EAST PALO ALTO SANITARY DISTRICT MASTER PLAN UPDATE

FINAL REPORT

March 2015

FREYER & LAURETA INC.

FREYER & LAURETA, INC.
CIVIL ENGINEERS • SURVEYORS • CONSTRUCTION MANAGERS
144 North San Mateo Drive • San Mateo, CA 94401
(650)344-9901 • Fax (650)344-9920 • www.freyerlaureta.com

Table of Contents

Table of Contents

Executive Summary

In May 2014, East Palo Alto Sanitary District (District) retained Freyer & Laureta, Inc. to update its wastewater collection system master plan. The 2014 Master Plan assesses the conveyance capacity of the District's current sewer collection system pipes and evaluates facilities that may require replacement, develops a prioritized capital improvement plan (CIP), and establishes a connection fee to assist in the funding for the proposed CIP.

ES.1 BACKGROUND AND INTRODUCTION

The main purpose of this update to the sewer collection system master plan (Master Plan) is to evaluate the District's sewer collection system with projected flows under a specific design storm, using a computerized hydraulic model. The purpose of the hydraulic model is to determine whether the system can handle flows without sanitary sewer overflows (SSOs). Where SSOs are predicted by the hydraulic model, this Master Plan provides recommendations to resolve the problem. The Master Plan also recommends a schedule for sewer main replacements.

The District completed a flow monitoring study in 2011/2012. This study provided the flow data that was used as a basis for development and calibration of the District's hydraulic model, which is a component of this Master Plan. The monitoring study performed by V&A Consulting Engineers, was successful in capturing flow data throughout the system during several storm events.

This Master Plan is comprised of the following nine chapters:

- Chapter 1 – Introduction
- Chapter 2 – Existing Wastewater System
- Chapter 3 – System Flows
- Chapter 4 – Inflow & Infiltration Analysis
- Chapter 5 – Hydraulic Model Development
- Chapter 6 – Planning Criteria
- Chapter 7 – Result Summary
- Chapter 8 –Recommendation
- Chapter 9 – Capital Improvement Program

The Master Plan was developed to meet the following objectives:

- Determine system-wide flow characteristics
- Evaluate the existing hydraulic capacity of the collection system
- Determine pipeline potential replacement needs; and
- Develop a prioritized capital improvement program (CIP) and funding approach to provide an affordable and sustainable level of service to the District's ratepayers.

The recommendations that are presented in this Master Plan are considered in conjunction with proposed development of:

1. Ravenswood Villages (University Square)
2. Ravenswood Business Park
3. Four Corners/Bay Road

Future plans of Woodland area and redevelopment are unknown at this time, therefore not included in the scope of this project. As planning in the area progresses, we recommend this Master Plan be updated.

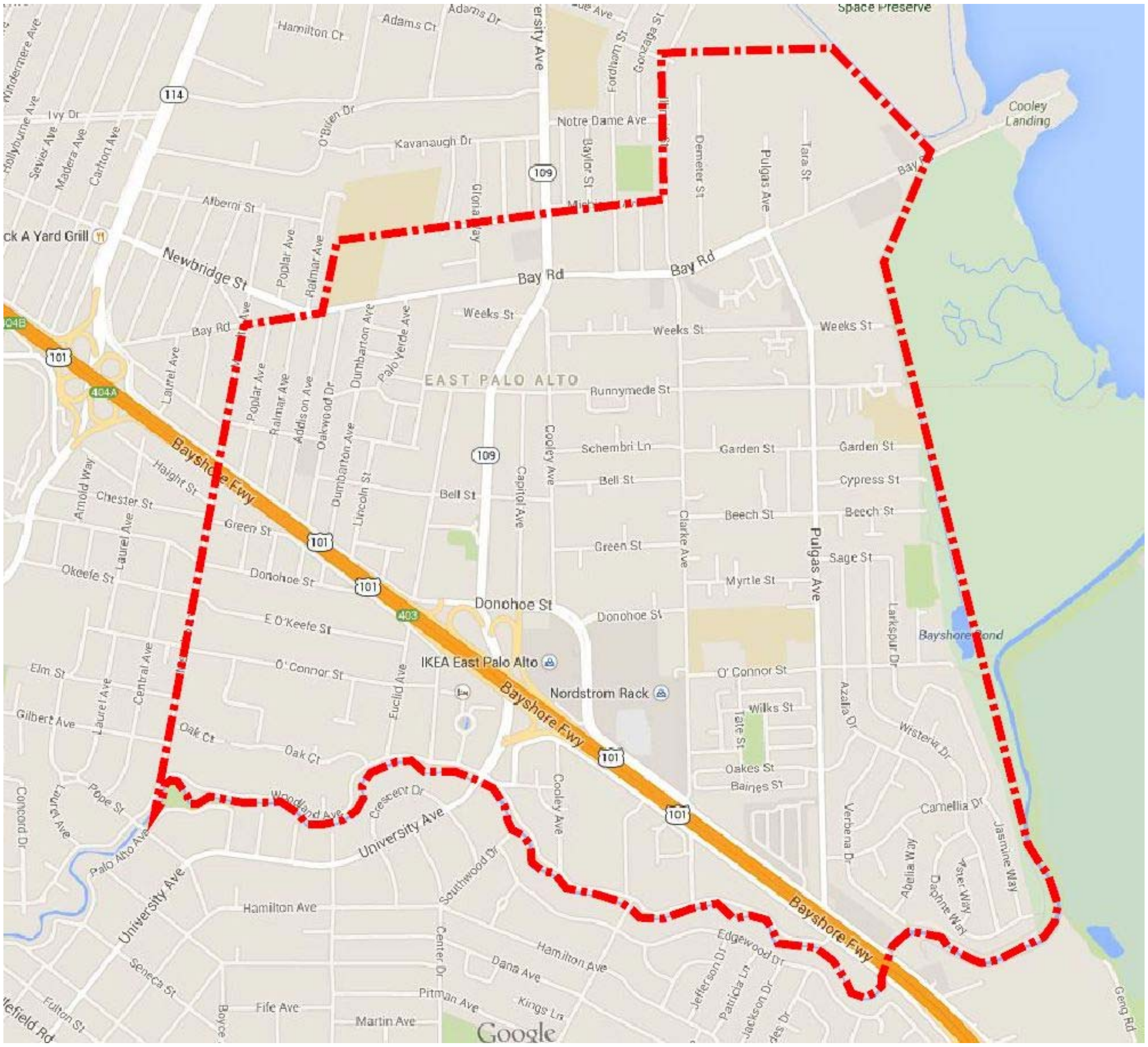
ES.2 EXISTING WASTEWATER SYSTEM

Chapter 2 describes the current system of the District. The District currently provides wastewater collection service to portions of the communities of Menlo Park and East Palo Alto, located in San Mateo County in the San Francisco Bay Area. The District's service area is primarily residential with a few commercial and industrial parcels.

The District's service area, shown on Figure ES-1, encompasses nearly 1,230 acres, or 1.92 square miles. The District's collection system is a gravity system. Approximately 70% of the pipelines are 6" in diameter. The larger collector lines range between 8" and 24" in diameter and contains a siphon beneath the San Francisquito Creek.

The most easterly portion of the system, in East Palo Alto, will experience the greatest change in sewer flows in the future. All pipelines will reach the end of their useful lives and require replacement; however a few sections of mainline will be required to be upsized to handle the future storms and flows.

The District operates and maintains the collection system in accordance with the requirements of the State Water Resources Control Board, as administered through the Statewide SSO Waste Discharge Requirements and RWQCB Sewer System Management Plan guidelines.



ES-1 District's Service Area

ES.3 SYSTEM FLOWS

The methods used to estimate the initial dry weather or base wastewater flow (BWF) component of the collection system hydraulic model is described in Chapter 3. These initial flows were further refined through additional flow meters and information gathered during master planning efforts. The District's BWF, as measured during the 2011/12 flow monitoring program that is discussed below, is 1.53 million gallon per day (mgd). This flow represents an average daily flow for the system.

The initial BWF component was given to us by the V&A study:

- From the data, a model in Hydra 7 was created showing existing conditions

Buildout flows were created by receiving predicted development flows and doing the following:

- Injecting flows into the Hydra model based on the location of predicted development.

ES.4 INFLOW & INFILTRATION ANALYSIS

The V&A Consulting Engineers (V&A) flow monitoring program captured rainfall data useful in our analyses. During their flow monitoring period, the District experienced several relatively short duration storm events, which are ideal for evaluating inflow and infiltration (I&I) and for calibrating the hydraulic model. Using collected data, V&A completed evaluation to quantify the extent of I&I entering the collection system by basin during this period. Chapter 4 further explains the results from the study.

ES.4.1 Data Collection

The flow monitoring program included gravity meters and rain gauges. The eleven meters were located in manholes that delineated the collection system into basins. Table ES-1 presents the flow meter locations and associated flow monitoring basins within the collection system. Depth and velocity readings were collected at each flow meter.

TABLE ES-1. List of Flow Monitoring Sites		
Site	**Location**	**Basin Size (acres)**
A15	Bay Rd, east of Demeter St.	118
B13	Intersection of Bay Rd and Poplar Ave	87
E1	Intersection of Cooley Ave and Green St.	101
E2	Cooley Ave, north of Donohoe St.	149
H3	Intersection of Clarke Ave and Beech St.	74
I3	East end of Beech St.	74
I12	Pulgas Ave, north of Sage St.	135
K4	Intersection O'Connor St and Larkspur Dr	107
K28	Larkspur Dr, south of O'Connor St.	95
T20	75 feet east of end of Cypress St.	171
T13	Along north edge of Palo Alto Municipal Golf Course	-

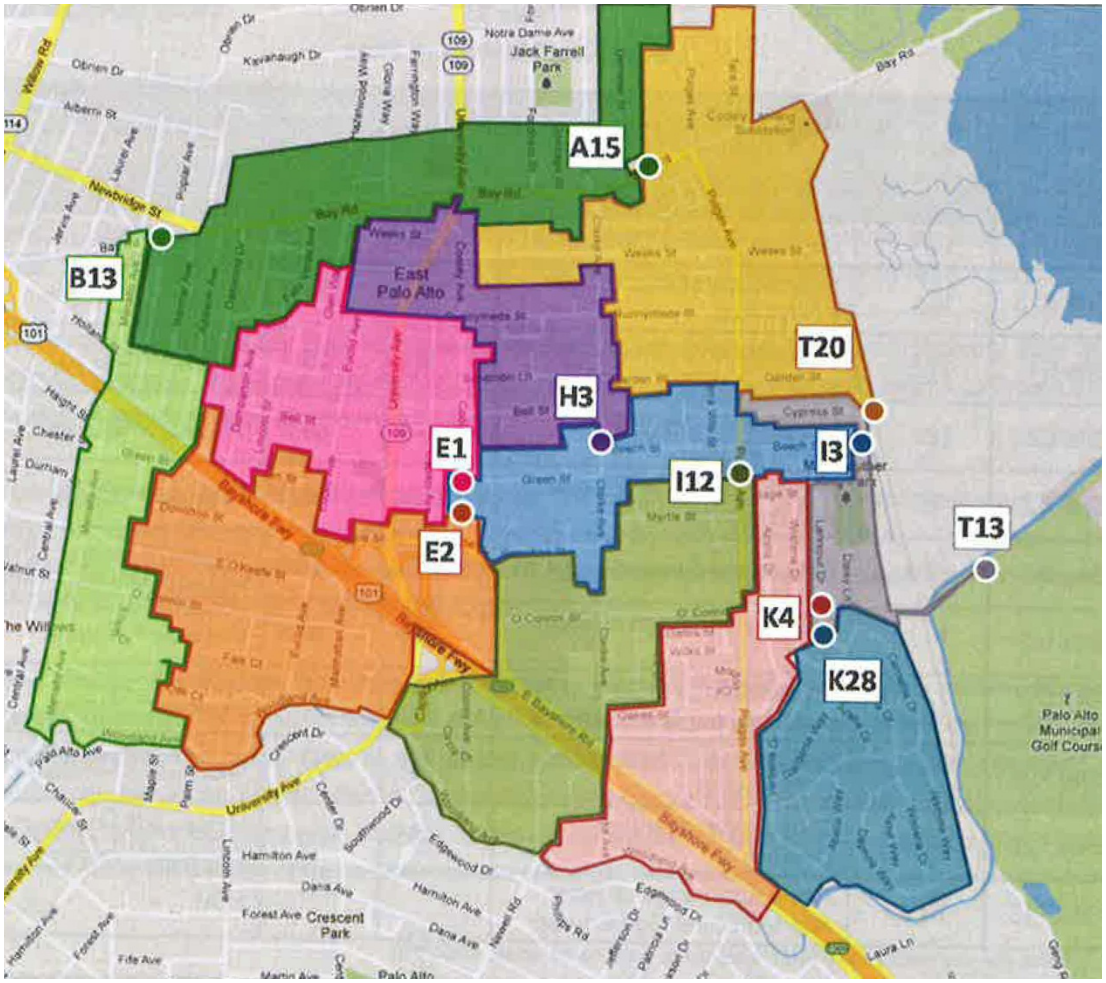


Figure ES-2 Site and Basin Location Map

ES.4.2 Description of Flows

The flow monitoring program measured dry and wet weather flows through the District. The District's BWF, measured across weekday and weekend periods, was 1.53 mgd. BWF includes the wastewater generated from all land uses. The peak wet weather measured flow was 2.80 mgd.

Three main rainfall events occurred during testing which were used in the analysis for the study. The rain events are presented in Table ES-2.

TABLE ES-2 RAINFALL EVENTS	
Rainfall Event	**Event Rainfall (inches)**
Event 1: March 16-17, 2012	0.56
Event 2: March 24-25, 2012	1.14
Event 3: March 27-28, 2012	0.52
Total Over Monitoring Period	**3.30**

ES.4.3 Inflow and Infiltration Analysis

The data collected during the flow monitoring study was plotted against the storm events to compare and analyze the inflow and infiltration. Flows were directly related to the storm events mainly because of specific structures such as downspouts, area drains, and cross connections to catch basins.

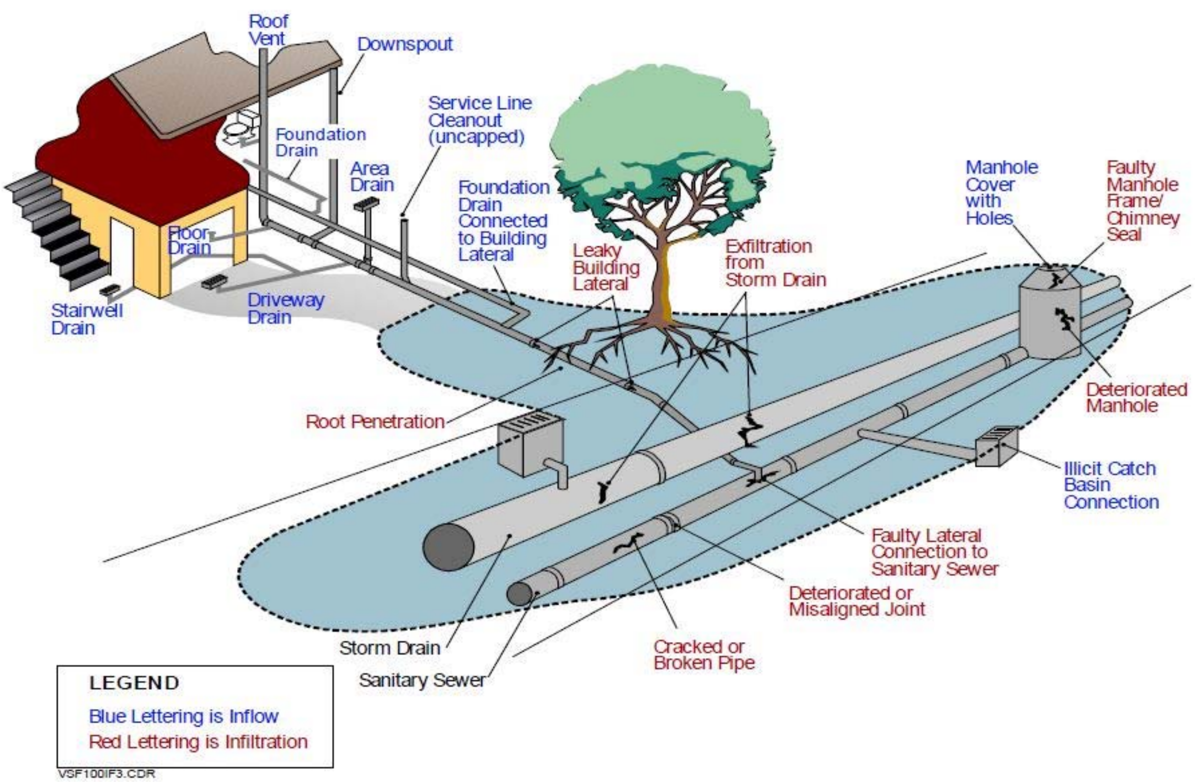


Figure ES-3 – Infiltration and Inflow Diagram

ES.5 HYDRAULIC MODEL DEVELOPMENT

Freyer & Laureta Inc. developed a computer model of the District's system using the program Hydra 7. The pipes were modeled based on the District System Maps, which contained rim & invert elevations and pipe sizes. Once the pipes were modeled with the available information, flows were introduced based on the flow data received. The model was further calibrated using data from flow monitoring performed by District staff using portable meters.

The average dry weather flows were injected into the system. After modeled, a peak wet weather flow scenario was created based on the recorded data. To analyze the system against a predicted storm event, the 10 year 24 hour storm, was modeled. From this model we obtained an understanding of system deficiencies.

Future development will add wastewater flow to the system. These flows were added to the storm event to determine improvement needs of the system.

ES.6 PLANNING CRITERIA

Chapter 6 presents the criteria used to evaluate the system's capacity. The criteria address items such as collection system capacity, pipe slopes, and flow elevation. The District selected a 10 year 24hr storm to be the design storm. Based on V&A's design storm summary, the following flows were used.

Table ES-3 – Design Storm Flows

Site	Peak Dry Weather Flow (mgd)	Peak Wet Weather Flow (mgd)
A15	0.43	1.19
B13	0.11	0.52
E1	0.19	0.59
E2	0.43	1.45
H3	0.23	0.58
I3	1.22	2.76
I12	0.39	0.76
K4	0.35	0.99
K28	0.17	0.68
T20	0.60	1.55
T13	2.31	5.78

ES.7 HYDRAULIC CAPACITY ANALYSIS RESULTS

The Hydra model evaluated the pipe system's ability to convey flows that are expected to occur during the selected 10 year 24 hour design storm. The analysis is further discussed in Chapter 7. The hydraulic model predicted peak hourly flow from the design storm of 5.8 mgd.

Analyses were conducted as follows:

- The system was evaluated for its ability to meet surcharging and flooding criteria. Pipe diameter upsizing that is required to convey peak flows and meet surcharge criteria were determined.
- Proposed improvements were developed and reviewed.

Table ES-4 – Results of Improvements

Monitoring Site	Rim	HGL before improvements	HGL after improvements
T29	4.98	4.82	0.39
B2	16	8.88	4.17
B16	20.39	18.08	14.71
D1	17.33	16.62	9.14
E1	12.09	13.5	4.5
T24	3.66	3.78	0.12
T22	2.81	3.33	-0.08
I11	8.07	7.6	0.84
T18	1.12	2.03	-0.94
T20	2.72	2.68	-0.24
K1	2.02	-0.54	-1.76
K28	3.27	1.23	0
M2	5.62	4.5	1.51
N1	5.32	0.78	-0.44
N8	13.8	4.33	4.33

ES.8 Recommendations

This chapter provides the recommended pipes to be replaced with larger pipes. Recommendations were based on the results from the model and the outcome of the size changes.

ES.9 Capital Improvement Program

This chapter shows a recommended schedule for the recommended improvements. The schedule breaks down the sections of pipe that should be replaced each year for 15 years. This will help set a budget for the District.

Chapter 1 - Introduction

Chapter 1 provides background information on the scope and objectives of the East Palo Alto Sanitary District Wastewater Collection System Master Plan (Master Plan).

1.1 BACKGROUND AND PROJECT OBJECTIVES

The East Palo Alto Sanitary District (District) is responsible for the operation and maintenance of the sanitary sewer collection system that serves most of East Palo Alto and a portion of Menlo Park. The City of East Palo Alto (City) is anticipating redevelopment of portions of the City. Other specific development plans have been submitted to the District for review, and some are currently under construction. The major areas within the District identified for redevelopment include:

- **Ravenswood Villages (University Square)**
- **Ravenswood Business Park**
- **Four Corners/Bay Road**

Future plans of Woodland area and redevelopment are unknown at this time, therefore not included in the scope of this project. As planning in the area progresses, this Master Plan will require updating.

The purpose of this study is to develop a mathematical model of the District's collection system to assess the impact that redevelopment and future projects will have on the District's collection system.

As a first step for this Master Planning effort, V&A created a report for the existing measured flows for the District's system. The report was then analyzed and implemented into a true model to discover problem areas in the network. The objective was to discover and improve capacity issues throughout the District. The plan was broken into tasks for analysis:

Task 1 EPASD Basemap

The existing base drawing of the EPASD collection system in AutoCAD was used with the GIS model provided from the District. These drawings provided the basemap for the system. Included within the drawings was information for pipe sizes, location, inverts and rims of each manhole.

Task 2 – Mathematical Model

A mathematical model of the main lines in the District's system using the computer software program HYDRA 7was developed. The following steps were taken in order to complete the mathematical model:

1) Data Collection

a) Review existing information provided from the District:

i) Physical Data: pipe sizes, pipe materials, pipe ages, manhole rim and inverts.

ii) System Geometry and locations

iii) Influent Flow Data.

iv) Rain Data

v) Troubled Areas.

b) Determine current dry and wet weather flows from the District's collection system.

2) Develop Model

a) Enter existing conditions into the model

Task 3 – Flow Data

Wet and dry weather flow monitoring at eleven manholes in the District was completed. The following steps were taken in order to complete the flow data:

1) Identify manholes monitored – Provided by the District

2) Input given flow data into the model

Task 4 – Mathematical Model Update and Review

The mathematical model was updated to include flow monitoring results and updated redevelopment plans for the City of East Palo Alto. The following steps were taken in order to complete the mathematical model:

1) Data Collection

a) Any additional monitoring information was reviewed and added to the system if necessary.

2) Review Model and Analyze Collection System

a) Utilize the model to evaluate the existing system. Identify capacity deficiencies of the sanitary sewer system for the current condition including both wet and dry weather scenarios.

b) Utilize the model to evaluate the future (with redevelopment) system. Identify capacity deficiencies of the sanitary sewer system for the current condition including both wet and dry weather scenarios.

3) Develop List of Improvements and Recommendations

a) Recommend improvement projects including replacement or parallel pipeline projects for the flooding locations.

1.2 REPORT ORGANIZATION

The Report comprises the following chapters. The sequence of chapters generally conforms to the tasks outlined in the scope of work for the project. This section describes the contents of each of the nine chapters and appendices.

1.2.1 Executive Summary

The Executive Summary provides a comprehensive overview of the Report contents and summarizes key aspects of each chapter.

1.2.2 Chapter 2 – Existing Wastewater System

This chapter describes the District's existing service areas and land uses.

1.2.3 Chapter 3 – System Flows

This chapter presents the methods for determining existing and future dry and wet weather wastewater flows for the purposes of collection system capacity modeling.

1.2.4 Chapter 4 – Flow Monitoring and Inflow/Infiltration Analysis

This chapter summarizes contributions to system-wide inflow and infiltration based on results from V&A Consulting Engineers (V&A).

1.2.5 Chapter 5 – Hydraulic Model Development

This chapter describes the tasks required to build and calibrate the Hydra 7 hydraulic model. The hydraulic model is the primary tool that was used to determine the flows and capacities of the District's major sewers. It was also used for the development of recommendations for the system.

1.2.6 Chapter 6 – Planning Criteria

This chapter documents the planning criteria used to calculate existing and future flows, and to assess whether any hydraulic deficiencies may occur in the collection system. These criteria are based on standard design criteria in use by the District, and modeled criteria that resulted from hydraulic model calibration as discussed in Chapter 4.

1.2.7 Chapter 7 – Capacity Analysis

This chapter presents the results of the existing and future system hydraulic capacity analyses of the District's wastewater collection system. The chapter presents the results of both analyses, identifies existing pipelines that are over capacity, and describes proposed the capital improvement projects.

1.2.8- Chapter 8 – Recommendations

This chapter describes the pipes that should be replaced to reduce surcharging and flooding based on the design scenario.

1.2.9 Chapter 9 – Capital Improvement Program

This chapter provides recommendations for the schedule of the Capital Improvement Plan. The replacements are spread over 15 years as well as the budget.

1.2.10 Appendices

The following appendices to this Wastewater Collection System Master Plan contain additional technical information and assumptions:

- Appendix A – EPASD map
- Appendix B – Flow Monitoring Station Map and Table
- Appendix C – Ravenswood Map
- Appendix D – Ravenswood Existing Land Use
- Appendix E – Ravenswood Plan Concept
- Appendix F – Pipe Recommendations
- Appendix G – CIP Timeline Map
- Appendix H – Flow Results at Downstream Basins
- Appendix I – Basin Map
- Appendix J – Recommended pipes to be upside with costs
- Appendix K – System Improvement Results

1.3 ACRONYMS AND ABBREVIATIONS

The following acronyms and abbreviations have been used throughout this Report to improve document clarity and readability.

ADWF	Average Dry Weather Flow
BWF	Base Wastewater Flow
CCTV	Closed Circuit Television
CIP	Capital Improvement Program
CIPP	Cured in Place Pipe
CIWQS	California Integrated Water Quality System
CMP	Corrugated Metal Pipe
County	County of San Mateo
District	East Palo Alto Sanitary District
DU	Dwelling Unit
DWF	Dry Weather Flow
EPASD	East Palo Alto Sanitary District
F&L	Freyer & Laureta, Inc.
fps	Feet Per Second
GPAD	Gallons Per Acre Per Day
gpcpd	Gallons Per Capita Per Day
gpd	Gallons Per Day
gpd-idm	Gallons Per Day Per Inch-Diameter-Mile
gpm	Gallons Per Minute
GWI	Groundwater Infiltration
HDD	Horizontal Direction Drilling
HDPE	High Density Polyethelyne
HGL	Hydraulic Grade Line
I&I	Inflow and Infiltration
ID	Identification Numbers

Master Plan	East Palo Alto Sanitary District Master Plan
Menlo Park	City of Menlo Park
mgd	Million Gallons Per Day
NASSCO	National Association of Sewer Service Companies
NOAA	National Oceanic and Atmospheric Administration
PVC	Polyvinyl Chloride
Q_A	Average Daily Dry Weather Flow
Q_{PDWF}	Peak Hourly Dry Weather Flow
Q_{PWWF}	Peak Wet Weather Flow
R&R	Rehabilitation and Replacement
Report	Collection System Master Plan Report
RDII	Rainfall-Dependent Inflow and Infiltration
SCS	Soil Conservation Service (now Natural Resource Conservation Service)
SSO	Sanitary Sewer Overflow
SUH	Synthetic Unit Hydrograph
SWRCB	State Water Resources Control Board
TCE	Temporary Construction Easement
V&A	V&A Consulting Engineers
VA	Veteran's Affairs
VCP	Vitrified Clay Pipe
WWF	Wet Weather Flow

CHAPTER 2 – EXISTING WASTEWATER SYSTEM

Chapter 2 describes the District's existing wastewater collection system. System information was obtained through the review of previous reports, documents from V&A, and miscellaneous documents from the District. The following sections of this chapter describe the components of the District's existing wastewater collection system:

- Existing Service Area
- Population Served and Land Use Characteristics
- Existing Collection System Facilities

2.1 EXISTING SERVICE AREA

The District currently provides wastewater collection service to all or portions of the communities of Menlo Park and East Palo Alto. The District's service area is primarily residential with a few commercial and industrial parcels.

As shown on Figure 2-1, the District service area encompasses nearly 1,230 acres, or 1.92 square miles.

The most Easterly portion of the system, in East Palo Alto, will experience the greatest change in sewer flows in the future.

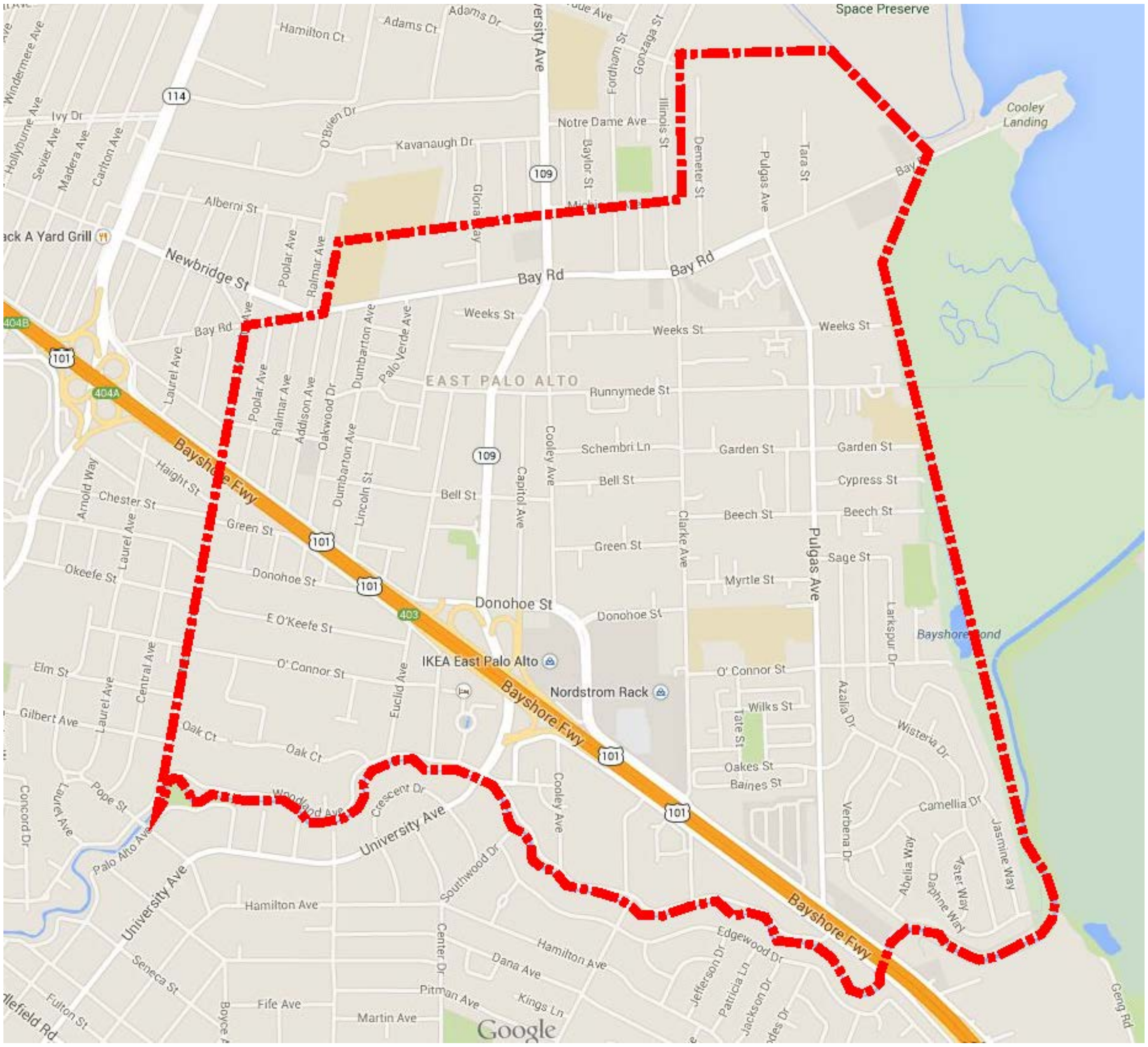


Figure 2-1 District's Service Area

2.2 POPULATION SERVED & LAND USE CHARACTERISTICS

Land use information was derived from several sources collected for the communities served by the District, including:

- Land Use Database – Existing land use data in Geographical Information System (GIS)
- General Plan Information – Additional land use data from East Palo Alto
- Aerial Photographs – Aerial photographs of the service area were reviewed to identify parcels and properties

2.2.2 Build-out and Land Use

The City of East Palo Alto (City) is anticipating redevelopment of portions of the City. Specific development plans have been submitted to the District for review, and some are currently under construction. The major areas within the District identified for redevelopment include:

- **Ravenswood Villages (University Square) –** Residential development on approximately 10 acres of land between Clarke and Pulgas Streets, just south of O'Connor Ave. The development plans include single family residences and apartments. Construction is nearing completion.
- **Ravenswood Business Park –** Approximately 130 acres located along Bay Road in the northeast corner of the District. Proposed development includes industrial, commercial, office and some residential as described in the August 2000 Preliminary Draft of the East Palo Alto Revitalization Plan.
- **Four Corners/Bay Road –** Creation of a new downtown center at the intersection of University Avenue and Bay Road. Proposed mixed-use development including government, community, office, and commercial spaces as described in the August 2000 Preliminary Draft of the East Palo Alto Revitalization Plan.

As previously stated, these locations were the focus of redevelopment for this model and analysis. All other developments were not included in the Master Plan.

2.3 EXISTING COLLECTION SYSTEM FACILITIES

The District is responsible for the operation and maintenance of the sanitary sewer collection system shown in Figure 2-1. The collection system serves most of East Palo Alto and a portion of Menlo Park. The collection system drains to the Palo Alto Regional Water Quality Control Plant (RWQCP) where the District's flows are treated and discharged to the San Francisco Bay by the RWQCP. The District's collection system is a gravity system consisting of sewer pipelines and manholes. Approximately 70% of the pipelines are 6" in diameter. The larger collector lines range between 8" and 24". The trunk line contains a siphon beneath San Francisquito Creek between manholes T15 and T14. The collection system is composed of 15 drainage basins. A letter, A-O, is used to designate each basin. The boundaries of the drainage basins are shown in Appendix I. Table 2-1 shows the characteristics of each basin. Sections of the system have been replaced; however most of the original pipelines and manholes remain in service. The new manholes are precast, while the original manholes were mostly constructed of brick and mortar. The pipelines were constructed with vitrified clay pipe (VCP), but newer pipelines are being constructed with heavy wall plastic pipe such as PVC or HDPE.

Table 2-1 Basin Information

Basin	Area (acres)	Land Use	Total Length of Sewers	Pipe Diameter (inches)	Approximate Age of Pipes and Manholes
A	106	Industrial	7,888	6-8	20-60 years
B	93	Low Density Residential / Commercial / Medium-High Density Residential	15,080	6-12	55 years <10 years along Menalto <2 years along Bay
C	73	Low Density Residential	12,852	6-8	40-55 years < 10 years along Menalto
D	128	Residential / Commercial	18,756	6-10	40-55 years <2 years on Euclid West Bayshore, and Oakwood.
E	122	Residential / Commercial	18,072	6-12	55 years < 2 years on Bell and Cooley
F	64	Industrial / Residential	4,235	6	55 years
G	30	Low Density Residential	3,715	6	55 years

Basin	Area (acres)	Land Use	Total Length of Sewers	Pipe Diameter (inches)	Approximate Age of Pipes and Manholes
H	124	Residential / Commercial	13,949	6-15	15-55 years
I	78	Low Density Residential	7,143	6-15	10-55 years <5 years on Pulgas
J	36	Low Density Residential	3,824	6-8	55 years <2 years on Cypress
K	66	Low Density Residential	9,046	6-14	15-55 years <2years on Gardenia, Camellia, and Larkspur
L	99	Low Density Residential	15,171	6-10	30-40 years
M	61	Residential / Commercial	5,434	6-10	15-55 years <5 years on O'Connor
N	38	Medium-High Density Residential	2,385	10	15 years
O	102	-	11,094	6-8	30-55 years
Trunk Line	-	-	11,281	18-24	4 years
Total	1,220	-	159,925	6-24	

Chapter 3 – System Flows

Chapter 3 presents the background and methodology used to determine existing and future dry weather wastewater flows for input to the District's collection system hydraulic model. This chapter is organized as follows:

- Sources of System Data
- Estimated Flows

3.1 SOURCES OF SYSTEM DATA

The main sources of data used to estimate wastewater flows for the District's hydraulic model include land use information, aerial photography, and District unit flow factors. All calculations and data were provided by V&A.

The Palo Alto Regional Water Quality Control Plant (RWQCP) records total wastewater flow for the District. These flows are measured from the District's meters. Typically, maximum daily flows in the District occur during the winter months between December and March. Daily flows are lowest during the months of September through November. The dry weather flow capacity of the RWQCP is 38 MGD. The District has an agreement with the RWQCP, which entitles the District to 7.63% of the dry weather capacity of the RWQCP, 2.9 MGD.

Wastewater in the District is composed of sanitary flows and inflow/infiltration (I/I). Sanitary flows are derived from three main sources in the District: commercial, residential, and industrial. I/I is composed mainly of storm water inflow, rain-dependent groundwater infiltration, and groundwater infiltration that enter the collection system through roof drain connections, storm drain cross connections, and manhole covers. Due to the proximity to the San Francisco Bay, the groundwater table within the eastern portion of the District is relatively high, and year-round groundwater infiltration is relatively high. The relative contribution from sanitary and I/I flows varies seasonally. Generally, the wastewater is composed primarily of sanitary flows and some groundwater infiltration during the drier months of summer and fall. I/I flows usually peak during the heavy rain events between January and March and can account for over 50% of the daily flows in the collection system.

3.2 – ESTIMATION OF FLOWS

The initial BWF (average dry weather flow) component was calculated using the following steps:

- Based on the monitoring system put in place by the District, flows were recorded. From those recordings, the flows were averaged to create the BWF. Not all sections were monitored; therefore flows were back calculated to properly distribute flow.
- Once the model was created, additional manholes were monitored and the model adjusted to conservatively show the actual flows.

TABLE 3-1. List of Flow Monitoring Sites

Site	Location	Basin Size (acres)
A15	Bay Rd, East of Demeter St.	118
B13	Intersection of Bay Rd and Poplar Ave	87
E1	Intersection of Cooley Ave and Green St.	101
E2	Cooley Ave, North of Donohoe St.	149
H3	Intersection of Clarke Ave and Beech St.	74
I3	East end of Beech St.	74
I12	Pulgas Ave, North of Sage St.	135
K4	Intersection O'Connor St and Larkspur Dr	107
K28	Larkspur Dr, South of O'Connor St.	95
T20	75 feet East of end of Cypress St.	171
T13	Along North edge of Palo Alto Municipal Golf Course	-

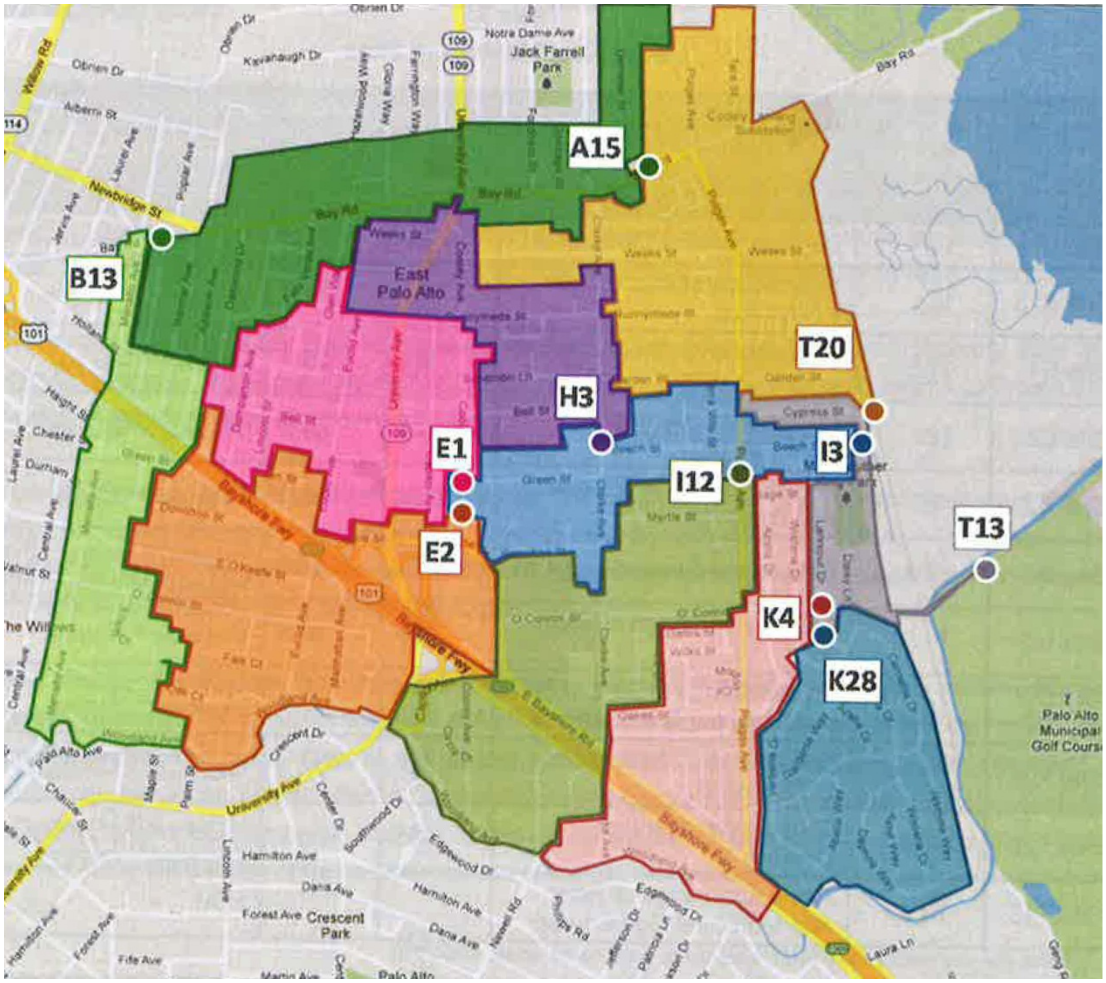


Figure 3-1 Monitoring Station Map

Buildout flows were created by injecting predicted development flows (0.91MGD for ADWF) as follows:

- Locating the development and probably sewer connection points
- Flows were inserted into the sewer model.
- Hydra calculated the flows and the effect on the system downstream and upstream.

3.3 Infiltration and Inflow

3.3.1 Dry Weather Infiltration

A portion of the metered average dry weather flow is due to sanitary flows and the remainder is due to dry weather infiltration. Groundwater infiltration flows studies were developed by taking the difference between the sanitary flows estimated from water use records and the dry weather flows that were measured during the flow metering performed as part of the study.

3.3.2 Wet Weather Infiltration and Inflow

Wet weather inflow and infiltration is directly related to rainfall amounts, groundwater levels, and soil saturation. Wet weather inflow and infiltration flow can vary dramatically from day to day and over the years. For the purpose of the model, a representative inflow and infiltration flow was developed by V&A.

Chapter 4 Inflow Analysis

4.1 FINDINGS AND RECOMMENDATIONS

The following findings were developed to address potential problems within the system that are the most significant contributors to I&I. Through the control of I&I, the District will also likely reduce the potential for wet weather related sewer system overflows (SSOs).

4.1.1 General Sources of Inflow and Infiltration

I&I are extra flows that enter the sanitary sewer system. I&I can negatively impact the capacity of wastewater collection systems by increasing both peak flows and total flow volume. Rainfall-dependent inflow and infiltration (RDII), groundwater infiltration (GWI), and inflow from illegal connections can all be contributors of I&I.

I&I can enter the collection system through different facilities. Inflow is water that enters the collection system through a direct improper connection. Inflow enters the sewer pipe independent of groundwater level and can be seen in the collection system immediately following a storm. Infiltration is water that enters the collection system by percolating through the ground and then into the collection system through defects in pipelines, manholes, and joints. Infiltration will occur over a longer period of time, and depending on conditions, can occur for days, weeks, or seasonally.

Figure 4-1 provides examples of common I&I sources.

RDII generally occurs after a rainfall event, and can enter the collection system on the same day that the rainfall event begins, and may continue to last for days after the rain event has ended. GWI patterns may reflect movement of the groundwater table, which generally rises gradually during the wet weather season and falls as the dry weather season takes place. GWI may occur rather steadily each day.

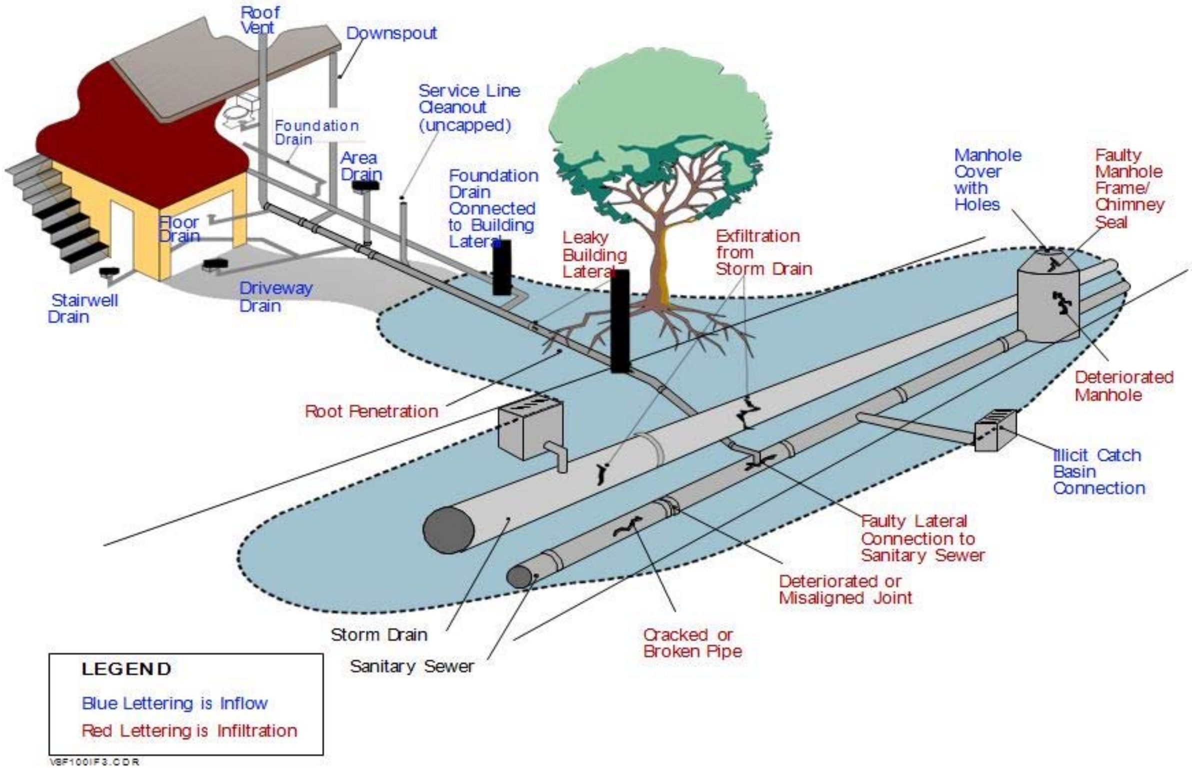


Figure 4-1 Inflow and Infiltration Map

Chapter 5 –Hydraulic Model Development

The computer-based hydraulic sewer model of the District's wastewater collection system, developed using Hydra 7 software, by Pizer Incorporated, is a tool to investigate the flows and to help identify problem areas to create a solution. The hydraulic model is also a tool for performing different scenarios to assess the impacts of future developments, land use changes, and system changes.

5.1 MODEL DEVELOPMENT

The District's hydraulic model creates a mathematical model from the physical and operational information of the system. Hydra simulates flow for the system by taking the given inputed data and running multiple calculations based on parameters set. The modeling results provide information on flow depth, velocity, surcharging, flows and flooding conditions that are used to identify possible system deficiencies. The model is also used to verify the capacity of the proposed system improvements.

The hydraulic model composed of a network of nodes and links. Several types of nodes and links are used for defining the physical entities within the District's system. The following descriptions provide information on elements used in the development of the District's model.

Node: Nodes can represent manholes, split manholes, storage facilities, and outfalls in a collection system. Nodes were also used to create simulated siphons by setting inverts midway through the siphon. All flows loaded into the model are attached to a node structure. The data required for node structures to include elevation data (pipe invert and manhole rim) and manhole diameter.

Links: Links represent pipes that convey wastewater from one point in the system to another. The physical data for the pipe mains include invert elevation, size, length, and friction factor.

5.1.1 Model Description

The hydraulic model configuration was developed using the District's AutoCAD and GIS pipe, manhole information obtained from the District, such as pipeline invert and manhole rim elevations, pipeline diameter and pipeline length data. The GIS model was inserted into the program Hydra. From there the pipe sizes, inverts, and rims were entered to match the provided information.

5.2 DATA VALIDATION

After the model network was constructed, the model was further checked and calibrated.

- Labeled manholes based on the District's label system
- Check the pipe connectivity
- Check for missing or inconsistent data such as missing manhole rim or pipe invert elevations, negative pipe slopes, or abrupt elevation changes
- Identify split manholes and flow distribution
- Field checks and descriptions based on past projects and recordings.

5.3 Model Scenarios

The model was run for both the existing and future flow scenarios. The following is a summary of the input flow files used in each scenario that analyzed:

1. **Average Flow**: The average sanitary flow based on the collected data.
2. **Peak Flows**: The peak sanitary flow files based on the collected data.
3. **10 year 24 hour storm**: The flows given based on a 10 year 24 hour storm estimated response summary from V&A.
4. **Future Flows:** The given predicted flows from future developments.

The scenarios were combined to create the design storm flows, which in this case is the 10 year storm with peak flows including future development. The pipes will be able to handle this situation without flooding.

Chapter 6 - Planning Criteria

Chapter 6 presents planning criteria that can be used to analyze system capacity and size any proposed new pipe recommendations. Planning criteria address items such as collection system capacity, pipe slopes, and maximum depth of flow. The major elements of this chapter include:

- Design Storm
- Hydraulic Deficiency Criteria, and
- New Pipeline Design Criteria

6.1 DESIGN STORM CRITERIA

Design storms are simulated rainfall events used to evaluate collection system capacity under wet weather flow conditions. A design storm has specific recurrence interval and rainfall duration. District's goal is to eliminate all sewer overflows for the 10-year, 24 hour storm event.

The master plan evaluates the ability of the system to convey flows with surcharging under the selected design storm scenario. The District has selected as its design storm a rainfall event of 10-year recurrence intervals and 24-hour duration (10-year, 24-hour storm), as defined by the NOAA rainfall atlas[1].

Table 6-1 shows recorded rainfall data from the V&A report. This information of rainfall was used to create a peak flow scenario combined with a predicted 10 year storm.

TABLE 6-1 RAINFALL EVENTS	
Rainfall Event	**Event Rainfall (inches)**
Event 1: March 16-17, 2012	0.56
Event 2: March 24-25, 2012	1.14
Event 3: March 27-28, 2012	0.52
Total Over Monitoring Period	**3.30**

6.2 EXISTING PIPELINE HYDRAULIC CAPACITY CRITERIA

Hydraulic capacity or deficiency criteria are presented for gravity mains. The criteria sets the standards for determining if a pipe is exceeding allowable surcharging. Under these criteria, a facility may exceed surcharge capacity, yet not overflow. For existing pipelines, the pipe is considered to have a capacity deficiency (surcharge) when, under peak wet weather flow conditions for the design storm, the water level or hydraulic grade line (HGL) is located above the top of pipe. Exceptions to these criteria may be made because of siphons in the system. All capacity deficient pipelines should be considered for replacement over time, as discussed in Chapter 9, Capital Improvement Program.

Chapter 7 Result Summary

Chapter 7.1 - Observations

The following is a summary of general observations about the results of the model:

1. Under the present flow scenarios, the capacity of the existing pipelines is adequate to handle current peak wet weather flows.

2. A large portion of the collection system, including sections of the main trunkline to the RWQCP, is at capacity now, and future buildout flows will overwhelm many of the mains in the existing system. Several sections of pipelines in the model were listed as overcapacity during peak wet weather flow scenarios. The dry weather flow capacity of the RWQCP is 38 MGD. The District has an agreement with the RWQCP, which entitles the District to 7.63% of the dry weather capacity of the RWQCP, approximately 2.9 MGD. The predicted average dry weather flow for both future buildout scenarios exceeds the capacity allotment from the RWQCP.

3. Some pipes may be relatively flat due to settlement

4. The slopes of the District's pipelines are relatively flat. As a result, calculated velocities at average dry weather flow for both the present and future scenarios were often low. The ideal minimum velocity of sewage flows in a gravity pipeline is 2.0 fps to prevent settling of the solids out of the flow. The calculated velocities indicate that the District may have a problem with blockages in the collection system due to the settling out of solids in the flow. In fact, EPASD maintenance crews are required to frequently clean sewer pipelines throughout the District to prevent blockages.

5. The siphon under San Francisquito Creek causes surcharging during both present and future peak flows. EPASD maintenance crews have verified the occurrence of surcharging in this pipeline. Additionally, grease gets trapped in the pipelines just upstream of the siphon requiring frequent routine maintenance.

7.1.1 Surcharged Pipes

The following pipes are surcharged during peak flow, but not including siphons. (Flows based on reported/recorded data)

Table 7-1 Surcharged Pipes			
Street	**Between MH's**	**Size**	**Length**
Woodland Ave	D56-D35	6	287
Woodland Ave	D35-D34	6	178
Oak Court	D36-D35	6	251
Menalto Ave	C3-C2	6	398
Menalto Ave	C2-C1	6	204
Bay Rd	B7-B6	12	380
Donohoe Street	D4-D3	8	297
Green Street	H74-H8	12	113
Green Street	H8-H7	12	234
Verbina Drive	L14-L13	6	302
Verbina Drive	L13-L9	6	311
Gaillardia Way	L11-L10	6	360
Azalia Drive	L10-L9	6	275
Azalia Drive	L9-L4	6	163
Gardenia Way	L8-L7	6	73
Gardenia Way	L7-L6	6	261
Gardenia Way	L6-L5	6	215
Gardenia Court	L61-L5	6	153
Gardenia Way	L5-L47	6	277
Abelia Way	L58-L57	6	296

Street	Between MH's	Size	Length
Abelia Way	L57-L53	6	203
Camellia Court	L56-L54	6	327
Camellia Dr	L55-L54	6	149
Camellia Dr	L54-L53	6	370
Camellia Dr	L53-L52	6	219
Camellia Dr	L52-L50	6	224
Camellia Dr	L51-L50	6	80
Azalia Dr	L50-L49	8	224
Azalia Dr	L49-L48	8	234
Azalia Dr	L48-L47	8	229
Azalia Dr	L47-L4	8	88
Gardenia Way	L4-L3	10	248
Wisteria Dr	L22-L3	6	366
Daphine Ct	L62-L34	6	147
Daphine Way	L34-L26	6	288
Aster Way	L30-L27	6	236
Wisteria Drive	L28-L27	6	363
Wisteria Drive	L27-L26	8	261
Wisteria Drive	L26-L25	8	216
Jasmine Way	L43-L44	8	335
Jasmine Way	L44-L45	8	239
Camellia Drive	L46-L45	6	136
Camellia Drive	L45-L25	8	202

Street	Between MH's	Size	Length
Wisteria Drive	L25-L24	8	342
Wisteria Drive	L24-L23	8	387
Wisteria Drive	L23-L3	8	352
Gardenia Way	L3-L2	10	84
Gardenia Way	L2-L1	10	179
Camellia Drive	K35-K34	6	280
Camellia Drive	K34-K33	6	279
Camellia Drive	K33-K32	6	131
Camellia Drive	K37-K32	6	351
Camellia Drive	K32-K30	8	227
Gardenia Way	K30-K31	8	109
Gardenia Way	K31-L1	8	148
Larkspur Dr	L1-L21	10	224
Larkspur Dr	L21-L28	10	69
Larkspur Dr	L28-K4	10	242
O'Connor Street	K5-K4	12	249
O'Connor Street	K4-K3	12	239
O'Connor Street	K3-K2	12	190
O'Connor Street	K2-K1	14	452
O'Connor Street	K1-T15	14	21
N/A	T14-T13	24	479
N/A	T8-T7	24	502
N/A	T3-T2	24	500

7.1.2 Flooding Conditions

The existing pipe system does not have the capacity to support the flows from a 10 year storm with peak flow. Each of the following manholes shows flooding during this condition.

Table 7-2 Manholes with Flooding Condition								
D37	D19	C4	E1	H17	A20	T19		
D36	D5	C3	H9	H14	A19	T18		
D24	D4	C2	H73	H12	A18	L43		
D26	D21	C19	H74	I14	F7	L45		
D25	D10	E44	H8	I9	T25	L24		
D22	D20	E7	H7	A14	T24			
D47	C6	E46	H75	A13	T22			
D21	C5	E6	H34	A12	T20			

Table 7-3 Design Storm Flows		
Site	**Peak Dry Weather Flow (mgd)**	**Peak Flow (mgd)**
A15	0.43	1.19
B13	0.11	0.52
E1	0.19	0.59
E2	0.43	1.45
H3	0.23	0.58
I3	1.22	2.76
I12	0.39	0.76
K4	0.35	0.99
K28	0.17	0.68
T20	0.60	1.55
T13	2.31	5.78

Chapter 8 – Recommendations

8.1 – Pipes to Be Upsized

Based on the model produced, the following pipes did not meet the standard criteria for an acceptable pipe. By upsizing the listed pipes, the capacity of the system increases and will handle future flows.

TABLE 8.1 Upsize Recommendations			
Section	**Current Size**	**Recommended Size**	**Approx Length**
C5-C4	6”	8”	328’
C4-C3	6”	8”	436’
C3-C2	6”	8”	398’
C2-C1	6”	8”	205’
D24-D23	8”	12”	350’
D23-D22	8”	12”	74’
D22-D21	8”	12”	149’
D21-D19	8”	12”	391’
D19-D10	10”	12”	49’
D10-D3	10”	12”	490
A14-A13	6”	8”	289’
A13-A12	6”	8”	412’
A12-A11	6”	8”	486’
A11-A10	6”	8”	418’
A20-A19	6”	8”	340’
A19-A18	6”	8”	214’
A18-A16	6”	8”	442’
M4-M3	8”	12”	358
M3-M2	8”	12”	380
M2-M43	8”	12”	48’
E1-H9	12”	18”	270’
H9-H73	12”	18”	247’
H73-H74	12”	18”	101’
H74-H8	12”	18”	113’
H8-H7	12”	18”	234’
H7-H75	12”	18”	90’
H75-H6	12”	18”	260’
H6-H5	12”	18”	9’
H5-H4	15”	18”	260’

Section	Current Size	Recommended Size	Approx Length
H4-H3	15”	18”	8’
H14-H13	8”	12”	447’
H13-H12	8”	12”	108’
H12-H11	8”	12”	334’
H11-H64	8”	12”	199’
H64-H71	8”	12”	161’
H71-H3	8”	12”	35’
H3-H2	15”	24”	31’
H2-I11	15”	24”	37’
I11-I10	15”	24”	380’
I10-I9	15”	24”	222’
I9-I8	15”	24”	155’
I8-I7	15”	24”	239’
I7-I6	15”	24”	259’
I6-I5	18”	24”	411’
I5-I31	18”	24”	135’
I31-I4	18”	24”	322’
I4-I3	18”	24”	243’
I3-T19	18”	24”	189’
A29-T29	18”	24”	346’
T29-T28	18”	24”	234’
T28-T27	18”	24”	163’
T27-T26	18”	24”	356’
T26-T25	18”	24”	306’
T25-T24	18”	24”	283’
T24-T23	18”	24”	317’
T23-T22	18”	24”	447’
T22-T21	18”	24”	198’
T21-T20	18”	24”	339’
T20-T19	18”	24”	332’
T19-T18	21”	24”	500’
T18-T17	21”	24”	541’
T17-T16	21”	24”	482’
T16-T15	24”	30”	35’
T15-T14	24”	30”	279’
T14-T13	24”	30”	479’
A23-A24	6"	8"	251'
A24-A25	6"	8"	254'
A25-A26	6"	8"	235'
A26-A27	6"	8"	311'

Table 8-2 shows the effects of the recommended pipe replacement. The HGL changes dramatically to relieve possible flooding in the system.

Table 8-2 Results of Improvements			
Monitoring Site	**Rim**	**HGL before improvements**	**HGL after improvements**
T29	4.98	4.82	0.39
B2	16	8.88	4.17
B16	20.39	18.08	14.71
D1	17.33	16.62	9.14
E1	12.09	13.5	4.5
T24	3.66	3.78	0.12
T22	2.81	3.33	-0.08
I11	8.07	7.6	0.84
T18	1.12	2.03	-0.94
T20	2.72	2.68	-0.24
K1	2.02	-0.54	-1.76
K28	3.27	1.23	0
M2	5.62	4.5	1.51
N1	5.32	0.78	-0.44
N8	13.8	4.33	4.33

Chapter 9 Capital Improvement Project

9.1 Phasing of the Improvements

A 15-year Capital Improvement Program is recommended to address capacity deficiencies in the system. The following phasing is recommended (Appendix G for addition information):

2015-2016 – replacing the siphon and downstream with 30” pipe (795LF)

2016-2017 – replacing part of Beech Street with 24” pipe (1300LF)

2017-2018 – replacing part of Beech Street with 24” pipe (1285LF)

2018-2019 – replacing part of Clarke Ave with 12” pipe (1600LF)

2019-2020 – replacing part of Green Street with 18” pipe (1325LF)

2020-2021 – replacing part of the 18” trunkline with 24” pipe (1025LF)

2021-2022 – replacing part of the 18” trunkline with 24” pipe (835LF)

2022-2023 – replacing part of the 18” trunkline with 24” pipe (985LF)

2023-2024 – replacing part of the 18” trunkline with 24” pipe (905LF)

2024-2025 – replacing part of the 18” trunkline with 24” pipe (1100LF)

2025-2026 – replace freeway crossing at Manhattan Avenue with a new 12” pipe (490LF)

2026-2027 – replacing pipe at two locations. One at O’Connor Street, and the other along Euclid and Bayshore Rd. (1025LF)

2027-2028 – replacing pipe on Pulgas Ave and Tara Street with new 8” pipe (2045LF)

2028-2029 – replacing pipe on Demeter Street with new 8” pipe (1605LF)

2029-2030 – replacing pipe on Menalto Ave with new 8” pipe (1370LF)

9.2 – Project Costs

The estimated cost of the project would be 12 million dollars, which is based on the number of manholes, length of pipe and includes engineering costs. This spread over a time period of 15 years would result in an average of $800,000.00/yr for 15 years. This does not include the cost for new laterals. In some cases, additional costs are included in the estimate to cover site-specific requirements such as work in high-traffic areas, contaminated soils, and environmentally sensitive areas. The price breakdown can be found on Appendix J.

In addition to these improvements, the District is continuing the televising of main lines, which will further determine pipe sections in need of replacement. Results from the televising may call for changes to scheduling and budget and should also be taken under consideration.

APPENDIX

SANITARY SEWER SYSTEM

EAST PALO ALTO SANITARY DISTRICT

Appendix A

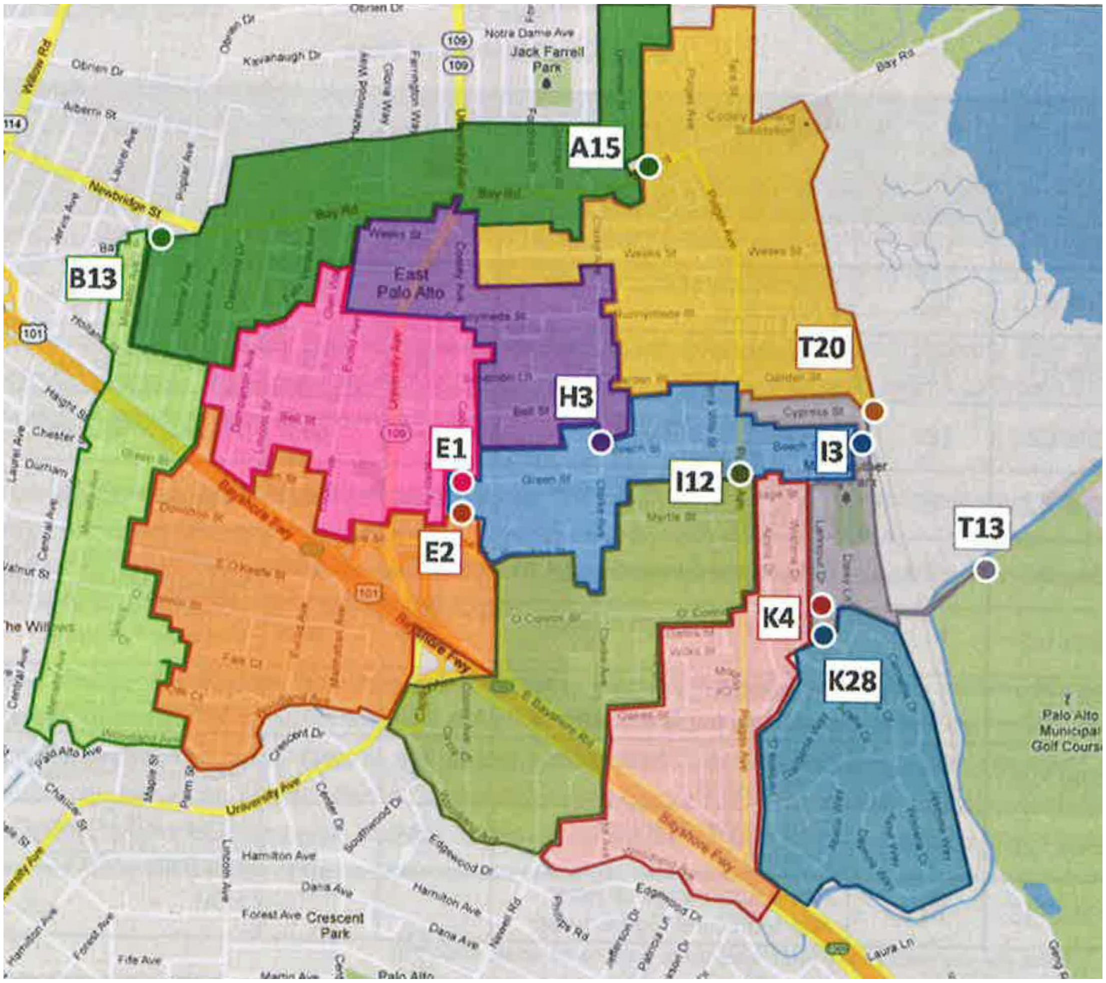
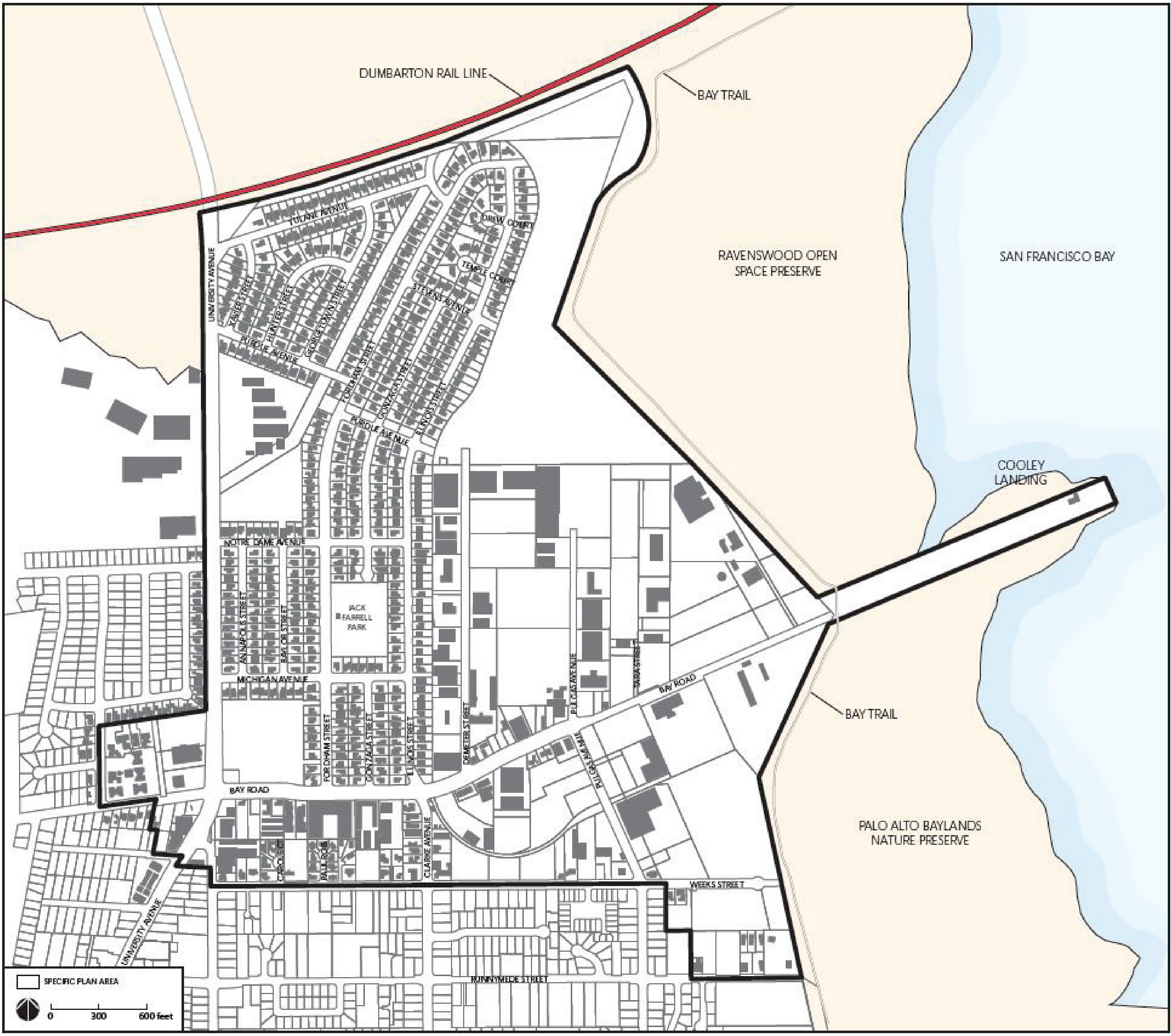
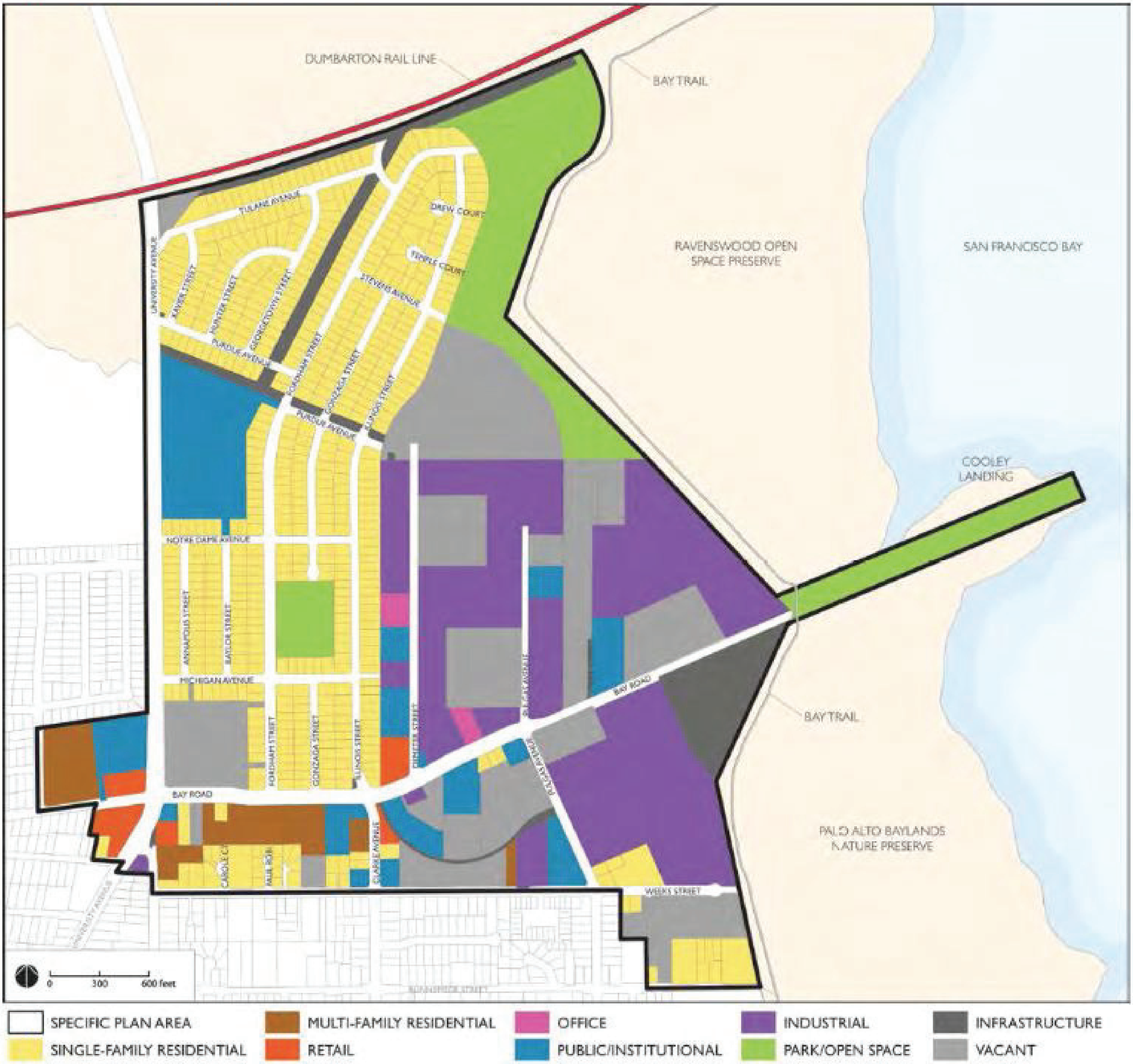


TABLE ES-1. List of Flow Monitoring Sites		
Site	**Location**	**Basin Size (acres)**
A15	Bay Rd, East of Demeter St.	118
B13	Intersection of Bay Rd and Poplar Ave	87
E1	Intersection of Cooley Ave and Green St.	101
E2	Cooley Ave, North of Donohoe St.	149
H3	Intersection of Clarke Ave and Beech St.	74
I3	East end of Beech St.	74
I12	Pulgas Ave, North of Sage St.	135
K4	Intersection O'Connor St and Larkspur Dr	107
K28	Larkspur Dr, South of O'Connor St.	95
T20	75 feet East of end of Cypress St.	171
T13	Along North edge of Palo Alto Municipal Golf Course	-


DUMBARTON RAIL LINE
BAY TRAIL
RAVENSWOOD OPEN SPACE PRESERVE
SAN FRANCISCO BAY
COOLEY LANDING
BAY TRAIL
PALO ALTO BAYLANDS NATURE PRESERVE
TULANE AVENUE
DREW COURT
TEMPLE COURT
STEVENS AVENUE
UNIVERSITY AVENUE
KAISER STREET
HUNTER STREET
GEORGETOWN STREET
PURDUE AVENUE
FORDHAM STREET
GONZAGA STREET
ILLINOIS STREET
PURDUE AVENUE
NOTRE DAME AVENUE
JACK FARRELL PARK
ANNAPOLIS STREET
BAYLOR STREET
MICHIGAN AVENUE
FORDHAM STREET
GONZAGA STREET
ILLINOIS STREET
DEMETER STREET
PULGAS AVENUE
TARA STREET
BAY ROAD
BAY ROAD
CAROL ST
PALS ROB
CLARKE AVENUE
WEEKS STREET
RUNNYMEDE STREET
UNIVERSITY AVENUE
SPECIFIC PLAN AREA
0
300
600 feet

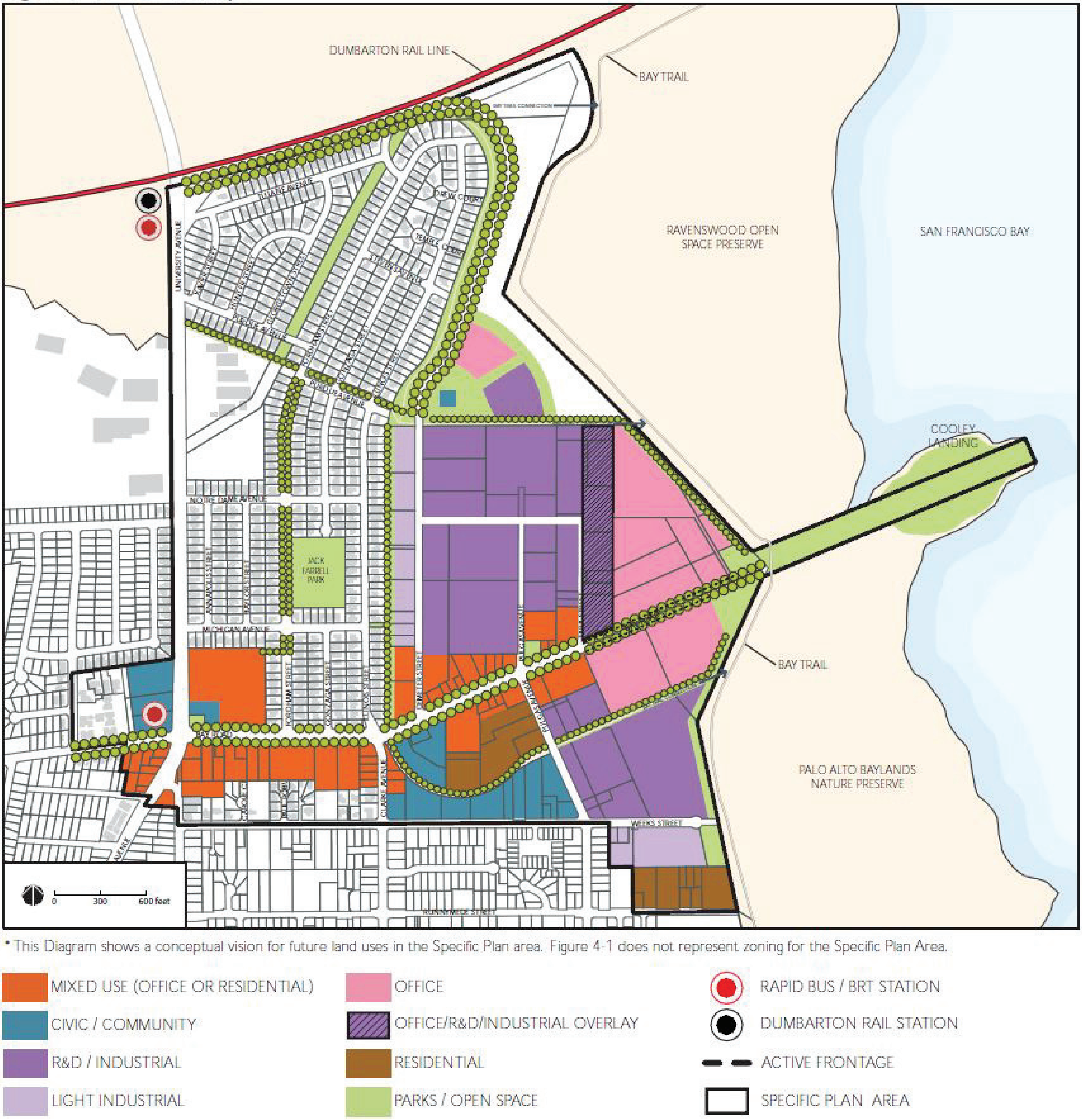
Appendix C

Figure 3-1: Existing Land Use



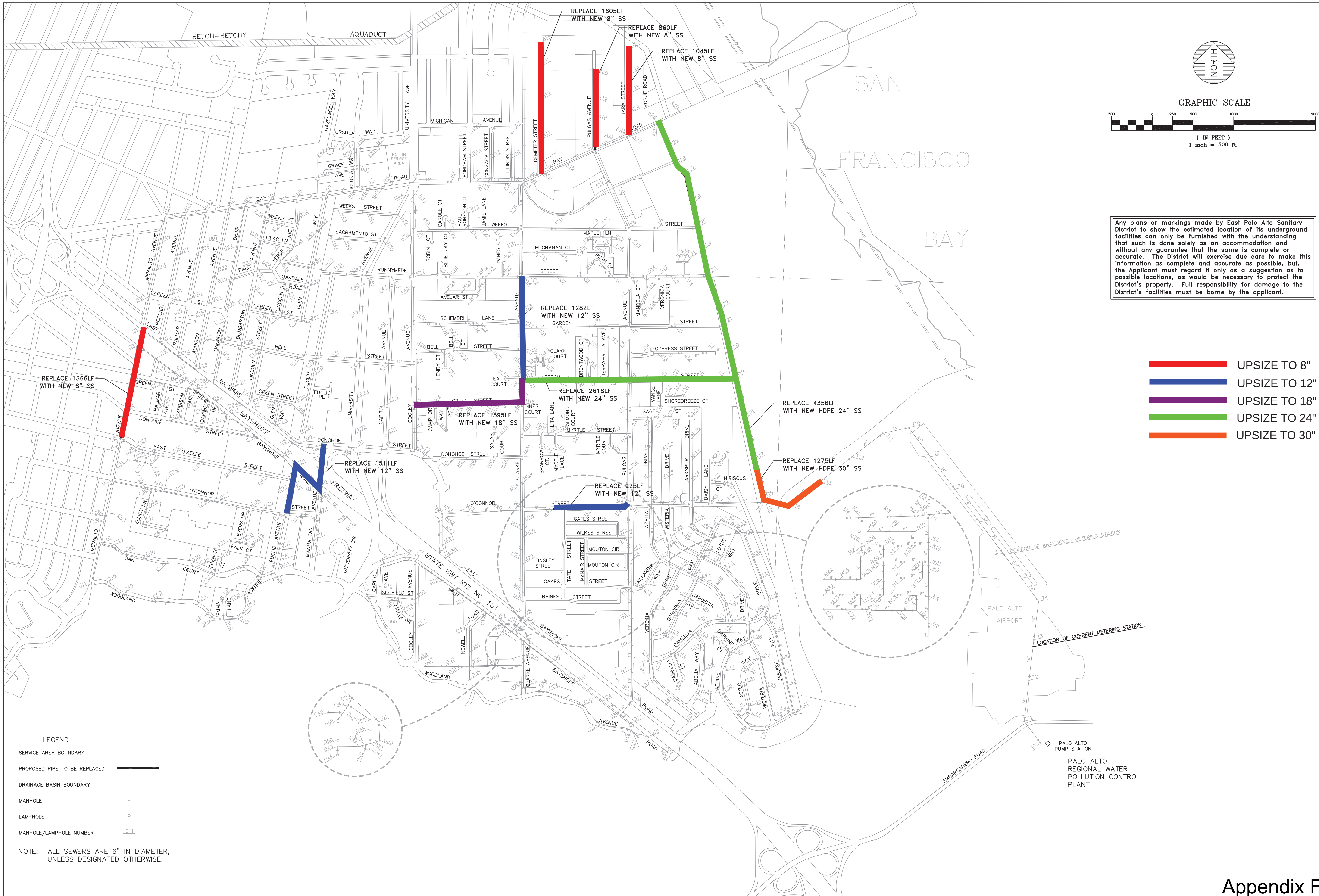
Appendix D

Figure 4-1: Plan Concept



* This Diagram shows a conceptual vision for future land uses in the Specific Plan area. Figure 4-1 does not represent zoning for the Specific Plan Area.

Appendix E



Appendix F

EPASD IMPROVEMENT PLAN
EAST PALO ALTO SANITARY DISTRICT
EAST PALO ALTO, CALIFORNIA

SUBCONSULTANT:

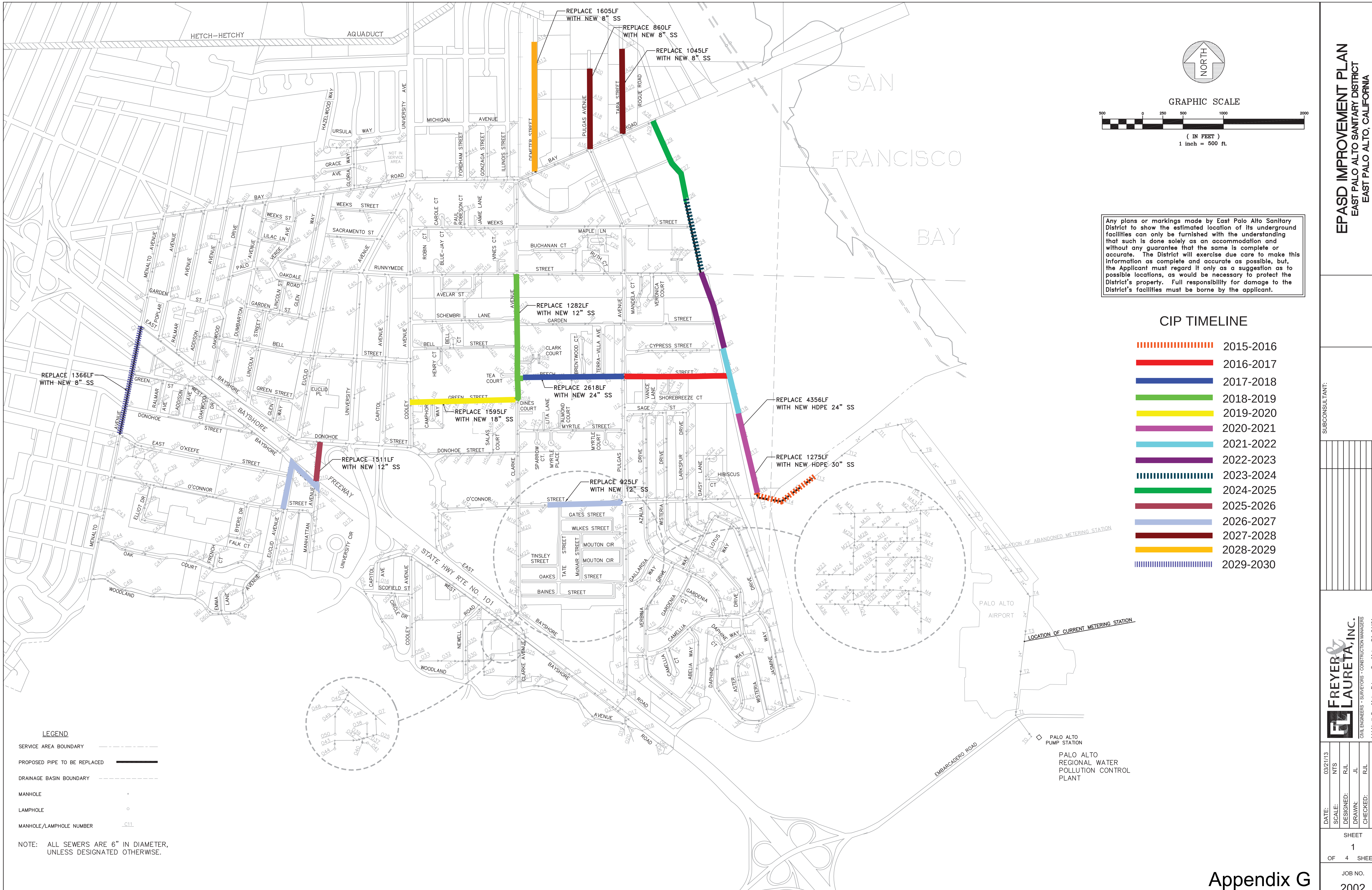
DATE	DESCRIPTION

FREYER & LAURETA, INC.
CIVIL ENGINEERS • SURVEYORS • CONSTRUCTION MANAGERS
144 North San Mateo Drive • San Mateo, CA 94401
(650)344-9901 • Fax (650)344-9920 • www.freyerlaureta.com

DATE:	03/21/13
SCALE:	NTS
DESIGNED:	RJL
DRAWN:	JL
CHECKED:	RJL
PROJ. ENGR:	RJL

SHEET
1
OF 4 SHEET

JOB NO.
2002

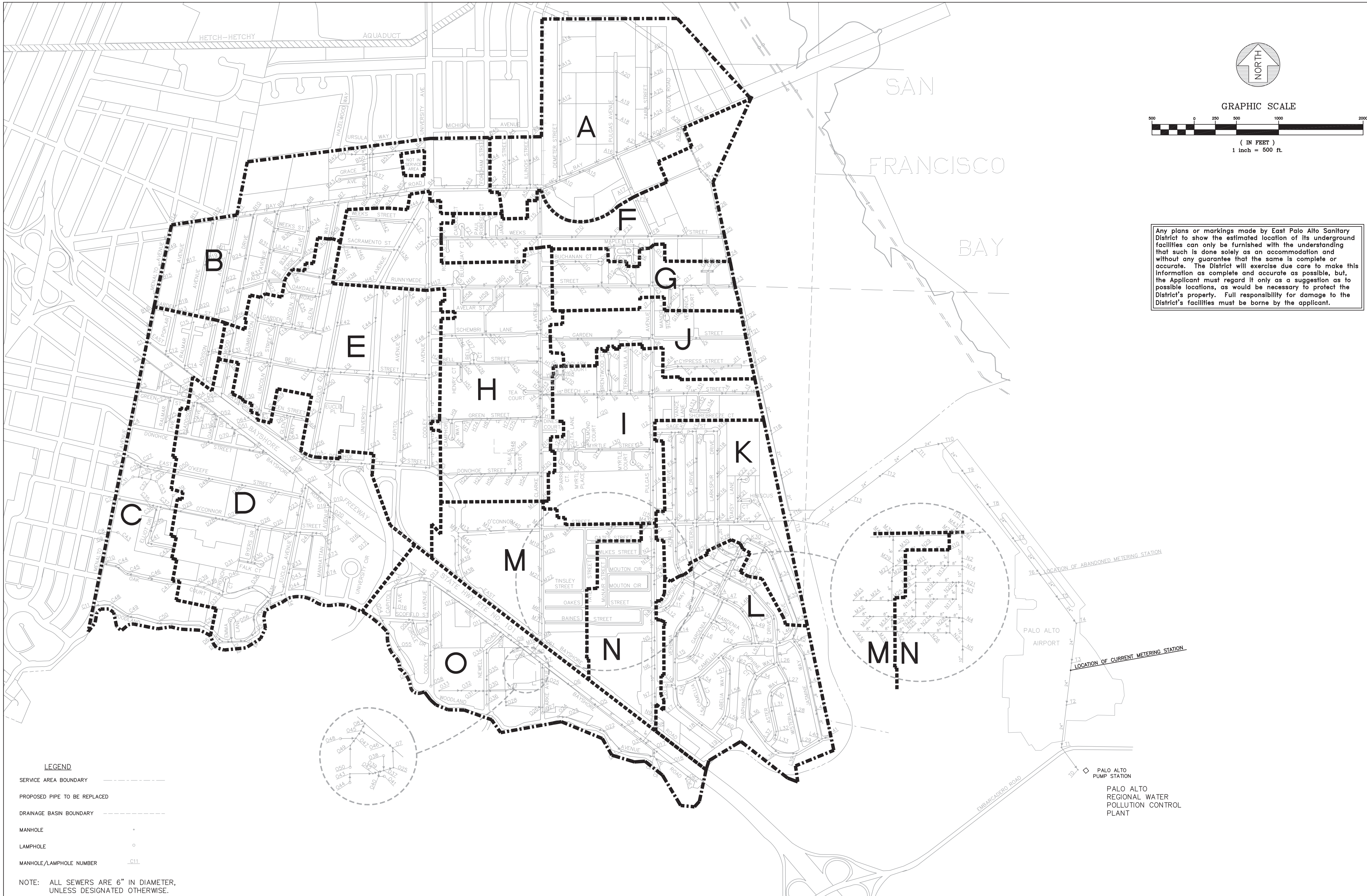

EPASD IMPROVEMENT PLAN
EAST PALO ALTO SANITARY DISTRICT
EAST PALO ALTO, CALIFORNIA
NORTH
GRAPHIC SCALE
(IN FEET)
1 inch = 500 ft.
Any plans or markings made by East Palo Alto Sanitary District to show the estimated location of its underground facilities can only be furnished with the understanding that such is done solely as an accommodation and without any guarantee that the same is complete or accurate. The District will exercise due care to make this information as complete and accurate as possible, but, the Applicant must regard it only as a suggestion as to possible locations, as would be necessary to protect the District's property. Full responsibility for damage to the District's facilities must be borne by the applicant.
CIP TIMELINE
2015-2016
2016-2017
2017-2018
2018-2019
2019-2020
2020-2021
2021-2022
2022-2023
2023-2024
2024-2025
2025-2026
2026-2027
2027-2028
2028-2029
2029-2030
REPLACE 1605LF WITH NEW 8" SS
REPLACE 860LF WITH NEW 8" SS
REPLACE 1045LF WITH NEW 8" SS
REPLACE 1282LF WITH NEW 12" SS
REPLACE 2618LF WITH NEW 24" SS
REPLACE 1595LF WITH NEW 18" SS
REPLACE 1366LF WITH NEW 8" SS
REPLACE 1511LF WITH NEW 12" SS
REPLACE 925LF WITH NEW 12" SS
REPLACE 4356LF WITH NEW HDPE 24" SS
REPLACE 1275LF WITH NEW HDPE 30" SS
SAN FRANCISCO BAY
HETCH-HETCHY AQUADUCT
STATE HWY RTE NO. 101
PALO ALTO AIRPORT
LOCATION OF CURRENT METERING STATION
LOCATION OF ABANDONED METERING STATION
PALO ALTO PUMP STATION
PALO ALTO REGIONAL WATER POLLUTION CONTROL PLANT
EMBARCADERO ROAD
LEGEND
SERVICE AREA BOUNDARY
PROPOSED PIPE TO BE REPLACED
DRAINAGE BASIN BOUNDARY
MANHOLE
LAMPHOLE
MANHOLE/LAMPHOLE NUMBER
NOTE: ALL SEWERS ARE 6" IN DIAMETER, UNLESS DESIGNATED OTHERWISE.
FREYER & LAURETA, INC.
CIVIL ENGINEERS • SURVEYORS • CONSTRUCTION MANAGERS
144 North San Mateo Drive • San Mateo, CA 94401
(650)344-9901 • Fax (650)344-9920 • www.freyerlaureta.com
SUBCONSULTANT:
DESCRIPTION
DATE
DATE: 03/21/13
SCALE: NTS
DESIGNED: RJL
DRAWN: JL
CHECKED: RJL
PROJ. ENGR: RJL
SHEET 1 OF 4 SHEET
JOB NO. 2002

Appendix G

Flow Results at Down stream Basins

Basin	Monitoring Site	Average Flow (cfs)	Peak Flow (cfs)	Storm and Peak Flow (cfs)
A	T29	0.6308	0.9712	3.899
B	B2	0.5438	0.8403	1.57
C	B16	0.171	0.3604	0.7693
D	D1	0.4121	1.2366	2.12
E	E1	0.6185	1.5098	3.026
F	T24	0.6948	1.0058	4.76
G	T22	0.7858	1.0354	4.9
H	I11	0.8969	1.8097	3.938
I	T18	2.1091	3.8491	10.15
J	T20	0.842	1.0574	5.01
K	K1	0.4075	0.98	1.56
L	K28	0.216	0.573	1.0554
M	M2	0.2574	0.8364	0.8976
N	N1	0.156	0.3156	0.4
O	N8	0.1108	0.19	0.2967

Basin	Monitoring Site	Average Flow (mgd)	Peak Flow (mgd)	Wet weather Peak Flow (mgd)
A	T29	0.98	1.50	6.03
B	B2	0.84	1.30	2.43
C	B16	0.26	0.56	1.19
D	D1	0.64	1.91	3.28
E	E1	0.96	2.34	4.68
F	T24	1.08	1.56	7.37
G	T22	1.22	1.60	7.58
H	I11	1.39	2.80	6.09
I	T18	3.26	5.96	15.71
J	T20	1.30	1.64	7.75
K	K1	0.63	1.52	2.41
L	K28	0.33	0.89	1.63
M	M2	0.40	1.29	1.39
N	N1	0.24	0.49	0.62
O	N8	0.17	0.29	0.46



Appendix I

EPASD BASIN MAP
EAST PALO ALTO SANITARY DISTRICT
EAST PALO ALTO, CALIFORNIA

SUBCONSULTANT:

DATE | DESCRIPTION

FREYER & LAURETA, INC.
CIVIL ENGINEERS • SURVEYORS • CONSTRUCTION MANAGERS
144 North San Mateo Drive • San Mateo, CA 94401
(650)344-9901 • Fax (650)344-9920 • www.freyerlaureta.com

DATE:	03/21/13
SCALE:	NTS
DESIGNED:	RJL
DRAWN:	JL
CHECKED:	RJL
PROJ. ENGR:	RJL

SHEET 1 OF 1 SHEET

JOB NO. 2002

Recommended Pipes to be Upsized

Section		Street	Current Size	Recommended Size	Approx Length	Unit Cost	Pipeline Cost	MH	Total Cost	Project Cost
C5	C4	Menalto Avenue	6"	8"	328	180	59,040	6,000	65,040	
C4	C3	Menalto Avenue	6"	8"	436	180	78,480	6,000	84,480	
C3	C2	Menalto Avenue	6"	8"	398	180	71,640	6,000	77,640	
C2	C1	Highway 101 Crossing	6"	8"	205	1200	246,000	10,000	256,000	
										$483,160
D24	D23	Euclid Avenue	8"	12"	350	200	70,000	6,000	76,000	
D23	D22	Euclid Avenue	8"	12"	74	200	14,800	6,000	20,800	
D22	D21	Euclid Avenue	8"	12"	149	200	29,800	6,000	35,800	
D21	D19	W. Bayshore	8"	12"	391	200	78,200	6,000	84,200	
D19	D10	W. Bayshore	10"	12"	49	200	9,800	6,000	15,800	
D10	D3	Highway 101 Crossing	10"	12"	490	1200	588,000	10,000	598,000	
										$830,600
A14	A13	Demeter Street	6"	8"	289	180	52,020	6,000	58,020	
A13	A12	Demeter Street	6"	8"	412	180	74,160	6,000	80,160	
A12	A11	Demeter Street	6"	8"	486	180	87,480	6,000	93,480	
A11	A10	Demeter Street	6"	8"	418	180	75,240	6,000	81,240	
										$312,900
A20	A19	Pulgas Ave. (north of Bay)	6"	8"	340	180	61,200	6,000	67,200	
A19	A18	Pulgas Ave. (north of Bay)	6"	8"	214	180	38,520	6,000	44,520	
A18	A16	Pulgas Ave. (north of Bay)	6"	8"	442	180	79,560	6,000	85,560	
										$197,280
A27	A26	Tara Street	6"	8"	311	180	55,980	6,000	61,980	
A26	A25	Tara Street	6"	8"	234	180	42,120	6,000	48,120	
A25	A24	Tara Street	6"	8"	253	180	45,540	6,000	51,540	
A24	A23	Tara Street	6"	8"	251	180	45,180	6,000	51,180	
										$212,820
M4	M3	O'Connor Street	8"	12"	358	200	71,600	6,000	77,600	
M3	M2	O'Connor Street	8"	12"	380	200	76,000	6,000	82,000	
M2	M43	O'Connor Street	8"	12"	48	200	9,600	6,000	15,600	
										$175,200
E1	H9	Green Street	12"	18"	270	220	59,400	6,000	65,400	
H9	H73	Green Street	12"	18"	247	220	54,340	6,000	60,340	
H73	H74	Green Street	12"	18"	101	220	22,220	6,000	28,220	
H74	H8	Green Street	12"	18"	113	220	24,860	6,000	30,860	
H8	H7	Green Street	12"	18"	234	220	51,480	6,000	57,480	
H7	H75	Green Street	12"	18"	90	220	19,800	6,000	25,800	
H75	H6	Green Street	12"	18"	260	220	57,200	6,000	63,200	
H6	H5	Clarke Street	12"	18"	9	220	1,980	6,000	7,980	
H5	H4	Clarke Street	15"	18"	260	220	57,200	6,000	63,200	
H4	H3	Clarke Street	15"	18"	8	220	1,760	6,000	7,760	
										$410,240
H14	H13	Clarke Street	8"	12"	447	200	89,400	6,000	95,400	
H13	H12	Clarke Street	8"	12"	108	200	21,600	6,000	27,600	
H12	H11	Clarke Street	8"	12"	334	200	66,800	6,000	72,800	
H11	H64	Clarke Street	8"	12"	199	200	39,800	6,000	45,800	
H64	H71	Clarke Street	8"	12"	161	200	32,200	6,000	38,200	
H71	H3	Clarke Street	8"	12"	35	200	7,000	6,000	13,000	
H3	H2	Beech Street	15"	24"	31	300	9,300	6,000	15,300	
H2	I11	Beech Street	15"	24"	37	300	11,100	6,000	17,100	
I11	I10	Beech Street	15"	24"	380	300	114,000	6,000	120,000	
I10	I9	Beech Street	15"	24"	222	300	66,600	6,000	72,600	
I9	I8	Beech Street	15"	24"	155	300	46,500	6,000	52,500	
I8	I7	Beech Street	15"	24"	239	300	71,700	6,000	77,700	
I7	I6	Beech Street	15"	24"	259	300	77,700	6,000	83,700	
I6	I5	Beech Street	18"	24"	411	300	123,300	6,000	129,300	
I5	I31	Beech Street	18"	24"	135	300	40,500	6,000	46,500	
I31	I4	Beech Street	18"	24"	322	300	96,600	6,000	102,600	
I4	I3	Beech Street	18"	24"	243	300	72,900	6,000	78,900	
I3	T19	Beech Street	18"	24"	189	300	56,700	6,000	62,700	
										$1,151,700
A29	T29	Bay Road	18"	24"	346	1000	346,000	10,000	356,000	
T29	T28	Easement (Levee)	18"	24"	234	1000	234,000	10,000	244,000	
T28	T27	Easement (Levee)	18"	24"	163	1000	163,000	10,000	173,000	
T27	T26	Easement (Levee)	18"	24"	356	1000	356,000	10,000	366,000	
T26	T25	Easement (Levee)	18"	24"	306	1000	306,000	10,000	316,000	
T25	T24	Easement (Levee)	18"	24"	283	1000	283,000	10,000	293,000	
T24	T23	Easement (Levee)	18"	24"	317	1000	317,000	10,000	327,000	
T23	T22	Easement (Levee)	18"	24"	447	1000	447,000	10,000	457,000	
T22	T21	Easement (Levee)	18"	24"	198	1000	198,000	10,000	208,000	
T21	T20	Easement (Levee)	18"	24"	339	1000	339,000	10,000	349,000	
T20	T19	Easement (Levee)	18"	24"	332	1000	332,000	10,000	342,000	
T19	T18	Easement (Levee)	21"	24"	500	1000	500,000	10,000	510,000	
T18	T17	Easement (Levee)	21"	24"	541	1000	541,000	10,000	551,000	
T17	T16	Easement (Levee)	21"	24"	482	1000	482,000	10,000	492,000	
T16	T15	Easement (Levee)	24"	30"	35	1200	42,000	10,000	52,000	
T15	T14	Siphon	24"	30"	279	2500	697,500	10,000	707,500	
T14	T13	Easement (Levee)	24"	30"	479	1200	574,800	10,000	584,800	
										$6,328,300

Total Linear Feet	**18,442**	**Anticipated Cost**	**$10,102,200**

System Improvement Results

Monitoring Site	Rim	HGL before improvements	HGL after improvements
T29	4.98	4.82	0.39
B2	16	8.88	4.17
B16	20.39	18.08	14.71
D1	17.33	16.62	9.14
E1	12.09	13.5	4.5
T24	3.66	3.78	0.12
T22	2.81	3.33	-0.08
I11	8.07	7.6	0.84
T18	1.12	2.03	-0.94
T20	2.72	2.68	-0.24
K1	2.02	-0.54	-1.76
K28	3.27	1.23	0
M2	5.62	4.5	1.51
N1	5.32	0.78	-0.44
N8	13.8	4.33	4.33



2011-2012 SANITARY SEWER FLOW MONITORING AND INFLOW / INFILTRATION STUDY

East Palo Alto Sanitary District

June 2012

V&A

SANITARY SEWER FLOW MONITORING AND INFLOW / INFILTRATION STUDY

East Palo Alto Sanitary District

Prepared for

EPASD

Prepared by

V&A

June 2012

TABLE OF CONTENTS

TABLES

FIGURES

APPENDIX

ABBREVIATIONS, TERMS AND DEFINITIONS USED IN THIS REPORT

Table i.
Abbreviations

Abbreviation	Term
ADWF	average dry weather flow
CCTV	closed-circuit television
CIP	capital improvement plan
CO	carbon monoxide
d/D	depth/diameter ratio
FM	flow monitor
gpd	gallons per day
gpm	gallons per minute
GWI	groundwater infiltration
H_2S	hydrogen sulfide
I/I	inflow and infiltration
IDM	inch-diameter-mile (miles of pipeline multiplied by the diameter of the pipeline in inches)
IDW	inverse distance weighting
LEL	lower explosive limit
mgd	million gallons per day
NOAA	National Oceanic and Atmospheric Administration
Q	flow rate
RDI	rainfall-dependent infiltration
RRI	rainfall-responsive infiltration
RG	rain gauge
SSO	sanitary sewer overflow
WEF	Water Environment Federation
WRCC	Western Regional Climate Center

Table ii.
Terms and Definitions

Term	Definition
Attenuation	Flow attenuation in a sewer collection system is the natural process of the reduction of the peak flow rate through redistribution of the same volume of flow over a longer period of time. This occurs as a result of friction (resistance), internal storage and a tendency to reach a steady state along the sewer pipes. As the flows from the basins combine within the trunk sewer lines, the peaks from each basin will (a) not necessary coincide at the same time, and (b) due to the length and time of travel through the trunk sewers, peak flows will ***attenuate*** as the peak flows move downstream. The sum of the peak flows of individual basins upstream will generally be greater than the measured peak flows observed at points downstream.
Average dry weather flow (ADWF)	Average flow rate or pattern from days without noticeable inflow or infiltration response. ADWF usage patterns for weekdays and weekends differ and must be computed separately. ADWF can be expressed as a numeric average or as a curve showing the variation in flow over a day. ADWF includes the influence of normal groundwater infiltration (not related to a rain event).
Basin	Sanitary sewer collection system upstream of a given location (often a flow meter), including all pipelines, inlets, and appurtenances. Also refers to the ground surface area near and enclosed by the pipelines. A basin may refer to the entire collection system upstream from a flow meter or exclude separately monitored basins upstream.
Depth/diameter (*d*/*D*) ratio	Depth of water in a pipe as a fraction of the pipe's diameter. A measure of fullness of the pipe used in capacity analysis.
Design storm	A theoretical storm event of a given duration and intensity that aligns with historical frequency records of rainfall events. For example, a 10-year, 24-hour design storm is a storm event wherein the volume of rain that falls in a 24-hour period would historically occur once every 10 years. Design storm events are used to predict I/I response and are useful for modeling how a collection system will react to a given set of storm event scenarios.
Infiltration and inflow	Infiltration and inflow (I/I) rates are calculated by subtracting the ADWF flow curve from the instantaneous flow measurements taken during and after a storm event. Flow in excess of the baseline consists of inflow, rainfall-responsive infiltration, and rainfall-dependent infiltration. **Combined I/I** is the total sum in gallons of additional flow attributable to a storm event.
Infiltration, *groundwater*	Groundwater infiltration (**GWI**) is groundwater that enters the collection system through pipe defects. GWI depends on the depth of the groundwater table above the pipelines as well as the percentage of the system submerged. The variation of groundwater levels and subsequent groundwater infiltration rates is seasonal by nature. On a day-to-day basis, groundwater infiltration rates are relatively steady and will not fluctuate greatly.
Infiltration, *rainfall-dependent*	Rainfall-dependent infiltration (**RDI**) is similar to groundwater infiltration but occurs as a result of storm water. The storm water percolates into the soil, submerges more of the pipe system, and enters through pipe defects. RDI is the slowest component of storm-related infiltration and inflow, beginning gradually and often lasting 24 hours or longer. The response time depends on the soil permeability and saturation levels.
Infiltration, *rainfall-responsive*	Rainfall-responsive infiltration (**RRI**) is storm water that enters the collection system through pipe defects, but normally in sewers constructed close to the ground surface such as private laterals. RRI is independent of the groundwater

Term	Definition
	table and reaches defective sewers via the pipe trench in which the sewer is constructed, particularly if the pipe is placed in impermeable soil and bedded and backfilled with a granular material. In this case, the pipe trench serves as a conduit similar to a French drain, conveying storm drainage to defective joints and other openings in the system.
Inflow	**Inflow** is defined as water discharged into the sewer system, including private sewer laterals, from **direct** connections such as downspouts, yard and area drains, holes in manhole covers, cross-connections from storm drains, or catch basins. Inflow creates a peak flow problem in the sewer system and often dictates the required capacity of downstream pipes and transport facilities to carry these peak instantaneous flows. Overflows are often attributable to high inflow rates.
Normalization	To run an "apples-to-apples" comparison amongst different basins, calculated metrics must be **normalized**. Individual basins will have different runoff areas, pipe lengths and sanitary flows. There are three common methods of normalization. Depending on the information available, one or all methods can be applied to a given project: ❖ <u>Pipe Length:</u> The metric is divided by the length of pipe in the upstream basin expressed in units of inch-diameter-mile (IDM). ❖ <u>Basin Area:</u> The metric is divided by the estimated drainage area of the basin in acres. ❖ <u>ADWF:</u> The metric is divided by the average dry weather sanitary flow (ADWF).
Normalization, *inflow*	The peak I/I flow rate is used to quantify inflow. Although the instantaneous flow monitoring data will typically show an inflow peak, the inflow response is measured from the I/I flow rate (in excess of baseline flow). This removes the effect of sanitary flow variations and measures only the I/I response: ❖ <u>Pipe Length:</u> The peak I/I flow rate is divided by the length of pipe (IDM) in the upstream basin. The result is expressed in gallons per day (gpd) per IDM (gpd/IDM). ❖ <u>Basin Area:</u> The peak I/I flow rate is divided by the geographic area of the upstream basin. The result is expressed in gpd per acre. ❖ <u>ADWF:</u> The peak I/I flow rate is divided by the average dry weather flow (ADWF). This is a ratio and is expressed without units.
Normalization, *GWI*	The estimated GWI rates are compared to acceptable GWI rates, as defined by the Water Environment Federation, and used to identify basins with high GWI: ❖ <u>Pipe Length:</u> The GWI flow rate is divided by the length of pipe (IDM) in the upstream basin. The result is expressed in gallons per day (gpd) per IDM (gpd/IDM). ❖ <u>Basin Area:</u> The GWI flow rate is divided by the geographic area of the upstream basin. The result is expressed in gpd per acre. ❖ <u>ADWF:</u> The GWI flow rate is divided by the average dry weather flow (ADWF). This is a ratio and is expressed without units.

Term	Definition
Normalization, *RDI*	The estimated RDI rates at a period 24 hours or more after the conclusion of a storm event are used to identify basins with high RDI: ❖ Pipe Length: The RDI flow rate is divided by the length of pipe (IDM) in the upstream basin. The result is expressed in gallons per day (gpd) per IDM (gpd/IDM). ❖ Basin Area: The RDI flow rate is divided by the geographic area of the upstream basin. The result is expressed in gpd per acre. ❖ ADWF: The RDI flow rate is divided by the average dry weather flow (ADWF). This is a ratio and is expressed without units.
Normalization, *total I/I*	The estimated totalized I/I in gallons attributable to a particular storm event is used to identify basins with high total I/I. Because this is a totalized value rather than a rate and can be attributable solely to an individual storm event, the volume of the storm event is also taken into consideration. This allows for a comparison not only between basins but also between storm events: ❖ Pipe Length: Total gallons of I/I is divided by the length of pipe (IDM) in the upstream basin and the rainfall total (inches) of the storm event. The result is expressed in gallons per IDM per inch of rain. ❖ Basin Area (R-Value): Total gallons of I/I is divided by total gallons of rainfall water that fell within the acreage of the basin area. This is a ratio and expressed as a percentage. R-Value is described as "the percentage of rainfall that enters the collection system." Systems with R-Values less than 5%[1] are often considered to be performing well. ❖ ADWF: Total gallons of I/I is divided by the ADWF and the rainfall total of the storm event. The result is expressed in million gallons per MGD of ADWF per inch of rain.
Peaking factor	Ratio of peak measured flow to average dry weather flow. This ratio expresses the degree of fluctuation in flow rate over the monitoring period and is used in capacity analysis.
Surcharge	When the flow level is higher than the crown of the pipe, then the pipeline is said to be in a **surcharged** condition. The pipeline is surcharged when the *d/D* ratio is greater than 1.0.
Synthetic hydrograph	A set of algorithms developed to approximate the actual I/I hydrograph. The synthetic hydrograph is developed strictly using rainfall data and response parameters representing response time, recession coefficient and soil saturation.
Weekend/weekday ratio	The ratio of weekend ADWFs to weekday ADWFs. In residential areas, this ratio is typically slightly higher than 1.0. In business districts, depending on type of service, this ratio can be significantly less than 1.0.

[1] Keefe, P.N. "Test Basins for I/I Reduction and SSO Elimination." 1998 WEF Wet Weather Specialty Conference, Cleveland.

EXECUTIVE SUMMARY

Scope and Purpose

V&A has completed sanitary sewer flow monitoring, rainfall monitoring, and inflow and infiltration (I/I) analysis within the City of East Palo Alto (City) for the East Palo Alto Sanitary District (District). Flow and rainfall monitoring was performed over a six-week period at 11 open-channel flow monitoring sites within the District. The flow monitoring period began on February 16, 2012, and ended on April 3, 2012.

The purpose of this study was to measure sanitary sewer flows at the flow monitoring sites and estimate available sewer capacity and infiltration and inflow (I/I) occurring in the basins upstream from the flow monitoring sites.

Site Flow Monitoring and Capacity Results

Peak measured flows and the corresponding flow levels (depths) are important to understand the capacity of the flow monitoring system. Table 1 summarizes the peak recorded flows, levels, *d*/*D* ratios, and peaking factors per site during the flow monitoring period. Capacity analysis data is presented on a site-by-site basis and represents the hydraulic conditions only at the site locations; hydraulic conditions in other areas of the collection system will differ.

Table 1.
Capacity Analysis Summary

Site	ADWF (mgd)	Peak Measured Flow (mgd)	Peaking Factor	Diameter (in)	Peak Level (in)	Peak *d*/*D* Ratio	Level Surcharged above Crown (ft)
Site A15	0.27	0.49	1.84	15	11.31	0.75	-
Site B13	0.06	0.18	3.04	12	4.44	0.37	-
Site E1	0.13	0.26	1.99	11.5	3.06	0.27	-
Site E2	0.25	0.60	2.37	18	4.90	0.27	-
Site H3	0.14	0.27	2.00	8	9.92	1.24	0.2
Site I3	0.83	1.45	1.74	17.5	11.85	0.68	-
Site I12	0.23	0.42	1.81	11.5	4.21	0.37	-
Site K4	0.22	0.53	2.44	12	8.82	0.74	-
Site K28	0.11	0.27	2.49	9.75	5.71	0.59	-
Site T20	0.40	0.73	1.83	17.5	8.42	0.48	-
Site T13	1.53	2.80	1.83	23.5	10.84	0.46	-

The following capacity analysis results are noted:

- **Peaking Factor:** Site B13 had a peaking factor that exceeded typical design threshold limits for the ratio of peak flow to average dry weather flow.
- ***d/D* Ratio:** Site H3 had a *d/D* ratio that exceeded the common design threshold for *d/D* ratio. This site exhibited a surcharged condition throughout a majority of the duration of the study. At the remainder of the sites, there were no capacity constraints during the rainfall events of this study; the local collection system had the ability to handle peak wet weather flows.

Figure 1 shows bar graphs of the capacity results. Figure 2 shows a schematic diagram of the peak measured flows with peak flow levels.

Figure 1. Capacity Summary Bar Graphs: Peaking Factors and Peak *d/D* Ratios

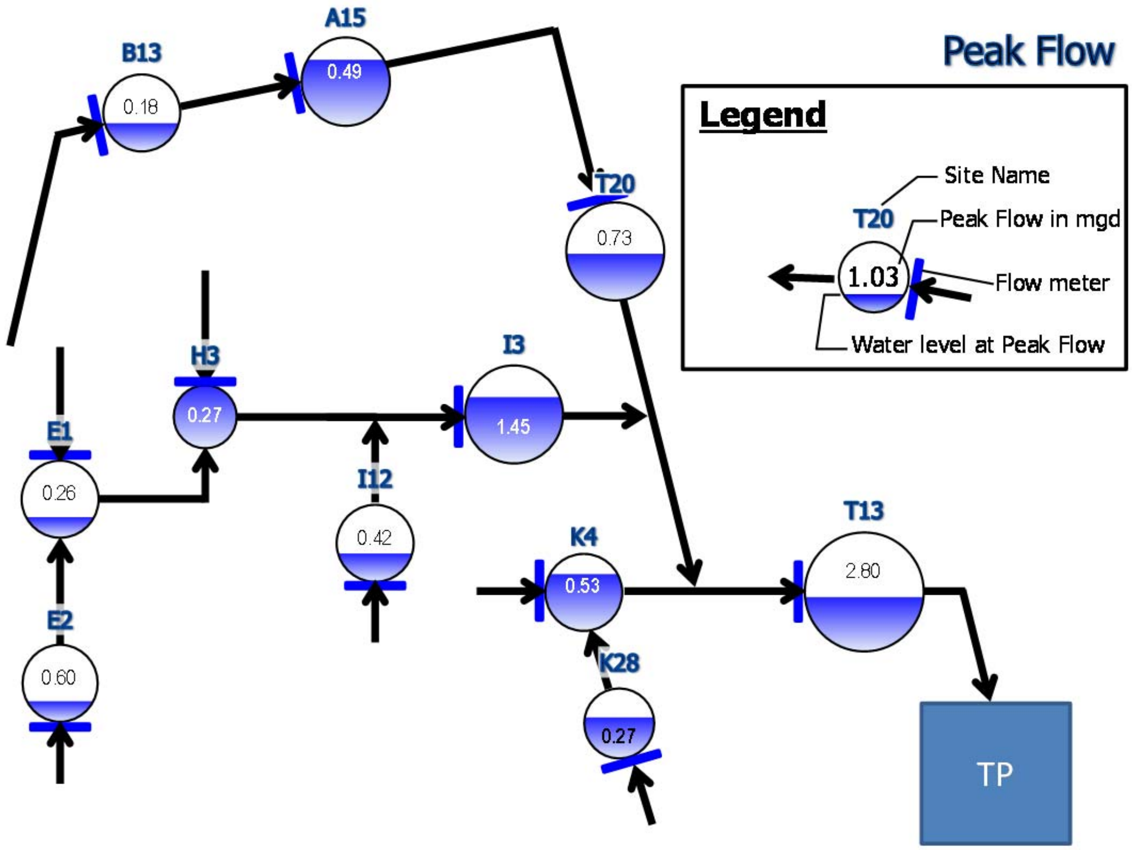


Figure 2. Peak Measured Flow (Flow Schematic)

Basin Inflow and Infiltration Analysis Results

Table 2 summarizes the flow monitoring and I/I results for the six flow monitoring basins that were isolated during this study. Infiltration and inflow rankings are shown such that 1 represents the highest infiltration or inflow contribution and 6 represents the least. Please refer to the *I/I Methods* section for more information on inflow and infiltration analysis methods and ranking methods.

Table 2.
I/I Analysis Summary

Basin	ADWF (mgd)	Inflow Ranking	RDI Ranking	Evidence of High GWI?	Combined I/I Ranking
Basin A15	0.21	10	8	No	6
Basin B13	0.059	4	9	No	7
Basin E1	0.13	6	3	Yes	9
Basin E2	0.25	3	5	No	5
Basin H3	0.14	5	6	No	10
Basin I3	0.08	9	4	No	4
Basin I12	0.23	8	10	No	8
Basin K4	0.22	1	2	Yes	2
Basin K28	0.11	2	1	Yes	1
Basin T20	0.14	7	7	Yes	3

The following inflow/infiltration analysis results are noted:

- **Inflow:** Basins K4 and K28 ranked highest for normalized inflow contribution.
- **Rainfall-Dependent Infiltration:** Basins K4 and K28 ranked highest for normalized RDI contribution.
- **Groundwater Infiltration:** Basins T20, E1, K4 and K28 have GWI rates that were ***above*** the WEF typical low-to-average ratio, indicating excessive groundwater infiltration.
- **Combined I/I:** Basin K28 ranked highest for normalized combined I/I contribution.

Figures 3 through 6 show temperature maps of the overall rankings for each inflow and infiltration component.

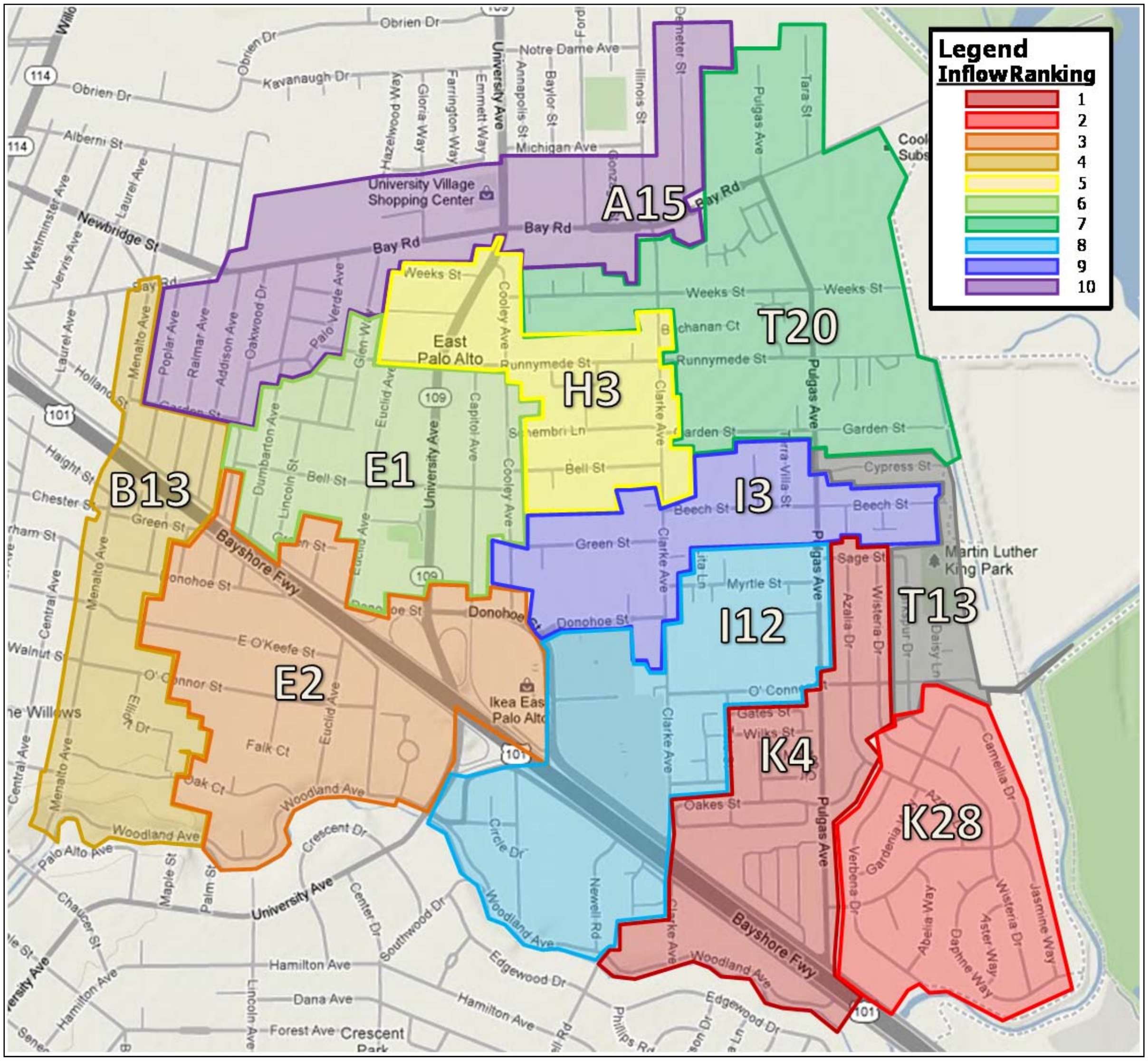


Figure 3. Inflow Temperature Map

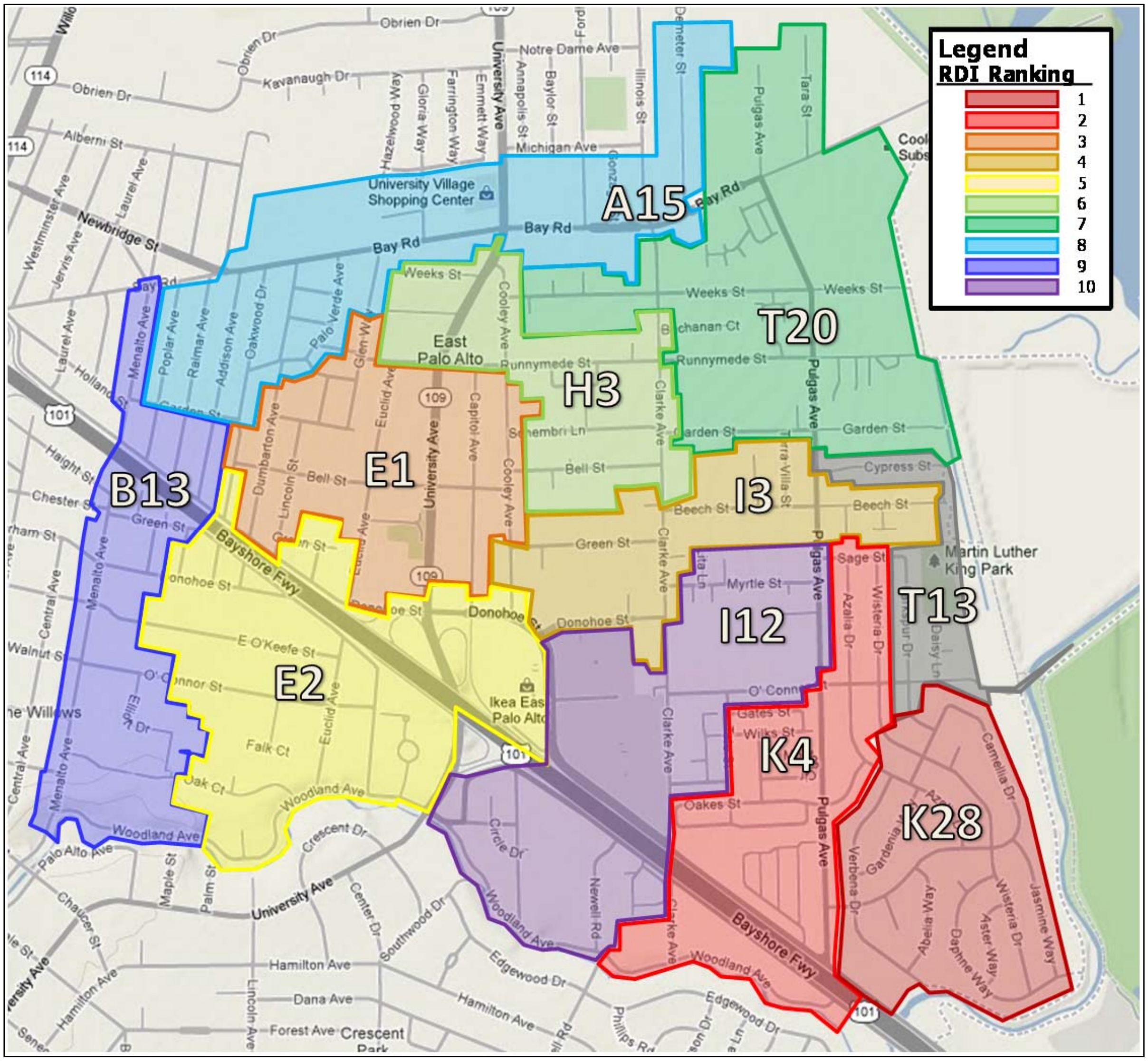


Figure 4. RDI Temperature Map

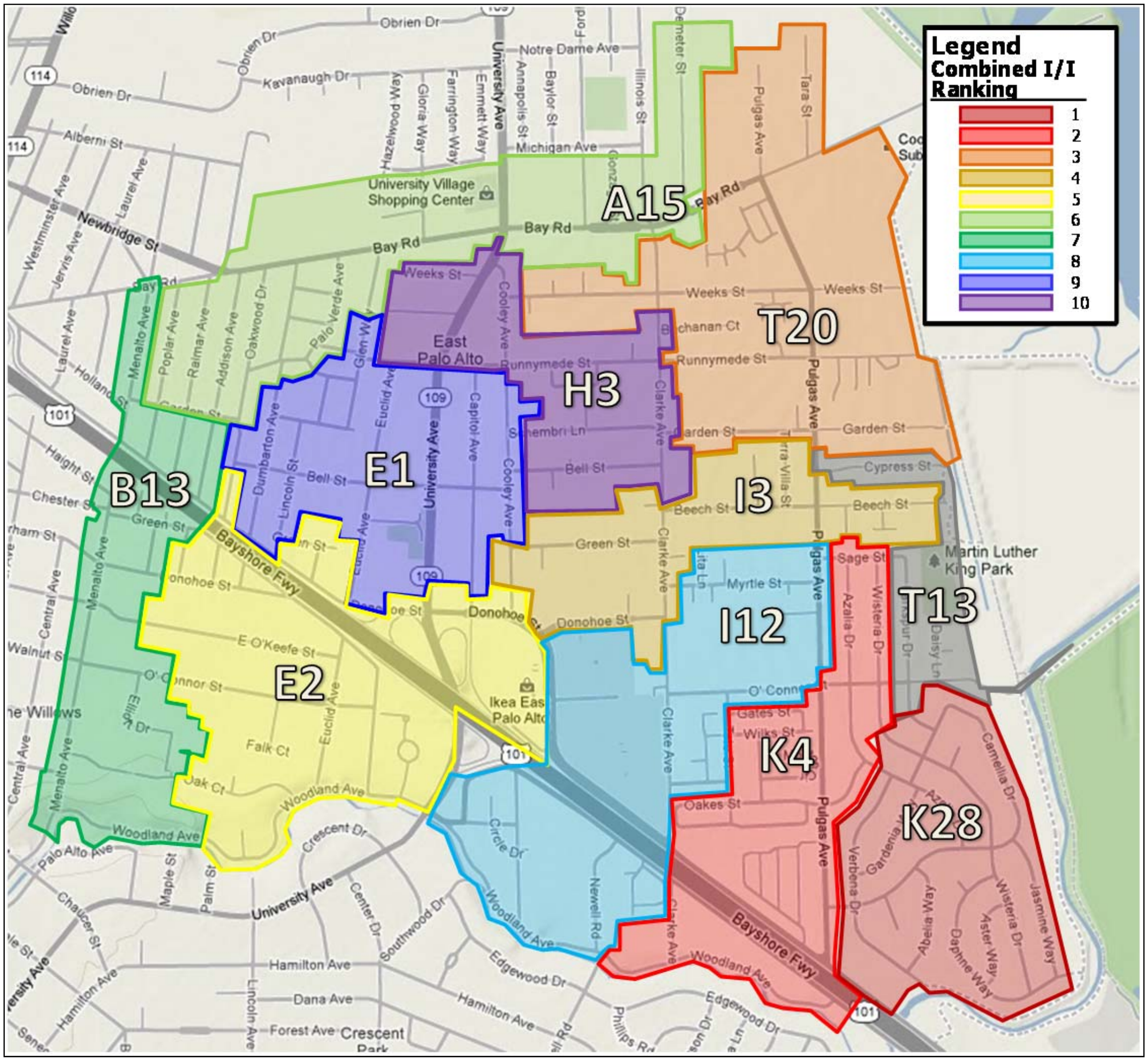


Figure 5. Combined I/I Temperature Map

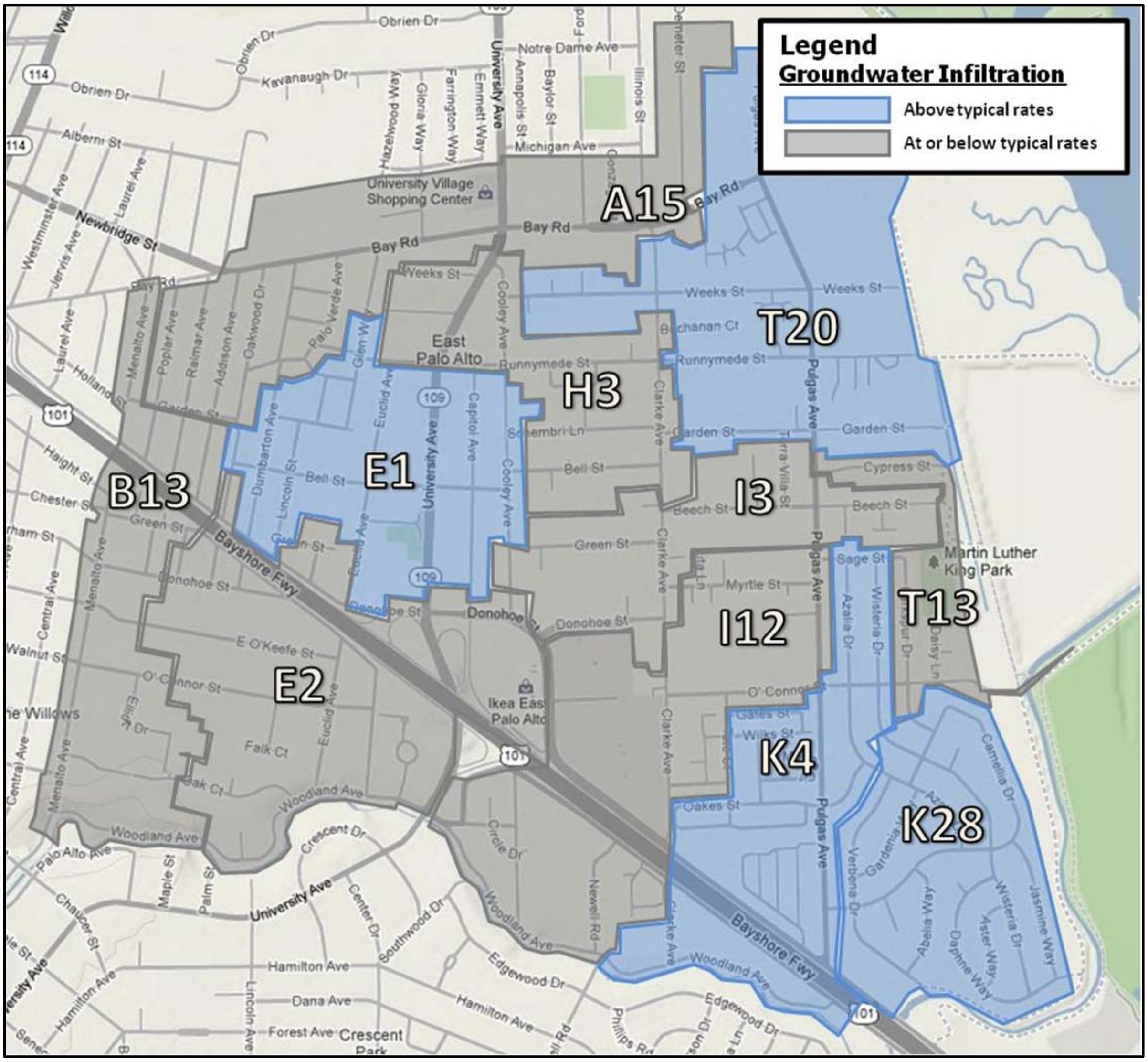


Figure 6. Groundwater Infiltration Temperature Map

Recommendations

V&A advises that future I/I reduction plans consider the following recommendations:

1. **Determine I/I Reduction Program:** The District should examine its I/I reduction needs to determine a future I/I reduction program.
    a. If peak flows, sanitary sewer overflows, and pipeline capacity issues are of greater concern, then priority can be given to investigate and reduce sources of inflow within the basins with the greatest inflow problems. The highest inflow occurred in Basins K4, K28 and E2.
    b. If total infiltration and general pipeline deterioration are of greater concern, then the program can be weighted to investigate and reduce sources of infiltration within the basins with the greatest infiltration problems.
        i. The highest normalized rainfall-dependent infiltration occurred in Basins K28, K4 and E1.
        ii. The highest groundwater infiltration occurred in Basins T13, K28, K4 and E1.
2. **I/I Investigation Methods:** Potential I/I investigation methods include the following:
    a. Smoke testing
    b. Mini-basin flow monitoring
    c. Nighttime reconnaissance work to (1) investigate and determine direct point sources of inflow and (2) determine the areas and pipe reaches responsible for high levels of infiltration contribution.
3. **I/I Reduction Cost-Effectiveness Analysis:** The District should conduct a study to determine which is more cost-effective: (1) locating the sources of inflow and infiltration and systematically rehabilitating or replacing the faulty pipelines or (2) continued treatment of the additional rainfall-dependent I/I flow.

INTRODUCTION

Scope and Purpose

V&A has completed sanitary sewer flow monitoring, rainfall monitoring, and inflow and infiltration (I/I) analysis within the East Palo Alto Sanitary District (District). Flow and rainfall monitoring was performed over a six-week period at 11 open-channel flow monitoring sites within the District's Sewer Basin 16. The flow monitoring period began on February 16, 2012, and ended on April 3, 2012.

The purpose of this study was to measure sanitary sewer flows at the flow monitoring sites and estimate available sewer capacity and infiltration and inflow (I/I) occurring in the basins upstream from the flow monitoring sites, as shown in Figure 7.

Flow Monitoring Sites: Flow monitoring sites are the locations where the flow monitors were placed. Flow monitoring site data may include the flows of one or many drainage basins. To isolate a flow monitoring basin, an addition or subtraction of flows may be required[2]. Capacity and flow rate information is presented on a site-by-site basis.

Flow Monitoring Basins: Flow monitoring basins are localized areas of a sanitary sewer collection system upstream of a given location (often a flow meter), including all pipelines, inlets, and appurtenances. The basin refers to the ground surface area near and enclosed by the pipelines[3]. A basin may refer to the entire collection system upstream from a flow meter or may exclude separately monitored basins upstream. I/I analysis in this report will be conducted on a basin-by-basin basis. For this study subtraction of flows was required to isolate the drainage areas of some flow monitoring basins.

Rain Gauges: Rain data was obtained from rain gauges that are maintained by weather enthusiasts. V&A performed a quality assurance and control review on the rain gauge data and normalized it to the system centroid.

Hydraulic Notes: The flow monitoring sites and associated basins are listed in Table 3 and illustrated in Figure 7. Also shown are the equations (in which *Q* refers to flow rate) used to calculate the flow rate results for each basin from the flow rates recorded at the monitoring sites. Detailed descriptions of the individual flow monitoring sites, including photographs, are included in *Appendix A*.

[2] There is error inherent in flow monitoring. Adding and subtracting flows increases error on an additive basis. For example, if Site A has an error of ±10% and Site B has an error of ±10%, then the resulting flow when subtracting Site A from Site B would have an error of up to ±20%.

[3] The basin areas (in acres) and basin pipe lengths (in IDM) were estimated by V&A by scaling maps provided by the District.

Table 3.
List of Flow Monitoring Sites

Site	Pipe Diameter (in)	Location	Basin Size (acres)	Basin Pipe Length (IDM[4])	Basin Flow Calculation
Site A15	15	Bay Rd., east of Demeter St.	118	30.5	$Q_{A15(Basin)} = Q_{A15(Site)} - Q_{B13(Site)}$
Site B13	12	Intersection of Bay Rd. and Poplar Ave.	87	21.3	$Q_{B13(Basin)} = Q_{B13(Site)}$
Site E1	11.5	Intersection of Cooley Ave. and Green St.	101	25.2	$Q_{E1(Basin)} = Q_{E1(Site)}$
Site E2	18	Cooley Ave., north of Donohoe St.	149	34.2	$Q_{E2(Basin)} = Q_{E2(Site)}$
Site H3	8	Intersection of Clarke Ave. and Beech St.	74	16.0	$Q_{H3(Basin)} = Q_{H3(Site)}$
Site I3	17.5	East end of Beech St.	74	18.8	$Q_{I3(Basin)} = Q_{I3(Site)} - [Q_{E1(Site)} + Q_{E2(Site)} + Q_{H3(Site)} + Q_{I12(Site)}]$
Site I12	11.5	Pulgas Ave., north of Sage St.	135	26.2	$Q_{I12(Basin)} = Q_{I12(Site)}$
Site K4	12	Intersection of O'Connor St. and Larkspur Dr.	107	29.8	$Q_{K4(Basin)} = Q_{K4(Site)}$
Site K28	9.75	Larkspur Dr., south of O'Connor St.	95	25.3	$Q_{K28(Basin)} = Q_{K28(Site)}$
Site T20	17.5	75 feet east of end of Cypress St.	171	35.8	$Q_{T20(Basin)} = Q_{T20(Site)} - [Q_{A15(Site)} + Q_{B13(Site)}]$
Site T13	23.5	Along north edge of Palo Alto Municipal Golf Course	-	-	N/A*

* This site was installed to provide systemwide data, not to isolate Basin T13.

[4] Inch-diameter-mile (miles of pipeline multiplied by the diameter of the pipeline in inches). This is the industry-standard unit of measurement for stating length of pipe within a sanitary drainage basin.

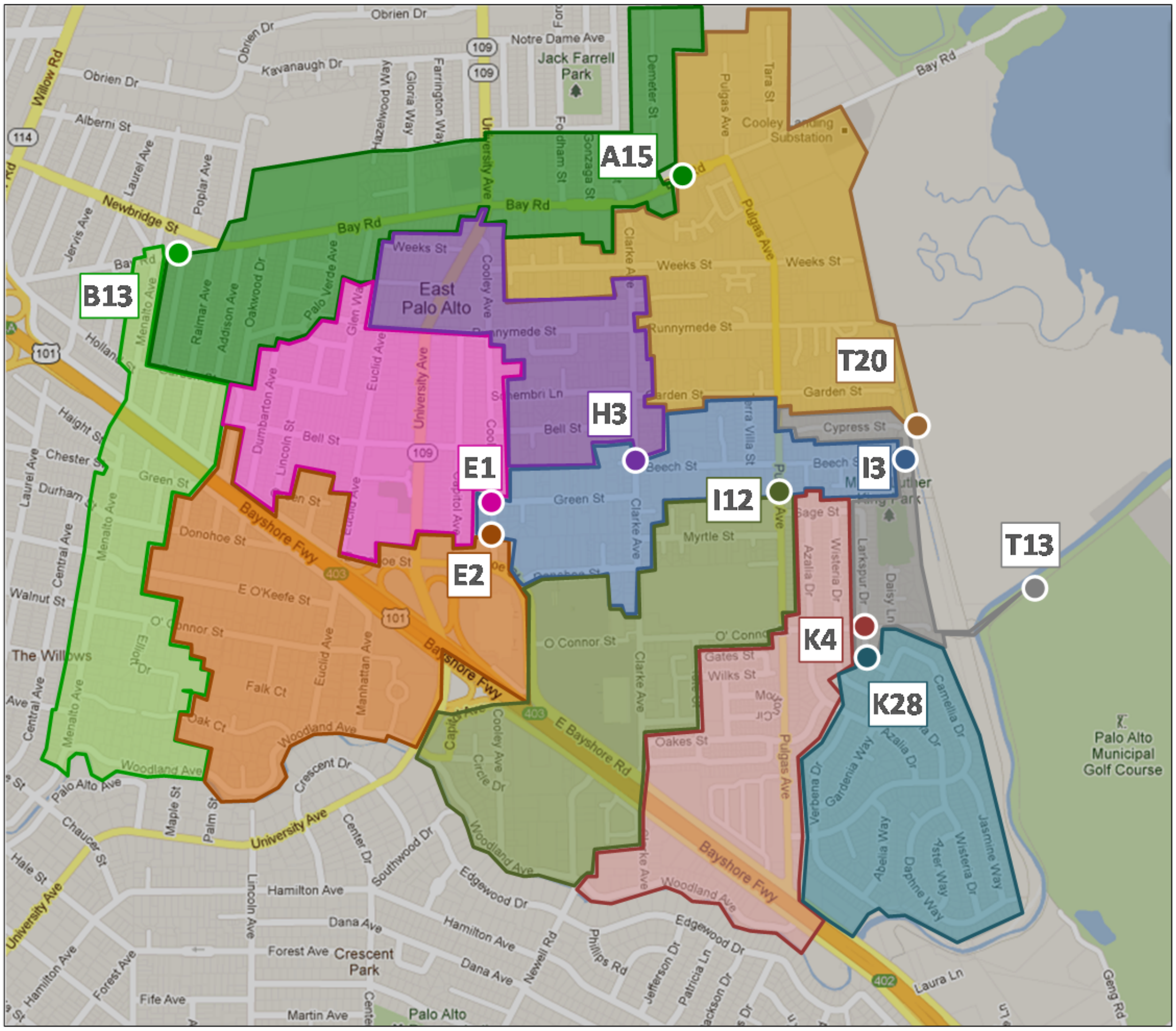


Figure 7. Site and Basin Location Map

METHODS AND PROCEDURES

Confined Space Entry

A confined space (Photo 1) is defined as any space that is large enough and so configured that a person can bodily enter and perform assigned work, has limited or restricted means for entry or exit and is not designed for continuous employee occupancy. In general, the atmosphere must be constantly monitored for sufficient levels of oxygen (19.5% to 23.0%) and the absence of hydrogen sulfide (H_2S) gas, carbon monoxide (CO) gas, and lower explosive limit (LEL) levels. A typical confined space entry crew has members with OSHA-defined responsibilities of Entrant, Attendant and Supervisor. The Entrant is the individual performing the work. He or she is equipped with the necessary personal protective equipment needed to perform the job safely, including a personal four-gas monitor (Photo 2). If it is not possible to maintain line-of-sight with the Entrant, then more Entrants are required until line-of-sight can be maintained. The Attendant is responsible for maintaining contact with the Entrants to monitor the atmosphere on another four-gas monitor and maintaining records of all Entrants, if there are more than one. The Supervisor develops the safe work plan for the job at hand prior to entering.

Photo 1. Confined Space Entry

Photo 2. Typical Personal Four-Gas Monitor

Flow Meter Installation

Eleven Teledyne Isco 2150 meters were installed by V&A in the sewer lines listed in Table 3. Isco 2150 meters use submerged sensors with a pressure transducer to collect depth readings and an ultrasonic Doppler sensor to determine the average fluid velocity. The ultrasonic sensor emits high-frequency (500 kHz) sound waves, which are reflected by air bubbles and suspended particles in the flow. The sensor receives the reflected signal and determines the Doppler frequency shift, which indicates the estimated average flow velocity. Figure 8 shows a typical installation for a flow meter with a submerged sensor.

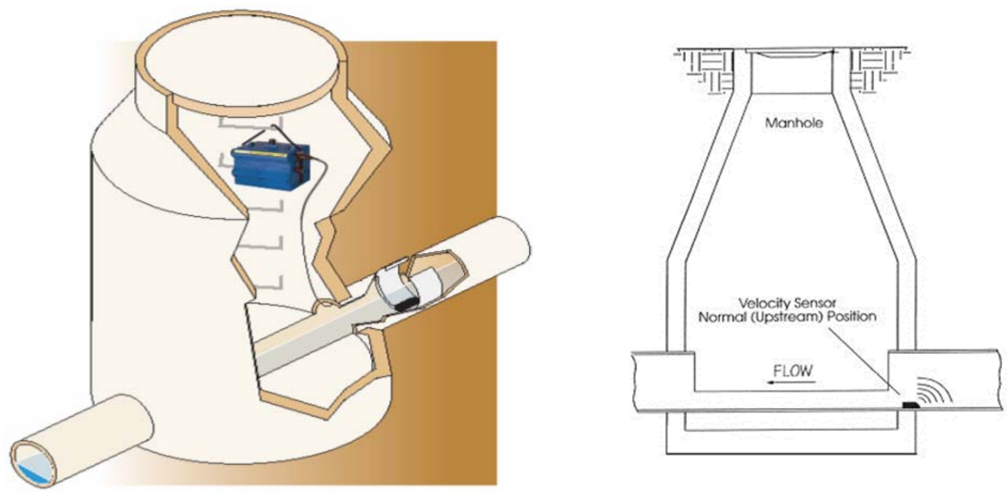


Figure 8. Typical Installation for Flow Meter with Submerged Sensor

Manual level and velocity measurements were taken during installation of the flow meters and again when they were removed. These manual measurements were compared to simultaneous level and velocity readings from the flow meters to ensure proper calibration and accuracy. The pipe diameter was also verified in order to accurately calculate the flow cross-section. The continuous depth and velocity readings were recorded by the flow meters on 5-minute intervals.

Flow Calculation

Data retrieved from the flow meter was placed into a spreadsheet program for analysis. Data analysis includes data comparison to field calibration measurements, as well as necessary geometric adjustments as required for sediment (sediment reduces the pipe's wetted cross-sectional area available to carry flow). Area-velocity flow metering uses the continuity equation,

$$Q = V \cdot A$$

where Q is the volume flow rate, V is the average velocity as determined by the ultrasonic sensor, and A is the cross-sectional area of flow as determined from the depth of flow. For circular pipe,

$$A = \left[\frac{D^2}{4}\cos^{-1}\left(1-\frac{2d}{D}\right)\right] - \left[\left(\frac{D}{2}-d\right)\left(\frac{D}{2}\right)\sin\left(\cos^{-1}\left(1-\frac{2d}{D}\right)\right)\right],$$

where D is the pipe diameter and d is the depth of flow.

RESULTS AND ANALYSIS

Rainfall: Rain Gauge Data

V&A utilized data from rain gauges that are maintained by weather enthusiasts. V&A performed a quality assurance and control review on the rain gauge data and normalized it to the system centroid (Figure 9). All of the rainfall results and subsequent I/I analysis are based on this centroid. There were three main rainfall events that were used for infiltration and inflow analysis for this study, as summarized in Table 4. Figure 10 graphically displays the rainfall activity recorded over the flow monitoring period. Figure 11 shows the rain accumulation plot of the period rainfall, as well as the historical average rainfall[5] in East Palo Alto during this project duration. Rainfall totals for East Palo Alto were at 79% of historical normal levels during this time period.

Figure 9. Rain Gauge Locations

[5] Historical data taken from the WRCC (Station 046646 in Palo Alto): http://www.wrcc.dri.edu/summary/climsmnca.html

Table 4.
Rainfall Events Used for I/I Analysis

Rainfall Event	Event Rainfall (in)
Event 1: March 16 – 17, 2012	0.56
Event 2: March 24 – 25, 2012	1.14
Event 3: March 27 – 28, 2012	0.52
Total over Monitoring Period	*3.30*

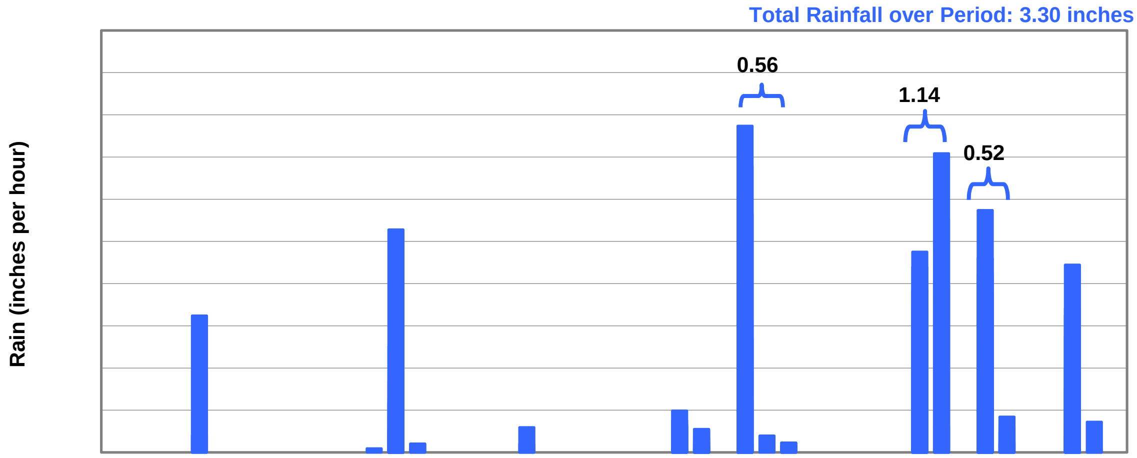


Figure 10. Rainfall Activity over Flow Monitoring Period

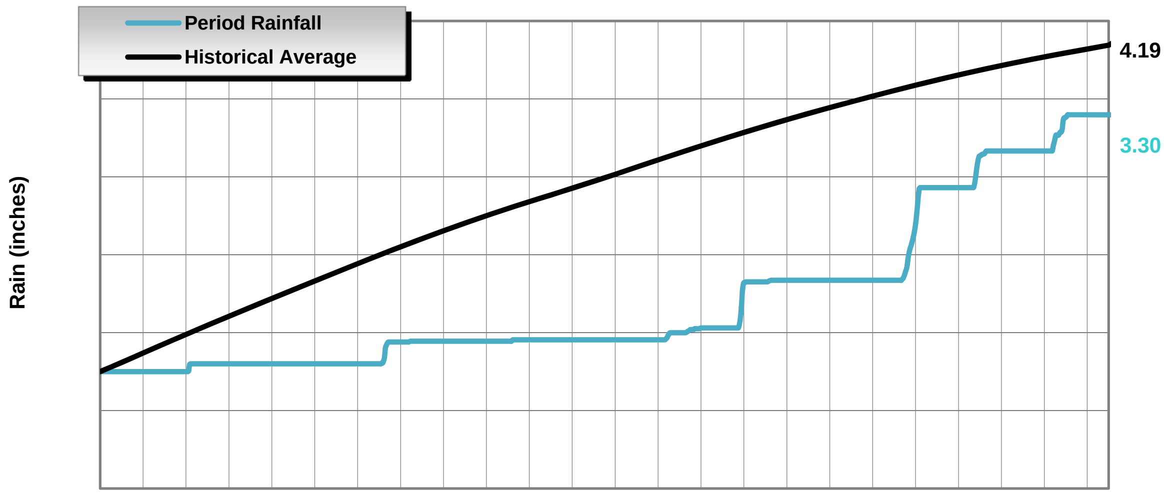


Figure 11. Rainfall Accumulation Plot

Rainfall: Storm Event Classification

It is important to classify the relative size of the major storm event that occurs over the course of a flow monitoring period[6]. Storm events are classified by intensity and duration. Based on historical data, frequency contour maps for storm events of given intensity and duration have been developed by the National Oceanic and Atmospheric Administration (NOAA) for all areas within the continental United States. For example, the NOAA Rainfall Frequency Atlas[7] classifies a 10-year, 24-hour storm event in East Palo Alto (at the location of the system centroid) as 2.69 inches (Figure 12). This means that in any given year, there is a 10% chance that 2.69 inches of rain will fall in any 24-hour period.

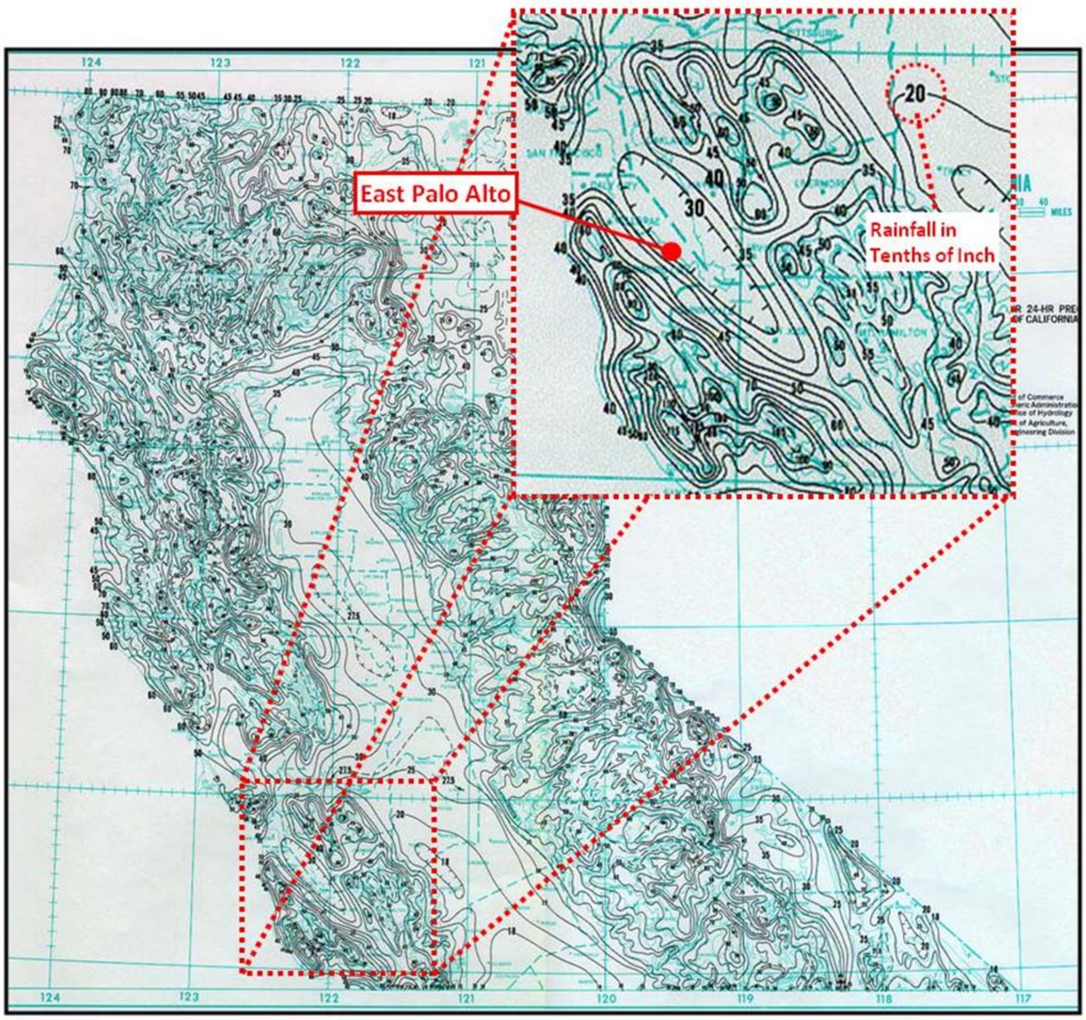


Figure 12. NOAA Northern California Rainfall Frequency Map

From the NOAA frequency maps, for a specific latitude and longitude, the rainfall densities for period durations ranging from 5 minutes to 60 days are known for rain events ranging from 1-year to 100-year

[6] Sanitary sewers are often designed to withstand I/I contribution to sanitary flows for specific-sized "design" storm events.

[7] NOAA Western U.S. Precipitation Frequency Maps Atlas 2, 1973: http://www.wrcc.dri.edu/pcpnfreq.html

intensities. These are plotted to develop a rain event frequency map specific to each rainfall monitoring site. Superimposing the peak measured densities for Events 1, 2 and 3 on the rain event frequency plot determines the classification of the storm event, shown in Figure 13.

All of the rain events that occurred during the flow-monitoring period were classified as being less than 2-year rainfall events.

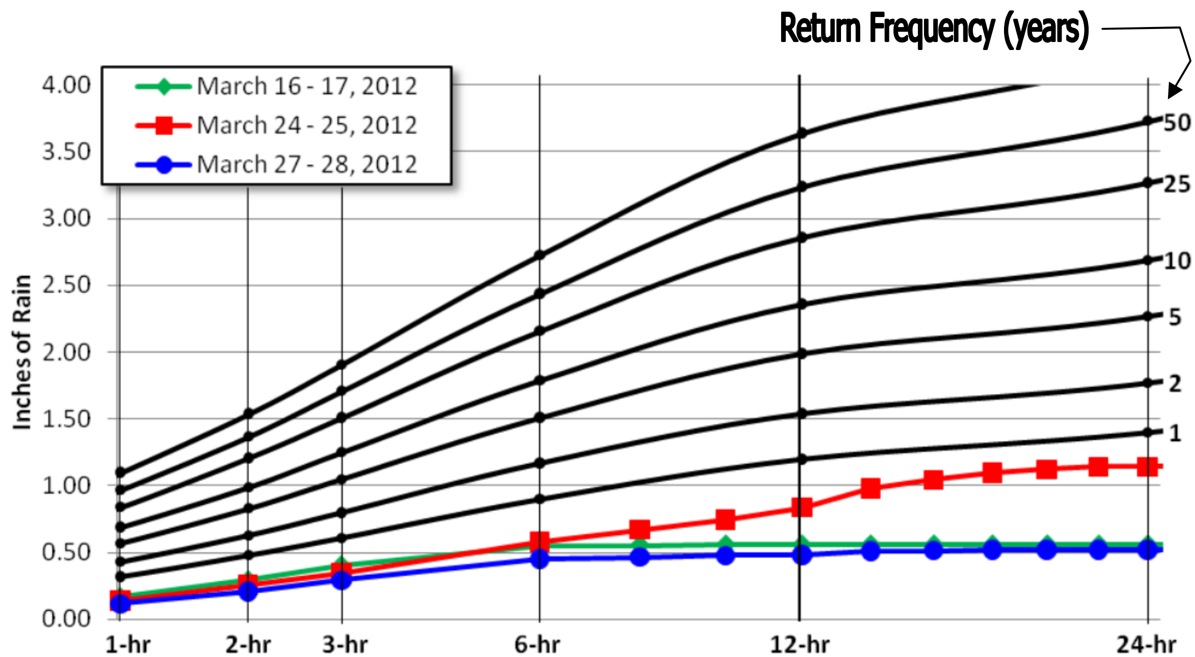


Figure 13. Storm Event Classification

Flow Monitoring: Average Dry Weather Flows

Weekday and weekend flow patterns differ and must be separated when determining average dry weather flows. Days least affected by rainfall were used to estimate weekend and weekday average flows. Table 5 lists the average dry weather flow (ADWF) recorded during this study for the flow monitoring sites. Figure 14 shows a schematic diagram of the average dry weather flows and flow levels. Detailed graphs of the flow monitoring data on a site-by-site basis are included in *Appendix A*.

Table 5.
Dry Weather Flow Summary

Monitoring Site	Weekday ADWF (mgd)	Weekend ADWF (mgd)	Overall ADWF (mgd)	Weekend/ Weekday Ratio
Site A15	0.26	0.27	0.27	1.02
Site B13	0.06	0.06	0.06	1.06
Site E1	0.13	0.13	0.13	1.00
Site E2	0.25	0.25	0.25	1.00
Site H3	0.13	0.14	0.14	1.06
Site I3	0.82	0.85	0.83	1.04
Site I12	0.22	0.25	0.23	1.12
Site K4	0.21	0.23	0.22	1.07
Site K28	0.11	0.12	0.11	1.07
Site T20	0.40	0.41	0.40	1.01
Site T13	1.51	1.59	1.53	1.06

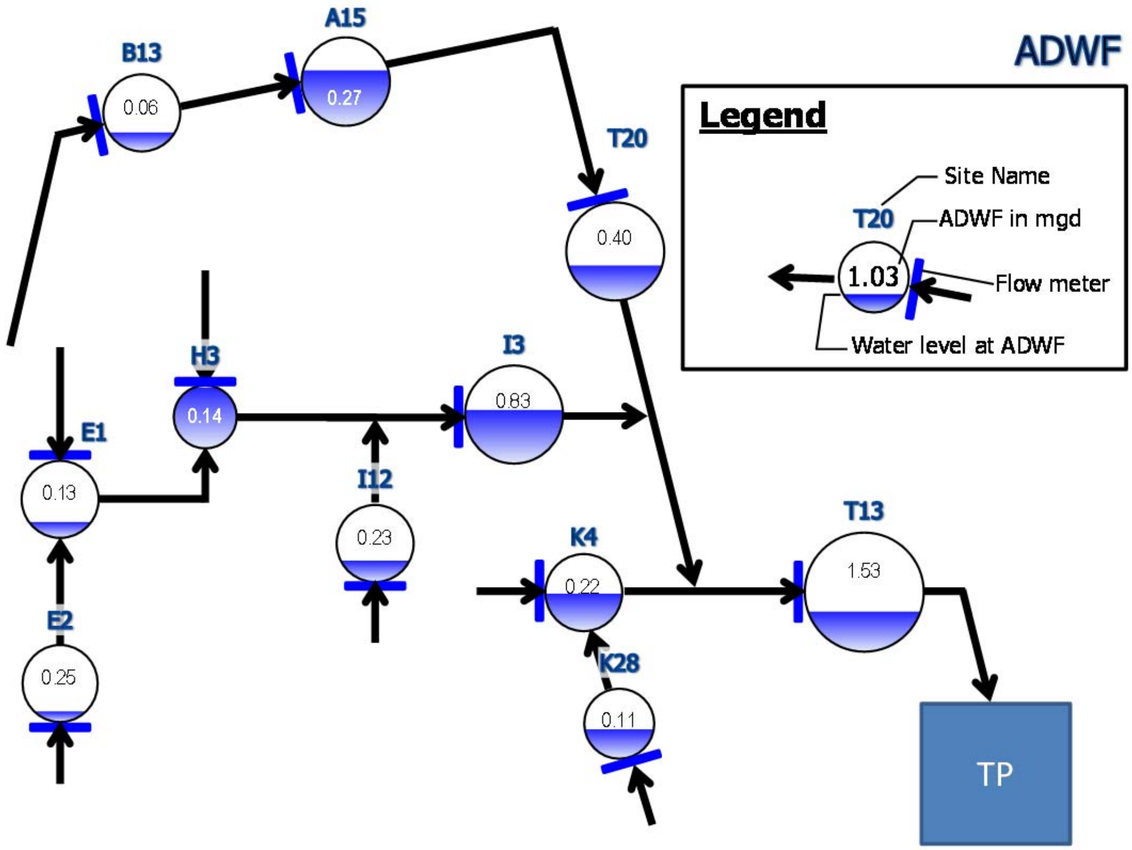


Figure 14. Average Dry Weather Flow (Flow Schematic)

Flow Monitoring: Peak Measured Flows and Pipeline Capacity Analysis

Peak measured flows and the corresponding flow levels (depths) are important to understand the capacity of the flow monitoring system. The peak flows and flow levels reported are from the peak measurements as taken across the entirety of the flow monitoring period and may or may not correspond to a rainfall event. It did not appear that there were any elevated flow levels due to blockages, grease or roots during the flow monitoring study. Additionally, there did not appear to be evidence of backflow conditions due to capacity constraints or the inability of the local collection system to handle peak wet weather flows.

The following capacity analysis terms are defined as follows:

- **Peaking Factor:** Peaking factor is defined as the peak measured flow divided by the average dry weather flow (ADWF). A peaking factor threshold value of 3.0 is commonly used for sanitary sewer design.
- ***d*/*D* Ratio:** The *d*/*D* ratio is the peak measured depth of flow (*d*) divided by the pipe diameter (*D*). A *d*/*D* ratio of 0.75 is a common maximum threshold value used for pipe design. The *d*/*D* ratio for each site was computed based on the maximum depth of flow from the flow monitoring study.

Table 6 summarizes the peak recorded flows, levels, *d*/*D* ratios, and peaking factors per site during the flow monitoring period. Capacity analysis data is presented on a site-by-site basis and represents the hydraulic conditions only at the site locations; hydraulic conditions in other areas of the collection system will differ.

Table 6.
Capacity Analysis Summary

Site	ADWF (mgd)	Peak Measured Flow (mgd)	Peaking Factor	Diameter (in)	Peak Level (in)	Peak *d*/*D* Ratio	Level Surcharged above Crown (ft)
Site A15	0.27	0.49	1.84	15	11.31	0.75	-
Site B13	0.06	0.18	3.04	12	4.44	0.37	-
Site E1	0.13	0.26	1.99	11.5	3.06	0.27	-
Site E2	0.25	0.60	2.37	18	4.90	0.27	-
Site H3	0.14	0.27	2.00	8	9.92	1.24	0.2
Site I3	0.83	1.45	1.74	17.5	11.85	0.68	-
Site I12	0.23	0.42	1.81	11.5	4.21	0.37	-
Site K4	0.22	0.53	2.44	12	8.82	0.74	-
Site K28	0.11	0.27	2.49	9.75	5.71	0.59	-
Site T20	0.40	0.73	1.83	17.5	8.42	0.48	-
Site T13	1.53	2.80	1.83	23.5	10.84	0.46	-

The following capacity analysis results are noted:

- **Peaking Factor:** Site B13 had a peaking factor that exceeded typical design threshold limits for the ratio of peak flow to average dry weather flow.
- ***d*/*D* Ratio:** Site H3 had a *d*/*D* ratio that exceeded the common design threshold for *d*/*D* ratio. This site exhibited a surcharged condition throughout a majority of the duration of the study. At the remainder of the sites, there were no capacity constraints during the rainfall events of this study; the local collection system had the ability to handle peak wet weather flows.

Figure 15 shows bar graphs of the capacity results. Figure 16 shows a schematic diagram of the peak measured flows with peak flow levels.

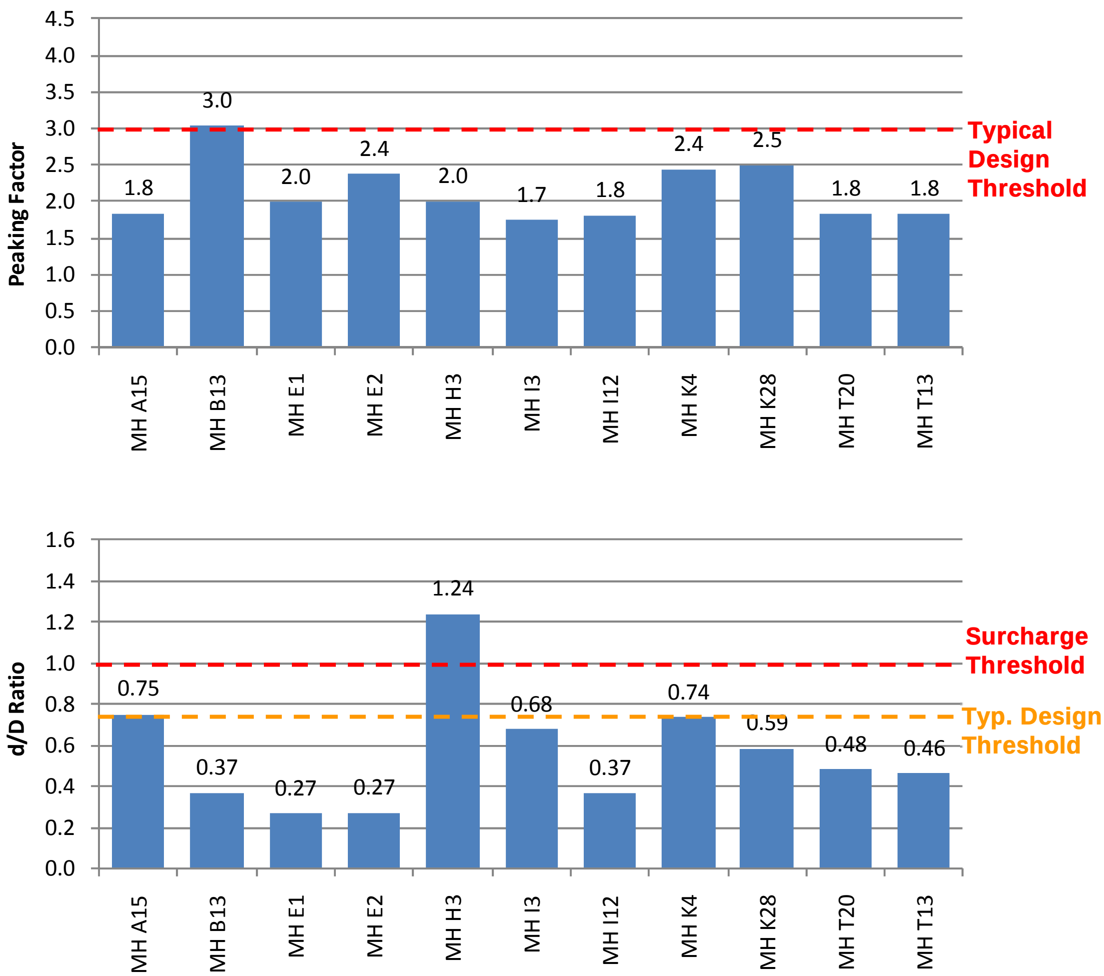


Figure 15. Capacity Summary Bar Graphs: Peaking Factors and Peak *d*/*D* Ratios

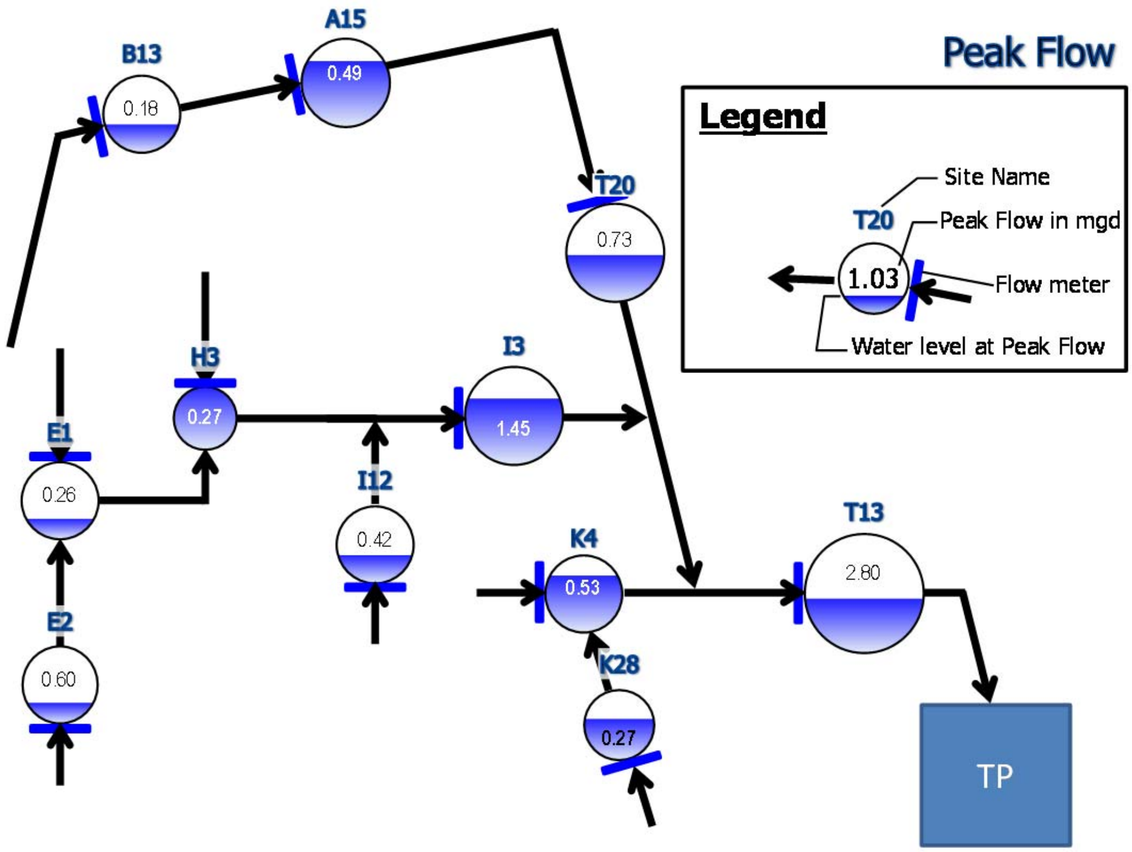


Figure 16. Peak Measured Flow (Flow Schematic)

Inflow / Infiltration Analysis: Definitions and Identification

Inflow and infiltration (I/I) consists of storm water and groundwater that enter the sewer system through pipe defects and improper storm drainage connections and is defined as follows:

Inflow

- **Definition:** Storm water inflow is defined as water discharged into the sewer system, including private sewer laterals, from direct connections such as downspouts, yard and area drains, holes in manhole covers, cross-connections from storm drains, or catch basins.
- **Impact:** This component of I/I creates a peak flow problem in the sewer system and often dictates the required capacity of downstream pipes and transport facilities to carry these peak instantaneous flows. Because the response and magnitude of inflow is tied closely to the intensity of the storm event, the short-term peak instantaneous flows may result in surcharging and overflows within a collection system. Severe inflow may result in sewage dilution, resulting in upsetting the biological treatment (secondary treatment) at the treatment facility.
- **Cost of Source Identification and Removal:** Inflow locations are usually less difficult to find and less expensive to correct. These sources include direct and indirect cross-connections with storm drainage systems, roof downspouts, and various types of surface drains. Generally, the costs to identify and remove sources of inflow are low compared to potential benefits to public health and safety or the costs of building new facilities to convey and treat the resulting peak flows.
- **Graphical Identification:** Inflow is usually recognized graphically by large-magnitude, short-duration spikes immediately following a rain event.

Infiltration

- **Definition:** Infiltration is defined as water entering the sanitary sewer system through defects in pipes, pipe joints, and manhole walls, which may include cracks, offset joints, root intrusion points, and broken pipes.
- **Impact:** Infiltration typically creates long-term annual volumetric problems. The major impact is the cost of pumping and treating the additional volume of water, and of paying for treatment (for municipalities that are billed strictly on flow volume).
- **Cost of Source Detection and Removal:** Infiltration sources are usually harder to find and more expensive to correct than inflow sources. Infiltration sources include defects in deteriorated sewer pipes or manholes that may be widespread throughout a sanitary sewer system.
- **Graphical Identification:** Infiltration is often recognized graphically by a gradual increase in flow after a wet-weather event. The increased flow typically sustains for a period after rainfall has stopped and then gradually drops off as soils become less saturated and as groundwater levels recede to normal levels.

Figure 17 shows sample graphs indicating the typical graphical response patterns for inflow and infiltration.

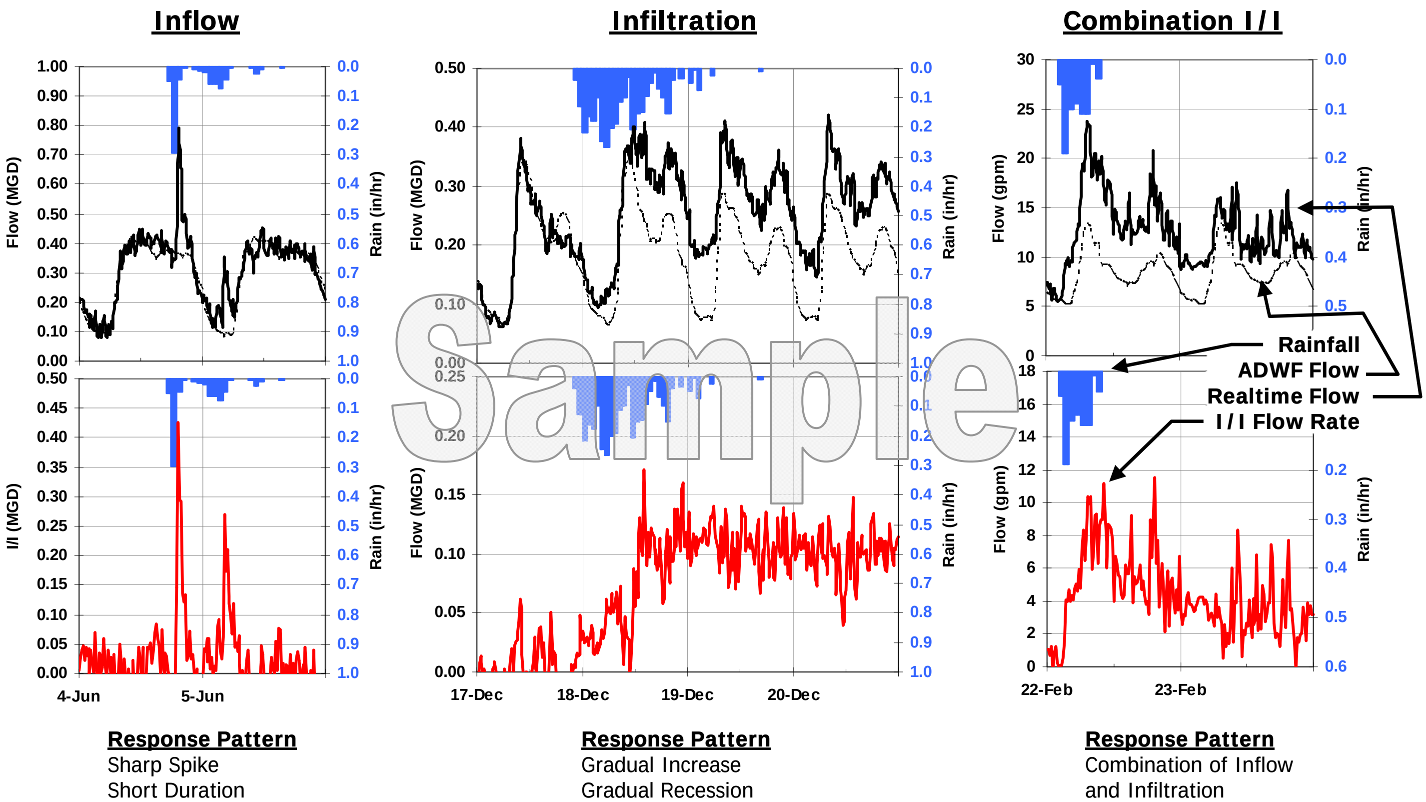


Figure 17. Inflow and Infiltration: Graphical Response Patterns

Infiltration Components

Infiltration can be further subdivided into components as follows:

- **Groundwater Infiltration:** Groundwater infiltration depends on the depth of the groundwater table above the pipelines as well as the percentage of the system submerged. The variation of groundwater levels and subsequent groundwater infiltration rates is seasonal by nature. On a day-to-day basis, groundwater infiltration rates are relatively steady and will not fluctuate greatly.
- **Rainfall-Dependent Infiltration:** This component occurs as a result of storm water and enters the sewer system through pipe defects, as with groundwater infiltration. The storm water first percolates directly into the soil and then migrates to an infiltration point. Typically, the time of concentration for rainfall-related infiltration may be 24 hours or longer, but this depends on the soil permeability and saturation levels.
- **Rainfall-Responsive Infiltration** is storm water which enters the collection system indirectly through pipe defects, but normally in sewers constructed close to the ground surface such as private laterals. Rainfall-responsive infiltration is independent of the groundwater table and reaches defective sewers via the pipe trench in which the sewer is constructed, particularly if the pipe is placed in impermeable soil and bedded and backfilled with a granular material. In this case, the pipe trench serves as a conduit similar to a French drain, conveying storm drainage to defective joints and other openings in the system. This type of infiltration can have a quick response and graphically can look very similar to inflow.

Figure 18 illustrates the possible sources and components of I/I.

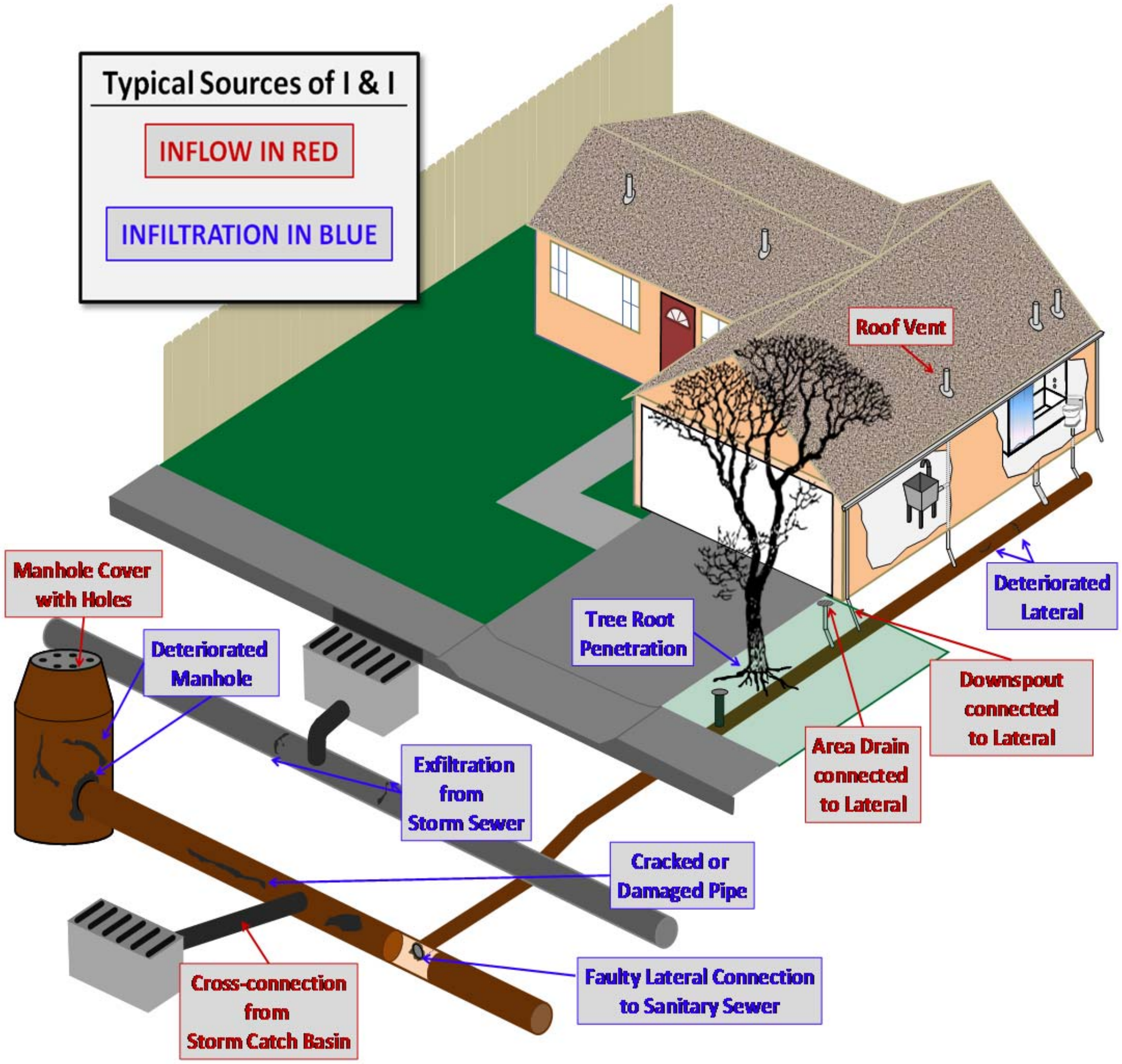


Figure 18. Typical Sources of Infiltration and Inflow

Inflow / Infiltration: Analysis Methods

After differentiating I/I flows from ADWF flows, various calculations can be made to determine which I/I component (inflow or infiltration) is more prevalent at a particular site and to compare the relative magnitudes of the I/I components between drainage basins and between storm events, as follows:

Inflow Indicators

Peak I/I Flow Rate: Inflow is characterized by sharp, direct spikes occurring during a rainfall event. Peak I/I rates are used for inflow analysis[8]. After determining the peak I/I flow rate for a given site, and for a given storm event, there are three ways to *normalize* the peak I/I rates for an "apples-to-apples" comparison amongst the different drainage basins:

- **Peak I/I Flow Rate per IDM:** Peak measured I/I rate divided by length of pipe within the drainage basin, expressed in units of inch-diameter-mile (IDM) (miles of pipeline multiplied by the diameter of the pipeline in inches). Final units are gallons per day (gpd) per IDM.
- **Peak I/I Flow Rate per Acre:** Peak measured I/I rate divided by the geographic area of the upstream basin in acres. Units are gpd per acre.
- **Peak I/I Flow Rate to ADWF Ratio:** Peak measured I/I rate divided by average dry weather flow (ADWF). This is a ratio and is expressed without units.

Infiltration Indicators

Dry Weather Groundwater Infiltration: GWI analysis is conducted by looking at minimum dry weather flow to average dry weather flow ratios and comparing them to established standards to quantify the rate of excess groundwater infiltration. As with inflow, GWI infiltration rates can be normalized by means of pipe length (IDM), basin area (acres), and dry weather flow rates (ADWF). These methods are discussed in further detail in the *Groundwater Analysis* section later in this report.

Rainfall-Dependent Infiltration: Infiltration occurring after the conclusion of a storm event is classified as rainfall-dependent infiltration. Analysis is conducted by looking at the infiltration rates at set periods after the conclusion of a storm event. Depending on the particular collection system and the time required for flows to return to ADWF levels, different set periods may be examined to determine the basins with the greatest or most sustained rainfall-dependent infiltration rates.

Combined I/I Indicators

Total Infiltration: The total inflow and infiltration is measured in gallons per site and per storm event. Because it is based on total I/I volume, it is an indicator of combined inflow and infiltration and is used to identify the overall volumetric influence of I/I within the monitoring basin. As with inflow, pipe length, basin area, and dry weather flow are used to normalize combined I/I for basin comparison:

- **Combined I/I Flow Rate per IDM:** Total infiltration (gallons) divided by length of pipe (IDM) and divided by storm event rainfall (inches of rain). Final units are gallons per day (gpd) per IDM per inch of rain.

[8] I/I flow rate is the realtime flow less the estimated average dry weather flow rate. It is an estimate of flows attributable to rainfall. By using peak measured flow rates (inclusive of ADWF), the I/I flow rate would be skewed higher or lower depending on whether the storm event I/I response occurs during low-flow or high-flow hours.

- **R-Value:** Total infiltration (gallons) divided by the total rainfall that fell within the acreage of that basin (gallons of rainfall). This is expressed as a percentage and is explained as "the percentage of rain that enters the sanitary sewer collection system." Systems with R-values less than 5%[9] are often considered to be performing well.
- **Combined I/I Flow Rate per ADWF:** Total infiltration (gallons) divided by the ADWF (gpd) and divided by storm event rainfall (inches of rain). Final units are million gallons per MGD of ADWF per inch of rain.

Realtime flows were plotted against ADWF flows to analyze the I/I response to rainfall events. Figure 19 illustrates a sample of how this analysis is conducted and some of the measurements that are used to distinguish infiltration and inflow. Similar graphs were generated for the individual flow monitoring sites and can be found in *Appendix A*.

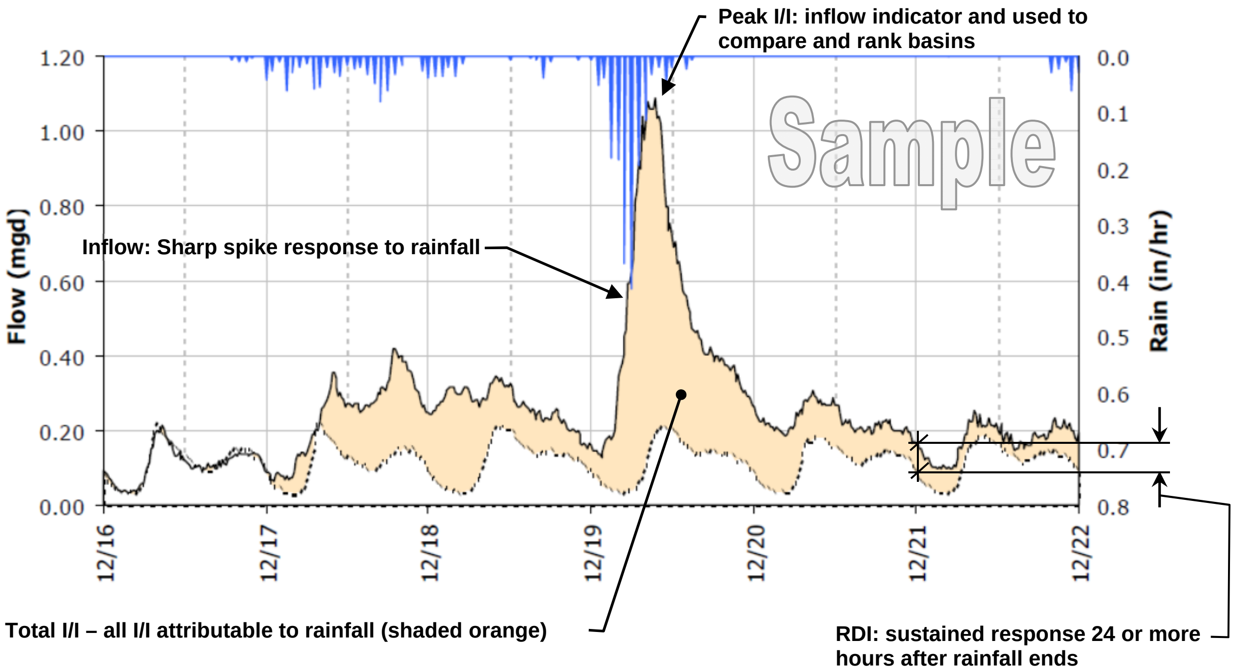


Figure 19. Sample Infiltration and Inflow Isolation Graph

The infiltration and inflow indicators were normalized by pipe length, basin area, and ADWF in this report. Final rankings were determined by weighting the normalization methods by 50%, 25%, and 25%, respectively, with ties broken by pipe length (IDM). The per-IDM method is given a higher weight including the tie-break because, for this study, future I/I rehabilitation and/or reduction efforts are typically budgeted per unit length of pipe. Additionally, the IDM measurement typically has a higher level of accuracy than drainage watershed area and low-flow ADWF.

[9] Keefe, P.N. "Test Basins for I/I Reduction and SSO Elimination." 1998 WEF Wet Weather Specialty Conference, Cleveland.

Inflow / Infiltration: Results

Inflow Results Summary

Inflow is storm water discharged into the sewer system through direct connections such as downspouts, area drains, cross-connections to catch basins, etc. These sources transport rain water into the sewer system directly and the corresponding flow rates are tied closely to the intensity of the storm. This component of I/I often causes a peak flow problem in the sewer system and often dictates the required capacity of downstream pipes and transport facilities to carry these peak instantaneous flows.

Table 7 summarizes the peak measured I/I flows and inflow analysis results for the storm events (refer to the *I/I Methods* section for more information on inflow analysis methods and ranking procedures). Figure 20 shows bar graph summaries of the inflow analysis. Figure 21 shows a temperature map summary of the inflow analysis results per basin.

Table 7.
Basins Inflow Analysis Summary

Basin	ADWF (mgd)	Peak I/I Rate[A] (mgd)	Peak I/I per IDM (gpd/IDM)	Peak I/I per Acre (gpd/acre)	Peak I/I per ADWF	Inflow Ranking[B]
Basin A15	0.21	0.047	1,550	400	0.23	10
Basin B13	0.059	0.09	4,250	1,050	1.55	4
Basin E1	0.13	0.10	3,810	950	0.74	6
Basin E2	0.25	0.21	6,240	1,430	0.84	3
Basin H3	0.14	0.09	5,420	1,170	0.64	5
Basin I3	0.08	0.053	2,820	720	0.66	9
Basin I12	0.23	0.08	3,120	600	0.35	8
Basin K4	0.22	0.21	7,120	1,990	0.97	1
Basin K28	0.11	0.16	6,140	1,630	1.41	2
Basin T20	0.14	0.109	3,050	640	0.81	7
System[C]	1.53	0.87	3,070	760	0.57	-

[A] Average Peak I/I rate for Events 1, 2 and 3.
[B] Ranking of 1 represents most inflow after normalization.
[C] The data for the "System" was taken from Site T13, which was installed for this purpose.

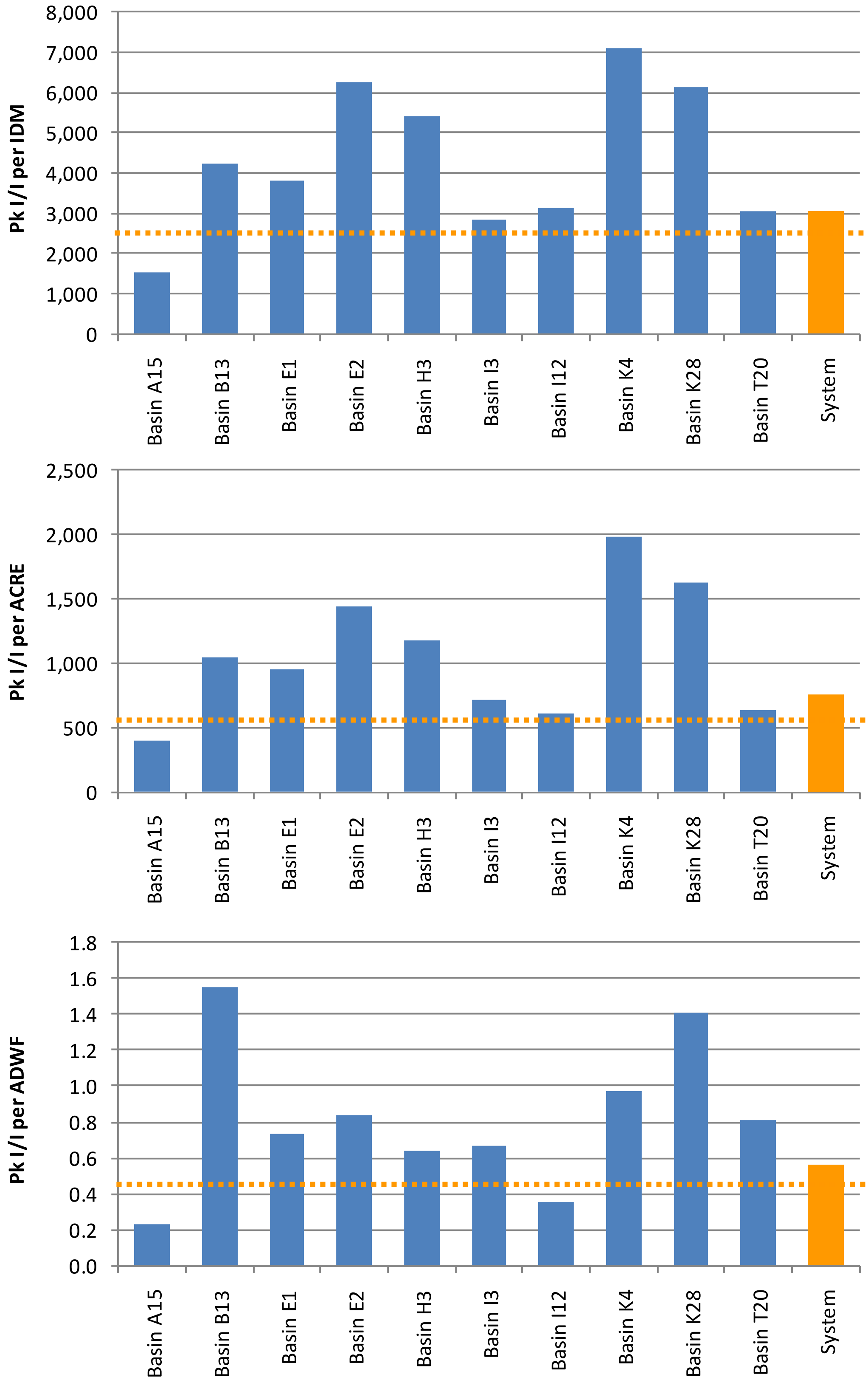


Figure 20. Bar Graphs: Inflow Analysis Summary

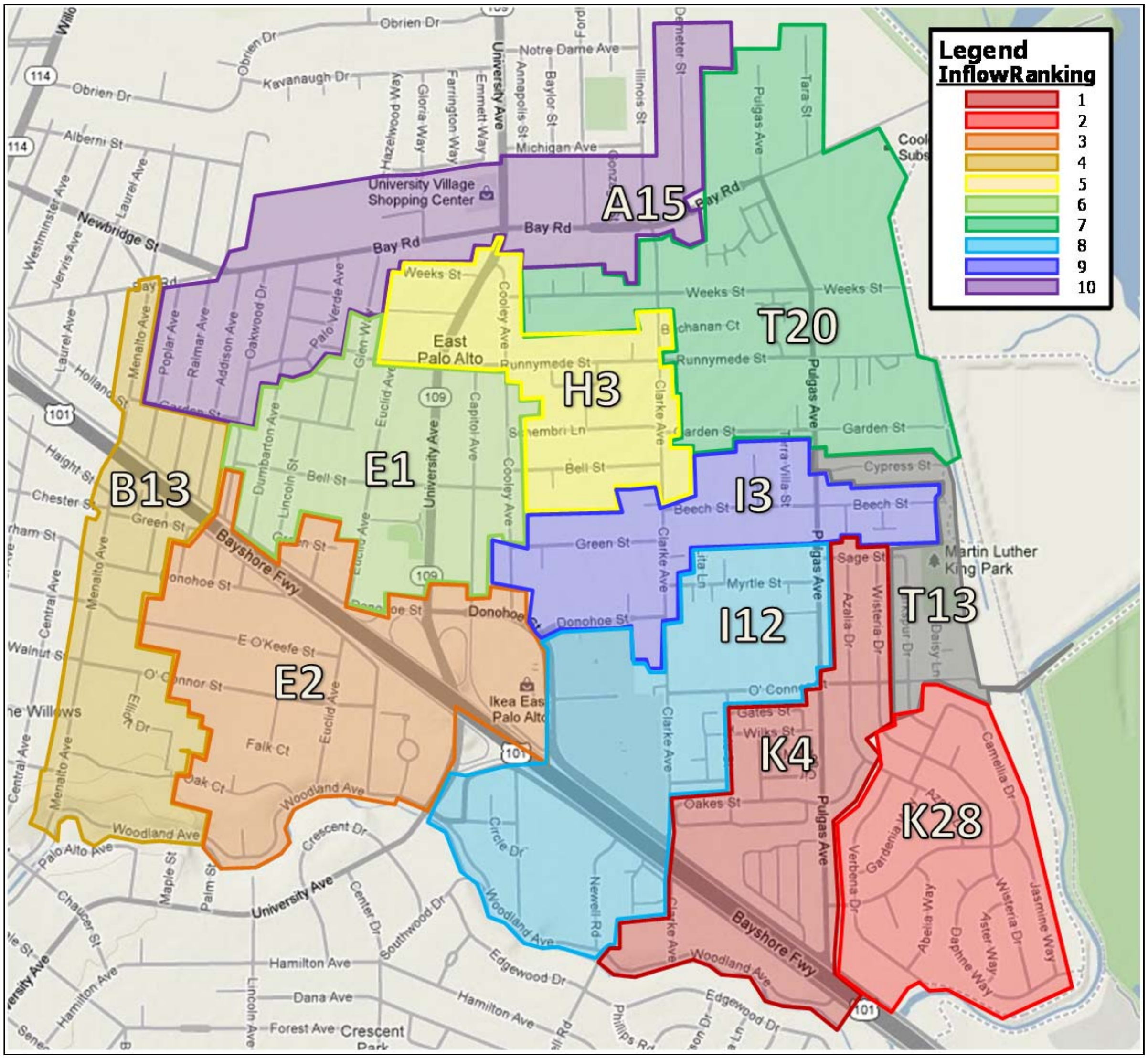


Figure 21. Inflow Temperature Map (by Rank)

The following inflow analysis results are noted:

- Basins K4, K28 and E2 ranked highest for normalized inflow contribution.

Rainfall-Dependent Infiltration Results Summary

Rainfall-dependent infiltration is defined as rain-derived water entering the sanitary sewer system through defects in pipes, pipe joints, and manhole walls, which may include cracks, offset joints, root intrusion points, and broken pipes. Increased flows into the sanitary sewer system are usually tied to groundwater levels and soil saturation levels. Infiltration sources transport rain water into the system *indirectly*; flow levels in the sanitary system increase gradually, are typically sustained for a period after rainfall has stopped, and then gradually drop off as soils become less saturated and as groundwater levels recede to normal. Infiltration typically creates long-term annual volumetric problems. The major impact is the cost of pumping and treating the additional volume of water, and of paying for treatment (for municipalities that are billed strictly on flow volume).

Table 8 summarizes the calculated average RDI flow rates for the three storm events (refer to the *I/I Methods* section for more information on RDI analysis methods and ranking methods). Figure 22 shows bar graph summaries of the RDI analysis. A temperature map by overall ranking is shown in Figure 23.

Table 8.
Basins RDI Analysis Summary

Basin	ADWF (mgd)	RDI Rate[A] (mgd)	RDI per IDM (gpd/IDM)	RDI per Acre (GPAD)	RDI per ADWF	RDI Ranking[B]
Basin A15	0.21	0.018	570	150	8%	8
Basin B13	0.059	0.006	300	70	11%	9
Basin E1	0.13	0.030	1,180	290	23%	3
Basin E2	0.25	0.040	1,170	270	16%	5
Basin H3	0.14	0.016	990	210	12%	6
Basin I3	0.08	0.021	1,100	280	26%	4
Basin I12	0.23	0.000	0	0	0%	10
Basin K4	0.22	0.038	1,280	360	18%	2
Basin K28	0.11	0.056	2,230	590	52%	1
Basin T20	0.14	0.024	660	140	18%	7
System[C]	1.53	0.267	950	230	18%	-

[A] Average RDI rates for Events 1, 2 and 3.
[B] Ranking of 1 represents most RDI after normalization.

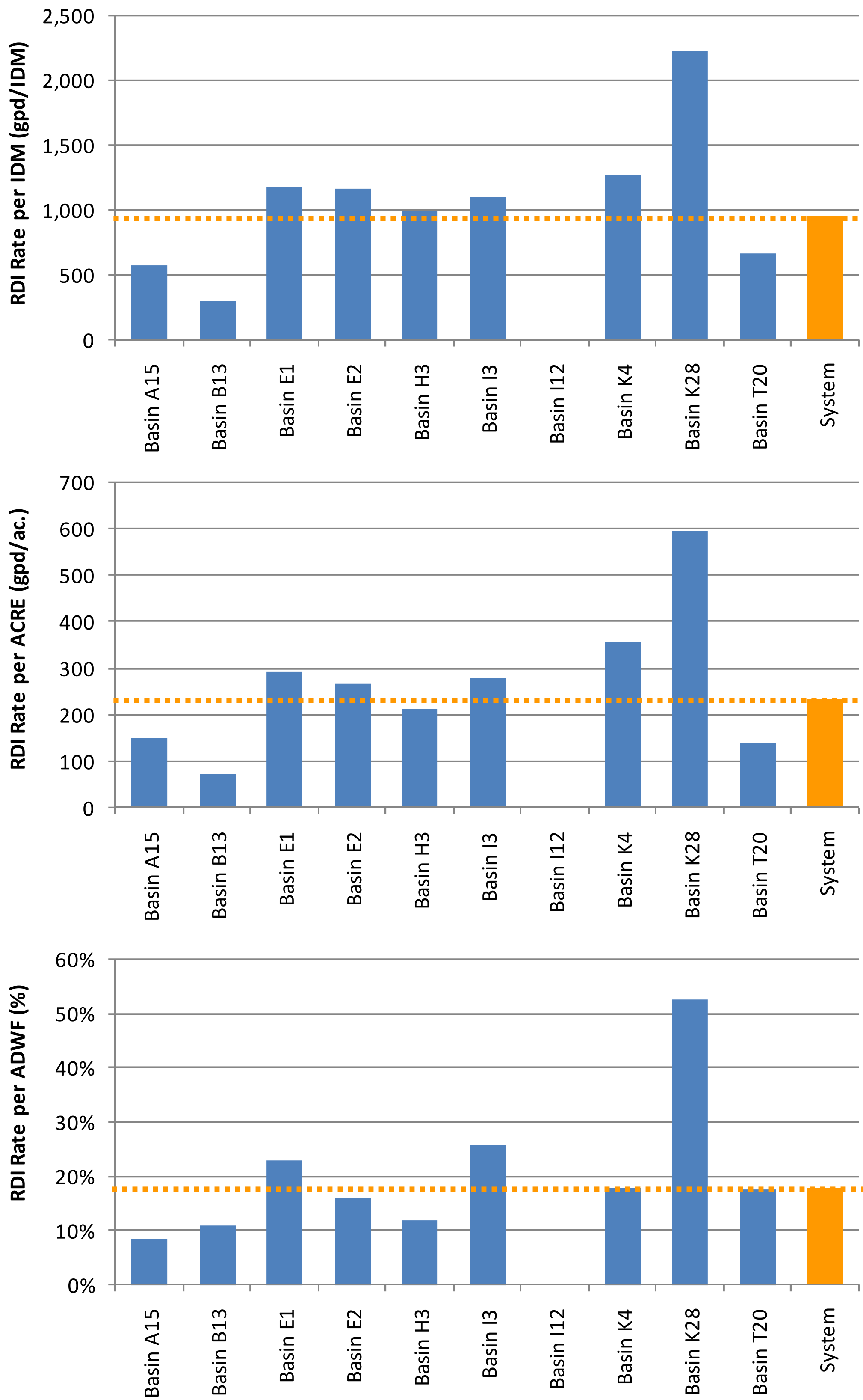


Figure 22. Bar Graphs: RDI Analysis Summary

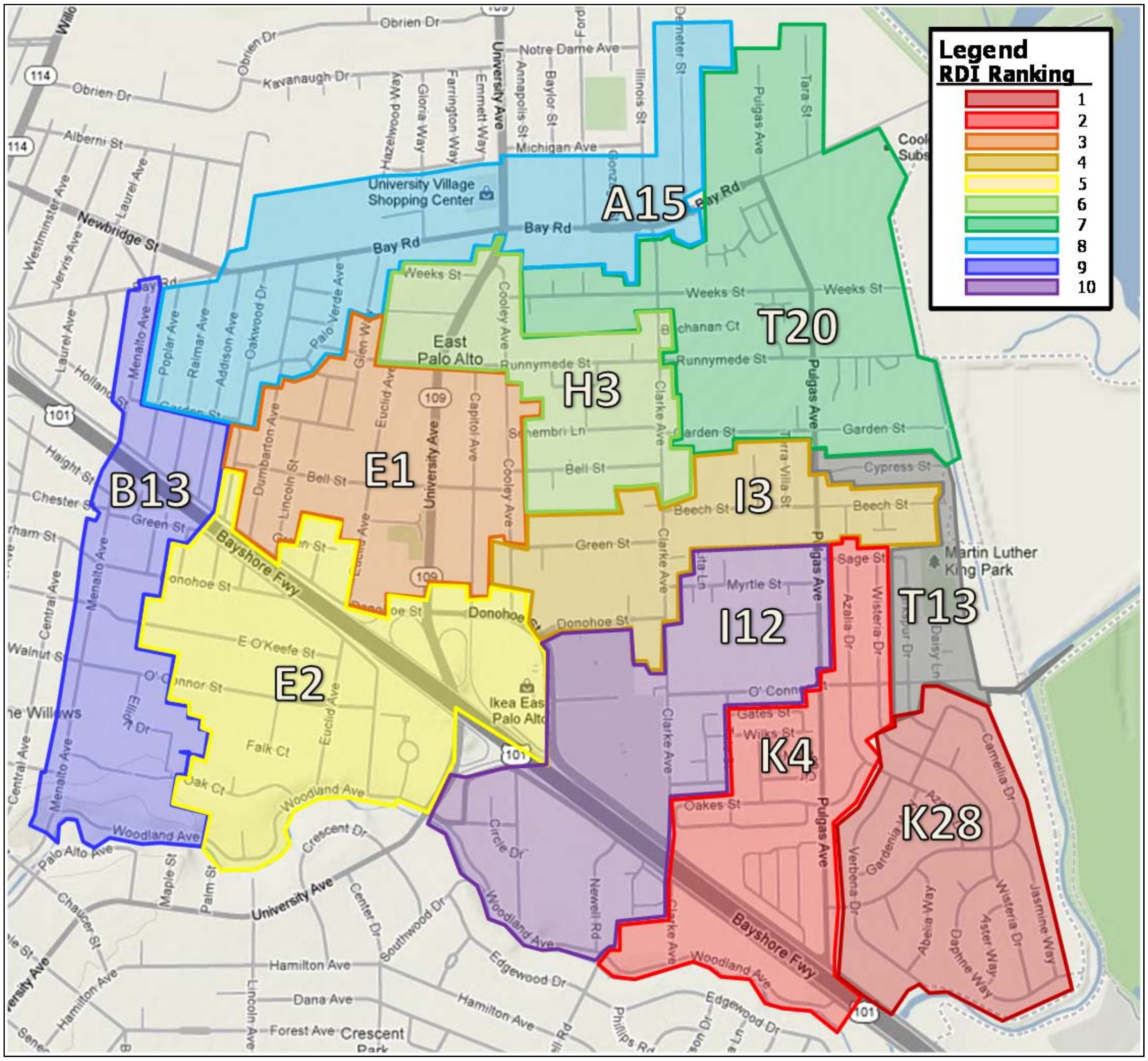


Figure 23. RDI Temperature Map (by Rank)

The following RDI analysis results are noted:

- ❖ Basins K28, K4 and E1 ranked highest for normalized RDI contribution.

Groundwater Infiltration Results Summary

Dry weather (ADWF) flow can be expected to have a predictable diurnal flow pattern. While each site is unique, experience has shown that, given a reasonable volume of flow and typical loading conditions, the daily flows fall into a predictable range when compared to the daily average flow. If a site has a large percentage of groundwater infiltration occurring during the periods of dry weather flow measurement, the amplitudes of the peak and low flows will be dampened[10]. Figure 24 shows a sample of two flow monitoring sites, both with nearly the same average daily flow, but with considerably different peak and low flows. In this *sample* case, Site B1 may have a considerable volume of groundwater infiltration.

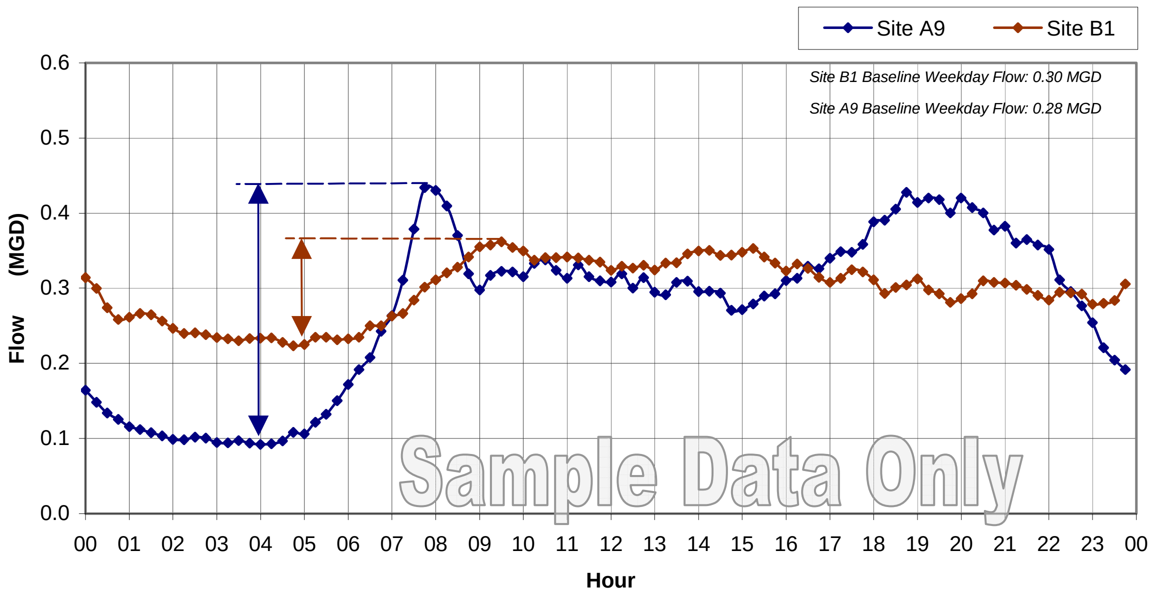


Figure 24. Groundwater Infiltration Sample Figure

It can be useful to compare the low-to-ADWF flow ratios for the flow metering sites. A site with abnormal ratios, and with no other reasons to suspect abnormal flow patterns (such as proximity to a pump station, treatment facilities, etc.), has a possibility of higher levels of groundwater infiltration in comparison to the rest of the collection system. Figure 25 plots the low-to-ADWF flow ratios against the ADWF flows for the sites monitored during this study. The dotted line shows "typical" low-to-ADWF ratios per the Water Environment Federation (WEF)[11]. The following GWI results are noted:

- Basins T20, K28, K4 and E1 have GWI rates that were **above** the WEF typical low-to-average ratio, indicating excessive groundwater infiltration.

Figure 26 shows a color-coded map of the basins with rates of groundwater infiltration considerably above typical groundwater infiltration standards (as set forth by WEF).

[10] In an extreme case, perhaps 0.2 mgd of ADWF flow and 2.0 mgd of groundwater infiltration, the peaks and lows would be barely recognizable; the ADWF flow would be nearly a straight line.

[11] WEF Manual of Practice No. 9, "Design and Construction of Sanitary and Storm Sewers."

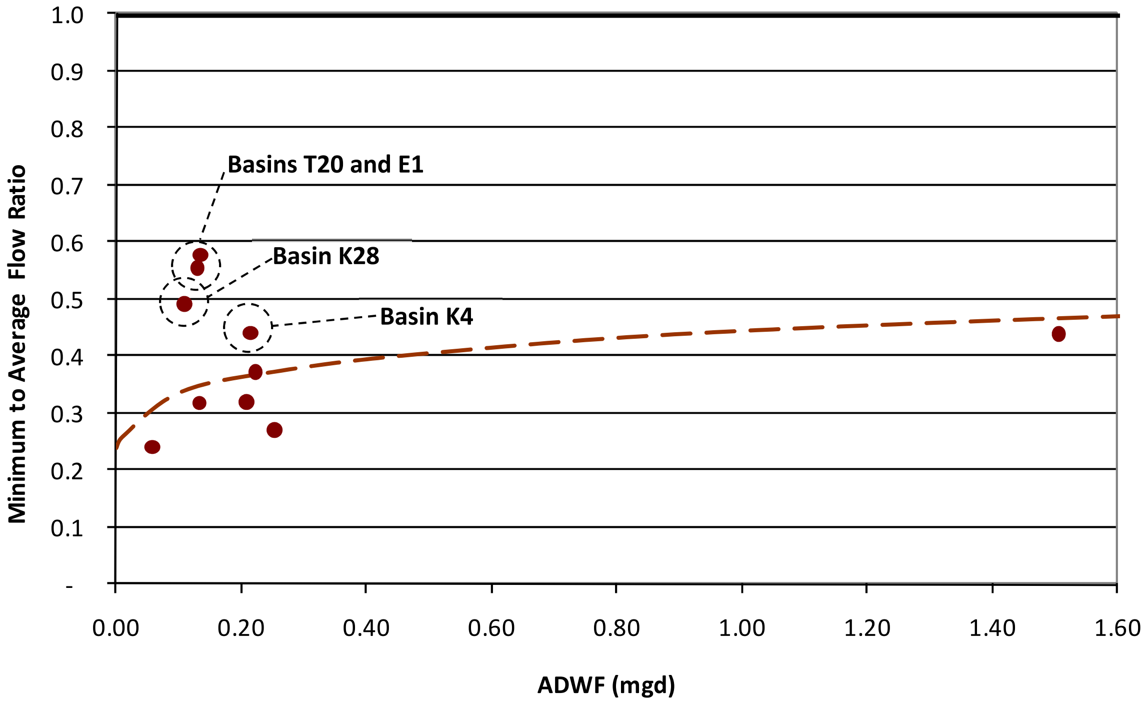


Figure 25. Minimum Flow Ratios vs. ADWF[12]

[12] Due to attenuation, it should be expected that sites with larger flow volumes should not have quite the peak-to-average and low-to-average flow ratios as sites with lesser flow volumes, which is why the WEF typical trend lines slope closer to 1.0 as the ADWF increases, as shown in the figure.

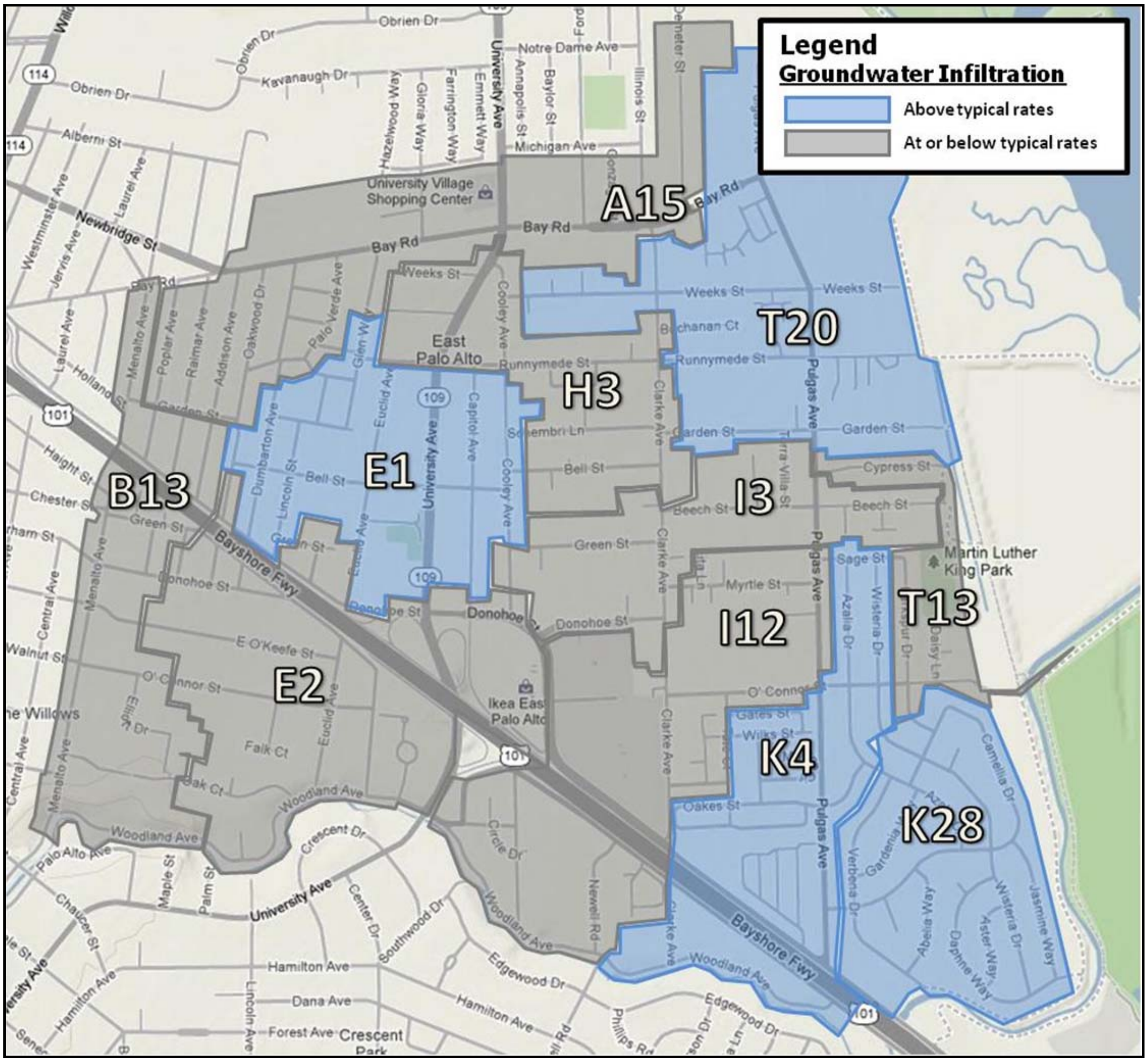


Figure 26. Basins with Groundwater Infiltration

Combined I/I Results Summary

Combined I/I analysis considers the totalized volume (in gallons) of both inflow and rainfall-dependent infiltration over the course of a storm event.

Table 9 summarizes the combined I/I flow results for the storm events (refer to the *I/I Methods* section for more information on combined I/I analysis methods and ranking methods). Figure 27 shows bar graph summaries of the combined I/I analysis. A temperature map by overall ranking is shown in Figure 28.

Table 9.
Basins Combined I/I Analysis Summary

Basin	ADWF (mgd)	Combined I/I [A] (gallons)	Combined I/I per IDM	R-Value (%)	Combined I/I per ADWF	Combined I/I Ranking[B]
Basin A15	0.21	96,000	1,890	1.8%	0.28	6
Basin B13	0.059	47,000	1,340	1.2%	0.49	7
Basin E1	0.13	53,000	1,270	1.2%	0.24	9
Basin E2	0.25	213,000	3,730	3.2%	0.50	5
Basin H3	0.14	29,000	1,090	0.9%	0.13	10
Basin I3	0.08	119,000	3,810	3.6%	0.89	4
Basin I12	0.23	57,000	1,320	0.9%	0.15	8
Basin K4	0.22	234,000	4,720	4.9%	0.64	2
Basin K28	0.11	302,000	7,180	7.0%	1.65	1
Basin T20	0.14	240,000	4,030	3.1%	1.07	3
System[C]	1.53	1,783,000	3,800	3.4%	0.70	-

[A] Sum of I/I for Events 2 and 3.
[B] Ranking of 1 represents most combined I/I (inflow and RDI) after normalization.

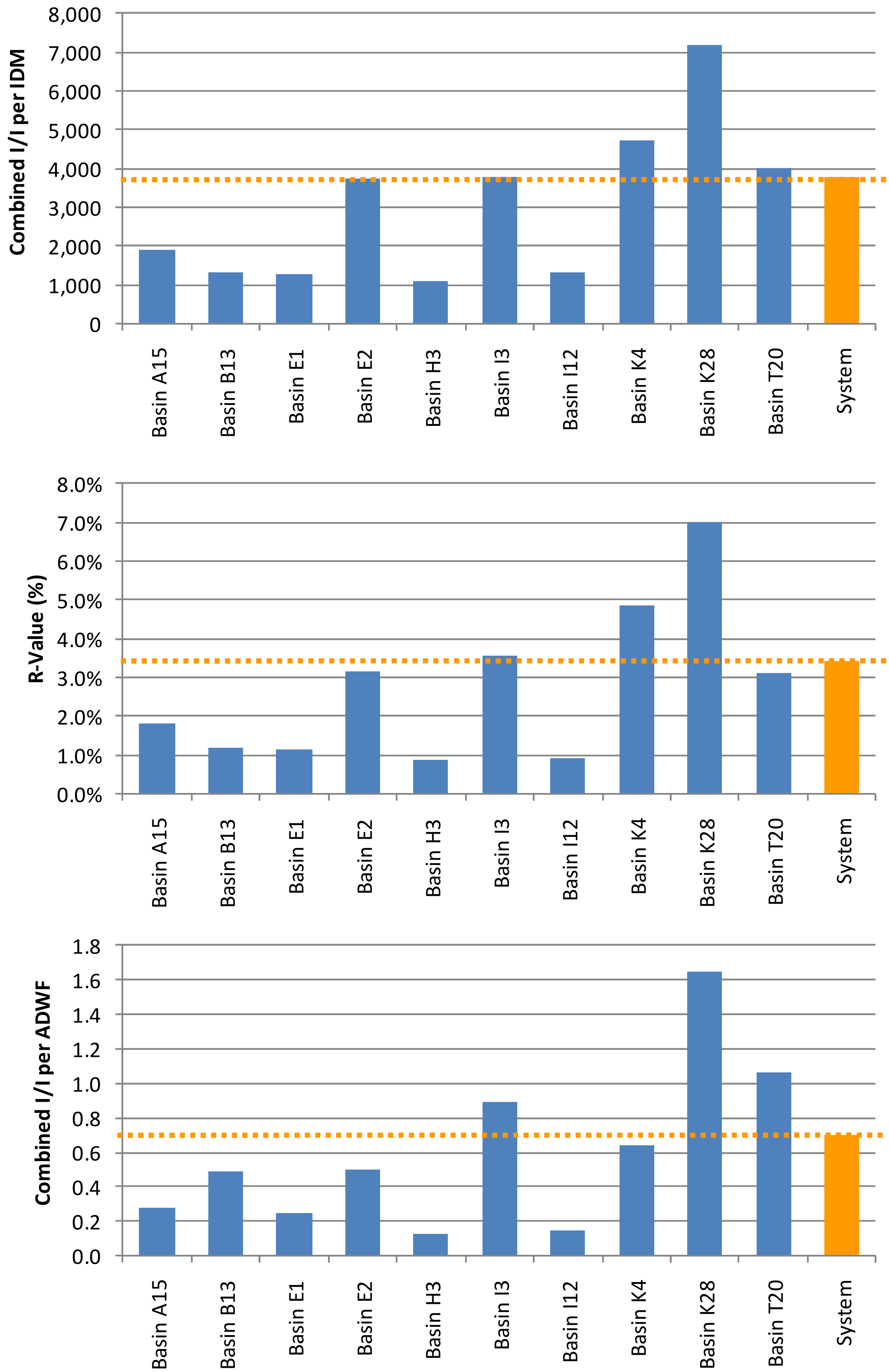


Figure 27. Bar Graphs: Combined I/I Analysis Summary

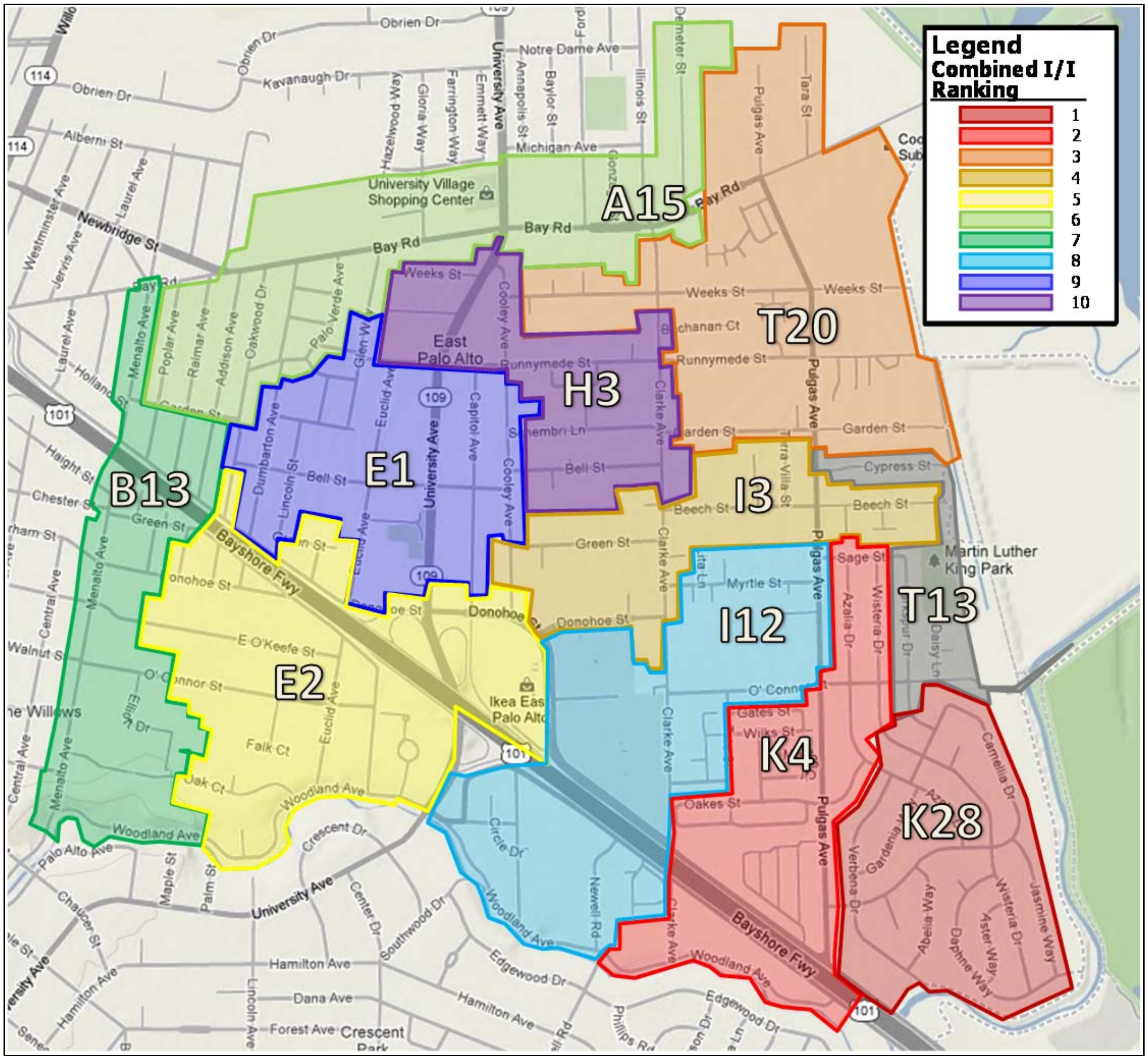


Figure 28. Combined I/I Temperature Map (by Rank)

The following combined I/I analysis results are noted:

- ❖ Basins T20, K28 and K4 ranked highest for normalized combined I/I contribution.

Inflow / Infiltration: Synthetic Hydrographs

In order to model design storms, synthetic hydrographs were developed to approximate the actual RDI hydrograph shape in terms of the time to the peak and the recession coefficient. The actual RDI hydrograph was best matched with a synthetic hydrograph by separating the synthetic hydrograph into seven volume components (R1 through R7). The seven components represent different response times to the rainfall event and, therefore, different infiltration or inflow paths into the sewer system. R1 is characterized by a short response time and is assumed to consist of mainly inflow. R7 represents slower response and longer recession times and consists of mostly infiltration. Levels of soil saturation are also considered. Using synthetic hydrograph analysis, appropriate time and recession parameters were estimated by a trial-and-error procedure until a good match was obtained. For example, the hydrograph and its component hydrographs for the period of March 24 to 30, 2012, for Site T13 is shown in Figure 29.

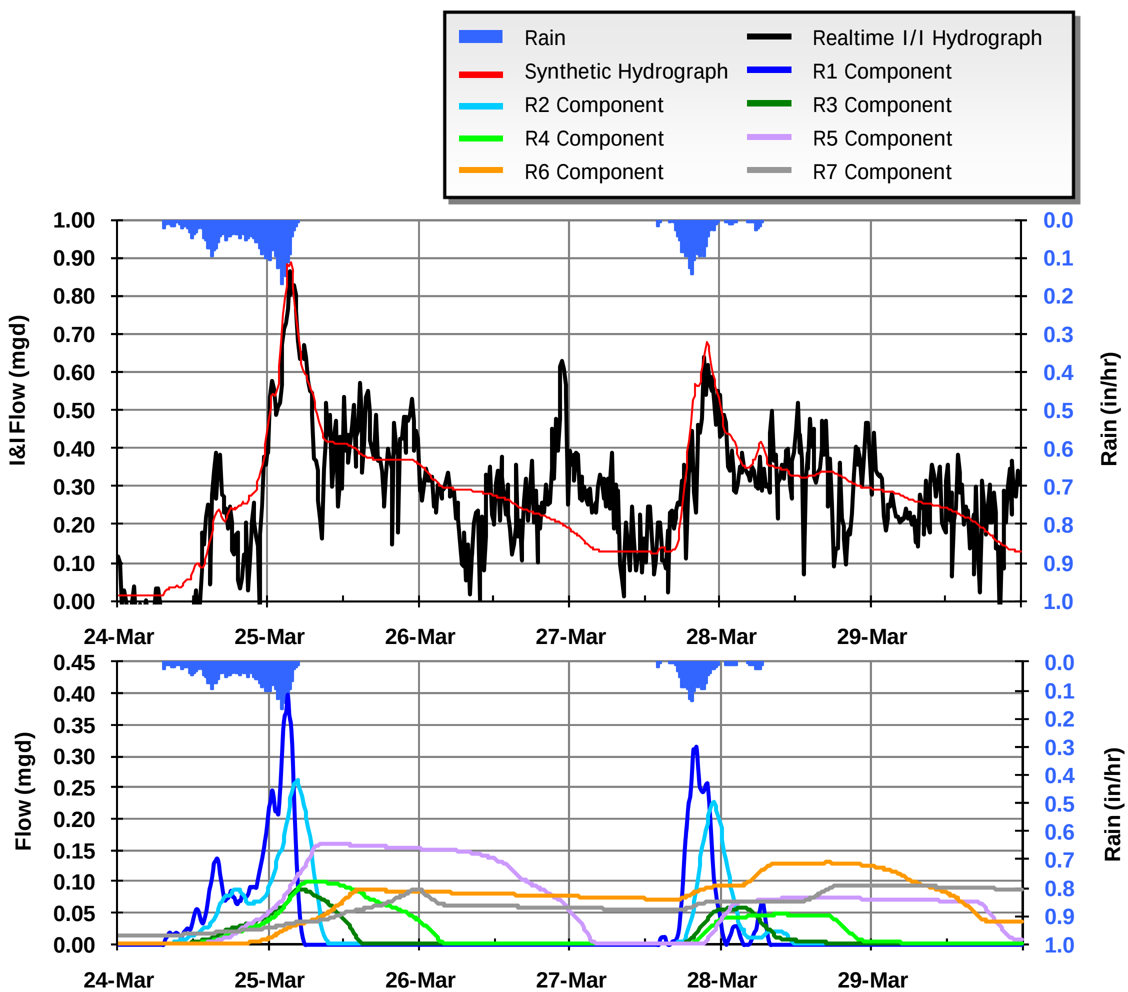


Figure 29. Site T13: Synthetic Hydrograph

Design Storm Development

With the I/I response modeled by a synthetic hydrograph, design storms can be applied. This serves two functions: (a) predicted flows are based on the same storm event and are therefore normalized to each other, making for easier and better comparisons, and (b) the resulting I/I flows can be predicted for a design storm event. This helps to calibrate modeling efforts that will determine if the collection system has adequate capacity to handle very large storm events.

V&A used a 10-year, 24-hour design storm for this analysis. Storm events were taken from the NOAA Precipitation-Frequency Atlas of the Western United States. Figure 30 summarizes the design storm magnitude and profile. This particular profile distribution also fits the NOAA criterion for 2-hour and 6-hour durations, in addition to the 24-hour duration.

10-Year, 24-hour Design Storm	
Hour	Inches of Rain
1	0.005
2	0.011
3	0.115
4	0.069
5	0.023
6	0.007
7	0.099
8	0.056
9	0.079
10	0.028
11	0.014
12	0.006
13	0.058
14	0.163
15	0.019
16	0.153
17	0.153
18	0.359
19	0.667
20	0.306
21	0.153
22	0.047
23	0.078
24	0.023
Total:	**2.69**

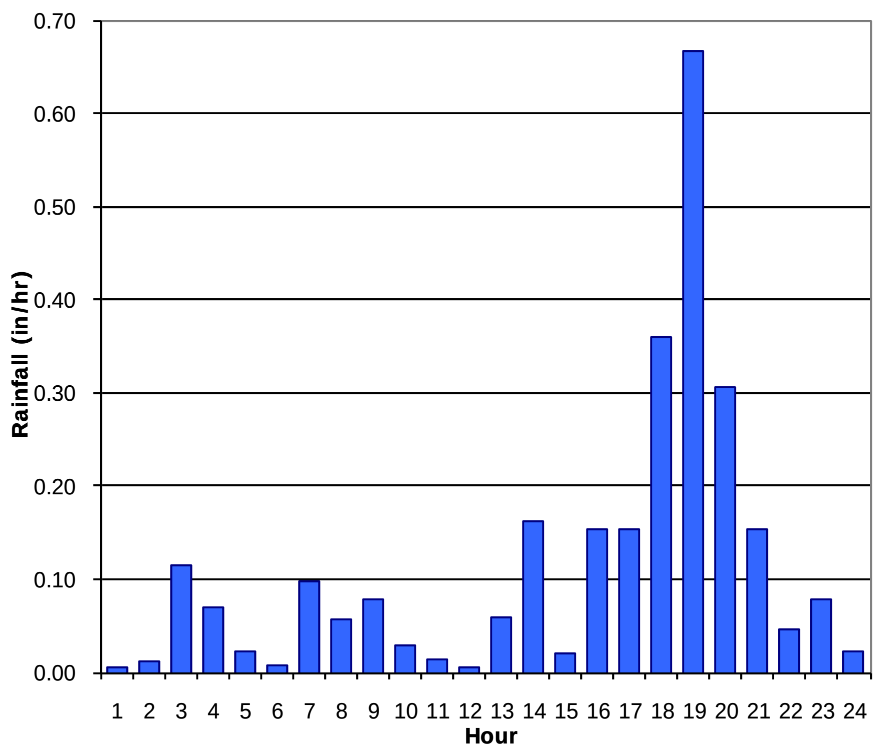


Figure 30. 10-Year, 24-Hour Design Storm Values and Profile

Design Storm Response Summary

The 10-year, 24-hour storm event was applied to the synthetic I/I hydrograph components developed for each flow monitoring site. This method produces the best estimated response to the design storm events. These results assume full ground saturation, and the peak I/I flows from the design storm coincide with peak sanitary flows to get a "worst-case" scenario of peak wet weather flows. Table 10 summarizes the final results for each design storm on a site-by-site basis. Figure 31 shows the synthetic hydrograph response for the design storm event at Site T13.

Table 10.
Design Storm I/I Analysis Summary

Site	Peak Dry Weather Flow (mgd)	Peak I/I Rate (mgd)	Peak Flow (mgd)	Total I/I (gallons)
Site A15	0.43	0.76	1.19	184,000
Site B13	0.11	0.41	0.52	95,000
Site E1	0.19	0.41	0.59	218,000
Site E2	0.43	1.02	1.45	514,000
Site H3	0.23	0.35	0.58	262,000
Site I3	1.22	1.54	2.76	1,048,000
Site I12	0.39	0.37	0.76	94,000
Site K4	0.35	0.65	0.99	481,000
Site K28	0.17	0.50	0.68	516,000
Site T13	0.60	0.95	1.55	729,000
Site T20	2.31	3.47	5.78	3,227,000

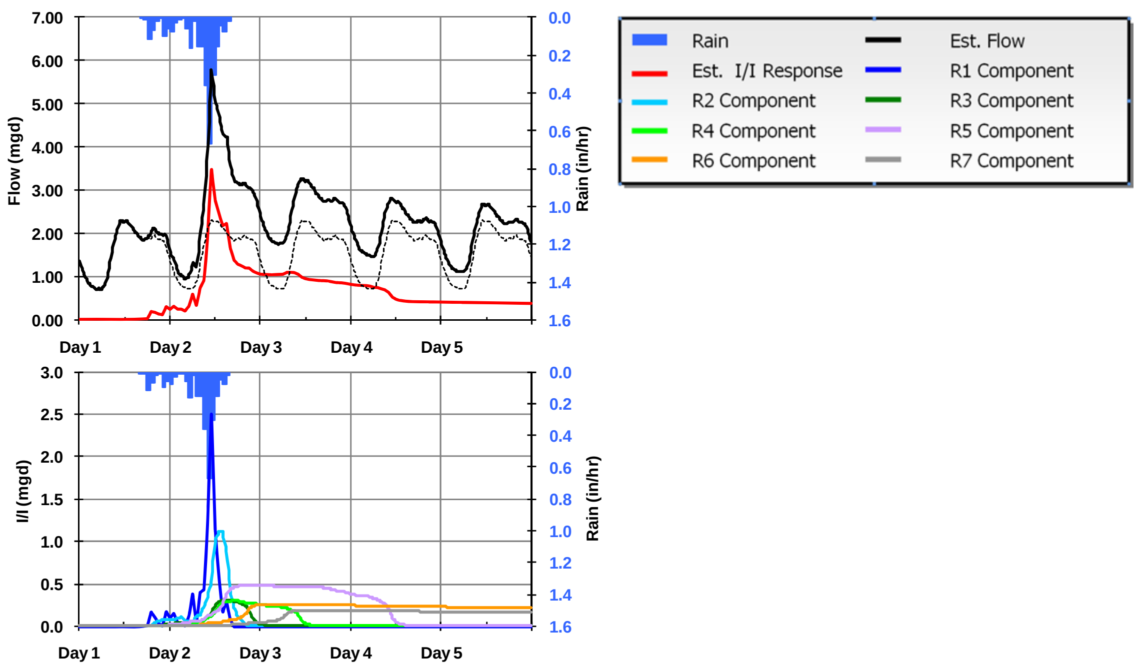


Figure 31. 10-Year, 24-Hour Design Storm: Estimated I/I Response at Site T13

RECOMMENDATIONS

V&A advises that future I/I reduction plans consider the following recommendations:

1. **Determine I/I Reduction Program:** The District should examine its I/I reduction needs to determine a future I/I reduction program.
    a. If peak flows, sanitary sewer overflows, and pipeline capacity issues are of greater concern, then priority can be given to investigate and reduce sources of inflow within the basins with the greatest inflow problems. The highest inflow occurred in Basins K4, K28 and E2.
    b. If total infiltration and general pipeline deterioration are of greater concern, then the program can be weighted to investigate and reduce sources of infiltration within the basins with the greatest infiltration problems.
        i. The highest normalized rainfall-dependent infiltration occurred in Basins K28, K4 and E1.
        ii. The highest groundwater infiltration occurred in Basins K28, K4 and E1.
2. **I/I Investigation Methods:** Potential I/I investigation methods include the following:
    a. Smoke testing
    b. Mini-basin flow monitoring
    c. Nighttime reconnaissance work to (1) investigate and determine direct point sources of inflow and (2) determine the areas and pipe reaches responsible for high levels of infiltration contribution.
3. **I/I Reduction Cost-Effectiveness Analysis:** The District should conduct a study to determine which is more cost-effective: (1) locating the sources of inflow and infiltration and systematically rehabilitating or replacing the faulty pipelines or (2) continued treatment of the additional rainfall-dependent I/I flow.

APPENDIX A

FLOW MONITORING SITES: DATA, GRAPHS, INFORMATION

East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

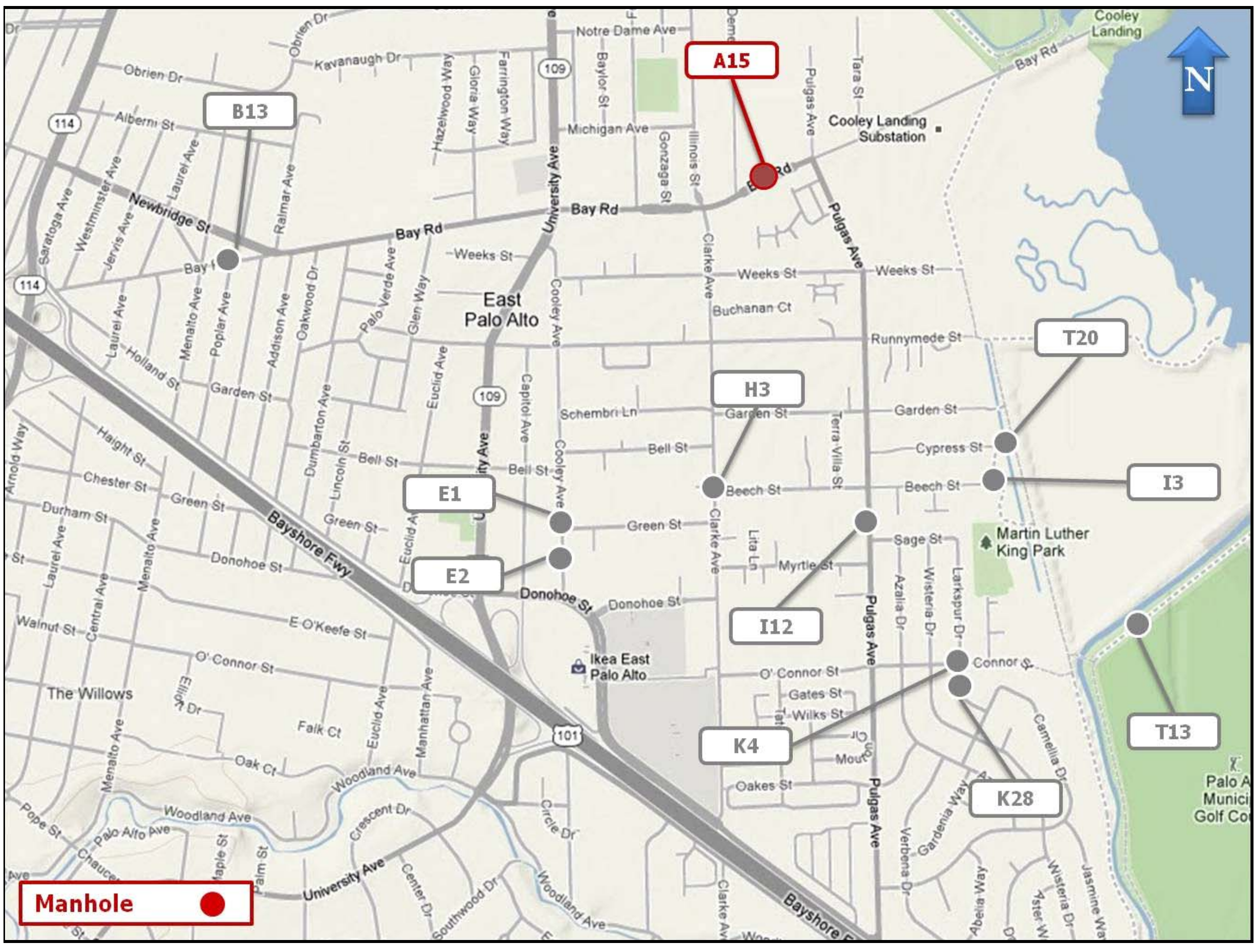
Year 2012

Monitoring Site: MH A15

Location: Bay Road between Demeter Street and Pulgas Avenue

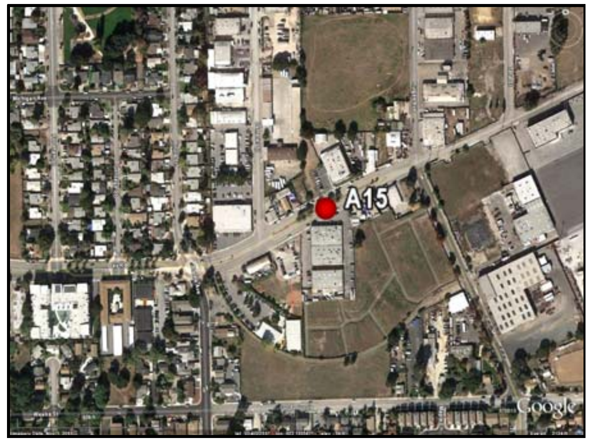
Data Summary Report

Vicinity Map:

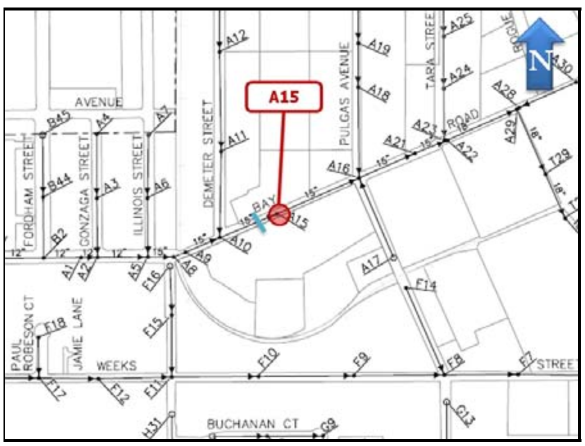


MH A15
Site Information Report

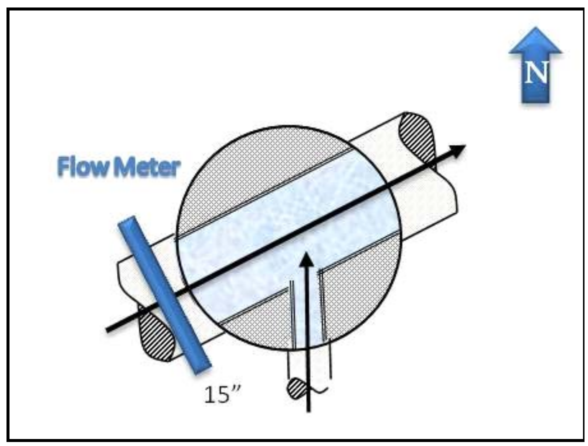
Location:	Bay Road between Demeter Street and Pulgas Avenue
Coordinates:	122.1332° W, 37.4724° N
Elevation:	14 feet
Diameter:	15 inches
Baseline Flow:	0.266 mgd
Peak Measured Flow:	0.683 mgd



Satellite Map



Sanitary Sewer Map



Flow Sketch

View from Street

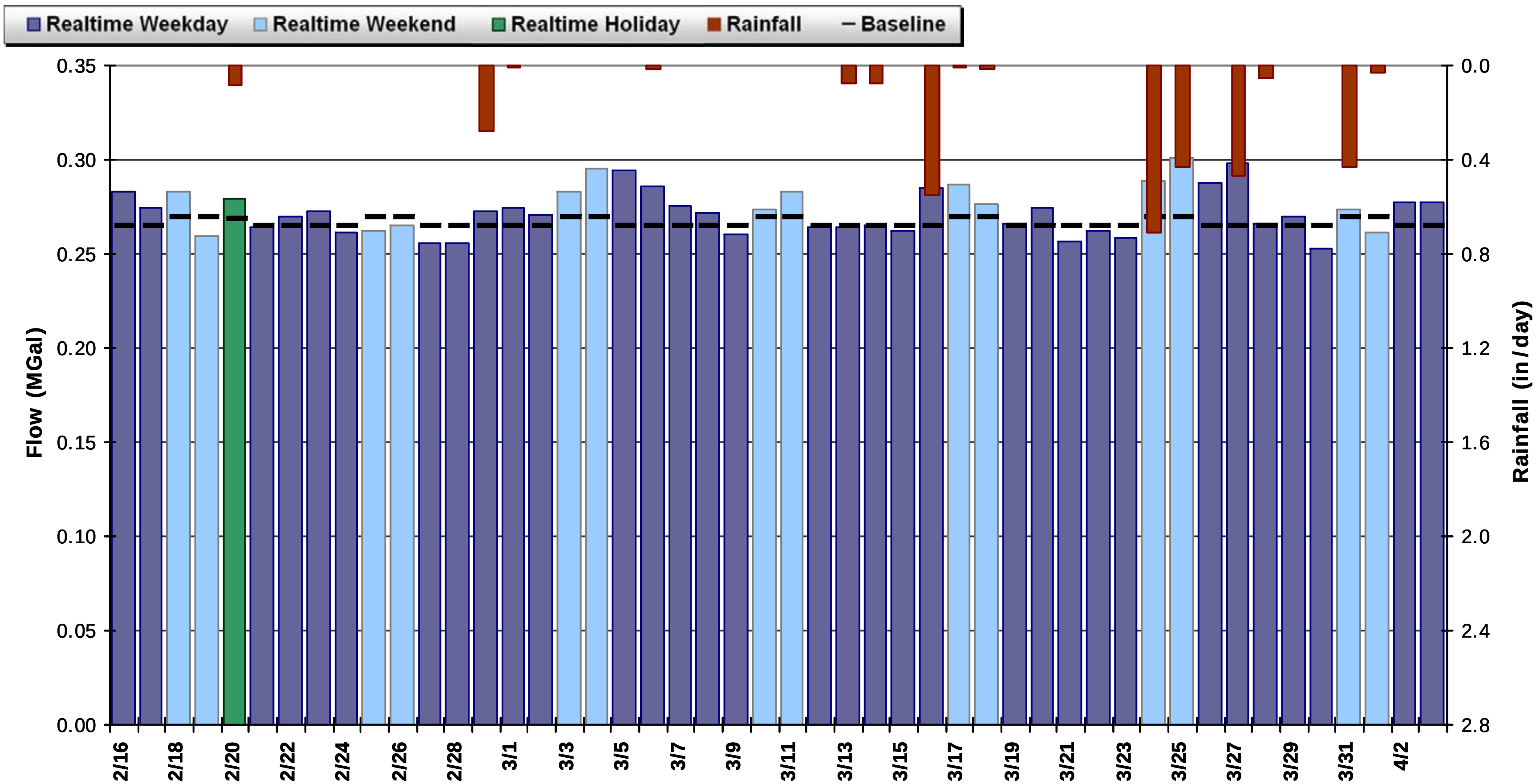
Plan View

MH A15

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.273 MGal **Peak Daily Flow: 0.301 MGal** **Min Daily Flow: 0.253 MGal**

Total Period Rainfall: 3.24 inches

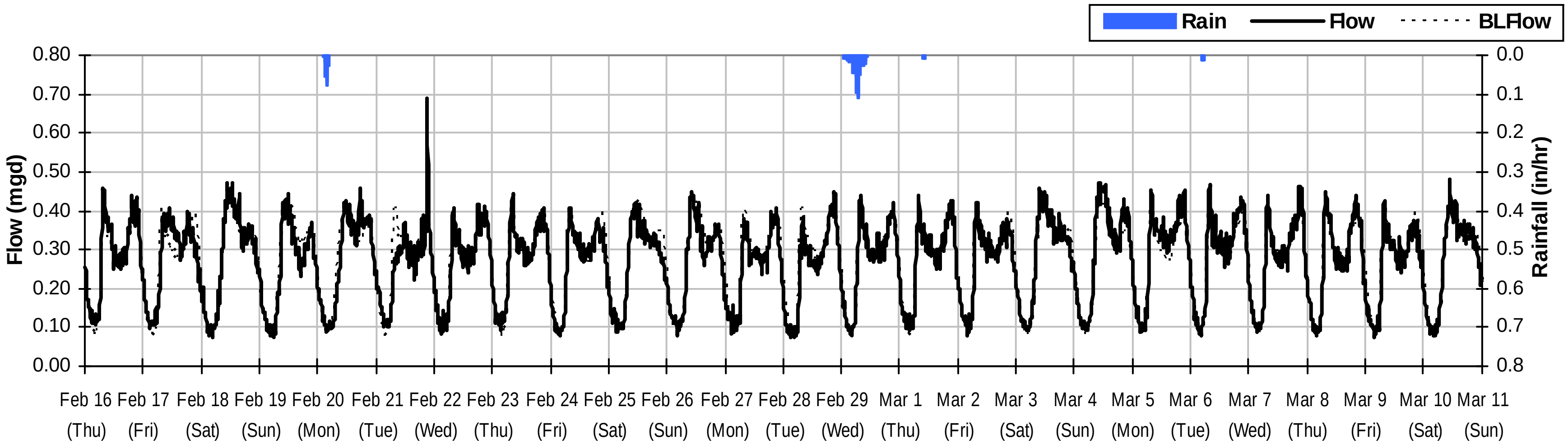


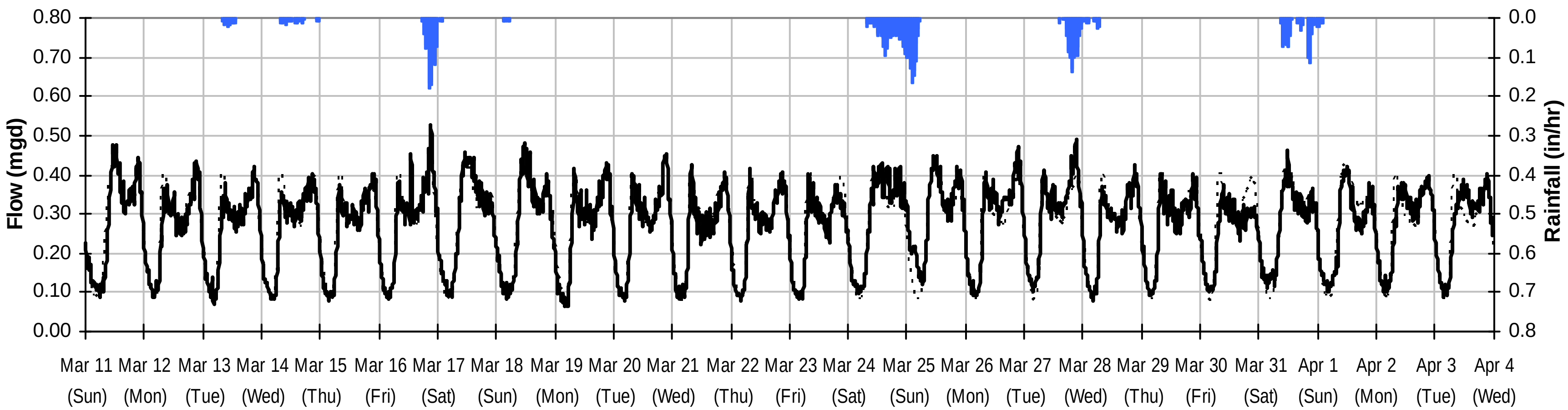
MH A15

Period Flow Summary: February 16 to April 4, 2012

Avg Flow: 0.273 mgd **Peak Flow: 0.683 mgd** **Min Flow: 0.065 mgd**

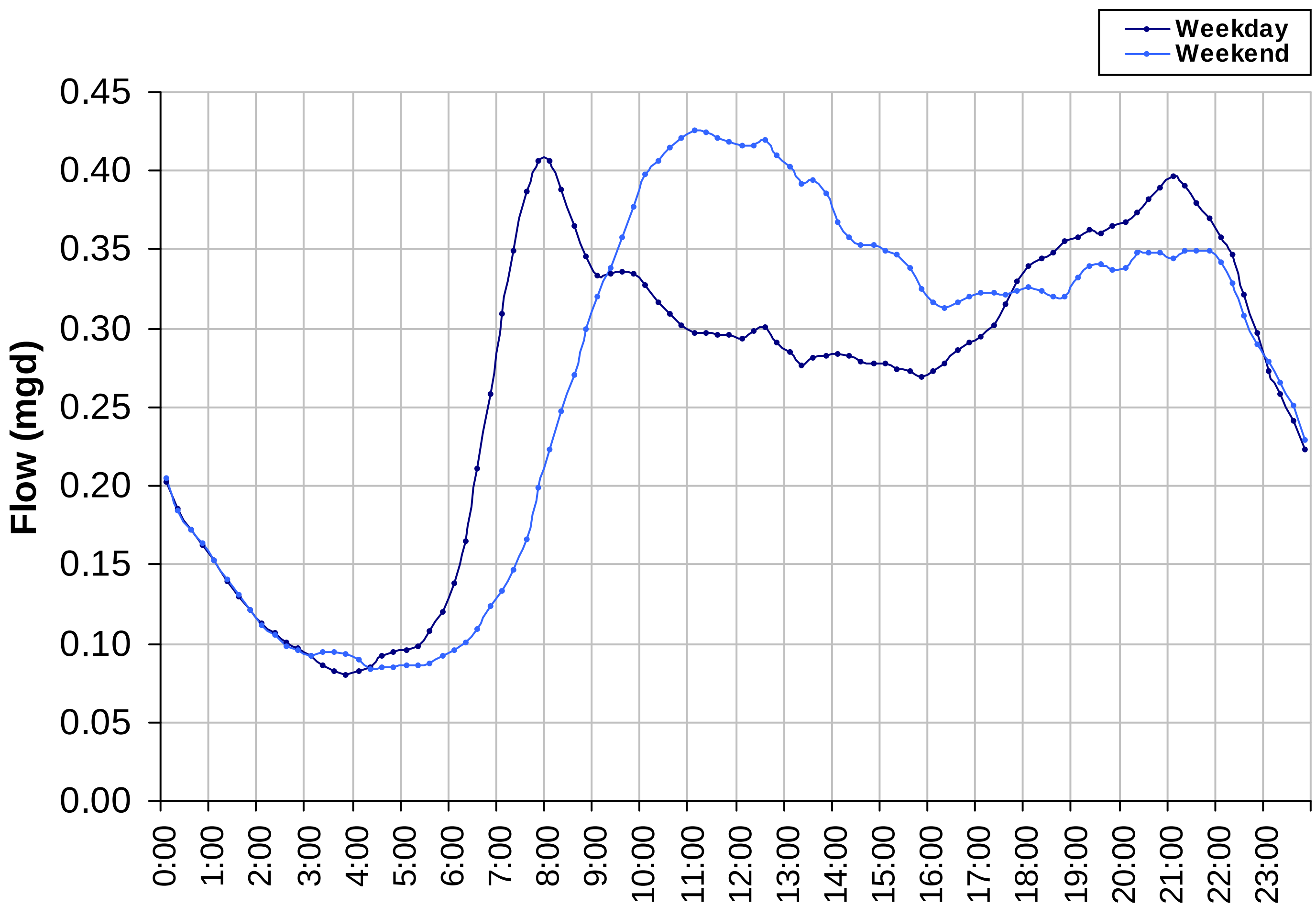
Total Period Rainfall: 3.24 inches





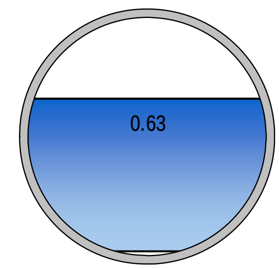
MH A15

Baseline Flow Hydrographs



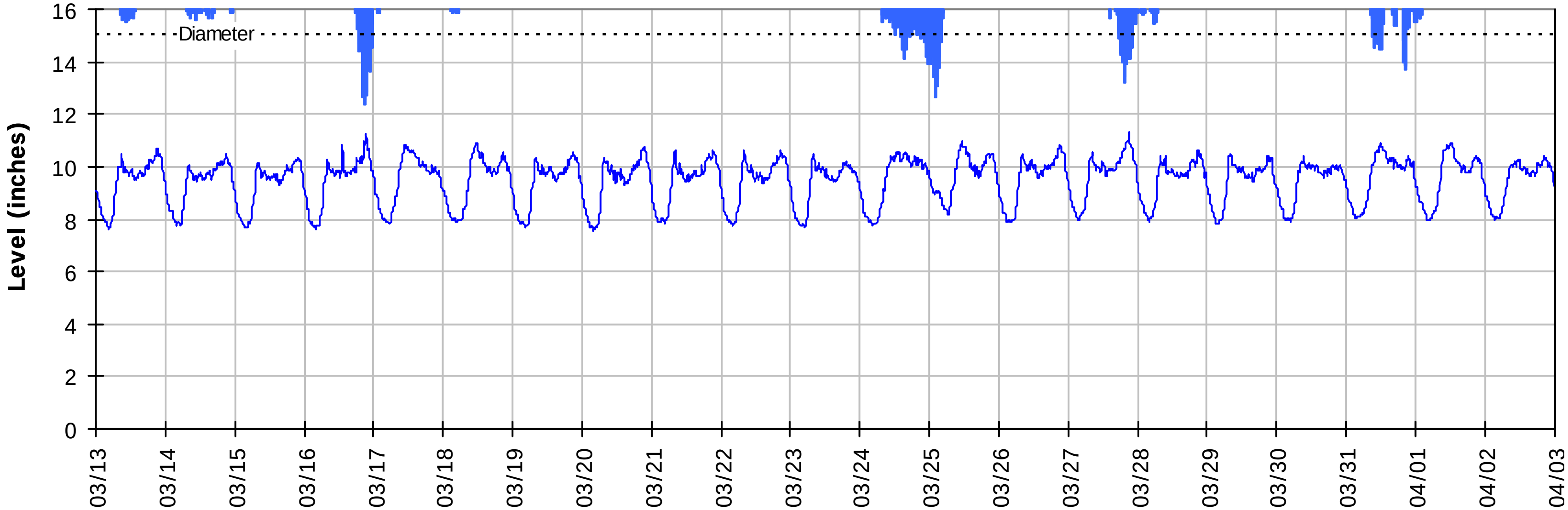
Baseline Flow:

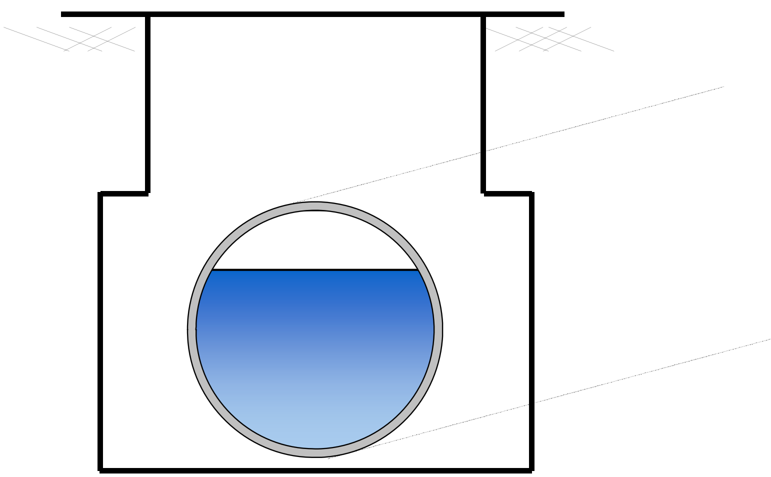
0.266 *mgd*



MH A15
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

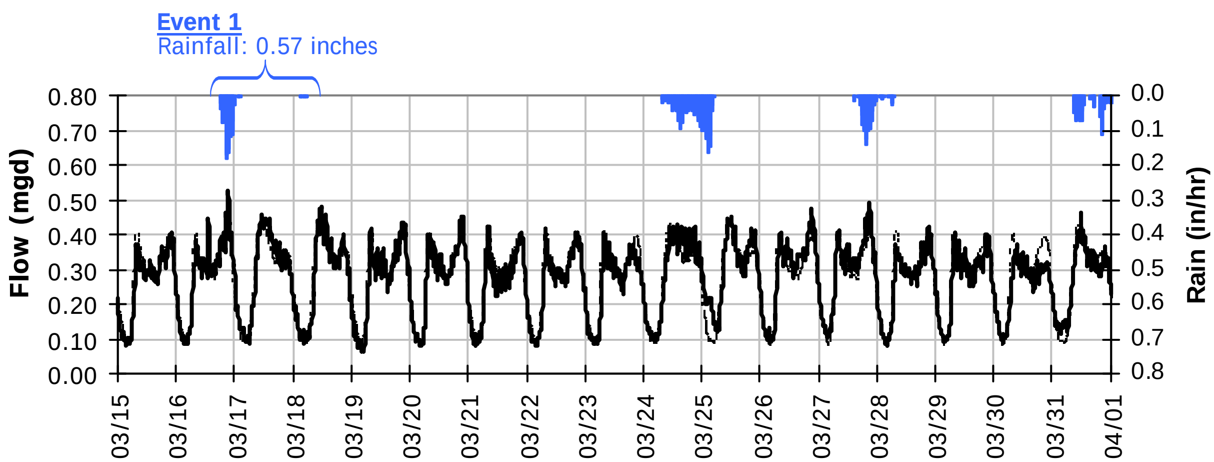




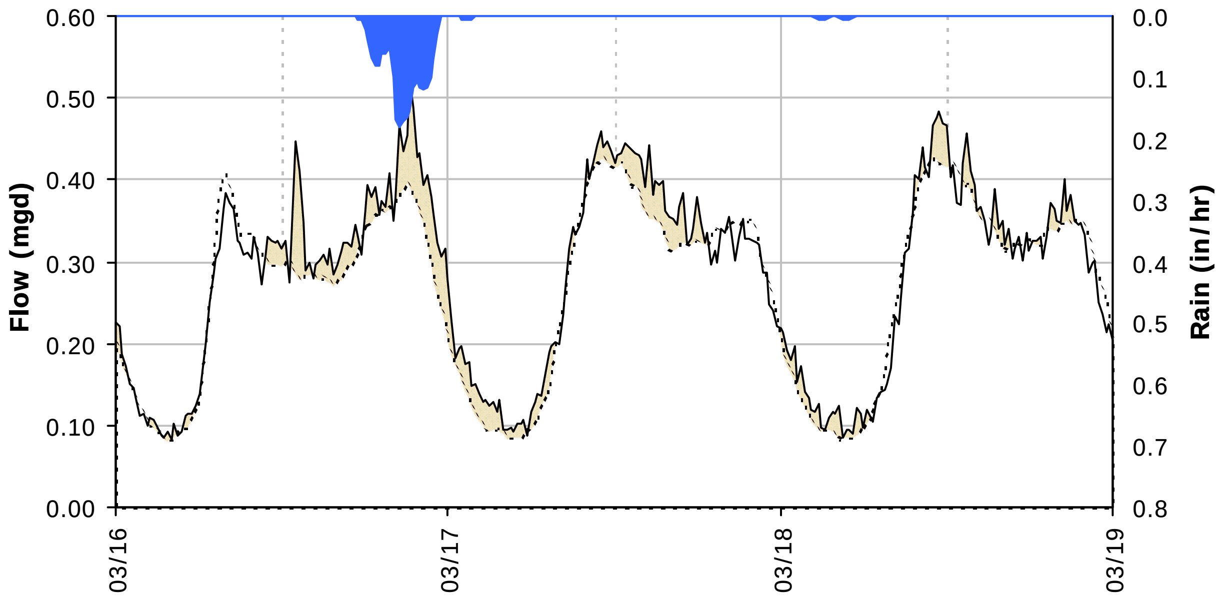
Pipe Diameter:	15 *inches*
Peak Measured Level:	11.3 *inches*
Peak d / D Ratio:	0.75

MH A15
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

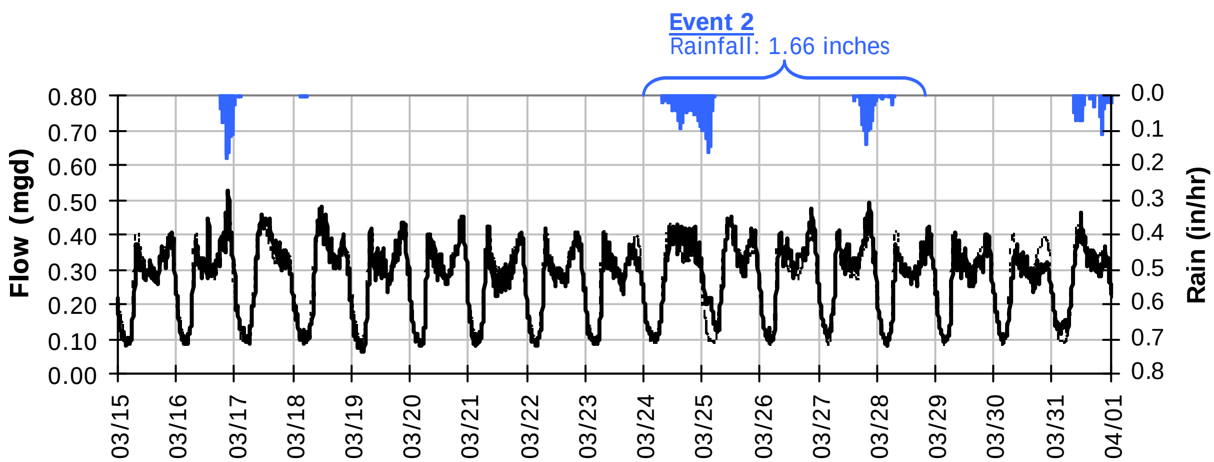


Storm Event I/I Analysis (Rain = 0.57 inches)

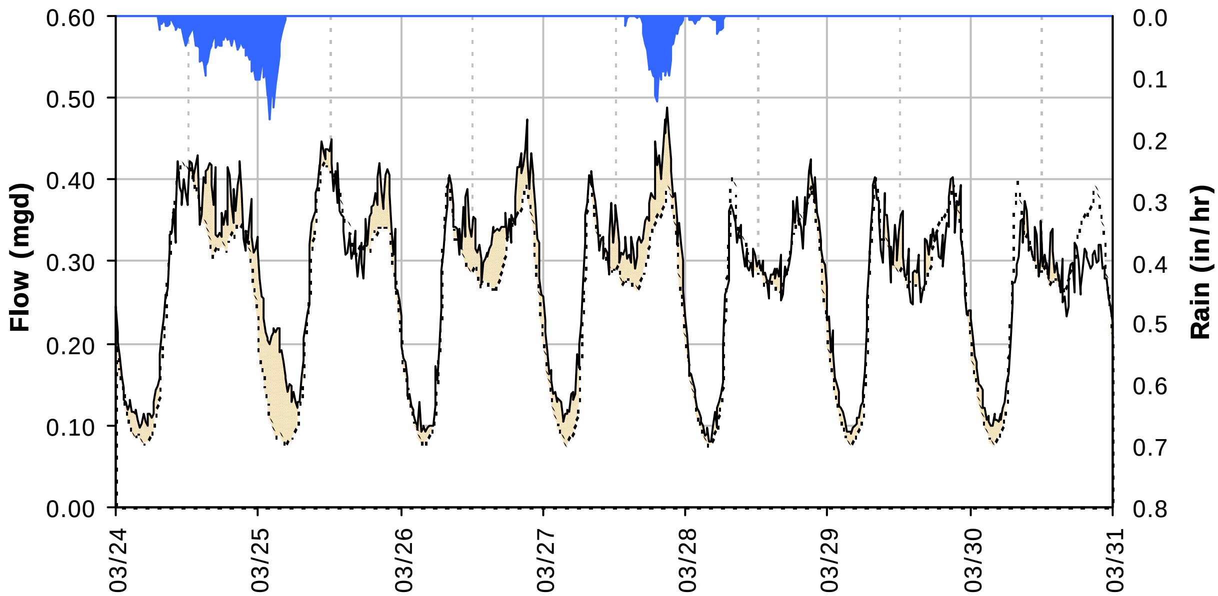
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	0.53 *mgd*	**Peak I/I Rate:**	0.14 *mgd*	**Infiltration Rate:** (3/18/2012)	0.006 *mgd*	**Total I/I:**	37,000 *gallons*
PF:	1.98	**PkI/I:IDM:**	2,617 *gpd/IDM*	**RDI:IDM:**	123 *gpd/IDM*	**Total I/I:IDM:**	1,244 *gal/IDM/in*
Peak Level:	11.23 *in*	**PkI/I:Acre:**	664 *gpd/acre*	**RDI:Acre:**	31 *gpd/acre*	**R-Value:**	1.2%
d/D Ratio:	0.75	**Pk I/I:ADWF:**	0.51	**RDI (% of BL):**	2%	**Total I/I:ADWF:**	0.24 *per in-rain*

MH A15
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



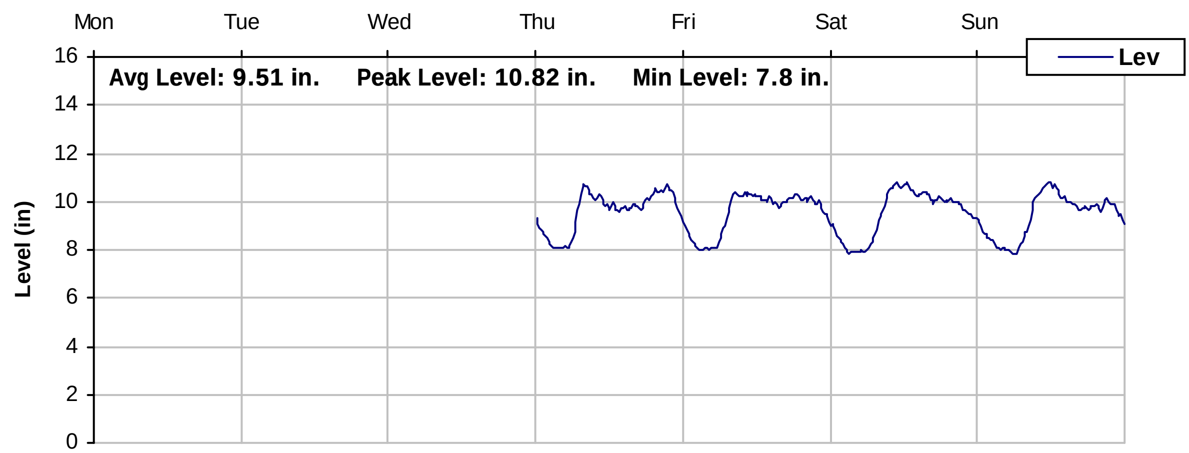
Event 2 Detail Graph

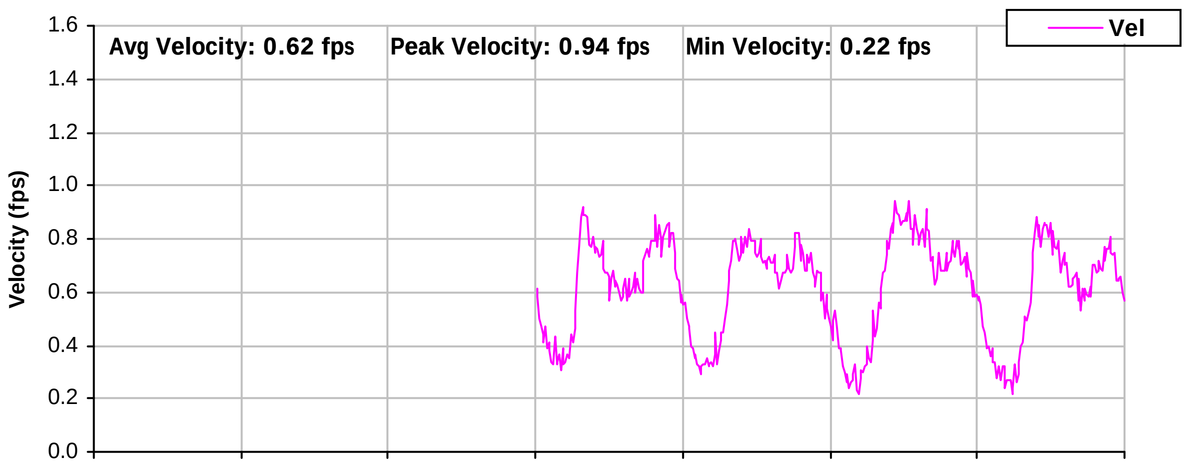


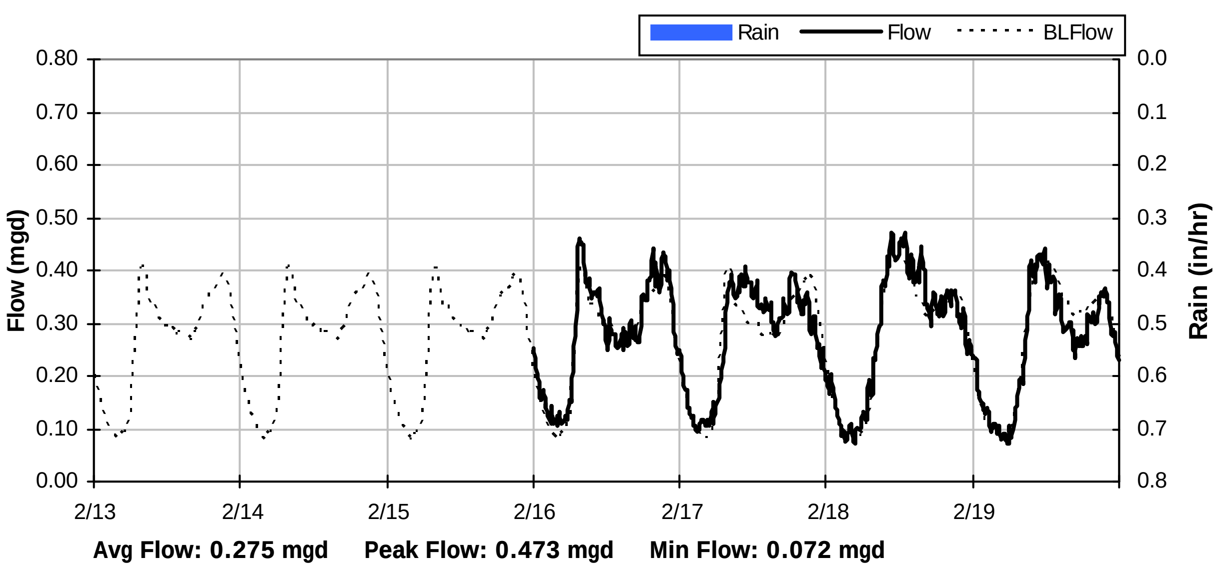
Storm Event I/I Analysis (Rain = 1.66 inches)

Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	0.49 *mgd*	**Peak I/I Rate:**	0.12 *mgd*	**Infiltration Rate:** (3/26/2012)	0.024 *mgd*	**Total I/I:**	143,000 *gallons*
PF:	1.84	**PkI/I:IDM:**	2,401 *gpd/IDM*	**RDI:IDM:**	460 *gpd/IDM*	**Total I/I:IDM:**	1,654 *gal/IDM/in*
Peak Level:	11.31 *in*	**PkI/I:Acre:**	609 *gpd/acre*	**RDI:Acre:**	117 *gpd/acre*	**R-Value:**	1.5%
d/D Ratio:	0.75	**Pk I/I:ADWF:**	0.47	**RDI (% of BL):**	9%	**Total I/I:ADWF:**	0.32 *per in-rain*

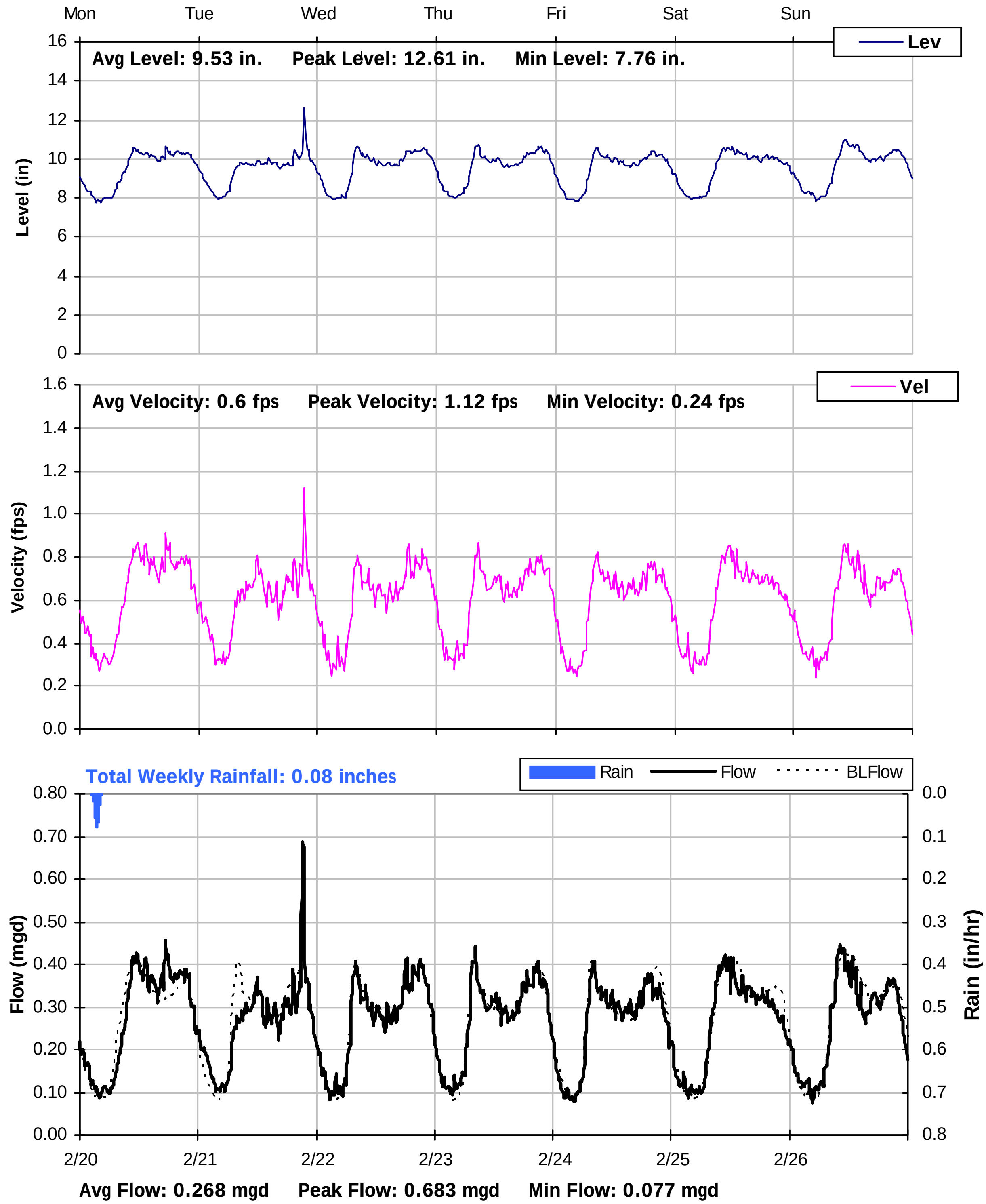
MH A15
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012



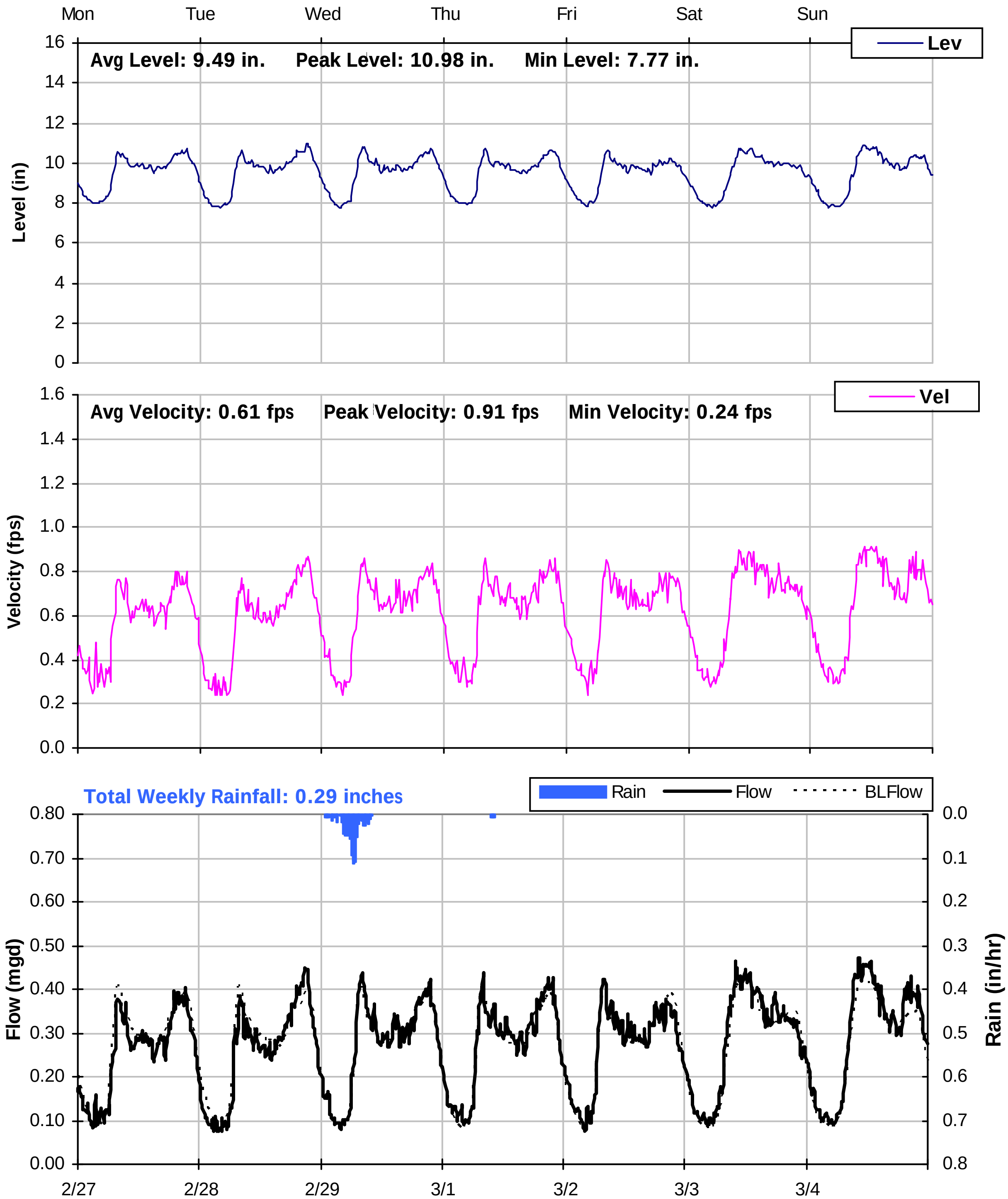




MH A15
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012

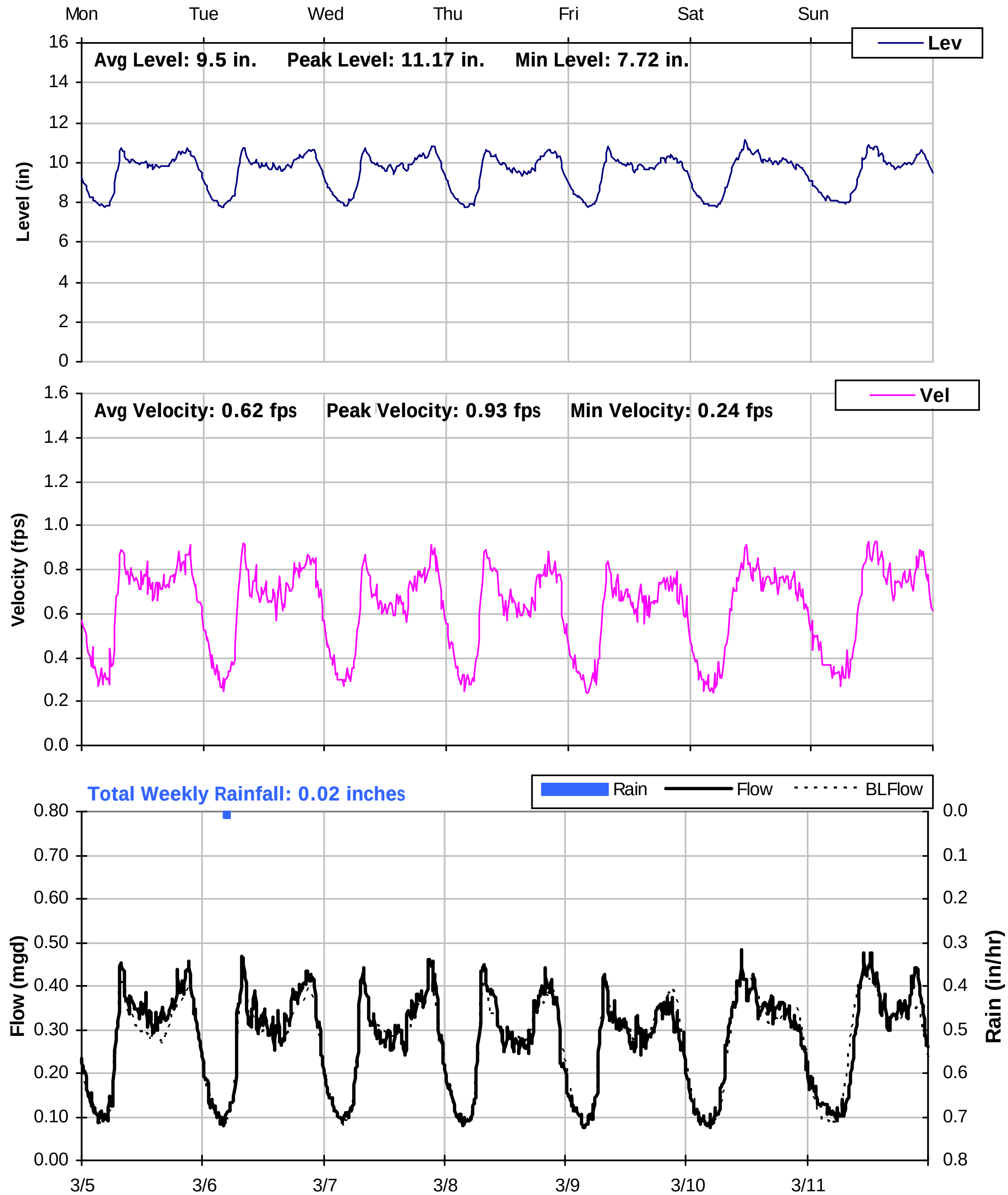


MH A15
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



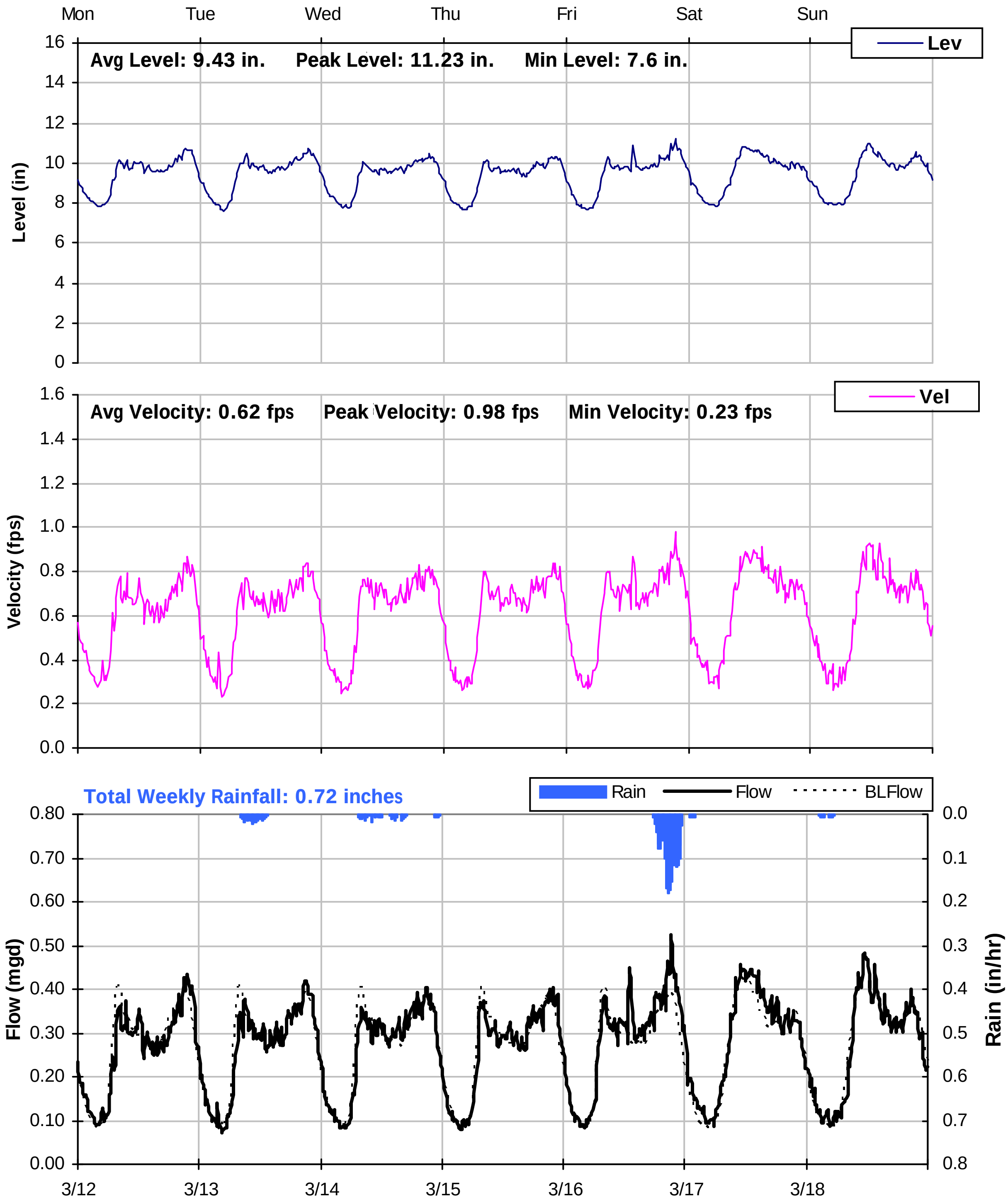
Avg Flow: 0.273 mgd Peak Flow: 0.471 mgd Min Flow: 0.075 mgd

MH A15
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



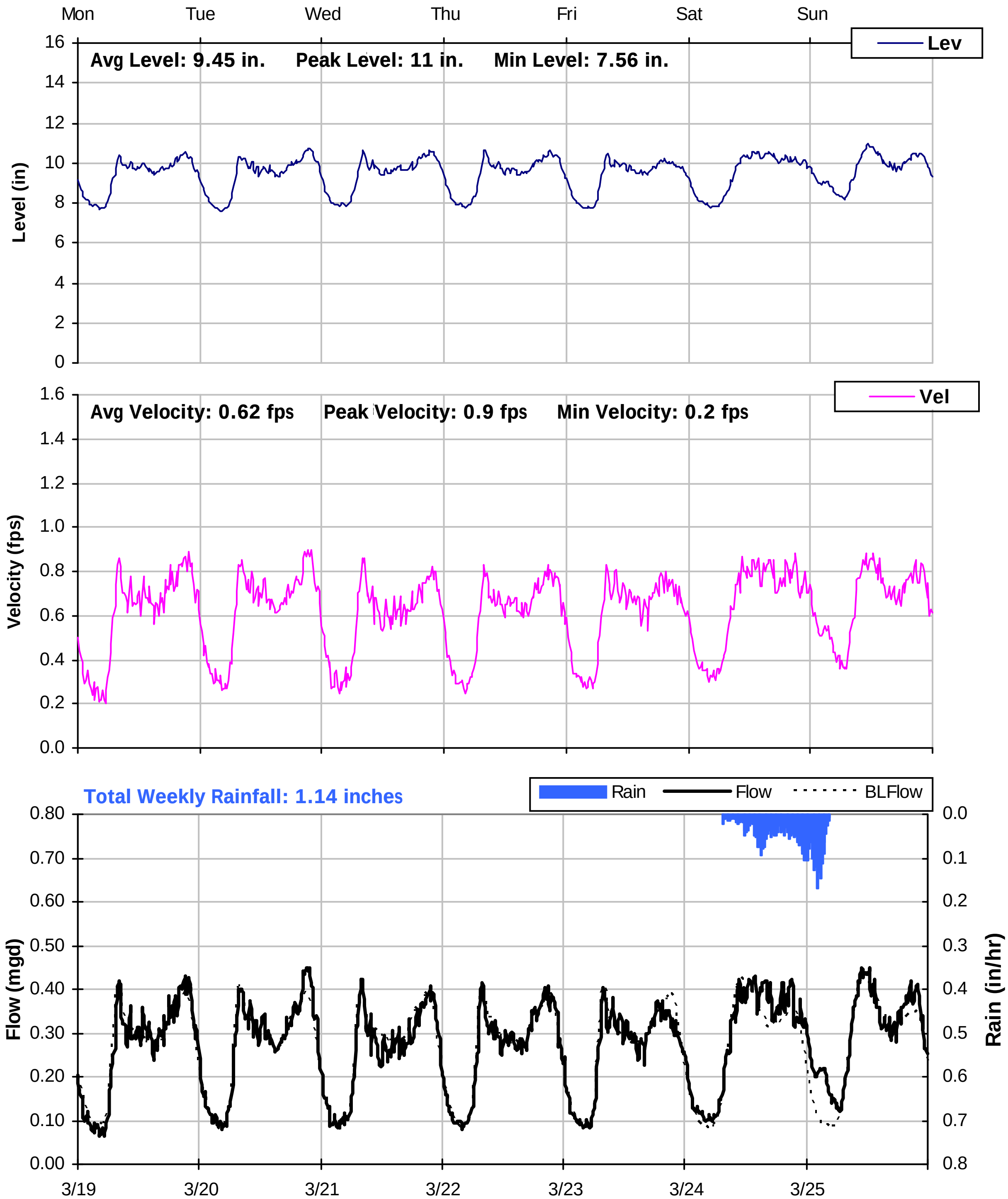
Avg Flow: 0.278 mgd **Peak Flow: 0.481 mgd** **Min Flow: 0.076 mgd**

MH A15
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



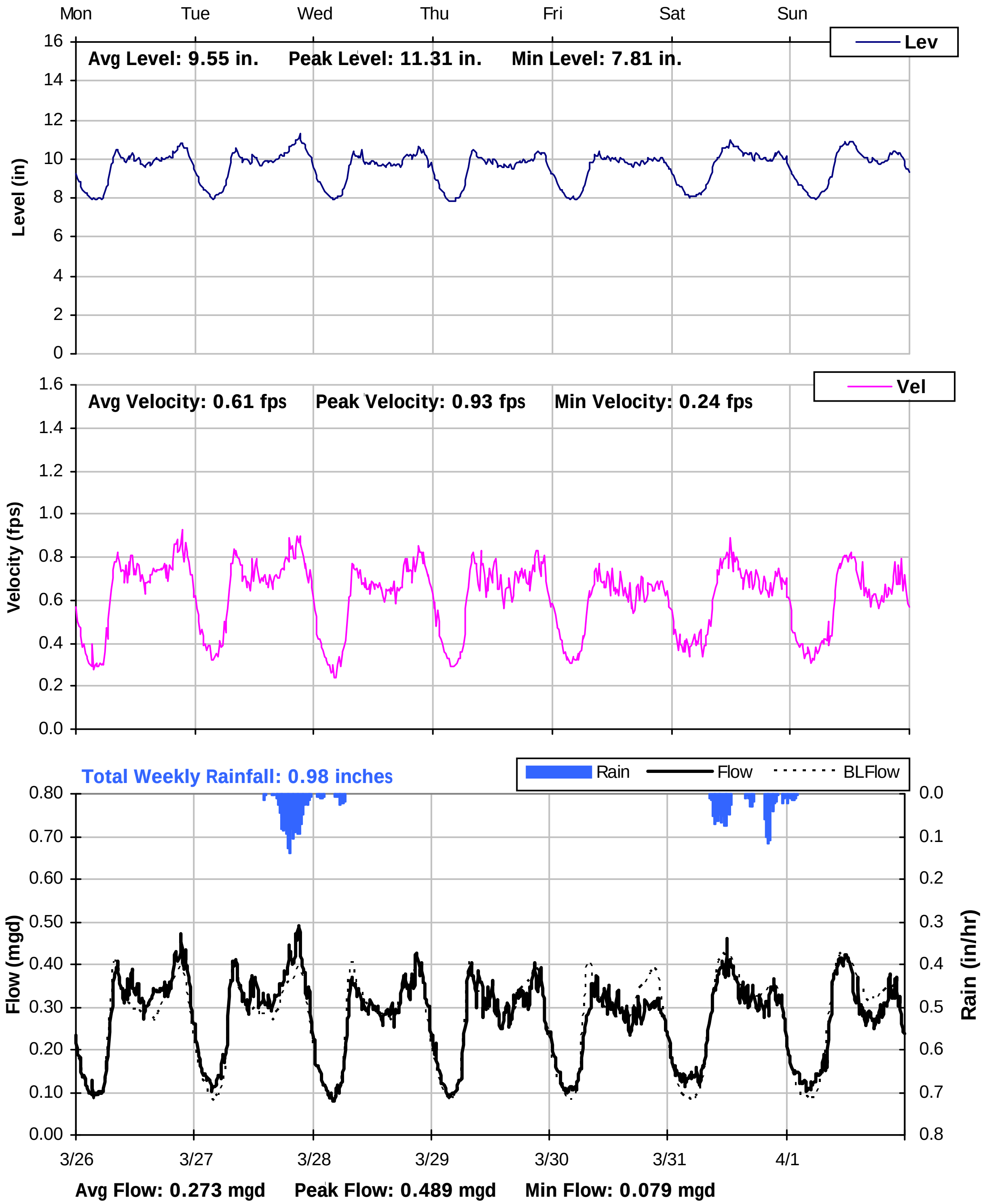
Avg Flow: 0.272 mgd **Peak Flow: 0.526 mgd** **Min Flow: 0.07 mgd**

MH A15
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012

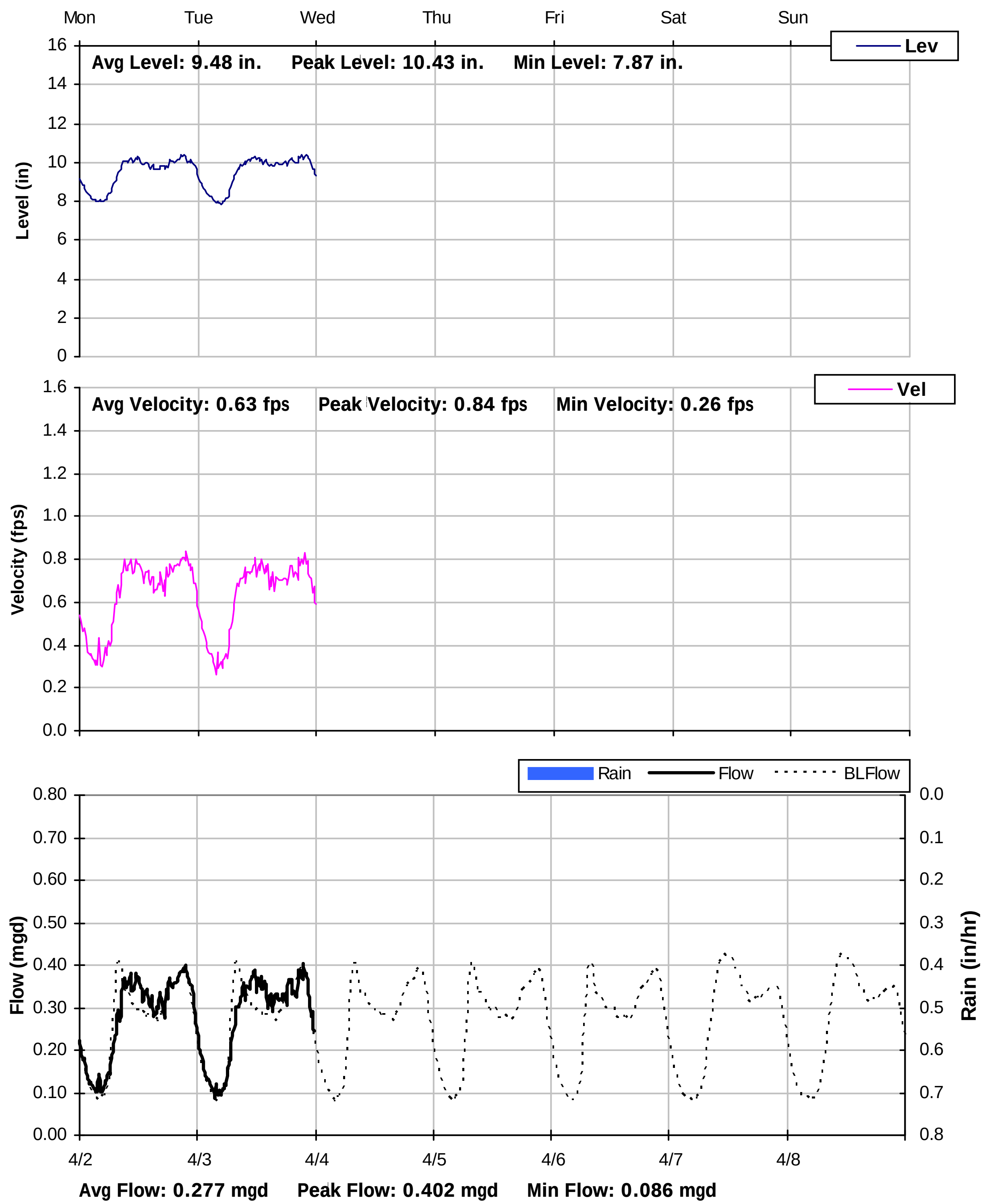


Avg Flow: 0.272 mgd   Peak Flow: 0.451 mgd   Min Flow: 0.065 mgd

MH A15
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



MH A15
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

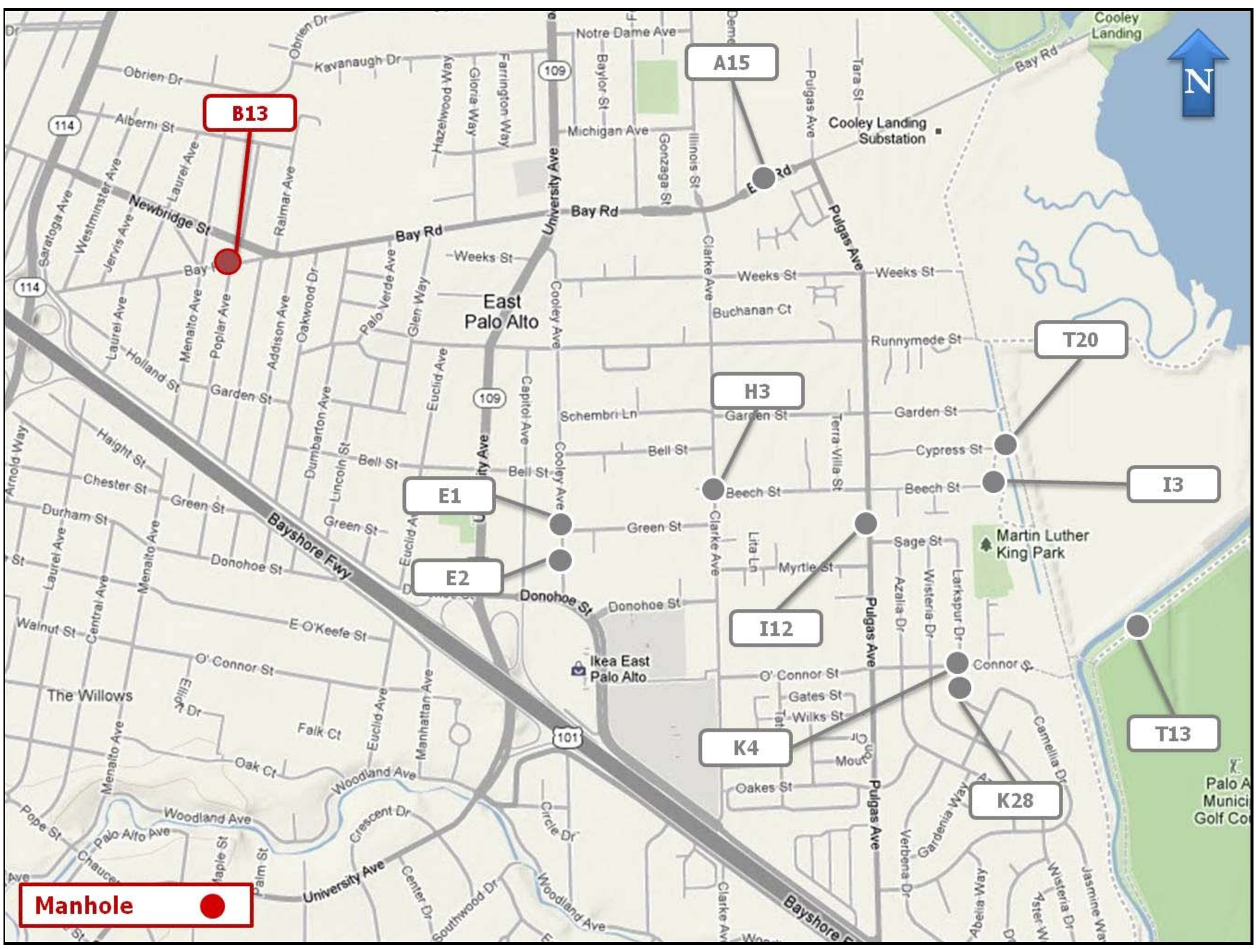
Year 2012

Monitoring Site: MH B13

Location: Bay Road at Poplar Avenue

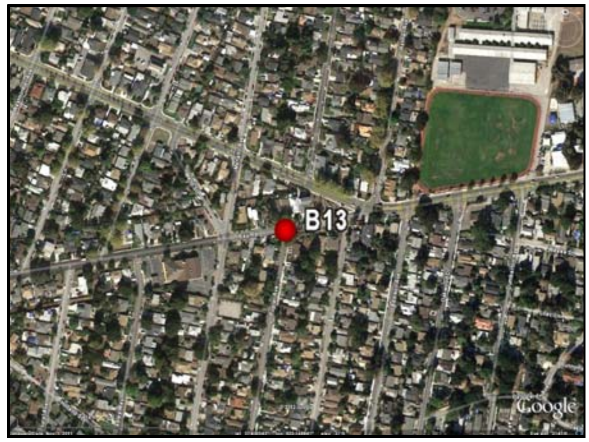
Data Summary Report

Vicinity Map:

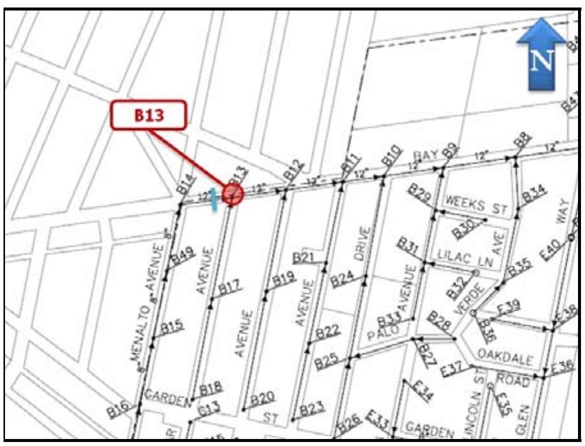


MH B13
Site Information Report

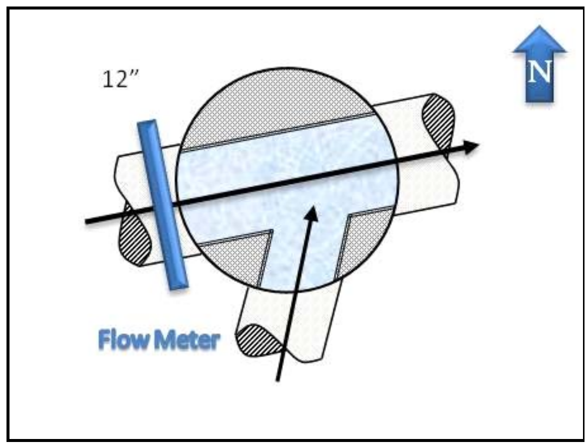
Location:	Bay Road at Poplar Avenue
Coordinates:	122.1491° W, 37.4705° N
Elevation:	17 feet
Diameter:	12 inches
Baseline Flow:	0.059 mgd
Peak Measured Flow:	0.259 mgd



Satellite Map



Sanitary Sewer Map



Flow Sketch

View from Street

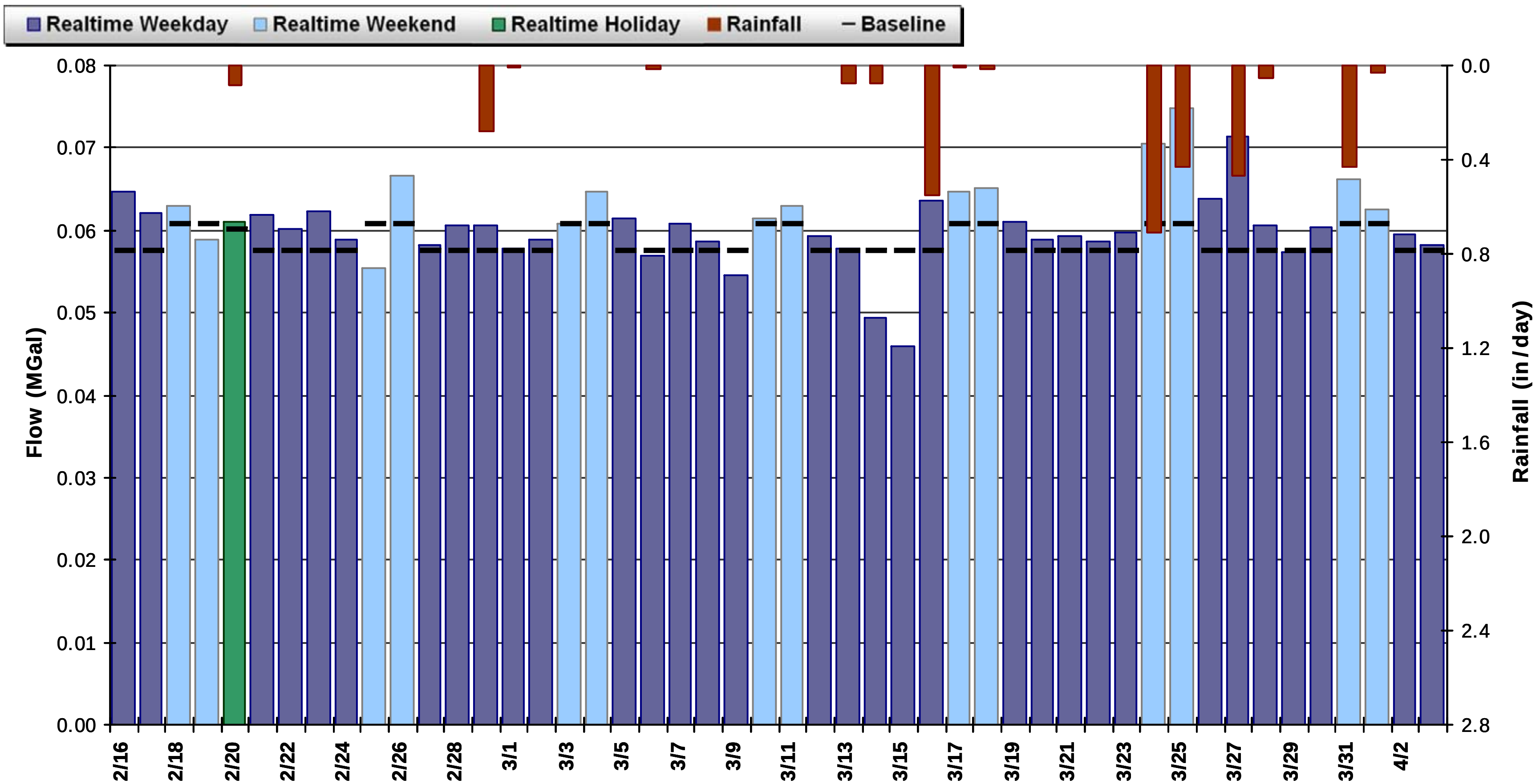
Plan View

MH B13

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.061 MGal **Peak Daily Flow: 0.075 MGal** **Min Daily Flow: 0.046 MGal**

Total Period Rainfall: 3.24 inches

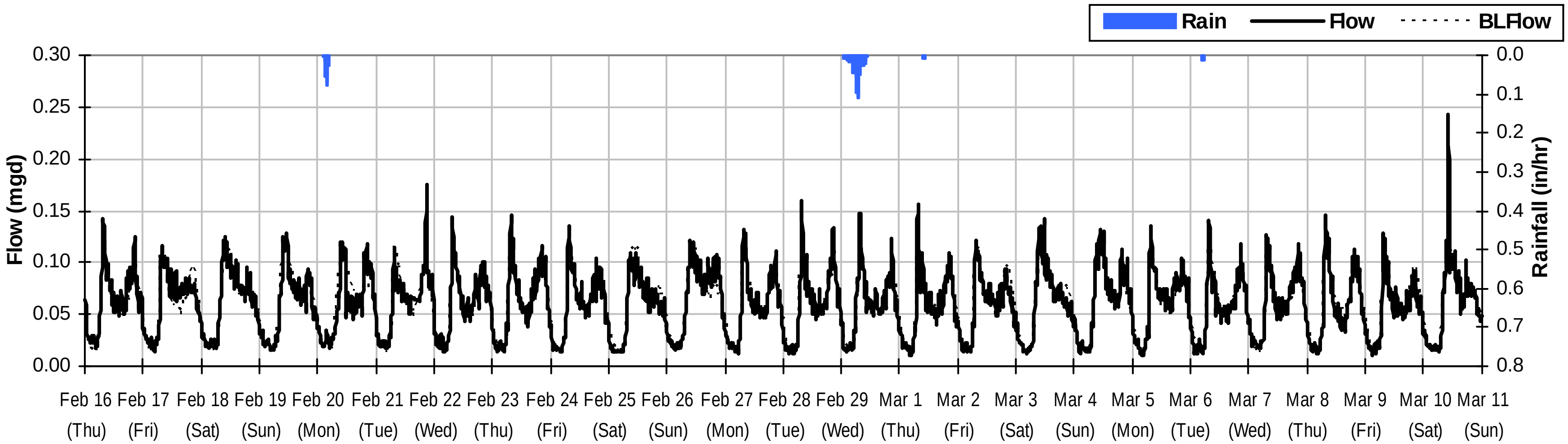


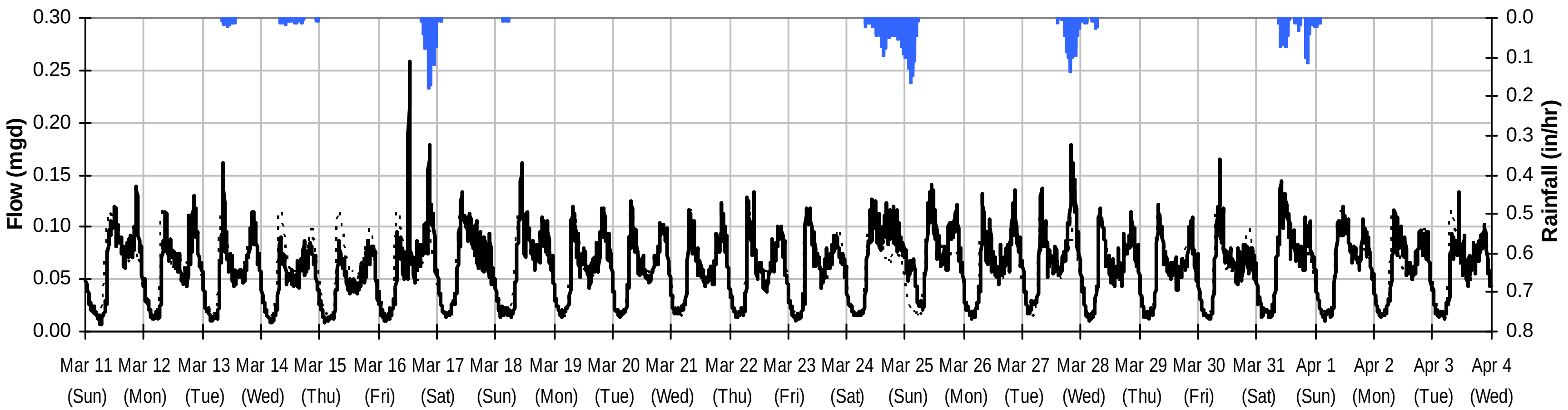
MH B13

Period Flow Summary: February 16 to April 4, 2012

Avg Flow: 0.061 mgd **Peak Flow: 0.259 mgd** **Min Flow: 0.007 mgd**

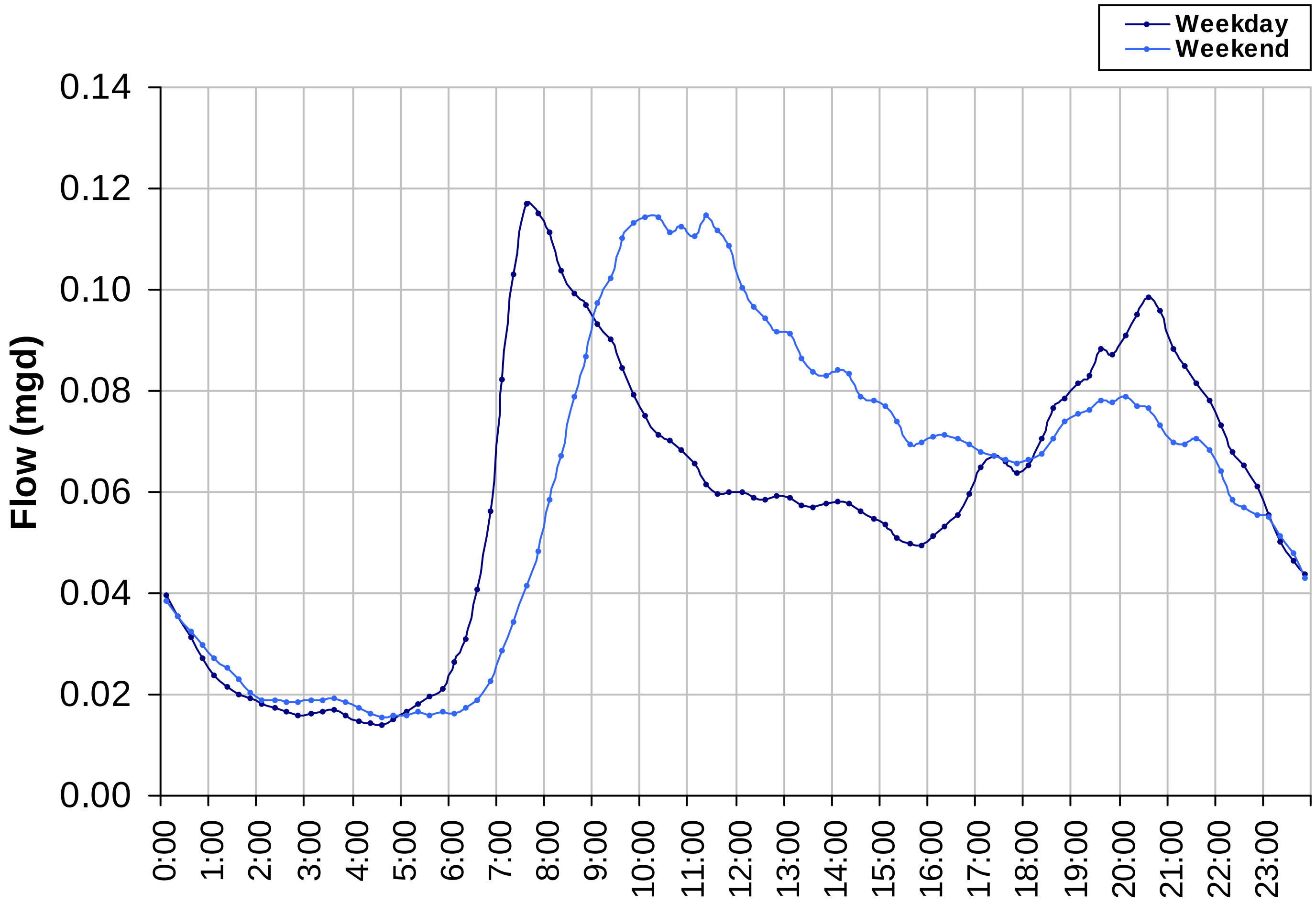
Total Period Rainfall: 3.24 inches





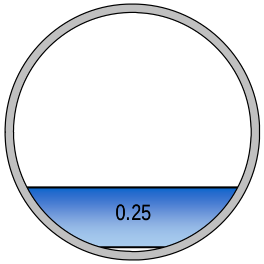
MH B13

Baseline Flow Hydrographs



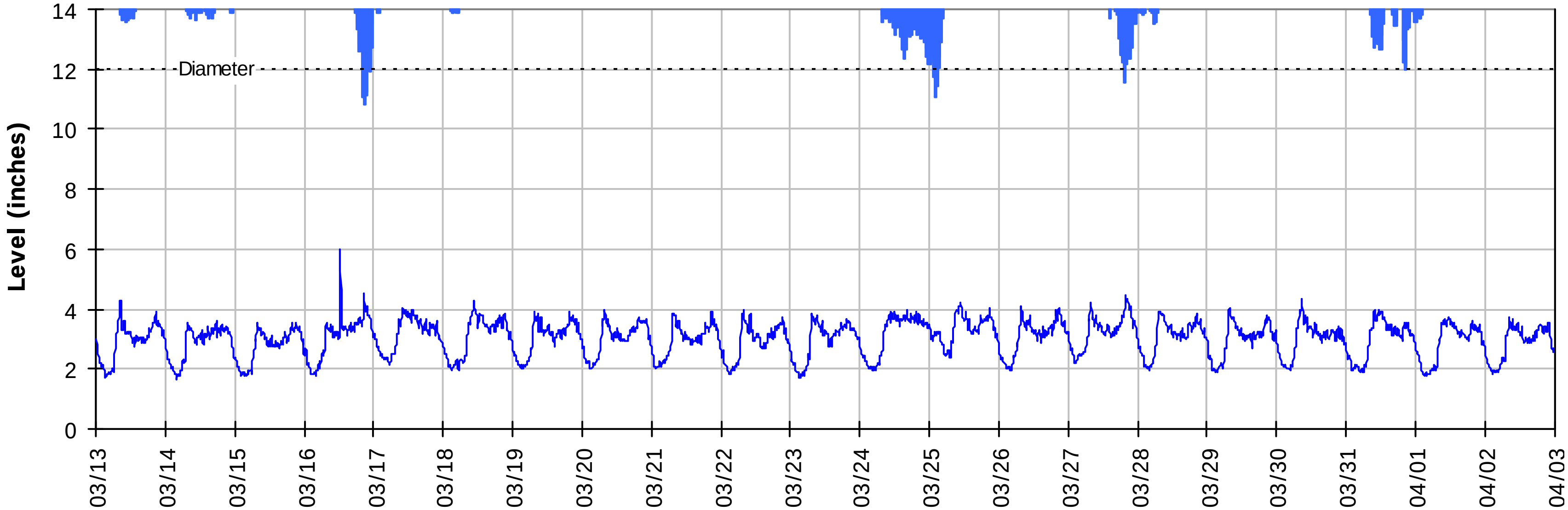
Baseline Flow:

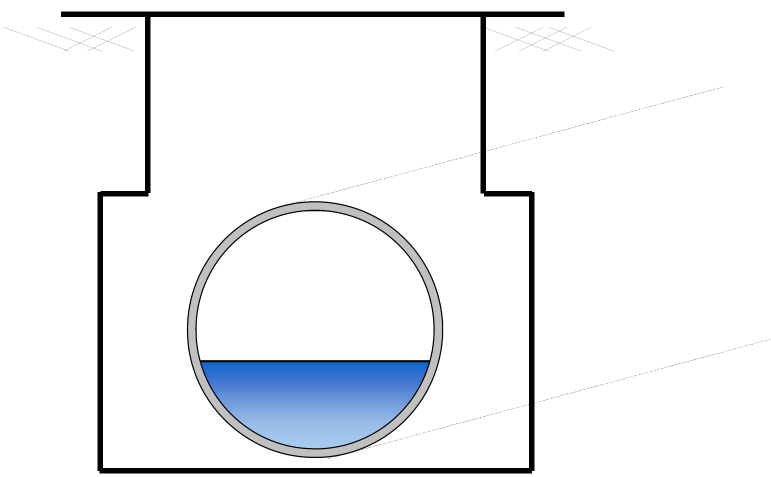
0.059 *mgd*



MH B13
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





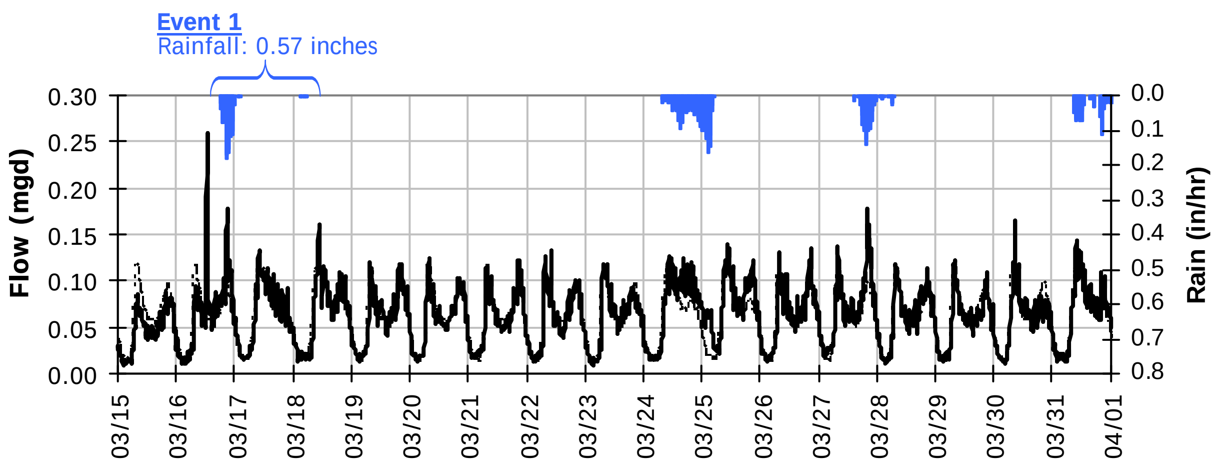
Pipe Diameter: 12 *inches*

Peak Measured Level: 4.54 *inches*

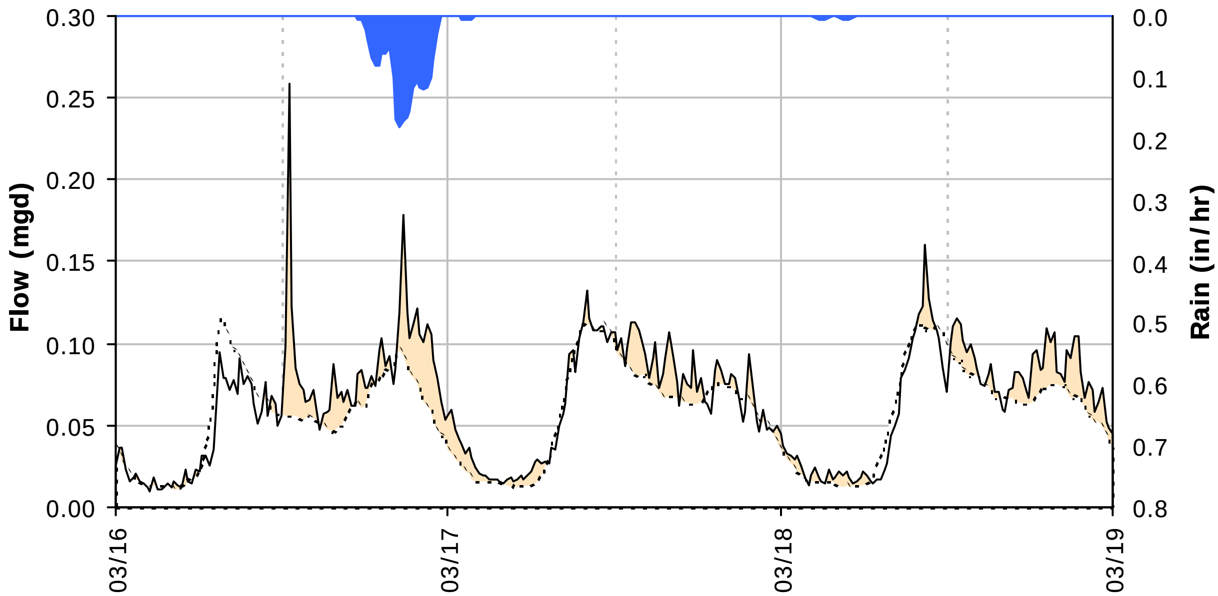
Peak d/D Ratio: 0.38

MH B13
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

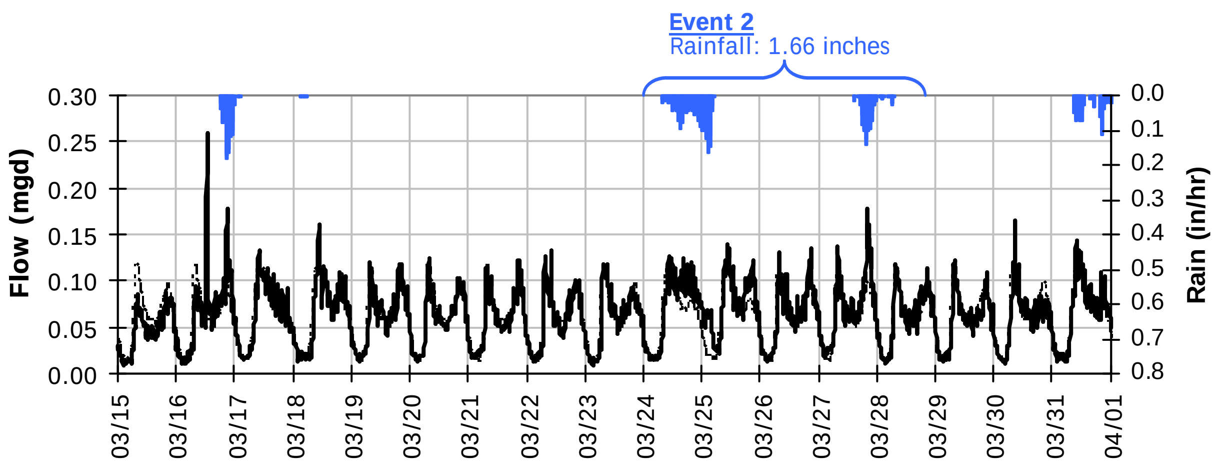


Storm Event I/I Analysis (Rain = 0.57 inches)

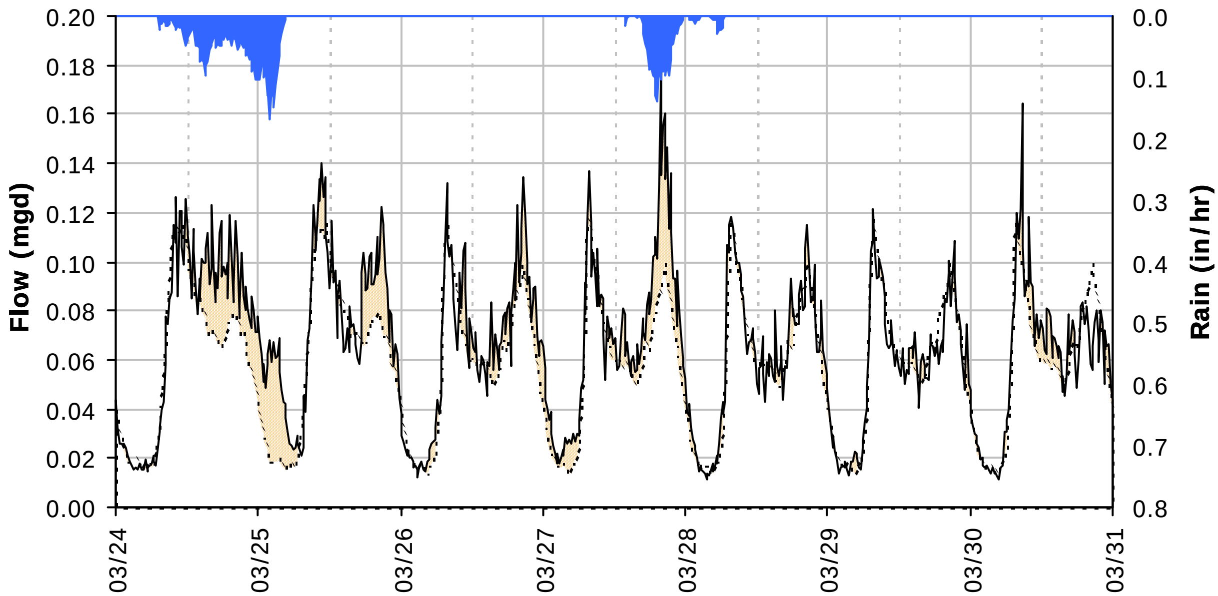
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	0.18 *mgd*	**Peak I/I Rate:**	0.08 *mgd*	**Infiltration Rate:** (3/18/2012)	0.007 *mgd*	**Total I/I:**	13,000 *gallons*
PF:	3.04	**PkI/I:IDM:**	3,852 *gpd/IDM*	**RDI:IDM:**	314 *gpd/IDM*	**Total I/I:IDM:**	1,042 *gal/IDM/in*
Peak Level:	4.54 *in*	**PkI/I:Acre:**	947 *gpd/acre*	**RDI:Acre:**	77 *gpd/acre*	**R-Value:**	0.9%
d/D Ratio:	0.38	**Pk I/I:ADWF:**	1.40	**RDI (% of BL):**	17%	**Total I/I:ADWF:**	0.38 *per in-rain*

MH B13
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



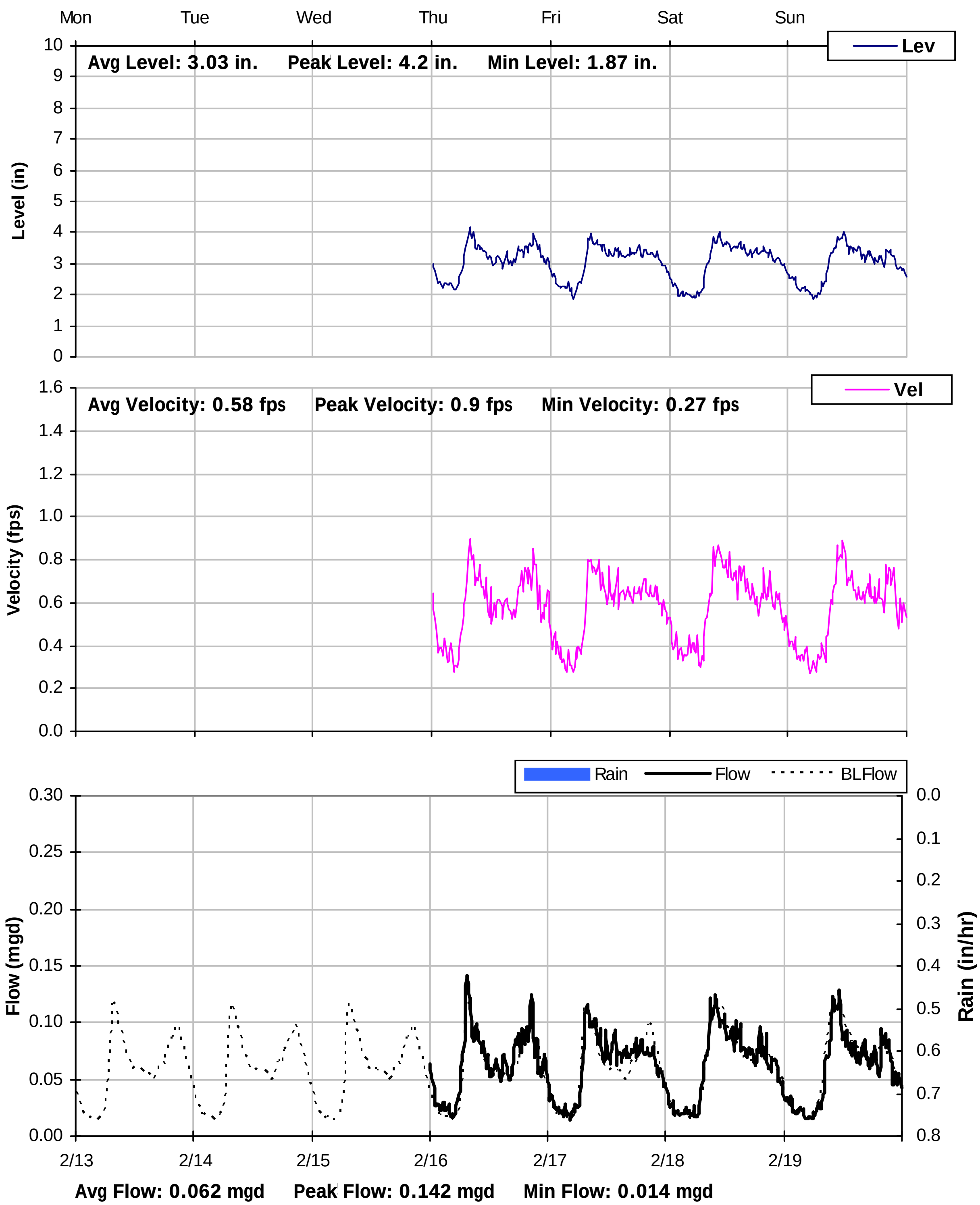
Event 2 Detail Graph



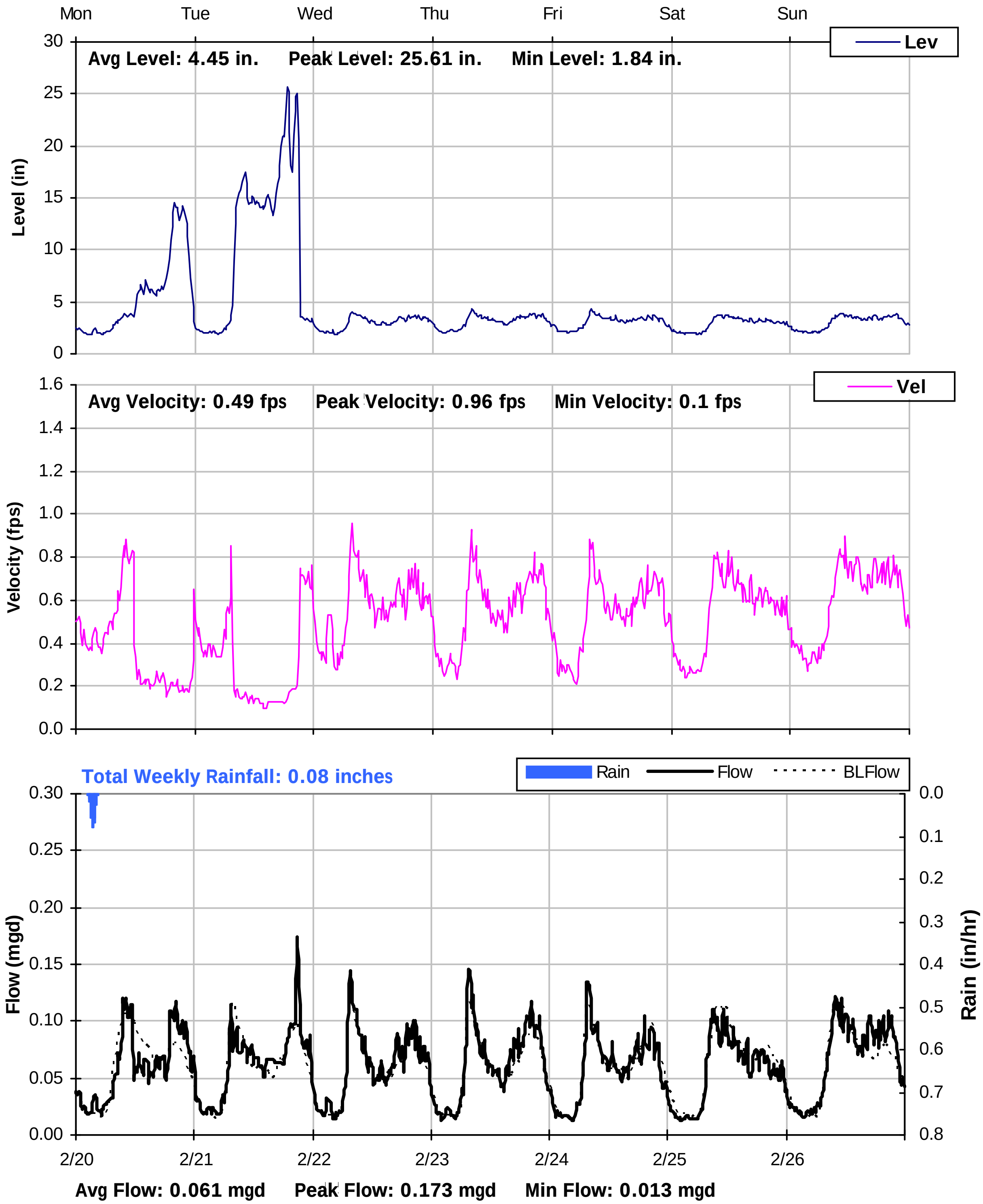
Storm Event I/I Analysis (Rain = 1.66 inches)

Capacity		**Inflow**		**RDI (infiltration)**		**Combined I/I**	
Peak Flow:	0.18 *mgd*	**Peak I/I Rate:**	0.09 *mgd*	**Infiltration Rate:** (3/26/2012)	0.006 *mgd*	**Total I/I:**	47,000 *gallons*
PF:	3.04	**PkI/I:IDM:**	4,250 *gpd/IDM*	**RDI:IDM:**	297 *gpd/IDM*	**Total I/I:IDM:**	1,336 *gal/IDM/in*
Peak Level:	4.44 *in*	**PkI/I:Acre:**	1,045 *gpd/acre*	**RDI:Acre:**	73 *gpd/acre*	**R-Value:**	1.2%
d/D Ratio:	0.37	**Pk I/I:ADWF:**	1.55	**RDI (% of BL):**	11%	**Total I/I:ADWF:**	0.49 *per in-rain*

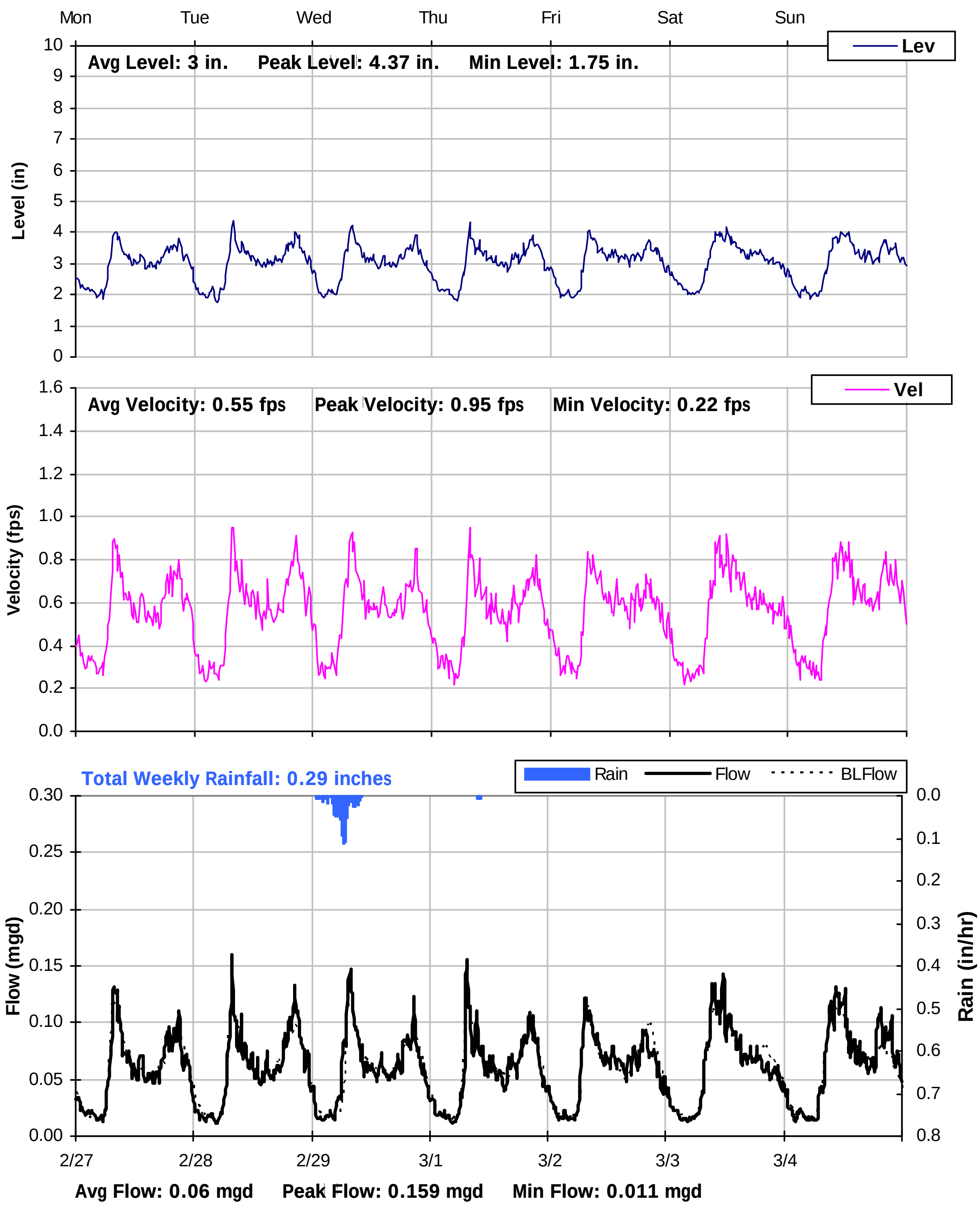
MH B13
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012



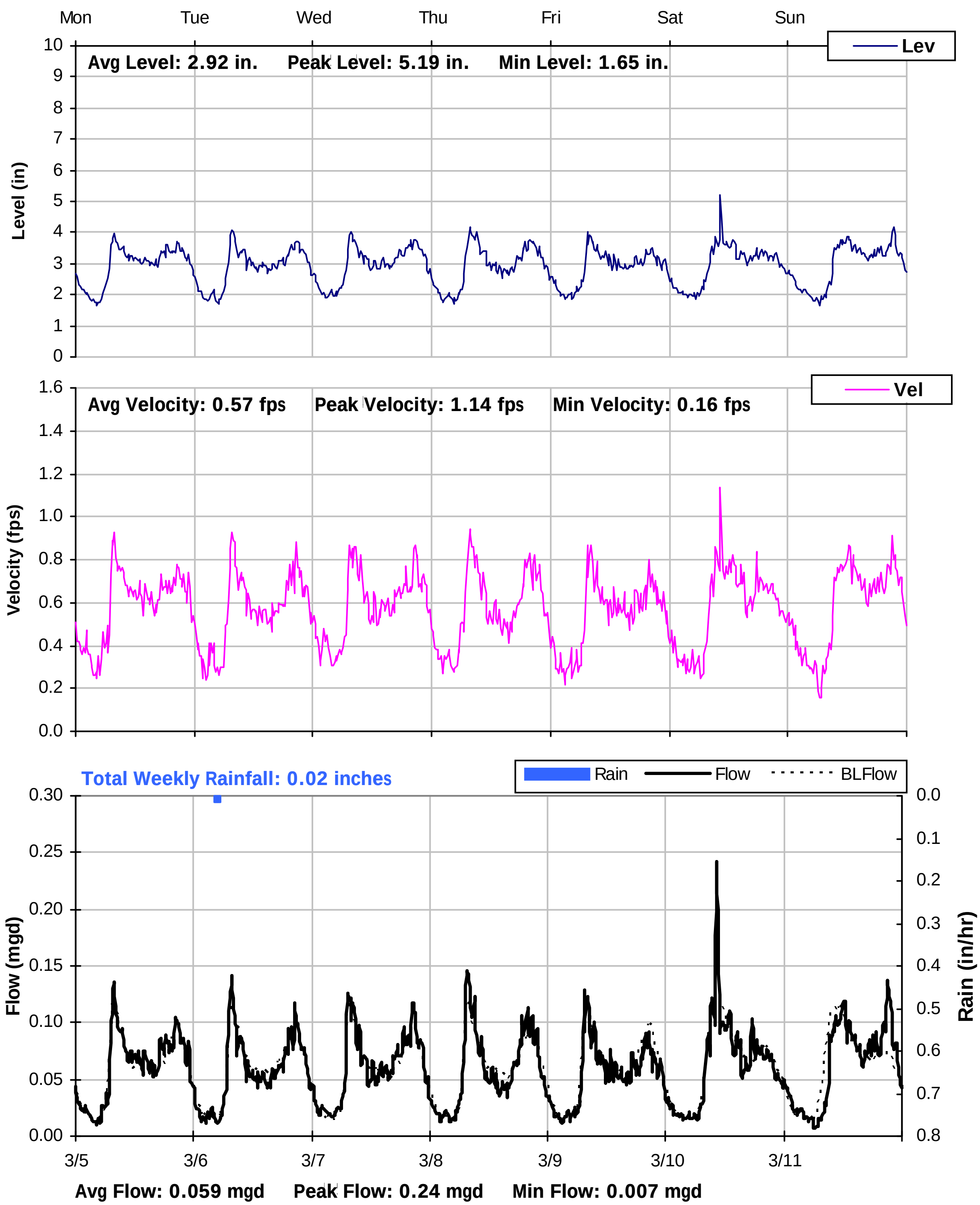
MH B13
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



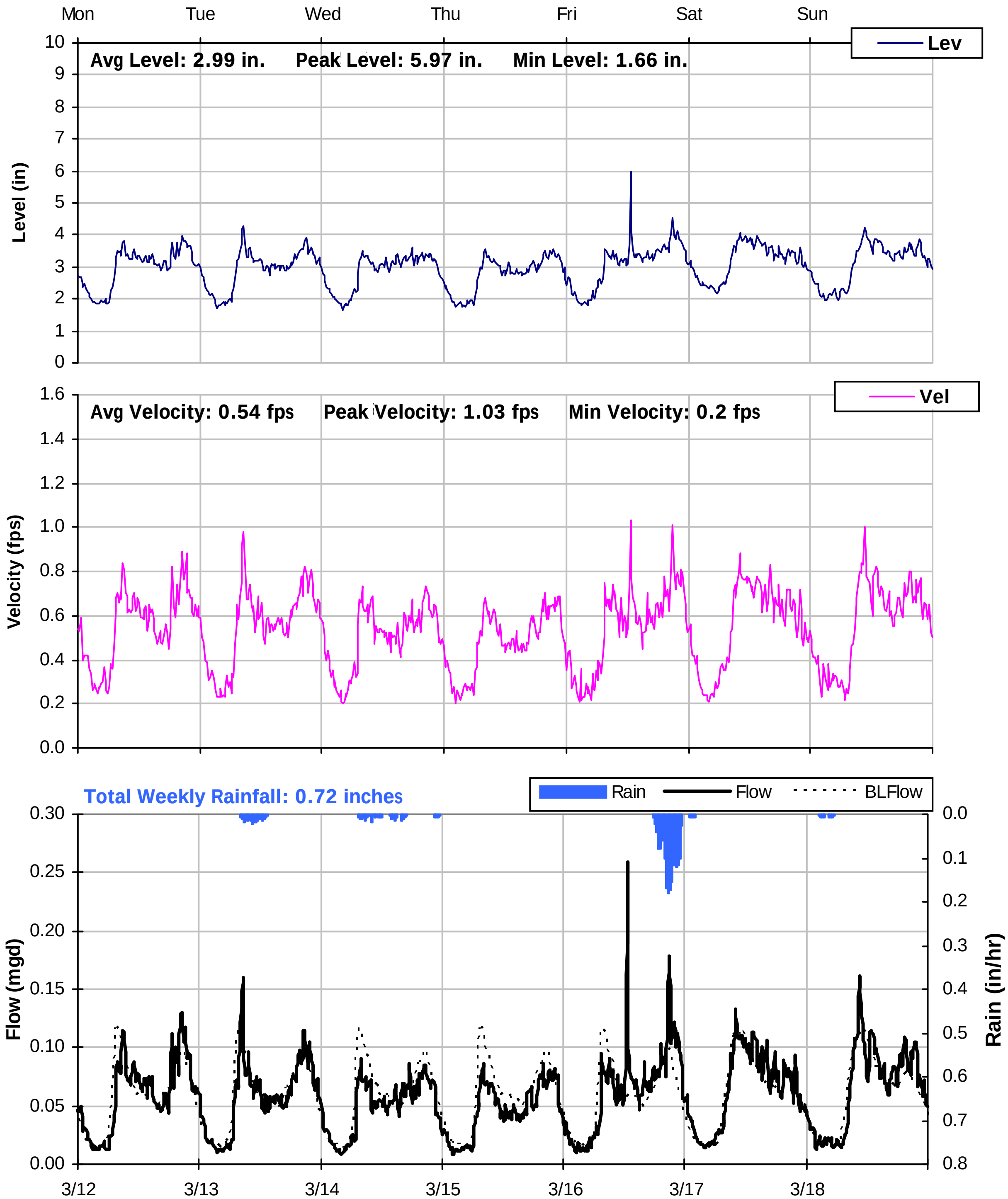
MH B13
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



MH B13
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012

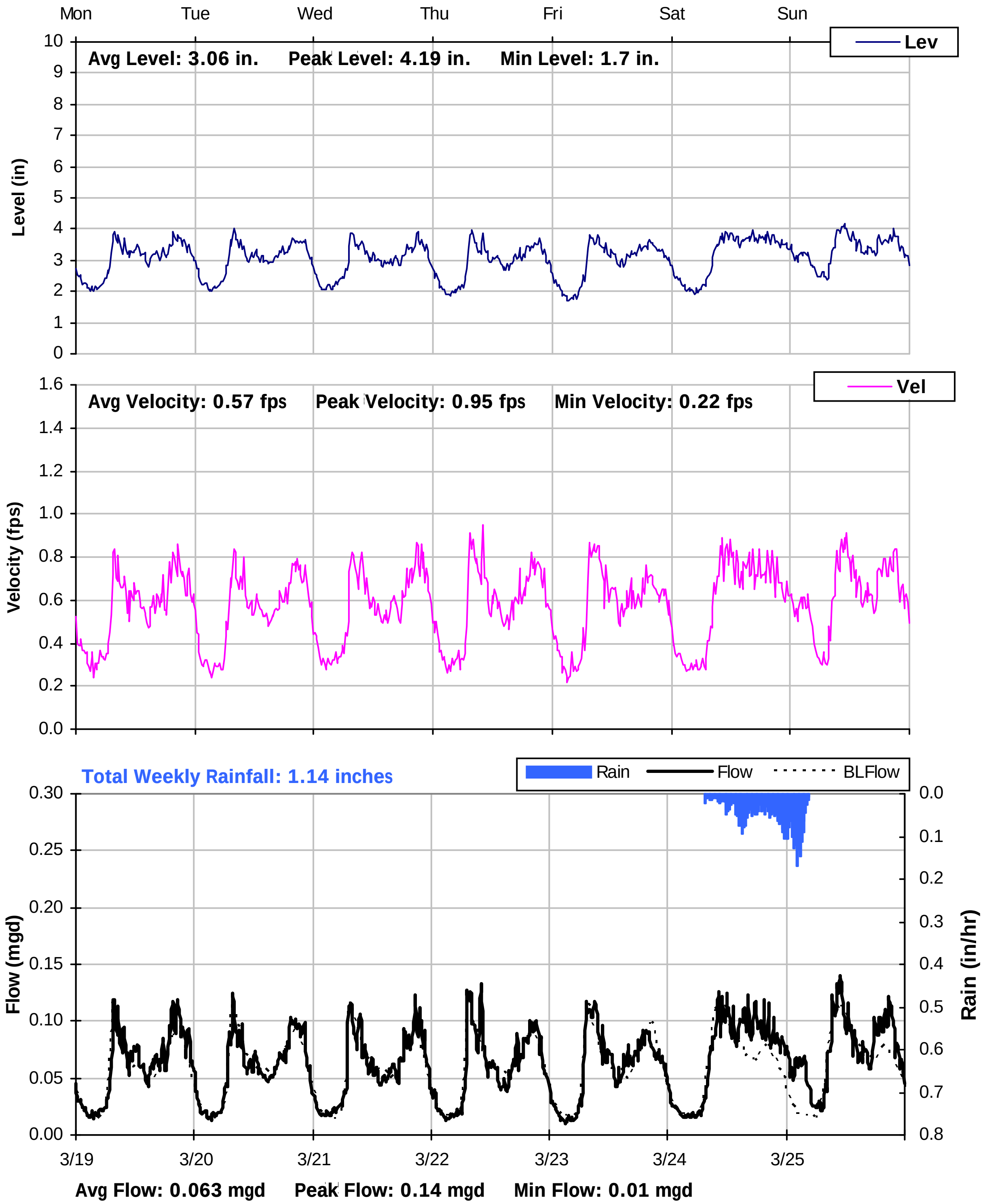


MH B13
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012

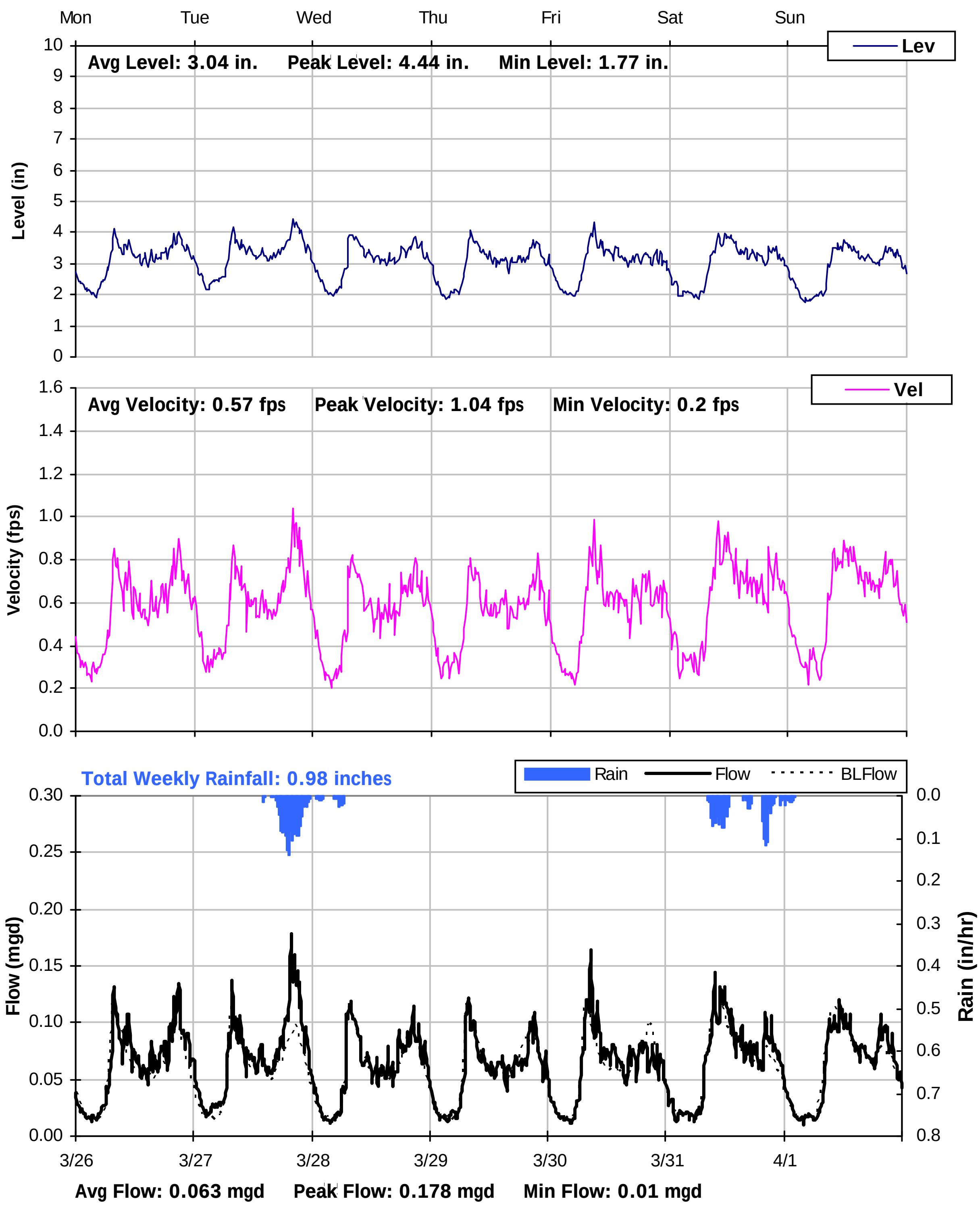


Avg Flow: 0.058 mgd Peak Flow: 0.259 mgd Min Flow: 0.009 mgd

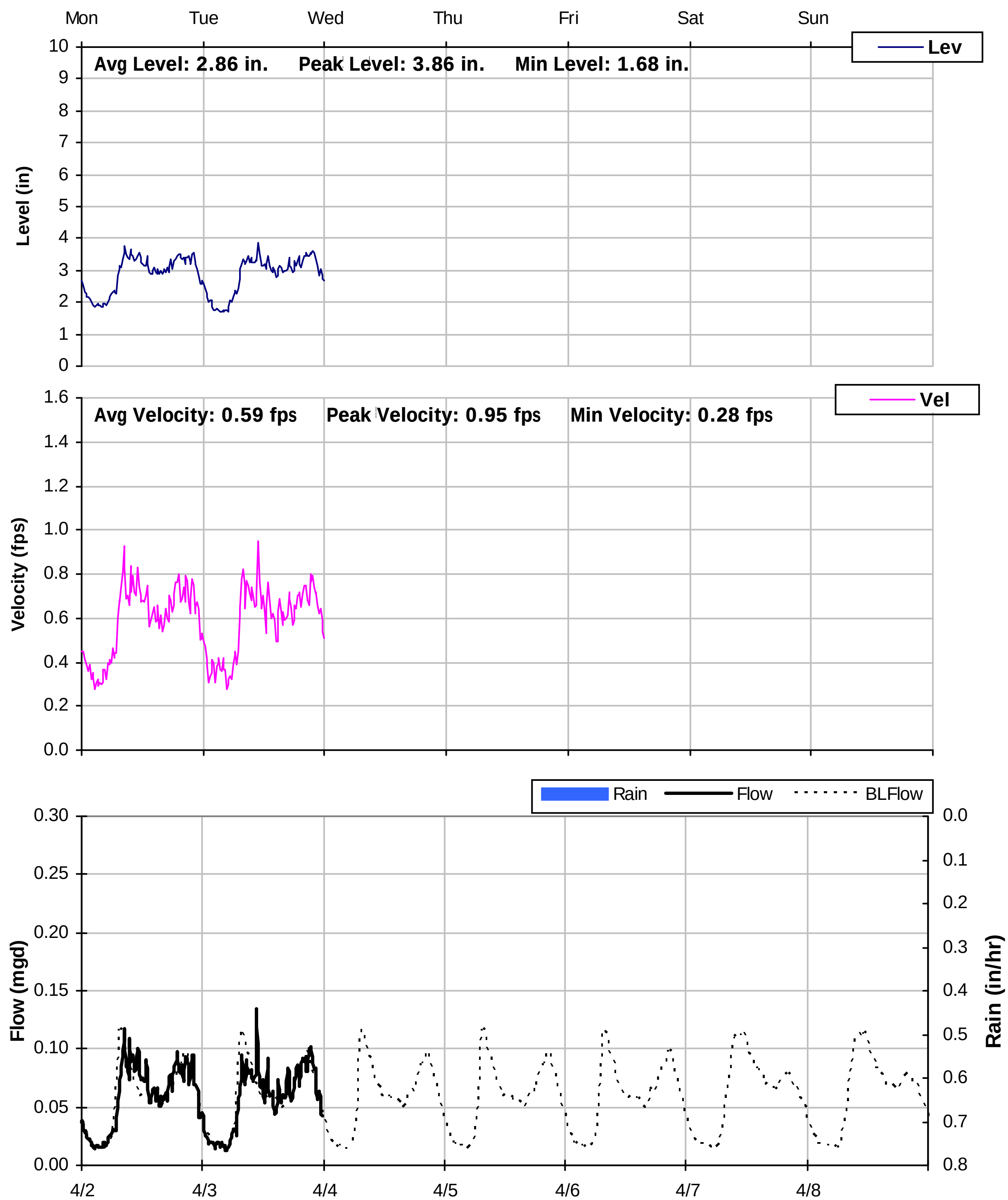
MH B13
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



MH B13
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



MH B13
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



Avg Flow: 0.059 mgd Peak Flow: 0.134 mgd Min Flow: 0.013 mgd

East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

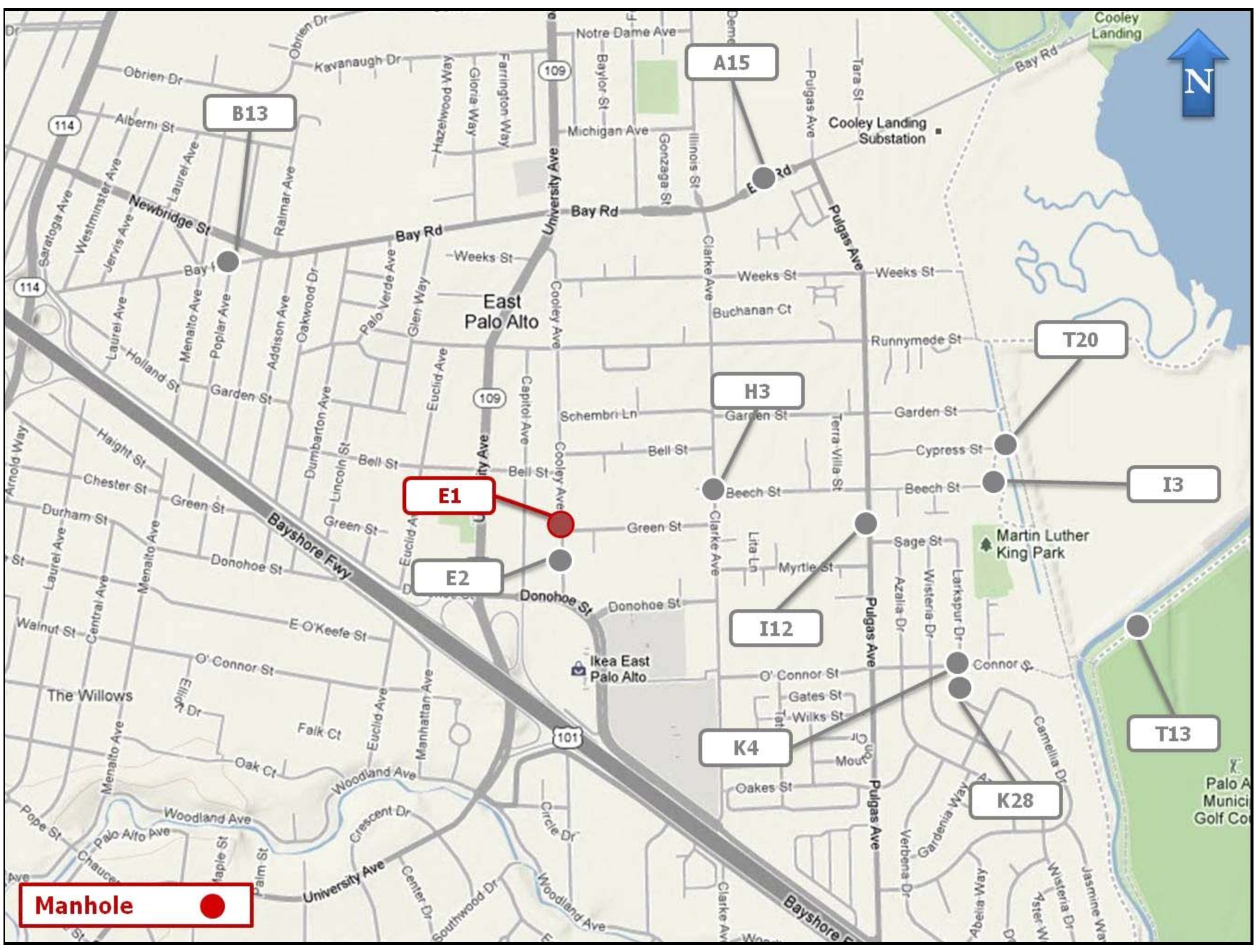
Year 2012

Monitoring Site: MH E1

Location: Cooley Avenue at Green Street

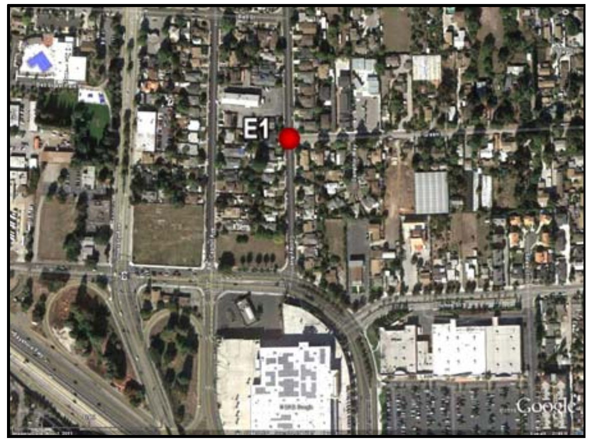
Data Summary Report

Vicinity Map:



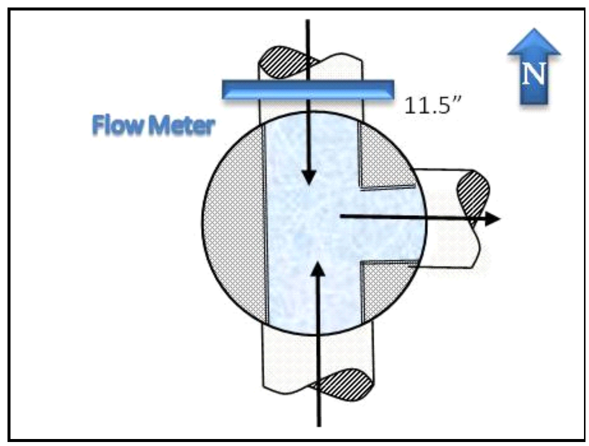
MH E1
Site Information Report

Location:	Cooley Avenue at Green Street
Coordinates:	122.1393° W, 37.4642° N
Elevation:	16 feet
Diameter:	11.5 inches
Baseline Flow:	0.13 mgd
Peak Measured Flow:	0.258 mgd



Satellite Map

Sanitary Sewer Map



Flow Sketch

View from Street

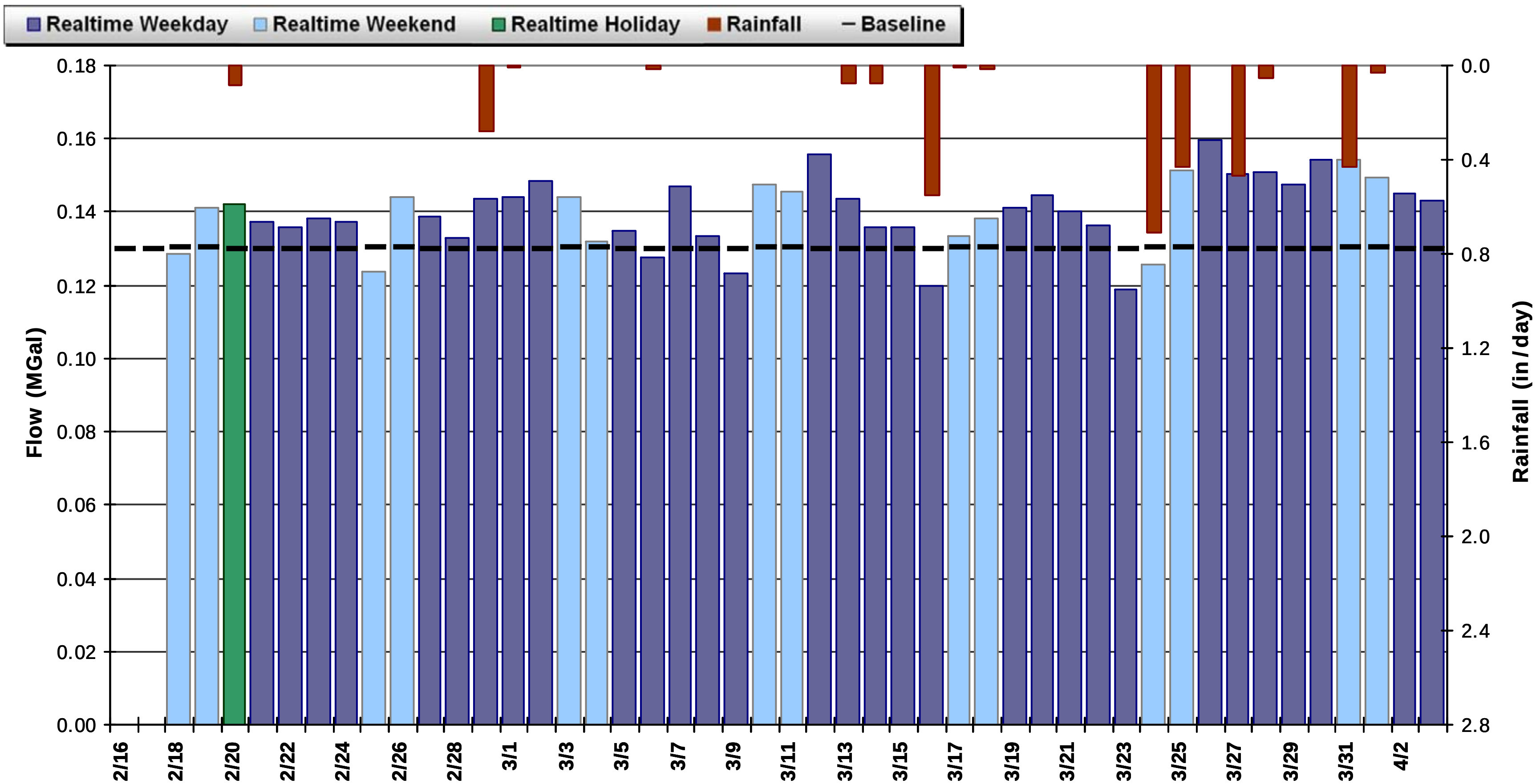
Plan View

MH E1

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.140 MGal **Peak Daily Flow: 0.160 MGal** **Min Daily Flow: 0.119 MGal**

Total Period Rainfall: 3.24 inches

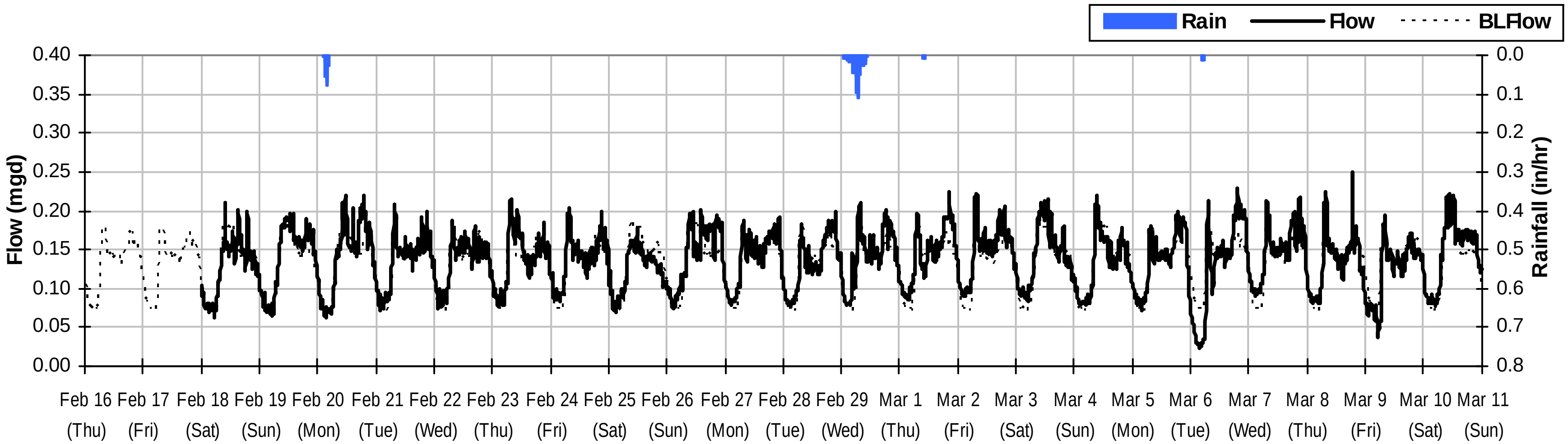


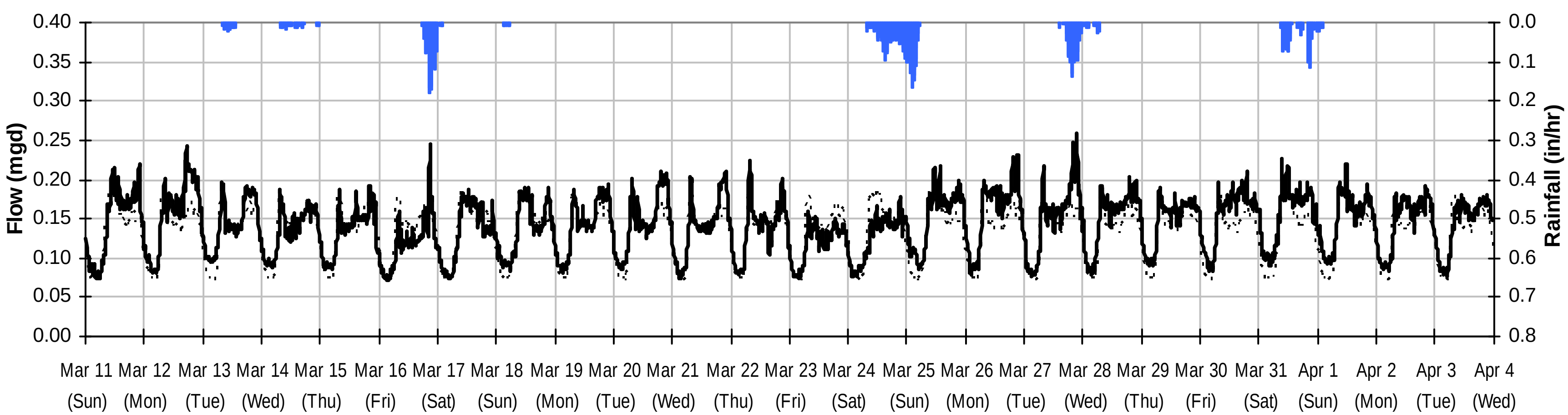
MH E1

Period Flow Summary: February 16 to April 4, 2012

Avg Flow: 0.140 mgd **Peak Flow: 0.258 mgd** **Min Flow: 0.023 mgd**

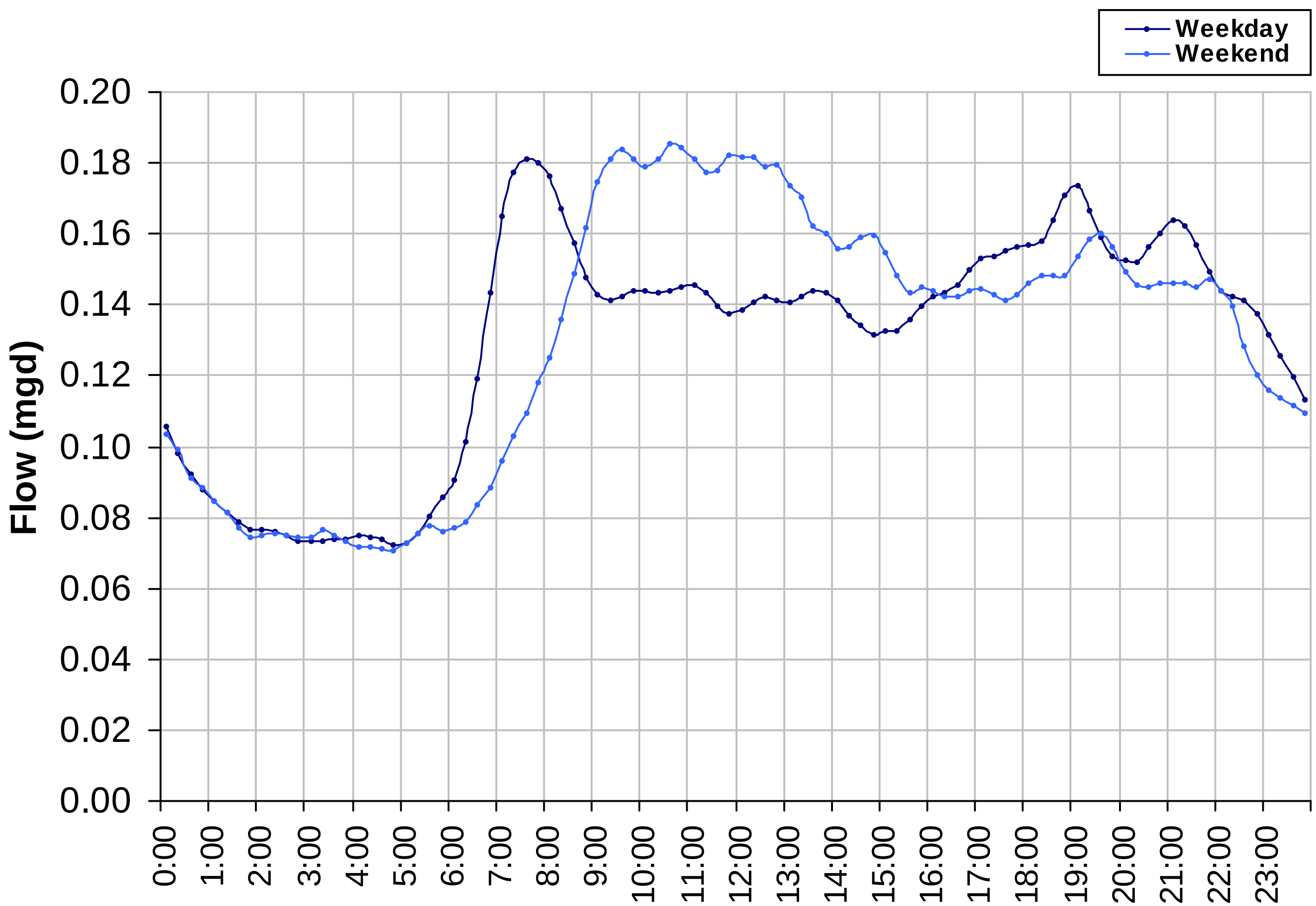
Total Period Rainfall: 3.24 inches





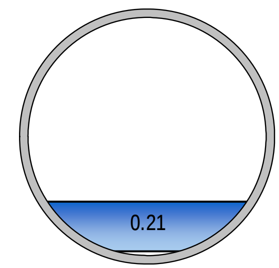
MH E1

Baseline Flow Hydrographs



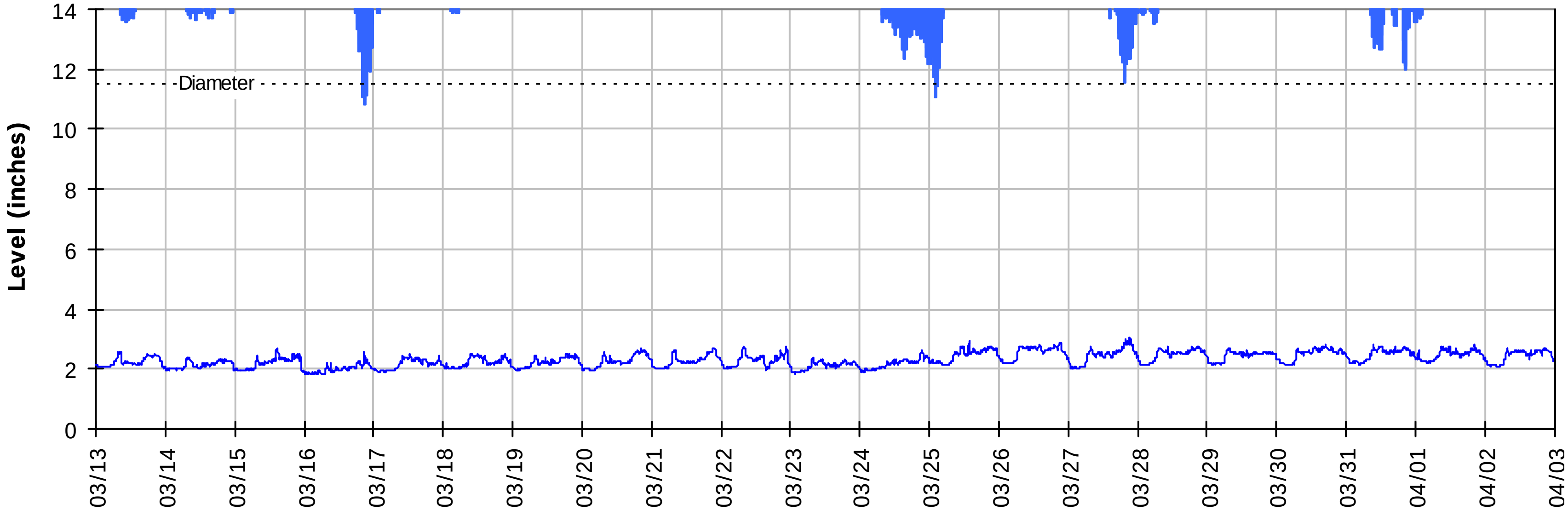
Baseline Flow:

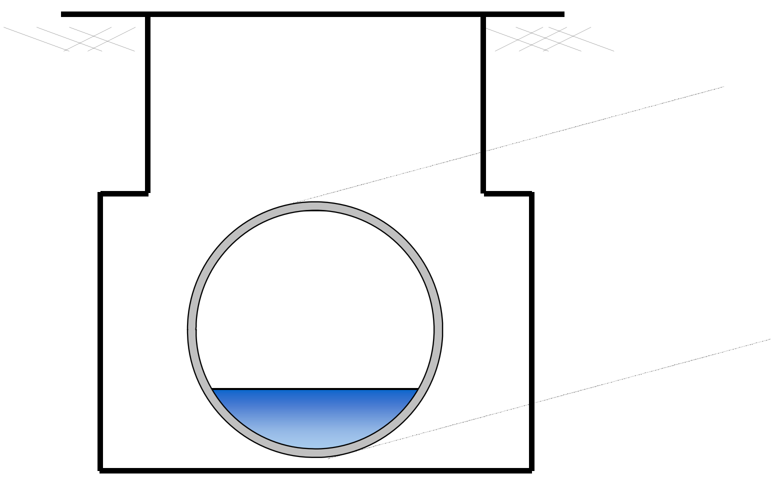
0.130 *mgd*



MH E1
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





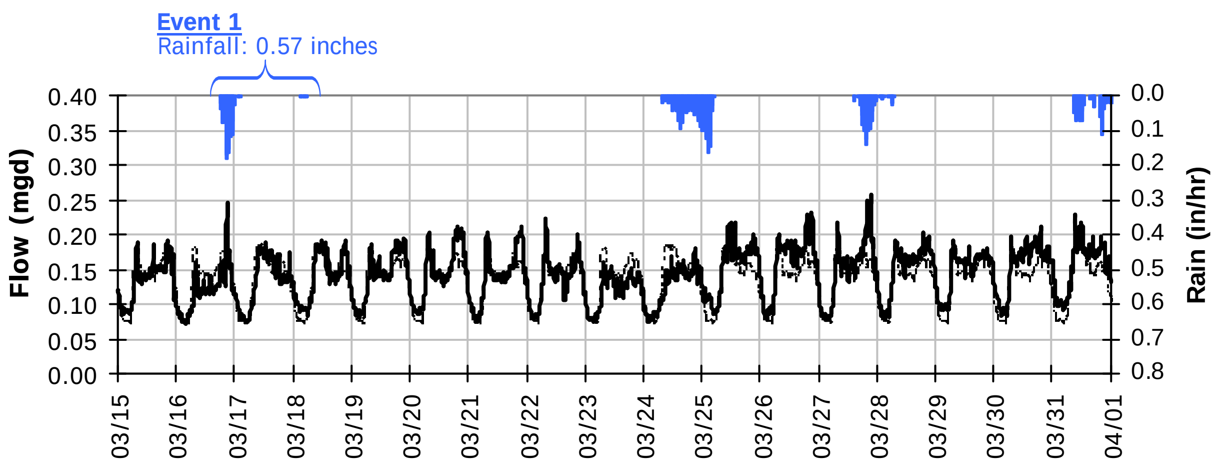
Pipe Diameter: 11.5 *inches*

Peak Measured Level: 3.06 *inches*

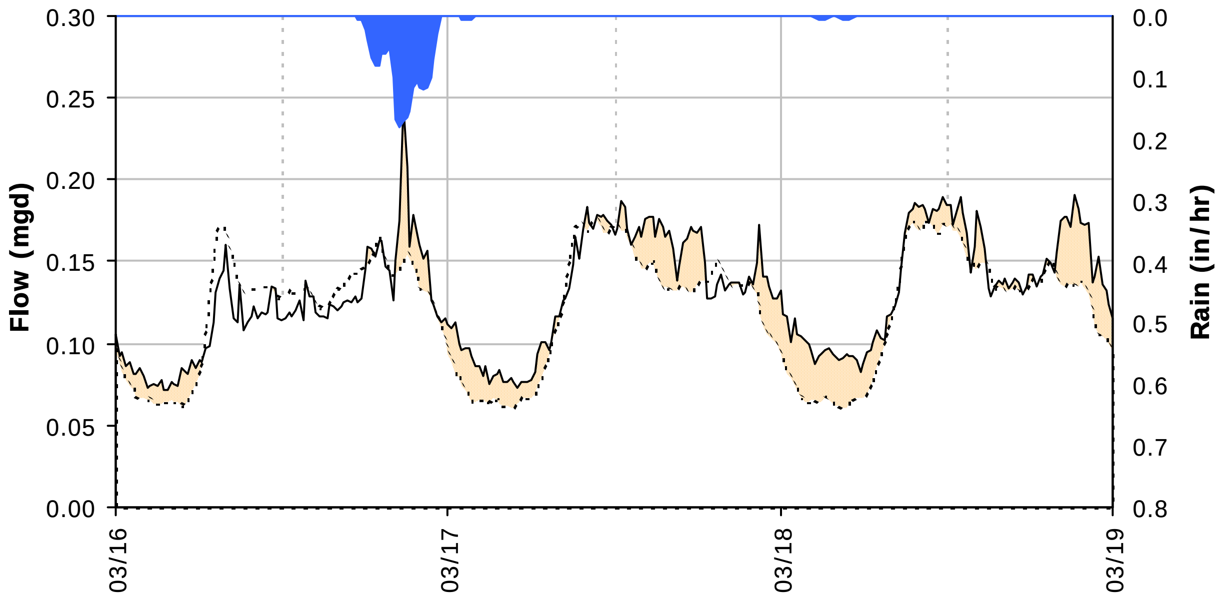
Peak d/D Ratio: 0.27

MH E1
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

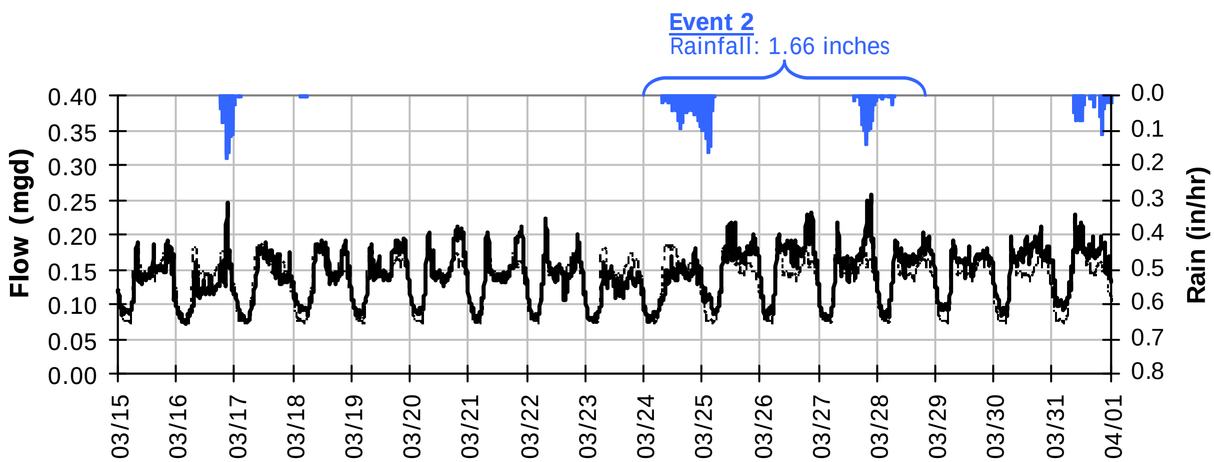


Storm Event I/I Analysis (Rain = 0.57 inches)

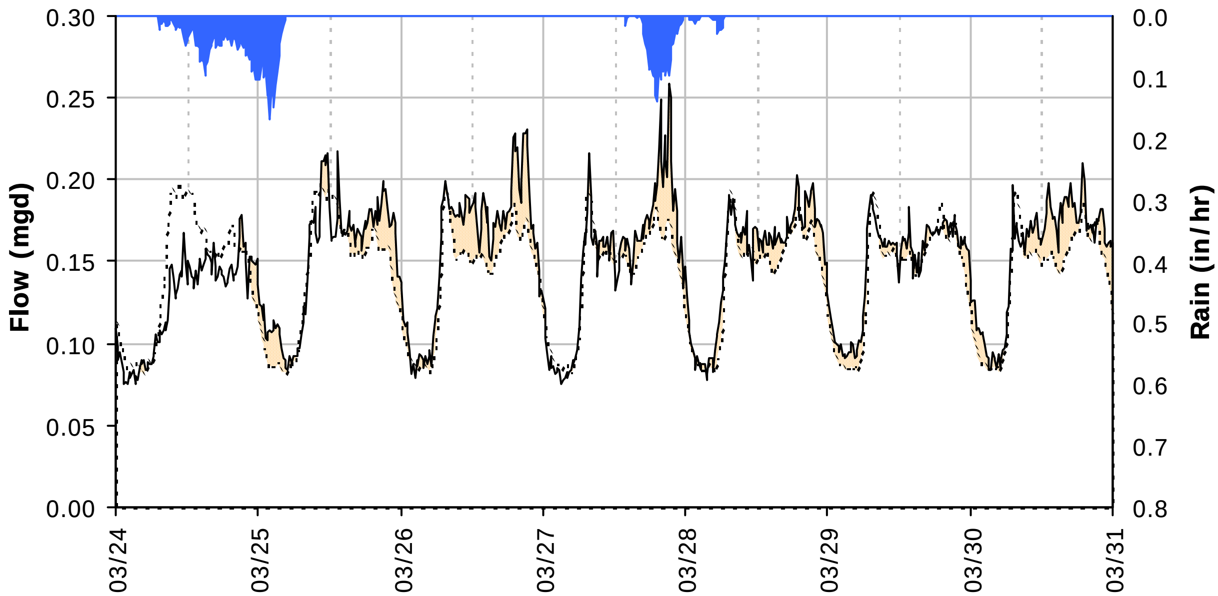
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	0.25 *mgd*	**Peak I/I Rate:**	0.08 *mgd*	**Infiltration Rate:** ()	*mgd*	**Total I/I:**	4,000 *gallons*
PF:	1.89	**PkI/I:IDM:**	3,372 *gpd/IDM*	**RDI:IDM:**	*gpd/IDM*	**Total I/I:IDM:**	255 *gal/IDM/in*
Peak Level:	2.57 *in*	**PkI/I:Acre:**	838 *gpd/acre*	**RDI:Acre:**	*gpd/acre*	**R-Value:**	0.2%
d/D Ratio:	0.22	**Pk I/I:ADWF:**	0.65	**RDI (% of BL):**		**Total I/I:ADWF:**	0.05 *per in-rain*

MH E1
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



Storm Event I/I Analysis (Rain = 1.66 inches)

Capacity

- **Peak Flow:** 0.26 *mgd*
- **PF:** 1.99
- **Peak Level:** 3.06 *in*
- **d/D Ratio:** 0.27

Inflow

- **Peak I/I Rate:** 0.10 *mgd*
- **PkI/I:IDM:** 3,813 *gpd/IDM*
- **PkI/I:Acre:** 948 *gpd/acre*
- **Pk I/I:ADWF:** 0.74

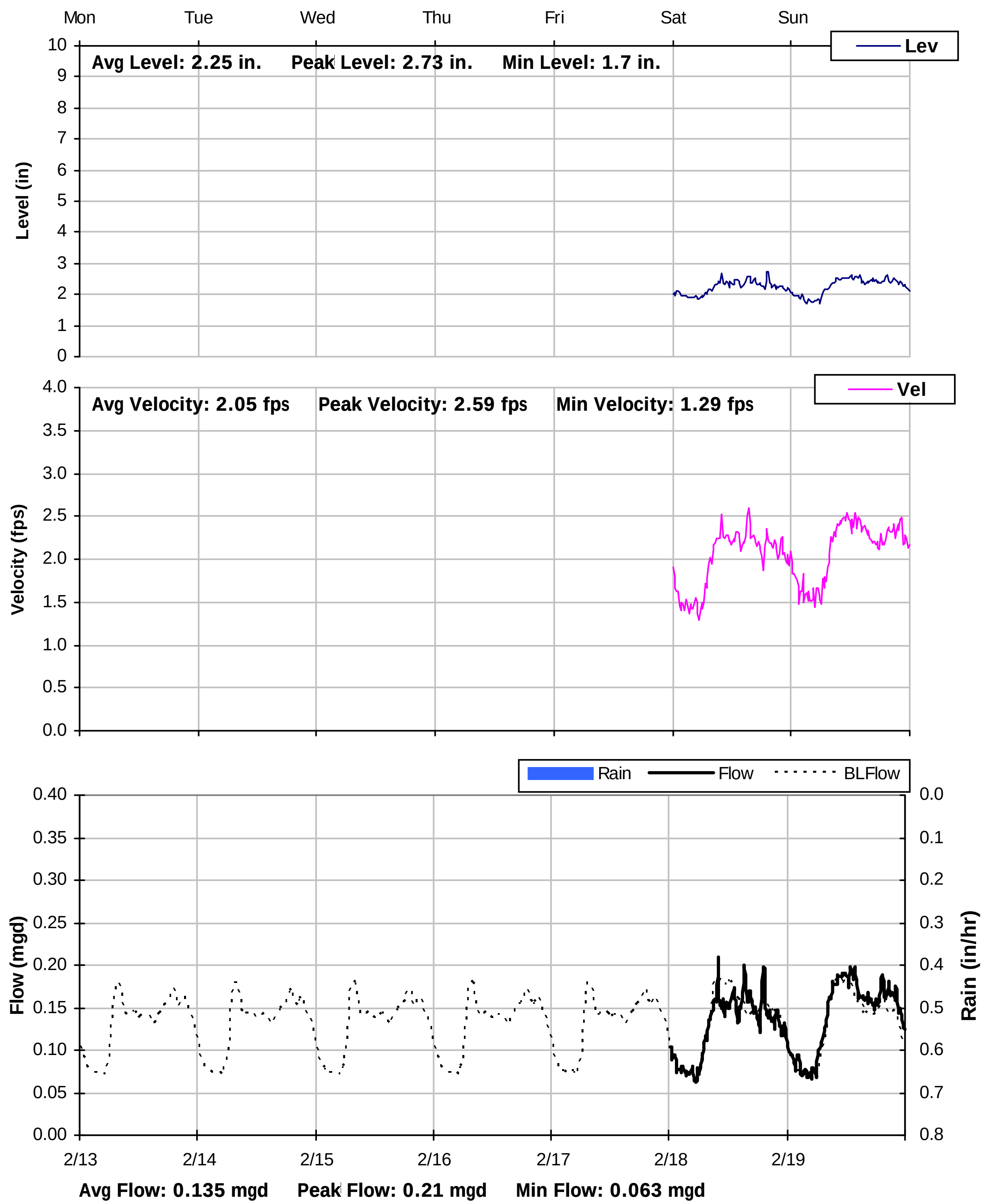
RDI (infiltration)

- **Infiltration Rate:** (3/26/2012) 0.030 *mgd*
- **RDI:IDM:** 1,182 *gpd/IDM*
- **RDI:Acre:** 294 *gpd/acre*
- **RDI (% of BL):** 23%

Combined I/I

- **Total I/I:** 53,000 *gallons*
- **Total I/I:IDM:** 1,265 *gal/IDM/in*
- **R-Value:** 1.2%
- **Total I/I:ADWF:** 0.24 *per in-rain*

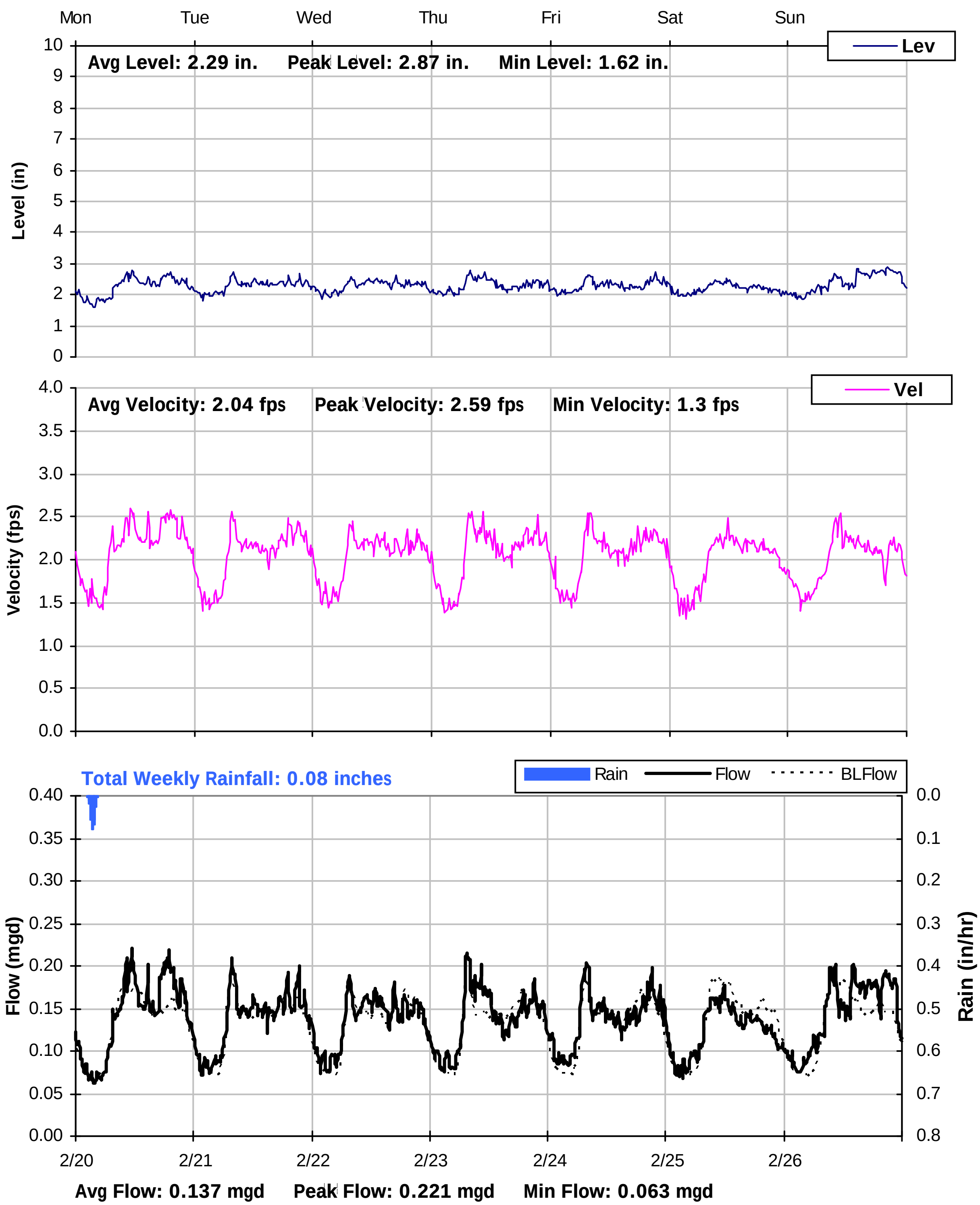
MH E1
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012



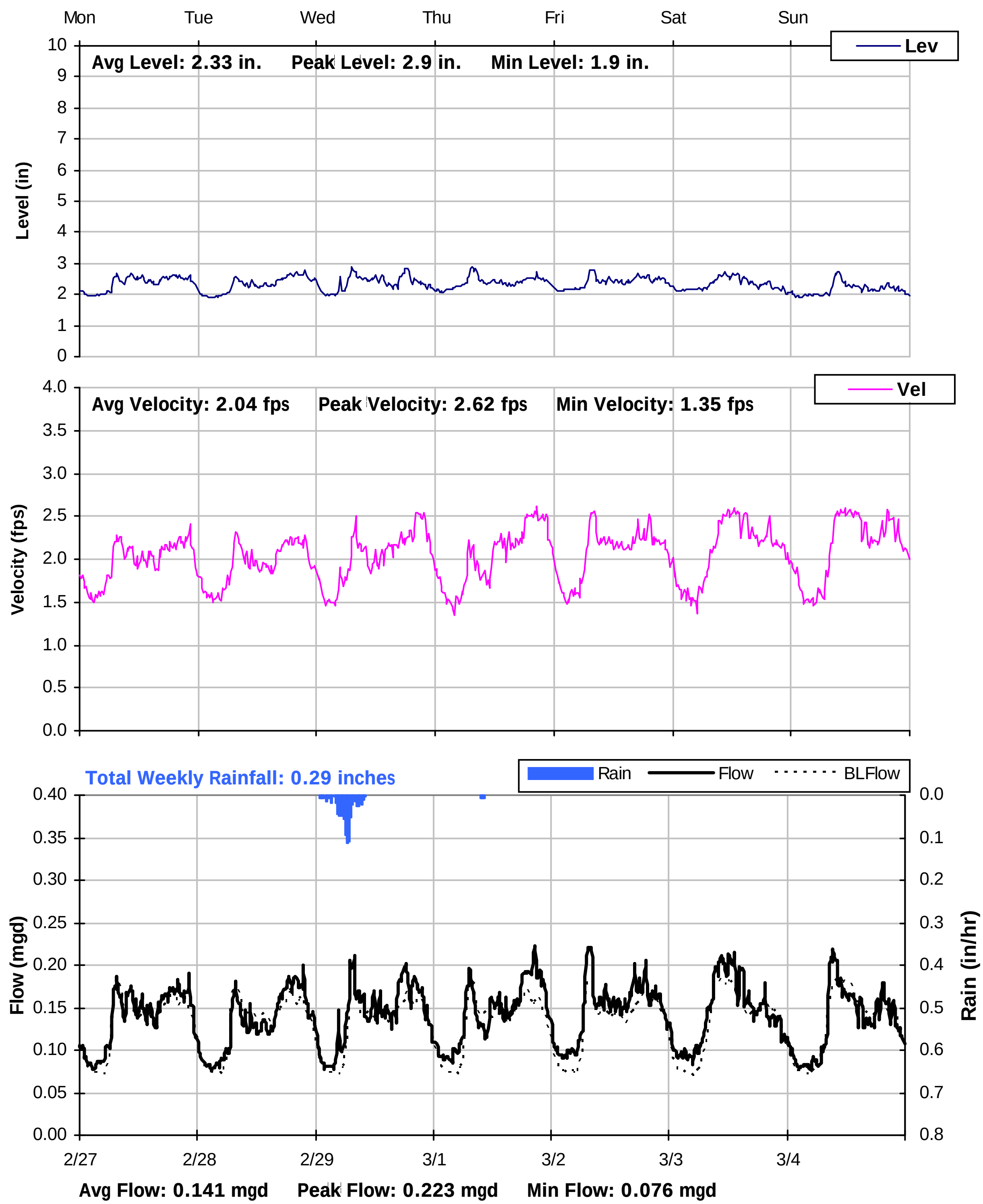
MH E1

Weekly Level, Velocity and Flow Hydrographs

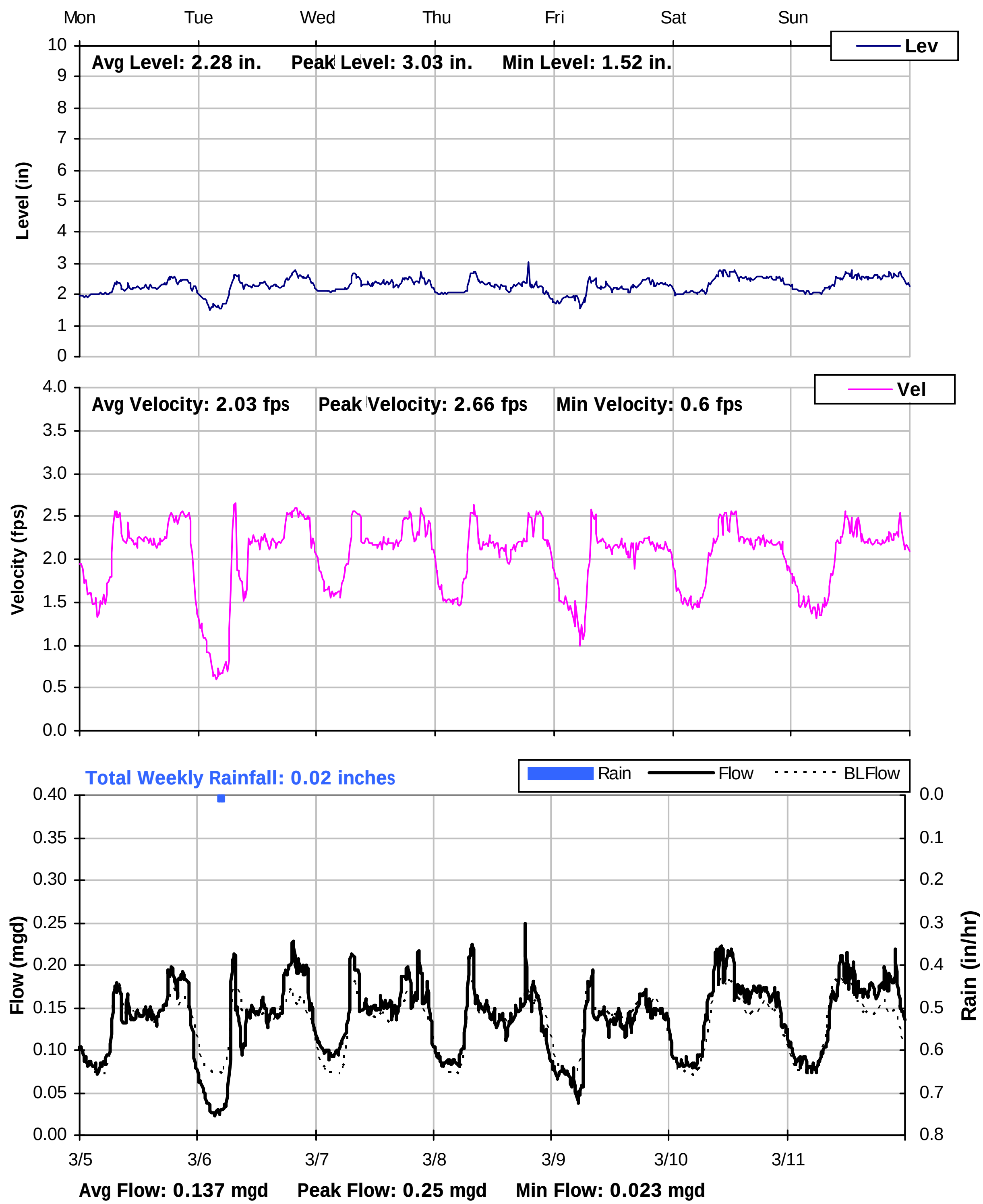
2/20/2012 to 2/27/2012



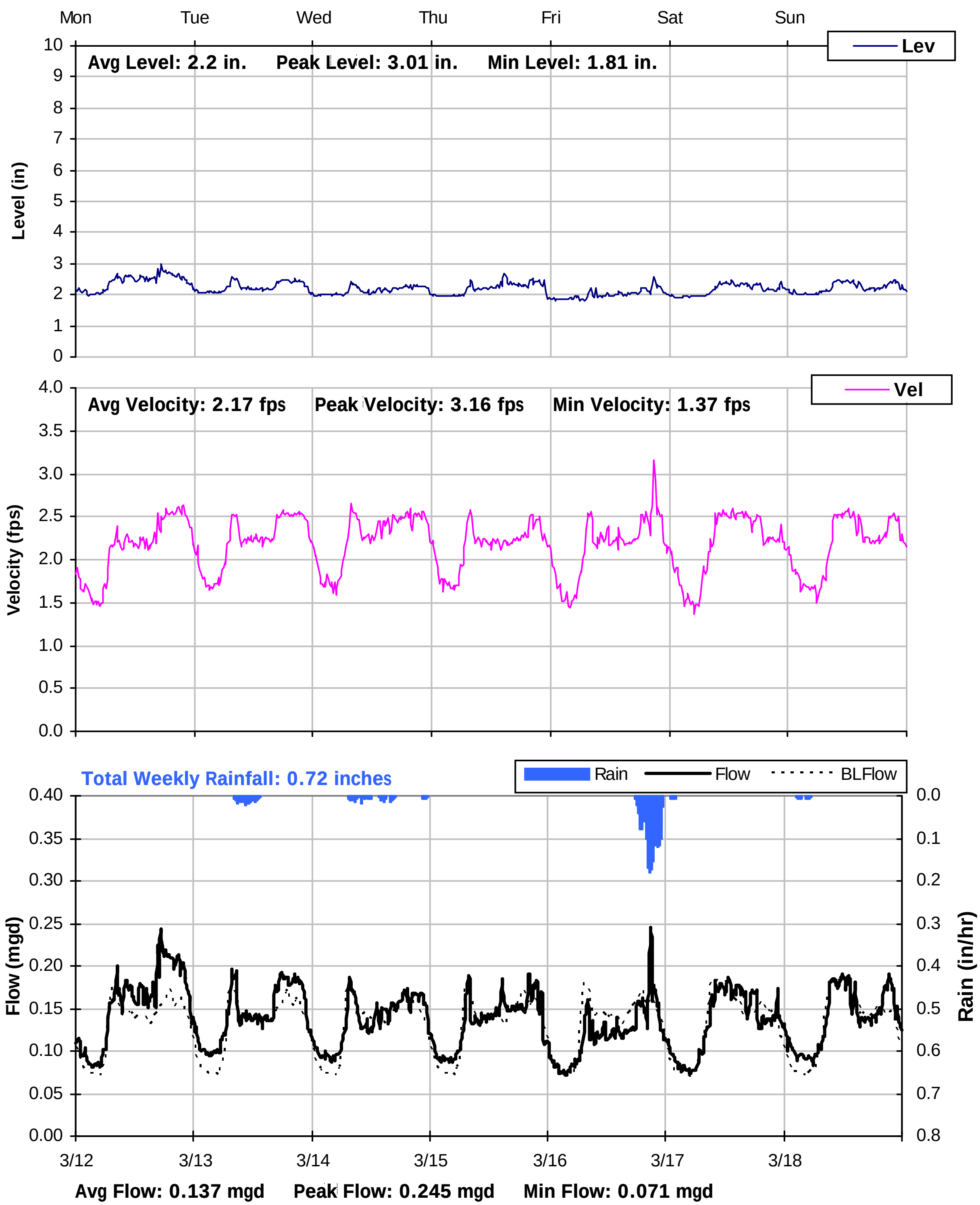
MH E1
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



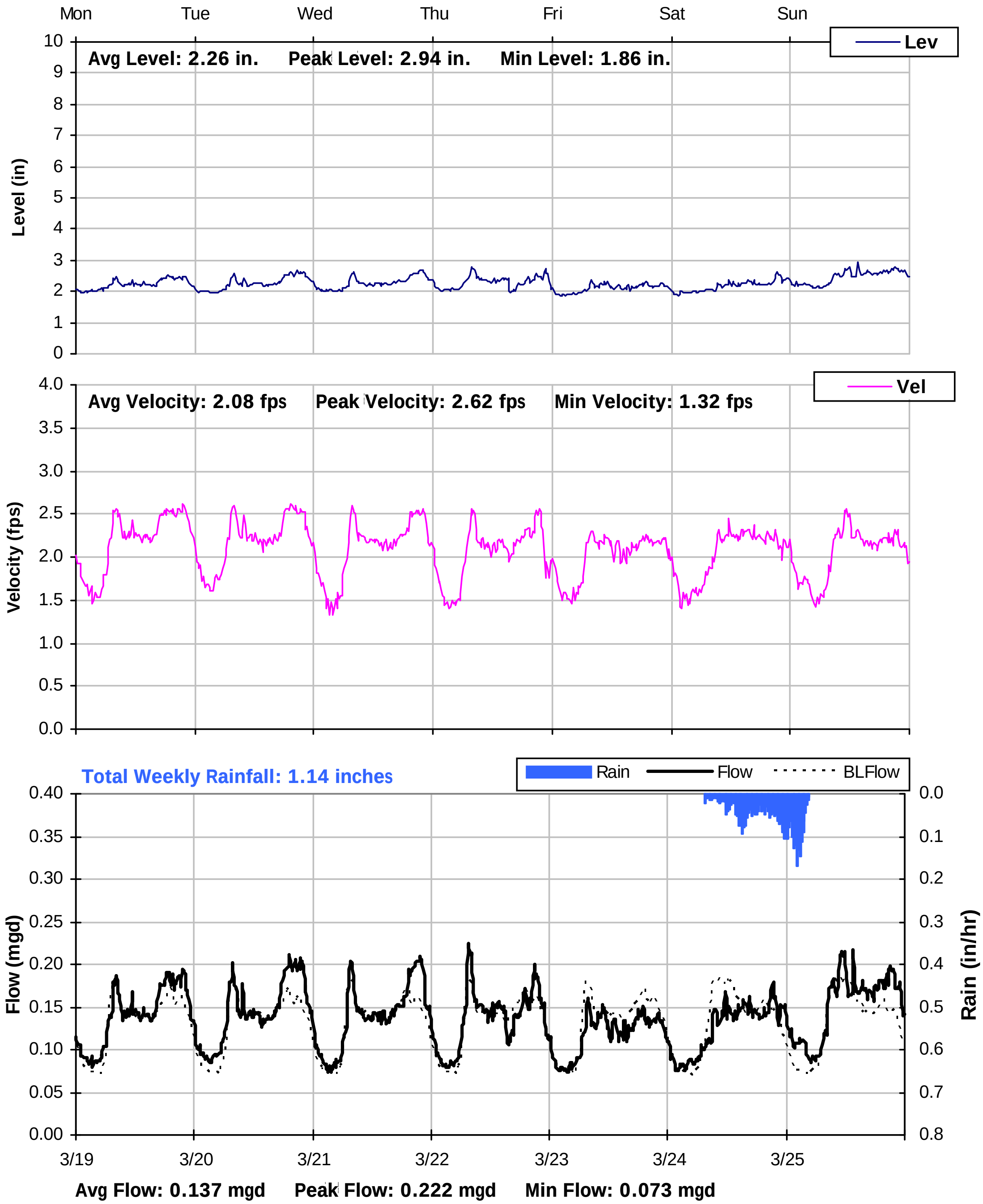
MH E1
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



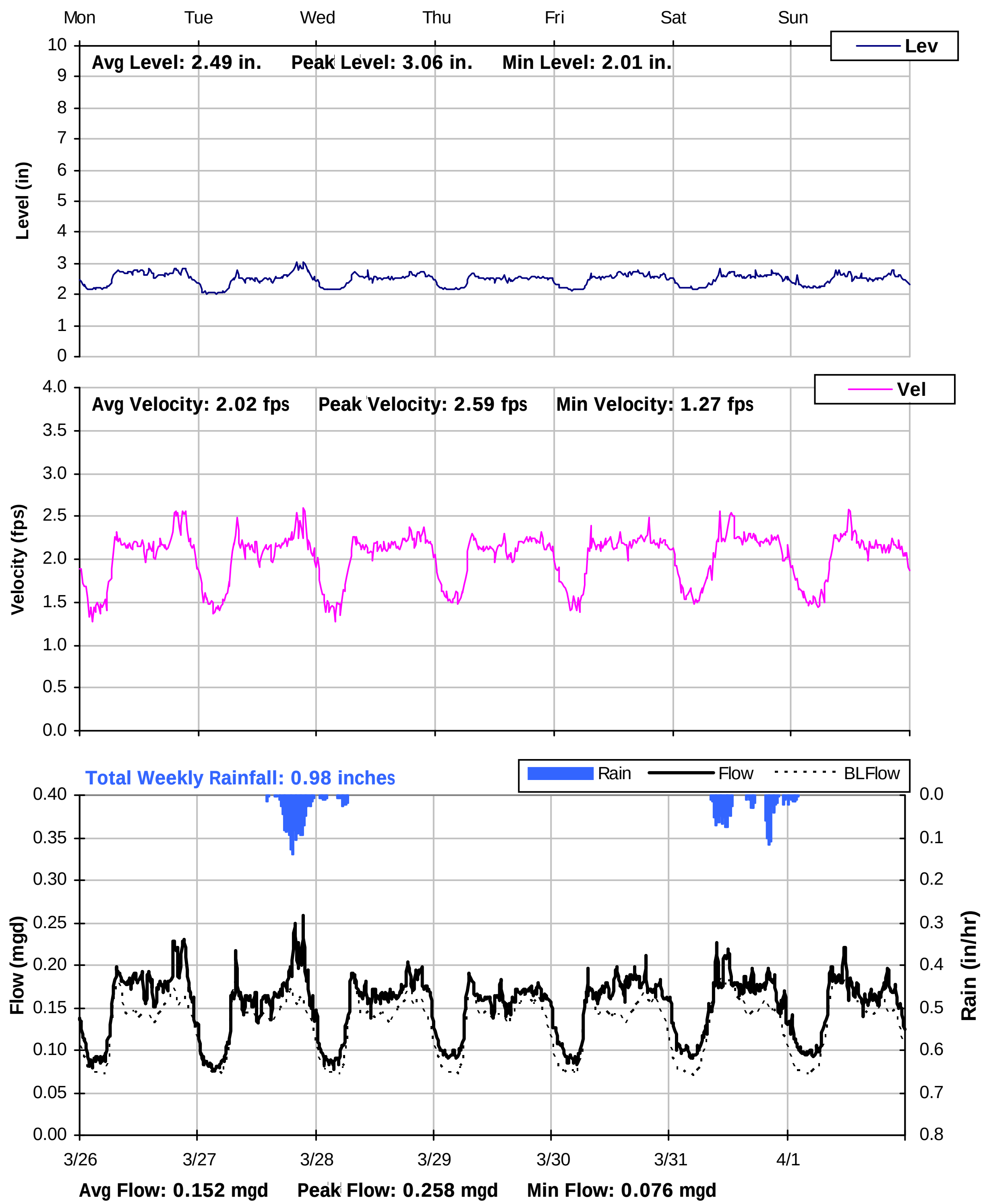
MH E1
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



MH E1
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



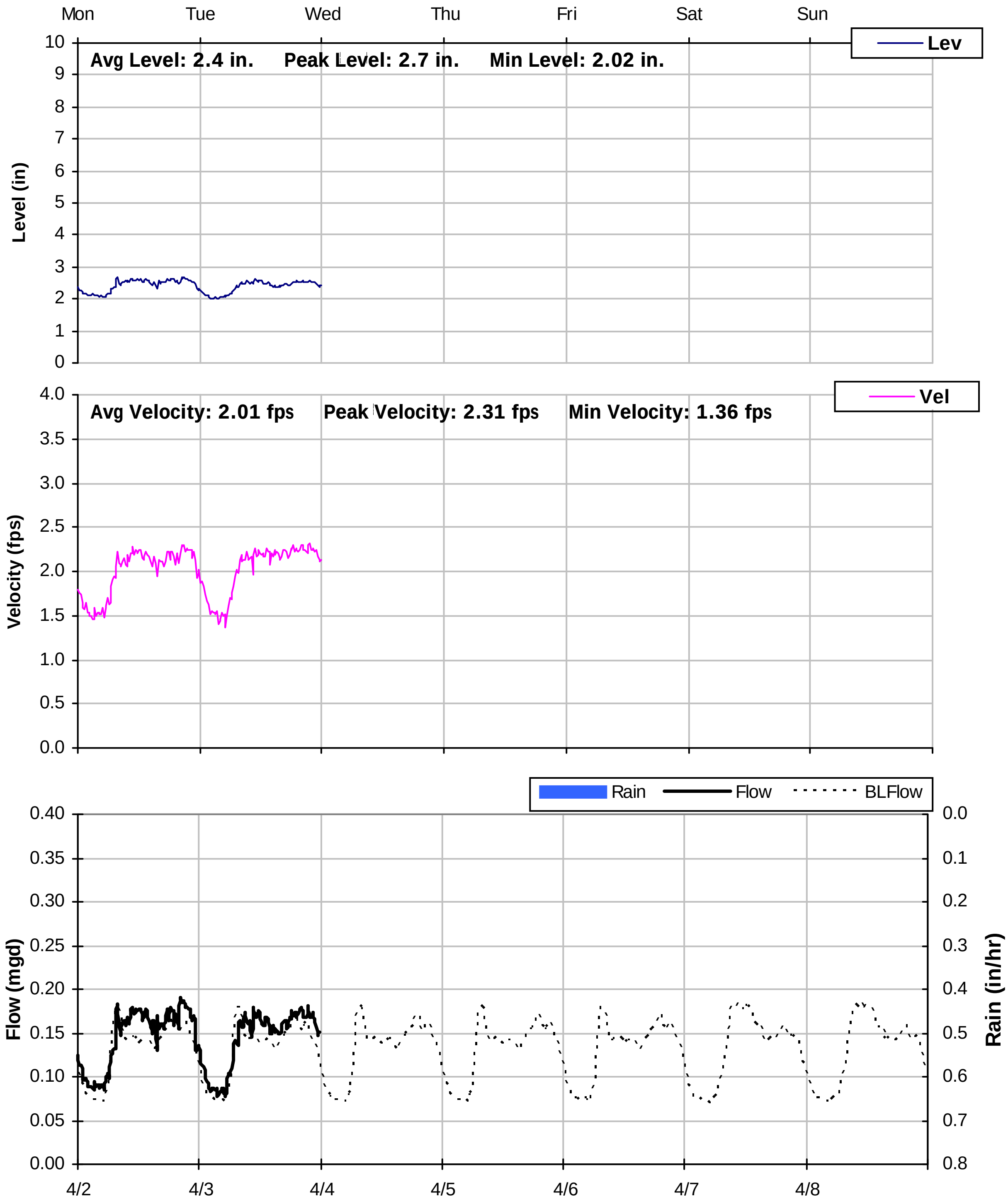
MH E1
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



MH E1

Weekly Level, Velocity and Flow Hydrographs

4/2/2012 to 4/9/2012



Avg Flow: 0.144 mgd **Peak Flow: 0.191 mgd** **Min Flow: 0.077 mgd**

East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

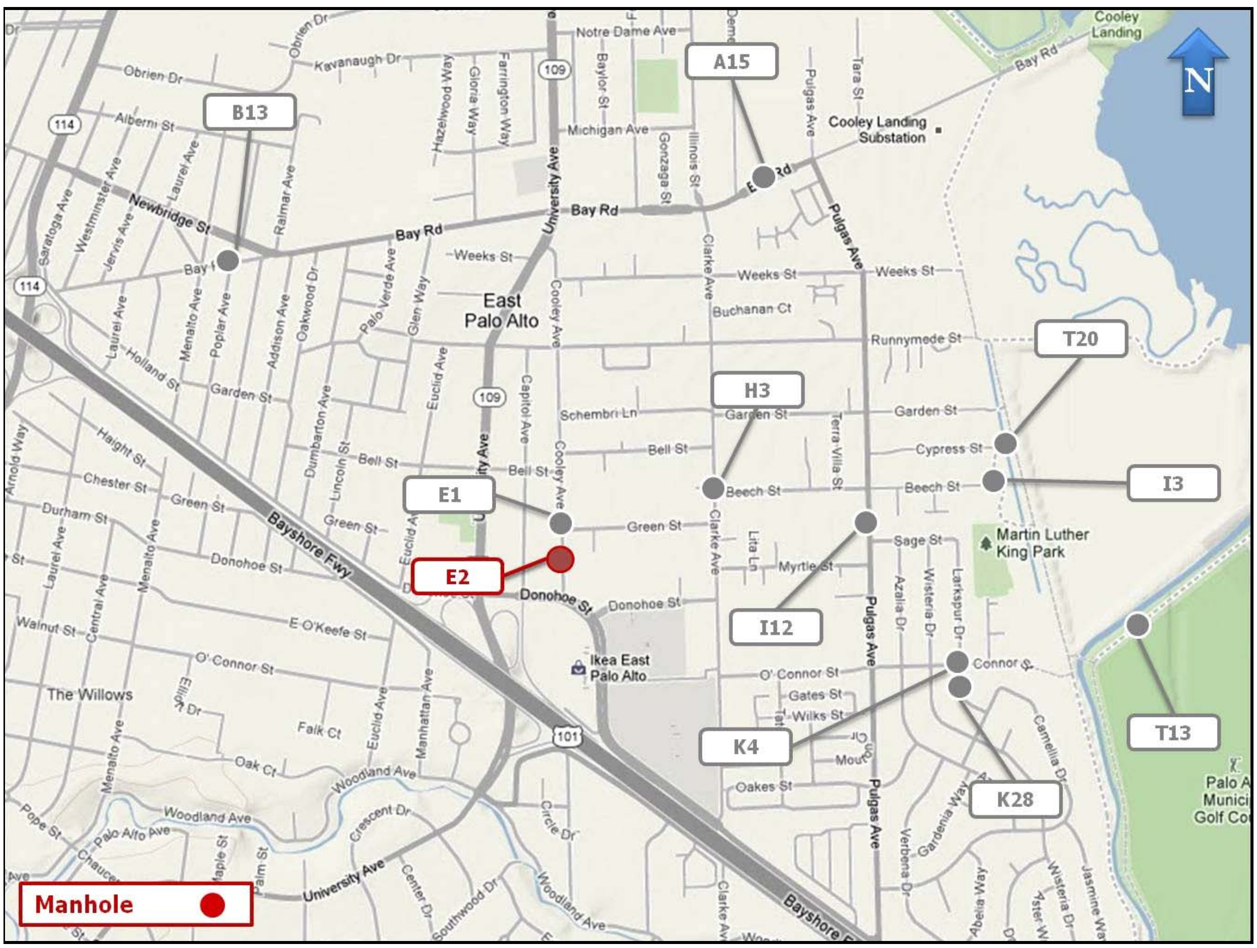
Year 2012

Monitoring Site: MH E2

Location: Cooley Avenue between East Bayshore Road and Green Street

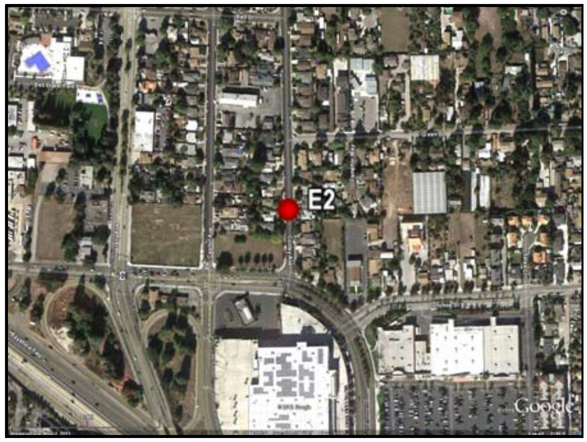
Data Summary Report

Vicinity Map:



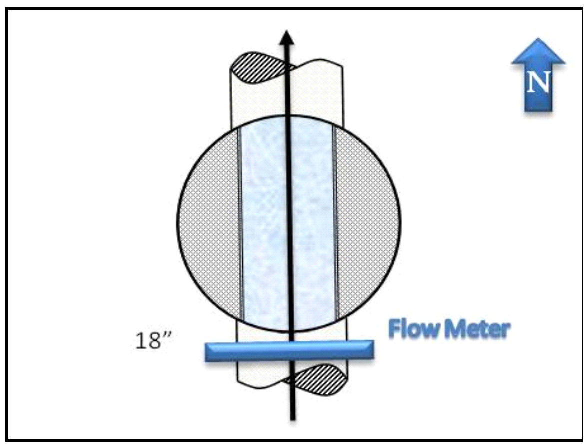
MH E2
Site Information Report

Location:	Cooley Avenue between East Bayshore Road and Green Street
Coordinates:	122.1393° W, 37.4634° N
Elevation:	16 feet
Diameter:	18 inches
Baseline Flow:	0.254 mgd
Peak Measured Flow:	0.632 mgd



Satellite Map

Sanitary Sewer Map



Flow Sketch

View from Street

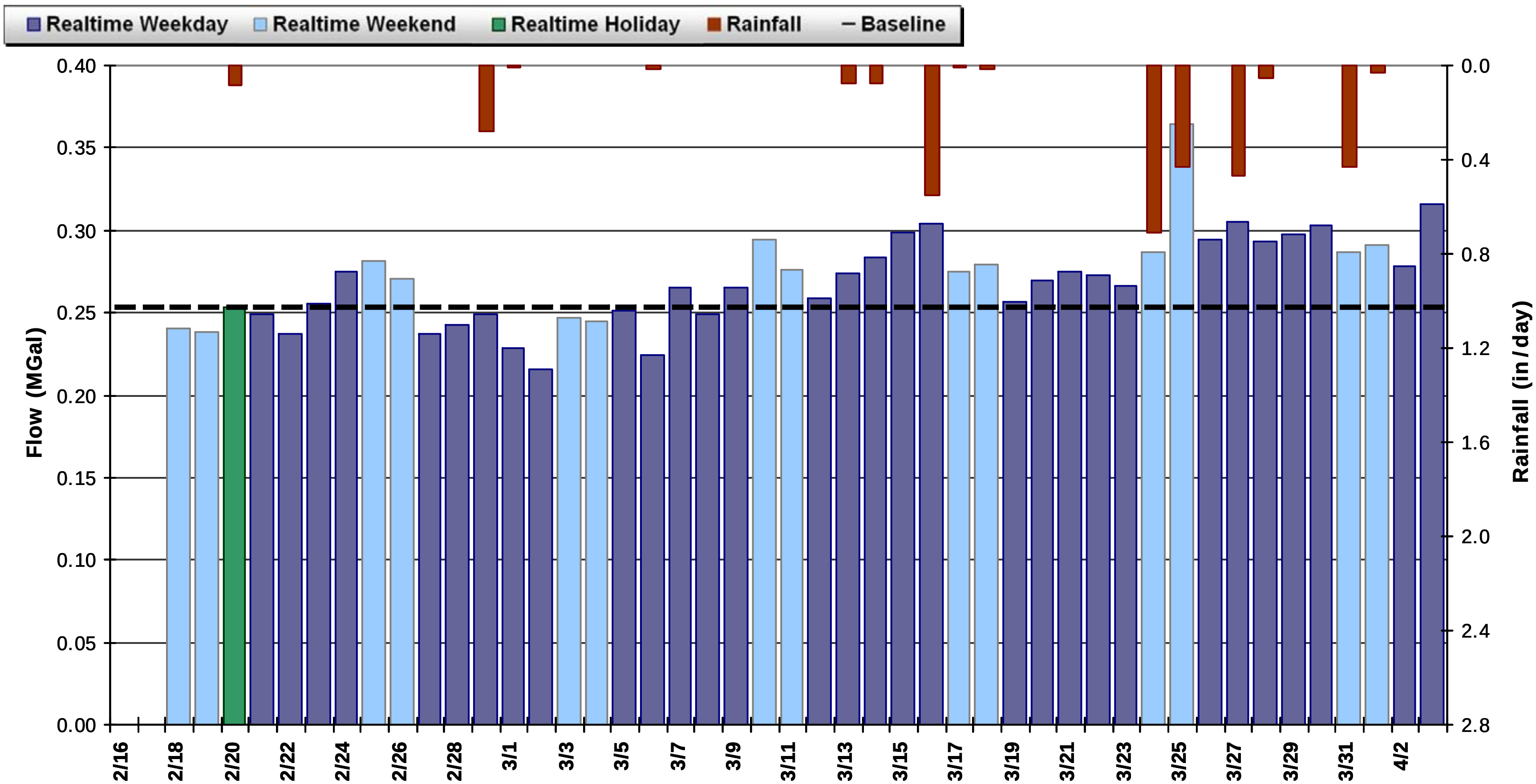
Plan View

MH E2

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.270 MGal **Peak Daily Flow: 0.364 MGal** **Min Daily Flow: 0.216 MGal**

Total Period Rainfall: 3.24 inches

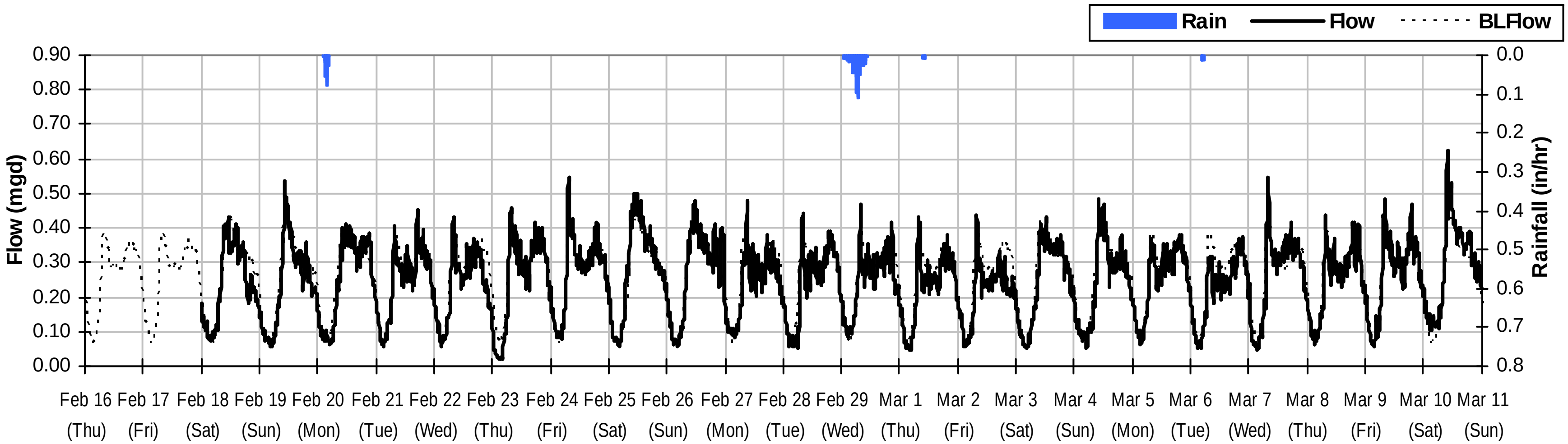


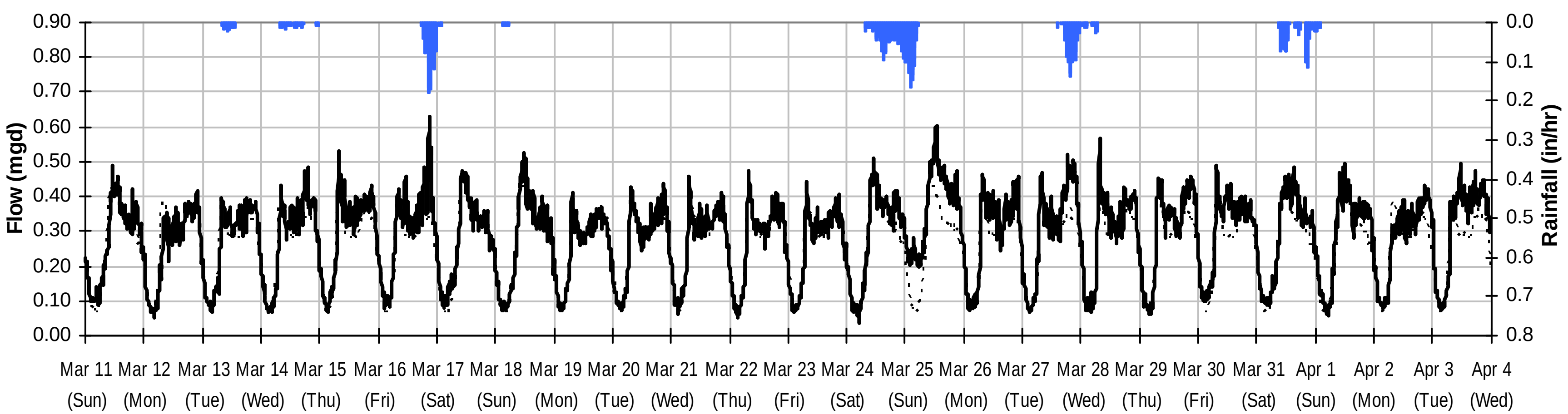
MH E2

Period Flow Summary: February 16 to April 4, 2012

Avg Flow: 0.270 mgd **Peak Flow: 0.632 mgd** **Min Flow: 0.021 mgd**

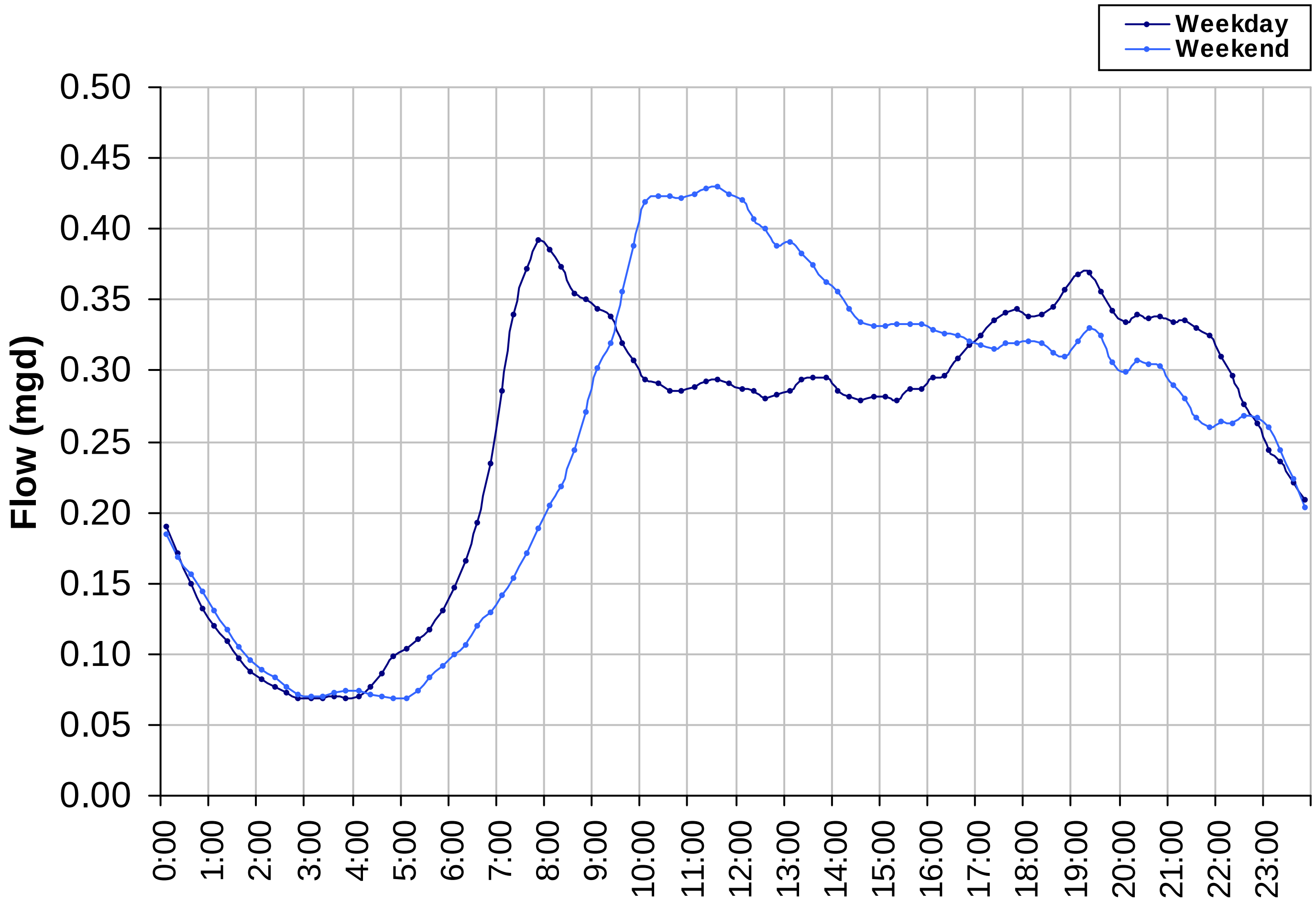
Total Period Rainfall: 3.24 inches





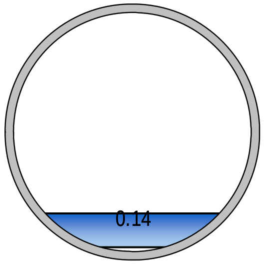
MH E2

Baseline Flow Hydrographs



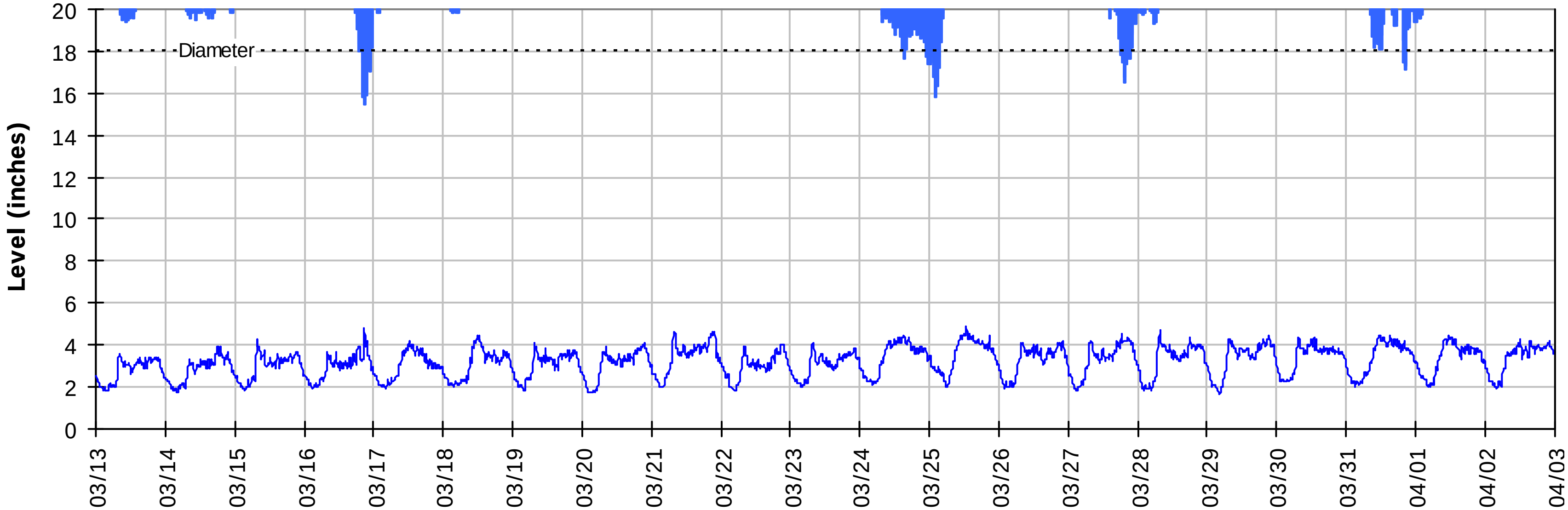
Baseline Flow:

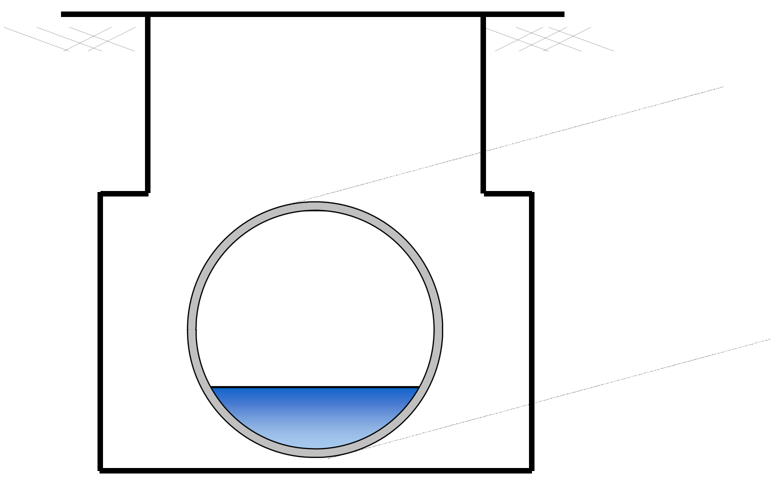
0.254 *mgd*



MH E2
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





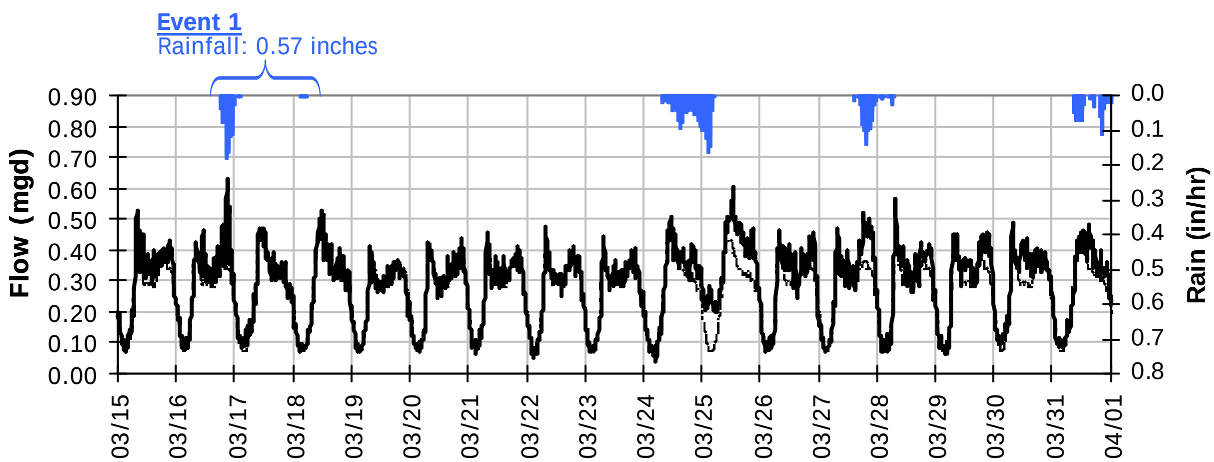
Pipe Diameter: 18 *inches*

Peak Measured Level: 4.9 *inches*

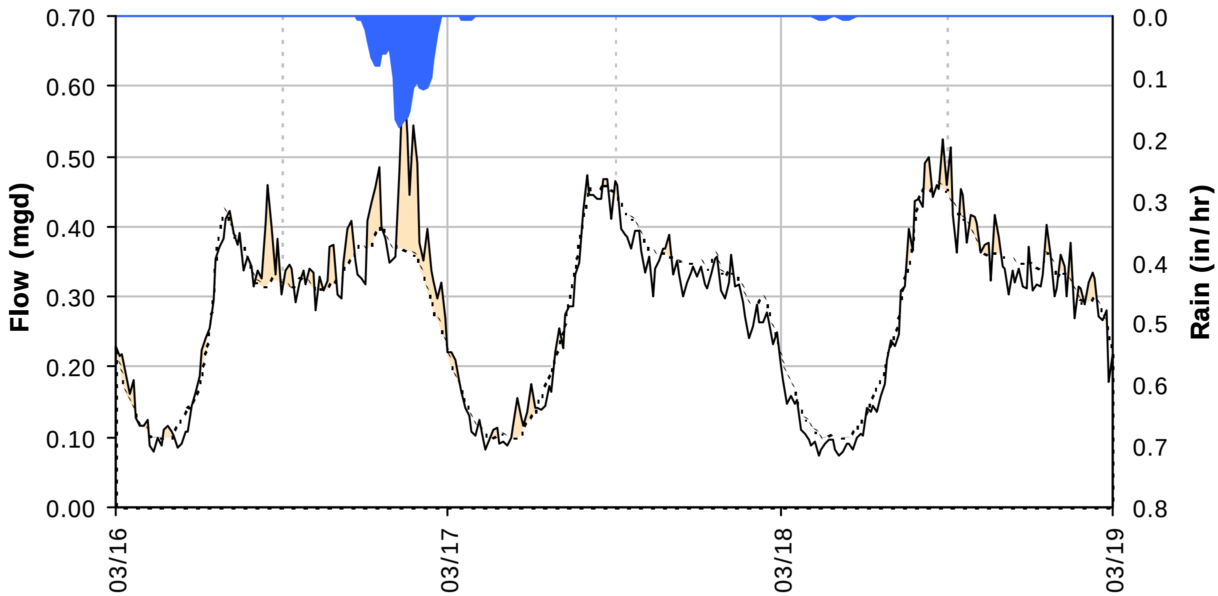
Peak d/D Ratio: 0.27

MH E2
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph



Storm Event I/I Analysis (Rain = 0.57 inches)

Capacity

Peak Flow: 0.63 *mgd*
PF: 2.49
Peak Level: 4.82 *in*
d/D Ratio: 0.27

Inflow

Peak I/I Rate: 0.29 *mgd*
PkI/I:IDM: 8,560 *gpd/IDM*
PkI/I:Acre: 1,969 *gpd/acre*
Pk I/I:ADWF: 1.16

RDI (infiltration)

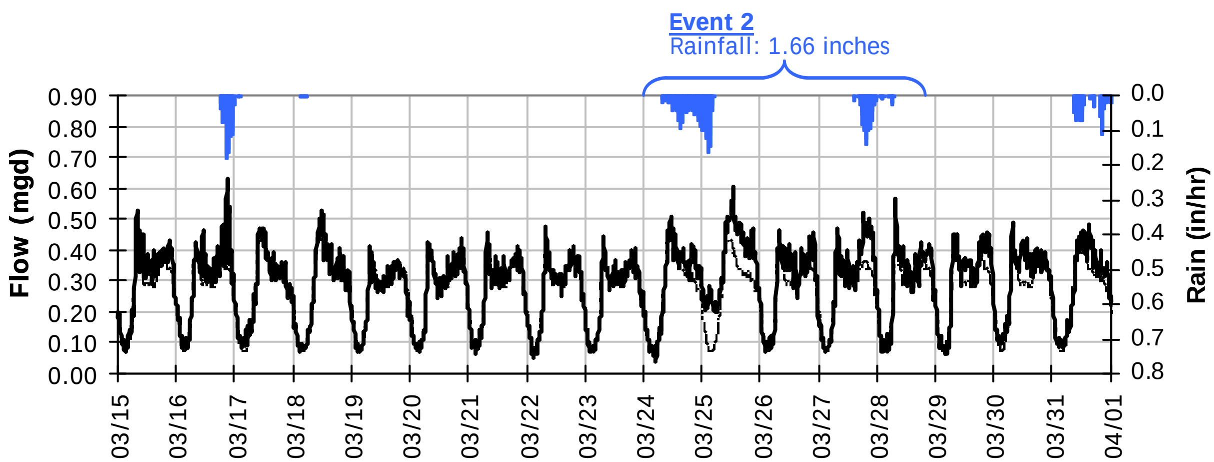
Infiltration Rate: *mgd*
()
RDI:IDM: *gpd/IDM*
RDI:Acre: *gpd/acre*
RDI (% of BL):

Combined I/I

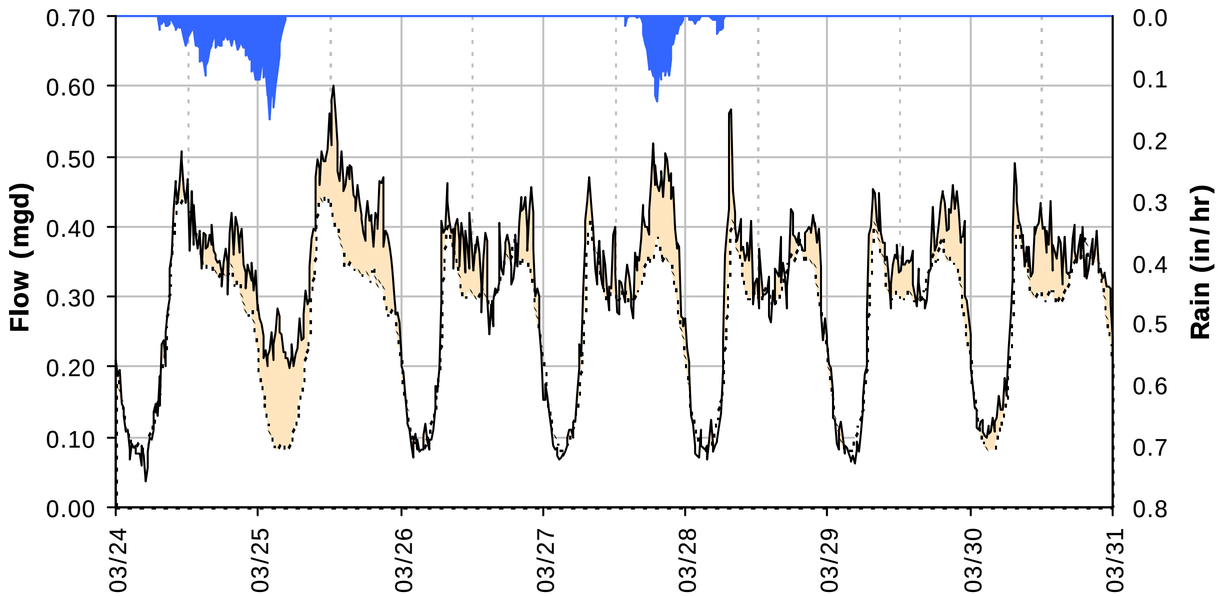
Total I/I: 17,000 *gallons*
Total I/I:IDM: 857 *gal/IDM/in*
R-Value: 0.7%
Total I/I:ADWF: 0.12 *per in-rain*

MH E2
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



Storm Event I/I Analysis (Rain = 1.66 inches)

Capacity

Peak Flow:	0.60	*mgd*
PF:	2.37	
Peak Level:	4.90	*in*
d/D Ratio:	0.27	

Inflow

Peak I/I Rate:	0.21	*mgd*
PkI/I:IDM:	6,237	*gpd/IDM*
PkI/I:Acre:	1,435	*gpd/acre*
Pk I/I:ADWF:	0.84	

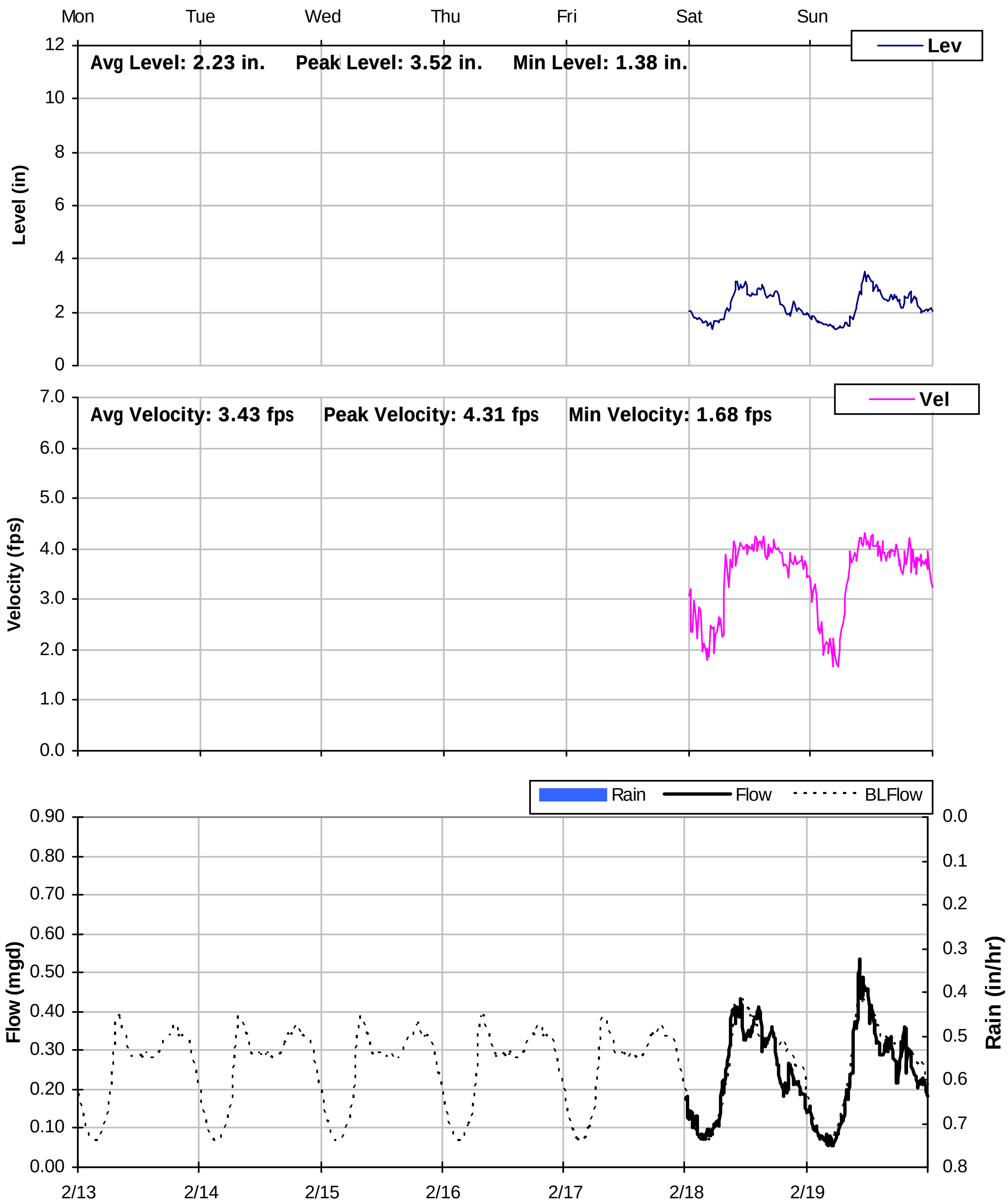
RDI (infiltration)

Infiltration Rate: (3/26/2012)	0.040	*mgd*
RDI:IDM:	1,169	*gpd/IDM*
RDI:Acre:	269	*gpd/acre*
RDI (% of BL):	16%	

Combined I/I

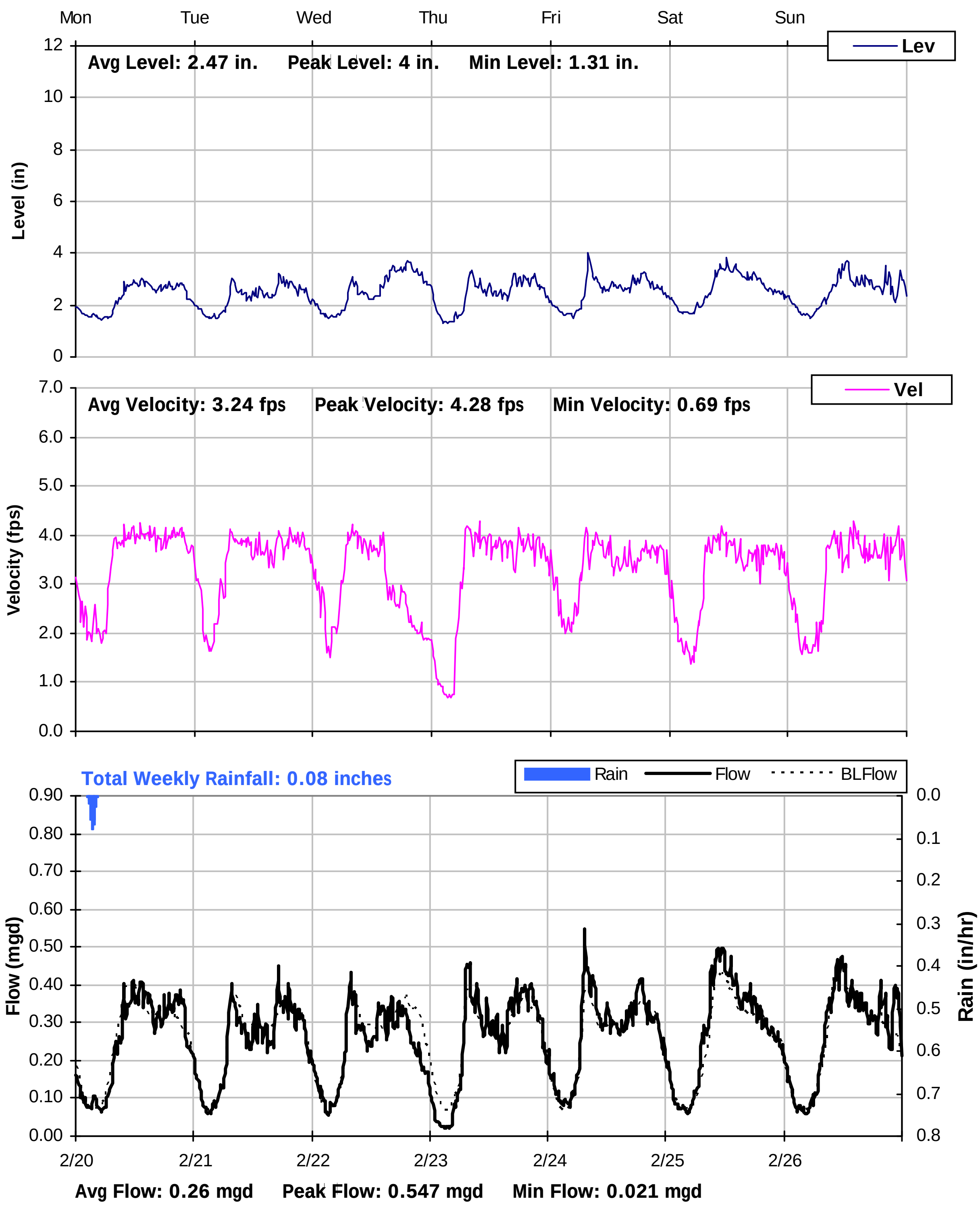
Total I/I:	213,000	*gallons*
Total I/I:IDM:	3,733	*gal/IDM/in*
R-Value:	3.2%	
Total I/I:ADWF:	0.50	*per in-rain*

MH E2
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012

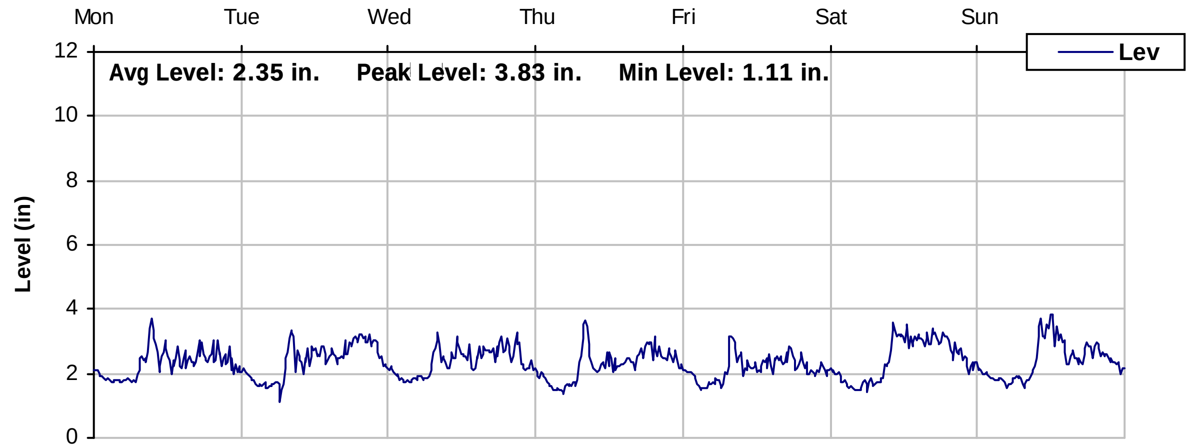


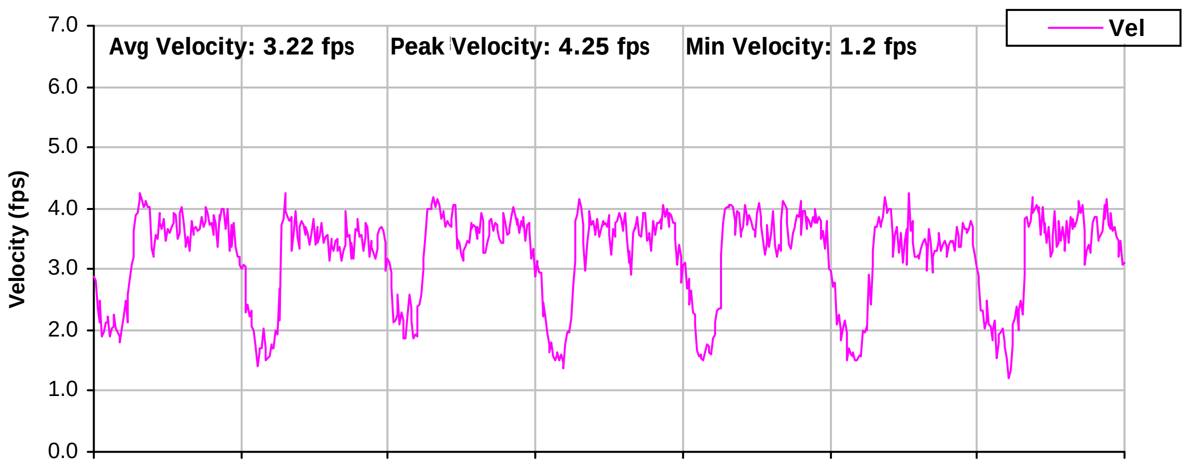
Avg Flow: 0.24 mgd **Peak Flow: 0.535 mgd** **Min Flow: 0.057 mgd**

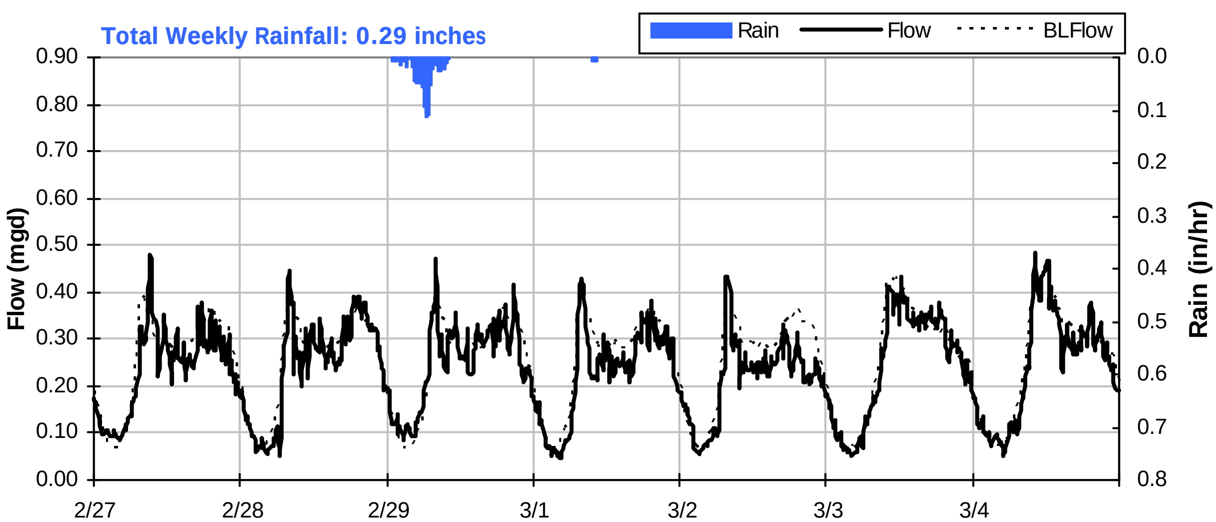
MH E2
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



MH E2
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012

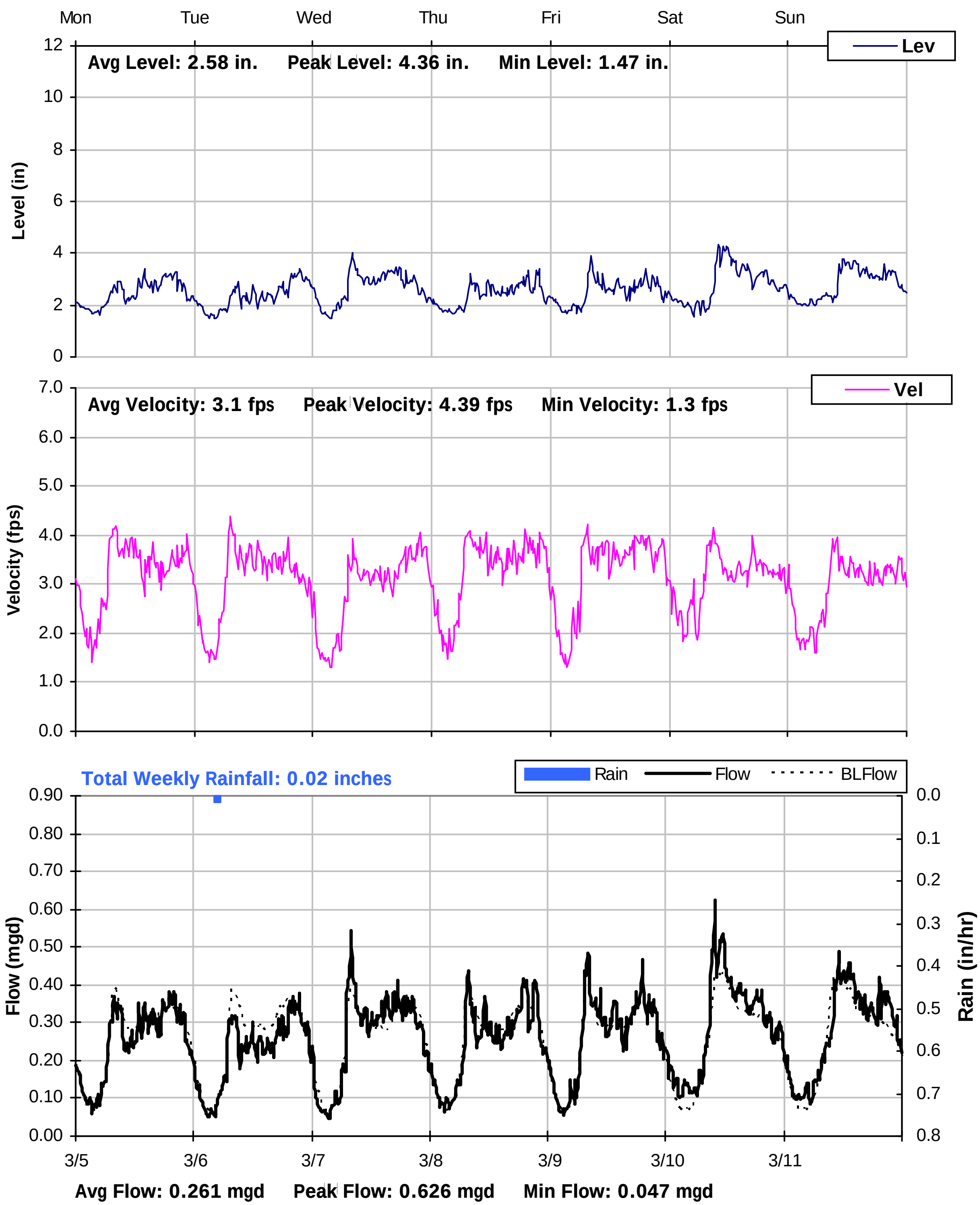




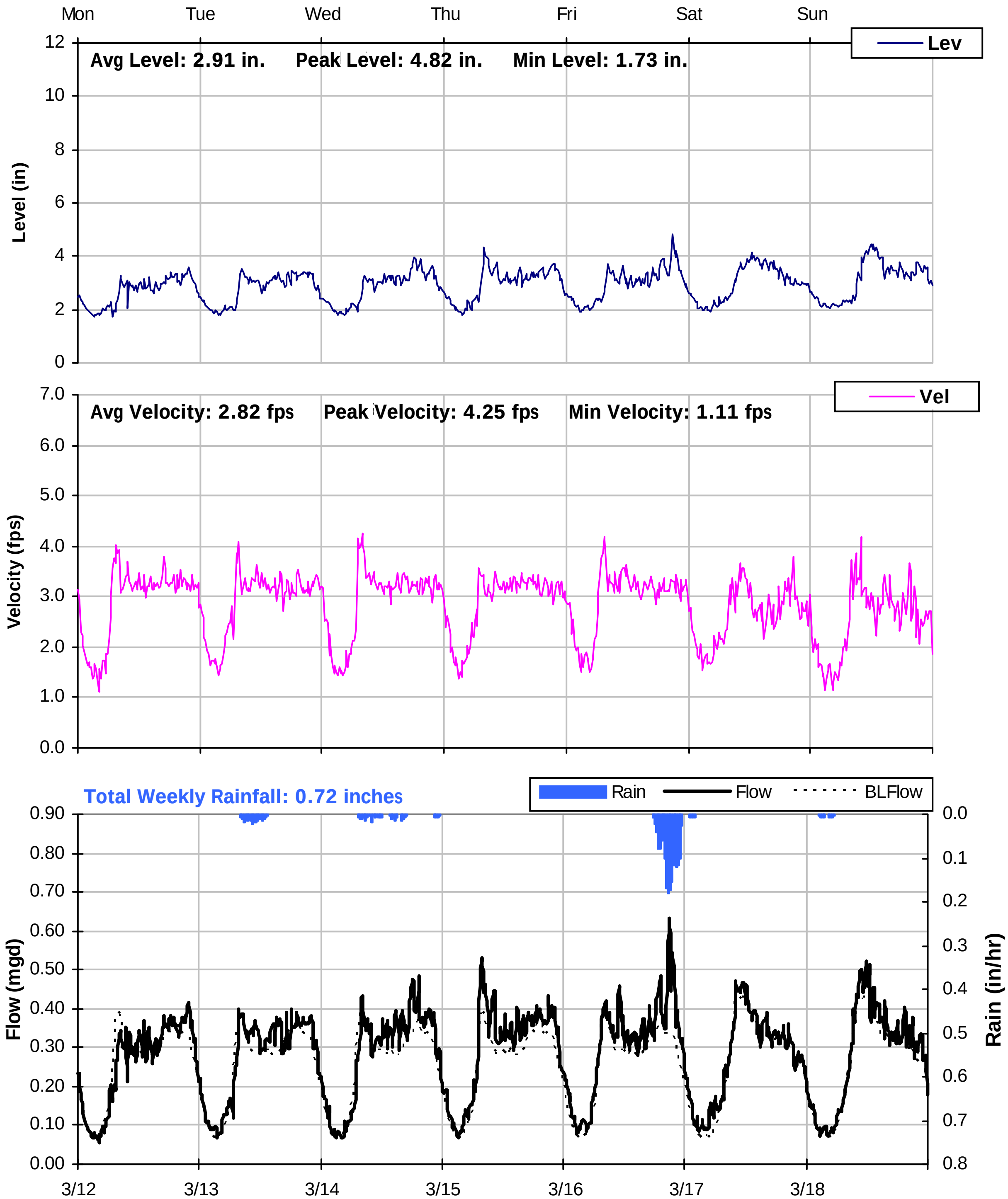


Avg Flow: 0.238 mgd **Peak Flow: 0.483 mgd** **Min Flow: 0.045 mgd**

MH E2
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012

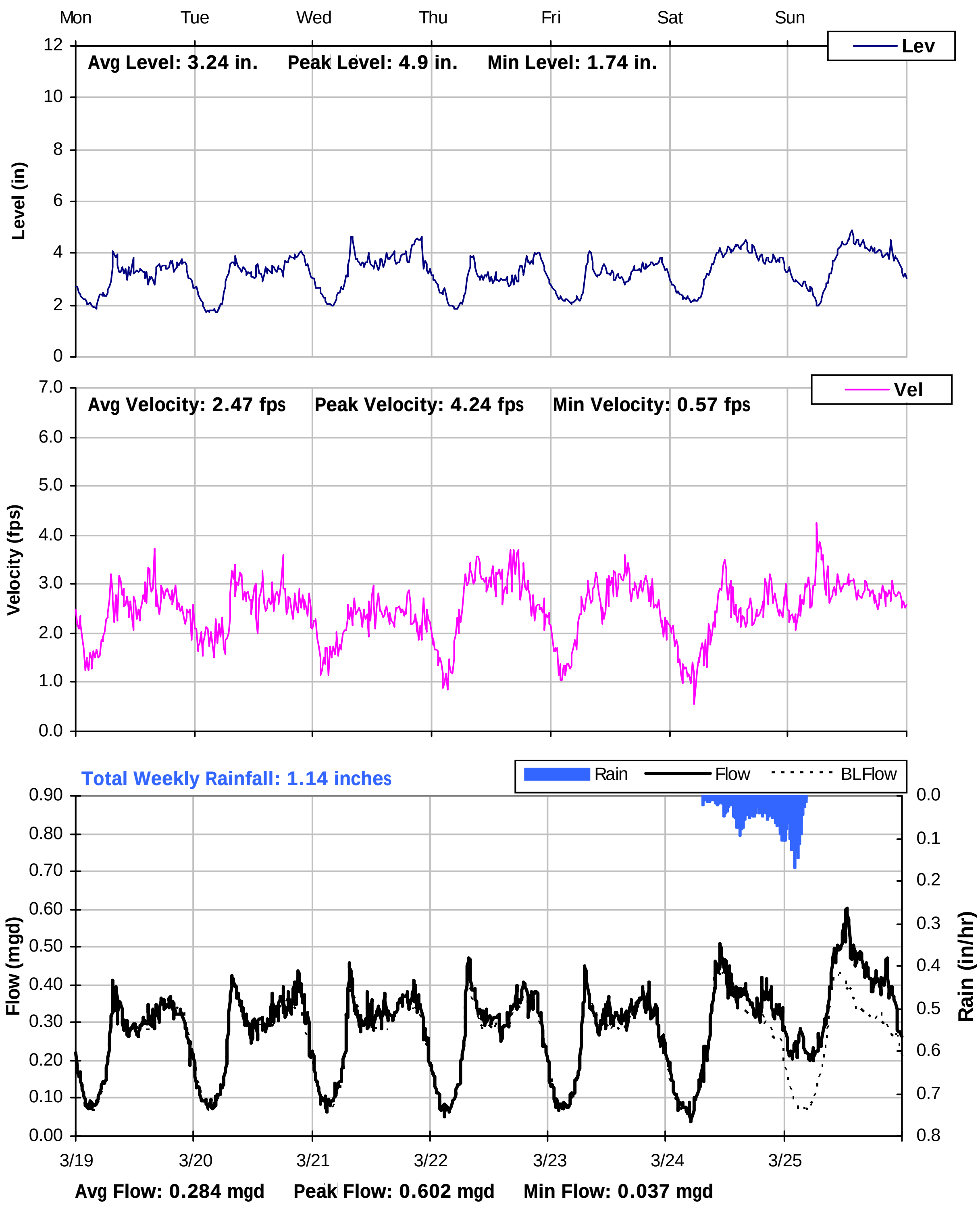


MH E2
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012

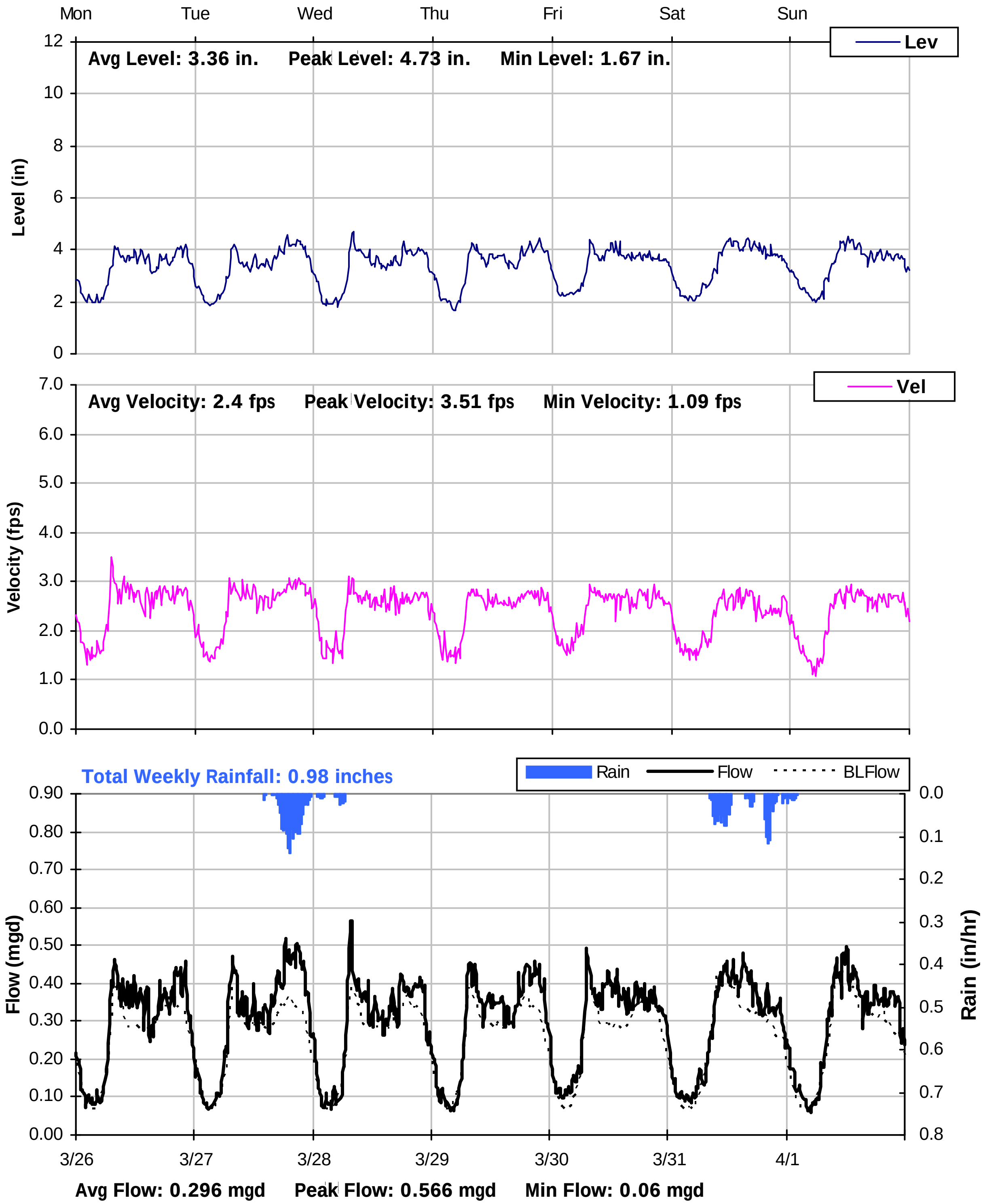


Avg Flow: 0.282 mgd Peak Flow: 0.632 mgd Min Flow: 0.055 mgd

MH E2
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



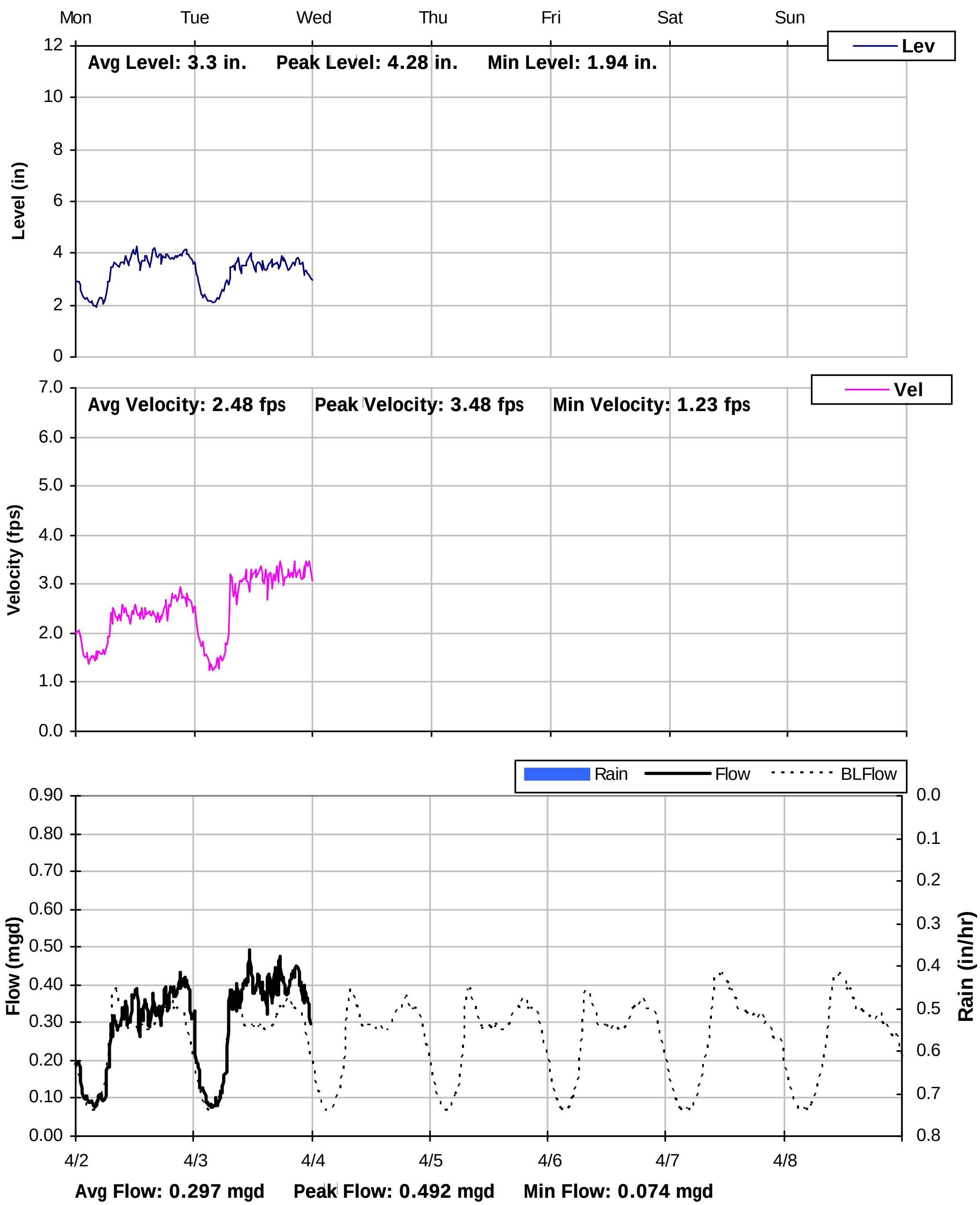
MH E2
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



MH E2

Weekly Level, Velocity and Flow Hydrographs

4/2/2012 to 4/9/2012



East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

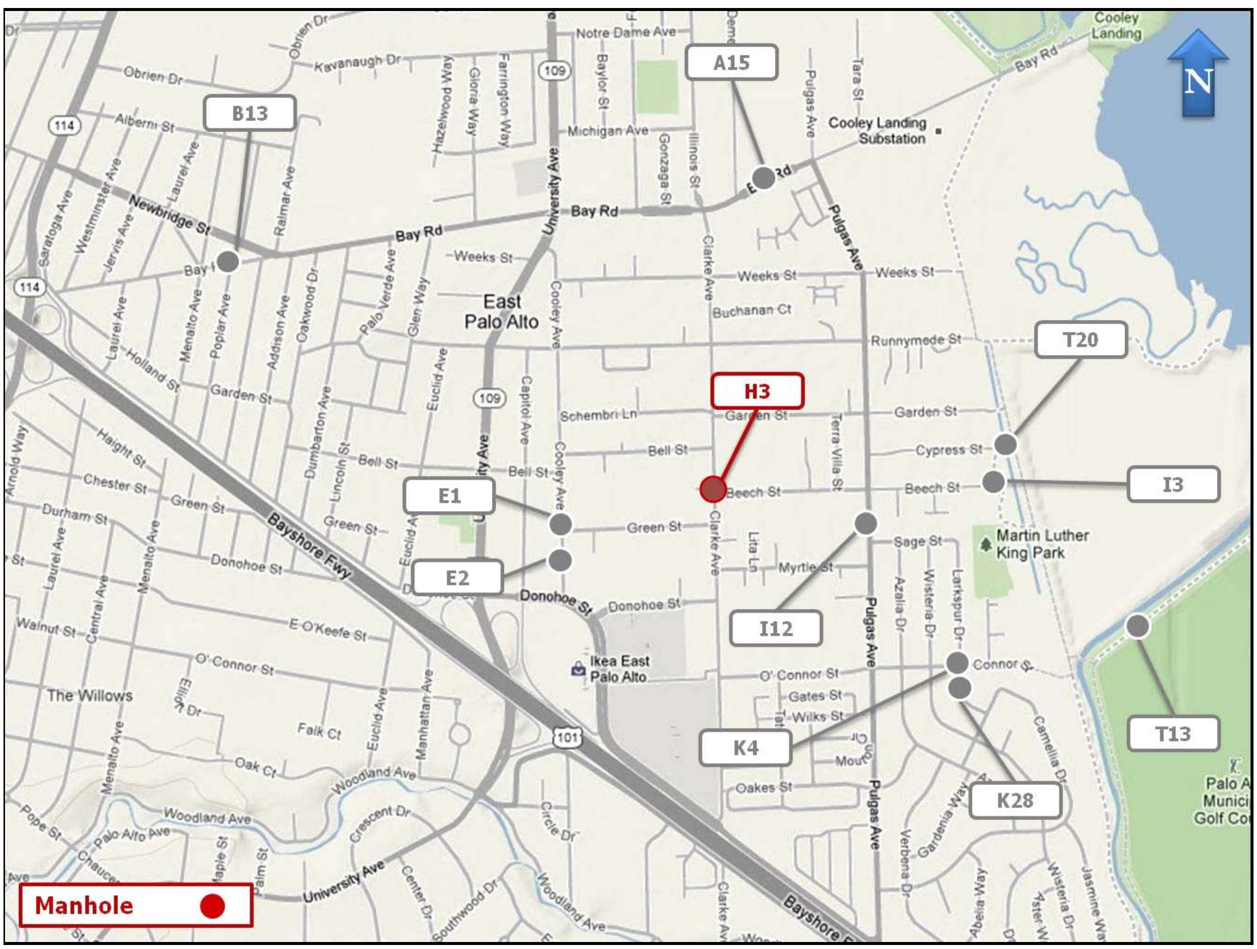
Year 2012

Monitoring Site: MH H3

Location: Clarke Avenue at Beech Street

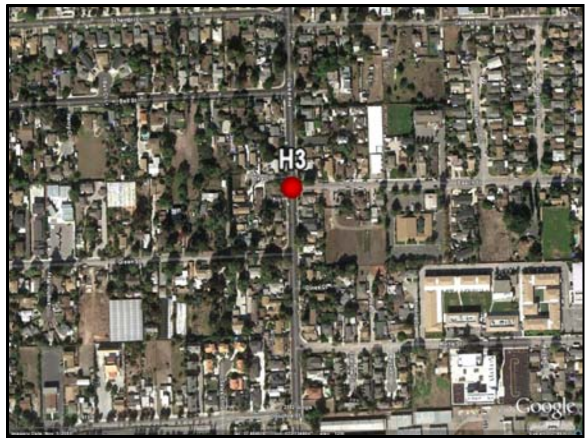
Data Summary Report

Vicinity Map:



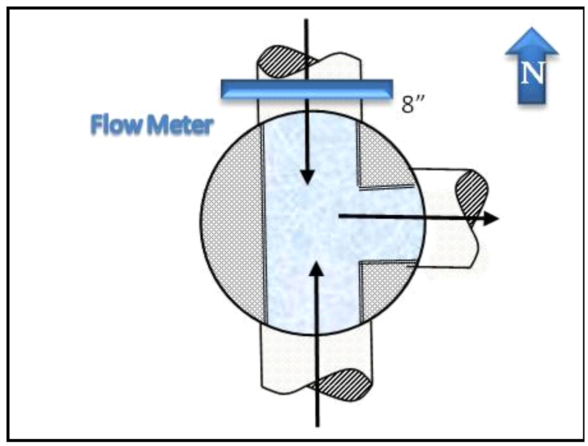
MH H3
Site Information Report

Location:	Clarke Avenue at Beech Street
Coordinates:	122.1347° W, 37.4651° N
Elevation:	12 feet
Diameter:	8 inches
Baseline Flow:	0.135 mgd
Peak Measured Flow:	0.308 mgd



Satellite Map

Sanitary Sewer Map



Flow Sketch

View from Street

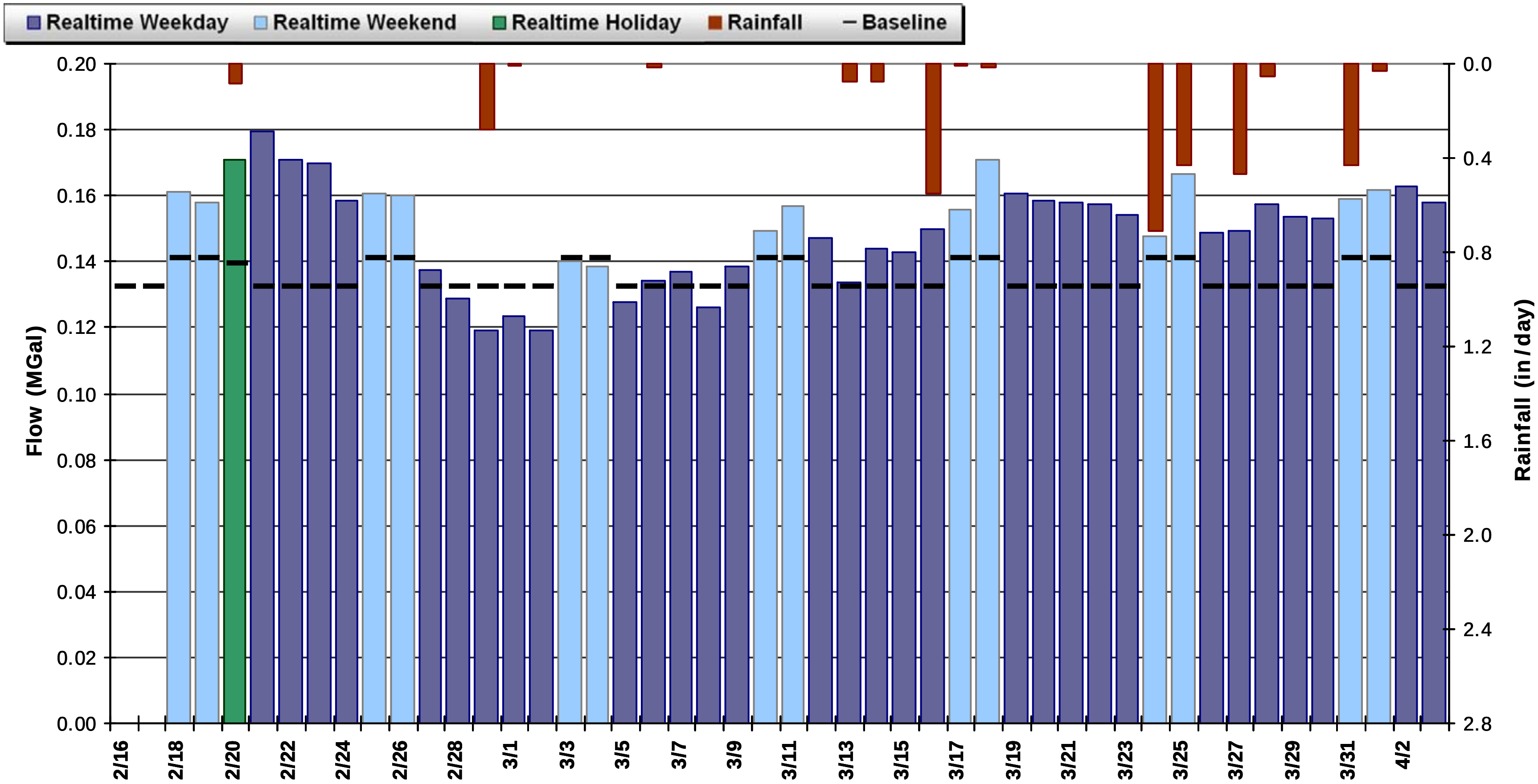
Plan View

MH H3

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.150 MGal **Peak Daily Flow: 0.180 MGal** **Min Daily Flow: 0.119 MGal**

Total Period Rainfall: 3.24 inches

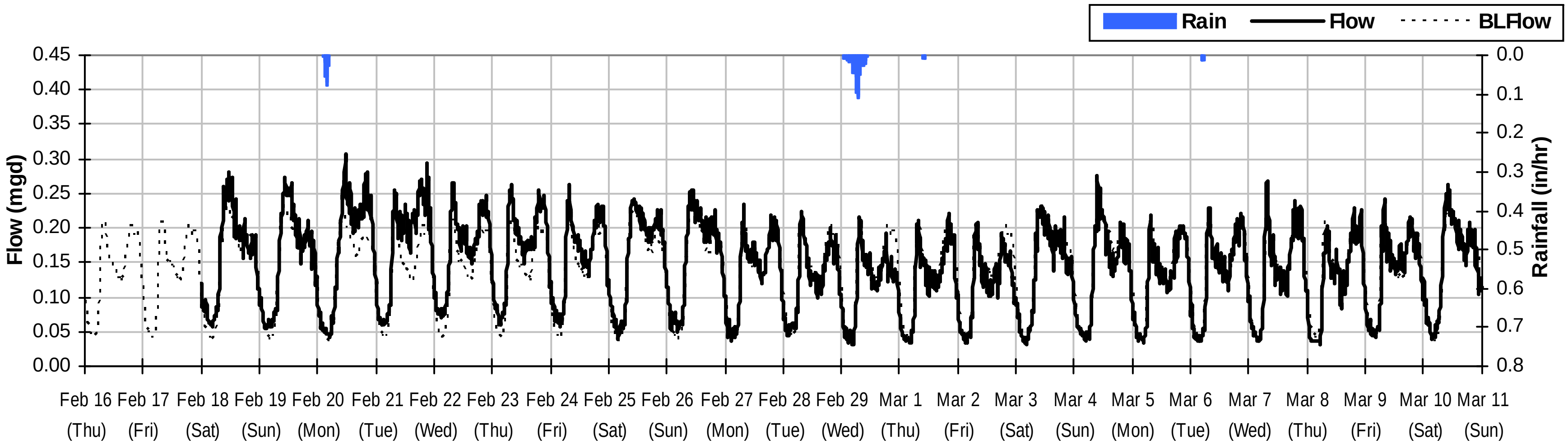


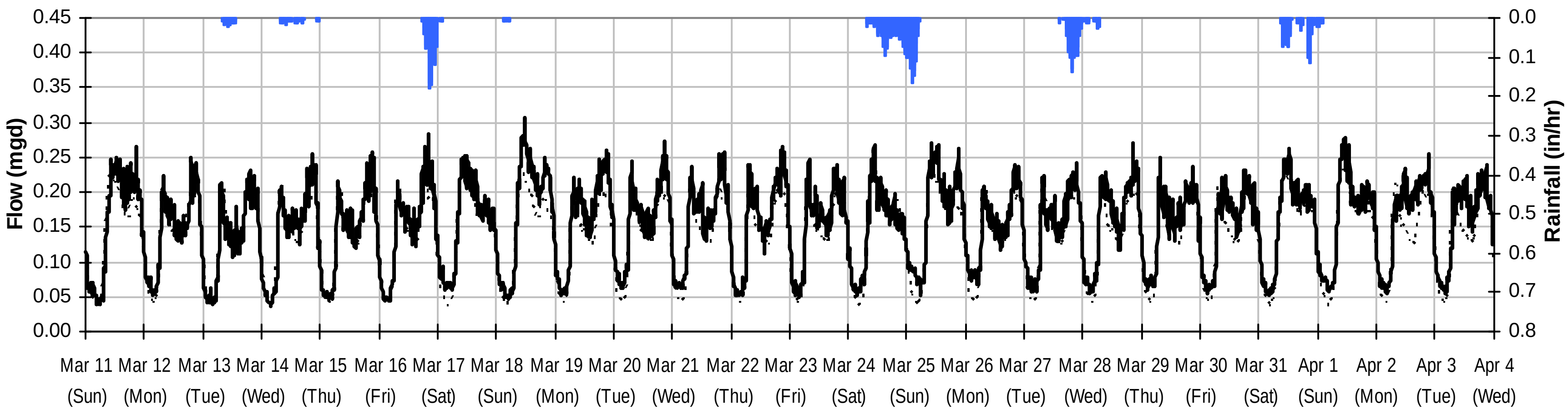
MH H3

Period Flow Summary: February 16 to April 4, 2012

Avg Flow: 0.150 mgd **Peak Flow: 0.308 mgd** **Min Flow: 0.030 mgd**

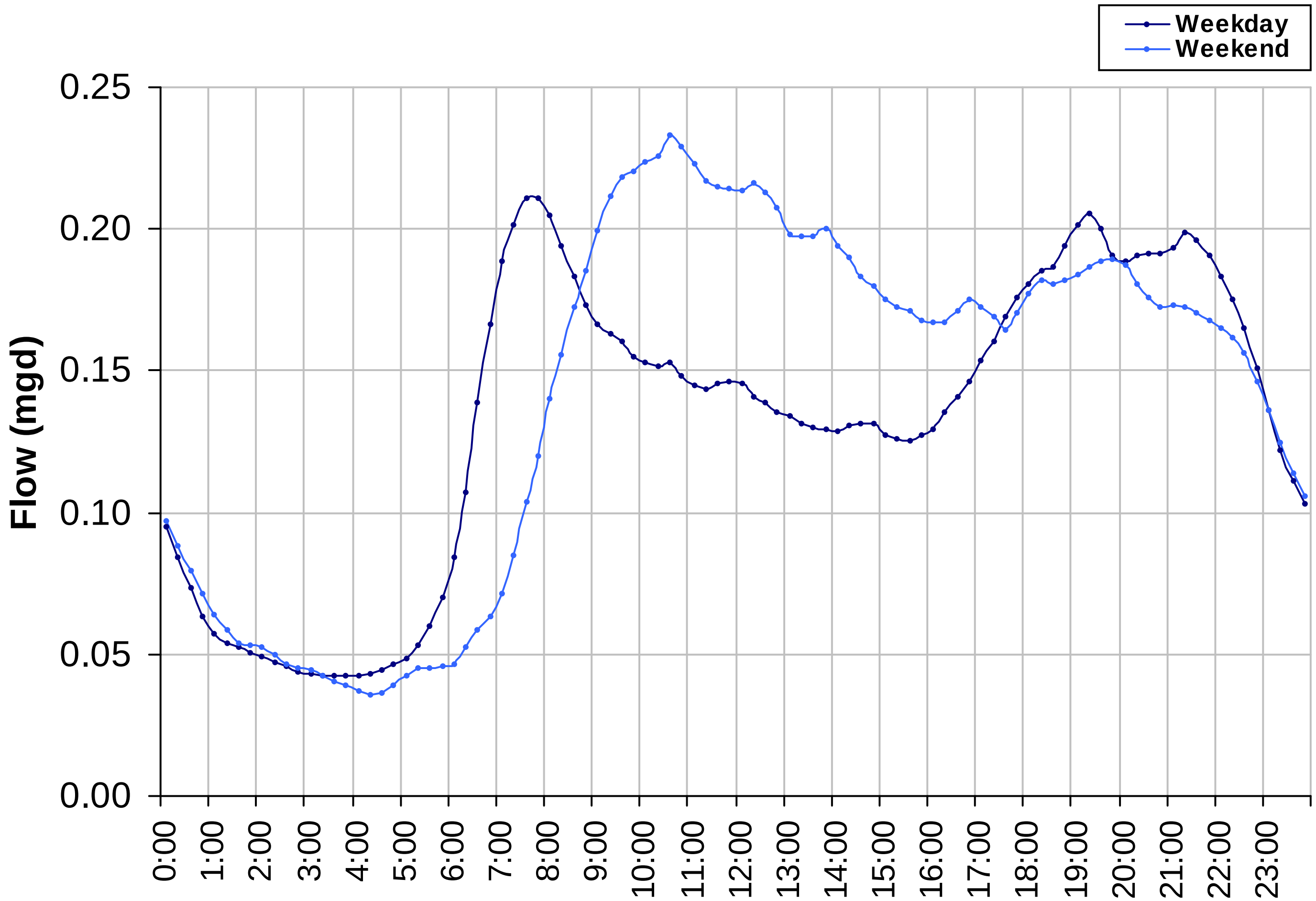
Total Period Rainfall: 3.24 inches





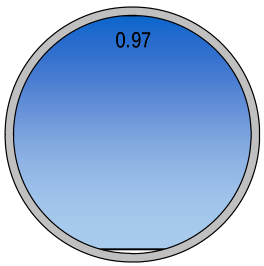
MH H3

Baseline Flow Hydrographs



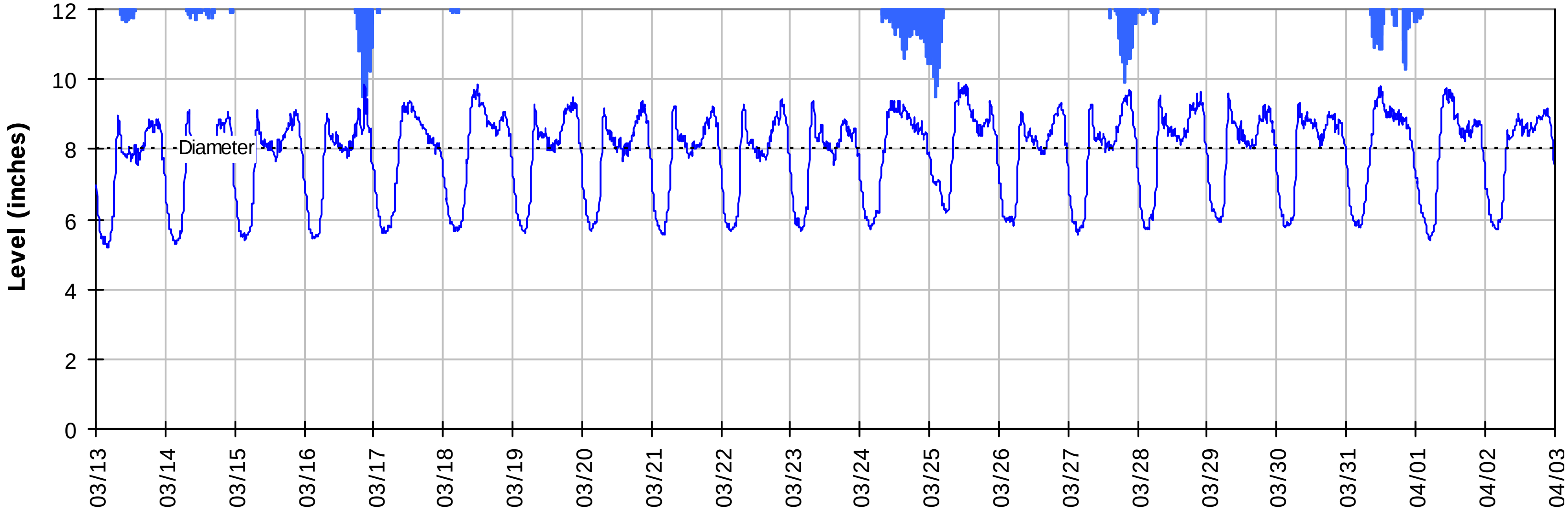
Baseline Flow:

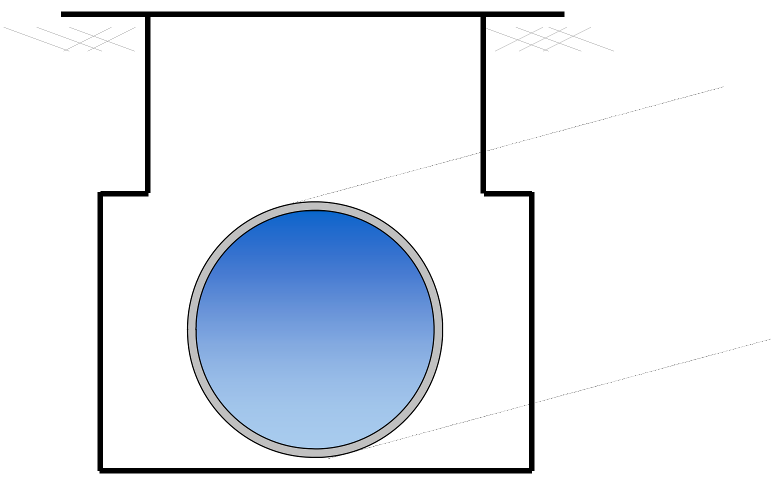
0.135 *mgd*



MH H3
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





Pipe Diameter: 8 *inches*

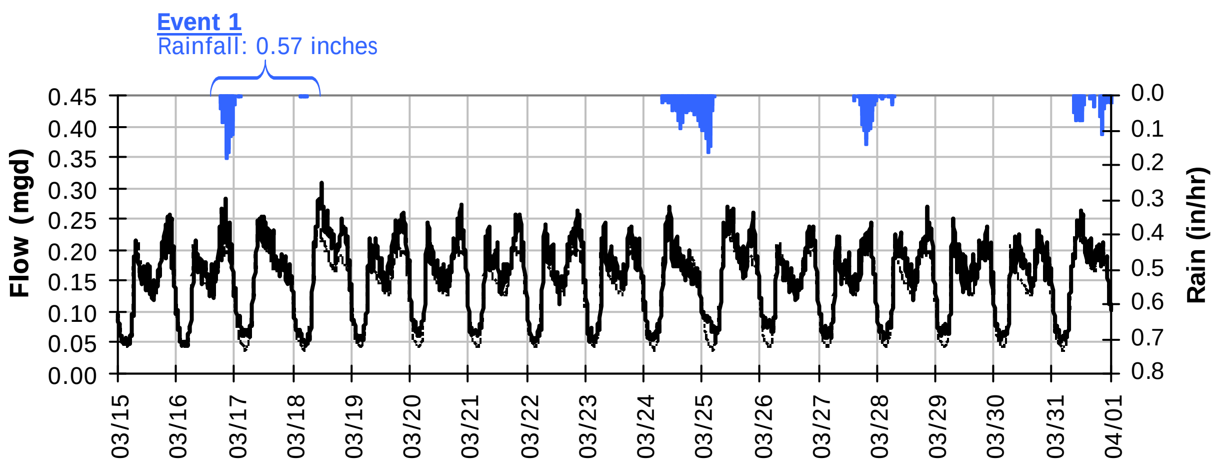
Peak Measured Level: 9.92 *inches*

Peak d/D Ratio: 1.24

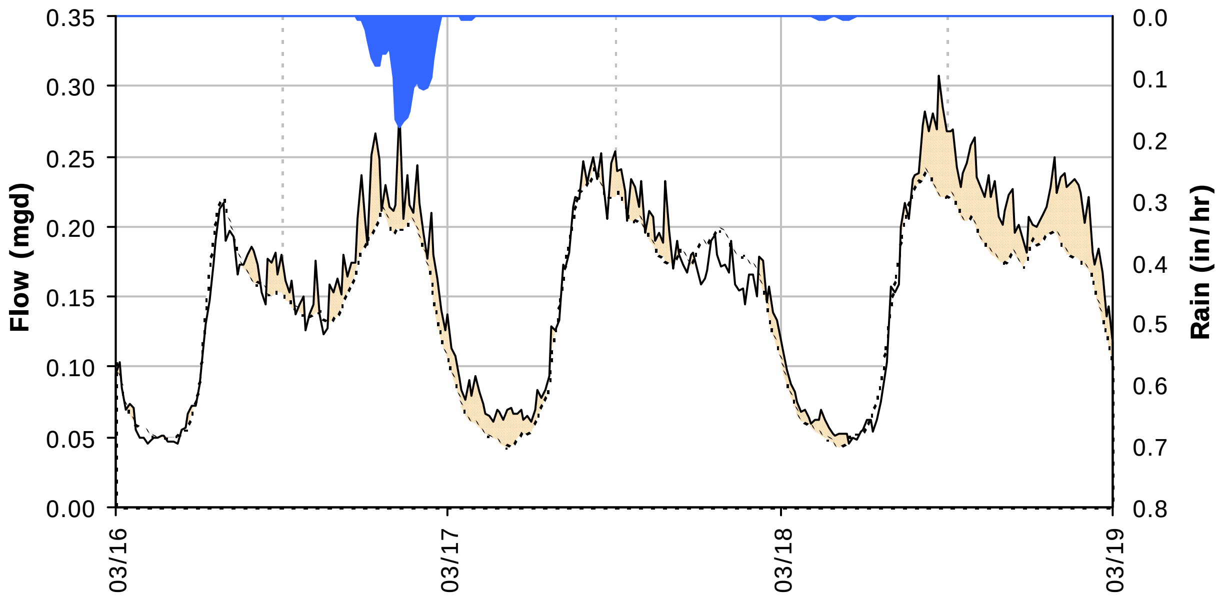
Surcharged 1.9 inches over crown

MH H3
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

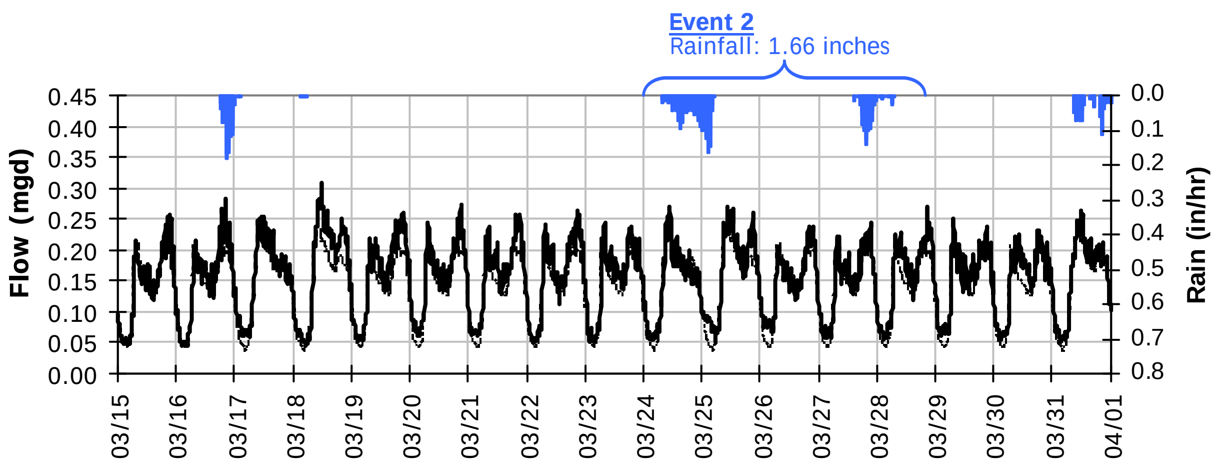


Storm Event I/I Analysis (Rain = 0.57 inches)

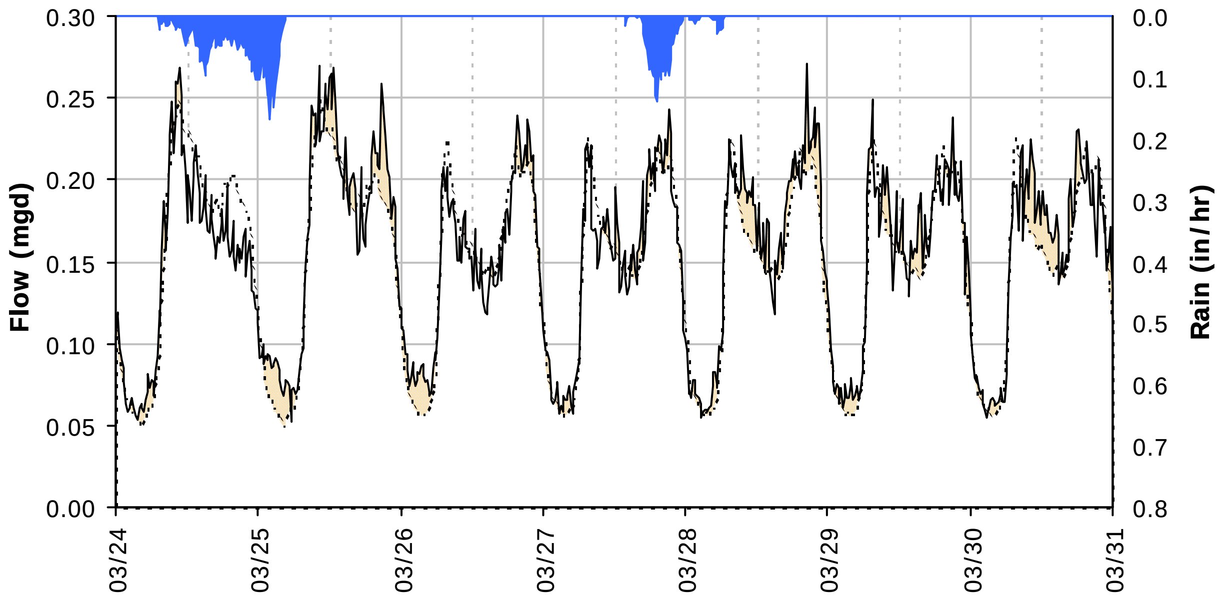
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	0.28 *mgd*	**Peak I/I Rate:**	0.09 *mgd*	**Infiltration Rate:** (3/18/2012)	0.014 *mgd*	**Total I/I:**	16,000 *gallons*
PF:	2.10	**PkI/I:IDM:**	5,802 *gpd/IDM*	**RDI:IDM:**	907 *gpd/IDM*	**Total I/I:IDM:**	1,748 *gal/IDM/in*
Peak Level:	9.87 *in*	**PkI/I:Acre:**	1,256 *gpd/acre*	**RDI:Acre:**	196 *gpd/acre*	**R-Value:**	1.4%
d/D Ratio:	1.23	**Pk I/I:ADWF:**	0.68	**RDI (% of BL):**	28%	**Total I/I:ADWF:**	0.21 *per in-rain*

MH H3
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



Storm Event I/I Analysis (Rain = 1.66 inches)

Capacity

Peak Flow:	0.27	*mgd*
PF:	2.00	
Peak Level:	9.92	*in*
d/D Ratio:	1.24	

Inflow

Peak I/I Rate:	0.09	*mgd*
PkI/I:IDM:	5,420	*gpd/IDM*
PkI/I:Acre:	1,173	*gpd/acre*
Pk I/I:ADWF:	0.64	

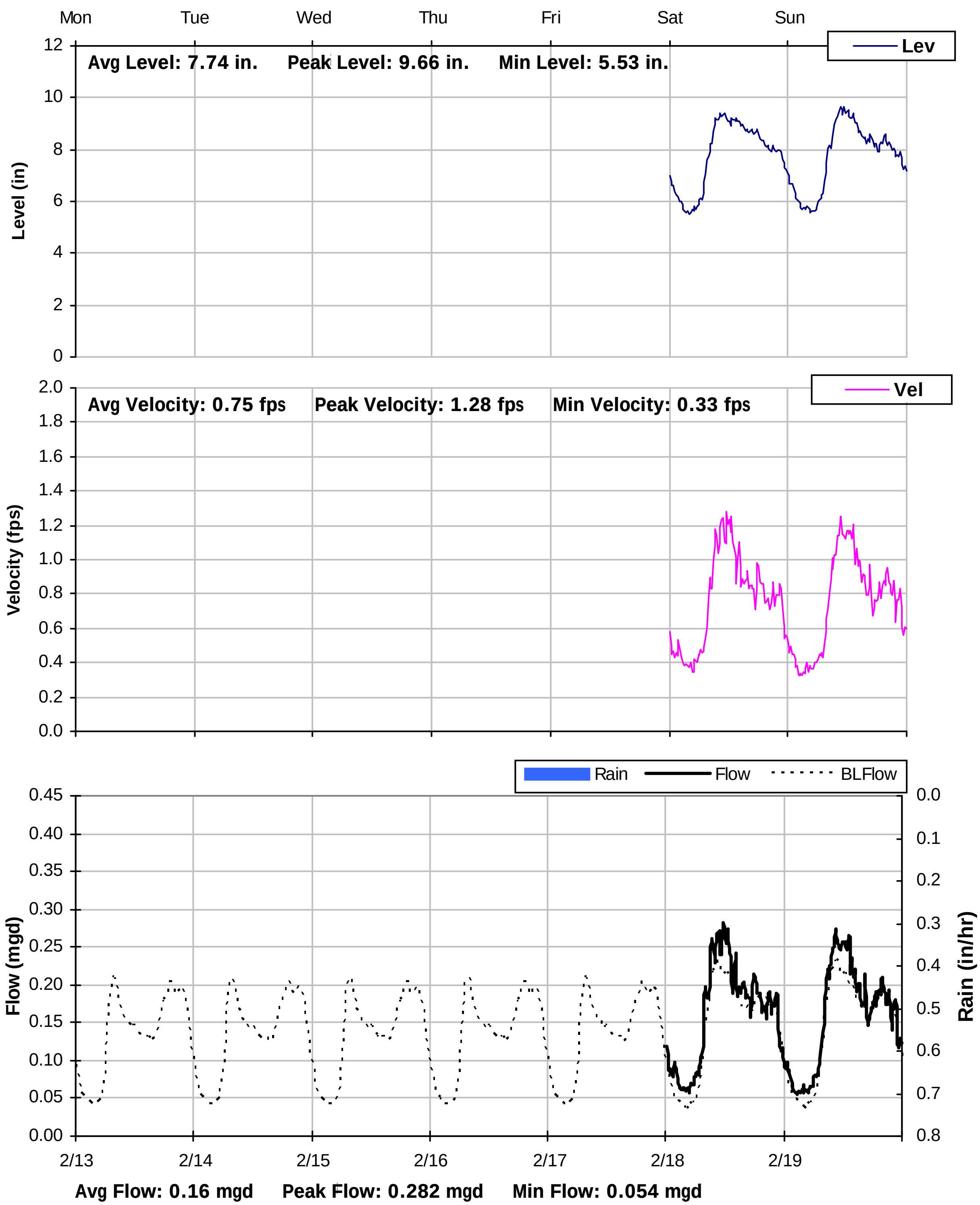
RDI (infiltration)

Infiltration Rate: (3/26/2012)	0.016	*mgd*
RDI:IDM:	988	*gpd/IDM*
RDI:Acre:	214	*gpd/acre*
RDI (% of BL):	12%	

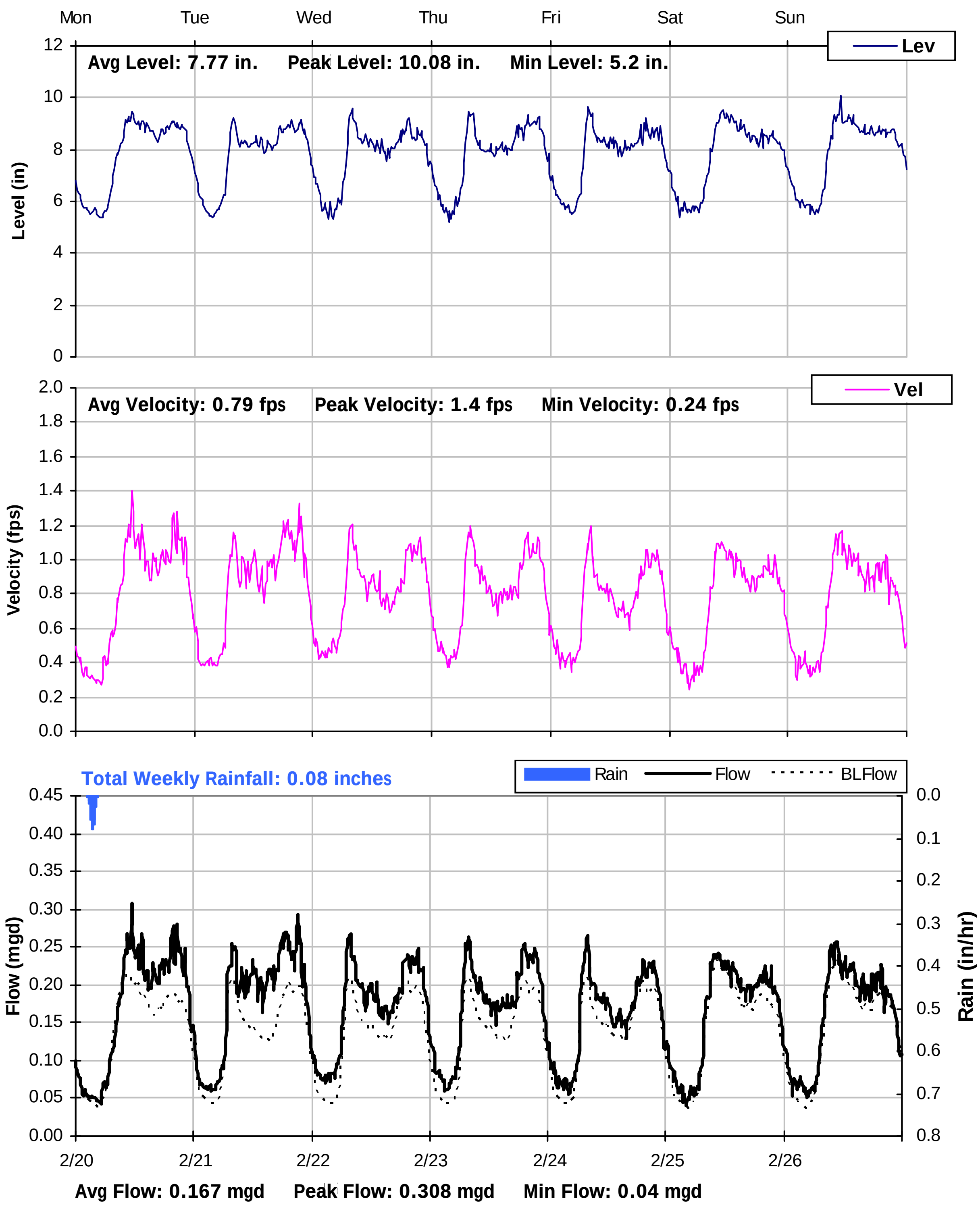
Combined I/I

Total I/I:	29,000	*gallons*
Total I/I:IDM:	1,091	*gal/IDM/in*
R-Value:	0.9%	
Total I/I:ADWF:	0.13	*per in-rain*

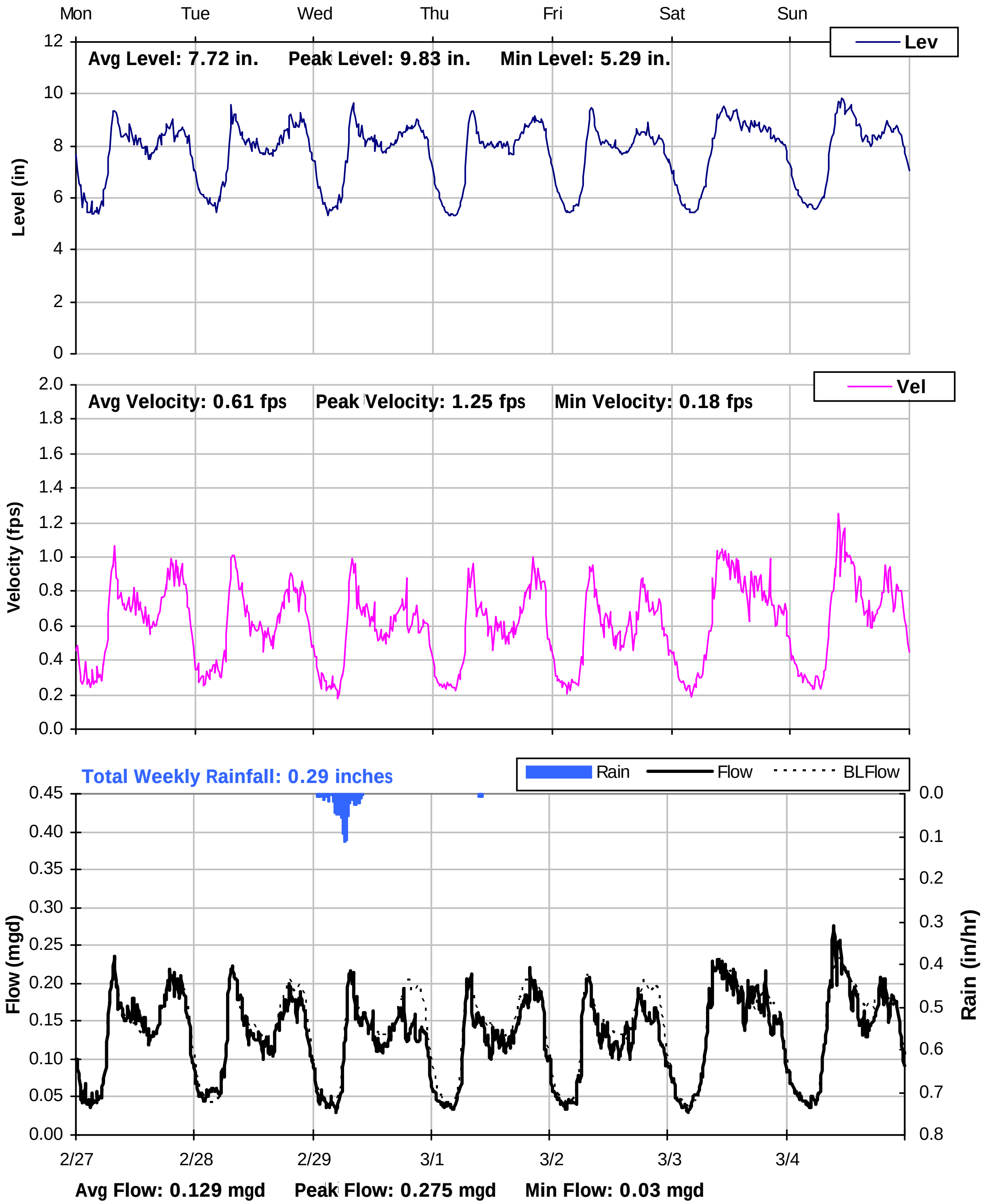
MH H3
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012



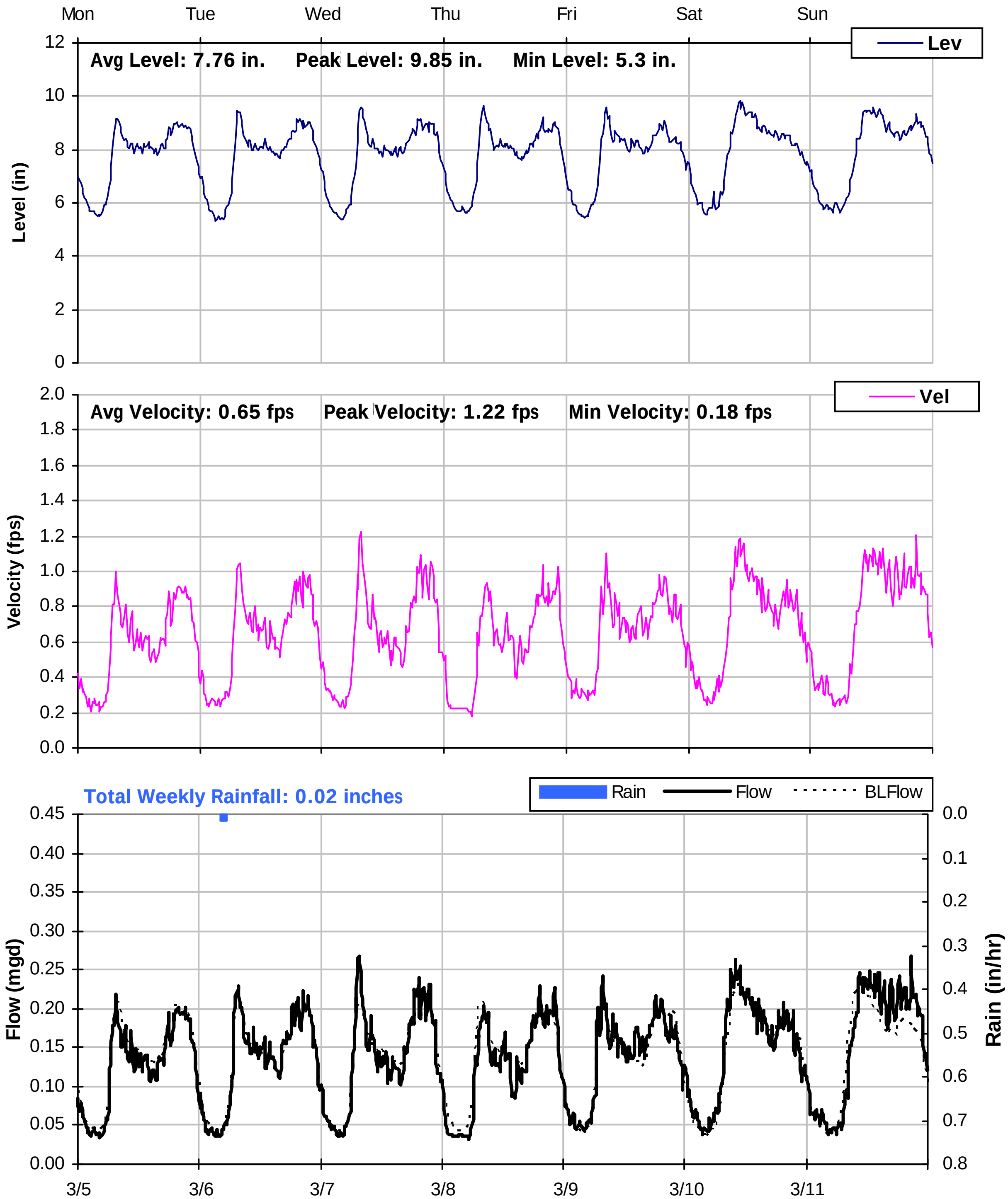
MH H3
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



MH H3
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012

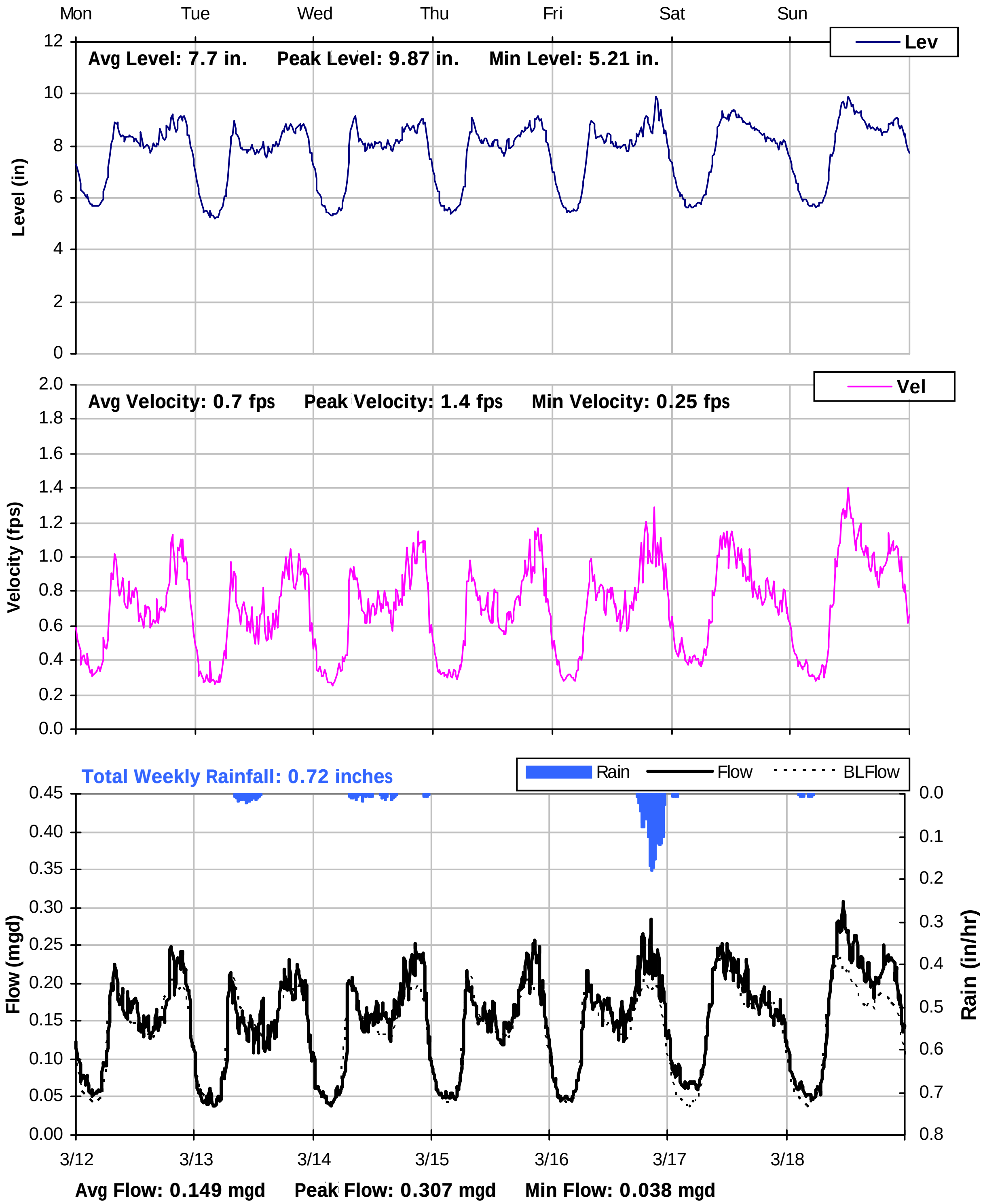


MH H3
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012

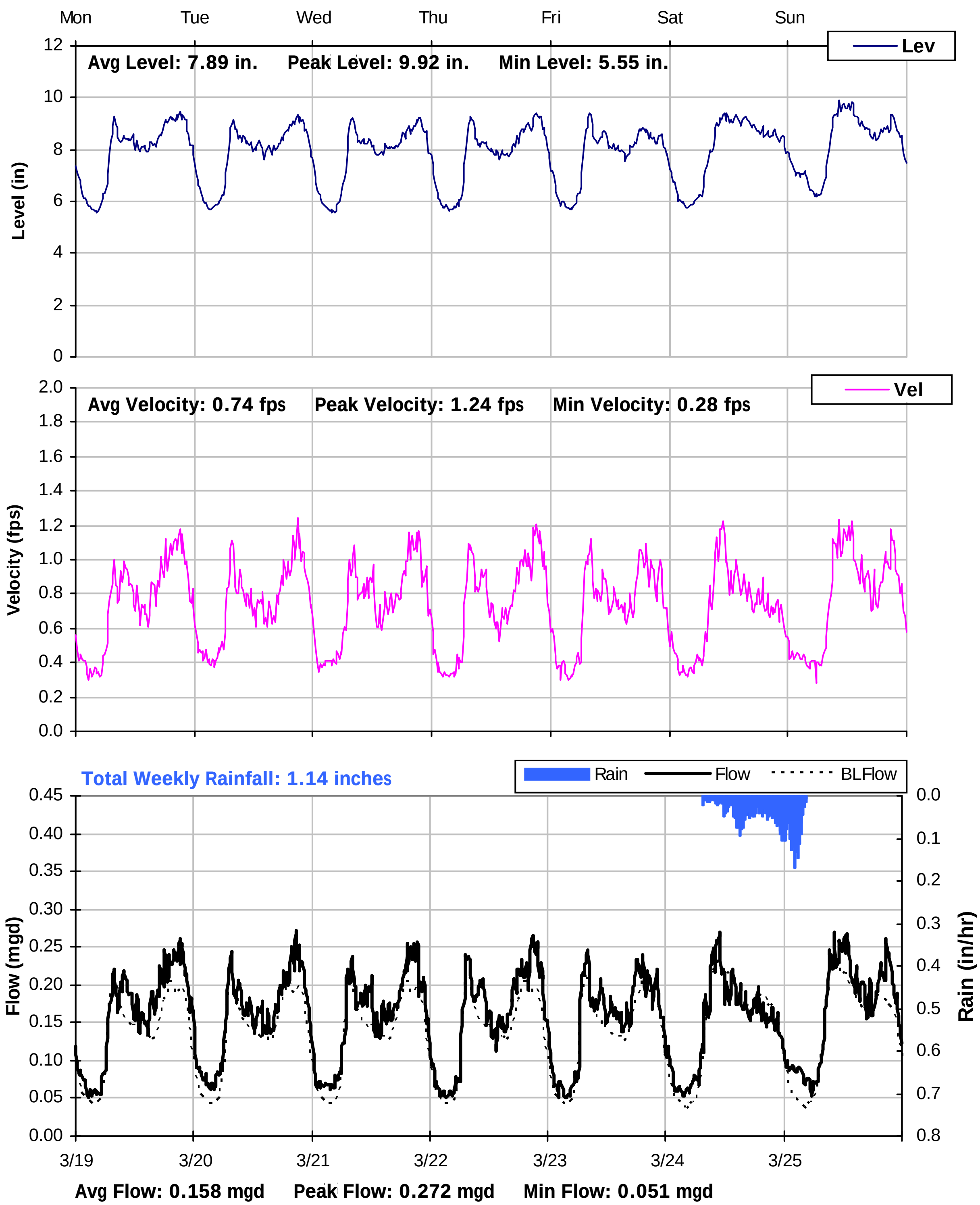


Avg Flow: 0.138 mgd Peak Flow: 0.267 mgd Min Flow: 0.031 mgd

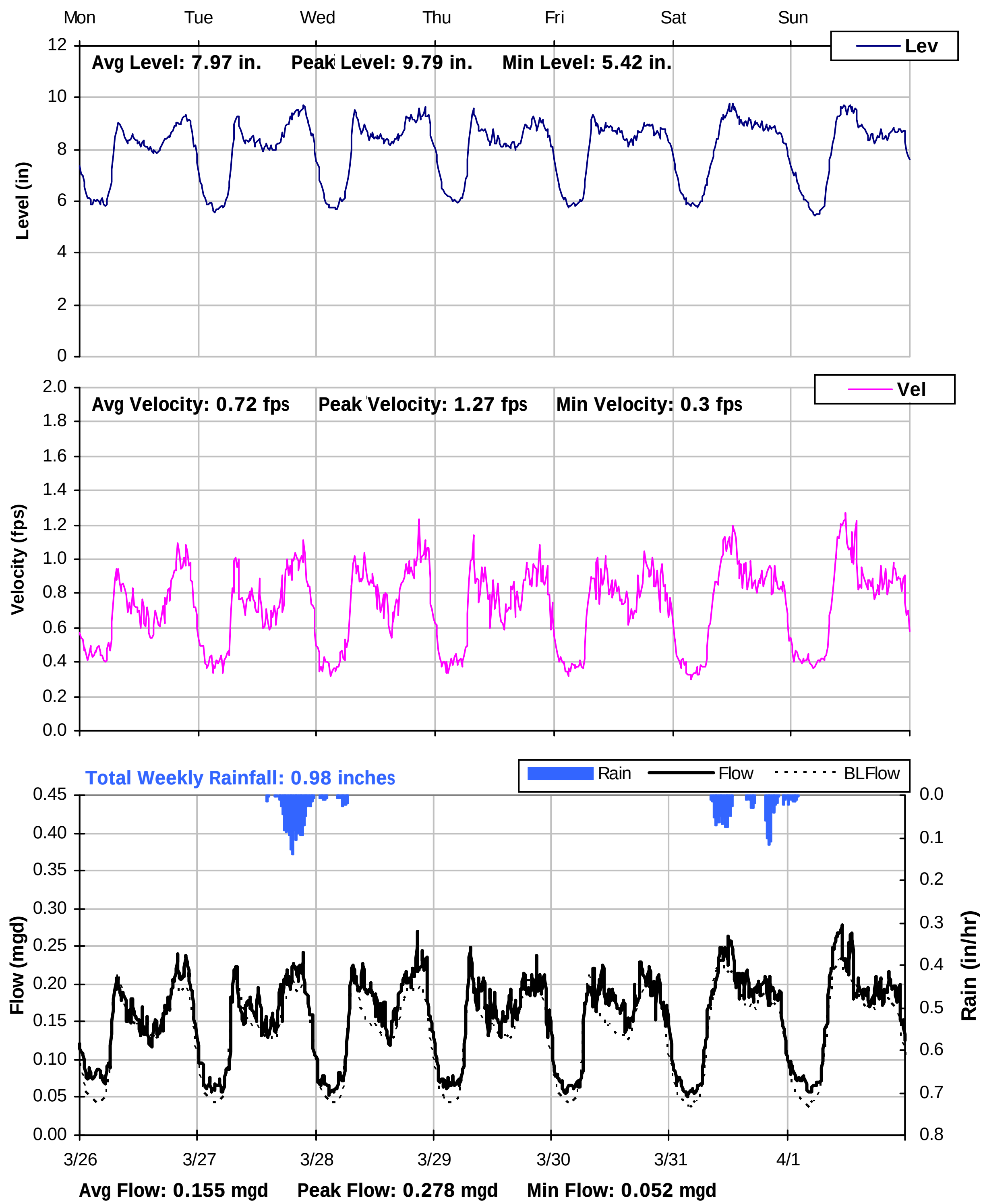
MH H3
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



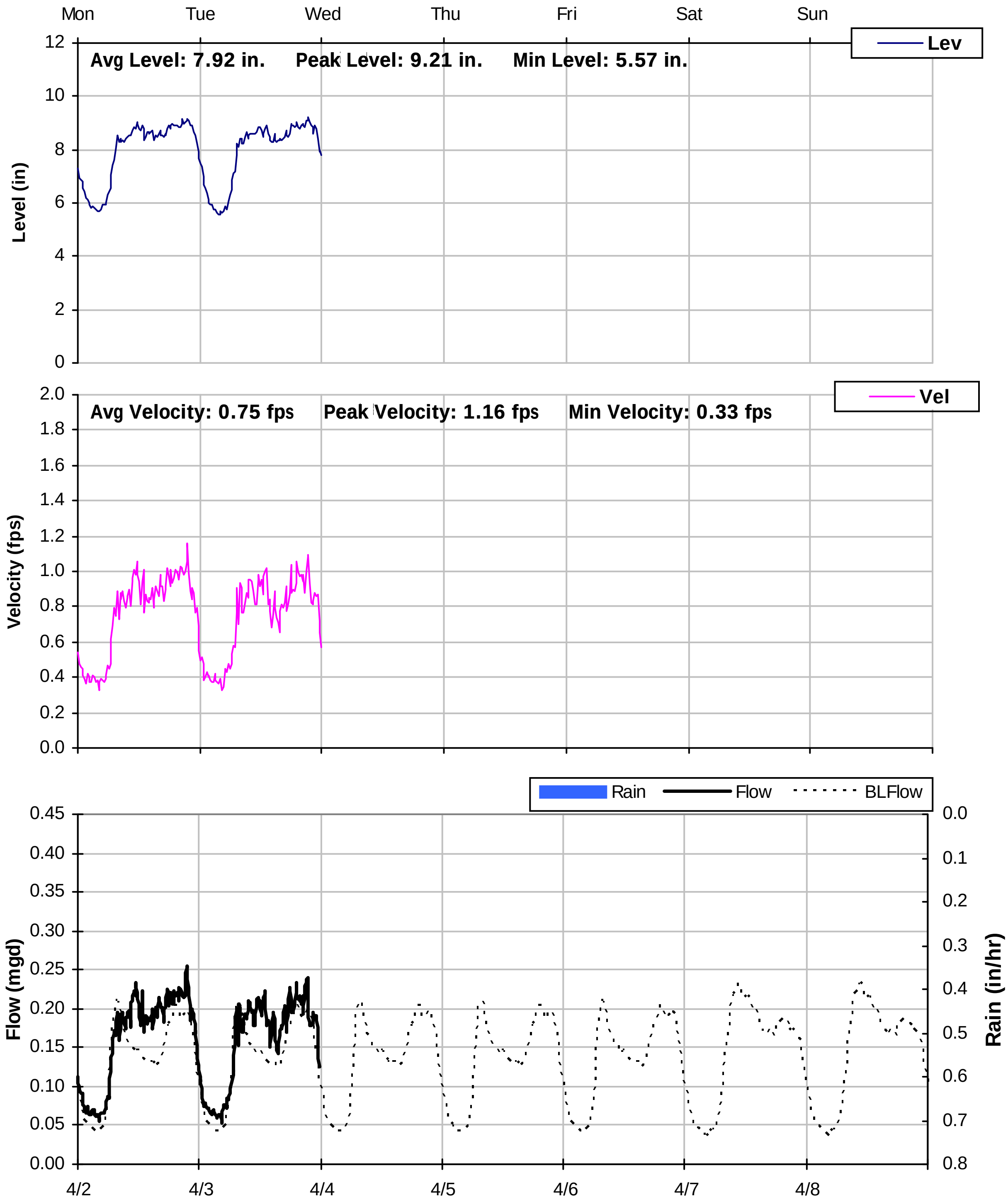
MH H3
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



MH H3
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



MH H3
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



Avg Flow: 0.16 mgd **Peak Flow: 0.254 mgd** **Min Flow: 0.054 mgd**

East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

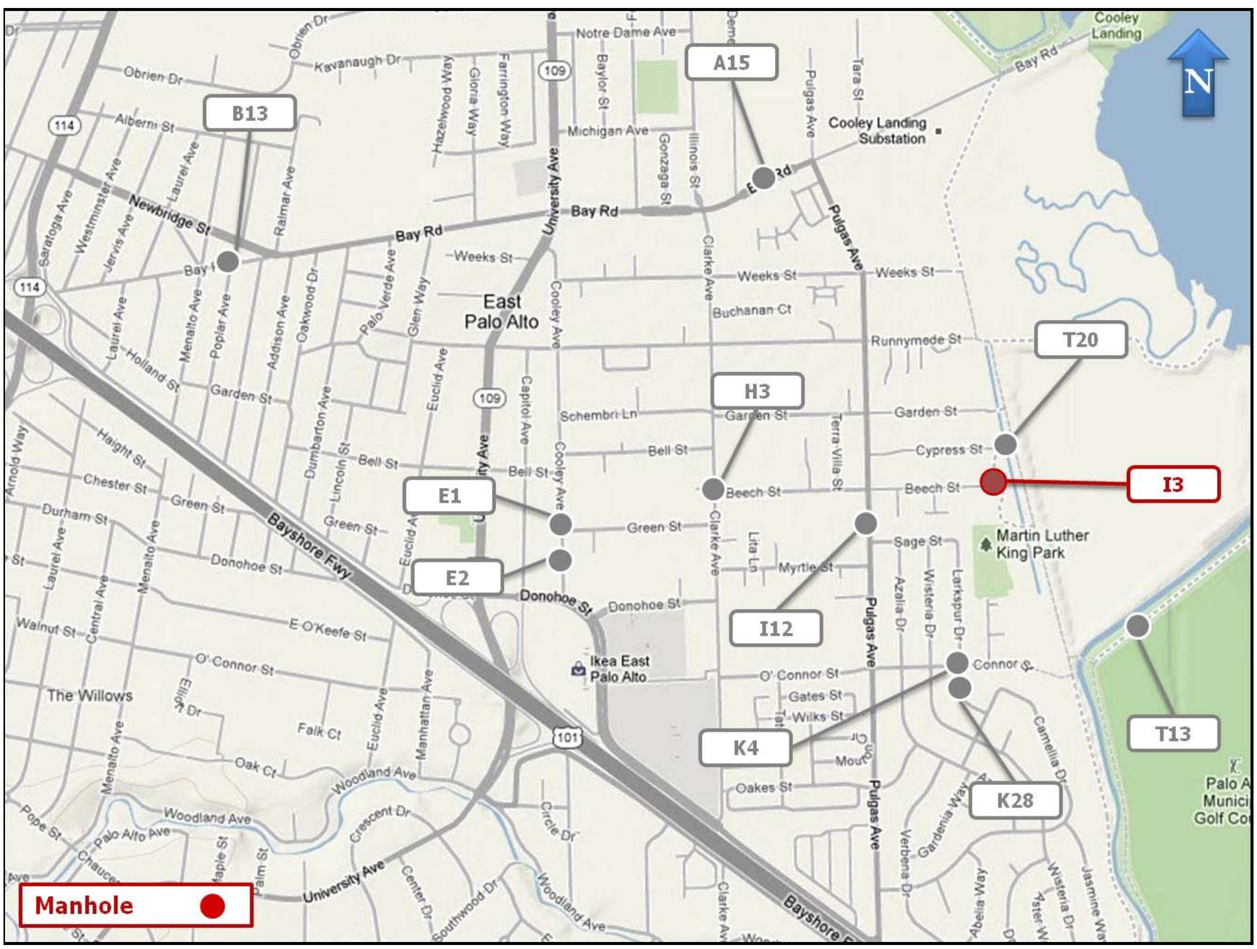
Year 2012

Monitoring Site: MH I3

Location: At the end of Beech Street, east of Pulgas Avenue

Data Summary Report

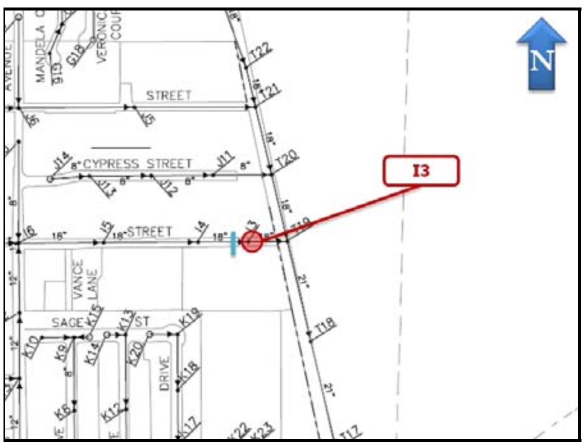
Vicinity Map:



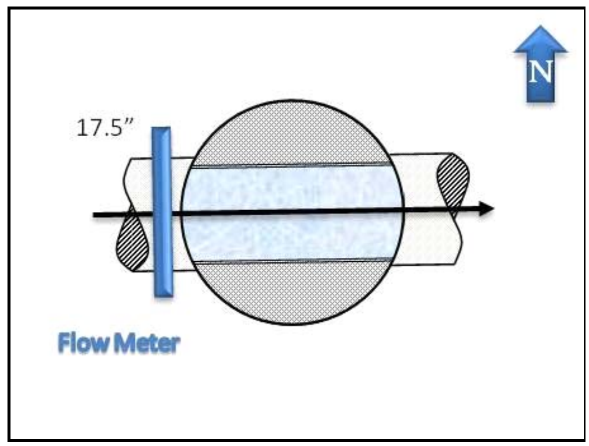
MH I3
Site Information Report

Location:	At the end of Beech Street, east of Pulgas Avenue
Coordinates:	122.1264° W, 37.4652° N
Elevation:	5 feet
Diameter:	17.5 inches
Baseline Flow:	0.829 mgd
Peak Measured Flow:	1.447 mgd

Satellite Map



Sanitary Sewer Map



Flow Sketch

View from Street

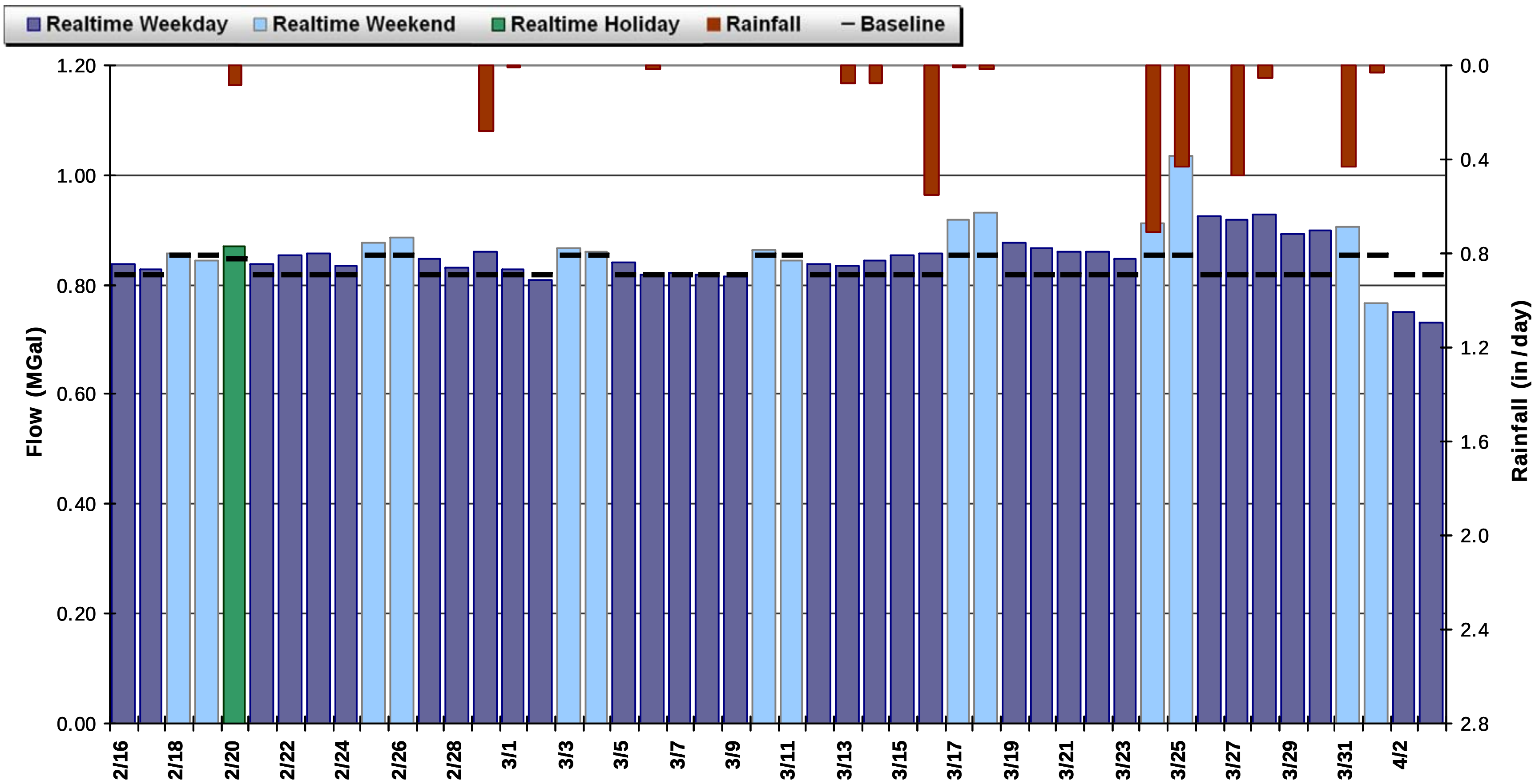
Plan View

MH I3

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.858 MGal **Peak Daily Flow: 1.036 MGal** **Min Daily Flow: 0.732 MGal**

Total Period Rainfall: 3.24 inches

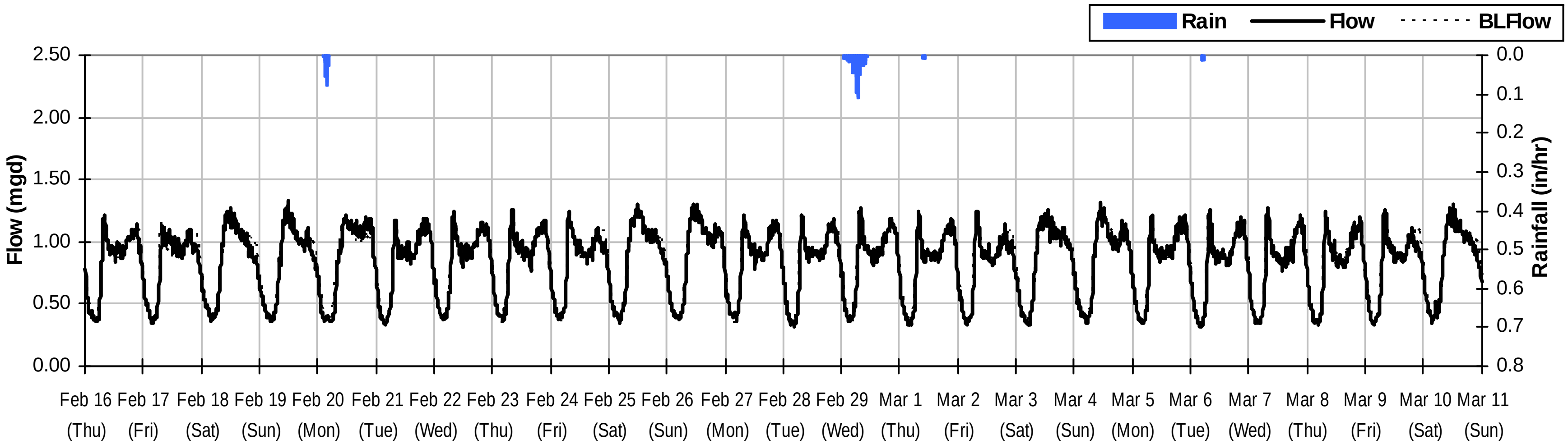


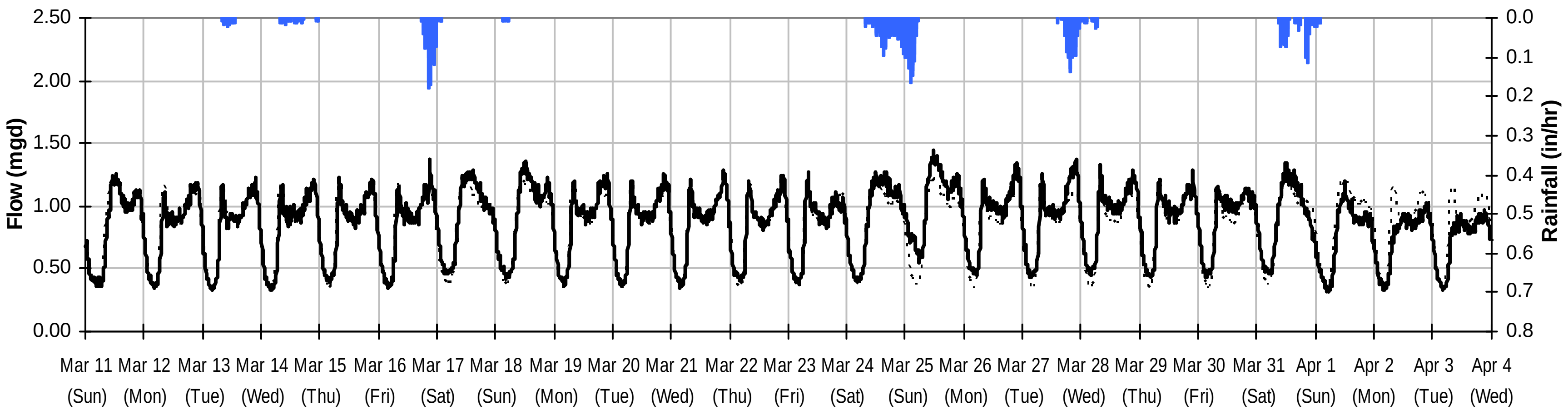
MH I3

Period Flow Summary: February 16 to April 4, 2012

Avg Flow: 0.858 mgd **Peak Flow: 1.447 mgd** **Min Flow: 0.312 mgd**

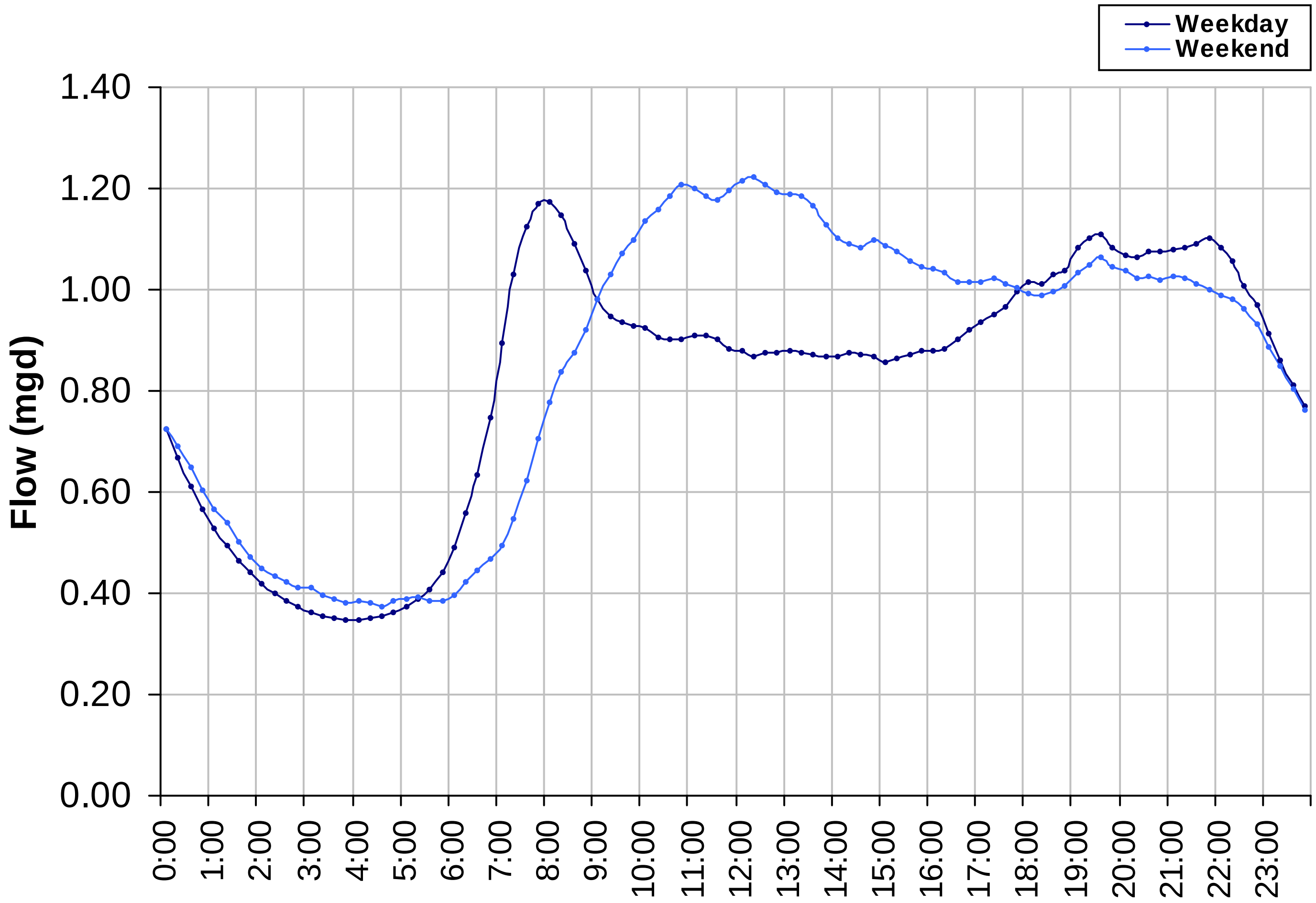
Total Period Rainfall: 3.24 inches





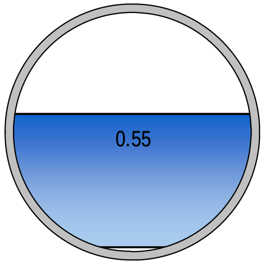
MH I3

Baseline Flow Hydrographs



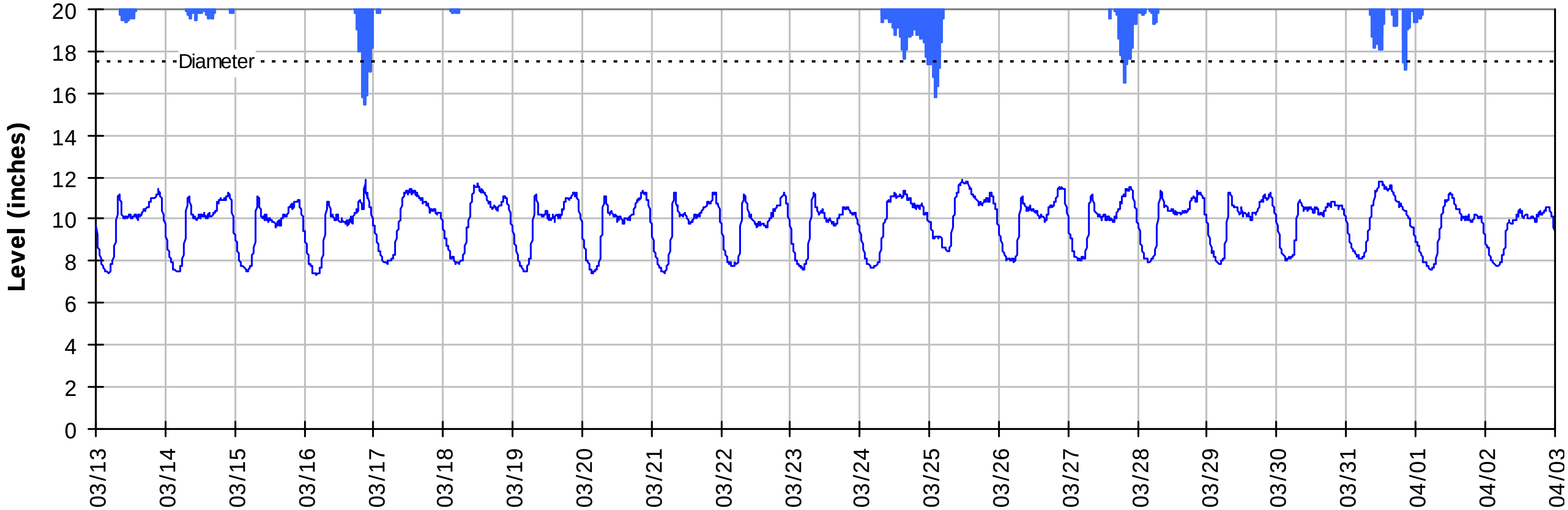
Baseline Flow:

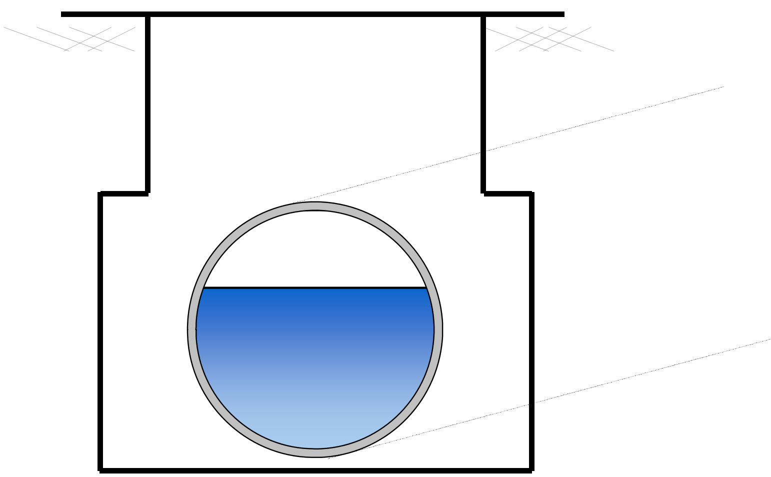
0.829 *mgd*



MH I3
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





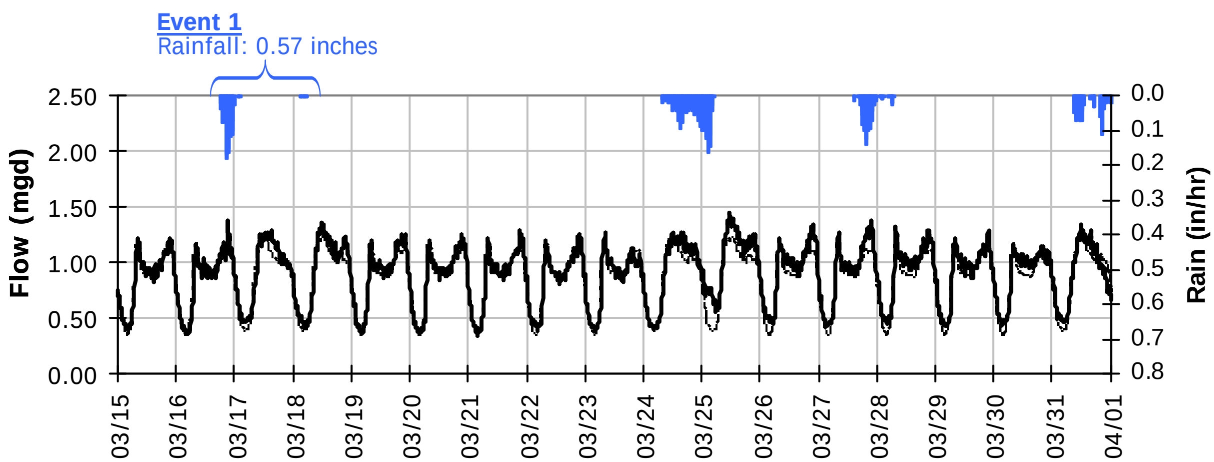
Pipe Diameter: 17.5 *inches*

Peak Measured Level: 11.9 *inches*

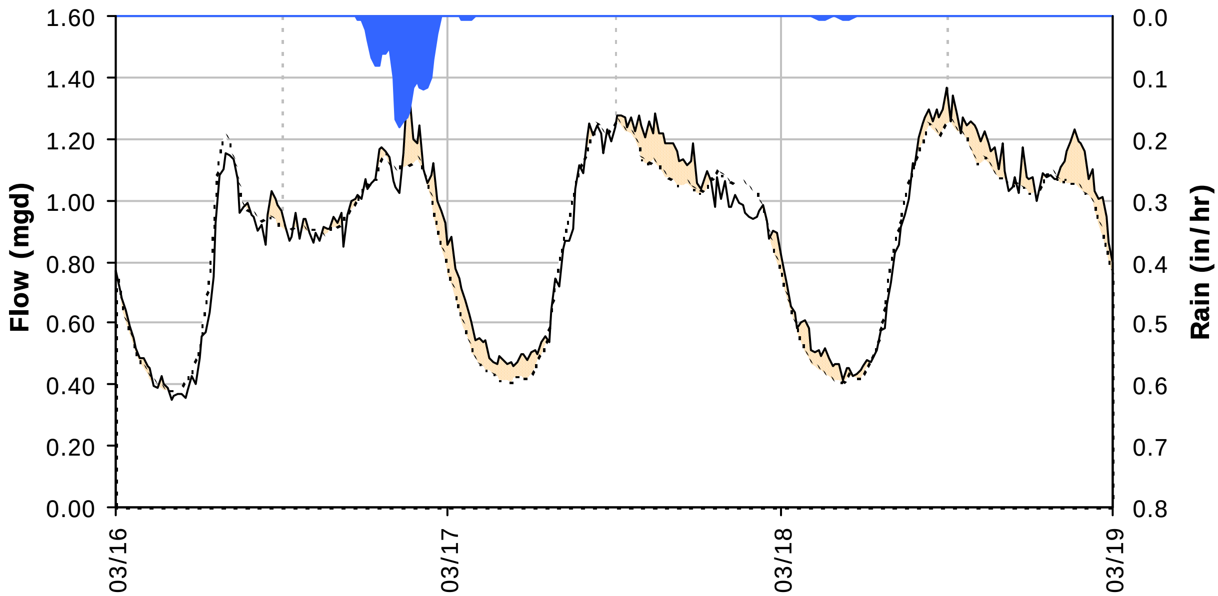
Peak d/D Ratio: 0.68

MH I3
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

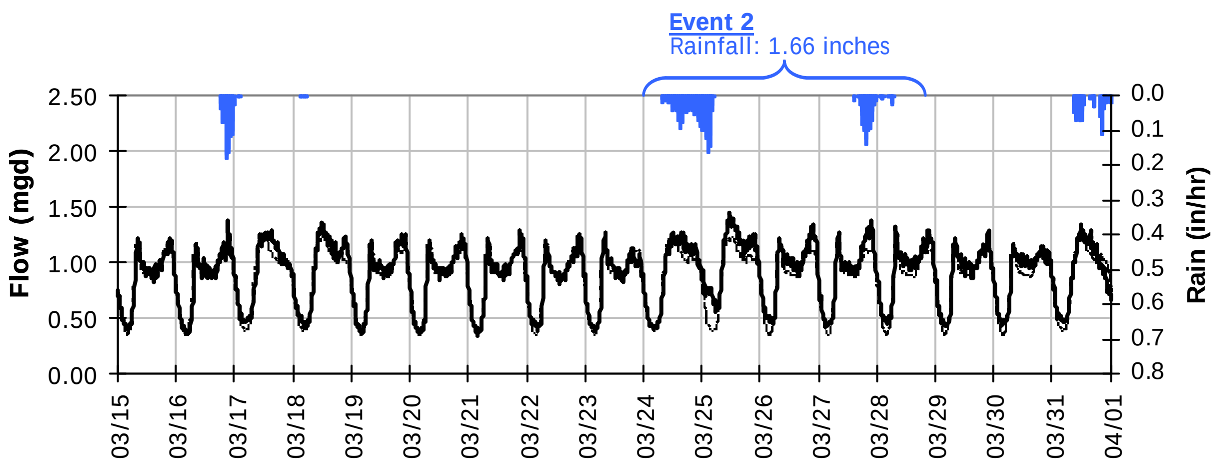


Storm Event I/I Analysis (Rain = 0.57 inches)

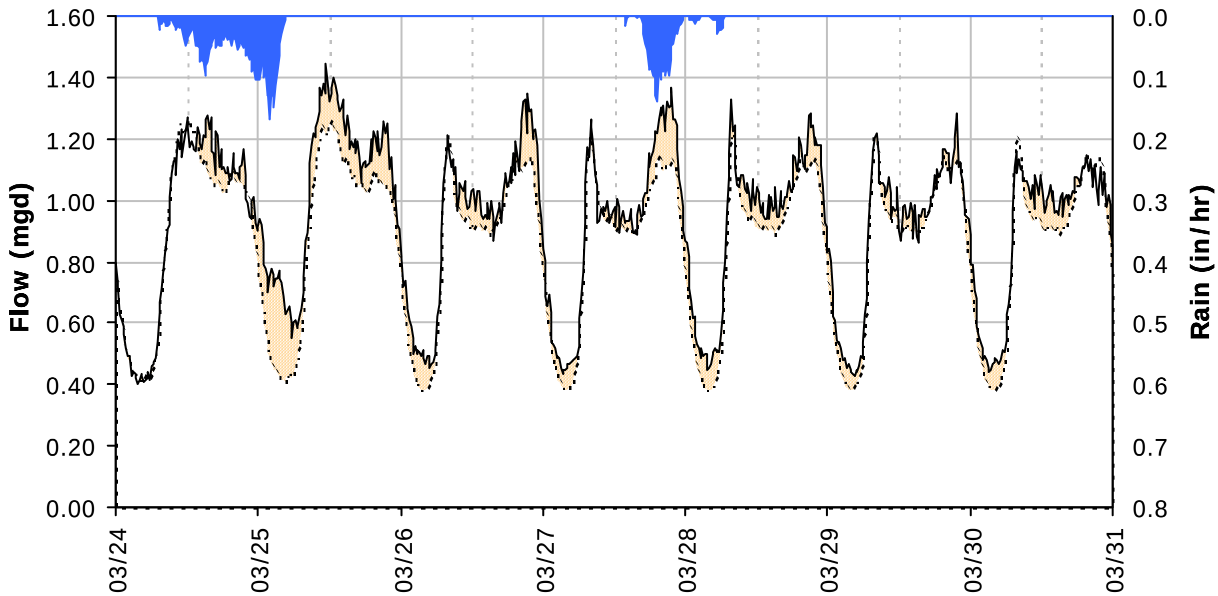
Capacity		**Inflow**		**RDI (infiltration)**		**Combined I/I**	
Peak Flow:	1.37 *mgd*	**Peak I/I Rate:**	0.29 *mgd*	**Infiltration Rate:** (3/18/2012)	0.080 *mgd*	**Total I/I:**	57,000 *gallons*
PF:	1.65	**PkI/I:IDM:**	2,412 *gpd/IDM*	**RDI:IDM:**	663 *gpd/IDM*	**Total I/I:IDM:**	828 *gal/IDM/in*
Peak Level:	11.90 *in*	**PkI/I:Acre:**	545 *gpd/acre*	**RDI:Acre:**	150 *gpd/acre*	**R-Value:**	0.7%
d/D Ratio:	0.68	**Pk I/I:ADWF:**	0.35	**RDI (% of BL):**	17%	**Total I/I:ADWF:**	0.12 *per in-rain*

MH I3
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



Storm Event I/I Analysis (Rain = 1.66 inches)

Capacity

Peak Flow:	1.45	*mgd*
PF:	1.74	
Peak Level:	11.85	*in*
d/D Ratio:	0.68	

Inflow

Peak I/I Rate:	0.38	*mgd*
PkI/I:IDM:	3,179	*gpd/IDM*
PkI/I:Acre:	718	*gpd/acre*
Pk I/I:ADWF:	0.46	

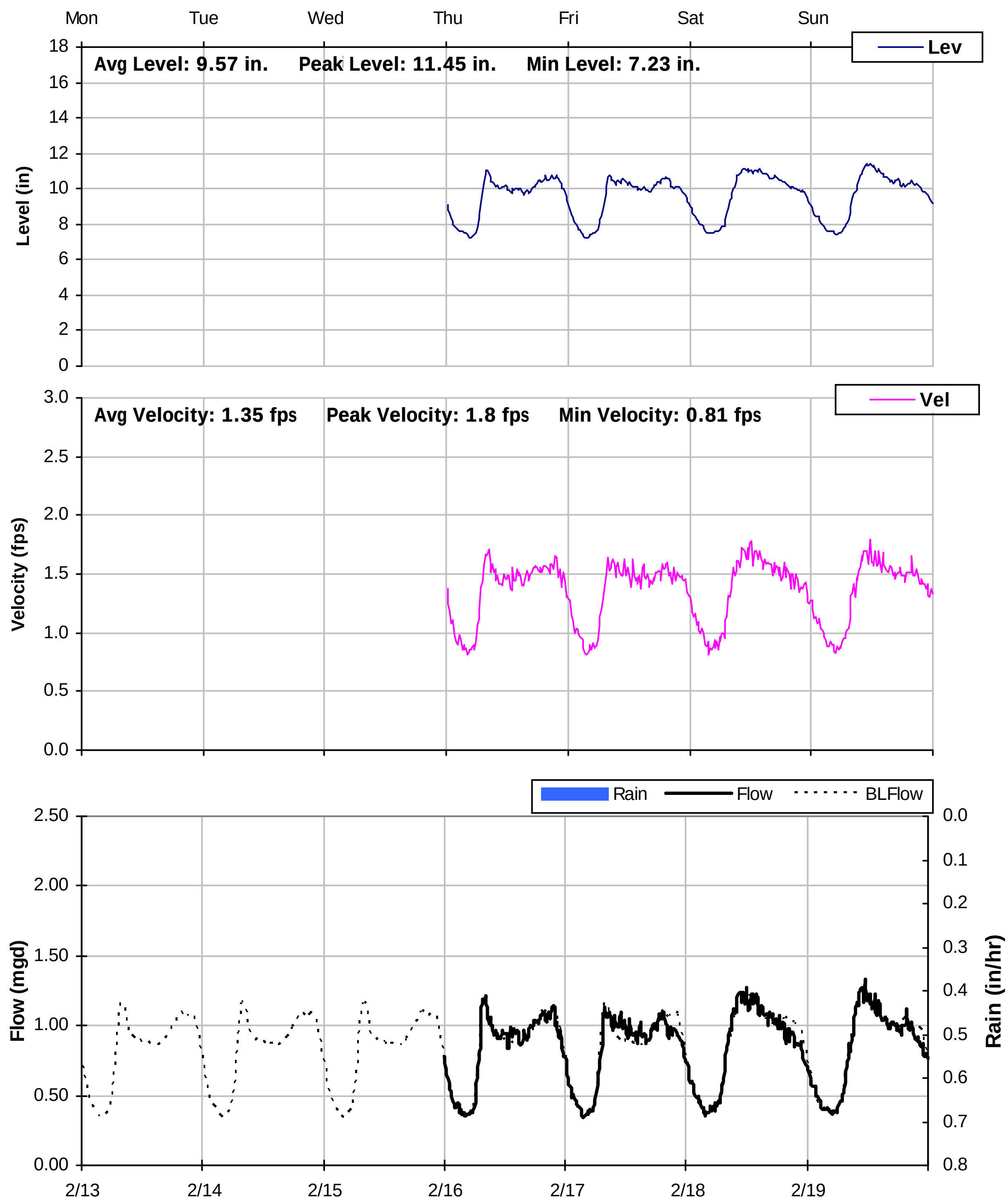
RDI (infiltration)

Infiltration Rate: (3/26/2012)	0.106	*mgd*
RDI:IDM:	883	*gpd/IDM*
RDI:Acre:	199	*gpd/acre*
RDI (% of BL):	13%	

Combined I/I

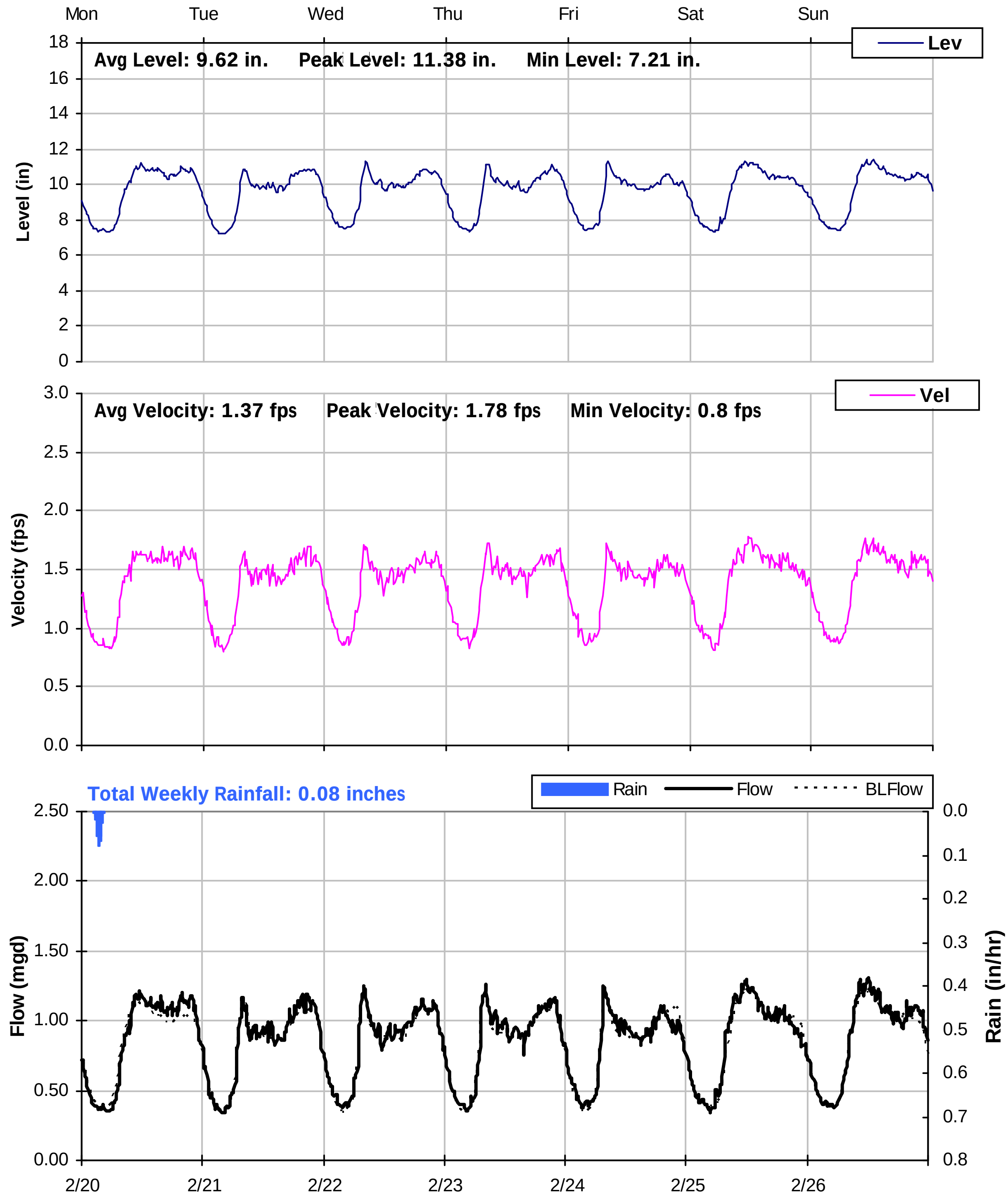
Total I/I:	471,000	*gallons*
Total I/I:IDM:	2,355	*gal/IDM/in*
R-Value:	2.0%	
Total I/I:ADWF:	0.34	*per in-rain*

MH I3
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012



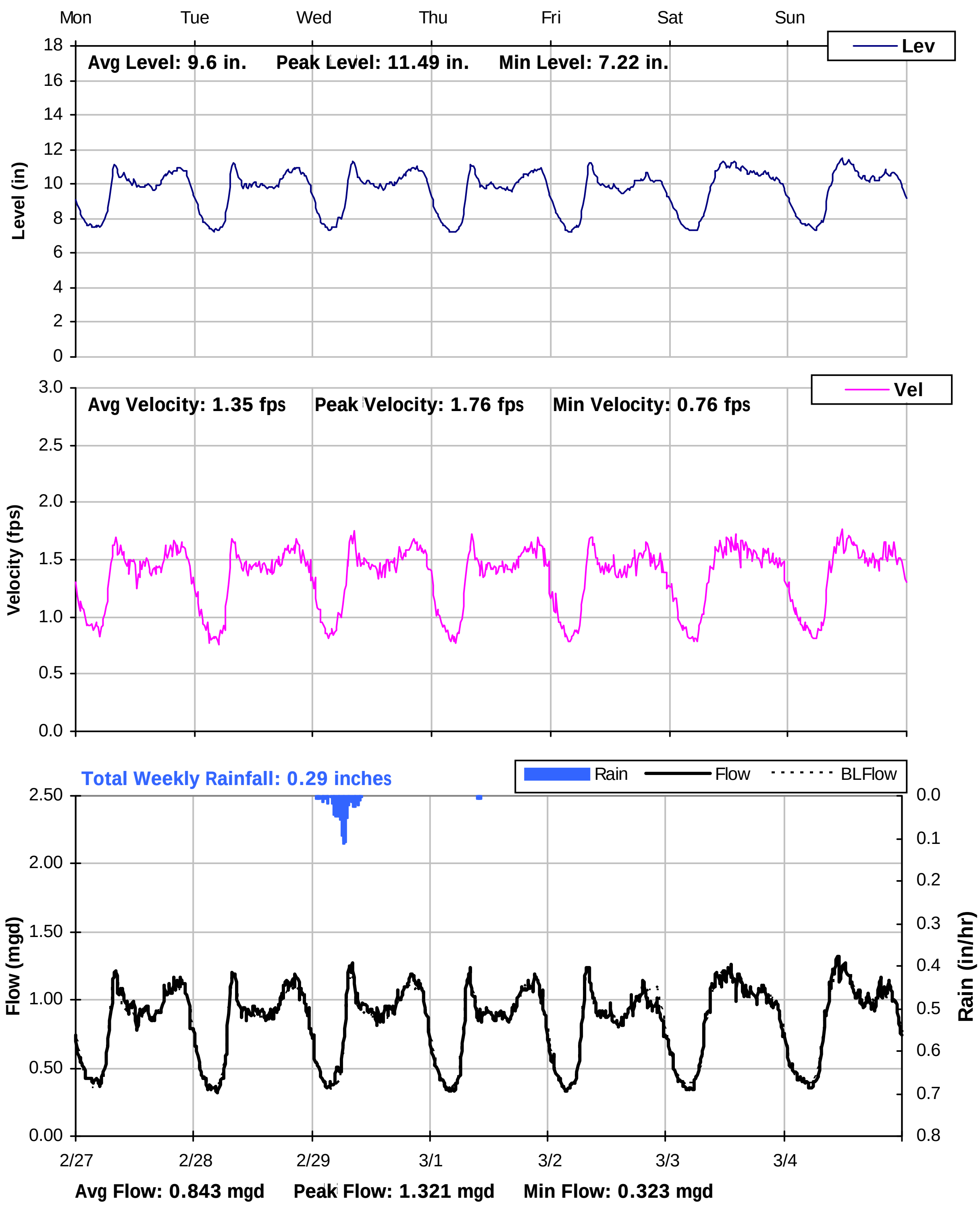
Avg Flow: 0.842 mgd   Peak Flow: 1.336 mgd   Min Flow: 0.345 mgd

MH I3
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012

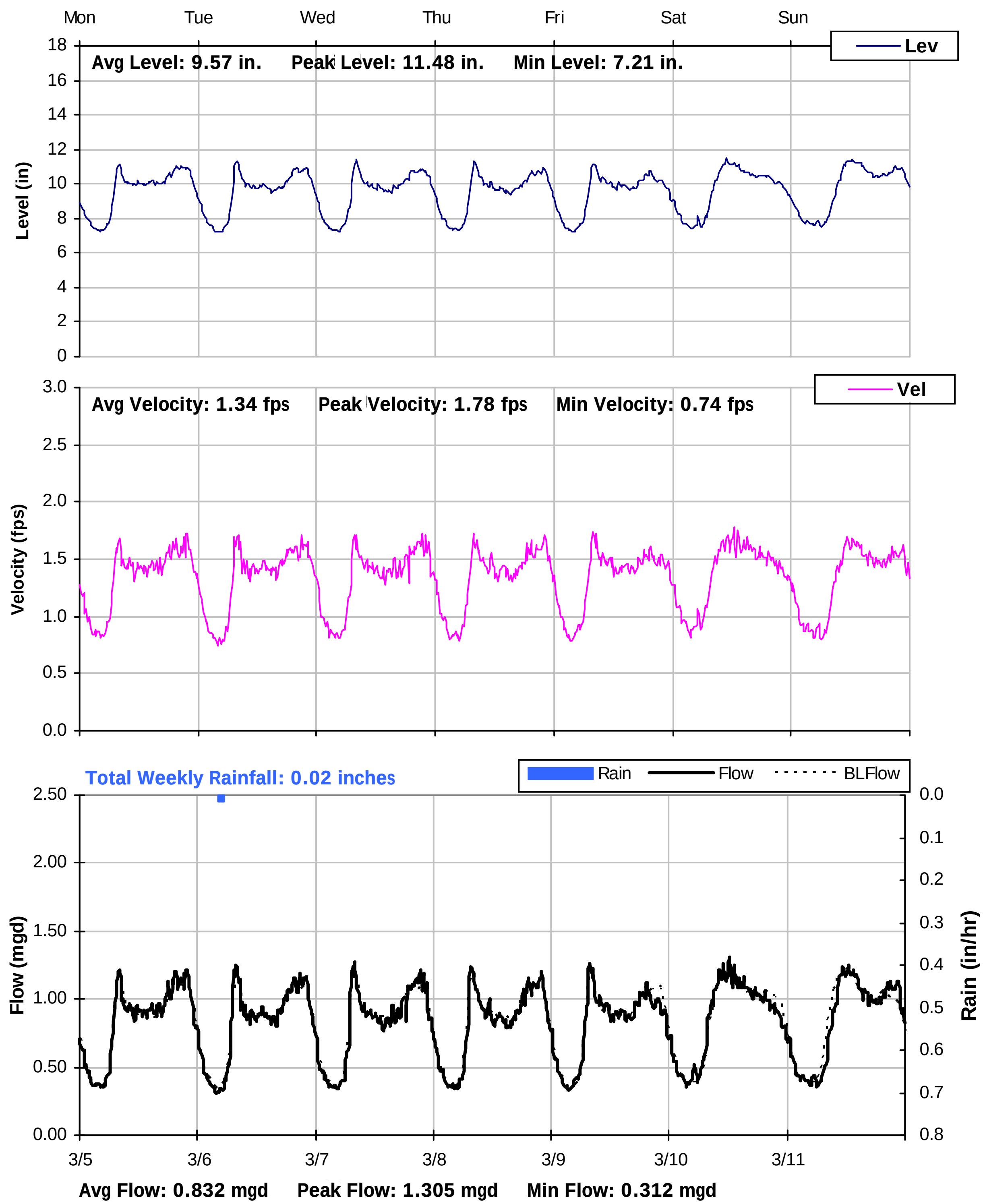


Avg Flow: 0.86 mgd **Peak Flow: 1.305 mgd** **Min Flow: 0.337 mgd**

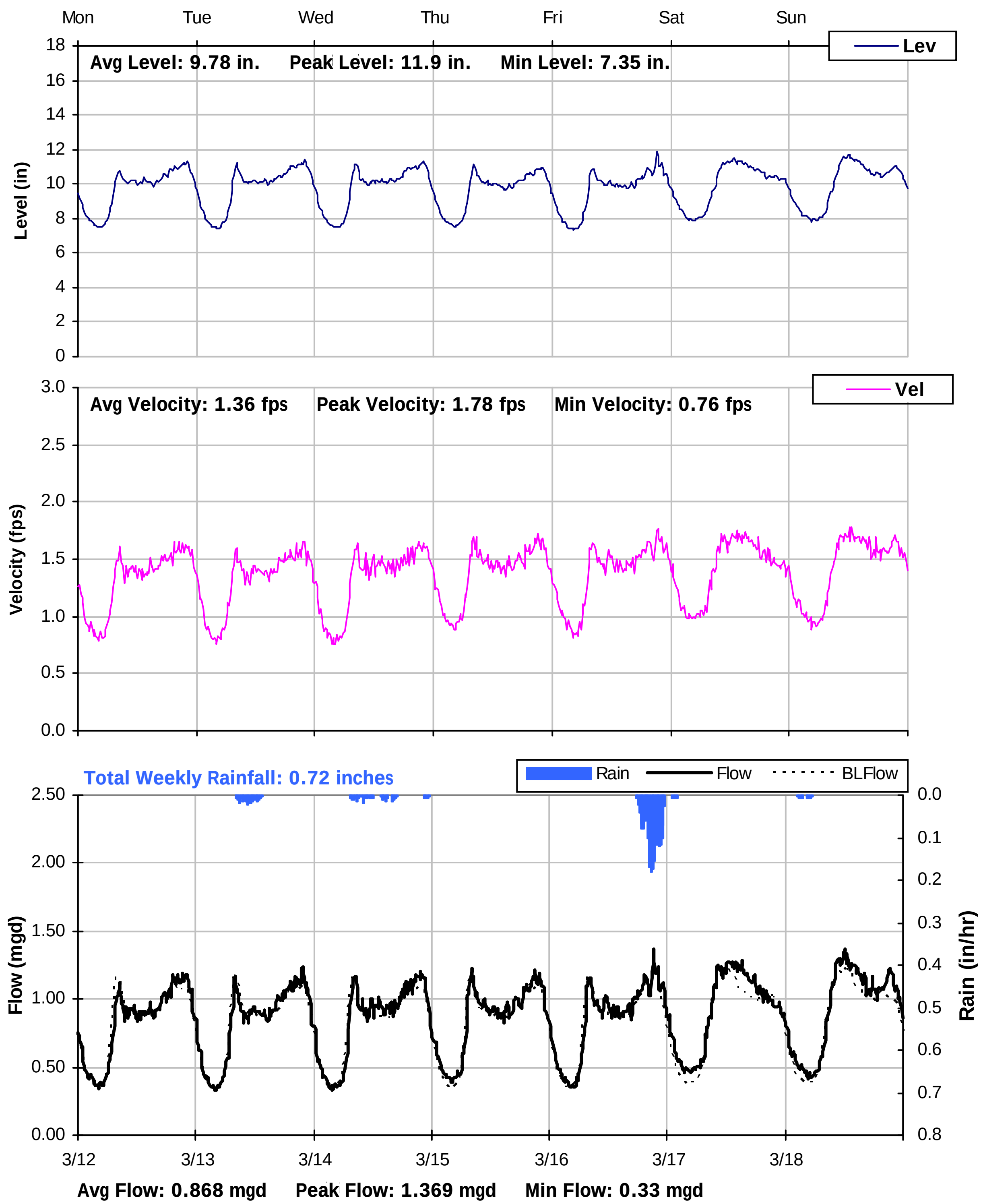
MH I3
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



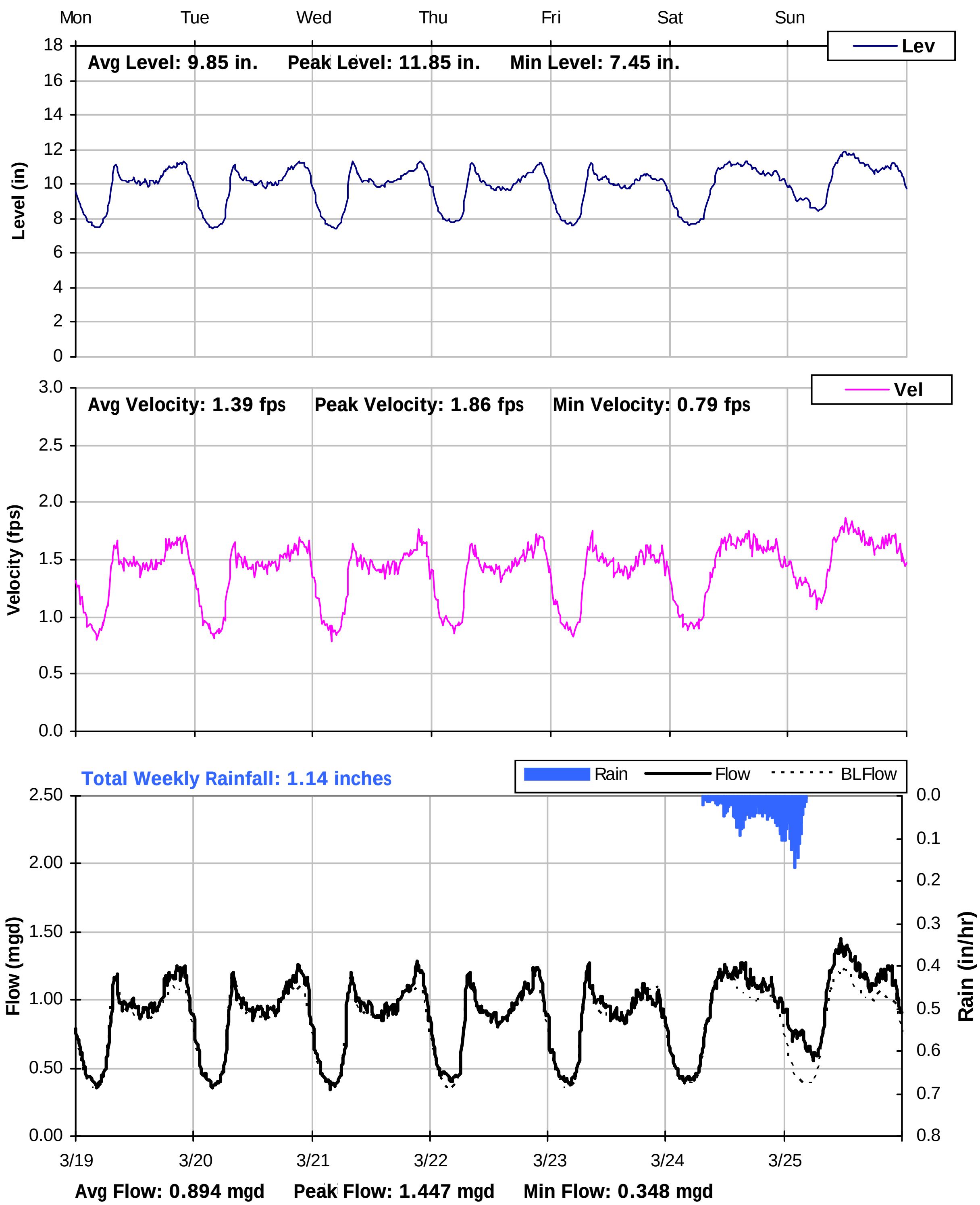
MH I3
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



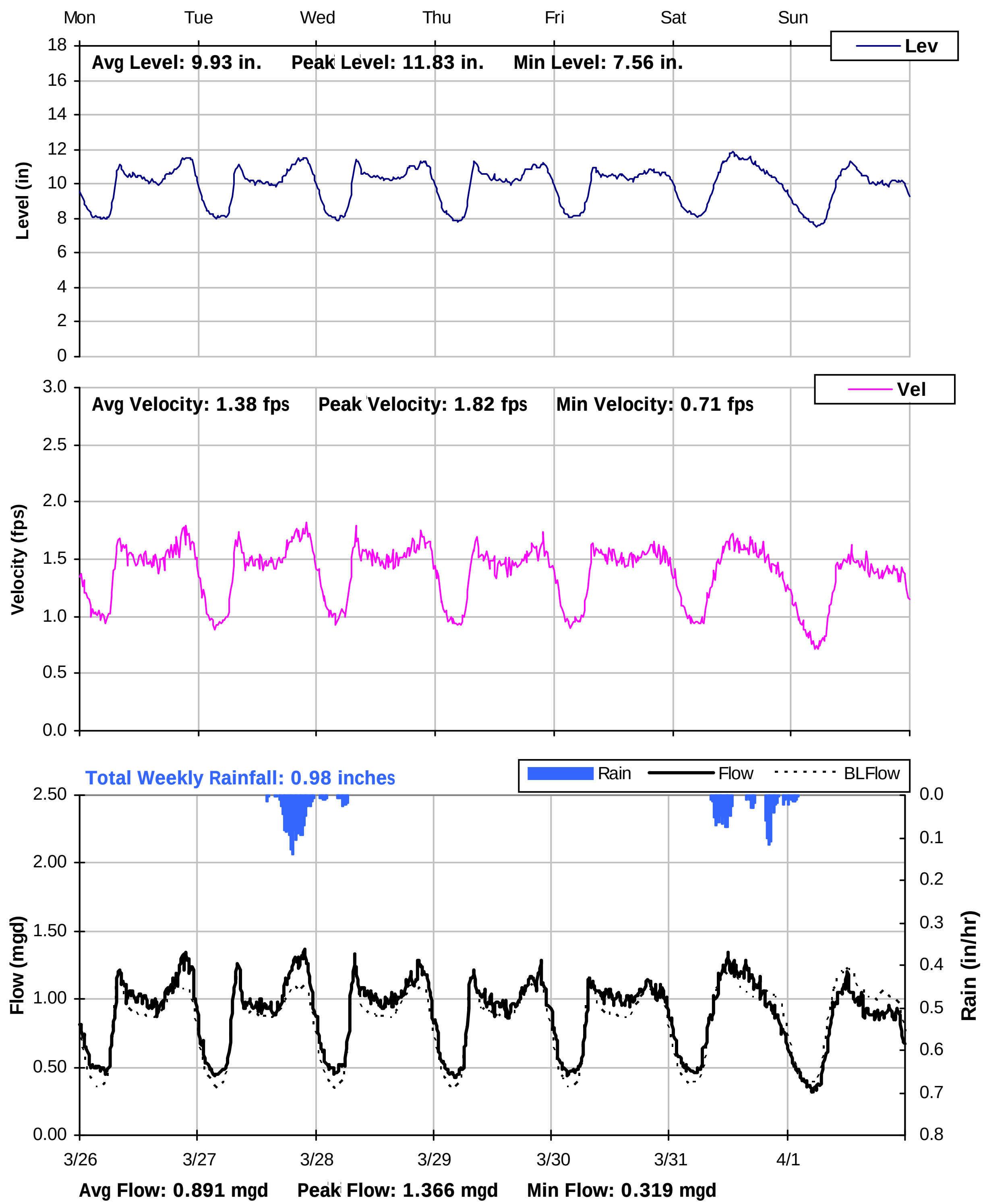
MH I3
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



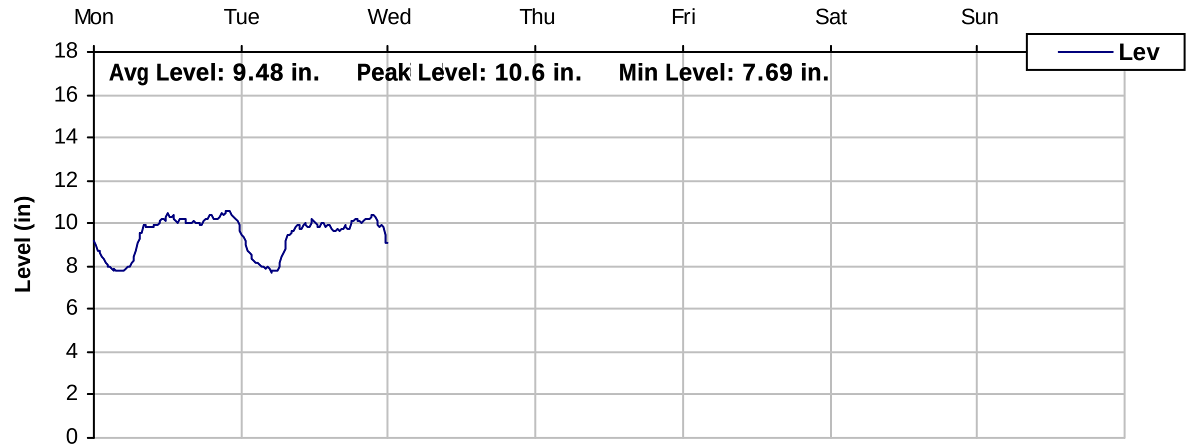
MH I3
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012

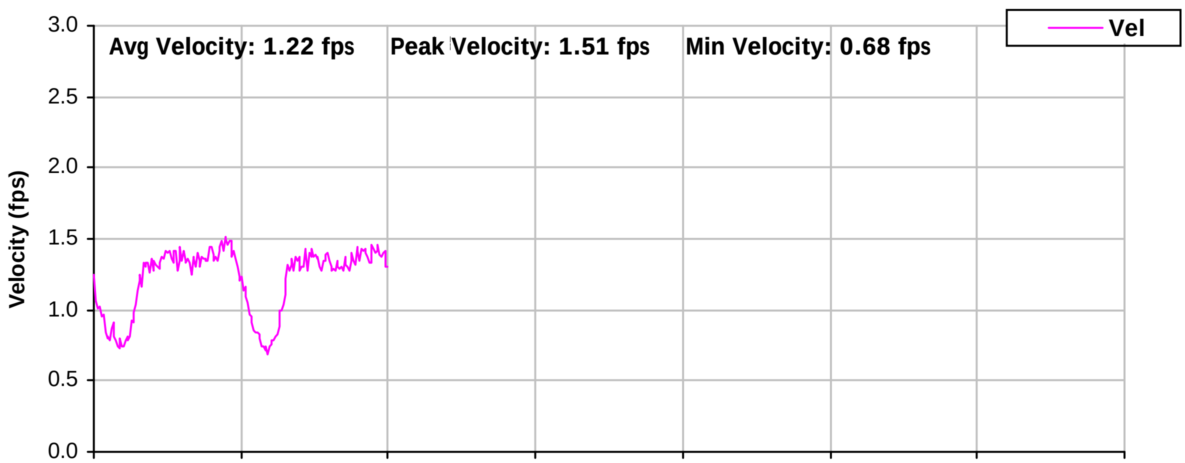


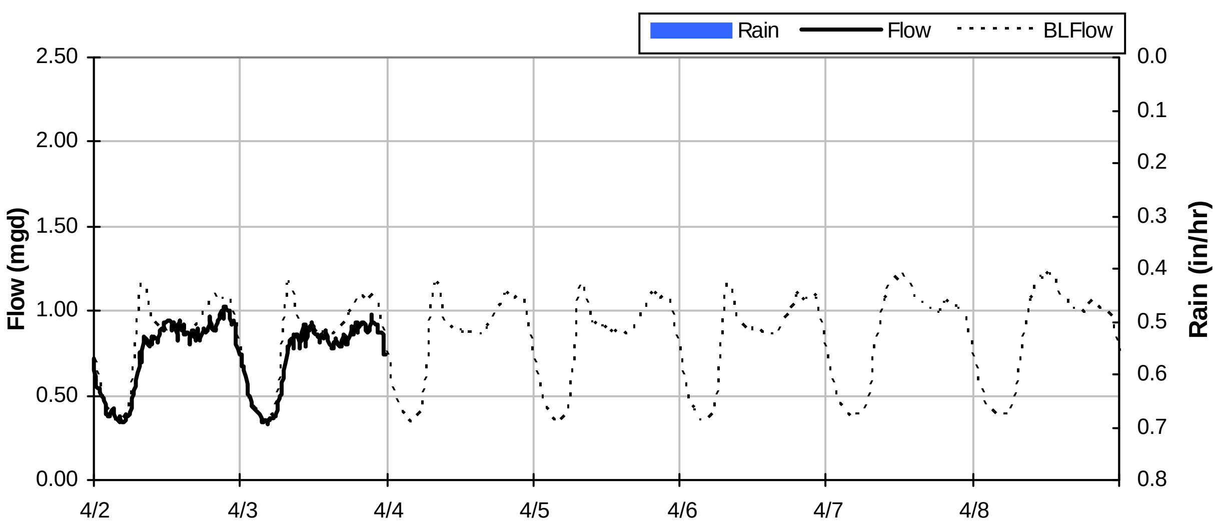
MH I3
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



MH I3
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012







Avg Flow: 0.741 mgd **Peak Flow: 1.027 mgd** **Min Flow: 0.327 mgd**

East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

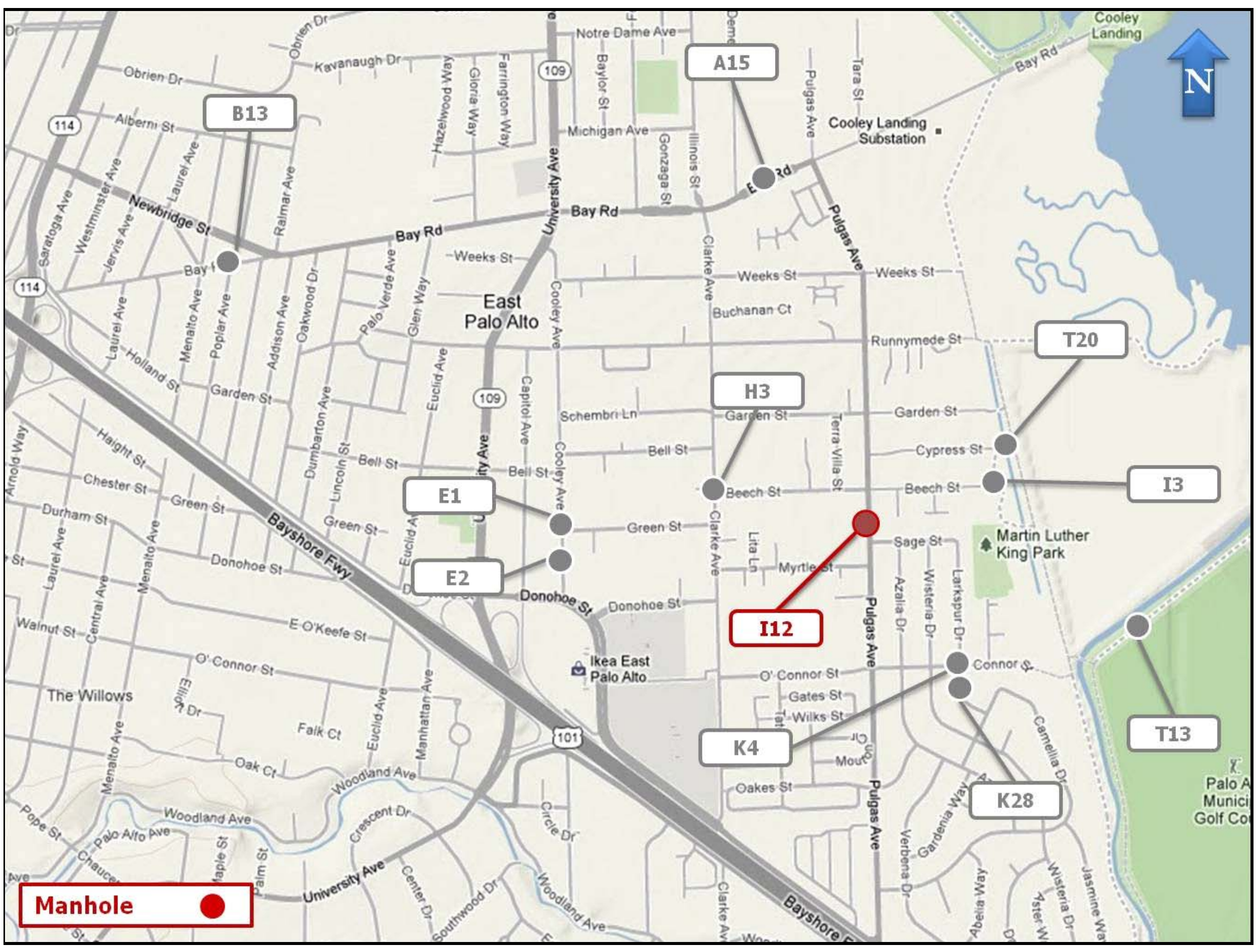
Year 2012

Monitoring Site: MH I12

Location: Pulgas Avenue, north of Sage Street

Data Summary Report

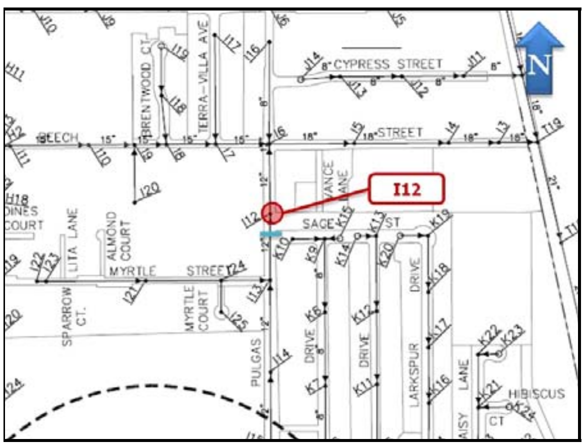
Vicinity Map:



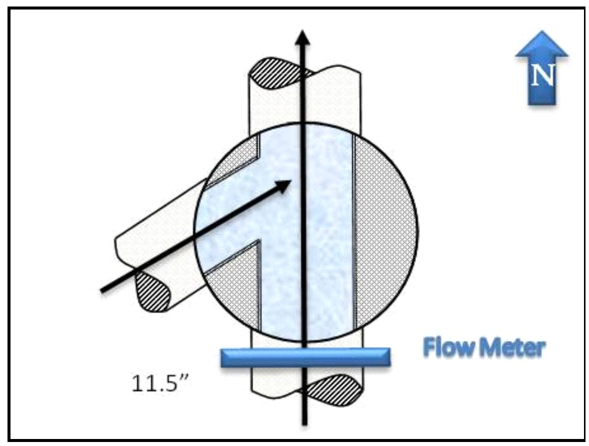
MH I12
Site Information Report

Location:	Pulgas Avenue, north of Sage Street
Coordinates:	122.1302° W, 37.4642° N
Elevation:	7 feet
Diameter:	11.5 inches
Baseline Flow:	0.231 mgd
Peak Measured Flow:	0.456 mgd

Satellite Map



Sanitary Sewer Map



Flow Sketch

View from Street

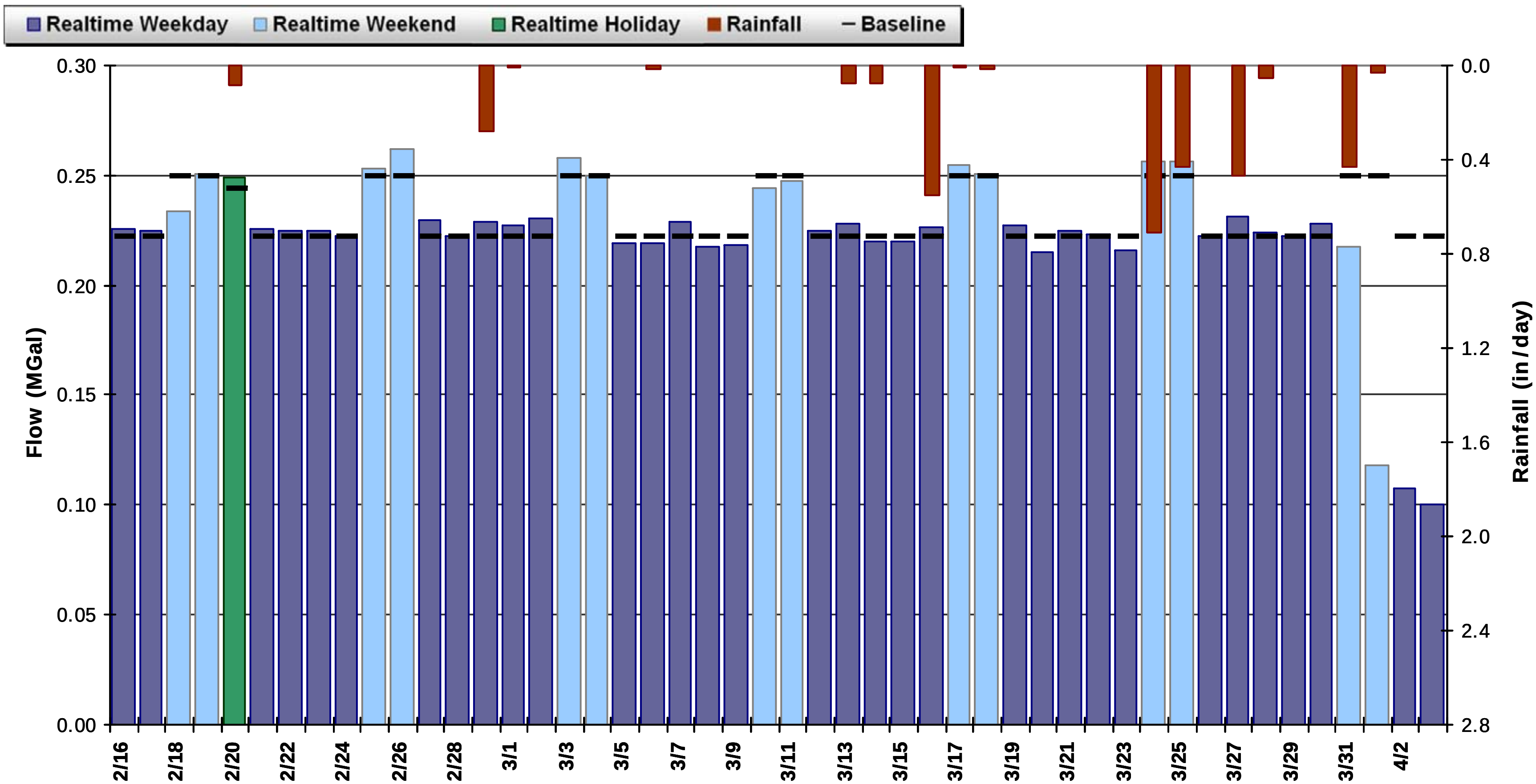
Plan View

MH I12

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.224 MGal **Peak Daily Flow: 0.262 MGal** **Min Daily Flow: 0.100 MGal**

Total Period Rainfall: 3.24 inches

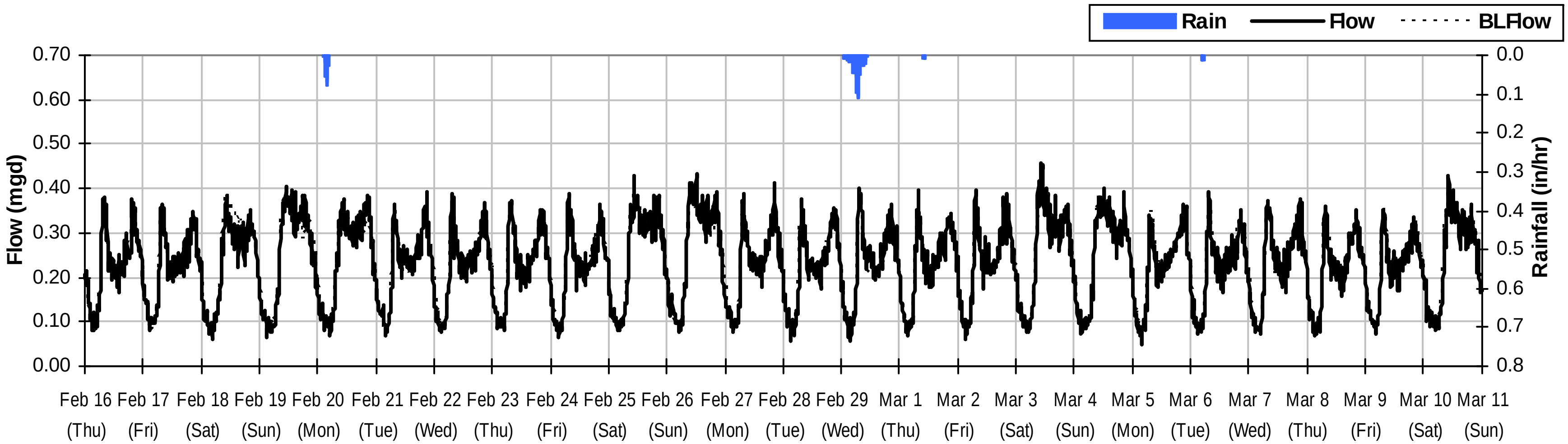


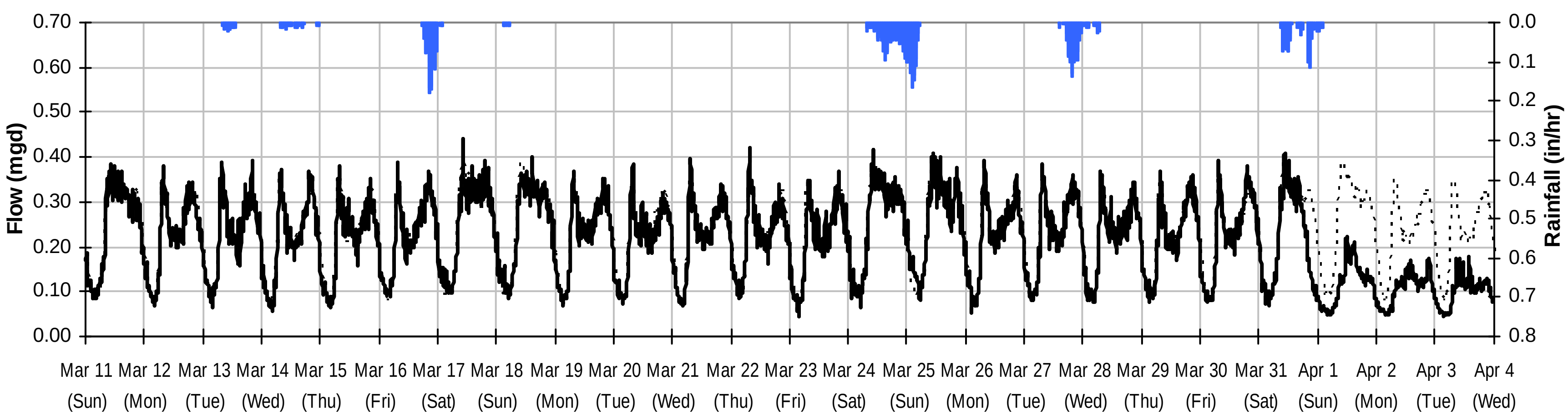
MH I12

Period Flow Summary: February 16 to April 4, 2012

Avg Flow: 0.224 mgd **Peak Flow: 0.456 mgd** **Min Flow: 0.045 mgd**

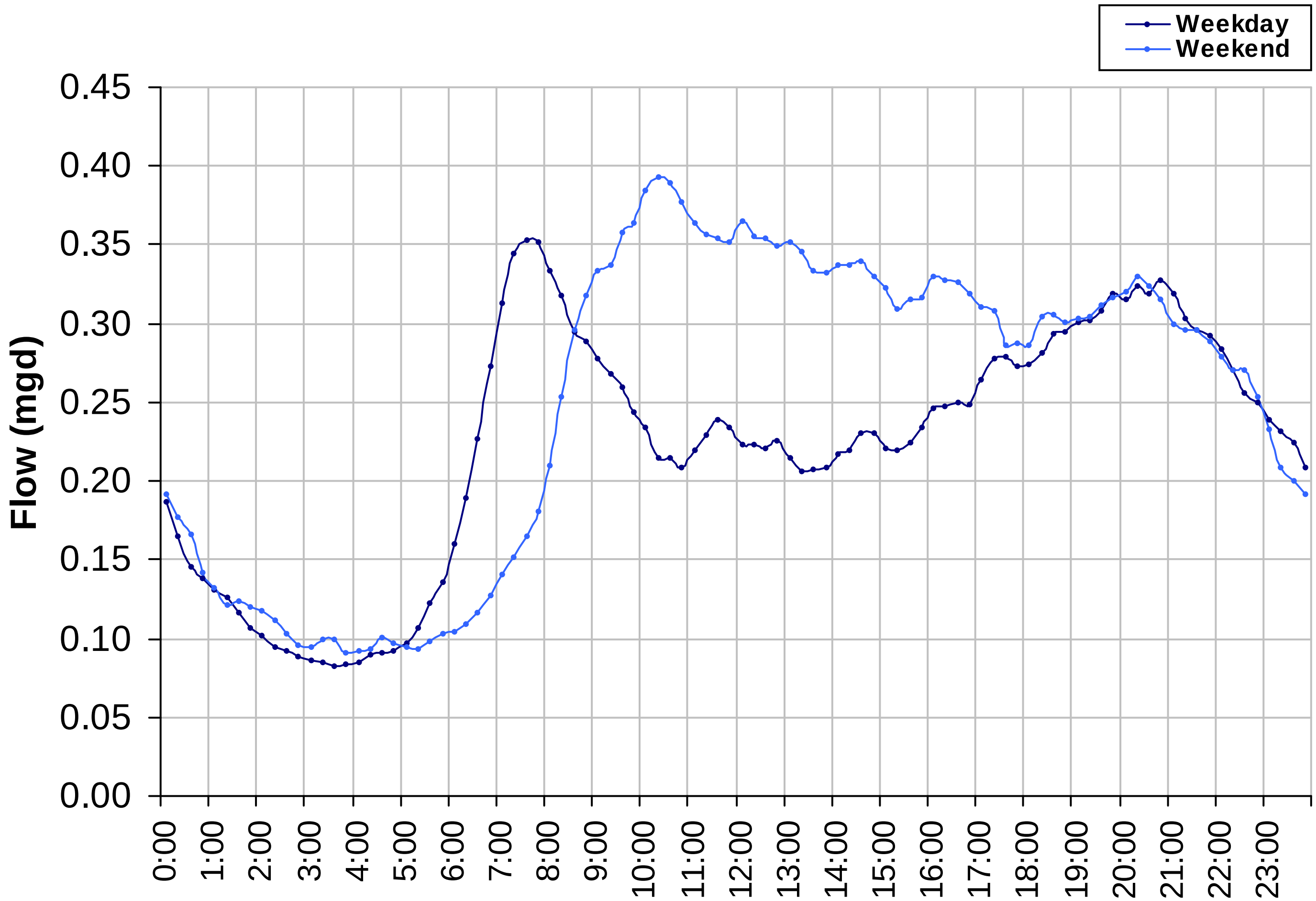
Total Period Rainfall: 3.24 inches





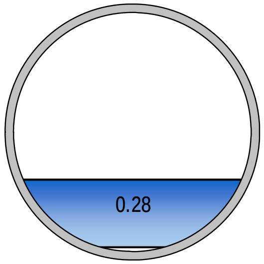
MH I12

Baseline Flow Hydrographs



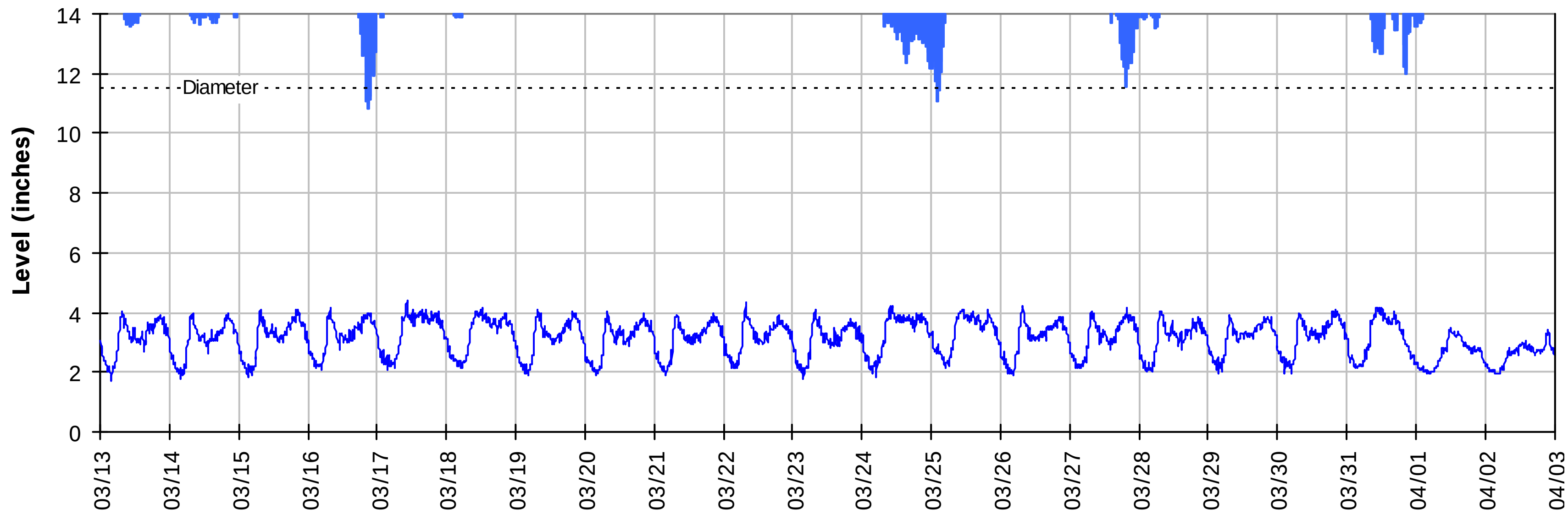
Baseline Flow:

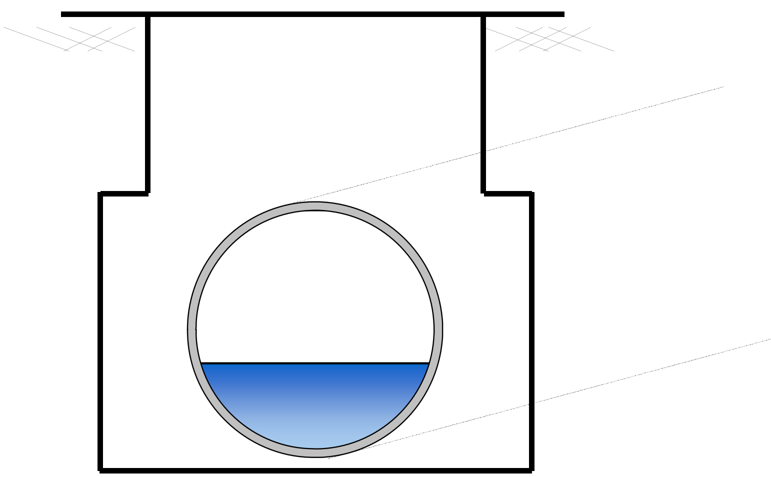
0.231 *mgd*



MH I12
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





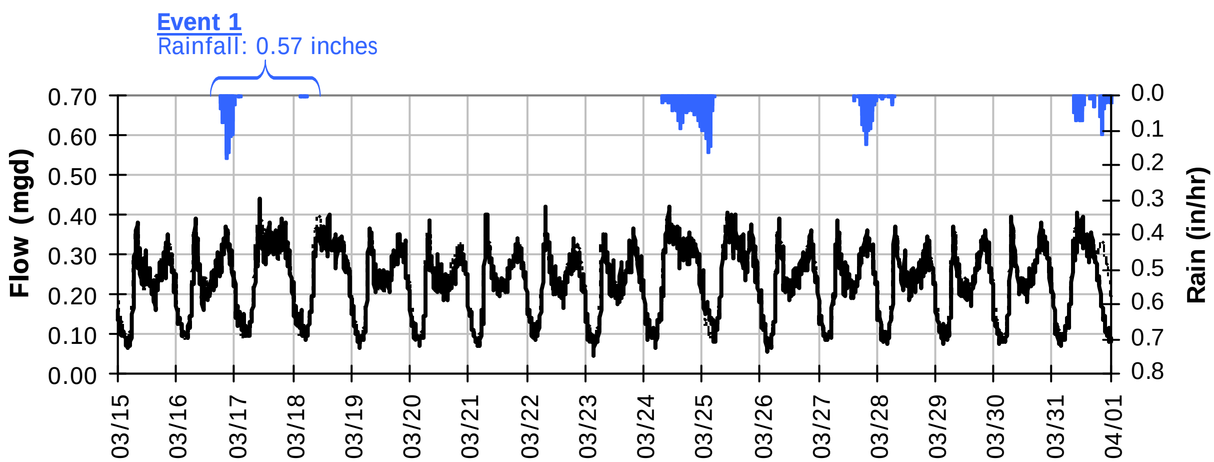
Pipe Diameter: 11.5 *inches*

Peak Measured Level: 4.21 *inches*

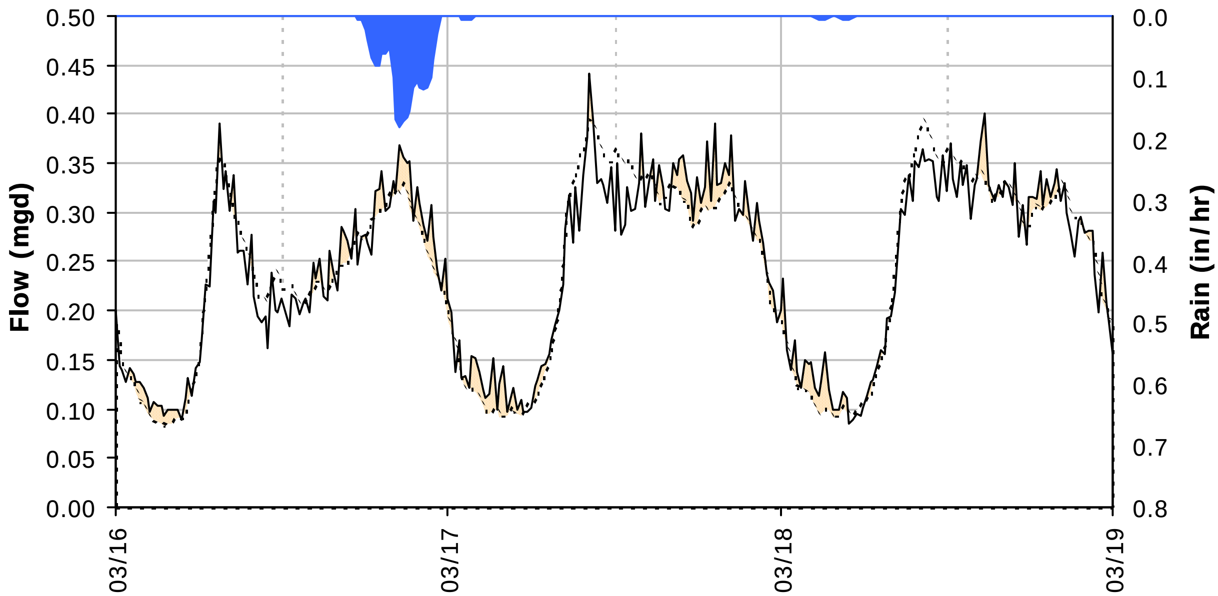
Peak d/D Ratio: 0.37

MH I12
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

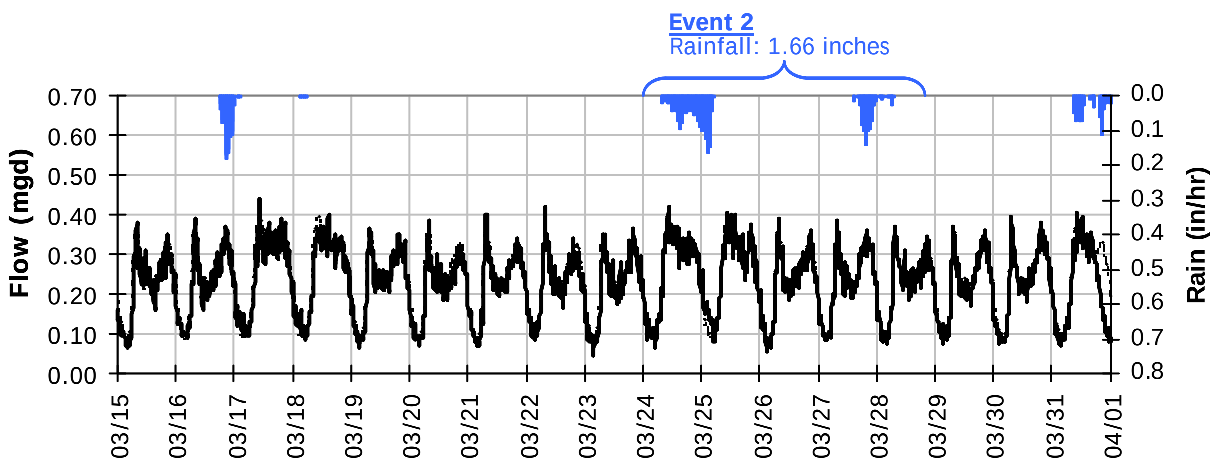


Storm Event I/I Analysis (Rain = 0.57 inches)

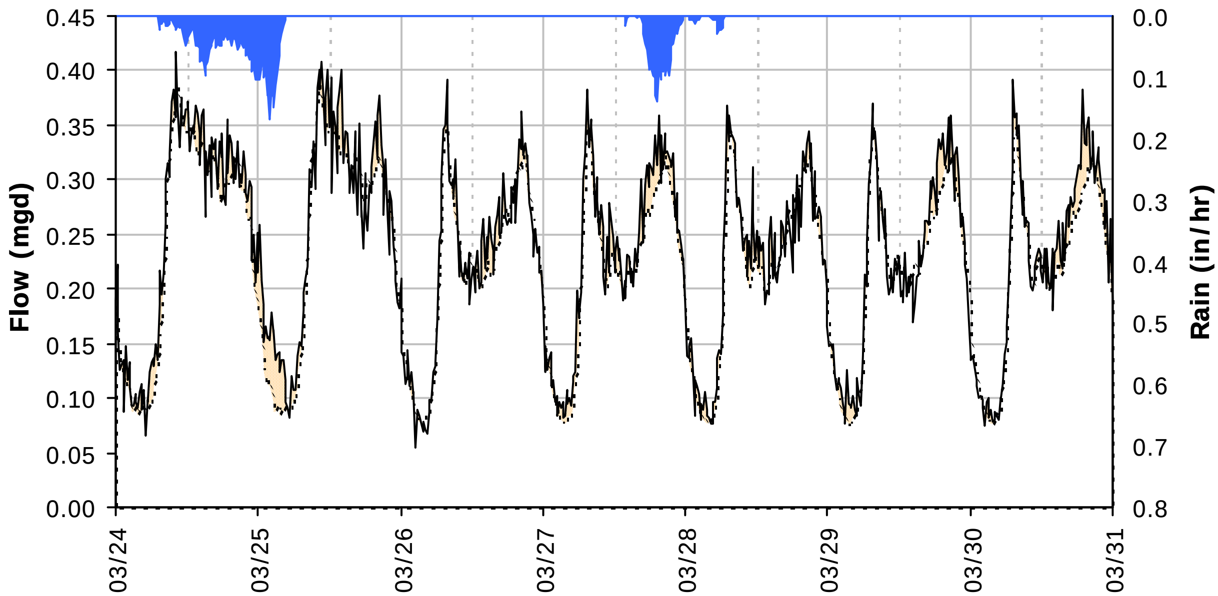
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	0.37 *mgd*	**Peak I/I Rate:**	0.06 *mgd*	**Infiltration Rate:** ()	*mgd*	**Total I/I:**	9,000 *gallons*
PF:	1.60	**PkI/I:IDM:**	2,228 *gpd/IDM*	**RDI:IDM:**	*gpd/IDM*	**Total I/I:IDM:**	601 *gal/IDM/in*
Peak Level:	3.97 *in*	**PkI/I:Acre:**	432 *gpd/acre*	**RDI:Acre:**	*gpd/acre*	**R-Value:**	0.4%
d/D Ratio:	0.35	**Pk I/I:ADWF:**	0.25	**RDI (% of BL):**		**Total I/I:ADWF:**	0.07 *per in-rain*

MH I12
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



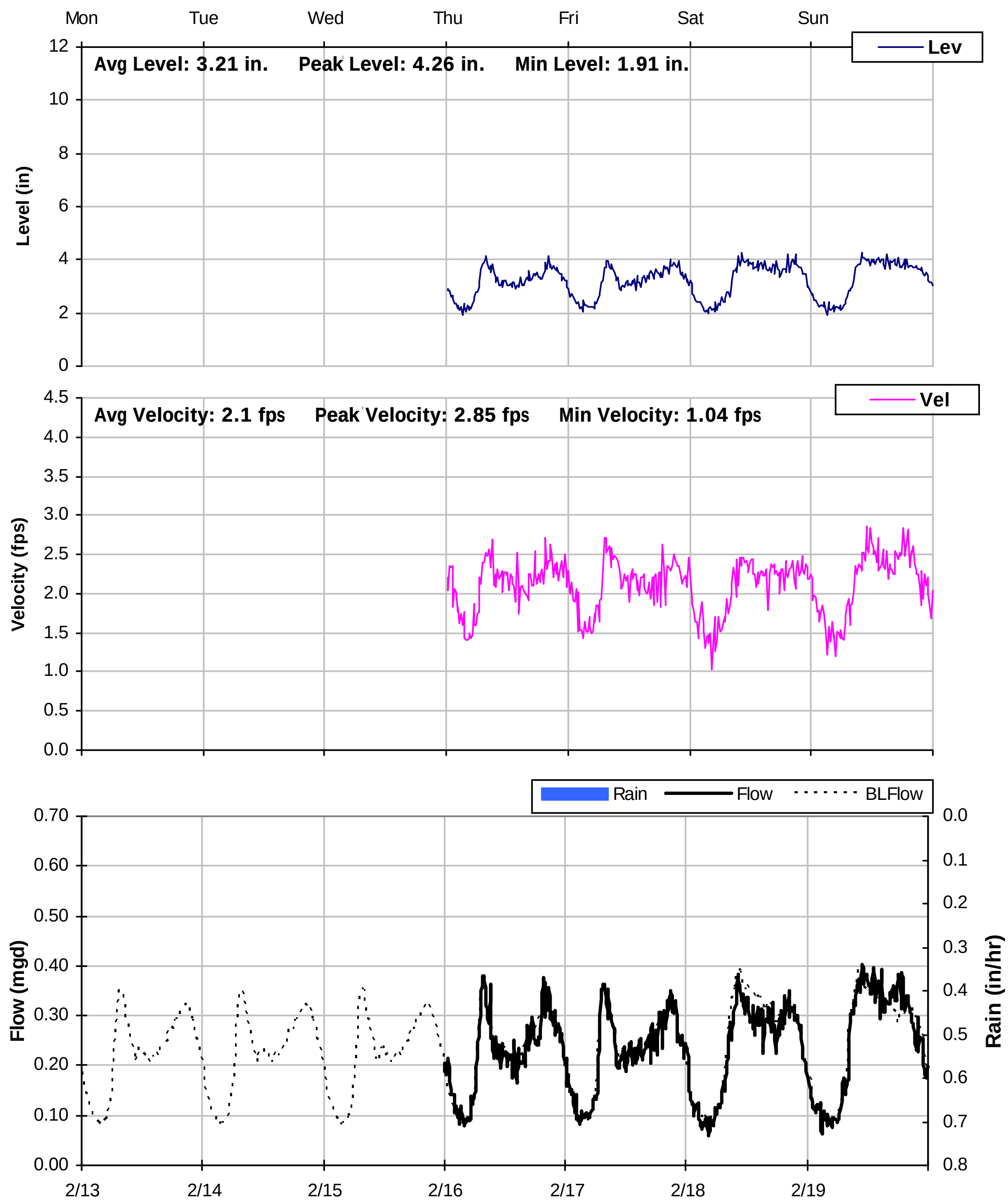
Event 2 Detail Graph



Storm Event I/I Analysis (Rain = 1.66 inches)

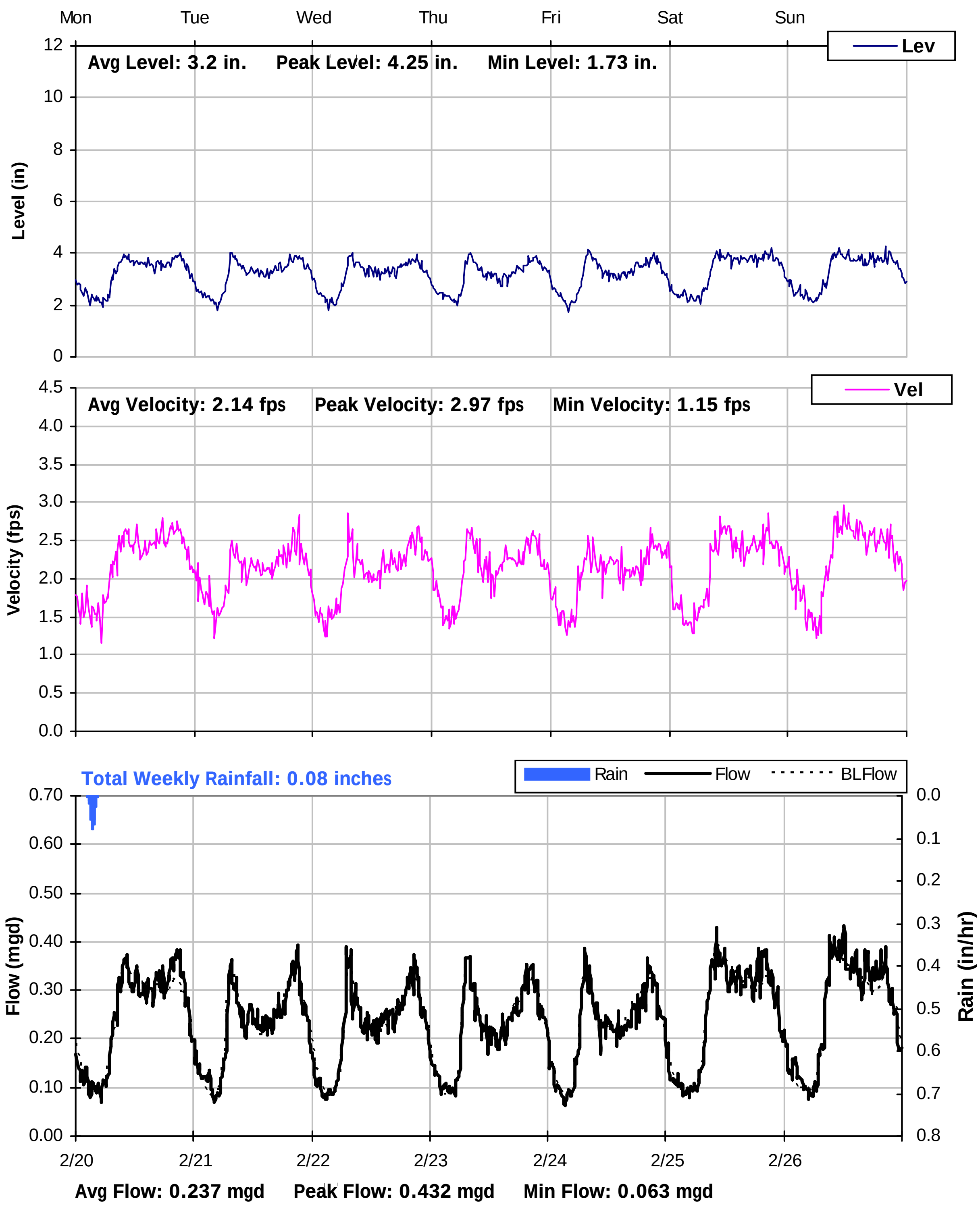
Capacity		**Inflow**		**RDI (infiltration)**		**Combined I/I**	
Peak Flow:	0.42 *mgd*	**Peak I/I Rate:**	0.08 *mgd*	**Infiltration Rate:** (3/26/2012)	0.000 *mgd*	**Total I/I:**	57,000 *gallons*
PF:	1.81	**PkI/I:IDM:**	3,117 *gpd/IDM*	**RDI:IDM:**	0 *gpd/IDM*	**Total I/I:IDM:**	1,316 *gal/IDM/in*
Peak Level:	4.21 *in*	**PkI/I:Acre:**	605 *gpd/acre*	**RDI:Acre:**	0 *gpd/acre*	**R-Value:**	0.9%
d/D Ratio:	0.37	**Pk I/I:ADWF:**	0.35	**RDI (% of BL):**	0%	**Total I/I:ADWF:**	0.15 *per in-rain*

MH I12
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012

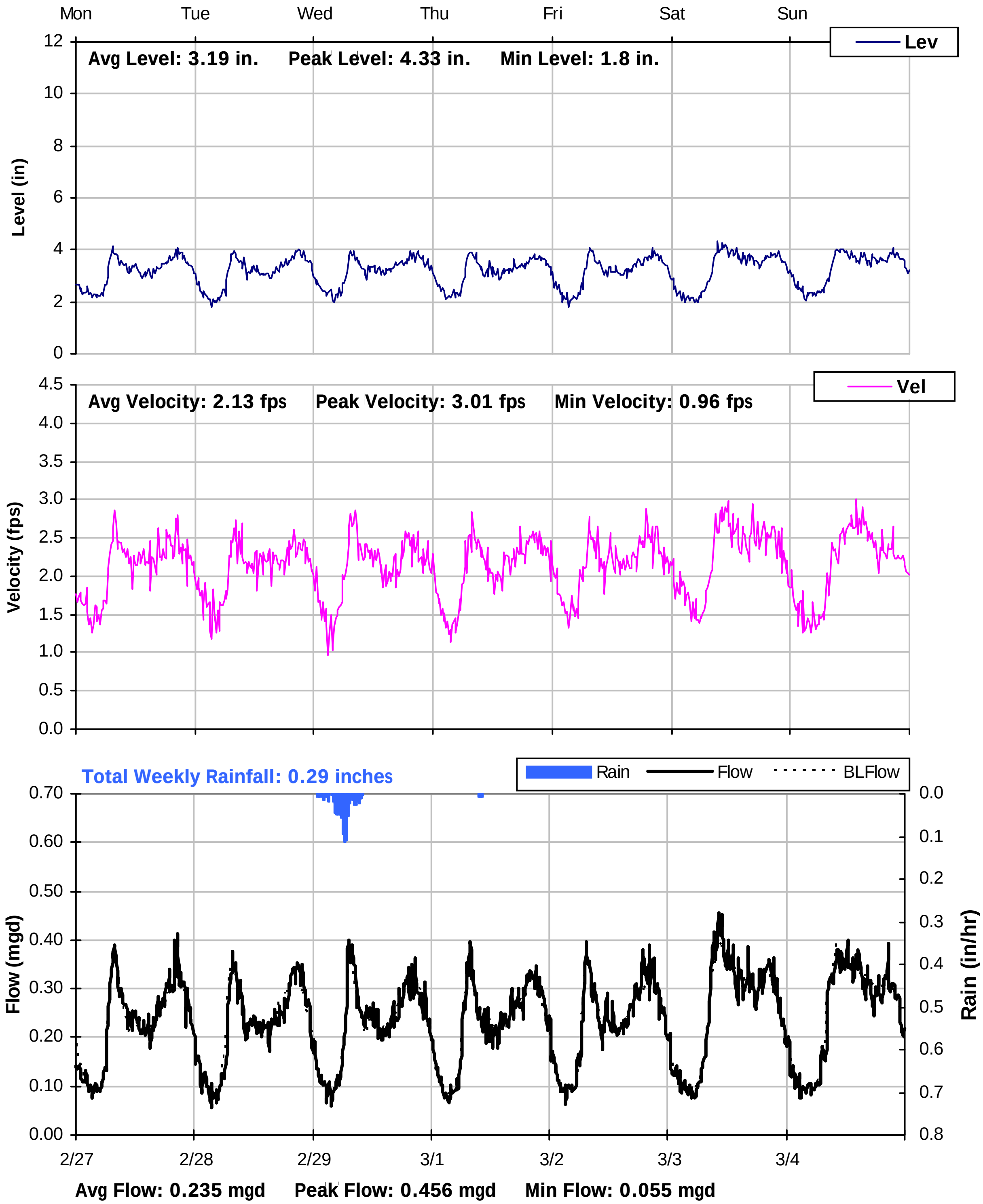


Avg Flow: 0.234 mgd **Peak Flow: 0.404 mgd** **Min Flow: 0.06 mgd**

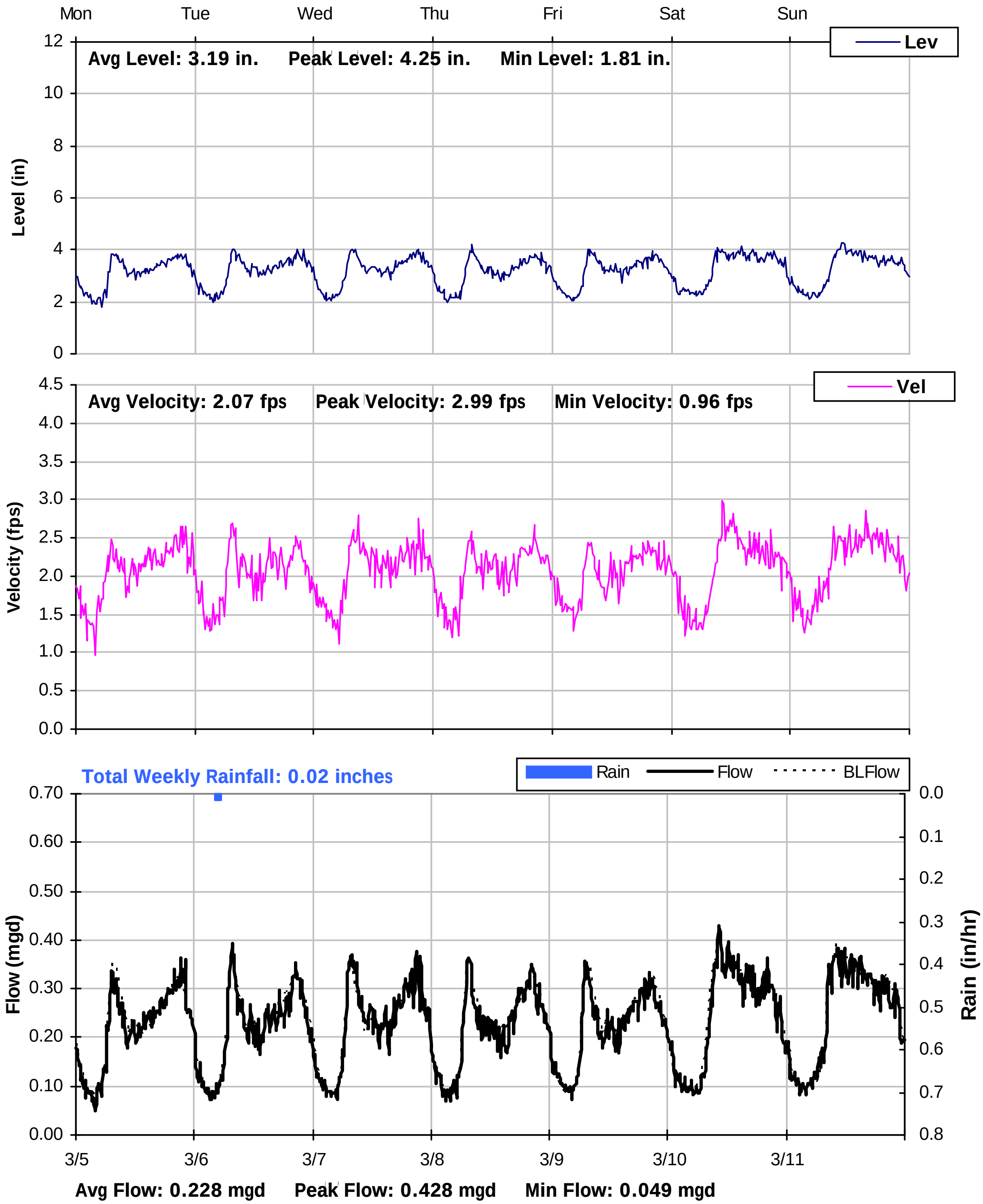
MH I12
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



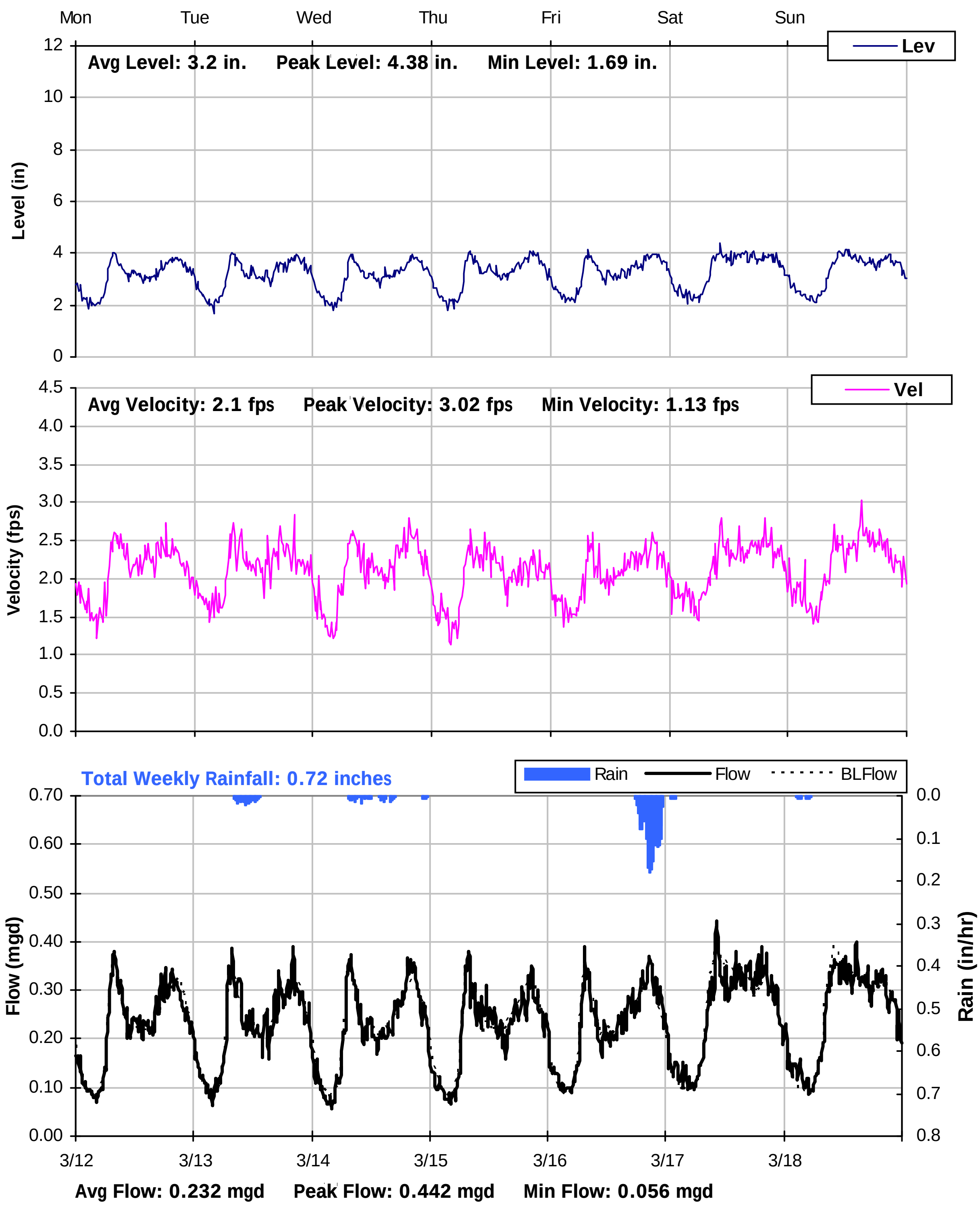
MH I12
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



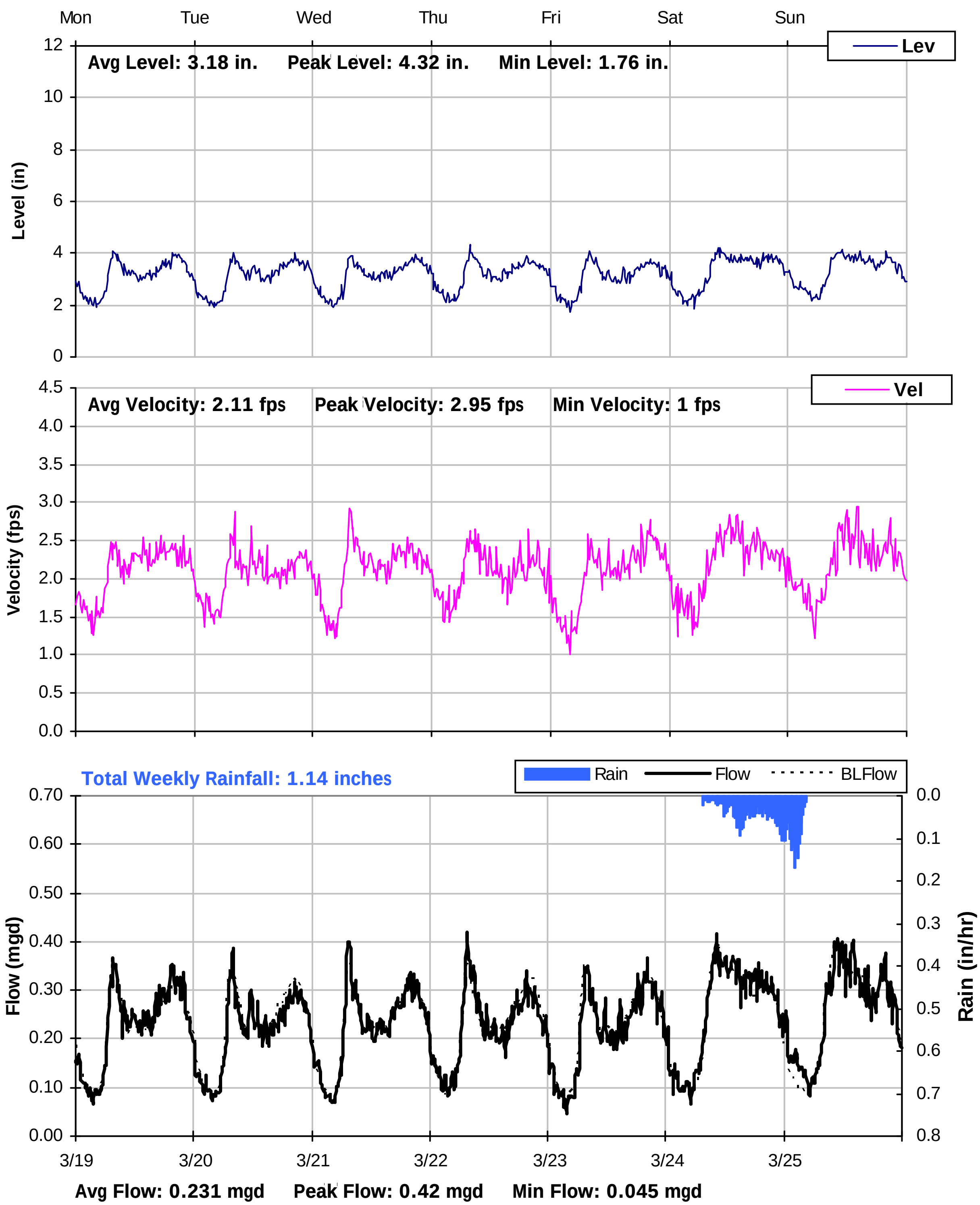
MH I12
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



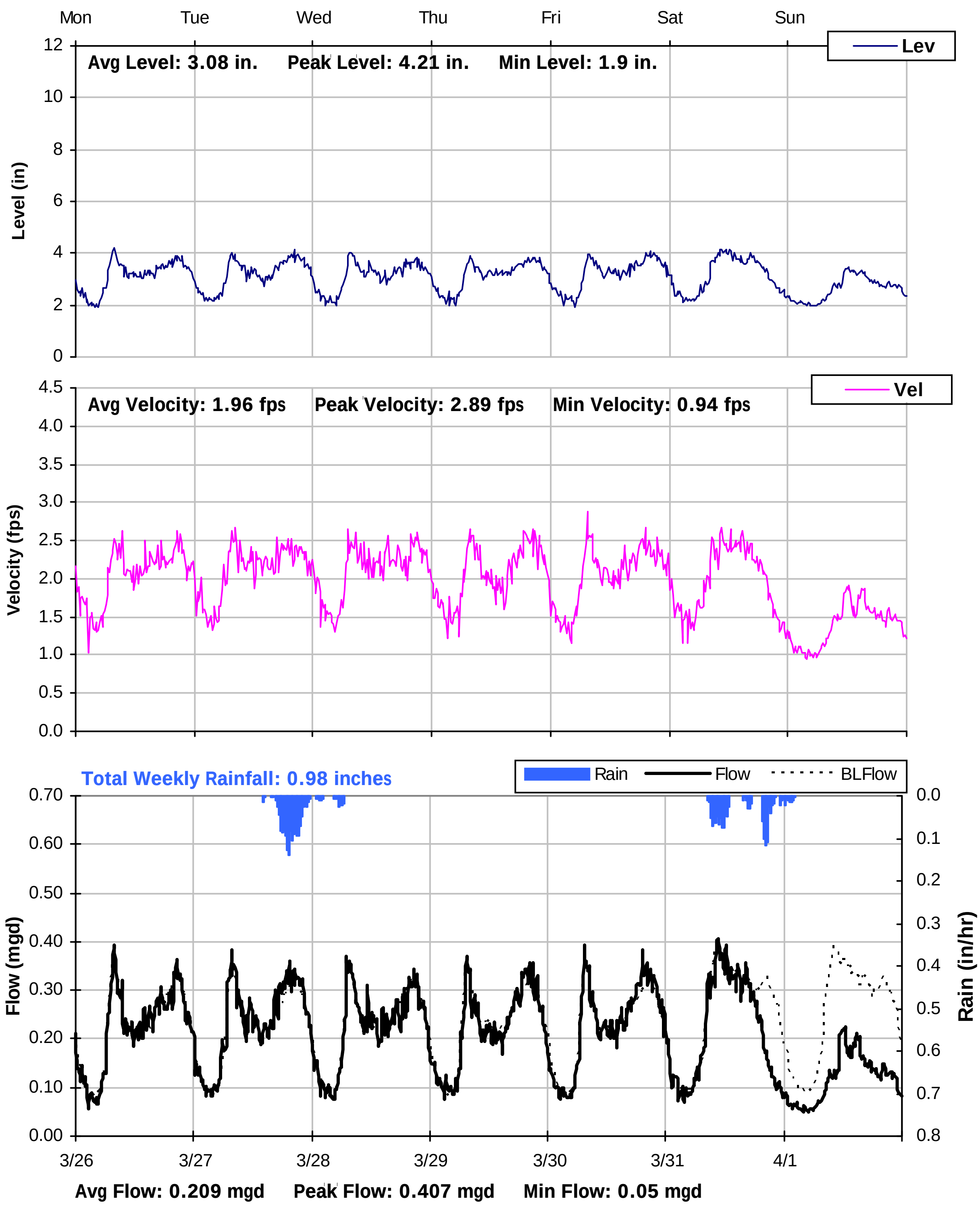
MH I12
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



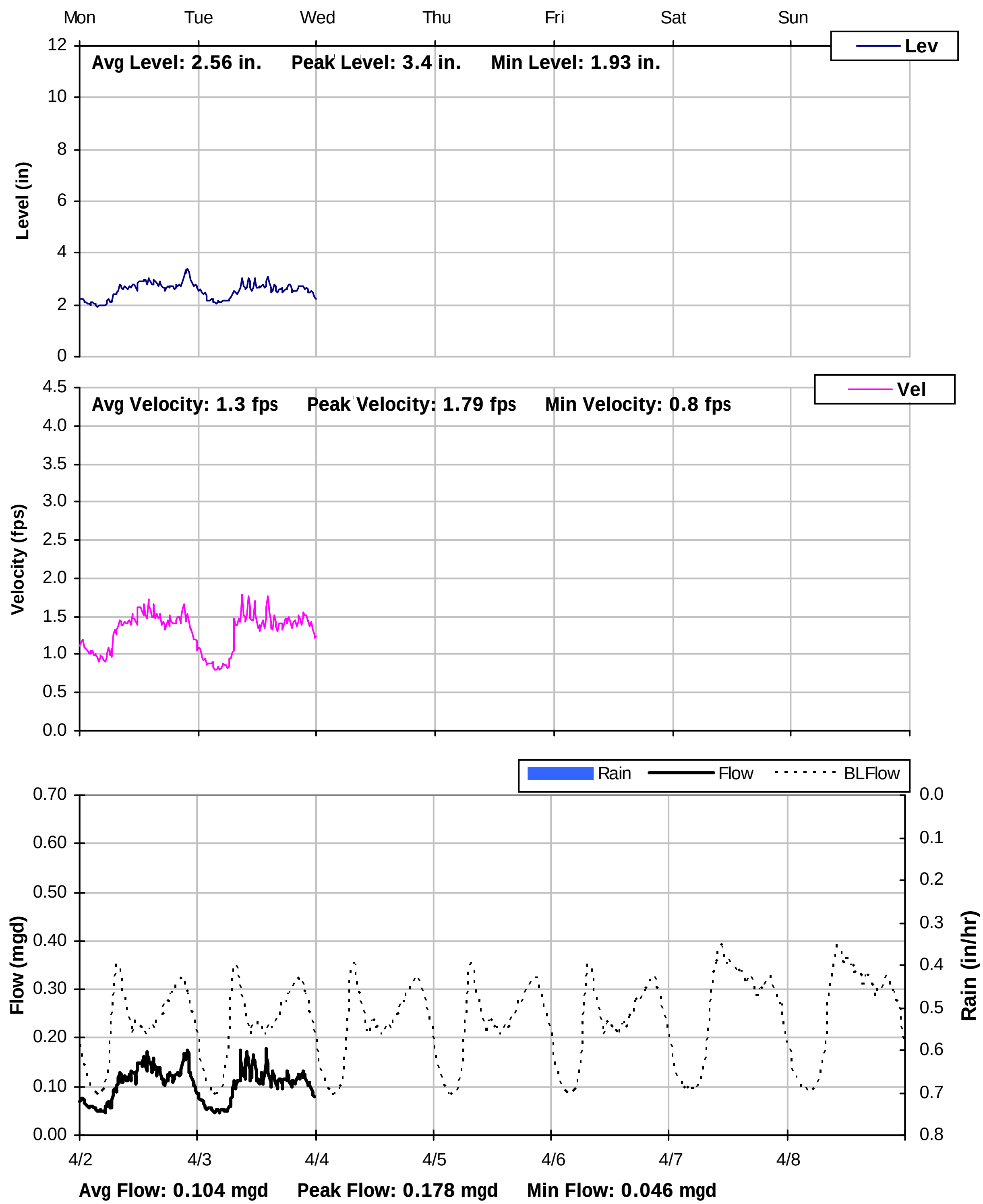
MH I12
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



MH I12
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



MH I12
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

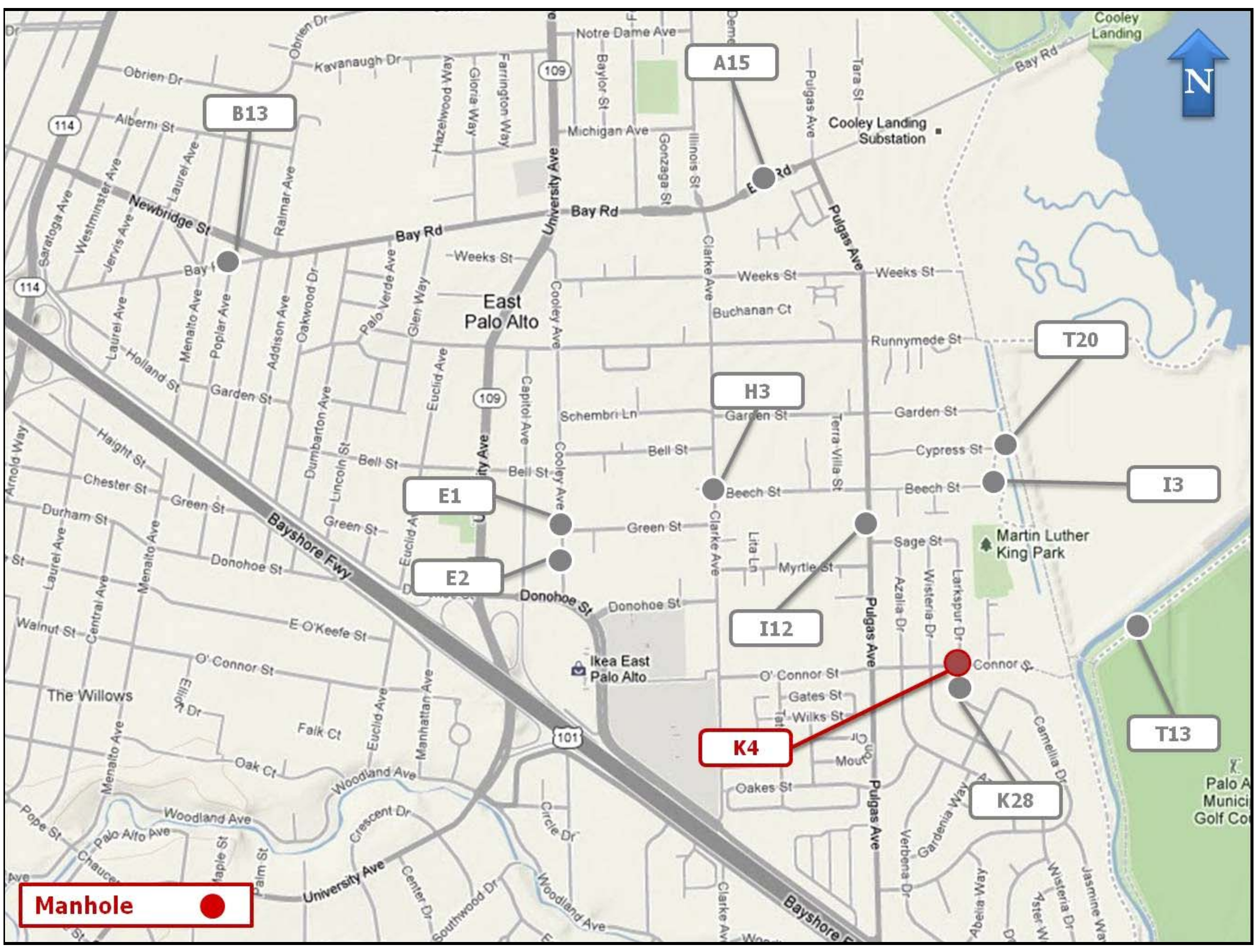
Year 2012

Monitoring Site: MH K4

Location: Intersection of O'Connor Street and Larkspur Drive

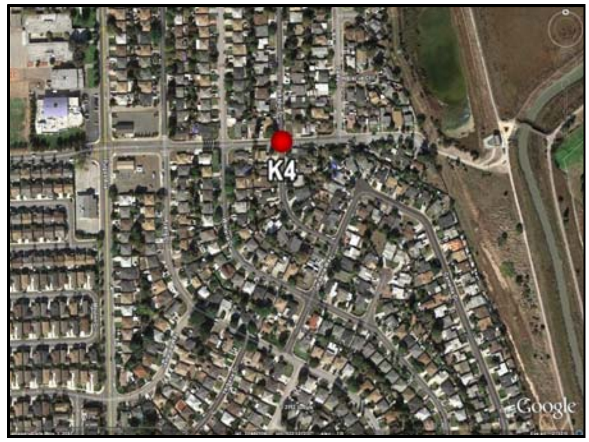
Data Summary Report

Vicinity Map:

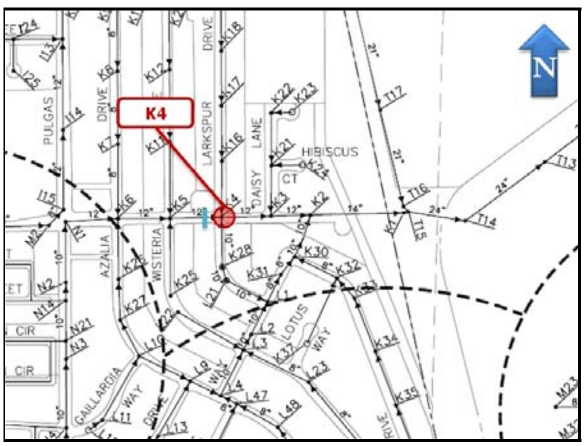


MH K4
Site Information Report

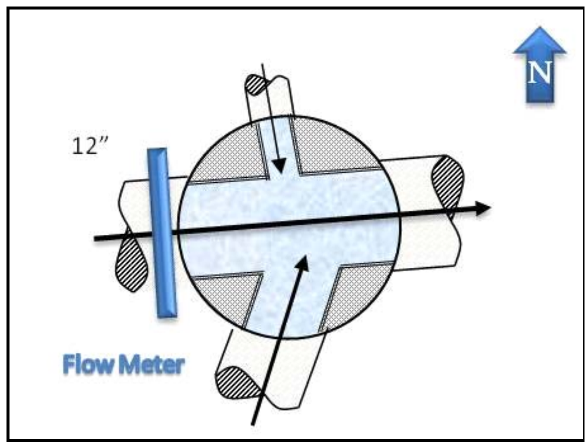
Location:	Intersection of O'Connor Street and Larkspur Drive
Coordinates:	122.1275° W, 37.4610° N
Elevation:	6 feet
Diameter:	12 inches
Baseline Flow:	0.218 mgd
Peak Measured Flow:	0.635 mgd



Satellite Map



Sanitary Sewer Map



Flow Sketch

View from Street

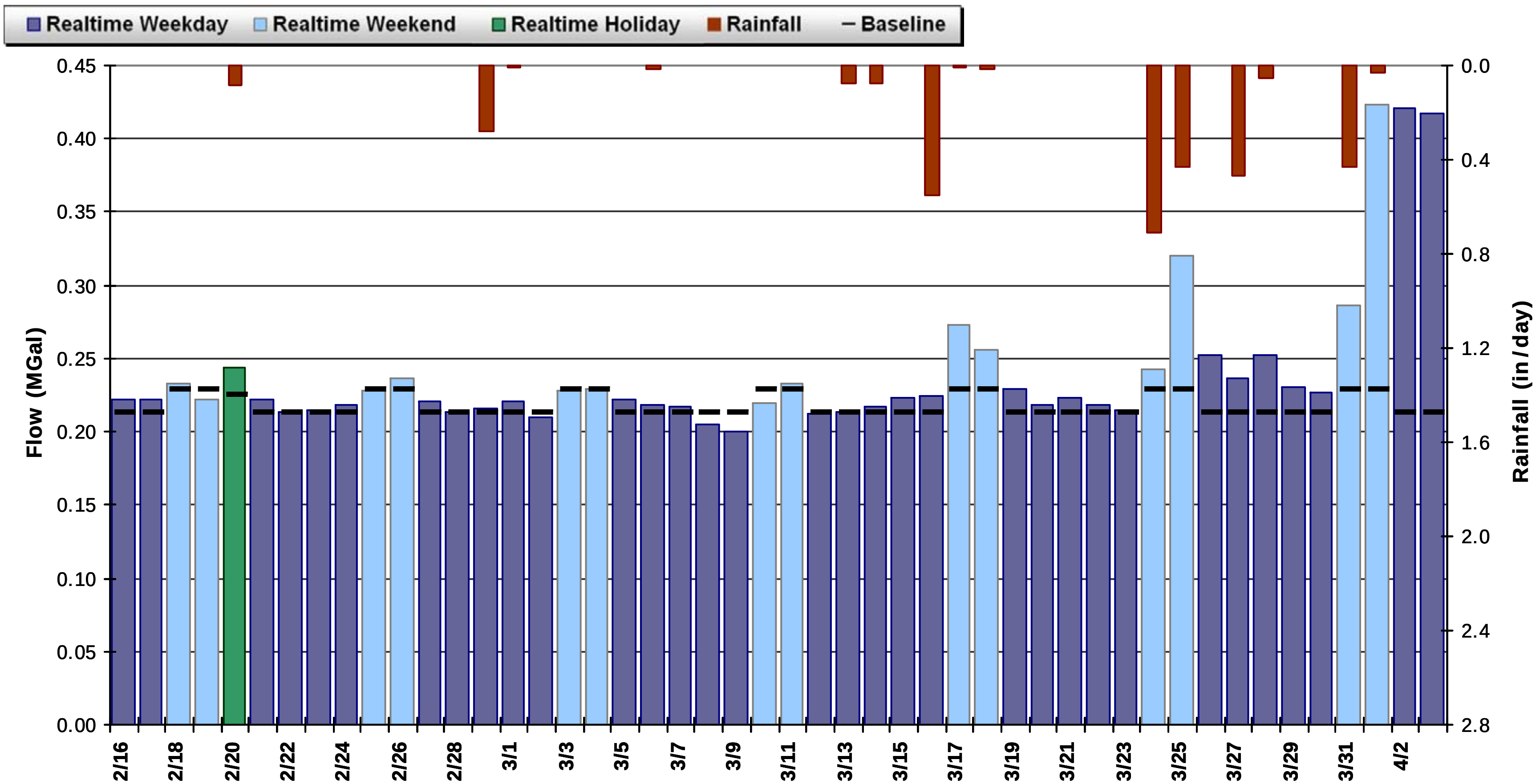
Plan View

MH K4

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.241 MGal **Peak Daily Flow: 0.424 MGal** **Min Daily Flow: 0.201 MGal**

Total Period Rainfall: 3.24 inches

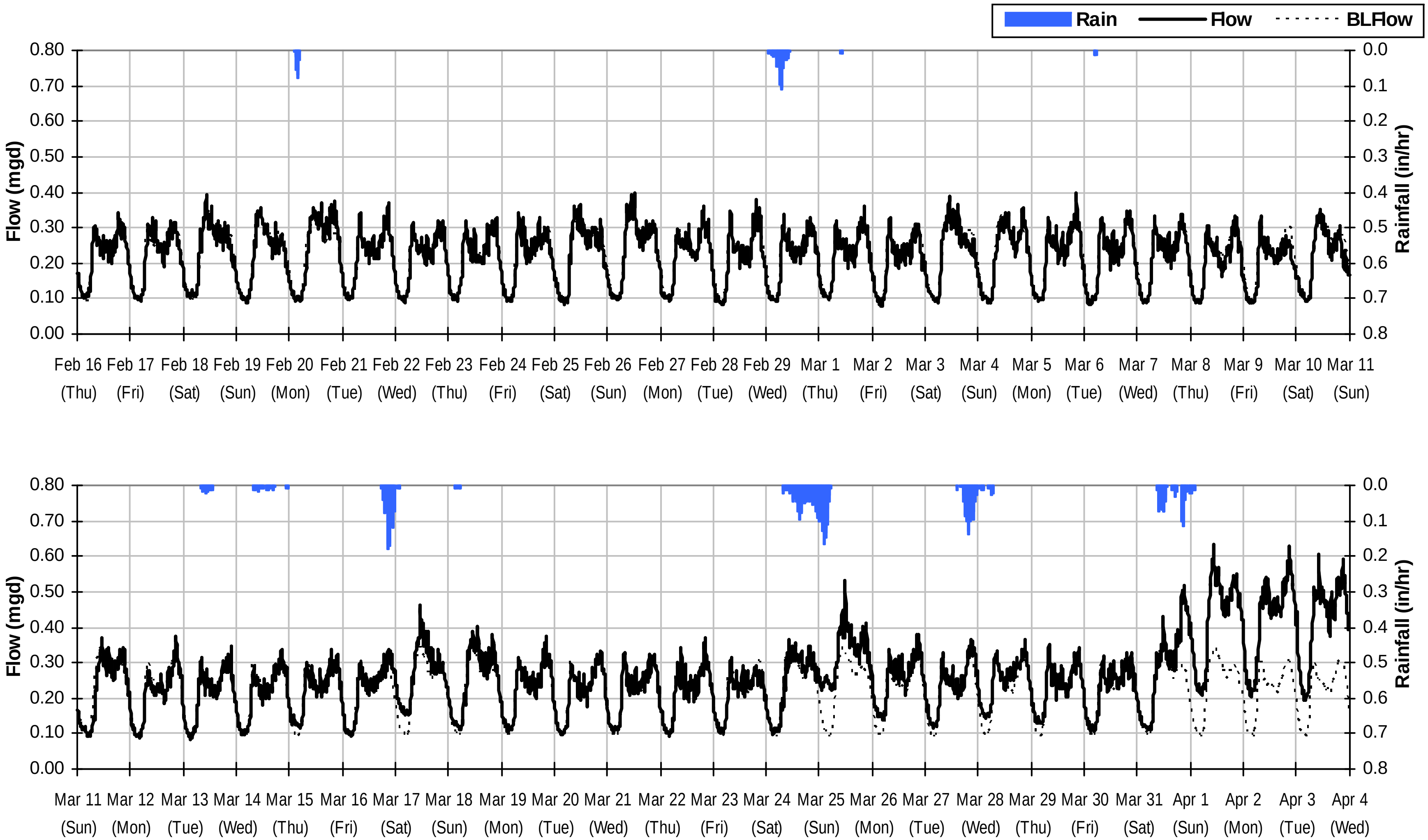


MH K4

Period Flow Summary: February 16 to April 4, 2012

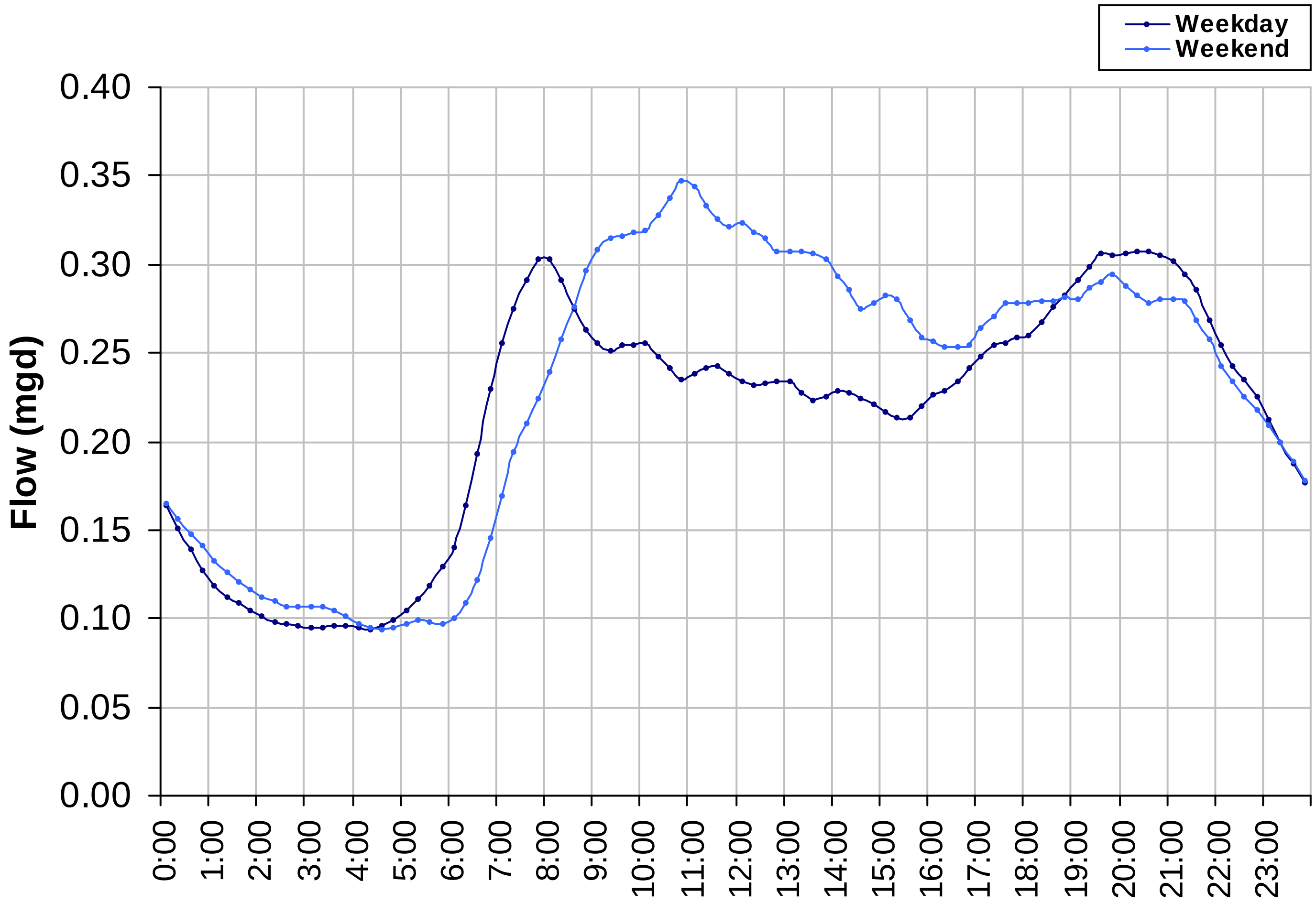
Avg Flow: 0.241 mgd **Peak Flow: 0.635 mgd** **Min Flow: 0.081 mgd**

Total Period Rainfall: 3.24 inches



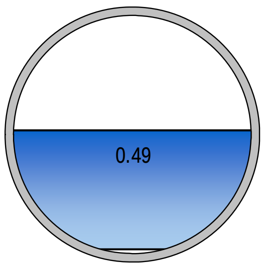
MH K4

Baseline Flow Hydrographs



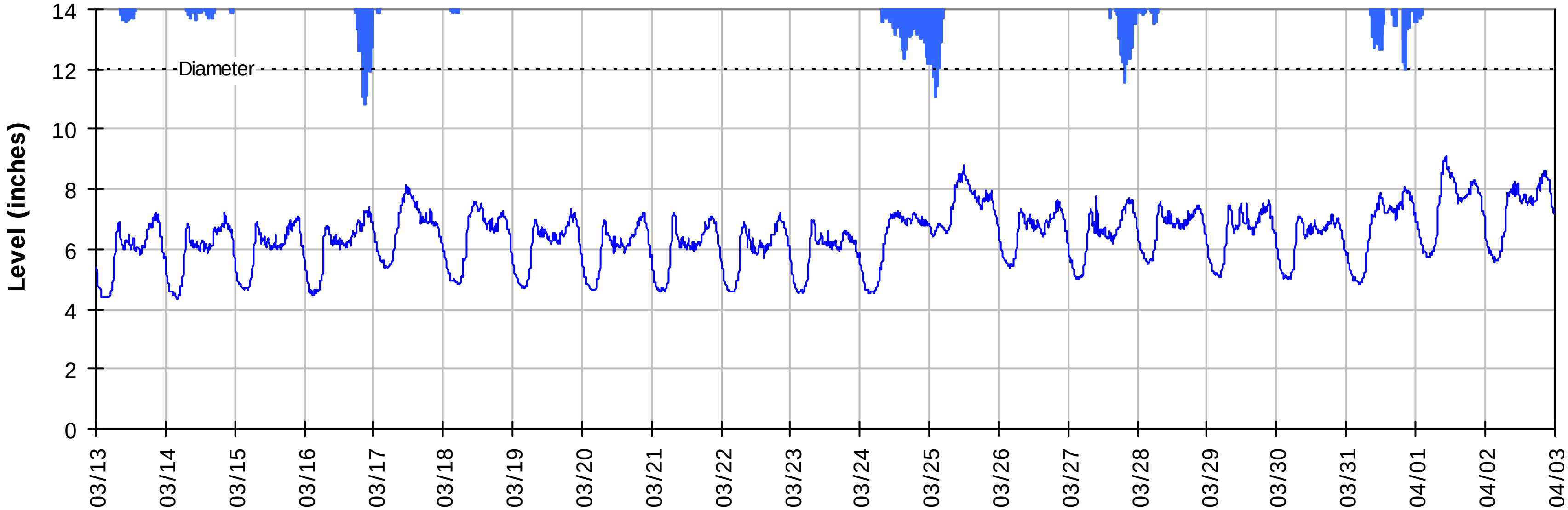
Baseline Flow:

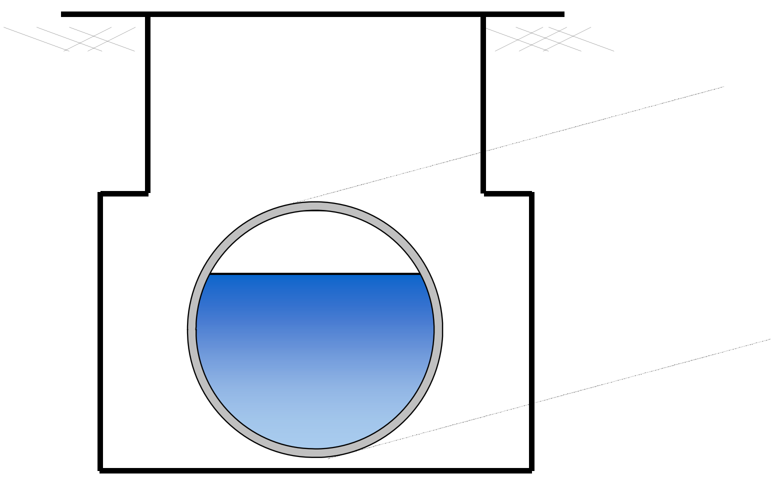
0.218 *mgd*



MH K4
Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

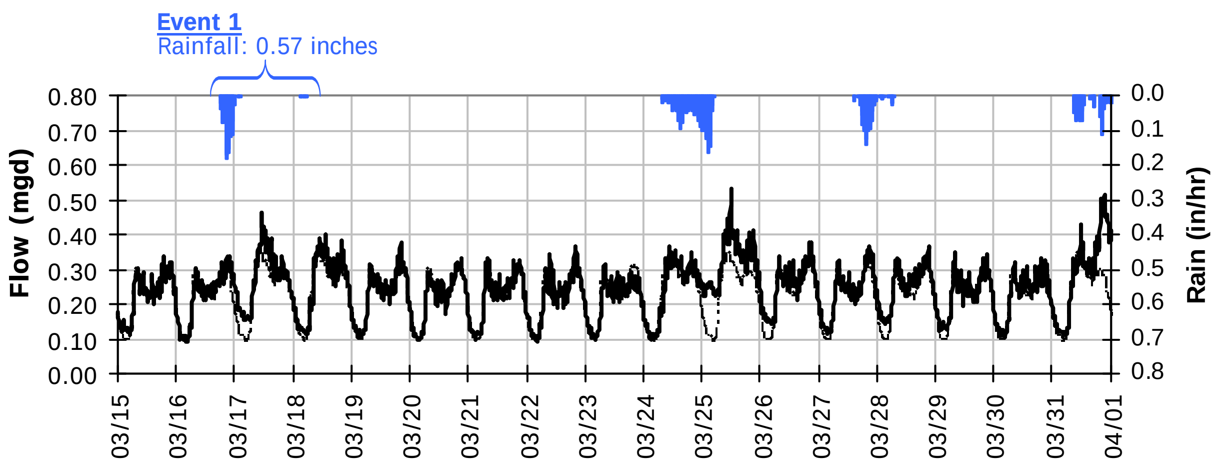




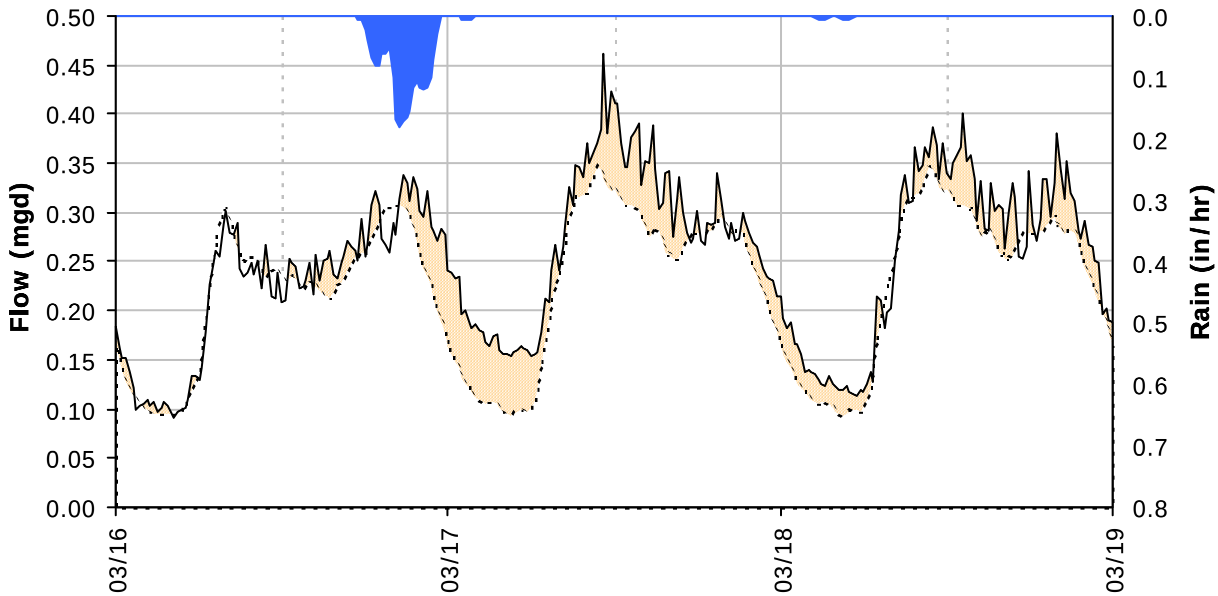
Pipe Diameter:	12	*inches*
Peak Measured Level:	8.82	*inches*
Peak d/D Ratio:	0.74	

MH K4
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph



Storm Event I/I Analysis (Rain = 0.57 inches)

Capacity

Peak Flow: 0.46 *mgd*
PF: 2.11
Peak Level: 8.14 *in*
d/D Ratio: 0.68

Inflow

Peak I/I Rate: 0.13 *mgd*
PkI/I:IDM: 4,278 *gpd/IDM*
PkI/I:Acre: 1,195 *gpd/acre*
Pk I/I:ADWF: 0.58

RDI (infiltration)

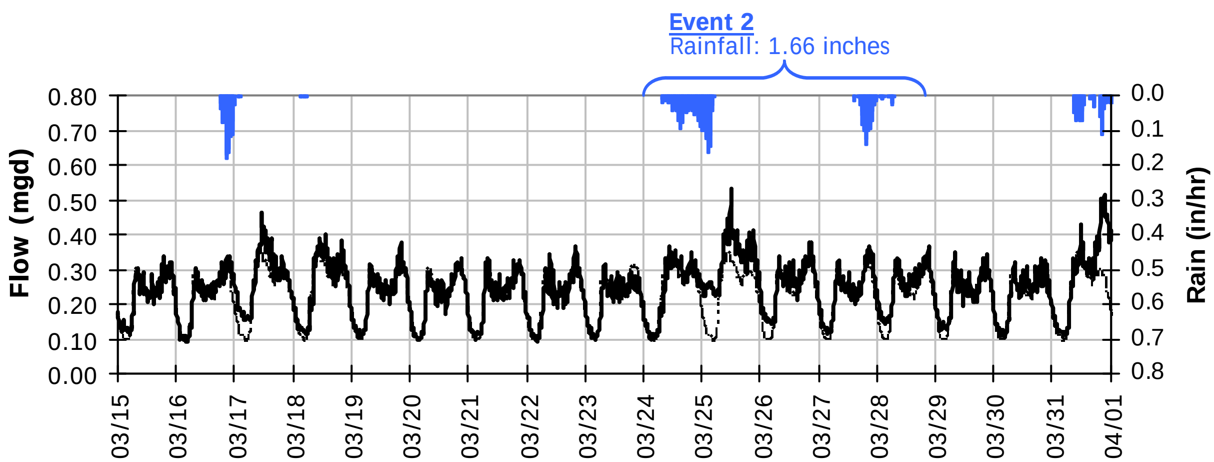
Infiltration Rate: 0.027 *mgd*
(3/18/2012)
RDI:IDM: 898 *gpd/IDM*
RDI:Acre: 251 *gpd/acre*
RDI (% of BL): 12%

Combined I/I

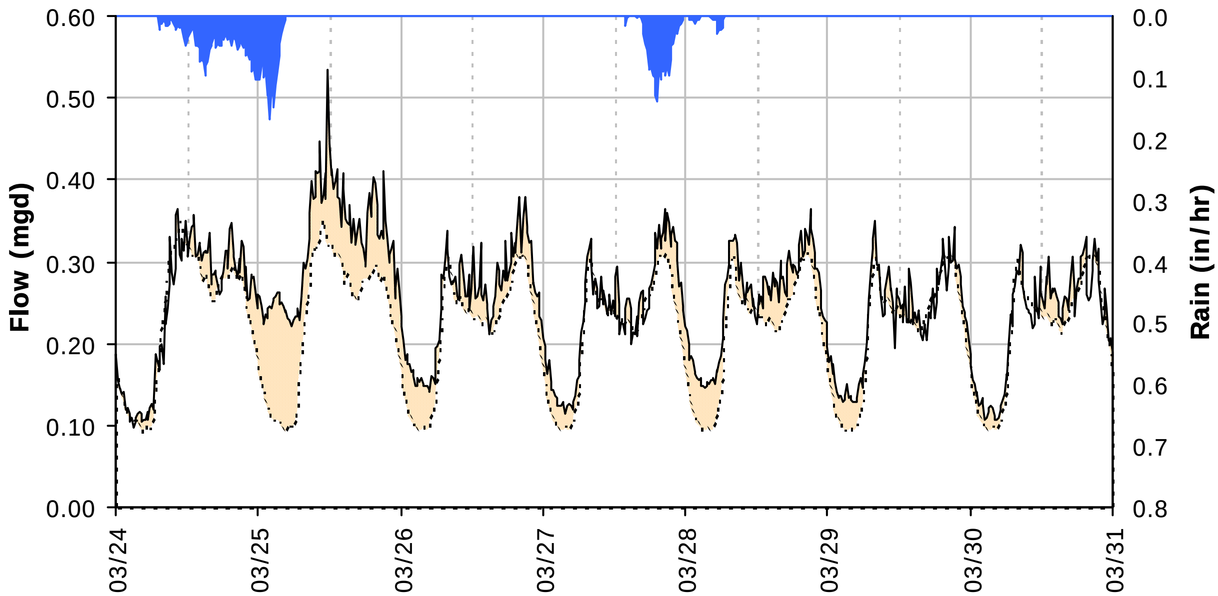
Total I/I: 78,000 *gallons*
Total I/I:IDM: 4,593 *gal/IDM/in*
R-Value: 4.7%
Total I/I:ADWF: 0.63 *per in-rain*

MH K4
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



Storm Event I/I Analysis (Rain = 1.66 inches)

Capacity

Peak Flow:	0.53 *mgd*
PF:	2.44
Peak Level:	8.82 *in*
d/D Ratio:	0.74

Inflow

Peak I/I Rate:	0.21 *mgd*
PkI/I:IDM:	7,116 *gpd/IDM*
PkI/I:Acre:	1,987 *gpd/acre*
Pk I/I:ADWF:	0.97

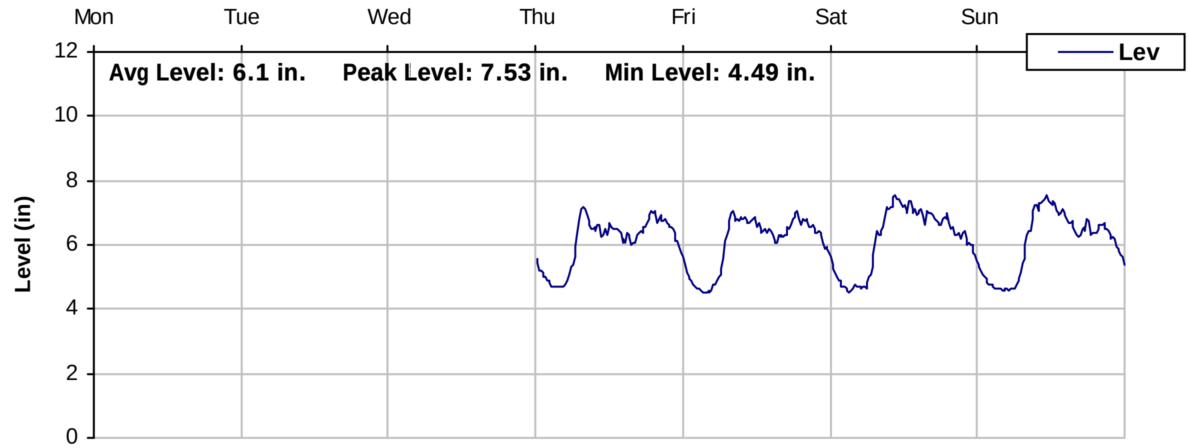
RDI (infiltration)

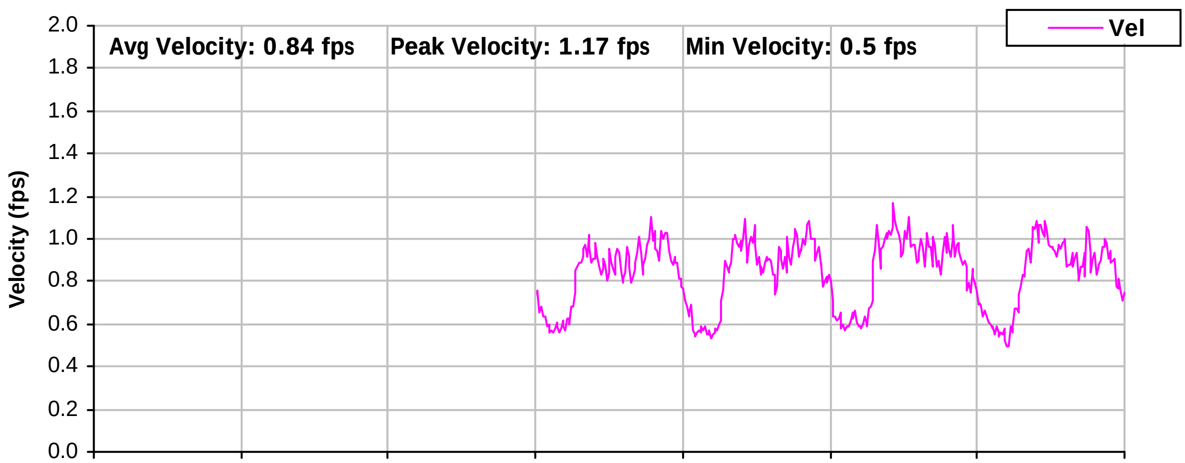
Infiltration Rate: (3/26/2012)	0.038 *mgd*
RDI:IDM:	1,276 *gpd/IDM*
RDI:Acre:	356 *gpd/acre*
RDI (% of BL):	18%

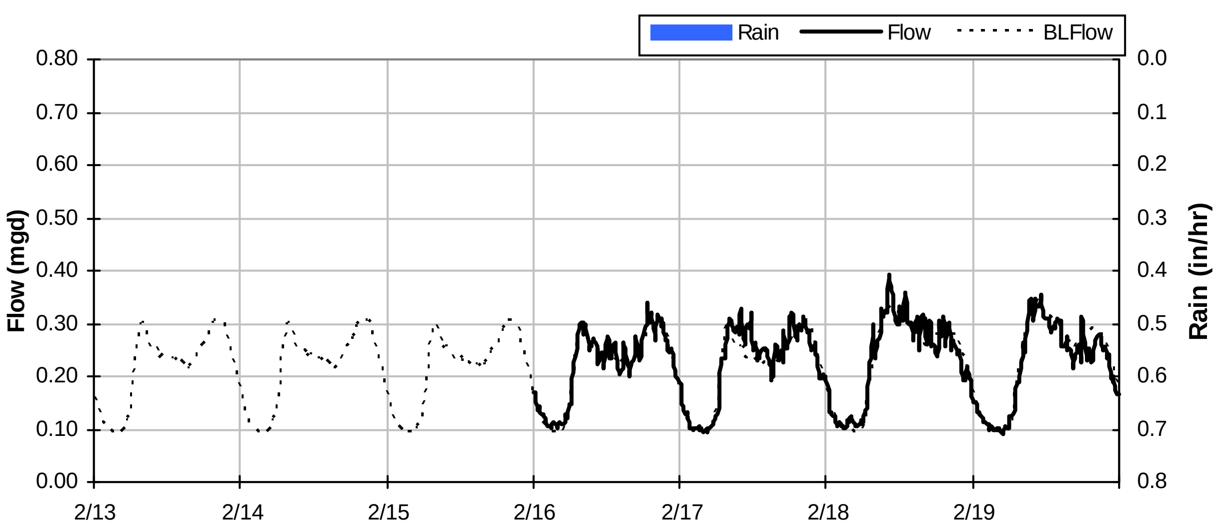
Combined I/I

Total I/I:	234,000 *gallons*
Total I/I:IDM:	4,724 *gal/IDM/in*
R-Value:	4.9%
Total I/I:ADWF:	0.64 *per in-rain*

MH K4
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012

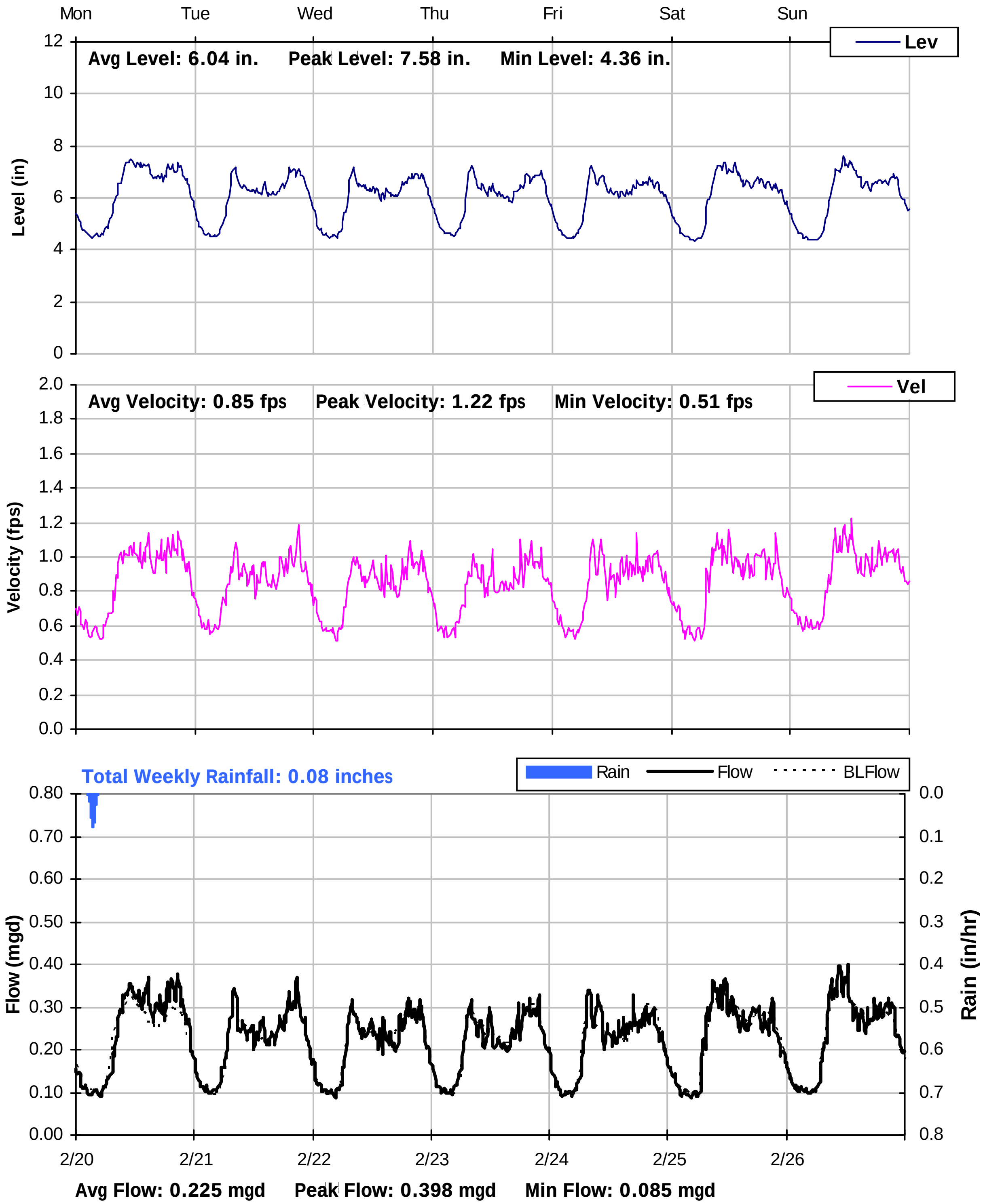




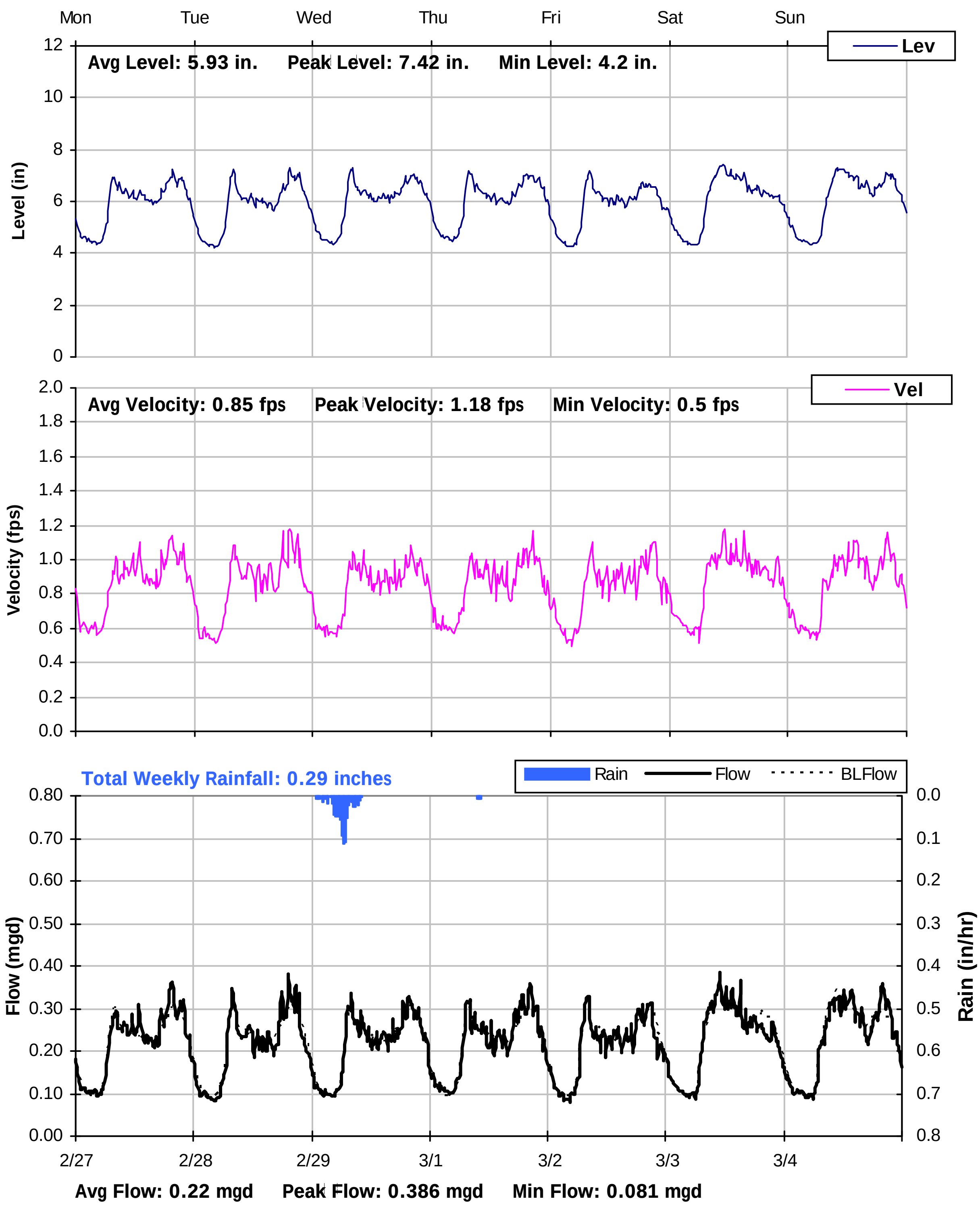


Avg Flow: 0.225 mgd **Peak Flow: 0.392 mgd** **Min Flow: 0.089 mgd**

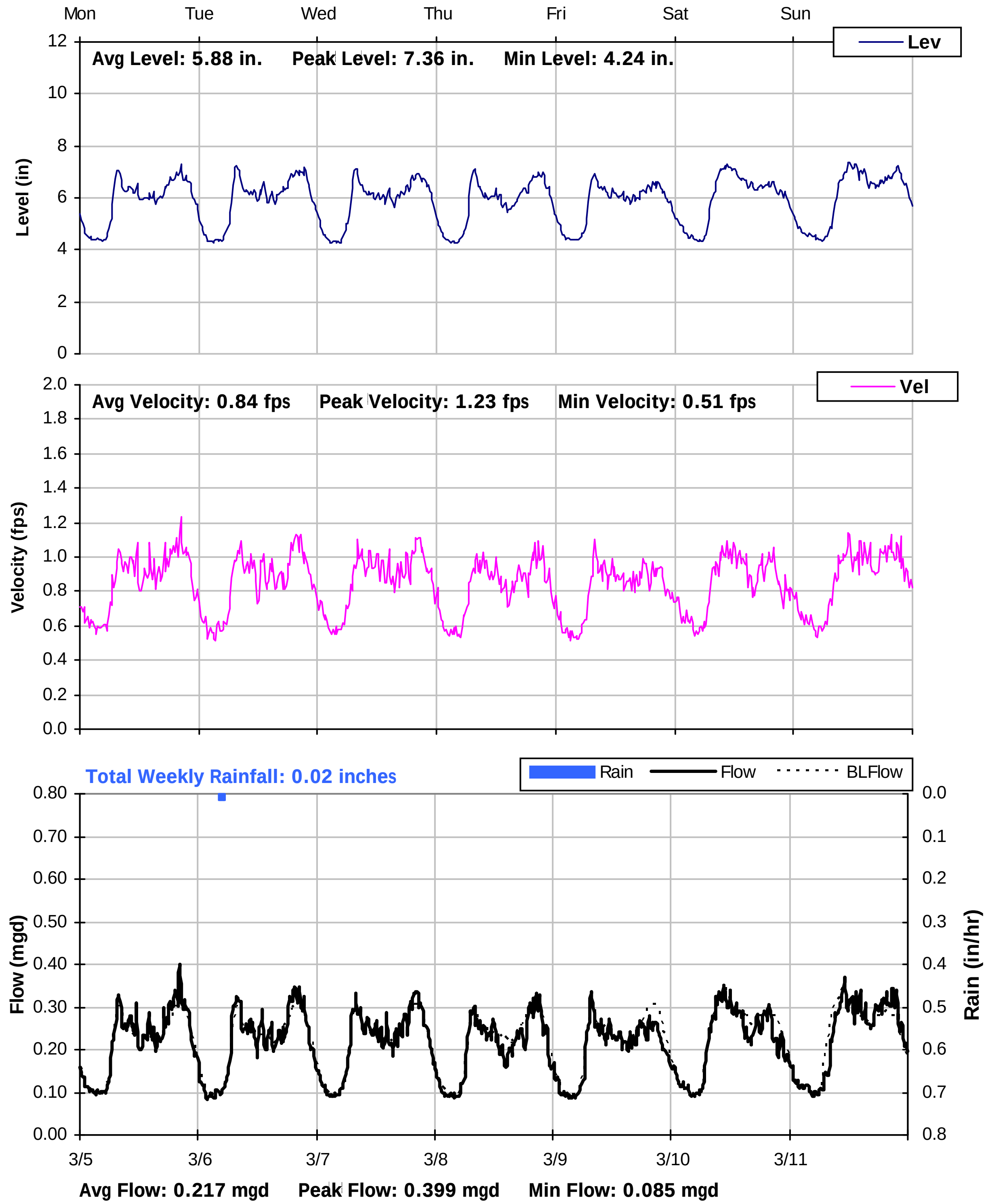
MH K4
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



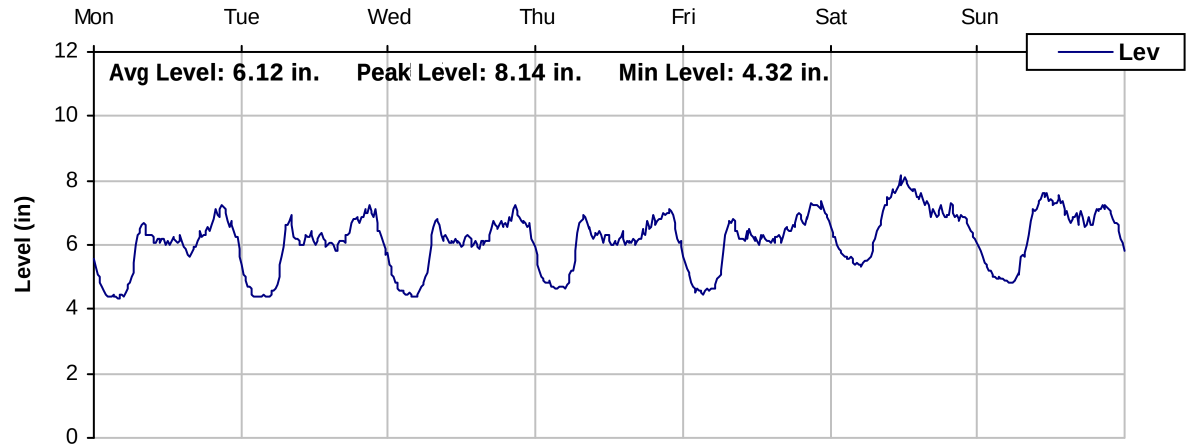
MH K4
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012

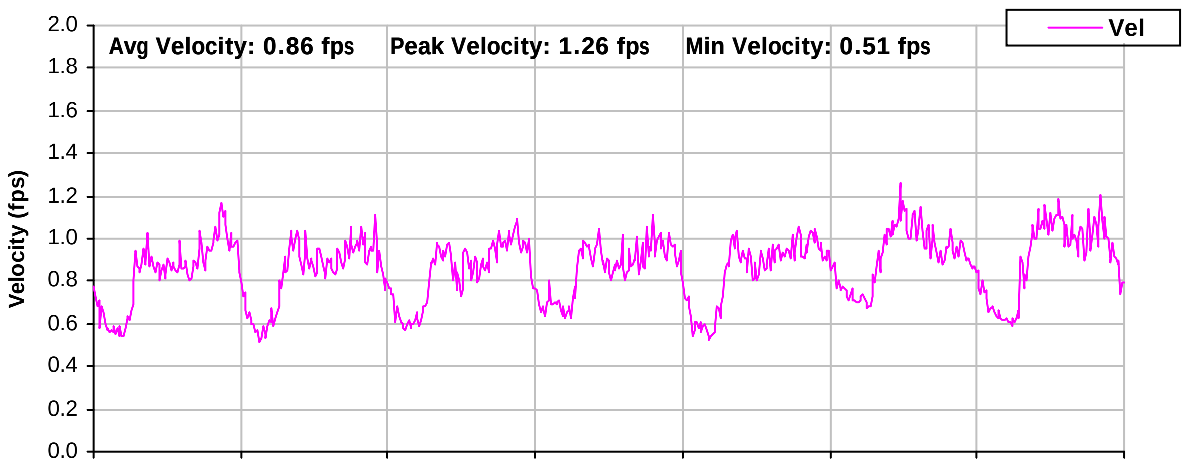


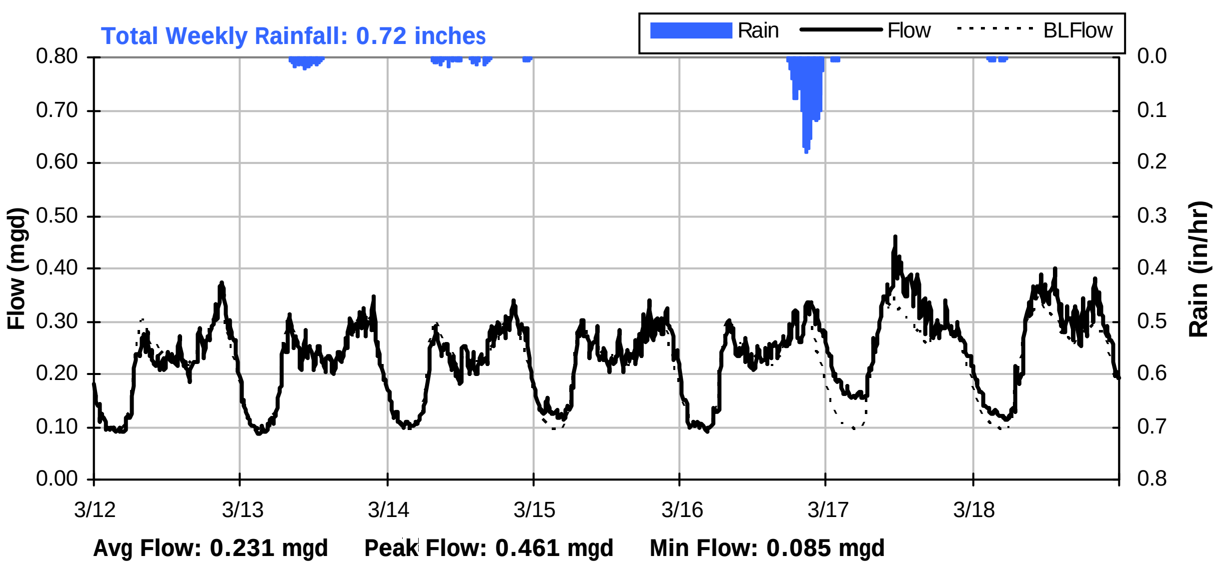
MH K4
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



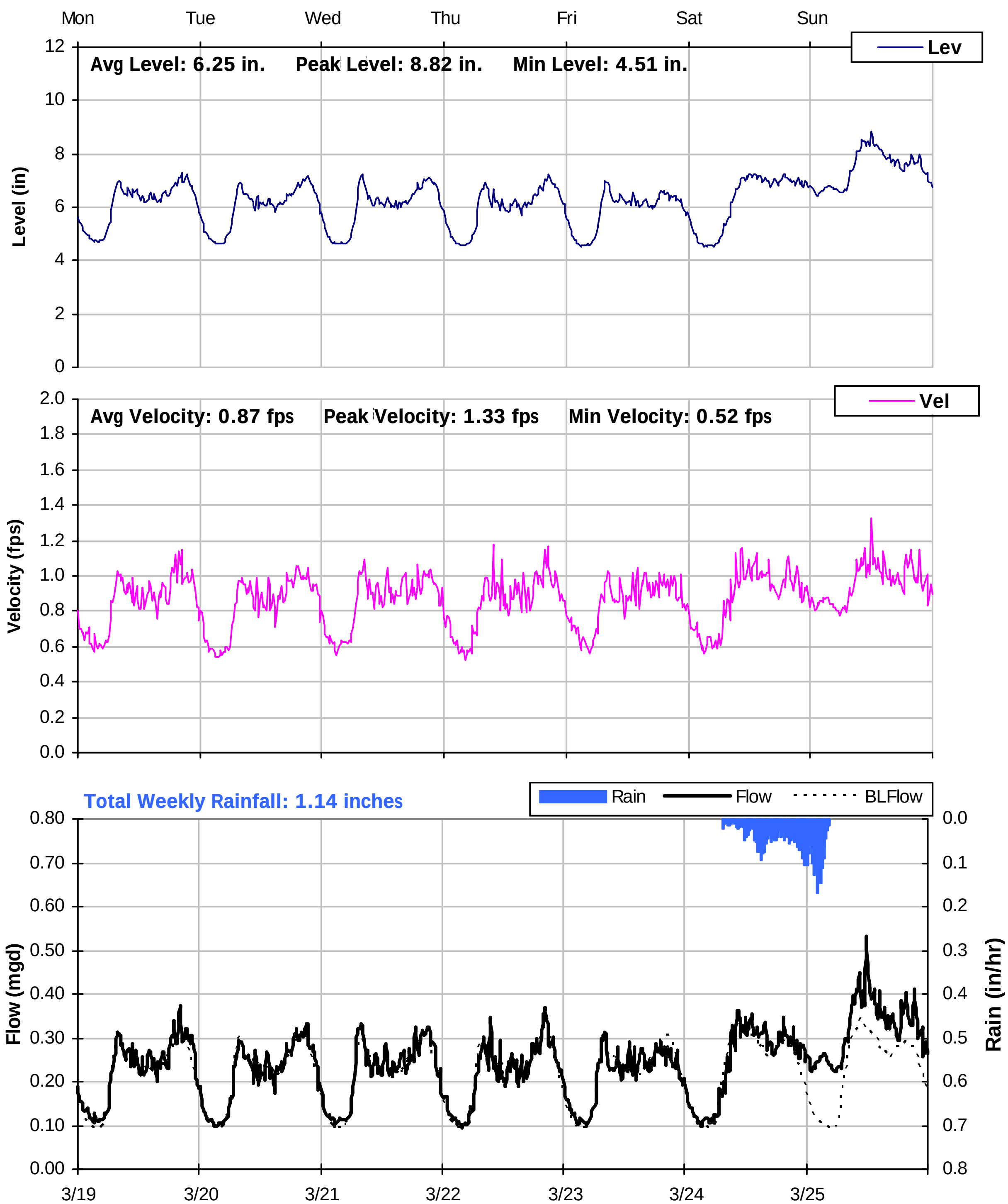
MH K4
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012





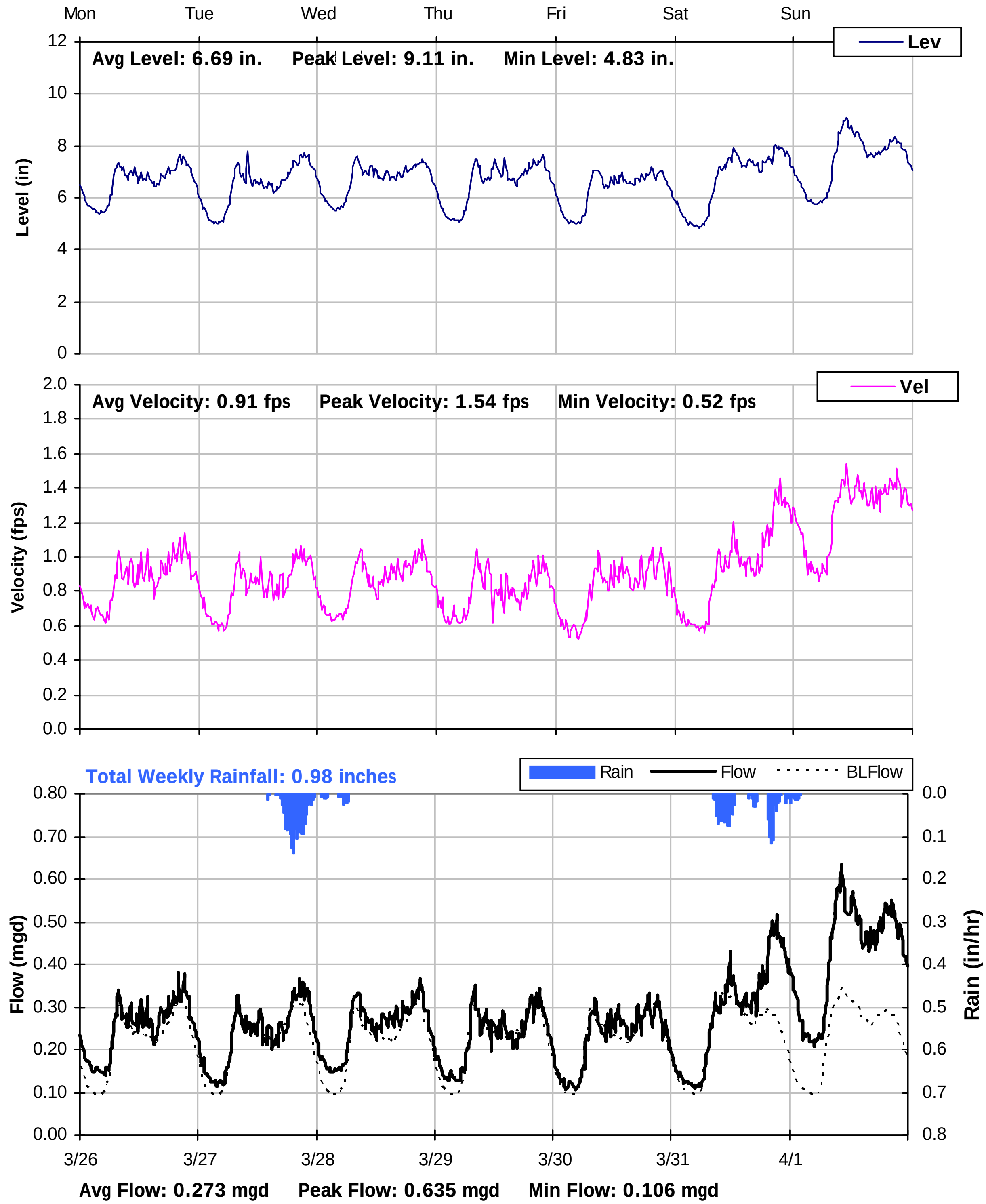


MH K4
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012

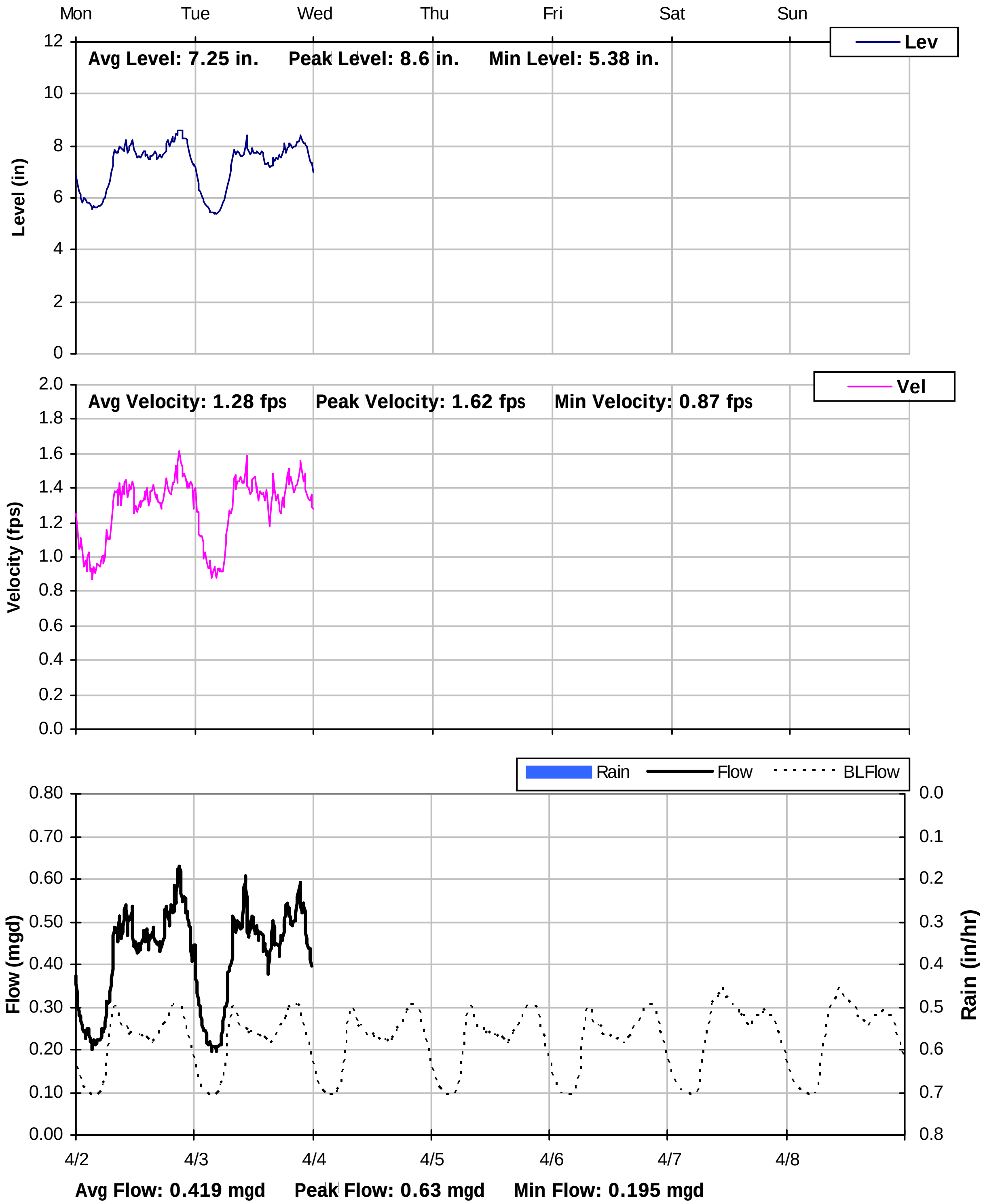


Avg Flow: 0.238 mgd   **Peak Flow: 0.533 mgd**   **Min Flow: 0.092 mgd**

MH K4
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



MH K4
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

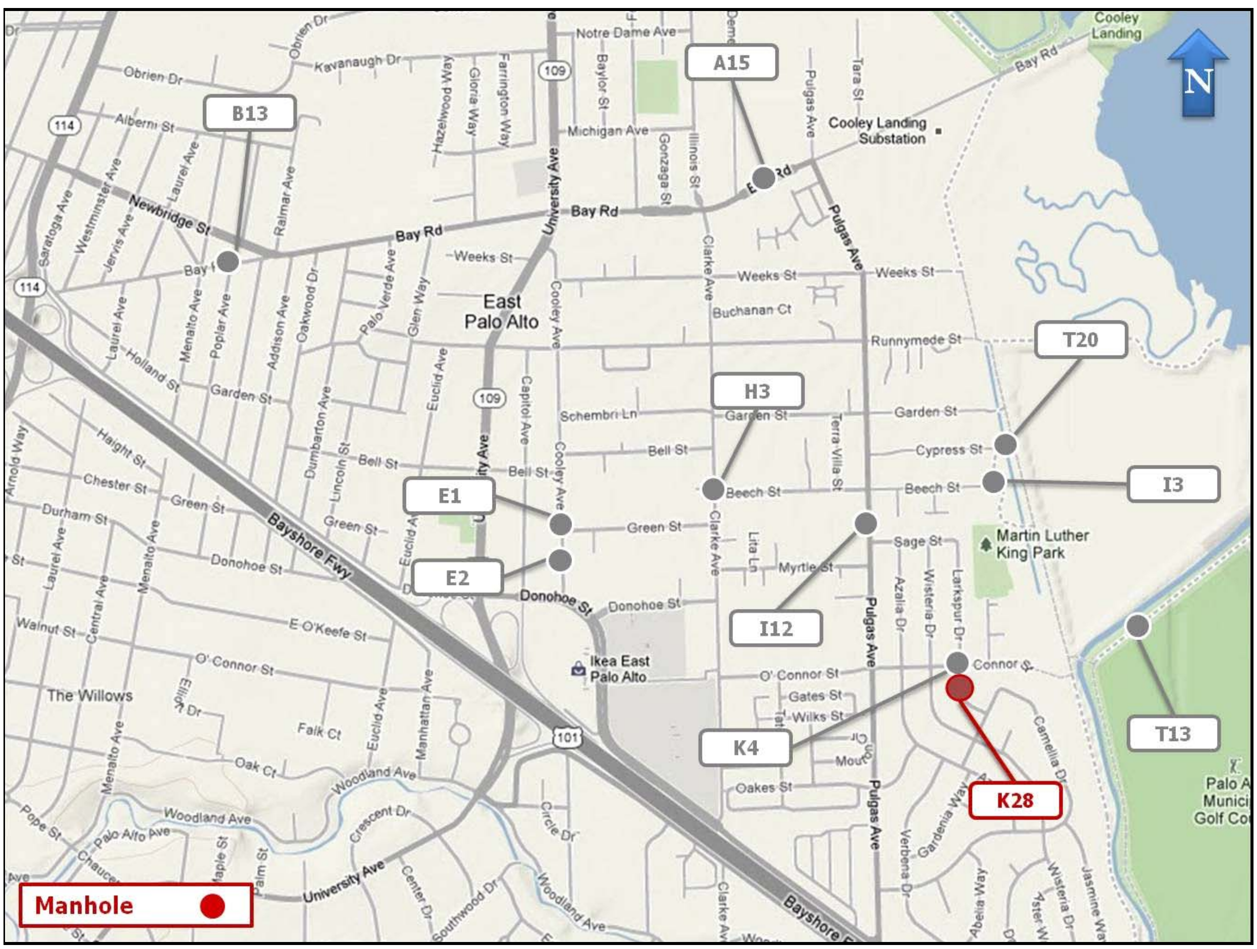
Year 2012

Monitoring Site: MH K28

Location: Larkspur Drive, south of O'Connor Street

Data Summary Report

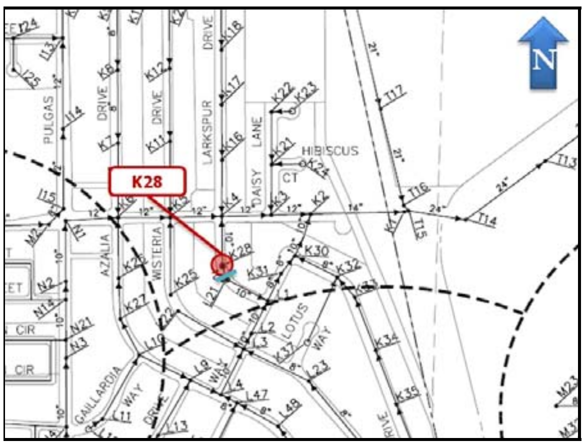
Vicinity Map:



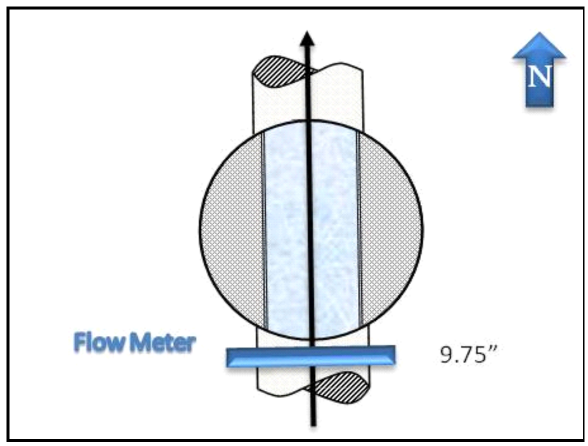
MH K28
Site Information Report

Location:	Larkspur Drive, south of O'Connor Street
Coordinates:	122.1274° W, 37.4603° N
Elevation:	7 feet
Diameter:	9.75 inches
Baseline Flow:	0.11 mgd
Peak Measured Flow:	0.274 mgd

Satellite Map



Sanitary Sewer Map



Flow Sketch

View from Street

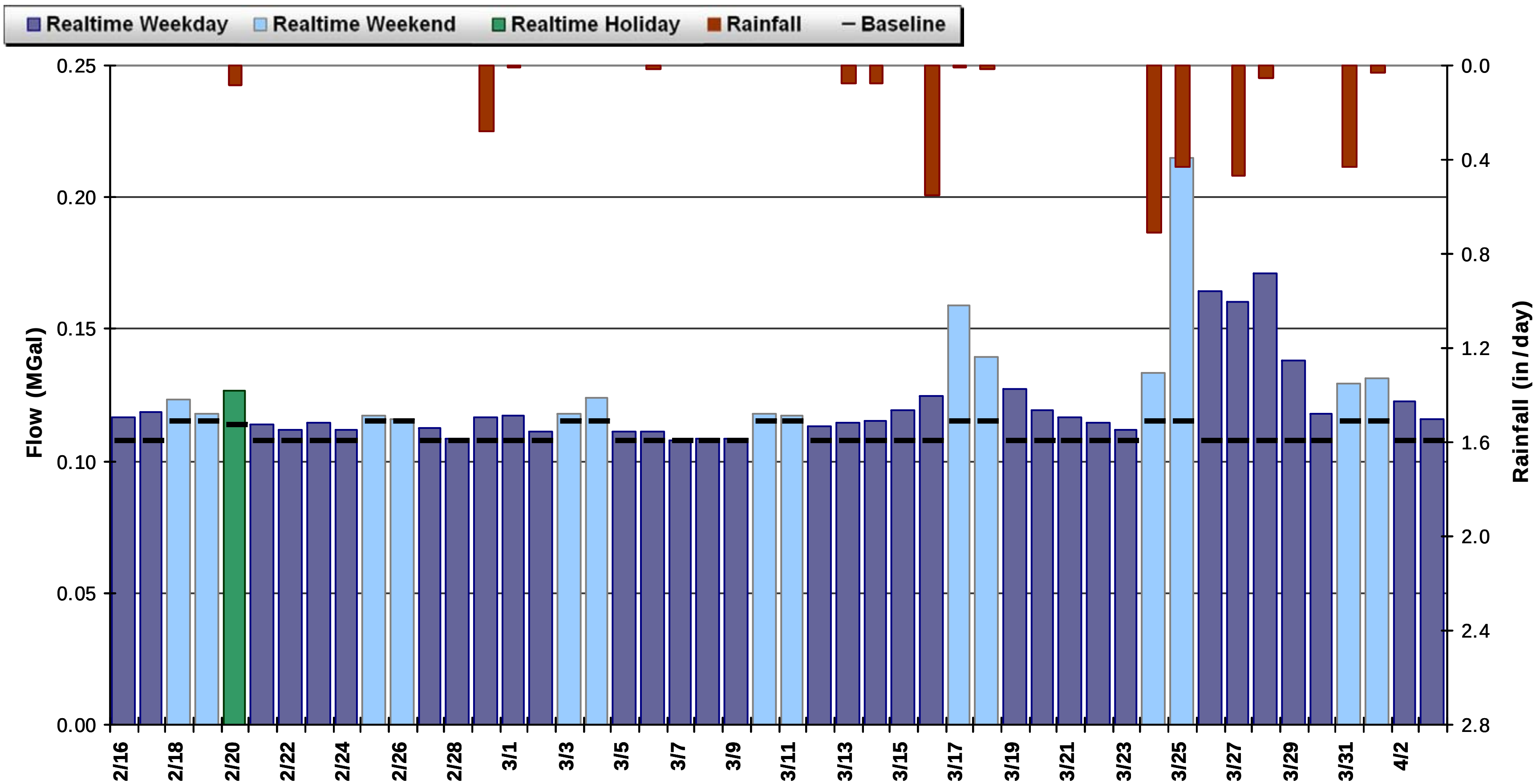
Plan View

MH K28

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.124 MGal **Peak Daily Flow: 0.215 MGal** **Min Daily Flow: 0.108 MGal**

Total Period Rainfall: 3.24 inches

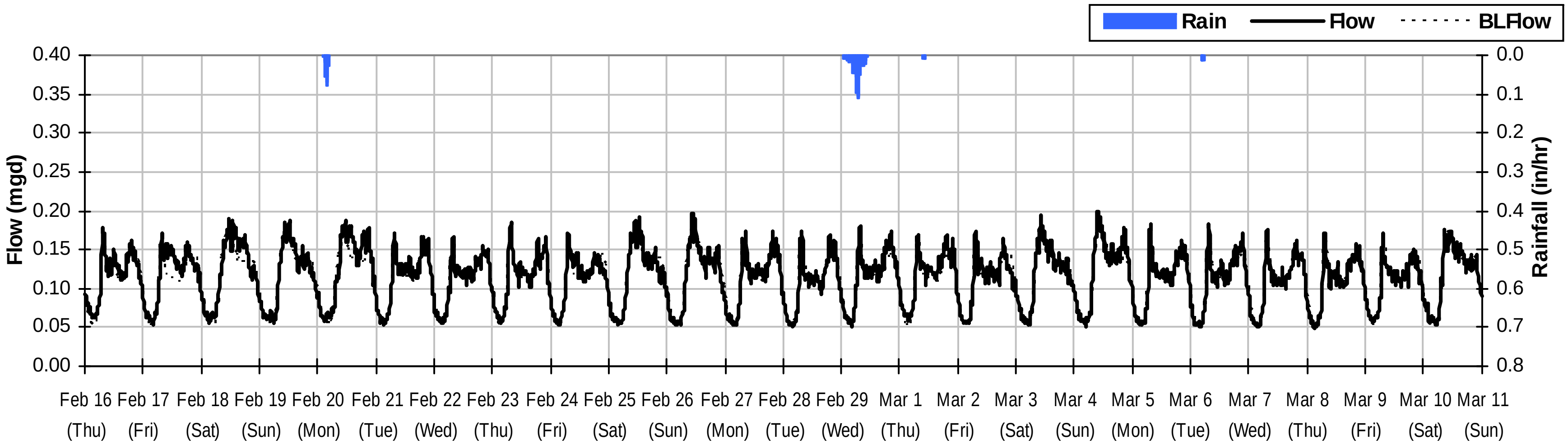


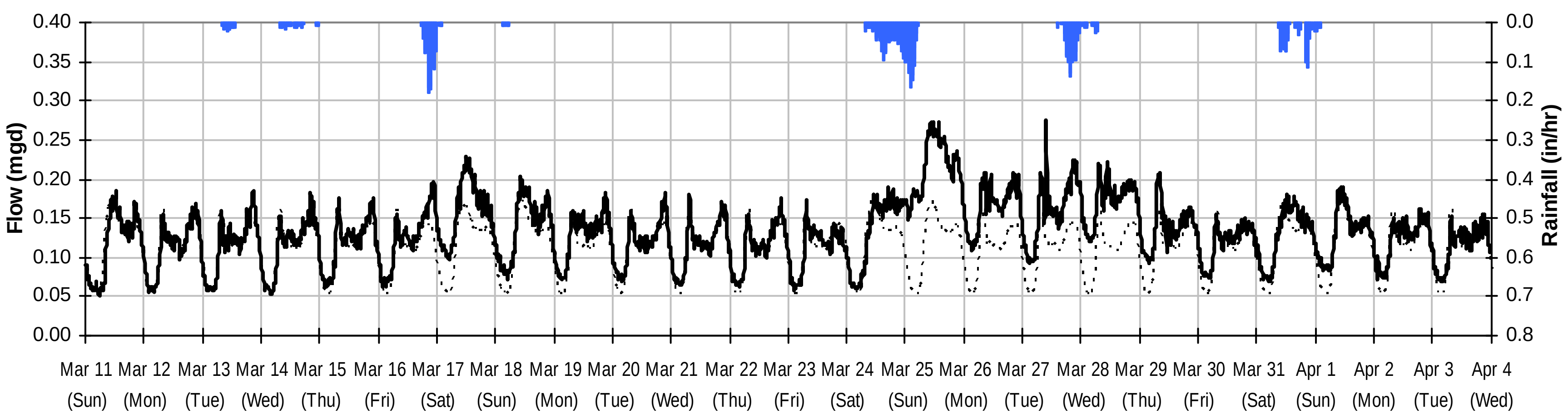
MH K28

Period Flow Summary: February 16 to April 4, 2012

Avg Flow: 0.124 mgd **Peak Flow: 0.274 mgd** **Min Flow: 0.049 mgd**

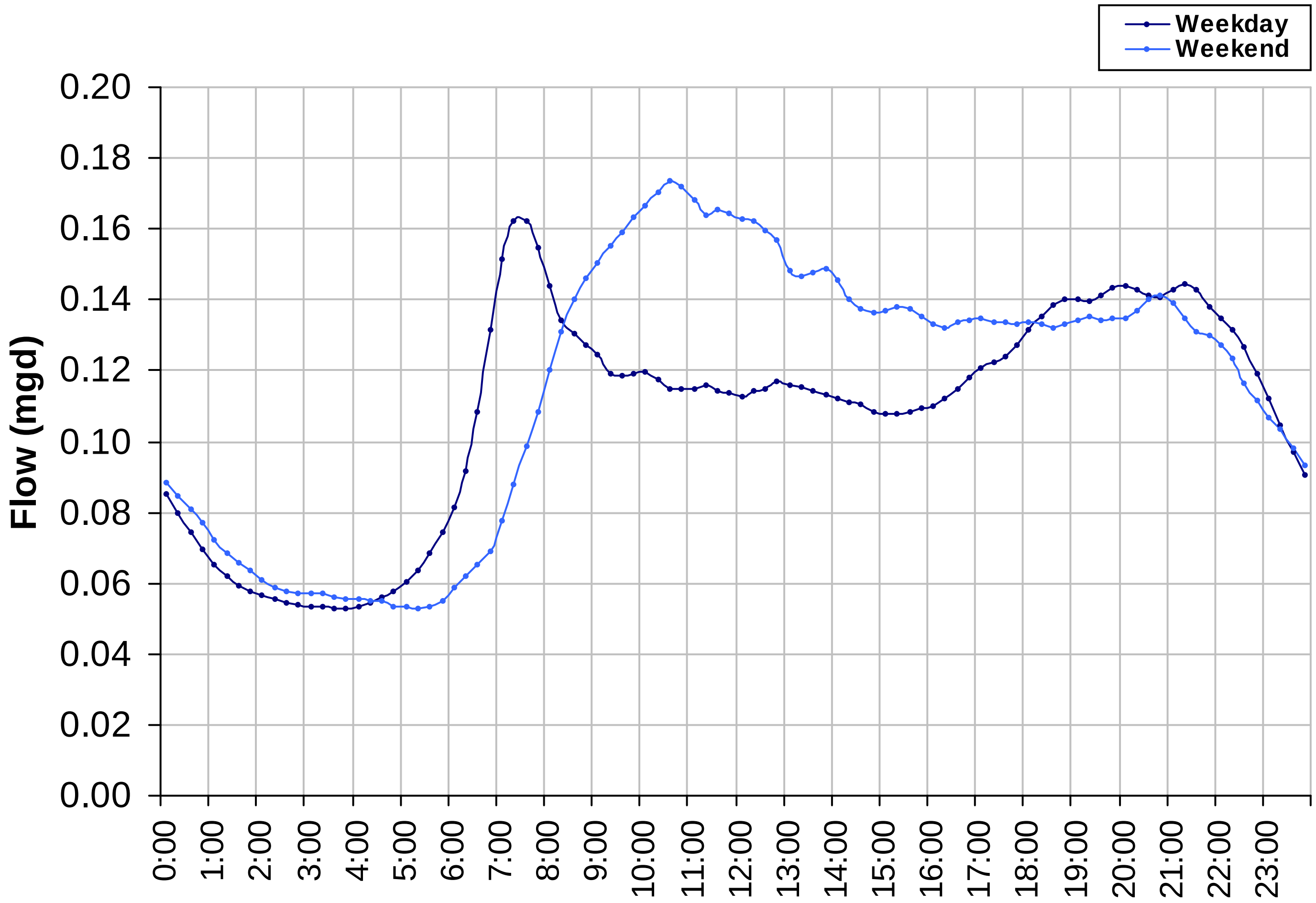
Total Period Rainfall: 3.24 inches





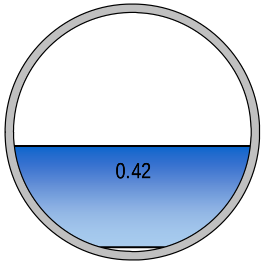
MH K28

Baseline Flow Hydrographs



Baseline Flow:

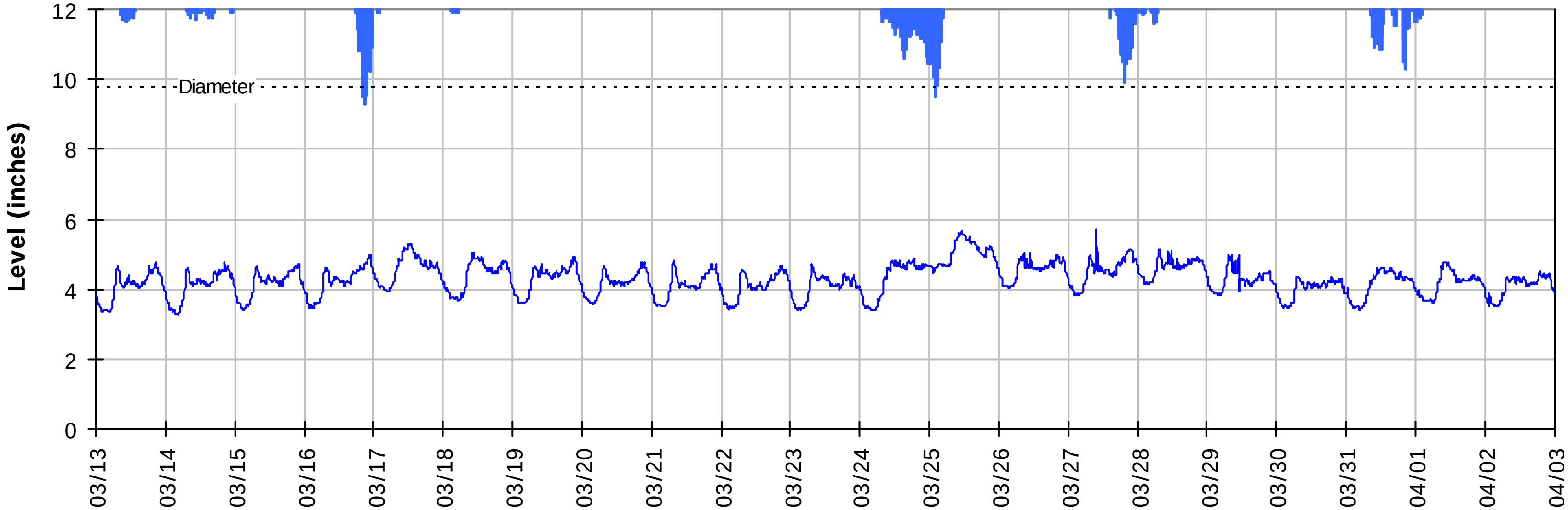
0.110 *mgd*

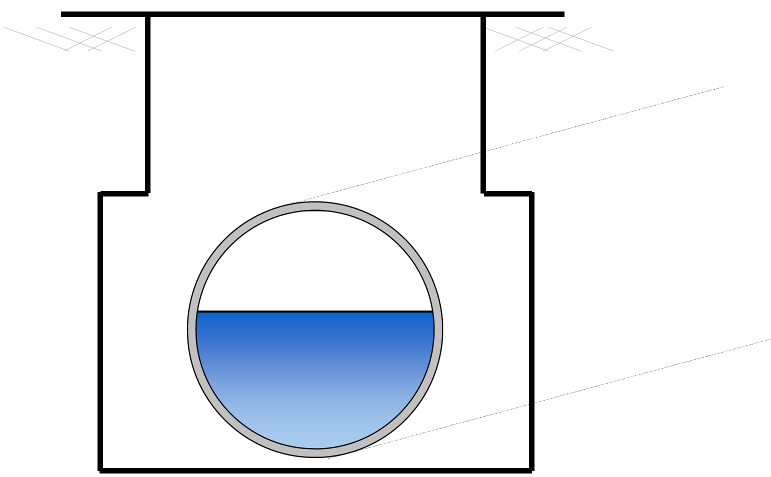


MH K28

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





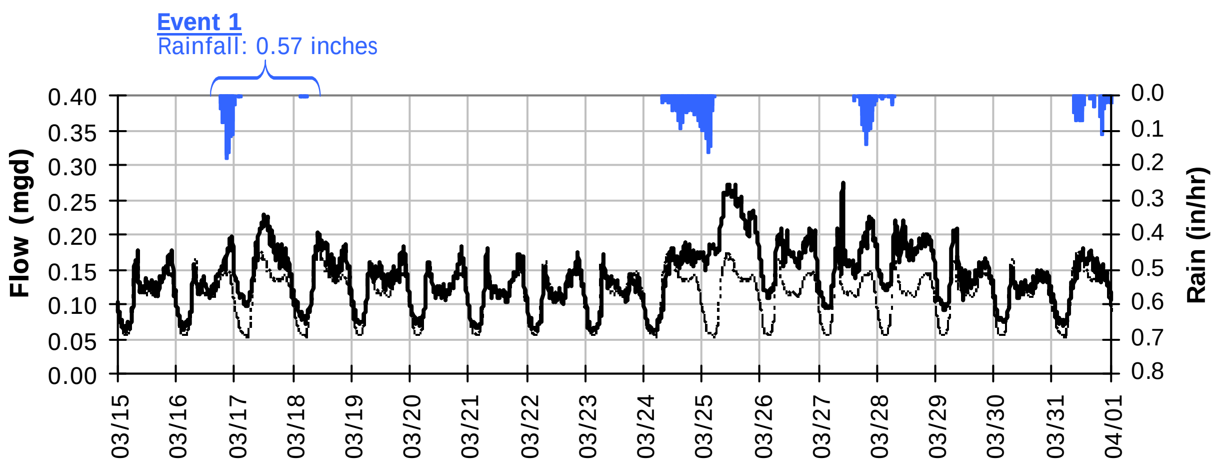
Pipe Diameter: 9.75 *inches*

Peak Measured Level: 5.71 *inches*

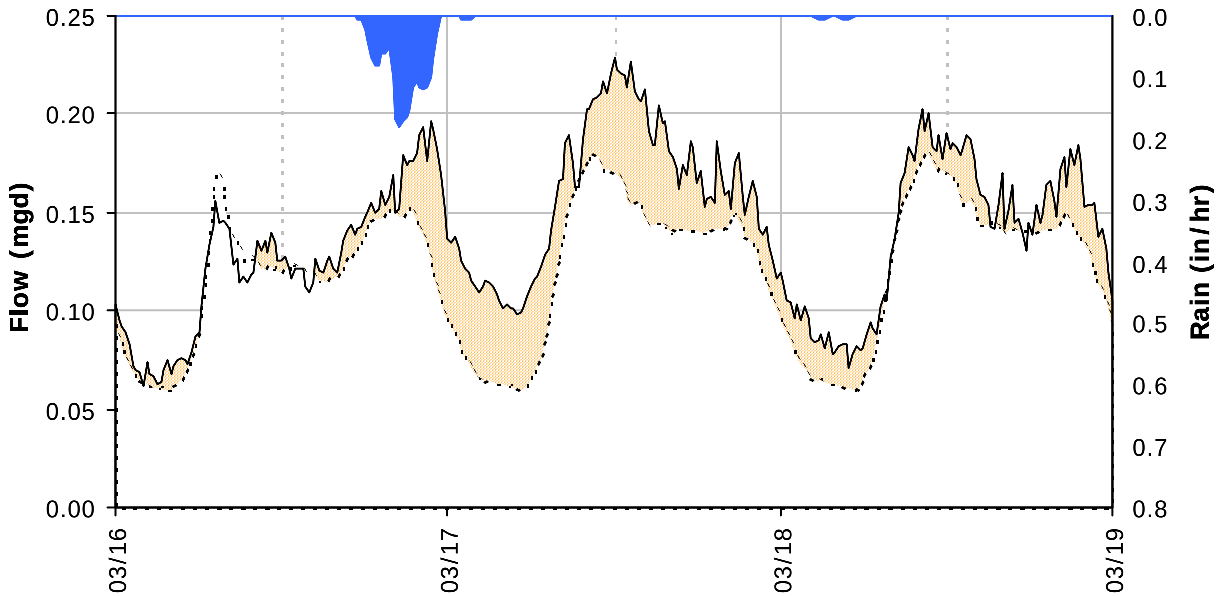
Peak d/D Ratio: 0.59

MH K28
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph



Storm Event I/I Analysis (Rain = 0.57 inches)

Capacity

Peak Flow: 0.23 *mgd*
PF: 2.07
Peak Level: 5.31 *in*
d/D Ratio: 0.54

Inflow

Peak I/I Rate: 0.08 *mgd*
PkI/I:IDM: 3,158 *gpd/IDM*
PkI/I:Acre: 840 *gpd/acre*
Pk I/I:ADWF: 0.73

RDI (infiltration)

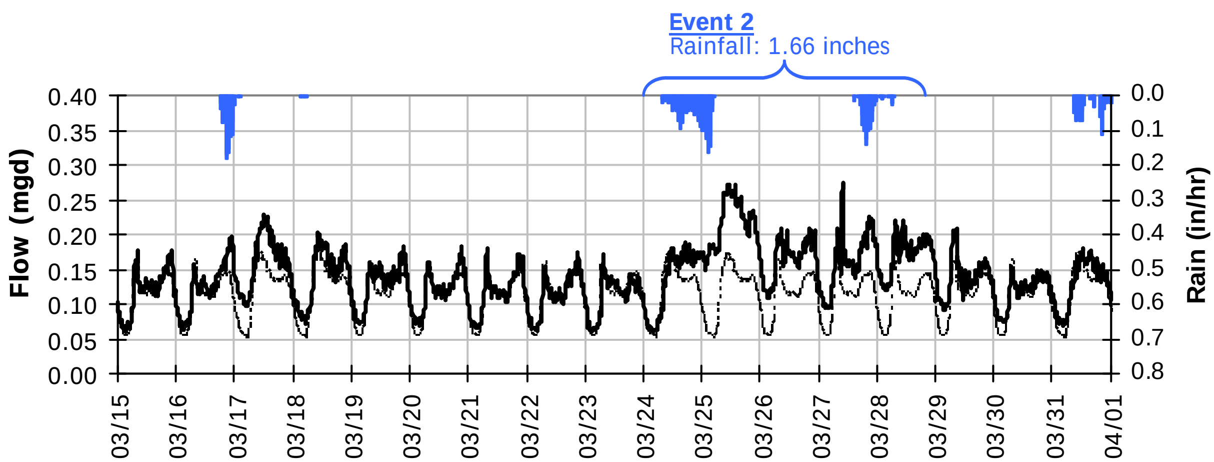
Infiltration Rate: (3/18/2012) 0.024 *mgd*
RDI:IDM: 950 *gpd/IDM*
RDI:Acre: 253 *gpd/acre*
RDI (% of BL): 21%

Combined I/I

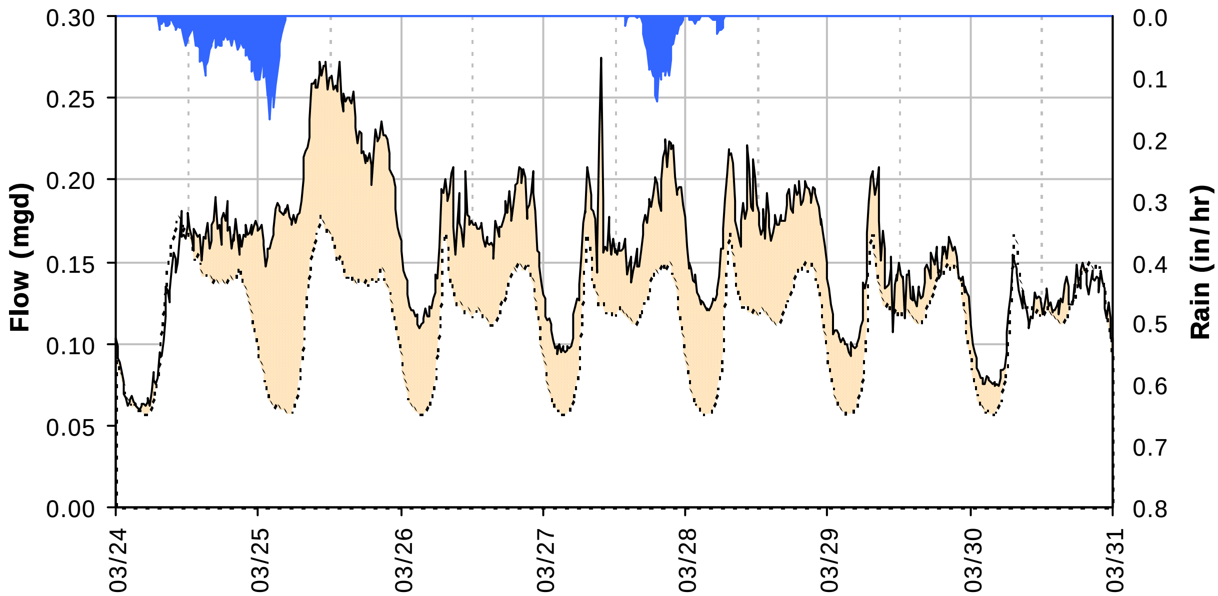
Total I/I: 61,000 *gallons*
Total I/I:IDM: 4,226 *gal/IDM/in*
R-Value: 4.1%
Total I/I:ADWF: 0.97 *per in-rain*

MH K28
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



Storm Event I/I Analysis (Rain = 1.66 inches)

Capacity

Peak Flow:	0.27	*mgd*
PF:	2.49	
Peak Level:	5.71	*in*
d/D Ratio:	0.59	

Inflow

Peak I/I Rate:	0.16	*mgd*
PkI/I:IDM:	6,135	*gpd/IDM*
PkI/I:Acre:	1,632	*gpd/acre*
Pk I/I:ADWF:	1.41	

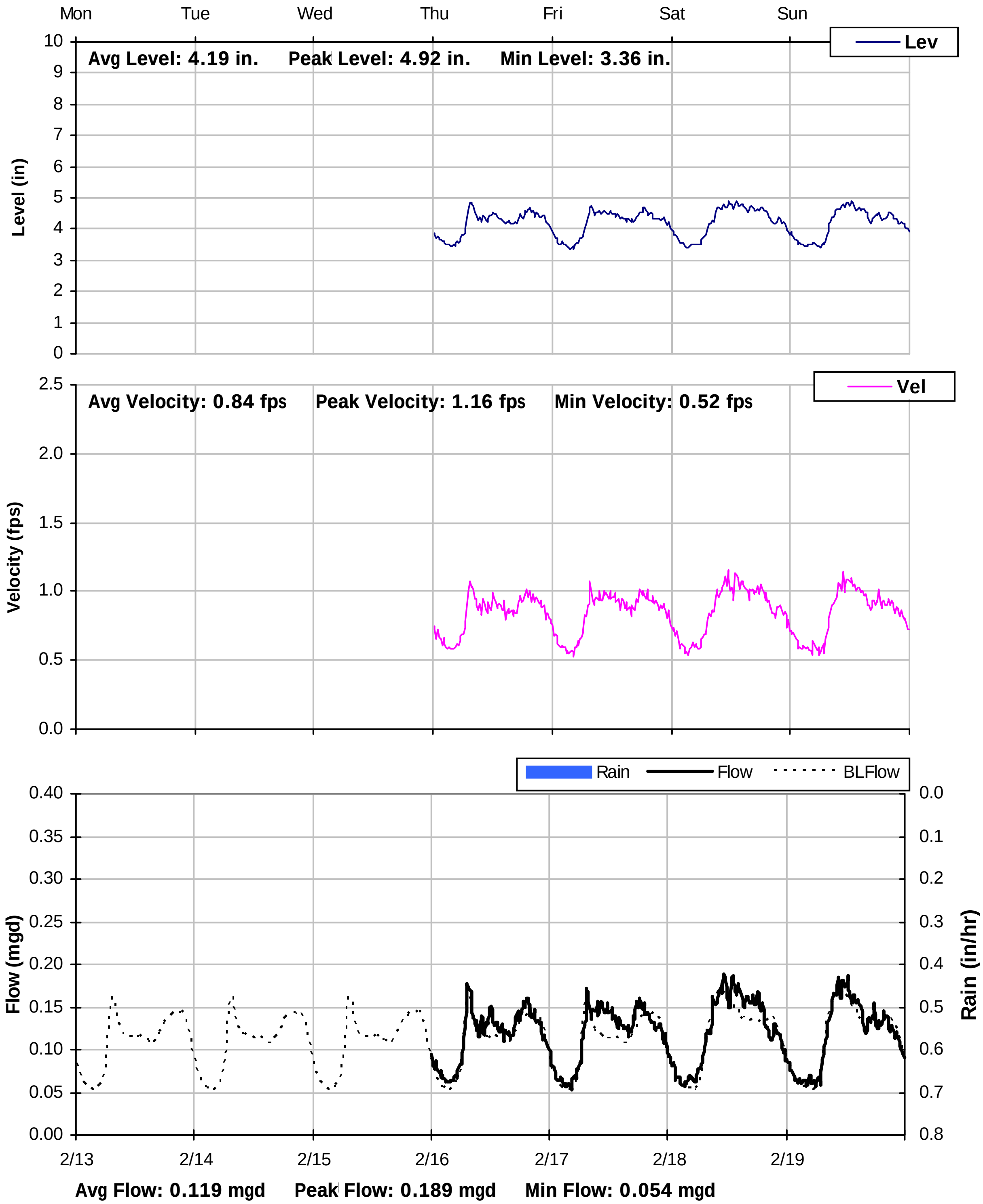
RDI (infiltration)

Infiltration Rate: (3/26/2012)	0.056	*mgd*
RDI:IDM:	2,229	*gpd/IDM*
RDI:Acre:	593	*gpd/acre*
RDI (% of BL):	52%	

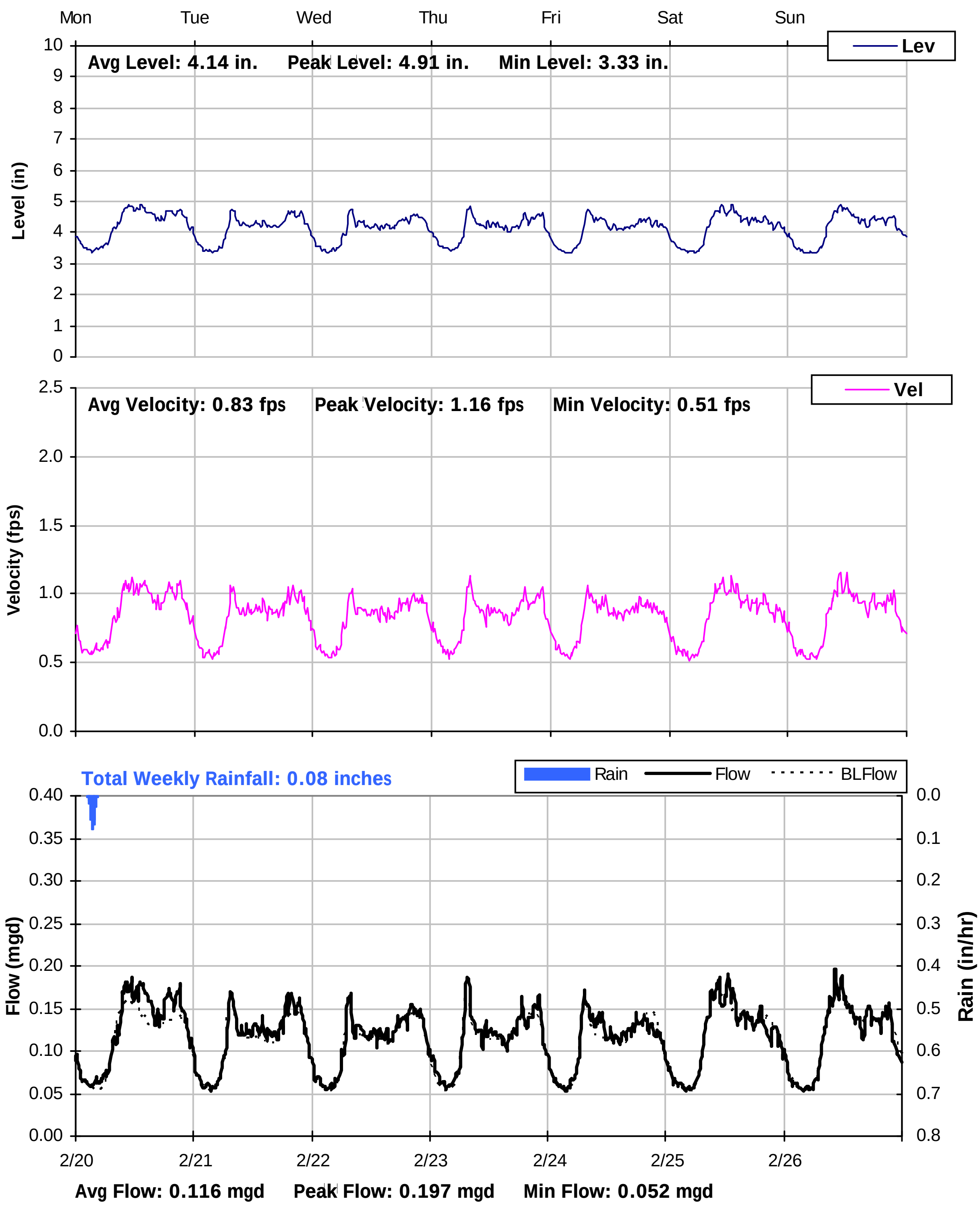
Combined I/I

Total I/I:	302,000	*gallons*
Total I/I:IDM:	7,176	*gal/IDM/in*
R-Value:	7.0%	
Total I/I:ADWF:	1.65	*per in-rain*

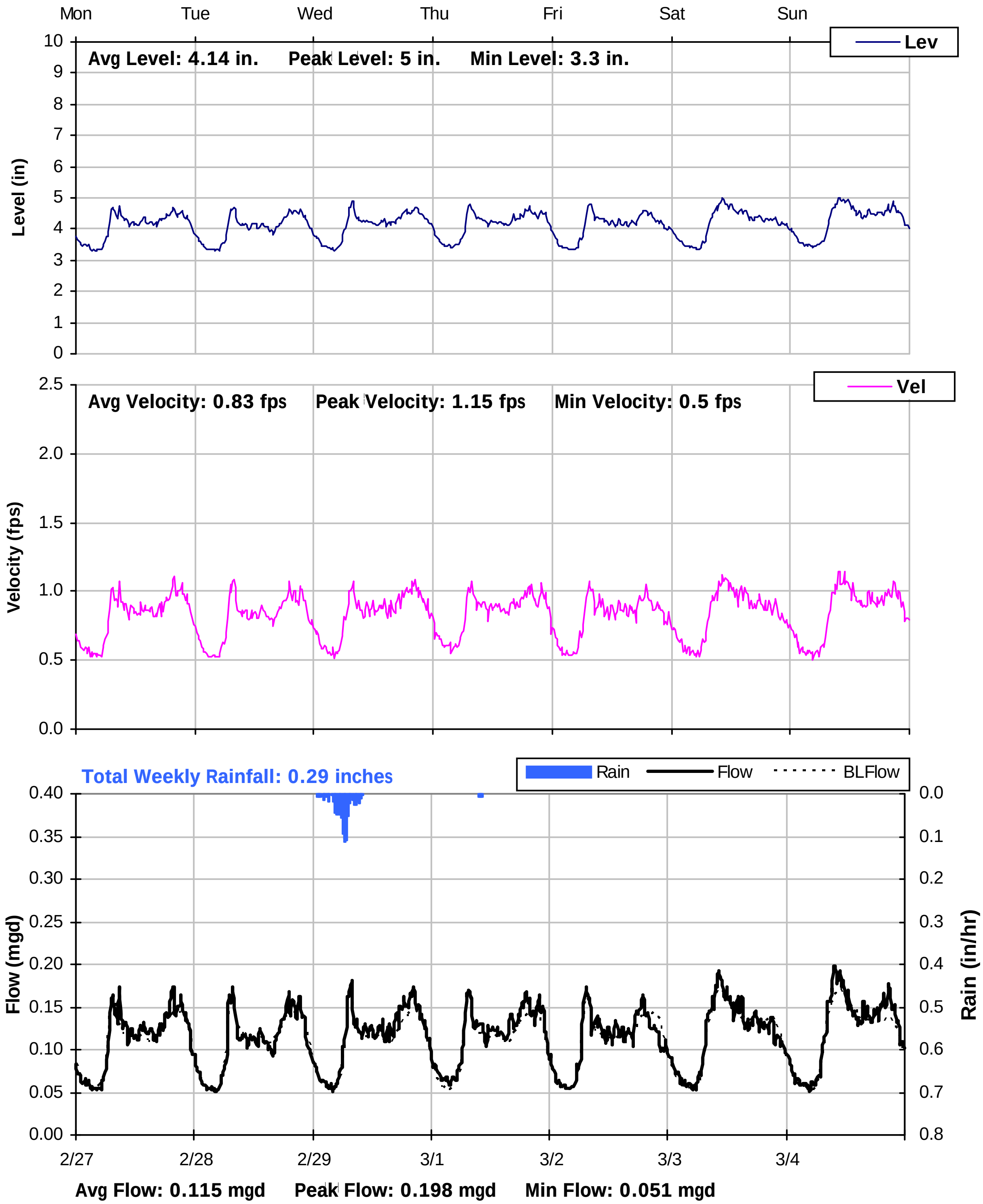
MH K28
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012



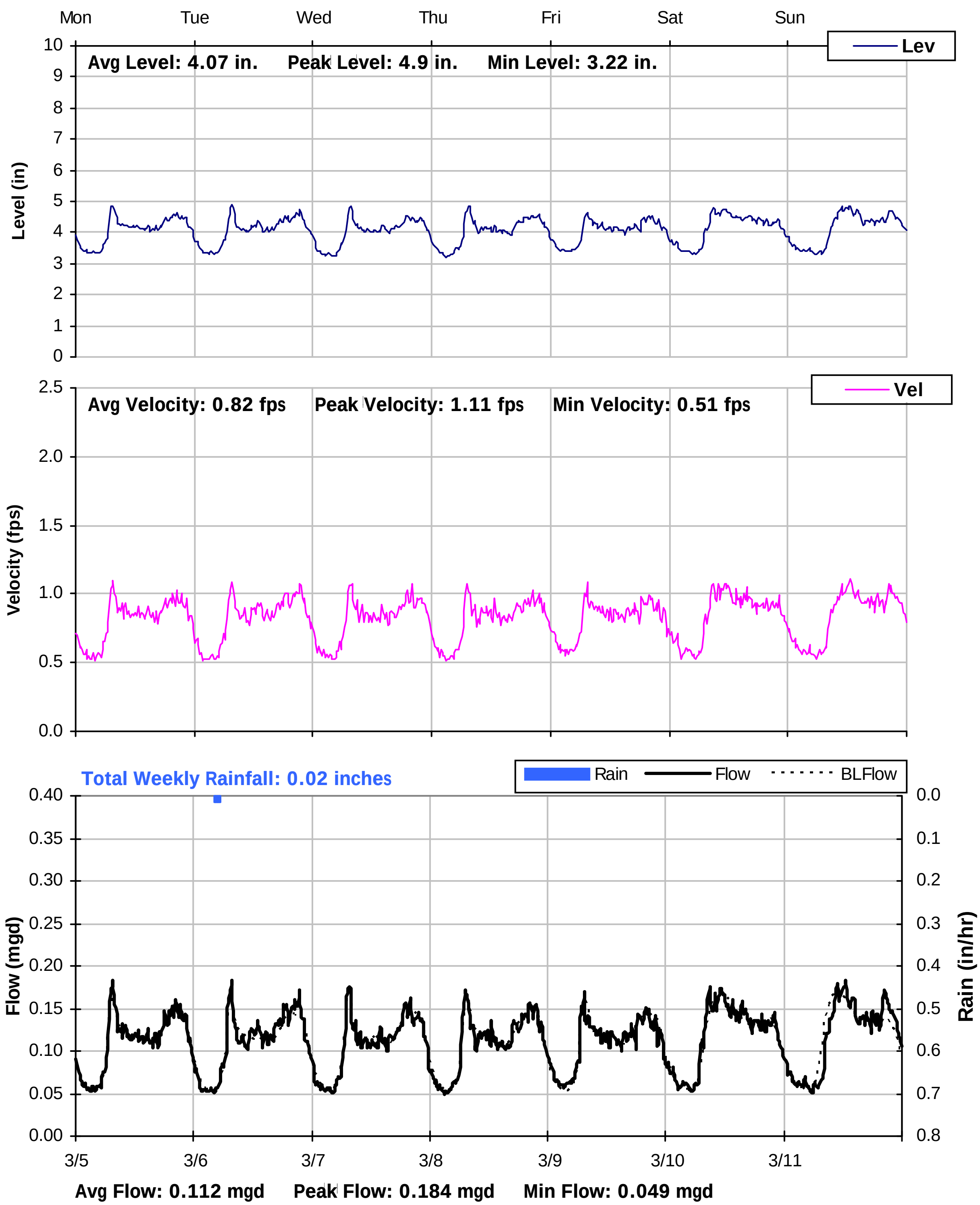
MH K28
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012



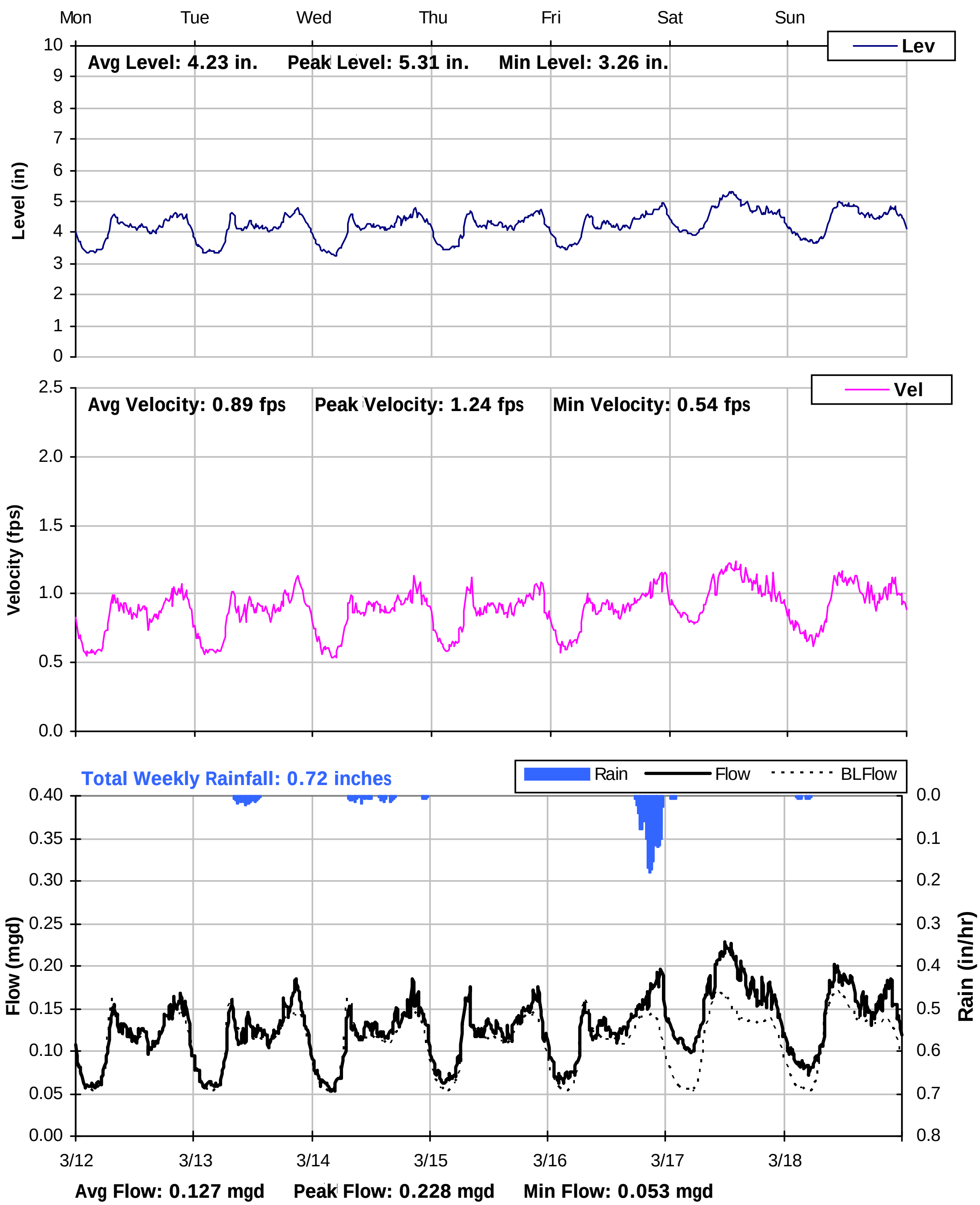
MH K28
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



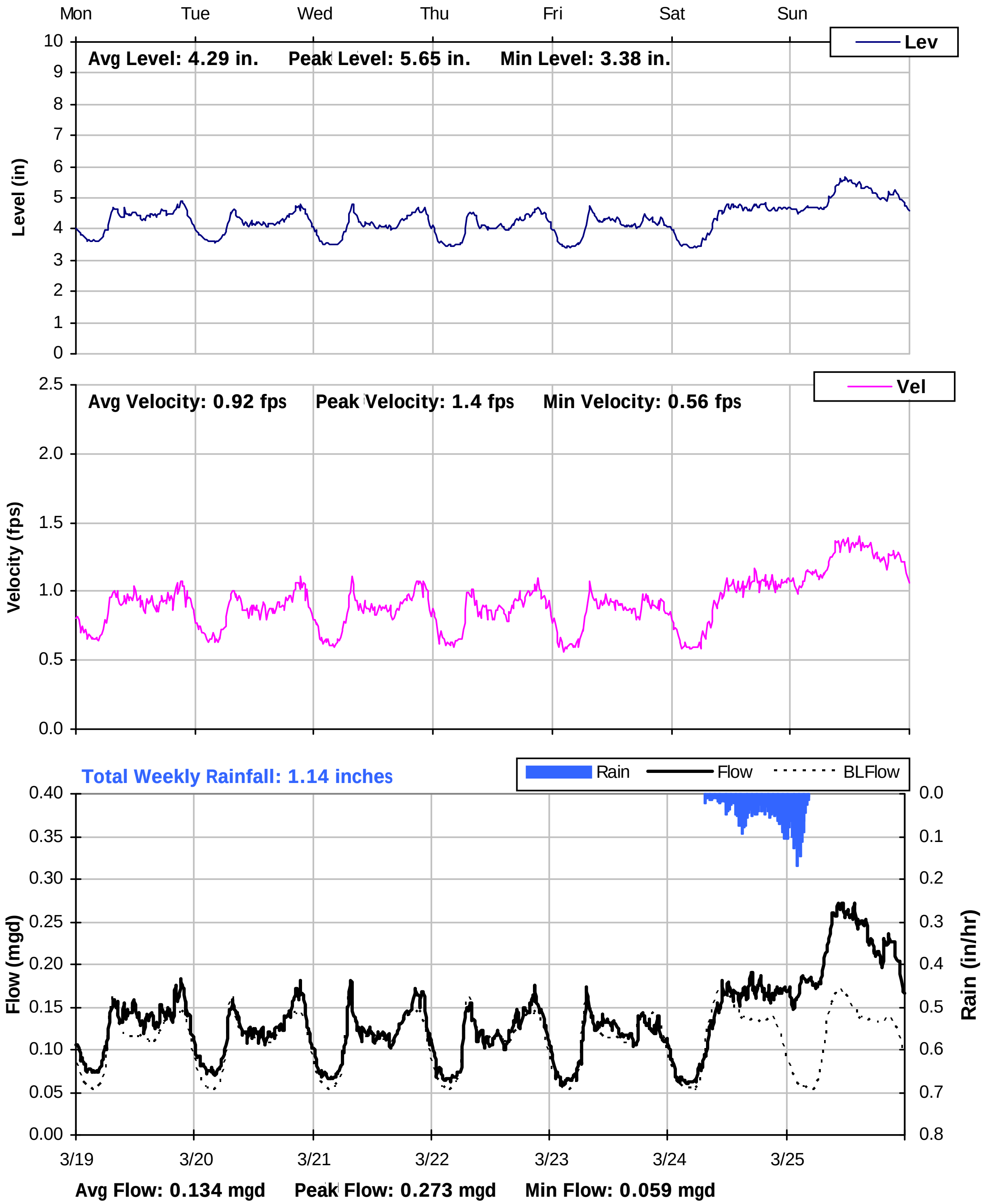
MH K28
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



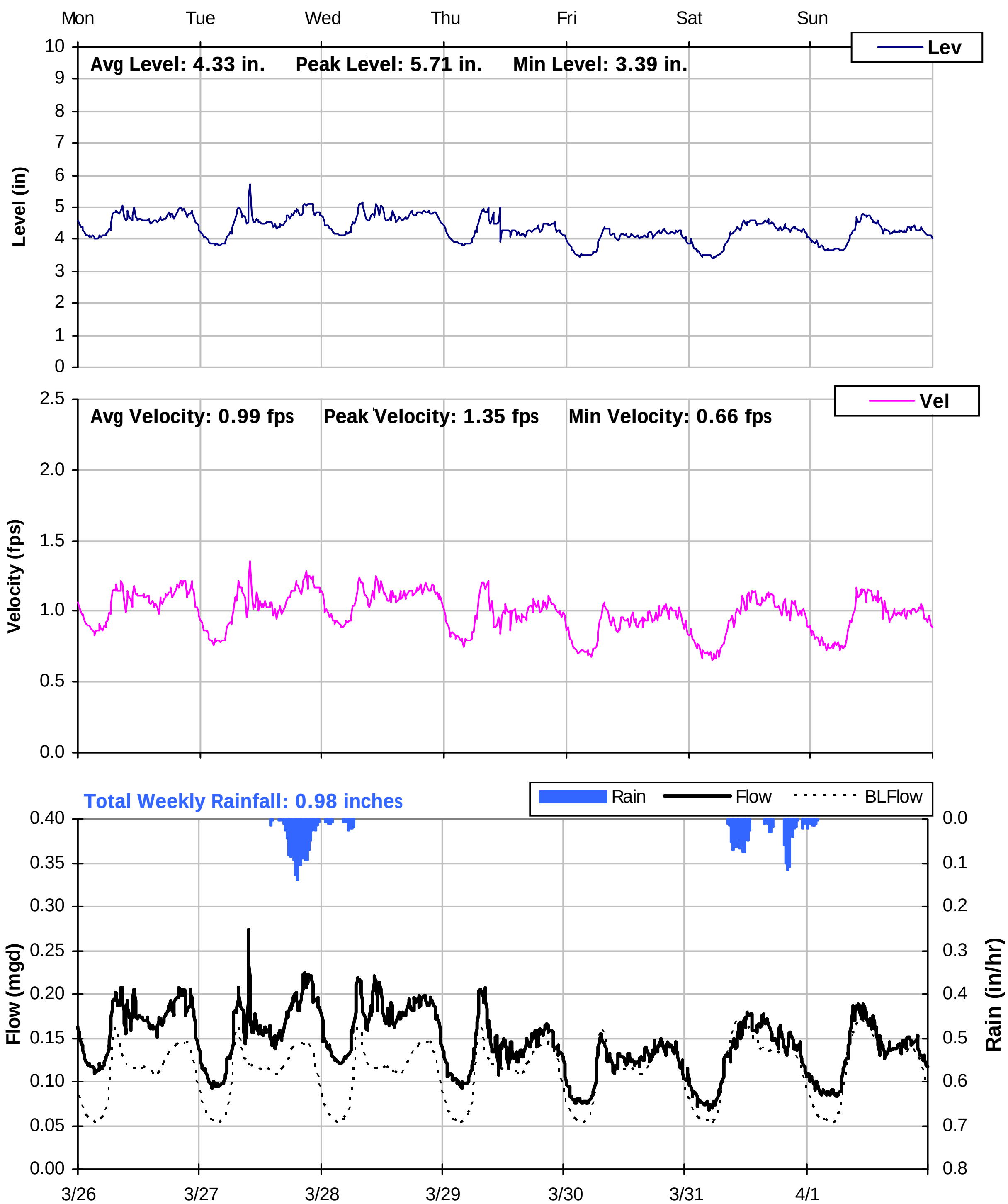
MH K28
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



MH K28
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012

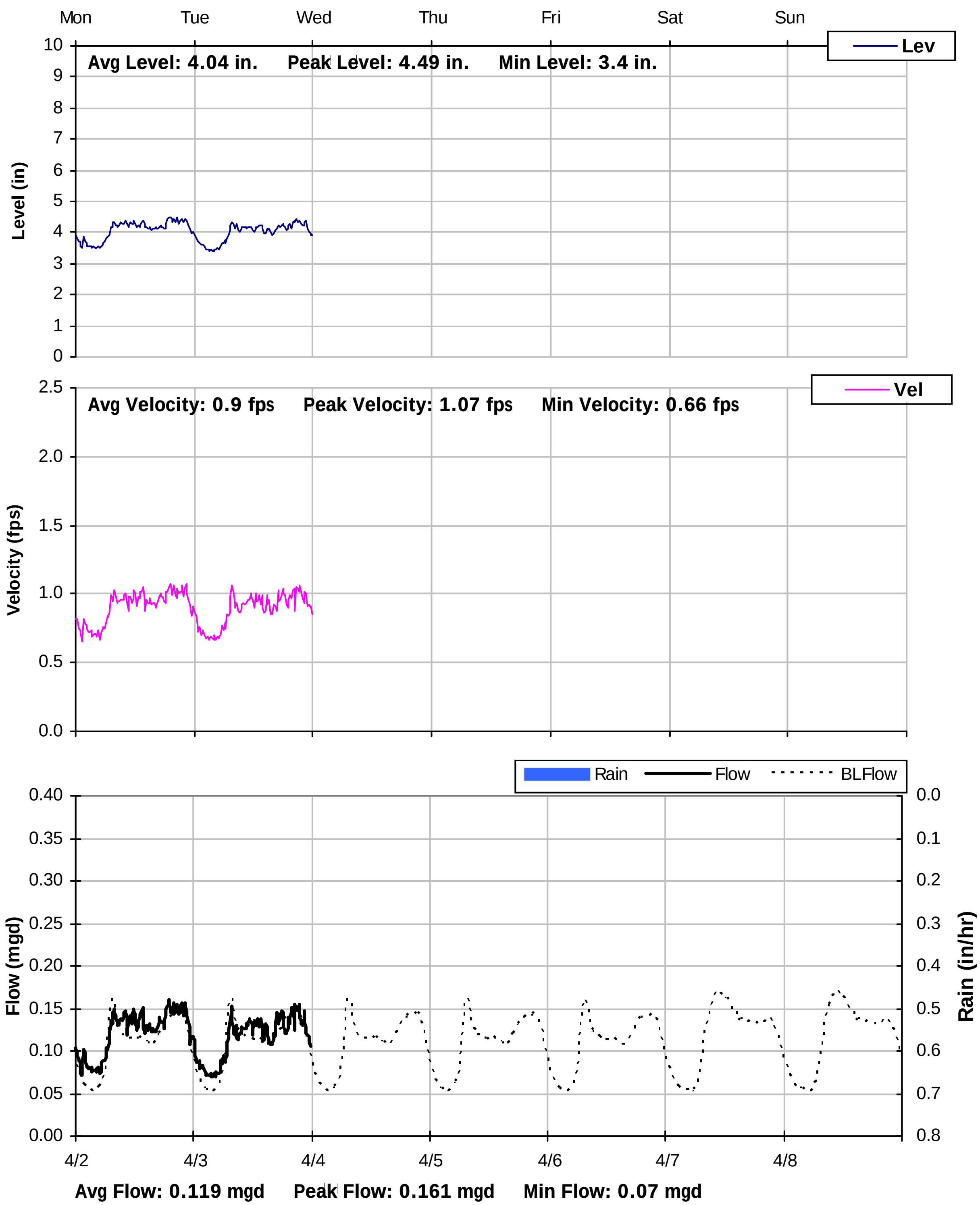


MH K28
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



Avg Flow: 0.145 mgd   Peak Flow: 0.274 mgd   Min Flow: 0.069 mgd

MH K28
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

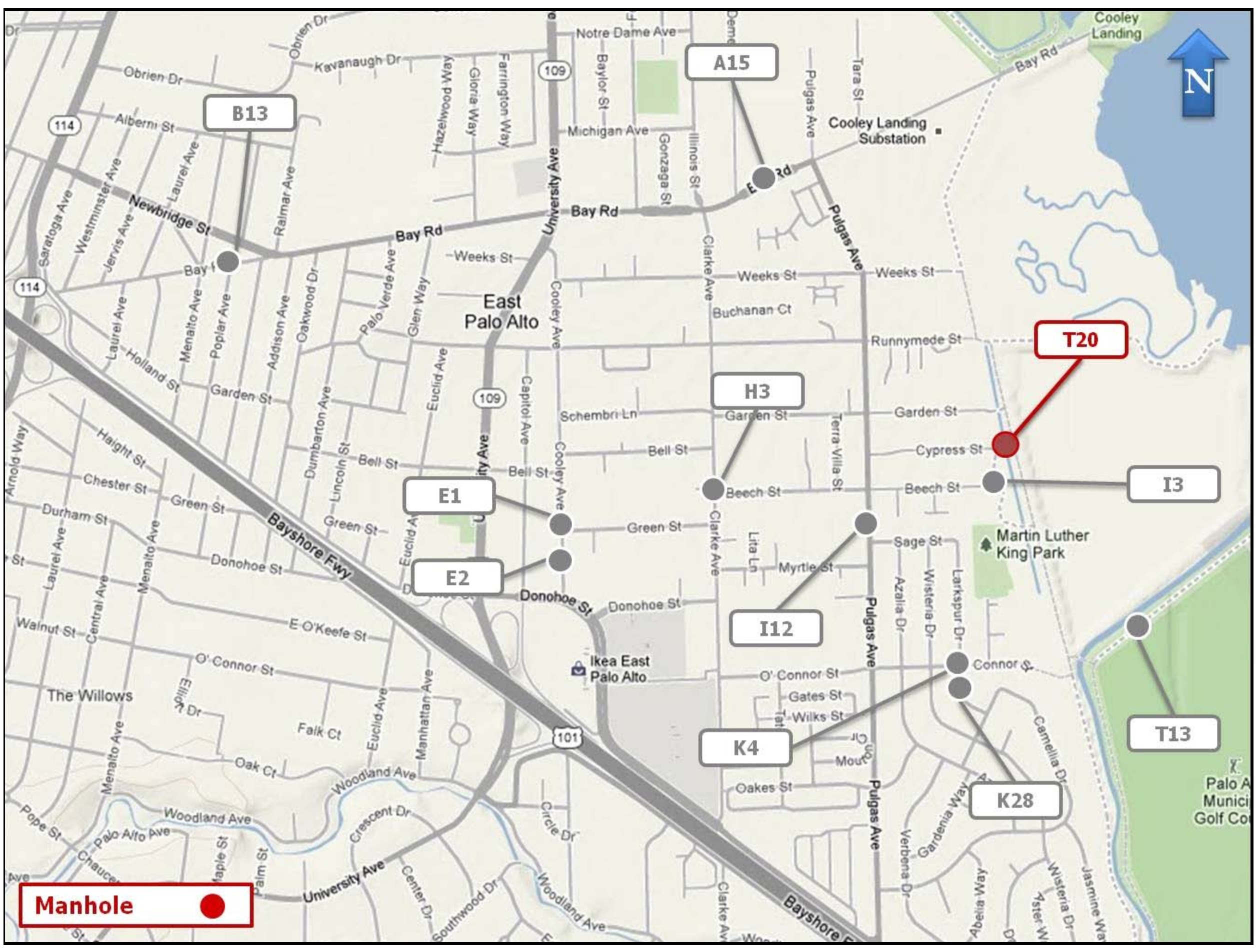
Year 2012

Monitoring Site: MH T20

Location: On the field, at the end of Cypress Street, east of Pulgas Avenue

Data Summary Report

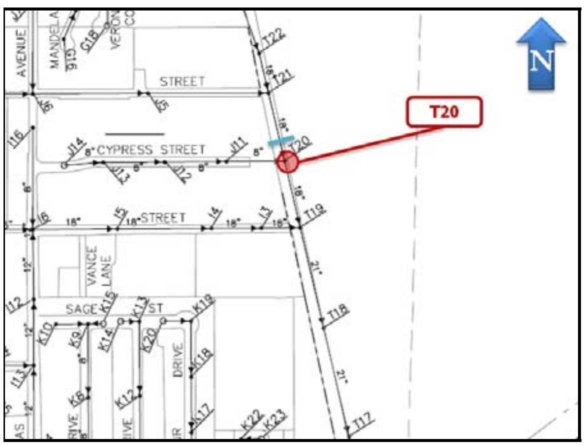
Vicinity Map:



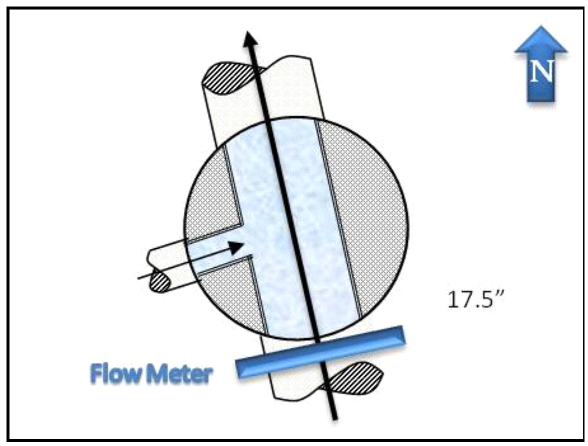
MH T20
Site Information Report

Location:	On the field, at the end of Cypress Street, east of Pulgas Avenue
Coordinates:	122.1260° W, 37.4661° N
Elevation:	5 feet
Diameter:	17.5 inches
Baseline Flow:	0.401 mgd
Peak Measured Flow:	0.763 mgd

Satellite Map



Sanitary Sewer Map



Flow Sketch

View from Street

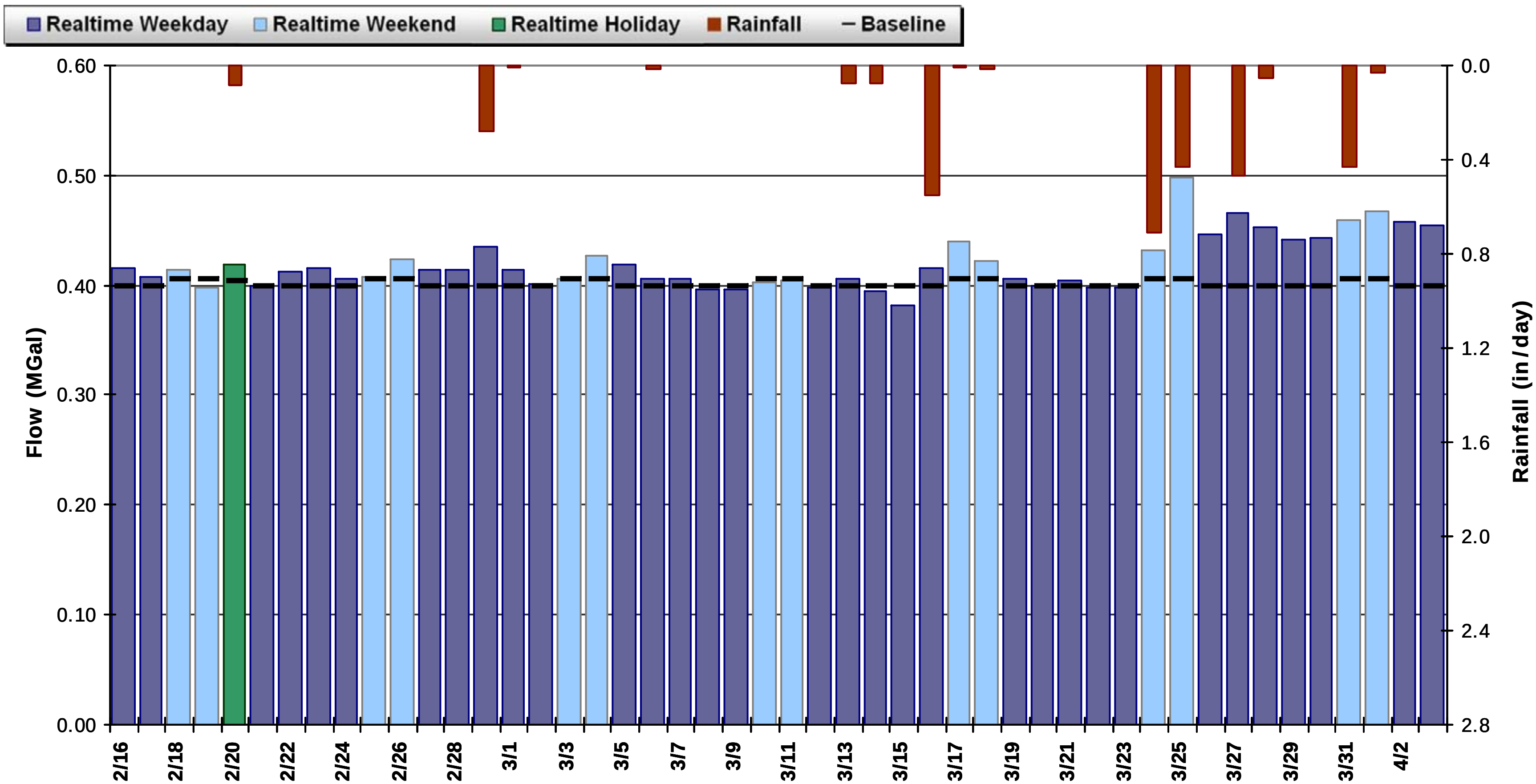
Plan View

MH T20

Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 0.420 MGal **Peak Daily Flow: 0.499 MGal** **Min Daily Flow: 0.382 MGal**

Total Period Rainfall: 3.24 inches

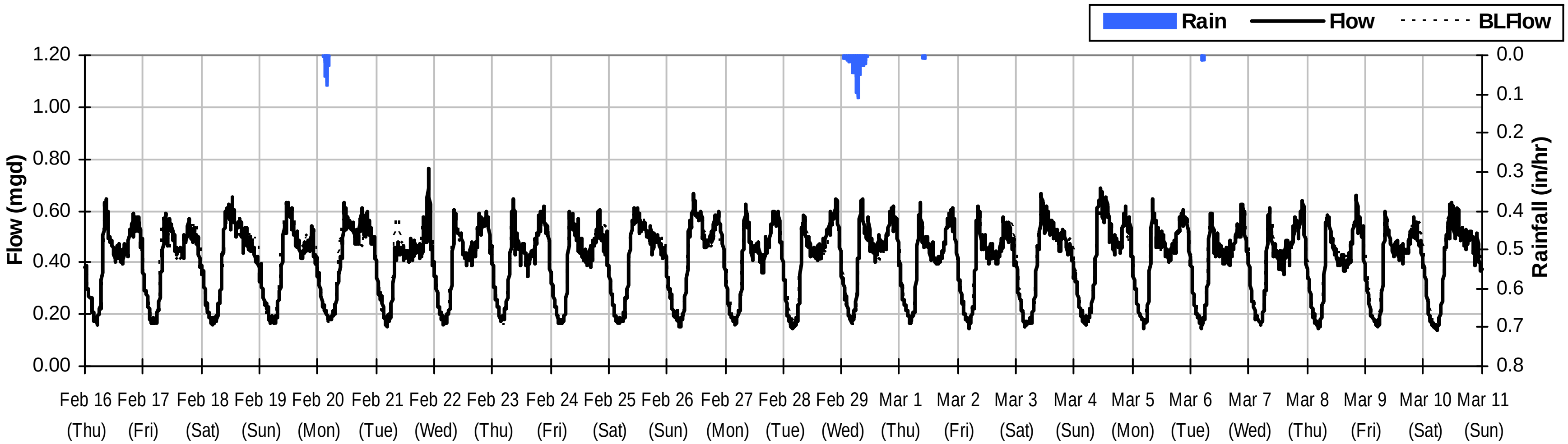


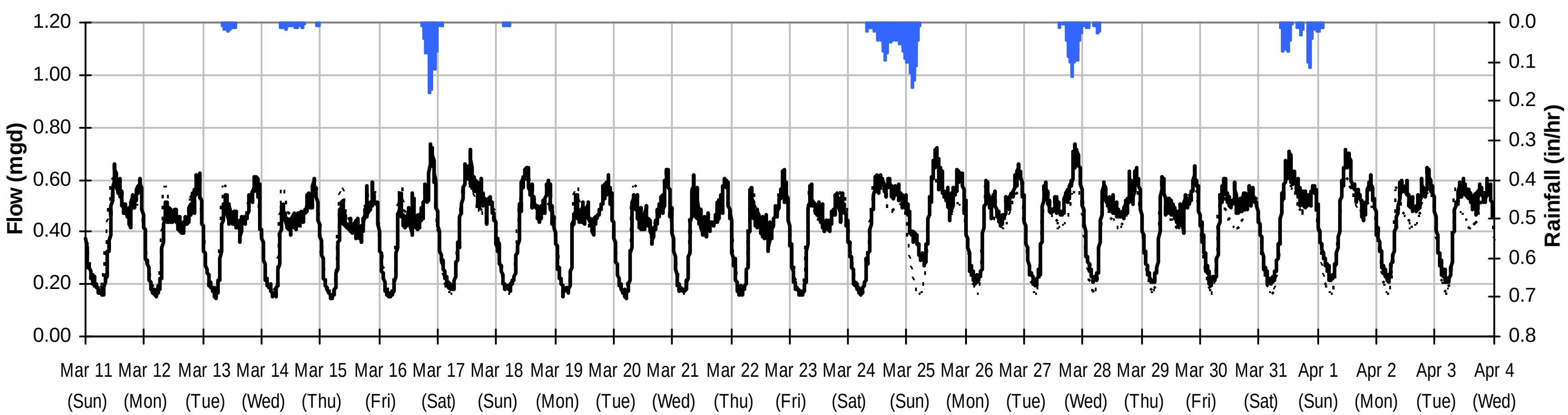
MH T20

Period Flow Summary: February 16 to April 4, 2012

Avg Flow: 0.420 mgd **Peak Flow: 0.763 mgd** **Min Flow: 0.140 mgd**

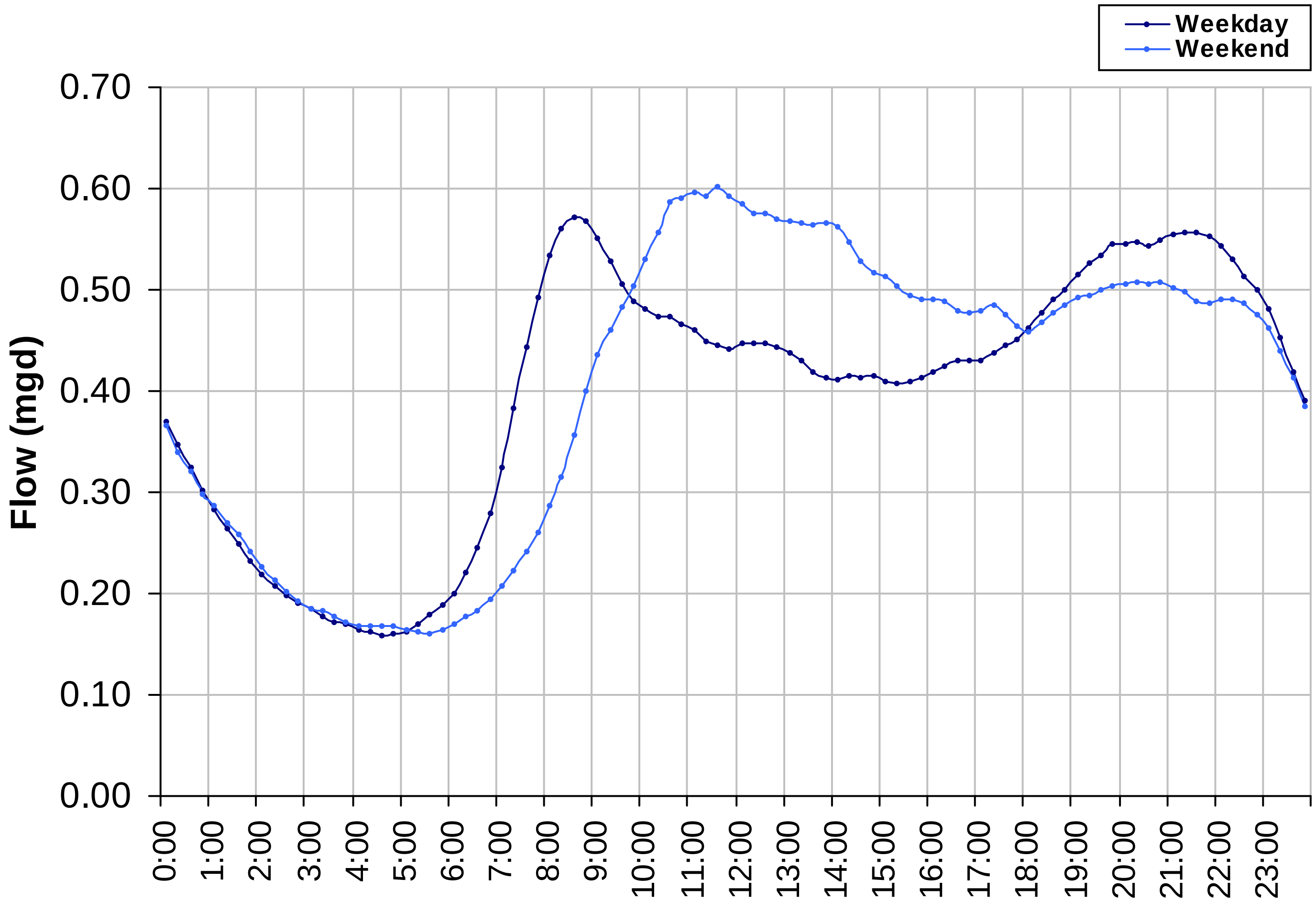
Total Period Rainfall: 3.24 inches





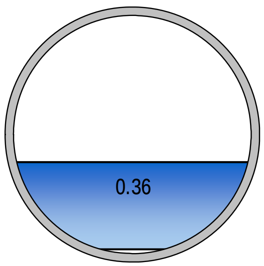
MH T20

Baseline Flow Hydrographs



Baseline Flow:

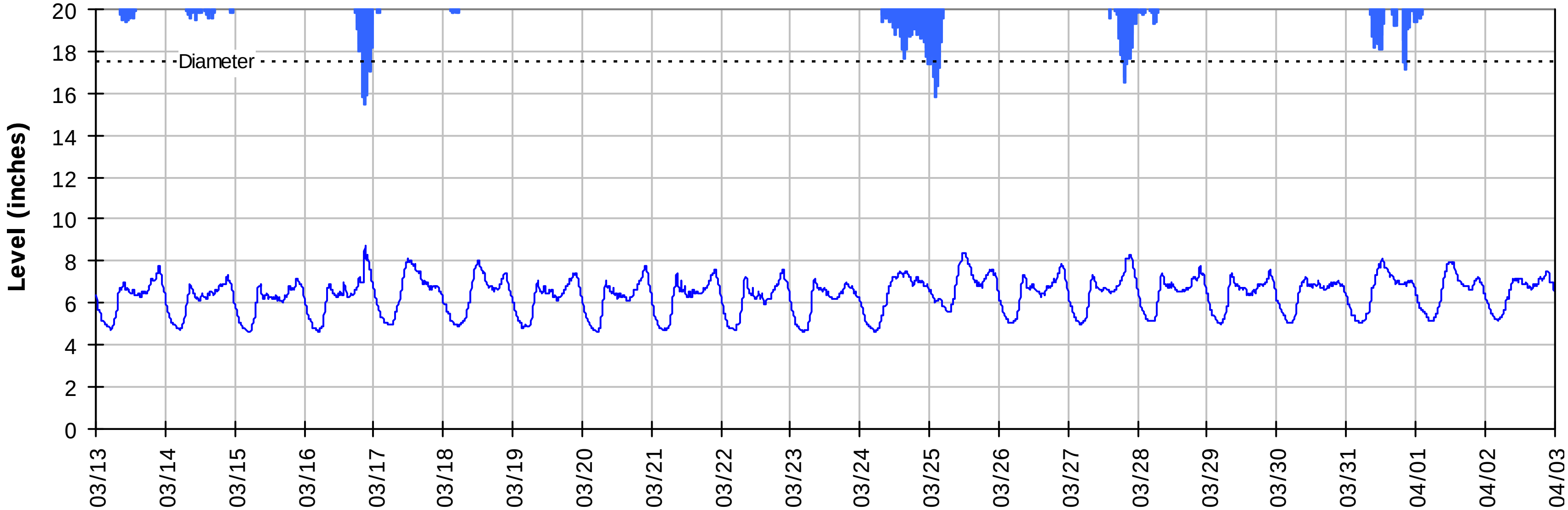
0.401 *mgd*

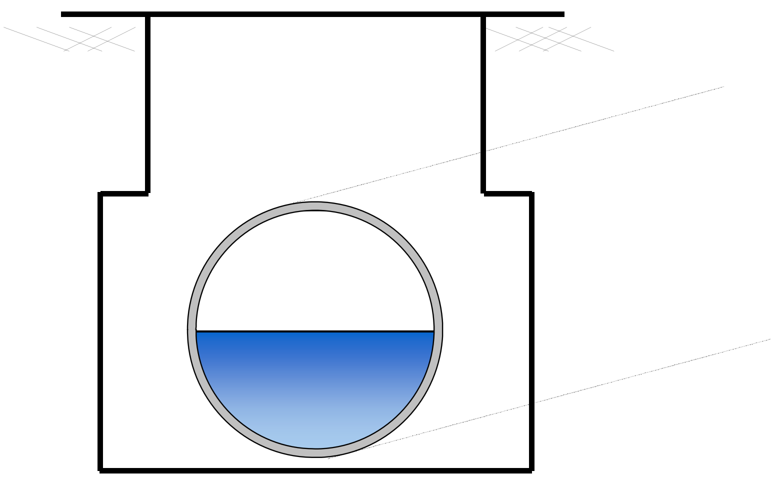


MH T20

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period





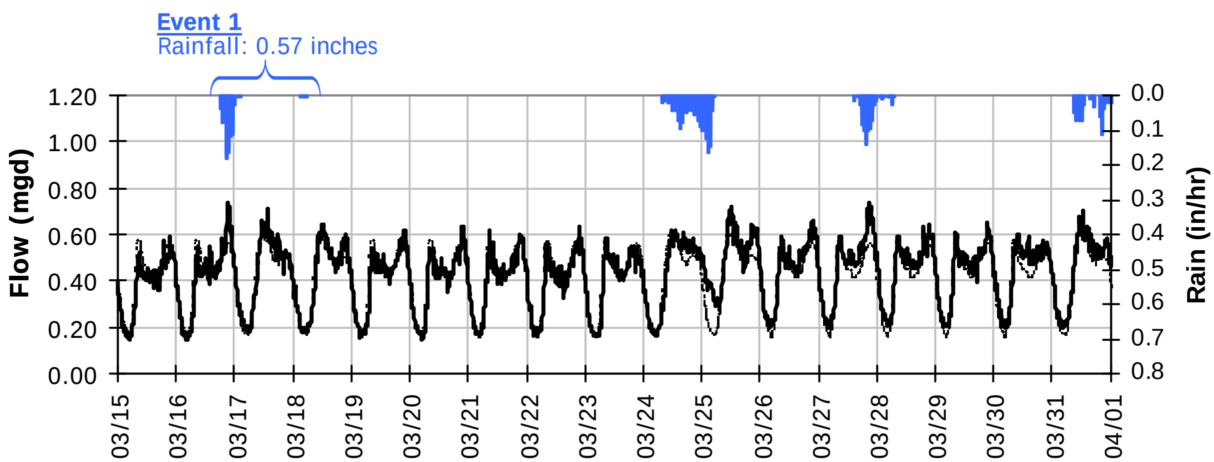
Pipe Diameter: 17.5 *inches*

Peak Measured Level: 8.7 *inches*

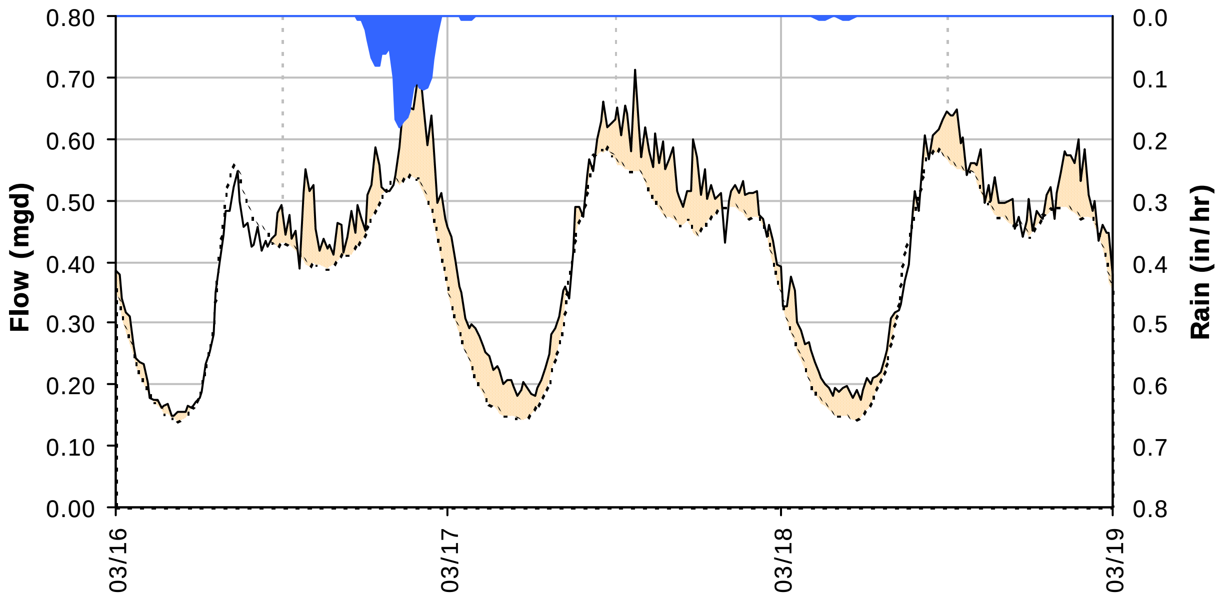
Peak d/D Ratio: 0.50

MH T20
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph

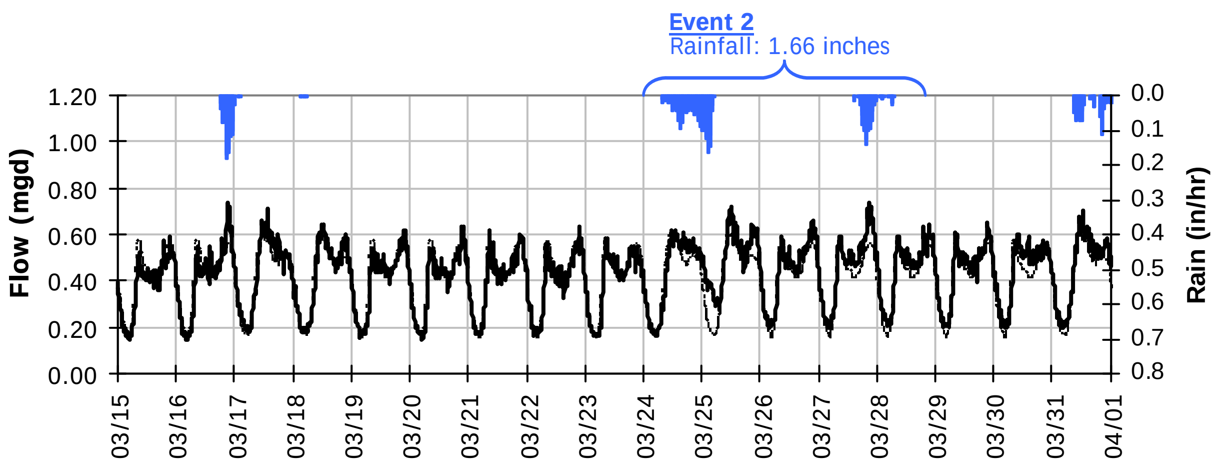


Storm Event I/I Analysis (Rain = 0.57 inches)

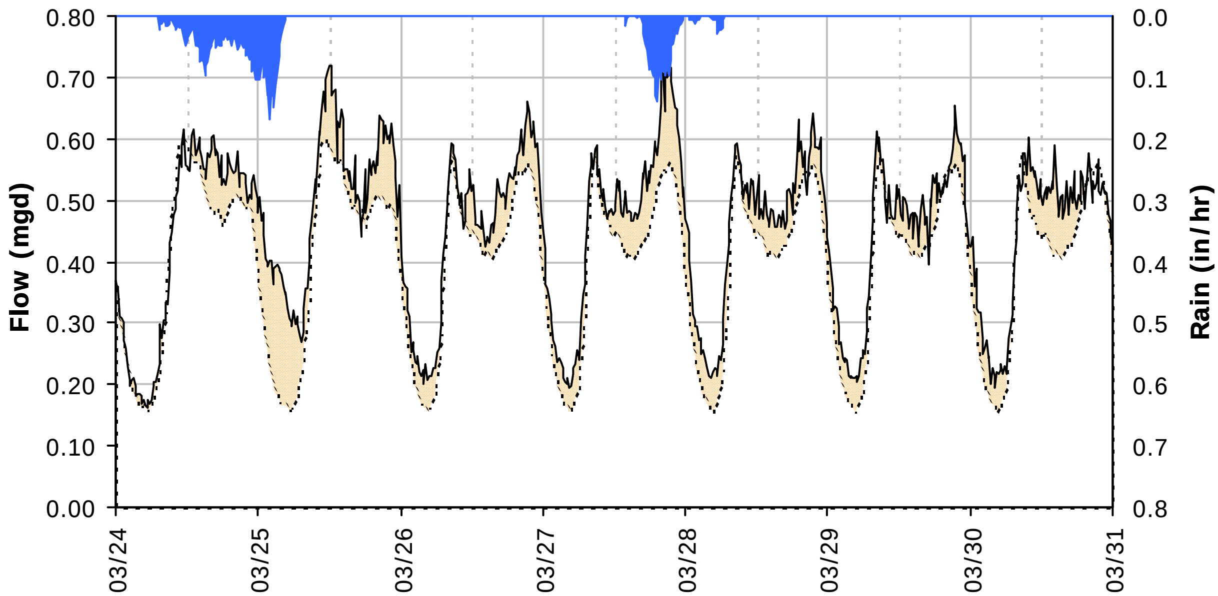
Capacity		Inflow		RDI (infiltration)		Combined I/I	
Peak Flow:	0.74 *mgd*	**Peak I/I Rate:**	0.18 *mgd*	**Infiltration Rate:** (3/18/2012)	0.017 *mgd*	**Total I/I:**	109,000 *gallons*
PF:	1.84	**PkI/I:IDM:**	2,074 *gpd/IDM*	**RDI:IDM:**	192 *gpd/IDM*	**Total I/I:IDM:**	2,177 *gal/IDM/in*
Peak Level:	8.70 *in*	**PkI/I:Acre:**	485 *gpd/acre*	**RDI:Acre:**	45 *gpd/acre*	**R-Value:**	1.9%
d/D Ratio:	0.50	**Pk I/I:ADWF:**	0.45	**RDI (% of BL):**	4%	**Total I/I:ADWF:**	0.48 *per in-rain*

MH T20
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



Storm Event I/I Analysis (Rain = 1.66 inches)

Capacity

Peak Flow:	0.73 *mgd*
PF:	1.83
Peak Level:	8.42 *in*
d/D Ratio:	0.48

Inflow

Peak I/I Rate:	0.22 *mgd*
PkI/I:IDM:	2,455 *gpd/IDM*
PkI/I:Acre:	574 *gpd/acre*
Pk I/I:ADWF:	0.54

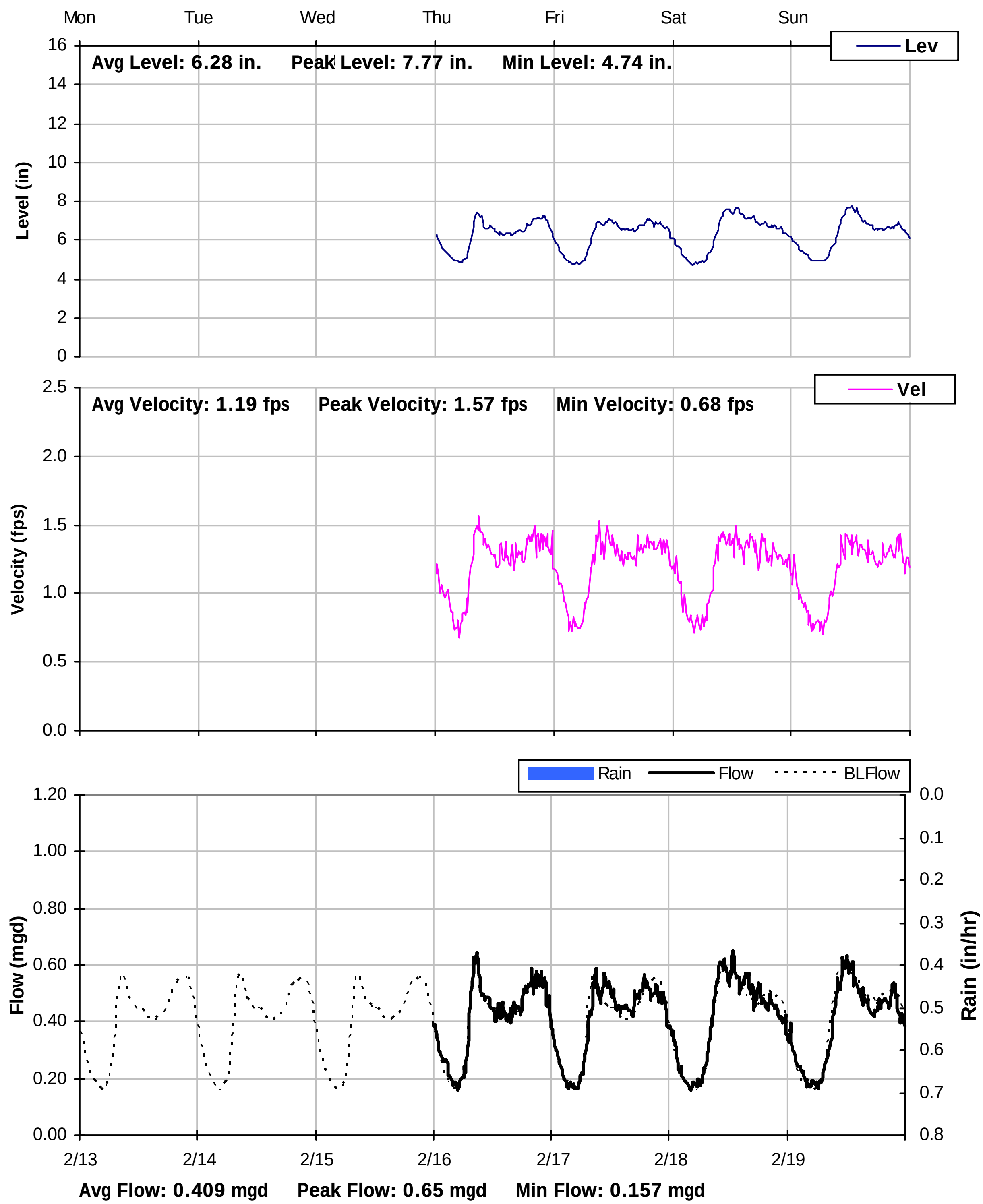
RDI (infiltration)

Infiltration Rate: (3/26/2012)	0.048 *mgd*
RDI:IDM:	543 *gpd/IDM*
RDI:Acre:	127 *gpd/acre*
RDI (% of BL):	12%

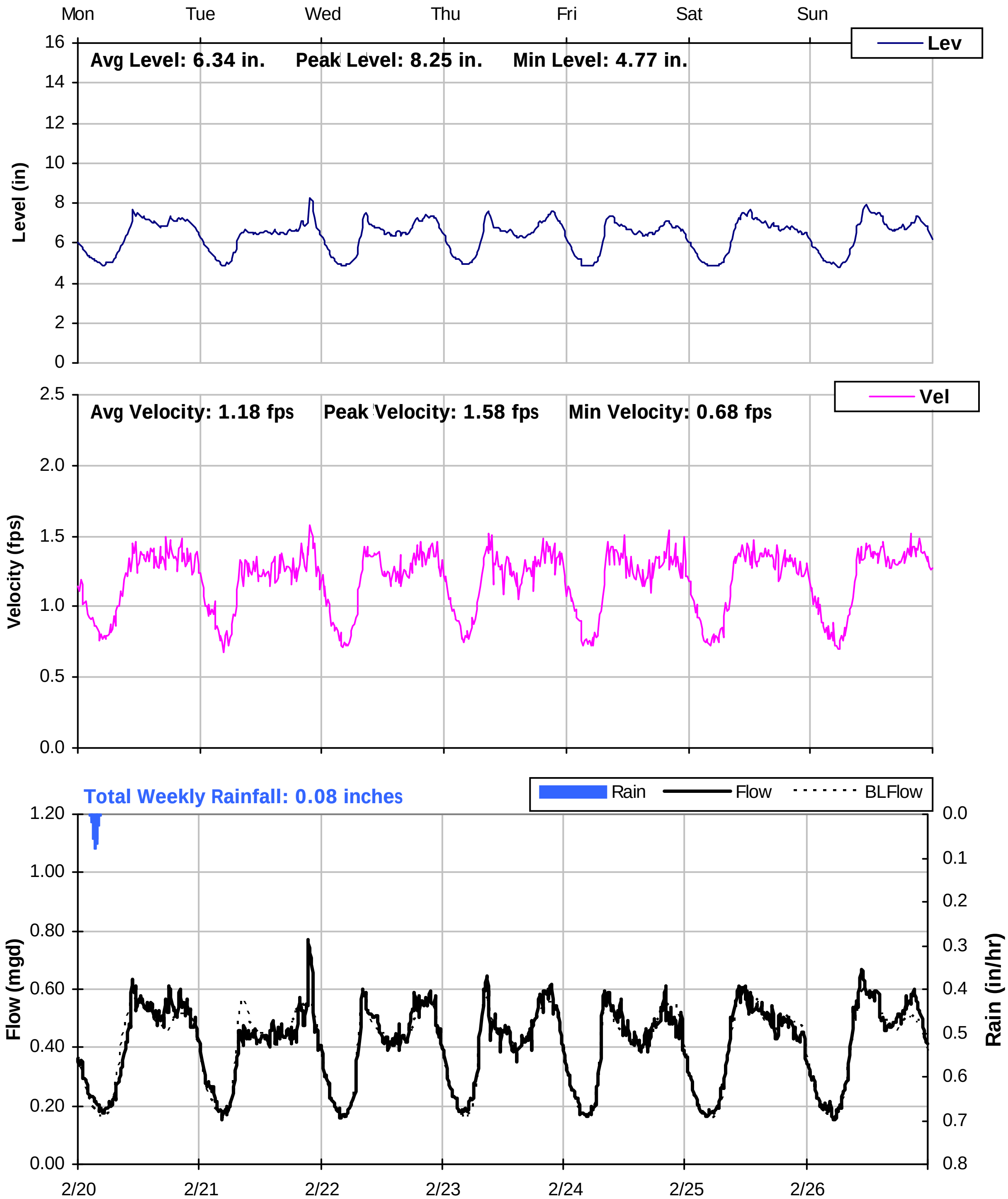
Combined I/I

Total I/I:	383,000 *gallons*
Total I/I:IDM:	2,624 *gal/IDM/in*
R-Value:	2.3%
Total I/I:ADWF:	0.57 *per in-rain*

MH T20
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012

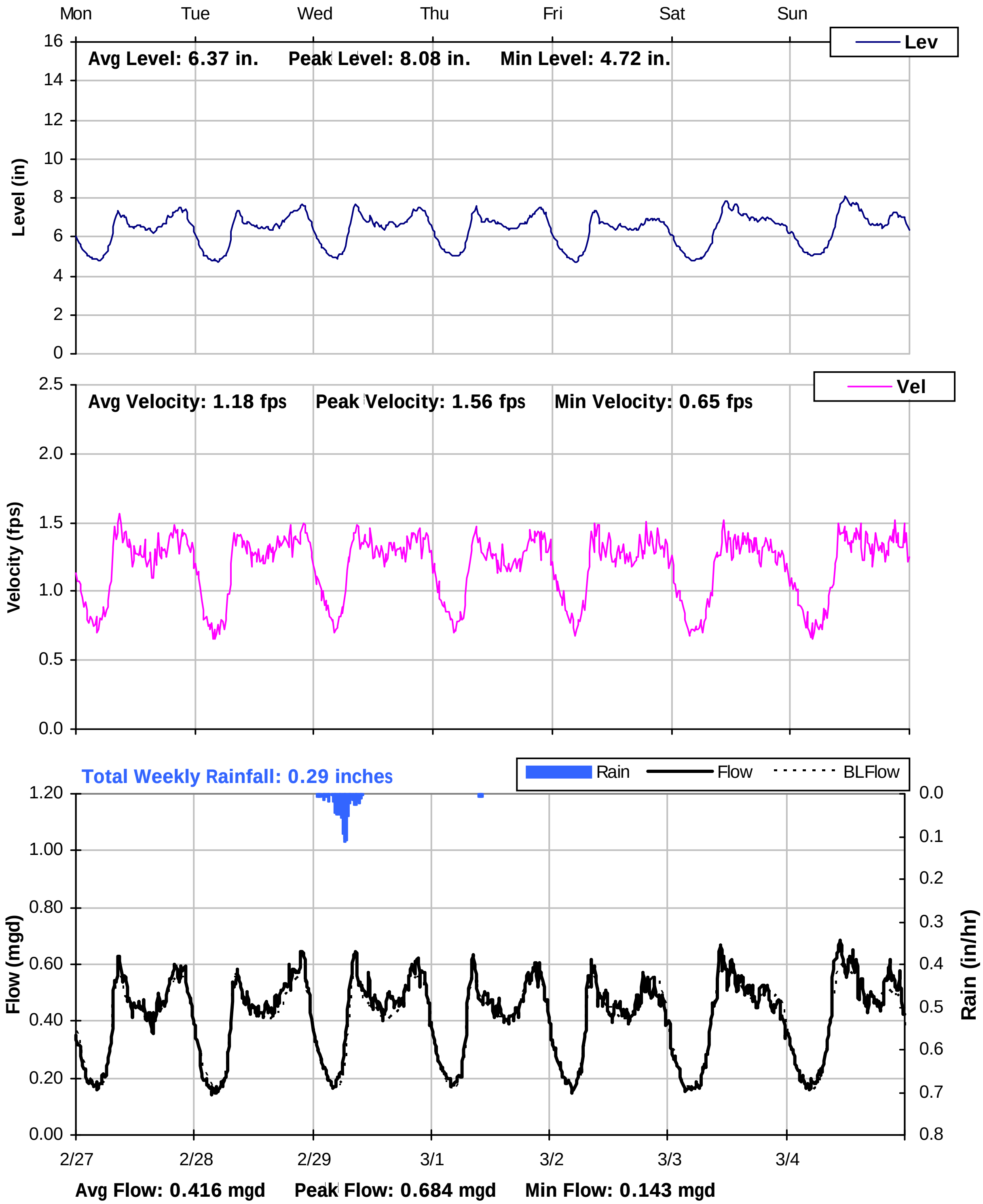


MH T20
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012

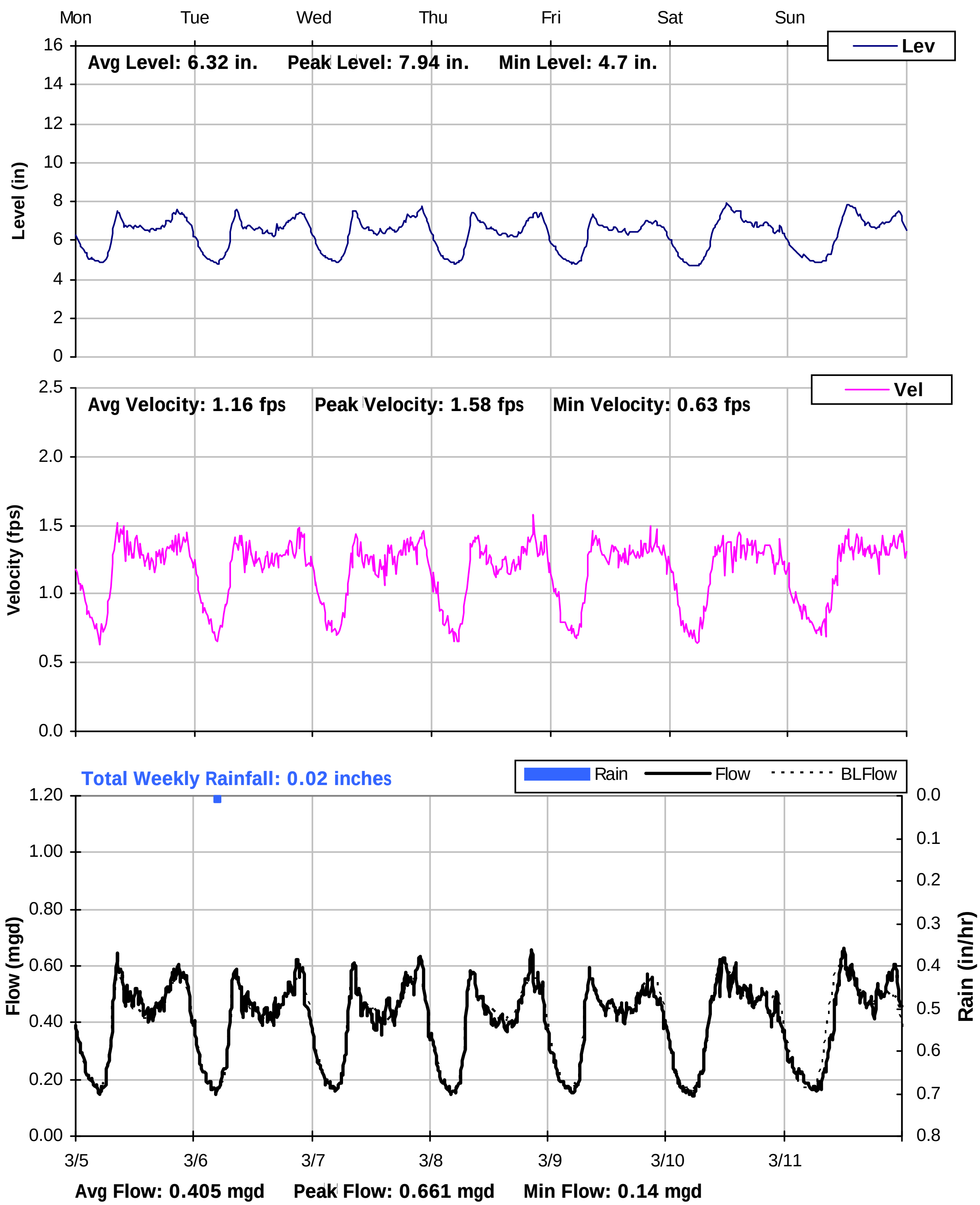


Avg Flow: 0.412 mgd Peak Flow: 0.763 mgd Min Flow: 0.154 mgd

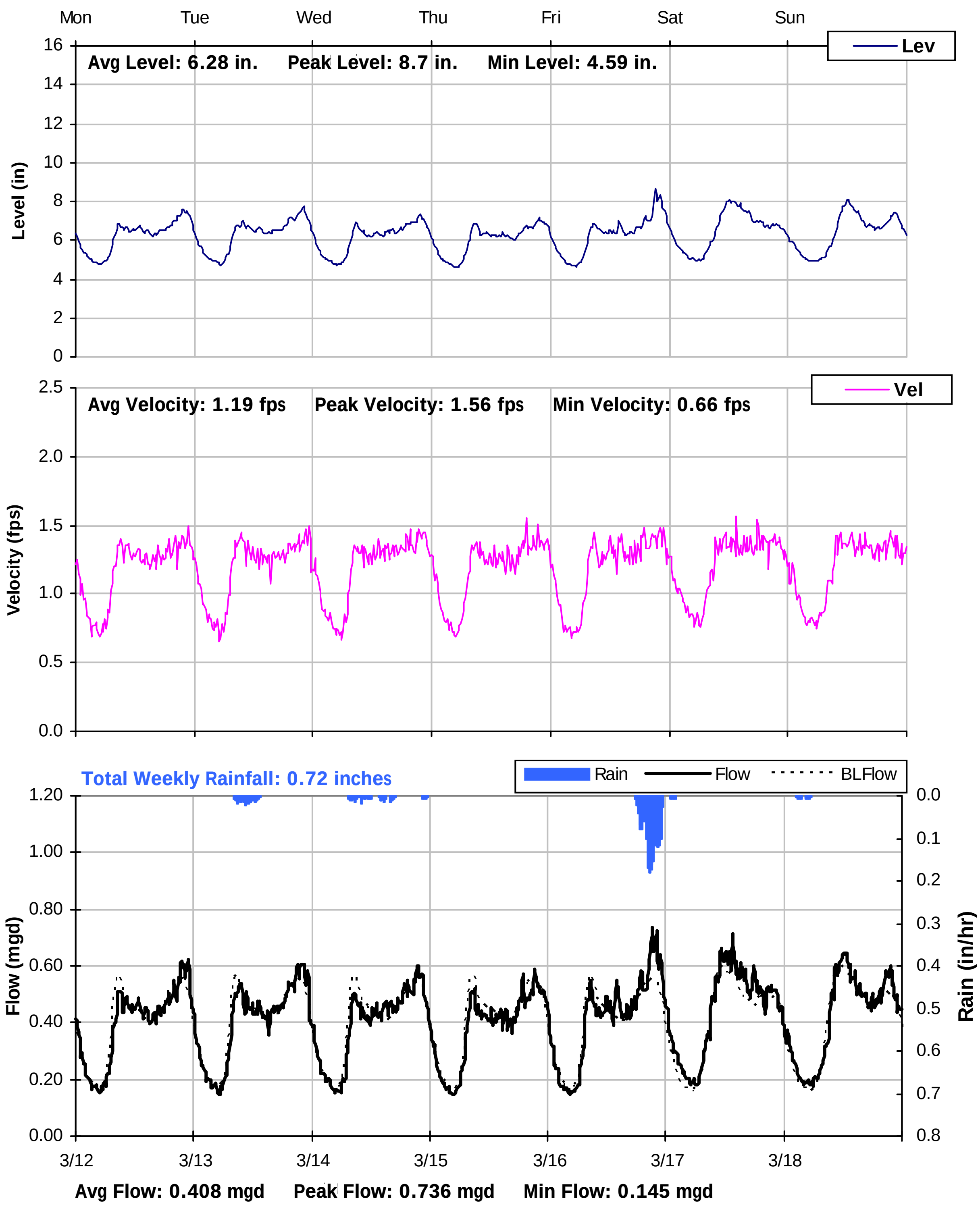
MH T20
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



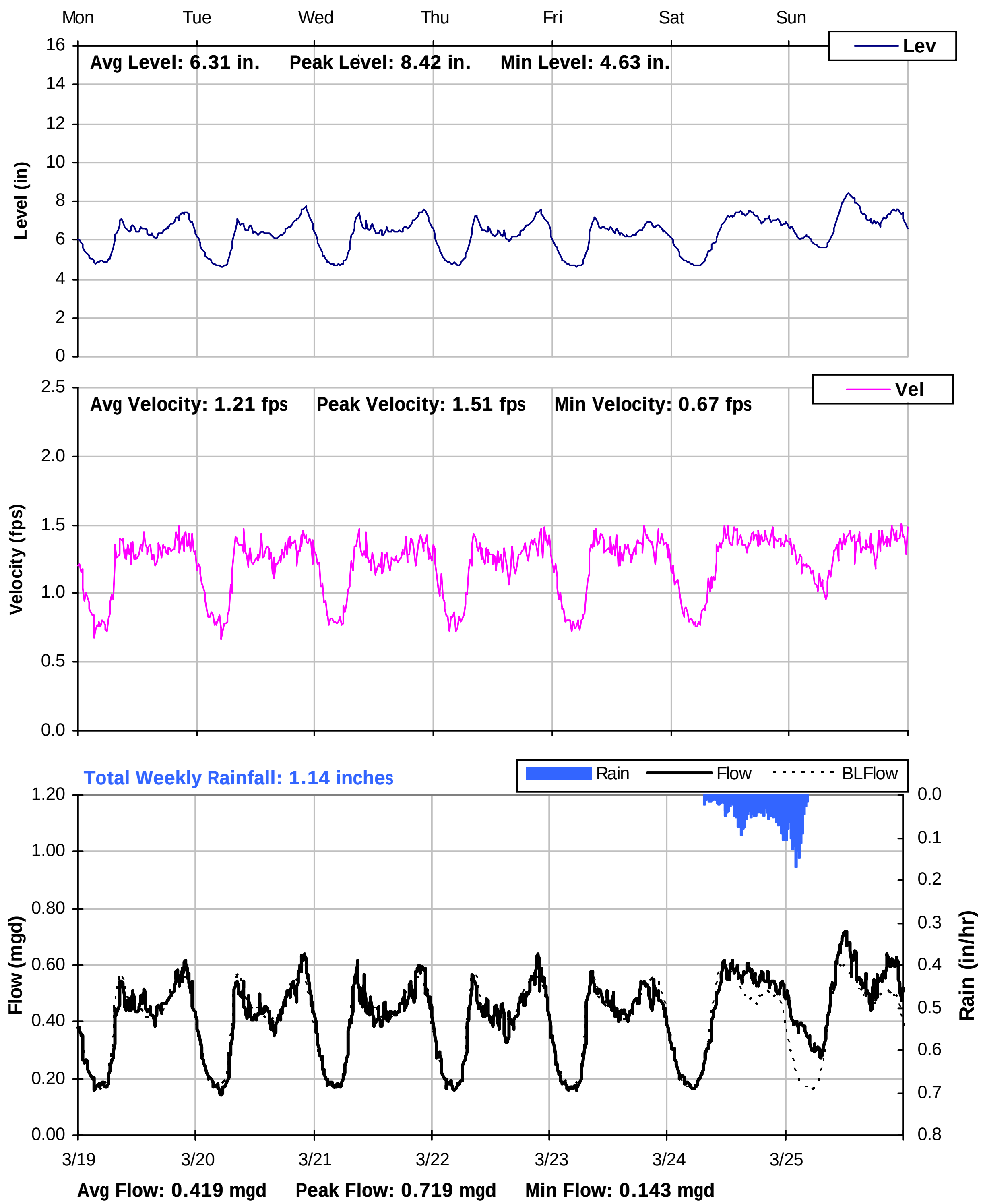
MH T20
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



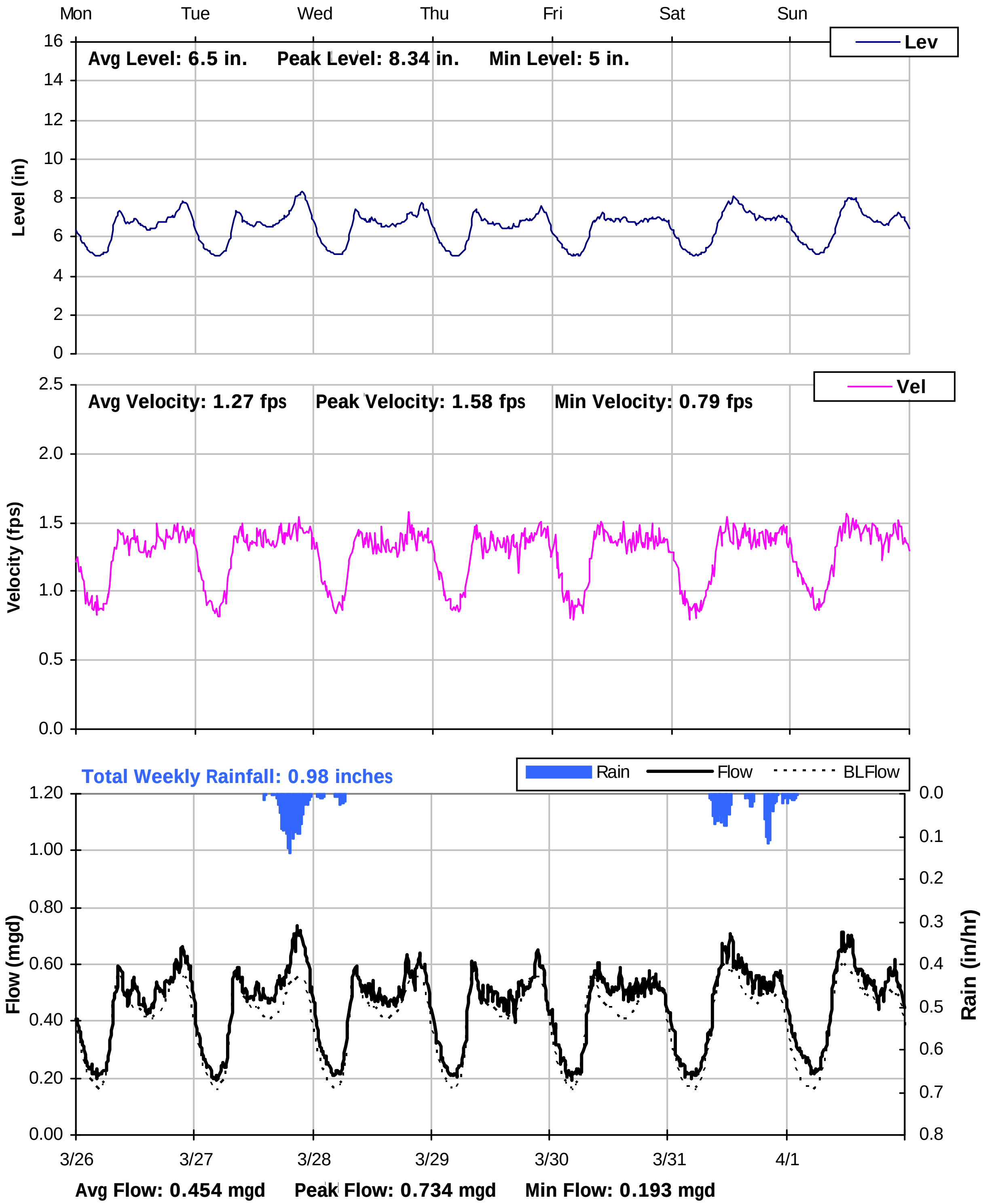
MH T20
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



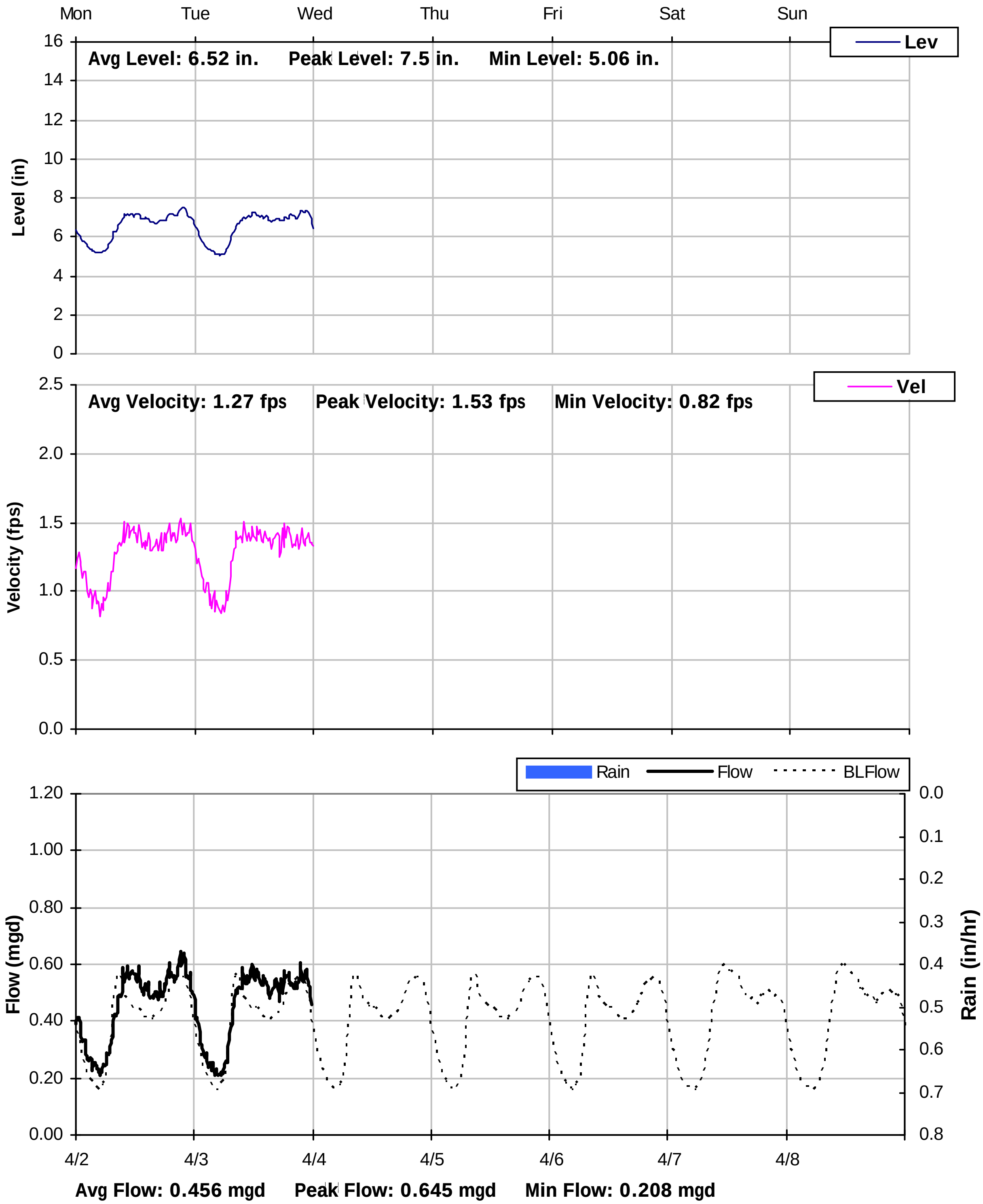
MH T20
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012



MH T20
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



MH T20
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012



East Palo Alto Sanitary District

Sanitary Sewer Flow Monitoring and I/I Study

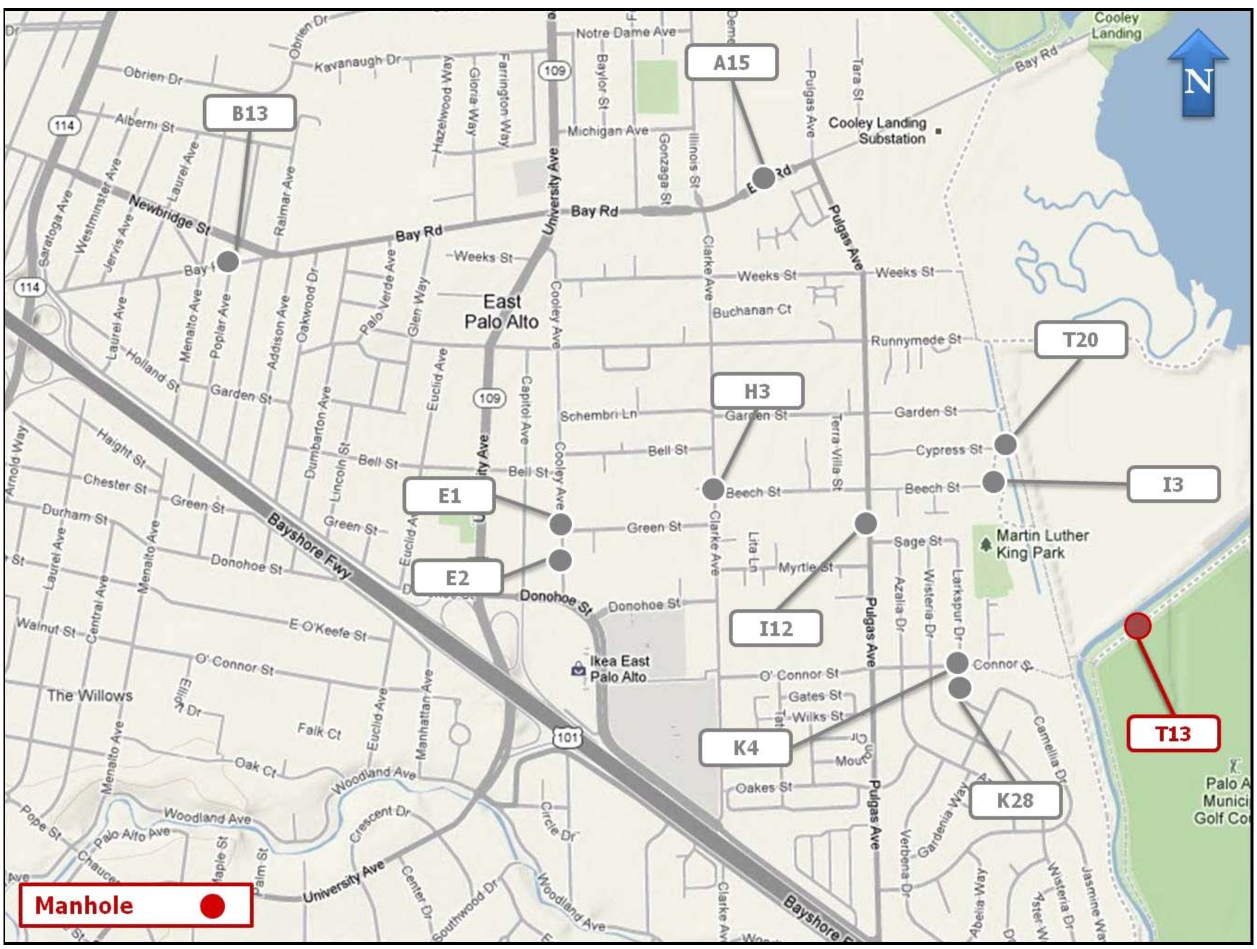
Year 2012

Monitoring Site: MH T13

Location: Northwest side of Palo Alto Golf Course

Data Summary Report

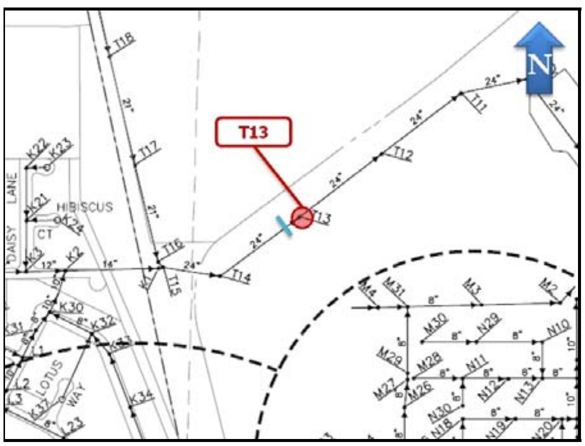
Vicinity Map:



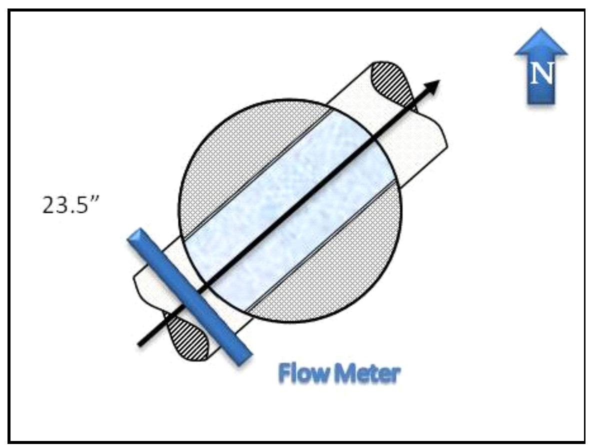
MH T13
Site Information Report

Location:	Northwest side of Palo Alto Golf Course
Coordinates:	122.1221° W, 37.4618° N
Elevation:	8 feet
Diameter:	23.5 inches
Baseline Flow:	1.53 mgd
Peak Measured Flow:	2.8 mgd

Satellite Map

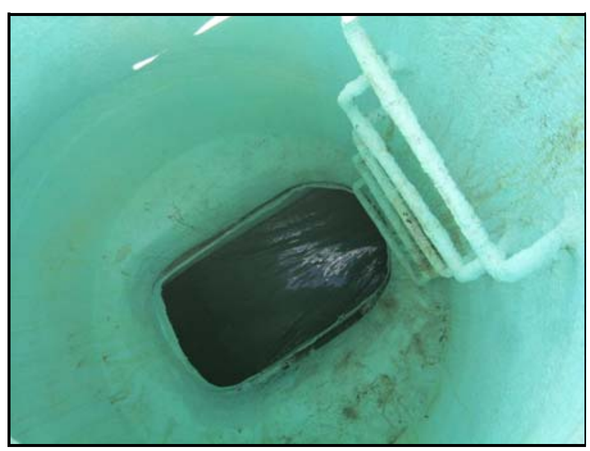


Sanitary Sewer Map



Flow Sketch

View from Street

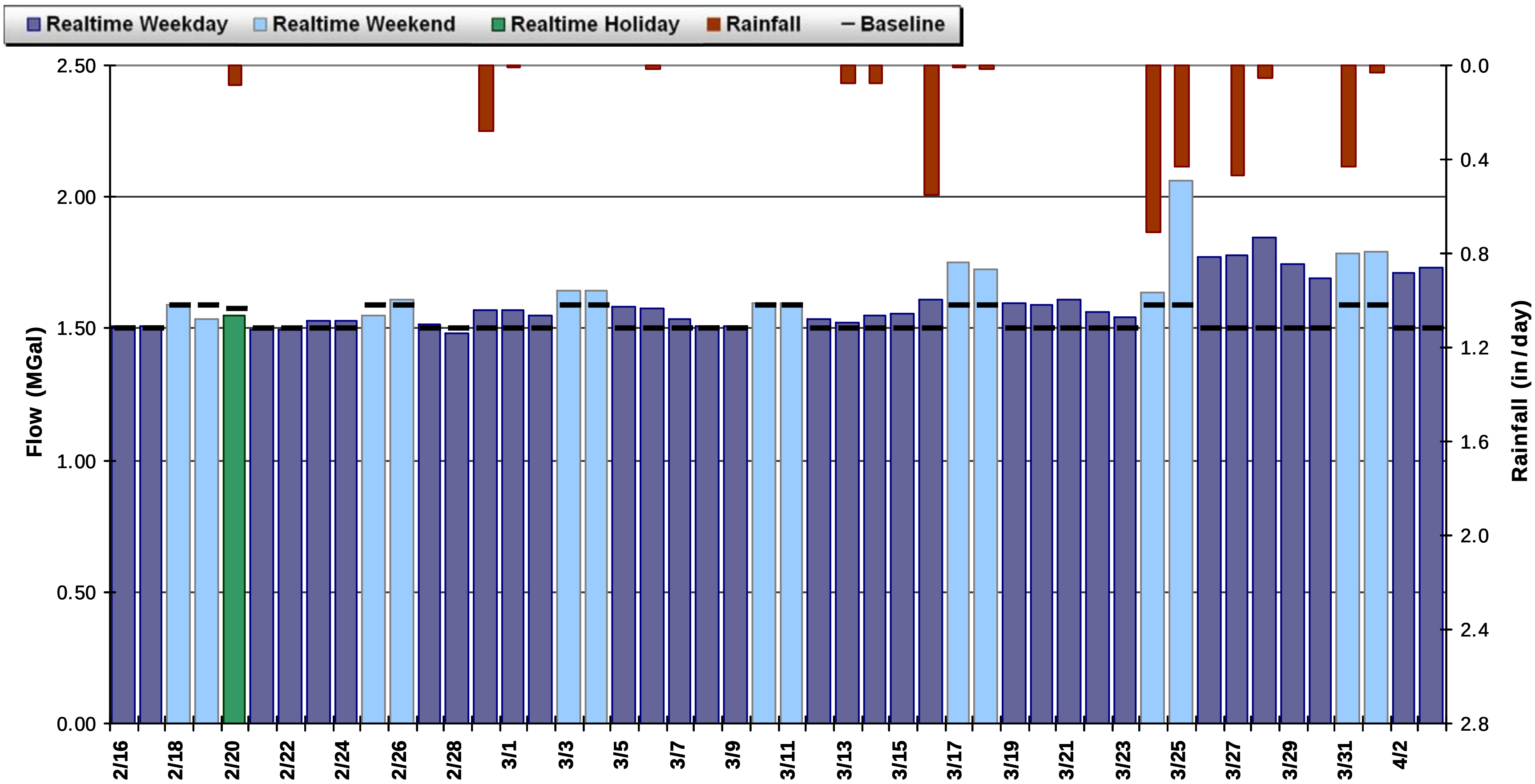


Plan View

MH T13
Period Flow Summary: Daily Flow Totals

Avg Daily Flow: 1.615 MGal Peak Daily Flow: 2.062 MGal Min Daily Flow: 1.484 MGal

Total Period Rainfall: 3.24 inches

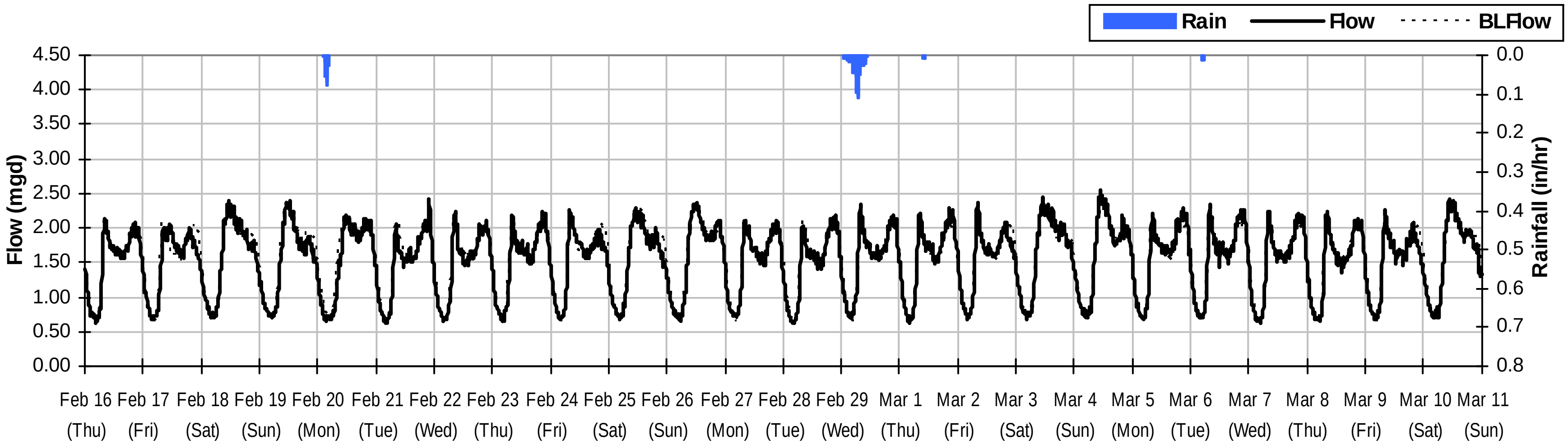


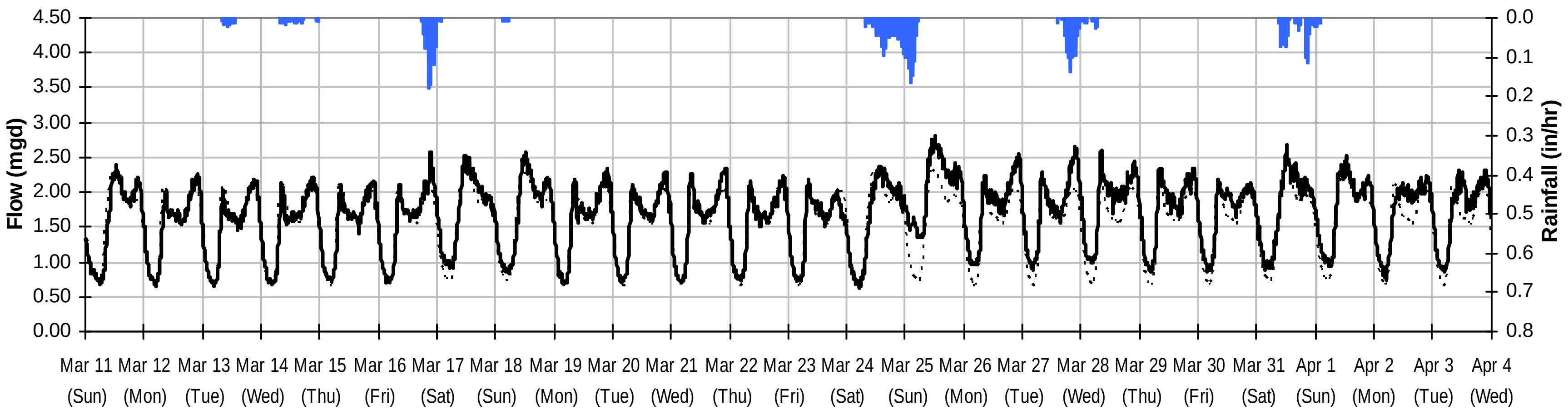
MH T13

Period Flow Summary: February 16 to April 4, 2012

Avg Flow: 1.615 mgd **Peak Flow: 2.800 mgd** **Min Flow: 0.625 mgd**

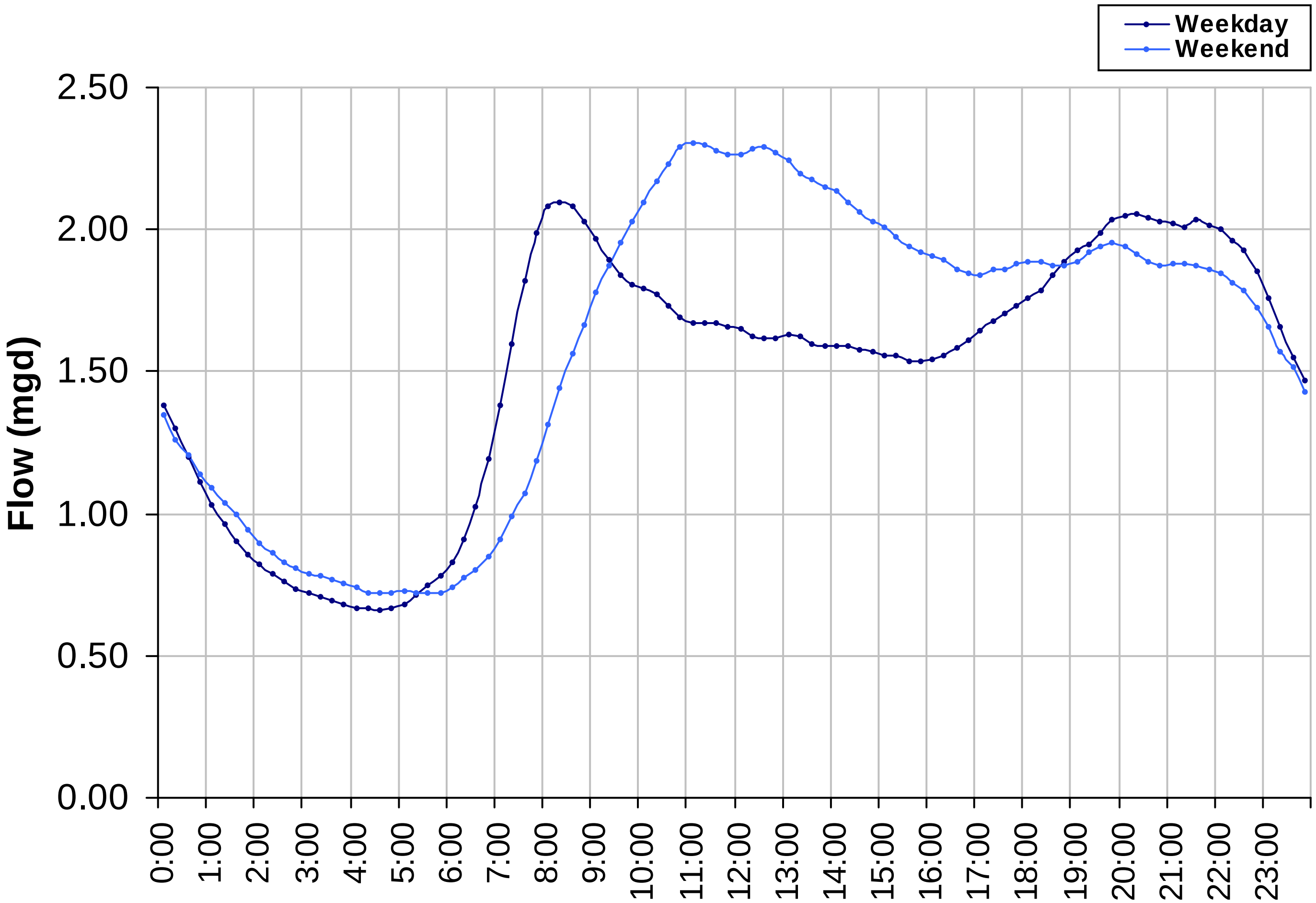
Total Period Rainfall: 3.24 inches





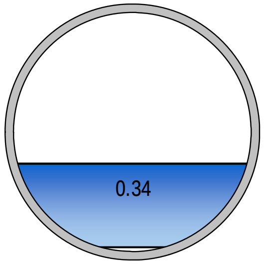
MH T13

Baseline Flow Hydrographs



Baseline Flow:

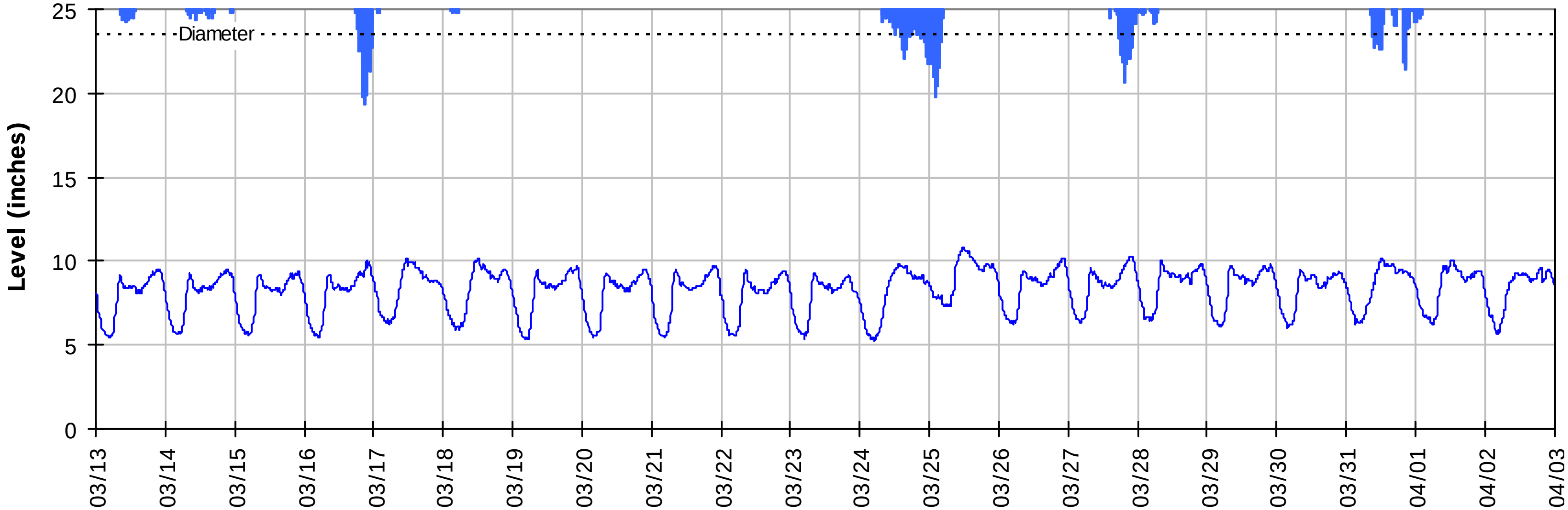
1.530 *mgd*

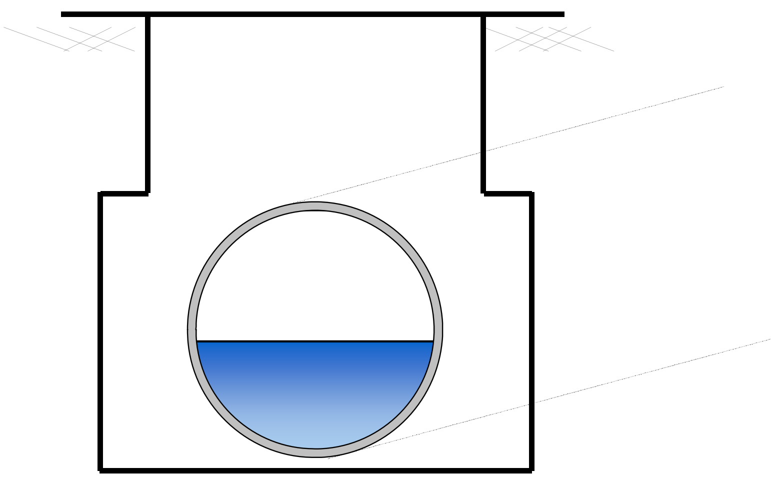


MH T13

Site Capacity and Surcharge Summary

Realtime Flow Levels with Rainfall Data over Monitoring Period

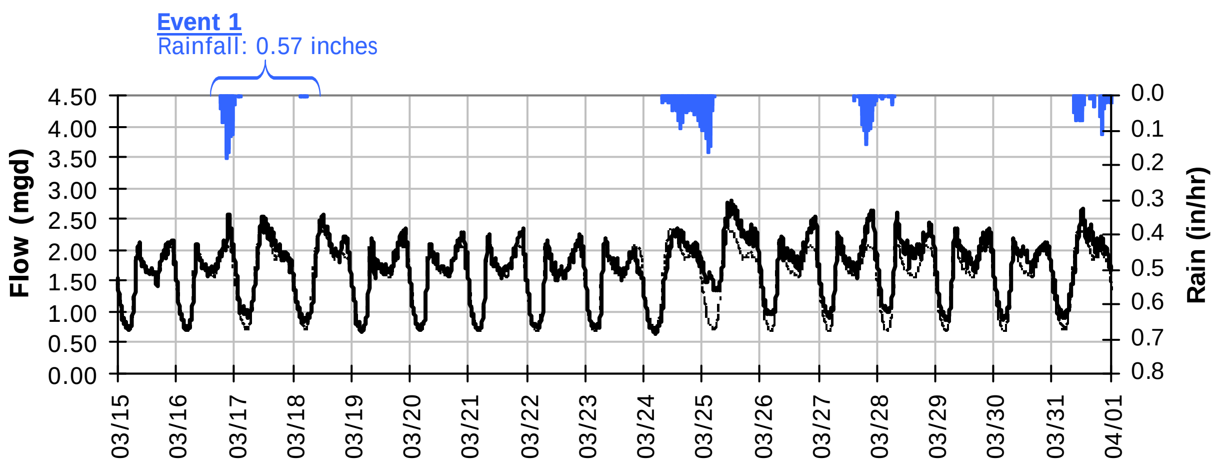




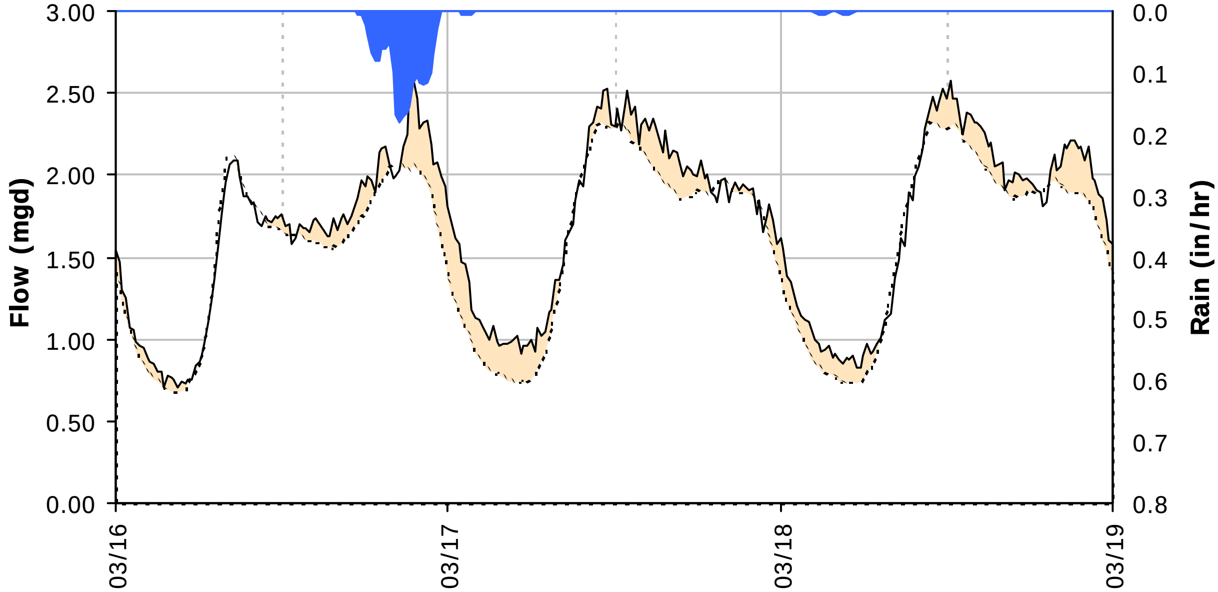
Pipe Diameter:	23.5 *inches*
Peak Measured Level:	10.8 *inches*
Peak d/D Ratio:	0.46

MH T13
I/I Summary: Event 1

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 1 Detail Graph



Storm Event I/I Analysis (Rain = 0.57 inches)

Capacity

Peak Flow: 2.58 *mgd*
PF: 1.69
Peak Level: 10.18 *in*
d/D Ratio: 0.43

Inflow

Peak I/I Rate: 0.55 *mgd*
PkI/I:IDM: 1,936 *gpd/IDM*
PkI/I:Acre: 477 *gpd/acre*
Pk I/I:ADWF: 0.36

RDI (infiltration)

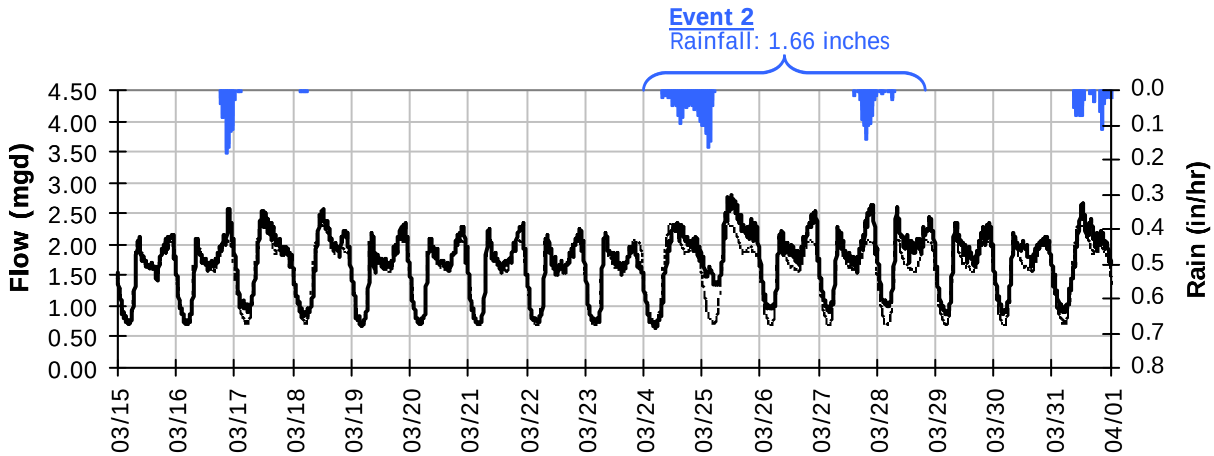
Infiltration Rate: 0.136 *mgd*
(3/18/2012)
RDI:IDM: 482 *gpd/IDM*
RDI:Acre: 119 *gpd/acre*
RDI (% of BL): 9%

Combined I/I

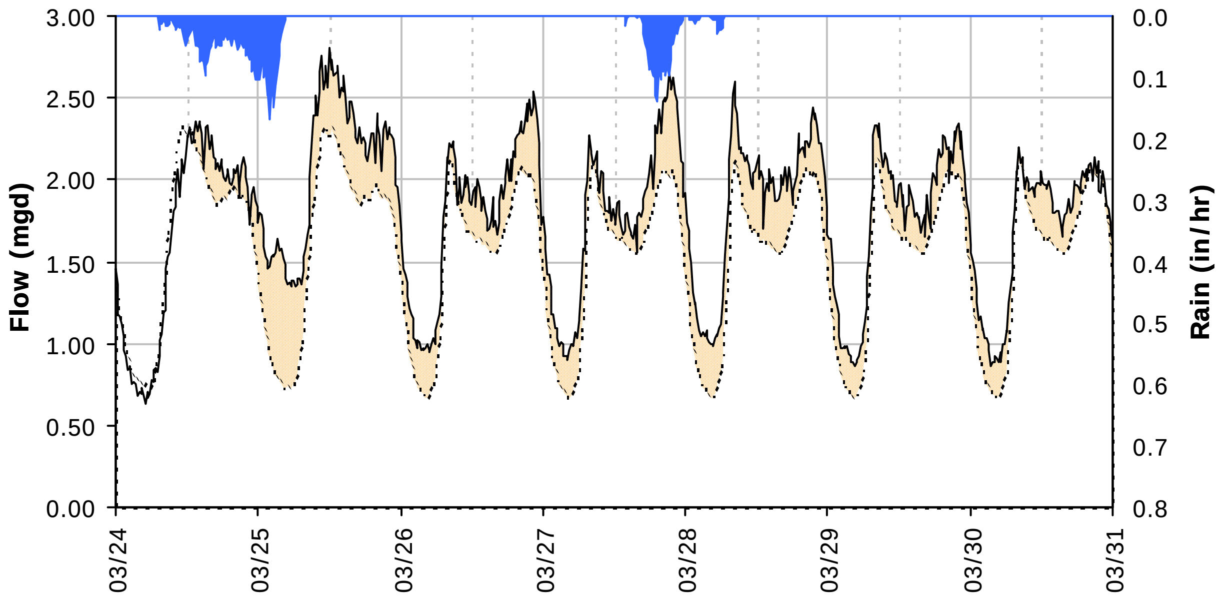
Total I/I: 323,000 *gallons*
Total I/I:IDM: 2,000 *gal/IDM/in*
R-Value: 1.8%
Total I/I:ADWF: 0.37 *per in-rain*

MH T13
I/I Summary: Event 2

Baseline and Realtime Flows with Rainfall Data over Monitoring Period



Event 2 Detail Graph



Storm Event I/I Analysis (Rain = 1.66 inches)

Capacity

Peak Flow:	2.80	*mgd*
PF:	1.83	
Peak Level:	10.84	*in*
d/D Ratio:	0.46	

Inflow

Peak I/I Rate:	0.87	*mgd*
PkI/I:IDM:	3,070	*gpd/IDM*
PkI/I:Acre:	756	*gpd/acre*
Pk I/I:ADWF:	0.57	

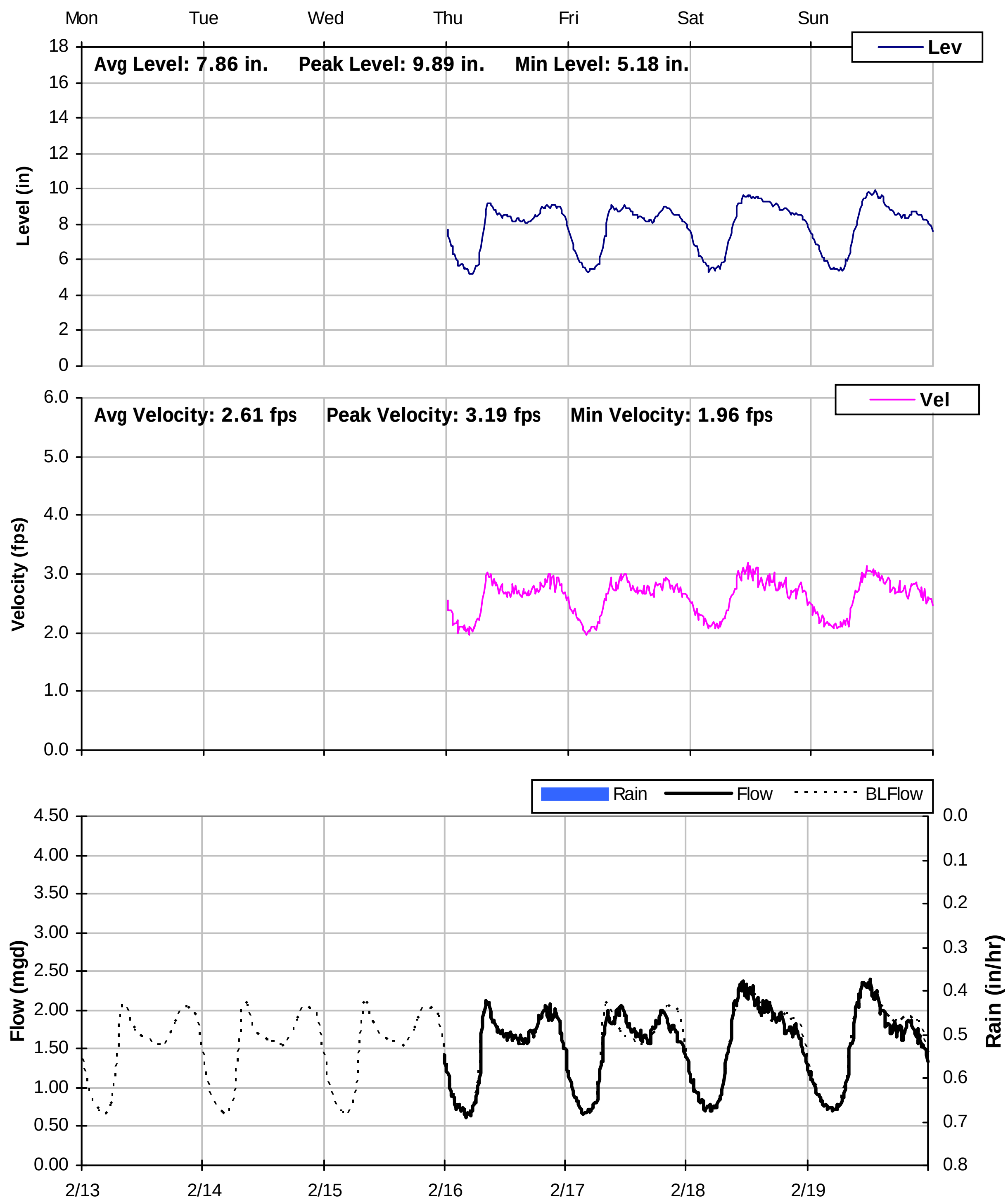
RDI (infiltration)

Infiltration Rate: (3/26/2012)	0.267	*mgd*
RDI:IDM:	948	*gpd/IDM*
RDI:Acre:	234	*gpd/acre*
RDI (% of BL):	18%	

Combined I/I

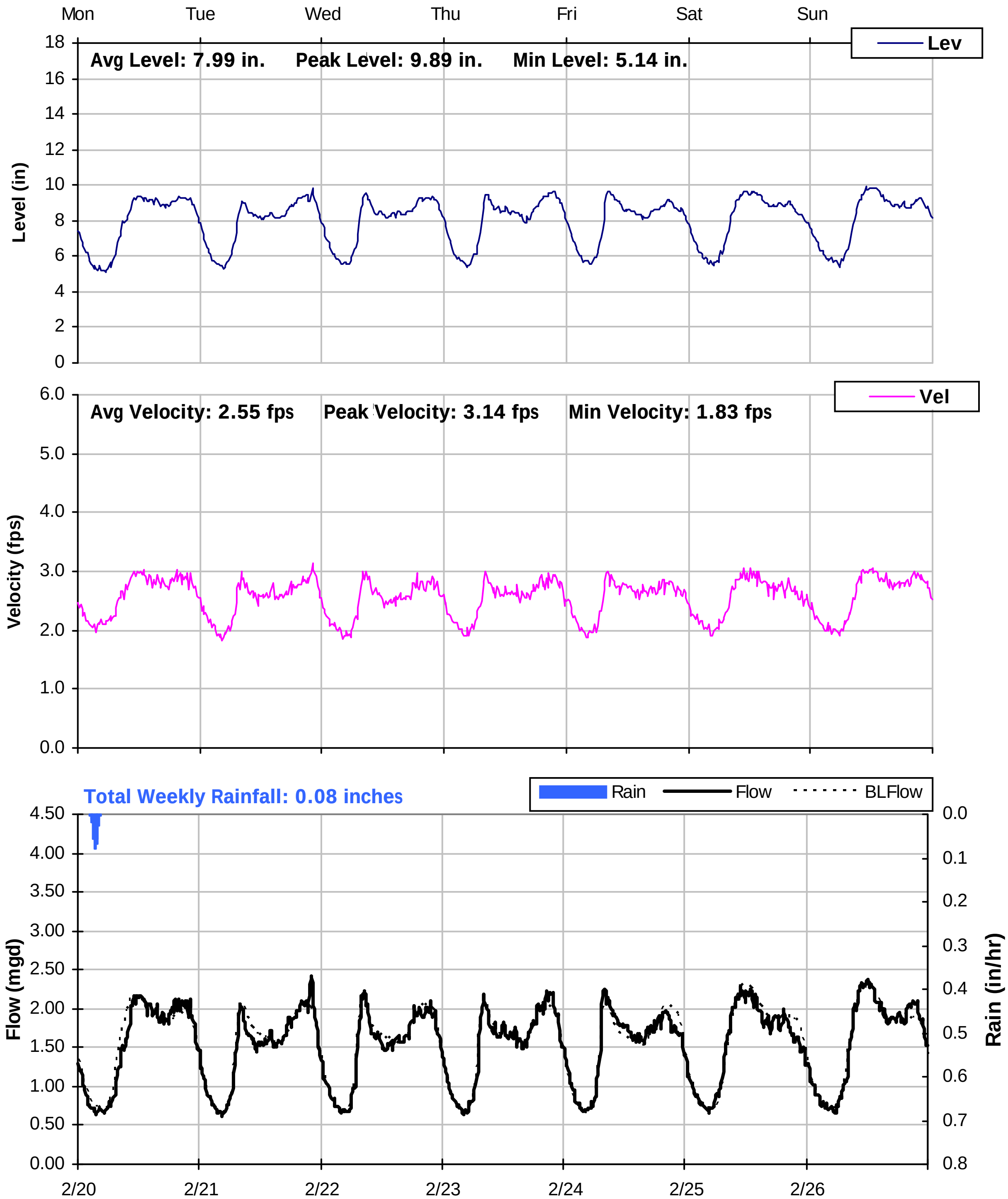
Total I/I:	1,783,000	*gallons*
Total I/I:IDM:	3,801	*gal/IDM/in*
R-Value:	3.4%	
Total I/I:ADWF:	0.70	*per in-rain*

MH T13
Weekly Level, Velocity and Flow Hydrographs
2/13/2012 to 2/20/2012



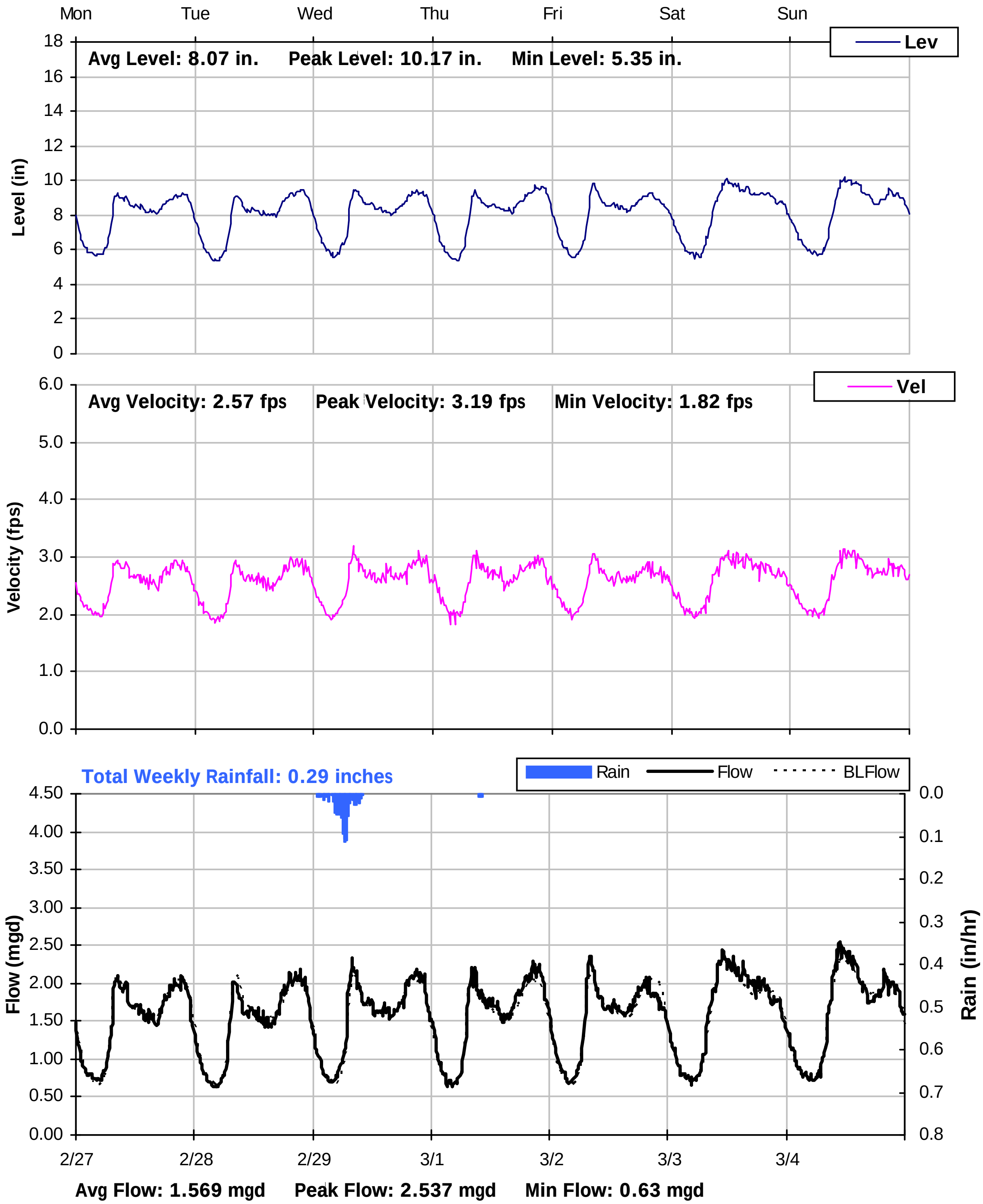
Avg Flow: 1.536 mgd **Peak Flow: 2.391 mgd** **Min Flow: 0.625 mgd**

MH T13
Weekly Level, Velocity and Flow Hydrographs
2/20/2012 to 2/27/2012

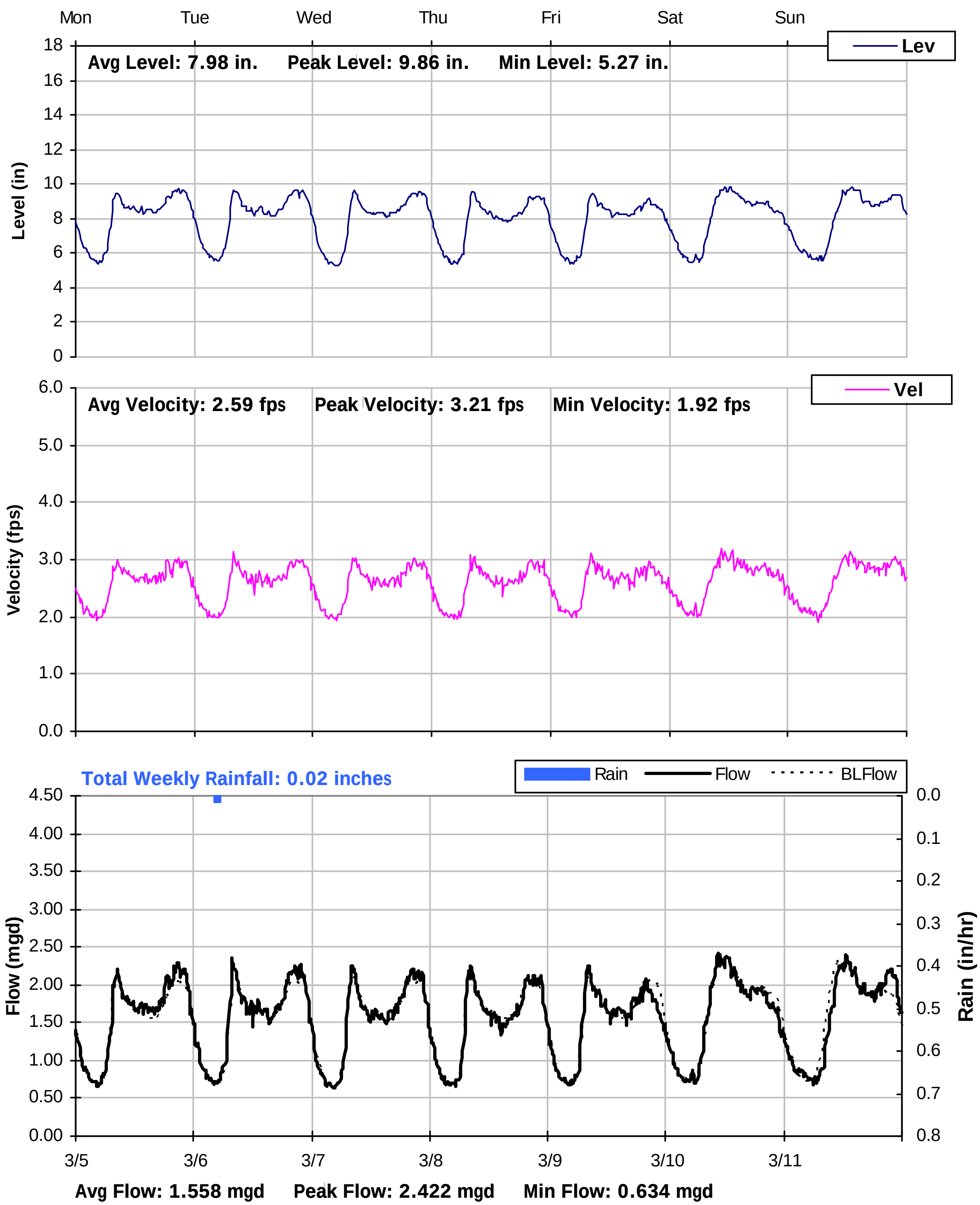


Avg Flow: 1.537 mgd **Peak Flow: 2.428 mgd** **Min Flow: 0.625 mgd**

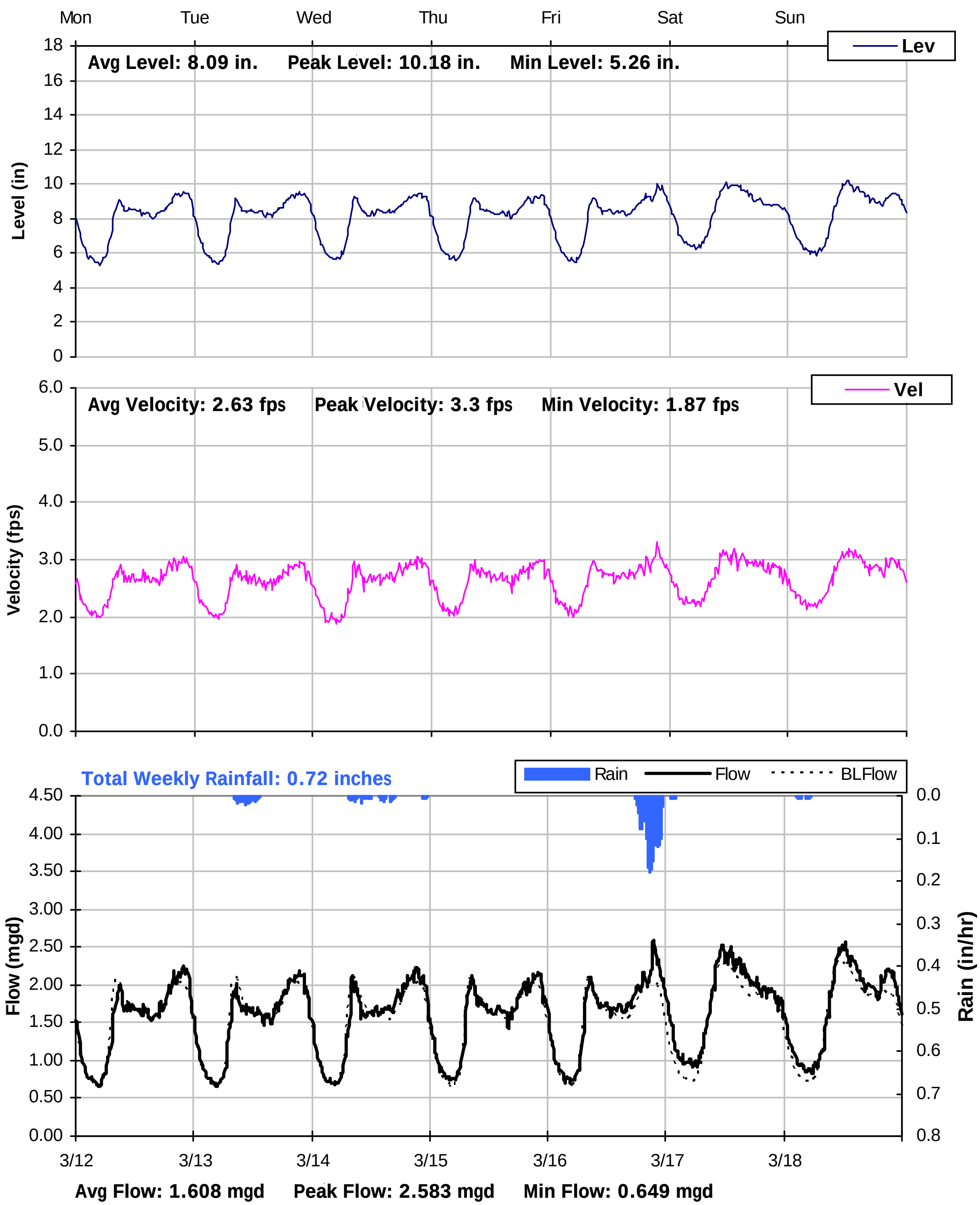
MH T13
Weekly Level, Velocity and Flow Hydrographs
2/27/2012 to 3/5/2012



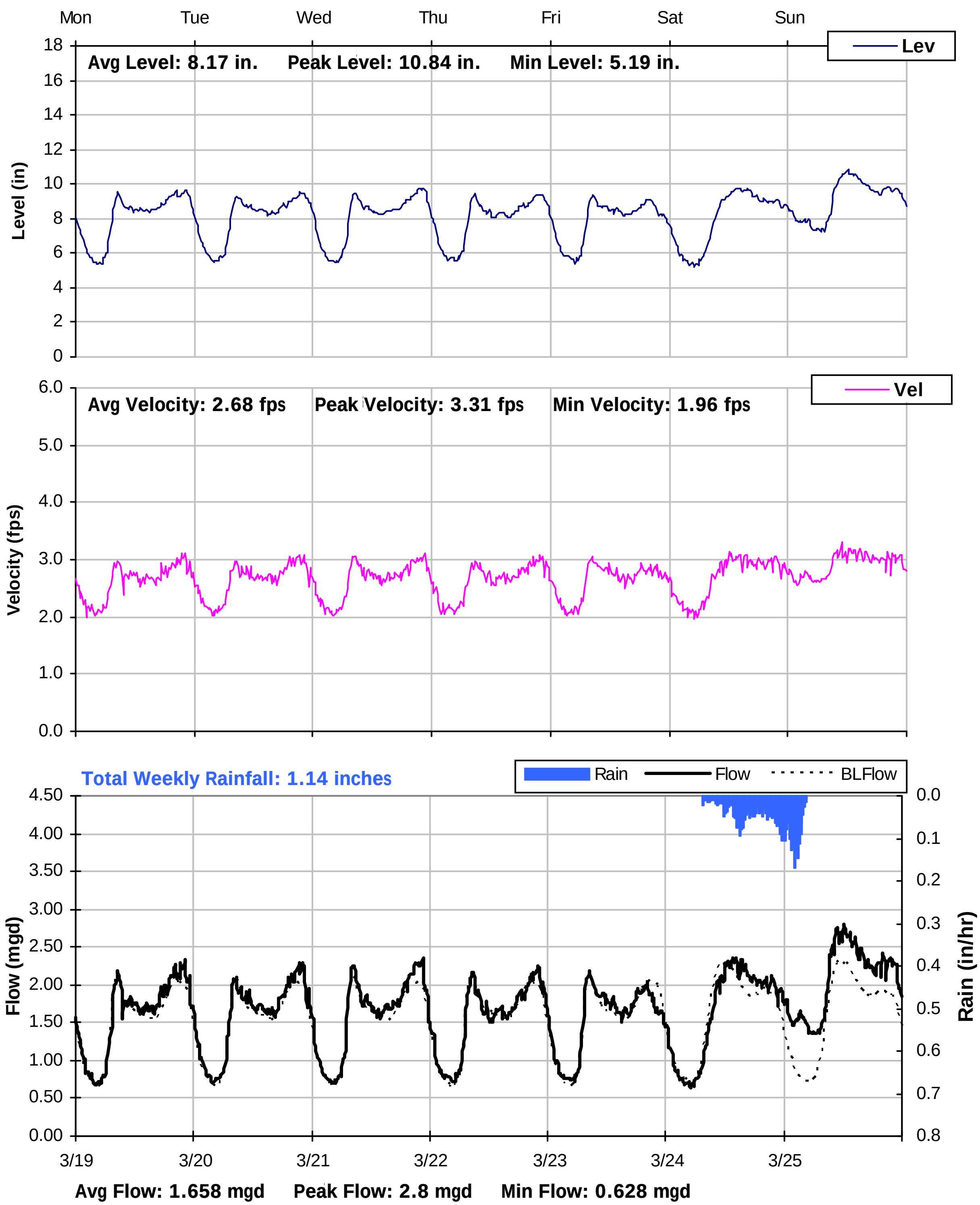
MH T13
Weekly Level, Velocity and Flow Hydrographs
3/5/2012 to 3/12/2012



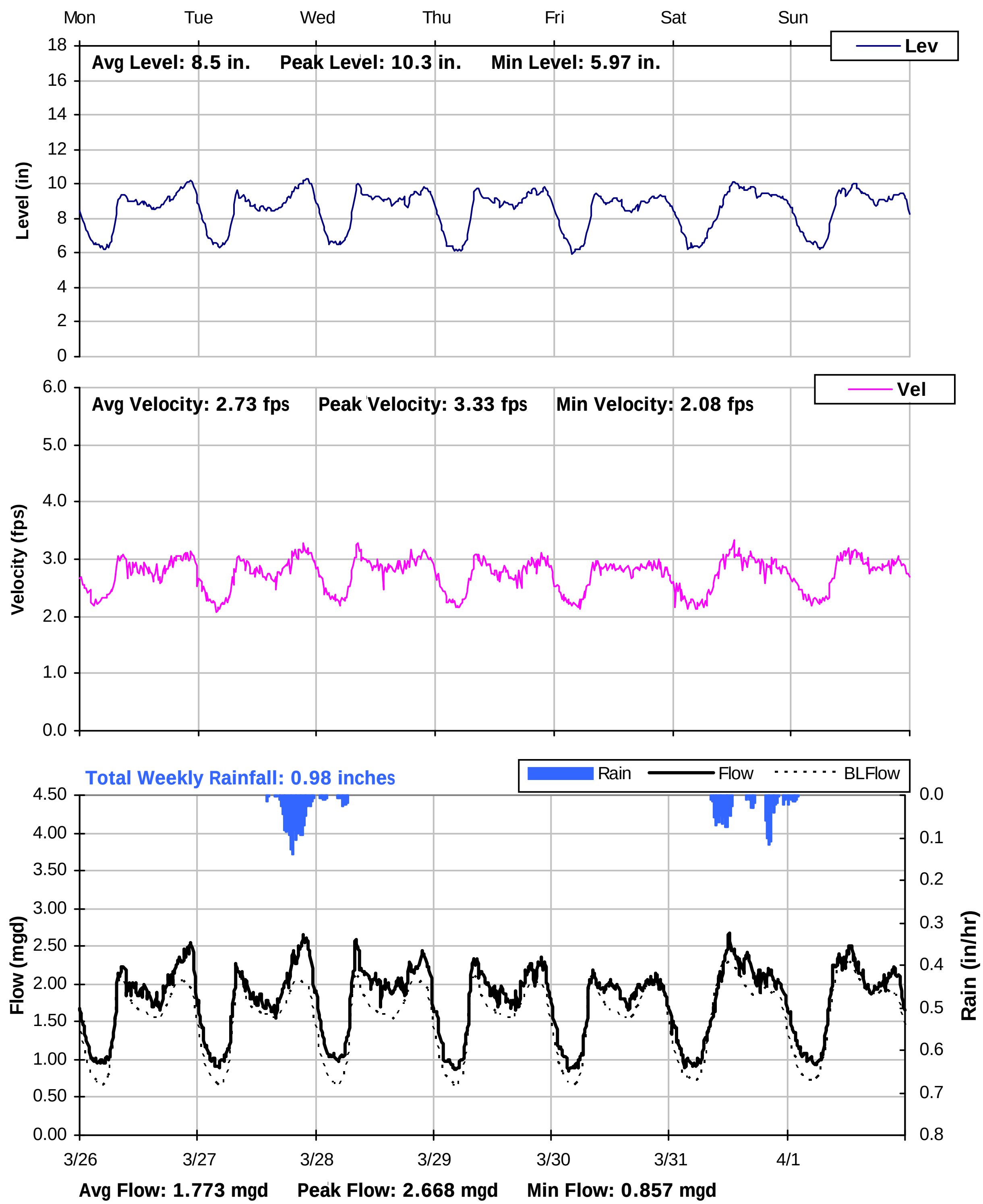
MH T13
Weekly Level, Velocity and Flow Hydrographs
3/12/2012 to 3/19/2012



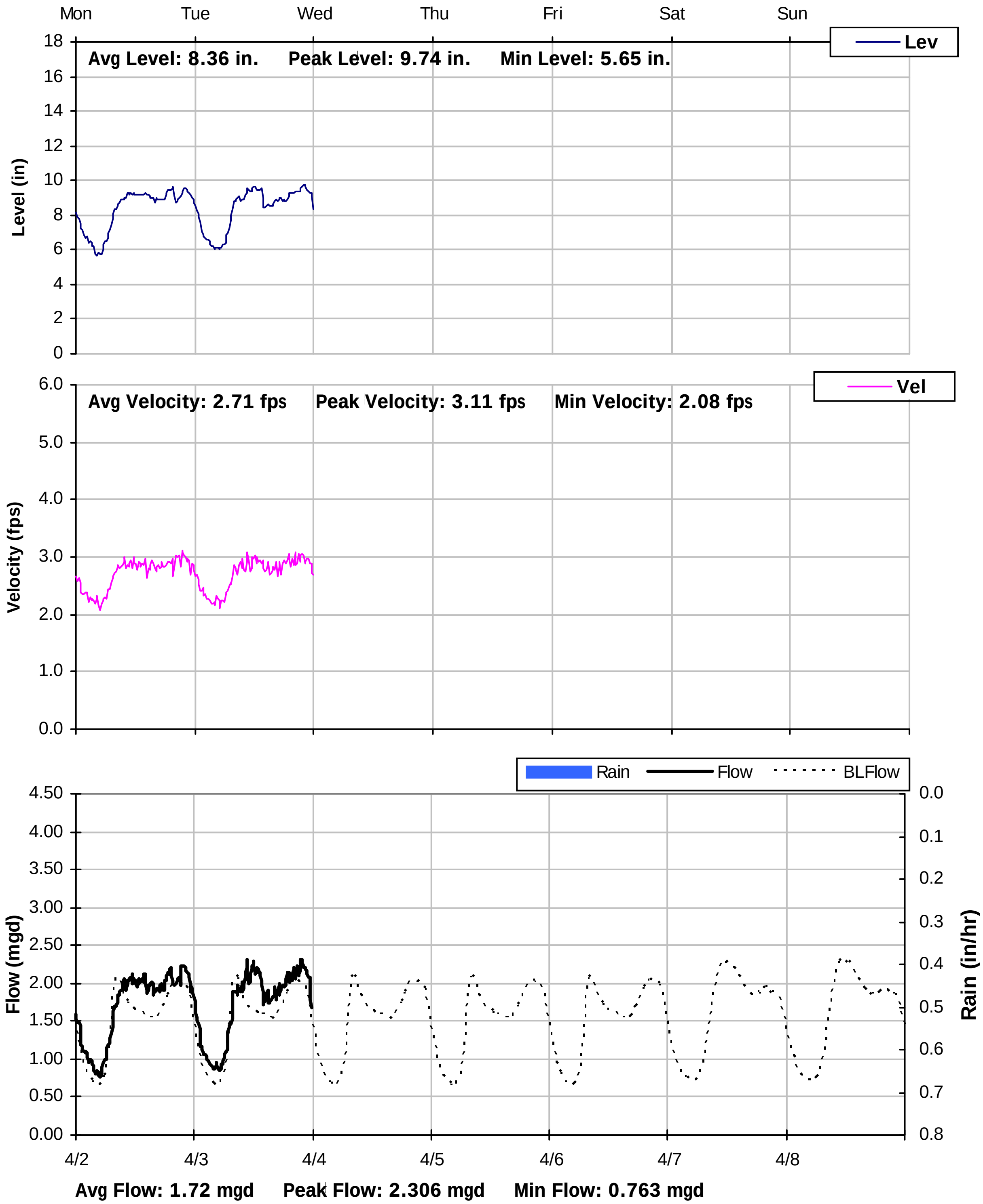
MH T13
Weekly Level, Velocity and Flow Hydrographs
3/19/2012 to 3/26/2012

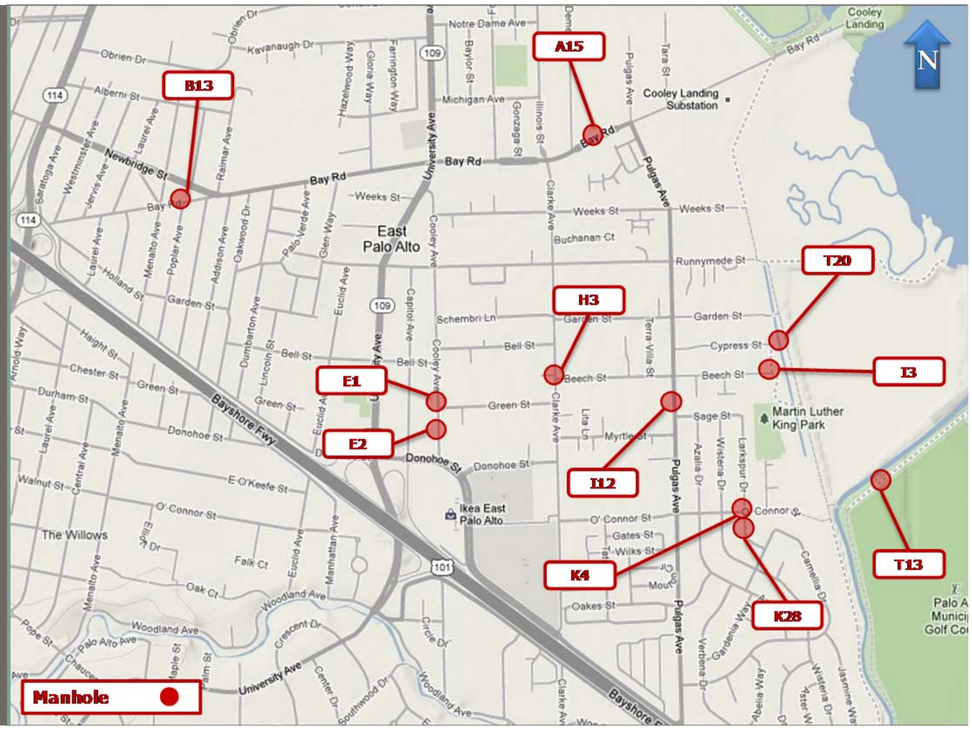


MH T13
Weekly Level, Velocity and Flow Hydrographs
3/26/2012 to 4/2/2012



MH T13
Weekly Level, Velocity and Flow Hydrographs
4/2/2012 to 4/9/2012





V&A

Oakland
155 Grand Avenue, Suite 700
Oakland, CA 94612
510.903.6600 **Tel**
510.903.6601 **Fax**

San Diego
11011 Via Frontera, Suite C
San Diego, CA 92127
858.576.0226 **Tel**
858.576.0004 **Fax**

Seattle
14900 Interurban Avenue, Suite 268
Seattle, WA 96818
206.674.4560 **Tel**
206.674.4561 **Fax**

Houston
8220 Jones Road, Suite 500
Houston, TX 77065
713.840.6490 **Tel**
713.840.6491 **Fax**

vaengineering.com