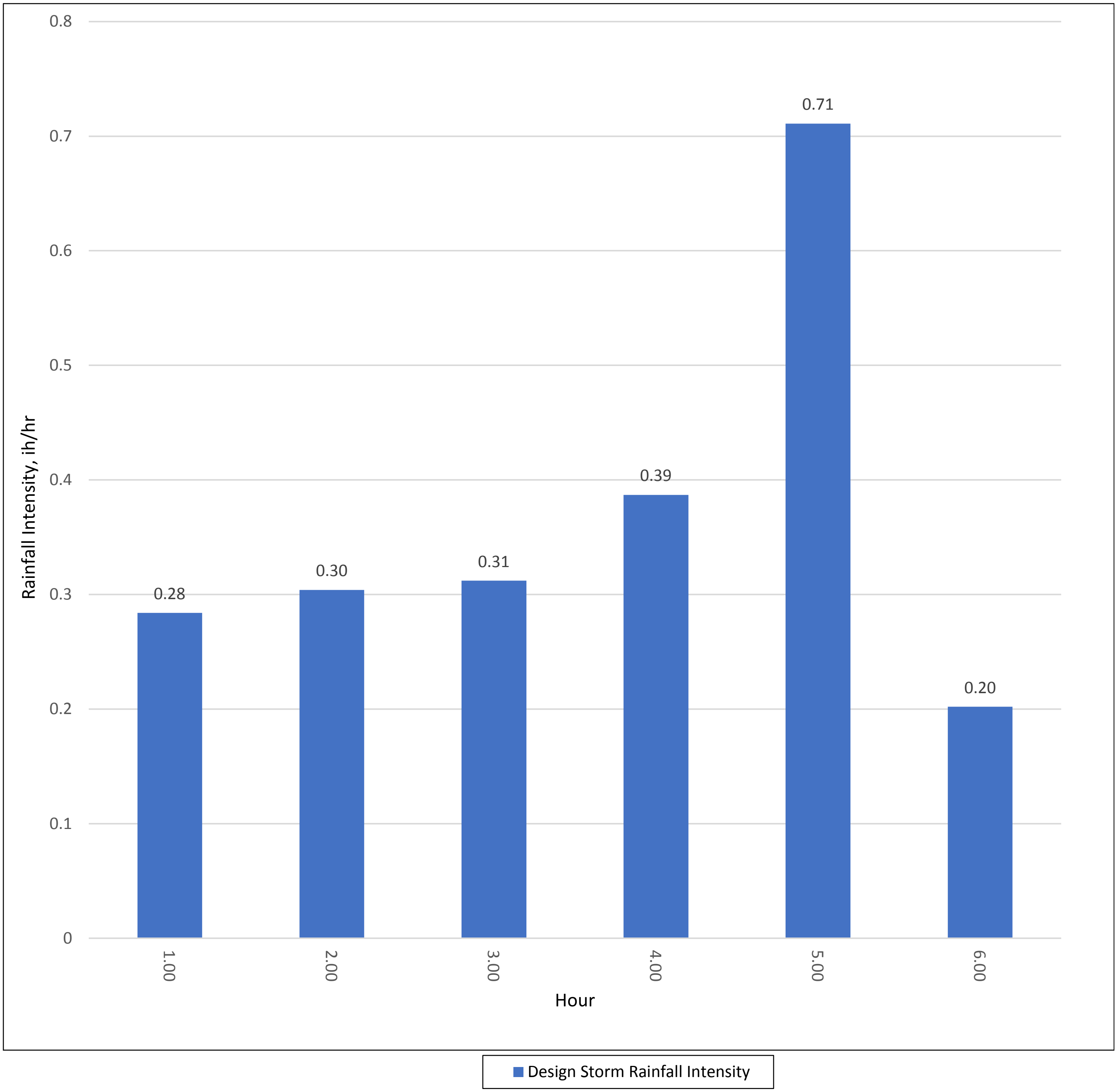
The value of the Hazen-Williams coefficient varies with the type of pipe material and is influenced by the type of construction and age of the pipe. A value of 120 is assumed to be the default value for this analysis.

4.2 DESIGN STORM CRITERIA

The use of wet weather design events as the basis for sewer capacity evaluation is standard practice in collection system planning and design. This process first involves calibrating a hydraulic model of the collection system to match wet weather flows from one or more observed storms (as described in Chapter 3), and then applying the calibrated model to a design rainfall event to identify capacity deficiencies and to size sewer improvements. The design event may be synthesized from rainfall statistics (synthetic design storm) or may be an actual historical rainfall event of appropriate duration and intensity. Other considerations for the design event include the spatial variation of the rainfall and the timing of the storm relative to the diurnal base wastewater flow pattern. For conservatism, it is assumed in this CSMP that the timing of the diurnal flow peak will approximately coincide with the peak of the RDII during the design storm.

Selection of a design storm is typically based on an allowable level of risk within the collection system, and the description of the design storm is most often expressed in terms of the return period and the duration of the storm. It is recognized that while wet weather overflows are highly undesirable, the cost of providing capacity increases with the return period of the design storm and the associated design flow. Regulatory agencies have not adopted standard criteria for return periods, so wastewater agencies utilize a target return period based on a balance of desired level of service, potential impacts of overflows, and cost of providing capacity.

As part of the 2000 Collection System Master Plan, the District developed a 20-year return period, 6-hour duration design storm as the basis for collection system planning. The 2005 Wastewater Collection System Master Plan Update also used this design storm basis. Discussion with District staff indicates that the balance of risk and cost represented by the existing 20-year, 6-hour storm remains appropriate. Consistency in design storm selection over time allows for tracking of collection system performance. For these reasons, the 20-year, 6-hour design storm has retained for the current CSMP, as shown on Figure 3-5. This storm projects a total rainfall of 2.2 inches in 6 hours. As a 20-year return frequency event, the CSMP design storm is associated with a 5 percent probability that such a storm would occur in any given year.



Notes:

1. Taken From 2005 Collection System Master Plan

Figure 4-1

20-year, 6-hour Design Storm

Dublin San Ramon Services District
Collection System Master Plan

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CHAPTER 5
Hydraulic Model Update

To meet the objective of guiding the District's remaining capital improvement projects and establishing appropriate Capacity Reserve Fees, the CSMP requires a comprehensive hydraulic evaluation of the District's collection system. As a result of this requirement, an updated hydraulic model of the District's wastewater collection system has been developed and utilized. This chapter contains a description of the model software, describes how the collection system infrastructure described in Chapter 2 was imported into the model, and describes how the design flows developed in Chapter 3 were integrated into the model. Accordingly, the major sections of this chapter include:

- Model Description
- Model Network Revisions
- Model Flow Updates

5.1 MODEL DESCRIPTION

As part of the 2005 Wastewater Collection System Master Plan Update, a hydraulic model of the District's collection system was developed utilizing H_2OMap Sewer Pro software (H_2OMap Sewer), a product of Innovyze, Inc. Recently, Innovyze announced that H_2OMap Sewer will no longer be supported, so West Yost updated the District's hydraulic model into the InfoSewer hydraulic modeling platform. InfoSewer utilizes a hydraulic modeling engine that is identical to that used in H_2OMap Sewer, so results are identical between the two software packages. However, InfoSewer runs in a GIS platform that integrates directly with the District's GIS platform.

InfoSewer was developed specifically for collection system capacity analysis and is widely used in the industry. The InfoSewer hydraulic model, updated as described below, has been used in this CSMP to identify hydraulic deficiencies under existing and future conditions, and to identify and evaluate potential relief sewers or other infrastructure improvements to address the identified hydraulic deficiencies.

There are two types of hydraulic simulations used to assess the capacity of collection systems: steady state/static simulations and extended period/dynamic simulations. Steady state simulations represent a snapshot of the system performance at a given point in time under specific flow generation conditions (typically a peak flow condition). Extended period/dynamic simulations employ a continuous simulation of the changes in system flow rates over time, and are typically used to analyze the operational performance of the system over a 24-hour or longer period. Extended period/dynamic simulation requires more extensive data input than a steady-state simulation, including appropriate 24-hour diurnal patterns for various land use categories within the collection system, as well as a representation of time-varying collection system response to rainfall. For the purposes of this CSMP, as with the 2005 Wastewater Collection System Master Plan Update, extended period/dynamic simulations have been used to perform hydraulic evaluation of the District's collection system over a 72-hour period.

5.2 MODEL NETWORK REVISIONS

The hydraulic model developed for the 2005 Wastewater Collection System Master Plan Update was a skeletonized model that contained only the larger-diameter trunk sewers in the District's collection system. For the current analysis, the District desired a more comprehensive evaluation of collection system capacity, including the small diameter gravity mains that predominate the collection system. Further, the District desired that a clear link be developed between individual parcel flows and their connection to the collection system. Such a link requires that all gravity mains, regardless of diameter, be included in the hydraulic model. Therefore, as part of this CSMP, the hydraulic model has been updated to include a network that contains all collection system gravity mains. Further, the model was updated to include all lift stations and force mains, and therefore represents the collection system as it currently exists.

The District has invested considerable effort in developing and maintaining a GIS database of the collection system, which, for this analysis, was current as of September 2017. To facilitate the update of the hydraulic model, the 2005 Wastewater Collection System Master Plan Update hydraulic model was compared against the GIS data to determine data gaps and discrepancies to be addressed in the model. The comparison yielded the following general classes of updates to the hydraulic model:

1. Structural improvements and areas of development later than the 2005 Master Plan were incorporated.
2. Discrepancies in gravity main diameters, gravity main invert elevations, and manhole rim elevations between the hydraulic model and the GIS were identified. Per District staff direction, data in the GIS was considered preeminent.
3. Infrastructure that appeared in the hydraulic model but not in the collection system GIS was identified and deactivated in the hydraulic model. This infrastructure was left in the hydraulic model to provide a record of model changes and updates. Because it is deactivated, it does not impact model results. It can be deleted from the hydraulic model at any time the District chooses.

In addition to the updates described above, the small diameter gravity mains and associated manholes that were not included in the 2005 Wastewater Collection System Master Plan Update hydraulic model were imported in a manner to preserve a one-to-one relationship with the District's GIS. A specific naming scheme was developed to maintain the ID relationship between the GIS and the hydraulic model. The naming scheme is described in the Collection System Hydraulic Modeler's Notebook, included as Appendix B of the CSMP. The following methods were used to update the model and maintain the GIS link:

1. Manhole and gravity main unique GIS identifiers (ID) were preserved as unique hydraulic model identifiers where possible. In some cases, multiple manholes and gravity mains had the same identifier in GIS. Because the hydraulic model does not allow non-unique identifiers, the identifier of one of the identically-named elements was altered in the hydraulic model as follows:
   a. Manholes with duplicated GIS ID values were given the prefix "DUP_".
   b. Inactivated infrastructure in the hydraulic model was given the prefix "WYA_". This infrastructure was left in the hydraulic model to provide a record of model changes and updates. Because it is deactivated, it does not impact model results. It can be deleted from the hydraulic model at any time the District chooses.

2. In some cases, there were discrepancies between manholes and gravity main hydraulic model ID values and GIS ID values in the current GIS database. In such case, the hydraulic model ID values were updated to the unique GIS ID to make the hydraulic model consistent with the current GIS. A comprehensive list of these updates is available in Attachment 1 of the Collection System Hydraulic Modeler's Notebook.
3. The hydraulic model requires an upstream manhole and downstream manhole for each gravity main. In some cases, this geometry was not properly represented in the GIS. In these cases, the geometry was fixed in the hydraulic model as follows:
    a. There were missing manholes in the collection system infrastructure of the Wallis development located in East Dublin. Accordingly, the missing manholes were added to the model, and a unique identifier was created for each new manhole by adding a unique numeric suffix to "WALLIS_" in the model.
    b. In some cases, a manhole appeared in the middle of a gravity main, but was not properly connected to that main. In such cases, the gravity main was split into two separate mains that were each connected to the manhole to reflect the proper upstream and downstream geometry in the network. The length of each of the two newly-created gravity mains was measured in GIS. Inverts for the split gravity main were determined through interpolation using the length and slope of the original gravity main.
    c. In some cases, the gravity main alignments were not aligned correctly, such that the upstream and downstream manhole were reversed in the hydraulic model. This situation can result from the model import process even if all attribute information is correct in the GIS. All such instances were corrected.
4. Because the small diameter gravity mains were being imported into the hydraulic model for the first time, some of the gravity mains did not have the upstream and downstream invert elevation data required for the hydraulic model. As part of its ongoing comprehensive collection system management policies, the District will be collecting and populating this invert elevation data. To facilitate the timely update of the hydraulic model, the following assumptions were made to provide preliminary values for the missing invert elevations. A comprehensive list of all such assumptions is included in Attachment 1 of the Collection System Hydraulic Modeler's Notebook:
    a. Where one invert elevation (either upstream or downstream) and the gravity main slope was known, the second invert elevation was calculated from the known invert and the pipe slope.
    b. Where an invert elevation was unknown on one gravity main, but the corresponding invert elevation was known on the gravity main sharing the manhole, the known invert elevation was assigned.
    c. Where the data listed above were not available, inverts were calculated assuming minimum standard slopes of gravity mains from the nearest known point.
5. For unknown rim elevations, the elevation was estimated through interpolation using District's 1-foot interval contour information for the region.

6. In some cases, discrepancies were found between gravity main diameter data in the GIS versus the existing hydraulic model. Such discrepancies were corrected with the input of District staff. A comprehensive list of all such assumption is included in Attachment 1 of the Collection System Hydraulic Modeler's Notebook.

In addition, data checks were conducted on the hydraulic model to identify missing data and physical inconsistencies (e.g., reverse slope, unrealistic gravity main lengths). Inconsistencies were identified for the District and corrected. A comprehensive list of all such corrections is included in Attachment 1 of the Collection System Hydraulic Modeler's Notebook. Figure 5-1 depicts the updated model network for this evaluation.

5.3 MODEL FLOW UPDATES

Chapter 3 of this CSMP detailed the development of existing, rebounded existing and future design flows within the District. This section describes how these flows were incorporated into the hydraulic model. Accordingly, the following topics are covered:

- ADWF Updates
- PDWF Updates
- PWWF Updates

5.3.1 ADWF Updates

ADWF values were developed on a parcel-to-manhole basis. The parcel-to-manhole linkage was established through a GIS proximity analysis that identified the manhole closest to each parcel. Manual linkage was performed where the results of the proximity analysis were inconclusive. Such areas included those with parallel gravity mains, and with both trunk and collector gravity mains in close proximity. The result of the development of the parcel-to-manhole linkage is that every parcel in the District's wastewater service area has existing and future flows identified for it, as wells as the loading manhole in the collection system for that parcel identified.

The parcel-to-manhole linkage used as the basis for ADWF calculations is detailed in the Collection System Hydraulic Modeler's Notebook provided as Appendix B. The InfoSewer modeling software contains ten loading fields that can be used to organize flows being imported into the model. For the District's hydraulic model, flows were organized into the loading columns as shown in Table 5-1. As discussed in Chapter 4, the GWI component of ADWF varies across the District and contributes significantly to ADWF in some areas. To facilitate the District's ability to vary GWI independent of BWF within the model in the future, GWI is loaded discreetly from BWF in separate load fields in the hydraulic model as shown.

As indicated in Table 5-1, existing flows in the hydraulic model were addressed with Loads 1 through 4. Future flows were addressed with Loads 5 through 8. Loads 9 and 10 are reserved for special analysis or for flows that are not anticipated at this time. The segregation of hydraulic model flows by type, land use, and timeframe allows for expedited adjustments in the future as development patterns change.

Table 5-1. Load Column Description in the Hydraulic Model

Load Column	Load Description
Load 1	Rebounded Existing BWF of Existing Residential Developed Areas in District Wastewater Collection Service Area(a)
Load 2	Rebounded Existing BWF of Existing Non-Residential Developed Areas in District Wastewater Collection Service Area(a)
Load 3	Rebounded Existing BWF of Existing Camp Parks Developed Areas in District Wastewater Collection Service Area(a)
Load 4	GWI of Existing Developed Areas in District Wastewater Collection Service Area(a)
Load 5	Projected BWF of Future Residential Development Projects in District Wastewater Collection Service Area
Load 6	Projected BWF of Future Non-Residential Development Projects in District Wastewater Collection Service Area
Load 7	Projected BWF of Future Camp Parks Development Projects in District Wastewater Collection Service Area
Load 8	Projected GWI of Future Development Projects in District Wastewater Service Area
Load 9	Blank for Future Use
Load 10	Blank for Future Use

(a) Existing developed areas include active parcels that have not been identified for Future Development projects.

5.3.2 PDWF Updates

To generate PDWF from ADWF in the hydraulic model, diurnal patterns were applied to ADWF values. Specific residential, non-residential, and Camp Parks diurnal patterns were developed for the District's collection system based upon the data generated during the 2017 Flow Monitoring Study. The appropriate diurnal pattern was applied to each flow in the model based upon the land use generating that flow. Because residential, non-residential, and Camp Parks-specific flows are segregated by load column, diurnal patterns can be conveniently applied by load column in the InfoSewer Model. When aggregated at the WWTP at the outlet of the hydraulic model, these diurnal patterns produce a peaking factor of 1.50, as described in Chapter 3.

The design residential and non-residential diurnal pattern are presented on Figure 5-2 and 5-3, respectively. Figure 5-4 shows the Camp Parks area diurnal patterns.

5.3.3 PWWF Updates

The R-T-K values developed in Chapter 3 and the associated design storm described in Chapter 4 are implemented in the hydraulic model to calculate the RDII. The R-T-K hydrograph applied to the acreage tributary of each manhole results in RDII for each individual manhole. It is assumed that the RDII values for existing areas will remain unchanged between the existing and future flow conditions. The area associated with new developments is added to the appropriate manhole for the timeframe appropriate to the development, as identified in Chapter 3.

RDII is generated in the hydraulic model when a particular rainfall event is applied to the collection system with its calibrated R-T-K values. Rainfall events are represented as hyetograph curves in InfoSewer. The District's hydraulic model contains hyetograph curves for measured calibration storms, as well as for the District's design storm. PWWF calibration plots showing the agreement of the hydraulic model to the measured field values captured in the 2017 Flow Monitoring Project are provided in the Hydraulic Modeler's Notebook found in Appendix B.

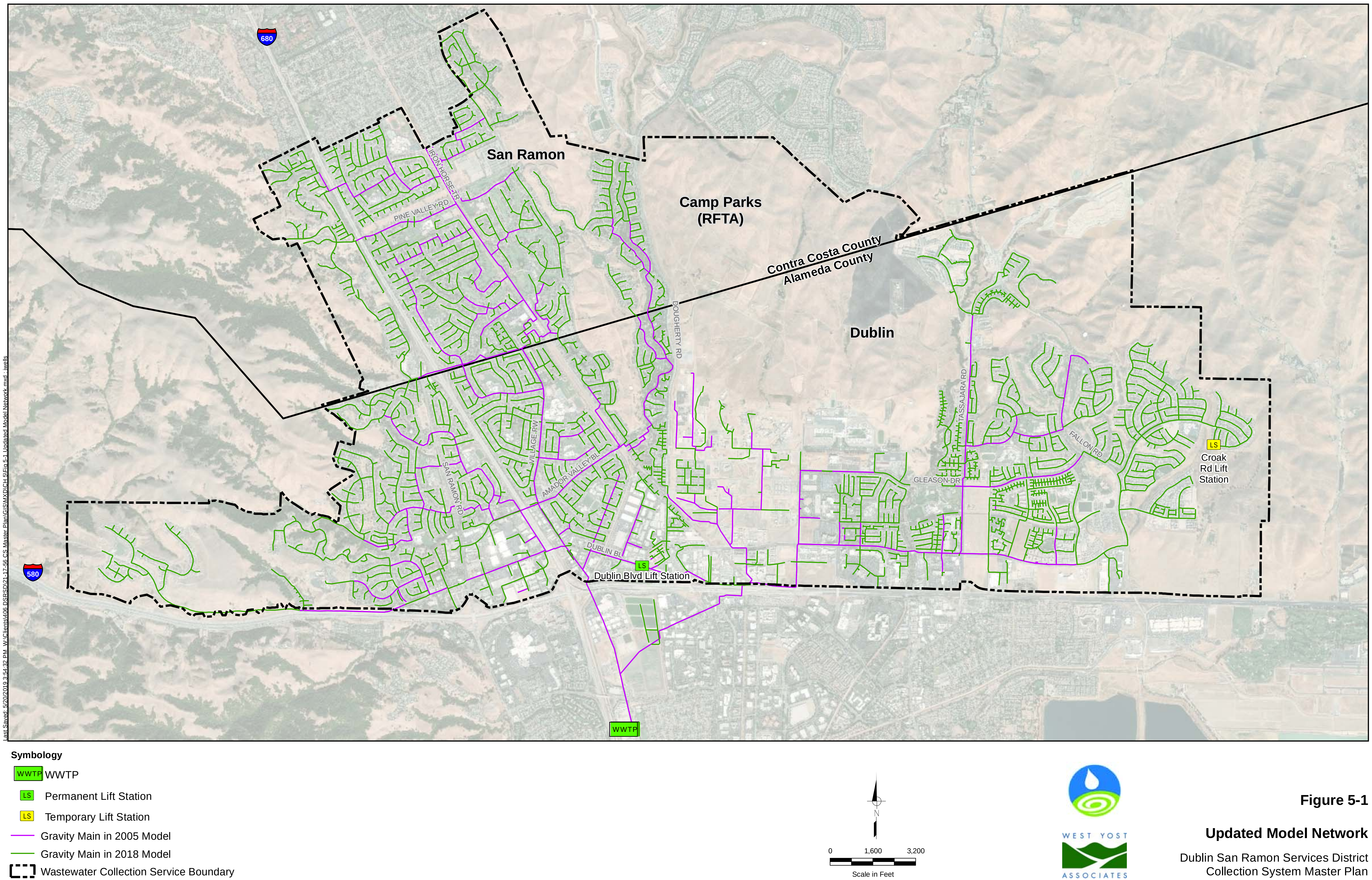

Figure 5-1

Updated Model Network

Dublin San Ramon Services District
Collection System Master Plan

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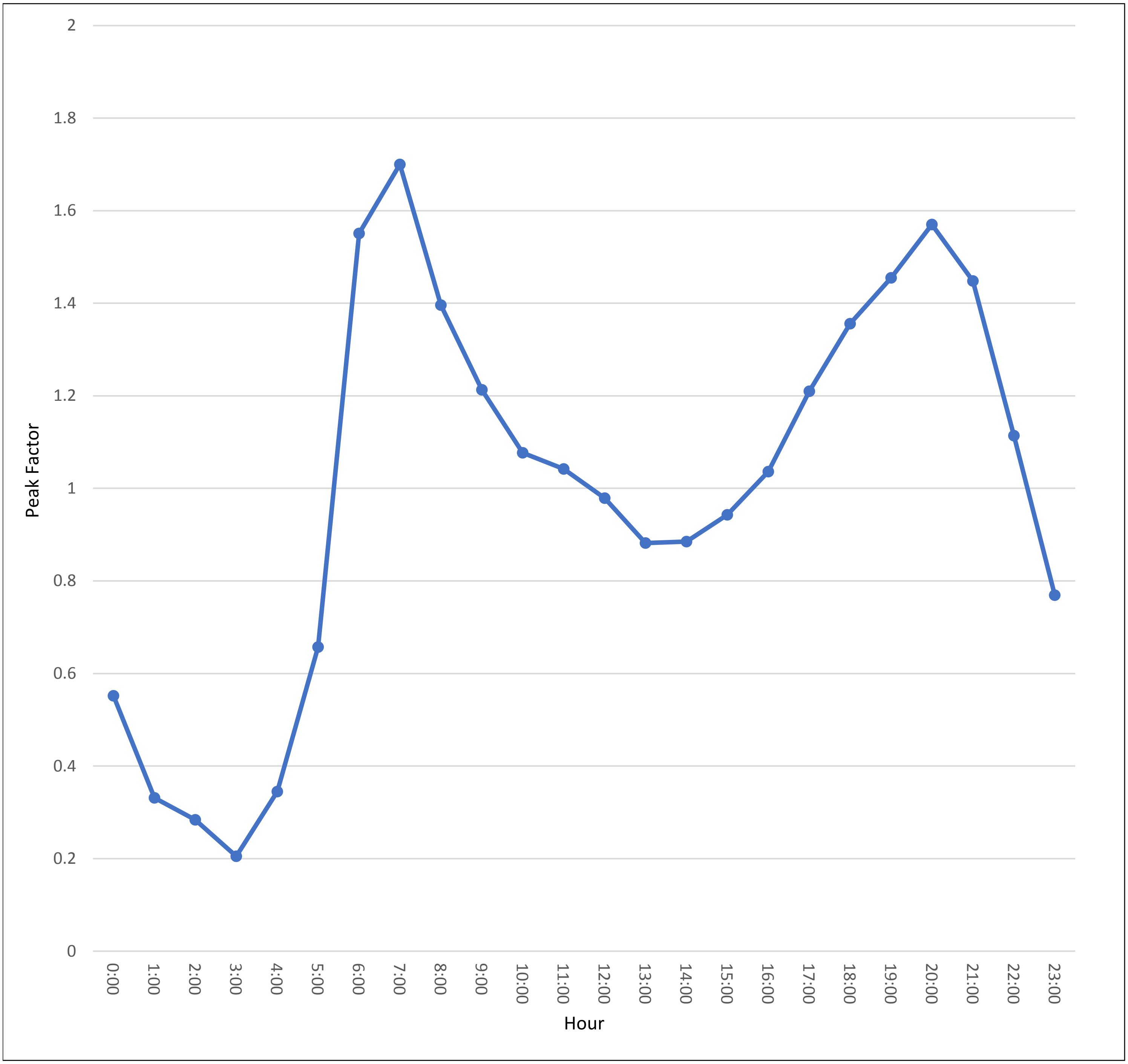

WEST YOST ASSOCIATES

Figure 5-2

Residential
Design Diurnal Pattern

Dublin San Ramon Services District
Collection System Master Plan

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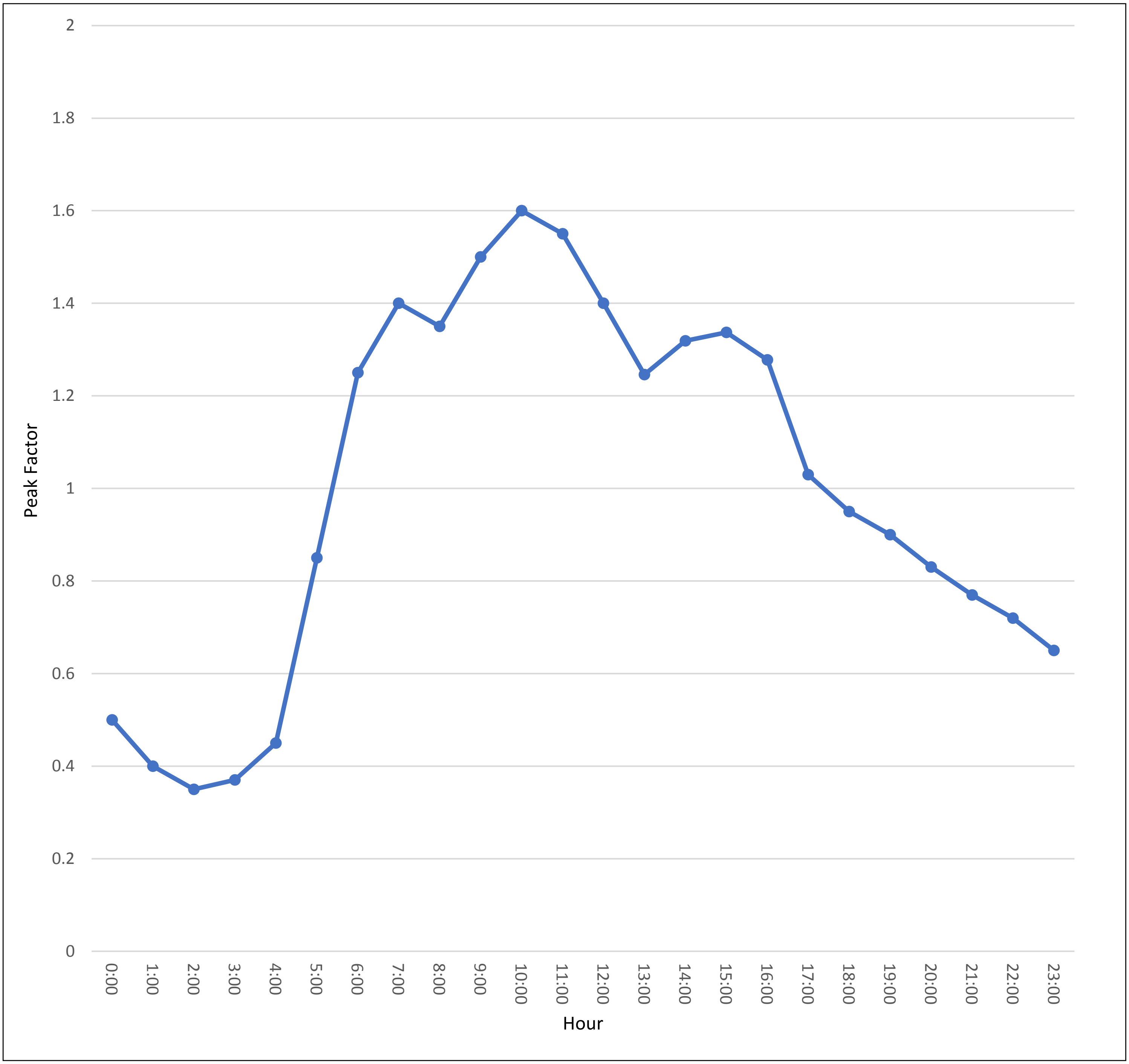

WEST YOST ASSOCIATES

Figure 5-3

Non-Residential Design Diurnal Pattern

Dublin San Ramon Services District
Collection System Master Plan

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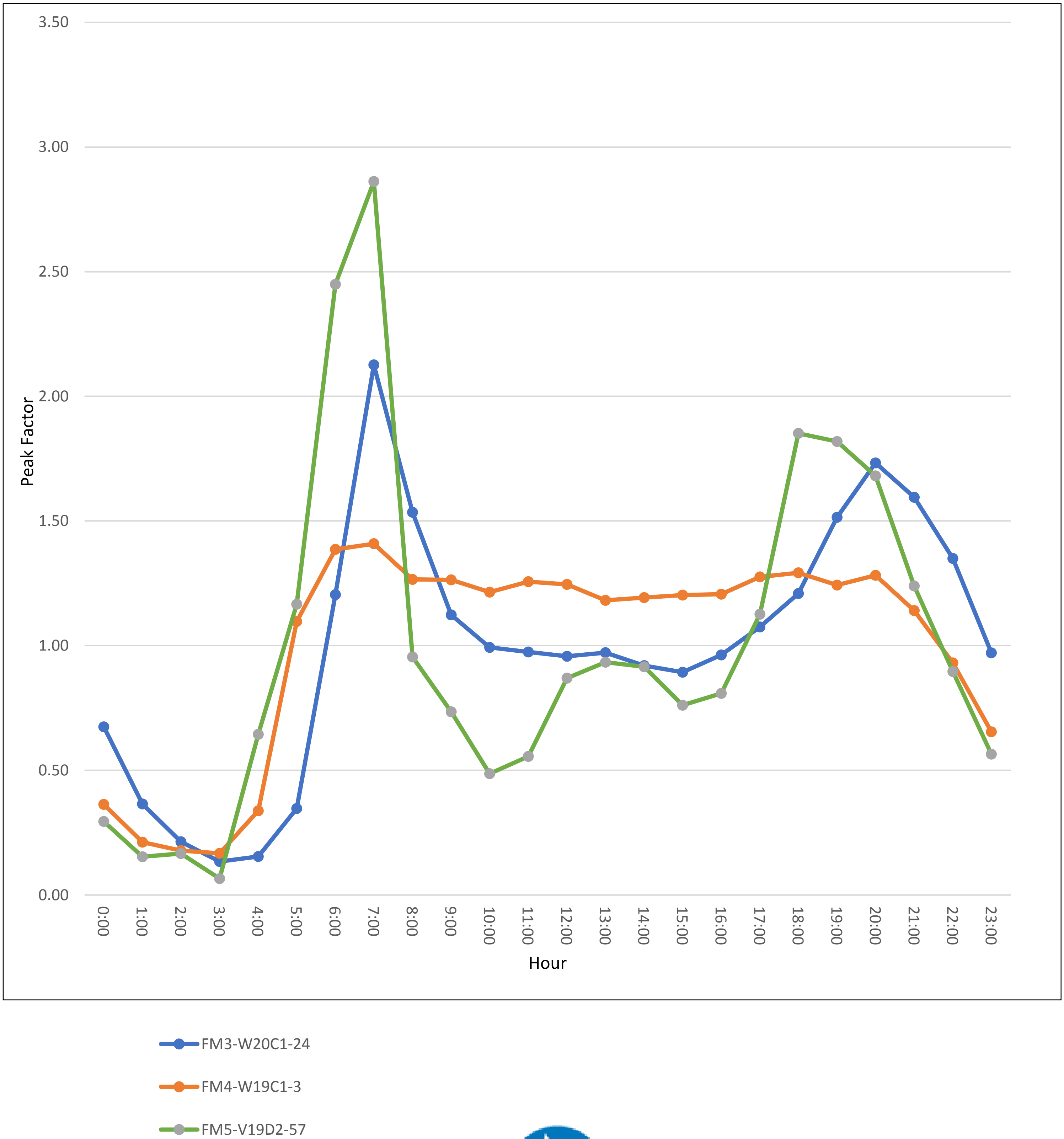

WEST YOST ASSOCIATES

Figure 5-4

Camp Parks
Design Diurnal Pattern

Dublin San Ramon Services District
Collection System Master Plan

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CHAPTER 6
Hydraulic Model Capacity Evaluation

Chapter 6 builds upon the work described in previous chapters to present the results of the capacity analysis of collection system. The collection system infrastructure to be analyzed is described in Chapter 2, the design flows to be analyzed in that infrastructure are described in Chapter 3, the performance criteria that govern the analysis is described in Chapter 4, and the hydraulic model that serves as the analysis tool is described in Chapter 5. The resulting synthesis of these elements into a capacity analysis is contained in this chapter. As detailed below, the District's proactive and diligent approach to developing capacity through the years results in a limited number of capacity deficiencies anticipated between now and 2035. The major sections presented in this chapter include:

- Capacity Analysis Overview
- Rebounded Existing Conditions Capacity Evaluation
- Future Conditions Capacity Evaluation

6.1 CAPACITY EVALUATION OVERVIEW

The hydraulic model was used to evaluate the capacity of the collection system under Rebounded Existing, 2020, 2025, and 2035 flow conditions. For each flow condition, the hydraulic model identified the gravity mains that violated the capacity performance criteria. In addition, the hydraulic model routed flows to the collection system lift stations so that the capacity of the lift stations could be assessed.

Each gravity main that was identified as having insufficient capacity under any flow conditions was manually reviewed to understand the reason for the preliminary capacity deficiency. In many cases, what initially appeared to be a capacity deficiency was in fact an error in the model (upstream and downstream invert elevations reversed, or typo in the invert elevations resulting in incorrect slope, for example). These errors were corrected using engineering judgement and the model was re-run to confirm capacity. This process is common in hydraulic evaluations, because the preliminary hydraulic analysis provides a "real-world" quality control check on GIS data.

In other cases, review of the preliminary hydraulic modeling results identified "outlier" gravity mains that did not present any obvious errors, but that engineering judgement suggests should not be confidently identified as capacity deficiencies to be improved. Examples of these cases include, for example, isolated gravity mains that have no slope (are perfectly flat) in the model. Review of the GIS confirmed that the GIS indicates that these gravity mains are flat as well. Because the capacity of gravity mains is evaluated using the Manning's equation as described in Chapter 4, a flat gravity main will by definition have no capacity and will be identified as a capacity deficiency no matter what the diameter. In reality, these gravity mains were probably constructed with some slope, and if the surrounding gravity mains have sufficient capacity, it is likely that this "flat" gravity main does as well. Furthermore, even if the gravity main were constructed as perfectly flat, while its mathematical capacity is zero, in reality the physical capacity of the flow transitioning through under momentum (which is not accounted for by the Manning's equation) is likely sufficient, assuming that the surrounding gravity mains have sufficient capacity.

For these reasons, such gravity mains were not identified as capacity deficient, because improvement plans for such gravity mains would not be realistic for budgeting and Capacity Reserve Fee purposes. Such gravity mains were rather identified as "Further Study/Monitoring Required." This further study could include field survey of the inverts to confirm slope, or it could include adding the gravity main to a more frequent inspection or maintenance schedule until a lack of surcharging is confirmed. The same logic was extended to some isolated gravity mains that have slope, but that are flatter than the surrounding gravity mains and therefore appear as isolated capacity deficiencies. It is unrealistic to identify and budget for improvement projects for such gravity mains, when once again the momentum of the flow is likely providing sufficient capacity. Therefore, these gravity mains were also identified as "Further Study/Monitoring Required." Such vetting of preliminary hydraulic modeling results is typical of the master planning evaluation process, and helps to produce realistic capacity improvement projects.

Finally, as discussed extensively in Chapter 3, the 2017 Flow Monitoring Study identified unusually high and rapid inflow into flow monitoring basin 7, particularly for a basin with such newly constructed infrastructure. Discussion with District staff indicated that construction that was ongoing during the flow monitoring period was responsible for inflow draining into the collection system. When the preliminary hydraulic evaluation was performed with the original wet weather factors for flow monitoring basin 7, these factors resulted in a large amount of RDII in flow monitoring basin 7 under design conditions, leading to numerous gravity mains identified as hydraulically deficient, particularly along Tassajara Road. Because the high and rapid inflow is expected to end when the construction ends, the decision was made to project design flows as if flow monitoring basin 7 behaved similarly to flow monitoring basin 6. Similar RDII behavior is expected because of similar construction dates, materials, and methods. The differing results that are produced by this adjustment are explained below.

In summary, the preliminary hydraulic results provided by the model have been reviewed and vetted to refine these results. The product of this process is that the gravity mains that have been identified as capacity deficient in the sections below can be confidently identified as such, and improvement projects can be confidently identified and budgeted. The gravity mains identified for further study or monitoring can be cost-effectively evaluated so that unnecessary improvement projects are not developed and budgeted. As information is refined and improved, the hydraulic model, which has been specifically developed for ease of update as a dynamic and growing tool, can be updated. Because of how the InfoSewer hydraulic model functions, the presence of the gravity mains that require further study or monitoring does not impact the hydraulic results elsewhere in the model in any way. The capacity evaluation for existing and future projected conditions is described in the sections below. Because the District has proactively worked throughout the years to identify and implement the capacity required for growth and development within the collection system service area, the capacity deficiencies identified in the sections below are relatively small in scope and extent.

6.2 REBOUNDED EXISTING CONDITIONS CAPACITY EVALUATION

This section presents the results of the capacity evaluation of the District's collection system under rebounded existing design flow conditions using the design and performance criteria described in Chapter 3. The major topics covered in this section include:

- Rebounded Existing Conditions Gravity Main Evaluation
- Rebounded Existing Conditions Lift Station Evaluation
- Rebounded Existing Conditions Force Main Evaluation

6.2.1 Rebounded Existing Conditions Gravity Main Hydraulic Evaluation

As described in Chapter 4, gravity mains are evaluated at design peak flow conditions versus full-pipe gravity flow capacity (q/Q) using the following criteria:

- Major Capacity Deficiency: $q/Q > 1.20$
- Minor Capacity Deficiency: $q/Q > 1.00$ and $q/Q \leq 1.20$
- No Capacity Deficiency: $q/Q \leq 1.00$

The results of the analysis of gravity mains under Rebounded Existing design PWWF conditions are depicted graphically on Figure 6-1, and in tabular format in Table 6-1. In both the figure and the table, the gravity mains have been categorized according to color as Major Capacity Deficiency, Minor Capacity Deficiency, No Capacity Deficiency, and Further Study/Monitoring Required.

As can be seen in the figure and the table, there are a number of gravity mains around the collection system for which further study or monitoring is recommended. There are three distinct areas of the collection system identified with capacity deficiencies: a major capacity deficiency in gravity mains running from Vomac Road down to Hillrose Drive, a minor capacity deficiency in the gravity mains in Dublin Boulevard between Clark Avenue and Sierra Court, and a minor capacity deficiency in the gravity mains beneath Village Parkway south of Dublin Boulevard.

The major capacity deficiency in and downstream of Vomac Road was identified as a deficiency in the 2005 Wastewater Collection System Master Plan Update, and an improvement project was identified but not implemented. This deficiency is immediately downstream of flow monitoring basin 10 and flow monitoring basin 11, which are situated in the older part of Dublin. As detailed in Chapter 3, these basins exhibited higher than average value for GWI and RDII, which most likely contribute to the deficiency.

The minor capacity deficiency in Dublin Boulevard was identified as a deficiency in the 2005 Wastewater Collection System Master Plan Update, and an improvement project was identified but not implemented. This deficiency is found in flow monitoring basin 14, which has relatively high GWI values. Also, this area has been the focus of intense development including intensification, which likely contributes to the deficiency.

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Table 6-1. Gravity Mains Not Meeting Performance Criteria Under Rebounded Existing Design Flow Conditions

Gravity Main ID	Upstream Manhole ID	Downstream Manhole ID	Length, linear feet (LF)	Diameter, in	Classifcation	Capacity Deficiency, MGD	Upstream Manhole Invert Elevation Source	Downstream Manhole Invert Elevation Source	Recommended Action
966	913	1817	56	10	Major Deficiency	-0.144	District	District	Upsizing as Ex-CIP-P02
1156	1094	1771	270	8	Major Deficiency	-0.310	District	District	Upsizing as Ex-CIP-P01
1159	1097	1094	235	8	Major Deficiency	-0.116	District	District	Upsizing as Ex-CIP-P01
1162	1100	1093	437	8	Major Deficiency	-0.361	District	District	Upsizing as Ex-CIP-P01
1221	1160	1971	257	8	Major Deficiency	-0.853	District	District	Relieving by Ex-CIP-P01
1222	1161	1975	181	8	Major Deficiency	-0.355	District	District	Upsizing as Ex-CIP-P01
1223	1976	1161	328	8	Major Deficiency	-0.372	District	District	Upsizing as Ex-CIP-P01
2061	1771	1100	237	8	Major Deficiency	-0.285	District	District	Upsizing as Ex-CIP-P01
2094	1162	1976	417	8	Major Deficiency	-0.382	District	District	Upsizing as Ex-CIP-P01
2101	1093	1162	150	8	Major Deficiency	-0.342	District	District	Upsizing as Ex-CIP-P01
955	1608	879	657	36	Minor Deficiency	-0.642	District	District	Upsizing as Ex-CIP-P03
951	896	892	439	10	Minor Deficiency	-0.114	District	District	Upsizing as Ex-CIP-P02
973	920	913	553	10	Minor Deficiency	-0.112	District	District	Upsizing as Ex-CIP-P02
2948	3532	1601	107	42	Nearly Flat	-12.597	District	District	Upsizing as 2025-CIP-P01
4324	1602	3532	123	42	Nearly Flat	-2.877	District	District	Upsizing as 2025-CIP-P01
877	2695	1583	74	36	Nearly Flat	-0.263	District	District	Monitoring/Surveying
4241	3108	4552	121	27	Nearly Flat	-0.125	District	Old Model	Monitoring/Surveying
7038	6463	3763	72	24	Zero/Negative Slope	-1.314	WY	District	Monitoring/Surveying
4154	4472	4471	350	15	Zero/Negative Slope	-0.605	District	District	Monitoring/Surveying
4979	5280	4475	232	15	Zero/Negative Slope	-0.511	District	District	Monitoring/Surveying
3902	4223	4222	287	15	Flatter than Proximate Gravity Mains	-0.087	District	District	Monitoring/Surveying
926	869	1605	88	12	Nearly Flat	-0.478	District	District	Monitoring/Surveying
1963	820	2830	364	12	Zero/Negative Slope	-0.693	District	District	Monitoring/Surveying
2521	1357	2017	116	12	Zero/Negative Slope	-0.673	District	District	Monitoring/Surveying
3608	3260	3259	228	10	Zero/Negative Slope	-0.225	District	District	Monitoring/Surveying
7342	3971	6585	178	10	Zero/Negative Slope	-0.375	Assumed Slope	Assumed Slope	Monitoring/Surveying
934	881	897	236	10	Zero/Negative Slope	-0.280	District	District	Monitoring/Surveying
4079	4398	4397	273	10	Flatter than Proximate Gravity Mains	-0.053	District	District	Monitoring/Surveying
1032	979	978	226	8	Zero/Negative Slope	-0.069	District	District	Monitoring/Surveying
1979	902	1606	70	8	Zero/Negative Slope	-0.051	WY	District	Monitoring/Surveying
222	226	2369	132	8	Zero/Negative Slope	-0.171	District	District	Monitoring/Surveying
2284	2221	44	314	8	Zero/Negative Slope	-0.026	District	District	Monitoring/Surveying
2929	1530	659	153	8	Zero/Negative Slope	-0.116	District	District	Monitoring/Surveying
3157	3657	3656	115	8	Zero/Negative Slope	-0.035	District	District	Monitoring/Surveying
4109	4428	4427	225	8	Zero/Negative Slope	-0.034	District	District	Monitoring/Surveying
4806	5090	2565	60	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4807	5091	5090	324	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4808	5092	5091	266	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4809	5093	5092	260	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4810	5094	5093	160	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4812	5096	5094	340	8	Zero/Negative Slope	-0.085	District	District	Monitoring/Surveying
4813	5097	5096	340	8	Zero/Negative Slope	-0.045	District	District	Monitoring/Surveying
5130	4517	3259	34	8	Zero/Negative Slope	-0.070	District	District	Monitoring/Surveying
5169	4821	4655	255	8	Zero/Negative Slope	-0.038	District	District	Monitoring/Surveying
5195	4857	4856	149	8	Zero/Negative Slope	-0.039	District	District	Monitoring/Surveying
5196	4859	4858	48	8	Zero/Negative Slope	-0.038	District	District	Monitoring/Surveying
550	523	2545	334	8	Zero/Negative Slope	-0.145	District	District	Monitoring/Surveying
6824	6292	6290	14	8	Zero/Negative Slope	-0.034	WY	WY	Monitoring/Surveying
7058	6405	6223	59	8	Zero/Negative Slope	-0.075	WY	WY	Monitoring/Surveying
7177	6509	2889	37	8	Zero/Negative Slope	-0.166	WY	District	Monitoring/Surveying
7333	6582	3772	108	8	Zero/Negative Slope	-0.031	Assumed Slope	Assumed Slope	Monitoring/Surveying
836	1869	814	13	8	Zero/Negative Slope	-0.049	District	District	Monitoring/Surveying
4773	5056	5057	269	8	Flatter than Proximate Gravity Mains	0.184	District	District	Monitoring/Surveying
1992	931	1829	30	6	Inconsistet Diameter	-0.066	District	District	Monitoring/Surveying

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The minor capacity deficiency in Village Parkway was not identified as a deficiency in the 2005 Wastewater Collection System Master Plan Update. This deficiency is downstream of the oldest parts of Dublin and San Ramon, and therefore downstream of several of several basins with high GWI and RDII values as discussed in Chapter 3. It is also downstream of significant new development in West Dublin, all of which factors likely contribute to the capacity deficiency. Improvement projects for each of the capacity deficiencies discussed above will be identified in Chapter 8.

6.2.2 Rebounded Existing Conditions Lift Station Evaluation

As described in Chapter 4, lift stations are not normally allowed per the District performance standards, but may be considered under extraordinary circumstances if specifically approved by the District Engineer. The District performance standards require that all collection system lift stations have sufficient capacity to convey design flows with the largest pump out of service, defined as the firm capacity of the lift station.

The District's only permanent lift station is the Dublin Boulevard Lift Station. The hydraulic model indicates that this lift station has sufficient firm capacity to convey rebounded existing design flows, as shown in Table 6-2.

The temporary lift station, the Croak Road Lift Station, serves 99 homes in an interim condition. It is designed to serve the homes until Croak Road is improved and extended south towards Dublin Boulevard. A gravity main is planned to be installed within the Croak Road right-of-way to serve the 99 homes that currently drain into the lift station, along with future development projects north of Dublin Boulevard along Croak Road. As shown in Table 6-2, the temporary Croak Road Lift Station is adequately sized for Rebounded Existing flow conditions.

Table 6-2. Lift Station and Force Main Capacity Results for Rebounded Existing Flow Conditions

Lift Station Name	Lift Station and Force Main Data				Evaluation Results		
	Pump Number	Pump Capacity, gpm	Firm Capacity, gpm	Force Main Diameter, in	Rebounded Existing Design Flow, gpm	Available Firm Capacity, gpm	Peak Force Main Velocity, fps
Dublin Blvd Lift Station	1	300	300	6	285	15	3.20
	2	300					
Croak Rd Lift Station (Temporary)	1	80	80	6	33	47	0.20
	2	80					

6.2.3 Rebounded Existing Conditions Force Main Evaluation

Peak flow velocities for the Dublin Boulevard Lift Station force main and Croak Road Lift Station force main are shown in Table 6-2. As indicated in the table, the force main velocity associated with rebounded existing peak flow conditions does not exceed the maximum velocity criterion of 7 fps under existing conditions. For the Dublin Boulevard Lift Station force main, the maximum force main velocity exceeds the minimum velocity standard of 2 fps, thus providing sufficient velocity to prevent solids deposition. This is not true for the Croak Road Lift Station force main, although this low velocity is probably acceptable for a temporary facility.

The hydraulic model, particularly the elements concerning lift station and force main capacity analysis, is a planning-level tool and is not intended for operational analysis. An operational analysis of the lift station and force main should be performed to confirm that the lift stations and force mains are operating as intended.

6.3 FUTURE CONDITIONS CAPACITY EVALUATION

This section presents the results of the capacity evaluation of the District's collection system under future flow conditions using the design and performance criteria described in Chapter 4. The major topics covered in this section include:

- Future Conditions Gravity Main Evaluation
- Future Conditions Lift Station Evaluation
- Future Conditions Force Main Evaluation

6.3.1 Future Conditions Gravity Main Evaluation

For the evaluation of gravity mains under future flow conditions, the same criteria are used for assessing major deficiencies, minor deficiencies, and non-deficiencies as are summarized above for existing flow conditions and were discussed in Chapter 4. The gravity mains that fail to meet performance criteria under 2020, 2025, and 2035 design flow conditions are indicated on Figures 6-2, 6-3, and 6-4, respectively. These same results are summarized in Tables 6-3, 6-4, and 6-5, respectively.

For projected 2020 flow conditions, a single new minor capacity deficiency was identified, consisting of 731 feet of 18-inch gravity main beneath Dublin Boulevard between Amador Plaza Road and Village Parkway. This deficiency is likely the result of continuing development in West Dublin. It was not identified in the 2005 Wastewater Master Plan Update.

For projected 2025 flow conditions, a single new minor capacity deficiency was identified, immediately upstream of the WWTP. The 42-inch diameter gravity main between Stoneridge Drive and the WWTP influent pipeline was identified as deficient. This deficiency was not identified in the 2005 Wastewater Master Plan Update.

When the projected 2035 flow conditions are applied to the collection system, a significant number of minor and major capacity deficiencies are identified along Tassajara Road. These deficiencies can be seen on Figure 6-4. These deficiencies are the result of the high and immediate inflow for flow monitoring basin 7 identified during the calibration process. As discussed previously in Chapter 3, the flow monitoring results for flow monitoring basin 7 showed high RDII values for a relatively new portion of the collection system, particularly when compared to the flow monitoring results for neighboring flow monitoring basin 6. It was determined that flow monitoring basin 7 was most likely experiencing temporary construction-related inflow that skewed the flow monitoring results but that will not continue past the construction period. Therefore, until further flow monitoring is conducted after this construction has ceased to confirm the long-term R-T-K values in flow monitoring basin 7, it was assumed that the results from flow monitoring basin 6 potentially represent the long-term performance of flow monitoring basin 7. This assumption is based upon the similar construction ages, materials, and methods in the two neighboring basins.

Because of the above, the hydraulic analysis of the collection system for the 2035 flow conditions was repeated but with R-T-K values measured for flow monitoring basin 6 representing flow monitoring basin 7. The results of this revised analysis are shown on Figure 6-5 and in Table 6-6. As can be seen, the insufficient capacity areas of the collection system identified in the eastern portion of the collection system do not appear with the revised R-T-K factors.

The hydraulic analysis with the revised R-T-K factors does not identify any further capacity improvements beyond those already identified for projected 2025 design flows. The requirements for capacity improvement projects for all of the capacity deficiencies identified in the gravity mains are discussed in Chapter 8.

6.3.2 Future Conditions Lift Station Evaluation

As noted above, the District's only permanent lift station is the Dublin Boulevard Lift Station. The hydraulic model indicates that this lift station has sufficient firm capacity to convey future design flows, as shown in Table 6-7. The temporary lift station on Croak Road is expected to be abandoned within the planning horizon. No additional developments are planned to connect to this lift station. Thus, future flows were not evaluated for the Croak Road Lift Station.

6.3.3 Future Conditions Force Main Evaluation

Peak flow velocities for the Dublin Boulevard Lift Station force main under future flow conditions are shown in Table 6-7. As indicated in the table, the force main velocity does not exceed the maximum velocity criterion of 7 fps under future conditions. Furthermore, the maximum force main velocity exceeds the minimum velocity standard of 2 fps, thus providing sufficient velocity to prevent solids deposition.

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Table 6-3. Gravity Mains Not Meeting Performance Criteria Under 2020 Design Flow Conditions

Gravity Main ID	Upstream Manhole ID	Downstream Manhole ID	Length, linear feet (LF)	Diameter, in	Classifcation	Capacity Deficiency, MGD	Upstream Manhole Invert Elevation Source	Downstream Manhole Invert Elevation Source	Recommended Action
966	913	1817	56	10	Major Deficiency	-0.144	District	District	Upsizing as Ex-CIP-P02
1156	1094	1771	270	8	Major Deficiency	-0.310	District	District	Upsizing as Ex-CIP-P01
1159	1097	1094	235	8	Major Deficiency	-0.116	District	District	Upsizing as Ex-CIP-P01
1162	1100	1093	437	8	Major Deficiency	-0.361	District	District	Upsizing as Ex-CIP-P01
1221	1160	1971	257	8	Major Deficiency	-0.853	District	District	Relieving by Ex-CIP-P01
1222	1161	1975	181	8	Major Deficiency	-0.355	District	District	Upsizing as Ex-CIP-P01
1223	1976	1161	328	8	Major Deficiency	-0.372	District	District	Upsizing as Ex-CIP-P01
2061	1771	1100	237	8	Major Deficiency	-0.285	District	District	Upsizing as Ex-CIP-P01
2094	1162	1976	417	8	Major Deficiency	-0.382	District	District	Upsizing as Ex-CIP-P01
2101	1093	1162	150	8	Major Deficiency	-0.342	District	District	Upsizing as Ex-CIP-P01
955	1608	879	657	36	Minor Deficiency	-0.830	District	District	Upsizing as Ex-CIP-P03
1993	1609	1615	19	18	Minor Deficiency	-0.183	District	District	Upsizing as 2020-CIP-P01
1996	901	1609	290	18	Minor Deficiency	-0.090	District	District	Upsizing as 2020-CIP-P01
951	896	892	439	10	Minor Deficiency	-0.114	District	District	Upsizing as Ex-CIP-P02
973	920	913	553	10	Minor Deficiency	-0.112	District	District	Upsizing as Ex-CIP-P02
2948	3532	1601	107	42	Nearly Flat	-14.113	District	District	Upsizing as 2025-CIP-P01
4324	1602	3532	123	42	Nearly Flat	-3.064	District	District	Upsizing as 2025-CIP-P01
877	2695	1583	74	36	Nearly Flat	-1.572	District	District	Monitoring/Surveying
4241	3108	4552	121	27	Nearly Flat	-0.125	District	Old Model	Monitoring/Surveying
7038	6463	3763	72	24	Zero/Negative Slope	-1.314	WY	District	Monitoring/Surveying
3902	4223	4222	287	15	Flatter than Proximate Gravity Mains	-1.057	District	District	Monitoring/Surveying
4154	4472	4471	350	15	Zero/Negative Slope	-1.643	District	District	Monitoring/Surveying
4979	5280	4475	232	15	Zero/Negative Slope	-1.558	District	District	Monitoring/Surveying
926	869	1605	88	12	Nearly Flat	-0.606	District	District	Monitoring/Surveying
1963	820	2830	364	12	Zero/Negative Slope	-0.712	District	District	Monitoring/Surveying
2521	1357	2017	116	12	Zero/Negative Slope	-0.673	District	District	Monitoring/Surveying
4079	4398	4397	273	10	Flatter than Proximate Gravity Mains	-0.053	District	District	Monitoring/Surveying
3608	3260	3259	228	10	Zero/Negative Slope	-0.225	District	District	Monitoring/Surveying
7342	3971	6585	178	10	Zero/Negative Slope	-0.375	Assumed Slope	Assumed Slope	Monitoring/Surveying
934	881	897	236	10	Zero/Negative Slope	-0.280	District	District	Monitoring/Surveying
4982	5278	5277	51	8	Flatter than Proximate Gravity Mains	-0.223	District	District	Monitoring/Surveying
5986	5728	5727	192	8	Flatter than Proximate Gravity Mains	-0.483	WY	WY	Monitoring/Surveying
5988	5727	5726	28	8	Flatter than Proximate Gravity Mains	-0.378	WY	WY	Monitoring/Surveying
5994	5304	5728	216	8	Flatter than Proximate Gravity Mains	-0.466	WY	WY	Monitoring/Surveying
6001	5743	5737	263	8	Flatter than Proximate Gravity Mains	-0.292	District	District	Monitoring/Surveying
6008	5746	5730	339	8	Flatter than Proximate Gravity Mains	-0.564	District	District	Monitoring/Surveying
6010	5739	5743	281	8	Flatter than Proximate Gravity Mains	-0.453	District	District	Monitoring/Surveying
6017	5730	5745	246	8	Flatter than Proximate Gravity Mains	-0.493	District	District	Monitoring/Surveying
7132	1817	896	165	8	Flatter than Proximate Gravity Mains	-0.341	District	District	Monitoring/Surveying
4773	5056	5057	269	8	Flater than Up- and Down-Streram	0.184	District	District	Monitoring/Surveying
5983	5720	5719	42	8	Flatter than Proximate Gravity Mains	-0.036	WY	WY	Monitoring/Surveying
6003	5738	5736	348	8	Flatter than Proximate Gravity Mains	0.000	District	District	Monitoring/Surveying
6006	5733	5732	82	8	Flatter than Proximate Gravity Mains	-0.076	District	District	Monitoring/Surveying
6009	5740	5739	109	8	Flatter than Proximate Gravity Mains	-0.077	District	District	Monitoring/Surveying
6013	5731	5746	211	8	Flatter than Proximate Gravity Mains	-0.106	District	District	Monitoring/Surveying
6015	5736	5735	107	8	Flatter than Proximate Gravity Mains	-0.059	District	District	Monitoring/Surveying
1032	979	978	226	8	Zero/Negative Slope	-0.069	District	District	Monitoring/Surveying
1979	902	1606	70	8	Zero/Negative Slope	-0.051	WY	District	Monitoring/Surveying
222	226	2369	132	8	Zero/Negative Slope	-0.171	District	District	Monitoring/Surveying
2284	2221	44	314	8	Zero/Negative Slope	-0.026	District	District	Monitoring/Surveying

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Table 6-3. Gravity Mains Not Meeting Performance Criteria Under 2020 Design Flow Conditions

Gravity Main ID	Upstream Manhole ID	Downstream Manhole ID	Length, linear feet (LF)	Diameter, in	Classifcation	Capacity Deficiency, MGD	Upstream Manhole Invert Elevation Source	Downstream Manhole Invert Elevation Source	Recommended Action
2929	1530	659	153	8	Zero/Negative Slope	-0.116	District	District	Monitoring/Surveying
3157	3657	3656	115	8	Zero/Negative Slope	-0.035	District	District	Monitoring/Surveying
4109	4428	4427	225	8	Zero/Negative Slope	-0.034	District	District	Monitoring/Surveying
4806	5090	2565	60	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4807	5091	5090	324	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4808	5092	5091	266	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4809	5093	5092	260	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4810	5094	5093	160	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4812	5096	5094	340	8	Zero/Negative Slope	-0.085	District	District	Monitoring/Surveying
4813	5097	5096	340	8	Zero/Negative Slope	-0.045	District	District	Monitoring/Surveying
5130	4517	3259	34	8	Zero/Negative Slope	-0.070	District	District	Monitoring/Surveying
5169	4821	4655	255	8	Zero/Negative Slope	-0.038	District	District	Monitoring/Surveying
5195	4857	4856	149	8	Zero/Negative Slope	-0.039	District	District	Monitoring/Surveying
5196	4859	4858	48	8	Zero/Negative Slope	-0.038	District	District	Monitoring/Surveying
550	523	2545	334	8	Zero/Negative Slope	-0.145	District	District	Monitoring/Surveying
6824	6292	6290	14	8	Zero/Negative Slope	-0.034	WY	WY	Monitoring/Surveying
7058	6405	6223	59	8	Zero/Negative Slope	-0.082	WY	WY	Monitoring/Surveying
7177	6509	2889	37	8	Zero/Negative Slope	-0.175	WY	District	Monitoring/Surveying
7333	6582	3772	108	8	Zero/Negative Slope	-0.031	Assumed Slope	Assumed Slope	Monitoring/Surveying
836	1869	814	13	8	Zero/Negative Slope	-0.049	District	District	Monitoring/Surveying
1992	931	1829	30	6	Inconsistet Diameter	-0.066	District	District	Monitoring/Surveying

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Table 6-4. Gravity Mains Not Meeting Performance Criteria Under 2025 Design Flow Conditions

Gravity Main ID	Upstream Manhole ID	Downstream Manhole ID	Length, linear feet (LF)	Diameter, in	Classifcation	Capacity Deficiency, MGD	Upstream Manhole Invert Elevation Source	Downstream Manhole Invert Elevation Source	Recommended Action
966	913	1817	56	10	Major Deficiency	-0.144	District	District	Upsizing as Ex-CIP-P02
1156	1094	1771	270	8	Major Deficiency	-0.310	District	District	Upsizing as Ex-CIP-P01
1159	1097	1094	235	8	Major Deficiency	-0.116	District	District	Upsizing as Ex-CIP-P01
1162	1100	1093	437	8	Major Deficiency	-0.361	District	District	Upsizing as Ex-CIP-P01
1221	1160	1971	257	8	Major Deficiency	-0.853	District	District	Relieving by Ex-CIP-P01
1222	1161	1975	181	8	Major Deficiency	-0.355	District	District	Upsizing as Ex-CIP-P01
1223	1976	1161	328	8	Major Deficiency	-0.372	District	District	Upsizing as Ex-CIP-P01
2061	1771	1100	237	8	Major Deficiency	-0.285	District	District	Upsizing as Ex-CIP-P01
2094	1162	1976	417	8	Major Deficiency	-0.382	District	District	Upsizing as Ex-CIP-P01
2101	1093	1162	150	8	Major Deficiency	-0.342	District	District	Upsizing as Ex-CIP-P01
1941	1601	1600	372	42	Minor Deficiency	-0.303	District	District	Upsizing as 2025-CIP-P01
890	1597	1598	397	42	Minor Deficiency	-0.293	District	District	Upsizing as 2025-CIP-P01
891	1600	1599	628	42	Minor Deficiency	-0.195	District	District	Upsizing as 2025-CIP-P01
955	1608	879	657	36	Minor Deficiency	-0.831	District	District	Upsizing as Ex-CIP-P03
1993	1609	1615	19	18	Minor Deficiency	-0.185	District	District	Upsizing as 2020-CIP-P01
1996	901	1609	290	18	Minor Deficiency	-0.092	District	District	Upsizing as 2020-CIP-P01
951	896	892	439	10	Minor Deficiency	-0.114	District	District	Upsizing as Ex-CIP-P02
973	920	913	553	10	Minor Deficiency	-0.112	District	District	Upsizing as Ex-CIP-P02
2948	3532	1601	107	42	Nearly Flat	-16.427	District	District	Upsizing as 2025-CIP-P01
4324	1602	3532	123	42	Nearly Flat	-3.066	District	District	Upsizing as 2025-CIP-P01
877	2695	1583	74	36	Nearly Flat	-3.886	District	District	Monitoring/Surveying
1935	1589	1588	335	36	Flatter than Proximate Gravity Mains	-2.155	District	District	Monitoring/Surveying
3816	4137	4136	237	36	Flatter than Proximate Gravity Mains	-0.719	District	District	Monitoring/Surveying
6033	3769	3754	144	36	Flatter than Proximate Gravity Mains	-0.026	WY	District	Monitoring/Surveying
4241	3108	4552	121	27	Nearly Flat	-0.125	District	Old Model	Monitoring/Surveying
7038	6463	3763	72	24	Zero/Negative Slope	-1.818	WY	District	Monitoring/Surveying
3825	4146	4145	350	15	Flatter than Proximate Gravity Mains	-1.140	District	District	Monitoring/Surveying
3901	4222	4149	321	15	Flatter than Proximate Gravity Mains	-1.550	District	District	Monitoring/Surveying
3902	4223	4222	287	15	Flatter than Proximate Gravity Mains	-2.951	District	District	Monitoring/Surveying
3906	4227	4226	350	15	Flatter than Proximate Gravity Mains	-1.762	District	District	Monitoring/Surveying
3907	4228	4227	316	15	Flatter than Proximate Gravity Mains	-1.801	District	District	Monitoring/Surveying
3908	4229	4228	266	15	Flatter than Proximate Gravity Mains	-1.268	District	District	Monitoring/Surveying
3909	4230	4229	350	15	Flatter than Proximate Gravity Mains	-0.943	District	District	Monitoring/Surveying
3826	4147	4146	349	15	Flatter than Proximate Gravity Mains	-0.928	District	District	Monitoring/Surveying
3827	4148	4147	350	15	Flatter than Proximate Gravity Mains	-0.597	District	District	Monitoring/Surveying
3828	4149	4148	350	15	Flatter than Proximate Gravity Mains	-0.788	District	District	Monitoring/Surveying
4156	4474	4473	317	15	Flatter than Proximate Gravity Mains	-0.133	District	District	Monitoring/Surveying
4157	4475	4474	344	15	Flatter than Proximate Gravity Mains	-0.108	District	District	Monitoring/Surveying
4154	4472	4471	350	15	Zero/Negative Slope	-3.536	District	District	Monitoring/Surveying
4979	5280	4475	232	15	Zero/Negative Slope	-3.449	District	District	Monitoring/Surveying
4975	5277	5276	149	12	Flatter than Proximate Gravity Mains	-1.209	District	District	Monitoring/Surveying
4976	5276	5275	325	12	Flatter than Proximate Gravity Mains	-1.267	District	District	Monitoring/Surveying
4977	5274	5272	244	12	Flatter than Proximate Gravity Mains	-1.121	District	District	Monitoring/Surveying
4980	5270	5280	226	12	Flatter than Proximate Gravity Mains	-1.250	District	District	Monitoring/Surveying
4981	5272	5271	223	12	Flatter than Proximate Gravity Mains	-1.357	District	District	Monitoring/Surveying
4983	5275	5274	325	12	Flatter than Proximate Gravity Mains	-1.287	District	District	Monitoring/Surveying
926	869	1605	88	12	Nearly Flat	-0.607	District	District	Monitoring/Surveying
1963	820	2830	364	12	Zero/Negative Slope	-0.714	District	District	Monitoring/Surveying
2521	1357	2017	116	12	Zero/Negative Slope	-0.673	District	District	Monitoring/Surveying
6601	6134	6135	250	10	Flatter than Proximate Gravity Mains	-0.714	WY	WY	Monitoring/Surveying
6602	6135	6136	298	10	Flatter than Proximate Gravity Mains	-0.707	WY	WY	Monitoring/Surveying
6603	6136	6137	267	10	Flatter than Proximate Gravity Mains	-0.711	WY	WY	Monitoring/Surveying

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Table 6-4. Gravity Mains Not Meeting Performance Criteria Under 2025 Design Flow Conditions

Gravity Main ID	Upstream Manhole ID	Downstream Manhole ID	Length, linear feet (LF)	Diameter, in	Classifcation	Capacity Deficiency, MGD	Upstream Manhole Invert Elevation Source	Downstream Manhole Invert Elevation Source	Recommended Action
7341	6512	5277	66	10	Flatter than Proximate Gravity Mains	-0.624	District	District	Monitoring/Surveying
4079	4398	4397	273	10	Flatter than Proximate Gravity Mains	-0.053	District	District	Monitoring/Surveying
3608	3260	3259	228	10	Zero/Negative Slope	-0.225	District	District	Monitoring/Surveying
7342	3971	6585	178	10	Zero/Negative Slope	-0.375	Assumed Slope	Assumed Slope	Monitoring/Surveying
934	881	897	236	10	Zero/Negative Slope	-0.280	District	District	Monitoring/Surveying
4982	5278	5277	51	8	Flatter than Proximate Gravity Mains	-0.223	District	District	Monitoring/Surveying
5986	5728	5727	192	8	Flatter than Proximate Gravity Mains	-0.483	WY	WY	Monitoring/Surveying
5988	5727	5726	28	8	Flatter than Proximate Gravity Mains	-0.378	WY	WY	Monitoring/Surveying
5994	5304	5728	216	8	Flatter than Proximate Gravity Mains	-0.466	WY	WY	Monitoring/Surveying
6001	5743	5737	263	8	Flatter than Proximate Gravity Mains	-0.292	District	District	Monitoring/Surveying
6008	5746	5730	339	8	Flatter than Proximate Gravity Mains	-0.564	District	District	Monitoring/Surveying
6010	5739	5743	281	8	Flatter than Proximate Gravity Mains	-0.453	District	District	Monitoring/Surveying
6017	5730	5745	246	8	Flatter than Proximate Gravity Mains	-0.493	District	District	Monitoring/Surveying
7132	1817	896	165	8	Flatter than Proximate Gravity Mains	-0.341	District	District	Monitoring/Surveying
7280	6514	6513	358	8	Flatter than Proximate Gravity Mains	-0.162	WY	WY	Monitoring/Surveying
4773	5056	5057	269	8	Flatter than Proximate Gravity Mains	0.184	District	District	Monitoring/Surveying
5983	5720	5719	42	8	Flatter than Proximate Gravity Mains	-0.036	WY	WY	Monitoring/Surveying
6003	5738	5736	348	8	Flatter than Proximate Gravity Mains	0.000	District	District	Monitoring/Surveying
6006	5733	5732	82	8	Flatter than Proximate Gravity Mains	-0.076	District	District	Monitoring/Surveying
6009	5740	5739	109	8	Flatter than Proximate Gravity Mains	-0.077	District	District	Monitoring/Surveying
6013	5731	5746	211	8	Flatter than Proximate Gravity Mains	-0.106	District	District	Monitoring/Surveying
6015	5736	5735	107	8	Flatter than Proximate Gravity Mains	-0.059	District	District	Monitoring/Surveying
7277	6513	5279	198	8	Flatter than Proximate Gravity Mains	-0.008	WY	WY	Monitoring/Surveying
1032	979	978	226	8	Zero/Negative Slope	-0.069	District	District	Monitoring/Surveying
1979	902	1606	70	8	Zero/Negative Slope	-0.051	WY	District	Monitoring/Surveying
222	226	2369	132	8	Zero/Negative Slope	-0.171	District	District	Monitoring/Surveying
2284	2221	44	314	8	Zero/Negative Slope	-0.026	District	District	Monitoring/Surveying
2929	1530	659	153	8	Zero/Negative Slope	-0.116	District	District	Monitoring/Surveying
3157	3657	3656	115	8	Zero/Negative Slope	-0.035	District	District	Monitoring/Surveying
4109	4428	4427	225	8	Zero/Negative Slope	-0.034	District	District	Monitoring/Surveying
4806	5090	2565	60	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4807	5091	5090	324	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4808	5092	5091	266	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4809	5093	5092	260	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4810	5094	5093	160	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4812	5096	5094	340	8	Zero/Negative Slope	-0.085	District	District	Monitoring/Surveying
4813	5097	5096	340	8	Zero/Negative Slope	-0.045	District	District	Monitoring/Surveying
5130	4517	3259	34	8	Zero/Negative Slope	-0.070	District	District	Monitoring/Surveying
5169	4821	4655	255	8	Zero/Negative Slope	-0.038	District	District	Monitoring/Surveying
5195	4857	4856	149	8	Zero/Negative Slope	-0.039	District	District	Monitoring/Surveying
5196	4859	4858	48	8	Zero/Negative Slope	-0.038	District	District	Monitoring/Surveying
550	523	2545	334	8	Zero/Negative Slope	-0.145	District	District	Monitoring/Surveying
6824	6292	6290	14	8	Zero/Negative Slope	-0.034	WY	WY	Monitoring/Surveying
7058	6405	6223	59	8	Zero/Negative Slope	-0.082	WY	WY	Monitoring/Surveying
7177	6509	2889	37	8	Zero/Negative Slope	-0.175	WY	District	Monitoring/Surveying
7269	6528	6527	54	8	Zero/Negative Slope	-0.441	WY	WY	Monitoring/Surveying
7333	6582	3772	108	8	Zero/Negative Slope	-0.031	Assumed Slope	Assumed Slope	Monitoring/Surveying
836	1869	814	13	8	Zero/Negative Slope	-0.049	District	District	Monitoring/Surveying
1992	931	1829	30	6	Inconsistet Diameter	-0.066	District	District	Monitoring/Surveying

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Table 6-5. Gravity Mains Not Meeting Performance Criteria Under 2035 Design Flow Conditions

Gravity Main ID	Upstream Manhole ID	Downstream Manhole ID	Length, linear feet (LF)	Diameter, in	Classifcation	Capacity Deficiency, MGD	Upstream Manhole Invert Elevation Source	Downstream Manhole Invert Elevation Source	Recommended Action
6033	3769	3754	144	36	Major Deficiency	-2.041	WY	District	Monitoring/Surveying
3825	4146	4145	350	15	Major Deficiency	-1.915	District	District	Monitoring/Surveying
3826	4147	4146	349	15	Major Deficiency	-1.703	District	District	Monitoring/Surveying
3827	4148	4147	350	15	Major Deficiency	-1.371	District	District	Monitoring/Surveying
3828	4149	4148	350	15	Major Deficiency	-1.563	District	District	Monitoring/Surveying
3901	4222	4149	321	15	Major Deficiency	-2.325	District	District	Monitoring/Surveying
3906	4227	4226	350	15	Major Deficiency	-2.533	District	District	Monitoring/Surveying
3907	4228	4227	316	15	Major Deficiency	-2.572	District	District	Monitoring/Surveying
3908	4229	4228	266	15	Major Deficiency	-2.039	District	District	Monitoring/Surveying
3909	4230	4229	350	15	Major Deficiency	-1.714	District	District	Monitoring/Surveying
4156	4474	4473	317	15	Major Deficiency	-0.902	District	District	Monitoring/Surveying
4157	4475	4474	344	15	Major Deficiency	-0.877	District	District	Monitoring/Surveying
4975	5277	5276	149	12	Major Deficiency	-1.958	District	District	Monitoring/Surveying
4976	5276	5275	325	12	Major Deficiency	-2.016	District	District	Monitoring/Surveying
4977	5274	5272	244	12	Major Deficiency	-1.871	District	District	Monitoring/Surveying
4980	5270	5280	226	12	Major Deficiency	-2.019	District	District	Monitoring/Surveying
4981	5272	5271	223	12	Major Deficiency	-2.107	District	District	Monitoring/Surveying
4983	5275	5274	325	12	Major Deficiency	-2.037	District	District	Monitoring/Surveying
6601	6134	6135	250	10	Major Deficiency	-0.714	WY	WY	Monitoring/Surveying
6602	6135	6136	298	10	Major Deficiency	-0.707	WY	WY	Monitoring/Surveying
6603	6136	6137	267	10	Major Deficiency	-0.711	WY	WY	Monitoring/Surveying
7341	6512	5277	66	10	Major Deficiency	-0.624	District	District	Monitoring/Surveying
966	913	1817	56	10	Major Deficiency	-0.155	District	District	Upsizing as Ex-CIP-P02
1156	1094	1771	270	8	Major Deficiency	-0.310	District	District	Upsizing as Ex-CIP-P01
1159	1097	1094	235	8	Major Deficiency	-0.116	District	District	Upsizing as Ex-CIP-P01
1162	1100	1093	437	8	Major Deficiency	-0.361	District	District	Upsizing as Ex-CIP-P01
1221	1160	1971	257	8	Major Deficiency	-0.688	District	District	Relieving by Ex-CIP-P01
1222	1161	1975	181	8	Major Deficiency	-0.355	District	District	Upsizing as Ex-CIP-P01
1223	1976	1161	328	8	Major Deficiency	-0.372	District	District	Upsizing as Ex-CIP-P01
2061	1771	1100	237	8	Major Deficiency	-0.285	District	District	Upsizing as Ex-CIP-P01
2094	1162	1976	417	8	Major Deficiency	-0.382	District	District	Upsizing as Ex-CIP-P01
2101	1093	1162	150	8	Major Deficiency	-0.342	District	District	Upsizing as Ex-CIP-P01
4982	5278	5277	51	8	Major Deficiency	-0.969	District	District	Monitoring/Surveying
4996	5281	5278	27	8	Major Deficiency	-0.573	District	District	Monitoring/Surveying
5000	5283	5282	92	8	Major Deficiency	-0.688	WY	WY	Monitoring/Surveying
5983	5720	5719	42	8	Major Deficiency	-0.781	WY	WY	Monitoring/Surveying
5986	5728	5727	192	8	Major Deficiency	-1.228	WY	WY	Monitoring/Surveying
5988	5727	5726	28	8	Major Deficiency	-1.123	WY	WY	Monitoring/Surveying
5989	5719	5283	123	8	Major Deficiency	-0.420	WY	WY	Monitoring/Surveying
5991	5726	5725	206	8	Major Deficiency	-0.740	WY	WY	Monitoring/Surveying
5994	5304	5728	216	8	Major Deficiency	-1.211	WY	WY	Monitoring/Surveying
6001	5743	5737	263	8	Major Deficiency	-1.037	District	District	Monitoring/Surveying
6008	5746	5730	339	8	Major Deficiency	-0.564	District	District	Monitoring/Surveying
6010	5739	5743	281	8	Major Deficiency	-1.198	District	District	Monitoring/Surveying
6017	5730	5745	246	8	Major Deficiency	-0.493	District	District	Monitoring/Surveying
7280	6514	6513	358	8	Major Deficiency	-0.162	WY	WY	Monitoring/Surveying
1941	1601	1600	372	42	Minor Deficiency	-3.055	District	District	Upsizing as 2025-CIP-P01
1943	1598	2703	262	42	Minor Deficiency	-2.338	District	District	Upsizing as 2025-CIP-P01
3026	3531	3532	124	42	Minor Deficiency	-2.235	District	District	Monitoring/Surveying

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Table 6-5. Gravity Mains Not Meeting Performance Criteria Under 2035 Design Flow Conditions

Gravity Main ID	Upstream Manhole ID	Downstream Manhole ID	Length, linear feet (LF)	Diameter, in	Classifcation	Capacity Deficiency, MGD	Upstream Manhole Invert Elevation Source	Downstream Manhole Invert Elevation Source	Recommended Action
890	1597	1598	397	42	Minor Deficiency	-3.044	District	District	Upsizing as 2025-CIP-P01
891	1600	1599	628	42	Minor Deficiency	-2.947	District	District	Upsizing as 2025-CIP-P01
3817	4138	4137	158	36	Minor Deficiency	-0.411	District	District	Monitoring/Surveying
875	2693	1581	266	36	Minor Deficiency	-0.878	District	District	Monitoring/Surveying
955	1608	879	657	36	Minor Deficiency	-0.982	District	District	Upsizing as Ex-CIP-P03
1993	1609	1615	19	18	Minor Deficiency	-0.209	District	District	Upsizing as 2020-CIP-P01
1996	901	1609	290	18	Minor Deficiency	-0.116	District	District	Upsizing as 2020-CIP-P01
3910	4231	4230	310	15	Minor Deficiency	-0.174	District	District	Monitoring/Surveying
3911	4232	4231	314	15	Minor Deficiency	-0.174	District	District	Monitoring/Surveying
4153	4471	4232	336	15	Minor Deficiency	-0.122	District	District	Monitoring/Surveying
951	896	892	439	10	Minor Deficiency	-0.125	District	District	Upsizing as Ex-CIP-P02
973	920	913	553	10	Minor Deficiency	-0.122	District	District	Upsizing as Ex-CIP-P02
5984	5724	5723	105	8	Minor Deficiency	-0.092	WY	WY	Monitoring/Surveying
5985	5721	5720	106	8	Minor Deficiency	-0.086	WY	WY	Monitoring/Surveying
5990	5725	5724	179	8	Minor Deficiency	-0.028	WY	WY	Monitoring/Surveying
5993	5723	5722	283	8	Minor Deficiency	-0.050	WY	WY	Monitoring/Surveying
6003	5738	5736	348	8	Minor Deficiency	0.000	District	District	Monitoring/Surveying
6006	5733	5732	82	8	Minor Deficiency	-0.076	District	District	Monitoring/Surveying
6009	5740	5739	109	8	Minor Deficiency	-0.077	District	District	Monitoring/Surveying
6013	5731	5746	211	8	Minor Deficiency	-0.106	District	District	Monitoring/Surveying
6015	5736	5735	107	8	Minor Deficiency	-0.059	District	District	Monitoring/Surveying
7277	6513	5279	198	8	Minor Deficiency	-0.008	WY	WY	Monitoring/Surveying
2948	3532	1601	107	42	Nearly Flat	-19.179	District	District	Upsizing as 2025-CIP-P01
4324	1602	3532	123	42	Nearly Flat	-3.226	District	District	Upsizing as 2025-CIP-P01
1935	1589	1588	335	36	Flatter than Proximate Gravity Mains	-4.752	District	District	Monitoring/Surveying
3816	4137	4136	237	36	Flatter than Proximate Gravity Mains	-2.709	District	District	Monitoring/Surveying
877	2695	1583	74	36	Nearly Flat	-6.483	District	District	Monitoring/Surveying
4241	3108	4552	121	27	Nearly Flat	-0.125	District	Old Model	Monitoring/Surveying
7038	6463	3763	72	24	Zero/Negative Slope	-2.137	WY	District	Monitoring/Surveying
3902	4223	4222	287	15	Flatter than Proximate Gravity Mains	-3.728	District	District	Monitoring/Surveying
4154	4472	4471	350	15	Zero/Negative Slope	-4.307	District	District	Monitoring/Surveying
4979	5280	4475	232	15	Zero/Negative Slope	-4.217	District	District	Monitoring/Surveying
926	869	1605	88	12	Nearly Flat	-0.609	District	District	Monitoring/Surveying
1963	820	2830	364	12	Zero/Negative Slope	-0.714	District	District	Monitoring/Surveying
2521	1357	2017	116	12	Zero/Negative Slope	-0.673	District	District	Monitoring/Surveying
2505	929	920	132	10	Flatter than Proximate Gravity Mains	-0.007	District	District	Monitoring/Surveying
4079	4398	4397	273	10	Flatter than Proximate Gravity Mains	-0.053	District	District	Monitoring/Surveying
3608	3260	3259	228	10	Zero/Negative Slope	-0.225	District	District	Monitoring/Surveying
7342	3971	6585	178	10	Zero/Negative Slope	-0.375	Assumed Slope	Assumed Slope	Monitoring/Surveying
934	881	897	236	10	Zero/Negative Slope	-0.280	District	District	Monitoring/Surveying
7132	1817	896	165	8	Flatter than Proximate Gravity Mains	-0.350	District	District	Monitoring/Surveying
4773	5056	5057	269	8	Flatter than Proximate Gravity Mains	0.184	District	District	Monitoring/Surveying
1032	979	978	226	8	Zero/Negative Slope	-0.069	District	District	Monitoring/Surveying
1979	902	1606	70	8	Zero/Negative Slope	-0.097	WY	District	Monitoring/Surveying
222	226	2369	132	8	Zero/Negative Slope	-0.171	District	District	Monitoring/Surveying
2284	2221	44	314	8	Zero/Negative Slope	-0.026	District	District	Monitoring/Surveying
2929	1530	659	153	8	Zero/Negative Slope	-0.116	District	District	Monitoring/Surveying
3157	3657	3656	115	8	Zero/Negative Slope	-0.035	District	District	Monitoring/Surveying
4109	4428	4427	225	8	Zero/Negative Slope	-0.034	District	District	Monitoring/Surveying

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Table 6-5. Gravity Mains Not Meeting Performance Criteria Under 2035 Design Flow Conditions

Gravity Main ID	Upstream Manhole ID	Downstream Manhole ID	Length, linear feet (LF)	Diameter, in	Classifcation	Capacity Deficiency, MGD	Upstream Manhole Invert Elevation Source	Downstream Manhole Invert Elevation Source	Recommended Action
4806	5090	2565	60	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4807	5091	5090	324	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4808	5092	5091	266	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4809	5093	5092	260	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4810	5094	5093	160	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4812	5096	5094	340	8	Zero/Negative Slope	-0.085	District	District	Monitoring/Surveying
4813	5097	5096	340	8	Zero/Negative Slope	-0.045	District	District	Monitoring/Surveying
4819	5102	5101	189	8	Zero/Negative Slope	-0.028	District	District	Monitoring/Surveying
5130	4517	3259	34	8	Zero/Negative Slope	-0.070	District	District	Monitoring/Surveying
5169	4821	4655	255	8	Zero/Negative Slope	-0.038	District	District	Monitoring/Surveying
5195	4857	4856	149	8	Zero/Negative Slope	-0.039	District	District	Monitoring/Surveying
5196	4859	4858	48	8	Zero/Negative Slope	-0.038	District	District	Monitoring/Surveying
550	523	2545	334	8	Zero/Negative Slope	-0.145	District	District	Monitoring/Surveying
6824	6292	6290	14	8	Zero/Negative Slope	-0.034	WY	WY	Monitoring/Surveying
7058	6405	6223	59	8	Zero/Negative Slope	-0.082	WY	WY	Monitoring/Surveying
7177	6509	2889	37	8	Zero/Negative Slope	-0.175	WY	District	Monitoring/Surveying
7269	6528	6527	54	8	Zero/Negative Slope	-0.441	WY	WY	Monitoring/Surveying
7333	6582	3772	108	8	Zero/Negative Slope	-0.031	Assumed Slope	Assumed Slope	Monitoring/Surveying
836	1869	814	13	8	Zero/Negative Slope	-0.049	District	District	Monitoring/Surveying
1992	931	1829	30	6	Inconsistet Diameter	-0.076	District	District	Monitoring/Surveying

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Table 6-6. Gravity Mains Not Meeting Performance Criteria Under 2035 Design Flow Conditions with Revised R-T-K Factors

Gravity Main ID	Upstream Manhole ID	Downstream Manhole ID	Length, linear feet (LF)	Diameter, in	Classifcation	Capacity Deficiency, MGD	Upstream Manhole Invert Elevation Source	Downstream Manhole Invert Elevation Source	Recommended Action
966	913	1817	56	10	Major Deficiency	-0.155	District	District	Upsizing as Ex-CIP-P02
1156	1094	1771	270	8	Major Deficiency	-0.310	District	District	Upsizing as Ex-CIP-P01
1159	1097	1094	235	8	Major Deficiency	-0.116	District	District	Upsizing as Ex-CIP-P01
1162	1100	1093	437	8	Major Deficiency	-0.361	District	District	Upsizing as Ex-CIP-P01
1221	1160	1971	257	8	Major Deficiency	-0.688	District	District	Relieving by Ex-CIP-P01
1222	1161	1975	181	8	Major Deficiency	-0.355	District	District	Upsizing as Ex-CIP-P01
1223	1976	1161	328	8	Major Deficiency	-0.372	District	District	Upsizing as Ex-CIP-P01
2061	1771	1100	237	8	Major Deficiency	-0.285	District	District	Upsizing as Ex-CIP-P01
2094	1162	1976	417	8	Major Deficiency	-0.382	District	District	Upsizing as Ex-CIP-P01
2101	1093	1162	150	8	Major Deficiency	-0.342	District	District	Upsizing as Ex-CIP-P01
1941	1601	1600	372	42	Minor Deficiency	-0.820	District	District	Upsizing as 2025-CIP-P01
1943	1598	2703	262	42	Minor Deficiency	-0.104	District	District	Upsizing as 2025-CIP-P01
890	1597	1598	397	42	Minor Deficiency	-0.810	District	District	Upsizing as 2025-CIP-P01
891	1600	1599	628	42	Minor Deficiency	-0.712	District	District	Upsizing as 2025-CIP-P01
955	1608	879	657	36	Minor Deficiency	-0.982	District	District	Upsizing as Ex-CIP-P03
1993	1609	1615	19	18	Minor Deficiency	-0.209	District	District	Upsizing as 2020-CIP-P01
1996	901	1609	290	18	Minor Deficiency	-0.116	District	District	Upsizing as 2020-CIP-P01
951	896	892	439	10	Minor Deficiency	-0.125	District	District	Upsizing as Ex-CIP-P02
973	920	913	553	10	Minor Deficiency	-0.122	District	District	Upsizing as Ex-CIP-P02
2948	3532	1601	107	42	Nearly Flat	-16.945	District	District	Upsizing as 2025-CIP-P01
4324	1602	3532	123	42	Nearly Flat	-3.226	District	District	Upsizing as 2025-CIP-P01
1935	1589	1588	335	36	Flatter than Proximate Gravity Mains	-2.514	District	District	Monitoring/Surveying
877	2695	1583	74	36	Nearly Flat	-4.245	District	District	Monitoring/Surveying
3816	4137	4136	237	36	Flatter than Proximate Gravity Mains	-0.373	District	District	Monitoring/Surveying
4241	3108	4552	121	27	Nearly Flat	-0.125	District	Old Model	Monitoring/Surveying
7038	6463	3763	72	24	Zero/Negative Slope	-2.137	WY	District	Monitoring/Surveying
3902	4223	4222	287	15	Flatter than Proximate Gravity Mains	-0.812	District	District	Monitoring/Surveying
4154	4472	4471	350	15	Zero/Negative Slope	-1.343	District	District	Monitoring/Surveying
4979	5280	4475	232	15	Zero/Negative Slope	-1.253	District	District	Monitoring/Surveying
926	869	1605	88	12	Nearly Flat	-0.609	District	District	Monitoring/Surveying
1963	820	2830	364	12	Zero/Negative Slope	-0.714	District	District	Monitoring/Surveying
2521	1357	2017	116	12	Zero/Negative Slope	-0.673	District	District	Monitoring/Surveying
2505	929	920	132	10	Flatter than Proximate Gravity Mains	-0.007	District	District	Monitoring/Surveying
4079	4398	4397	273	10	Flatter than Proximate Gravity Mains	-0.053	District	District	Monitoring/Surveying
3608	3260	3259	228	10	Zero/Negative Slope	-0.225	District	District	Monitoring/Surveying
7342	3971	6585	178	10	Zero/Negative Slope	-0.375	Assumed Slope	Assumed Slope	Monitoring/Surveying
934	881	897	236	10	Zero/Negative Slope	-0.280	District	District	Monitoring/Surveying
7132	1817	896	165	8	Flatter than Proximate Gravity Mains	-0.350	District	District	Monitoring/Surveying
4773	5056	5057	269	8	Flatter than Proximate Gravity Mains	0.184	District	District	Monitoring/Surveying
1032	979	978	226	8	Zero/Negative Slope	-0.069	District	District	Monitoring/Surveying
1979	902	1606	70	8	Zero/Negative Slope	-0.097	WY	District	Monitoring/Surveying
222	226	2369	132	8	Zero/Negative Slope	-0.171	District	District	Monitoring/Surveying
2284	2221	44	314	8	Zero/Negative Slope	-0.026	District	District	Monitoring/Surveying
2929	1530	659	153	8	Zero/Negative Slope	-0.116	District	District	Monitoring/Surveying
3157	3657	3656	115	8	Zero/Negative Slope	-0.035	District	District	Monitoring/Surveying
4109	4428	4427	225	8	Zero/Negative Slope	-0.034	District	District	Monitoring/Surveying
4806	5090	2565	60	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4807	5091	5090	324	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4808	5092	5091	266	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4809	5093	5092	260	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4810	5094	5093	160	8	Zero/Negative Slope	-0.091	District	District	Monitoring/Surveying
4812	5096	5094	340	8	Zero/Negative Slope	-0.085	District	District	Monitoring/Surveying

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Table 6-6. Gravity Mains Not Meeting Performance Criteria Under 2035 Design Flow Conditions with Revised R-T-K Factors

Gravity Main ID	Upstream Manhole ID	Downstream Manhole ID	Length, linear feet (LF)	Diameter, in	Classifcation	Capacity Deficiency, MGD	Upstream Manhole Invert Elevation Source	Downstream Manhole Invert Elevation Source	Recommended Action
4813	5097	5096	340	8	Zero/Negative Slope	-0.045	District	District	Monitoring/Surveying
4819	5102	5101	189	8	Zero/Negative Slope	-0.028	District	District	Monitoring/Surveying
5130	4517	3259	34	8	Zero/Negative Slope	-0.070	District	District	Monitoring/Surveying
5169	4821	4655	255	8	Zero/Negative Slope	-0.038	District	District	Monitoring/Surveying
5195	4857	4856	149	8	Zero/Negative Slope	-0.039	District	District	Monitoring/Surveying
5196	4859	4858	48	8	Zero/Negative Slope	-0.038	District	District	Monitoring/Surveying
550	523	2545	334	8	Zero/Negative Slope	-0.145	District	District	Monitoring/Surveying
6824	6292	6290	14	8	Zero/Negative Slope	-0.034	WY	WY	Monitoring/Surveying
7058	6405	6223	59	8	Zero/Negative Slope	-0.082	WY	WY	Monitoring/Surveying
7177	6509	2889	37	8	Zero/Negative Slope	-0.175	WY	District	Monitoring/Surveying
7269	6528	6527	54	8	Zero/Negative Slope	-0.188	WY	WY	Monitoring/Surveying
7333	6582	3772	108	8	Zero/Negative Slope	-0.031	Assumed Slope	Assumed Slope	Monitoring/Surveying
836	1869	814	13	8	Zero/Negative Slope	-0.049	District	District	Monitoring/Surveying
1992	931	1829	30	6	Inconsistet Diameter	-0.076	District	District	Monitoring/Surveying

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Table 6-7. Lift Station and Force Main Capacity Results for Future Flow Conditions

Lift Station Name	Lift Station Data				Evaluation Results								
	Pump Number	Pump Capacity, gpm	Firm Capacity, gpm	Force Main Diameter, in	2020 Design Flow, gpm	Available Firm Capacity, gpm	Peak Force Main Velocity, fps	2025 Design Flow, gpm	Available Firm Capacity, gpm	Peak Force Main Velocity, fps	2035 Design Flow, gpm	Available Firm Capacity, gpm	Peak Force Main Velocity, fps
Dublin Blvd Lift Station	1	300	300	6	285	15	3.20	285	15	3.20	292	8	3.30
	2	300											
Croak Rd Lift Station (Temporary)	1	80	80	6	33	47	0.20	33	47	0.20	-	-	-
	2	80											

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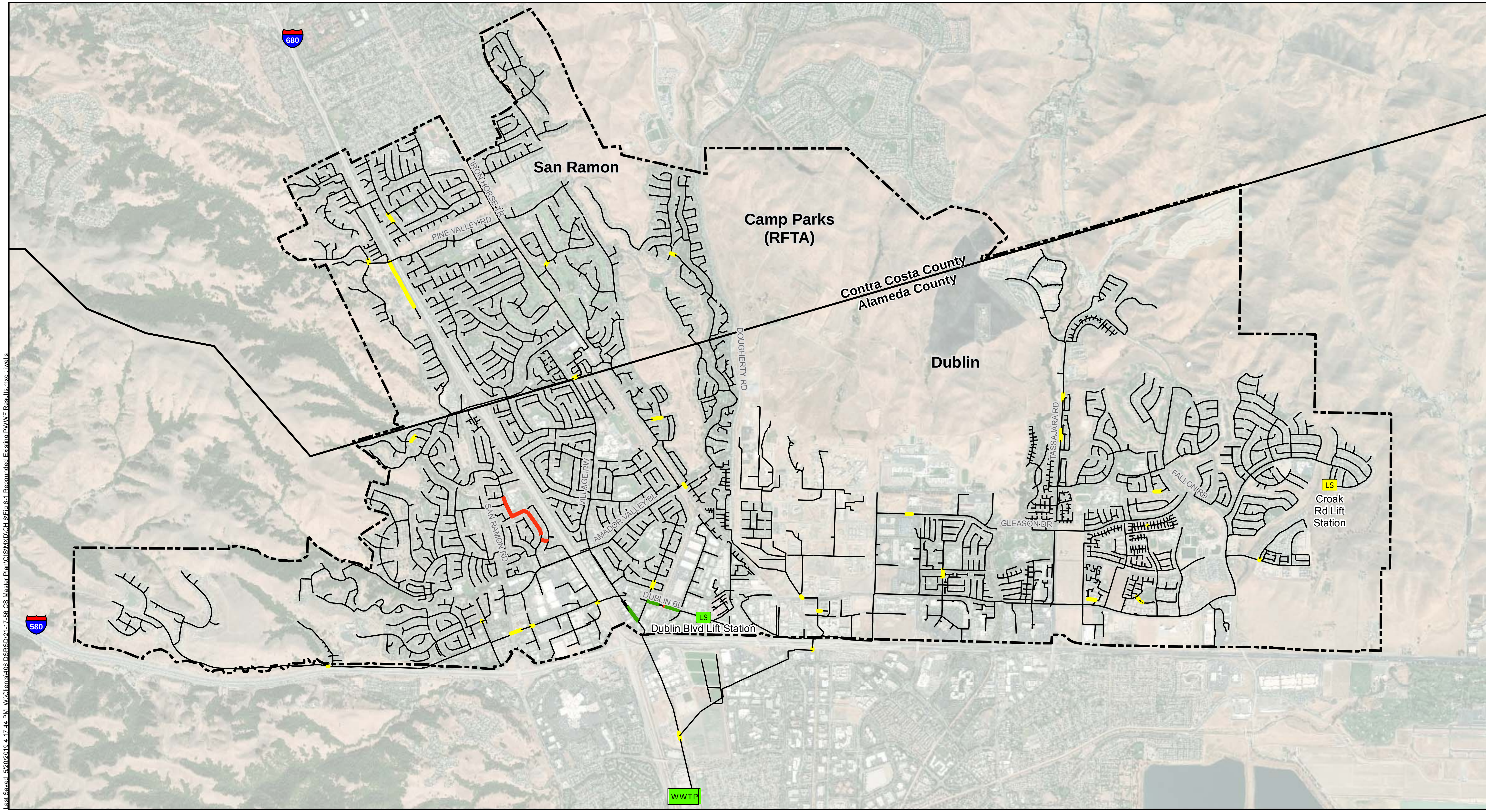

Symbology

WWTP WWTP

LS Permanent Lift Station

LS Temporary Lift Station

Wastewater Collection Service Boundary

Gravity Main by q/Q

>1.20 (Major Deficiency)

>1.00 and ≤1.20 (Minor Deficiency)

Further Study/Monitoring Required

≤1.00 (No Deficiency)

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 6-1

Hydraulic Evaluation Results
Rebounded Existing PWWF

Dublin San Ramon Services District
Collection System Master Plan

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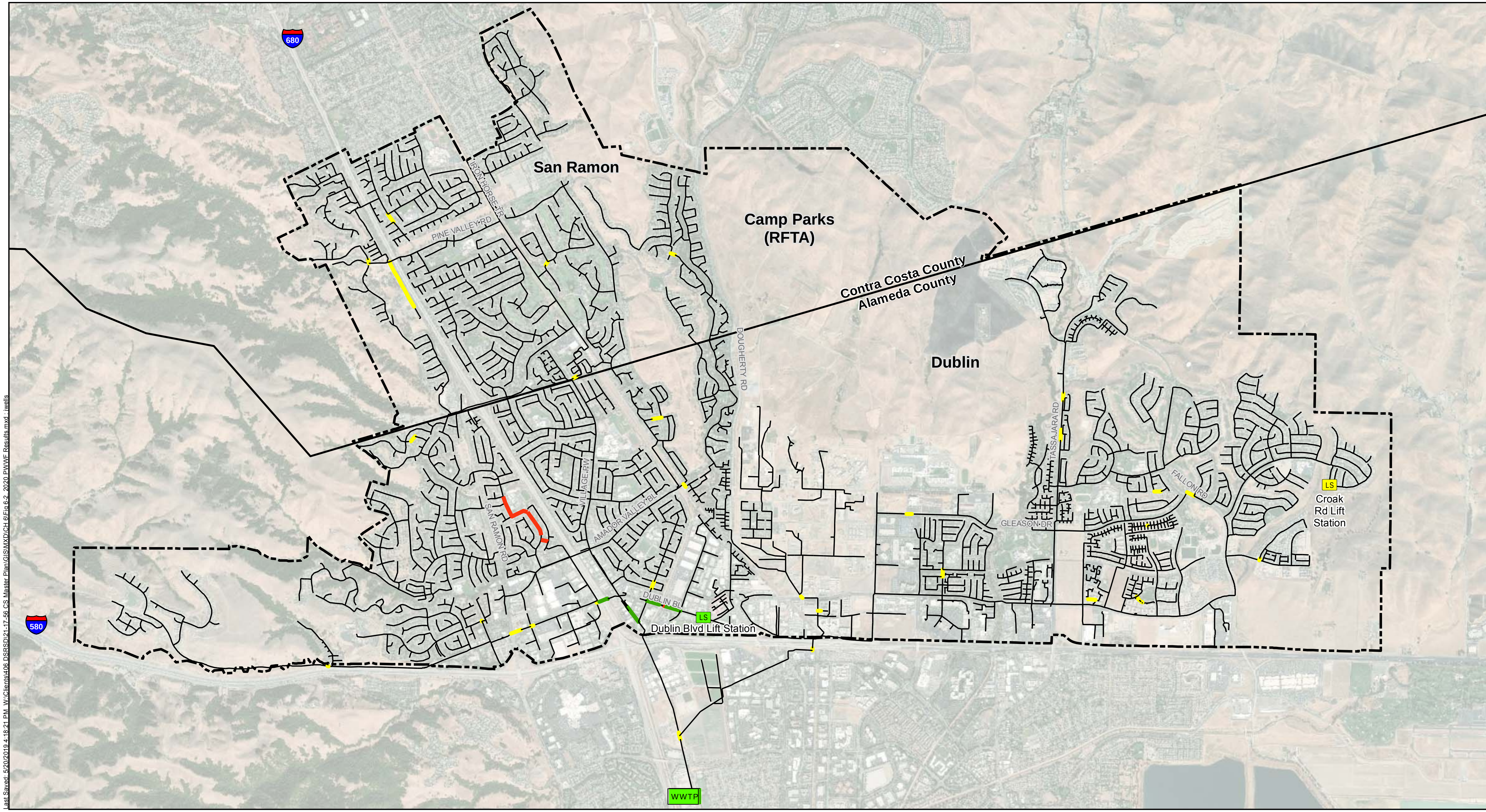

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Symbology

WWTP WWTP

LS Permanent Lift Station

LS Temporary Lift Station

Wastewater Collection Service Boundary

Gravity Main by q/Q

>1.20 (Major Deficiency)

>1.00 and ≤1.20 (Minor Deficiency)

Further Study/Monitoring Required

≤1.00

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 6-2

Hydraulic Evaluation Results
2020 PWWF

Dublin San Ramon Services District
Collection System Master Plan

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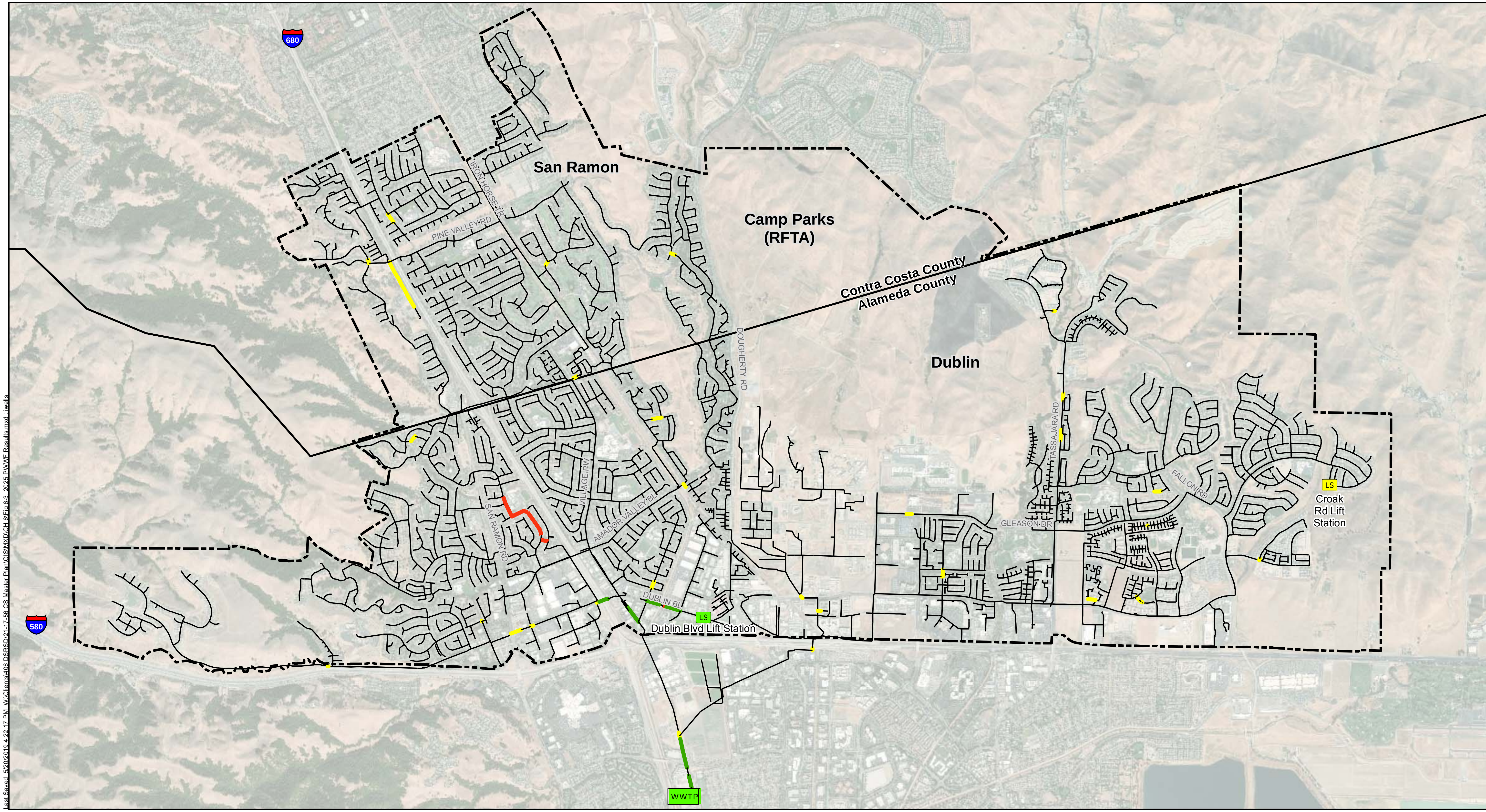

Symbology

WWTP WWTP

LS Permanent Lift Station

LS Temporary Lift Station

Wastewater Collection Service Boundary

Gravity Main by q/Q

>1.20 (Major Deficiency)

>1.00 and ≤1.20 (Minor Deficiency)

Further Study/Monitoring Required

≤1.00

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 6-3

Hydraulic Evaluation Results 2025 PWWF

Dublin San Ramon Services District
Collection System Master Plan

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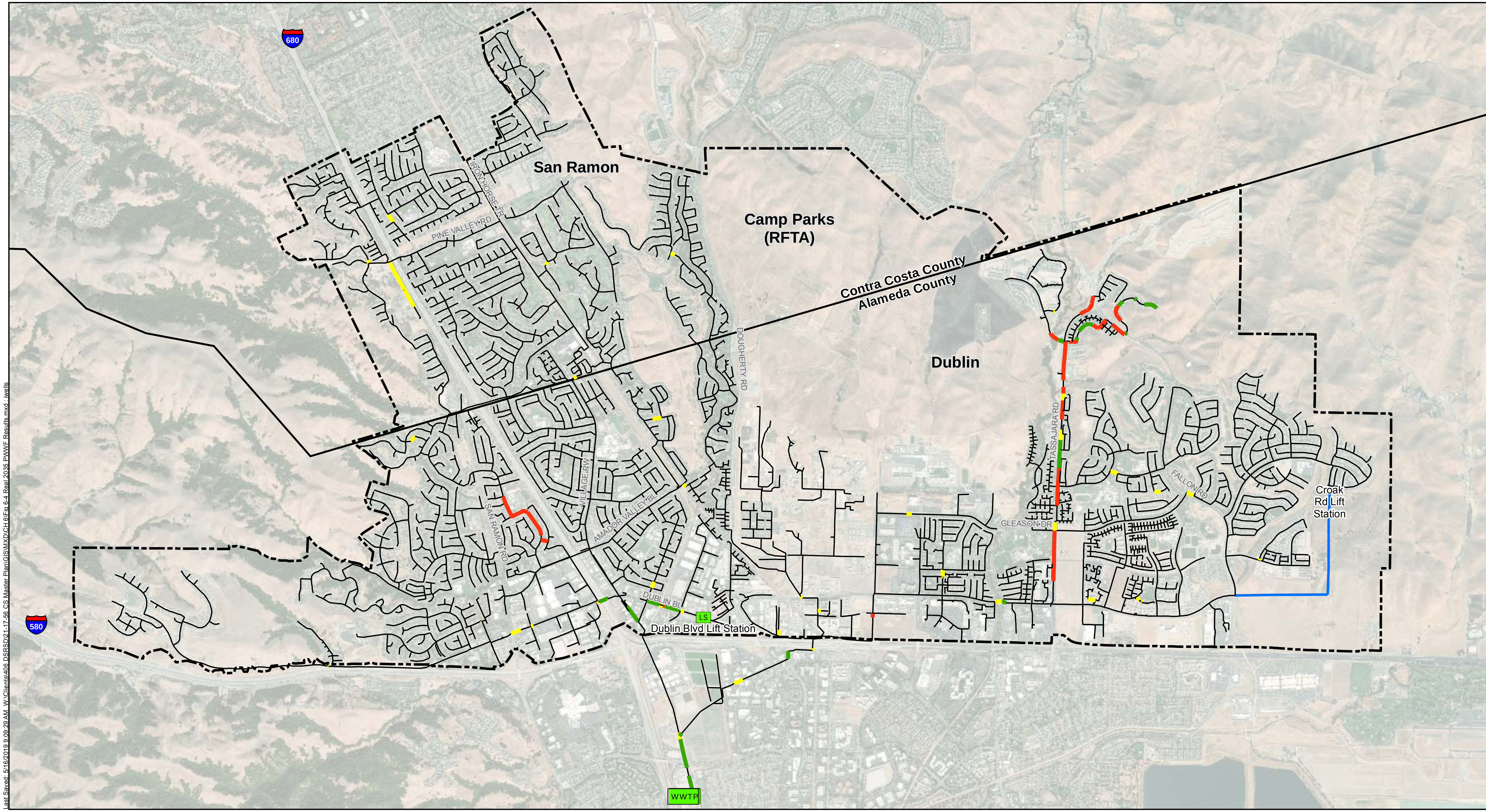

Last Saved: 5/16/2019 9:09:29 AM W:\Clients\406 DSRSD\21-17-56 CS Master Plan\GIS\MXD\CH 6\Fig 6-4 Real 2035 PWWF Results.mxd : jwells

Symbology

WWTP WWTP

LS Permanent Lift Station

Wastewater Collection Service Boundary

Future Gravity Main

Gravity Main by q/Q

>1.20 (Major Deficiency)

>1.00 and ≤1.20 (Minor Deficiency)

Further Study/Monitoring Required; Flatter than Proximate Gravity Mains

≤1.00

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 6-4

Hydraulic Evaluation Results
2035 PWWF

Dublin San Ramon Services District
Collection System Master Plan

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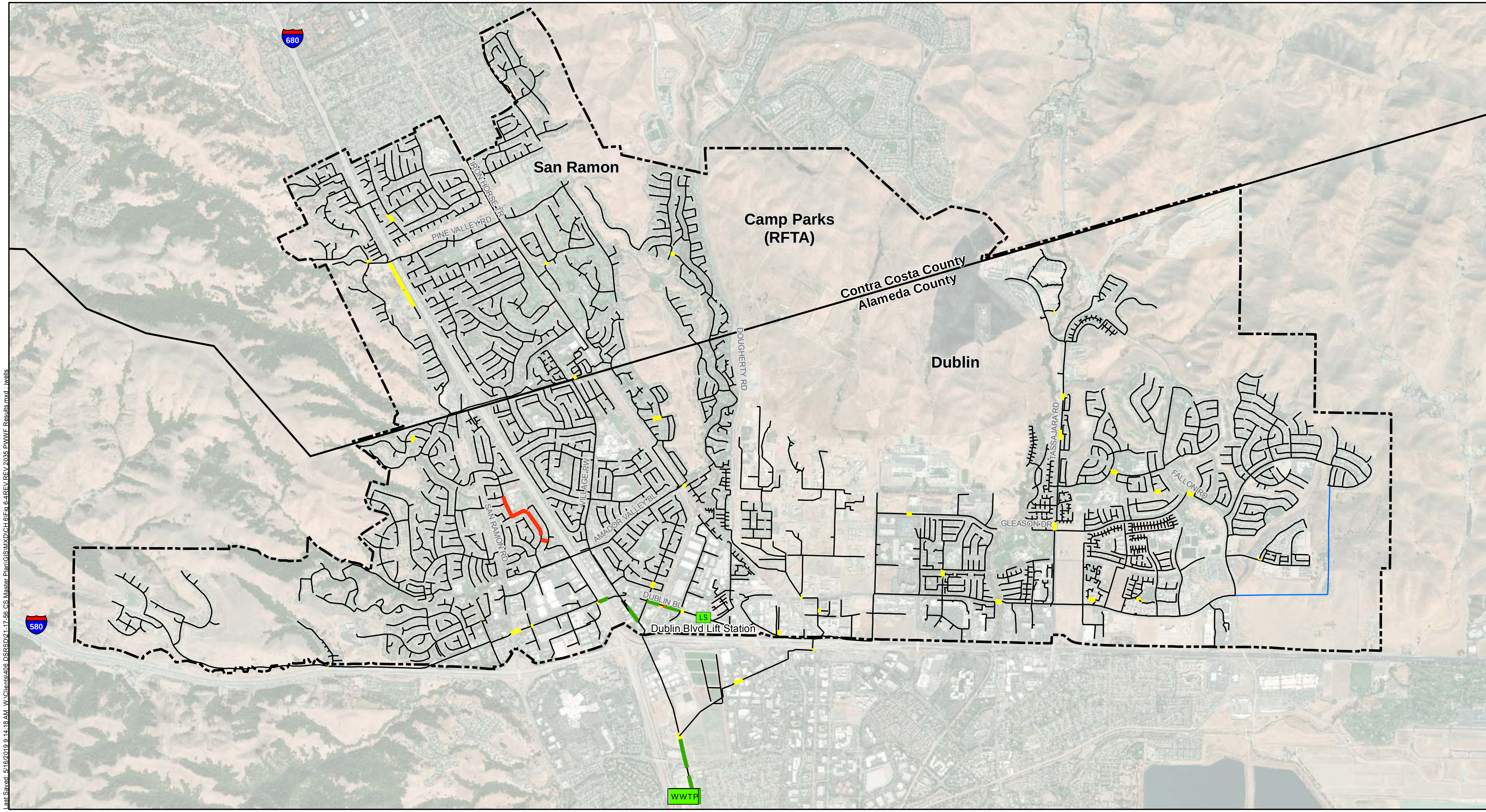

Symbology

- WWTP WWTP
- LS Permanent Lift Station
- Wastewater Collection Service Boundary
- Future Gravity Main

Gravity Main by q/Q

- >1.20 (Major Deficiency)
- >1.00 and ≤1.20 (Minor Deficiency)
- Further Study/Monitoring Required; Flatter than Proximate Gravity Mains
- ≤1.00

Notes:
1. RDII factors for new development projects located in flow monitoring basin 7 have been modified to be identical to those for flow monitoring basin 6.

N

0 1,600 3,200
Scale in Feet

WEST YOST ASSOCIATES

Figure 6-5

Hydraulic Evaluation Results 2035 PWWF with Revised R-T-K Factors

Dublin San Ramon Services District
Collection System Master Plan

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CHAPTER 7
Long-Term Management Strategy

Previous chapters in this CSMP have dealt primarily with the capacity of the District's collection system. As described in Chapter 6, a small number of capacity deficiencies have been identified under existing and future conditions. This limited number of capacity deficiencies is a result of the investment that the District has made throughout the years. By contrast Chapter 7 evaluates the collection system from a long-term perspective that focuses on the condition of the collection system assets. A focus on the condition of the collection system will become increasingly critical for the District as growth and development rates decline, and as the collection system assets age. The following sections discuss the components of a long-term management strategy for the collection system.

7.1 INTRODUCTION TO LONG-TERM MANAGEMENT

Many wastewater agencies in California are facing challenges in the operation and management of their collection systems that go beyond providing capacity for new growth and development. Deferred maintenance that took place as resources were focused on new growth has resulted in a need for focus on the condition of infrastructure assets. Aging infrastructure requires a different management strategy than younger systems; one which addresses system condition, performance, and current maintenance issues. A long-term management plan can provide proactive utility management strategies which allow utilities to sustainably manage their collection systems both now and into the future.

The District is currently experiencing the transition from owning and operating a younger growth-driven collection system to owning and operating an older, maintenance-focused collection system. As discussed previously, the District's wastewater service area is approximately 84 percent developed by dwelling unit count – 99 percent within the City of San Ramon and 74.5 percent within the City of Dublin. Much of this development in these two cities has occurred over the past 10 years, during which the population in the Cities of San Ramon and Dublin increased by almost 50 percent.

This historical growth required the District to establish a development-focused management strategy. Resources went to tasks such as ensuring compliant construction of collection system infrastructure and handling increased flows with new conveyance and treatment infrastructure. Now that the District wastewater service area is getting closer to build-out, the focus of management strategies requires a shift to a more long-term planning outlook. Although the age of infrastructure within the District is still relatively new, making the shift now will minimize future system problems, and maximize life expectancy from system infrastructure. It is to the credit of the District's management, planning, engineering, and operations staff that the District has begun the transition from development-focused to maintenance-focused collection system management without experiencing an increase in Sanitary Sewer Overflows (SSOs) or other performance issues within the collection system.

The District has identified management of Private Sewer Laterals (PSLs) and management of I&I as two areas of focus for long-term management of the collection system. Strategies include evaluation of PSL policy and identification of areas of emphasis for reduction of I&I. The following sections provide background on the potential focus areas and an evaluation of each based on the District's current and long-term needs. This chapter concludes with long-term management strategy recommendations including integration of the hydraulic capacity evaluation results found in Chapter 6.

7.2 PRIVATE SEWER LATERAL MANAGEMENT

Previous chapters in this CSMP have identified and analyzed only the District-owned gravity mains, manholes, pump stations, and force mains in the collection system. However, infrastructure is required to connect individual buildings to this District-owned infrastructure so that wastewater can exit the building and enter the collection system. These pieces of connecting infrastructure are known as PSLs. Defects in aging infrastructure increase the likelihood that sewage may leak or spill out of the collection system as a SSO, as well as the potential for both rain and groundwater to enter the collection system as I&I. To reduce the likelihood of these events, utility agencies are becoming more proactive in their operation and maintenance strategies, employing rehabilitation programs to address aging and defective infrastructure. PSLs, which typically make up around half of the total collection system by length, are often not included in these maintenance activities. This leaves PSLs in a state of unknown and possibly poor condition, and leaves the public wastewater agency with little authority to address the issue. Unmaintained PSLs can allow large amounts of I&I into the collection system, and even if I&I is not an issue, defective PSLs can cause problems such as blockages in public mains/pump stations when roots, sediment, broken pipes, and soil flow downstream. In summary, the condition of PSLs, which are private property that is owned and maintained by individual customers, can have significant impacts on the capacity and condition of a utility agency's collection system. The costs of these impacts to the collection system are borne by all ratepayers, not just by the owners of the unmaintained PSLs.

A long-term PSL management policy allows utility agencies to better track and manage private property improvements that affect the publicly-owned collection system. A robust PSL policy can protect customers, reduce private and public collection system SSOs, reduce overall system I&I, allow the agency to implement comprehensive I&I efforts, and reduce blockages and other SSO-related maintenance issues.

7.2.1 District Experience

PSLs in the District are owned by the private property owner, which includes the lateral from the building envelope, up to and including the connection to the public main. In this ownership scenario, the private property owner is responsible for testing, inspection, maintenance, repair, and replacement of the PSL. Therefore, SSOs that originate in the PSL are the responsibility of the property owner according to the California State Water Resources Control Board (SWRCB). Public SSOs (those SSOs that originate in a public portion of the collection system, regardless of where the SSO actually appears) have been eliminated in the District since 2014 through proactive inspection and maintenance activities. Although regulations do not require the District to track private SSOs (those SSOs originating in a PSL), it appears that a small number of private SSOs are occurring annually.

As observed from the 2017 Flow Monitoring Study and corroborated by District staff, the collection system is not currently experiencing any significant I&I issues leading to surcharging or SSOs. While there are areas within the collection system that experience higher I&I than other areas, even these areas are not experiencing significant capacity problems or SSOs. Although the

District is not experiencing significant PSL condition-related impacts ("significant" being defined as impacts that can be connected to surcharging or SSOs) to the District-owned collection system, the District wishes to approach PSL Maintenance proactively with collection system customers.

The District has developed a proactive approach to the operation and maintenance of its collection system. In continuing this approach, it is important to develop a long-term management strategy for PSLs. PSLs do not currently pose a critical problem regarding I&I and SSOs, but that risk will only increase as the collection system ages. I&I that enters the collection system through PSLs could potentially require upsizing of collection system gravity mains, which would present increased cost of all of the District's ratepayers.

Private SSOs are not currently a District responsibility, but California regulatory policy trends indicate there is the possibility private SSOs will be required to be tracked by utility agencies in the future. By developing policies before the PSL issue becomes critical, the District can manage the risk and cost of any action over time. Proactively establishing a PSL policy will allow the District the flexibility to address PSL issues as necessary in the future.

7.2.2 PSL Policy Evaluation Technical Memorandum

A PSL Policy Evaluation Technical Memorandum (TM) was prepared during the CSMP development process and is included as Appendix C. The TM includes the following sections:

- Definition and background on PSLs;
- Overview of the District's existing policies and practices as they relate to PSLs;
- PSL policy and practice options (including ownership, condition mandate, inspection, enforcement, and public protection);
- A survey of 11 local agencies and their PSL policies; and
- PSL policy funding options.

Information within the TM is intended to provide a basis for discussion within the District, as private lateral policies can have significant legal, administrative, and financial implications. The TM was presented to the District at a workshop-style meeting in April 2018. Outcomes from the TM and associated dialogue are summarized below.

7.2.3 PSL Summary and Recommendation

The District is in the process of evaluating various PSL policy options and understands the importance of proactively implementing a PSL policy. The District's interests in developing a PSL policy include:

- Continued proactive management of the collection system;
- Flexibility in policy including the ability to modify based on later needs;
- Balancing District liability and costs with value provided; and
- Protecting vulnerable customers.

The District has a clearly established policy that individual building owners also own the PSL connecting their building to the gravity main, and the District does not intend to change this policy. Such a policy is typical of wastewater utility agencies across California (approximately 70%). As the next step in developing a PSL policy, the District may wish to consider establishing a PSL condition requirement. Such a requirement could specify that although a PSL is private property, because the PSL connects to and potentially impacts the District's collection system, the District requires that each PSL owner keep the PSL in good condition and resistant to I&I. Six of the eleven Bay Area wastewater utility agencies surveyed for the TM have such requirements. As part of the condition requirement, the District could establish events (for example sale or significant improvement of a property, downstream SSO, or replacement of the gravity main that the PSL connects to) that trigger a mandatory inspection of a PSL by its owner. Because of the condition requirement, owners would be obligated to repair or replace PSLs that fail the inspections. A PSL condition requirement coupled with one or more inspection triggers would give the District a means to identify and improve PSLs whose condition is a threat to the collection system. The costs for inspection and improvement of the PSLs are borne by the property owners. The District costs would be the administrative time and effort required to track, implement, and enforce the triggers. In some cases, this effort would include coordinate with other agencies such as the City of Dublin and the City of San Ramon.

The District may also wish to consider establishing via policy that PSLs constitute a public good. Wastewater utility agencies often establish this concept as part of a PSL ordinance by explaining the various ways that good PSL condition contributes to the protection of public health and public property. With this concept established, public funds (i.e. District funds) can be spent to improve PSL conditions. District funds could be spent as part of reimbursement to PSL owners who replace poor PSLs, or they could be spent directly replacing poor PSLs as part of gravity main rehabilitation and repair projects. Seven of the eleven agencies surveyed for the TM provide agency money via grant or loan to property owners who improve their PSL.

The District will be evaluating the policy options described above in the upcoming years. This evaluation and the policies that result will provide the District maximum flexibility in developing a comprehensive PSL program at the time in the future when the District determines such a program to be necessary, and when adequate resources are available.

7.3 I&I MANAGEMENT

When a collection system receives excessive I&I, it can overwhelm the system during storms, burden operational and maintenance staff, and reduce the life expectancy of the infrastructure. When pipes, pump stations, and treatment facilities are over-capacity and unable to handle flows, it can result in sewage bypasses at treatment facilities which releases partially/under-treated wastewater to the environment, and SSOs that release raw sewage on both public and private property. These events pose significant health and environmental concerns and can involve costly cleanup for both public agencies and homeowners.

In principle, there are two options to address I&I: 1) increase the hydraulic capacity of the system through upsizing pipelines and facilities, or 2) eliminate I&I at the source through the disconnection of illegal connections or the rehabilitation of existing infrastructure. Increasing capacity is often unfeasible and always costly, both initially in capital infrastructure costs and long-term in operating and maintenance costs. For this reason, utility agencies are becoming more proactive in their operation and maintenance strategies, employing rehabilitation programs to address the aging or defective infrastructure responsible for I&I. In the sections below, the factors that contribute to I&I are examined in detail, along with the I&I patterns observed in the District's collection system. The purpose of this examination is to identify the I&I reduction actions with the most potential to benefit the long-term management of the District's collection system.

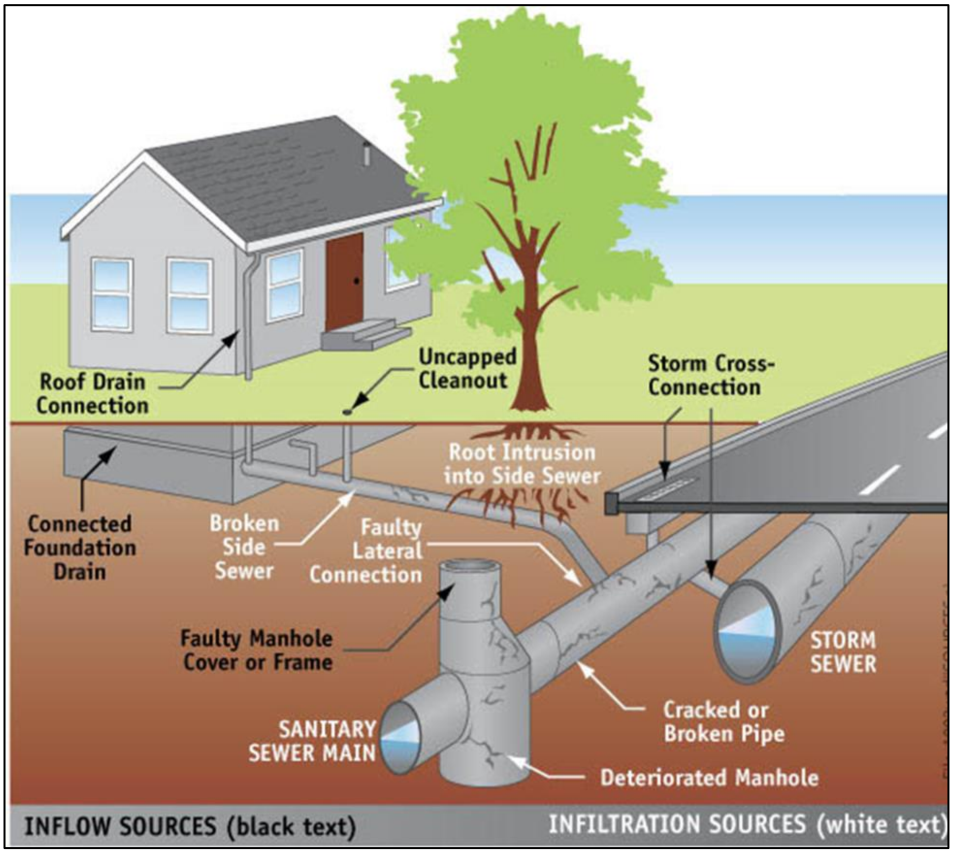
7.3.1 I&I Components

Peak wet-weather flow is significantly greater than peak dry-weather flow, primarily because of the presence of I&I. I&I is considered to have a rainfall-dependent component – RDII, and a non-rainfall-dependent component –GWI. RDII consists of a combination of inflow and rainfall-dependent infiltration and is the larger contributing factor of overall I&I. Inflow is defined as storm water runoff entering a wastewater collection system through system leaks/porosity (such as perforated manhole covers) and improper/illicit storm water connections (such as catch basins, roof leaders, cleanouts, foundation drains, drainage sump pumps, and area drains). Infiltration is defined as water traveling through the ground and entering the collection system through defective pipes, pipe joints, damaged lateral connections, and manhole walls. Rainfall-dependent infiltration occurs when groundwater levels briefly rise during storms to submerge portions of the wastewater collection system. Non-rainfall-dependent GWI occurs when portions of a wastewater collection system are below the groundwater table for extended periods of time, even during dry weather periods.

7.3.2 I&I Sources

Typical sources of I&I into wastewater collection systems are shown on Figure 7-1. Aging and damaged PSLs are generally accepted to be a major contributor of I&I as described previously in this chapter. PSLs are typically located on private property, poorly maintained, buried at shallow depths, and subject to tree root intrusions.

Figure 7-1. Sources of I&I



7.4 APPROACH TO I&I REDUCTION

General reduction approaches are discussed in the sections below.

7.4.1 I&I Reduction Background

Sewer rehabilitation can significantly reduce I&I, depending on the type and amount of rehabilitation performed. In addition to reducing I&I rates into the collection system, sewer rehabilitation can also address structural and maintenance issues, such as root intrusions and grease accumulation, and thus reduce the occurrence of dry weather blockages and SSOs.

Collection system rehabilitation can take several forms. Experience throughout the country has shown that rehabilitation should occur on an area-wide approach. With such an approach, the entire collection system within a designated area or sub-basin is rehabilitated as compared to trying to identify and correct specific defects. The latter approach may prove ineffective because storm water can migrate past the rehabilitated defects and enter the collection system through defects that were not rehabilitated.

Sewer rehabilitation can involve challenges related to developing and administering a program to correct I&I sources on private property. Many studies have found that approximately one half of I&I enters the collection system through defective PSLs, which are primarily located on private property. As discussed previously, District PSLs are owned by the private property owner, therefore, a specific PSL policy would be required to allow comprehensive I&I rehabilitation that involves PSL rehabilitation or repair.

7.4.2 Repair and Rehabilitation Methods

A variety of methods are available for identifying sources of I&I in a sewer system. Beyond flow monitoring and closed circuit television (CCTV) inspection which the District has already completed, localized testing can be performed to identify direct inflow connections and defects in public mains and private sewer laterals. Methods include smoke testing, dye testing, pressure testing, visual inspection, rainfall simulation, Focused Electrode Leak Location testing, and salinity monitoring.

This remainder of this section provides a brief summary of repair methods available for sewer improvements to reduce I&I. These methods include open-cut replacement, pipe bursting, chemical grouting, cured-in-place pipe (CIPP) lining, and HDD. In addition to in-situ repair methods, I&I reduction can be achieved through identification and removal of interconnections to local or regional storm water collectors.

Open-Cut Replacement

Open-cut replacement is the traditional pipeline construction method applicable to both PSL and mainline sewer replacements. If the route of the sewer lateral is relatively clear of expensive landscaping/hardscaping and structures, open cut replacement would generally be most cost effective.

Pipe Bursting

Lateral pipe bursting involves excavations at the sewer main connection and at each building, and results in a continuous HDPE replacement lateral following the same line and grade as the original lateral. The necessary excavations can increase the cost and level of disruption with pipe bursting compared to other trenchless methods such as CIPP.

Chemical Grouting

Grouts are typically made of products that are not structurally independent and require that the host pipe be structurally stable. Additionally, chemical grouts are typically most applicable in relatively wet soils with a consistent groundwater table elevation to avoid wet-dry cycles on the grout, which can significantly reduce the product’s useful service life. To avoid the need to periodically re-grout and maintain such a product, sewer lateral grouting is typically not considered an ideal long-term solution. However, grouting may be performed in advance of other methods such as CIPP lateral lining in order to stop large quantities of infiltration and to fill soils voids, which helps facilitate a CIPP lateral lining installation.

Cured-in-Place Pipe

Available methods for rehabilitation installations include short CIPP lateral liners known as "top hats" and longer CIPP lateral liners up to approximately 90 linear feet. The final length desired can depend on an assessment of groundwater depths and/or a lateral CCTV inspection.

Horizontal Directional Drilling

Horizontal directional drilling (HDD) relocation is an additional method available for replacing sewers. This method requires small excavations at both ends of the pipe; and while in the case of a sewer lateral, it would disturb private property at the building, it is less intrusive than a full open-cut excavation.

Removal of Interconnections

Direct inflow sources can include illegally connected roof drains, foundation drains, or storm water interconnections. These sources contribute to the RDII component of I&I and can introduce a significant volume of water to the collection system during storm events. Property owners would be responsible for the removal of illegal interconnections originating from private property.

7.5 DISTRICT BASIN-LEVEL I&I ANALYSIS

As described in Chapter 3, the District's collection system was divided into 15 separate hydraulic basins for purposes of the 2017 Flow Monitoring Study. These 15 basins collect wastewater from within the District's service area and convey it, via the collection system, to the WWTP located in the City of Pleasanton. A basin-level I&I analysis of the collection system was performed to identify candidates for high-value long-term management strategies and to better understand the role that I&I plays in the hydraulic deficiencies identified in Chapter 6. The basins were evaluated against an established set of criteria to establish priorities, as documented in the sections below. The evaluation considers factors that increase the likelihood of I&I occurring in each basin, relative to other basins. Factors that increase the likelihood of I&I include some obvious ones such as the GWI and RDII values measured during the 2017 Flow Monitoring Study. In addition, these factors include some other indicators such as age and presence of defects that contribute to I&I. These latter factors identify the long-term potential of each basin to contribute I&I to the collection system.

7.5.1 Likelihood Factor Rating Methodology

A standard method for multi-factor prioritization is to sort the range of values for that factor along a scale from one to five. The scale break points between values are chosen so that there is statistical distribution along the scale for each factor, not necessarily for technical reasons. This method allows us to do comparisons and prioritizations among the various factors using standardized values. This method was applied to the I&I likelihood factors for the District's collection system. Each of the 15 flow monitoring basins was rated for each likelihood of I&I factor on a scale of one to five with five indicating the highest likelihood of I&I. The rating scale of each factor is summarized in Table 7-1. The development of ratings for each flow monitoring basin is described below.

Table 7-1. Likelihood of I&I Rating Factors

Factor	Metric	Rating (1 being the lowest, 5 being the highest)				
		1	2	3	4	5
GWI	GWI Value (gpd)	0-100	101-200	201-400	401-500	501+
RDII	Total R Value (%)	0-1	1-2	2-3	3-4	5+
Age	Average age by basin	0-37 (present-1981)	38-47 (1980-1971)	48-57 (1970-1961)	58-67 (1960-1951)	68+ (1950-older)
CCTV I&I Contributing Defects	CCTV I&I Score per mile of pipe inspected	<150	150-300	300-400	450-600	≥600

7.5.2 GWI and RDII

Basin GWI values (in gpd) as presented in Chapter 3 are shown on Figure 7-2 along with the hydraulic deficiencies for 2035 projected flow conditions as discussed in Chapter 6. RDII "Total R" values as presented in Chapter 3 are shown in Figure 7-3 along with the hydraulic deficiencies for 2035 projected flow conditions. The Total R value represents total percentage of rain falling over a basin that enters the collection system during and after a storm event.

As can be seen on Figure 7-2, flow monitoring basins 8, 9, 11, and 14, which have higher than average GWI rates for the collection system, are upstream of several of the identified capacity deficiencies. The high GWI values in flow monitoring basins 6 and 7 are upstream of only the deficiency near the WWTP. Similarly, the high Total R values in flow monitoring basins 8, 9, and 10 that are shown on Figure 7-3 are upstream of several of the identified deficiencies. The high Total R values identified in flow monitoring basin 3 are upstream of the deficiency near the WWTP.

7.5.3 Sewer Main Age

Greater I&I values are typically associated with older and deteriorated gravity mains, placing importance on evaluating the age of gravity mains in the system. The District provided GIS data containing the construction dates of all collection system pipes. This data was used to calculate the age of each pipe and average pipe age for each basin. Figure 7-4 shows individual pipe age and the Total R value for comparison values for each of the collection system flow monitoring basins.

As would be expected for a topic as complex as I&I, there is no perfect correlation between gravity main age and Total R value in the collection system flow monitoring basins. However, all of the flow monitoring basins with high Total R values contain a significant portion of older (1950s or 1960s installation) gravity mains.

7.5.4 CCTV I&I Contributing Defects

CCTV condition assessment data for the gravity portions of the collection system was provided by the District for each basin. The data consisted of 3372 unique CCTV inspections covering 125 miles of gravity pipeline. Each of the CCTV inspections followed the standardized method of coding defects developed by the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment Certification Program (PACP). A customized scoring system was developed to identify defects with the highest potential for I&I (for example offset joints and cracks in the top of the gravity main). This system uses PACP guidelines for coding defects in the field, but assigns a customized scoring to these defects to provide higher consideration of defects that might cause a larger volume of I&I to enter the system. This "I&I severity" scale defines a system for ranking maintenance and structural defects on a 1 to 5 scale, with 5 being the most severe. The defects identified in the I&I severity scoring are shown on Figure 7-5. A normalized I&I defect score for each sub-basin was developed by dividing the total I&I severity score for each defect within a basin by the total miles of inspection length.

As presented on Figure 7-5, the I&I contributing defects are prevalent in the older portions of the collection system in Central Dublin and San Ramon. Although there is not a perfect correlation between such defects and the Total R value recorded during flow monitoring, there does appear to be strong clusters of severe I&I contributing defects in flow monitoring basins with high Total R values, particularly flow monitoring basins 8 and 10.

7.5.5 Basin Analysis Results

The I&I likelihood factors that are described above and presented graphically on the referenced figures were summarized numerically for each flow monitoring basin according to the ratings presented above in Table 7-1. Because the importance of the likelihood factors is not equal, importance weight values were assigned to the factors. The importance factors were assigned using pair-wise comparison to identify the most important or influential factors. The values of the importance weight are used to show relative, not absolute importance. With the importance weight established, basins were evaluated using a weighted screening matrix as shown in Table 7-2. The total weighted rating was ranked to identify priority basins for potential I&I reduction (with a value of 1 having the highest priority).

Table 7-2. Basin Analysis Results

Basin	Rating Factor/Importance Weight[(a)]								Total Weighted Rating	Overall Ranking
	GWI/5		RDII/10		Age/4		CCTV/8			
	Rating	WR	Rating	WR	Rating	WR	Rating	WR		
1	1	5	2	20	1	4	1	8	37	11
2	1	5	1	10	1	4	1	8	27	12
3	1	5	3	30	1	4	1	8	47	8
4	1	5	1	10	1	4	1	8	27	12
5	1	5	1	10	3	12	4	32	59	3
6	5	25	1	10	1	4	1	8	47	8
7	4	20	2	20	1	4	1	8	52	6
8	5	25	5	50	1	4	2	16	95	2
9	2	10	3	30	2	8	1	8	56	5
10	1	5	5	50	3	12	5	40	107	1
11	3	15	2	20	1	4	1	8	47	8
12	1	5	2	20	2	8	2	16	49	7
13	1	5	1	10	1	4	1	8	27	12
14	5	25	2	20	1	4	1	8	57	4
15	1	5	1	10	1	4	1	8	27	12

(a) Importance weight was assigned using a Pair-wise comparison of all factors; normalized totals become the factor importance weight on a scale from 1 to 10, with 10 being the most favorable/important.

7.5.6 Priority Basin Summaries

From the analysis described above, flow monitoring basins 10, 8, 5, and 14 have been identified as priority basins for long-term I&I reduction strategies. The priority basins are briefly described below.

Basin 10

Basin 10 collects flow from a small, primarily residential area west of Highway 680 and south of Alcosta Boulevard and deposits flow downstream to Basin 13. Flow from Basin 11 and a small part of Basin 12 flow into Basin 10 at San Ramon Road. Basin 10 scored among the lowest for GWI, but has the highest RDII, pipe age, and CCTV rating. The majority of pipe was built in the 1960s and contains a high proportion of root-related defects, which are known to be pathways for I&I into collection systems.

Basin 8

Basin 8 is located in the City of San Ramon and serves the most northwest portion of the District's collection system service area. There is no basin upstream of Basin 8 which means all flow through the pipes originates internally. Flow from Basin 8 is conveyed to Basin 12, and further downstream to Basin 13, before reaching the pipes outside of the service area south of Highway 580. Basin 8 sewer mains have a fairly even distribution of age, with construction dates ranging from 1968 to

2001. There is a concentration of older pipes built in the mid-1960s located east of Highway 680. Basin 8 had among the highest GWI and RDII values and a high proportion of structural defects.

Basin 5

Basin 5 is a small catchment on the southwest edge of the Camp Parks property. The basin experiences minimal observed GWI and RDII, but contains the oldest average pipe age at 54 years. Basin 5 also had the second highest rating of CCTV defects with a high proportion of structural defects.

Basin 14

Basin 14 is located in the middle of the City of Dublin adjacent to Highway 580. There are no other basins that flow into Basin 14 which means all the flow through the pipes originates internally. The eastern portion of the Basin serves the mostly commercial area just north of Highway 580 while the western section serves a residential community. Pipe age in this basin varies significantly. Pipes in the residential portion of the basin west of the Alamo Canal were built in the mid-1960s. Pipes east of the Canal have construction dates ranging from 1961 to 2006. Basin 14 had the highest GWI rating, but scored among the lowest in all other categories.

Basin 14 contains the only permanent lift station in the collection system which lifts flow from the eastern portion of the system to the trunk gravity mains leading to the WWTP.

7.6 I&I MANAGEMENT AS A LONG-TERM SUPPLEMENT TO IMPROVING CAPACITY DEFICIENCIES

To provide the District with a long-term supplement to gravity main upsizing as a solution to the hydraulic deficiencies identified in Chapter 6, the hydraulic model was analyzed to estimate the required RDII reduction to eliminate each deficiency. RDII was chosen for reduction because it has the largest influence on total I&I. Table 7-3 lists the recommended RDII reduction percentage and target basin which is required to eliminate hydraulic deficiencies. Basin percentages were chosen to optimize impact (i.e. basins which influenced multiple deficiencies were given higher reductions).

The reduction percentage requirements shown in Table 7-3 indicate that between 30% and 50% reduction is required in the priority flow monitoring basins to eliminate the hydraulic deficiencies identified in the collection system. Reduction percentages such as this are possible only with comprehensive rehabilitation of a basin, usually including repair/replacement of all PSLs in the basin as well. Because comprehensive rehabilitation would be an expensive undertaking, and because no rehabilitation plan is guaranteed to reduce I&I to predicted levels, it is not recommended that the District pursue I&I reduction in lieu of capital improvements to the hydraulic deficiencies that have been identified. However, flow monitoring basin 10 and flow monitoring basin 8 would be good basins for pilot projects to evaluate the effectiveness of I&I reduction strategies, including PSL improvement.

Table 7-3. Required RDII Reduction to Eliminate Hydraulic Deficiencies

Hydraulic Deficiency	Target Basin	Reduction %
Vomac Road and downstream	FM-10	40%
Dublin Boulevard between Clark Avenue and Sierra Court	FM-14	30%
Village Parkway south of Dublin Boulevard	FM-08	50%
	FM-10	40%
Dublin Boulevard between Amador Plaza Road and Village Parkway	FM-10	40%
Stoneridge Drive downstream to the WWTP	FM-08	50%
	FM-10	40%
	FM-14	30%

7.7 LONG-TERM MANAGEMENT RECOMMENDED STRATEGY

Based on the evaluations described above, the following long-term management strategies and associated time frames are recommended for the District:

- Continue evaluating PSL policy options, with the next step of establishing a condition requirement for PSLs that connect to the District's collection system.
- Consider an I&I reduction pilot program based on prioritized basins flow monitoring basin 10 and flow monitoring basin 8). Evaluate cost/benefit of means and methods and consider pilot program to field-test a program before basin-wide implementation.

These recommendations are summarized in Table 7-4.

Table 7-4. Recommended Long-Term Management Strategy and Timeframe

Strategy	Sub-Task	Timeframe
Implement a private sewer lateral policy	1. Continue evaluating PSL policy options	Current – ongoing
	2. Consider establishing a condition requirement for PSLs that connect to the District collection system 3. Investigate funding options, available resources, and cooperation with cities of San Ramon and Dublin	2-5 Years
	4. Monitor need for full PSL policy and implement when resources are in place	Ongoing
Develop an I&I reduction program based on prioritized basins	1. Evaluate cost/benefit of rehabilitation means and methods 2. Consider pilot program to field-test a program 3. Consider prioritizing I&I reduction in specific basins to eliminate CIPs	2 Years

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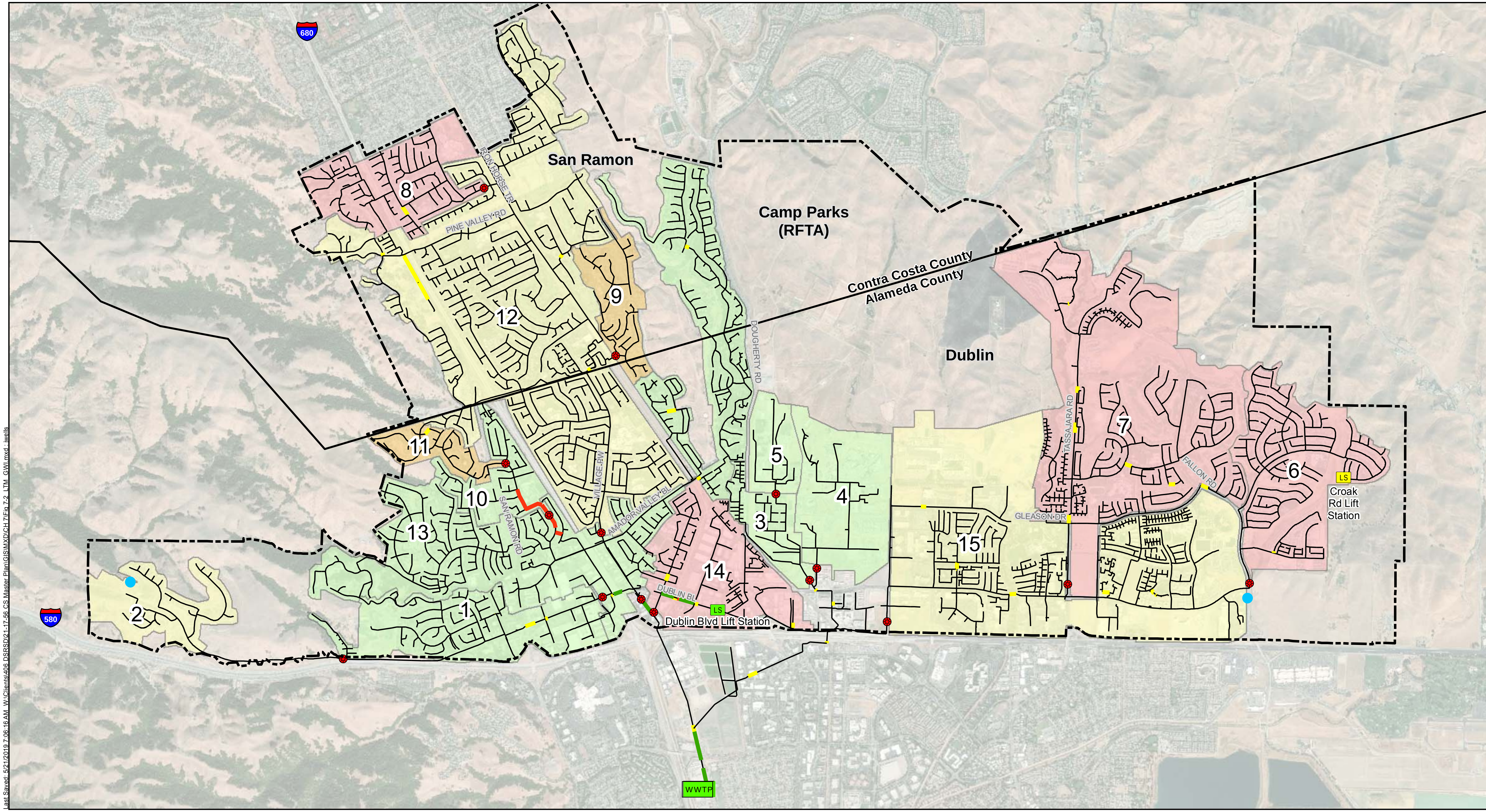

Symbology

- WWTP — WWTP
- LS — Permanent Lift Station
- LS — Temporary Lift Station
- Flow Meter Location
- Rain Gauge
- Wastewater Collection Service Boundary

GWI(gallons/acre-day)

- 0
- 0-200
- 201-400
- 401-670

Gravity Main by q/Q

- >1.20 (Major Deficiency)
- >1.00 and ≤1.20 (Minor Deficiency)
- Further Study/Monitoring Required
- ≤1.00

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 7-2

Groundwater Infiltration by Basin
2035 PWWF

Dublin San Ramon Services District
Collection System Master Plan

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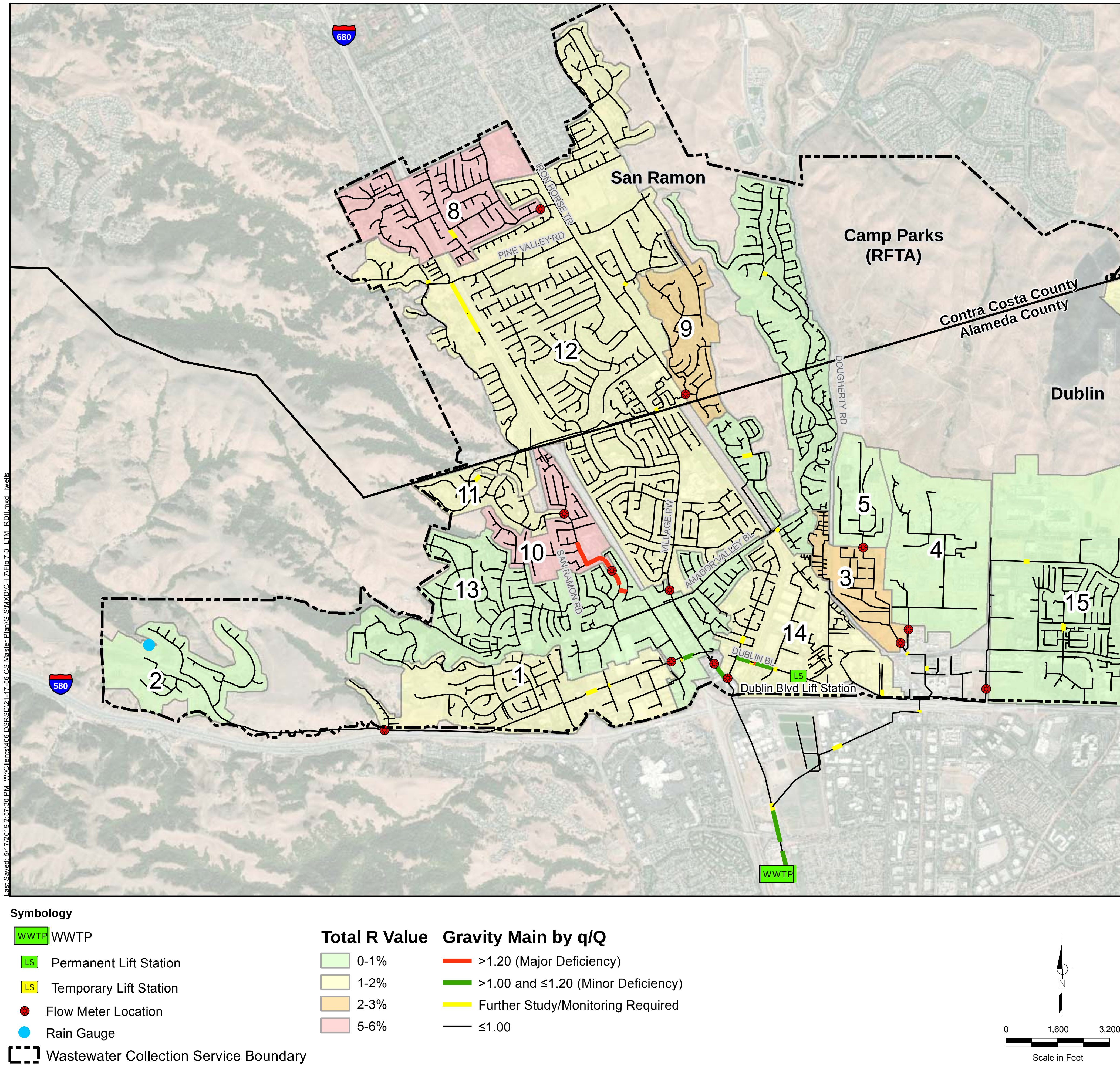

WEST YOST ASSOCIATES

Figure 7-3

Total R Value by Basin
2035 PWWF

Dublin San Ramon Services District
Collection System Master Plan

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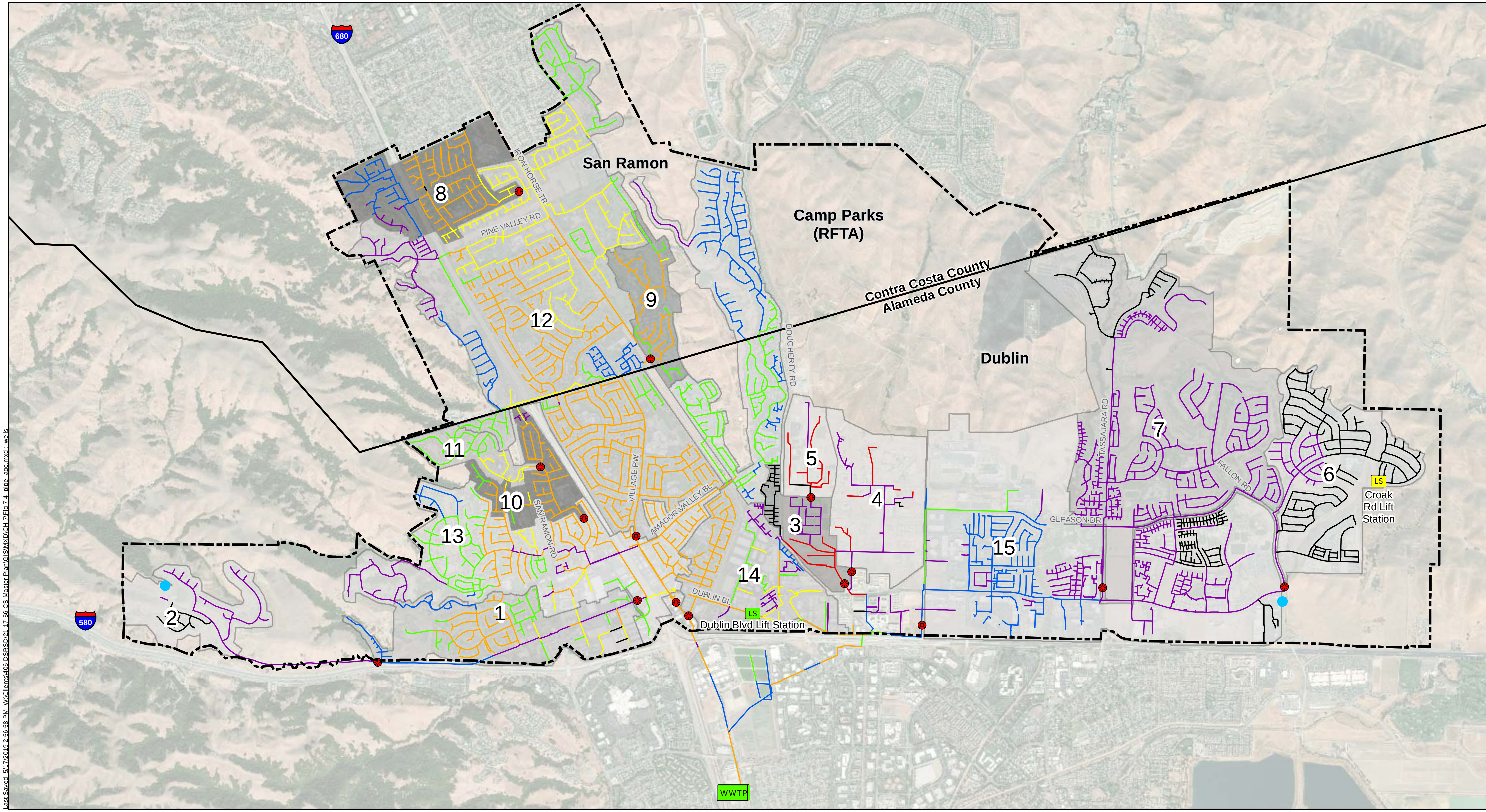

Symbology

- WWTP WWTP
- LS Permanent Lift Station
- LS Temporary Lift Station
- Wastewater Collection Service Boundary
- Flow Meter Location
- Rain Gauge

Decade of Construction

- 2010s
- 2000s
- 1990s
- 1980s
- 1970s
- 1960s
- 1950s

Basin Total R Value

- 0-1%
- 1-2%
- 2-3%
- 5-6%

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 7-4

Sewer Main Age and Basin Infiltration

Dublin San Ramon Services District
Collection System Master Plan

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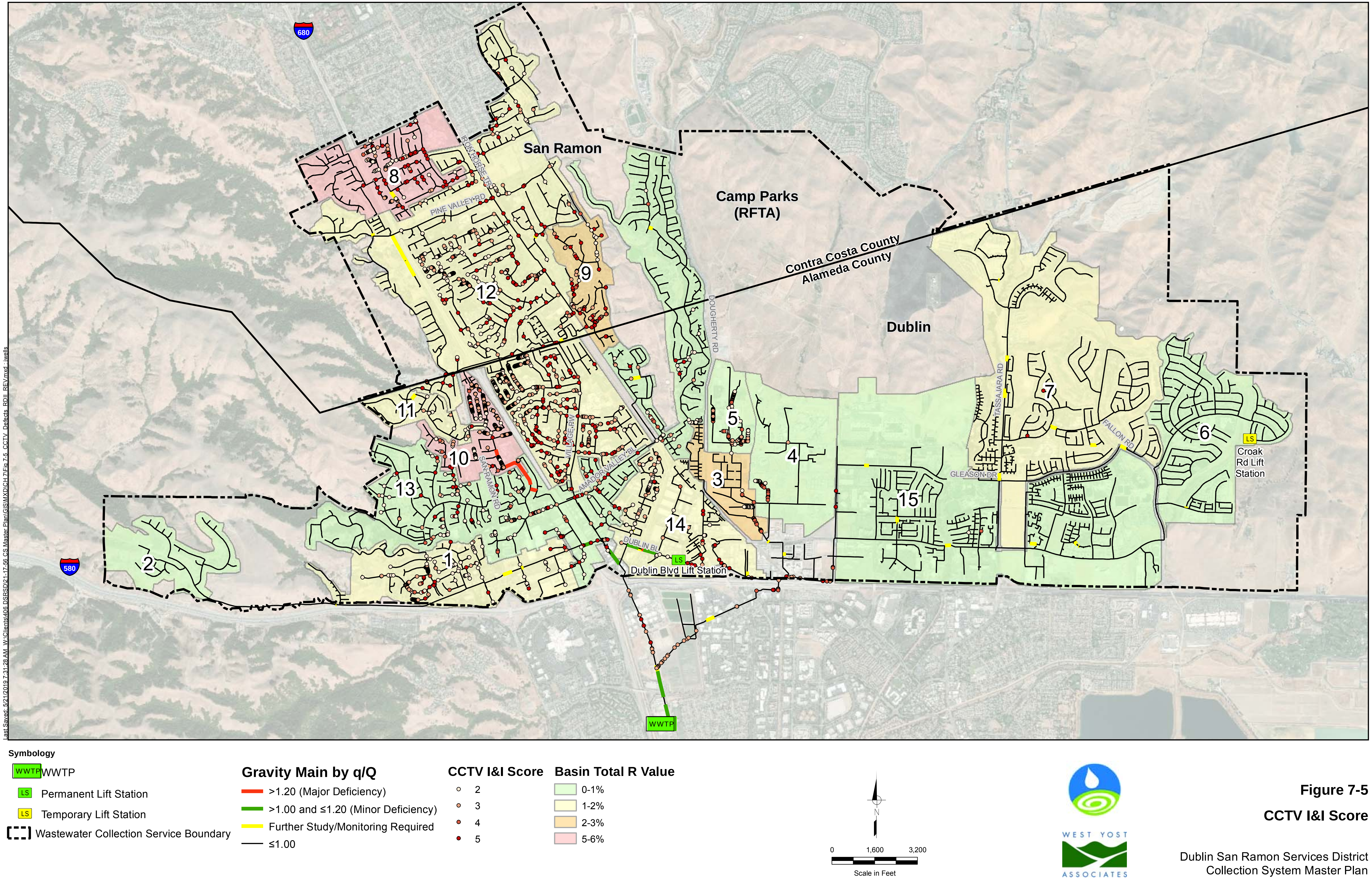

WEST YOST ASSOCIATES

Figure 7-5

CCTV I&I Score

Dublin San Ramon Services District
Collection System Master Plan

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CHAPTER 8
Prioritized Capital Improvement Program

Chapter 8 provides details of the recommended CIP projects that were identified in Chapter 6 and Chapter 7. These CIP projects have been prioritized based on the development timeline that drives the need for the project as well as the risk posed by the deficiency being corrected or each project. Conceptual costs for each project have been developed and are provided as well.

8.1 RECOMMENDED WASTEWATER COLLECTION SYSTEM CIP PROJECTS

The recommended collection system CIP projects are described below, listed in Table 8-1 and shown on Figure 8-1. It should be noted that the recommended projects only identify improvements at a Master Planning level and do not constitute a design of such improvements. Subsequent detailed design will be required to determine the exact sizes and locations of these proposed improvements and to refine the estimate of probable construction cost.

8.1.1 Wastewater Collection System Capital Improvement Program for Existing Rebounded Flows

Chapter 6 provided a summary of the evaluation of the District's collection system and its ability to meet the recommended design and performance criteria described in Chapter 4 for existing rebounded design flow conditions. Based on this collection system evaluation, CIP projects have been developed to eliminate system deficiencies present with existing rebounded flows. The recommended CIP projects have been developed to meet the recommended performance criteria for future design flows, not just for the existing rebounded design flows. The proposed improvements provide sufficient capacity for future design flow.

Chapter 7 provided the results of hydraulic evaluation that was performed to estimate the effectiveness of I&I reduction in eliminating hydraulic bottlenecks as a supplement to capacity improvement projects. As described in Chapter 7, comprehensive I&I reduction in the priority basins would be required to impact the necessity of CIP projects, which would be an expensive and extensive undertaking. For the purposes of the development of the CIP projects for this chapter, it was assumed that no comprehensive I&I management is being implemented. Because the reductions achieved by I&I management are not certain, and because I&I management may require that the District become involved in activities related to PSL condition that are beyond the current legal scope of District activities, it is important that CIP projects that don't rely on I&I management be developed, scoped, and budgeted by the District. Should the District decide to pursue comprehensive I&I management in the future, adjustments to the recommended projects can be evaluated using the hydraulic model.

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Table 8-1. Summary of Recommended Capital Improvement Projects and Estimated Cost

CIP ID	Improvement Type	Was this a project in the 2005 SMP?	Improvement Description	Estimated Conceptual Construction Cost, dollars	Estimated Conceptual Total Project Cost, dollars	Funding Allocation
EX-CIP-P01	Gravity Main Upsize	Yes	Upsize 2,413 feet of 8-inch to 12-inch gravity main starting on Vomac Road from Shannon Avenue and continuing east on Landale Avenue, Donohue Drive, and Irving Way to Ironwood Drive. The 8-inch gravity main in Donohue Drive between Gardella Drive and Hillrose Drive would be blocked to prevent splitting flow from gravity main in Hillrose Drive to gravity main in Donohue Drive. This project includes extra costs for work in a dense residential neighborhood in which community impacts during construction must be evaluated and mitigated.	$ 832,000	$ 1,410,000	Fund 210 (Replacement): 100% Fund 220 (Expansion): 0%
EX-CIP-P02	Gravity Main Upsize	Yes	Upsize 1,048 feet of 10-inch gravity main to 12-inch gravity main in Dublin Boulevard between Clark Avenue and Sierra Court. The siphons are not included as part of the project. This project includes extra costs for both increased traffic control and nighttime construction due to the heavy daytime traffic on Dublin Boulevard.	$ 398,000	$ 675,000	Fund 210 (Replacement): 100% Fund 220 (Expansion): 0%
2023-CIP-P01	Gravity Main Upsize	No	Upsize 1,262 feet of 36-inch and 39-inch gravity main to 42-inch gravity main in Village Parkway south of Dublin Boulevard. This project includes a tunneling component, as well as increased costs for deep construction, extra traffic control, and potential nighttime construction.	$ 1,676,000	$ 2,832,000	Fund 210 (Replacement): 0% Fund 220 (Expansion): 100%
2023-CIP-P02	Gravity Main Upsize	No	Upsize 731 feet of 18-inch gravity main to 21-inch gravity main in Dublin Boulevard between Amador Plaza Road and Village Parkway. This project includes increased costs for deep construction, extra traffic control, and potential nighttime construction.	$ 485,000	$ 820,000	Fund 210 (Replacement): 0% Fund 220 (Expansion): 100%
2025-CIP-P01	New Construction	Yes	Construction of 1,300 feet of 15-inch gravity main east from the existing collection system at the intersection of Dublin Blvd. and Fallon Rd. Future development that is planned within the District's wastewater service area will require an extension of the collection system to serve currently undeveloped and unserved areas. These 15-inch gravity mains represent the trunk lines that will be constructed by the District; smaller diameter gravity mains will be the responsibility of the developers and are described in Table 8-2. The exact layout of the gravity mains will be determined as development occurs.	$ 776,000	$ 1,311,500	Fund 210 (Replacement): 0% Fund 220 (Expansion): 100%
2035-CIP-P01	New Construction	Yes	Construction of a parallel relief gravity main for the existing 42-inch trunk from Stoneridge Drive downstream to the wastewater treatment plant (WWTP) influent line (to the point where it becomes 48-inch pipe and turns west into the WWTP). This project includes extra costs for deep construction, as well as extra costs for the limited site access which will make mobilization, staging, and construction difficult for this project.	$ 3,991,000	$ 6,745,000	Fund 210 (Replacement): 0% Fund 220 (Expansion): 100%
			Total	$ 8,158,000	$ 13,793,500	

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The recommended collection system improvements for existing rebounded design flows are as follows:

- Upsize 2,413 feet of 8-inch to 12-inch gravity main starting on Vomac Road from Shannon Ave and continuing east on Landale Ave, Donohue Drive, and Irving Way to Ironwood Drive (Project No. EX-CIP-P01). The 8-inch gravity main in Donohue Drive between Gardella Drive and Hillrose Drive should be blocked to prevent splitting flow from the gravity main in Hillrose Drive to the gravity main in Donohue Drive. This blockage would prevent an extension of the required improvement project further to the southeast, which is located in easement area.
- Upsize 1,048 feet of 10-inch gravity main to 12-inch gravity main in Dublin Boulevard between Clark Avenue and Sierra Court. The siphons proximate to these gravity mains are not included as part of the project. (Project No. EX-CIP-P02).
- Upsize 1,262 feet of 36-inch and 39-inch gravity main to 42-inch gravity main in Village Parkway south of Dublin Boulevard (Project No. 2023-CIP-P01). These gravity mains are recently lined but are still recommend for upsizing due to hydraulic deficiency.

The recommended existing system improvements should be implemented in the near-term. The locations of the recommended existing collection system improvement projects are shown on Figure 8-1. It should be noted that the recommended improvements for the collection system under rebounded existing design flows include only gravity main improvements. The District's permanent and temporary lift stations and associated force mains have sufficient capacity under existing conditions.

8.1.2 Wastewater Collection System Capital Improvement Program for Future Flows

Chapter 6 provided a summary of the evaluation of the District's collection system under future flow conditions and its ability to meet the recommended design and performance design criteria described in Chapter 4. Based on the collection system evaluation for future design flows, improvements were recommended to eliminate future system deficiencies and to meet projected flows at future development stages. These improvements do not include improvements for the gravity mains with substandard slopes identified in Chapter 6. It is anticipated that these identified gravity mains do not represent true hydraulic bottlenecks in the collection system, and therefore have not been included in this Collection System Master Plan as recommended projects. However, it is recommended that in the future the District perform field verification of these isolated gravity mains so their true capacity can be determined and the assumption of no hydraulic bottleneck confirmed.

As described above, the recommended improvement projects for future design flows do not assume any comprehensive I&I management. The recommended collection system improvements for future design flows are as follows:

- Upsize 731 feet of 18-inch gravity main to 21-inch gravity main in Dublin Boulevard between Amador Plaza Road and Village Parkway in 2020 (Project No. 2023-CIP-P02). The recommended future system improvements should be implemented when flows approach those projected for 2020.

- Construction of 1,300 feet of 15-inch gravity mains in Croak Rd from N. Terracina Dr to Dublin Blvd (Project No. 2025-CIP-P01). Future development that is planned within the District's wastewater service area will require an extension of the collection system to serve currently undeveloped and unserved areas. These 15-inch gravity mains represent the trunk lines that will be constructed by the District; smaller diameter gravity mains will be the responsibility of the developers.
- Construction of a parallel relief gravity main for the existing 42-inch trunk from Stoneridge Drive downstream to the WWTP influent line (to the point where it becomes 48-inch pipe and turns west into the WWTP) in 2025. This project includes difficult construction because of easement alignments (Project No. 2035-CIP-P01). The recommended future system improvements should be implemented when flows approach those projected for 2035.

The locations of the recommended future collection system improvement projects are also shown on Figure 8-1. It should be noted that the recommended improvements for the collection system under future design flows include only gravity main improvements. The District's permanent and temporary lift stations and associated force mains have sufficient capacity under future conditions.

8.2 FUTURE DEVELOPMENT INFRASTRUCTURE

In addition to the improvements to the District's collection system described above, future development that is planned within the District's wastewater service area will require an extension of the collection system to serve currently undeveloped and unserved areas. Although this extension of infrastructure will be funded entirely by the future developer(s) and therefore is not included in the CIP improvements, a preliminary layout and sizing plan for this infrastructure was developed in the hydraulic model to aid in the orderly extension of the collection system in the future.

The preliminary layout of the future infrastructure is based upon the likely future orientation of roads but is subject to change as development plan changes. The estimated slopes of the proposed gravity mains were estimated based upon the topography of the area to be developed. The proposed infrastructure is shown on Figure 8-1, and the infrastructure is summarized with conceptual costs in Table 8-2.

Table 8-2. Summary of Future Development Project and Estimated Cost

Project ID	Improvement Type	Was this a project in the 2005 SMP?	Improvement Description	Estimated Conceptual Construction Cost, dollars	Estimated Conceptual Total Project Cost, dollars
Proposed-GM-01	New Construction	Yes	Construction of 1,300 feet of 8-inch, 1,500 feet of 10-inch, and 2,800 feet of 12-inch gravity mains south from the temporary Croak Rd LS and then west to connect the future District trunk main extending from Fallon Rd and Dublin Blvd (see description of 2025-CIP-P01 in Table 8-1). Future development that is planned within the District's wastewater service area will require an extension of the collection system to serve currently undeveloped and unserved areas. These gravity mains represent the collection lines that will be constructed by the developers; larger diameter gravity mains will be the responsibility of the District, as described in Table 8-1.	$ 1,627,000	$ 2,750,000
			Total	$ 1,627,000	$ 2,750,000

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8.3 CAPITAL IMPROVEMENT PROGRAM COSTS AND IMPLEMENTATION

The conceptual costs and implementation assumptions for the projects identified above are described below.

8.3.1 Cost Assumptions

The estimate of probable construction cost for recommended collection system improvements is presented in May 2018 dollars based on an Engineering News Record (ENR) Construction Cost Index (CCI) of 12,015 (San Francisco Bay Area). Base construction costs were developed based on recent bids on other wastewater facilities design projects and from standard cost estimating guides. The total project cost includes a mark-up equal to 69 percent of the base construction costs, which includes an estimating contingency of 30 percent, and a markup of 30 percent for design period services construction period services.

For this Collection System Master Plan, it is assumed that new collection system facilities will be developed in public rights-of-way or on public property; therefore, land acquisition costs have not been included. The estimate of probable construction cost does not include costs for annual operation and maintenance. In addition to the standard unit construction costs, the following factors are added to the cost estimate for facilities when it is identified that construction conditions will likely deviate from typical conditions:

- Difficult Access
- High Depth
- Community Impact
- High Traffic
- Night Work

A complete description of the assumptions used in the development of the estimate of probable construction cost is provided in Appendix D. The probable construction costs are included for each project in Table 8-1 and Table 8-2. Table 8-1 also contains an allocation of probable construction cost between replacement and expansion funding sources within the District.

8.4 ADDITIONAL COLLECTION SYSTEM HYDRAULIC ANALYSIS

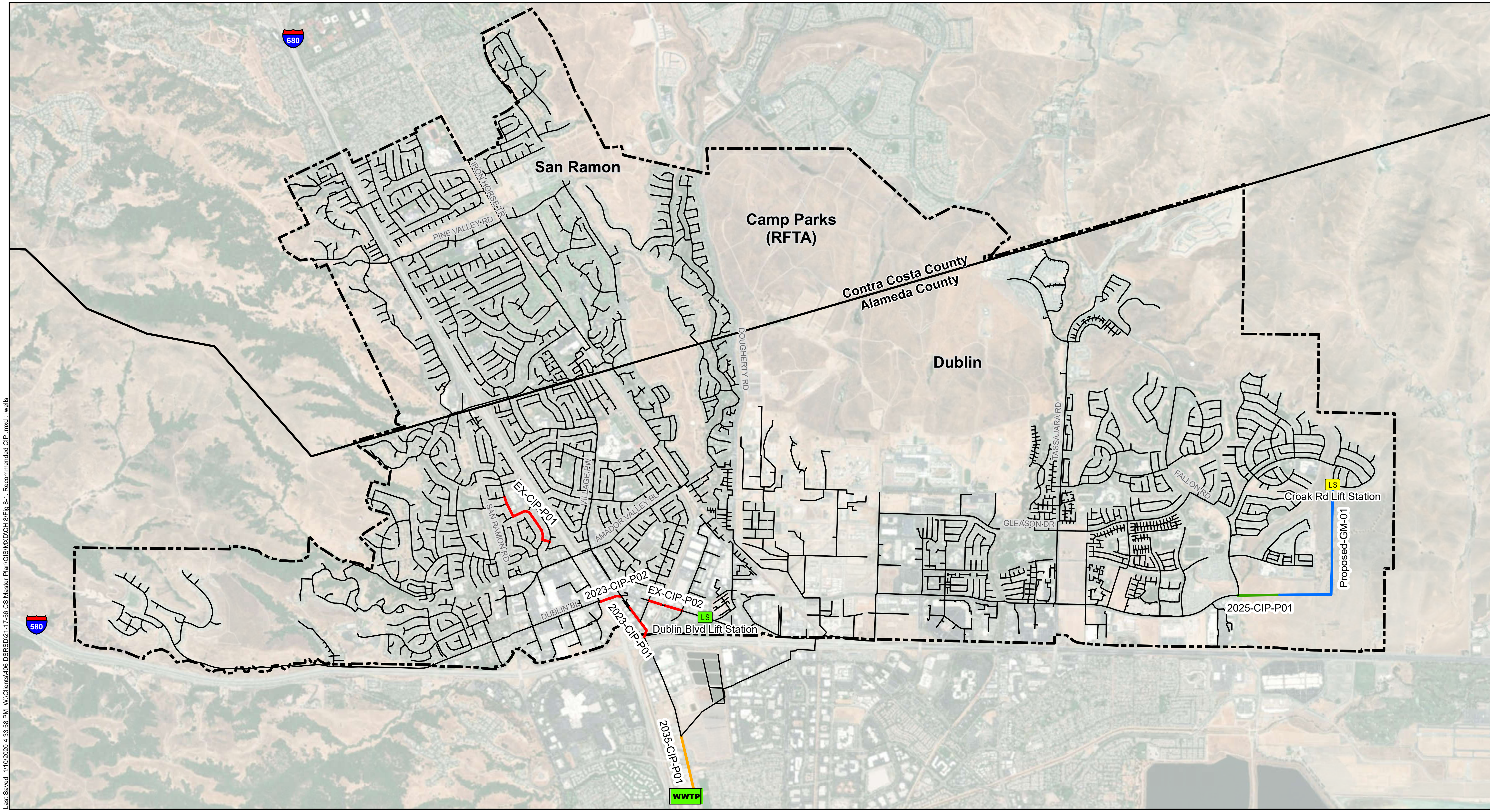
Over the course of the Collection System Master Plan, and particularly as the CIP projects were identified and refined, several distinct hydraulic analyses were run to evaluate specific conditions within the collection system, and to confirm that these conditions did not impact the number and size of the CIP projects. The following additional analyses were performed as part of this Collection System Master Plan:

- **Dublin Boulevard Siphons.** While useful for simulating average and peak flow conditions throughout the collection system for planning level-analysis, InfoSewer is not a fully-dynamic model, and as such is not well-suited for simulating time-varying flow conditions in parallel pathways or where backwater curves will impact results. Accordingly, a fully-dynamic InfoSWMM model that is well-suited for simulating the dynamic conditions in siphons, gates, and junction boxes was used for the analysis of Dublin Boulevard Siphons.

  For purposes of analyzing these siphons, it was not necessary to use InfoSWMM to model the entire District collection system, but merely the portion of the system that runs from immediately upstream to downstream of the siphons. The evaluation of InfoSWMM model results for the Dublin Boulevard Siphons shows that the siphons don't require upsizing, as they barely impact upstream flow through the creation of a backwater curve. The maximum velocity through the siphons is approximately 2 fps, and it is recommended that the siphons be frequently cleaned to prevent settling of solids and blockage.

- **Croak Road Lift Station Removal and Rerouting of Flow to Croak Road and Dublin Boulevard Trunk.** Per discussion with District staff, West Yost analyzed a specific scenario including the removal of Croak Road Lift Station from service. Such a scenario results in the rerouting of all buildout peak design flows associated with that lift station, including all future development projects located south of the lift station (Development Number 28 through Development Number 34 as described in Chapter 3) to the 24-inch trunk gravity main in Dublin Boulevard. The result of this analysis is the future development infrastructure described above and shown on Figure 8-1. The estimate of probable construction cost for this infrastructure is summarized in Table 8-2 (Project No. Proposed-GM-01).

- **Discharging Wastewater Flow to District's Collection System for Supplemental Recycled Water Supply.** To provide the District with the ability to produce more recycled water during summer months when demand is high, the District is investigating the feasibility of discharging some or all of the Larwin Lift Station influent to the District's collection system during summer months. Similarly, East Bay Municipal Utility District (EBMUD), the District's recycled water program partner, proposes to discharge groundwater into the manhole north of the Alcosta Boulevard and Pine Valley Boulevard intersection. It was determined that if the influent is discharged during summer months only with no addition of wet weather flow, the influent does not impact the collection system, and no further system improvement is needed to accommodate the flows.



Symbology

WWTP WWTP

LS Permanent Lift Station

LS Temporary Lift Station

Gravity Main

Parallel Existing Gravity Main

Replace Existing Gravity Main

New Gravity Main (Developer Funded)

New Gravity Main (District Project)

Wastewater Collection Service Boundary

N

0 1,600 3,200

Scale in Feet

WEST YOST ASSOCIATES

Figure 8-1

Recommended CIP Projects

Dublin San Ramon Services District
Collection System Master Plan

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APPENDIX A

2017 Flow Monitoring Study Technical Memorandum

TECHNICAL MEMORANDUM

DATE: October 24, 2017

Project No.: 406-21-17-44
SENT VIA: EMAIL

TO: Rhodora Biagtan, PE, DSRSD

FROM: Chris Malone, PE, RCE #51009

REVIEWED BY: Jon Wells, PE, RCE #67782
Jeff Pelz, PE RCE #46088

SUBJECT: Collection System Flow Monitoring Results, March–May 2017

The purpose of this technical memorandum (TM) is to summarize the results of the flow monitoring program conducted within the Dublin San Ramon Services District (DSRSD) wastewater service area during the period of March through May of this year. The major topics covered in this TM include:

- Monitoring Program Overview
- Rainfall Results
- Flow Monitoring Results
- Summary and Conclusions

MONITORING PROGRAM OVERVIEW

The purpose of the monitoring effort is to provide data to be used to identify areas of high infiltration and inflow (I&I), to provide suitable data for the calibration of the hydraulic model of the collection system, and to identify capacity constraints within the system. The selection of monitoring locations was driven by the findings of the Wastewater Collection System Master Plan Update 2005 (2005 Master Plan), and by collection system flow observations made more recently by DSRSD staff.

The locations and purpose of each monitoring site is described in detail in the TM titled "Flow Monitoring Plan 2017" (Flow Monitoring Plan), dated March 1, 2017. The locations are presented schematically on Figure 1, and labeled with the meter number (e.g., "FM 1") and the manhole number (e.g., "U20D1-40"). Summary information about the flow monitoring locations is presented in Table 1. The areas tributary to each meter are depicted on Figure 2, with the intent of each flow monitoring location shown by color.

A total of 15 flow monitoring locations and two rainfall gauging sites were monitored during the period of data collection. Key information collected at each flow monitoring location includes flows rates, flow depths, flow velocities, and wastewater temperatures. No attempt is made in this

TM to perform a flow balance of the key storm events. That step will be performed under the separate 2017 Wastewater Collection System Master Plan Update (2017 WWCS Master Plan).

Table 1. Summary of Flow Monitoring Locations

Site	Manhole	Nominal Pipe Diameter, in	Location	Tributary Area	Monitoring Period
1	U20D1-40	12	Dublin Boulevard east of Amador Plaza Road	Areas M11 and M12	3/17/17–5/25/17
2	T20C1-13	8	Dublin Boulevard west of Brigadoon Way; upstream of Site 1	New development areas at the western end of Dublin Boulevard in Area M11	3/31/17–5/25/17
3	W20C1-24	24	Between 3rd Street and Fernandez Ave	The Parks RFTA except the southeastern corner, plus areas along Dougherty Road	3/13/17–5/26/17
4	W19C1-3	15	Fernandez Avenue (site 19 from 2005 MP)	Southeast portion of the Parks RFTA plus FCI	3/13/17–5/26/17
5	V19D2-57	12	North of Powers Street and Cornwell Avenue; upstream of Site 3	The northern portion of the Parks RFTA from 8th Street northward	3/15/17–5/26/17
6	Y20C2-7	15	Fallon Road just north of Dublin Boulevard	New development areas in the eastern DSRSD service area	3/17/17–5/25/17
7	X20A4-16	18	Tassajara Road north of Dublin Blvd	New development areas in the eastern DSRSD service area, primarily north of Gleason Drive	3/17/17–5/25/17
8	T16D3-1	15	Bernard Avenue (site 1 from 2005 MP)	All of Area M01	3/14/17–5/25/17
9	V18A1-2	10	Iron Horse Trail near Craydon Court (site 5 from 2005 MP)	All of Area M05	3/13/17–5/26/17
10	U19C4-18	8	Donahue Drive (site 10 from 2005 MP)	All of Area M10	3/16/17–5/25/17
11	U19A2-12	8	Vomac Road east of San Ramon Road	Northern portion of Area M10	3/17/17–5/25/17
12	U19D1-4	33	Village Pkwy north of Amador Valley Blvd (site 7 from 2005 MP)	Areas M01–M07	3/16/17–5/25/17
13	U20D2-1	36	Village Pkwy south of Dublin Blvd (site 13 from 2005 MP)	Areas M01–M13 and M15	3/15/17–5/25/17
14	V20A1-38	15	Clark Avenue south of Dublin Blvd (site 14 from 2005 MP)	Areas M14 and M16	3/16/17–5/25/17
15	W20C1-11	36	Arnold Road south of Martinelli Way	Areas M20–M23	3/17/17–5/25/17

RAINFALL RESULTS

Two rain gauges were established within the DSRSD service area for the collection system monitoring program. The two rain gauge locations are summarized as follows:

- RG-1: Located in the southwestern corner of the DSRSD service area near Schaeffer Ranch Park
- RG-2: Located in the southeastern corner of the DSRSD service area near Fallon Road and Dublin Boulevard (adjacent to Flow Monitoring Site 6, FM 6)

In addition, long-term rainfall gauges are maintained at nearby locations in Dublin, San Ramon, and Pleasanton. The data from these gauges has been used in this analysis to assess longer-term rainfall trends. In addition, rainfall return period information for this analysis was obtained from the National Oceanic and Atmospheric Administration (NOAA).

According to the two rain gauges deployed for this study, the two most significant rainfall events of the monitoring period occurred on March 21–22, 2017 and April 6–7, 2017. According to NOAA return period information, neither event achieved a 1-year return period, with the exception of the peak 6-hour rainfall during the April 6–7 event at Rain Gauge 2, during which a 2-year return period occurred. Otherwise, neither storm is especially noteworthy in terms of magnitude.

The storm events in question are more noteworthy in terms of antecedent rainfall, especially season-to-date rainfall. High antecedent rainfall tends to result in elevated groundwater levels that add baseline infiltration flows and increase the impacts of short-term rainfall-dependent I&I (RDII). Based on daily rainfall data from long-term rain gauges in Dublin, San Ramon, and Pleasanton, between 23 and 31 inches of season-to-date rainfall occurred prior to the March 21–22 event. The previous 30-day rainfall totals were less significant, however, ranging from 3.3 to 4.6 inches at these same gauges. In other words, the period of heavy extended rainfall during the 2016/2017 wet season generally occurred more than a month before the flow monitoring period.

FLOW MONITORING RESULTS

The flow monitoring results are discussed on a per site basis in this section. Summary flow information for each site is presented in Table 2. Charts depicting daily average flows throughout the monitoring periods are presented in Appendix A of this TM. Detailed information for each site is presented in a separate report prepared by Infrastructure Engineering Corporation (IEC). For most of the flow monitoring sites, there exists a data gap covering a period of days in late March and/or early April, during which time no significant rainfall occurred.

Pipe slopes have not been definitively determined as part of this study. Nevertheless, for comparison purposes, the peak hourly average flow at each site is compared to the full-pipe capacity of the given line assuming a minimum standard slope to indicate whether a given line may have approached its flow capacity during the study. This result is compared to the maximum measured flow depth (d) versus the pipe diameter (D). The measurement of d/D may also provide evidence of a pipe approaching it gravity flow capacity; however, a high d/D value may also indicate backwater flows conditions due to a downstream flow occlusion that may or may not be related to gravity flow capacity.

Table 2. Summary of Flow Metering Results

Site	Manhole	Nominal Diameter, in	Average Measured Flow, mgd	Peak Day Flow, mgd	Date of Peak Day Flow	Peak Hour Flow, mgd	Time of Peak Flow	Full-Pipe Capacity at Min. Std. Slope, mgd	Peak Hour Flow / Std. Slope Capacity	Max d/D
1	U20D1-40	12	0.31	0.41	5/17/2017	0.62	5/17/2017 7:45	1.03	0.60	0.41
2	T20C1-13	8	0.076	0.091	5/14/2017	0.18	5/15/2017 7:15	0.46	0.40	0.40
3	W20C1-24	24	0.14	0.25	3/22/2017	0.49	3/22/2017 7:05	4.64	0.11	0.15
4	W19C1-3	15	0.29	0.31	3/22/2017	0.44	3/22/2017 6:10	1.62	0.27	0.40
5	V19D2-57	12	0.020	0.049	3/23/2017	0.11	5/1/2017 6:50	1.03	0.11	0.20
6	Y20C2-7	15	0.31	0.51	5/21/2017	0.98	5/15/2017 7:15	1.62	0.60	0.33
7	X20A4-16	18	0.59	0.74	5/16/2017	1.26	5/17/2017 7:40	2.36	0.53	0.28
8	T16D3-1	15	0.38	0.66	3/22/2017	0.87	3/22/2017 7:20	1.62	0.54	0.65
9	V18A1-2	10	0.15	0.24	5/11/2017	0.65	3/22/2017 7:35	0.71	0.91	0.59
10	U19C4-18	8	0.13	0.23	4/9/2017	0.41	4/8/2017 9:35	0.46	0.89	1.00
11	U19A2-12	8	0.090	0.12	5/20/2017	0.21	4/16/2017 9:50	0.46	0.46	0.43
12	U19D1-4	33	2.85	3.44	3/22/2017	4.50	3/22/2017 8:05	10.84	0.42	0.51
13	U20D2-1	36	3.74	4.39	3/22/2017	5.88	3/22/2017 8:15	13.67	0.43	0.57
14	V20A1-38	15	0.48	0.58	3/22/2017	0.82	3/22/2017 8:00	1.62	0.51	0.54
15	W20C1-11	36	2.13	2.35	4/23/2017	4.01	4/14/2017 8:20	13.67	0.29	0.44

Site 1: U20D1-40

Site 1 is a 12-inch diameter line located on Dublin Boulevard serving the southwest portion of the DSRSD service area west of I-680 and along and north of I-580. Flow data from this site is characterized by lower flows prior to the data gap, which increased significantly after the data gap, and then continued to increase throughout the monitoring period, thus making it somewhat difficult to determine baseline flow conditions. The highest reported flow occurred in late May during an extended period of dry weather. Sensitivity to storm events appears low, and seems to be overwhelmed by other influences. As part of the 2017 WWCS Master Plan, West Yost is working with DSRSD staff to determine if development was coming online in this area during the flow monitoring period, or if there are other likely explanations for the increasing flows. Wastewater temperatures did not increase inordinately during the monitoring period, and flow velocities appear to have been in the higher range, averaging about 3.5 feet per second (fps). Neither the d/D evidence nor the comparison of peak flows versus full-pipe capacity at standard minimum slope suggest that the flows ever approached the capacity of the line.

Site 2: W20C1-24

Site 2 is an 8-inch diameter line located on Dublin Boulevard serving areas tributary to Site 1 in the hilly areas in the southwesternmost area of the DSRSD service area. The flow meter did not become operation until the end of March, and therefore the March 21–22 storm event was not captured. This site had the second lowest average flows of any of the monitored sites. Flows fluctuated throughout the monitoring period and sensitivity to storm events appears low. The highest reported flow occurred in mid-May during an extended period of dry weather. Flows in the line were slightly sluggish, averaging about 1.9 fps. Wastewater temperatures did not increase inordinately during the monitoring period. Neither the d/D evidence nor the comparison of peak flows versus full-pipe capacity at standard minimum slope suggest that the flows ever approached the capacity of the line.

Site 3: T20C1-13

Site 3 is a 24-inch diameter line located north of Dublin Boulevard serving the Camp Parks area, plus residential areas west of Dougherty Road. This site showed a high sensitivity to rainfall events, and flows generally declined throughout the monitoring period, thus suggesting a significant influence from groundwater infiltration. Peak flows occurred during the March 21–22 storm event. Flows in the line were slightly sluggish, averaging about 1.8 fps. Wastewater temperatures increased during the monitoring period in a manner typical of the monitored sites. This site had the lowest maximum d/D of any of the monitored sites, thus suggesting that no capacity concerns exist in this line.

Site 4: W19C1-3

Site 4 is a 15-inch diameter line located on Fernandez Street serving the southeastern Camp Parks area, plus the Federal Corrections Institute. This site showed a relatively low sensitivity to rainfall events, and flows fluctuated but generally declined slightly throughout the monitoring period, thus suggesting a possible influence from groundwater infiltration. Peak flows occurred during the March 21–22 storm event. Flows in the line were sluggish, averaging about 1.5 fps. Wastewater temperatures increased during the monitoring period more than at any of the other sites, which may also suggest a declining influence from groundwater infiltration. Neither the d/D evidence nor the comparison of peak flows versus full-pipe capacity at standard minimum slope suggest that the flows ever approached the capacity of the line.

Site 5: V19D2-57

Site 5 is a 12-inch diameter line located on Cromwell Avenue serving the upper Camp Parks area. This site had the lowest average flows of any of the monitored sites, and also had the highest peaking factors. Flow velocities were also the lowest of any monitoring site, averaging around 0.9 fps. The site initially showed a high sensitivity to storm events, but then flows began increasing substantially in late April and early May before declining again in late May. Peak flows occurred during the March 21–22 storm event, but those peaks were almost matched again during the dry period flow increase in May. Wastewater temperatures increased during the monitoring period more than at any of the other sites except Site 4. The secondary flow peak and the temperature increase are suggestive that the flows to this site are highly variable based upon the transitory training population in this part of Camp Parks, and that significant sanitary flow-producing activities may have been occurring in the upper Camp Parks area during the high flow period in question. This site had the second lowest maximum d/D of any of the monitored sites, thus suggesting that no capacity concerns exist in this line.

Site 6: Y20C2-7

Site 6 is a 15-inch diameter line located on Fallon Road just north of Dublin Boulevard serving the northeasternmost part of the DSRSD service area. Flow data from this site is characterized by increasing flows throughout the monitoring period, thus making it somewhat difficult to determine baseline flow conditions. The highest reported flows occurred in May during an extended period of dry weather. Sensitivity to storm events appears low, and seems to be overwhelmed by other influences. As part of the 2017 WWCS Master Plan, West Yost is working with DSRSD staff to determine if development was coming online in this area during the flow monitoring period, or if there are other likely explanations for the increasing flows. Wastewater temperatures did not increase inordinately during the monitoring period, and flow velocities appear to have been in the higher range, averaging about 3.5 fps. Neither the d/D evidence nor the comparison of peak flows versus full-pipe capacity at standard minimum slope suggest that the flows ever approached the capacity of the line. Previously, DSRSD staff expressed concern that flow depths at this location were unexpectedly high, but no such flow conditions occurred during the monitoring period.

Site 7: X20A4-16

Site 7 is an 18-inch diameter line located on Tassajara Road just north of Dublin Boulevard serving northeastern areas along and tributary to Tassajara Road. Flow data from this site is characterized by increasing flows throughout the monitoring period, thus making it somewhat difficult to determine baseline flow conditions. The highest reported flows occurred in May during an extended period of dry weather. Sensitivity to storm events appears low, and seems to be overwhelmed by other influences. As part of the 2017 WWCS Master Plan, West Yost is working with DSRSD staff to determine if development was coming online in this area during the flow monitoring period, or if there are other likely explanations for the increasing flows. Wastewater temperatures did not increase inordinately during the monitoring period, and flow velocities are generally high, averaging about 4.6 fps. Neither the d/D evidence nor the comparison of peak flows versus full-pipe capacity at standard minimum slope suggest that the flows ever approached the capacity of the line.

Site 8: T16D3-1

Site 8 is a 15-inch diameter line located along Bernard Avenue serving the northwesternmost portion of the service area in southern San Ramon. This site showed a high sensitivity to rainfall events, and flows generally declined throughout the monitoring period, thus suggesting a significant influence from groundwater infiltration. Peak flows occurred during the March 21–22 storm event. Flows in the line were sluggish, averaging about 1.2 fps. Wastewater temperatures did not increase inordinately during the monitoring period. The d/D evidence shows that the line flowed more than half full during the peak flow events, thus indicating some possibility that capacity concerns may existing during larger storm events.

Site 9: V18A1-2

Site 9 is a 10-inch diameter line located off of Craydon Court serving a relatively small tributary area along Alcosta Boulevard. The site initially showed a moderate sensitivity to storm events, but then flows began increasing substantially in early May and remained high through the end of the monitoring period. A sudden and anomalous-looking flow spike lasting about 30 minutes occurred during the March 21–22 storm event, but otherwise peak flows at this site occurred in mid-May. Wastewater temperatures did not increase inordinately during the monitoring period, and flow velocities are generally high, averaging about 3.7 fps. The d/D evidence shows that the line flowed less than half full at all times except during the anomalous flow spike just noted.

Site 10: T16D3-1

Site 10 is an 8-inch diameter line located along Donahue Drive serving areas of northwest Dublin west of I-680. This site showed a slight sensitivity to rainfall events; however, peak flow conditions occurred on April 9, 2017, which either indicates a delayed response to the storm event of April 6–7, or is due to some other influence. During that time, flow depths spiked upward for a brief period to surcharge levels, but no other surcharging was observed. Nevertheless, the pipe commonly flows about half full during sanitary peak flows, thus suggesting that the line may be undersized to handle large storm events. Flows in the line were slightly sluggish, averaging about 1.6 fps, and wastewater temperatures did not increase inordinately during the monitoring period.

Site 11: U19A2-12

Site 11 is an 8-inch diameter line located along Vomac Road serving areas of northwest Dublin upstream and north of Site 10. This site showed a slight sensitivity to rainfall events, but flows started increasing in mid-May, thus indicating that peak flows are influenced by other factors. The peak hour flow occurred on April 16, which coincides with a minor storm event, while the peak day flow occurred on May 20, which is not associated with a rainfall event at all. Flow velocities in the line are relatively high, averaging about 2.9 fps, while wastewater temperatures did not increase inordinately during the monitoring period. Neither the d/D evidence nor the comparison of peak flows versus full-pipe capacity at standard minimum slope suggest that the flows ever approached the capacity of the line.

Site 12: U19D1-4

Site 12 is a 33-inch diameter line located along Village Parkway capturing the majority of the northwest portion of the service area. This site showed a somewhat high sensitivity to rainfall events, and flows generally declined throughout the monitoring period, thus suggesting a significant influence from groundwater infiltration. Peak flows occurred during the March 21–22 storm event. Flow velocities in the line were moderate, averaging about 1.9 fps. Wastewater temperatures increased less than at any of the other monitoring locations. The d/D evidence shows that the line flowed about half full during the peak flow events.

Site 13: U19D1-4

Site 13 is a 36-inch diameter line located along Village Parkway capturing the entire northwest portion of the service area. This site responded similarly to Site 12, showing a somewhat high sensitivity to rainfall events, and with flows generally declined throughout the monitoring period, thus suggesting a significant influence from groundwater infiltration. Peak flows occurred during the March 21–22 storm event. Flow velocities in the line were moderate, averaging about 2.0 fps. Wastewater temperature increases were the second lowest of any of the monitoring locations. The d/D evidence shows that the line flowed slightly more than half full during the peak flow events.

Site 14: V20A1-38

Site 14 is a 15-inch diameter line located off of Village Parkway serving a relatively small tributary area northeast of the freeway interchange. The site showed a slight sensitivity to storm events, although flows fluctuated throughout the monitoring period. Peak flows occurred during the March 21–22 storm event. Flows in the line were slightly sluggish, averaging about 1.5 fps, and wastewater temperatures did not increase inordinately during the monitoring period. The d/D evidence shows that the line flowed about half full during the peak flow events.

Site 15: W20C1-11

Site 15 is a 36-inch diameter line located on Arnold Road south of Dublin Boulevard, and serving the entire eastern portion of the DSRSD service area. Flows fluctuated throughout the monitoring period and sensitivity to storm events appears low. The highest reported flows occurred in mid to late April, and were not associated with rainfall events. Flows in the line were slightly sluggish, averaging about 1.6 fps, and wastewater temperatures did not increase notably during the monitoring period. Neither the d/D evidence nor the comparison of peak flows versus full-pipe capacity at standard minimum slope suggest that the flows ever approached the capacity of the line.

SUMMARY AND CONCLUSIONS

The 2017 Collection System Flow Monitoring Program successfully captured both dry weather and wet weather data that can be used to characterize the wastewater flows in the DSRSD collection system. The wet weather events captured were relatively small, and wet weather flow characterization would benefit from a flow monitoring program that captures flows from more intense precipitation events. Nevertheless, the data obtained to date provide an adequate starting point for a comprehensive flow modeling analysis, as will be performed under the 2017 WWCS Master Plan.

The results from the 2017 collection system flow monitoring program indicate that flows in the DSRSD collection system are driven by complex interactions of sanitary flow, groundwater infiltration, and RDII. The characterization of sanitary flow is complicated by the growth occurring in the DSRSD service area, and by the occupancy patterns of the Camp Parks area. A full analysis of the flows in these areas will include an investigation of water billing history and hydraulic connectivity information. That level of analysis is being performed as part of the 2017 WWCS Master Plan.

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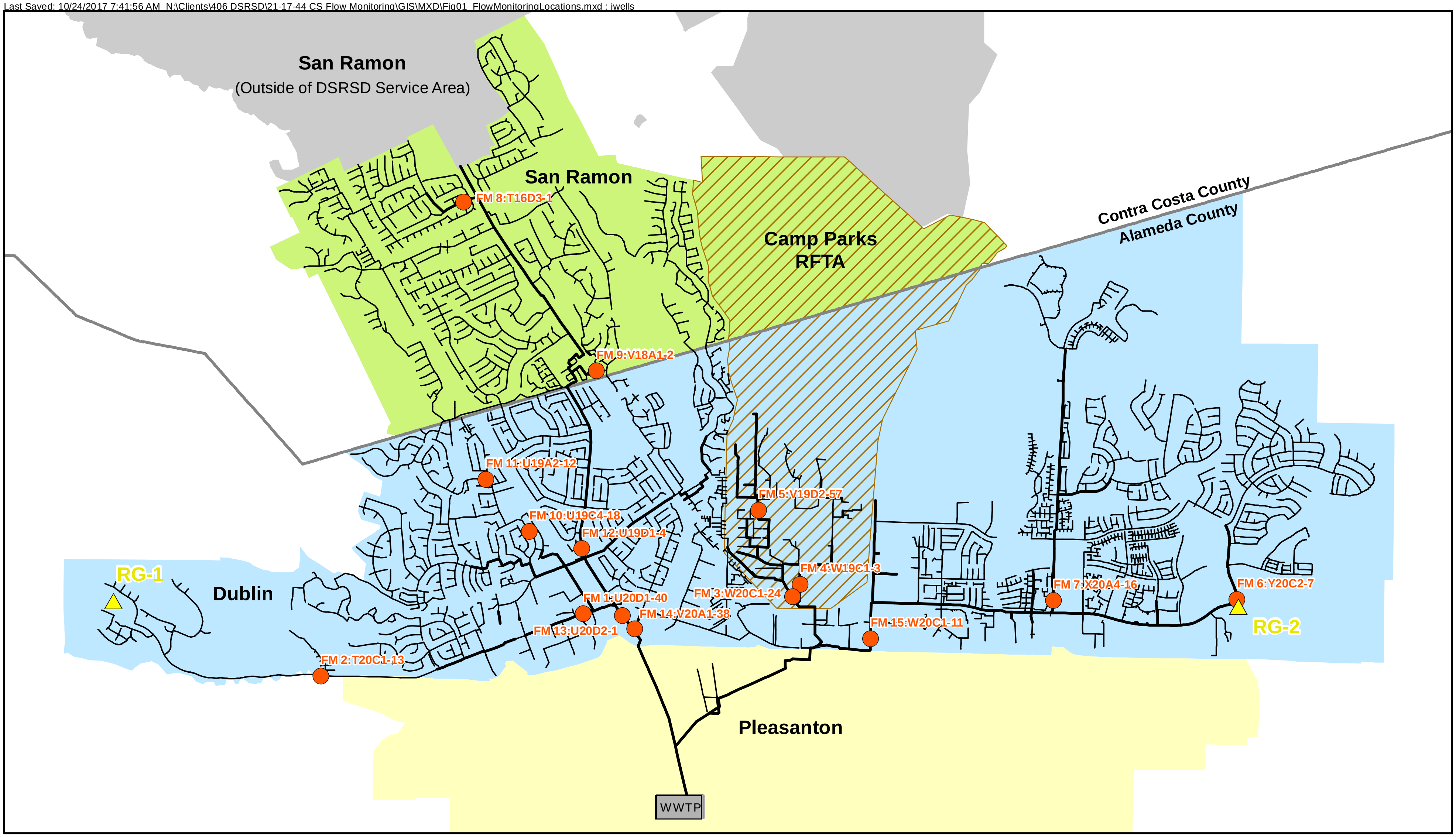

Symbology

WWTP Wastewater Treatment Plant

Gravity Sewer Trunk (12 to 48-inches)

Gravity Sewer Collector (4 to 10-inches)

Installed Flow Meter

Installed Rain Gauge

N

0 2,400 4,800

Scale in Feet

Dublin San Ramon Services District
Water, wastewater, recycled water

WEST YOST ASSOCIATES

Figure 1

Flow Monitoring and Rain Gauge Locations

Dublin San Ramon Services District
Collection System Flow Monitoring

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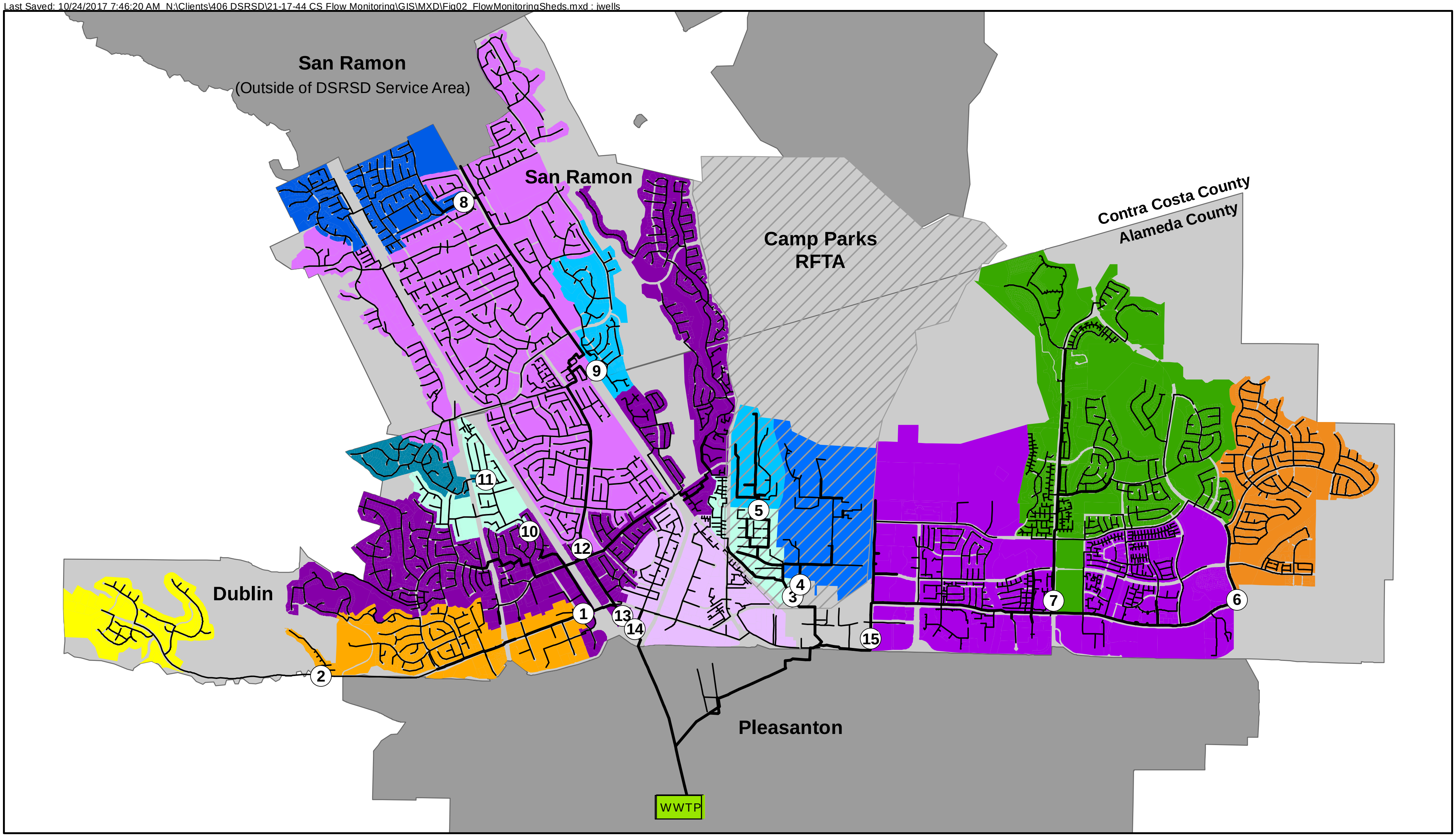


Symbology

(#) Installed Flow Meter

Gravity Sewer Trunk (12 to 48-inches)

Gravity Sewer Collector (4 to 10-inches)

Flow Monitoring Category

Recent Wet-Weather Observations

New Development Area

Further Investigation of High I&I Areas

Hydraulic Model Calibration

N

0 2,400 4,800

Scale in Feet

Dublin San Ramon Services District

Water, wastewater, recycled water

WEST YOST ASSOCIATES

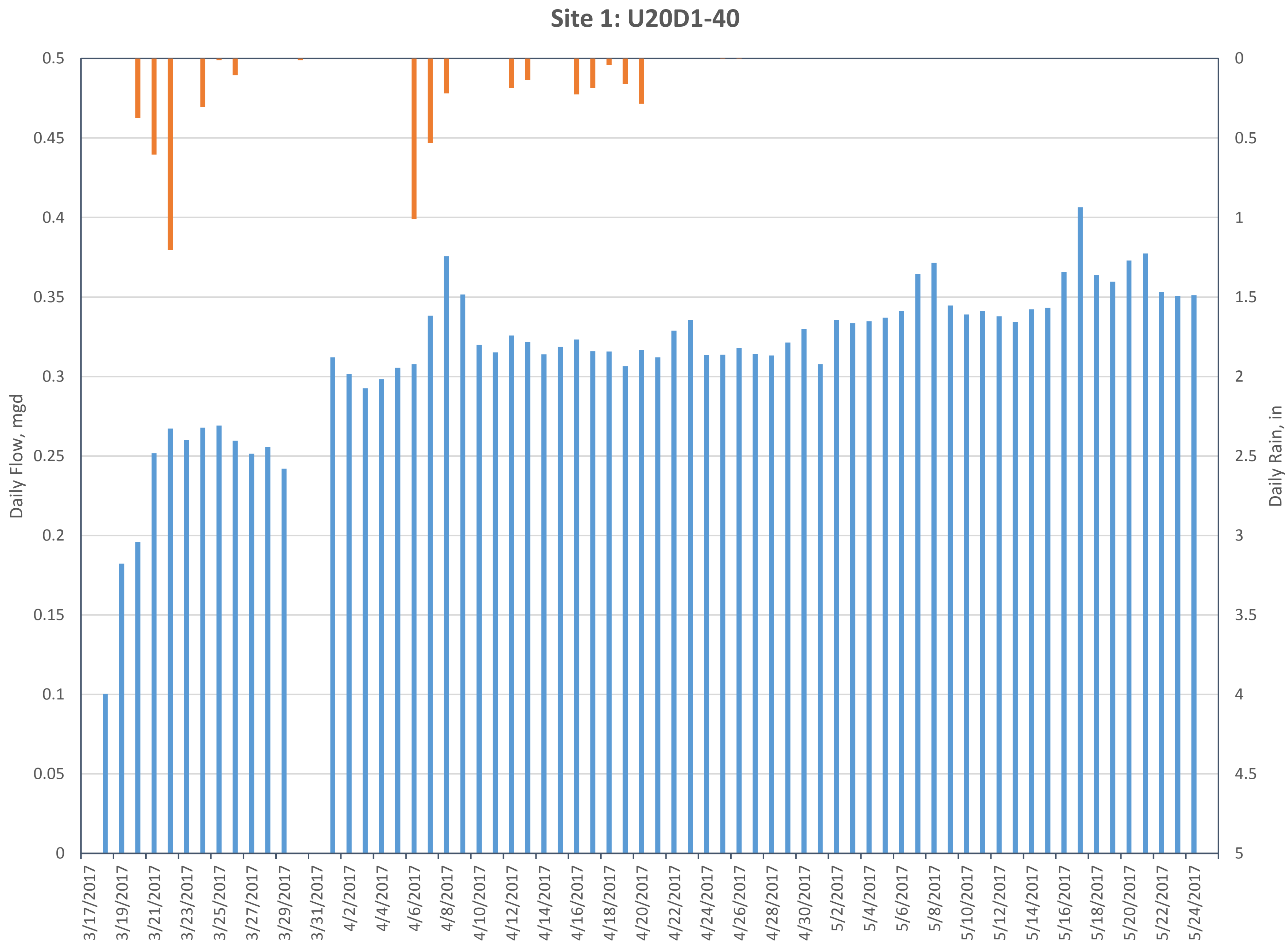
Figure 2

Flow Monitoring Sheds

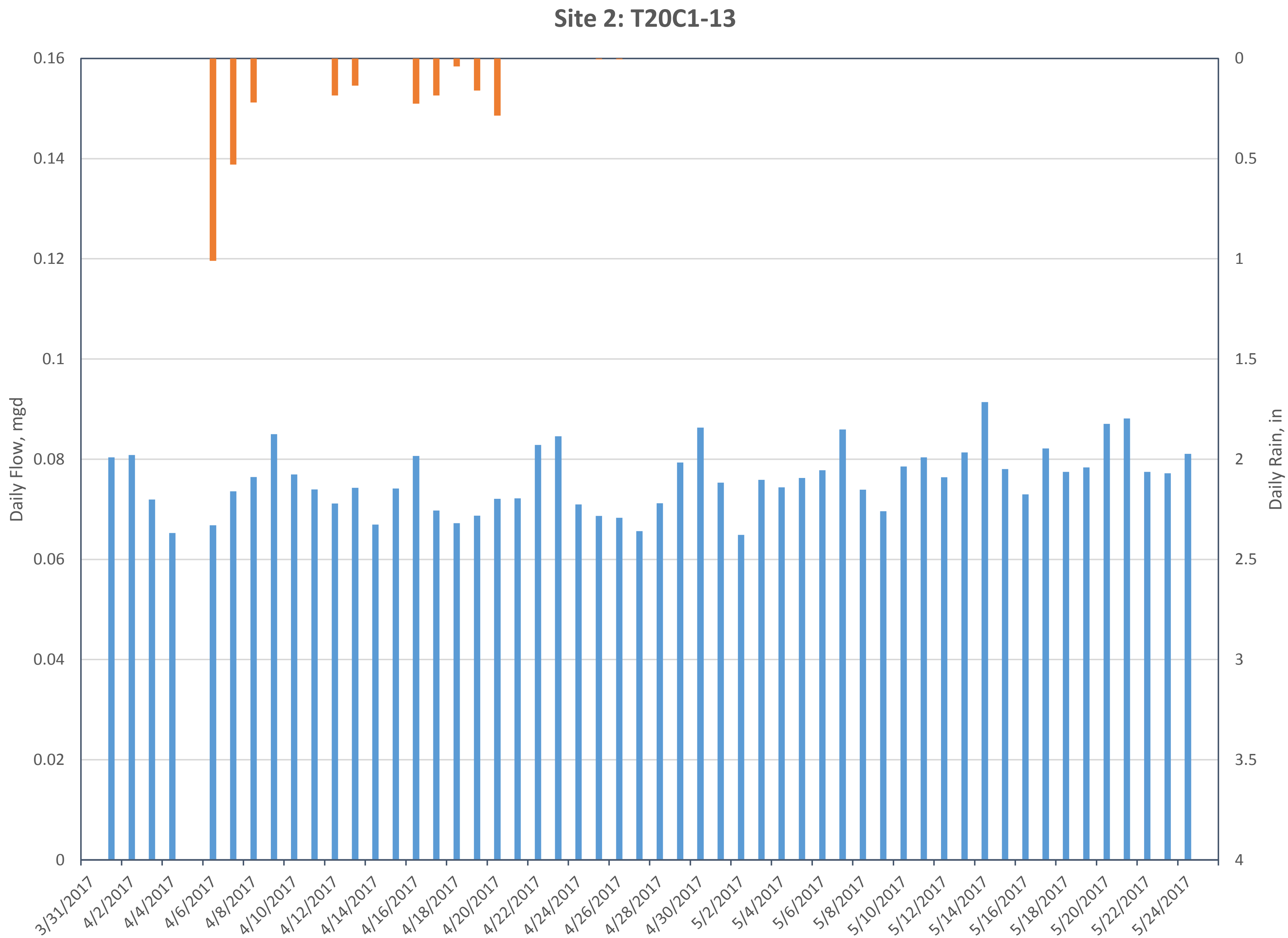
Dublin San Ramon Services District
Collection System Flow Monitoring

APPENDIX A

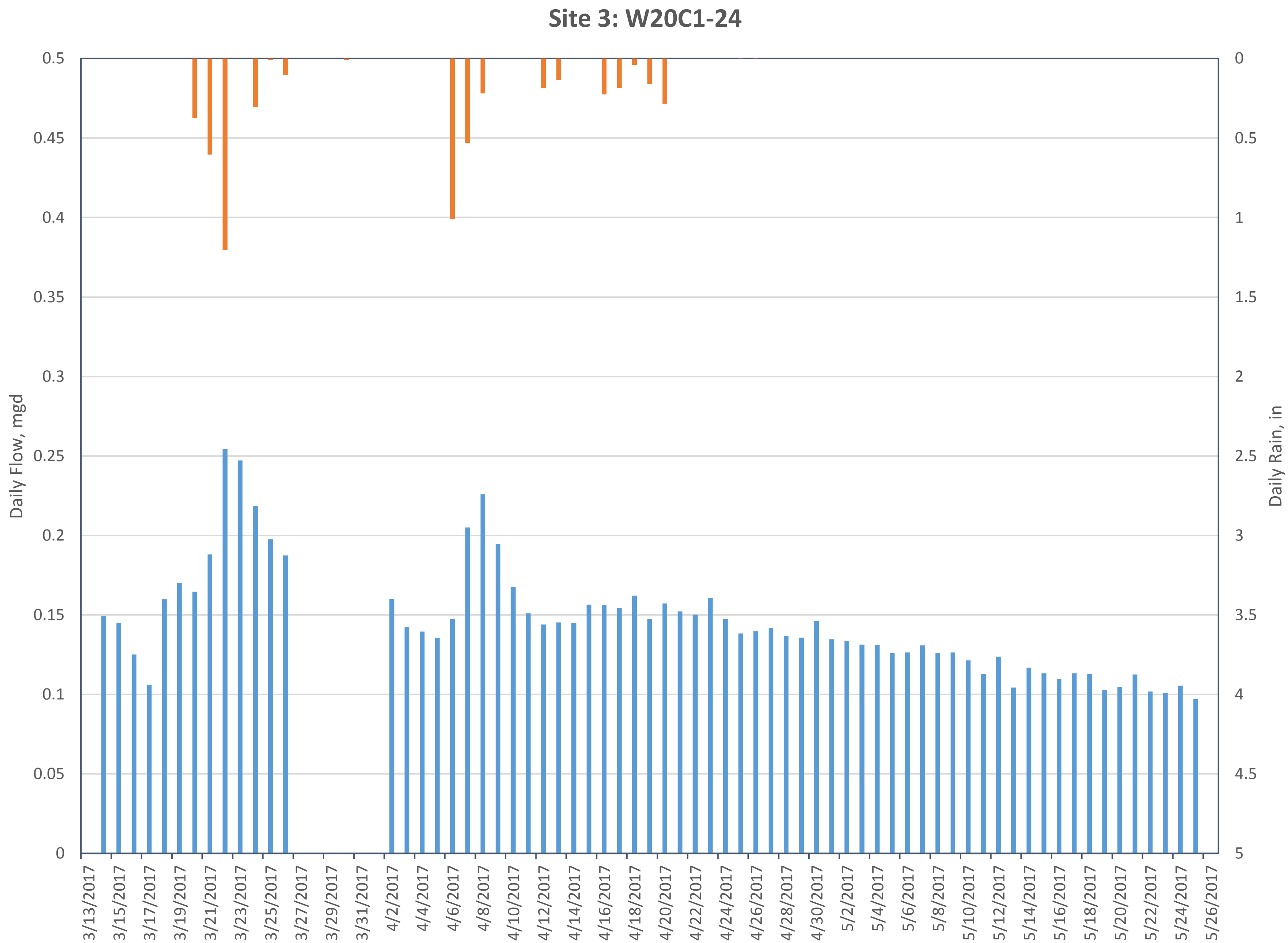
Average Daily Flow Charts



Site 1: U20D1-40
Daily Flow, mgd
Daily Rain, in
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
3/17/2017
3/19/2017
3/21/2017
3/23/2017
3/25/2017
3/27/2017
3/29/2017
3/31/2017
4/2/2017
4/4/2017
4/6/2017
4/8/2017
4/10/2017
4/12/2017
4/14/2017
4/16/2017
4/18/2017
4/20/2017
4/22/2017
4/24/2017
4/26/2017
4/28/2017
4/30/2017
5/2/2017
5/4/2017
5/6/2017
5/8/2017
5/10/2017
5/12/2017
5/14/2017
5/16/2017
5/18/2017
5/20/2017
5/22/2017
5/24/2017

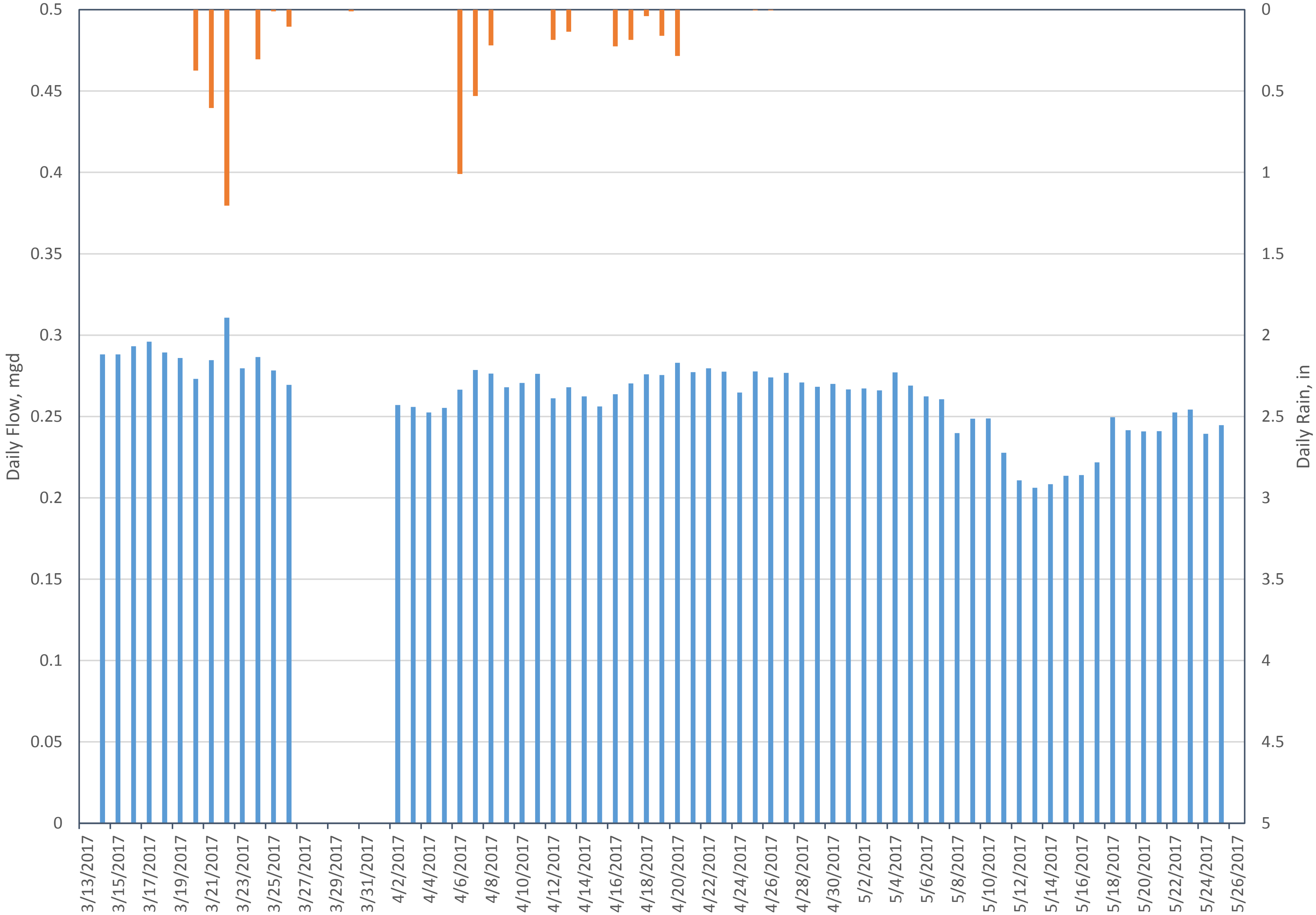


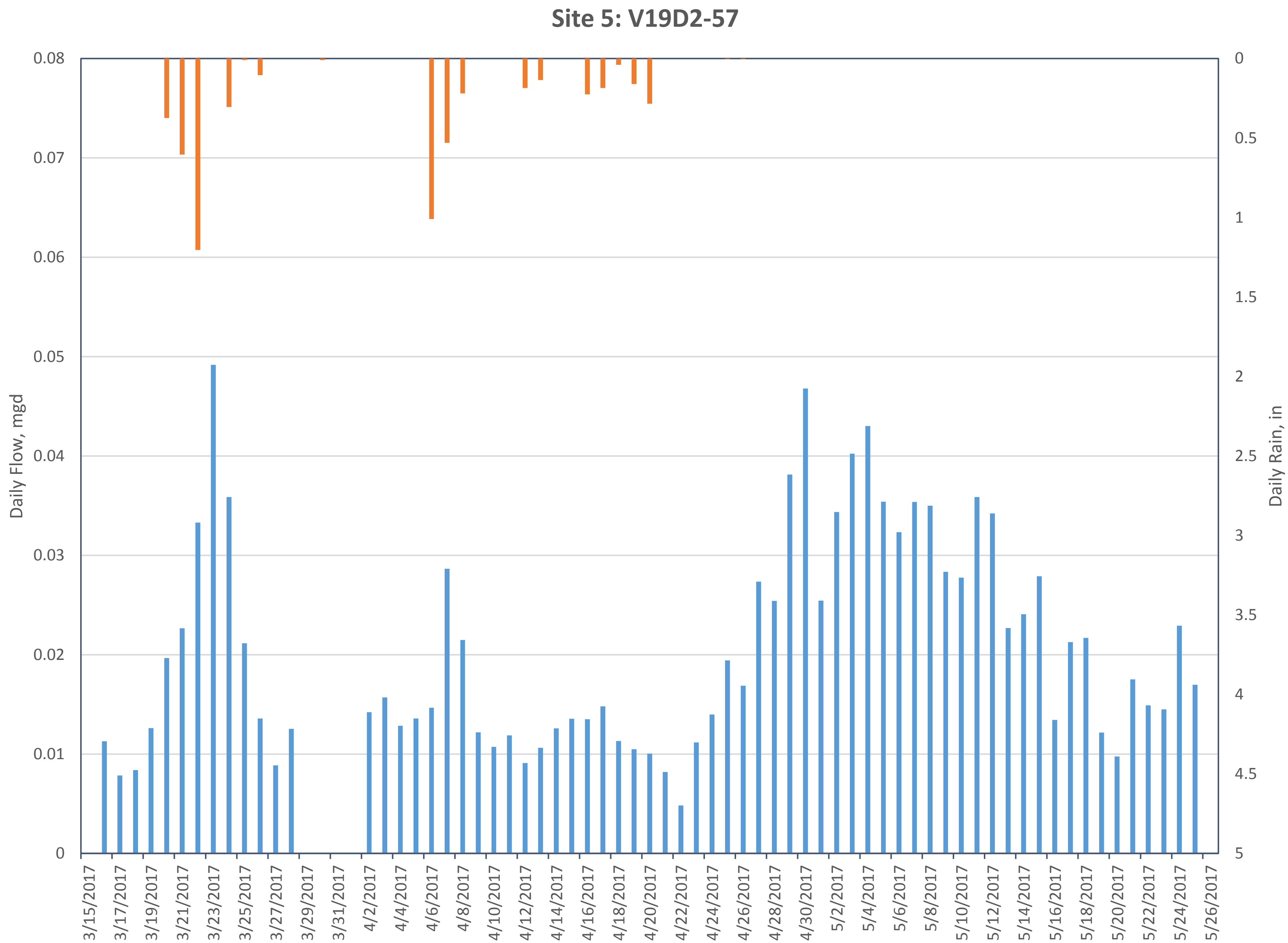
Site 2: T20C1-13
Daily Flow, mgd
Daily Rain, in
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.5
1
1.5
2
2.5
3
3.5
4
3/31/2017
4/2/2017
4/4/2017
4/6/2017
4/8/2017
4/10/2017
4/12/2017
4/14/2017
4/16/2017
4/18/2017
4/20/2017
4/22/2017
4/24/2017
4/26/2017
4/28/2017
4/30/2017
5/2/2017
5/4/2017
5/6/2017
5/8/2017
5/10/2017
5/12/2017
5/14/2017
5/16/2017
5/18/2017
5/20/2017
5/22/2017
5/24/2017



Site 3: W20C1-24
Daily Flow, mgd
Daily Rain, in
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
3/13/2017
3/15/2017
3/17/2017
3/19/2017
3/21/2017
3/23/2017
3/25/2017
3/27/2017
3/29/2017
3/31/2017
4/2/2017
4/4/2017
4/6/2017
4/8/2017
4/10/2017
4/12/2017
4/14/2017
4/16/2017
4/18/2017
4/20/2017
4/22/2017
4/24/2017
4/26/2017
4/28/2017
4/30/2017
5/2/2017
5/4/2017
5/6/2017
5/8/2017
5/10/2017
5/12/2017
5/14/2017
5/16/2017
5/18/2017
5/20/2017
5/22/2017
5/24/2017
5/26/2017

Site 4: W19C1-3





Site 5: V19D2-57
Daily Flow, mgd
Daily Rain, in
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
3/15/2017
3/17/2017
3/19/2017
3/21/2017
3/23/2017
3/25/2017
3/27/2017
3/29/2017
3/31/2017
4/2/2017
4/4/2017
4/6/2017
4/8/2017
4/10/2017
4/12/2017
4/14/2017
4/16/2017
4/18/2017
4/20/2017
4/22/2017
4/24/2017
4/26/2017
4/28/2017
4/30/2017
5/2/2017
5/4/2017
5/6/2017
5/8/2017
5/10/2017
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5/14/2017
5/16/2017
5/18/2017
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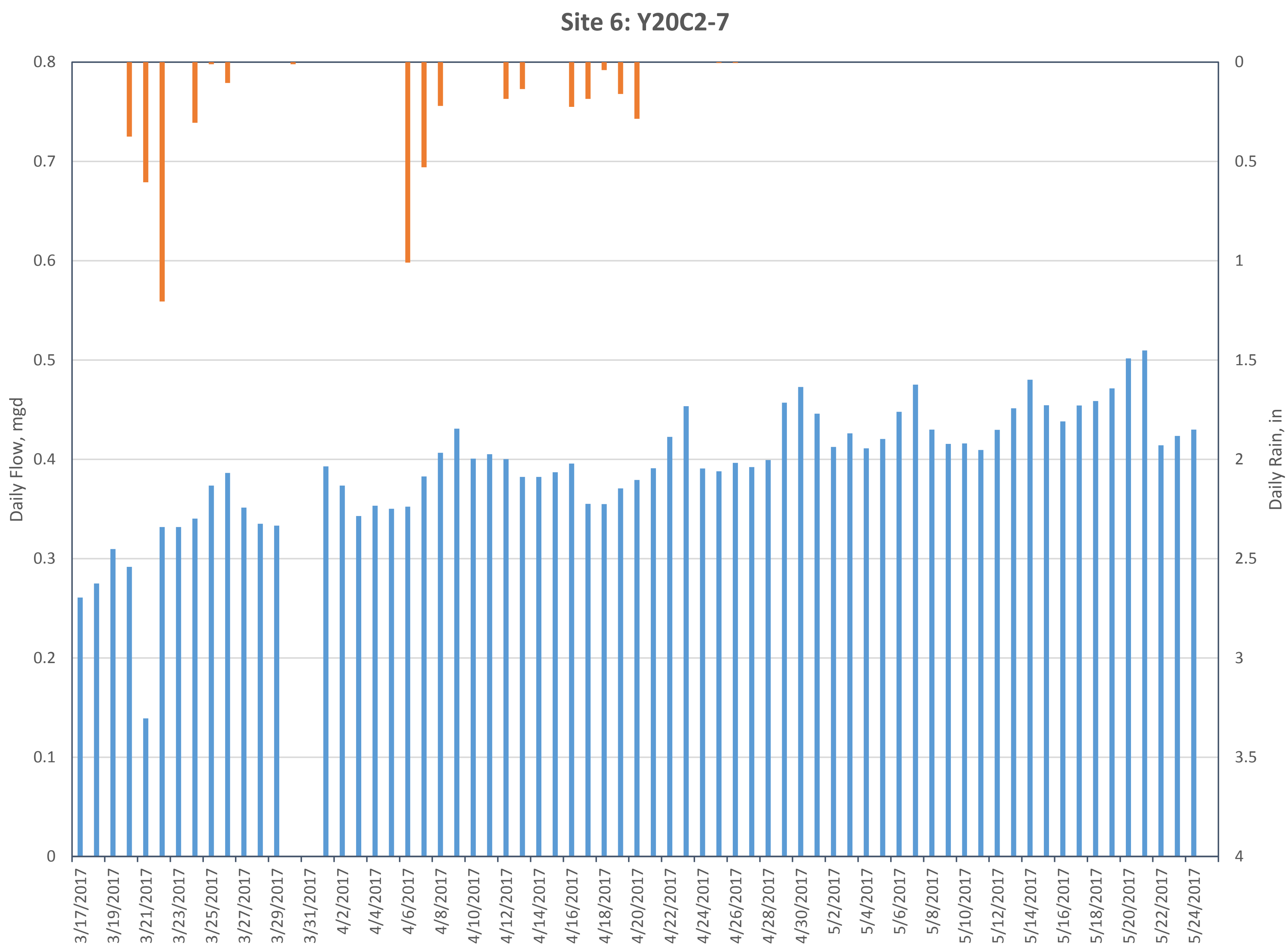
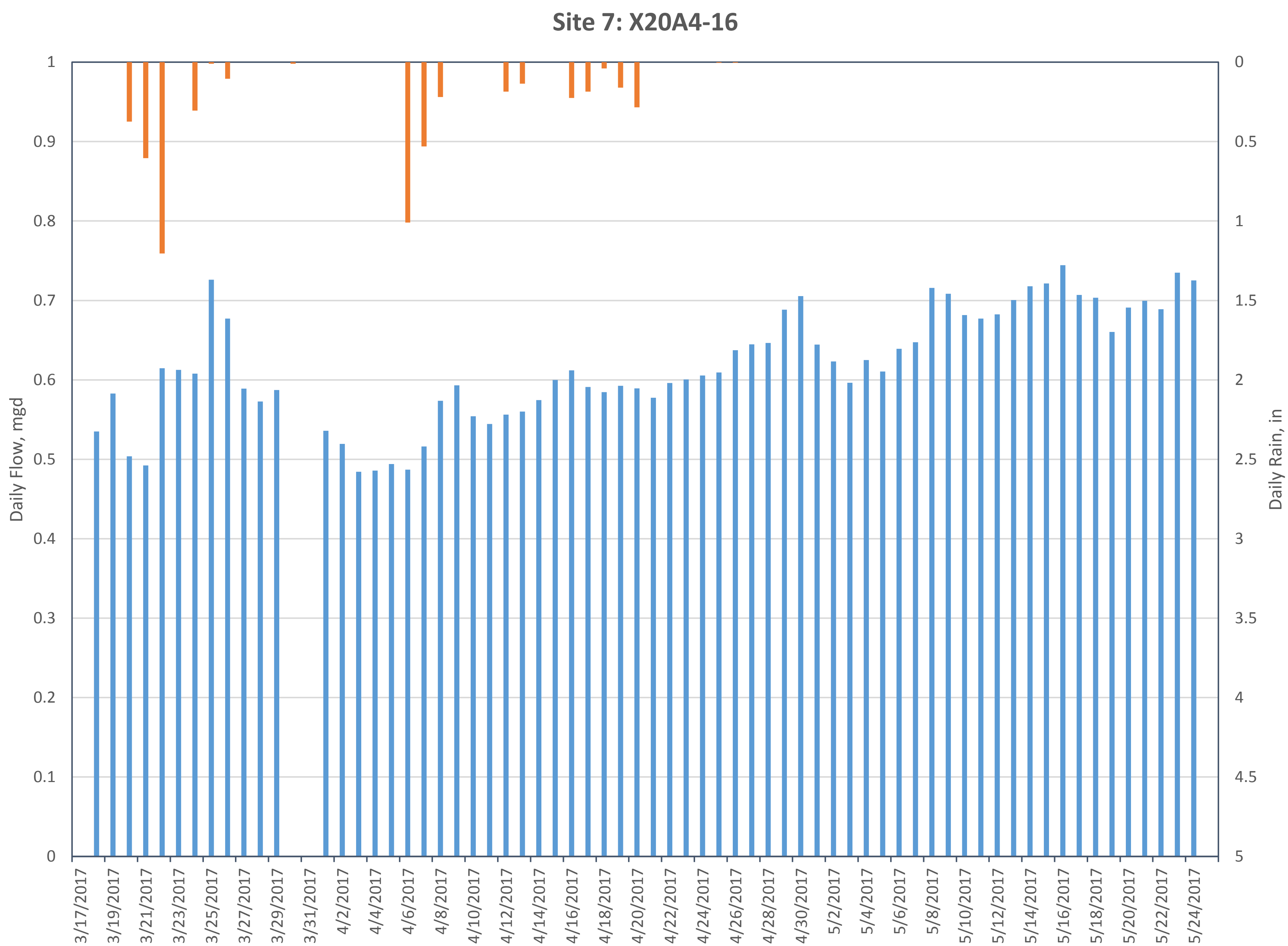
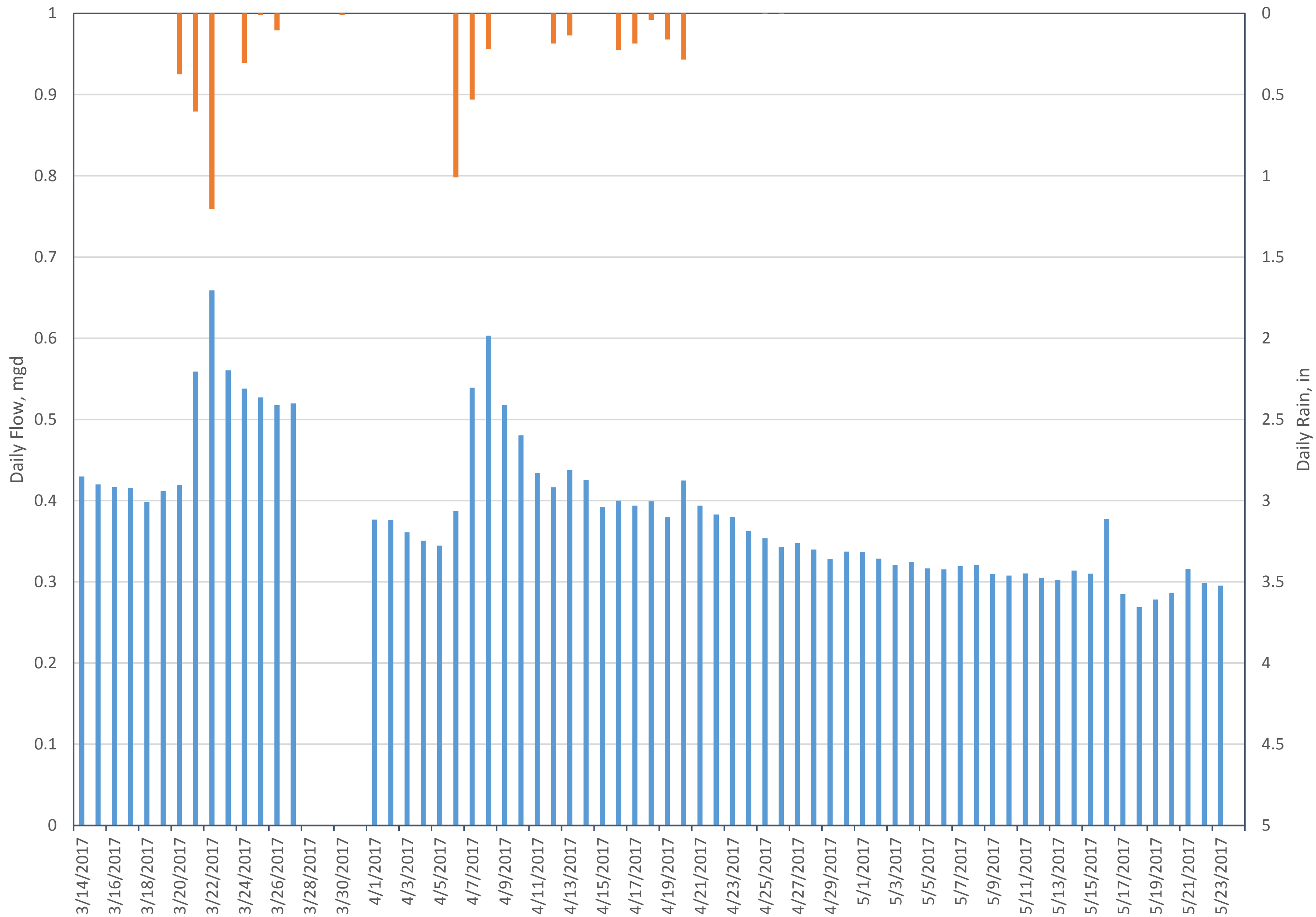
5/22/2017
5/24/2017
5/26/2017

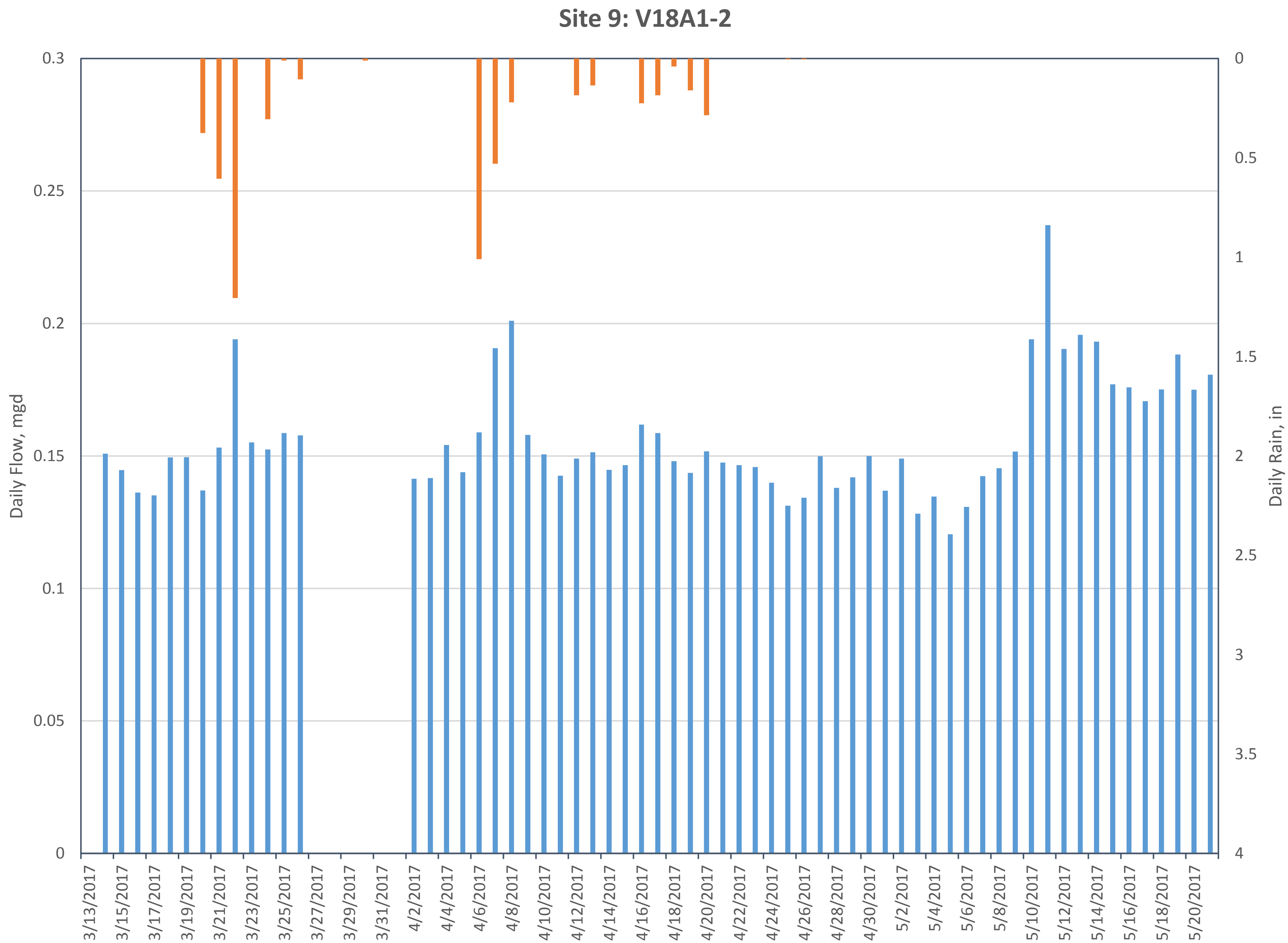


Site 6: Y20C2-7
Daily Flow, mgd
Daily Rain, in
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
3/17/2017
3/19/2017
3/21/2017
3/23/2017
3/25/2017
3/27/2017
3/29/2017
3/31/2017
4/2/2017
4/4/2017
4/6/2017
4/8/2017
4/10/2017
4/12/2017
4/14/2017
4/16/2017
4/18/2017
4/20/2017
4/22/2017
4/24/2017
4/26/2017
4/28/2017
4/30/2017
5/2/2017
5/4/2017
5/6/2017
5/8/2017
5/10/2017
5/12/2017
5/14/2017
5/16/2017
5/18/2017
5/20/2017
5/22/2017
5/24/2017

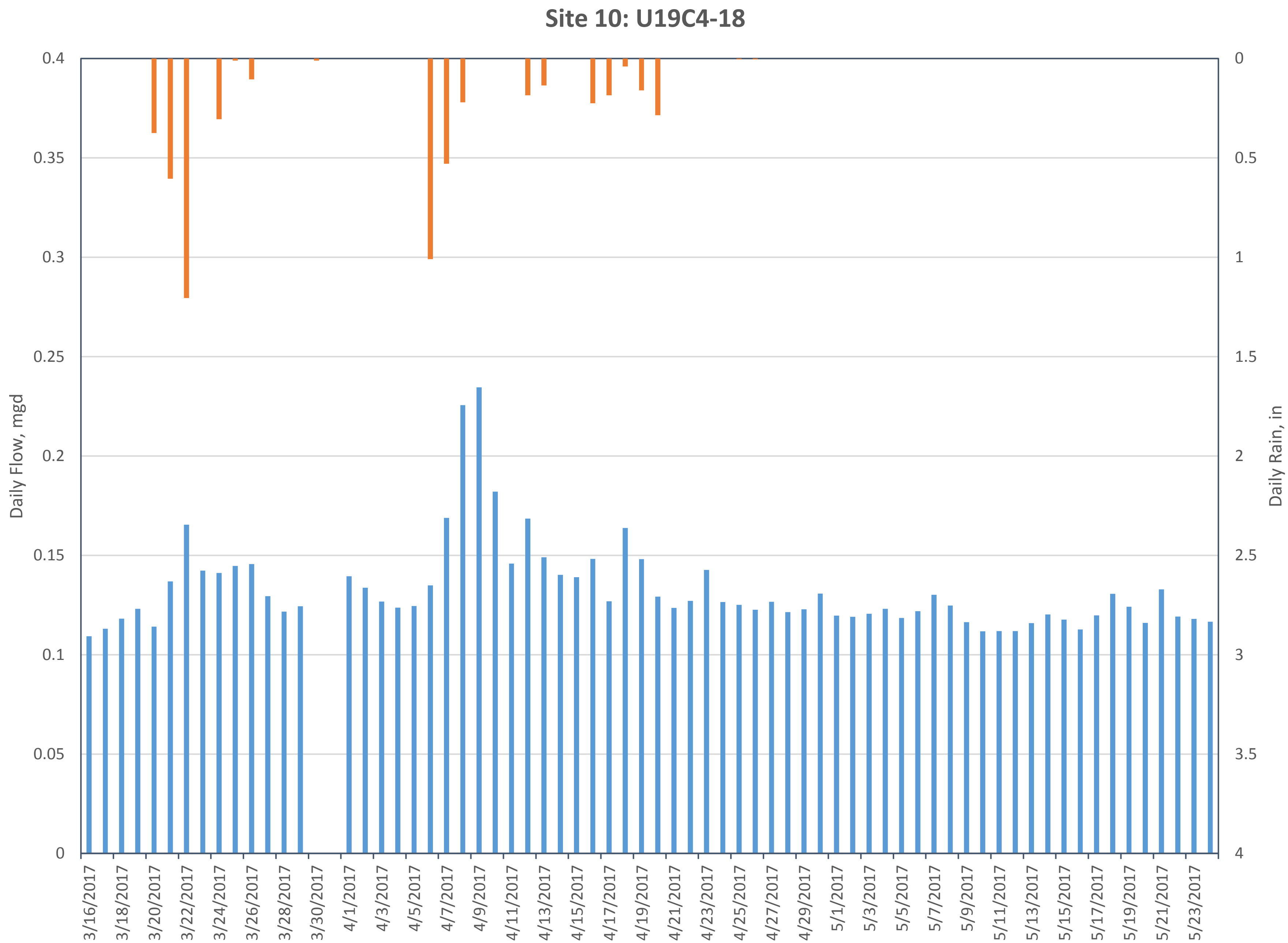

Site 7: X20A4-16
Daily Flow, mgd
Daily Rain, in
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.5
1.5
2
2.5
3
3.5
4
4.5
5
3/17/2017
3/19/2017
3/21/2017
3/23/2017
3/25/2017
3/27/2017
3/29/2017
3/31/2017
4/2/2017
4/4/2017
4/6/2017
4/8/2017
4/10/2017
4/12/2017
4/14/2017
4/16/2017
4/18/2017
4/20/2017
4/22/2017
4/24/2017
4/26/2017
4/28/2017
4/30/2017
5/2/2017
5/4/2017
5/6/2017
5/8/2017
5/10/2017
5/12/2017
5/14/2017
5/16/2017
5/18/2017
5/20/2017
5/22/2017
5/24/2017

Site 8: T16D3-1

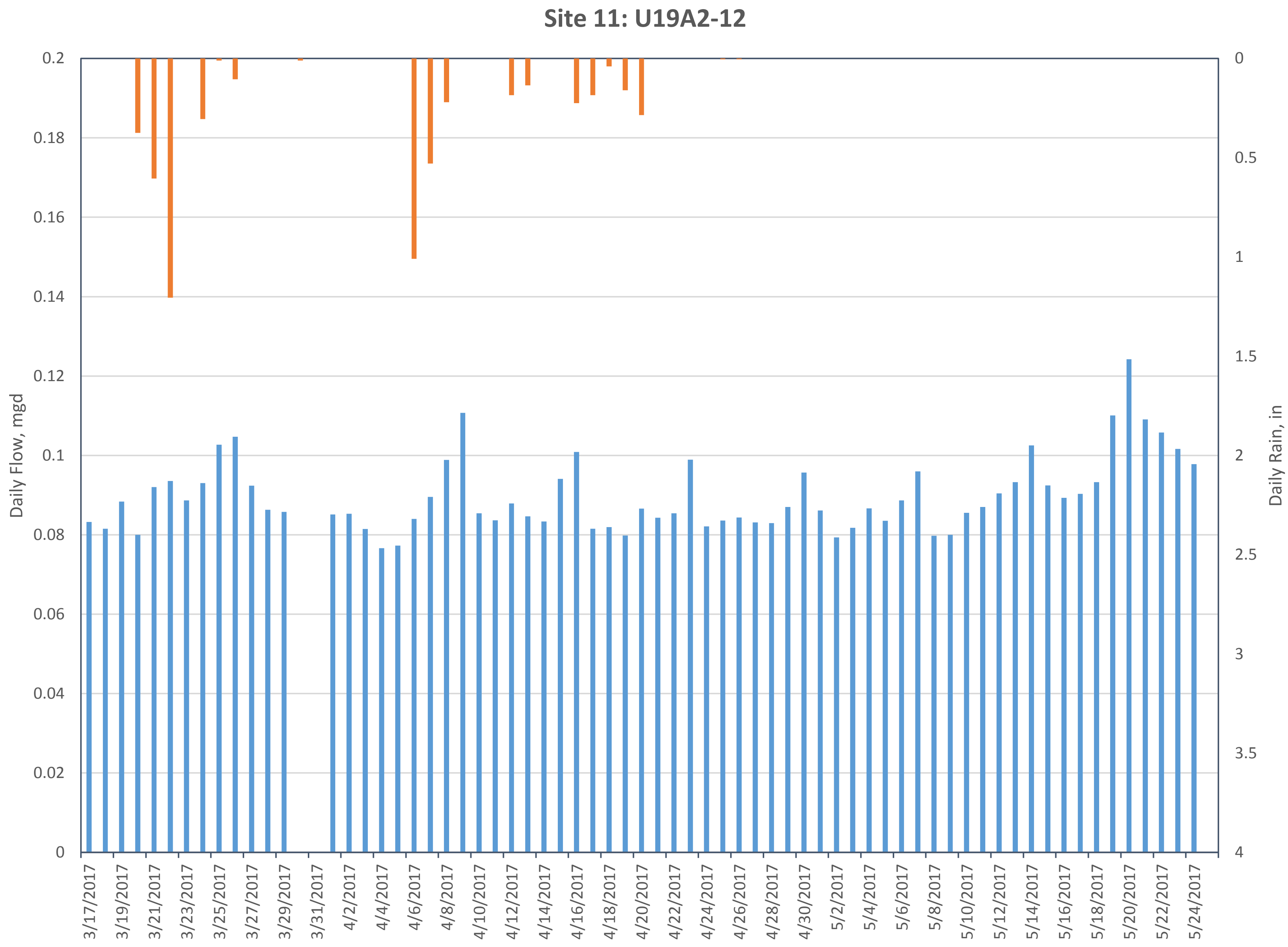


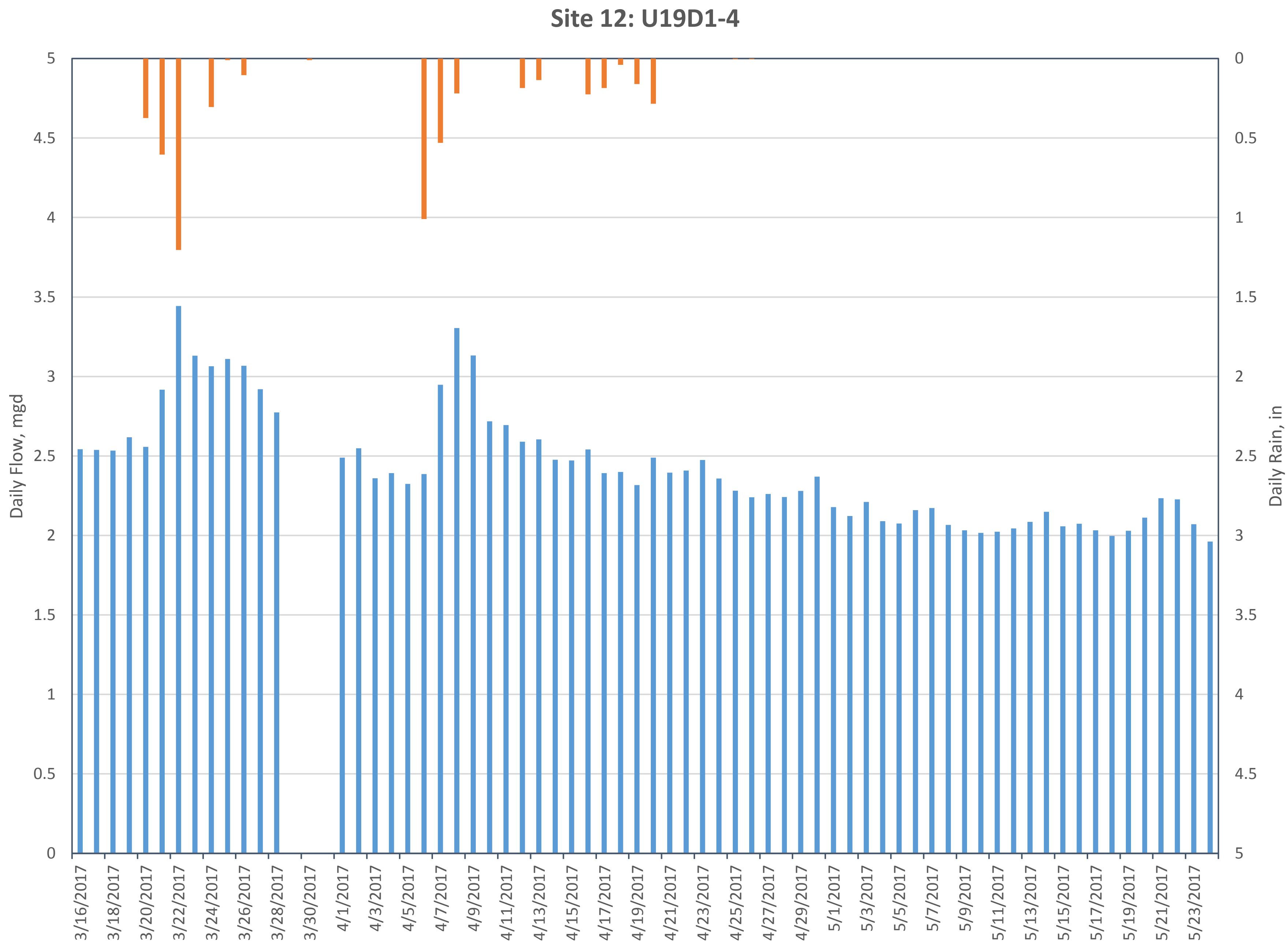


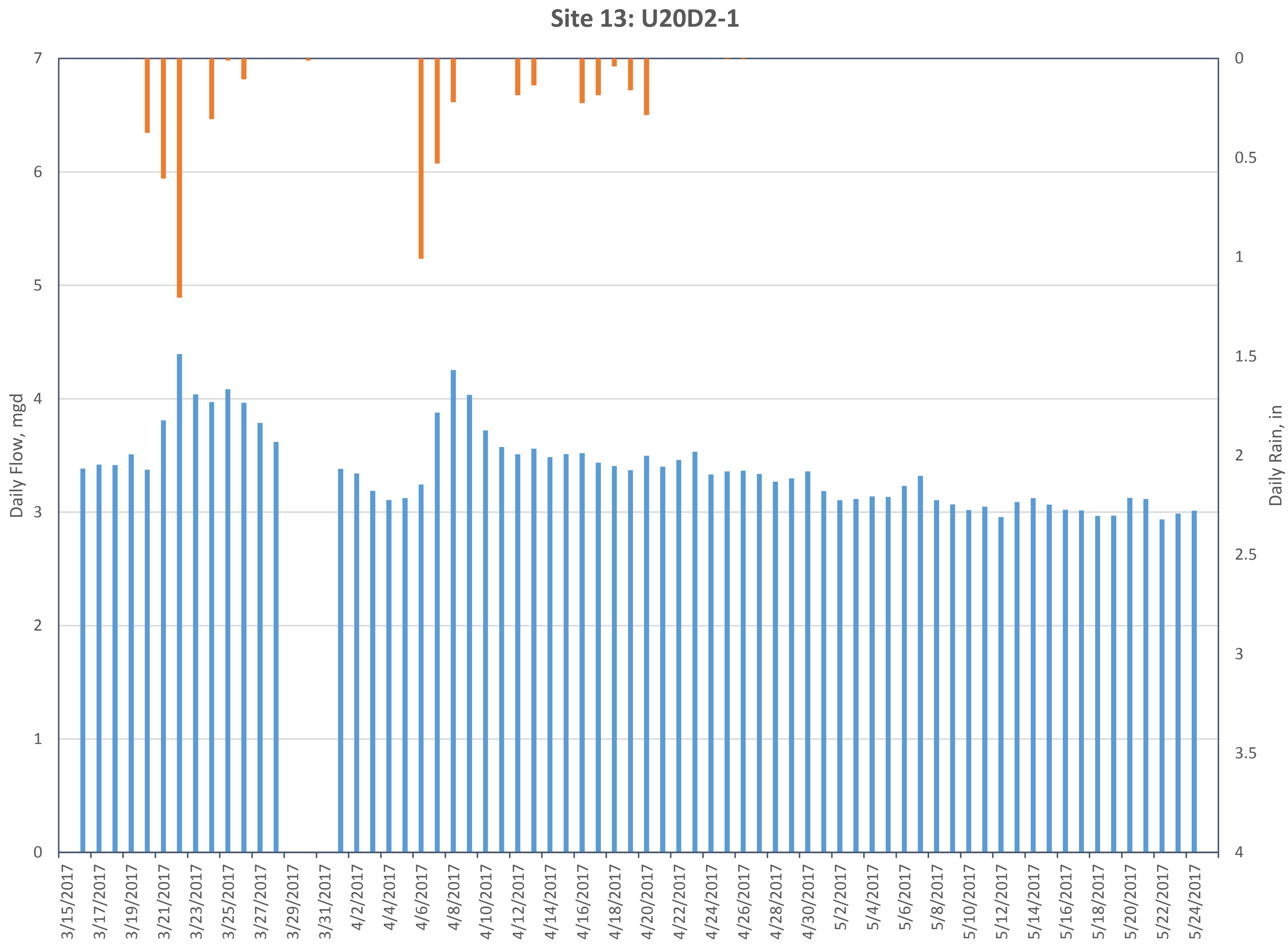
Site 9: V18A1-2
Daily Flow, mgd
Daily Rain, in
0
0.05
0.1
0.15
0.2
0.25
0.3
0
0.5
1
1.5
2
2.5
3
3.5
4
3/13/2017
3/15/2017
3/17/2017
3/19/2017
3/21/2017
3/23/2017
3/25/2017
3/27/2017
3/29/2017
3/31/2017
4/2/2017
4/4/2017
4/6/2017
4/8/2017
4/10/2017
4/12/2017
4/14/2017
4/16/2017
4/18/2017
4/20/2017
4/22/2017
4/24/2017
4/26/2017
4/28/2017
4/30/2017
5/2/2017
5/4/2017
5/6/2017
5/8/2017
5/10/2017
5/12/2017
5/14/2017
5/16/2017
5/18/2017
5/20/2017



Site 10: U19C4-18
Daily Flow, mgd
Daily Rain, in
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
3.5
4
3/16/2017
3/18/2017
3/20/2017
3/22/2017
3/24/2017
3/26/2017
3/28/2017
3/30/2017
4/1/2017
4/3/2017
4/5/2017
4/7/2017
4/9/2017
4/11/2017
4/13/2017
4/15/2017
4/17/2017
4/19/2017
4/21/2017
4/23/2017
4/25/2017
4/27/2017
4/29/2017
5/1/2017
5/3/2017
5/5/2017
5/7/2017
5/9/2017
5/11/2017
5/13/2017
5/15/2017
5/17/2017
5/19/2017
5/21/2017
5/23/2017

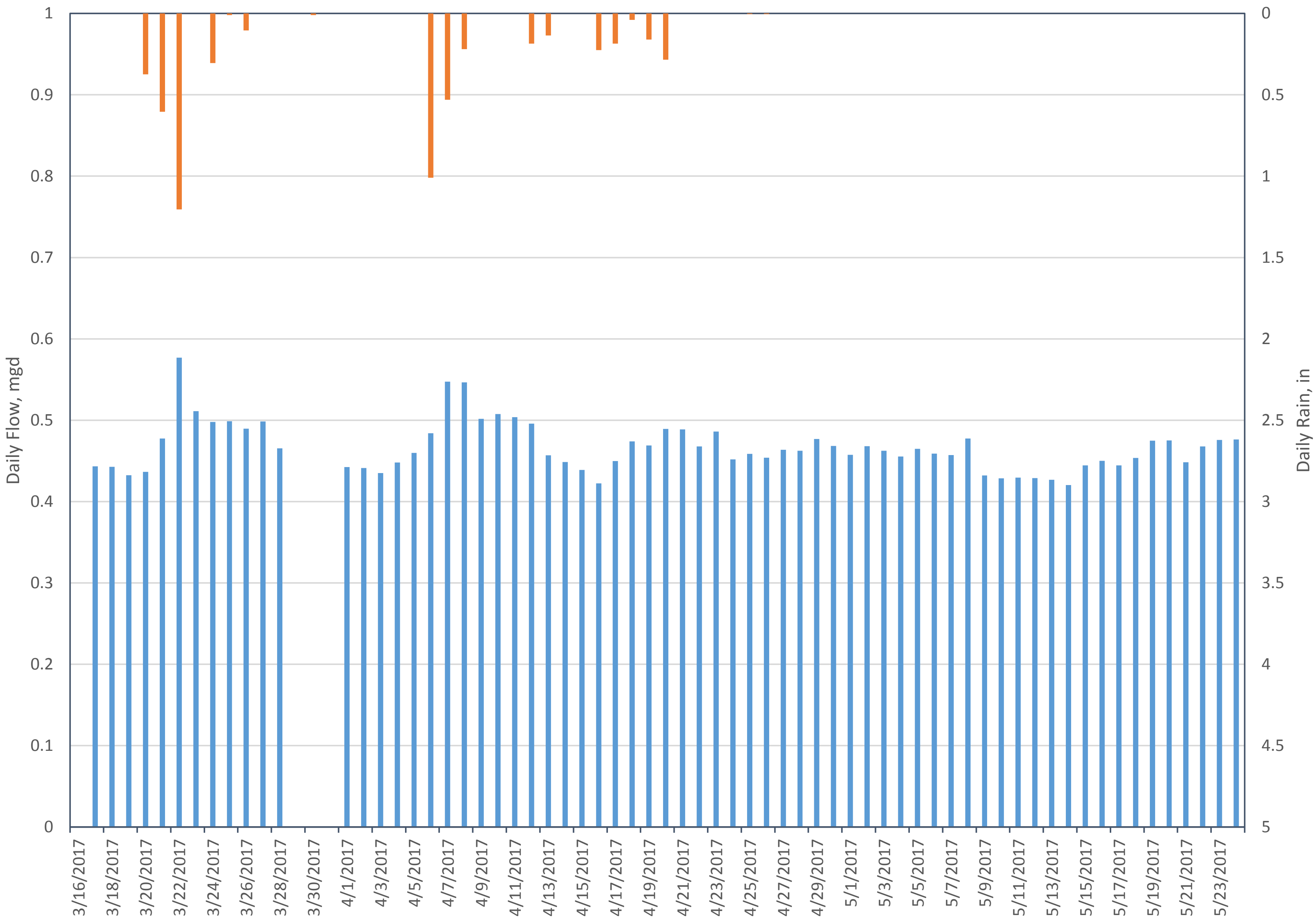

Site 11: U19A2-12
Daily Flow, mgd
Daily Rain, in
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0
0.5
1
1.5
2
2.5
3
3.5
4
3/17/2017
3/19/2017
3/21/2017
3/23/2017
3/25/2017
3/27/2017
3/29/2017
3/31/2017
4/2/2017
4/4/2017
4/6/2017
4/8/2017
4/10/2017
4/12/2017
4/14/2017
4/16/2017
4/18/2017
4/20/2017
4/22/2017
4/24/2017
4/26/2017
4/28/2017
4/30/2017
5/2/2017
5/4/2017
5/6/2017
5/8/2017
5/10/2017
5/12/2017
5/14/2017
5/16/2017
5/18/2017
5/20/2017
5/22/2017
5/24/2017

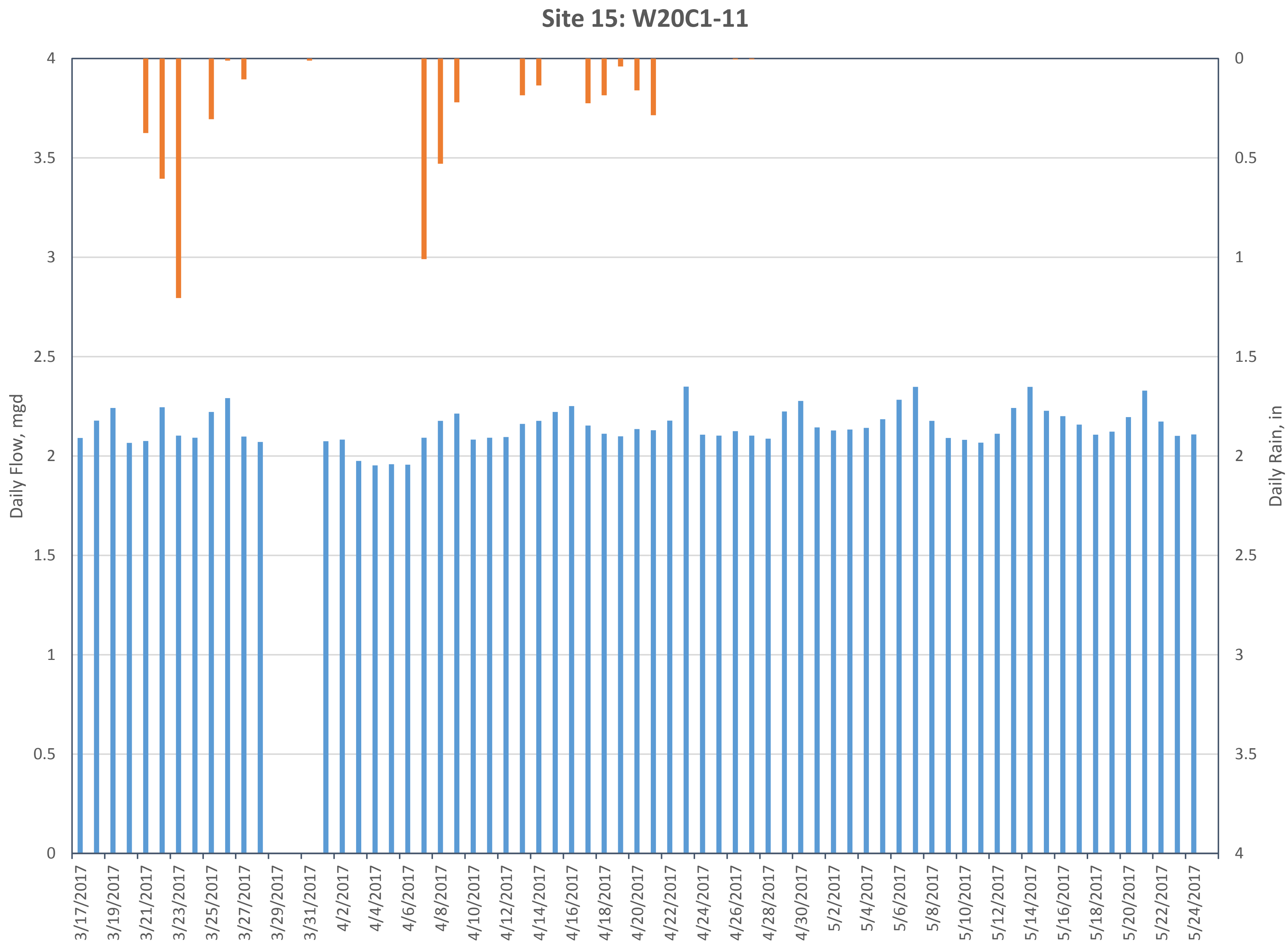

Site 12: U19D1-4
Daily Flow, mgd
Daily Rain, in
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
3/16/2017
3/18/2017
3/20/2017
3/22/2017
3/24/2017
3/26/2017
3/28/2017
3/30/2017
4/1/2017
4/3/2017
4/5/2017
4/7/2017
4/9/2017
4/11/2017
4/13/2017
4/15/2017
4/17/2017
4/19/2017
4/21/2017
4/23/2017
4/25/2017
4/27/2017
4/29/2017
5/1/2017
5/3/2017
5/5/2017
5/7/2017
5/9/2017
5/11/2017
5/13/2017
5/15/2017
5/17/2017
5/19/2017
5/21/2017
5/23/2017



Site 13: U20D2-1
Daily Flow, mgd
Daily Rain, in
0
1
2
3
4
5
6
7
0
0.5
1
1.5
2
2.5
3
3.5
4
3/15/2017
3/17/2017
3/19/2017
3/21/2017
3/23/2017
3/25/2017
3/27/2017
3/29/2017
3/31/2017
4/2/2017
4/4/2017
4/6/2017
4/8/2017
4/10/2017
4/12/2017
4/14/2017
4/16/2017
4/18/2017
4/20/2017
4/22/2017
4/24/2017
4/26/2017
4/28/2017
4/30/2017
5/2/2017
5/4/2017
5/6/2017
5/8/2017
5/10/2017
5/12/2017
5/14/2017
5/16/2017
5/18/2017
5/20/2017
5/22/2017
5/24/2017

Site 14: V20A1-38




Site 15: W20C1-11
Daily Flow, mgd
Daily Rain, in
4
3.5
3
2.5
2
1.5
1
0.5
0
1.5
2.5
3.5
3/17/2017
3/19/2017
3/21/2017
3/23/2017
3/25/2017
3/27/2017
3/29/2017
3/31/2017
4/2/2017
4/4/2017
4/6/2017
4/8/2017
4/10/2017
4/12/2017
4/14/2017
4/16/2017
4/18/2017
4/20/2017
4/22/2017
4/24/2017
4/26/2017
4/28/2017
4/30/2017
5/2/2017
5/4/2017
5/6/2017
5/8/2017
5/10/2017
5/12/2017
5/14/2017
5/16/2017
5/18/2017
5/20/2017
5/22/2017
5/24/2017

APPENDIX B

Collection System Hydraulic Model Modeler’s Notebook

INTRODUCTION

The purpose of this Collection System Hydraulic Model Modeler's Notebook (Modeler's Notebook) is to document the facilities that are included in the Dublin San Ramon Services District's (District's) wastewater collection system and the manner in which these facilities are simulated in the District's wastewater collection system hydraulic model. This Modeler's Notebook and associated database are compiled from the information available at the time of the model development. West Yost Associates (West Yost) developed this Modeler's Notebook to provide the District with a means to evaluate and review the information that West Yost has incorporated into the hydraulic model, as well as to provide the District with a "living" reference for use by the District's modeling staff and outside parties that will be using the hydraulic model. The facility information provided is current as of September 2017.

This Modeler's Notebook is organized as follows:

- Model Development Notes
- Model Scenarios
- Calibration Simulations and Results

MODEL DEVELOPMENT NOTES

Information on the District hydraulic model development is included below.

Hydraulic Model Background

As part of the 2005 Master Plan, a hydraulic model of the District's collection system was developed utilizing H2OMap Sewer Pro software (H2OMap Sewer), a product of Innovyze, Inc. H2OMap Sewer was developed specifically for collection system capacity analysis and is widely used in the industry. The hydraulic model developed for the 2005 Master Plan was a skeletonized model that contained only the trunk gravity mains from the District's collection system. Small diameter gravity mains were excluded from the hydraulic model.

For this Wastewater Master Plan, the District desired a more comprehensive evaluation of collection system capacity, including the small diameter gravity mains that predominate the collection system. Further, the District desired that a clear link be developed between individual parcel flows and their connection to the collection system. Such a link requires that all gravity mains, regardless of diameter, be included in the hydraulic model. Therefore, as part of this Wastewater Master Plan, the hydraulic model has been updated to include a network that contains all collection system gravity mains. As shown on Figure 1, the model was updated so that all infrastructure; including gravity mains, lift stations, and force mains, is up to date and represents the collection system as it currently exists in the field.

Recently, Innovyze announced that H20Map Sewer will no longer be supported, so West Yost updated the District's hydraulic model into the InfoSewer hydraulic modeling platform. InfoSewer utilizes a hydraulic modeling engine that is identical to that used in H20Map Sewer, so results are identical between the two software packages. However, InfoSewer runs in a GIS platform that integrates directly with the District's GIS platform..

Model Naming Scheme

A specific naming scheme for network elements is used in the hydraulic model and is presented in Table 1. The gravity main and force main naming schemes are based on the "Unique Number" field in GIS. Further identification for wet wells, manholes, chambers, and outlets will be based on unique identification for each facility. Naming schemes for lift stations also include a reference to the associated wet well identification.

Manhole and gravity main unique GIS identifiers were preserved as unique hydraulic model identifiers, where possible. In some cases, multiple manholes or gravity mains model identifiers were different from their GIS identifiers. To provide a clear link between model and GIS, their model identifiers have been updated to GIS identifiers. Additionally, some future manholes and gravity mains in the model have been aligned differently than recommended in the 2005 Master Plan, and their model identifiers have been assigned to the other facilities in GIS. Because the hydraulic model does not allow non-unique identifiers, the identifier of these elements was altered and they became inactivated in the model. Tables 2 and 3 list all old and new gravity mains, manholes identifiers, and element's status in the model, respectively.

The hydraulic model requires both an upstream and downstream manhole for each gravity main. In Wallis Ranch development, this geometry was not present in some cases in the GIS. In these cases (i.e., non-existent upstream and/or downstream manhole), the appropriate manhole was created in the hydraulic model. A unique identifier was created for this new manhole in the form of "WALLIS_number" and listed in Table 3.

Table 1. Naming Scheme for Network Elements

Model Component	Naming Scheme
Gravity Pipelines	Unique Number
Force Main	Unique Number
Normal Manholes	Unique Number
Chamber Manholes	CH-Lift Station Name "CH" = Chamber
Outlet Manholes	Unique Number
Wet Wells	WW-Lift Station Name "WW" = Wet Well
Wet Well Lift Station	LS-Lift Station Name "LS" = Lift Station

Table 2. List of New Gravity Main ID in Model

Old Gravity Main ID	New Gravity Main ID	Status in Model
1731	5289	Active
3516	5094	Active
868	5026	Active
1939	5027	Active
4371	7132	Active
4186	5569	Active
3317	6032	Active
4523	5946	Active
4499	6135	Active
4500	6136	Active
4501	6134	Active
4502	6133	Active
1897	458	Active
458	7134	Active
G08	5018	Active
G03	4842	Active
G01	4840	Active
G09	4851	Active
G02	4841	Active
DPS02	982	Active
3549	5098	Active
4340	5594	Active
3439	6196	Active
3379	5061	Active
3517	5095	Active
985	7128	Active
984	7129	Active
T01	4979	Active
T02	4980	Active
T03	4978	Active
T04	4981	Active
T05	4977	Active
T06	4983	Active
T07	4976	Active
T08	4975	Active
D01	4897	Active
D02	4893	Active
D03	4894	Active
D04	5016	Active
D05	5017	Active
G07	4846	Active
G06	4845	Active

Table 2. List of New Gravity Main ID in Model

Old Gravity Main ID	New Gravity Main ID	Status in Model
G05	4844	Active
G04	4843	Active
TP01	4316	Active
G10	4852	Active
G11	4853	Active
G12	4854	Active
G13	4855	Active
G14	4857	Active
TP02	4202	Active
2932	WYA_001	Inactive
3380	WYA_002	Inactive
3381	WYA_003	Inactive
3382	WYA_004	Inactive
3358	WYA_005	Inactive
3359	WYA_006	Inactive
3360	WYA_007	Inactive
3361	WYA_008	Inactive
3362	WYA_009	Inactive
3363	WYA_010	Inactive
3364	WYA_011	Inactive
3365	WYA_012	Inactive
3384	WYA_013	Inactive
3385	WYA_014	Inactive
3386	WYA_015	Inactive
3387	WYA_016	Inactive
3366	WYA_017	Inactive
3388	WYA_018	Inactive
3519	WYA_019	Inactive
3518	WYA_020	Inactive
3520	WYA_021	Inactive
3521	WYA_022	Inactive
3522	WYA_023	Inactive
1918	WYA_024	Inactive
861	WYA_025	Inactive
3523	WYA_026	Inactive
3383	WYA_027	Inactive
D06	WYA_028	Inactive
PROJECT_DB01	WYA_029	Inactive
PROJECT_TRUNK	WYA_030	Inactive
PROJECT_ED01	WYA_031	Inactive
PROJECT_ED02	WYA_032	Inactive
PROJECT_ED03	WYA_033	Inactive

Table 2. List of New Gravity Main ID in Model

Old Gravity Main ID	New Gravity Main ID	Status in Model
PROJECT_ED04	WYA_034	Inactive
PROJECT_ED05	WYA_035	Inactive
PROJECT_ED06	WYA_036	Inactive
PROJECT_ED07	WYA_037	Inactive
PROJECT_ED09	WYA_038	Inactive
PROJECT_ED10	WYA_039	Inactive
PROJECT_ED11	WYA_040	Inactive
PROJECT_ED12	WYA_041	Inactive
PROJECT_ED13	WYA_042	Inactive
PROJECT_ED18	WYA_043	Inactive
PROJECT_ED17	WYA_044	Inactive
PROJECT_ED16	WYA_045	Inactive
PROJECT_ED15	WYA_046	Inactive
PROJECT_ED14	WYA_047	Inactive
PROJECT_ED19	WYA_048	Inactive
PROJECT_ED23	WYA_049	Inactive
PROJECT_ED22	WYA_050	Inactive
PROJECT_ED21	WYA_051	Inactive
PROJECT_ED20	WYA_052	Inactive
PROJECT_ED37	WYA_053	Inactive
PROJECT_ED36	WYA_054	Inactive
PROJECT_ED35	WYA_055	Inactive
PROJECT_ED34	WYA_056	Inactive
PROJECT_ED40	WYA_057	Inactive
PROJECT_ED39	WYA_058	Inactive
PROJECT_ED38	WYA_059	Inactive
PROJECT_ED31A	WYA_060	Inactive
PROJECT_ED31B	WYA_061	Inactive
PROJECT_ED31C	WYA_062	Inactive
ALAMO	WYA_063	Inactive
ALAMO_01	WYA_064	Inactive
ALAMO_02	WYA_065	Inactive
2313	WYA_066	Inactive
2315	WYA_067	Inactive
2319	WYA_068	Inactive
2321	WYA_069	Inactive
2323	WYA_070	Inactive
2325	WYA_071	Inactive
2327	WYA_072	Inactive
2329	WYA_073	Inactive
2331	WYA_074	Inactive
2333	WYA_075	Inactive

Table 2. List of New Gravity Main ID in Model

Old Gravity Main ID	New Gravity Main ID	Status in Model
2337	WYA_076	Inactive
2339	WYA_077	Inactive
2343	WYA_078	Inactive
2345	WYA_079	Inactive
2351	WYA_080	Inactive
2941	WYA_081	Inactive
1893	WYA_082	Inactive
3442	WYA_083	Inactive
2859	WYA_084	Inactive

Table 3. List of New Manhole ID in Model		
Old Manhole ID	New Manholen ID	Status in Model
G08	5164	Active
T08	5277	Active
T08	5277	Active
1573	5313	Active
TP01	2703	Active
WWTP	4516	Active
TP02	4545	Active
3899	5127	Active
G01	5135	Active
G02	5149	Active
G03	5150	Active
G04	5151	Active
G05	5152	Active
G06	5153	Active
G07	5154	Active
G09	5159	Active
G10	5160	Active
G11	5161	Active
G12	5162	Active
G13	5163	Active
G08	5164	Active
G14	5165	Active
D01	5194	Active
D02	5195	Active
D03	5196	Active
D05	5197	Active
T02	5270	Active
T03	5271	Active
T04	5272	Active
T05	5274	Active
T06	5275	Active
T07	5276	Active
T08	5277	Active
T01	5280	Active
D04	5311	Active
1514	WYA_001	Inactive
1514	WYA_001	Inactive
1514	WYA_002	Inactive
3868	WYA_003	Inactive
3867	WYA_004	Inactive
3866	WYA_005	Inactive
3865	WYA_006	Inactive

Table 3. List of New Manhole ID in Model

Old Manhole ID	New Manholen ID	Status in Model
3864	WYA_007	Inactive
3891	WYA_008	Inactive
3890	WYA_009	Inactive
3889	WYA_010	Inactive
3888	WYA_011	Inactive
3887	WYA_012	Inactive
3886	WYA_013	Inactive
3885	WYA_014	Inactive
3871	WYA_015	Inactive
3870	WYA_016	Inactive
3869	WYA_017	Inactive
3930	WYA_018	Inactive
3928	WYA_019	Inactive
D06	WYA_020	Inactive
PROJECT_ED01	WYA_021	Inactive
PROJECT_ED02	WYA_022	Inactive
PROJECT_ED03	WYA_023	Inactive
PROJECT_ED04	WYA_024	Inactive
PROJECT_ED05	WYA_025	Inactive
PROJECT_ED06	WYA_026	Inactive
PROJECT_ED07	WYA_027	Inactive
PROJECT_ED09	WYA_028	Inactive
PROJECT_ED10	WYA_029	Inactive
PROJECT_ED11	WYA_030	Inactive
PROJECT_ED12	WYA_031	Inactive
PROJECT_ED13	WYA_032	Inactive
PROJECT_ED14	WYA_033	Inactive
PROJECT_ED15	WYA_034	Inactive
PROJECT_ED16	WYA_035	Inactive
PROJECT_ED17	WYA_036	Inactive
PROJECT_ED18	WYA_037	Inactive
PROJECT_ED19	WYA_038	Inactive
PROJECT_ED20	WYA_039	Inactive
PROJECT_ED21	WYA_040	Inactive
PROJECT_ED22	WYA_041	Inactive
PROJECT_ED23	WYA_042	Inactive
PROJECT_ED31	WYA_043	Inactive
PROJECT_ED34	WYA_044	Inactive
PROJECT_ED35	WYA_045	Inactive
PROJECT_ED36	WYA_046	Inactive
PROJECT_ED37	WYA_047	Inactive
PROJECT_ED38	WYA_048	Inactive

Table 3. List of New Manhole ID in Model

Old Manhole ID	New Manholen ID	Status in Model
PROJECT_ED39	WYA_049	Inactive
PROJECT_ED40	WYA_050	Inactive
PROJECT_ED31B	WYA_051	Inactive
PROJECT_ED31C	WYA_052	Inactive
848	WYA_053	Inactive
ALAMO_01	WYA_054	Inactive
ALAMO_02	WYA_055	Inactive
U20D1-16	WYA_056	Inactive
U20D1-20	WYA_057	Inactive
U20D1-42	WYA_058	Inactive
U20D1-41	WYA_059	Inactive
U20D1-22	WYA_060	Inactive
NEWMH1	WYA_061	Inactive
NEWMH3	WYA_062	Inactive
U20D1-17	WYA_063	Inactive
U20D1-18	WYA_064	Inactive
U20D1-19	WYA_065	Inactive
U20D1-23	WYA_066	Inactive
U20D1-24	WYA_067	Inactive
U20D2-15	WYA_068	Inactive
NEWMH2	WYA_069	Inactive
3494	WYA_070	Inactive
3884	WYA_071	Inactive
3944	WYA_072	Inactive
3945	WYA_073	Inactive
3946	WYA_074	Inactive
3947	WYA_075	Inactive
3948	WYA_076	Inactive
3949	WYA_077	Inactive
3901	WYA_078	Inactive
3900	WYA_079	Inactive
3803	WYA_080	Inactive

Model Element Information

The information associated with each element in the hydraulic model includes several data fields that have been added or filled by West Yost to include additional information for future reference and/or use. These additional data fields, along with a brief description, are listed below.

Manhole

- 2017MP – This field indicates if the manhole was exported from GIS to the hydraulic model, if it was existing in the hydraulic model, or if it is inactivated in the model

Pipe

- 2017MP – This field indicates if the pipeline was exported from GIS to the hydraulic model, if it was existing in the hydraulic model, or if it is inactivated in the model
- US_INV_SRC – Summarizes the source of upstream pipeline invert elevation
- DS_INV_SRC – Summarizes the source of downstream pipeline invert elevation
- CIP_ID – Summarizes the CIP project ID
- Material – Material of the pipelines

GIS Gap Analysis

West Yost's GIS data gap analysis includes identifying the required additional data and determining the discrepancy between GIS and Model. The result of this analysis was discussed with District staff and was requested where available. Per District staff direction, in a case of discrepancy between model and GIS data, data in the GIS was considered preeminent and updated into the hydraulic model. In the case of lacking required data, West Yost has implemented different approaches to estimate them, as discussed in Chapter 5. Attachment 1 includes the discussed information and proposed results that were confirmed by District's staff.

GIS Mapping Import

The September 2017 Geodatabase update was used to import properties and data into the modeling facilities. The unique ID developed for each facility was used to import data into the hydraulic model based on the mapping scheme for gravity mains, as shown in Table 4, and manholes, as shown in Table 5.

Wet wells, lift stations and force mains were included in the hydraulic model based on as-built drawings provided by District staff.

Table 4. Gravity Main Pipeline Mapping

GIS Data Field	Description	Model Data Field
Material	Pipeline material	PIPEHYD->MATERIAL
Unique Number [(a)]	Upstream Manhole ID	LINK->FROM
Unique Number [(a)]	Downstream Manhole ID	LINK->TO
Dia/Height	Pipeline diameter in inches	PIPEHYD->DIAMETER
Length	Pipe length in feet	PIPEHYD->LENGTH
US Invert	Upstream Invert Elevation in feet	PIPEHYD->FROM_INV
DS Invert	Downstream Invert Elevation in feet	PIPEHYD->TO_INV

(a) Unique number is extracted from Manhole database based on US Structure and DS Structure field in Gravity Main database

Table 5. Manhole Mapping

GIS Data Field	Description	Model Data Field
Rim Elevation	Upstream Rim Elevation in feet	MHHYD->RIM_ELEV

Model Load Fields

ADWF values were developed on an individual parcel basis. These values were imported into the hydraulic model through the establishment of a parcel-to-manhole link made possible by the inclusion of all gravity mains and manholes in the hydraulic model. The parcel-to-manhole link was initiated using GIS proximity analysis to identify the manhole closest to each parcel. The parcel-to-manhole linkage established a loading manhole for each parcel in the District. ADWF values were summarized by manhole and these summarized flows were imported into the hydraulic model. The InfoSewer modeling software contains 10 loading fields that can be used to organize flows being imported into the model. For the District's hydraulic model, flows were organized into the loading columns as shown in Table 6.

Table 6. Load Column Description in the Hydraulic Model	
Load Column	Load Description
Load 1	Rebounded BWF of Existing Residential Developed Areas in District Wastewater Service Area[(a)]
Load 2	Rebounded BWF of Existing Non-Residential Developed Areas in District Wastewater Service Area[(a)]
Load 3	Rebounded BWF of Existing Camp Parks Developed Areas in District Wastewater Service Area[(a)]
Load 4	GWI of Existing Developed Areas in District Wastewater Service Area[(a)]
Load 5	Projected BWF of Future Residential Development Projects in District Wastewater Service Area
Load 6	Projected BWF of Future Non-Residential Development Projects in District Wastewater Service Area
Load 7	Projected BWF of Future Camp Parks Development Projects in District Wastewater Service Area
Load 8	Projected GWI of Future Development Projects in District Wastewater Service Area
Load 9[(b)]	Blank for Future Use
Load 10[(b)]	Blank for Future Use

(a) Existing developed areas include active parcels that have not been identified for Future Development projects.
(b) Value assigned only in Larwin-PS Scenario

MODEL SCENARIOS

InfoSewer software allows the user to create unique scenarios to differentiate between different conditions for analysis within the same hydraulic model. In addition to the base scenarios, 18 additional scenarios were created in the model. These scenarios were created to evaluate various hydraulic conditions which include the following:

- Wet Weather Flow – Nine scenarios were created in the hydraulic model
- Average Dry Weather Flow – Four scenarios were created in the hydraulic model
- Peak Dry Weather Flow –Five scenarios were created in the hydraulic model

The scenario names and associated descriptions are presented in Table 7.

Table 7. Model Scenario Descriptions

Scenario Name	Scenario Description
BASE	Base Network
RBND_EX_ ADWF_2017	2017 Existing System and Rebounded Existing Average Dry Weather Flow
RBND_EX_ PDWF_2017	2017 Existing System and Rebounded Existing Peak Dry Weather Flow
RBND_EX_ PWWF_2017	2017 Existing System and Rebounded Existing Peak Wet Weather Flow
RBND_EX_DESIGN_2017	2017 Existing System and Rebounded Existing Peak Wet Weather Flow with Existing CIP
ADWF_2020	2017 Existing System and 2020 Average Dry Weather Flow
PDWF_2020	2017 Existing System and 2020 Peak Dry Weather Flow
PWWF_2020	2017 Existing System and Peak Wet Weather Flow in 2020
ADWF_2025	2017 Existing System and 2025 Average Dry Weather Flow
PDWF_2025	2017 Existing System and 2025 Peak Dry Weather Flow
PWWF_2025	2017 Existing System and Peak Wet Weather Flow in 2025
PWWF_2025_ATDUBLIN	2017 Existing System and AT Dublin Flow and PWWF in 2025
PWWF_2025_ATDUBLIN_REVFM7	2017 Existing System and AT Dublin Flow and PWWF in 2025 with Revised FM 7
ADWF_2035	2017 Existing System and Average Dry Weather Flow in 2035
PDWF_2035	2017 Existing System and Peak Dry Weather Flow in 2035
LARWIN_PS	2017 Existing System with Larwin PS Flow and Peak Dry Weather Flow in 2035
PWWF_2035	2017 Existing System and Peak Wet Weather Flow in 2035
PWWF_2035_REVFM7	2017 Existing System and Peak Wet Weather Flow in 2035 with Revised FM 7
DESIGN_2035	2025 System and Build-out Peak Wet Weather Flow with Build-out CIP

Note: Revised FM 7 Scenarios: RDII factors for new development projects located in FM-7 are changed to RDII factors of FM-6 in these scenarios. LARWIN PS Scenario includes the 1.47 mgd extra wastewater flow rerouted from Larwin PS to District's collection system during summer to satisfy District's recycle water demand.

In addition, Table 21 of this Modeler's Notebook summarizes and defines the organization of each scenario in the hydraulic model, based on the following items discussed below.

Model Data Sets

Within each scenario, data sets are used to describe specific system facilities and system conditions. Data sets can be common to multiple scenarios or they can be unique to a specific scenario. A brief description of each type of data set is provided below.

Manhole Sets

Manhole sets store the loads assigned to each individual manhole under a specified condition. Developed ADWF data is used to develop the associated patterns for each manhole. For the scenarios listed in Table 5, a unique manhole set is used to represent the various load conditions associated with each scenario, as shown in Table 8.

Table 8. Manhole Sets	
Manhole Set	Definition
BASE	Default
RBND_EX_ADWF_2017	Rebounded Existing Average Dry Weather Flow
RBND_EX_PDWF_2017	Diurnal Patterns with Peakable Rebounded Existing Average Dry Weather Flow
RBND_EX_PWWF_2017	R-T-K Hydrograph, Sub-basin Area, and Diurnal Patterns with Peakable Rebounded Existing Average Dry Weather Flow
2020_ADWF	2020 Average Dry Weather Flow
2020_PDWF	Diurnal Patterns with Peakable 2020 Average Dry Weather Flow
2020_PWWF	R-T-K Hydrograph, Sub-basin Area, and Diurnal Patterns with Peakable 2020 Average Dry Weather Flow
2025_ADWF	2025 Average Dry Weather Flow
2025_PDWF	Diurnal Patterns with Peakable 2025 Average Dry Weather Flow
2025_PWWF	R-T-K Hydrograph, Sub-basin Area, and Diurnal Patterns with Peakable 2025 Average Dry Weather Flow
AT DUBLIN_PWWF_2025	2025 PWWF for AT Dublin Development Project
AT DUBLIN_PWWF_2025_REVFM7	2025 PWWF for AT Dublin Development Project and R-T-K hydrograph of FM 6 is used for new development projects located in FM-7.
2035 _ADWF	2035 Average Dry Weather Flow
2035 _PDWF	Diurnal Patterns with Peakable 2035 Average Dry Weather Flow
LARWIN_PS_2035_PDWF	Diurnal Patterns with Peakable 2035 Average Dry Weather Flow and Flow rerouted from Larwin PS to District's collection system
2035_PWWF	R-T-K Hydrograph, Sub-basin Area, and Diurnal Patterns with Peakable 2035 Average Dry Weather Flow
2035_PWWF_REROUTE_LS	2035 Peak Wet Weather Flow and assuming flow from Fallon Rd LS rerouted to Dublin Blvd Trunk
2035_PWWF_REV_REROUTE_LS	2035 Peak Wet Weather Flow and assuming flow from Fallon Rd LS rerouted to Dublin Blvd Trunk and R-T-K hydrograph of FM 6 is used for new development projects located in FM-7.

Wet Well Sets

Wet Well sets store the hydraulic modeling information (e.g., diameter, bottom elevation, minimum level, maximum level, and initial level) assigned to each individual wet well under a specified condition. Table 9 lists the wet well sets used in the hydraulic model.

Table 9. Wet Well Sets

Wet Well Set	Description	Definition
BASE	Base Wet Well Set	Default (no data)
2017-EXSYS	2017 Existing Wet Wells	Wet Well data for 2017 scenarios

Pipe Sets

Pipe sets store the hydraulic modeling information (e.g., diameter, length, slope, roughness coefficient, and presence of parallel pipes of the same characteristics) assigned to each individual pipe or open channel under a specified condition. Pipes can be either gravity or force mains. Unique pipe sets were created and are shown in Table 10.

Table 10. Pipe Sets

Pipe Set	Description	Definition
BASE	Base Pipe Set	Default
2017PIPESET	2017 Existing Pipe System	Piping system for use in dry weather 2017 scenarios
RBND_EX_CIP	CIP to Serve Existing Design Flow	Improved piping system to serve the existing design flow
2035_CIP	CIP to Serve 2035 Design Flow	Improved piping system to serve the 2035 design flow

Pump Sets

Pump sets store hydraulic modeling information (e.g., type of pump, diameter, elevation, design flow, design head, pump curve) assigned to each individual pump under a specified condition. Table 11 lists the pump sets used in the hydraulic model.

Table 11. Pump Sets

Pump Set	Description	Definition
BASE	Base Pump Set	Default
2017-EXSYS	2017 Existing Pump System	Pump data for 2017 scenarios

Pump Control Sets

Pump Control sets store hydraulic modeling information (e.g., type of control method and on/off settings) assigned to each pump under a specified condition. Table 12 lists the pump control sets used in the hydraulic model.

Table 12. Pump Control Sets

Pump Set	Description	Definition
BASE	Base Pump Set	Default
2017-EXSYS	2017 Existing Pump Controls	Pump operational control for 2017 scenarios

Extra Loading Sets

Extra Loading sets store additional loading hydraulic modeling information (e.g., unpeakable flow, peakable flow, and load patterns) assigned to each manhole under a specified condition. Table 13 lists the extra loading sets used in the hydraulic model.

Table 13. Extra Loading Sets

Extra Loading Sets	Description	Definition
BASE	Base Extra Loading Set	Default
2017-EXSYS	2017 Existing System Extra Loading Set	Default

Flow Split Sets

Flow Split sets store the flow split method information (e.g., fixed percentage, variable flow, inflow-outflow, or automatic split methods) assigned to each pipeline. Table 14 lists the flow split sets used in the hydraulic model.

Table 14. Flow Split Sets

Flow Split Set	Description	Definition
BASE	Base Flow Split Set	Flow Split at each manhole
2017-EXSYS	2017 Existing System Flow Split Set	Flow Split at each manhole
DESIGN-SYSTEM	Future Flow Split – 2017 MP	Blocked the 8-inch gravity main in Donohue Dr. between Gardella Dr. and Hillrose Dr.

Pipe Design Sets

Pipe Design sets store depth-to-diameter design curves, depth-to-diameter analysis curves, replacement and parallel cost curves and user specified criteria for pipeline design. Table 15 lists the pipe design sets used in the hydraulic model.

Table 15. Pipe Design Sets

Pipe Design Set	Definition
BASE	Default
2017-EXSYS	Default

Pipe Infiltration Sets

Pipe Infiltration sets store the infiltration type information (e.g., none, pipe length, pipe diameter-length, pipe surface area, count-based, or pattern-based methods) assigned to each pipeline. Table 16 lists the pipe infiltration sets used in the hydraulic model.

Table 16. Pipe Infiltration Sets

Pipe Infiltration Set	Definition
BASE	Default
2017-EXSYS	Default

Operation Sets

Operation sets store the pattern and curve information (e.g., pump curve data) assigned to each facility. Table 17 lists the operation sets used in the hydraulic model.

Table 17. Operation Sets

Operation Set	Definition
BASE	Default
2017-EXSYS	Default

Facility Manager

The Facility Manager defines the active facilities for each specified scenario by using query sets. Table 18 lists the query sets that are used in the Facility Manager under each specified condition. In the event that a facility is abandoned, a new facility as replacement will be added in the hydraulic model with a unique identification. The abandoned facility will also remain within the hydraulic model as inactive to keep historical mapping facilities (i.e. if a gravity main is replaced and abandoned due to a new gravity main, a parallel gravity main will be drawn in the hydraulic model and the "replaced" facility will be retired as opposed to changing the facility information of the "replaced" gravity main).

Table 18. Query Sets in Facility Manager		
Query Set	Description	Condition
EX_SYSTEM_2017	2017 Existing System Facilities	Use with rebounded existing, 2020, 2025scenarios
ATDUBLIN_SCENARIO_2025	AT Dublin Utilities and 2017 Existing System Facilities	Use with AT Dublin development project scenarios; Includes AT Dublin scenario per AT Dublin capacity analysis TM
LARWIN_PS_EX_SYSTEM_2017	Larwin PS Flow Rerouting System&2017 Exis System Facilities	Use with Larwin PS scenario; Includes the new system to reroute Larwin PS flow to District's collection system
FUTURE_SYSTEM_2017MP	2035 System Facilities	Use with 2035 scenarios; Includes the new system to reroute the Fallon Rd. PS flow to 24-inch trunk in Dublin Blvd.
DESIGN_SYSTEM_2017MP	2035 System Facilities and Parallel CIPs	Use with 2035 Design Scenario; Includes the proposed parallel CIP

Simulation Options

Simulation Options contain the hydraulic simulation criteria necessary for the hydraulic engine to run. The Simulation Option can be altered to associate with a given condition. Table 19 lists the Simulation Options used in the hydraulic model.

Table 19. Simulation Options	
Simulation Option	Description
BASE	Base Simulation Option
2017	2017 Simulation Option for ADWF scenarios
PEAKING	2017 Simulation Option for PDWF and PWWF scenarios

Simulation Time

Simulation Time contains the hydraulic simulation time-step information. The Simulation Time can be altered to associate with a given condition. Table 20 lists the Simulation Time used in the hydraulic model.

Table 20. Simulation Time	
Simulation Time	Description
BASE	Base Simulation Time (Steady State)
PEAKING[(a)]	72-hour Extended Period Simulation

(a) Three Day simulation time required fifteen-minute report time step, one-minute pump hydraulic time step, and one-hour flow pattern time step.

Model Scenario Organization

As discussed previously, each scenario in the hydraulic model is developed using various data sets, query sets, simulation options, and simulation time settings. Table 21 summarizes the data sets, query set, simulation option, and simulation time assigned to each scenario.

Table 21. Organization of Model Scenarios

Scenario Name	Specific Report Option	Simulation Option	Simulation Time	Facility Query Set	Manhole Set	Wet Well Set	Pipe Set	Pump Set	Pump Control Set	Extra Loading Set	Flow Split Set	Pipe Design Set	Pipe Infiltration Set	Operation Set
BASE	BASE	BASE	BASE	ENTIRE NETWORK	BASE	BASE	BASE	BASE	BASE	BASE	BASE	BASE	BASE	BASE
RBND_EX_ ADWF_2017	2017	2017	BASE	EX_SYSTEM_2017	RBND_EX_ADWF_2017	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
RBND_EX_ PDWF_2017	2017	PEAKING	PEAKING	EX_SYSTEM_2017	RBND_EX_PDWF_2017	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
RBND_EX_ PWWF_2017	2017	PEAKING	PEAKING	EX_SYSTEM_2017	RBND_EX_PWWF_2017	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	DESIGN-SYSTEM	2017-EXSYS	2017-EXSYS	2017-EXSYS
DESIGN_RBND_EX_2017	2017	PEAKING	PEAKING	EX_SYSTEM_2017	RBND_EX_PWWF_2017	2017-EXSYS	RBND_EX_CIP	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
ADWF_2020	2017	2017	BASE	EX_SYSTEM_2017	ADWF_2020	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
PDWF_2020	2017	PEAKING	PEAKING	EX_SYSTEM_2017	PDWF_2020	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
PWWF_2020	2017	PEAKING	PEAKING	EX_SYSTEM_2017	2020_PWWF	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
ADWF_2025	2017	2017	BASE	EX_SYSTEM_2017	ADWF_2025	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
PDWF_2025	2017	PEAKING	PEAKING	EX_SYSTEM_2017	PDWF_2025	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
PWWF_2025	2017	PEAKING	PEAKING	EX_SYSTEM_2017	2025_PWWF	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
PWWF_2025_ATDUBLIN	2017	PEAKING	PEAKING	ATDUBLIN_SCENARIO_2025	ATDUBLIN_PWWF_2025	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
PWWF_2025_ATDUBLIN_REVFM7	2017	PEAKING	PEAKING	ATDUBLIN_SCENARIO_2025	ATDUBLIN_PWWF_2025_REVFM7	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
ADWF_2035	2017	2017	BASE	FUTURE_SYSTEM_2017MP	ADWF_2035	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
PDWF_2035	2017	PEAKING	PEAKING	FUTURE_SYSTEM_2017MP	PDWF_2035	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
Larwin_PS	2017	PEAKING	PEAKING	LARWIN_PS_EX_SYSTEM_2017	LARWIN_PS_2035_PDWF	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
PWWF_2035	2017	PEAKING	PEAKING	FUTURE_SYSTEM_2017MP	2035_PWWF_REROUTE_LS	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
PWWF_2035_REVFM7_NEW DEVELOPMENT	2017	PEAKING	PEAKING	FUTURE_SYSTEM_2017MP	2035_PWWF_REV_REROUTE_LS	2017-EXSYS	2017PIPESET	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS	2017-EXSYS
DESIGN_2035	2017	PEAKING	PEAKING	DESIGN_SYSTEM_2017MP	2035_PWWF_REV_REROUTE_LS	2017-EXSYS	2035_CIP	2017-EXSYS	2017-EXSYS	2017-EXSYS	DESIGN-SYSTEM	2017-EXSYS	2017-EXSYS	2017-EXSYS

Average Dry Weather Flow

A 48-hour EPS was modeled using the ADWF values allocated into the hydraulic model with no peaking or diurnal patterns. The EPS ADWF scenarios are intended only as reference scenarios for how flows are peaked during the peak dry weather flow analysis.

Peak Dry Weather Flow

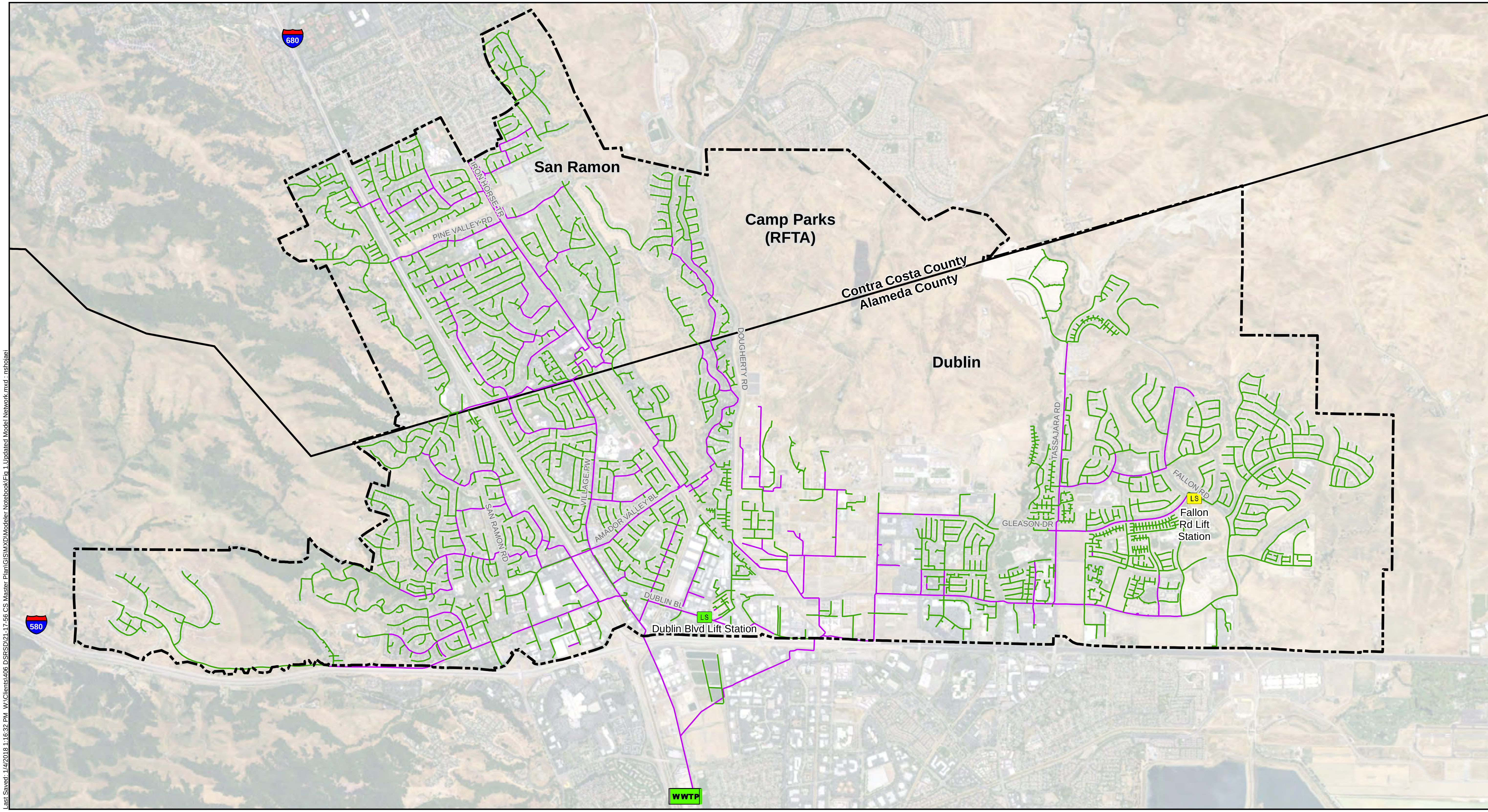
A 72-hour EPS was modeled using the ADWF values allocated into the hydraulic model and applying a diurnal peaking factor to simulate the PDWF. Diurnal patterns were developed for residential and non-residential type land uses and applied within the hydraulic model. These design diurnal patterns are independent of location within the collection system and provide all new development and growth with consistent peak factors typical of their usage patterns. The design residential diurnal pattern can be seen on Figure 2. The non-residential diurnal pattern can be seen on Figure 3. Separated diurnal patterns are developed for camp parks area and Larwin PS rerouted flow to District's collection system per their unique pattern.

Peak Wet Weather Flow

As discussed in Chapter 4 of the Wastewater Master Plan, PWWF is calculated by adding RDII to the PDWF. For this Wastewater Master Plan, the R-T-K factors are utilized to generate hydrographs from each tributary area that represent estimated flows during and immediately after rainfall events caused by potential seepage of precipitation into the collection system. The R-T-K factors used in the 2018 Wastewater Master Plan were estimated via EPA Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox. The R-T-K factors for each flow monitoring basin are shown in Table 22.

Table 22. Calibrated RTK Values for PWWF

Basin	Total R	R1	R2	R3	T1, hours	T2, hours	T3, hours	K1	K2	K3
1	1.20%	0.10%	0.10%	1.00%	1	4.00	12.00	1.00	2.00	5.00
2	0.24%	0.16%	0.04%	0.04%	1	4.00	12.00	1.00	2.00	5.00
3	2.80%	0.30%	0.50%	2.00%	2	4.00	12.00	1.00	1.00	6.00
4	0.48%	0.10%	0.10%	0.28%	1	3.00	10.00	1.00	2.00	2.00
5	0.64%	0.21%	0.21%	0.22%	1	4.00	12.00	1.00	2.00	5.00
6	0.16%	0.16%	0.00%	0.00%	1	4.00	6.00	0.75	2.00	2.00
7	1.40%	1.00%	0.40%	0.00%	1	2.00	6.00	1.00	2.00	2.00
8	6.00%	0.50%	0.50%	5.00%	1	2.00	12.00	1.00	2.00	5.00
9	2.90%	0.40%	0.50%	2.00%	2	4.00	12.00	1.00	2.00	2.00
10	5.00%	1.00%	2.00%	2.00%	2	4.00	12.00	1.00	2.00	2.00
11	1.15%	0.30%	0.25%	0.60%	1	4.00	10.00	1.00	2.00	2.00
12	1.80%	0.25%	0.55%	1.00%	2	4.00	12.00	1.00	2.00	2.00
13	0.62%	0.12%	0.20%	0.30%	1	4.00	12.00	1.00	2.00	2.00
14	1.75%	0.10%	0.90%	0.75%	1	4.00	10.00	1.00	2.00	4.00
15	0.40%	0.17%	0.13%	0.10%	1	4.00	12.00	1.00	2.00	2.00



Symbology

- WWTP WWTP
- LS Permanent Lift Station
- LS Temporary Lift Station
- Gravity Main in 2005 Model
- Gravity Main in 2018 Model
- Wastewater Service Boundary

0 1,600 3,200
Scale in Feet

WEST YOST ASSOCIATES

Figure 1

Updated Model Network

Dublin San Ramon Services District
Collection System Master Plan

Last Saved: 1/4/2018 1:16:32 PM W:\Clients\406 DSRSD\21-17-56 CS Master Plan\GIS\MXD\Modeler Notebook\Fig 1.Updated Model Network.mxd : nshojaei

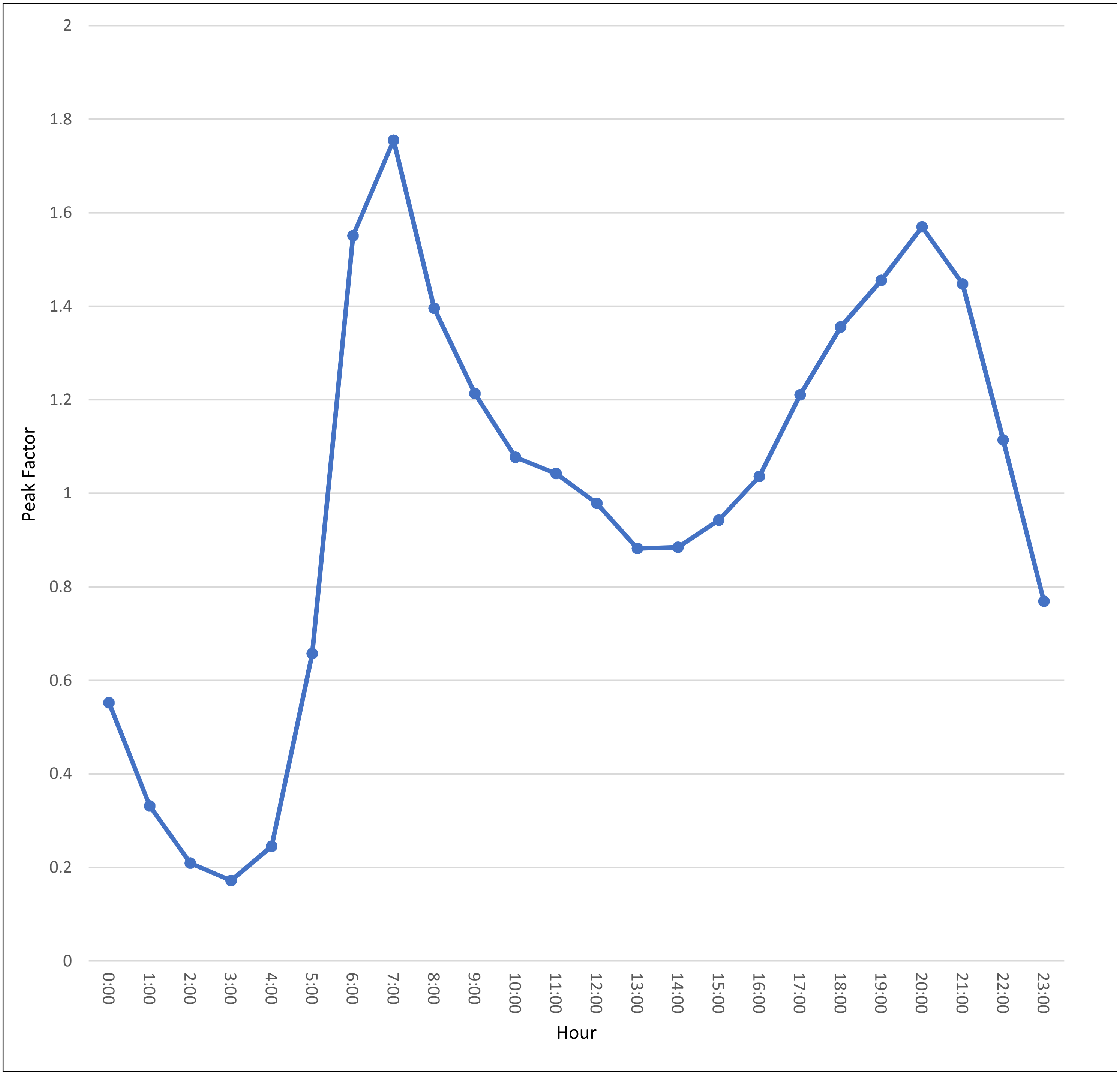
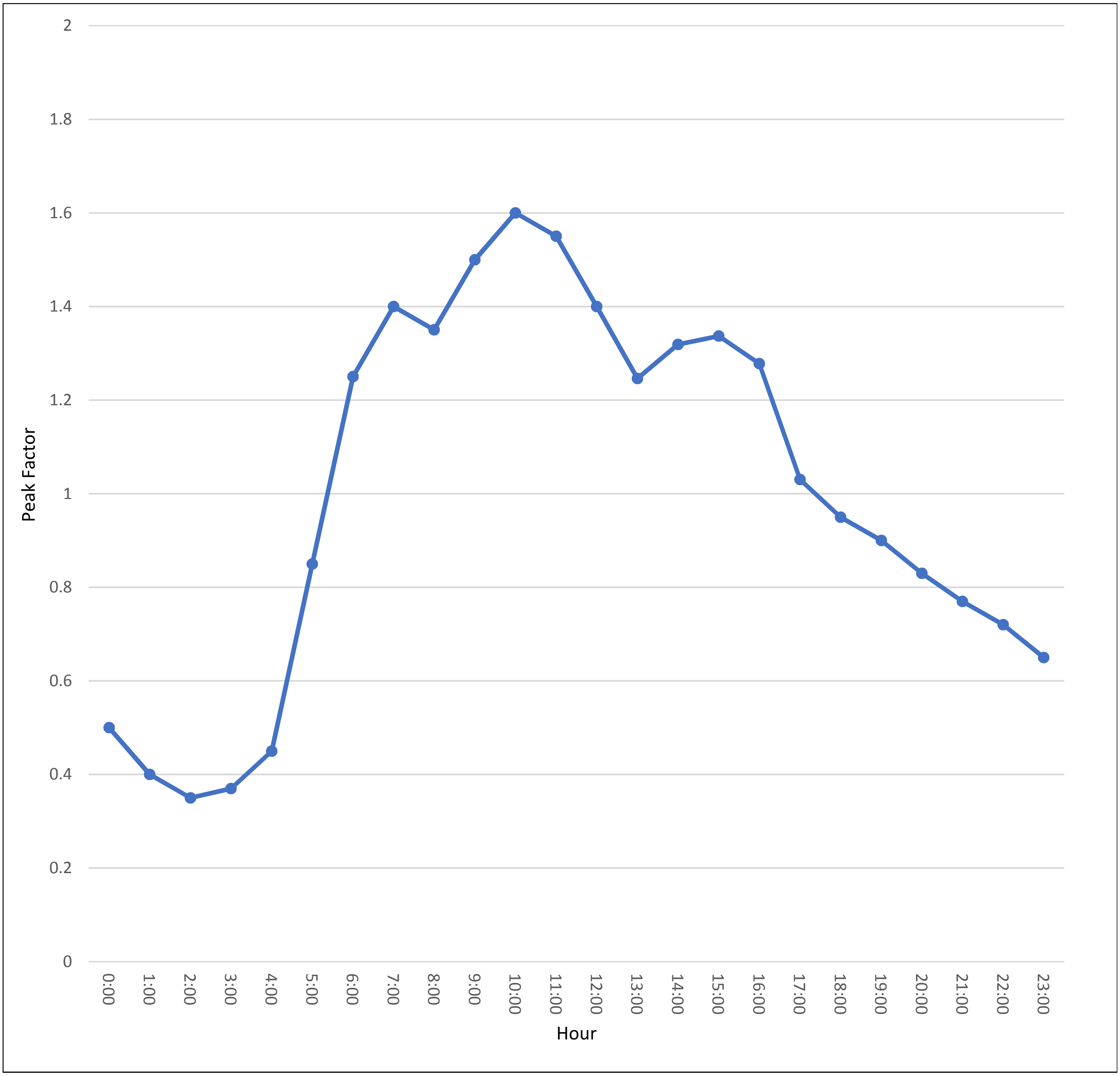


Figure 2

Residential
Design Diurnal Pattern

WEST YOST ASSOCIATES



WEST YOST ASSOCIATES

Figure 3

Non-Residential Design Diurnal Pattern

Dublin San Ramon Services District
Collection System Master Plan

ATTACHMENT 1

GIS Gap Analysis

Table 1. List of Gravity Mains with Unknown Invert Elevation(s)

GIS Information From Gravity Main Shapefile								Proposed Invert Elevations		West Yost Comment
Pipe ID	Diameter	Length, ft	Slope	Upstream Manhole ID	Downstream Manhole ID	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	
4926	8	43	0	X19A2-2	X19A2-1	0	0	389	386	Unknown US and DS Invert Elevation
4850	8	319	0	X19D3-10	X19D3-9	0	0	409	408	Unknown US and DS Invert Elevation
923	8	432	0	U20D1-27	U20D1-26	0	0	339	338	Unknown US and DS Invert Elevation
1454	10	131	0	V19A2-44	V19A2-43	0	0	340	340	Unknown US and DS Invert Elevation
3493	8	226	0	V20D1-25	V20D1-40	0	0	321	320	Unknown US and DS Invert Elevation
4848	8	243	0	X19D3-9	X19D3-8	0	0	408	407	Unknown US and DS Invert Elevation
4849	8	100	0	X19D3-11	X19D3-10	0	0	410	409	Unknown US and DS Invert Elevation
1441	8	114	0	V19A2-32	V19A2-29	0	0	341	341	Unknown US and DS Invert Elevation
1607	8	225	0	U18A1-27	U18A1-26	0	0	371	370	Unknown US and DS Invert Elevation
7182	8	183	0	U18B2-34	U18B2-33	0	0	351	350	Unknown US and DS Invert Elevation
1293	8	175	0	U19B2-15	U19B2-14	0	0	339	338	Unknown US and DS Invert Elevation
1294	8	261	0	U19B2-16	U19B2-14	0	0	339	338	Unknown US and DS Invert Elevation
2129	8	166	0	U19B2-17	U19B2-16	0	0	340	339	Unknown US and DS Invert Elevation
2304	8	103	0	V18B1-3	V18B1-2	0	0	375	375	Unknown US and DS Invert Elevation
83	8	103	0	V18B1-4	V18B1-2	0	0	376	375	Unknown US and DS Invert Elevation
69	8	153	0	V18B1-2	V18B1-1	0	0	375	374	Unknown US and DS Invert Elevation
2189	8	121	0	V19A2-29	V19A2-27	0	0	341	340	Unknown US and DS Invert Elevation
1438	8	140	0	V19A2-28	V19A2-27	0	0	341	340	Unknown US and DS Invert Elevation
1437	8	84	0	V19A2-27	V19A2-26	0	0	340	340	Unknown US and DS Invert Elevation
1440	8	165	0	V19A2-31	V19A2-30	0	0	341	340	Unknown US and DS Invert Elevation
2190	10	135	0	V19A2-30	V19A2-26	0	0	340	340	Unknown US and DS Invert Elevation
1436	10	122	0	V19A2-26	V19A2-43	0	0	340	340	Unknown US and DS Invert Elevation
1674	42	176	0	V21A2-13	V21A2-12	0	0	314	314	Unknown US and DS Invert Elevation
2095	8	68	0	U19C4-14	U19C4-13	0	0	343	343	Unknown US and DS Invert Elevation
5846	8	193	0	X20B5-16	X20B5-15	0	0	365	364	Unknown US and DS Invert Elevation
5754	8	104	0	X20B4-45	X20B4-43	0	0	376	375	Unknown US and DS Invert Elevation
6059	8	112	0	X20B4-41	X20B4-39	0	0	376	375	Unknown US and DS Invert Elevation
6060	8	98	0	X20B4-40	X20B4-39	0	0	376	375	Unknown US and DS Invert Elevation
303	8	118	0	U18C2-16	U18C2-15	0	0	354	353	Unknown US and DS Invert Elevation
2645	8	72	0	V20D1-31	V20D1-30	0	0	322	322	Unknown US and DS Invert Elevation
2644	8	14	0	V20D1-32	V20D1-31	0	0	322	322	Unknown US and DS Invert Elevation
2639	8	223	0	V20D1-37	V20D1-31	0	0	323	322	Unknown US and DS Invert Elevation
2638	8	288	0	V20D1-38	V20D1-37	0	0	324	323	Unknown US and DS Invert Elevation
2637	8	328	0	V20D1-39	V20D1-38	0	0	325	324	Unknown US and DS Invert Elevation
2646	8	236	0	V20D1-30	V20D1-29	0	0	322	321	Unknown US and DS Invert Elevation
2643	8	87	0	V20D1-33	V20D1-32	0	0	322	322	Unknown US and DS Invert Elevation
2642	8	78	0	V20D1-34	V20D1-33	0	0	322	322	Unknown US and DS Invert Elevation
2641	8	76	0	V20D1-35	V20D1-34	0	0	323	322	Unknown US and DS Invert Elevation
2640	8	127	0	V20D1-36	V20D1-35	0	0	323	323	Unknown US and DS Invert Elevation
6044	8	229	0	W20C1-28	W20C1-27	0	0	325	324	Unknown US and DS Invert Elevation
5850	8	122	0	X20B4-39	X20B4-38	0	0	375	375	Unknown US and DS Invert Elevation
5781	8	118	0	X20B4-44	X20B4-43	0	0	376	375	Unknown US and DS Invert Elevation
6128	8	57	0	X19D3-63	X19D3-62	0	0	414	414	Unknown US and DS Invert Elevation
6394	8	97	0	W19C3-35	W19C3-34	0	0	347	346	Unknown US and DS Invert Elevation
6395	8	20	0	W19C3-34	W19C3-33	0	0	346	346	Unknown US and DS Invert Elevation
6396	8	118	0	W19C3-33	W19C3-31	0	0	346	346	Unknown US and DS Invert Elevation
6397	8	20	0	W19C3-32	W19C3-31	0	0	346	346	Unknown US and DS Invert Elevation
6150	8	276	0	Y20A5-14	Y20A5-13	0	0	345	344	Unknown US and DS Invert Elevation
6805	8	33	0	X20D1-14	X20D1-13	0	0	342	342	Unknown US and DS Invert Elevation
6804	8	44	0	X20D1-15	X20D1-14	0	0	342	342	Unknown US and DS Invert Elevation
6803	8	68	0	X201-16	X20D1-15	0	0	342	342	Unknown US and DS Invert Elevation
6981	8	57	0	Y20A5-16	Y20A5-15	0	0	345	344	Unknown US and DS Invert Elevation
6985	8	15	0	Y20A5-17	Y20A5-16	0	0	345	345	Unknown US and DS Invert Elevation
6984	8	50	0	Y20A5-18	Y20A5-17	0	0	345	345	Unknown US and DS Invert Elevation
6983	8	56	0	Y20A5-19	Y20A5-18	0	0	345	345	Unknown US and DS Invert Elevation
6982	8	149	0	Y20A5-20	Y20A5-19	0	0	345	345	Unknown US and DS Invert Elevation
6989	8	182	0	X20A6-2	X20A6-1	0	0	331	330	Unknown US and DS Invert Elevation
6988	8	354	0	X20A6-3	X20A6-2	0	0	332	331	Unknown US and DS Invert Elevation
6987	8	329	0	X20A6-4	X20A6-3	0	0	333	332	Unknown US and DS Invert Elevation
6991	8	362	0	W19D3-51	W19D3-50	0	0	370	369	Unknown US and DS Invert Elevation
6992	8	186	0	W19D3-50	W19D3-49	0	0	369	369	Unknown US and DS Invert Elevation
6993	8	149	0	W19D3-49	W19D3-48	0	0	369	368	Unknown US and DS Invert Elevation
6994	8	141	0	W19D3-48	W19D3-47	0	0	368	368	Unknown US and DS Invert Elevation
6995	8	157	0	W19D3-47	W19D3-46	0	0	368	367	Unknown US and DS Invert Elevation
6996	8	74	0	W19D3-46	W19D3-39	0	0	367	367	Unknown US and DS Invert Elevation
7007	8	86	0	Y20A6-66	Y20A6-65	0	0	439	430	Unknown US and DS Invert Elevation
5806	8	115	0	X20B5-7	X20B5-6	0	0	354	353	Unknown US and DS Invert Elevation
5764	8	44	0	X20B4-42	X20B4-38	0	0	375	375	Unknown US and DS Invert Elevation
5780	8	122	0	X20B4-43	X20B4-42	0	0	375	375	Unknown US and DS Invert Elevation
917	10	129	0	U20D1-44	U20D1-1	0	0	325	342	Unknown US and DS Invert Elevation
7041	12	348	0	U20A1-54	U20A1-55	0	0	332	331	Unknown US and DS Invert Elevation
7042	12	72	0	U20A1-55	U20A1-56	0	0	323	322	Unknown US and DS Invert Elevation
7066	8	160	0	W19D3-54	W19D3-53	0	0	372	371	Unknown US and DS Invert Elevation
7067	8	137	0	W19D3-53	W19D3-43	0	0	371	371	Unknown US and DS Invert Elevation
7068	8	312	0	W19D3-59	W19D3-58	0	0	375	374	Unknown US and DS Invert Elevation
7069	8	315	0	W19D3-58	W19D3-57	0	0	374	373	Unknown US and DS Invert Elevation
7070	8	49	0	W19D3-57	W19D3-56	0	0	373	373	Unknown US and DS Invert Elevation
7071	8	101	0	W19D3-56	W19D3-55	0	0	373	372	Unknown US and DS Invert Elevation
7072	8	103	0	W19D3-55	W19D3-54	0	0	372	372	Unknown US and DS Invert Elevation
7340	10	94	0	U20D1-2	U20D1-44	0	0	325	325	Unknown US and DS Invert Elevation
7283	8	385	0	U20D2-27	U20D2-26	0	0	328	327	Unknown US and DS Invert Elevation
7284	8	189	0	U20D2-28	U20D2-27	0	0	336	335	Unknown US and DS Invert Elevation
7285	8	66	0	U20D2-26	U20D2-17	0	0	327	327	Unknown US and DS Invert Elevation
1453	10	88	0	V19A2-43	V19A2-25	0	0	340	339	Unknown US and DS Invert Elevation
4821	8	390	0	V20D1-44	V20D1-43	-8	-8	323	321	Unknown US and DS Invert Elevation Known Slope
4822	8	73	0	V20D1-45	V20D1-44	-8	-8	323	323	Unknown US and DS Invert Elevation Known Slope
4511	8	86	0	W19C2-14	W19C2-13	0	0	379	379	Unknown US and DS Invert Elevation Known Slope
2806	8	300	0	T20A1-2	T20A1-1	0	0	434	432	Unknown US and DS Invert Elevation Known Slope
2805	8	202	0	T20A1-3	T20A1-2	0	0	434	434	Unknown US and DS Invert Elevation Known Slope
2804	8	181	0	T20A1-57	T20A1-3	0	0	435	434	Unknown US and DS Invert Elevation Known Slope
2803	8	181	0	T20A1-4	T20A1-57	0	0	468	435	Unknown US and DS Invert Elevation Known Slope
2802	8	107	0	T20A1-5	T20A1-4	0	0	468	468	Unknown US and DS Invert Elevation Known Slope
2801	8	221	0	T20A1-6	T20A1-5	0	0	469	468	Unknown US and DS Invert Elevation Known Slope
3323	24	284	0	W20C1-24	W20C1-23	0	0	327	326	Unknown US and DS Invert Elevation Known Slope
3324	24	340	0	W20C1-25	W20C1-24	0	0	328	327	Unknown US and DS Invert Elevation Known Slope
3325	24	282	0	W20C1-26	W20C1-25	0	0	329	328	Unknown US and DS Invert Elevation Known Slope
3344	18	411	0	V19D1-1	W20C1-26	0	0	330	329	Unknown US and DS Invert Elevation Known Slope
3346	8	568	0	V19D1-3	V19D1-2	0	0	331	330	Unknown US and DS Invert Elevation Known Slope
3345	8	362	0	V19D1-2	V19D1-1	0	0	330	330	Unknown US and DS Invert Elevation Known Slope
3352	18	373	0	V19D1-9	V19D1-4	0	0	334	331	Unknown US and DS Invert Elevation Known Slope
3353	18	128	0	V19D1-10	V19D1-9	0	0	335	334	Unknown US and DS Invert Elevation Known Slope
3347	18	108	0	V19D1-4	V19D1-1	0	0	331	330	Unknown US and DS Invert Elevation Known Slope
3348	8	112	0	V19D1-5	V19D1-4	0	0	331	331	Unknown US and DS Invert Elevation Known Slope
3350	8	302	0	V19D1-7	V19D1-6	0	0	331	331	Unknown US and DS Invert Elevation Known Slope
3351	8	189	0	V19D1-8	V19D1-7	0	0	332	331	Unknown US and DS Invert Elevation Known Slope
3354	18	138	0	V19D1-11	V19D1-10	0	0	336	335	Unknown US and DS Invert Elevation Known Slope
3349	8	188	0	V19D1-6	V19D1-5	0	0	331	331	Unknown US and DS Invert Elevation Known Slope
2800	8	250	0	T20A1-7	T20A1-6	0	0	470	469	Unknown US and DS Invert Elevation Known Slope
2770	8	86	0	T20A1-52	T20A1-51	0	0	728	727	Unknown US and DS Invert Elevation Known Slope
2769	8	125	0	T20A1-53	T20A1-52	0	0	728	728	Unknown US and DS Invert Elevation Known Slope
2768	8	312	0	T20A1-54	T20A1-53	0	0	730	728	Unknown US and DS Invert Elevation Known Slope
2767	8	236	0	T20A1-55	T20A1-54	0	0	730	730	Unknown US and DS Invert Elevation Known Slope
2762	8	214	0	T20A1-56	T20A1-55	0	0	731	730	Unknown US and DS Invert Elevation Known Slope
406	21	69	0	U16C2-1	U16C1-1	0	0	368	368	Unknown US and DS Invert Elevation Known Slope
6135	12	265	0	V20B3-1	W20C1-26	0	0	330	329	Unknown US and DS Invert Elevation Known Slope
6136	12	48	0	V20B3-2	V20B3-1	0	0	330	330	Unknown US and DS Invert Elevation Known Slope
6134	12	340	0	V20B3-3	V20B3-2	0	0	330	329	Unknown US and DS Invert Elevation Known Slope
662	8	214	0	U16B1-34	U16B1-18	0	0	473	423	Unknown US and DS Invert Elevation Known Slope
5570	12	290	0	V21A3-FSLSNV	V21A3-FSLSNFM	0	0	317	313	Unknown US and DS Invert Elevation Known Slope
4429	8	155	0	V20B1-31	V20B1-20	0	0	326	326	Unknown US and DS Invert Elevation Known Slope
4436	8	270	0	V20B1-38	V20B1-31	0	0	327	326	Unknown US and DS Invert Elevation Known Slope
4437	8	126	0	V20B1-39	V20B1-38	0	0	328	327	Unknown US and DS Invert Elevation Known Slope
4438	8	134	0	V20B1-40	V20B1-39	0	0	328	328	Unknown US and DS Invert Elevation Known Slope
4440	8	97	0	V20B1-42	V20B1-40	0	0	329	328	Unknown US and DS Invert Elevation Known Slope
4439	8	81	0	V20B1-41	V20B1-40	0	0	329	328	Unknown US and DS Invert Elevation Known Slope
4430	8	150	0	V20B1-32	V20B1-31	0	0	327	326	Unknown US and DS Invert Elevation Known Slope
4431	8	87	0	V20B1-33	V20B1-32	0	0	327	327	Unknown US and DS Invert Elevation Known Slope
4432	8	185	0	V20B1-34	V20B1-33	0	0	328	327	Unknown US and DS Invert Elevation Known Slope
4434	8	133	0	V20B1-36	V20B1-34	0	0	328	328	Unknown US and DS Invert Elevation Known Slope
4435	8	80	0	V20B1-37	V20B1-36	0	0	329	328	Unknown US and DS Invert Elevation Known Slope
4433	8	86	0	V20B1-35	V20B1-34	0	0	328	328	Unknown US and DS Invert Elevation Known Slope
2551	8	40	0	V19B1-54	V19B1-37	0	0	377	377	Unknown US and DS Invert Elevation Known Slope
1679	6	129	1	T16D1-11	T16D1-9	0	0	399	397	Unknown US and DS Invert Elevation Known Slope
598	8	185	1	T16D4-9	T16D4-6	0	0	389	387	Unknown US and DS Invert Elevation Known Slope
584	8	261	1	T16D4-10	T16D4-9	0	0	393	391	Unknown US and DS Invert Elevation Known Slope
3531	15	82	0	W19D3-21	W19D3-20	0	0	346	345	Unknown US and DS Invert Elevation Known Slope
5094	15	396	0	W19D3-6	W19D3-5	0	0	340	339	Unknown US and DS Invert Elevation Known Slope
3564	8	37	0	W19D1-7	W19D1-6	0	0	340	340	Unknown US and DS Invert Elevation Known Slope
3565	8	66	0	W19D1-8	W19D1-6	0	0	340	340	Unknown US and DS Invert Elevation Known Slope
3566	8	84	0	W19D1-9	W19D1-8	0	0	340	340	Unknown US and DS Invert Elevation Known Slope
2137	8	129	0	V19A3-31	V19A3-30	0	0	332	332	Unknown US and DS Invert Elevation Known Slope
3810	8	99	0	W20D1-42	W20D1-41	0	0	345	345	Unknown US and DS Invert Elevation Known Slope
3811	8	90	0	W20D1-43	W20D1-42	0	0	346	345	Unknown US and DS Invert Elevation Known Slope
3809	8	101	0	W20D1-41	W20D1-40	0	0	345	345	Unknown US and DS Invert Elevation Known Slope
1986	8	106	1	V20A2-21	V20A2-20	0	0	329	328	Unknown US and DS Invert Elevation Known Slope
974	8	151	1	V20A2-20	V20A2-19	0	0	328	327	Unknown US and DS Invert Elevation Known Slope
971	8	163	1	V20A2-17	V20A2-16	0	0	329	327	Unknown US and DS Invert Elevation Known Slope
970	8	94	1	V20A2-16	V20A2-15	0	0	327	326	Unknown US and DS Invert Elevation Known Slope
3393	8	209	0	V19D2-15	V19D2-14	0	0	373	371	Unknown US and DS Invert Elevation Known Slope
3394	8	160	0	V19D2-16	V19D2-15	0	0	377	373	Unknown US and DS Invert Elevation Known Slope
3395	8	58	0	V19D2-17	V19D2-16	0	0	379	377	Unknown US and DS Invert Elevation Known Slope
3397	12	10	0	V19D2-18	V19D2-19	0	0	360	360	Unknown US and DS Invert Elevation Known Slope
3398	12	129	0	V19D2-20	V19D2-19	0	0	361	360	Unknown US and DS Invert Elevation Known Slope
3399	12	58	0	V19D2-21	V19D2-20	0	0	361	361	Unknown US and DS Invert Elevation Known Slope
3400	12	169	0	V19D2-22	V19D2-21	0	0	361	361	Unknown US and DS Invert Elevation Known Slope
3401	12	109	0	V19D2-23	V19D2-22	0	0	362	361	Unknown US and DS Invert Elevation Known Slope

Table 1. List of Gravity Mains with Unknown Invert Elevation(s)

GIS Information From Gravity Main Shapefile								Proposed Invert Elevations		West Yost Comment
Pipe ID	Diameter	Length, ft	Slope	Upstream Manhole ID	Downstream Manhole ID	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	
3402	12	363	0	V19D2-24	V19D2-23	0	0	363	362	Unknown US and DS Invert Elevation Known Slope
3403	12	36	0	V19D2-25	V19D2-23	0	0	362	362	Unknown US and DS Invert Elevation Known Slope
3404	12	125	0	V19D2-26	V19D2-25	0	0	363	362	Unknown US and DS Invert Elevation Known Slope
3405	12	173	0	V19D2-27	V19D2-26	0	0	364	363	Unknown US and DS Invert Elevation Known Slope
3368	12	45	0	V19D1-25	V19D1-24	0	0	362	362	Unknown US and DS Invert Elevation Known Slope
3369	12	216	0	V19D1-26	V19D1-25	0	0	364	362	Unknown US and DS Invert Elevation Known Slope
462	21	819	0	U16C3-7	U16C2-1	0	0	373	368	Unknown US and DS Invert Elevation Known Slope
1843	8	145	2	U15C1-30	U15C1-29	0	0	483	457	Unknown US and DS Invert Elevation Known Slope
461	24	419	0	U16C3-2	U17A2-1	0	0	365	363	Unknown US and DS Invert Elevation Known Slope
3477	8	297	0	W19C3-29	W19C3-28	0	0	358	358	Unknown US and DS Invert Elevation Known Slope
3581	8	100	0	W19D1-24	W19D1-23	0	0	347	348	Unknown US and DS Invert Elevation Known Slope
3408	12	45	0	V19D2-30	V19D2-29	0	0	366	365	Unknown US and DS Invert Elevation Known Slope
3420	8	170	0	V19D2-49	V19D2-48	0	0	361	361	Unknown US and DS Invert Elevation Known Slope
3410	12	195	0	V19D2-40	V19D2-18	0	0	360	360	Unknown US and DS Invert Elevation Known Slope
3411	10	213	0	V19D2-41	V19D2-40	0	0	360	360	Unknown US and DS Invert Elevation Known Slope
3396	12	134	0	V19D2-19	V19D2-10	0	0	360	359	Unknown US and DS Invert Elevation Known Slope
3389	8	347	0	V19D2-11	V19D2-10	0	0	361	359	Unknown US and DS Invert Elevation Known Slope
3390	8	74	0	V19D2-12	V19D2-11	0	0	363	361	Unknown US and DS Invert Elevation Known Slope
3391	8	87	0	V19D2-13	V19D2-12	0	0	365	363	Unknown US and DS Invert Elevation Known Slope
3392	8	181	0	V19D2-14	V19D2-13	0	0	376	365	Unknown US and DS Invert Elevation Known Slope
3370	12	67	0	V19D1-27	V19D1-26	0	0	364	364	Unknown US and DS Invert Elevation Known Slope
3371	12	173	0	V19D1-28	V19D1-27	0	0	365	364	Unknown US and DS Invert Elevation Known Slope
3372	12	208	0	V19D1-29	V19D1-28	0	0	366	365	Unknown US and DS Invert Elevation Known Slope
3373	12	168	0	V19D1-30	V19D1-29	0	0	370	366	Unknown US and DS Invert Elevation Known Slope
3374	12	216	0	V19D1-31	V19D1-30	0	0	373	370	Unknown US and DS Invert Elevation Known Slope
3375	12	68	0	V19D1-32	V19D1-31	0	0	373	372	Unknown US and DS Invert Elevation Known Slope
3376	12	99	0	V19D1-33	V19D1-32	0	0	373	373	Unknown US and DS Invert Elevation Known Slope
3414	8	159	0	V19D2-43	V19D2-42	0	0	360	360	Unknown US and DS Invert Elevation Known Slope
3412	10	360	0	V19D2-42	V19D2-41	0	0	360	360	Unknown US and DS Invert Elevation Known Slope
3415	8	134	0	V19D2-44	V19D2-42	0	0	360	360	Unknown US and DS Invert Elevation Known Slope
3417	8	235	0	V19D2-46	V19D2-45	0	0	360	360	Unknown US and DS Invert Elevation Known Slope
3418	8	291	0	V19D2-47	V19D2-46	0	0	361	360	Unknown US and DS Invert Elevation Known Slope
3419	8	205	0	V19D2-48	V19D2-47	0	0	361	361	Unknown US and DS Invert Elevation Known Slope
3421	8	226	0	V19D2-50	V19D2-49	0	0	361	361	Unknown US and DS Invert Elevation Known Slope
3554	8	257	0	W19D3-43	W19D3-42	0	0	371	370	Unknown US and DS Invert Elevation Known Slope
3553	8	248	0	W19D3-42	W19D3-41	0	0	370	369	Unknown US and DS Invert Elevation Known Slope
3778	8	50	0	W20D1-10	W20D1-9	0	0	342	342	Unknown US and DS Invert Elevation Known Slope
5095	15	355	0	W19D3-7	W19D3-6	0	0	340	340	Unknown US and DS Invert Elevation Known Slope
3474	8	59	0	W19C3-26	W19C3-25	0	0	357	357	Unknown US and DS Invert Elevation Known Slope
3475	8	491	0	W19C3-27	W19C3-26	0	0	358	357	Unknown US and DS Invert Elevation Known Slope
2757	8	163	0	V20B1-28	V20B1-24	0	0	331	330	Unknown US and DS Invert Elevation Known Slope
1666	8	162	0	V20B1-24	V20B1-23	0	0	330	330	Unknown US and DS Invert Elevation Known Slope
999	8	229	0	V20B1-23	V20B1-22	0	0	330	329	Unknown US and DS Invert Elevation Known Slope
3860	8	162	0	X20A3-17	X20A3-16	0	0	349	348	Unknown US and DS Invert Elevation Known Slope
3862	8	112	0	X20A3-19	X20A3-18	0	0	349	348	Unknown US and DS Invert Elevation Known Slope
3864	8	162	0	X20A3-21	X20A3-20	0	0	349	349	Unknown US and DS Invert Elevation Known Slope
3866	8	112	0	X20A3-23	X20A3-22	0	0	349	349	Unknown US and DS Invert Elevation Known Slope
3868	8	162	0	X20A3-25	X20A3-24	0	0	350	349	Unknown US and DS Invert Elevation Known Slope
3861	8	73	0	X20A3-18	X20A3-16	0	0	348	348	Unknown US and DS Invert Elevation Known Slope
3863	8	96	0	X20A3-20	X20A3-18	0	0	349	348	Unknown US and DS Invert Elevation Known Slope
3865	8	70	0	X20A3-22	X20A3-20	0	0	349	349	Unknown US and DS Invert Elevation Known Slope
3867	8	104	0	X20A3-24	X20A3-22	0	0	349	349	Unknown US and DS Invert Elevation Known Slope
3869	8	54	0	X20A3-26	X20A3-24	0	0	350	349	Unknown US and DS Invert Elevation Known Slope
3900	8	106	0	X20A3-57	X20A3-56	0	0	351	351	Unknown US and DS Invert Elevation Known Slope
3423	8	151	0	V19D2-52	V19D2-51	0	0	361	361	Unknown US and DS Invert Elevation Known Slope
3424	8	50	0	V19D2-53	V19D2-52	0	0	361	361	Unknown US and DS Invert Elevation Known Slope
3425	8	74	0	V19D2-54	V19D2-53	0	0	361	361	Unknown US and DS Invert Elevation Known Slope
3426	8	225	0	V19D2-55	V19D2-54	0	0	362	361	Unknown US and DS Invert Elevation Known Slope
4253	8	350	0	T17A3-7	T17A3-3	0	0	403	401	Unknown US and DS Invert Elevation Known Slope
4250	8	120	0	T17A3-4	T17A3-3	0	0	402	401	Unknown US and DS Invert Elevation Known Slope
4251	8	94	0	T17A3-5	T17A3-4	0	0	402	402	Unknown US and DS Invert Elevation Known Slope
4252	8	177	0	T17A3-6	T17A3-5	0	0	403	402	Unknown US and DS Invert Elevation Known Slope
3081	8	214	0	V17C2-15	V17C2-16	0	0	485	484	Unknown US and DS Invert Elevation Known Slope
1017	8	325	1	V20D1-26	V20D1-25	0	0	322	321	Unknown US and DS Invert Elevation Known Slope
5098	10	375	0	W19D3-39	W19D3-38	0	0	367	366	Unknown US and DS Invert Elevation Known Slope
5099	8	260	0	W19D3-40	W19D3-39	0	0	368	367	Unknown US and DS Invert Elevation Known Slope
3551	8	264	0	W19D3-41	W19D3-40	0	0	369	368	Unknown US and DS Invert Elevation Known Slope
3407	12	17	0	V19D2-29	V19D2-28	0	0	365	365	Unknown US and DS Invert Elevation Known Slope
3406	12	224	0	V19D2-28	V19D2-27	0	0	365	364	Unknown US and DS Invert Elevation Known Slope
3416	8	16	0	V19D2-45	V19D2-44	0	0	360	360	Unknown US and DS Invert Elevation Known Slope
3378	12	330	0	V19D1-35	V19D1-34	0	0	376	374	Unknown US and DS Invert Elevation Known Slope
3377	12	137	0	V19D1-34	V19D1-33	0	0	374	373	Unknown US and DS Invert Elevation Known Slope
3135	8	253	0	T18B1-53	T18B1-50	0	0	557	556	Unknown US and DS Invert Elevation Known Slope
3136	8	105	0	T18B1-54	T18B1-53	0	0	557	557	Unknown US and DS Invert Elevation Known Slope
3422	8	244	0	V19D2-51	V19D2-50	0	0	361	361	Unknown US and DS Invert Elevation Known Slope
3028	8	144	0	T16C1-2	T16C1-1	0	0	402	400	Unknown US and DS Invert Elevation Known Slope
3476	8	165	0	W19C3-28	W19C3-27	0	0	358	358	Unknown US and DS Invert Elevation Known Slope
3322	24	55	0	W20C1-23	W20C1-22	0	0	326	325	Unknown US and DS Invert Elevation Known Slope
4247	8	80	0	T17A3-1	T16C1-1	0	0	401	400	Unknown US and DS Invert Elevation Known Slope
1677	8	248	0	T17A3-8	T17A3-7	0	0	404	403	Unknown US and DS Invert Elevation Known Slope
4255	8	250	0	T17A3-9	T17A3-8	0	0	405	404	Unknown US and DS Invert Elevation Known Slope
4256	8	326	0	T17A3-10	T17A3-9	0	0	406	405	Unknown US and DS Invert Elevation Known Slope
4257	8	139	0	T17A3-11	T17A3-10	0	0	407	406	Unknown US and DS Invert Elevation Known Slope
1249	8	97	0	U20A1-22	U20A1-21	0	0	356	350	Unknown US and DS Invert Elevation Known Slope
3556	8	181	0	W19D3-45	W19D3-44	0	0	373	372	Unknown US and DS Invert Elevation Known Slope
3555	8	240	0	W19D3-44	W19D3-43	0	0	372	371	Unknown US and DS Invert Elevation Known Slope
1913	8	97	1	U20C1-3	U20C1-2	0	0	366	365	Unknown US and DS Invert Elevation Known Slope
5629	8	284	0	U20C1-2	U20C1-1	0	0	365	364	Unknown US and DS Invert Elevation Known Slope
831	8	267	0	U20C1-1	U20C2-3	0	0	364	361	Unknown US and DS Invert Elevation Known Slope
2519	10	190	0	V19A2-38	V19A2-37	0	0	351	349	Unknown US and DS Invert Elevation Known Slope
2513	12	157	0	V19A2-37	V19A2-36	0	0	350	349	Unknown US and DS Invert Elevation Known Slope
2514	12	200	0	V19A2-36	V19A2-35	0	0	349	348	Unknown US and DS Invert Elevation Known Slope
4248	8	50	0	T17A3-2	T17A3-1	0	0	401	401	Unknown US and DS Invert Elevation Known Slope
4249	8	140	0	T17A3-3	T17A3-1	0	0	401	401	Unknown US and DS Invert Elevation Known Slope
3355	18	282	0	V19D1-12	V19D1-11	0	0	337	336	Unknown US and DS Invert Elevation Known Slope
4386	4	194	1	U20D1-39	U20D1-38	0	0	347	345	Unknown US and DS Invert Elevation Known Slope
3356	12	339	0	V19D1-13	V19D1-12	0	0	340	337	Unknown US and DS Invert Elevation Known Slope
3357	12	369	0	V19D1-14	V19D1-13	0	0	341	340	Unknown US and DS Invert Elevation Known Slope
3483	8	381	0	W19C2-6	W19C2-4	0	0	373	373	Unknown US and DS Invert Elevation Known Slope
1994	18	451	3	U20D1-1	U20B3-8	0	0	342	328	Unknown US and DS Invert Elevation Known Slope
7129	18	266	0	U20B3-9	U20D1-1	0	0	342	342	Unknown US and DS Invert Elevation Known Slope
4387	18	496	0	U20B3-12	U20B3-11	0	0	326	325	Unknown US and DS Invert Elevation Known Slope
1245	8	241	0	U20A1-16	U20A1-15	0	0	340	339	Unknown US and DS Invert Elevation Known Slope
2105	8	255	0	U20A1-17	U20A1-16	0	0	349	348	Unknown US and DS Invert Elevation Known Slope
985	18	60	0	U20B3-11	U20B3-10	0	0	325	325	Unknown US and DS Invert Elevation Known Slope
7128	18	135	0	U20B3-10	U20B3-9	0	0	325	325	Unknown US and DS Invert Elevation Known Slope
4901	15	167	0	Y20C2-7	Y20C2-6	0	338	338	338	Unknown US Invert Elevation
4974	12	32	0	X18D1-37	X18D1-36	0	417	417	417	Unknown US Invert Elevation
4921	8	21	0	X19A2-1	X19C2-46	0	386	386	386	Unknown US Invert Elevation
4941	8	39	0	X19A2-9	X19A2-8	0	391	391	391	Unknown US Invert Elevation
6392	8	137	0	V20B1-43	V20B1-6	0	323	323	323	Unknown US Invert Elevation
6393	8	108	0	V20B1-44	V20B1-4	0	322	322	322	Unknown US Invert Elevation
2120	10	164	0	V19A4-2	V19A4-1	0	329	330	329	Unknown US Invert Elevation
2719	10	39	0	U18C2-6	U18C2-2	-9	341	342	341	Unknown US Invert Elevation
293	8	85	0	U18B2-45	U18B2-30	0	342	343	342	Unknown US Invert Elevation
2051	8	125	0	U19C5-16	U19C5-15	0	401	402	401	Unknown US Invert Elevation
1594	10	110	0	V19B1-52	V19B1-26	0	364	363	364	Unknown US Invert Elevation
928	8	386	0	U20D1-33	U20D1-32	0	349	351	349	Unknown US Invert Elevation
2615	10	364	0	U20D1-37	U20D1-30	0	347	352	347	Unknown US Invert Elevation
1401	8	64	0	V19B1-29	V19B1-28	0	366	364	366	Unknown US Invert Elevation
1528	10	108	0	T18D1-1	U18C2-31	0	413	421	413	Unknown US Invert Elevation
2715	8	305	0	V20D1-22	V20D1-21	0	323	324	323	Unknown US Invert Elevation
2339	8	407	0	U17C2-5	U17C2-4	0	357	328	357	Unknown US Invert Elevation
1220	8	173	0	U19C4-13	U19C4-12	0	343	343	343	Unknown US Invert Elevation
84	8	163	0	V18B1-40	V18B1-10	0	378	379	378	Unknown US Invert Elevation
4839	8	193	0	V20A2-30	V20A2-23	0	327	328	327	Unknown US Invert Elevation
4847	8	268	0	X19D3-8	X19D3-7	0	0	407	407	Unknown US Invert Elevation
5049	8	253	0	V19D1-48	V19D1-46	0	351	352	351	Unknown US Invert Elevation
162	8	204	0	U18A1-25	U18A1-24	0	368	369	368	Unknown US Invert Elevation
163	8	293	0	U18A1-26	U18A1-25	0	0	370	369	Unknown US Invert Elevation
286	8	313	0	U18B2-33	U18B2-32	0	349	350	349	Unknown US Invert Elevation
2463	8	95	0	V17A1-12	V17A1-11	0	441	442	441	Unknown US Invert Elevation
1894	8	119	0	U16D1-14	U16D1-13	0	411	411	411	Unknown US Invert Elevation
1865	8	185	0	U16B1-27	U16B1-21	0	473	474	473	Unknown US Invert Elevation
725	8	297	0	T19D1-37	T19D1-12	0	503	504	503	Unknown US Invert Elevation
2332	8	244	0	U18A1-7	U18A1-2	0	360	335	360	Unknown US Invert Elevation
90	8	53	0	V18D1-12	V18D1-3	0	377	341	377	Unknown US Invert Elevation
1265	6	190	0	U19B3-13	U19B3-12	0	332	333	332	Unknown US Invert Elevation
2125	6	69	0	U19B2-28	U19B2-27	0	342	342	342	Unknown US Invert Elevation
2130	8	266	0	U19B2-14	U19B2-12	0	337	338	337	Unknown US Invert Elevation
1967	8	23	0	V20A1-27	V20A1-25	0	323	323	323	Unknown US Invert Elevation
897	8	85	0	U20B1-13	U20B1-12	0	322	322	322	Unknown US Invert Elevation
1493	8	107	0	V19C1-25	V19C1-24	0	324	325	324	Unknown US Invert Elevation
2448	8	108	0	V17C1-7	V17C1-6	0	395	395	395	Unknown US Invert Elevation
1317	8	124	0	V19A3-17	V19A3-16	0	328	329	328	Unknown US Invert Elevation
2208	8	104	0	V19C1-22	V19C1-20	0	325	325	325	Unknown US Invert Elevation
1513	8	139	0	V19C2-22	V19C2-21	0	327	328	327	Unknown US Invert Elevation
1520	8	73	0	V19C2-32	V19C2-31	0	330	330	330	Unknown US Invert Elevation
1435	8	147	0	V19A2-25	V19A2-23	0	339	339	339	Unknown US Invert Elevation
1353	8	77	0	U19D2-15	U19D2-14	0	324	324	324	Unknown US Invert Elevation
1362	8	97	0	U19D2-4	U19D2-3	0	324	325	324	Unknown US Invert Elevation
2114	6	162	0	U19B3-15	U19B3-14	0	336	337	336	Unknown US Invert Elevation
614	10	130	0	T16D2-28	T16D2-19	0	383	384	383	Unknown US Invert Elevation
3494	8	85	0	V20D1-40	V20D1-24	0	320	320	320	Unknown US Invert Elevation
889	42	544	0	V21A2-12	V21A2-11	0	314	314	314	Unknown US Invert Elevation
4907	8	89	0	Y20C1-11	Y20C1-10	0	376	376	376	Unknown US Invert Elevation

Table 1. List of Gravity Mains with Unknown Invert Elevation(s)

GIS Information From Gravity Main Shapefile								Proposed Invert Elevations		West Yost Comment
Pipe ID	Diameter	Length, ft	Slope	Upstream Manhole ID	Downstream Manhole ID	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	
6391	8	162	0	X19C2-53	X19C2-50	0	393	394	393	Unknown US Invert Elevation
5847	8	193	0	X20B5-15	X20B5-14	0	0	364	363	Unknown US Invert Elevation
341	24	550	0	U18B3-6	U18B3-5	0	339	341	339	Unknown US Invert Elevation
302	8	184	0	U18C2-15	U18C2-13	0	352	353	352	Unknown US Invert Elevation
136	8	60	0	V18D1-36	V18D1-16	0	380	381	380	Unknown US Invert Elevation
559	6	107	0	T17B1-25	T17B1-3	0	393	393	393	Unknown US Invert Elevation
5566	12	22	0	V21A3-FSLSNFM	V21A3-6	0	313	313	313	Unknown US Invert Elevation
5567	42	21	0	V21A3-CPIFM	V21A3-6	0	313	313	313	Unknown US Invert Elevation
2647	8	142	0	V20D1-29	V20D1-11	0	320	321	320	Unknown US Invert Elevation
5833	8	268	0	X20B5-6	X20B5-5	0	0	353	352	Unknown US Invert Elevation
2354	24	1072	0	U17A2-1	U17A1-1	0	357	363	357	Unknown US Invert Elevation
1327	8	156	0	V19A3-30	V19A3-24	0	331	332	331	Unknown US Invert Elevation
5779	8	193	0	X20B4-38	X20B4-5	0	374	375	374	Unknown US Invert Elevation
6127	8	59	0	X19D3-62	X19D3-59	0	0	414	414	Unknown US Invert Elevation
6186	8	96	0	V20b4-12	V20b4-5	0	0	323	322	Unknown US Invert Elevation
6311	8	302	0	Y19B7-7	Y19B7-1	0	0	600	599	Unknown US Invert Elevation
6144	8	70	0	Y20A5-13	Y20A5-12	0	0	344	344	Unknown US Invert Elevation
6574	8	173	0	W19C3-31	W19C3-30	0	0	346	345	Unknown US Invert Elevation
6312	8	74	0	Z19A1-17	Z19A1-16	0	0	580	580	Unknown US Invert Elevation
6802	8	352	0	X20D1-13	X20D1-10	0	0	342	340	Unknown US Invert Elevation
6882	8	107	0	X20B5-63	X20B5-60	0	0	385	385	Unknown US Invert Elevation
6986	8	39	0	Y20A5-15	Y20A5-12	0	0	344	344	Unknown US Invert Elevation
6990	12	208	0	X20A6-1	X20A4-4	0	0	330	330	Unknown US Invert Elevation
6999	12	23	0	V19D2-10	V19D2-59	0	0	359	357	Unknown US Invert Elevation
5987	8	98	0	X18B2-12	X18B2-10	0	0	494	494	Unknown US Invert Elevation
7022	8	132	0	Y20A6-65	Y20A6-6	0	0	430	429	Unknown US Invert Elevation
7006	8	55	0	Y20A6-71	Y20A6-72	0	0	448	448	Unknown US Invert Elevation
7015	8	51	0	Y20A6-86	Y20A6-74	0	0	444	443	Unknown US Invert Elevation
6020	8	13	0	X20C1-12	X20C1-11	0	345	345	345	Unknown US Invert Elevation
2504	39	158	0	V21A2-15	V21A2-16	0	314	315	314	Unknown US Invert Elevation
7043	12	302	0	U20A1-56	U20A1-1	0	0	322	322	Unknown US Invert Elevation
7257	8	162	0	X18A1-25	X18A1-24	0	0	503	502	Unknown US Invert Elevation
4581	8	182	0	X20B2-37	X20B2-27	0	342	342	342	Unknown US Invert Elevation Known Slope
4522	8	207	0	W19C2-25	W19C2-23	0	383	383	383	Unknown US Invert Elevation Known Slope
4510	8	97	0	W19C2-13	W19C2-12	0	378	379	378	Unknown US Invert Elevation Known Slope
1842	8	160	2	U15C1-32	U15C1-31	0	487	490	487	Unknown US Invert Elevation Known Slope
2807	8	82	0	T20A1-1	T20B1-3	0	432	432	432	Unknown US Invert Elevation Known Slope
2850	8	271	0	T20C1-34	T20C1-9	0	530	539	530	Unknown US Invert Elevation Known Slope
3436	8	251	0	W19C1-10	W19C1-9	0	331	331	331	Unknown US Invert Elevation Known Slope
922	12	163	1	U20D1-26	U20D1-25	0	336	338	336	Unknown US Invert Elevation Known Slope
958	8	188	1	U20D2-17	U20D2-15	0	325	327	325	Unknown US Invert Elevation Known Slope
2910	8	322	0	V20D1-28	V20D1-24	0	320	321	320	Unknown US Invert Elevation Known Slope
2771	8	15	0	T20A1-51	T20A1-31	0	727	727	727	Unknown US Invert Elevation Known Slope
3525	15	68	0	W19D3-15	W19D3-14	0	342	342	342	Unknown US Invert Elevation Known Slope
4503	12	188	0	V20B3-5	V20B3-4	0	0	331	331	Unknown US Invert Elevation Known Slope
3782	8	46	0	W20D1-14	W20D1-13	0	342	342	342	Unknown US Invert Elevation Known Slope
2958	8	119	0	U18C4-41	U18C4-38	0	344	344	344	Unknown US Invert Elevation Known Slope
1611	8	102	2	V19B1-37	V19B1-36	0	375	377	375	Unknown US Invert Elevation Known Slope
1002	8	155	1	V20B1-27	V20B1-3	0	319	321	319	Unknown US Invert Elevation Known Slope
2919	8	131	0	V20B1-20	V20B1-17	0	325	326	325	Unknown US Invert Elevation Known Slope
1681	8	130	1	T16D1-9	T16D1-8	0	396	397	396	Unknown US Invert Elevation Known Slope
1595	8	112	1	T16D4-14	T16D4-12	0	386	387	386	Unknown US Invert Elevation Known Slope
596	8	281	1	T16D4-6	T16D4-5	0	384	387	384	Unknown US Invert Elevation Known Slope
3530	15	68	0	W19D3-20	W19D3-19	0	345	345	345	Unknown US Invert Elevation Known Slope
3515	15	40	0	W19D3-5	W19D3-4	0	339	339	339	Unknown US Invert Elevation Known Slope
2355	24	548	0	U17A3-4	U17D1-1	0	351	353	351	Unknown US Invert Elevation Known Slope
1241	8	346	1	U20A1-10	U20A1-9	0	341	344	341	Unknown US Invert Elevation Known Slope
3561	8	74	0	W19D1-51	W19D1-4	0	334	335	334	Unknown US Invert Elevation Known Slope
3563	8	207	0	W19D1-6	W19D1-5	0	339	340	339	Unknown US Invert Elevation Known Slope
3572	8	48	0	W19D1-15	W19D1-14	0	365	365	365	Unknown US Invert Elevation Known Slope
4052	8	26	0	X19B1-7	X19B1-6	0	395	395	395	Unknown US Invert Elevation Known Slope
972	10	225	1	V20A2-19	V20A2-18	0	324	327	324	Unknown US Invert Elevation Known Slope
1988	10	79	1	V20A2-15	V20A2-14	0	325	326	325	Unknown US Invert Elevation Known Slope
3801	8	30	0	W20D1-33	W20D1-32	0	343	343	343	Unknown US Invert Elevation Known Slope
3808	8	39	0	W20D1-40	W20D1-39	0	345	345	345	Unknown US Invert Elevation Known Slope
660	8	296	0	U16B1-18	U16B1-14	0	422	423	422	Unknown US Invert Elevation Known Slope
3823	18	116	0	X20A4-9	X20A4-8	0	336	331	336	Unknown US Invert Elevation Known Slope
3580	8	93	0	W19D1-23	W19D1-22	0	347	348	347	Unknown US Invert Elevation Known Slope
3548	10	400	0	W19D3-38	W19D3-37	0	365	366	365	Unknown US Invert Elevation Known Slope
3754	8	53	0	W20B2-13	W20B2-12	0	339	339	339	Unknown US Invert Elevation Known Slope
3777	8	60	0	W20D1-9	W20D1-8	0	342	342	342	Unknown US Invert Elevation Known Slope
632	8	126	2	U15C1-29	U15C1-25	0	454	457	454	Unknown US Invert Elevation Known Slope
260	8	200	0	U18B1-21	U18B1-20	0	353	354	353	Unknown US Invert Elevation Known Slope
3481	8	145	0	W19C2-4	W19C2-3	0	373	373	373	Unknown US Invert Elevation Known Slope
3473	12	598	0	W19C3-25	W19C3-24	0	348	357	348	Unknown US Invert Elevation Known Slope
1476	6	210	1	U19D1-35	U19D1-34	0	334	336	334	Unknown US Invert Elevation Known Slope
1300	8	116	0	U19B2-26	U19B2-25	0	354	355	354	Unknown US Invert Elevation Known Slope
1347	6	90	1	U19B1-5	U19B1-4	0	331	331	331	Unknown US Invert Elevation Known Slope
2168	8	80	1	V19A1-16	V19A1-15	0	328	329	328	Unknown US Invert Elevation Known Slope
62	8	137	0	V18B1-1	V19B1-51	0	375	374	375	Unknown US Invert Elevation Known Slope
2305	8	245	0	V18B1-39	V18B1-38	0	380	381	380	Unknown US Invert Elevation Known Slope
2550	8	30	2	V19B1-47	V19B1-39	0	370	371	370	Unknown US Invert Elevation Known Slope
1013	10	84	1	V20D1-19	V20D1-15	-8	320	321	320	Unknown US Invert Elevation Known Slope
2612	39	161	0	U20B2-3	U20B2-2	0	315	315	315	Unknown US Invert Elevation Known Slope
998	8	247	0	V20B1-22	V20B1-21	0	328	329	328	Unknown US Invert Elevation Known Slope
2036	8	50	1	U19A2-31	U19A2-30	0	398	399	398	Unknown US Invert Elevation Known Slope
3859	8	161	0	X20A3-16	X20A3-15	0	347	348	347	Unknown US Invert Elevation Known Slope
3899	8	29	0	X20A3-56	X20A3-55	0	351	351	351	Unknown US Invert Elevation Known Slope
3897	8	135	0	X20A3-54	X20A3-53	0	350	350	350	Unknown US Invert Elevation Known Slope
3889	8	364	0	X20A3-46	X20A3-45	0	352	353	352	Unknown US Invert Elevation Known Slope
3080	8	305	0	V17C2-16	V17C2-13	0	483	484	483	Unknown US Invert Elevation Known Slope
3218	8	195	0	V17A2-28	V17A2-1	0	410	411	410	Unknown US Invert Elevation Known Slope
4277	8	200	0	T17A1-9	T17A1-8	0	581	582	581	Unknown US Invert Elevation Known Slope
3441	8	208	0	W19C1-15	W19C1-14	0	302	333	302	Unknown US Invert Elevation Known Slope
3468	8	226	0	W19C3-20	W19C3-19	0	350	350	350	Unknown US Invert Elevation Known Slope
5636	10	129	0	V21A3-18	V21A3-16	0	329	329	329	Unknown US Invert Elevation Known Slope
3249	8	75	0	V17A2-15	V17A2-14	0	420	420	420	Unknown US Invert Elevation Known Slope
6051	8	280	1	W20C1-44	W20C1-43	0	328	330	328	Unknown US Invert Elevation Known Slope
5627	12	47	0	U20C2-3	U20C2-27	0	361	361	361	Unknown US Invert Elevation Known Slope
3132	8	123	0	T18B1-50	T18B1-49	0	555	556	555	Unknown US Invert Elevation Known Slope
3462	8	201	0	W19C3-14	W19C3-13	0	353	353	353	Unknown US Invert Elevation Known Slope
577	8	122	1	T16D1-29	T16D1-27	0	405	406	405	Unknown US Invert Elevation Known Slope
3027	8	346	0	T16C1-1	T17B1-4	0	394	400	394	Unknown US Invert Elevation Known Slope
3578	8	49	0	W19D1-21	W19D1-20	0	327	327	327	Unknown US Invert Elevation Known Slope
1259	12	58	0	U20A1-32	U20A1-20	0	352	352	352	Unknown US Invert Elevation Known Slope
1248	8	190	0	U20A1-21	U20A1-18	0	349	350	349	Unknown US Invert Elevation Known Slope
932	12	162	1	U20D1-9	U20D1-8	0	327	329	327	Unknown US Invert Elevation Known Slope
2030	6	79	1	U19A2-10	U19A2-9	0	377	378	377	Unknown US Invert Elevation Known Slope
2515	12	70	0	V19A2-35	V19A2-34	0	344	348	344	Unknown US Invert Elevation Known Slope
2517	12	183	0	V19A2-42	V19A2-33	0	341	344	341	Unknown US Invert Elevation Known Slope
6033	36	144	0	W20C1-27	W20C1-12	0	324	324	324	Unknown US Invert Elevation Known Slope
4330	27	75	0	U18B4-41	U18C2-1	0	333	333	333	Unknown US Invert Elevation Known Slope
4244	15	80	0	V20A1-38	V20A1-1	0	316	317	316	Unknown US Invert Elevation Known Slope
6132	8	88	0	W20D1-44	W20D1-30	0	340	341	340	Unknown US Invert Elevation Known Slope
2006	10	87	1	V20D1-27	V20D1-12	0	318	319	318	Unknown US Invert Elevation Known Slope
3838	8	255	0	X20C1-2	X20C1-1	0	0	340	339	Unknown US Invert Elevation Known Slope
4385	6	178	1	U20D1-38	U20D1-24	0	344	345	344	Unknown US Invert Elevation Known Slope
3367	12	85	0	V19D1-24	V19D2-62	0	0	362	361	Unknown US Invert Elevation Known Slope
4478	6	122	1	U20D1-36	U20D1-11	0	332	332	332	Unknown US Invert Elevation Known Slope
3321	24	26	0	W20C1-22	W20C1-59	0	325	325	325	Unknown US Invert Elevation Known Slope
1995	18	196	3	U20B3-8	U20D1-7	0	323	328	323	Unknown US Invert Elevation Known Slope
2106	8	268	0	U20A1-15	U20A1-7	0	338	339	338	Unknown US Invert Elevation Known Slope
393	21	594	0	U16C1-1	U16D1-1	0	0	368	366	Unknown US Invert Elevation Known Slope
7045	15	348	0	W19D3-30	W19D3-52	0	352	353	352	Unknown US Invert Elevation Known Slope
4927	8	172	0	X19A2-3	X19A2-2	390	0	390	389	Unknown DS Invert Elevation
412	10	242	0	U16C2-2	U16C2-1	370	0	370	369	Unknown DS Invert Elevation
1880	15	262	0	U16C1-2	U16C1-1	370	0	370	368	Unknown DS Invert Elevation
284	8	242	0	U18B2-31	U18B2-45	344	0	344	343	Unknown DS Invert Elevation
667	8	203	0	U16B1-28	U16B1-27	494	0	494	494	Unknown DS Invert Elevation
63	8	39	0	V18B1-11	V18B1-40	380	0	380	380	Unknown DS Invert Elevation
1984	8	153	0	V20A2-26	V20A2-30	329	0	329	328	Unknown DS Invert Elevation
7181	8	254	0	U18A1-10	U18A1-7	364	0	364	335	Unknown DS Invert Elevation
610	10	384	0	T16D2-22	T16D2-28	387	0	387	384	Unknown DS Invert Elevation
464	8	245	0	V17A1-13	V17A1-12	466	0	466	442	Unknown DS Invert Elevation
453	8	314	0	U16D1-18	U16D1-14	414	0	414	411	Unknown DS Invert Elevation
451	8	169	0	U16D1-16	U16D1-14	425	0	425	411	Unknown DS Invert Elevation
450	8	201	0	U16D1-15	U16D1-14	412	0	412	411	Unknown DS Invert Elevation
1892	18	306	0	U16C3-8	U16C3-7	375	0	375	373	Unknown DS Invert Elevation
2411	10	225	0	U17A2-2	U17A2-1	370	0	370	364	Unknown DS Invert Elevation
446	18	139	0	U16D1-1	U16C3-2	366	0	366	365	Unknown DS Invert Elevation
2003	8	169	0	V20D1-20	V20D1-19	321	-8	321	321	Unknown DS Invert Elevation
677	10	180	0	V17C1-1	V18B1-39	387	0	387	380	Unknown DS Invert Elevation
261	8	173	0	U18B1-22	U18B1-21	356	0	356	354	Unknown DS Invert Elevation
170	8	346	0	U18A1-8	U18A1-7	367	0	367	335	Unknown DS Invert Elevation
2313	8	83	0	V18D1-13	V18D1-12	378	0	378	341	Unknown DS Invert Elevation
1282	10	169	0	V19A4-3	V19A4-2	331	0	331	330	Unknown DS Invert Elevation
85	8	154	0	V18B1-5	V18B1-4	376	0	376	376	Unknown DS Invert Elevation
66	10	276	0	V18B1-16	V18B1-1	375	0	375	374	Unknown DS Invert Elevation
933	39	209	0	V20A1-1	U20B2-3	316	0	316	315	Unknown DS Invert Elevation
204	6	171	0	U17C2-6	U17C2-5	361	0	361	328	Unknown DS Invert Elevation
249	24	333	0	U18B1-1	U18B3-6	342	0	342	341	Unknown DS Invert Elevation
5798	8	201	0	X20B5-17	X20B5-16	366	0	366	365	Unknown DS Invert Elevation
1323	8	99	0	V19A3-26	V19A3-30	332	0	332	332	Unknown DS Invert Elevation
2718	10	44	0	U18C2-7	U18C2-6	341	-9	341	342	Unknown DS Invert Elevation
4910	8	334	0	Y20A4-1	Y20C1-11	0	0	379	378	Unknown DS Invert Elevation
4913	8	381	0	Y20A3-1	Y20C1-11	391	0	391	390	Unknown DS Invert Elevation

Table 1. List of Gravity Mains with Unknown Invert Elevation(s)

GIS Information From Gravity Main Shapefile								Proposed Invert Elevations		West Yost Comment
Pipe ID	Diameter	Length, ft	Slope	Upstream Manhole ID	Downstream Manhole ID	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	
2383	8	156	0	U18C2-17	U18C2-16	355	0	355	354	Unknown DS Invert Elevation
5565	12	17	0	V21A3-7	V21A3-FSLSNV	317	0	317	317	Unknown DS Invert Elevation
5687	15	204	0	Y20C2-8	Y20C2-7	0	0	361	361	Unknown DS Invert Elevation
5980	8	156	0	X18B2-14	X18B2-12	0	0	495	494	Unknown DS Invert Elevation
5982	8	154	0	X18B2-13	X18B2-12	0	0	495	495	Unknown DS Invert Elevation
1765	8	184	0	T19D1-30	T19D1-37	514	0	514	514	Unknown DS Invert Elevation
509	24	698	0	U17A1-1	U17A3-4	357	0	357	353	Unknown DS Invert Elevation
911	6	39	0	U20D1-10	U20D1-9	329	0	329	329	Unknown DS Invert Elevation
5975	8	174	0	X18B2-15	X18B2-12	0	0	498	497	Unknown DS Invert Elevation
6308	8	307	0	Y19B7-10	Y19B7-7	0	0	640	639	Unknown DS Invert Elevation
6793	8	395	0	W20C1-51	W20C1-27	0	0	330	324	Unknown DS Invert Elevation
6926	8	108	0	X20B5-64	X20B5-63	0	0	392	392	Unknown DS Invert Elevation
6927	8	132	0	X20B5-65	X20B5-63	0	0	390	389	Unknown DS Invert Elevation
6930	8	107	0	X20B5-66	X20B5-63	0	0	391	390	Unknown DS Invert Elevation
6307	8	415	0	Y19B7-8	Y19B7-7	0	0	637	636	Unknown DS Invert Elevation
7020	8	157	0	Y20A6-76	Y20A6-65	0	0	441	441	Unknown DS Invert Elevation
7019	8	72	0	Y20A6-67	Y20A6-66	0	0	439	439	Unknown DS Invert Elevation
7065	8	104	0	Y20A6-72	Y20A6-86	0	0	448	448	Unknown DS Invert Elevation
5805	8	151	0	X20B5-8	X20B5-7	355	0	355	354	Unknown DS Invert Elevation
1937	42	130	0	V21A2-17	V21A2-13	314	0	314	314	Unknown DS Invert Elevation
925	10	284	0	U20D1-3	U20D1-2	326	0	326	325	Unknown DS Invert Elevation
7040	12	327	0	U20A1-41	U20A1-54	0	0	332	332	Unknown DS Invert Elevation
7228	8	117	0	X18A1-26	X18A1-25	0	0	482	482	Unknown DS Invert Elevation
7287	8	176	0	X18A1-37	X18A1-25	0	0	480	479	Unknown DS Invert Elevation
7286	8	30	0	U20D1-18	U20D2-28	0	0	336	336	Unknown DS Invert Elevation
2799	8	286	0	T20A1-8	T20A1-7	471	0	471	470	Unknown DS Invert Elevation Known Slope
4818	8	32	0	V20D1-41	V20D1-19	320	-8	320	321	Unknown DS Invert Elevation Known Slope
4581	8	92	0	X20B2-38	X20B2-27	345	0	345	342	Unknown DS Invert Elevation Known Slope
2849	8	246	0	T20C1-10	T20C1-34	543	0	543	539	Unknown DS Invert Elevation Known Slope
3427	21	113	0	W19C1-1	W20C1-23	326	0	326	326	Unknown DS Invert Elevation Known Slope
924	12	339	1	U20D1-28	U20D1-26	341	0	341	338	Unknown DS Invert Elevation Known Slope
4383	18	330	0	X20A4-16	X20A4-9	341	0	341	331	Unknown DS Invert Elevation Known Slope
6133	12	303	0	V20B3-4	V20B3-3	0	0	331	330	Unknown DS Invert Elevation Known Slope
4243	15	139	0	V20A1-2	V20A1-38	317	0	317	317	Unknown DS Invert Elevation Known Slope
4428	8	104	0	U16B1-21	U16B1-34	473	0	473	473	Unknown DS Invert Elevation Known Slope
4241	27	121	0	U18B4-1	U18B4-41	333	0	333	333	Unknown DS Invert Elevation Known Slope
2959	8	51	0	U18C4-42	U18C4-41	345	0	345	344	Unknown DS Invert Elevation Known Slope
2516	12	21	0	V19A2-34	V19A2-42	344	0	344	344	Unknown DS Invert Elevation Known Slope
4326	8	267	0	V20B1-21	V20B1-20	328	0	328	327	Unknown DS Invert Elevation Known Slope
1963	12	364	1	U20C2-1	U20D1-37	357	0	357	357	Unknown DS Invert Elevation Known Slope
1700	8	275	1	T16D4-11	T16D4-10	396	0	396	393	Unknown DS Invert Elevation Known Slope
1407	10	143	2	V19B1-38	V19B1-52	366	0	366	363	Unknown DS Invert Elevation Known Slope
2187	8	80	2	V19B1-32	V19B1-29	366	0	366	364	Unknown DS Invert Elevation Known Slope
1402	8	193	2	V19B1-30	V19B1-29	373	0	373	369	Unknown DS Invert Elevation Known Slope
597	6	153	1	T16D4-7	T16D4-6	391	0	391	390	Unknown DS Invert Elevation Known Slope
6057	36	387	0	W20C1-13	W20C1-27	325	0	325	324	Unknown DS Invert Elevation Known Slope
3562	8	51	0	W19D1-5	W19D1-51	339	0	339	338	Unknown DS Invert Elevation Known Slope
3567	8	264	0	W19D1-10	W19D1-6	360	0	360	359	Unknown DS Invert Elevation Known Slope
3573	8	226	0	W19D1-16	W19D1-15	325	0	325	325	Unknown DS Invert Elevation Known Slope
7319	8	379	0	X19B1-8	X19B1-7	400	0	400	395	Unknown DS Invert Elevation Known Slope
975	10	178	1	V20A2-22	V20A2-19	326	0	326	324	Unknown DS Invert Elevation Known Slope
1987	10	262	1	V20A2-18	V20A2-15	324	0	324	322	Unknown DS Invert Elevation Known Slope
661	8	237	0	U16B1-19	U16B1-18	481	0	481	480	Unknown DS Invert Elevation Known Slope
3582	8	50	0	W19D1-25	W19D1-24	347	0	347	347	Unknown DS Invert Elevation Known Slope
634	8	205	2	U15C1-31	U15C1-30	487	0	487	483	Unknown DS Invert Elevation Known Slope
2000	8	148	1	V20B1-4	V20B1-27	322	0	322	320	Unknown DS Invert Elevation Known Slope
6398	8	141	0	U20D2-25	U20D2-17	327	0	327	327	Unknown DS Invert Elevation Known Slope
2549	8	168	2	V19B1-40	V19B1-47	372	0	372	368	Unknown DS Invert Elevation Known Slope
1010	10	287	1	V20D1-13	V20D1-27	319	0	319	316	Unknown DS Invert Elevation Known Slope
1936	42	357	0	U20B2-1	V21A2-15	315	0	315	315	Unknown DS Invert Elevation Known Slope
3219	8	142	0	V17A2-29	V17A2-28	414	0	414	413	Unknown DS Invert Elevation Known Slope
2935	8	134	0	V20B1-29	V20B1-28	331	0	331	331	Unknown DS Invert Elevation Known Slope
3409	12	114	0	V19D2-31	V19D2-30	366	0	366	366	Unknown DS Invert Elevation Known Slope
3133	8	75	0	T18B1-51	T18B1-50	556	0	556	555	Unknown DS Invert Elevation Known Slope
3250	8	118	0	V17A2-16	V17A2-15	425	0	425	425	Unknown DS Invert Elevation Known Slope
3437	8	184	0	W19C1-11	W19C1-10	330	0	330	330	Unknown DS Invert Elevation Known Slope
1680	6	268	1	T16D1-10	T16D1-9	401	0	401	398	Unknown DS Invert Elevation Known Slope
5569	42	377	0	V21A3-4	V21A3-CPIFM	313	0	313	313	Unknown DS Invert Elevation Known Slope
4293	8	71	0	V20B2-1	V20B1-23	328	0	328	328	Unknown DS Invert Elevation Known Slope
1250	8	141	0	U20A1-23	U20A1-22	357	0	357	356	Unknown DS Invert Elevation Known Slope
1246	8	75	0	U20A1-18	U20A1-17	349	0	349	349	Unknown DS Invert Elevation Known Slope
851	8	98	1	U20C1-4	U20C1-3	367	0	367	366	Unknown DS Invert Elevation Known Slope
856	12	270	2	U20C2-10	U20C2-3	367	0	367	362	Unknown DS Invert Elevation Known Slope
1958	12	281	1	U20D1-14	U20D1-9	332	0	332	329	Unknown DS Invert Elevation Known Slope
2334	12	274	0	V19A2-39	V19A2-37	351	0	351	350	Unknown DS Invert Elevation Known Slope
4219	8	66	0	T16C1-49	T16C1-2	404	0	404	402	Unknown DS Invert Elevation Known Slope
1749	8	69	1	T18D1-2	T18D1-1	422	0	422	421	Unknown DS Invert Elevation Known Slope
6131	8	97	0	W20D1-31	W20D1-44	341	0	341	341	Unknown DS Invert Elevation Known Slope
5061	18	365	0	V19D1-36	V19D1-12	342	0	342	337	Unknown DS Invert Elevation Known Slope
3839	8	20	0	X20C1-3	X20C1-2	345	0	345	345	Unknown DS Invert Elevation Known Slope
4378	18	165	0	U20B3-13	U20B3-12	327	0	327	326	Unknown DS Invert Elevation Known Slope
4984	8	119	0	X18B1-2	X18B1-1	0	427	439	427	Invert Elevation Calculated by West Yost
4998	8	98	0	X18B1-6	X18B1-4	0	0	449	445	Invert Elevation Calculated by West Yost
5983	8	42	0	X18B2-2	X18B2-1	0	0	446	445	Invert Elevation Calculated by West Yost
5989	8	123	0	X18B2-1	X18B1-3	0	0	445	442	Invert Elevation Calculated by West Yost
5000	8	92	0	X18B1-3	X18B1-2	0	0	442	439	Invert Elevation Calculated by West Yost
5984	8	105	0	X18B2-6	X18B2-5	0	0	481	476	Invert Elevation Calculated by West Yost
5990	8	179	0	X18B2-7	X18B2-6	0	0	489	481	Invert Elevation Calculated by West Yost
5991	8	206	0	X18B2-8	X18B2-7	0	0	493	489	Invert Elevation Calculated by West Yost
5992	8	225	0	X18B2-4	X18B2-3	0	0	463	451	Invert Elevation Calculated by West Yost
5985	8	106	0	X18B2-3	X18B2-2	0	0	451	446	Invert Elevation Calculated by West Yost
5986	8	192	0	X18B2-10	X18B2-9	0	0	494	493	Invert Elevation Calculated by West Yost
5993	8	283	0	X18B2-5	X18B2-4	0	0	476	463	Invert Elevation Calculated by West Yost
5005	8	121	0	X18B1-4	X18B1-3	0	0	445	442	Invert Elevation Calculated by West Yost
4989	8	174	0	X18B1-8	X18B1-6	0	0	456	449	Invert Elevation Calculated by West Yost
4997	8	171	0	X18B1-10	X18B1-8	0	0	462	456	Invert Elevation Calculated by West Yost
4990	8	139	0	X18B1-12	X18B1-10	0	0	465	462	Invert Elevation Calculated by West Yost
5994	8	216	0	X17D1-1	X18B2-10	0	0	494	494	Invert Elevation Calculated by West Yost
4992	8	159	0	X18B1-5	X18B1-4	0	0	448	445	Invert Elevation Calculated by West Yost
4993	8	159	0	X18B1-11	X18B1-10	0	0	463	462	Invert Elevation Calculated by West Yost
4994	8	160	0	X18B1-9	X18B1-8	0	0	457	456	Invert Elevation Calculated by West Yost
5007	8	160	0	X18B1-7	X18B1-6	0	0	450	449	Invert Elevation Calculated by West Yost
5988	8	28	0	X18B2-9	X18B2-8	0	0	493	493	Invert Elevation Calculated by West Yost
5018	10	219	0	X19D3-12	X19D3-7	0	0	416	407	Invert Elevation Calculated by West Yost
4845	10	295	0	X19D3-6	X19D3-5	0	0	406	401	Invert Elevation Calculated by West Yost
4842	10	399	0	X19D3-3	X19D3-2	0	0	391	388	Invert Elevation Calculated by West Yost
5662	8	104	0	X19D3-19	X19D3-12	0	0	417	416	Invert Elevation Calculated by West Yost
4840	10	278	0	X19D3-1	X19C1-1	0	369	383	369	Invert Elevation Calculated by West Yost
4376	8	41	1	U20D2-15	U20D2-23	325	0	325	324	Invert Elevation Calculated by West Yost
4375	8	45	1	U20D2-24	U20D2-23	0	0	324	324	Invert Elevation Calculated by West Yost
4374	8	109	1	U20D2-23	U20D2-22	0	0	324	324	Invert Elevation Calculated by West Yost
4373	8	144	1	U20D2-22	U20D2-21	0	0	324	323	Invert Elevation Calculated by West Yost
4372	8	86	1	U20D2-21	U20D2-20	0	0	323	323	Invert Elevation Calculated by West Yost
4504	12	350	0	V20B3-6	V20B3-4	0	0	331	331	Invert Elevation Calculated by West Yost
4505	12	282	0	V20B3-7	V20B3-6	0	0	334	331	Invert Elevation Calculated by West Yost
4506	12	317	0	V20B3-8	V20B3-7	0	0	335	334	Invert Elevation Calculated by West Yost
4508	12	256	0	V20B3-9	V20B3-8	0	0	335	335	Invert Elevation Calculated by West Yost
4507	12	174	0	V20B1-25	V20B3-9	335	0	335	335	Invert Elevation Calculated by West Yost
1978	6	351	1	U20D2-16	U20D2-24	327	0	327	324	Invert Elevation Calculated by West Yost
957	8	203	1	U20D2-20	U20D2-14	0	0	323	322	Invert Elevation Calculated by West Yost
2487	8	124	1	U20D2-14	U20D2-13	0	0	322	322	Invert Elevation Calculated by West Yost
1979	8	70	1	U20D2-13	U20B3-6	0	322	322	322	Invert Elevation Calculated by West Yost
4843	10	366	0	X19D3-4	X19D3-3	0	0	399	391	Invert Elevation Calculated by West Yost
4844	10	367	0	X19D3-5	X19D3-4	0	0	401	399	Invert Elevation Calculated by West Yost
4846	10	407	0	X19D3-7	X19D3-6	0	0	407	406	Invert Elevation Calculated by West Yost
4851	10	350	0	X19D3-13	X19D3-12	0	0	423	416	Invert Elevation Calculated by West Yost
4852	10	350	0	X19D3-14	X19D3-13	0	0	428	423	Invert Elevation Calculated by West Yost
4853	10	350	0	X19D3-15	X19D3-14	0	0	438	428	Invert Elevation Calculated by West Yost
4854	10	350	0	X19D3-16	X19D3-15	0	0	452	438	Invert Elevation Calculated by West Yost
4855	10	350	0	X19D3-17	X19D3-16	0	0	467	452	Invert Elevation Calculated by West Yost
4857	10	350	0	X19D3-18	X19D3-17	0	0	471	467	Invert Elevation Calculated by West Yost
4858	10	177	0	Y19A2-2	X19D3-18	471	0	471	471	Invert Elevation Calculated by West Yost
1920	8	92	0	U20C2-5	U20C2-27	363	0	363	361	Invert Elevation Calculated by West Yost
1531	8	132	1	T18D1-13	T18D1-12	491	0	491	488	Invert Elevation Calculated by West Yost
1532	8	229	1	T18D1-14	T18D1-12	481	0	481	488	Invert Elevation Calculated by West Yost
1745	8	305	1	T18D1-12	T18D1-11	0	461	488	461	Invert Elevation Calculated by West Yost
5839	8	70	0	X19D4-2	X19D4-1	0	395	397	395	Invert Elevation Calculated by West Yost
5840	8	350	0	X19D4-4	X19D4-3	0	0	414	407	Invert Elevation Calculated by West Yost
5841	8	345	0	X19D4-5	X19D4-4	0	0	419	414	Invert Elevation Calculated by West Yost
5842	8	160	0	X19D4-6	X19D4-5	0	0	425	419	Invert Elevation Calculated by West Yost
4841	10	350	0	X19D3-2	X19D3-1	0	0	388	383	Invert Elevation Calculated by West Yost
5720	8	100	0	Y19B2-11	Y19B2-10	0	0	540	539	Invert Elevation Calculated by West Yost
5721	8	265	0	Y19B2-14	Y19B2-13	0	0	556	553	Invert Elevation Calculated by West Yost
5722	8	281	0	Y19B2-13	Y19B2-10	0	0	553	539	Invert Elevation Calculated by West Yost
5723	8	297	0	Y19B2-9	Y19B2-8	0	0	529	528	Invert Elevation Calculated by West Yost
5733	8	165	0	Y19B3-10	Y19B3-5	0	0	555	545	Invert Elevation Calculated by West Yost
5724	8	105	0	Y19B2-8	Y19B2-7	0	0	528	527	Invert Elevation Calculated by West Yost
6221	8	141	0	Y19B4-41	Y19B4-3	0	0	598	592	Invert Elevation Calculated by West Yost
5734	8	128	0	Y19B3-14	Y19B3-13	0	0	597	593	Invert Elevation Calculated by West Yost
5749	8	310	0	Y19B3-13	Y19B3-12	0	0	593	581	Invert Elevation Calculated by West Yost
5735	8	46	0	Y19B3-8	Y19B3-7	0	0	578	575	Invert Elevation Calculated by West Yost
5725	8	149	0	Y19B2-7	Y19B2-5	0	0	527	521	Invert Elevation Calculated by West Yost
5726	8	132	0	Y19B2-5	Y19B2-4	0	0	521	517	Invert Elevation Calculated by West Yost
5727	8	268	0	Y19B2-4	Y19B2-3	0	0	517	514	Invert Elevation Calculated by West Yost
5728	8	187	0	Y19B2-2	Y19B2-1	0	0	523	514	Invert Elevation Calculated by West Yost
5736	8	215	0	Y19B3-9	Y19B3-8	0	0	595	578	Invert Elevation Calculated by West Yost

Table 1. List of Gravity Mains with Unknown Invert Elevation(s)

GIS Information From Gravity Main Shapefile								Proposed Invert Elevations		West Yost Comment
Pipe ID	Diameter	Length, ft	Slope	Upstream Manhole ID	Downstream Manhole ID	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	
5729	8	255	0	Y19B2-6	Y19B2-5	0	0	537	521	Invert Elevation Calculated by West Yost
5737	8	290	0	Y19B3-3	Y19B3-2	0	0	555	542	Invert Elevation Calculated by West Yost
5738	8	138	0	Y19B3-17	Y19B3-16	0	0	615	615	Invert Elevation Calculated by West Yost
5739	8	181	0	Y19B3-11	Y19B3-10	0	0	567	555	Invert Elevation Calculated by West Yost
5965	8	80	0	X18B1-24	X18B1-20	0	0	474	473	Invert Elevation Calculated by West Yost
5966	8	131	0	X18B1-18	X18B1-13	0	0	471	467	Invert Elevation Calculated by West Yost
5003	8	54	0	X18B1-16	X18B1-15	0	0	470	469	Invert Elevation Calculated by West Yost
5967	8	80	0	X18B1-15	X18B1-13	0	0	469	467	Invert Elevation Calculated by West Yost
5968	8	76	0	X18B1-17	X18B1-13	0	0	471	467	Invert Elevation Calculated by West Yost
5969	8	69	0	X18B1-13	X18B1-12	0	0	467	465	Invert Elevation Calculated by West Yost
5970	8	61	0	X18B1-14	X18B1-15	0	0	470	469	Invert Elevation Calculated by West Yost
5750	8	104	0	X20B4-34	X20B4-32	0	401	409	401	Invert Elevation Calculated by West Yost
5752	8	103	0	X20B4-22	X20B4-20	0	394	401	394	Invert Elevation Calculated by West Yost
5845	8	131	0	X20B5-12	X20B5-11	0	0	361	360	Invert Elevation Calculated by West Yost
5756	8	107	0	X20B4-14	X20B4-13	0	388	397	388	Invert Elevation Calculated by West Yost
5757	8	107	0	X20B4-16	X20B4-15	0	391	399	391	Invert Elevation Calculated by West Yost
5758	8	110	0	X20B4-31	X20B4-30	0	399	406	399	Invert Elevation Calculated by West Yost
5759	8	103	0	X20B4-37	X20B4-35	0	403	410	403	Invert Elevation Calculated by West Yost
5760	8	110	0	X20B4-27	X20B4-26	0	396	406	396	Invert Elevation Calculated by West Yost
5765	8	105	0	X20B4-36	X20B4-35	0	403	410	403	Invert Elevation Calculated by West Yost
5766	8	104	0	X20B4-33	X20B4-32	0	401	408	401	Invert Elevation Calculated by West Yost
5768	8	104	0	X20B4-29	X20B4-28	0	398	406	398	Invert Elevation Calculated by West Yost
4908	8	282	0	Y20A4-3	Y20A4-2	0	0	394	391	Invert Elevation Calculated by West Yost
4909	8	354	0	Y20A4-2	Y20A4-1	0	0	391	379	Invert Elevation Calculated by West Yost
5704	8	161	0	Y19B1-11	Y19B1-10	0	0	538	537	Invert Elevation Calculated by West Yost
5705	8	142	0	Y19B1-5	Y19B1-3	0	0	567	561	Invert Elevation Calculated by West Yost
5706	8	191	0	Y19B1-4	Y19B1-3	0	0	574	561	Invert Elevation Calculated by West Yost
5707	8	248	0	Y19B1-2	Y19B1-1	0	0	539	521	Invert Elevation Calculated by West Yost
5708	8	206	0	Y19B1-10	Y19B1-8	0	0	537	530	Invert Elevation Calculated by West Yost
5709	8	149	0	Y19B1-12	Y19B1-10	0	0	543	537	Invert Elevation Calculated by West Yost
5710	8	228	0	Y19B1-8	Y19B1-1	0	0	530	521	Invert Elevation Calculated by West Yost
5711	8	172	0	Y19B1-6	Y19B1-2	0	0	545	539	Invert Elevation Calculated by West Yost
5712	8	183	0	Y19B1-1	Y19C1-6	0	0	521	518	Invert Elevation Calculated by West Yost
5689	10	218	0	Y19C1-9	Y19C1-8	0	0	563	559	Invert Elevation Calculated by West Yost
5690	10	340	0	Y19C1-8	Y19C1-7	0	0	559	540	Invert Elevation Calculated by West Yost
5691	10	368	0	Y19C1-7	Y19C1-6	0	0	540	518	Invert Elevation Calculated by West Yost
5713	8	209	0	Y19B1-15	Y19B1-14	0	0	567	562	Invert Elevation Calculated by West Yost
5719	8	323	0	Y19B2-12	Y19B2-11	0	0	550	540	Invert Elevation Calculated by West Yost
5848	8	323	0	X20B5-14	X20B5-13	0	0	363	362	Invert Elevation Calculated by West Yost
5803	8	138	0	X20B5-13	X20B5-11	0	0	362	360	Invert Elevation Calculated by West Yost
5663	8	262	0	X19D3-35	X19D3-34	0	0	465	462	Invert Elevation Calculated by West Yost
5664	8	124	0	X19D3-34	X19D3-31	0	0	462	465	Invert Elevation Calculated by West Yost
5665	8	160	0	X19D3-31	X19D3-30	0	0	465	463	Invert Elevation Calculated by West Yost
5666	8	274	0	X19D3-30	X19D3-29	0	0	463	459	Invert Elevation Calculated by West Yost
5667	8	274	0	X19D3-29	X19D3-28	0	0	459	448	Invert Elevation Calculated by West Yost
5668	8	350	0	X19D3-28	X19D3-24	0	0	448	435	Invert Elevation Calculated by West Yost
5669	8	179	0	X19D3-25	X19D3-24	0	0	442	435	Invert Elevation Calculated by West Yost
5670	8	136	0	X19D3-24	X19D3-23	0	0	435	430	Invert Elevation Calculated by West Yost
5671	8	149	0	X19D3-23	X19D3-21	0	0	430	425	Invert Elevation Calculated by West Yost
5672	8	262	0	X19D3-22	X19D3-21	0	0	436	425	Invert Elevation Calculated by West Yost
5673	8	332	0	X19D3-21	X19D3-20	0	0	425	423	Invert Elevation Calculated by West Yost
5674	8	88	0	X19D3-20	X19D3-19	0	0	423	417	Invert Elevation Calculated by West Yost
5675	8	220	0	X19D3-34	X19D3-33	0	0	462	459	Invert Elevation Calculated by West Yost
5676	8	220	0	X19D3-33	X19D3-32	0	0	459	456	Invert Elevation Calculated by West Yost
5677	8	350	0	X19D3-32	X19D3-27	0	0	456	448	Invert Elevation Calculated by West Yost
5678	8	341	0	X19D3-27	X19D3-26	0	0	448	438	Invert Elevation Calculated by West Yost
5679	8	269	0	X19D3-26	X19D3-24	0	0	438	435	Invert Elevation Calculated by West Yost
5680	8	181	0	X19D3-36	X19D3-35	0	0	467	465	Invert Elevation Calculated by West Yost
5681	12	350	0	Y20C2-14	Y20C2-13	0	0	448	427	Invert Elevation Calculated by West Yost
5682	12	275	0	Y20C2-15	Y20C2-14	0	0	464	448	Invert Elevation Calculated by West Yost
5683	15	350	0	Y20C2-9	Y20C2-8	0	0	376	361	Invert Elevation Calculated by West Yost
5684	15	252	0	Y20C2-10	Y20C2-9	0	0	384	376	Invert Elevation Calculated by West Yost
5686	12	350	0	Y20C2-12	Y20C2-11	0	0	411	399	Invert Elevation Calculated by West Yost
5849	8	180	0	X20B5-11	X20B5-3	0	0	360	350	Invert Elevation Calculated by West Yost
5807	8	242	0	X20B5-5	X20B5-4	0	0	352	351	Invert Elevation Calculated by West Yost
5808	8	226	0	X20B5-4	X20B5-3	0	0	351	350	Invert Elevation Calculated by West Yost
6062	8	204	0	T20C2-7	T20C2-6	0	0	689	676	Invert Elevation Calculated by West Yost
5870	8	272	0	T20C2-6	T20C2-5	0	0	676	671	Invert Elevation Calculated by West Yost
5871	8	350	0	T20C2-15	T20C2-14	0	0	796	791	Invert Elevation Calculated by West Yost
5873	8	324	0	T20C2-12	T20C2-11	0	0	775	759	Invert Elevation Calculated by West Yost
5874	8	350	0	T20C2-4	T20C2-3	0	0	651	621	Invert Elevation Calculated by West Yost
5875	8	350	0	T20C2-3	T20C2-2	0	0	621	588	Invert Elevation Calculated by West Yost
5876	8	350	0	T20C2-16	T20C2-15	0	0	805	796	Invert Elevation Calculated by West Yost
5877	8	290	0	T20C2-13	T20C2-12	0	0	785	775	Invert Elevation Calculated by West Yost
5879	8	212	0	T20C2-9	T20C2-8	0	0	725	708	Invert Elevation Calculated by West Yost
5880	8	204	0	T20C2-8	T20C2-7	0	0	708	689	Invert Elevation Calculated by West Yost
5881	8	202	0	T20C2-5	T20C2-4	0	0	671	651	Invert Elevation Calculated by West Yost
5882	8	350	0	T20C2-2	T20C2-1	0	0	588	579	Invert Elevation Calculated by West Yost
5883	8	203	0	T20C2-1	T20C1-35	0	573	579	573	Invert Elevation Calculated by West Yost
6065	8	305	0	S20C2-29	S20C2-27	0	0	970	967	Invert Elevation Calculated by West Yost
6066	8	329	0	S20C2-27	S20C2-25	0	0	967	964	Invert Elevation Calculated by West Yost
6067	8	357	0	S20C2-25	S20C2-24	0	0	964	962	Invert Elevation Calculated by West Yost
6068	8	282	0	S20C2-24	S20C2-23	0	0	962	960	Invert Elevation Calculated by West Yost
6069	8	283	0	S20C2-23	S20C2-22	0	0	960	958	Invert Elevation Calculated by West Yost
6070	8	285	0	S20C2-22	S20C2-21	0	0	958	954	Invert Elevation Calculated by West Yost
6071	8	283	0	S20C2-21	S20C2-17	0	0	954	949	Invert Elevation Calculated by West Yost
5911	8	350	0	S20C2-17	S20C2-16	0	0	949	943	Invert Elevation Calculated by West Yost
6072	8	368	0	S20C2-16	S20C2-15	0	0	943	936	Invert Elevation Calculated by West Yost
6073	8	319	0	S20C2-15	S20C2-8	0	0	936	930	Invert Elevation Calculated by West Yost
6074	8	63	0	S20C2-8	S20C2-4	0	0	930	930	Invert Elevation Calculated by West Yost
5888	8	297	0	S20C2-4	S20C2-3	0	0	930	907	Invert Elevation Calculated by West Yost
5889	8	185	0	S20C2-3	S20C2-2	0	0	907	887	Invert Elevation Calculated by West Yost
6014	8	218	0	X17D1-2	X17D1-1	388	0	388	494	Invert Elevation Calculated by West Yost
6075	8	198	0	S20C2-28	S20C2-27	0	0	967	967	Invert Elevation Calculated by West Yost
6076	8	202	0	S20C2-26	S20C2-25	0	0	969	964	Invert Elevation Calculated by West Yost
6077	8	173	0	S20C2-19	S20C2-18	0	0	966	950	Invert Elevation Calculated by West Yost
6078	8	301	0	S20C1-18	S20C1-16	0	0	970	961	Invert Elevation Calculated by West Yost
6079	8	151	0	S20C1-16	S20C1-15	0	0	961	959	Invert Elevation Calculated by West Yost
6080	8	149	0	S20C1-15	S20C1-13	0	0	959	958	Invert Elevation Calculated by West Yost
6081	8	288	0	S20C1-13	S20C1-11	0	0	958	953	Invert Elevation Calculated by West Yost
6082	8	272	0	S20C1-11	S20C1-9	0	0	953	951	Invert Elevation Calculated by West Yost
6083	8	287	0	S20C1-9	S20C1-8	0	0	951	943	Invert Elevation Calculated by West Yost
6084	8	259	0	S20C1-8	S20C1-7	0	0	943	923	Invert Elevation Calculated by West Yost
6085	8	219	0	S20C1-7	S20C1-6	0	0	923	906	Invert Elevation Calculated by West Yost
5908	8	274	0	S20C2-14	S20C2-12	0	0	947	944	Invert Elevation Calculated by West Yost
5909	8	360	0	S20C2-12	S20C2-11	0	0	944	941	Invert Elevation Calculated by West Yost
6086	8	342	0	S20C2-11	S20C2-10	0	0	941	940	Invert Elevation Calculated by West Yost
6087	8	326	0	S20C2-10	S20C2-9	0	0	940	937	Invert Elevation Calculated by West Yost
5896	8	164	0	S20C2-9	S20C2-8	0	0	937	930	Invert Elevation Calculated by West Yost
5887	8	181	0	S20C2-5	S20C2-4	0	0	932	930	Invert Elevation Calculated by West Yost
6088	8	80	0	S20C2-7	S20C2-6	0	0	938	934	Invert Elevation Calculated by West Yost
6089	8	93	0	S20C2-6	S20C2-5	0	0	934	932	Invert Elevation Calculated by West Yost
6090	8	126	0	S20C2-20	S20C2-19	0	0	975	966	Invert Elevation Calculated by West Yost
6091	8	73	0	S20C2-18	S20C2-17	0	0	950	949	Invert Elevation Calculated by West Yost
6092	8	266	0	S20C1-10	S20C1-9	0	0	956	951	Invert Elevation Calculated by West Yost
6093	8	193	0	S20C1-12	S20C1-11	0	0	958	953	Invert Elevation Calculated by West Yost
6094	8	291	0	S20C1-14	S20C1-13	0	0	965	958	Invert Elevation Calculated by West Yost
6095	8	192	0	S20C1-17	S20C1-16	0	0	965	961	Invert Elevation Calculated by West Yost
6096	8	128	0	S20C2-13	S20C2-12	0	0	945	944	Invert Elevation Calculated by West Yost
6106	8	192	0	S20C2-1	T20C2-19	0	0	870	856	Invert Elevation Calculated by West Yost
5924	8	257	0	S20C1-31	S20C1-30	0	0	988	983	Invert Elevation Calculated by West Yost
6107	8	304	0	S20C1-6	S20C1-5	0	0	906	895	Invert Elevation Calculated by West Yost
5936	8	247	0	S20C1-5	S20C1-4	0	0	895	871	Invert Elevation Calculated by West Yost
5937	8	205	0	S20C1-4	S20C1-3	0	0	871	859	Invert Elevation Calculated by West Yost
5938	8	289	0	S20C1-3	S20C1-2	0	0	859	858	Invert Elevation Calculated by West Yost
5939	8	247	0	S20C1-2	S20C1-1	0	0	858	857	Invert Elevation Calculated by West Yost
5940	8	238	0	S20C1-1	T20C2-19	0	0	857	856	Invert Elevation Calculated by West Yost
5941	8	349	0	T20C2-19	T20C2-18	0	0	856	853	Invert Elevation Calculated by West Yost
6064	8	345	0	T20C2-18	T20C2-17	0	0	853	825	Invert Elevation Calculated by West Yost
5942	8	348	0	T20C2-17	T20C2-16	0	0	825	805	Invert Elevation Calculated by West Yost
6109	8	181	0	S20C2-2	S20C2-1	0	0	887	870	Invert Elevation Calculated by West Yost
5740	8	218	0	Y19B3-12	Y19B3-11	0	0	581	567	Invert Elevation Calculated by West Yost
5741	8	223	0	Y19B3-15	Y19B3-12	0	0	595	581	Invert Elevation Calculated by West Yost
5742	8	285	0	Y19B3-16	Y19B3-15	0	0	615	595	Invert Elevation Calculated by West Yost
5743	8	230	0	Y19B3-7	Y19B3-6	0	0	575	561	Invert Elevation Calculated by West Yost
5744	8	276	0	Y19B3-6	Y19B3-5	0	0	561	545	Invert Elevation Calculated by West Yost
5745	8	297	0	Y19B3-5	Y19B3-1	0	0	545	524	Invert Elevation Calculated by West Yost
5746	8	283	0	Y19B3-2	Y19B3-1	0	0	542	524	Invert Elevation Calculated by West Yost
6225	8	310	0	Y19B4-2	Y19B4-1	0	0	590	571	Invert Elevation Calculated by West Yost
6222	8	307	0	Y19B4-4	Y19B4-3	0	0	606	592	Invert Elevation Calculated by West Yost
6223	8	37	0	Y19B4-3	Y19B4-2	0	0	592	590	Invert Elevation Calculated by West Yost
5696	10	251	0	Y19C1-5	Y19C1-4	0	0	513	508	Invert Elevation Calculated by West Yost
5697	10	260	0	Y19C1-6	Y19C1-5	0	0	518	513	Invert Elevation Calculated by West Yost
5698	10	350	0	Y19C1-4	Y19C1-3	0	0	508	493	Invert Elevation Calculated by West Yost
5699	10	332	0	Y19C1-2	Y19C1-1	0	0	482	466	Invert Elevation Calculated by West Yost
5700	10	195	0	Y19C1-1	Y20C2-15	0	0	466	464	Invert Elevation Calculated by West Yost
5701	10	350	0	Y19C1-3	Y19C1-2	0	0	493	482	Invert Elevation Calculated by West Yost
5730	8	181	0	Y19B2-1	Y19C1-5	0	0	514	513	Invert Elevation Calculated by West Yost
5731	8	284	0	Y19B2-10	Y19B2-7	0	0	539	527	Invert Elevation Calculated by West Yost
5732	8	313	0	Y19B2-15	Y19B2-13	0	0	570	553	Invert Elevation Calculated by West Yost
5747	8	191	0	Y19B3-1	Y19C1-6	0	0	524	518	Invert Elevation Calculated by West Yost
5748	8	297	0	Y19B3-4	Y19B3-3	0	0	568	555	Invert Elevation Calculated by West Yost
6220	8	172	0	Y19B4-42	Y19B4-4	0	0	613	606	Invert Elevation Calculated by West Yost
6224	8	133	0	Y19B4-1	Y19C1-9	0	0	571	563	Invert Elevation Calculated by West Yost
5714	8	362	0	Y19B1-3	Y19B1-2	0	0	561	539	Invert Elevation Calculated by West Yost
5715	8	321	0	Y19B1-7	Y19B1-6	0	0	563	545	Invert Elevation Calculated by West Yost

Table 1. List of Gravity Mains with Unknown Invert Elevation(s)

GIS Information From Gravity Main Shapefile								Proposed Invert Elevations		West Yost Comment
Pipe ID	Diameter	Length, ft	Slope	Upstream Manhole ID	Downstream Manhole ID	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	
5716	8	212	0	Y19B1-14	Y19B1-13	0	0	562	554	Invert Elevation Calculated by West Yost
5717	8	315	0	Y19B1-13	Y19B1-12	0	0	554	543	Invert Elevation Calculated by West Yost
5718	8	184	0	Y19B1-9	Y19B1-8	0	0	533	530	Invert Elevation Calculated by West Yost
5979	8	159	0	X18B2-16	X18B2-15	0	0	500	498	Invert Elevation Calculated by West Yost
5947	8	110	0	X18B1-33	X18B1-30	0	0	486	483	Invert Elevation Calculated by West Yost
5948	8	82	0	X18B1-32	X18B1-31	0	0	485	485	Invert Elevation Calculated by West Yost
5949	8	66	0	X18B1-30	X18B1-28	0	0	483	480	Invert Elevation Calculated by West Yost
5950	8	34	0	X18B1-31	X18B1-30	0	0	485	483	Invert Elevation Calculated by West Yost
5951	8	77	0	X18B1-34	X18B1-33	0	0	490	486	Invert Elevation Calculated by West Yost
5952	8	73	0	X18B1-35	X18B1-33	0	0	488	486	Invert Elevation Calculated by West Yost
5953	8	49	0	X18B1-38	X18B1-36	0	0	493	491	Invert Elevation Calculated by West Yost
5954	8	75	0	X18B1-36	X18B1-35	0	0	491	488	Invert Elevation Calculated by West Yost
5955	8	76	0	X18B1-37	X18B1-36	0	0	492	491	Invert Elevation Calculated by West Yost
5956	8	49	0	X18B1-39	X18B1-35	0	0	489	488	Invert Elevation Calculated by West Yost
5957	8	72	0	X18B1-40	X18B1-39	0	0	493	489	Invert Elevation Calculated by West Yost
5958	8	100	0	X18B1-27	X18B1-26	0	0	480	477	Invert Elevation Calculated by West Yost
5959	8	89	0	X18B1-26	X18B1-24	0	0	477	474	Invert Elevation Calculated by West Yost
5960	8	61	0	X18B1-23	X18B1-21	0	0	477	475	Invert Elevation Calculated by West Yost
4988	8	53	0	X18B1-22	X18B1-21	0	0	477	475	Invert Elevation Calculated by West Yost
5961	8	72	0	X18B1-20	X18B1-18	0	0	473	471	Invert Elevation Calculated by West Yost
4995	8	81	0	X18B1-21	X18B1-20	0	0	475	473	Invert Elevation Calculated by West Yost
5962	8	72	0	X18B1-29	X18B1-28	0	0	483	480	Invert Elevation Calculated by West Yost
5963	8	96	0	X18B1-25	X18B1-24	0	0	480	474	Invert Elevation Calculated by West Yost
5001	8	76	0	X18B1-19	X18B1-18	0	0	476	471	Invert Elevation Calculated by West Yost
5964	8	55	0	X18B1-28	X18B1-26	0	0	480	477	Invert Elevation Calculated by West Yost
5869	8	212	0	T20C2-10	T20C2-9	0	0	743	725	Invert Elevation Calculated by West Yost
5771	8	110	0	X20B4-24	X20B4-23	0	395	404	395	Invert Elevation Calculated by West Yost
5773	8	105	0	X20B4-21	X20B4-20	0	394	399	394	Invert Elevation Calculated by West Yost
5775	8	106	0	X20B4-19	X20B4-17	0	392	401	392	Invert Elevation Calculated by West Yost
5972	8	110	0	X18B2-23	X18B2-22	0	0	504	504	Invert Elevation Calculated by West Yost
5973	8	85	0	X18B2-21	X18B2-18	0	0	503	501	Invert Elevation Calculated by West Yost
5974	8	40	0	X18B2-22	X18B2-21	0	0	504	503	Invert Elevation Calculated by West Yost
5976	8	180	0	X18B2-18	X18B2-15	0	0	501	498	Invert Elevation Calculated by West Yost
5977	8	122	0	X18B2-19	X18B2-18	0	0	502	501	Invert Elevation Calculated by West Yost
5978	8	152	0	X18B2-20	X18B2-18	0	0	503	501	Invert Elevation Calculated by West Yost
5659	8	77	0	X19D3-37	X19D3-3	392	0	392	391	Invert Elevation Calculated by West Yost
5643	8	202	0	X19D3-39	X19D3-38	0	397	404	397	Invert Elevation Calculated by West Yost
6121	8	140	0	X19D3-43	X19D3-42	0	0	417	414	Invert Elevation Calculated by West Yost
6120	8	182	0	X19D3-44	X19D3-42	0	0	417	414	Invert Elevation Calculated by West Yost
6119	8	153	0	X19D3-45	X19D3-41	0	0	410	406	Invert Elevation Calculated by West Yost
5648	8	234	0	X19D3-46	X19D3-45	0	0	412	410	Invert Elevation Calculated by West Yost
6122	8	135	0	X19D3-47	X19D3-46	0	0	418	412	Invert Elevation Calculated by West Yost
5654	8	136	0	X19D3-48	X19D3-47	0	0	423	418	Invert Elevation Calculated by West Yost
6117	8	342	0	X19D3-49	X19D3-38	0	397	402	397	Invert Elevation Calculated by West Yost
5652	8	258	0	X19D3-50	X19D3-49	0	0	404	402	Invert Elevation Calculated by West Yost
6123	8	54	0	X19D3-51	X19D3-50	0	0	404	404	Invert Elevation Calculated by West Yost
5651	8	41	0	X19D3-52	X19D3-51	0	0	405	404	Invert Elevation Calculated by West Yost
5650	8	161	0	X19D3-53	X19D3-52	0	0	405	405	Invert Elevation Calculated by West Yost
6116	8	180	0	X19D3-56	X19D3-53	0	0	409	405	Invert Elevation Calculated by West Yost
6115	8	108	0	X19D3-57	X19D3-56	0	0	411	409	Invert Elevation Calculated by West Yost
6113	8	260	0	X19D3-58	X19D3-57	0	0	424	411	Invert Elevation Calculated by West Yost
6114	8	184	0	X19D3-59	X19D3-57	0	0	414	411	Invert Elevation Calculated by West Yost
6129	8	188	0	X19D3-61	X19D3-60	0	0	422	414	Invert Elevation Calculated by West Yost
6146	8	210	0	Y20A5-11	Y20A5-10	0	0	344	343	Invert Elevation Calculated by West Yost
6182	8	347	0	V20b4-11	V20b4-6	0	0	325	323	Invert Elevation Calculated by West Yost
6183	8	230	0	V20b4-7	V20b4-6	0	0	324	323	Invert Elevation Calculated by West Yost
6185	8	127	0	V20b4-6	V20b4-5	0	0	323	322	Invert Elevation Calculated by West Yost
6176	8	100	0	V20b4-23	V20b4-17	0	0	326	325	Invert Elevation Calculated by West Yost
6177	8	88	0	V20b4-17	V20b4-15	0	0	325	323	Invert Elevation Calculated by West Yost
6179	8	156	0	V20b4-15	V20b4-14	0	0	323	322	Invert Elevation Calculated by West Yost
6180	8	74	0	V20b4-14	V20b4_13	0	0	322	322	Invert Elevation Calculated by West Yost
6188	8	99	0	V20b4_13	V20b4-4	0	0	322	322	Invert Elevation Calculated by West Yost
6187	8	187	0	V20b4-8	V20b4-5	0	0	324	322	Invert Elevation Calculated by West Yost
6189	8	89	0	V20b4-5	V20b4-4	0	0	322	322	Invert Elevation Calculated by West Yost
6190	8	98	0	V20b4-9	V20b4-4	0	0	323	322	Invert Elevation Calculated by West Yost
6184	8	131	0	V20b4-4	V20b4-3	0	0	322	321	Invert Elevation Calculated by West Yost
6181	8	96	0	V20b4-10	V20b4-9	0	0	324	323	Invert Elevation Calculated by West Yost
6192	8	121	0	V20b4-3	V20b4-2	0	0	321	320	Invert Elevation Calculated by West Yost
6172	8	97	0	V20b4-22	V20b4-21	0	0	323	323	Invert Elevation Calculated by West Yost
6173	8	29	0	V20b4-21	V20b4-20	0	0	323	323	Invert Elevation Calculated by West Yost
6174	8	124	0	V20b4-20	V20b4-19	0	0	323	322	Invert Elevation Calculated by West Yost
6175	8	94	0	V20b4-19	V20b4-18	0	0	322	321	Invert Elevation Calculated by West Yost
6193	8	84	0	V20b4-18	V20b4-2	0	0	321	320	Invert Elevation Calculated by West Yost
6191	8	42	0	V20b4-2	V20b4-1	0	0	320	320	Invert Elevation Calculated by West Yost
6178	8	118	0	V20b4-16	V20b4-15	0	0	323	323	Invert Elevation Calculated by West Yost
6208	8	101	0	U20D1-43	U20D1-42	0	0	341	337	Invert Elevation Calculated by West Yost
6209	8	135	0	U20D1-42	U20D1-41	0	0	337	336	Invert Elevation Calculated by West Yost
6210	8	274	0	U20D1-41	U20D1-18	0	0	336	336	Invert Elevation Calculated by West Yost
6237	8	79	0	Y19B4-27	Y19B4-5	0	0	621	618	Invert Elevation Calculated by West Yost
6259	8	314	0	Y19B5-7	Y19B5-4	0	0	633	610	Invert Elevation Calculated by West Yost
6255	8	183	0	Y19B5-10	Y19B5-9	0	0	659	647	Invert Elevation Calculated by West Yost
6236	8	60	0	Y19B4-37	Y19B4-35	0	0	623	622	Invert Elevation Calculated by West Yost
6234	8	305	0	Y19B4-38	Y19B4-37	0	0	647	623	Invert Elevation Calculated by West Yost
6294	8	131	0	Y19B6-7	Y19B6-6	0	0	666	656	Invert Elevation Calculated by West Yost
6295	8	112	0	Y19B6-6	Y19B6-5	0	0	656	648	Invert Elevation Calculated by West Yost
6282	8	63	0	Y19B6-3	Y19B6-2	0	0	630	629	Invert Elevation Calculated by West Yost
6310	8	184	0	Y19B7-1	Y19C1-12	0	0	599	590	Invert Elevation Calculated by West Yost
6254	8	189	0	Y19B5-11	Y19B5-10	0	0	666	659	Invert Elevation Calculated by West Yost
6238	8	266	0	Y19B4-28	Y19B4-27	0	0	633	621	Invert Elevation Calculated by West Yost
6235	8	63	0	Y19B4-40	Y19B4-6	0	0	628	627	Invert Elevation Calculated by West Yost
6232	8	258	0	Y19B4-10	Y19B4-7	0	0	644	634	Invert Elevation Calculated by West Yost
6245	8	114	0	Y19B3-22	Y19B3-21	0	0	631	629	Invert Elevation Calculated by West Yost
6252	8	193	0	Y19B4-26	Y19B5-11	0	0	678	666	Invert Elevation Calculated by West Yost
6229	8	203	0	Y19B4-16	Y19B4-15	0	0	682	669	Invert Elevation Calculated by West Yost
6257	8	335	0	Y19B5-8	Y19B5-7	0	0	649	633	Invert Elevation Calculated by West Yost
6316	8	280	0	Z19A1-10	Z19A1-9	0	0	627	600	Invert Elevation Calculated by West Yost
6326	8	225	0	Z19A3-6	Z19A3-5	0	0	671	657	Invert Elevation Calculated by West Yost
6331	8	330	0	Z19A2-4	Z19A3-6	0	0	685	671	Invert Elevation Calculated by West Yost
6313	8	328	0	Z19A1-15	Z19A1-14	0	0	620	603	Invert Elevation Calculated by West Yost
6322	8	114	0	Z19A3-19	Z19A3-18	0	0	722	711	Invert Elevation Calculated by West Yost
6323	8	54	0	Z19A3-18	Z19A3-17	0	0	711	710	Invert Elevation Calculated by West Yost
6324	8	214	0	Z19A3-16	Z19A3-13	0	0	699	686	Invert Elevation Calculated by West Yost
6325	8	310	0	Z19A3-13	Z19A3-10	0	0	686	663	Invert Elevation Calculated by West Yost
6227	8	177	0	Y19B4-19	Y19B4-18	0	0	699	689	Invert Elevation Calculated by West Yost
6228	8	340	0	Y19B4-18	Y19B4-17	0	0	689	661	Invert Elevation Calculated by West Yost
6251	8	371	0	Y19B5-13	Y19B5-12	0	0	685	674	Invert Elevation Calculated by West Yost
6341	8	34	0	Z19A1-16	Z19A1-18	0	0	580	575	Invert Elevation Calculated by West Yost
6339	8	670	0	Z19A1-18	Z19A1-1	0	0	575	604	Invert Elevation Calculated by West Yost
6373	8	142	0	Y19B5-6	Y19B5-5	0	0	623	617	Invert Elevation Calculated by West Yost
6375	8	194	0	Y19B5-5	Y19B5-4	0	0	617	610	Invert Elevation Calculated by West Yost
6376	8	308	0	Y19B5-4	Y19B5-3	0	0	610	590	Invert Elevation Calculated by West Yost
6377	8	39	0	Y19B5-3	Y19B5-2	0	0	590	589	Invert Elevation Calculated by West Yost
6378	8	205	0	Y19B5-2	Y19B5-1	0	0	589	587	Invert Elevation Calculated by West Yost
6379	8	185	0	Y19B5-1	Y19B3-18	0	0	587	585	Invert Elevation Calculated by West Yost
6381	8	250	0	Y19B3-23	Y19B3-21	0	0	644	629	Invert Elevation Calculated by West Yost
6389	8	261	0	Y19B5-24	Y19B5-23	0	0	715	704	Invert Elevation Calculated by West Yost
6390	8	306	0	Y19B5-25	Y19B5-24	0	0	730	715	Invert Elevation Calculated by West Yost
6388	8	320	0	Y19B5-26	Y19B5-25	0	0	749	730	Invert Elevation Calculated by West Yost
6244	8	184	0	Y19B3-24	Y19B3-23	0	0	654	644	Invert Elevation Calculated by West Yost
6402	8	160	0	Z19A3-4	Z19A3-3	0	0	632	627	Invert Elevation Calculated by West Yost
6405	8	47	0	Z19A3-7	Z19A3-3	0	0	631	627	Invert Elevation Calculated by West Yost
6406	8	99	0	Z19A3-3	Z19A3-2	0	0	627	620	Invert Elevation Calculated by West Yost
6329	8	173	0	Z19A2-5	Z19A2-2	0	0	688	672	Invert Elevation Calculated by West Yost
6330	8	257	0	Z19A2-2	Z19A2-1	0	0	672	652	Invert Elevation Calculated by West Yost
6320	8	140	0	Z19A2-1	Z19A1-6	0	0	652	641	Invert Elevation Calculated by West Yost
6319	8	176	0	Z19A1-2	Z19A1-1	0	0	616	604	Invert Elevation Calculated by West Yost
6321	8	240	0	Z19A1-6	Z19A1-7	0	0	641	624	Invert Elevation Calculated by West Yost
6318	8	328	0	Z19A1-7	Z19A1-8	0	0	624	598	Invert Elevation Calculated by West Yost
6317	8	302	0	Z19A1-8	Z19A1-12	0	0	598	581	Invert Elevation Calculated by West Yost
6314	8	226	0	Z19A1-14	Z19A1-13	0	0	603	583	Invert Elevation Calculated by West Yost
6315	8	149	0	Z19A1-12	Z19A1-16	0	0	581	580	Invert Elevation Calculated by West Yost
6427	8	68	0	Z19A1-5	Z19A1-6	0	0	642	641	Invert Elevation Calculated by West Yost
6428	8	63	0	Y19B1-20	Y19B1-18	0	0	573	572	Invert Elevation Calculated by West Yost
6429	8	241	0	Y19B1-18	Y19B1-17	0	0	572	565	Invert Elevation Calculated by West Yost
6430	8	198	0	Y19B1-23	Y19B1-17	0	0	568	565	Invert Elevation Calculated by West Yost
6431	8	313	0	Y19B1-24	Y19B1-23	0	0	571	568	Invert Elevation Calculated by West Yost
6432	8	328	0	Y19B1-22	Y19B1-21	0	0	584	580	Invert Elevation Calculated by West Yost
6433	8	242	0	Y19B1-27	Y19B1-26	0	0	578	573	Invert Elevation Calculated by West Yost
6216	8	246	0	Y19B1-26	Y19B1-17	0	0	573	565	Invert Elevation Calculated by West Yost
6435	8	208	0	Y19B1-17	Y19B1-16	0	0	565	558	Invert Elevation Calculated by West Yost
6436	8	284	0	Y19B3-18	Y19B3-4	0	0	585	568	Invert Elevation Calculated by West Yost
6281	8	309	0	Y19B6-2	Y19B6-1	0	0	629	606	Invert Elevation Calculated by West Yost
6280	8	181	0	Y19B6-1	Y19C1-16	0	0	606	596	Invert Elevation Calculated by West Yost
6446	8	231	0	Y19B4-9	Y19B4-8	0	0	652	644	Invert Elevation Calculated by West Yost
6447	8	206	0	Y19B4-8	Y19B4-7	0	0	644	634	Invert Elevation Calculated by West Yost
6219	8	261	0	Y19B4-6	Y19B4-5	0	0	627	618	Invert Elevation Calculated by West Yost
6450	8	72	0	Y19B4-30	Y19B4-29	0	0	614	608	Invert Elevation Calculated by West Yost
6239	8	97	0	Y19B4-31	Y19B4-30	0	0	623	614	Invert Elevation Calculated by West Yost
6453	8	117	0	Y19B4-32	Y19B4-31	0	0	633	623	Invert Elevation Calculated by West Yost
6454	8	123	0	Y19B4-34	Y19B4-33	0	0	601	596	Invert Elevation Calculated by West Yost
6380	8	221	0	Y19B3-20	Y19B3-19	0	0	619	609	Invert Elevation Calculated by West Yost
6374	8	327	0	Y19B3-19	Y19B3-18	0	0	609	585	Invert Elevation Calculated by West Yost
6256	8	230	0	Y19B5-9	Y19B5-7	0	0	647	633	Invert Elevation Calculated by West Yost
6253	8	277	0	Y19B5-12	Y19B5-10	0	0	674	659	Invert Elevation Calculated by West Yost
6250	8	172	0	Y19B5-14	Y19B5-12	0	0	680	674	Invert Elevation Calculated by West Yost
6463	8	82	0	Y19B5-15	Y19B5-14	0	0	683	680	Invert Elevation Calculated by West Yost

Table 1. List of Gravity Mains with Unknown Invert Elevation(s)

GIS Information From Gravity Main Shapefile								Proposed Invert Elevations		West Yost Comment
Pipe ID	Diameter	Length, ft	Slope	Upstream Manhole ID	Downstream Manhole ID	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	
6248	8	307	0	Y19B5-22	Y19B5-21	0	0	721	708	Invert Elevation Calculated by West Yost
6386	8	75	0	Y19B5-16	Y19B5-15	0	0	685	683	Invert Elevation Calculated by West Yost
6387	8	226	0	Y19B5-17	Y19B5-16	0	0	696	685	Invert Elevation Calculated by West Yost
6385	8	238	0	Y19B5-18	Y19B5-17	0	0	705	696	Invert Elevation Calculated by West Yost
6489	8	258	0	Y19B4-20	Y19B4-18	0	0	703	689	Invert Elevation Calculated by West Yost
6382	8	300	0	Y19B4-21	Y19B4-20	0	0	719	703	Invert Elevation Calculated by West Yost
6383	8	260	0	Y19B4-22	Y19B4-21	0	0	735	719	Invert Elevation Calculated by West Yost
6215	8	350	0	Y19B1-21	Y19B1-20	0	0	580	573	Invert Elevation Calculated by West Yost
6152	8	109	0	Y20A5-9	Y20A5-8	0	0	343	342	Invert Elevation Calculated by West Yost
6148	8	94	0	Y20A5-10	Y20A5-9	0	0	343	343	Invert Elevation Calculated by West Yost
6145	8	106	0	Y20A5-12	Y20A5-11	0	0	344	344	Invert Elevation Calculated by West Yost
6149	8	390	0	Y20A5-6	Y20A5-5	0	0	347	346	Invert Elevation Calculated by West Yost
3837	8	145	0	X20C1-1	X20A2-11	339	0	339	339	Invert Elevation Calculated by West Yost
6487	12	94	0	Y20C2-13	Y20C2-16	0	0	427	423	Invert Elevation Calculated by West Yost
5685	12	257	0	Y20C2-16	Y20C2-12	0	0	423	411	Invert Elevation Calculated by West Yost
6491	8	55	0	X20C1-21	X20C1-1	345	0	345	339	Invert Elevation Calculated by West Yost
6500	8	48	0	V19D3-17	V19D3-15	0	0	348	347	Invert Elevation Calculated by West Yost
6516	8	310	0	V19D3-14	V19D3-13	0	0	350	347	Invert Elevation Calculated by West Yost
6517	8	140	0	V19D3-15	V19D3-16	0	0	347	351	Invert Elevation Calculated by West Yost
6518	8	316	0	V19D3-18	V19D3-17	0	0	351	348	Invert Elevation Calculated by West Yost
6512	8	140	0	V19D3-6	V19D3-4	0	0	347	346	Invert Elevation Calculated by West Yost
6520	8	307	0	V19D3-22	V19D3-21	0	0	350	349	Invert Elevation Calculated by West Yost
6299	8	40	0	Y19B7-3	Y19B7-2	0	0	604	604	Invert Elevation Calculated by West Yost
6300	8	190	0	Y19B7-4	Y19B7-3	0	0	605	604	Invert Elevation Calculated by West Yost
6568	8	264	0	Y19B4-5	Y19B4-4	0	0	618	606	Invert Elevation Calculated by West Yost
6573	8	73	0	Y19B4-33	Y19B4-3	0	0	596	592	Invert Elevation Calculated by West Yost
6554	8	170	0	Y19B6-4	Y19B6-2	0	0	642	629	Invert Elevation Calculated by West Yost
6560	8	272	0	Y19B6-8	Y19B6-7	0	0	674	666	Invert Elevation Calculated by West Yost
6558	8	181	0	Y19B4-38	Y19B4-39	0	0	647	643	Invert Elevation Calculated by West Yost
6559	8	193	0	Y19B4-39	Y19B4-40	0	0	643	628	Invert Elevation Calculated by West Yost
6562	8	301	0	Y19B4-14	Y19B4-10	0	0	650	644	Invert Elevation Calculated by West Yost
6549	8	151	0	V19D3-2	V19D3-1	0	0	344	343	Invert Elevation Calculated by West Yost
6548	8	76	0	V19D3-3	V19D3-2	0	0	345	344	Invert Elevation Calculated by West Yost
6495	8	16	0	V19D3-7	V19D3-4	0	0	346	346	Invert Elevation Calculated by West Yost
6496	8	110	0	V19D3-9	V19D3-7	0	0	346	346	Invert Elevation Calculated by West Yost
6497	8	86	0	V19D3-11	V19D3-9	0	0	347	346	Invert Elevation Calculated by West Yost
6498	8	48	0	V19D3-13	V19D3-11	0	0	347	347	Invert Elevation Calculated by West Yost
6499	8	80	0	V19D3-15	V19D3-13	0	0	347	347	Invert Elevation Calculated by West Yost
6504	8	112	0	V19D3-21	V19D3-19	0	0	349	348	Invert Elevation Calculated by West Yost
6522	8	45	0	V19D3-25	V19D3-24	0	0	351	351	Invert Elevation Calculated by West Yost
6569	8	68	0	V20b4-1	V20B1-2	0	0	320	318	Invert Elevation Calculated by West Yost
6503	8	68	0	V19D3-24	V19D3-23	0	0	351	351	Invert Elevation Calculated by West Yost
6514	8	156	0	V19D3-10	V19D3-9	0	0	349	346	Invert Elevation Calculated by West Yost
6513	8	140	0	V19D3-8	V19D3-7	0	0	349	346	Invert Elevation Calculated by West Yost
6547	8	86	0	V19D3-4	V19D3-3	0	0	346	345	Invert Elevation Calculated by West Yost
6575	8	104	0	X19A2-13	X19A2-12	395	0	395	391	Invert Elevation Calculated by West Yost
6565	8	134	0	Y19B5-23	Y19B5-20	0	0	704	699	Invert Elevation Calculated by West Yost
6563	8	267	0	Y19B4-15	Y19B4-14	0	0	669	650	Invert Elevation Calculated by West Yost
6566	8	73	0	Y19B6-5	Y19B6-4	0	0	648	642	Invert Elevation Calculated by West Yost
6564	8	140	0	Y19B4-17	Y19B4-14	0	0	661	650	Invert Elevation Calculated by West Yost
6579	8	30	0	Y19B2-3	Y19B2-1	0	0	514	514	Invert Elevation Calculated by West Yost
6367	8	146	0	Y19B1-19	Y19B1-18	0	0	577	572	Invert Elevation Calculated by West Yost
6581	8	213	0	X18B3-29	X18B3-28	0	0	564	552	Invert Elevation Calculated by West Yost
6582	8	268	0	X18B3-28	X18B3-27	0	0	552	539	Invert Elevation Calculated by West Yost
6584	8	46	0	X18B3-26	X18B3-25	0	0	525	524	Invert Elevation Calculated by West Yost
6585	8	197	0	X18B3-25	X18B3-24	0	0	524	512	Invert Elevation Calculated by West Yost
6588	8	47	0	X18B3-22	X18B3-21	0	0	491	490	Invert Elevation Calculated by West Yost
6589	8	127	0	X18B3-21	X18B3-20	0	0	490	486	Invert Elevation Calculated by West Yost
6590	8	428	0	X18B3-19	X18B3-18	0	0	500	482	Invert Elevation Calculated by West Yost
6593	8	329	0	X18B3-16	X18B3-15	0	0	484	475	Invert Elevation Calculated by West Yost
6594	8	237	0	X18B3-15	X18B3-13	0	0	475	471	Invert Elevation Calculated by West Yost
6595	8	256	0	X18B3-14	X18B3-13	0	0	479	471	Invert Elevation Calculated by West Yost
6596	8	140	0	X18B3-13	X18B3-9	0	0	471	471	Invert Elevation Calculated by West Yost
6599	8	113	0	X18B3-11	X18B3-10	0	0	482	477	Invert Elevation Calculated by West Yost
6600	8	103	0	X18B3-8	X18B3-7	0	0	463	462	Invert Elevation Calculated by West Yost
6604	10	291	0	X18B3-4	X18B3-3	0	0	460	454	Invert Elevation Calculated by West Yost
6605	10	293	0	X18B3-3	X18B3-2	0	0	454	449	Invert Elevation Calculated by West Yost
6606	10	349	0	X18B3-2	X18B3-1	0	0	449	442	Invert Elevation Calculated by West Yost
6603	10	267	0	X18B3-5	X18B3-4	0	0	460	460	Invert Elevation Calculated by West Yost
6602	10	299	0	X18B3-6	X18B3-5	0	0	461	460	Invert Elevation Calculated by West Yost
6601	10	250	0	X18B3-7	X18B3-6	0	0	462	461	Invert Elevation Calculated by West Yost
6608	8	112	0	X18B3-9	X18B3-8	0	0	471	463	Invert Elevation Calculated by West Yost
6598	8	125	0	X18B3-12	X18B3-10	0	0	481	477	Invert Elevation Calculated by West Yost
6597	8	138	0	X18B3-10	X18B3-9	0	0	477	471	Invert Elevation Calculated by West Yost
6591	8	124	0	X18B3-18	X18B3-17	0	0	482	478	Invert Elevation Calculated by West Yost
6580	8	73	0	X18B3-20	X18B3-18	0	0	486	482	Invert Elevation Calculated by West Yost
6587	8	179	0	X18B3-23	X18B3-22	0	0	499	491	Invert Elevation Calculated by West Yost
6586	8	244	0	X18B3-24	X18B3-23	0	0	512	499	Invert Elevation Calculated by West Yost
6583	8	270	0	X18B3-27	X18B3-26	0	0	539	525	Invert Elevation Calculated by West Yost
6592	8	101	0	X18B3-17	X18B3-15	0	0	478	475	Invert Elevation Calculated by West Yost
6712	8	141	0	Y19C2-36	Y19C2-26	0	0	468	460	Invert Elevation Calculated by West Yost
6729	8	229	0	Y19C2-27	Y19C2-26	0	0	463	460	Invert Elevation Calculated by West Yost
6758	10	276	0	Y20A6-2	Y20A6-1	0	0	404	402	Invert Elevation Calculated by West Yost
6756	10	295	0	Y20A6-4	Y20A6-3	0	0	422	408	Invert Elevation Calculated by West Yost
6755	10	189	0	Y20A6-5	Y20A6-4	0	0	424	422	Invert Elevation Calculated by West Yost
6754	10	121	0	Y20A6-6	Y20A6-5	0	0	429	424	Invert Elevation Calculated by West Yost
6751	10	296	0	Y20A6-7	Y20A6-6	0	0	435	429	Invert Elevation Calculated by West Yost
6750	10	302	0	Y20A6-8	Y20A6-7	0	0	441	435	Invert Elevation Calculated by West Yost
6748	10	185	0	Y20A6-9	Y20A6-8	0	0	444	441	Invert Elevation Calculated by West Yost
6747	10	218	0	Y20A6-10	Y20A6-9	0	0	445	444	Invert Elevation Calculated by West Yost
6743	10	138	0	Y20A6-11	Y20A6-10	0	0	446	445	Invert Elevation Calculated by West Yost
6741	10	146	0	Y20A6-12	Y20A6-11	0	0	446	446	Invert Elevation Calculated by West Yost
6739	10	328	0	Y20A6-13	Y20A6-12	0	0	447	446	Invert Elevation Calculated by West Yost
6626	8	184	0	Y20A6-15	Y20A6-14	0	0	464	452	Invert Elevation Calculated by West Yost
6628	8	276	0	Y20A6-16	Y20A6-14	0	0	454	452	Invert Elevation Calculated by West Yost
6629	8	181	0	Y20A6-17	Y20A6-16	0	0	455	454	Invert Elevation Calculated by West Yost
6631	8	187	0	Y20A6-18	Y20A6-22	0	0	453	452	Invert Elevation Calculated by West Yost
6745	10	50	0	Y20A6-19	Y20A6-10	0	0	446	445	Invert Elevation Calculated by West Yost
6744	10	120	0	Y20A6-20	Y20A6-19	0	0	448	446	Invert Elevation Calculated by West Yost
6643	10	226	0	Y20A6-21	Y20A6-20	0	0	451	448	Invert Elevation Calculated by West Yost
6632	8	140	0	Y20A6-22	Y20A6-21	0	0	452	451	Invert Elevation Calculated by West Yost
6627	8	231	0	Y20A6-23	Y20A6-22	0	0	461	452	Invert Elevation Calculated by West Yost
6624	8	216	0	Y20A6-24	Y20A6-23	0	0	464	461	Invert Elevation Calculated by West Yost
6642	10	347	0	Y20A6-25	Y20A6-21	0	0	461	451	Invert Elevation Calculated by West Yost
6641	10	292	0	Y20A6-26	Y20A6-25	0	0	471	461	Invert Elevation Calculated by West Yost
6639	10	114	0	Y20A6-27	Y20A6-26	0	0	474	471	Invert Elevation Calculated by West Yost
6637	10	128	0	Y20A6-28	Y20A6-27	0	0	478	474	Invert Elevation Calculated by West Yost
6635	10	121	0	Y20A6-29	Y20A6-28	0	0	481	478	Invert Elevation Calculated by West Yost
6703	8	113	0	Y20A6-31	Y20A6-30	0	0	433	429	Invert Elevation Calculated by West Yost
6701	8	120	0	Y20A6-32	Y20A6-31	0	0	436	433	Invert Elevation Calculated by West Yost
6699	8	55	0	Y20A6-33	Y20A6-32	0	0	438	436	Invert Elevation Calculated by West Yost
6706	8	105	0	Y20A6-34	Y20A6-33	0	0	439	438	Invert Elevation Calculated by West Yost
6697	8	266	0	Y20A6-35	Y20A6-34	0	0	447	439	Invert Elevation Calculated by West Yost
6695	8	246	0	Y20A6-36	Y20A6-35	0	0	452	447	Invert Elevation Calculated by West Yost
6693	8	86	0	Y20A6-37	Y20A6-33	0	0	441	438	Invert Elevation Calculated by West Yost
6690	8	24	0	Y20A6-38	Y20A6-37	0	0	443	441	Invert Elevation Calculated by West Yost
6688	8	106	0	Y20A6-39	Y20A6-38	0	0	445	443	Invert Elevation Calculated by West Yost
6685	8	86	0	Y20A6-40	Y20A6-39	0	0	449	445	Invert Elevation Calculated by West Yost
6683	8	47	0	Y20A6-41	Y20A6-40	0	0	449	449	Invert Elevation Calculated by West Yost
6681	8	141	0	Y20A6-42	Y20A6-41	0	0	452	449	Invert Elevation Calculated by West Yost
6679	8	139	0	Y20A6-43	Y20A6-42	0	0	455	452	Invert Elevation Calculated by West Yost
6676	8	117	0	Y20A6-44	Y20A6-43	0	0	458	455	Invert Elevation Calculated by West Yost
6623	8	124	0	Y20A6-45	Y20A6-44	0	0	460	458	Invert Elevation Calculated by West Yost
6674	8	91	0	Y20A6-46	Y20A6-45	0	0	461	460	Invert Elevation Calculated by West Yost
6673	8	66	0	Y20A6-47	Y20A6-46	0	0	464	461	Invert Elevation Calculated by West Yost
6671	8	23	0	Y20A6-48	Y20A6-47	0	0	465	464	Invert Elevation Calculated by West Yost
6669	8	100	0	Y20A6-49	Y20A6-48	0	0	468	465	Invert Elevation Calculated by West Yost
6667	8	40	0	Y20A6-50	Y20A6-49	0	0	468	468	Invert Elevation Calculated by West Yost
6665	8	89	0	Y20A6-51	Y20A6-50	0	0	471	468	Invert Elevation Calculated by West Yost
6663	8	35	0	Y20A6-52	Y20A6-51	0	0	471	471	Invert Elevation Calculated by West Yost
6661	8	113	0	Y20A6-53	Y20A6-52	0	0	474	471	Invert Elevation Calculated by West Yost
6659	8	29	0	Y20A6-54	Y20A6-53	0	0	475	474	Invert Elevation Calculated by West Yost
6657	8	95	0	Y20A6-55	Y20A6-54	0	0	478	475	Invert Elevation Calculated by West Yost
6655	8	56	0	Y20A6-56	Y20A6-55	0	0	478	478	Invert Elevation Calculated by West Yost
6650	8	43	0	Y20A6-59	Y20A6-58	0	0	480	479	Invert Elevation Calculated by West Yost
6649	8	53	0	Y20A6-60	Y20A6-59	0	0	481	480	Invert Elevation Calculated by West Yost
6647	8	134	0	Y20A6-61	Y20A6-60	0	0	482	481	Invert Elevation Calculated by West Yost
6644	8	108	0	Y20A6-62	Y20A6-61	0	0	483	482	Invert Elevation Calculated by West Yost
6771	8	129	0	Y19C2-8	Y19C2-7	0	0	447	447	Invert Elevation Calculated by West Yost
6768	8	260	0	Y19C2-8	Y19C2-19	0	0	447	446	Invert Elevation Calculated by West Yost
6765	8	208	0	Y19C2-19	Y19C2-20	0	0	446	442	Invert Elevation Calculated by West Yost
6766	8	89	0	Y19C2-20	Y19C2-21	0	0	442	441	Invert Elevation Calculated by West Yost
6770	8	185	0	Y19C2-21	Y19C2-11	0	0	441	440	Invert Elevation Calculated by West Yost
6769	8	85	0	Y19C2-14	Y19C2-13	0	0	460	459	Invert Elevation Calculated by West Yost
6760	8	285	0	Y19C2-25	Y19C2-14	0	0	465	460	Invert Elevation Calculated by West Yost
6761	8	293	0	Y19C2-25	Y19C2-24	0	0	465	459	Invert Elevation Calculated by West Yost
6764	8	241	0	Y19C2-24	Y19C2-23	0	0	459	457	Invert Elevation Calculated by West Yost
6763	8	160	0	Y19C2-23	Y19C2-22	0	0	457	456	Invert Elevation Calculated by West Yost
6762	8	190	0	Y19C2-26	Y19C2-22	0	0	460	456	Invert Elevation Calculated by West Yost
6714	8	215	0	Y19C2-28	Y19C2-27	0	0	463	463	Invert Elevation Calculated by West Yost
6730	8	105	0	Y19C2-29	Y19C2-28	0	0	471	463	Invert Elevation Calculated by West Yost
6715	8	268	0	Y19C2-30	Y19C2-28	0	0	467	463	Invert Elevation Calculated by West Yost
6736	8	121	0	Y19C2-31	Y19C2-30	0	0	469	467	Invert Elevation Calculated by West Yost
6737	8	188	0	Y19C2-54	Y19C2-30	0	0	471	467	Invert Elevation Calculated by West Yost
6735	8	171	0	Y19C2-32	Y19C2-31	0	0	477	469	Invert Elevation Calculated by West Yost
6734	8	78	0	Y19C2-33	Y19C2-32	0	0	480	477	Invert Elevation Calculated by West Yost

Table 1. List of Gravity Mains with Unknown Invert Elevation(s)

GIS Information From Gravity Main Shapefile								Proposed Invert Elevations		West Yost Comment
Pipe ID	Diameter	Length, ft	Slope	Upstream Manhole ID	Downstream Manhole ID	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	
6733	8	148	0	Y19C2-55	Y19C2-33	0	0	485	480	Invert Elevation Calculated by West Yost
6732	8	239	0	Y19C2-34	Y19C2-33	0	0	487	480	Invert Elevation Calculated by West Yost
6731	8	349	0	Y19C2-34	Y19C2-35	0	0	487	471	Invert Elevation Calculated by West Yost
6713	8	144	0	Y19C2-35	Y19C2-36	0	0	471	468	Invert Elevation Calculated by West Yost
6725	8	167	0	Y19C2-41	Y19C2-40	0	0	489	488	Invert Elevation Calculated by West Yost
6724	8	114	0	Y19C2-42	Y19C2-41	0	0	490	489	Invert Elevation Calculated by West Yost
6708	8	261	0	Y19C2-43	Y19C2-42	0	0	491	490	Invert Elevation Calculated by West Yost
6710	8	149	0	Y19C2-48	Y19C2-42	0	0	499	490	Invert Elevation Calculated by West Yost
6716	8	153	0	Y19C2-49	Y19C2-48	0	0	507	499	Invert Elevation Calculated by West Yost
6717	8	302	0	Y19C2-50	Y19C2-49	0	0	510	507	Invert Elevation Calculated by West Yost
6718	8	301	0	Y19C2-51	Y19C2-50	0	0	513	510	Invert Elevation Calculated by West Yost
6719	8	171	0	Y19C2-52	Y19C2-51	0	0	517	513	Invert Elevation Calculated by West Yost
6720	8	155	0	Y19C2-53	Y19C2-52	0	0	523	517	Invert Elevation Calculated by West Yost
6773	8	235	0	Y19C2-18	Y19C2-47	0	0	491	492	Invert Elevation Calculated by West Yost
6721	8	196	0	Y19C2-47	Y19C2-46	0	0	492	494	Invert Elevation Calculated by West Yost
6722	8	348	0	Y19C2-46	Y19C2-45	0	0	494	493	Invert Elevation Calculated by West Yost
6723	8	243	0	Y19C2-45	Y19C2-44	0	0	493	492	Invert Elevation Calculated by West Yost
6709	8	271	0	Y19C2-44	Y19C2-43	0	0	492	491	Invert Elevation Calculated by West Yost
6726	8	198	0	Y19C2-40	Y19C2-39	0	0	488	484	Invert Elevation Calculated by West Yost
6727	8	132	0	Y19C2-39	Y19C2-38	0	0	484	480	Invert Elevation Calculated by West Yost
6728	8	146	0	Y19C2-38	Y19C2-37	0	0	480	476	Invert Elevation Calculated by West Yost
6711	8	265	0	Y19C2-37	Y19C2-36	0	0	476	468	Invert Elevation Calculated by West Yost
6772	8	185	0	Y19C2-22	Y19C2-10	0	0	456	454	Invert Elevation Calculated by West Yost
6757	10	123	0	Y20A6-3	Y20A6-2	0	0	408	404	Invert Elevation Calculated by West Yost
6607	10	188	0	X18B3-1	X18D1-42	0	0	442	427	Invert Elevation Calculated by West Yost
6792	8	400	0	W20C1-52	W20C1-51	0	0	332	330	Invert Elevation Calculated by West Yost
6794	8	333	0	W20C1-53	W20C1-52	0	0	334	332	Invert Elevation Calculated by West Yost
6785	8	105	0	X20B5-39	X20B5-38	0	0	357	347	Invert Elevation Calculated by West Yost
6788	8	166	0	X20B5-45	X20B5-24	0	0	370	359	Invert Elevation Calculated by West Yost
6934	8	75	0	X20B5-49	X20B5-46	0	0	372	371	Invert Elevation Calculated by West Yost
6935	8	105	0	X20B5-50	X20B5-49	0	0	377	372	Invert Elevation Calculated by West Yost
6937	8	54	0	X20B5-51	X20B5-50	0	0	377	377	Invert Elevation Calculated by West Yost
6938	8	135	0	X20B5-52	X20B5-51	0	0	384	377	Invert Elevation Calculated by West Yost
6939	8	70	0	X20B5-53	X20B5-51	0	0	378	377	Invert Elevation Calculated by West Yost
6940	8	116	0	X20B5-55	X20B5-53	0	0	378	378	Invert Elevation Calculated by West Yost
7060	8	127	0	X20B5-54	X20B5-53	0	0	386	378	Invert Elevation Calculated by West Yost
6936	8	72	0	X20B5-56	X20B5-50	0	0	382	377	Invert Elevation Calculated by West Yost
6933	8	122	0	X20B5-57	X20B5-56	0	0	387	382	Invert Elevation Calculated by West Yost
6932	8	51	0	X20B5-58	X20B5-56	0	0	383	382	Invert Elevation Calculated by West Yost
6931	8	145	0	X20B5-59	X20B5-58	0	0	384	383	Invert Elevation Calculated by West Yost
6883	8	66	0	X20B5-60	X20B5-58	0	0	385	383	Invert Elevation Calculated by West Yost
6929	8	134	0	X20B5-61	X20B5-60	0	0	389	385	Invert Elevation Calculated by West Yost
6928	8	132	0	X20B5-62	X20B5-60	0	0	387	385	Invert Elevation Calculated by West Yost
6925	8	108	0	X20B5-67	X20B5-66	0	0	394	391	Invert Elevation Calculated by West Yost
6924	8	132	0	X20B5-68	X20B5-66	0	0	391	391	Invert Elevation Calculated by West Yost
6789	8	33	0	X20B5-46	X20B5-45	0	0	371	370	Invert Elevation Calculated by West Yost
6791	8	190	0	X20B5-48	X20B5-47	0	0	378	374	Invert Elevation Calculated by West Yost
6914	8	157	0	X20B5-73	X20B5-48	0	0	378	378	Invert Elevation Calculated by West Yost
7048	8	152	0	X20B5-72	X20B5-47	0	0	375	374	Invert Elevation Calculated by West Yost
6784	8	59	0	X20B5-40	X20B5-39	0	0	360	357	Invert Elevation Calculated by West Yost
6922	8	154	0	X20B5-71	X20B5-41	0	0	364	361	Invert Elevation Calculated by West Yost
6920	8	169	0	X20B5-74	X20B5-42	0	0	366	362	Invert Elevation Calculated by West Yost
6966	8	33	0	X20B5-75	X20B5-43	0	0	363	363	Invert Elevation Calculated by West Yost
6918	8	85	0	X20B5-76	X20B5-75	0	0	369	363	Invert Elevation Calculated by West Yost
6787	8	108	0	X20B5-37	X20B5-2	0	0	346	344	Invert Elevation Calculated by West Yost
6786	8	130	0	X20B5-38	X20B5-37	0	0	347	346	Invert Elevation Calculated by West Yost
6967	8	113	0	X20B5-79	X20B5-38	0	0	349	347	Invert Elevation Calculated by West Yost
6911	8	347	0	X20B5-80	X20B5-79	0	0	354	349	Invert Elevation Calculated by West Yost
6909	8	347	0	X20B5-81	X20B5-80	0	0	357	354	Invert Elevation Calculated by West Yost
6777	10	330	0	Y19A4-3	Y19A4-2	0	0	374	360	Invert Elevation Calculated by West Yost
6776	10	333	0	Y19A4-4	Y19A4-3	0	0	390	374	Invert Elevation Calculated by West Yost
6775	10	328	0	Y19A4-5	Y19A4-4	0	0	395	390	Invert Elevation Calculated by West Yost
6774	10	222	0	Y19A4-6	Y19A4-5	0	0	397	395	Invert Elevation Calculated by West Yost
6945	8	86	0	Y19A4-7	Y19A4-6	0	0	398	397	Invert Elevation Calculated by West Yost
6947	8	112	0	Y19A4-8	Y19A4-7	0	0	408	398	Invert Elevation Calculated by West Yost
6946	8	66	0	Y19A4-9	Y19A4-7	0	0	407	398	Invert Elevation Calculated by West Yost
7061	8	107	0	Y19A4-10	Y19A4-7	0	0	398	398	Invert Elevation Calculated by West Yost
6950	8	112	0	Y19A4-11	Y19A4-10	0	0	409	398	Invert Elevation Calculated by West Yost
6949	8	65	0	Y19A4-12	Y19A4-10	0	0	404	398	Invert Elevation Calculated by West Yost
7062	8	107	0	Y19A4-13	Y19A4-10	0	0	399	398	Invert Elevation Calculated by West Yost
6953	8	112	0	Y19A4-14	Y19A4-13	0	0	407	399	Invert Elevation Calculated by West Yost
6952	8	96	0	Y19A4-15	Y19A4-13	0	0	403	399	Invert Elevation Calculated by West Yost
7063	8	107	0	Y19A4-16	Y19A4-13	0	0	399	399	Invert Elevation Calculated by West Yost
6956	8	96	0	Y19A4-17	Y19A4-16	0	0	401	399	Invert Elevation Calculated by West Yost
6976	8	55	0	Y19A4-18	Y19A4-16	0	0	399	399	Invert Elevation Calculated by West Yost
6960	8	60	0	Y19A4-19	Y19A4-18	0	0	400	399	Invert Elevation Calculated by West Yost
6975	8	36	0	Y19A4-24	Y19A4-18	0	0	400	399	Invert Elevation Calculated by West Yost
6961	8	57	0	Y19A4-25	Y19A4-24	0	0	401	400	Invert Elevation Calculated by West Yost
6964	8	128	0	Y19A4-26	Y19A4-25	0	0	402	401	Invert Elevation Calculated by West Yost
6962	8	81	0	Y19A4-27	Y19A4-25	0	0	404	401	Invert Elevation Calculated by West Yost
6957	8	75	0	Y19A4-20	Y19A4-19	0	0	400	400	Invert Elevation Calculated by West Yost
6959	8	68	0	Y19A4-21	Y19A4-19	0	0	400	400	Invert Elevation Calculated by West Yost
6958	8	57	0	Y19A4-22	Y19A4-21	0	0	398	400	Invert Elevation Calculated by West Yost
7064	8	17	0	Y19A2-23	Y19A4-21	0	0	400	400	Invert Elevation Calculated by West Yost
7051	8	109	0	X19D4-8	X19D4-2	0	0	402	397	Invert Elevation Calculated by West Yost
5843	8	205	0	X19D4-3	X19D4-8	0	0	407	402	Invert Elevation Calculated by West Yost
5844	8	263	0	X19D4-7	X19D4-6	0	0	430	425	Invert Elevation Calculated by West Yost
6878	8	91	0	X19D4-64	X19D4-7	0	0	431	430	Invert Elevation Calculated by West Yost
6877	8	173	0	X19D4-65	X19D4-64	0	0	435	431	Invert Elevation Calculated by West Yost
6813	8	9	0	X19D4-66	X19D4-64	0	0	431	431	Invert Elevation Calculated by West Yost
6876	8	130	0	X19D4-67	X19D4-66	0	0	432	431	Invert Elevation Calculated by West Yost
6812	8	98	0	X19D4-68	X19D4-66	0	0	432	431	Invert Elevation Calculated by West Yost
6874	8	166	0	X19D4-69	X19D4-68	0	0	439	432	Invert Elevation Calculated by West Yost
6811	8	19	0	X19D4-70	X19D4-68	0	0	432	432	Invert Elevation Calculated by West Yost
6873	8	131	0	X19D4-71	X19D4-70	0	0	433	432	Invert Elevation Calculated by West Yost
6834	8	99	0	X19D4-9	X19D4-8	0	0	404	402	Invert Elevation Calculated by West Yost
6835	8	134	0	X19D4-10	X19D4-9	0	0	406	404	Invert Elevation Calculated by West Yost
6836	8	97	0	X19D4-11	X19D4-9	0	0	405	404	Invert Elevation Calculated by West Yost
6879	8	43	0	X19D4-12	X19D4-11	0	0	406	405	Invert Elevation Calculated by West Yost
6837	8	112	0	X19D4-13	X19D4-12	0	0	408	406	Invert Elevation Calculated by West Yost
6839	8	130	0	X19D4-14	X19D4-11	0	0	408	405	Invert Elevation Calculated by West Yost
6838	8	139	0	X19D4-15	X19D4-14	0	0	412	408	Invert Elevation Calculated by West Yost
6832	8	67	0	X19D4-16	X19D4-11	0	0	406	405	Invert Elevation Calculated by West Yost
6840	8	137	0	X19D4-17	X19D4-16	0	0	409	406	Invert Elevation Calculated by West Yost
6831	8	14	0	X19D4-18	X19D4-16	0	0	407	406	Invert Elevation Calculated by West Yost
6841	8	135	0	X19D4-19	X19D4-18	0	0	409	407	Invert Elevation Calculated by West Yost
6830	8	98	0	X19D4-20	X19D4-18	0	0	408	407	Invert Elevation Calculated by West Yost
6829	8	14	0	X19D4-22	X19D4-20	0	0	409	408	Invert Elevation Calculated by West Yost
6842	8	136	0	X19D4-21	X19D4-20	0	0	412	408	Invert Elevation Calculated by West Yost
6843	8	134	0	X19D4-23	X19D4-22	0	0	412	409	Invert Elevation Calculated by West Yost
6828	8	98	0	X19D4-24	X19D4-22	0	0	411	409	Invert Elevation Calculated by West Yost
6844	8	136	0	X19D4-25	X19D4-24	0	0	415	411	Invert Elevation Calculated by West Yost
6827	8	14	0	X19D4-26	X19D4-24	0	0	411	411	Invert Elevation Calculated by West Yost
6845	8	134	0	X19D4-27	X19D4-26	0	0	414	411	Invert Elevation Calculated by West Yost
6826	8	98	0	X19D4-28	X19D4-26	0	0	414	411	Invert Elevation Calculated by West Yost
6825	8	14	0	X19D4-30	X19D4-28	0	0	414	414	Invert Elevation Calculated by West Yost
6846	8	135	0	X19D4-29	X19D4-28	0	0	417	414	Invert Elevation Calculated by West Yost
6848	8	98	0	X19D4-32	X19D4-30	0	0	416	414	Invert Elevation Calculated by West Yost
6847	8	134	0	X19D4-31	X19D4-30	0	0	417	414	Invert Elevation Calculated by West Yost
6849	8	134	0	X19D4-33	X19D4-32	0	0	420	416	Invert Elevation Calculated by West Yost
6824	8	14	0	X19D4-34	X19D4-32	0	0	416	416	Invert Elevation Calculated by West Yost
6850	8	134	0	X19D4-35	X19D4-34	0	0	419	416	Invert Elevation Calculated by West Yost
6823	8	98	0	X19D4-36	X19D4-34	0	0	418	416	Invert Elevation Calculated by West Yost
6851	8	134	0	X19D4-37	X19D4-36	0	0	422	418	Invert Elevation Calculated by West Yost
6822	8	14	0	X19D4-38	X19D4-36	0	0	418	418	Invert Elevation Calculated by West Yost
6852	8	134	0	X19D4-39	X19D4-38	0	0	420	418	Invert Elevation Calculated by West Yost
6821	8	103	0	X19D4-40	X19D4-38	0	0	420	418	Invert Elevation Calculated by West Yost
6855	8	137	0	X19D4-41	X19D4-40	0	0	425	420	Invert Elevation Calculated by West Yost
6853	8	10	0	X19D4-42	X19D4-40	0	0	421	420	Invert Elevation Calculated by West Yost
6854	8	134	0	X19D4-43	X19D4-42	0	0	422	421	Invert Elevation Calculated by West Yost
6856	8	106	0	X19D4-44	X19D4-42	0	0	422	421	Invert Elevation Calculated by West Yost
6857	8	171	0	X19D4-45	X19D4-44	0	0	423	422	Invert Elevation Calculated by West Yost
6820	8	16	0	X19D4-46	X19D4-44	0	0	423	422	Invert Elevation Calculated by West Yost
6860	8	131	0	X19D4-47	X19D4-46	0	0	427	423	Invert Elevation Calculated by West Yost
6819	8	96	0	X19D4-48	X19D4-46	0	0	425	423	Invert Elevation Calculated by West Yost
6861	8	168	0	X19D4-49	X19D4-48	0	0	426	425	Invert Elevation Calculated by West Yost
6818	8	28	0	X19D4-50	X19D4-48	0	0	425	425	Invert Elevation Calculated by West Yost
6864	8	127	0	X19D4-51	X19D4-50	0	0	430	425	Invert Elevation Calculated by West Yost
6817	8	84	0	X19D4-52	X19D4-50	0	0	426	425	Invert Elevation Calculated by West Yost
6865	8	204	0	X19D4-53	X19D4-52	0	0	427	426	Invert Elevation Calculated by West Yost
6816	8	39	0	X19D4-54	X19D4-52	0	0	429	426	Invert Elevation Calculated by West Yost
6867	8	128	0	X19D4-55	X19D4-54	0	0	433	429	Invert Elevation Calculated by West Yost
6815	8	70	0	X19D4-56	X19D4-54	0	0	429	429	Invert Elevation Calculated by West Yost
6833	8	210	0	X19D4-57	X19D4-56	0	0	430	429	Invert Elevation Calculated by West Yost
6814	8	54	0	X19D4-58	X19D4-56	0	0	433	429	Invert Elevation Calculated by West Yost
6870	8	126	0	X19D4-59	X19D4-58	0	0	437	433	Invert Elevation Calculated by West Yost
6866	8	85	0	X19D4-60	X19D4-58	0	0	435	433	Invert Elevation Calculated by West Yost
6872	8	110	0	X19D4-61	X19D4-60	0	0	439	435	Invert Elevation Calculated by West Yost
6871	8	158	0	X19D4-62	X19D4-61	0	0	442	439	Invert Elevation Calculated by West Yost
6881	8	200	0	X19D4-63	X19D4-60	0	0	441	435	Invert Elevation Calculated by West Yost
6778	10	45	0	Y19A4-2	Y19A4-1	0	0	360	359	Invert Elevation Calculated by West Yost
6965	8	76	0	Y19A4-28	Y19A4-2	0	0	361	360	Invert Elevation Calculated by West Yost
6897	8	73	0	Y19A4-29	Y19A4-28	0	0	365	361	Invert Elevation Calculated by West Yost
6891	8	339	0	Y19A4-44	Y19A4-29	0	0	379	365	Invert Elevation Calculated by West Yost
6896	8	76	0	Y19A4-45	Y19A4-44	0	0	379	379	Invert Elevation Calculated by West Yost
6895	8	79	0	Y19A4-48	Y19A4-45	0	0	383	379	Invert Elevation Calculated by West Yost

Table 1. List of Gravity Mains with Unknown Invert Elevation(s)

GIS Information From Gravity Main Shapefile								Proposed Invert Elevations		West Yost Comment
Pipe ID	Diameter	Length, ft	Slope	Upstream Manhole ID	Downstream Manhole ID	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	
6893	8	351	0	Y19A4-46	Y19A4-45	0	0	394	379	Invert Elevation Calculated by West Yost
6899	8	127	0	Y19A4-33	Y19A4-32	0	0	384	377	Invert Elevation Calculated by West Yost
6903	8	39	0	Y19A4-35	Y19A4-34	0	0	378	378	Invert Elevation Calculated by West Yost
6902	8	214	0	Y19A4-36	Y19A4-35	0	0	388	378	Invert Elevation Calculated by West Yost
6901	8	149	0	Y19A4-37	Y19A4-36	0	0	394	388	Invert Elevation Calculated by West Yost
6889	8	229	0	Y19A4-38	Y19A4-34	0	0	385	378	Invert Elevation Calculated by West Yost
6907	8	112	0	Y19A4-40	Y19A4-39	0	0	391	387	Invert Elevation Calculated by West Yost
6906	8	181	0	Y19A4-41	Y19A4-40	0	0	397	391	Invert Elevation Calculated by West Yost
6888	8	130	0	Y19A4-43	Y19A4-38	0	0	390	385	Invert Elevation Calculated by West Yost
6898	8	16	0	Y19A4-30	Y19A4-29	0	0	366	365	Invert Elevation Calculated by West Yost
6904	8	112	0	Y19A4-31	Y19A4-30	0	0	370	366	Invert Elevation Calculated by West Yost
6900	8	212	0	Y19A4-32	Y19A4-31	0	0	377	370	Invert Elevation Calculated by West Yost
6890	8	215	0	Y19A4-34	Y19A4-31	0	0	378	370	Invert Elevation Calculated by West Yost
6908	8	46	0	Y19A4-39	Y19A4-38	0	0	387	385	Invert Elevation Calculated by West Yost
6905	8	177	0	Y19A4-42	Y19A4-41	0	0	403	397	Invert Elevation Calculated by West Yost
6892	8	339	0	Y19A4-47	Y19A4-46	0	0	407	394	Invert Elevation Calculated by West Yost
6885	8	142	0	X20B5-69	X20B5-40	0	0	362	360	Invert Elevation Calculated by West Yost
6923	8	95	0	X20B5-70	X20B5-69	0	0	367	362	Invert Elevation Calculated by West Yost
6781	8	108	0	X20B5-43	X20B5-42	0	0	363	362	Invert Elevation Calculated by West Yost
6780	8	242	0	X20B5-44	X20B5-43	0	0	365	363	Invert Elevation Calculated by West Yost
6917	8	65	0	X20B5-77	X20B5-44	0	0	367	365	Invert Elevation Calculated by West Yost
6916	8	335	0	X20B5-78	X20B5-77	0	0	384	367	Invert Elevation Calculated by West Yost
6783	8	131	0	X20B5-41	X20B5-39	0	0	361	357	Invert Elevation Calculated by West Yost
6779	10	95	0	Y19A4-1	X20b2-15	0	0	359	358	Invert Elevation Calculated by West Yost
6738	8	55	0	Y20A6-63	Y20A6-13	0	0	447	447	Invert Elevation Calculated by West Yost
7059	8	113	0	Y20A6-14	Y20A6-63	0	0	452	447	Invert Elevation Calculated by West Yost
7058	8	59	0	Y20A6-64	Y20A6-5	0	0	424	424	Invert Elevation Calculated by West Yost
6705	8	102	0	Y20A6-30	Y20A6-64	0	0	429	424	Invert Elevation Calculated by West Yost
6652	8	54	0	Y20A6-58	Y20A6-56	0	0	479	478	Invert Elevation Calculated by West Yost
5037	12	30	0	V19D2-57	V19D2-56	0	360	355	360	Invert Elevation Calculated by West Yost
6997	12	58	0	V19D2-58	V19D2-57	0	0	356	355	Invert Elevation Calculated by West Yost
6998	12	286	0	V19D2-59	V19D2-58	0	0	357	356	Invert Elevation Calculated by West Yost
7000	12	59	0	V19D2-60	V19D2-59	0	0	357	357	Invert Elevation Calculated by West Yost
7002	12	376	0	V19D2-61	V19D2-60	0	0	360	357	Invert Elevation Calculated by West Yost
7001	12	333	0	V19D2-62	V19D2-61	0	0	361	360	Invert Elevation Calculated by West Yost
5971	8	132	0	X18B2-17	X18B2-11	0	0	499	498	Invert Elevation Calculated by West Yost
7052	8	35	0	X18B2-11	X18B2-15	0	0	498	498	Invert Elevation Calculated by West Yost
7030	8	83	0	Y19C1-14	Y19C1-13	0	0	594	593	Invert Elevation Calculated by West Yost
7031	8	281	0	Y19C1-16	Y19C1-15	0	0	596	613	Invert Elevation Calculated by West Yost
6213	8	281	0	Y19C1-15	Y19C1-14	0	0	613	594	Invert Elevation Calculated by West Yost
6217	8	102	0	Y19C1-10	Y19C1-9	0	0	567	563	Invert Elevation Calculated by West Yost
7028	8	299	0	Y19C1-11	Y19C1-10	0	0	584	567	Invert Elevation Calculated by West Yost
6211	8	219	0	Y19C1-12	Y19C1-11	0	0	590	584	Invert Elevation Calculated by West Yost
7032	8	198	0	Y19C1-13	Y19C1-12	0	0	593	590	Invert Elevation Calculated by West Yost
6212	8	199	0	Y19C1-18	Y19C1-17	0	0	604	590	Invert Elevation Calculated by West Yost
6346	8	45	0	Y19C1-19	Y19C1-18	0	0	604	604	Invert Elevation Calculated by West Yost
6363	8	78	0	Z19A1-1	Y19C1-19	0	0	604	604	Invert Elevation Calculated by West Yost
6362	8	51	0	Z19A3-1	Y19C1-19	0	0	605	604	Invert Elevation Calculated by West Yost
7057	8	289	0	Y19B7-6	Y19B6-1	0	0	621	606	Invert Elevation Calculated by West Yost
7056	8	175	0	Y19B7-15	Y19B7-14	0	0	692	679	Invert Elevation Calculated by West Yost
6302	8	353	0	Y19B7-13	Y19B7-12	0	0	674	672	Invert Elevation Calculated by West Yost
6555	8	200	0	Y19B7-14	Y19B7-13	0	0	679	674	Invert Elevation Calculated by West Yost
6303	8	247	0	Y19B7-12	Y19B7-11	0	0	672	656	Invert Elevation Calculated by West Yost
6305	8	230	0	Y19B7-16	Y19B7-10	0	0	656	640	Invert Elevation Calculated by West Yost
6306	8	279	0	Y19B7-11	Y19B7-10	0	0	656	640	Invert Elevation Calculated by West Yost
6304	8	288	0	Y19B7-17	Y19B7-11	0	0	672	656	Invert Elevation Calculated by West Yost
6301	8	65	0	Y19B7-18	Y19B7-17	0	0	675	672	Invert Elevation Calculated by West Yost
6298	8	214	0	Y19B7-19	Y19B7-18	0	0	691	675	Invert Elevation Calculated by West Yost
6556	8	245	0	Y19B7-20	Y19B7-19	0	0	695	691	Invert Elevation Calculated by West Yost
6272	8	225	0	Y19B7-21	Y19B7-19	0	0	699	691	Invert Elevation Calculated by West Yost
7053	8	254	0	Y19B7-9	Y19B7-8	0	0	647	637	Invert Elevation Calculated by West Yost
6442	8	302	0	Y19B7-9	Y19B6-3	0	0	647	630	Invert Elevation Calculated by West Yost
6309	8	399	0	Y19B7-5	Y19B7-1	0	0	619	599	Invert Elevation Calculated by West Yost
6240	8	263	0	Y19B4-26	Y19B4-25	0	0	678	668	Invert Elevation Calculated by West Yost
6241	8	214	0	Y19B4-25	Y19B4-24	0	0	668	653	Invert Elevation Calculated by West Yost
6242	8	294	0	Y19B4-24	Y19B4-23	0	0	653	638	Invert Elevation Calculated by West Yost
6243	8	243	0	Y19B4-23	Y19B4-6	0	0	638	627	Invert Elevation Calculated by West Yost
6230	8	225	0	Y19B4-13	Y19B4-12	0	0	692	680	Invert Elevation Calculated by West Yost
6231	8	251	0	Y19B4-12	Y19B4-11	0	0	680	661	Invert Elevation Calculated by West Yost
6233	8	277	0	Y19B4-11	Y19B4-10	0	0	661	644	Invert Elevation Calculated by West Yost
7054	8	166	0	V19D3-27	V19D3-26	0	0	352	352	Invert Elevation Calculated by West Yost
6502	8	113	0	V19D3-26	V19D3-25	0	0	352	351	Invert Elevation Calculated by West Yost
6524	8	205	0	V19D3-28	V19D3-27	0	0	353	352	Invert Elevation Calculated by West Yost
6525	8	203	0	V19D3-29	V19D3-28	0	0	354	353	Invert Elevation Calculated by West Yost
6526	8	62	0	V19D3-30	V19D3-29	0	0	355	354	Invert Elevation Calculated by West Yost
6545	8	37	0	V19D3-32	V19D3-31	0	0	351	351	Invert Elevation Calculated by West Yost
6544	8	114	0	V19D3-33	V19D3-32	0	0	352	351	Invert Elevation Calculated by West Yost
6543	8	126	0	V19D3-34	V19D3-33	0	0	352	352	Invert Elevation Calculated by West Yost
6542	8	175	0	V19D3-35	V19D3-34	0	0	354	352	Invert Elevation Calculated by West Yost
6541	8	164	0	V19D3-36	V19D3-35	0	0	355	354	Invert Elevation Calculated by West Yost
6506	8	134	0	V19D3-37	V19D3-36	0	0	355	355	Invert Elevation Calculated by West Yost
6527	8	140	0	V19D3-38	V19D3-37	0	0	359	355	Invert Elevation Calculated by West Yost
6528	8	38	0	V19D3-39	V19D3-37	0	0	356	355	Invert Elevation Calculated by West Yost
6505	8	163	0	V19D3-40	V19D3-39	0	0	356	356	Invert Elevation Calculated by West Yost
6529	8	52	0	V19D3-41	V19D3-40	0	0	360	356	Invert Elevation Calculated by West Yost
6530	8	32	0	V19D3-42	V19D3-40	0	0	358	356	Invert Elevation Calculated by West Yost
6533	8	117	0	V19D3-43	V19D3-42	0	0	360	358	Invert Elevation Calculated by West Yost
6534	8	107	0	V19D3-44	V19D3-43	0	0	360	360	Invert Elevation Calculated by West Yost
6535	8	95	0	V19D3-45	V19D3-44	0	0	361	360	Invert Elevation Calculated by West Yost
6507	8	128	0	V19D3-46	V19D3-37	0	0	356	355	Invert Elevation Calculated by West Yost
6531	8	142	0	V19D3-47	V19D3-46	0	0	360	356	Invert Elevation Calculated by West Yost
6508	8	12	0	V19D3-48	V19D3-46	0	0	356	356	Invert Elevation Calculated by West Yost
6532	8	137	0	V19D3-49	V19D3-48	0	0	360	356	Invert Elevation Calculated by West Yost
6509	8	116	0	V19D3-50	V19D3-48	0	0	357	356	Invert Elevation Calculated by West Yost
6536	8	142	0	V19D3-51	V19D3-50	0	0	362	357	Invert Elevation Calculated by West Yost
6510	8	198	0	V19D3-52	V19D3-50	0	0	358	357	Invert Elevation Calculated by West Yost
6537	8	143	0	V19D3-53	V19D3-52	0	0	362	358	Invert Elevation Calculated by West Yost
6511	8	144	0	V19D3-54	V19D3-52	0	0	359	358	Invert Elevation Calculated by West Yost
6540	8	115	0	V19D3-55	V19D3-52	0	0	359	358	Invert Elevation Calculated by West Yost
6538	8	145	0	V19D3-56	V19D3-55	0	0	364	359	Invert Elevation Calculated by West Yost
6539	8	218	0	V19D3-57	V19D3-55	0	0	360	359	Invert Elevation Calculated by West Yost
7055	8	74	0	V19D3-58	V19D3-21	0	0	349	349	Invert Elevation Calculated by West Yost
6546	8	299	0	V19D3-31	V19D3-58	0	0	351	349	Invert Elevation Calculated by West Yost
7013	8	69	0	Y20A6-75	Y20A6-76	0	0	441	441	Invert Elevation Calculated by West Yost
7014	8	151	0	Y20A6-74	Y20A6-75	0	0	443	441	Invert Elevation Calculated by West Yost
7012	8	38	0	Y20A6-73	Y20A6-74	0	0	447	443	Invert Elevation Calculated by West Yost
7016	8	140	0	Y20A6-85	Y20A6-72	0	0	449	448	Invert Elevation Calculated by West Yost
7021	8	132	0	Y20A6-77	Y20A6-8	0	0	442	441	Invert Elevation Calculated by West Yost
7011	8	280	0	Y20A6-84	Y20A6-77	0	0	450	442	Invert Elevation Calculated by West Yost
7008	8	40	0	Y20A6-83	Y20A6-84	0	0	451	450	Invert Elevation Calculated by West Yost
7003	8	206	0	Y20A6-82	Y20A6-84	0	0	456	450	Invert Elevation Calculated by West Yost
7005	8	60	0	Y20A6-78	Y20A6-77	0	0	444	442	Invert Elevation Calculated by West Yost
7004	8	99	0	Y20A6-79	Y20A6-78	0	0	449	444	Invert Elevation Calculated by West Yost
7010	8	49	0	Y20A6-80	Y20A6-79	0	0	453	449	Invert Elevation Calculated by West Yost
7009	8	231	0	Y20A6-81	Y20A6-79	0	0	455	449	Invert Elevation Calculated by West Yost
7018	8	155	0	Y20A6-69	Y20A6-67	0	0	443	439	Invert Elevation Calculated by West Yost
6698	8	56	0	Y20A6-68	Y20A6-34	0	0	440	439	Invert Elevation Calculated by West Yost
7017	8	62	0	Y20A6-68	Y20A6-67	0	0	440	439	Invert Elevation Calculated by West Yost
7024	8	202	0	W20C1-56	W20C1-55	0	0	325	324	Invert Elevation Calculated by West Yost
7026	8	39	0	W20C1-54	W20C1-17	0	0	323	323	Invert Elevation Calculated by West Yost
7025	8	200	0	W20C1-55	W20C1-54	0	0	324	323	Invert Elevation Calculated by West Yost
6455	8	299	0	Y19B4-35	Y19B4-34	0	0	622	601	Invert Elevation Calculated by West Yost
6445	8	202	0	Y19B4-36	Y19B4-35	0	0	626	622	Invert Elevation Calculated by West Yost
6553	8	443	0	Y19B7-2	Y19B7-1	0	0	604	599	Invert Elevation Calculated by West Yost
6557	8	217	0	Y19B7-6	Y19B7-5	0	0	621	619	Invert Elevation Calculated by West Yost
7029	8	312	0	Y19C1-17	Y19C1-16	0	0	590	596	Invert Elevation Calculated by West Yost
6218	8	267	0	Y19B4-7	Y19B4-6	0	0	634	627	Invert Elevation Calculated by West Yost
6153	8	105	0	Y19C2-1	Y20C2-16	0	0	423	423	Invert Elevation Calculated by West Yost
6154	8	24	0	Y19C2-2	Y19C2-1	0	0	426	423	Invert Elevation Calculated by West Yost
6155	8	125	0	Y19C2-3	Y19C2-2	0	0	435	426	Invert Elevation Calculated by West Yost
6163	8	229	0	Y19C2-11	Y19C2-3	0	0	440	435	Invert Elevation Calculated by West Yost
6164	8	110	0	Y19C2-12	Y19C2-11	0	0	448	440	Invert Elevation Calculated by West Yost
6165	8	217	0	Y19C2-13	Y19C2-12	0	0	459	448	Invert Elevation Calculated by West Yost
6167	8	216	0	Y19C2-15	Y19C2-13	0	0	469	459	Invert Elevation Calculated by West Yost
6168	8	312	0	Y19C2-16	Y19C2-15	0	0	481	469	Invert Elevation Calculated by West Yost
6169	8	343	0	Y19C2-17	Y19C2-16	0	0	491	481	Invert Elevation Calculated by West Yost
6170	8	237	0	Y19C2-18	Y19C2-17	0	0	491	491	Invert Elevation Calculated by West Yost
6156	8	142	0	Y19C2-4	Y19C2-3	0	0	440	435	Invert Elevation Calculated by West Yost
6157	8	545	0	Y19C2-5	Y19C2-4	0	0	446	440	Invert Elevation Calculated by West Yost
6158	8	40	0	Y19C2-6	Y19C2-5	0	0	446	446	Invert Elevation Calculated by West Yost
6159	8	176	0	Y19C2-7	Y19C2-6	0	0	447	446	Invert Elevation Calculated by West Yost
6161	8	273	0	Y19C2-9	Y19C2-7	0	0	453	447	Invert Elevation Calculated by West Yost
6162	8	84	0	Y19C2-10	Y19C2-9	0	0	454	453	Invert Elevation Calculated by West Yost
6368	8	69	0	Y19B1-16	Y19B1-13	0	0	558	554	Invert Elevation Calculated by West Yost
6332	8	313	0	Z19A1-3	Z19A1-2	0	0	638	616	Invert Elevation Calculated by West Yost
6333	8	328	0	Z19A1-4	Z19A1-3	0	0	655	638	Invert Elevation Calculated by West Yost
6334	8	202	0	Z19A1-11	Z19A1-10	0	0	641	627	Invert Elevation Calculated by West Yost
6336	8	256	0	Z19A1-4	Z19A1-5	0	0	655	642	Invert Elevation Calculated by West Yost
6338	8	69	0	Z19A1-13	Z19A1-12	0	0	583	581	Invert Elevation Calculated by West Yost
6422	8	63	0	Z19A1-9	Z19A1-8	0	0	600	598	Invert Elevation Calculated by West Yost
6342	8	64	0	Z19A2-3	Z19A2-2	0	0	673	672	Invert Elevation Calculated by West Yost
6414	8	256	0	Z19A2-6	Z19A2-5	0	0	708	688	Invert Elevation Calculated by West Yost
6413	8	115	0	Z19A2-7	Z19A2-6	0	0	713	708	Invert Elevation Calculated by West Yost
6355	8	113	0	Z19A3-20	Z19A3-19	0	0	730	722	Invert Elevation Calculated by West Yost
6412	8	40	0	Z19A3-14	Z19A3-13	0	0	687	686	Invert Elevation Calculated by West Yost
6350	8	234	0	Z19A3-15	Z19A3-14	0	0	704	687	Invert Elevation Calculated by West Yost

Table 1. List of Gravity Mains with Unknown Invert Elevation(s)

GIS Information From Gravity Main Shapefile								Proposed Invert Elevations		West Yost Comment
Pipe ID	Diameter	Length, ft	Slope	Upstream Manhole ID	Downstream Manhole ID	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	
6409	8	41	0	Z19A3-11	Z19A3-10	0	0	665	663	Invert Elevation Calculated by West Yost
6351	8	224	0	Z19A3-12	Z19A3-11	0	0	687	665	Invert Elevation Calculated by West Yost
6410	8	217	0	Z19A3-10	Z19A3-9	0	0	663	646	Invert Elevation Calculated by West Yost
6411	8	62	0	Z19A3-9	Z19A3-8	0	0	646	645	Invert Elevation Calculated by West Yost
6404	8	219	0	Z19A3-8	Z19A3-7	0	0	645	631	Invert Elevation Calculated by West Yost
6348	8	277	0	Z19A3-21	Z19A3-8	0	0	668	645	Invert Elevation Calculated by West Yost
6403	8	267	0	Z19A3-22	Z19A3-21	0	0	689	668	Invert Elevation Calculated by West Yost
6349	8	250	0	Z19A3-23	Z19A3-22	0	0	700	689	Invert Elevation Calculated by West Yost
6352	8	340	0	Z19A3-5	Z19A3-4	0	0	657	632	Invert Elevation Calculated by West Yost
6767	10	284	0	Y20A6-1	Y20C2-17	0	0	402	398	Invert Elevation Calculated by West Yost
5751	8	103	0	X20B4-25	X20B4-23	0	395	403	395	Invert Elevation Calculated by West Yost
5753	8	103	0	X20B4-18	X20B4-17	0	392	400	392	Invert Elevation Calculated by West Yost
6130	8	132	0	X19D3-41	X19D3-39	0	0	406	404	Invert Elevation Calculated by West Yost
5646	8	229	0	X19D3-42	X19D3-41	0	0	414	406	Invert Elevation Calculated by West Yost
6124	8	193	0	X19D3-46	X19D3-50	0	0	412	404	Invert Elevation Calculated by West Yost
6118	8	32	0	X19D3-60	X19D3-59	0	0	414	414	Invert Elevation Calculated by West Yost
6147	8	159	0	Y20A5-7	Y20A5-6	0	0	348	347	Invert Elevation Calculated by West Yost
6139	10	187	0	Y20A5-1	Y20C2-3	0	0	338	339	Invert Elevation Calculated by West Yost
6140	10	98	0	Y20A5-2	Y20A5-1	0	0	341	338	Invert Elevation Calculated by West Yost
6151	8	190	0	Y20A5-8	Y20A5-2	0	0	342	341	Invert Elevation Calculated by West Yost
6141	8	322	0	Y20A5-3	Y20A5-2	0	0	344	341	Invert Elevation Calculated by West Yost
6142	8	339	0	Y20A5-4	Y20A5-3	0	0	345	344	Invert Elevation Calculated by West Yost
6143	8	216	0	Y20A5-5	Y20A5-4	0	0	346	345	Invert Elevation Calculated by West Yost
6451	8	65	0	Y19B4-29	Y19B4-4	0	0	608	606	Invert Elevation Calculated by West Yost
6464	8	240	0	Y19B5-19	Y19B5-15	0	0	692	683	Invert Elevation Calculated by West Yost
6465	8	188	0	Y19B5-20	Y19B5-19	0	0	699	692	Invert Elevation Calculated by West Yost
6366	8	214	0	Y19B1-25	Y19B1-24	0	0	579	571	Invert Elevation Calculated by West Yost
6484	8	157	0	U20A1-53	U20A1-52	0	0	368	365	Invert Elevation Calculated by West Yost
6485	8	200	0	U20A1-52	U20A1-51	0	0	365	361	Invert Elevation Calculated by West Yost
6486	8	33	0	U20A1-51	U20A1-50	0	0	361	360	Invert Elevation Calculated by West Yost
6490	8	254	0	X20C1-11	X20C1-21	345	0	345	345	Invert Elevation Calculated by West Yost
6521	8	191	0	V19D3-23	V19D3-22	0	0	351	350	Invert Elevation Calculated by West Yost
6550	8	297	0	V19D3-1	V20B1-25	0	0	343	335	Invert Elevation Calculated by West Yost
5794	8	220	0	X20B5-3	X20B5-2	0	344	350	344	Invert Elevation Calculated by West Yost
7033	15	36	0	Y20C2-11	Y20C2-17	0	0	399	398	Invert Elevation Calculated by West Yost
7034	15	412	0	Y20C2-17	Y20C2-10	0	0	398	384	Invert Elevation Calculated by West Yost
5872	8	293	0	T20C2-14	T20C2-13	0	0	791	785	Invert Elevation Calculated by West Yost
5878	8	319	0	T20C2-11	T20C2-10	0	0	759	743	Invert Elevation Calculated by West Yost
5660	8	220	0	X19D3-40	X19D3-39	0	0	411	404	Invert Elevation Calculated by West Yost
6125	8	371	0	X19D3-54	X19D3-53	0	0	421	405	Invert Elevation Calculated by West Yost
6126	8	96	0	X19D3-55	X19D3-54	0	0	424	421	Invert Elevation Calculated by West Yost
6357	8	340	0	Z19A3-17	Z19A3-16	0	0	710	699	Invert Elevation Calculated by West Yost
6343	8	286	0	Z19A2-4	Z19A2-3	0	0	685	673	Invert Elevation Calculated by West Yost
6384	8	291	0	Y19B3-21	Y19B3-19	0	0	629	609	Invert Elevation Calculated by West Yost
6407	8	189	0	Z19A3-2	Z19A3-1	0	0	620	605	Invert Elevation Calculated by West Yost
6246	8	330	0	Y19B5-21	Y19B5-20	0	0	708	699	Invert Elevation Calculated by West Yost
6515	8	140	0	V19D3-12	V19D3-11	0	0	351	347	Invert Elevation Calculated by West Yost
6519	8	140	0	V19D3-20	V19D3-19	0	0	352	348	Invert Elevation Calculated by West Yost
6501	8	80	0	V19D3-19	V19D3-17	0	0	348	348	Invert Elevation Calculated by West Yost
6782	8	187	0	X20B5-42	X20B5-41	0	0	362	361	Invert Elevation Calculated by West Yost
7035	39	45	0	V21A2-16	V21A2-14	0	314	314	314	Invert Elevation Calculated by West Yost
7036	42	86	0	V21A2-14	V21A2-17	314	0	314	314	Invert Elevation Calculated by West Yost
7038	24	72	0	W20C1-59	W20C1-21	0	325	325	325	Invert Elevation Calculated by West Yost
7135	8	146	0	T16C1-72	T16C1-71	0	0	497	488	Invert Elevation Calculated by West Yost
7141	8	58	0	S20C1-40	S20C1-39	0	0	863	856	Invert Elevation Calculated by West Yost
7142	8	41	0	S20C1-39	S20C1-3	0	0	856	859	Invert Elevation Calculated by West Yost
7143	8	214	0	S20C1-37	S20C1-35	0	0	932	928	Invert Elevation Calculated by West Yost
7144	8	214	0	S20C1-38	S20C1-35	0	0	934	928	Invert Elevation Calculated by West Yost
7145	8	236	0	S20C1-21	S20C1-20	0	0	922	914	Invert Elevation Calculated by West Yost
7146	8	270	0	S20C1-20	S20C1-19	0	0	914	910	Invert Elevation Calculated by West Yost
7147	8	184	0	S20C1-22	S20C1-20	0	0	914	914	Invert Elevation Calculated by West Yost
7148	8	197	0	S20C1-23	S20C1-22	0	0	918	914	Invert Elevation Calculated by West Yost
7149	8	346	0	S20C1-35	S20C1-22	0	0	928	914	Invert Elevation Calculated by West Yost
7150	8	348	0	S20C1-28	S20C1-36	0	0	960	938	Invert Elevation Calculated by West Yost
7151	8	196	0	S20C1-47	S20C1-46	0	0	965	927	Invert Elevation Calculated by West Yost
7152	8	90	0	S20C1-45	S20C1-44	0	0	927	921	Invert Elevation Calculated by West Yost
7153	8	349	0	S20C1-43	S20C1-42	0	0	908	885	Invert Elevation Calculated by West Yost
7154	8	202	0	S20C1-19	S20C1-43	0	0	910	908	Invert Elevation Calculated by West Yost
7155	8	70	0	S20C1-36	S20C1-35	0	0	938	928	Invert Elevation Calculated by West Yost
7156	8	190	0	S20C1-34	S20C1-26	0	0	970	962	Invert Elevation Calculated by West Yost
7157	8	348	0	S20C1-26	S20C1-25	0	0	962	946	Invert Elevation Calculated by West Yost
7158	8	238	0	S20C1-25	S20C1-24	0	0	946	933	Invert Elevation Calculated by West Yost
7159	8	94	0	S20C1-27	S20C1-28	0	0	960	960	Invert Elevation Calculated by West Yost
7160	8	286	0	S20C1-32	S20C1-28	0	0	967	960	Invert Elevation Calculated by West Yost
7161	8	181	0	S20C1-29	S20C1-32	0	0	975	967	Invert Elevation Calculated by West Yost
7162	8	246	0	S20C1-24	S20C1-23	0	0	933	918	Invert Elevation Calculated by West Yost
7163	8	251	0	S20C1-44	S20C1-19	0	0	921	910	Invert Elevation Calculated by West Yost
7164	8	110	0	S20C1-46	S20C1-45	0	0	927	927	Invert Elevation Calculated by West Yost
7165	8	55	0	S20C1-42	S20C1-41	0	0	885	882	Invert Elevation Calculated by West Yost
7166	8	114	0	S20C1-41	S20C1-40	0	0	882	863	Invert Elevation Calculated by West Yost
7139	8	194	0	S20C1-30	S20C1-29	0	0	983	975	Invert Elevation Calculated by West Yost
7177	8	37	0	T20C1-35	T20C1-13	0	573	573	573	Invert Elevation Calculated by West Yost
7188	8	230	0	X18A1-10	X18A1-9	0	0	519	509	Invert Elevation Calculated by West Yost
7189	8	233	0	X18A1-9	X18A1-8	0	0	509	495	Invert Elevation Calculated by West Yost
7190	8	200	0	X18A1-3	X18A1-2	0	0	432	430	Invert Elevation Calculated by West Yost
7191	8	377	0	X18A1-4	X18A1-3	0	0	453	432	Invert Elevation Calculated by West Yost
7196	8	317	0	X18A1-12	X18A1-11	0	0	548	533	Invert Elevation Calculated by West Yost
7197	8	324	0	X18A1-11	X18A1-10	0	0	533	519	Invert Elevation Calculated by West Yost
7198	8	209	0	X18A1-8	X18A1-7	0	0	495	490	Invert Elevation Calculated by West Yost
7199	8	197	0	X18A1-7	X18A1-6	0	0	490	480	Invert Elevation Calculated by West Yost
7200	8	343	0	X18A1-6	X18A1-5	0	0	480	454	Invert Elevation Calculated by West Yost
7293	8	250	0	X18A1-55	X18A1-54	0	0	523	518	Invert Elevation Calculated by West Yost
7292	8	233	0	X18A1-54	X18A1-53	0	0	518	514	Invert Elevation Calculated by West Yost
7206	8	265	0	X18A1-53	X18A1-52	0	0	514	508	Invert Elevation Calculated by West Yost
7288	8	252	0	X18A1-52	X18A1-48	0	0	508	497	Invert Elevation Calculated by West Yost
7209	8	270	0	X18A1-36	X18A1-35	0	0	520	505	Invert Elevation Calculated by West Yost
7210	8	286	0	X18A1-35	X18A1-34	0	0	505	492	Invert Elevation Calculated by West Yost
7211	8	101	0	X18A1-34	X18A1-33	0	0	492	489	Invert Elevation Calculated by West Yost
7213	8	32	0	X18A1-33	X18A1-32	0	0	489	488	Invert Elevation Calculated by West Yost
7215	8	49	0	X18A1-32	X18A1-31	0	0	488	487	Invert Elevation Calculated by West Yost
7217	8	104	0	X18A1-31	X18A1-30	0	0	487	485	Invert Elevation Calculated by West Yost
7219	8	76	0	X18A1-30	X18A1-29	0	0	485	485	Invert Elevation Calculated by West Yost
7289	8	76	0	X18A1-29	X18A1-28	0	0	485	484	Invert Elevation Calculated by West Yost
7224	8	68	0	X18A1-28	X18A1-27	0	0	484	483	Invert Elevation Calculated by West Yost
7226	8	71	0	X18A1-27	X18A1-26	0	0	483	482	Invert Elevation Calculated by West Yost
7230	8	50	0	X18A1-51	X18A1-50	0	0	502	501	Invert Elevation Calculated by West Yost
7231	8	114	0	X18A1-50	X18A1-49	0	0	501	497	Invert Elevation Calculated by West Yost
7291	8	110	0	X18A1-49	X18A1-48	0	0	497	497	Invert Elevation Calculated by West Yost
7235	8	94	0	X18A1-48	X18A1-47	0	0	497	495	Invert Elevation Calculated by West Yost
7237	8	75	0	X18A1-47	X18A1-46	0	0	495	494	Invert Elevation Calculated by West Yost
7290	8	123	0	X18A1-46	X18A1-45	0	0	494	492	Invert Elevation Calculated by West Yost
7242	8	141	0	X18A1-45	X18A1-44	0	0	492	490	Invert Elevation Calculated by West Yost
7244	8	141	0	X18A1-44	X18A1-56	0	0	490	489	Invert Elevation Calculated by West Yost
7246	8	77	0	X18A1-56	X18A1-43	0	0	489	488	Invert Elevation Calculated by West Yost
7247	8	94	0	X18A1-43	X18A1-42	0	0	488	487	Invert Elevation Calculated by West Yost
7248	8	87	0	X18A1-42	X18A1-41	0	0	487	486	Invert Elevation Calculated by West Yost
7249	8	79	0	X18A1-41	X18A1-40	0	0	486	485	Invert Elevation Calculated by West Yost
7250	8	83	0	X18A1-40	X18A1-39	0	0	485	483	Invert Elevation Calculated by West Yost
7252	8	299	0	X18A1-39	X18A1-38	0	0	483	480	Invert Elevation Calculated by West Yost
7254	8	59	0	X18A1-38	X18A1-37	0	0	480	480	Invert Elevation Calculated by West Yost
7258	8	88	0	X18A1-24	X18A1-23	0	0	502	469	Invert Elevation Calculated by West Yost
7260	8	100	0	X18A1-23	X18A1-22	0	0	469	467	Invert Elevation Calculated by West Yost
7261	8	88	0	X18A1-22	X18A1-21	0	0	467	465	Invert Elevation Calculated by West Yost
7262	8	88	0	X18A1-21	X18A1-20	0	0	465	463	Invert Elevation Calculated by West Yost
7263	8	150	0	X18A1-20	X18A1-19	0	0	463	459	Invert Elevation Calculated by West Yost
7265	8	160	0	X18A1-19	X18A1-18	0	0	459	457	Invert Elevation Calculated by West Yost
7267	8	86	0	X18A1-18	X18A1-17	0	0	457	456	Invert Elevation Calculated by West Yost
7268	8	64	0	X18A1-17	X18A1-16	0	0	456	456	Invert Elevation Calculated by West Yost
7269	8	54	0	X18A1-16	X18A1-15	0	0	456	456	Invert Elevation Calculated by West Yost
7270	8	181	0	X18A1-15	X18A1-14	0	0	456	455	Invert Elevation Calculated by West Yost
7271	8	155	0	X18A1-14	X18A1-5	0	0	455	454	Invert Elevation Calculated by West Yost
7272	8	204	0	X18A1-5	X18A1-4	0	0	454	453	Invert Elevation Calculated by West Yost
7274	8	166	0	X18A1-13	X18A1-4	0	0	467	453	Invert Elevation Calculated by West Yost
7280	8	358	0	X18A1-2	X18A1-1	0	0	430	428	Invert Elevation Calculated by West Yost
7277	8	195	0	X18A1-1	X18D1-42	0	0	428	427	Invert Elevation Calculated by West Yost
4828	8	102	0	X19A1-33	X19A1-32	10	393	393	393	Suspicious US Invert
4825	8	121	0	X19A1-30	X19A1-26	11	391	391	391	Suspicious US Invert
4706	8	108	1	Y18C1-16	Y18C1-15	8	625	626	625	Suspicious US Invert
4441	8	319	0	X19C2-41	X19C2-25	9	383	385	383	Suspicious US Invert
4000	8	94	0	X19D2-11	X19D2-10	6	392	392	392	Suspicious US Invert
3486	8	316	0	W19C2-9	W19C2-8	21	369	370	369	Suspicious US Invert
4262	8	171	0	T17A2-5	T17A2-4	11	496	500	496	Suspicious US Invert
4826	8	117	0	X19A1-31	X19A1-30	393	11	393	496	Suspiciouc DS Invert
4827	8	61	0	X19A1-32	X19A1-30	393	11	393	393	Suspiciouc DS Invert
4707	8	258	1	Y18C1-17	Y18C1-16	630	8	630	392	Suspiciouc DS Invert
4447	8	341	0	X19C2-47	X19C2-41	387	9	387	626	Suspiciouc DS Invert
4442	8	178	0	X19C2-42	X19C2-41	387	9	387	386	Suspiciouc DS Invert
4443	8	182	0	X19C2-43	X19C2-41	382	9	382	386	Suspiciouc DS Invert
4263	8	205	0	T17A2-6	T17A2-5	502	11	502	381	Suspiciouc DS Invert
4264	8	371	0	T17A2-7	T17A2-5	500	11	500	500	Suspiciouc DS Invert
5065	8	581	0	W19C2-10	W19C2-9	373	21	373	500	Suspiciouc DS Invert

Table 2. GIS and Model Discrepancy by Diameter					
Pipe ID	Manhole Upstream ID	Manhole Downstream ID	GIS Diameter, inch	Model Diameter, inch	Proposed Diameter, inch
4324	V21A2-7	V21A3-1	42	39	42
2943	V21A3-5	V21A3-4	42	36	42
2942	V20D2-1	V21A3-5	42	36	42
1937	V21A2-17	V21A2-13	42	39	42
1936	U20B2-1	V21A2-15	42	39	42
1674	V21A2-13	V21A2-12	42	39	42
889	V21A2-12	V21A2-11	42	39	42
3301	W20C1-3	W20C1-2	39	36	39
3299	W20C1-1	V20D2-16	39	36	39
2011	U20B2-2	U20B2-1	39	33	39
879	V20D2-16	V20D2-15	39	36	39
878	V20D2-15	V20D2-14	39	36	39
4498	U19D1-1	U20B1-26	36	33	36
2945	V21A3-3	V21A3-2	36	42	36
1500	U19D3-7	U19B1-1	33	27	33
4548	X20b2-4	X20b2-3	30	36	30
4547	X20b2-3	X20b2-2	30	36	30
4546	X20b2-2	X20b2-1	30	36	30
4545	X20b2-1	X20B1-17	30	36	30
4353	X20B1-17	X20B1-4	30	36	30
4339	X20B1-3	X20B1-2	30	36	30
3513	W19D3-3	W19D3-2	27	15	27
3512	W19D3-2	W19D3-1	27	15	27
3511	W19D3-1	W20B4-1	27	15	27
1655	U19B1-7	U19D3-4	18	33	18
446	U16D1-1	U16C3-2	18	21	18
2179	V19B1-18	V19B1-17	12	10	12
1963	U20C2-1	U20D1-37	12	8	12
1958	U20D1-14	U20D1-9	12	10	12
1953	U20D1-29	U20D1-28	12	8	12
1610	V19B1-11	V19B1-10	12	10	12
1396	V19B1-24	V19B1-23	12	10	12
1395	V19B1-23	V19B1-19	12	10	12
1392	V19B1-19	V19B1-18	12	10	12
1391	V19B1-17	V19B1-12	12	10	12
1386	V19B1-12	V19B1-11	12	10	12
932	U20D1-9	U20D1-8	12	10	12
926	U20D1-30	U20D1-29	12	8	12
924	U20D1-28	U20D1-26	12	8	12
922	U20D1-26	U20D1-25	12	8	12
921	U20D1-25	U20D1-15	12	8	12
913	U20D1-15	U20D1-14	12	10	12
857	U20C2-12	U20C2-11	12	8	12
856	U20C2-10	U20C2-3	12	8	12
2	U20C2-11	U20C2-10	12	8	12
2615	U20D1-37	U20D1-30	10	8	10
2362	U18B2-30	U18B2-29	10	8	10
1891	U16C2-4	U16C2-2	10	12	10
422	U16C2-5	U16C2-4	10	12	10
412	U16C2-2	U16C2-1	10	15	10
4325	V20D1-24	V20D2-15	8	36	8
3559	W19D1-3	W19D1-2	8	12	8
3558	W19D1-2	W19D1-1	8	12	8
3557	W19D1-1	W20B4-5	8	12	8
3465	W19C3-17	W19C3-16	8	12	8
3464	W19C3-16	W19C3-15	8	12	8
3463	W19C3-15	W19C3-8	8	12	8
3456	W19C3-8	W19C3-7	8	12	8
3455	W19C3-7	W19C3-6	8	12	8
3454	W19C3-6	W19C3-5	8	12	8
3453	W19C3-5	W19C3-3	8	12	8
3441	W19C1-15	W19C1-14	8	12	8
3440	W19C1-14	W19C1-12	8	12	8
3437	W19C1-11	W19C1-10	8	12	8
3436	W19C1-10	W19C1-9	8	12	8
3435	W19C1-9	W19C1-6	8	12	8
3395	V19D2-17	V19D2-16	8	12	8
3394	V19D2-16	V19D2-15	8	12	8
3393	V19D2-15	V19D2-14	8	12	8
3392	V19D2-14	V19D2-13	8	12	8
3391	V19D2-13	V19D2-12	8	12	8
3390	V19D2-12	V19D2-11	8	12	8
3389	V19D2-11	V19D2-10	8	12	8
2750	U20B1-8	U20B1-7	8	10	8
2319	U17C1-15	U17C1-14	8	6	8
2315	V18D1-24	V18D1-23	8	6	8

Table 2. GIS and Model Discrepancy by Diameter

Pipe ID	Manhole Upstream ID	Manhole Downstream ID	GIS Diameter, inch	Model Diameter, inch	Proposed Diameter, inch
2313	V18D1-13	V18D1-12	8	6	8
2305	V18B1-39	V18B1-38	8	10	8
2110	U20A1-2	U20B3-13	8	12	8
2109	U20A1-4	U20A1-3	8	12	8
2005	V20D1-14	V20D1-13	8	10	8
1860	U16A1-6	U16A1-4	8	10	8
1697	T16D4-2	T16D4-1	8	12	8
1457	V19A2-8	V19A2-2	8	12	8
1260	U20A1-42	U20A1-4	8	12	8
1256	U20A1-3	U20A1-2	8	12	8
1221	U19C4-15	U19C4-6	8	10	8
1200	U19C3-1	U19C4-22	8	12	8
952	V20A1-6	V20A1-5	8	4	8
62	V18B1-1	V19B1-51	8	10	8
8	U18D2-2	U18D2-1	8	10	8
2337	U17C2-15	U17C2-14	6	8	6

Table 3. GIS and Model Discrepancy by Length

Pipe ID	Manhole Upstream ID	Manhole Downstream ID	GIS Length, ft	Model Length, ft	Length Difference, ft	Absolute Percentage Difference
4550	X20B2-6	X20B2-5	40	330	290	725%
4553	X20B2-9	X20B2-8	46	330	284	617%
3432	W19C1-6	W19C1-5	57	285	228	400%
882	V20D2-3	V20D2-2	92	454	362	393%
4548	X20b2-4	X20b2-3	69	330	261	378%
4551	X20B2-7	X20B2-6	74	330	256	346%
4687	Y19A3-13	Y19A3-12	60	254	194	323%
4219	T16C1-49	T16C1-2	66	210	144	218%
3501	W20B4-1	W20C1-14	61	180	119	195%
4677	Y19a3-3	Y19A3-1	87	254	167	192%
2519	V19A2-38	V19A2-37	190	505	315	166%
1993	U20B3-4	U20B3-3	19	47	28	147%
1180	U19C2-2	U19C2-1	73	178	105	144%
677	V17C1-1	V18B1-39	180	396	216	120%
4556	X20B2-12	X20B2-11	163	330	167	102%
2750	U20B1-8	U20B1-7	406	42	-364	90%
988	U20B3-6	U20D2-12	32	58	26	81%
2044	U19C1-13	U19C1-12	149	257	108	72%
3502	W20B4-2	W20B4-1	336	110	-226	67%
3504	W20B4-4	W20B4-3	391	132	-259	66%
4495	U20B1-29	U20B1-28	234	388	154	66%
4688	Y19A3-14	Y19A3-13	155	254	99	64%
3512	W19D3-2	W19D3-1	110	180	70	64%
3513	W19D3-3	W19D3-2	300	110	-190	63%
964	U20D2-8	U20B3-1	28	45	17	61%
2846	T20C1-13	T20C1-12	127	203	76	60%
933	V20A1-1	U20B2-3	209	332	123	59%
4483	U19C1-28	U19C1-1	12	19	7	58%
4680	Y19A3-6	Y19A3-5	161	254	93	58%
3377	V19D1-34	V19D1-33	137	215	78	57%
3508	W20B4-8	W20B4-7	183	83	-100	55%
1123	U19C1-12	U19C1-28	172	265	93	54%
2548	V19B1-39	V19B1-53	121	186	65	54%
3740	W20B1-1	W20B4-7	363	168	-195	54%
1457	V19A2-8	V19A2-2	235	358	123	52%
481	V17A1-4	V17A1-3	47	70	23	49%
3503	W20B4-3	W20B4-2	393	567	174	44%
4559	X20b2-15	X20B2-14	229	330	101	44%
3394	V19D2-16	V19D2-15	160	90	-70	44%
3445	W19C1-19	W19C1-18	350	202	-148	42%
2521	V19A2-20	V19A2-8	116	163	47	41%
878	V20D2-15	V20D2-14	324	455	131	40%
4493	U20A1-42	U20A1-41	25	15	-10	40%
141	T17D1-10	T17D1-5	172	239	67	39%
968	V20A2-13	V20A2-12	93	129	36	39%
1652	U18C2-2	U18C2-1	127	79	-48	38%
1154	U19C5-8	U19C5-5	32	20	-12	38%
1173	U19C2-1	U19C3-19	240	150	-90	38%
881	V20D2-2	V20D2-1	360	225	-135	38%
461	U16C3-2	U17A2-1	419	575	156	37%
2005	V20D1-14	V20D1-13	232	313	81	35%
97	T17D1-5	T17D1-4	135	181	46	34%
2522	V19A2-24	V19A2-23	181	120	-61	34%
3390	V19D2-12	V19D2-11	74	50	-24	32%
1594	V19B1-52	V19B1-26	110	76	-34	31%
1407	V19B1-38	V19B1-52	143	186	43	30%
1114	T19D2-3	T19D2-2	20	14	-6	30%
3511	W19D3-1	W20B4-1	180	233	53	29%
2461	V17A1-5	V17A1-4	73	52	-21	29%
1942	V21A2-4	V21A2-3	283	203	-80	28%
4494	U20A1-1	U20B1-29	50	36	-14	28%
2246	U18C1-7	U18C1-6	140	101	-39	28%
4387	U20B3-12	U20B3-11	496	634	138	28%
3207	V17A3-7	V17A3-4	205	262	57	28%
4684	Y19A3-10	Y19A3-9	350	254	-96	27%
4683	Y19A3-9	Y19A3-8	350	254	-96	27%
4682	Y19A3-8	Y19A3-7	350	254	-96	27%
221	U17D1-7	U17D1-6	74	94	20	27%
3391	V19D2-13	V19D2-12	87	110	23	26%
3505	W20B4-5	W20B4-4	387	285	-102	26%
2396	U18B3-5	U18B3-4	191	141	-50	26%
1418	V19B1-49	V19B1-48	165	122	-43	26%
879	V20D2-16	V20D2-15	98	73	-25	26%
4681	Y19A3-7	Y19A3-6	340	254	-86	25%
307	U18C2-21	U18C2-20	256	320	64	25%
2251	V19A2-3	V19A2-2	52	65	13	25%
2338	U17C2-8	U17C2-7	177	221	44	25%
3407	V19D2-29	V19D2-28	17	21	4	24%
184	U18C3-4	U18C3-3	157	193	36	23%
972	V20A2-19	V20A2-18	225	174	-51	23%
1105	T19D2-2	T19D2-1	106	130	24	23%
1725	T17D1-17	T17D1-13	270	210	-60	22%
3323	W20C1-24	W20C1-23	284	347	63	22%
426	U17A2-13	U17A2-12	236	288	52	22%
1933	V20D2-8	V20D2-7	133	104	-29	22%

Table 3. GIS and Model Discrepancy by Length						
Pipe ID	Manhole Upstream ID	Manhole Downstream ID	GIS Length, ft	Model Length, ft	Length Difference, ft	Absolute Percentage Difference
3201	V17A3-2	V17A3-1	306	370	64	21%
62	V18B1-1	V19B1-51	137	165	28	20%
1796	T20B2-25	T20B2-18	20	16	-4	20%
4689	Y19A3-15	Y19A3-14	317	254	-63	20%
1068	U19A1-32	U19A1-28	81	65	-16	20%
441	U17A2-36	U17A2-32	175	209	34	19%
1571	U18C1-24	U18C1-23	108	88	-20	19%
113	U17C1-3	U17C1-2	289	238	-51	18%
2436	V17C1-39	V17C1-38	176	207	31	18%
424	U16C2-8	U16C2-7	125	147	22	18%
2615	U20D1-37	U20D1-30	364	300	-64	18%
72	V18B1-25	V18B1-24	57	67	10	18%
926	U20D1-30	U20D1-29	88	73	-15	17%
1727	T17D1-11	T17D1-10	142	166	24	17%
4552	X20B2-8	X20B2-5	397	330	-67	17%
4549	X20B2-5	X20b2-4	397	330	-67	17%
2054	U19C5-3	U19C5-1	72	60	-12	17%
2253	V19A2-2	V19A2-1	78	65	-13	17%
220	U17D1-6	U17D1-2	123	103	-20	16%
1580	U18C1-6	U18C1-1	167	140	-27	16%
2476	U17D1-1	U17A3-2	551	640	89	16%
2399	U17A2-23	U17A2-17	275	231	-44	16%
88	V18D1-1	V19B1-51	133	112	-21	16%
1010	V20D1-13	V20D1-27	287	242	-45	16%
190	U17C2-12	U17C2-11	256	296	40	16%
4545	X20b2-1	X20B1-17	391	330	-61	16%
829	T20D1-7	T20D1-6	77	89	12	16%
1996	U20D2-12	U20B3-4	290	245	-45	16%
1217	U19C4-1	U20B3-13	451	520	69	15%
893	V21A2-8	V21A2-7	834	708	-126	15%
1621	U17C1-2	U17C1-1	273	314	41	15%
2099	U19C4-4	U19C4-3	87	100	13	15%
816	T20D1-44	T20D1-41	94	80	-14	15%
445	U17A2-7	U17A2-3	229	263	34	15%
423	U16C2-6	U16C2-5	182	155	-27	15%
2007	V20D1-12	V20D1-8	151	173	22	15%
683	V17C1-18	V17C1-17	263	301	38	14%
1674	V21A2-13	V21A2-12	176	201	25	14%
3440	W19C1-14	W19C1-12	192	219	27	14%
4497	U20B1-27	U20B1-26	224	255	31	14%
1601	U18C3-18	U18C3-17	233	265	32	14%
1784	T19D2-4	T19D2-3	132	114	-18	14%
2501	T20B2-13	T20B2-12	169	192	23	14%
193	U17C2-17	U17C2-12	297	257	-40	13%
2411	U17A2-2	U17A2-1	225	255	30	13%
248	U17A3-2	U17C2-1	466	405	-61	13%
406	U16C2-1	U16C1-1	69	60	-9	13%
2393	V18A1-3	V18A1-2	31	35	4	13%
2987	U18B4-7	U18B4-6	47	53	6	13%
891	V21A2-5	V21A2-4	628	708	80	13%
4679	Y19A3-5	Y19a3-4	291	254	-37	13%
4678	Y19a3-4	Y19a3-3	291	254	-37	13%
731	T20B2-14	T20B2-13	126	110	-16	13%
2410	U17A2-3	U17A2-2	284	248	-36	13%
856	U20C2-10	U20C2-3	270	236	-34	13%
2435	V17C1-37	V17C1-34	129	113	-16	12%
309	U18C2-24	U18C2-23	97	109	12	12%
2378	U18C2-22	U18C2-21	267	300	33	12%
983	U20B3-1	U20D2-1	423	475	52	12%
3082	V17A3-1	V17C1-23	295	259	-36	12%
343	T16D3-1	U16C1-2	232	204	-28	12%
4546	X20b2-2	X20b2-1	295	330	35	12%
4686	Y19A3-12	Y19A3-11	288	254	-34	12%
188	U17C2-10	U17C2-9	155	137	-18	12%
1739	T17D2-11	T17D2-9	226	252	26	12%
2079	U19C2-34	U19C2-29	175	195	20	11%
2243	U18C1-23	U18C1-20	132	147	15	11%
1985	V20A2-23	V20A2-22	407	453	46	11%
3408	V19D2-30	V19D2-29	45	40	-5	11%
206	U17C2-9	U17C2-8	416	370	-46	11%
2849	T20C1-10	T20C1-34	246	273	27	11%
4685	Y19A3-11	Y19A3-10	285	254	-31	11%
294	U18B2-5	U18B2-4	176	157	-19	11%
4353	X20B1-17	X20B1-4	359	397	38	11%
2371	U18B2-4	U18B2-3	125	138	13	10%
3208	V17A3-8	V17A3-7	183	164	-19	10%
738	T20B2-26	T20B2-25	222	245	23	10%
1989	V20A2-12	V20A2-11	503	452	-51	10%
2061	U19C6-9	U19C6-2	237	261	24	10%
135	V18D1-35	V18D1-34	240	264	24	10%
4489	U19C3-1	U20A1-44	80	88	8	10%
3020	U18B4-39	U18B4-38	71	64	-7	10%
185	U18C3-5	U18C3-4	213	192	-21	10%
2394	V18A1-4	V18A1-3	61	55	-6	10%
2929	V17A1-1	V17C1-39	153	168	15	10%

Table 3. GIS and Model Discrepancy by Length

Pipe ID	Manhole Upstream ID	Manhole Downstream ID	GIS Length, ft	Model Length, ft	Length Difference, ft	Absolute Percentage Difference
1971	V20A1-16	V20A1-12	102	112	10	10%
1192	U19C2-45	U19C2-34	217	196	-21	10%
4554	X20B2-10	X20B2-8	365	330	-35	10%
183	U18C3-3	U18C3-2	136	149	13	10%
4330	U18B4-41	U18C2-1	75	82	7	9%
2340	U17C2-2	U17C2-1	338	369	31	9%
2361	U18B2-36	U18B2-35	220	240	20	9%
2505	V20A2-5	V20A2-2	132	120	-12	9%
3453	W19C3-5	W19C3-3	187	170	-17	9%
2497	U16C2-9	U16C2-5	198	180	-18	9%
2401	U17A2-8	U17A2-7	287	261	-26	9%
2433	U17A1-22	U17A1-20	144	131	-13	9%
884	V20D2-7	V20D2-6	455	496	41	9%
2927	T16D4-1	T16D3-9	336	366	30	9%
4528	V19D2-37	V19D2-36	224	244	20	9%
952	V20A1-6	V20A1-5	135	147	12	9%
2237	U18D1-5	U18D1-4	271	295	24	9%
519	U17A1-23	U17A1-22	161	175	14	9%
455	U16D1-2	U16D1-1	104	113	9	9%
1690	T16D3-2	T16D3-1	313	340	27	9%
1692	T16D3-7	T16D3-6	151	164	13	9%
2014	U19A1-28	U19A1-27	152	165	13	9%
308	U18C2-23	U18C2-22	364	395	31	9%
2060	U19C6-11	U19C6-10	201	218	17	8%
178	U18C3-17	U18C3-13	142	130	-12	8%
283	U18B2-3	U18B2-2	155	142	-13	8%
2398	U17A2-37	U17A2-36	191	175	-16	8%
1287	U19B2-1	U19D3-7	466	505	39	8%
222	U17D1-8	U17D1-7	132	143	11	8%
171	U18C3-1	U18C1-24	314	340	26	8%
329	V18A1-2	V18A1-1	280	303	23	8%
77	V18B1-31	V18B1-30	61	66	5	8%
3355	V19D1-12	V19D1-11	282	305	23	8%
1697	T16D4-2	T16D4-1	395	363	-32	8%
925	U20D1-3	U20D1-2	284	261	-23	8%
2006	V20D1-27	V20D1-12	87	94	7	8%
3019	U18B4-38	U18B4-37	100	108	8	8%
75	V18B1-29	V18B1-28	75	69	-6	8%
284	U18B2-31	U18B2-45	242	223	-19	8%
435	U17A2-25	U17A2-24	400	431	31	8%
2214	U19B1-1	U19B1-7	207	191	-16	8%
2375	U18C2-31	U18C2-30	235	253	18	8%
1894	U16D1-14	U16D1-13	119	110	-9	8%
4187	V21A3-6	V21A3-3	531	491	-40	8%
2443	V17C1-17	V17C1-16	362	335	-27	7%
1021	V20D1-7	V20D1-6	190	204	14	7%
2986	U18B4-6	U18B4-1	136	146	10	7%
512	U17A1-14	U17A1-2	246	264	18	7%
4675	Y19A3-1	X19B2-24	274	254	-20	7%
4557	X20B2-13	X20B2-12	308	330	22	7%
4547	X20b2-3	X20b2-2	308	330	22	7%
1060	U19A1-22	U19A1-21	280	300	20	7%
2024	U19A1-2	U19A1-1	196	210	14	7%
699	V17C1-38	V17C1-37	126	117	-9	7%
288	U18B2-37	U18B2-36	211	196	-15	7%
948	V20A1-32	V20A1-30	156	167	11	7%
1451	V19A2-41	V19A2-40	143	133	-10	7%
487	U17B1-1	U17D1-11	130	139	9	7%
70	V18B1-21	V18B1-20	88	94	6	7%
4690	Y19A3-16	Y19A3-15	238	254	16	7%
410	U16C2-17	U16C2-9	255	272	17	7%
1900	T20D1-35	T20D1-34	136	145	9	7%
463	V17A1-11	V17A1-5	318	339	21	7%
252	U18B1-12	U18B1-11	318	297	-21	7%
3455	W19C3-7	W19C3-6	243	259	16	7%
2377	U18C2-25	U18C2-24	290	309	19	7%
2311	V18D1-2	V18D1-1	275	293	18	7%
434	U17A2-24	U17A2-23	429	457	28	7%
1386	V19B1-12	V19B1-11	169	180	11	7%
205	U17C2-7	U17C2-2	200	187	-13	7%
2376	U18C2-27	U18C2-26	339	317	-22	6%
1880	U16C1-2	U16C1-1	262	245	-17	6%
1207	U19C3-2	U19C3-1	278	260	-18	6%
949	V20A1-33	V20A1-32	31	29	-2	6%
1163	U19C6-20	U19C6-15	423	450	27	6%
1899	T20D1-36	T20D1-35	141	150	9	6%
1891	U16C2-4	U16C2-2	332	311	-21	6%
4498	U19D1-1	U20B1-26	16	15	-1	6%
1007	V20D1-1	V20A2-8	321	301	-20	6%
2120	V19A4-2	V19A4-1	164	174	10	6%
986	U20B3-2	U20B3-1	164	174	10	6%
1020	V20D1-6	V20D1-4	285	302	17	6%
2165	V19A3-1	U19D2-22	305	287	-18	6%
3005	V18A1-1	U18B4-24	68	72	4	6%
947	V20A1-30	V20A1-28	240	226	-14	6%

Table 3. GIS and Model Discrepancy by Length

Pipe ID	Manhole Upstream ID	Manhole Downstream ID	GIS Length, ft	Model Length, ft	Length Difference, ft	Absolute Percentage Difference
810	T20D1-34	T20D1-33	139	147	8	6%
2219	V19C1-13	V19C3-3	175	185	10	6%
414	U16C2-22	U16C2-21	228	241	13	6%
1052	U19A1-1	U19A2-13	88	83	-5	6%
2370	U18B2-25	U18B2-5	282	298	16	6%
2486	U20D1-7	U20B3-6	53	56	3	6%
812	T20D1-39	T20D1-36	159	150	-9	6%
157	U18A1-2	U18A1-1	177	167	-10	6%
449	U16D1-13	U16D1-11	372	393	21	6%
694	V17C1-32	V17C1-31	161	170	9	6%
1898	U16D1-3	U16D1-2	163	172	9	6%
1603	U18C3-2	U18C3-1	202	191	-11	5%
2158	U19D2-22	U19D2-21	280	295	15	5%
966	V20A2-1	V20A1-6	56	53	-3	5%
2442	V17C1-19	V17C1-18	187	177	-10	5%
143	T17D1-13	T17D1-11	244	257	13	5%
1187	U19C2-3	U19C2-2	132	139	7	5%
3372	V19D1-29	V19D1-28	208	219	11	5%
3409	V19D2-31	V19D2-30	114	120	6	5%
2925	U18C2-30	U18C2-69	248	261	13	5%
352	T16D3-6	T16D3-2	306	290	-16	5%
1083	U19A2-2	U19A2-1	58	61	3	5%
4555	X20B2-11	X20B2-10	348	330	-18	5%
1859	U16A1-9	U16A1-8	353	371	18	5%
66	V18B1-16	V18B1-1	276	290	14	5%
1988	V20A2-15	V20A2-14	79	83	4	5%
1271	U19B3-6	U19B2-1	257	270	13	5%
2254	V19A4-1	V19A2-7	356	338	-18	5%
1162	U19C6-2	U19C6-1	437	459	22	5%
2008	V20D1-8	V20D1-7	441	419	-22	5%
1222	U19C4-17	U19C4-16	181	172	-9	5%
688	V17C1-23	V17C1-19	302	317	15	5%
287	U18B2-35	U18B2-31	121	115	-6	5%
2215	U19D3-4	U19D1-9	323	339	16	5%
429	U17A2-17	U17A2-13	243	255	12	5%
1812	T20D1-40	T20D1-39	143	150	7	5%
196	U17C2-20	U17C2-19	143	150	7	5%
967	V20A2-11	V20A2-10	334	350	16	5%
1419	V19B1-51	V19B1-50	377	395	18	5%
2355	U17A3-4	U17D1-1	548	522	-26	5%
1560	U18D1-4	U18D1-2	253	265	12	5%
1833	T20D2-21	T20D2-20	211	221	10	5%
310	U18C2-26	U18C2-25	296	310	14	5%
208	U17D1-11	U17D1-9	127	133	6	5%
2017	U19A1-23	U19A1-22	320	335	15	5%
1823	T20D1-6	T20D1-5	108	113	5	5%
76	V18B1-30	V18B1-29	65	68	3	5%
1158	U19C6-13	U19C6-12	87	83	-4	5%
509	U17A1-1	U17A3-4	698	730	32	5%
1223	U19C4-18	U19C4-17	328	343	15	5%
1157	U19C6-12	U19C6-11	374	391	17	5%
1610	V19B1-11	V19B1-10	66	69	3	5%
74	V18B1-28	V18B1-25	66	69	3	5%
521	U17A1-27	U17A1-25	243	254	11	5%
876	V20D2-12	V20D2-11	426	445	19	4%
254	U18B1-15	U18B1-6	315	329	14	4%
3368	V19D1-25	V19D1-24	45	47	2	4%
1730	T17D1-4	T17D1-3	135	129	-6	4%
2517	V19A2-42	V19A2-33	183	191	8	4%
2357	U18B1-26	U18B1-23	231	241	10	4%
1059	U19A1-21	U19A1-14	232	222	-10	4%
262	U18B1-27	U18B1-26	141	135	-6	4%
505	U17B1-7	U17B1-1	454	435	-19	4%
1396	V19B1-24	V19B1-23	170	177	7	4%
2424	U17A1-25	U17A1-23	222	231	9	4%
3027	T16C1-1	T17B1-4	346	332	-14	4%
1076	U19A1-8	U19A1-7	124	129	5	4%
4338	X20B1-2	X20B1-1	300	312	12	4%
67	V18B1-18	V18B1-17	75	78	3	4%
2025	U19A1-7	U19A1-2	25	24	-1	4%
774	T20D2-19	T20D2-11	225	216	-9	4%
71	V18B1-23	V18B1-21	101	97	-4	4%
2220	V19C3-3	V19C3-2	230	221	-9	4%
1569	U18C1-20	U18C1-16	308	320	12	4%
3398	V19D2-20	V19D2-19	129	124	-5	4%
2545	U17C1-1	U18B1-23	440	457	17	4%
1809	T20D1-48	T20D1-47	130	125	-5	4%
3015	U18B4-34	U18B4-25	105	109	4	4%
516	U17A1-2	U17A1-1	237	228	-9	4%
2245	U18C1-16	U18C1-15	317	329	12	4%
195	U17C2-19	U17C2-18	317	329	12	4%
1503	V19C3-9	V19C1-1	345	358	13	4%
1528	T18D1-1	U18C2-31	108	104	-4	4%
147	T17D1-2	T17D1-1	299	310	11	4%
814	T20D1-41	T20D1-40	82	79	-3	4%

Table 3. GIS and Model Discrepancy by Length

Pipe ID	Manhole Upstream ID	Manhole Downstream ID	GIS Length, ft	Model Length, ft	Length Difference, ft	Absolute Percentage Difference
1507	V19C2-14	V19C2-13	165	171	6	4%
1518	V19C2-29	V19C2-16	250	259	9	4%
2094	U19C4-19	U19C4-18	417	402	-15	4%
251	U18B1-11	U18B1-10	281	291	10	4%
1994	U20D1-1	U20B3-8	451	467	16	4%
1391	V19B1-17	V19B1-12	114	118	4	4%
2342	U17D1-2	U17D1-1	376	389	13	3%
704	T19D1-1	T19D2-4	376	363	-13	3%
268	U18B2-1	V18A1-4	261	270	9	3%
3395	V19D2-17	V19D2-16	58	60	2	3%
730	T20B2-11	T20B2-10	174	168	-6	3%
422	U16C2-5	U16C2-4	147	152	5	3%
682	V17C1-16	V17C1-15	324	335	11	3%
1224	U19C4-21	U19C4-15	148	143	-5	3%
1127	U19C1-19	U19C1-13	298	288	-10	3%
604	T16D2-15	T16D2-1	239	247	8	3%
985	U20B3-11	U20B3-10	60	58	-2	3%
1156	U19C6-10	U19C6-9	270	261	-9	3%
1204	U19C3-15	U19C3-10	121	117	-4	3%
2034	U19A2-11	U19A2-2	153	148	-5	3%
411	U16C2-19	U16C2-17	247	255	8	3%
1860	U16A1-6	U16A1-4	248	256	8	3%
1420	V19B1-53	V19B1-38	379	391	12	3%
2509	U19C4-16	U19C4-15	158	163	5	3%
1395	V19B1-23	V19B1-19	95	98	3	3%
2511	V19B1-10	V19B1-1	413	426	13	3%
3454	W19C3-6	W19C3-5	286	295	9	3%
4337	X20B1-1	X20A4-8	162	157	-5	3%
1710	T17B1-4	T17B1-3	360	371	11	3%
4378	U20B3-13	U20B3-12	165	160	-5	3%
189	U17C2-11	U17C2-10	165	160	-5	3%
1917	U20C2-13	U20C2-12	166	171	5	3%
1098	T19D2-1	U19C1-9	266	258	-8	3%
2489	U19A2-13	U19A2-12	333	323	-10	3%
1947	U20B1-9	U20B1-8	100	97	-3	3%
1279	V19A4-21	V19A4-18	268	276	8	3%
2354	U17A2-1	U17A1-1	1072	1040	-32	3%
1129	U19C1-21	U19C1-19	269	277	8	3%
858	U20C2-14	U20C2-13	269	261	-8	3%
2217	V19C3-10	V19C3-9	371	360	-11	3%
969	V20A2-14	V20A2-11	340	350	10	3%
2294	V18B1-20	V18B1-19	68	66	-2	3%
2484	V20D2-5	V20D2-4	342	352	10	3%
805	T20D1-27	T20D1-26	138	134	-4	3%
1711	T17B1-2	T17B1-1	312	321	9	3%
610	T16D2-22	T16D2-28	384	395	11	3%
1975	V20A1-3	V20A1-2	562	546	-16	3%
695	V17C1-34	V17C1-32	352	362	10	3%
1801	T20B2-12	T20B2-11	248	255	7	3%
2021	U19A1-12	U19A1-11	179	184	5	3%
3203	V17A3-4	V17A3-2	287	279	-8	3%
3403	V19D2-25	V19D2-23	36	35	-1	3%
267	U18B1-8	U18B1-7	217	223	6	3%
1356	U19D2-21	U19D2-19	255	248	-7	3%
354	T16D3-9	T16D3-8	401	412	11	3%
8	U18D2-2	U18D2-1	404	415	11	3%
2101	U19C6-1	U19C4-19	150	154	4	3%
3356	V19D1-13	V19D1-12	339	330	-9	3%
2059	U19C5-1	U19C6-13	154	150	-4	3%
560	T17B1-3	T17B1-2	310	302	-8	3%
95	T17D1-3	T17D1-2	351	342	-9	3%
689	V17C1-24	V17C1-19	236	230	-6	3%
2191	V19A2-7	V19A2-6	395	385	-10	3%
951	V20A1-5	V20A1-3	439	450	11	3%
517	U17A1-20	U17A1-18	282	289	7	2%
4241	U18B4-1	U18B4-41	121	124	3	2%
2847	T20C1-12	T20C1-11	323	315	-8	2%
2488	U19A1-10	U19A1-9	162	166	4	2%
266	U18B1-6	U18B1-2	332	324	-8	2%
813	T20D1-4	T20D1-2	291	298	7	2%
3404	V19D2-26	V19D2-25	125	128	3	2%
1055	U19A1-14	U19A1-12	253	259	6	2%
3400	V19D2-22	V19D2-21	169	173	4	2%
1282	V19A4-3	V19A4-2	169	165	-4	2%
599	T16D2-1	T16D3-9	255	261	6	2%
2431	U17A1-18	U17A1-16	259	265	6	2%
194	U17C2-18	U17C2-17	259	265	6	2%
1077	U19A2-1	U19C6-20	217	212	-5	2%
1987	V20A2-18	V20A2-15	262	268	6	2%
804	T20D1-26	T20D1-25	131	134	3	2%
306	U18C2-20	U18C2-19	352	360	8	2%
776	T20D2-22	T20D2-21	132	135	3	2%
3308	W20C1-10	W20C1-9	22	22.5	0.5	2%
1822	T20D1-8	T20D1-7	222	217	-5	2%
1931	V20D2-13	V20D2-12	135	138	3	2%

Table 3. GIS and Model Discrepancy by Length

Pipe ID	Manhole Upstream ID	Manhole Downstream ID	GIS Length, ft	Model Length, ft	Length Difference, ft	Absolute Percentage Difference
768	T20D2-1	T20D1-1	275	281	6	2%
282	U18B2-29	U18B2-25	230	235	5	2%
2231	V19C2-11	V19C2-1	235	240	5	2%
4485	U19C2-46	U19C2-45	47	48	1	2%
1655	U19B1-7	U19D3-4	568	556	-12	2%
1479	U19D1-4	U19D1-1	333	340	7	2%
1763	T19B1-2	T19B1-1	143	146	3	2%
132	V18D1-31	V18D1-30	334	341	7	2%
1814	T20D1-33	T20D1-27	144	147	3	2%
1131	U19C1-24	U19C1-21	242	247	5	2%
1063	U19A1-27	U19A1-23	194	198	4	2%
2934	T19B1-1	U19A1-32	146	143	-3	2%
1837	T20D2-11	T20D2-10	244	239	-5	2%
1995	U20B3-8	U20D1-7	196	200	4	2%
1810	T20D1-45	T20D1-44	147	150	3	2%
749	T20B2-7	T20B2-5	247	242	-5	2%
3376	V19D1-33	V19D1-32	99	97	-2	2%
1736	T17D2-19	T17D2-17	298	304	6	2%
2995	U18B4-15	U18B4-8	199	195	-4	2%
2139	V19A3-18	V19A3-16	252	247	-5	2%
513	U17A1-16	U17A1-14	255	260	5	2%
391	T17D2-9	T17D2-1	307	301	-6	2%
3004	U18B4-24	U18B4-18	103	105	2	2%
3402	V19D2-24	V19D2-23	363	370	7	2%
4484	U19C2-38	U19C2-45	52	53	1	2%
1821	T20D1-10	T20D1-9	161	164	3	2%
2306	V18D1-29	V18D1-28	322	316	-6	2%
2179	V19B1-18	V19B1-17	215	219	4	2%
3374	V19D1-31	V19D1-30	216	220	4	2%
19	U18D3-1	U18D4-7	54	55	1	2%
2335	U18C3-19	U18C3-18	384	391	7	2%
2108	U20A1-6	U20A1-42	222	226	4	2%
981	V20A2-6	V20A2-5	668	680	12	2%
2100	U19C4-2	U19C4-1	167	164	-3	2%
1935	V20D2-4	V20D2-3	335	341	6	2%
1314	V19A3-13	V19A3-12	280	275	-5	2%
2438	V17C1-26	V17C1-24	282	287	5	2%
820	T20D1-5	T20D1-4	284	289	5	2%
1229	U19C4-3	U19C4-2	341	335	-6	2%
1504	V19C2-1	V20A1-33	234	230	-4	2%
2011	U20B2-2	U20B2-1	235	239	4	2%
1506	V19C2-13	V19C2-11	294	289	-5	2%
3301	W20C1-3	W20C1-2	120	122	2	2%
1567	U18C1-15	U18C1-7	181	184	3	2%
1018	V20D1-3	V20D1-1	303	308	5	2%
2395	U17C2-1	U18B3-7	610	600	-10	2%
447	U16D1-10	U16D1-9	428	421	-7	2%
1316	V19A3-16	V19A3-13	246	250	4	2%
4491	U20A1-43	U20A1-6	123	125	2	2%
336	V18A1-6	V18A1-3	308	303	-5	2%
442	U17A2-39	U17A2-37	377	371	-6	2%
2252	V19A2-4	V19A2-3	64	65	1	2%
460	U16D1-9	U16D1-8	385	379	-6	2%
3211	V17A3-11	V17A3-8	259	263	4	2%
2379	U18C2-19	U18C2-8	454	461	7	2%
614	T16D2-28	T16D2-19	130	132	2	2%
2216	V19A2-1	V19C3-11	261	265	4	2%
953	V20A1-8	V20A1-3	457	450	-7	2%
1620	U18B1-28	U18B1-27	197	200	3	2%
353	T16D3-8	T16D3-7	468	461	-7	1%
3370	V19D1-27	V19D1-26	67	68	1	1%
78	V18B1-32	V18B1-31	67	66	-1	1%
3375	V19D1-32	V19D1-31	68	69	1	1%
2988	U18B4-8	U18B4-7	140	142	2	1%
2546	U18C3-12	U18C3-5	214	211	-3	1%
1803	T20B2-5	T20B2-1	289	293	4	1%
2518	V19A2-33	V19A2-23	145	147	2	1%
1816	T20D1-25	T20D1-6	147	149	2	1%
2230	V19C2-16	V19C2-14	223	220	-3	1%
1152	U19C5-5	U19C5-4	299	303	4	1%
3017	U18B4-36	U18B4-35	75	74	-1	1%
457	U16D1-4	U16D1-3	150	148	-2	1%
2470	U18D2-3	U18D2-2	376	371	-5	1%
817	T20D1-46	T20D1-45	151	149	-2	1%
2010	V20B1-1	V20D1-1	306	302	-4	1%
641	U16A1-1	U16C2-22	230	227	-3	1%
1159	U19C6-15	U19C6-10	235	238	3	1%
448	U16D1-11	U16D1-10	392	397	5	1%
934	V20A1-12	V20A1-8	236	233	-3	1%
412	U16C2-2	U16C2-1	242	245	3	1%
1397	V19B1-25	V19B1-24	162	164	2	1%
377	T17D2-17	T17D2-15	244	247	3	1%
830	T20D1-9	T20D1-8	164	166	2	1%
175	U18C3-13	U18C3-12	164	162	-2	1%
2437	V17C1-31	V17C1-29	165	167	2	1%

Table 3. GIS and Model Discrepancy by Length						
Pipe ID	Manhole Upstream ID	Manhole Downstream ID	GIS Length, ft	Model Length, ft	Length Difference, ft	Absolute Percentage Difference
311	U18C2-29	U18C2-27	249	246	-3	1%
1885	U16C2-21	U16C2-19	250	253	3	1%
2996	U18B4-16	U18B4-15	335	339	4	1%
3373	V19D1-30	V19D1-29	168	166	-2	1%
438	U17A2-32	U17A2-25	253	256	3	1%
2142	V19A3-12	V19A3-1	423	428	5	1%
293	U18B2-45	U18B2-30	85	84	-1	1%
938	V20A1-17	V20A1-16	170	168	-2	1%
1221	U19C4-15	U19C4-6	257	260	3	1%
2086	U19C3-10	U19C3-3	259	256	-3	1%
1990	V20A2-10	V20A2-2	346	350	4	1%
875	V20D2-10	V20D2-9	266	269	3	1%
2850	T20C1-34	T20C1-9	271	274	3	1%
1455	V19A2-5	V19A2-4	465	470	5	1%
1200	U19C3-1	U19C4-22	186	188	2	1%
3006	U18B4-25	U18B4-15	189	187	-2	1%
1563	U18C1-1	U18D1-5	286	289	3	1%
2608	U18D1-1	U18D2-3	286	283	-3	1%
2169	V19A1-14	V19A1-10	415	411	-4	1%
913	U20D1-15	U20D1-14	208	210	2	1%
1483	U19D1-9	U19D1-4	525	520	-5	1%
68	V18B1-19	V18B1-18	106	107	1	1%
1805	T20B2-1	U19C1-9	321	318	-3	1%
3369	V19D1-26	V19D1-25	216	218	2	1%
889	V21A2-12	V21A2-11	544	549	5	1%
3401	V19D2-23	V19D2-22	109	110	1	1%
681	V17C1-15	V17C1-1	330	327	-3	1%
1497	V19C1-5	U19D2-1	441	445	4	1%
1500	U19D3-7	U19B1-1	665	671	6	1%
1277	V19A4-18	V19A4-3	222	220	-2	1%
1225	U19C4-22	U19C4-21	222	220	-2	1%
775	T20D2-20	T20D2-19	222	220	-2	1%
2477	U18B1-23	U18B1-20	223	225	2	1%
1151	U19C5-4	U19C5-3	338	335	-3	1%
3427	W19C1-1	W20C1-23	113	114	1	1%
1502	V19C3-2	U19D1-1	454	450	-4	1%
2400	U17A2-12	U17A2-8	457	453	-4	1%
769	T20D2-10	T20D2-1	239	237	-2	1%
1963	U20C2-1	U20D1-37	364	361	-3	1%
1791	T20B1-1	T20B2-26	366	369	3	1%
2159	U19D2-18	U19B1-7	366	363	-3	1%
3357	V19D1-14	V19D1-13	369	372	3	1%
2295	V18B1-17	V18B1-16	123	124	1	1%
2178	V19B1-50	V19B1-49	123	122	-1	1%
1139	U19C5-14	U19C1-24	248	250	2	1%
3016	U18B4-35	U18B4-34	124	125	1	1%
4327	U20B1-1	U20B1-7	504	508	4	1%
376	T17D2-15	T17D2-13	252	254	2	1%
1458	U20B1-26	U20B1-1	887	880	-7	1%
885	V20D2-9	V20D2-8	635	640	5	1%
2218	U19D2-1	V19C1-13	261	259	-2	1%
758	T20B1-2	T20B1-1	397	400	3	1%
131	V18D1-30	V18D1-29	265	263	-2	1%
652	U16A1-7	U16A1-6	267	265	-2	1%
149	T17D1-21	T17D1-17	272	270	-2	1%
654	U16B1-1	U16A1-9	278	280	2	1%
446	U16D1-1	U16C3-2	139	140	1	1%
857	U20C2-12	U20C2-11	139	138	-1	1%
3018	U18B4-37	U18B4-36	141	140	-1	1%
1501	V19C3-11	V19C3-10	141	140	-1	1%
130	V18D1-28	V18D1-2	426	423	-3	1%
1379	V19A1-3	U19D2-19	286	288	2	1%
1669	U18A1-1	U18B1-28	144	145	1	1%
691	V17C1-29	V17C1-26	293	295	2	1%
2543	U18D1-2	U18D1-1	296	298	2	1%
1484	V19C1-1	V19A1-1	445	442	-3	1%
650	U16A1-4	U16A1-1	149	150	1	1%
3022	U18B3-4	U18B4-40	150	151	1	1%
276	U18B2-2	U18B2-1	152	151	-1	1%
2087	U19C3-16	U19C3-15	307	305	-2	1%
1934	V20D2-6	V20D2-5	154	153	-1	1%
372	T17D2-1	U17A1-27	310	312	2	1%
2022	U19A1-9	U19A1-8	156	155	-1	1%
2293	V18B1-24	V18B1-23	160	159	-1	1%
2474	V19A2-21	V19A2-20	162	163	1	1%
932	U20D1-9	U20D1-8	162	163	1	1%
922	U20D1-26	U20D1-25	163	164	1	1%
1053	U19A1-11	U19A1-10	165	166	1	1%
924	U20D1-28	U20D1-26	339	337	-2	1%
3324	W20C1-25	W20C1-24	340	342	2	1%
729	T20B2-10	T20B2-7	341	343	2	1%
1416	V19B1-48	V19B1-39	171	172	1	1%
3405	V19D2-27	V19D2-26	173	174	1	1%
1398	V19B1-26	V19B1-25	178	179	1	1%
975	V20A2-22	V20A2-19	178	177	-1	1%

Table 3. GIS and Model Discrepancy by Length						
Pipe ID	Manhole Upstream ID	Manhole Downstream ID	GIS Length, ft	Model Length, ft	Length Difference, ft	Absolute Percentage Difference
3392	V19D2-14	V19D2-13	181	180	-1	1%
973	V20A2-2	V20A2-1	553	550	-3	1%
3464	W19C3-16	W19C3-15	187	188	1	1%
2473	V19A2-23	V19A2-21	190	191	1	1%
2472	V19A2-6	V19A2-5	383	385	2	1%
1155	U19C5-9	U19C5-8	192	193	1	1%
2171	V19A1-9	V19A1-3	385	387	2	1%
818	T20D1-47	T20D1-46	195	196	1	1%
1263	U19B3-1	U19B3-6	586	589	3	1%
895	U20B1-11	U20B1-9	197	198	1	1%

Table 4. GIS and Model Discrepancy by Invert Elevation

Pipe ID	Manhole Upstream ID	GIS Upstream Invert Elevation, ft	Model Upstream Invert Elevation, ft	Upstream Invert Elevation Difference, ft	Manhole Downstream ID	GIS Downstream Invert Elevation, ft	Model Downstream Invert Elevation, ft	Downstream Invert Elevation Difference, ft	Status
891	V21A2-5	330	310.15	-19.85	V21A2-4	312.44	309.7	-2.74	Different Down and Upstream Invert Elevation
1941	V21A2-6	327.3	310.7	-16.6	V21A2-5	330	310.15	-19.85	Different Down and Upstream Invert Elevation
881	V20D2-2	325.5	314	-11.5	V20D2-1	313.44	313.4	-0.04	Different Down and Upstream Invert Elevation
882	V20D2-3	325.2	314.2	-11	V20D2-2	325.5	314	-11.5	Different Down and Upstream Invert Elevation
3725	X20A2-11	339.2	329.2	-10	X20A2-10	329	329	0	Different Upstream Invert Elevation
4684	Y19A3-10	596.23	586.23	-10	Y19A3-9	578.73	578.73	0	Different Upstream Invert Elevation
1942	V21A2-4	312.44	309.7	-2.74	V21A2-3	311.38	309.1	-2.28	Different Down and Upstream Invert Elevation
893	V21A2-8	314.4	311.9	-2.5	V21A2-7	311.6	311	-0.6	Different Down and Upstream Invert Elevation
890	V21A2-3	311.38	309.1	-2.28	V21A2-2	310.38	309	-1.38	Different Down and Upstream Invert Elevation
4366	X20C2-2	344.2	341.97	-2.23	X20C2-1	333.18	333.18	0	Different Upstream Invert Elevation
682	V17C1-16	395.7	393.7	-2	V17C1-15	392.86	392.86	0	Different Upstream Invert Elevation
969	V20A2-14	325.33	323.86	-1.47	V20A2-11	323.56	323.56	0	Different Upstream Invert Elevation
1458	U20B1-26	320.03	318.65	-1.38	U20B1-1	317.74	317.74	0	Different Upstream Invert Elevation
4688	Y19A3-14	614.11	613.1	-1.01	Y19A3-13	609	609	0	Different Upstream Invert Elevation
1936	U20B2-1	314.79	314.05	-0.74	V21A2-15	-	313.7	-	Different Upstream Invert Elevation
4324	V21A2-7	311.6	311	-0.6	V21A3-1	310.95	310.75	-0.2	Different Down and Upstream Invert Elevation
3443	W19C1-17	331.83	331.23	-0.6	W19C1-5	329.57	329.82	0.25	Different Down and Upstream Invert Elevation
8	U18D2-2	334.88	334.3	-0.58	U18D2-1	327.87	332.28	4.41	Different Down and Upstream Invert Elevation
1938	V21A2-11	313.6	313.05	-0.55	V21A2-10	312.92	312.2	-0.72	Different Down and Upstream Invert Elevation
3547	W19D3-37	365	364.5	-0.5	W19D3-36	363.4	363.4	0	Different Upstream Invert Elevation
2470	U18D2-3	335.99	335.5	-0.49	U18D2-2	334.88	334.3	-0.58	Different Down and Upstream Invert Elevation
2295	V18B1-17	375.64	375.3	-0.34	V18B1-16	375	374.13	-0.87	Different Down and Upstream Invert Elevation
876	V20D2-12	319.39	319.1	-0.29	V20D2-11	318.03	318.2	0.17	Different Down and Upstream Invert Elevation
3428	W19C1-2	326.51	326.26	-0.25	W19C1-1	325.99	325.99	0	Different Upstream Invert Elevation
2293	V18B1-24	377.41	377.19	-0.22	V18B1-23	376.95	376.7	-0.25	Different Down and Upstream Invert Elevation
2948	V21A3-1	310.95	310.75	-0.2	V21A2-6	327.3	310.7	-16.6	Different Down and Upstream Invert Elevation
67	V18B1-18	375.86	375.66	-0.2	V18B1-17	375.64	375.3	-0.34	Different Down and Upstream Invert Elevation
4187	V21A3-6	312.75	312.55	-0.2	V21A3-3	312.16	312.05	-0.11	Different Down and Upstream Invert Elevation
3026	V21A3-2	311.09	310.95	-0.14	V21A3-1	310.95	310.75	-0.2	Different Down and Upstream Invert Elevation
2945	V21A3-3	312.16	312.05	-0.11	V21A3-2	311.09	310.95	-0.14	Different Down and Upstream Invert Elevation
875	V20D2-10	317.66	317.55	-0.11	V20D2-9	317.25	317.2	-0.05	Different Down and Upstream Invert Elevation
2943	V21A3-5	313.3	313.2	-0.1	V21A3-4	313.18	313	-0.18	Different Down and Upstream Invert Elevation
3427	W19C1-1	325.99	325.89	-0.1	W20C1-23	-	325.78	-	Different Upstream Invert Elevation
933	V20A1-1	315.72	315.62	-0.1	U20B2-3	-	315.435	-	Different Upstream Invert Elevation
885	V20D2-9	317.25	317.2	-0.05	V20D2-8	315.93	316.25	0.32	Different Down and Upstream Invert Elevation
2942	V20D2-1	313.44	313.4	-0.04	V21A3-5	313.3	313.2	-0.1	Different Down and Upstream Invert Elevation
72	V18B1-25	377.61	377.6	-0.01	V18B1-24	377.41	377.19	-0.22	Different Down and Upstream Invert Elevation
68	V18B1-19	376.18	376.17	-0.01	V18B1-18	375.86	375.66	-0.2	Different Down and Upstream Invert Elevation
2608	U18D1-1	339.19	339.18	-0.01	U18D2-3	335.99	335.99	0	Different Upstream Invert Elevation
3815	X20A4-1	329.3	329.3	0	X20A2-11	339.2	329.2	-10	Different Downstream Invert Elevation
4685	Y19A3-11	586.66	586.66	0	Y19A3-10	596.23	586.23	-10	Different Downstream Invert Elevation
4337	X20B1-1	331.43	331.43	0	X20A4-8	335.5	331.1	-4.4	Different Downstream Invert Elevation
3905	X19C2-1	376.3	376.3	0	X19C3-2	378.4	374.4	-4	Different Downstream Invert Elevation
2443	V17C1-17	394.52	394.52	0	V17C1-16	395.7	393.7	-2	Different Downstream Invert Elevation
3444	W19C1-18	332.71	332.71	0	W19C1-17	331.83	331.33	-0.5	Different Downstream Invert Elevation
3816	X20A4-2	329.22	329.22	0	X20A4-1	329.3	329.2	-0.1	Different Downstream Invert Elevation
2251	V19A2-3	324.65	324.65	0	V19A2-2	324.16	324.24	0.08	Different Downstream Invert Elevation
1457	V19A2-8	337.2	337.2	0	V19A2-2	324.16	324.24	0.08	Different Downstream Invert Elevation
3465	W19C3-17	345.01	345.01	0	W19C3-16	343.85	343.95	0.1	Different Downstream Invert Elevation
3463	W19C3-15	343.01	343.01	0	W19C3-8	342.18	342.28	0.1	Different Downstream Invert Elevation
3433	W19C1-7	330.77	330.77	0	W19C1-6	329.98	330.08	0.1	Different Downstream Invert Elevation
3430	W19C1-4	328.46	328.46	0	W19C1-3	327.36	327.46	0.1	Different Downstream Invert Elevation
2394	V18A1-4	337.09	337.09	0	V18A1-3	336.68	336.78	0.1	Different Downstream Invert Elevation
336	V18A1-6	337.8	337.8	0	V18A1-3	336.68	336.78	0.1	Different Downstream Invert Elevation
3456	W19C3-8	342.18	342.18	0	W19C3-7	341.06	341.16	0.1	Different Downstream Invert Elevation
3450	W19C3-2	337.2	337.2	0	W19C3-1	335.77	335.87	0.1	Different Downstream Invert Elevation
3434	W19C1-8	331.68	331.68	0	W19C1-7	330.77	330.87	0.1	Different Downstream Invert Elevation
3431	W19C1-5	329.57	329.57	0	W19C1-4	328.46	328.56	0.1	Different Downstream Invert Elevation
3464	W19C3-16	343.85	343.85	0	W19C3-15	343.01	343.11	0.1	Different Downstream Invert Elevation
3455	W19C3-7	341.06	341.06	0	W19C3-6	339.95	340.05	0.1	Different Downstream Invert Elevation
3454	W19C3-6	339.95	339.95	0	W19C3-5	338.71	338.81	0.1	Different Downstream Invert Elevation
3445	W19C1-19	334.22	334.22	0	W19C1-18	332.71	332.81	0.1	Different Downstream Invert Elevation
3449	W19C3-1	335.77	335.77	0	W19C1-19	334.22	334.45	0.23	Different Downstream Invert Elevation
3453	W19C3-5	338.71	338.71	0	W19C3-3	337.7	337.95	0.25	Different Downstream Invert Elevation
1502	V19C3-2	320.12	320.12	0	U19D1-1	318.3	318.65	0.35	Different Downstream Invert Elevation
1479	U19D1-4	318.99	318.99	0	U19D1-1	318.3	318.65	0.35	Different Downstream Invert Elevation
3723	X20A2-9	328.8	328.8	0	X20A2-5	328.1	328.6	0.5	Different Downstream Invert Elevation
3822	X20A4-8	335.5	335.5	0	X20A4-7	330.58	331.1	0.52	Different Downstream Invert Elevation
986	U20B3-2	317.07	317.07	0	U20B3-1	315.99	316.72	0.73	Different Downstream Invert Elevation
964	U20D2-8	316.76	316.76	0	U20B3-1	315.99	316.72	0.73	Different Downstream Invert Elevation
2171	V19A1-9	324.96	324.96	0	V19A1-3	323.1	323.89	0.79	Different Downstream Invert Elevation
4690	Y19A3-16	628.68	628.68	0	Y19A3-15	613.1	614.1	1	Different Downstream Invert Elevation
2717	U18C2-8	349.13	349.13	0	U18C2-7	341.38	342.82	1.44	Different Downstream Invert Elevation
2509	U19C4-16	336.61	336.61	0	U19C4-15	333.15	335.13	1.98	Different Downstream Invert Elevation
1224	U19C4-21	336.25	336.25	0	U19C4-15	333.15	335.13	1.98	Different Downstream Invert Elevation
689	V17C1-24	401.39	401.39	0	V17C1-19	394.53	398.36	3.83	Different Downstream Invert Elevation
688	V17C1-23	400.77	400.77	0	V17C1-19	394.53	398.36	3.83	Different Downstream Invert Elevation
2100	U19C4-2	330.6	330.6	0	U19C4-1	324.5	329.5	5	Different Downstream Invert Elevation
3715	X20A2-1	328.3	328.37	0.07	W20B4-10	328.1	328.1	0	Different Upstream Invert Elevation
2253	V19A2-2	324.16	324.24	0.08	V19A2-1	324.24	324.16	-0.08	Different Down and Upstream Invert Elevation
2393	V18A1-3	336.68	336.78	0.1	V18A1-2	336.78	336.68	-0.1	Different Down and Upstream Invert Elevation
1934	V20D2-6	315.4	315.5	0.1	V20D2-5	314.8	315.2	0.4	Different Down and Upstream Invert Elevation
3451	W19C3-3	337.7	337.85	0.15	W19C3-2	337.2	337.3	0.1	Different Down and Upstream Invert Elevation
1935	V20D2-4	314.34	314.5	0.16	V20D2-3	325.2	314.2	-11	Different Down and Upstream Invert Elevation
884	V20D2-7	315.83	316	0.17	V20D2-6	315.4	315.5	0.1	Different Down and Upstream Invert Elevation
3435	W19C1-9	330.67	330.9	0.23	W19C1-6	329.98	330.67	0.69	Different Down and Upstream Invert Elevation
66	V18B1-16	375	375.26	0.26	V18B1-1	-	374.44	-	Different Upstream Invert Elevation
3409	V19D2-31	365.9	366.2	0.3	V19D2-30	-	365.5	-	Different Upstream Invert Elevation
1933	V20D2-8	315.93	316.25	0.32	V20D2-7	315.83	316	0.17	Different Down and Upstream Invert Elevation
4498	U19D1-1	318.3	318.65	0.35	U20B1-26	320.03	318.65	-1.38	Different Down and Upstream Invert Elevation
4507	V20B1-25	334.8	335.16	0.36	V20B3-9	0	334.7	-	Different Upstream Invert Elevation
2484	V20D2-5	314.8	315.2	0.4	V20D2-4	314.34	314.5	0.16	Different Down and Upstream Invert Elevation
3719	X20A2-5	328.1	328.6	0.5	X20A2-1	328.3	328.37	0.07	Different Down and Upstream Invert Elevation
650	U16A1-4	383.67	384.22	0.55	U16A1-1	384.22	383.67	-0.55	Different Down and Upstream Invert Elevation
983	U20B3-1	315.99	316.72	0.73	U20D2-1	316.01	316.01	0	Different Upstream Invert Elevation
1379	V19A1-3	323.1	323.89	0.79	U19D2-19	323.27	323.1	-0.17	Different Down and Upstream Invert Elevation
4689	Y19A3-15	613.1	614.1	1	Y19A3-14	614.11	613.1	-1.01	Different Down and Upstream Invert Elevation
4325	V20D1-24	319.56	320.56	1	V20D2-15	319.92	319.92	0	Different Upstream Invert Elevation
2098	U19C4-6	332.35	333.5	1.15	U19C4-4	332.39	332.33	-0.06	Different Down and Upstream Invert Elevation
2718	U18C2-7	341.38	342.82	1.44	U18C2-6	-8.5	342.06	350.56	Different Down and Upstream Invert Elevation
1221	U19C4-15	333.15	335	1.85	U19C4-6	332.35	333.67	1.32	Different Down and Upstream Invert Elevation
3437	W19C1-11	329.57	331.57	2	W19C1-10	-	330.13	-	Different Upstream Invert Elevation
4367	X20C2-3	341.97	344.2	2.23	X20C2-2	344.2	341.97	-2.23	Different Down and Upstream Invert Elevation
1200	U19C3-1	339.29	341.79	2.5	U19C4-22	338.19	338.19	0	Different Upstream Invert Elevation
424	U16C2-8	373.85	376.85	3	U16C2-7	375.29	375.29	0	Different Upstream Invert Elevation
4559	X20B2-15	357.5	361.01	3.51	X20B2-14	354.41	354.41	0	Different Upstream Invert Elevation
2442	V17C1-19	394.53	398.36	3.83	V17C1-18	395.25	395.25	0	Different Upstream Invert Elevation
1217	U19C4-1	324.5	329.5	5	U20B3-13	326.66	326.66	0	Different Upstream Invert Elevation
3559	W19D1-3	333.2	341.78	8.58	W19D1-2	339.78	339.78	0	Different Upstream Invert Elevation
3440	W19C1-14	301.68	332.9	31.22	W19C1-12	329.98	331.87	1.89	Different Down and Upstream Invert Elevation
2719	U18C2-6	-8.5	342.06	350.56	U18C2-2	341.38	341.38	0	Different Upstream Invert Elevation
1988	V20A2-15	-	324.12	-	V20A2-14	325.33	323.86	-1.47	Different Downstream Invert Elevation
62	V18B1-1	-	374.4	-	V19B1-51	374.92	374.03	-0.89	Different Downstream Invert Elevation
3548	W19D3-38	-	365.9	-	W19D3-37	365	364.5	-0.5	Different Downstream Invert Elevation
889	V21A2-12	-	313.4	-	V21A2-11	313.6	313.19	-0.41	Different Downstream Invert Elevation
2615	U20D1-37	-	351.17	-	U20D1-30	346.65	346.64	-0.01	Different Downstream Invert Elevation
3436	W19C1-10	-	331.13	-	W19C1-9	330.67	330.9	0.23	Different Downstream Invert Elevation
3473	W19C3-25	-	356.9	-	W19C3-24	348	351.4	3.4	Different Downstream Invert Elevation
3441	W19C1-15	-	352.9	-	W19C1-14	301.68	346.6	44.92	Different Downstream Invert Elevation

Table 6. Miscellanious GIS Updates/Comments for Gravity Mains

Pipe ID	Existing/Proposed Upstream Manhole ID	Existing/Proposed Downstream Manhole ID	Diameter, inch	Length, ft	Existing Upstream Invert Elevation	Existing Downstream Invert Elevation	Proposed Upstream Invert Elevation	Proposed Downstream Invert Elevation	West Yost Comment
4975	X18D1-41	X18D1-40	12	149	425.94	424.64	425.94	424.64	New Upstream manhole ID based on manhole database
1453	V19A2-43	V19A2-25	10	88	Unknown	Unknown	339.61	339.38	Upstream and Downstream manhole ID were exchanged.
4351	X20B1-15	X20B1-14	8	96	351.88	351.68	351.88	351.68	Upstream and Downstream manhole ID were exchanged.
4350	X20B1-14	X20B1-10	8	24	351.68	349.68	351.68	349.68	Upstream and Downstream manhole ID were exchanged.
2888	T20B3-16	T20B3-15	8	129	573.91	554.21	573.91	554.21	Upstream and Downstream manhole ID were exchanged.
1611	V19B1-37	V19B1-36	8	102	0.00	374.70	376.74	374.70	Upstream and Downstream manhole ID were exchanged.
965	U20D2-9	U20D2-8	8	219	323.00	316.76	323.00	316.76	Upstream and Downstream manhole ID were exchanged.
4525	V19D2-34	V19D2-33	12	350	370.80	367.17	370.80	367.17	Upstream and Downstream manhole ID were exchanged.
828	T20D1-60	T20D1-59	8	60	706.00	704.00	706.00	704.00	Upstream and Downstream manhole ID were exchanged.
733	T20B2-18	T20B2-14	8	40	406.69	402.55	406.69	402.55	Upstream and Downstream manhole ID were exchanged.
3077	V17C2-11	V17C2-10	8	147	477.59	476.88	477.59	476.88	Upstream and Downstream manhole ID were exchanged.
3204	V17A3-5	V17A3-4	8	159	406.69	406.02	406.69	406.02	Upstream and Downstream manhole ID were exchanged.
2663	V17C2-8	V17C2-7	8	122	468.99	468.40	468.99	468.40	Upstream and Downstream manhole ID were exchanged.
3235	V17A2-3	V17A2-2	8	329	415.89	414.69	415.89	414.69	Upstream and Downstream manhole ID were exchanged.
4585	X20B2-41	X20B2-39	8	176	345.84	349.62	349.62	345.84	Upstream and Downstream manhole ID were exchanged.
2896	T20B3-9	T20B3-7	8	209	493.75	492.19	493.75	492.19	Upstream and Downstream manhole ID were exchanged.
3492	T20B3-2	T20B3-1	8	136	425.48	416.86	425.48	416.86	Upstream and Downstream manhole ID were exchanged.
1387	V19B1-13	V19B1-12	8	175	358.00	355.93	358.00	355.93	Upstream and Downstream manhole ID were exchanged.
3936	X19C1-26	X19C1-25	8	150	381.78	377.13	381.78	377.13	Upstream and Downstream manhole ID were exchanged.
6603	X18B3-5	X18B3-4	10	267	Unknown	Unknown	460.48	459.60	New Downstream manhole ID based on manhole database.
4984	X18B1-2	X18B1-1	8	119	Unknown	427.40	439.39	427.40	New Downstream manhole ID based on manhole database
4996	X18B1-1	X18D1-43	8	30	427.40	426.64	427.40	426.64	New Upstream and Downstream manhole ID based on manhole database.
4982	X18D1-43	X18D1-41	8	52	426.64	425.94	426.64	425.94	New Upstream and Downstream manhole ID based on manhole database.
7194	WALLIS_01	X18D1-37	8	154	Unknown	Unknown	417.34	416.82	New Downstream manhole ID based on manhole database, but upstream manhole ID is unknown.
7195	WALLIS_02	X18A1-12	8	99	Unknown	Unknown	547.96	547.62	New Downstream manhole ID based on manhole database, but upstream manhole is not in GIS.
7264	WALLIS_03	X18A1-19	8	66	Unknown	Unknown	459.51	459.28	New Downstream manhole ID based on manhole database, but upstream manhole is not in GIS.
7266	WALLIS_04	X18A1-18	8	33	Unknown	Unknown	457.34	457.23	New Downstream manhole ID based on manhole database, but upstream manhole is not in GIS.
7273	WALLIS_05	X18A1-13	8	59	Unknown	Unknown	466.90	466.70	New Downstream manhole ID based on manhole database, but upstream manhole is not in GIS.
7192	WALLIS_06	WALLIS_01	8	14	Unknown	Unknown	417.39	417.34	Upstream and downstream manholes are not in GIS.
7193	WALLIS_07	WALLIS_01	8	35	Unknown	Unknown	417.46	417.34	Upstream and downstream manholes are not in GIS.
7205	WALLIS_08	X18A1-53	8	63	Unknown	Unknown	514.22	514.00	Upstream manhole is not in GIS.
7212	WALLIS_09	X18A1-33	8	36	Unknown	Unknown	489.13	489.01	Upstream manhole is not in GIS.
7214	WALLIS_10	X18A1-32	8	36	Unknown	Unknown	487.69	487.57	Upstream manhole is not in GIS.
7216	WALLIS_11	X18A1-31	8	63	Unknown	Unknown	487.03	486.82	Upstream manhole is not in GIS.
7218	WALLIS_12	X18A1-30	8	36	Unknown	Unknown	485.38	485.26	Upstream manhole is not in GIS.
7220	WALLIS_13	X18A1-29	8	36	Unknown	Unknown	484.66	484.54	Upstream manhole is not in GIS.
7223	WALLIS_14	X18A1-28	8	36	Unknown	Unknown	483.91	483.79	Upstream manhole is not in GIS.
7225	WALLIS_15	X18A1-27	8	36	Unknown	Unknown	483.00	482.88	Upstream manhole is not in GIS.
7227	WALLIS_16	X18A1-26	8	36	Unknown	Unknown	482.11	481.99	Upstream manhole is not in GIS.
7229	WALLIS_17	X18A1-51	8	28	Unknown	Unknown	502.28	502.18	Upstream manhole is not in GIS.
7232	WALLIS_18	X18A1-49	8	33	Unknown	Unknown	497.41	497.30	Upstream manhole is not in GIS.
7236	WALLIS_19	X18A1-47	8	33	Unknown	Unknown	495.33	495.22	Upstream manhole is not in GIS.
7238	WALLIS_20	X18A1-46	8	59	Unknown	Unknown	494.39	494.19	Upstream manhole is not in GIS.
7241	WALLIS_21	X18A1-45	8	33	Unknown	Unknown	492.60	492.49	Upstream manhole is not in GIS.
7243	WALLIS_22	X18A1-44	8	33	Unknown	Unknown	490.16	490.05	Upstream manhole is not in GIS.
7245	WALLIS_23	X18A1-56	8	33	Unknown	Unknown	488.69	488.58	Upstream manhole is not in GIS.
7251	WALLIS_24	X18A1-39	8	73	Unknown	Unknown	483.13	482.88	Upstream manhole is not in GIS.
7253	WALLIS_25	X18A1-38	8	54	Unknown	Unknown	480.21	480.02	Upstream manhole is not in GIS.
7259	WALLIS_26	X18A1-23	8	33	Unknown	Unknown	469.26	469.15	Upstream manhole is not in GIS.

Table 6. Miscellanious GIS Updates/Comments for Gravity Mains

Pipe ID	Existing/Proposed Upstream Manhole ID	Existing/Proposed Downstream Manhole ID	Diameter, inch	Length, ft	Existing Upstream Invert Elevation	Existing Downstream Invert Elevation	Proposed Upstream Invert Elevation	Proposed Downstream Invert Elevation	West Yost Comment
4975	X18D1-41	X18D1-40	12	149	425.94	424.64	425.94	424.64	New Upstream manhole ID based on manhole database
1453	V19A2-43	V19A2-25	10	88	Unknown	Unknown	339.61	339.38	Upstream and Downstream manhole ID were exchanged.
4351	X20B1-15	X20B1-14	8	96	351.88	351.68	351.88	351.68	Upstream and Downstream manhole ID were exchanged.
4350	X20B1-14	X20B1-10	8	24	351.68	349.68	351.68	349.68	Upstream and Downstream manhole ID were exchanged.
2888	T20B3-16	T20B3-15	8	129	573.91	554.21	573.91	554.21	Upstream and Downstream manhole ID were exchanged.
1611	V19B1-37	V19B1-36	8	102	0.00	374.70	376.74	374.70	Upstream and Downstream manhole ID were exchanged.
965	U20D2-9	U20D2-8	8	219	323.00	316.76	323.00	316.76	Upstream and Downstream manhole ID were exchanged.
4525	V19D2-34	V19D2-33	12	350	370.80	367.17	370.80	367.17	Upstream and Downstream manhole ID were exchanged.
828	T20D1-60	T20D1-59	8	60	706.00	704.00	706.00	704.00	Upstream and Downstream manhole ID were exchanged.
733	T20B2-18	T20B2-14	8	40	406.69	402.55	406.69	402.55	Upstream and Downstream manhole ID were exchanged.
3077	V17C2-11	V17C2-10	8	147	477.59	476.88	477.59	476.88	Upstream and Downstream manhole ID were exchanged.
3204	V17A3-5	V17A3-4	8	159	406.69	406.02	406.69	406.02	Upstream and Downstream manhole ID were exchanged.
2663	V17C2-8	V17C2-7	8	122	468.99	468.40	468.99	468.40	Upstream and Downstream manhole ID were exchanged.
3235	V17A2-3	V17A2-2	8	329	415.89	414.69	415.89	414.69	Upstream and Downstream manhole ID were exchanged.
4585	X20B2-41	X20B2-39	8	176	345.84	349.62	349.62	345.84	Upstream and Downstream manhole ID were exchanged.
2896	T20B3-9	T20B3-7	8	209	493.75	492.19	493.75	492.19	Upstream and Downstream manhole ID were exchanged.
3492	T20B3-2	T20B3-1	8	136	425.48	416.86	425.48	416.86	Upstream and Downstream manhole ID were exchanged.
1387	V19B1-13	V19B1-12	8	175	358.00	355.93	358.00	355.93	Upstream and Downstream manhole ID were exchanged.
3936	X19C1-26	X19C1-25	8	150	381.78	377.13	381.78	377.13	Upstream and Downstream manhole ID were exchanged.
6603	X18B3-5	X18B3-4	10	267	Unknown	Unknown	460.48	459.60	New Downstream manhole ID based on manhole database.
4984	X18B1-2	X18B1-1	8	119	Unknown	427.40	439.39	427.40	New Downstream manhole ID based on manhole database
4996	X18B1-1	X18D1-43	8	30	427.40	426.64	427.40	426.64	New Upstream and Downstream manhole ID based on manhole database.
4982	X18D1-43	X18D1-41	8	52	426.64	425.94	426.64	425.94	New Upstream and Downstream manhole ID based on manhole database.
7194	WALLIS_01	X18D1-37	8	154	Unknown	Unknown	417.34	416.82	New Downstream manhole ID based on manhole database, but upstream manhole ID is unknown.
7195	WALLIS_02	X18A1-12	8	99	Unknown	Unknown	547.96	547.62	New Downstream manhole ID based on manhole database, but upstream manhole is not in GIS.
7264	WALLIS_03	X18A1-19	8	66	Unknown	Unknown	459.51	459.28	New Downstream manhole ID based on manhole database, but upstream manhole is not in GIS.
7266	WALLIS_04	X18A1-18	8	33	Unknown	Unknown	457.34	457.23	New Downstream manhole ID based on manhole database, but upstream manhole is not in GIS.
7273	WALLIS_05	X18A1-13	8	59	Unknown	Unknown	466.90	466.70	New Downstream manhole ID based on manhole database, but upstream manhole is not in GIS.
7192	WALLIS_06	WALLIS_01	8	14	Unknown	Unknown	417.39	417.34	Upstream and downstream manholes are not in GIS.
7193	WALLIS_07	WALLIS_01	8	35	Unknown	Unknown	417.46	417.34	Upstream and downstream manholes are not in GIS.
7205	WALLIS_08	X18A1-53	8	63	Unknown	Unknown	514.22	514.00	Upstream manhole is not in GIS.
7212	WALLIS_09	X18A1-33	8	36	Unknown	Unknown	489.13	489.01	Upstream manhole is not in GIS.
7214	WALLIS_10	X18A1-32	8	36	Unknown	Unknown	487.69	487.57	Upstream manhole is not in GIS.
7216	WALLIS_11	X18A1-31	8	63	Unknown	Unknown	487.03	486.82	Upstream manhole is not in GIS.
7218	WALLIS_12	X18A1-30	8	36	Unknown	Unknown	485.38	485.26	Upstream manhole is not in GIS.
7220	WALLIS_13	X18A1-29	8	36	Unknown	Unknown	484.66	484.54	Upstream manhole is not in GIS.
7223	WALLIS_14	X18A1-28	8	36	Unknown	Unknown	483.91	483.79	Upstream manhole is not in GIS.
7225	WALLIS_15	X18A1-27	8	36	Unknown	Unknown	483.00	482.88	Upstream manhole is not in GIS.
7227	WALLIS_16	X18A1-26	8	36	Unknown	Unknown	482.11	481.99	Upstream manhole is not in GIS.
7229	WALLIS_17	X18A1-51	8	28	Unknown	Unknown	502.28	502.18	Upstream manhole is not in GIS.
7232	WALLIS_18	X18A1-49	8	33	Unknown	Unknown	497.41	497.30	Upstream manhole is not in GIS.
7236	WALLIS_19	X18A1-47	8	33	Unknown	Unknown	495.33	495.22	Upstream manhole is not in GIS.
7238	WALLIS_20	X18A1-46	8	59	Unknown	Unknown	494.39	494.19	Upstream manhole is not in GIS.
7241	WALLIS_21	X18A1-45	8	33	Unknown	Unknown	492.60	492.49	Upstream manhole is not in GIS.
7243	WALLIS_22	X18A1-44	8	33	Unknown	Unknown	490.16	490.05	Upstream manhole is not in GIS.
7245	WALLIS_23	X18A1-56	8	33	Unknown	Unknown	488.69	488.58	Upstream manhole is not in GIS.
7251	WALLIS_24	X18A1-39	8	73	Unknown	Unknown	483.13	482.88	Upstream manhole is not in GIS.
7253	WALLIS_25	X18A1-38	8	54	Unknown	Unknown	480.21	480.02	Upstream manhole is not in GIS.
7259	WALLIS_26	X18A1-23	8	33	Unknown	Unknown	469.26	469.15	Upstream manhole is not in GIS.

Table 7. Miscellanious GIS Updates/Comments for Manholes							
Structure ID	Manhole ID	Proposed Structure ID	Proposed Manhole ID	Manhole Depth, feet	Manhole Rim Elevation, feet	Proposed Manhole Rim Elevation, feet	West Yost Comment
Y19A2-23	5078	Y19A2-23	DUP_5078	6.35	406.60	406.60	Duplicated Manhole ID
-	-	WALLIS_01	WALLIS_01	11.20	519.80	519.80	Unknown Structure ID and Manhole ID, with GIS Object ID 9552
-	-	WALLIS_02	WALLIS_02	Unknown	Unknown	608.52	Manhole is not in GIS.
-	-	WALLIS_03	WALLIS_03	Unknown	Unknown	448.77	Manhole is not in GIS.
-	-	WALLIS_04	WALLIS_04	Unknown	Unknown	447.50	Manhole is not in GIS.
-	-	WALLIS_05	WALLIS_05	Unknown	Unknown	465.07	Manhole is not in GIS.
-	-	WALLIS_06	WALLIS_06	Unknown	Unknown	434.91	Manhole is not in GIS.
-	-	WALLIS_07	WALLIS_07	Unknown	Unknown	435.47	Manhole is not in GIS.
-	-	WALLIS_08	WALLIS_08	Unknown	Unknown	525.13	Manhole is not in GIS.
-	-	WALLIS_09	WALLIS_09	Unknown	Unknown	479.96	Manhole is not in GIS.
-	-	WALLIS_10	WALLIS_10	Unknown	Unknown	475.14	Manhole is not in GIS.
-	-	WALLIS_11	WALLIS_11	Unknown	Unknown	479.19	Manhole is not in GIS.
-	-	WALLIS_12	WALLIS_12	Unknown	Unknown	471.27	Manhole is not in GIS.
-	-	WALLIS_13	WALLIS_13	Unknown	Unknown	471.69	Manhole is not in GIS.
-	-	WALLIS_14	WALLIS_14	Unknown	Unknown	468.33	Manhole is not in GIS.
-	-	WALLIS_15	WALLIS_15	Unknown	Unknown	468.48	Manhole is not in GIS.
-	-	WALLIS_16	WALLIS_16	Unknown	Unknown	467.52	Manhole is not in GIS.
-	-	WALLIS_17	WALLIS_17	Unknown	Unknown	491.59	Manhole is not in GIS.
-	-	WALLIS_18	WALLIS_18	Unknown	Unknown	490.29	Manhole is not in GIS.
-	-	WALLIS_19	WALLIS_19	Unknown	Unknown	481.18	Manhole is not in GIS.
-	-	WALLIS_20	WALLIS_20	Unknown	Unknown	480.29	Manhole is not in GIS.
-	-	WALLIS_21	WALLIS_21	Unknown	Unknown	474.00	Manhole is not in GIS.
-	-	WALLIS_22	WALLIS_22	Unknown	Unknown	471.59	Manhole is not in GIS.
-	-	WALLIS_23	WALLIS_23	Unknown	Unknown	470.17	Manhole is not in GIS.
-	-	WALLIS_24	WALLIS_24	Unknown	Unknown	467.87	Manhole is not in GIS.
-	-	WALLIS_25	WALLIS_25	Unknown	Unknown	467.55	Manhole is not in GIS.
-	-	WALLIS_26	WALLIS_26	Unknown	Unknown	460.15	Manhole is not in GIS.
W20C1-37	3780	-	-	30.90	357.97	357.97	Suspicious manhole depth
W20C1-38	3781	-	-	30.90	359.42	359.42	Suspicious manhole depth
V19C2-24	1425	-	-	30.46	360.00	360.00	Suspicious manhole depth
U18D1-12	2259	-	-	36.00	372.80	372.80	Suspicious manhole depth
X19C2-41	4733	-	-	385.00	393.80	393.80	Suspicious manhole depth
X20B5-63	6360	-	-	389.37	397.20	397.20	Suspicious manhole depth
X19D2-11	4321	-	-	395.60	402.00	402.00	Suspicious manhole depth
U17B1-19	473	-	-	31.06	402.60	402.60	Suspicious manhole depth
X19A1-30	5108	-	-	392.07	402.90	402.90	Suspicious manhole depth
X19A1-33	5111	-	-	393.65	403.70	403.70	Suspicious manhole depth
V19B1-3	1333	-	-	107.88	464.43	464.43	Suspicious manhole depth
U19A2-35	1039	-	-	59.12	466.00	466.00	Suspicious manhole depth
T20D2-40	751	-	-	34.93	495.00	495.00	Suspicious manhole depth
V17A1-9	1521	-	-	57.66	503.18	503.18	Suspicious manhole depth
X18B2-12	5710	-	-	494.01	504.80	504.80	Suspicious manhole depth
U16B1-10	621	-	-	107.05	530.93	530.93	Suspicious manhole depth
X19B2-23	4419	-	-	36.10	560.10	560.10	Suspicious manhole depth
Y19B7-7	5966	-	-	619.60	631.30	631.30	Suspicious manhole depth
Y18C1-16	4992	-	-	625.08	633.30	633.30	Suspicious manhole depth
T17A2-5	4570	-	-	0.00	11.38	514.00	Suspicious manhole rim elevation
W19C2-9	3847	-	-	0.00	21.30	393.00	Suspicious manhole rim elevation

APPENDIX C

Private Sewer Lateral Technical Memorandum

WEST YOST ASSOCIATES
Consulting Engineers

TECHNICAL MEMORANDUM

DATE:	January 26, 2018	Project No.: 406-21-17-56 SENT VIA: EMAIL
TO:	Stan Kolodzie, PE	
FROM:	Anne Girtz, EIT #11625 Lani Good, PE, RCE #73677	
REVIEWED BY:	Jon Wells PE, RCE #67782	
SUBJECT:	Collection System Master Plan – Private Lateral Policy Evaluation	

1.0 INTRODUCTION

Dublin San Ramon Services District (District) is in the process of completing their Collection System Master Plan (CSMP). One of the CSMP elements the District has identified as a priority is development of a long-term management strategy which would facilitate sustainable operation of the collection system both now and into the future. An effective long-term management plan contains proactive utility management strategies that manage wastewater flows through means other than pipe and facility upsizing. One of the components identified as a critical part of the long-term management strategy is addressing the challenges associated with collection system private sewer laterals (PSLs).

This Technical Memorandum (TM) provides definition and background on PSLs including the challenges they present to utility agencies; an overview of the District's existing policies and practices as they relate to PSLs; and PSL policy and practice options including examples from other agencies. This TM concludes with a brief discussion of next steps in developing a District PSL Program.

The information within this TM is intended to provide a basis for discussion within the District, as private lateral policies can have significant legal, administrative, and financial implications. Outcomes from this TM and associated dialogue will be developed into PSL policy recommendations and integrated into the final CSMP report.

This TM is organized in the following sections:

- 1.0 Introduction
- 2.0 Background
- 3.0 Existing Policies and Practices
- 4.0 Policy Options and Discussion
- 5.0 Funding
- 6.0 Summary and Next Steps

2.0 BACKGROUND

2.1 PSL Definition

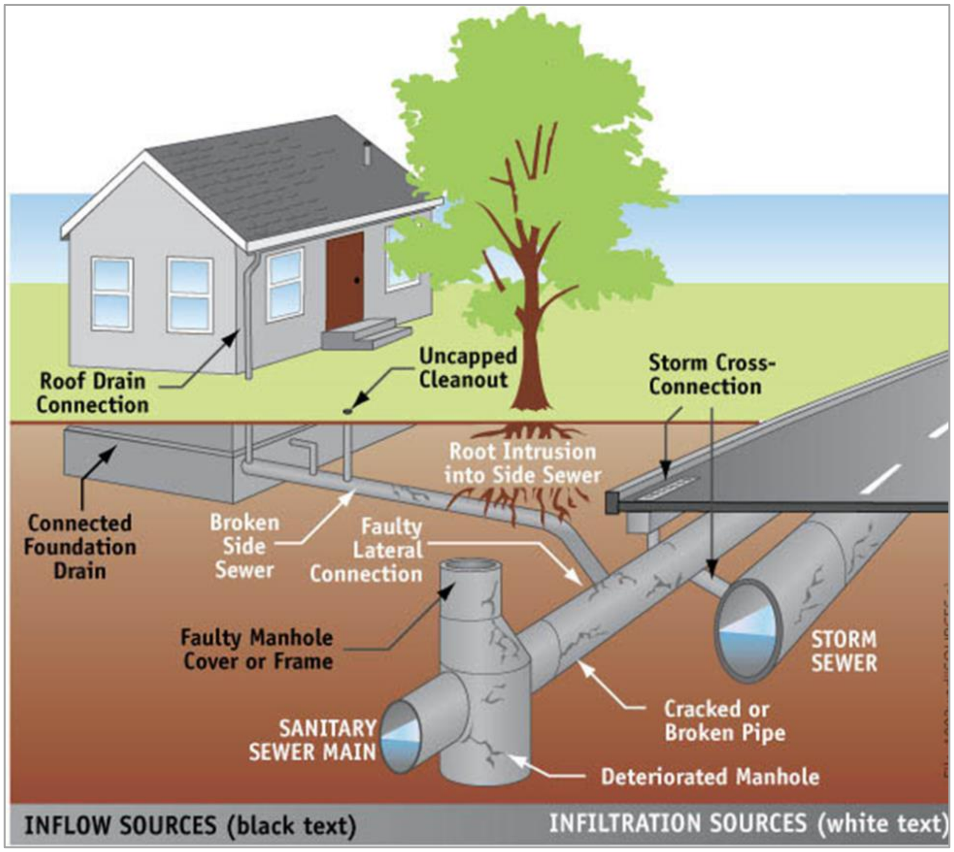
A sewer lateral is the small-diameter pipeline which connects and conveys wastewater flow from a building on private property to the publicly-owned collection system. Sewer laterals are a significant part of the collection system, typically composing approximately half of the total sewer system by length[1]. In the District, as with over 70 percent of California utilities[2], sewer laterals are privately-owned, meaning the responsibility for inspection, maintenance, and repair is that of the property owner. Under this scenario, private ownership of the lateral extends from the building envelope, up to and including the connection to the public main. In approximately 20 percent of public utilities, property owners are responsible for the portion of the lateral from the building to the cleanout, often located near the property line. The remaining 10 percent of public utilities own the entire lateral, from the public main up to the building envelope. In the more common private ownership scenarios, property owners are often unaware of their responsibility for the lateral, or unaware of the condition of their sewer lateral until a problem occurs.

2.2 PSL Challenges

In the San Francisco Bay Area, many collection systems have significant portions that are approaching the end of their expected service life and that are in need of repair or replacement. Defects in aging infrastructure increase the likelihood that sewage may leak or spill out of the collection system, as well increase the potential for both rain and groundwater to enter the collection system. This clean rain and groundwater, called inflow and infiltration (I&I) enters the collection system through direct connections, leaky joints, cracks, illegal connections, or broken pipes (see Figure 1). When a collection system receives excessive I&I, it can overwhelm the system during storms, burden operational and maintenance staff (particularly when responding to emergency calls), and reduce the life expectancy of the infrastructure. When pipes, pump stations, and treatment facilities are over-capacity and unable to handle flows, it can result in sewage bypasses at treatment facilities which releases partially/under-treated wastewater to the environment, and sanitary sewer overflows (SSOs) that release raw sewage on both public and private property. These events pose significant health and environmental concerns and can involve costly cleanup for both public agencies and homeowners.

[1] *https://www3.epa.gov/region1/sso/pdfs/PrivateSewerLaterals.pdf*
[2] *North Bay Watershed Association Marin Lateral Program Report. Larson Consulting. 2010.*

Figure 1. Sources of I&I



In principle, there are two options to address I&I: 1) increase the hydraulic capacity of the system through upsizing pipelines and facilities, or 2) eliminate I&I at the source through the disconnection of illegal connections or the rehabilitation of existing infrastructure. Increasing capacity is often unfeasible and always costly, both initially in capital infrastructure costs and long-term in operating and maintenance costs. For this reason, utility agencies are becoming more proactive in their operation and maintenance strategies, employing rehabilitation programs to address the aging or defective infrastructure responsible for I&I. The private sewer laterals, which make up such a large part of the collection system, are most often not included in these maintenance activities, leaving laterals in a state of unknown and possibly poor condition, and leaving the public wastewater agency with little authority to address the issue. It is estimated that PSLs contribute between 40-60 percent of all collection system I&I[1,3]. Unmaintained PSLs prevent comprehensive I&I efforts, and even if I&I is not an issue, defective PSLs can cause problems such as blockages in public mains/pump stations when roots, sediment, broken pipes, and soil flow downstream.

[3] *https://www3.epa.gov/npdes/pubs/ssodesc.pdf*

2.3 Local Policy Trends

In 2006, the California State Water Resources Control Board (State Water Board) established its SSO Reduction Program through its adoption of the Statewide General Waste Discharge Requirements. This program established the California Integrated Water Quality System (CIWQS) and associated reporting requirements for public utility agencies to track, report, and minimize the number of SSOs in their systems. In the following years, there was an increase in regulatory actions and third-party lawsuits focused on reducing SSOs, and many of the resulting legal orders included requirements for funding and/or mandating PSL improvements. As a result, many collection system agencies in the San Francisco Bay Area have established financial assistance programs and/or implemented PSL policies that allow public utilities to mandate private property improvements that affect the publicly-owned collection system.

While it is currently voluntary to report private SSOs in Region 2 (San Francisco Regional Water Quality Control Board), it is required in Region 9 (San Diego). It is also clear that the State Water Board is focused on increasing their involvement in PSL SSOs because of their continued data collection surveys about existing PSL policies and procedures. Growing interest from both the public and non-government organizations is moving state regulators to further define and reduce private spills via future regulatory solutions.

The goal of this TM is to better understand local trends and anticipated regulatory direction with respect to PSLs, and to help the District proactively identify PSL best management practices and policies, before there is an exterior driver to force policy action.

2.4 District Experience

The District completed comprehensive wet weather flow monitoring in 2017. The results of this flow monitoring, which are corroborated by the District collection system staff, indicate that the District is not currently experiencing any significant I&I issues within the collection system. There are areas within the collection system that experience higher I&I than other areas, whether groundwater or rainfall driven. However, even these areas are not experiencing significant capacity problems or SSOs. Public SSOs (those SSOs caused by a problem in a public portion of the collection system, regardless of where the SSO actually appears) have been eliminated since 2014 through proactive inspection and maintenance activities. Although regulations do not require the District to track private SSOs (those SSOs caused by a problem in a PSL), it appears that a small number of private SSOs are occurring annually.

The District has received reports from customers who have been subject to dishonest practices by local plumbing contractors hired for PSL inspection and repair work. The District takes such reports seriously, and always looks for ways to protect and support customers in such instances. However, this protection and support must be balanced with the costs and liabilities incurred to the District by any action in this regard.

The District recognizes the importance of PSLs in the effective long-term management of their collection system, and is experiencing an opportune moment to act proactively and deliberately in addressing PSLs. PSLs do not currently pose a critical problem regarding I&I and SSOs, but the risk will only increase as the collection system and the PSLs in the system age. Private SSOs are not a District responsibility currently, but there is the possibility that they will be required to be tracked by the District in the future. By developing policies before the PSL issue becomes critical, the District can manage the risk and cost of any action over time.

3.0 EXISTING POLICIES AND PRACTICES

3.1 Ownership and Responsibility

The District Code, *Section 1.20.0080 Definitions*, defines a *side sewer* (or PSL) as "the sewer lateral and the building sewer pipe, at the point of connection to the sewer main to the house or building piping". Further, s*ewer lateral* is defined as the sewer pipe in a public street or easement connecting a house or building sewer to the District's sewer main. *Building sewer* is defined as the sewer pipe on private property connecting a house or a building with the sewer lateral on public property at the property line. Both the sewer lateral and building sewer are owned, operated, and maintained by the owner of the property which it serves.

3.2 PSL Policies

The District has no policy to mandate condition, allow access or inspection, or to enforce follow up on PSLs with known deficiencies.

The District has specifications for new construction and replacement of PSLs, which can be found in the standard drawing database on the District website. Specifications include the standard detail for *Side Sewer Installation* (Standard Drawing S-8) and standard detail for *Lateral Sewer Connection to Existing Sewer Main* (Standard Drawing S-9) The standard side sewer consists of a saddle connection or wye fitting at the sewer main (depending on wet or dry tap), a long-radius bend, lateral/building pipeline, plug for air testing, cleanout, and overflow prevention device. The standard details were revised in 2011 and 2004, respectively.

3.3 PSL Programs

The District is currently working with a private insurance company, Home Emergency Insurance Solutions (HEIS) to provide optional insurance coverage to District customers for exterior water and sewer pipelines. The program also aims to educate customers about their responsibility for maintaining and repairing their PSL. Program information is mailed via post to customers.

The District Engineering Department also provides a free program to sewer customers in which a District inspector will visit a private property to assess the need for a sewer overflow prevention device. If a device is already installed, the inspector will demonstrate how to make sure it is operating properly. Although a sewer overflow prevention device is now required by District construction standards, many older properties do not have a device installed.

Information on these programs is found on the District website. The website also contains information on maintaining PSLs, including tips to avoid potential sewage overflows.

3.4 PSL Operation and Maintenance Practices

Property owners are responsible for their own lateral testing, inspection, maintenance, repair, and replacement. In the event that the District improves the connecting sewer main, the District will reinstate lateral connections. However, the District does not inspect, rehabilitate, or replace PSLs as part of sewer main improvement projects.

Condition assessment of District mainline sewers are conducted using CCTV inspection approximately every eight (8) years. These CCTV inspections provide some information at the lateral connection to the main, but conditions of the lateral pipelines are not observed. The District has used the extensive CCTV data gathered by its inspection program to develop a preliminary inventory of PSL locations throughout the collection system.

3.4.1 Sanitary Sewer Overflows

Since private property owners are responsible for maintenance of the entire sanitary sewer lateral, the District is not required to report private SSOs to CIWQS. SSOs due to problems in the PSL are the responsibility of the property owner.

In the past, the District has undertaken work to identify properties within the service area that are at risk of overflow and would benefit from a cleanout and overflow device. With the assistance of GIS mapping, building slab and upstream manhole elevations can be compared to identify properties which are in danger of overflows due to elevation.

4.0 POLICY OPTIONS AND DISCUSSION

There are a range of PSL policy options available to wastewater utilities. The specification of chosen policy options will determine their potential effectiveness in managing PSL issues, and also the degree of responsibility placed on both property owner and District.

This section presents a range of specific options for ownership, policies, and practices related to PSLs. A survey of eleven (11) San Francisco Bay Area agencies is also included at the end of this section to better understand the PSL policy status in the region and support discussion within the District.

4.1 Ownership Approach

Lateral ownership explicitly defines the responsibility of inspection, maintenance and repair. When laterals are privately owned, the agency assumes no risk or cost, but assumes no control over management of the lateral and thus has no control over I&I. When the lateral is publicly owned, the agency can inspect and repair laterals as it would for the sewer main, exercising full control over I&I. In a hybrid approach, the lower (sewer) lateral is owned by the agency and the upper (building) lateral is the responsibility of the property owner. Table 1 outlines the various lateral ownership options.

Table 1. Lateral Ownership Options

Ownership Option	Comments
Property owner owns entire lateral (up to connection to public main)	• Current approach of District and over 70% of California utilities[2] • No control over lateral condition without supporting PSL policies • No cost or liability
Agency owns lower lateral; property owner owns upper lateral	• Approach of ~20% of California utilities • Control of lower lateral and connection to main can improve I&I; I&I may just migrate to upper lateral • Comprehensive I&I reduction possible with aggressive supporting PSL policies • SSOs originating in lower lateral are responsibility of agency • Costs for additional staffing and equipment
Agency owns entire lateral	• Approach of ~10% of California utilities • Full control over lateral condition • Access and ownership issues would need to be coordinated with Cities of San Ramon and Dublin • Highest cost and liability

Although alternate ownership options are available, changes to the District's current lateral ownership approach would require policy modifications, considerable political effort, and result in additional cost and liability. PSL policies have proven effective both locally and nationally and it is not necessary for a utility agency to establish ownership of laterals to effectively manage the challenges they present.

4.2 Policy Approach

In an ownership scenario where the property owner is responsible for all or part of the lateral, the District will require policy ordinances to mandate control over condition, inspection, and repair of PSLs. A PSL policy approach will include the following steps: 1) implement condition ordinance; 2) establish inspection triggers; and 3) enforce inspection and remediation.

4.2.1 PSL Condition

Implementing a PSL condition ordinance is the first step in establishing a robust PSL policy. This gives the District authority to enforce remediation of any of the prohibited conditions. An ordinance would be added to the District Code prohibiting any combination of the following: Inflow and/or infiltration, obstructions, voids/cracks, overflows/malfunctions, lack of maintenance, or public health threats (at the District's discretion).

Once a PSL condition ordinance has been established, the District can then develop specific inspection and enforcement mechanisms as they are required. If PSL condition is not a current issue or priority for the District, these next steps could be delayed until a time in the future when greater control over PSL condition becomes necessary.

4.2.2 PSL Inspection

The next step in a developing a full PSL program is mandating inspection of the lateral. Here, a defined event, termed "trigger", initiates an inspection. Triggers can range from passive, long-term methods (sale of property), to proactive, shorter-term methods (rehabilitation of public mains). Triggers can be implemented for mandatory inspection by the property owner or for the agency's right to inspect. Various triggers are detailed in Table 2.

Table 2. PSL Inspection Triggers

Inspection Trigger	Comments
Sale of property, transfer of title	• Offers additional protection for homebuyers • District must coordinate with Cities for information
Major remodel or addition of plumbing fixtures	• Cost threshold or percentage of building can be set • District must coordinate with Cities for information
Repair or change of water meter	• Can indicate similar condition in lateral
Change in land use	• Can indicate higher flows
Lateral age	• Based on age or most recent inspection
PSL SSO	• Private property SSO tracking required
Flow monitoring	• Can identify areas of high I&I
Protect public health	• At agency discretion • Most broad and empowering
Agency improvement of public main	
Agency investigation of SSO, blockage, or sewer malfunction	
Agency inspection of public mains	

The method of inspection can be mandated based on the type of trigger or in an escalated structure (e.g. if the PSL cannot pass the pressure test, a CCTV inspection is required to determine the problem cause). The most common types of inspection methods are CCTV and air/water pressure tests. If an inspection identifies a PSL in violation of the condition ordinance, remedial action is required.

4.2.3 Enforcement

Once an inspection has been triggered, PSL programs function by requiring certification of compliance within a set time frame. Certification usually comes in the form of a Certificate issued by the agency after verification of a passing test. Time frames allowed to undertake inspection, repairs, or submittal of Certificate can be mandated by time frame ordinances. If time frames are violated, the District could establish enforcement methods to have recourse on those out of compliance – this could include fines, liens, or other penalties. Often, eligibility for funding assistance (discussed in more detail below) is made contingent upon meeting these time frames.

4.2.4 Public Protection

PSL programs present an opportunity to establish policies which offer certain levels of protection to customers. Solutions could range from pre-qualifying sewer contractors for any PSL related work to providing District resources for inspection or testing of PSLs. Each solution will incur different costs and liabilities to the District. These impacts should be defined and weighed during consideration of any policy adoption. Any decision the District makes with respect to the extent of customer protection and possible District involvement should be formally included in the program as a PSL policy.

5.0 FUNDING

PSL programs have costs associated with them, both internally for administering and enforcing a program, and externally for undertaking inspections, testing, and repairs. Depending on the selected PSL policy range, there may be new and unexpected costs placed on property owners. Many agencies passing PSL policies choose to institute a public financial assistance program. This not only provides some relief of the financial burden placed on property owners, it can also help build initial political support and improve program compliance once implemented. Forms of public financial assistance could include:

- Free inspections or wavier of inspection fee when repairs are performed
- Rebate for repair costs
- Low or zero-interest loans
- Assistance to low-income or senior customers
- Performing inspection or repairs in conjunction with agency sewer work

To fund public assistance programs and internal costs, agencies can utilize funding mechanisms such as:

- Taxes and fees: increase of property taxes or addition of a special fee
- Insurance coverage: mandatory enrollment in insurance coverage which is paid along with sewer service change; agency manages the insurance pool

It may also be possible for agencies to procure funding from external sources, although this mechanism has not yet been established in California[4]. Grant and loan programs from the Clean Water State Revolving Fund (CWSRF), U.S. Department of Agriculture Office of Rural Development, or the California EPA's Clean Beaches Initiative can be explored as potential funding sources. Other local, state, or federal grant funding may become available over time.

5.1 Survey of Local Agencies

West Yost conducted a survey of eleven utility agencies who operate wastewater collection systems in or near the San Francisco Bay Area. The survey collected data regarding each agency's PSL definition, inspection and maintenance responsibilities, availability of public financial assistance, and typical practices for replacing laterals during sewer main improvement projects. This information is intended to give a better understanding of the current PSL policy status in the region and support discussion within the District.

The full survey results can be found in Table 3 at the end of this document. Most agencies defined PSLs as the lateral that extends from the building to the sewer main. Over half the agencies surveyed had an ordinance to mandate good PSL condition – including prohibiting I&I, and three of these six agencies defined conditions that provided rights for the agency to inspect a PSL.

The same six agencies that had an ordinance to mandate PSL condition also defined triggers mandating PSL inspections by the property owner. The property owners are required to pay for inspections such as smoke testing, pressure testing, and/or CCTV inspection, which could be triggered by events such as: sale of property/title transfer; building remodel; water meter change/installation; sewer main construction; and lateral SSO/blockage/leak.

Some agencies also defined time frames in which inspections must be completed, depending on the type of trigger. In these instances, certain triggers may require an inspection be completed immediately if there is potential for negative environmental impacts. These agencies can adjust the time frames based on unique needs and potential permitting requirements.

Most agencies also have some form of financial assistance available for these programs with grants ranging from $1,000 to $5,000 and with different financial structures splitting costs between the property owner and the local agency. Additional details on each agency are provided including the available public outreach webpages that these agencies maintain. Table 3 is organized generally in order from the least to most stringent PSL policies.

6.0 SUMMARY AND NEXT STEPS

The District has developed a proactive approach to the operation and maintenance of its collection system. In continuing this approach, it is important to develop a long-term management strategy for PSLs. As discussed, PSLs do not currently pose a critical problem for the District, however, proactively establishing a PSL policy will allow the District the flexibility to address PSL issues as necessary in the future.

The District's interests in developing a PSL policy include:

- Continued proactive management of the collection system;
- Flexibility in policy (the ability to modify based on later needs);
- Balancing District liability and costs with value provided; and
- Protecting vulnerable customers.

[4] *http://www.sfestuary.org/wp-content/uploads/2017/08/Private-Sewer-Lateral-Ordinance-Report-8-1-17-1.pdf*

6.1 Next Steps

This section outlines the next steps and other considerations in development a PSL Program.

Step 1: Consider Policy Stance

A strong policy stance would be the foundation for the PSL Program. The District could adopt a policy stance that specifies rehabilitation of the collection system is a public good, and that public money can be spent on this public good. The following statement is a possible template: *The District has determined that it is in the public interest to reduce SSOs and ensure reliable wastewater service. Private sewer laterals are a significant component of the collection system and improvement of PSLs has become a priority for the District.*

Step 2: Consider and Confirm Ownership Arrangement

Step 3: Consider Feasibility of PSL Program

Evaluate internal funding: District resources will be required for any PSL program, in addition to funding needs if the District chooses to offer financial assistance to customers.

Build Cooperation with Cities of San Ramon and Dublin: Many of the trigger criteria and enforcement mechanisms are tracked by agencies other than the District. Buy-in and cooperation from the Cities of San Ramon and Dublin at an early stage would be required to implement a PSL program.

Step 4: Evaluate and Develop Condition Ordinance

Once a PSL condition ordinance is established, there may be no need for the District to take further steps in a PSL program. At the time when the District determines PSL condition needs to be addressed and adequate resources are available, a full program including inspection and enforcement mechanisms can be developed. Alternatively, the District could start with a full program under a more passive strategy, such as establishing inspection triggers for longer-term events like sale of property or transfer of title. This would require greater short-term administrative effort from the District, but would establish a method and expectation from property owners that could be built upon in the future.

Table 3. Results of San Francisco Bay Area PSL Policy Survey

PSL Program Approach	Dublin San Ramon Services District	Central Contra Costa Sanitation District	Delta Diablo Sanitation District	City of Richmond	City of San Mateo	Castro Valley Sanitary District	EBMUD	South San Francisco	City of Millbrae	City of Sausalito	Ross Valley Sanitary District	City of San Carlos
Definition of a PSL:	Building to Main	Building to Main	Building to Main	Building to Main	Building to Main	Building to Main	Building to Main	Building to standard wye or other connection to the public sewer if existed unless to public main	Building to standard wye or other connection to the public sewer if existed unless to public main	Building to Main	Building to Main	Building to Main
Ordinance to mandate PSL condition:	None	None	None	None	None	None	Ord. No. 362-14 Upper Lateral: Obstructions prohibited, Voids/cracks prohibited	Ordinance No. 14533-2012 Obstructions prohibited Voids/cracks prohibited Up to Agency's discretion	Ordinance No. 738, and Municipal code Ch 8.20. I/I prohibited Obstructions prohibited Voids/cracks prohibited Agency's discretion	Ordinance 1072, 18.12.100: http://www.codepublishing.com/CA/Sausalito/?Sausalito18/Sausalito1812.html I/I prohibited	Ordinance 66 http://www.rvsd.org/documentcenter/view/168 Agency's discretion	Inspection should verify: Section 13.05.050-090, I/I prohibited Obstructions prohibited Voids/cracks prohibited
Agency right-to-inspect PSL:	None	None	None	None	None	None	None	None	None	Agency repair or replacement of public main.	Agency repair or replacement of public main. When evaluating an SSO.	Agency repair or replacement of public main. When evaluating an SSO or blockage Agency discretion to smoke test.
Mandatory triggers for property-owner-paid inspection:	None	None	None	None	None	None	Sale of property Significant remodel Change water meter Shared lateral	Sale of property Significant remodel (more than 25% of the building remodeled, altered, or enlarged) Blockage, Agency discretion, Leaks, breaks and improper sanitary sewer connection	**Smoke Testing:** Leaks, breaks and improper sanitary sewer connection **CCTV Inspection:** Plumbing fixture, Significant remodel (more than 25% of the building remodeled, altered, or enlarged), Sale of property	**CCTV Inspection or Pressure Test**: Sale of property or remodel	**CCTV Inspection**: SSO/blockage, Agency discretion, Transfer of title. **Pressure Test**: Sale of property, $75K remodel, or addition of bathroom	**CCTV Inspection:** SSO/blockage, Agency discretion, Remodel **Smoke Test or dye testing:** Rehab of public main
Time frame allowed for inspection:	None	None	None	None	None	90-days from the District approval	**Certificate of Compliance per title transfer:** prior title transfer extendable to 180-days by a $4,500 refundable deposit **Shared Lateral:** 10-years after ordinance	**Roots, leaks, breaks, and improper connections:** 30-days after the issuance of a notice. **To be eligible for grant:** 60-days from approval **Existing conditions or remodel:** 120-days after receive notification **SSO:** 120-days unless financial hardship or extensive remodel **Transfer of title:** extendable to 180-days	**Leaks, breaks, and improper connections:** 30-days after the issuance of a notice **Existing conditions:** 90-days after receive notification **Root Removal**: 120-days after the issuance of a notice **SSO:** 180-days unless financial hardship or extensive remodel	None	90-days from date of approval	90-days after the issuance of a notice to repair **Root Removal:** 120-days after the issuance of a notice

Table 3. Results of San Francisco Bay Area PSL Policy Survey

PSL Program Approach	Dublin San Ramon Services District	Central Contra Costa Sanitation District	Delta Diablo Sanitation District	City of Richmond	City of San Mateo	Castro Valley Sanitary District	EBMUD	South San Francisco	City of Millbrae	City of Sausalito	Ross Valley Sanitary District	City of San Carlos
Required inspection/testing method:	None	None	None	CCTV unless you are planning to replace your ENTIRE lateral.	None	CCTV	Inspection: CCTV Verification: Water or air test	CCTV	Smoke test, CCTV	CCTV or pressure test upon initial inspection. CCTV for approval upon completion of any remedial work.	CCTV and/or Pressure Test (see notes under triggers above)	Smoke Test or dye testing and/or CCTV (see notes under triggers above)
Type and amount of public financial assistance:	None	None	None	Grant: 50% of the lowest competitive bid for the required work, or 50% of actual costs incurred for the required work (whichever is less), up to a maximum award of $3,000.	Grant: 50% (up to a maximum of $5,000) of the cost of a full sewer lateral replacement.	Grant: 50% of the approved cost up to a maximum reimbursement of $2,000.	None	Grant: 50% (up to a maximum of $2,500) of the cost of a complete replacement of the building lateral or repair in excess of $2,500 that completely eliminate I/I sewer lateral replacement	Sewer laterals at risk of overflowing and broken sewer laterals, may qualify for a rebate from the City in the amount of 20% or up to $1,000.	Refund 100% of the cost of a video inspection, dye testing efforts and sewer ejection system testing performed by qualified video inspectors/plumbers upon successful completion of the repair or replacement. Grant: 50% of the repair or replacement cost of a private sewer lateral up to a maximum of $1,000.	Grant: 50% of the lowest qualified bid up to $2,000 Loan: up to $10,000 over a period not to exceed 10 years at an annual interest rate of 3.60%	None
Agency's typical practice for replacing lower laterals during agency CIP project:	None	None	None	None	Only for full lateral replacement, cleanout, if necessary, permits, and wye connection, if necessary.	Only a replacement of more than 50% of the building lateral, that completely eliminates infiltration and inflow, is eligible for the program.	None	None	Replace deficient laterals only	None	None	Replace deficient laterals only
PSL outreach program webpage:	http://www.dsrsd.com/outreach/who-s-responsible-for-pipeline-repairs/taking-care-of-your-sewer-lateral	http://www.centralsan.org/index.cfm?navId=350	None	http://www.ci.richmond.ca.us/1500/Sewer-Lateral	None	None	http://www.eastbaypsl.com/eastbaypsl/	None	http://www.ci.millbrae.ca.us/departments-services/public-works/testing-sanitary-sewer-lateral-upon-transfer-of-ownership	http://www.sausalito.gov/home/showdocument?id=7383	http://www.rvsd.org/175/Laterals-Permits	http://cityofsancarlos.org/civicax/filebank/blobdload.aspx?blobid=12652

APPENDIX D

Cost Estimating Assumptions

APPENDIX D
Cost Estimating Assumptions

1.1 OVERVIEW

This appendix provides the assumptions used by West Yost to develop an opinion of the probable construction cost for the planning and design of recommended sewer system facilities for the District's wastewater collection system. The opinion of probable construction cost was developed based on a combination of data supplied by manufacturers, published industry standard cost data and curves, construction costs for similar facilities built by other public agencies, and construction costs previously estimated by West Yost for similar facilities with similar construction cost indexes.

Additionally, the costs presented in this appendix are for construction only and do not include uncertainties in estimation or unexpected construction costs (e.g., variations in final quantities) or cost estimates for land acquisition, engineering, legal costs, environmental review, soils investigation, surveying, construction management, and inspections and/or contract administration. Some of these additional cost items are referred to as contingency costs or mark-ups, and are further described in the last section of this appendix.

The opinion of probable construction cost has been adjusted to reflect May 2018 costs at an Engineering News Record (ENR) Construction Cost Index (CCI) of 12,015 (San Francisco Bay Area). These construction costs are to be used for conceptual cost estimates only, and should be updated regularly. Construction costs presented in this appendix are not intended to represent the lowest prices in the industry for each type of construction; rather they are representative of average or typical construction costs. These planning-level construction costs have been prepared for guidance in evaluating various facility improvement options, and are intended for budgetary purposes only, within the context of this master planning effort.

The following sections of this appendix describe the assumptions used to develop the opinion of probable construction cost for the planning and design of recommended sewer system facilities for the District's collection system. The cost estimates prepared for this collection system master plan are in accordance with the guidelines of the Association for the Advancement of Cost Engineering (AACE) International for a Class 5 Estimate, suitable for long-range capital planning, with an accuracy range of -50 percent to +100 percent.

1.2 PIPELINE REHABILITATION, REPAIR, AND REPLACEMENT METHODS AND BASE COSTS

The following base costs include sales tax, overhead and profit, and general conditions. They do not include estimating contingency, which is discussed separately in Section 1.3 below.

1.2.1 Rehabilitation, Repair and Replacement Methods

The following rehabilitation, repair, and replacement methods are potential options for the District's gravity main and force main projects: open cut construction, pipe bursting, pipe reaming, and tunneling. For projects that require the installation of a new relief sewer to address wet weather flows, in-situ methods for the existing pipe, such as the use of cured-in-place pipe, may be considered in conjunction with construction of the new relief sewer pipeline. Specific to the District's projects, factors that determine the most cost-effective rehabilitation method include geological and physical setting, existing pipeline material and condition, and available construction access.

1.2.1.1 Open Cut Construction

Description: Open cut or open trench construction, also known as cut and cover, has historically been the most widely used approach for sewer pipe replacements. A trench is excavated that is approximately 18 inches to 2 feet wider than the replacement pipe, and 6 to 12 inches deeper than the bottom of pipe. A new pipe is installed, backfill material placed and compacted, and pavement and surface facilities restored. Often, the new pipe is installed in a different location than the original pipe, and the original pipe abandoned in place. In this case, sewer flow continues through the original pipe, and a planned shutdown is scheduled during the “tie-in,” when the new pipe is connected to the existing pipe. Alternatively, the existing pipe is removed to allow replacement of the new pipe in the same location. The existing flow is bypassed through a temporary pumped system during construction operations.

Advantages and Limitations: Historically, open cut construction has been more cost effective than trenchless technologies, and consequently, more widely used for pipe replacement. Open cut construction is appropriate in most soil conditions, and could be beneficial in locations where significant utility crossings are present, depending on the depths of existing utilities. An open trench can be adjusted in the field to avoid existing underground obstructions, or to otherwise relocate the new pipe. This method enables installation of a larger diameter pipeline where capacity issues are present, or improved materials when available or needed.

One limitation to open cut construction is in shoring and dewatering. Shoring of the trench walls is required for personnel safety and an engineered shoring system is required when a trench is greater than 5 feet in depth, in accordance with California Labor Code Section 6705. Excavation below the groundwater table, or in soils that permit infiltration of groundwater into the open trench, necessitate aggressive dewatering methods. The added cost of these requirements can decrease the economic viability of open cut construction in specific situations. For pipeline installations in new alignments, a geotechnical investigation is recommended during the design phase to determine shoring requirements and whether groundwater is anticipated during construction.

Open cut construction is also difficult where construction access is limited, or on steep hillsides. Open cut construction also impacts surface features and traffic, may introduce safety concerns in highly used or highly traveled locations, and creates temporary noise and dust impacts. Historically, Caltrans has required trenchless construction methods to be used for the installation of new pipelines within their rights of way.

1.2.1.2 Pipe Bursting

Description: Pipe bursting is a trenchless construction method by which existing pipe is replaced with the same size or typically one size larger pipe in the same location. Pipe bursting is most effective in replacing pipes that are less than 24 inches in diameter and are at least 4 feet deep. This method is the most cost effective when there are few lateral connections, when the old pipe is structurally deteriorated or is easily fractured (e.g., vitrified clay pipe), and when additional capacity is needed and trenchless methods are desired or required.

A conical pipe bursting head is conveyed through the pipe, exerting outward forces that fracture the existing pipe and displace fragments outward into the soil. The head is driven by pneumatic pressure, hydraulic expansion, or static pull; the head is connected to and pulls in the new pipe. The pipe bursting head is inserted and also retrieved through new access pits that are located at approximately 400- to 500-foot intervals.

The optimal pull length is dependent upon the size of the host pipe, the degree of upsize required, and the type of soil in the surrounding subsurface. Additional pits, typically 2 feet wide by 2 feet long, are required at each service lateral connection and at crossing utilities. Pipes suitable for pipe bursting are those made of brittle materials, such as vitrified clay. Special bursting heads with cutting elements are required for more ductile pipe materials such as steel, polyvinyl chloride (PVC) and ductile iron. Typically, the replacement pipe material will be high-density polyethylene (HDPE) or fused PVC. Construction using PVC requires longer pit lengths than with HDPE because PVC requires a longer bending radius.

Advantages and Limitations: Pipe bursting is quickly gaining popularity as a replacement methodology for small diameter sewers. If HDPE pipe is used, a relatively small pit (as compared to open trench) is required for entry of the pipe bursting head, which can be extracted through an existing manhole. Pipe bursting replaces the existing pipe by up to two diameter sizes without significant open trenching, and therefore reduces surface impacts. The unit cost of pipe bursting is decreasing, and often comparable to open cut methods.

Existing conditions must be considered carefully when specifying pipe bursting. Flowing soils such as sand, highly incompressible soils such as rock, installations below the groundwater table, sensitive utilities located within two to three pipe diameters of the pipe to be burst, historical point repairs that are not conducive to bursting such as steel couplings, or significant sags or pipe collapses will limit the success of pipe bursting operations. Pipe bursting may also create ground vibrations and outward ground displacements adjacent to the pipe alignment; these displacements are exacerbated in shallow installations or when the pipe is significantly upsized. When the existing pipe is shallow, this ground displacement may be controlled by saw cutting pavement over the pipe in advance of the bursting operation. This approach localizes surface heave and provides for more simplified trench patch repair.

Pipe bursting is performed between pits spaced 400 to 500 feet apart. A manhole can be used in lieu of the receiving pit. During the pipe bursting process, the rehabilitated pipe segment must be taken out of service by rerouting or bypassing sewer flows. Laterals are reconnected through external pits after the pipe bursting activities are completed.

1.2.1.3 Cured in Place Pipe (CIPP)

Description: CIPP is a trenchless repair method that installs a resin-saturated felt liner into the host pipe through existing manholes. The liner is made of interwoven polyester and may be fiber-reinforced for additional strength. Commonly manufactured resins include unsaturated polyester, vinyl ester, and epoxy, each having distinct chemical resistance to domestic wastewater. The CIPP liner is installed by inversion using water or pressurized air; after the liner is in place, the resin-impregnated tube is cured using hot water, steam, or high-intensity ultraviolet light, creating a seamless pipe that fits tightly against the host pipe wall. Laterals are then connected to the mainline pipe using a remote-controlled cutting device.

Advantages and Limitations: CIPP is a viable rehabilitation technology in 6-inch or larger gravity sewers where the existing pipe has sufficient capacity. Because laterals are connected from inside the lined pipe, little or no trenching is required. Therefore, CIPP may be a preferred alternative in pipelines where trenching would be cost prohibitive. The CIPP method can be used to address structural problems such as cracks and structurally deficient segments, as well as root intrusions because the liner forms itself generally to the shape of the host pipe, and can span gaps caused by roots up to 1 inch in diameter. Larger gaps and alignment deficiencies such as offset joints and sags would require a point repair prior to lining.

The flexibility of the resin tube allows installation through existing bends, further minimizing the need for excavation. The liner is resistant to chemical attack, eliminates groundwater from entering the sewer, and retards further corrosion and erosion of the pipeline.

The thickness of CIPP liner typically ranges from ½ inch to 1 inch and therefore, the final inside diameter is approximately 1 to 2 inches less than the inside diameter of the existing pipe. The liner typically has less flow friction compared to the host pipe, so the reduction in diameter does not result in a reduction in hydraulic capacity, particularly for pipe above 8 inches in diameter.

CIPP installation requires bypass pumping and groundwater dewatering, if in a high groundwater area. Installation length is generally limited to approximately 800 feet due to curing limitations. Therefore, if manholes are located further apart than 800 feet, intermediate trenched access locations are required. Another challenge associated with using CIPP is the procurement, treatment, and/or disposal of water used during the curing process; during the curing process of any resin system, volatile organic compounds are released and must be closely monitored.

CIPP is a viable alternative to pipeline replacement when pipeline replacement options are cost-prohibitive, and when existing pipe diameter can be reduced without compromising system performance. CIPP is not recommended when pipeline slopes or other constraints limit the use of hydroflushing as a cleaning method.

1.2.1.4 Pipe Reaming

Description: Pipe reaming is very similar to pipe bursting in that an existing pipe is drilled out and a new pipe of equal or greater diameter inserted in its place. Because pipe reaming does not displace the broken pieces of the old pipe into the soil, this method is better suited to pipe rehabilitation where nearby pipes or utilities might be impacted by the displaced soil.

Pipe reaming employs a directional drill which pulverizes and grinds up the existing pipe while a new pipe is inserted behind it. The old pipe is accessed by an insertion trench, and the drill head is pulled through the pipe by a drill line which runs from an insertion trench where the pipe is accessed to the next manhole. The broken pipe is carried away through the old pipe by drill fluid and collected at the downstream manhole.

Pipe reaming can be used to remove brittle pipes such as those composed of vitrified clay, PVC, asbestos concrete, or ductile iron. Fused PVC or HDPE are typically used for the replacement pipe. Pipe reaming has been effective at replacing sections of sewer over 1,000 feet in length or more with little soil disruption.

Advantages and Limitations: Like other trenchless technologies, pipe reaming is advantageous when trying to minimize the impact of construction on traffic and business. When using pipe reaming as a rehabilitation technology, adequate space must be available for the insertion pit and the heavy machinery necessary for directional drilling and handling of the solids generated by the drilling process. Pipe reaming can become very expensive if there are a large number of laterals that must be reconnected to the replaced pipe.

1.2.1.5 Tunneling

Description: Where open cut construction is not feasible, practical, or cost effective, trenchless methods can be used to install the sewer pipe. Commonly used trenchless methods include jack-and-bore above the water table, micro tunneling below the water table, and horizontal direction drilling. These methods involve pre-drilling the pipeline alignment and then installing new pipe through the opening. When installed below Caltrans or railroad right of ways, an additional casing may be required by the governing jurisdiction.

Advantages and Limitations: Tunneling presents similar advantages to pipe bursting and pipe reaming related to minimized surface impacts when compared to open cut construction. Pipe size increase is not limited with tunneling methods and longer lengths of pipe can be replaced through a single bore.

Tunneling requires precise location of existing utilities and is not always appropriate where the new pipeline must maintain a precise slope or avoid numerous underground facilities. Additionally, tunneling requires an understanding of the materials to be tunneled through. Tunneling requires experienced equipment operators that are skilled with the location and guidance of the necessary equipment. Tunneling is assumed to be required along and across Caltrans and railroad rights-of-way.

1.2.2 Pipeline Cost Estimates

For the wastewater collection system master plan, it was assumed that pipelines would be installed using open cut methods under normal conditions. The descriptions for pipe bursting and pipe reaming are included for reference, in the event that preliminary design indicates that these methods are more feasible for a particular project. Tunneling methods are assumed to be used when normal conditions are not present, such as when construction must take place under a freeway, railroad track, or similar obstacle. The standard pipeline unit construction costs used in the Sewer Master Plan are shown in Table 1. The tunneling costs are shown in Table 2.

Table 1. Unit Construction Costs for Pipelines[a,b]

Pipeline Diameter, inches	Unit Construction Cost (Normal Construction), $/linear foot
8	248
10	310
12	300
15	375
18	450
21	420
24	480
27	540
30	600
33	660
36	720

(a) Costs based on San Francisco Peninsula pipeline cost estimates, scaled up to May 2018 ENR CCI of 12,015 (San Francisco Average).
(b) Costs based on polyvinyl chloride pipe.

Table 2. Unit Construction Costs for Tunneling (Bore and Jack)[a,b]

Pipeline Size	Unit Construction Cost, $/linear foot
8-inch diameter (16-inch diameter casing)	530
12-inch diameter (21-inch diameter casing)	695
15-inch diameter (24-inch diameter casing)	795
21-inch diameter (30-inch diameter casing)	990

(a) Costs based on San Francisco Peninsula pipeline cost estimates, scaled up to May 2018 ENR CCI of 12,015 (San Francisco Average).
(b) Conductor pipe is not included in cost.

In addition to the standard unit construction costs listed above, the following factors are added when it is identified that construction conditions will likely deviate from typical conditions:

- Difficult Access (75 percent): Unit costs are escalated by 75 percent when difficult surface access will make mobilization, staging, and construction more expensive. Difficult access conditions increase cost of construction and extend project duration.
- High Depth (25 percent): Unit costs are escalated by 25 percent when construction depth is estimated to exceed eight feet.

- Community Impact (15 percent): Unit costs are escalated by 15 percent when construction is to take place in densely populated residential neighborhoods. The need to mitigate negative community impacts extends project durations.
- High Traffic (10 percent): Unit costs are escalated by 10 percent when construction is to take place in high traffic rights-of-way. The escalation represents the cost of more rigorous traffic control.
- Night Work (15 percent): Unit costs are escalated by a further 15 percent when traffic is such that only nighttime construction is feasible.

1.3 LIFT STATION CONSTRUCTION AND CAPACITY UPGRADE CONCEPTUAL COSTS

Lift station new construction and capacity upgrade construction cost estimates are based upon pre-established West Yost costs curves for wastewater lift stations, which combine the cost curves presented in Shank's "Pumping Station Design" with cost data from actual projects completed in the last 10 years.

The lift station firm capacity (the capacity of the station with the largest pump in reserve) is the key value to input to the curves. From the capacity value, a line is drawn to where capacity intersects the cost curve lines. Two lines are provided to reflect difficult construction conditions and comparatively easy construction conditions.

1.4 CONTINGENCY COSTS AND MARK-UPS

Contingency costs or mark-ups must be reviewed on a case-by-case basis because they will vary considerably with each construction project. However, to assist District staff with budgeting for recommended water system facility improvements, the following percentages were developed.

- Estimating Contingencies (30 percent): The construction costs presented above are representative of the construction of wastewater collection system facilities under normal construction conditions and schedules; consequently, it is appropriate to allow for estimating and construction uncertainties unavoidably associated with the conceptual planning of projects. Factors such as unexpected construction conditions, the need for unforeseen mechanical items, and variations in design and final quantities are only a few of the items that can increase project costs.
- Design and Construction Period Services (30 percent): Design period services associated with new facilities include preliminary investigations and reports, right-of-way acquisition, foundation explorations, preparation of drawings and specifications for construction, surveying and staking, sampling of testing material, and start-up services. Design period services also include permitting and regulatory compliance, as well as District administration, legal, and associated activities. Construction period services cover items such as contract management and inspection during construction.

The total markup, including contingencies and professional services, is compounded, and amounts to 69 percent of the estimated construction cost. However, it must be noted that for smaller or more complicated projects, the design cost may increase by 10 to 20 percent of the estimated construction cost.

An example application of these standard mark-ups to a project with an assumed base construction cost of $1.0 million is shown in Table 3. As shown, the total cost of all project markups is 69 percent of the base construction cost for each construction project.

Table 3. Example Application of Project Cost Mark-ups

Cost Component	Percent	Cost
Base Construction Cost[a]		$1,000,000
Estimating Contingency	30%	$300,000
Total Construction Cost		$1,300,000
Design and Construction Period Services (Consultant/District) to perform construction management, inspection, testing, programming, engineering support, change order contingency. Consultant/District to perform design, bid, permitting, CEQA, regulatory, legal, outreach, administration)	30%	$390,000
Total Project Cost		**$1,690,000**

(a) Assumed cost of an example project.

Dublin San Ramon
Services District
Water, wastewater, recycled water