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CITY OF MILLBRAE

Storm Drain Master Plan

FINAL

AUGUST 2018

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FINAL REPORT | AUGUST 2018

Storm Drain Master Plan

Prepared for

City of Millbrae

Project No. 478-10-16-05

REGISTERED PROFESSIONAL ENGINEER
MILLICENT A. CRAWFORD
No. C66597
Exp. 6-30-20
CIVIL
STATE OF CALIFORNIA

Project Manager: Millicent A. Crawford, PE	8-23-18 Date
QA/QC Review: Douglas T. Moore, PE	8-23-18 Date

WEST YOST ASSOCIATES

Davis

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

E. Sacramento

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

Eugene

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

Irvine

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

Phoenix

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

Pleasanton

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

Portland

4949 Meadows Road, Suite 125
Lake Oswego, OR 97035
(503) 451-4500

Sacramento

2725 Riverside Boulevard, Suite 5
Sacramento, CA 95818
(916) 504-4915

Santa Rosa

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

Walnut Creek

1777 Botelho Drive, Suite 240
Walnut Creek, CA 94596
(925) 949-5800

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Airport	San Francisco International Airport
BART	Bay Area Rapid Transit
Bay	San Francisco Bay
C	Runoff Coefficients
cfs	Cubic feet per Second
CIP	Capital Improvement Program
City	City of Millbrae
F	Intensity Factor
FEMA	Federal Emergency Management Agency
FIRMs	Flood Insurance Rate Maps
GIS	Geographic Information System
gpm	Gallons Per Minute
GR	General Recommendation
HGL	Hydraulic Grade Line
I	Rainfall Intensities
I-280	Interstate 280
M	Million
MSASP	Millbrae Station Area Specific Plan
NAVD88	North American Vertical Datum of 1988
NGVD 29	National Geodata Vertical Datum of 1929
NPDES	Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Services
O&M	Operations and Maintenance
Q = CIAF	Rational Method
RPM	Revolutions Per Minute
SDMP	Storm Drain Master Plan
TDH	Total Dynamic Head
West Yost	West Yost Associates

CHAPTER 1
Introduction, Project Purpose and Goals

This Storm Drain Master Plan (SDMP) for the City of Millbrae (City) describes and evaluates the City's existing storm drain system using performance criteria developed in this SDMP and identifies recommended improvements to mitigate system deficiencies. This chapter provides an overview of the City of Millbrae's storm drain system and watersheds, discusses known flooding issues, and outlines the purpose and goals of this SDMP.

1.1 INTRODUCTION

The City is 3.2 square miles in area. As shown on Figure 1-1, it is located on the San Francisco Peninsula bordered by the San Francisco International Airport (Airport) and San Francisco Bay (Bay) to the east, the City of Burlingame to the south, the City of San Bruno to the north, and the State of California Fish and Wildlife refuge to the west. Elevations within the City range from 620 feet North American Vertical Datum of 1988 (NAVD88) on the City's western boundary near sea level at the Bay. With this topography, the area west of Interstate 280 (I-280) drains into San Andreas Lake, and I-280 and the areas east of I-280 generally drain through the City to the Bay. Water from San Andreas Lake does not cross I-280 and enter the City. The City's drainage system consists of a network of 21 miles of storm drains, 3 pump stations, and approximately three miles of open creeks and ditches that route storm runoff through the City to the Bay.

The City is divided into the following watersheds (see Figure 1-1).

- Northern Lomita Canal Watershed (225 acres) - This watershed drains the northern part of the City through a piped storm drain system (42-inch to 48-inch diameter) into Lomita Creek and the Lomita Canal. The runoff from this watershed is lifted by the Airport Pump Station (Photograph 1-4) into the Highline Canal east of the Bay Area Rapid Transit (BART) tracks.
- Southern Lomita Canal Watershed (164 acres) - This watershed drains through a piped storm drain system, which in turn flows into the Lomita Creek, which in turn flows into the Lomita Canal at the Landing Lane Bowl. The runoff from this watershed is lifted by the Airport Pump Station into the Highline Canal east of the BART tracks.
- Central Millbrae Watershed - (942 acres) - This watershed drains through several storm drainage systems to the Highline Canal (Photograph 1-1). Water from the Bay is prevented from entering the Highline Canal by twin box culverts (near South McDonnell Road), each 15 feet wide by 15 feet tall, each with a large flap gate (see Photograph 1-2). Flap gates allow water to flow from the City to the Bay, but prevent back flow from the Bay to the City. However, these flap gates sometimes do not close completely because mud accumulates below the gates and prevents the gates from sealing closed. This watershed also includes the Hillcrest Pump Station (Photograph 1-3), which lifts water from the Hillcrest Drive undercrossing under the BART tracks.
- Millbrae Station Area Specific Plan (MSASP) Watershed (67 acres) – This watershed drains through a piped storm drain system to the open channels in the US-101 interchange and then flows into a storm drain to the Cowan Pump Station (Photograph 1-7).

- Murchison Drive Watershed (430 acres) - This watershed drains through series of storm drains and Millbrae Creek to the El Portal Canal (Photograph 1-5). The El Portal Canal drains to the Bay. Water from the Bay is blocked from entering the El Portal Canal by twin 84-inch diameter culverts (under the Old Bayshore Highway), each with a flap gate (see Photograph 1-6).
- Mills Estates Watershed (130 acres) – This watershed drains through a 45-inch storm drain into a City of Burlingame storm drain system. The runoff from this watershed flows to the Cowan Pump Station, where it is lifted by the Cowan Pump Station (Photograph 1-7) into the El Portal Canal (Photograph 1-5).

Average temperatures in Millbrae range from a daily average low of 42°F in the winter (December and January) to an average daily high temperature of about 72°F in August and September. Average annual rainfall totals 20.1 inches at the Airport to about 40 inches per year at San Andreas Lake. Most of the rainfall occurs between October and May. January is typically the wettest month, with an average rainfall of almost 4.5 inches. July is typically the driest month, with an average rainfall of only 0.03 inches.

There are several known flooding problems within the City. The locations of the flooding problems are shown on Figure 1-1 with red stars (red numbering on Figure 1-1 corresponds to the descriptions below).

1. Flooding of the Landing Lane and San Anselmo Avenue Neighborhood has been reported to occur due to the Lomita Canal being overgrown with riparian and aquatic vegetation. Because of the presence of San Francisco Garter Snake habitat, it is difficult for San Francisco Airport staff to obtain permits to adequately maintain the Lomita Canal.
2. Flooding of the MSASP Area near Millbrae Avenue and the Highway 101 Interchange occurs when inlets become blocked by vegetation and trash from the interchange. The drainage channels through this area are also overgrown with aquatic and riparian vegetation that may contribute to poor drainage. The vegetation cannot be regularly maintained because of the presence of endangered species. The MSASP area floods about every year to the top of curb. The downstream drainage channel flows to the Cowan Pump Station.
3. At the east corner of the Green Hills Golf Course, flooding occurs where flow enters a 42-inch storm drain and a 48-inch storm drain flow split structure. The entrance conditions restrict the ability of the water to enter the storm drains efficiently, thereby contributing to the flooding. The area is also lower than downstream areas of the City.
4. Along Hillcrest Avenue between Minorca Way and El Paseo Avenue, flooding has also occurred in the past at a house that is below the street level. At this location, the ground changes from hill slopes to flatter ground and the storm drain serving this area is only 12-inches in diameter. The City recently constructed a new storm drain line to serve this area.
5. Some flooding has occurred at Taylor School because, although there is a 24-inch storm drain stub available to the school, the school has not yet connected to the storm drain system.

1.2 PROJECT PURPOSE AND GOALS

The purpose of this SDMP is to identify improvements needed to eliminate or reduce flooding during the appropriate design storms. The purpose has been accomplished by achieving the following goals:

- Collect and utilize to the extent possible previous relevant studies and data (Chapter 2) and collect field data on the storm drain system, including pipe and channel sizes, materials, and elevations (Chapter 3).
- Review and confirm the flood protection performance and design criteria (Chapter 4).
- Prepare a hydrologic and hydraulic model of the storm drain system to determine its performance capabilities (Chapter 5).
- Identify the known flooding problems from historical storm events and from the modeling of the 10-year and 100-year design storms (Chapter 5).
- Determine the causes of the flooding problems (Chapter 6).
- Identify and size improvements to achieve the desired flood control performance and design criteria (Chapter 6).
- Estimate the construction and capital costs of the improvements (Chapter 6).
- Summarize the conclusions and recommendations from this SDMP (Chapter 7).

Photo 1-1. Highline Canal near South McDonnell Road

Photo 1-2. Highline Canal Box Culvert Flap Gates

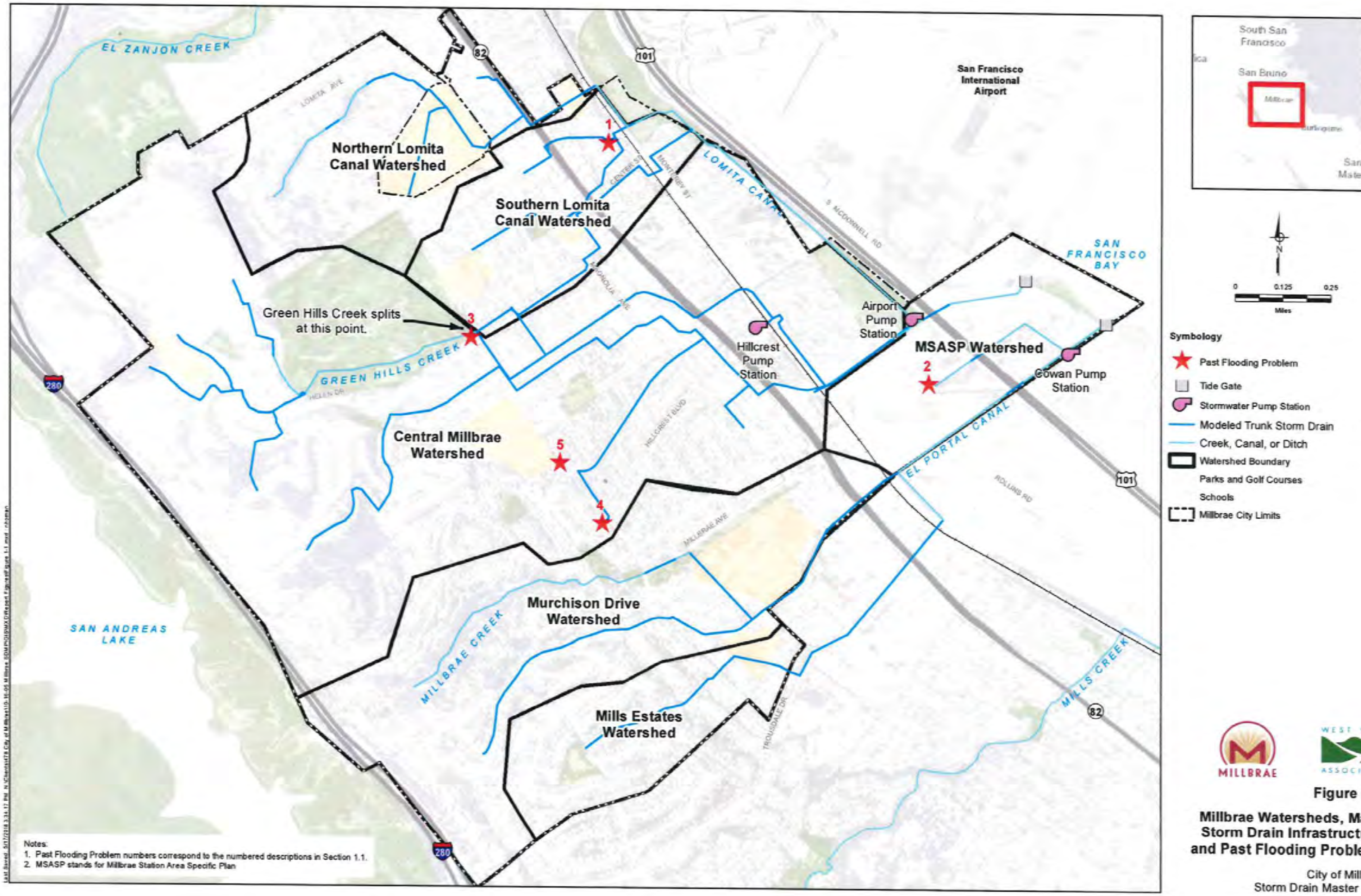
Photo 1-3. Hillcrest Pump Station

Photo 1-4. Airport Pump Station

Photo 1-5. El Portal Canal near the Old Bayshore Highway

Photo 1-6. El Portal Canal Culvert Flap Gates at the Old Bayshore Highway

Photo 1-7. Cowan Pump Station



Notes:
1. Past Flooding Problem numbers correspond to the numbered descriptions in Section 1.1.
2. MSASP stands for Millbrae Station Area Specific Plan

Figure 1-1

Millbrae Watersheds, Major Storm Drain Infrastructure, and Past Flooding Problems

City of Millbrae
Storm Drain Master Plan

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CHAPTER 2
Summary of Relevant Studies and Data

This chapter of the SDMP identifies and summarizes past and current studies and reports relevant to this SDMP, and presents the topographic mapping data used in this SDMP. Chapter 3 describes the field investigations.

2.1 RELEVANT STUDIES AND REPORTS

Provided below is a summary of the studies and reports collected during the development of the SDMP, and relevant to the master planning effort.

2.1.1 Storm Drain Technical Memoranda D1, D2, D3a, F2 and F3, 1

Combined, these memoranda represent a storm drain master plan for the City, published in 1999. These memoranda identify and model the major stormwater infrastructure in the City. However, the effort divided the City into five watersheds (Northern Lomita Creek, Lomita Creek, Central Millbrae, Murchison Drive, and Trousdale Basin), modeled separately. The storm drain system modeling for these memoranda was prepared using HydraGraphics (Version 5.85) and Hydra (Version 6.0). These very old modeling programs lack the capabilities of current software (like the XP-SWMM model used for this SDMP). The old software lacks the ability to model backwater from the bay, meaning all the modeled storm drains were assumed to free-flow into the Bay. These memoranda also identify several flooding problems within the City, and identify improvements to address the flooding, with costs ranging from \$1.2 to \$1.9 million. With inflation to 2016, the cost of these improvements would be about \$2.0 to \$3.2 million.

These memoranda provide information about the sizes and connectivity of several major trunk storm drains, and this information was used where field work was unable to confirm drainage system configuration.

2.1.2 Airport Pump Station Data

Information about the Airport Pump Station was received from the City and from the Airport), and includes:

- Millbrae Drainage Pump Station Improvement As-Built Drawings (October, 2010)
- Drainage Pumping Station No. 3 Architectural Plan and Sections (April, 1966)
- Cascade Pump Curves, Drawings and Specifications (Various dates)
- Interviews with City staff

The Airport Pump Station is operated jointly by the City and the Airport. The Airport side of the pump station receives water from the South Lomita Canal and pumps it into the Highline Canal. The City side of the pump station receives water from a 33-inch storm drain running under the Highline Canal and pumps it up into the Canal. The wet well on the airport-owned side of the pump station is 23 feet wide by 18 feet deep by approximately 40 feet long, with a floor elevation of -18.0 feet National Geodata Vertical Datum of 1929 (NGVD29) and a sump floor elevation of -24.5 feet NGVD29. This pump station has three main pumps, as summarized below, with an additional small summer pump on each side of the pump station:

- Pumps 1 & 2 on the Airport-operated side of the pump station – Johnston model 36PO vertical pumps with capacities of 53,000 gallons per minute (gpm) at a total dynamic head (TDH) of 7.5 feet, 500 revolutions per minute (RPM), 200 horsepower motors. Pump on elevation for pump 1 is -10.0 feet NGVD29, and pump off elevation is -12.5 feet NGVD29. Pump on elevation for pump 2 is -9.0 feet NGVD29, and pump off elevation is -12.5 feet NGVD29.
- Pump 3 on the City-operated side of the pump station – Cascade Pump 24 MF with a capacity of 18,000 gpm at 22 feet of head, 700 RPM, 125 horsepower motor, Cascade Pump Company pump curve number MF2410CD4. The pump turns on at a wet well depth of 12 feet and off at a depth of 2 feet. The datum was assumed to be NAVD88.

2.1.3 Hillcrest Pump Station Data

Data about the Hillcrest Pump Station was received from the City, and includes:

- San Francisco Bay Area Rapid Transit District Hillcrest Boulevard Site Grading and Drainage Drawings (November, 2003)
- Pump curves (August, 2008) and
- Maintenance records (October, 2015)

The pump station receives water from the Hillcrest Boulevard underpass below the BART tracks and discharges water to the 66-inch line on the east side of the tracks. The wet well is 10.5 feet wide by 11 feet long and 15 feet deep. This pump station has 2 main pumps, that alternate in use, as summarized below, and one smaller 50 gpm pump, used only for dewatering:

- Pumps 1 & 2 operate alternately, with one pump always acting as a backup for the other. They are each ITT Flygt CP3170x-443 with capacities of 1,500 gpm each at 40 feet of head, 1,750 RPM, 30 horsepower motors, Flygt pump curve number 63-443-00-2330, pump on elevation for pump 1 is 5.75 ft (likely NGVD29, based on a comparison between LiDAR elevations at the pump station and the elevations shown on available drawings), and pump off elevation for pump 1 is 3.25 feet in the same datum. Pump 2 alternates at the same on/off elevations.

2.1.4 Cowan Pump Station Data

Cowan Pump Station is operated and maintained by the City of Burlingame, but the station serves both Burlingame and Millbrae and maintenance costs are shared. Information about the Cowan Pump Station was received from the City and the City of Burlingame's consultant Mott MacDonald, currently undertaking a rehabilitation of the pump station, and includes:

- Pump Curves for the existing pumps 1, 2 & 3
- Correspondence with City staff, detailing the layout of the pump station

- Drawings produced during the ongoing rehabilitation of the pump station by Mott MacDonald
- Discussions with City staff regarding Burlingame's drainage to the pump station

The pump station lifts water from the Millbrae Station Area as well as the City of Burlingame and discharges into the El Portal Canal. According to City staff, the relative contributions are approximately 40 percent from the City and 60 percent from the City of Burlingame. The wet well is 30 feet in diameter, with a bottom elevation of -11.25 (assumed to be in the NAVD 88 from comparisons of the as-built drawing with LiDAR data). This pump station has three major pumps and a small 5-horsepower dewatering pump. The three major pumps are described below (with elevations assumed to be in the NAVD88 Datum):

- Pumps 1 & 2 – Johnston 20PO with a capacity of 9,000 gpm at 16 feet of head, 875 RPM, pump number JQ-1851-52, 40 horsepower motor, Pump 1 on elevation is -5.35 feet, Pump 2 on elevation is -5.05 and both pumps' off elevation is -7.25 feet.
- Pump 3 – Johnston 30PO with a capacity of 22,500 gpm at 16 feet of head, 585 RPM, pump number JQ-1850, 100 horsepower motor, pump on elevation is -4.25 feet, and pump off elevation is -7.25 feet.

2.1.5 Asset Vulnerability Profile, San Mateo County Sea Level Rise Vulnerability Assessment, Highline Canal Tide Gates, April 2017

This document identifies the Highline Canal Tide Gates as twin 15 foot by 15-foot tide gates that protect the City, Caltrain Station, and the Lomita Canal from flooding from high tides. The gates currently stick in the mud and stay open during much of the year. Clearing the mud from this area is difficult due to permitting issues, but the gates could be rehabilitated to alleviate issues in the canal. The annual Operations and Maintenance (O&M) cost of the tide gate is identified as $250,000. The tide gate could be replaced at a cost of about $1.5 million. One alternative to the tide gate is identified and includes sealing the gate and constructing a pump station (no cost is identified for the pump station).

2.1.6 Sea Level Rise & Overtopping Analysis for San Mateo County's Bayshore, Final Report, May 2016

This document develops a series of future inundation maps for various sea level rise values ranging from 12 inches to 108 inches. Table 2-1 of this document identifies the most likely sea level rise value for 2030 is 6-inches, for 2050 is 11 inches, and for 2100 is 36 inches. Table 3-1 of the document provides current extreme tide elevations for the Bay near the City, including the following:

- Mean Higher High Tide: 6.81 feet NAVD88
- 10-Year Extreme Tide: 9.06 feet NAVD88
- 25-Year Extreme Tide: 9.49 feet NAVD88
- 50-Year Extreme Tide: 9.86 feet NAVD88
- 100-Year Extreme Tide: 10.28 feet NAVD88
- 500-Year Extreme Tide: 11.50 feet NAVD88

This document also states that extreme tides in the future can be estimated by adding the sea level rise values to the current extreme tide values.

2.1.7 Millbrae Technical Provisions for Public Works Construction

The City's existing drainage design criteria are provided in the City's, Department of Public Works Engineering Division, Part II Technical Provisions for Public Works Construction (March 2005), Section 6 Storm Drainage Systems. These criteria are primarily for the evaluation of drainage systems in support of land development projects. The Technical Provisions were referenced in this effort for existing storm drain design standards and hydrologic analysis requirements. The City's Time of Concentration and rainfall intensity table was used in conjunction with the Rational Formula with the City's specified Intensity Factor to calibrate the hydrologic model update prepared as part of this master planning effort. The calibration is further discussed in Chapter 5.

2.1.8 Draft Millbrae 2040 General Plan Update

Information in the Draft Millbrae General Plan Update provides an overview of the City's storm drainage system, including a review of climate, system layout, and past problems that informed some of the proposed improvements that are analyzed and discussed in Chapters 5 and 6 of this SDMP.

2.1.9 Millbrae Green Infrastructure Workplan

The City has developed a green infrastructure workplan with the goal of meeting its regional water quality control board municipal stormwater National Pollutant Discharge Elimination System (NPDES) permit requirements to reduce pollutants in stormwater runoff. "Green Infrastructure" is infrastructure that uses vegetation, soils, and natural processes to improve stormwater runoff water quality. While site specific green infrastructure opportunities will likely be sought during the design phase of each system improvement identified in this SDMP, green infrastructure is an important consideration throughout the planning and implementation process and thus is included as a design criterion, as discussed in Chapter 4.

2.1.10 Federal Emergency Management Agency Flood Insurance Study Update

The Federal Emergency Management Agency (FEMA) published preliminary Flood Insurance Rate Maps (FIRMs) in August 2015 that show 127 acres of the City would be inundated in the 1 percent chance flood (100-year event) and an additional 46 acres in the 0.2 percent chance flood (500-year event). This preliminary floodplain is much larger than the floodplain shown on the current FIRMs that were published in October 2012, which had about 21 acres of 1 percent floodplain and 88.4 acres of 0.2 percent flood plain within the City. This proposed larger floodplain indicates many more houses and businesses are at risk of flooding than was previously known. When adopted, the new FIRMs will result in many flood protection requirements for development and redevelopment within the floodplain. This information informed some recommendations proposed in Chapter 6 of this SDMP.

2.2 TOPOGRAPHIC MAPPING

LiDAR data was provided by the City and was collected by the San Francisco Airport Authority. The date of the data collection was not available. The LiDAR mapping appears to have been developed using the NAD83 horizontal datum and NAVD88 vertical datum, based on a comparison with other available data sets in these datums. Topographic mapping was developed from the LiDAR data, including Figure 2-1 depicting the regional topography of the entire watershed.

2.3 DATUM CONVERSAION

Many data sources provided information in the NGVD29 datum and it was necessary to convert elevations into the NAVD88 Datum for use in modeling. For this purpose, the National Geodetic Survey's VertCon program (https://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl) was used to estimate the correct conversion. The conversion between datums varies by location. For the City of Millbrae, the difference is approximately NGVD29 + 2.8 feet = NAVD88 and this was the conversion used for the SDMP.

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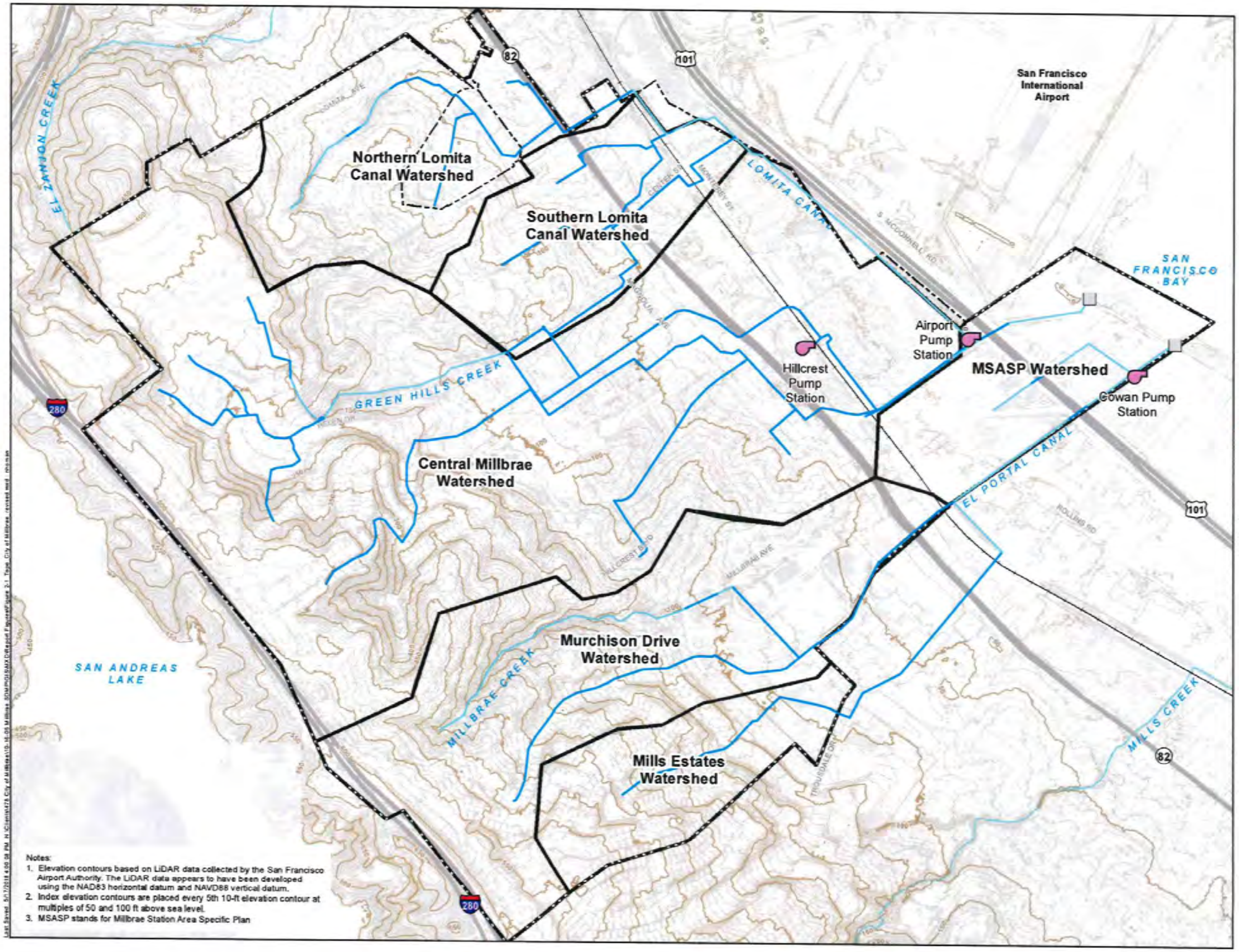

Notes:
1. Elevation contours based on LiDAR data collected by the San Francisco Airport Authority. The LiDAR data appears to have been developed using the NAD83 horizontal datum and NAVD88 vertical datum.
2. Index elevation contours are placed every 5th 10-ft elevation contour at multiples of 50 and 100 ft above sea level.
3. MSASP stands for Millbrae Station Area Specific Plan

0 0.125 0.25 Miles

Symbology
- Tide Gate
- Stormwater Pump Station
- Modeled Trunk Storm Drain
- Creek, Canal, or Ditch
- Ground Surface Elevation Contour (10-ft Interval)
- Ground Surface Elevation Index Contour (50-ft interval)
- Watershed Boundary
- Millbrae City Limits

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Figure 2-1

Regional Topography of the Millbrae Watershed

City of Millbrae
Storm Drain Master Plan

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CHAPTER 3
Field Evaluations

This chapter of the SDMP describes the site visits conducted by West Yost Associates (West Yost) and presents photographs of critical drainage infrastructure. In addition, this chapter describes the methodology used to systematically gather data required for the model (discussed further in Chapter 5) and how it was incorporated into the City's Geographic Information System (GIS) database.

3.1 SITE VISITS

Site visits were conducted by West Yost, in collaboration with City staff, at three different times during the preparation of this plan. The initial field visits occurred over several weeks in August and September 2016 and focused on mapping and measuring storm drain inlets and some manholes in the lower portions of the watershed. Several locations were unable to be accessed and a second field visit was scheduled for December 2016. The second visit focused on visiting the interior of the Airport, Cowan, and Hillcrest pump stations and Capuchino High School. After initial model setup and GIS mapping, additional locations were visited in August 2017 to capture information at previously obstructed, buried, or unknown locations. The City of Millbrae also performed extensive reconnaissance of stormdrains and manholes, both visually, and with closed circuit television where access was limited. The following photos show a selection of critical drainage infrastructure.

Photo 3-1. Exterior, Airport Pump Station, August 2016

Photo 3-2. Highline Canal Tide, August 2016

Photo 3-3. Interior, Cowan Pump Station, December 2016

Photo 3-4. Cowan Pump Station Outfalls to El Portal Canal, December 2016

Photo 3-5. El Portal Canal Tide Gates, August 2017

Photo 3-6. Interior, Hillcrest Pump Station Wet Well, December 2016

Photo 3-7. Exterior, Hillcrest Pump Station, December 2016

Photo 3-8. Landing Lane Bowl and Trash Capture Devices at Lomita Canal behind Landing Lane, August 2017

Photo 3-8. Highline Canal east of Millbrae Station, looking west, August 2017

3.2 FIELD EVALUATIONS

Field data collection was focused on collecting the information needed to better define the drainage system and to perform modeling. The following sections describe the format of the data collection records as links and nodes and the information collected for each type of feature in the stormdrain system.

3.2.1 Link and Node Naming Scheme and City Grid System

A link and node naming scheme was developed, based on a City grid system provided by AIMS Team, LLC (AIMS, 2016), and based on mapping developed as part of the City's Sewer SDMP Update. The grid naming includes grid elements A1, A2, A3, A4, B1, B2, B3, B4, B5, C1, C2, C3, C4, C5, D1, D2, D3, D4, D5, E2, E3, E4, F2, F3, F4. Note that there is no grid element E1 or F1 in the City's Grid. The grid system is shown on Figure 3-1.

3.2.1.1 Node Naming Scheme

The node naming scheme creates a six-character, four-part alpha-numeric node name, as shown in the following example:

Node Name: U M D3 01

Where:

U = Watershed Name (See Figure 3-1)

M = Type of Node

D3 = Grid Number

01 = Point Number

Watershed names form the first component of the node name and are represented by the following letter scheme:

Mills Estates	=	E
Central Millbrae	=	C
Northern Lomita Creek	=	N
Southern Lomita Creek	=	S
San Bruno	=	B
MSASP	=	M
Murchison Drive	=	U

Type of node forms the second component of the node name and are represented by the following notations:

Drainage Inlet	=	D
Maintenance Hole	=	M
Underground Pipe Junction	=	J
Bubble Out	=	B
Culvert Inlet	=	I
Culvert Outlet	=	O
Pump Station	=	P
Flow Split	=	F

The third component of the node name represents the grid element, which indicates the node's location within the City's grid. Each grid element includes two alphanumeric characters.

The fourth component of the node name is a two-digit number from 01-99, based on the number of nodes in each grid element.

3.2.1.2 Link Naming Scheme

The link naming scheme creates a 13-character alpha numeric link name, based on the combination of the upstream node name and the downstream node name, separated by a hyphen, as shown in the following example:

Link: UMD301–UMD302

which links node UMD301 to node UMD302

3.2.2 Data Collected

The following data was collected, whenever possible during the field visits. All elevations were recorded in feet, NAVD88. Field data collected was updated in the City's storm drain system GIS file, and was used to create the hydrologic and hydraulic modeling discussed in Chapter 5.

Manholes

- Invert Elevation
- Rim Elevation

Drain Inlets

- Invert Elevation
- Grate Elevation

Pipes and Culverts

- Upstream node name, based on node naming convention
- Downstream node name, based on node naming convention
- Upstream invert elevation
- Downstream invert elevation
- Type (pipe, box culvert, etc)
- Size (diameter or measurements)

Channel Segments

- Upstream node name
- Downstream node name
- Upstream invert elevation
- Downstream invert elevation
- Bottom width, if applicable
- Manning's n value

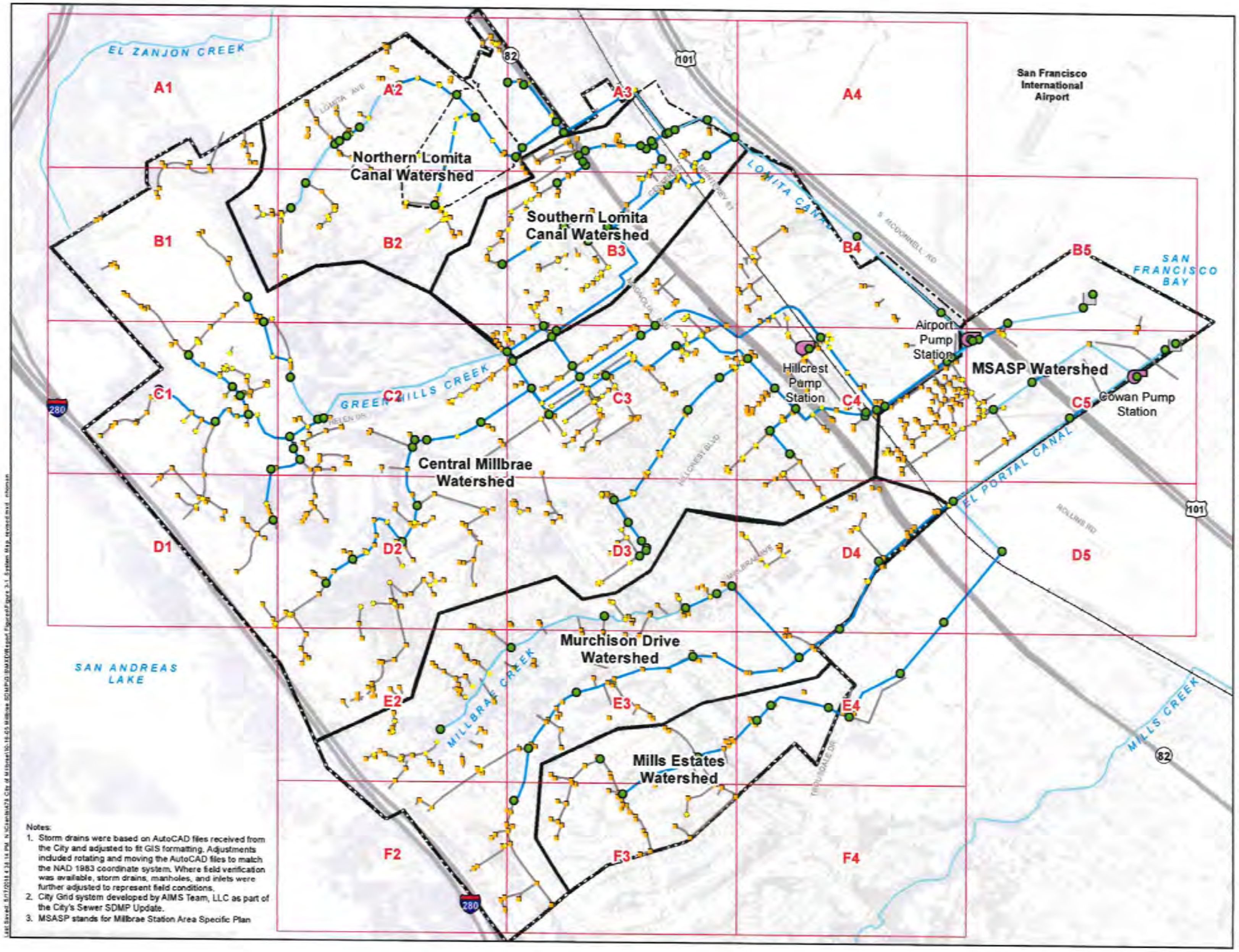
Not all links, diameters, and invert elevations could be field verified and thus, assumptions were made where necessary to characterize the system in the XPSMM model, including:

- Determining open channel cross sections from LiDAR
- Defining inlet inverts from the LiDAR ground elevation minus a standard value
- Interpolating inlet inverts from adjacent known invert elevations
- Inferring pipe diameters from adjacent pipe diameters

Such assumed information is noted in the GIS database.

3.3 GIS DATABASE

Information collected for the trunk drainage system is detailed in the new GIS database prepared as a part of this planning effort, and as shown in the mapbook provided as Appendix A. For the purposes of producing a complete system map, updated data is displayed with the City's existing AutoCAD mapping to create a single file. However, areas of the system that were not field verified as a part of the SDMP development may reflect legacy mapping issues, including links that do not join to adjacent nodes, do not include pipe size data, isolated sub-systems that may or may not connect to the larger drainage network, and outdated information. As the City continues to maintain and assess the system, updates can be incorporated and managed in the GIS database to improve system knowledge.



Symbology

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
- Unmodeled Storm Drain
- Modeled Trunk Storm Drain
- Creek, Canal, or Ditch
- City Grid
- Watershed Boundary
- Millbrae City Limits

0 0.125 0.25 Miles

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Figure 3-1

Millbrae Storm Drain Infrastructure and City Infrastructure Map Grid

City of Millbrae
Storm Drain Master Plan

Notes:
1. Storm drains were based on AutoCAD files received from the City and adjusted to fit GIS formatting. Adjustments included rotating and moving the AutoCAD files to match the NAD 1983 coordinate system. Where field verification was available, storm drains, manholes, and inlets were further adjusted to represent field conditions.
2. City Grid system developed by AIMS Team, LLC as part of the City's Sewer SDMP Update.
3. MSASP stands for Millbrae Station Area Specific Plan

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CHAPTER 4
Performance and Design Criteria

This chapter summarizes and reviews storm drain system performance criteria and design criteria used by various local municipalities and agencies. These criteria were used to develop the performance criteria used to evaluate the existing system in this SDMP as well as the design criteria used to size the new storm drain facilities recommended in this SDMP, both of which are presented at the end of this chapter.

4.1 SUMMARY AND REVIEW OF CITY OF MILLBRAE DESIGN CRITERIA

This City's drainage design criteria are provided in the City of Millbrae, Department of Public Works Engineering Division, Part II Technical Provisions for Public Works Construction (March 2005), Section 6 Storm Drainage Systems. These criteria are primarily for the evaluation of drainage systems in support of land development projects. The criteria relevant to this SDMP are summarized below:

- Post development peak flows and velocities shall be less than or equal to the predevelopment peak flows and velocities. Mitigation (for increased flows) can include on-site detention basins or downstream conveyance improvements.
- For projects within a floodplain or bounding an existing drainage course, the design storm shall be a 100-year event. For most other projects, a 10-year design storm recurrence interval may be used.
- Peak flows can be determined using the rational method (Q = CIAF) or other methods. The variable F is defined as the intensity factor and is set at 1.1.
- Rainfall intensities (I) are provided for the 10-year and 100-year design storms for durations of 10 minutes to 24 hours.
- Runoff coefficients (C) are provided for several land uses.
- All storm drainage facilities shall have sufficient capacity for the anticipated peak flows.

4.2 SUMMARY AND REVIEW OF RELEVANT SAN MATEO COUNTY DESIGN CRITERIA

San Mateo County's drainage criteria match the City's criteria very closely, as summarized below:

- Post development peak flows and velocities shall be less than or equal to the predevelopment peak flows and velocities in areas where there are no existing downstream storm drain systems and no additional runoff may cross property lines. Where downstream storm drain systems exist, they must be sized to accept the increased runoff, or mitigation measures must be taken. Mitigation measures may include on-site detention, including dry wells, or off-site storm drain improvements.
- For projects within a floodplain or bounding an existing drainage course, the design storm shall be a 100-year event.
- Peak flows can be determined using the rational method (Q = CIA) or other methods.

- Permanent structures built over existing drainage facilities or drainage courses shall allow sufficient capacity to protect existing and proposed development. Access shall be provided for maintenance, and redundancy should be provided in case the primary system fails.
- Drainage systems that rely on pumps are not allowed.

4.3 SUMMARY AND REVIEW OF RELEVANT SANTA CLARA COUNTY DESIGN CRITERIA

Drainage criteria for Santa Clara County are provided in the County's Drainage Manual of 2007 and are summarized below:

- Ten-year runoff shall be contained by a storm drain system consisting of underground pipe and/or stable open channels. New storm sewers and channels shall be designed to safely convey the 10-year storm without surcharge. Existing storm drain facilities may be used to convey flow, as long as one foot of freeboard is provided for the ten-year design flow.
- A safe release shall be provided for the design 100-year flow. Within urbanized areas, the 100-year discharge may be carried by a combination of a storm drain system and surface flow on the street, as long as the hydraulic grade line is contained within street rights-of-way.
- Where necessary, detention storage may be implemented to ensure the above criteria are met.
- The 24-hour design storm rainfall is provided for various areas throughout the County.
- Improvements to facilities that are part of a FEMA Flood Insurance Study must be designed to contain the FEMA 100-year water surface elevation using FEMA criteria. The rational method may be used for small drainage areas (less than or equal to 200 acres where storage effects are not significant, or less than 50 acres with detention and storage). C values are specified in the Drainage Manual.
- The unit hydrograph method shall be used for areas over 200 acres, or for more complex situations.

4.4 SUMMARY AND REVIEW OF RELEVANT CITY OF VACAVILLE DRAINAGE DESIGN CRITERIA

The City of Vacaville drainage design standards are specified in the City of Vacaville Standard Specifications, adopted September 11, 1990, with Revisions through June 23, 2015, and summarized below:

- Calculation Methods – The hydrologic design shall be based on the methodologies in the Solano County Water Agency Hydrology Manual, except as modified by the City of Vacaville's standards. Areas less than 200 acres can be evaluated using the rational method or a hydrograph method. Areas greater than 200 acres, areas with pumping, areas with detention basins shall be evaluated with a hydrograph method.

- Storm Drainage Conveyance Systems – A 10-year storm shall be used for design of piped systems with the Hydraulic Grade Line (HGL) to remain at least 1.0 feet below the gutter flow line. For storm drains discharging to creeks, the 10-year creek water elevation shall be used as the starting water level for hydraulic evaluations. The minimum pipe size is 15 inches.
- Streets – Streets shall be designed to provide an overland release of runoff for the 100-year flow assuming the underground storm drain is plugged, all upstream areas are fully developed, and that antecedent rainfall has saturated the tributary watershed. 100-year flows shall be safely routed through or around new development to an acceptable downstream drainage facility, while maintaining 1.0 feet vertical clearance to building pads and shall not be higher than 0.5 feet above the roadway centerline elevation.
- Detention Basins – All detention facilities shall be designed for the 100-year, 24-hour storm event. Detention basin facilities shall maintain a minimum freeboard of 2 feet above the emergency spillway. The emergency spillway shall be located six inches above the100-year water surface elevation in the detention basin.
- Ditches (capacity less than or equal to 25 cubic feet per second (cfs) – Typically, ditches are only allowed as a temporary facility. Permanent ditches shall be sized for a 100-year storm with at least 0.5 feet of freeboard. Ditches shall not be more than 3 feet deep.
- Open Channels (capacity greater than 25 cfs) – Channels shall be sized for a 100-year storm with at least 1.0 feet of freeboard. Channels with levees are not allowed.
- Pump Stations – Currently no pump station criteria are provided, but the City of Vacaville is considering adding pump station design criteria.

4.5 SUMMARY AND REVIEW OF RELEVANT VALLEJO SANITATION AND FLOOD CONTROL DISTRICT

The Vallejo Sanitation and Flood Control District drainage design standards are identified in the Vallejo Sanitation and Flood Control District, Solano County, California, Engineering Design Standards and Policies, dated May 2002.

- Level of Protection – For tributary areas less than 640 acres, the level of protection shall be based on the 15-year storm. For areas greater than 640 acres, the level of protection shall be based on the 100-year storm.
- Runoff Calculation Methods – For tributary areas less than 200 acres, the rational method shall be used. For tributary areas greater than 200 acres a unit hydrograph method shall be used. Drainage facilities shall be sized for the ultimate development of all upstream tributary areas.

- Storm Drain Systems – For the design of all pipeline conveyance facilities, the HGL shall be maintained at a minimum of two feet below the inlet grates and maintenance hole covers. The minimum size of storm drains shall be 15 inches. The minimum design velocity shall be 2.5 feet per second. The maximum design velocity shall be 10 feet per second.
- Street Flow – Although streets are primarily for vehicle traffic, the street sections shall be designed to convey or store floodwater from storms greater than the storm drain capacity.
- Detention Basins – Detention basins may be used to reduce the downstream storm drain costs and problems. However, no detention basin design criteria are provided.

4.6 SUMMARY AND REVIEW OF RELEVANT CITY OF DIXON DRAINAGE DESIGN CRITERIA

The City of Dixon storm drain design criteria are defined in the *City of Dixon Engineering Standards and Specifications*, dated April 2007, and include:

- Storm Drain Conveyance Systems – All pipeline conveyance facilities shall be designed to maintain the HGL at a minimum of one foot below the gutter flow line of all drain inlets during a 10-year, 24-hour storm event.
- Street Flow – Storm drainage systems for new development shall be designed to convey the 10-year storm. During a 100-year storm event, flow greater than the capacity of the pipe system shall be conveyed or detained in the street section while maintaining a water surface at least 1 foot below the adjacent building pad elevations.
- Open channels – If allowed by the City Engineer, open channels shall be designed to convey the 100-year peak flow with a freeboard of 1 foot if the design water level is below the adjacent ground surface and with 3 feet of freeboard if the design water surface is above the adjacent ground (for levees).
- Detention Basins – A 100-year, 4-day storm shall be used for sizing major detention storage facilities. Minimum freeboard during the 100-year storm shall be 1 foot if the design water level is below the surrounding ground surface, and 3 feet if the design water level is above the surrounding ground surface (for embankments). The release rate from detention basin must be authorized by the City Engineer on a case-by-case basis.

4.7 SUMMARY OF RECOMMENDED PERFORMANCE AND DESIGN CRITERIA TO BE USED IN THIS STORM DRAIN MASTER PLAN

Both performance criteria and design criteria are recommended for use in this SDMP. Performance criteria are used to evaluate existing storm drain facilities. If the performance criteria are not met, then storm drain improvements will be developed to mitigate the deficiencies. If storm drain improvements are needed, the improvements should be sized to achieve the design criteria, to the extent possible. The performance criteria used to evaluate existing facilities are less stringent than the criteria used to design new facilities. The reason for using different criteria for the existing system and for proposed improvements is to preclude potential identification of many millions of dollars of storm drain improvements to solve very minor storm drain issues that only occur once every 10 years to 50 years and do not cause property damage.

4.7.1 Recommended Performance Criteria

The following performance criteria should be used to evaluate existing storm drain facilities, and were used to assess the system performance, as discussed in Chapter 5:

- Storm Drain Systems – Existing storm drain systems shall convey the peak 10-year, 24-hour storm flow with a depth less than 6-inches above drain inlets (representing overland flow containment within the street at a curb height of 6-inches).
- Street Flow – During a 100-year storm event, for new developments, flow greater than the capacity of the pipe system shall be conveyed or detained in the street section while maintaining a water surface at least 6-inches below the adjacent building pad elevations. During a 100-year storm event, flood hazard (the product of depth and velocity) shall be no greater than 6.0.
- Open Channels – Open channels shall convey the 100-year peak flow with a freeboard of 0.5 feet if the design water level is below the adjacent ground surface and with 2.0 feet of freeboard if the design water surface is above the adjacent ground (for levees).
- Tide Level – For the 10-year model evaluations, a 10-year tide level of 9.06 feet NAVD88 shall be used as the tailwater level in the Bay. For the 100-year model evaluations, a 100-year tide level of 10.28 feet NAVD88 shall be used as the tailwater level in the Bay. These water levels are consistent with the 10-year and 100-year extreme tide levels in the Sea Level Rise & Overtopping Analysis for San Mateo County's Bayshore, Final Report, May 2016 (see Chapter 2).

4.7.2 Recommended Design Criteria

The following design criteria should be used to size new storm drain facilities, and were used to design system improvements, as discussed in Chapter 6:

- Storm Drain Systems – New storm drains shall be sized so that the peak 10-year, 24-hour storm event water levels are at least one foot below the storm drain inlet grate elevations.
- Street Flow – During a 100-year storm event, for new developments, flow greater than the capacity of the pipe system shall be conveyed or detained in the street section while maintaining a water surface at least 1.0 feet below the adjacent building pad elevations. For improvements to existing systems, during a 100-year storm event, flood hazard (the product of depth and velocity) shall be no greater than 6.0.
- Open Channels – If allowed by the City Engineer, new open channels shall be designed to convey the 100-year peak flow with a freeboard of 1 foot if the design water level is below the adjacent ground surface and with 3 feet of freeboard if the design water surface is above the adjacent ground (for levees).

- Detention Basins – If allowed by the City Engineer, a 100-year, 4-day storm shall be used for sizing major detention storage facilities. Minimum freeboard during the 100-year storm shall be 1 foot if the design water level is below the surrounding ground surface, and 3 feet if the design water level is above the surrounding ground surface (for levees). The release rate from detention basin must be authorized by the City Engineer on a case-by-case basis.
- Tide Levels – For the design of new facilities, the future 10-year and 100-year tide levels of 9.97 and 11.20 feet NAVD88 shall be used as the tailwater level in the Bay. These tide levels are 11 inches higher than current extreme tide levels. The increase of 11 inches is consistent with the most likely 2050 increase in extreme tides in the Sea Level Rise & Overtopping Analysis for San Mateo County's Bayshore, Final Report, May 2016 (see Chapter 2).
- Green Infrastructure – An effort shall be made during the design of storm drainage improvements to incorporate green infrastructure components.

CHAPTER 5
Model Development and Existing Conditions Evaluations

This chapter describes the development of an integrated hydrologic and hydraulic model using XPSWMM software version 2017.2.1 by Innovyze. Major components of the model include the hydrologic runoff layer and the hydraulics layer. The data and assumptions that were used in creating each layer of the modeling are discussed within this chapter, and the model results are compared to the performance criteria in Chapter 2 in order to identify the locations for system improvements, presented in Chapter 6.

5.1 HYDROLOGIC MODEL DEVELOPMENT AND RESULTS

Hydrologic modeling reflects the precipitation and terrain that, together, drive runoff flow rates and volumes that must be routed through the City's stormdrain system. This section outlines the inputs and assumptions made in the hydrologic modeling of the City.

5.1.1 Climate

As described in the City's *Administrative Review Draft General Plan Update* (unpublished), average temperatures in Millbrae range from a daily average low of 42°F in December and January to an average daily high temperature of about 72°F in August and September. Average annual rainfall totals 20 inches at the Airport to about 40 inches per year at San Andreas Lake. Most of the rainfall occurs between October and May. January is typically the wettest month, with an average rainfall of almost 4.5 inches. July is typically the driest month, with an average rainfall of only 0.03 inches.

Because the annual rainfall for Millbrae ranges so widely between the higher and lower elevations, the 10-year and 100-year design storm should also vary across the City. West Yost developed a range of design storms for the City based on an adjustment of the 10-year, 24-hour and 100-year, 24-hour intensity distributions outlined in the City's *Technical Provisions* (Millbrae, 2005) and presented in Table 5-1.

Table 5-1. Intensity, Duration and Frequency of Rainfall in Millbrae (Millbrae, 2005)

Time of Concentration, Hrs:Mins	Intensity, Inches per Hour 10-Year	Intensity, Inches per Hour 100-Year
0:10	2.45	3.60
0:15	2.05	3.00
0:20	1.73	2.55
0:25	1.50	2.22
0:30	1.33	1.95
0:35	1.20	1.75
0:40	1.10	1.61
0:45	1.02	1.49
0:50	0.95	1.37
0:55	0.90	1.28
1:00	0.86	1.21
1:15	0.75	1.07
1:30	0.67	0.95
1:45	0.61	0.87
2:00	0.56	0.80
2:30	0.49	0.70
3:00	0.44	0.63
3:30	0.40	0.57
4:00	0.37	0.53
4:30	0.34	0.49
5:00	0.32	0.45
6:00	0.29	0.41
7:00	0.26	0.38
8:00	0.24	0.35
9:00	0.23	0.33
10:00	0.21	0.30
12:00	0.19	0.27
24:00	0.13	0.18

The distributions from the *Technical Provisions* were converted to hyetographs that represented each rainfall event at an average elevation. As indicated in the regional isopluvials shown in *NOAA Atlas 14, Volume 6* (NOAA, 2011) and an analysis of point-precipitation frequency data, rainfall intensity is approximately 5 percent higher in the upper elevations of the City and 5 percent lower along the shoreline, as compared to the central elevation zone. Elevations within the City range from 620 feet above Mean Sea Level on the City's western boundary to 5 feet below Mean Sea Level near San Francisco Bay. Based on this information, West Yost developed an elevation-based distribution, with "moderate" rainfall intensity in the central elevations, and a five percent shift in the "high" and "low" elevations of the City, as shown on Figure 5-1. The corresponding 10-year, 24-hour and 100-year, 24-hour rainfall depths for each isopluvial are provided in Table 5-2.

Table 5-2. Spatial Distribution of Rainfall Intensity Across Millbrae, based on Elevation

	10-year Rainfall Depth, inches			100-year Rainfall Depth, inches		
Duration	Low	Moderate	High	Low	Moderate	High
5 min	0.19	0.20	0.21	0.29	0.30	0.32
10 min	0.39	0.41	0.43	0.57	0.60	0.63
15 min	0.49	0.51	0.54	0.71	0.75	0.79
30 min	0.63	0.67	0.70	0.93	0.98	1.02
1 hr	0.82	0.86	0.90	1.15	1.21	1.27
2 hr	1.06	1.12	1.18	1.52	1.60	1.68
3 hr	1.25	1.32	1.39	1.80	1.89	1.98
6 hr	1.65	1.74	1.83	2.34	2.46	2.58
12 hr	2.17	2.28	2.39	3.08	3.24	3.40
1 day	2.96	3.12	3.28	4.10	4.32	4.54

The spatial distribution of rainfall was used to set the total rainfall depth for each catchment in the XPSWMM model. Rainfall depths by catchment are identified in Appendix B.

5.1.2 Watersheds

As shown on Figure 3-1, the City's stormwater generally drains east/southeast out of the hills into the flatter regions of the City and, ultimately, out to the Bay south of the Airport. The major watersheds are described below, and include:

- Northern Lomita Canal Watershed (225 acres) - This watershed drains the northern part of the City through a piped storm drain system (42-inch to 48-inch diameter) into Lomita Creek and the Lomita Canal. The runoff from this watershed is lifted by the Airport Pump Station into the Highline Canal east of the BART tracks.
- Southern Lomita Canal Watershed (164 acres) - This watershed drains through a piped storm drain system, which in turn flows into the Lomita Creek, which in turn flows into the Lomita Canal at the Landing Lane Bowl. The runoff from this watershed is lifted by the Airport Pump Station into the Highline Canal east of the BART tracks.
- Central Millbrae Watershed - (942 acres) - This watershed drains through several storm drainage systems to the Highline Canal. Water from the Bay is prevented from entering the Highline Canal by twin box culverts (near South McDonnell Road), each 15 feet wide by 15 feet tall, each with a large flap gate. Flap gates allow water to flow from the City to the Bay, but prevent back flow from the Bay to the City. However, these flap gates sometimes do not close completely because mud accumulates below the gates and prevents the gates from sealing closed. This watershed also includes the Hillcrest Pump Station, which lifts water from the Hillcrest Drive undercrossing under the BART tracks.

- MSASP Watershed (67 acres) – This watershed drains through a piped storm drain system to the open channels in the US-101 interchange and then flows into a storm drain to the Cowan Pump Station.
- Murchison Drive Watershed (393 acres) - This watershed drains through series of storm drains and Millbrae Creek to the El Portal Canal. The El Portal Canal drains to the Bay. Water from the Bay is blocked from entering the El Portal Canal by twin 84-inch diameter culverts (under the Old Bayshore Highway), each with a flap gate.
- Mills Estates Watershed (130 acres) – This watershed drains through a 45-inch storm drain into a City of Burlingame storm drain system, which returns with additional collected flows to the upstream end of the El Portal Canal.

5.1.3 Catchments

Establishment of the hydrologic modeling layer of XPSWMM includes not only the determination of the regional rainfall and drainage sheds based on topography and drainage system layout, but also individual catchment geometry, abstraction, infiltration, and runoff rate. A number of catchments were identified within each watershed. Generally, catchments were delineated for each node in the drainage network where a major junction or link geometry change occurs. The following model parameters were developed to define each catchment:

- Catchment Area
- Catchment Width
- Soil Type
- Imperviousness
- Slope

The area of each catchment was computed in GIS. The determination of width, soil, land use and slope are further discussed in the following sections. The resulting hydrologic input data for catchments is presented in Appendix B and further discussed in the sections below.

5.1.3.1 Catchment Width

Calibration of the XP-SWMMM Runoff Method is difficult. The XP-SWMM manual provides guidance for most of the input variables, and most of the variables can be defined with easily defined physical values. However, the watershed width is a very difficult parameter to estimate using the guidance in the manual unless the watershed is rectangular, with a well-defined channel flowing down the center of the watershed, such as an urban residential block with houses on each side of the street. The street is then considered the channel. Most watersheds do not fit this ideal configuration. Thus, other methods of estimating the watershed width are needed, and the watershed width value often becomes the primary runoff calibration variable.

West Yost has developed an equation for calculating the initial watershed width for the 10-year storm, based on extensive experience calibrating XPSWMM modeling. This equation was used to estimate the watershed width for Millbrae catchments, as follows:

Initial watershed width (feet) = 155 * (Area (in acres) ^ 0.64)

5.1.3.2 Catchment Hydrologic Soil Group

Catchment hydrologic soil group influences the amount of runoff retained by the soil, and thus, influences the amount of runoff to be modeled. The hydrologic soil groups are poorly defined in this area, but the majority of soil types delineated by the US Department of Agriculture's Natural Resources Conservation Service (NRCS) Soil Web Survey reflect hydrologic soil group C. hydrologic soil group C was therefore used for catchments with undefined soil types.

5.1.3.3 Catchment Land Use & Imperviousness

Much of the City is developed, with parks, schools, and steep hillsides representing much of the pervious area. Impervious surfaces prevent runoff from infiltrating into the soil, and thus generate more runoff. The impervious percentage of each catchment was correlated to the land uses from the City's General Plan update (Mintier & Harnish, 2016) shown on Figure 5-2 and verified with aerial imagery.

5.1.3.4 Catchment Slope

The slope of each catchment influences how rapidly runoff moves through the watershed. The slope values were based on the LiDAR data provided by the City and County of San Francisco's Airport Authority. The difference in elevation from the upstream end of the catchment to the downstream end, divided by the distance between the two points was computed within XPSWMM.

5.1.3.5 Rainfall Losses and Infiltration

Rainfall losses represent the loss or "initial abstraction" caused by such phenomena as surface ponding, surface wetting, interception and evaporation. For the storm drain master plan, initial losses for pervious portions of the watershed were globally computed in XPSWMM, using the Horton method, which reflects the idea that infiltration capacity rapidly declines during the early part of a storm and then tends towards an approximately constant value after a couple of hours for the remainder of the event.

Depression storage values for all catchments of 0.1 inch and 0.35 inches were assumed for impervious and pervious areas, respectively. Not all impervious areas provide depression storage, however. It was estimated that 25 percent of the City's impervious area provided direct connection to runoff. For hydrologic soil group C, the maximum and minimum infiltration rates were assumed to be 1.42 inches per hour and 0.14 inches per hour, respectively, in accordance with the National Engineering Handbook (NRCS, 2007).

5.1.3.6 Manning's Roughness Coefficients for Catchments

The Manning's roughness for catchment pervious and impervious areas are used to represent the overland or sheet flow that occurs before runoff enters a defined channel. Values for Manning's roughness coefficients vary greatly for different land surface types for overland flow, but average values of 0.014 and 0.35 were used for Millbrae's impervious and pervious areas, respectively, in accordance with the XPSWMM manual (XPSWMM, 2013).

5.2 HYDROLOGIC MODEL CALIBRATION AND RESULTS

5.2.1 Hydrologic Model Calibration

This section presents the calibration of computed runoff for several different land uses and catchment sizes using the City's Rational Method. As outlined in the City's Technical Provisions for Public Works Construction (Millbrae, 2005), a peak runoff was computed for various catchment types. The Rational Method Evaluation is described by the following relationship:

$$Q = C\,i\,A\,F$$

where:

- C is a runoff coefficient for the catchment from the Technical Provisions, presented below in Table 5-3 for relevant land uses.
- i is the rainfall intensity in inches/hour as specified in the Technical Provisions based on each catchment's time of concentration
- A is the catchment area in acres, and
- F is the intensity factor of 1.1, as specified in the Technical Provisions

Table 5-3. Rational Method Runoff Coefficients (Millbrae, 2005)

Type of Development	Runoff Coefficient
Parks & Cemeteries	0.30
Residential - Acres	0.40
Residential - Regular	0.50
Commercial	0.75
Paved Areas	0.85

The runoff unit flows computed with the rational method were compared to the runoff unit flows computed for the same sheds with the XPSWMM model. The differences were minimized by adjusting the watershed widths used in the model, as this value is one of the most variable, particularly in a system like Millbrae's where catchments varied widely in shape and size. The initial watershed width was reduced by 30 percent to achieve the calibration, as shown in Table 5-4. Further adjustment of this variable resulted in an overcorrection of unit flow and thus, a total error or 0.33 cfs/acre over the subject catchments was deemed acceptable.

Table 5-4. Calibration of the Watershed Width in XPSWMM to Match Millbrae's Rational Method Runoff Computation

Catchment Identifier	Catchment Land Use	Catchment Area, acres	Isohyetal Zone	Rational Method		XPSWMM Method		Unit Flow Difference, cfs/acre
				Runoff, cfs	Unit Flow, cfs/acre	Runoff, cfs	Unit Flow, cfs/acre	
87	Open Space/Residential	47.52	Low	75.27	1.58	76.00	1.60	0.02
50	Residential	20.67	Low	40.93	1.98	41.00	1.98	0.00
51	Residential/Commercial	23.41	Low	69.53	2.97	59.00	2.52	-0.45
105	Open Space/Residential	26.34	Central	41.72	1.58	54.00	2.05	0.47
92	Residential	28.95	Central	57.32	1.98	60.00	2.07	0.09
100	Commercial	22.46	Central	47.25	2.10	57.00	2.54	0.43
104	Open Space	31.86	High	37.85	1.19	19.00	0.60	-0.59
85	Residential	27.40	High	54.25	1.98	64.00	2.34	0.36
							Total	0.33

5.2.2 Hydrologic Model Results

This section presents a summary of XPSWMM hydrologic model results for existing conditions for each catchment in the Millbrae Watershed, along with hydrologic outputs including peak runoff rates and peak unit runoff rates under existing conditions. Results for individual catchments are presented in Appendix B. Peak flows during the 10-year, and 100-year, 24-hour events for each watershed are approximately as indicated in Table 5-5.

It has been noted by City staff that flows in the upper reaches of the Central Millbrae watershed may be increasing in the near future as the storm drain system is disconnected from the sewer system in the vicinity of Helen Drive, Tioga Drive and Ridgewood Drive. The City expects approximately 110,000 gallons per day during a 10-year, 24-hour event to enter the storm drainage system. However, the additional amount of expected runoff (0.17 cfs) represents a very small percentage of total runoff and therefore flows were not adjusted to reflect the change.

Table 5-5. Peak Runoff by Watershed for the 10-year and 100-year Events

Watershed Name	Most Downstream Link(s)	10-year, 24-hour peak flow, cfs	100-year, 24-hour peak flow, cfs
Northern Lomita Creek	NMA303-NOA301	81.8	107.3
Southern Lomita Creek	NDA303-NOA302	63.4	104.3
Central Millbrae	CJA301-NOA303	122.1	126.0
	MOC401-NIC501	589.4	841.1
	CJC401-MPC503	25.3	47.8
	Central Millbrae Total	736.8	1,014.9
Murchison Drive	UDD402-UMD401	331.1	456.0
Mills Estate	EOD501-UMD401	309.1	497.5
MSASP	MMC501-MIC501	75.9	124.5

5.3 HYDRAULIC MODEL DEVELOPMENT

A hydraulic model of the City's trunk drainage system was developed in XPSWMM version 2017.2.1 by Innovyze. This modeling software was selected based on its broad application to stormwater master planning, its stability in modeling one-dimensional systems, and its integration between hydrologic and hydraulic datasets. This section presents the hydraulic model, including geometric and hydraulic inputs and assumptions.

5.3.1 Geometry

The storm drain network was defined in the hydraulic model as a limited subset of all drainage serving the City. To identify improvements to the drainage system that would have the greatest impact to flood risk in the City, and to optimize return on investment in system improvements, model geometry was generally limited to storm drains greater than 18-inches in diameter. Where possible, the City's CAD file was used as a reference to set pipe sizes, although there were numerous locations where field investigations or new development required an update to the system. The storm drain network is shown on Figure 3-1.

5.3.1.1 Node Invert Assumptions

In some cases, it was not possible to verify node inverts during field investigations. This occurred where manholes were blocked or no manhole access was available in sealed lines. For the nodes where it was not possible to verify the invert, the invert was either estimated based on interpolation or extrapolation from nearby nodes or based an assumed depth, coupled with available LiDAR and aerial imagery.

5.3.1.2 Culvert and Bridge Crossings

Bridge and culvert crossings were not surveyed during the field investigations. Inverts upstream and downstream of each crossing were interpolated from surrounding information, or assumed where none was available (such as at outfall locations). Opening sizes were also assumed, based on photography or available records. Bridges were modeled as culverts, due to limitations in the model. Contraction and expansion coefficients were set at 0.3 and 0.1, respectively, unless the configuration warranted a change.

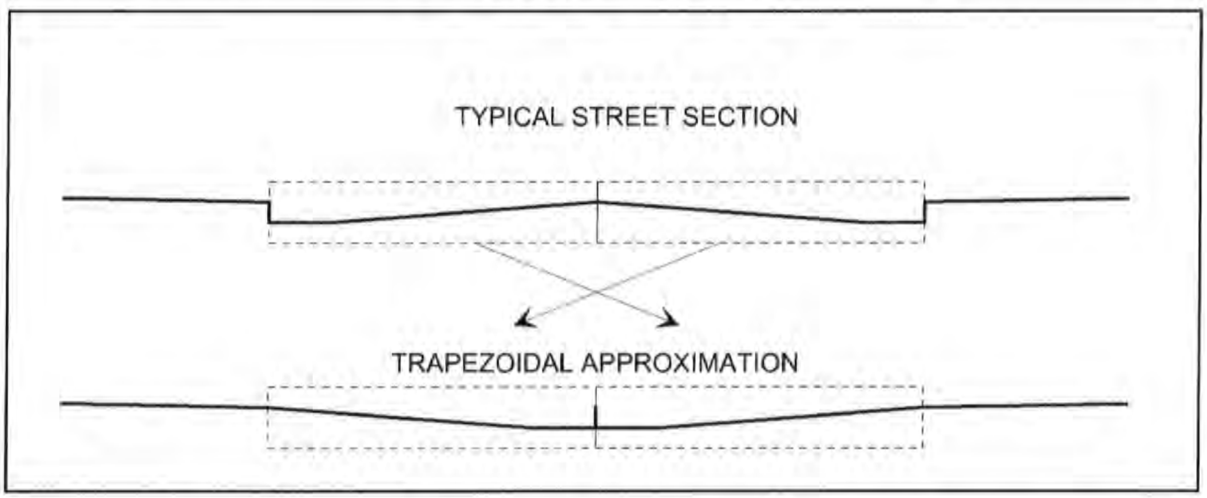
5.3.1.3 Open Channel Cross Sections

For creeks and other naturally shaped channels, XPSWMM was used to cut representative cross sections from the LiDAR data. Trapezoidal channels were added to the model using data from the City or aerial imagery and LiDAR. Channel roughness was estimated from the degree of vegetation present in the main channel and overbanks, as discussed in Section 5.3.2.1.

5.3.1.4 Street Section Assumptions

Where the storm drain system capacity was exceeded, streets were modeled to convey excess flow from the surcharge location to downstream inlets with capacity to direct flow back into the system. The cross sections of each street were created to match the width of the street, with a curb depth of 6-inches. As indicated on Figure 5-3, a typical street section with a roadway crown can be visualized, and was modeled, as an equivalent trapezoidal section.

Figure 5-3. Transforming a Typical Street Section to a Trapezoidal Approximation (City of Sacramento, 1996)



In order to add flow in the street, the ground elevation at the upstream and downstream nodes had to be artificially raised to contain that flow. The artificially modified ground elevations were removed during model post-processing to obtain the true depth of flooding in street sections.

5.3.1.5 Overland Flow Sections

There are numerous locations where any drainage system surcharges would not be conveyed in a street. Principally, this situation arises when streets run perpendicular to the natural elevation changes within the City and there is no nearby perpendicular street to draw the flow downhill. In these instances, flow would likely be conveyed through a park or a neighborhood. Cross sections were created in the model to represent these broad, shallow flow paths to a downstream inlet with capacity, where flow could return to the system. These sections were set up with varying trapezoidal channel sizes to represent the potential capacity of each location.

5.3.2 Hydraulic Model Inputs

This section describes the information supplied to the hydraulic model to define the hydraulic performance of the storm drain system, including the roughness of materials and channels, pump station performance, boundary conditions, and locations where flow entered the system from outside the City.

5.3.2.1 Manning's N Values for Pipe Materials and Channels

Video tapes from a storm drain system inspection were reviewed during a previous Storm Drain Master Planning effort (KJ, 1998). Some pitting was observed on the interior of the storm drain pipelines at that time. For this SDMP, it was assumed that the condition of the pipelines has not significantly changed, and therefore the same roughness factor of n = 0.014 was used in the XPSWMM model for pipelines.

Open channels were mainly observed to be densely vegetated, with the exception of the channel through the golf course at Green Hills Country Club, in the Central Millbrae Watershed. As indicated in Appendix C, open channel roughness was set to range from 0.035 over the less vegetated portions to 0.050 through densely vegetated sections of the channels.

5.3.2.2 Pump Station Data

The City has three pump stations: Hillcrest, Airport, and Cowan, as discussed in Chapter 2. Sufficient data was available to model most pumps as dynamic, but pump curves were not obtained for the Airport side of the Airport pump station, where static pumping was used to reflect the maximum capacity of each pump. Pump station inputs to the hydraulic model are indicated in Table 5-6.

Table 5-6. Hydraulic Model Existing Condition Pump Station Input Data

Pump Station	Pump Number	Model Link ID	Pump Start Elevation, feet NAVD88	Pump Stop Elevation, feet NAVD88	Ground Elevation feet NAVD88	Invert Elevation, feet NAVD88	Wet Well Area, feet^2
Hillcrest	1	CPC401-CMC406	8.5	6	15	-15	115
	2		8.5	6			
Airport - SFO	1	MPC501-NIC501	-10	-12.5	11	-18	1,400
	2		-9	-12.5			
Airport - Millbrae	1	MOC503-NIC501	-3.25	-13.25	11	-18	700
Cowan	1	MPC502-NOC502	-5.35	-7.25	5.5	-11.75	707
	2		-5.05	-7.25			
	3		-4.25	-7.25			

5.3.2.3 Boundary Conditions

Model results are driven by the ability of runoff to escape the system at the tide gates on the Bay. To represent the time-varying tidal conditions for different events, a synthetic tide was created for both a 10-year and 100-year event. For the existing conditions 10-year model evaluations, a 10-year tide level of 9.06 feet NAVD88 was used as the tailwater level in the Bay. For the existing conditions 100-year model evaluations, a 100-year tide level of 10.28 feet NAVD88 was used as the tailwater level in the Bay.

For the design of improvements, the future 10-year and 100-year tide levels of 9.97 and 11.20 feet NAVD88 were used as the tailwater level in the Bay. These tide levels are 11 inches higher than current extreme tide levels. The 10-year and 100-year tide levels and the increase of 11 inches are consistent with the current information and most likely 2050 increase in extreme tides in the Sea Level Rise & Overtopping Analysis for San Mateo County's Bayshore, Final Report, May 2016 (see Chapter 2).

5.3.2.4 External Flow Assumptions

There are several areas outside the model for which no data on drainage was available. A watershed within the southern portion of the City of San Bruno drains to the Lomita Canal at the northeastern corner of the City of Millbrae's boundary, eventually discharging to the Highline Canal via the Airport Pump Station. The flow for this shed, was estimated based on the shed area indicated by GHD in San Bruno's recent *Storm Drain Master Plan Update* (GHD, 2014). The shed area of 151.5 acres resulted in a 196.5 cfs peak flow for the 10-year event and 320.8 cfs peak flow for the 100-year event, input just downstream of Landing Lane Bowl.

In addition, an area of the northern portion of the City of Burlingame, to the south of the City of Millbrae, drains to the El Portal Canal, via the Cowan Pump Station. The maintenance spending on Cowan Pump Station is proportionate to the areas of Burlingame and Millbrae served by the pump station, according to City staff. Therefore, a flow split of 60 percent to 40 percent, respectively, was assumed in the modeling, resulting in a peak flow of 66.3 cfs for the 10-year event and 109.4 cfs in the 100-year event from the City of Burlingame.

5.4 HYDRAULIC MODEL RESULTS AND VERIFICATION

For the 10-year, 24-hour event, flooding was predicted by the model at nearly all the locations noted by the City to have experienced flooding during previous significant storm events. An exception occurred at the Millbrae Station Specific Plan watershed outfall near the 101 Freeway interchange, where City staff indicated backups have occurred in the past due drain inlets being blocked by debris, rather than hydraulic underperformance of the system. Such debris is not accounted for in the hydraulic modeling. A second location near the intersection of Ashton and Hillcrest was indicated to be a problem where a single residence was constructed below street elevation. It is possible that nuisance flooding will persist at this location, even with system improvements, due to overland flows, as sites below drainage inlet elevations cannot discharge into the system without ponding.

For the 100-year, 24-hour event, excessive flood hazards were present in many modeled streets. It is important to note that the hydraulic modeling performed was one-dimensional, and did not allow lateral spreading of surcharge flows. Therefore, in situations where topography is relatively flat, and flooding would likely spread throughout a network of connected streets, the flood hazard modeling is conservative. In areas with steep topography, flow is unlikely to seek an alternate path and excessive flood hazards should be considered a risk to pedestrians. In addition, there were many locations during the 100-year event where open channels lacked sufficient freeboard.

Appendix D presents the results of the hydraulic model of the existing system for the 10-year and 100-year events.

5.5 COMPLIANCE WITH PERFORMANCE CRITERIA

The results of the hydraulic modeling were compared with the performance criteria outlined in Chapter 4. Violations of the performance criteria are discussed in relation to the model results in the subsections below. The main criterion that was used to evaluate the storm drain collection system was its ability to convey runoff without excessive flooding (i.e. pipelines were allowed to surcharge, but flow was not allowed to overtop an assumed curb height of 6-inches) during the 10-year, 24-hour event. Flooding during the 100-year, 24-hour event was also assessed for both flood hazard (depth times velocity) and open channel freeboard. Locations where the depth and freeboard performance criteria were violated during the 10-year event are shown on Figure 5-4. Locations where the freeboard, and flood hazard criteria were violated during the 100-year event are shown on Figure 5-5.

5.5.1 Northern Lomita Creek Watershed

The Northern Lomita Creek Watershed is the northern-most drainage basin in the City. The system serves the residential areas west of Capuchino High School and the high school itself. The area drains into the Lomita Canal via a 48-inch storm drain line where the San Felipe Canal flows into the Lomita Canal south of Santa Helena Avenue in Millbrae. In the upper reaches of the watershed, runoff is conveyed by an open channel that runs through the neighborhood from Meadow Glen School to just west of Cypress Avenue, where it enters a 42-inch storm drain. The 42-inch storm drain transitions to a 30-inch line and heads south, crossing Capuchino High School where it receives additional flow from a 24-inch line that drains part of Barcelona Drive and the High School. The 24-inch line and the 30-inch line are connected by a 2-foot by 4-foot box culvert. The main 42-inch line turns east at Capuchino Drive where it becomes a 48-inch pipe. The 48-inch storm drain line is joined by a 24-inch line at El Camino Real, and jogs down San Juan Avenue to discharge into the Lomita Canal.

As shown on Figure 5-4, there were two locations with surcharging during the 10-year event, but no surcharges exceeded performance criteria in the Northern Lomita Creek Watershed.

Although there is some street flooding expected in this watershed during the 100-year, 24-hour event, flood hazards are expected to be below the threshold of concern, as shown on Figure 5-5. Much of the overflow from surcharged storm drains is expected to be stored in the fields at Capuchino High School.

5.5.2 Southern Lomita Creek Watershed

The Southern Lomita Creek Watershed begins in the west at Green Hills Country Club, where a portion of the drainage of the Central Millbrae Watershed discharges into a flow split between the 42-inch line that enters the Southern Lomita Creek Watershed and the 48-inch line that continues through Central Millbrae. The 42-inch line is sealed for most of its length down to the discharge on Lomita Canal at Spruce Street, but receives drainage from the south side of Green Hills Elementary School near Laurel Avenue at Helen Drive. Drainage from the neighborhood north and west of Green Hills Elementary School splits, with a 27-inch line draining to the south end of Landing Lane Bowl via Ludeman Lane, while the remainder flows north, becoming a 42-inch line the empties to the north end of Landing Lane Bowl. The watershed discharges to Lomita Canal at Spruce Street and Landing Lane Bowl.

As shown on Figure 5-4, flood depths during the 10-year, 24-hour event in this watershed were generally acceptable, with the exception of the area around Landing Lane Bowl, where there were several nodes with surcharging in excess of 6-inches. Although high water levels in Lomita Canal contribute to the poor drainage of this area, hydraulic constrictions are also present. Three 24-inch trash capture devices were recently placed in the Landing Lane Bowl. Modeling indicates that the weir that ensures low flows pass through the trash capture devices prior to exiting the Bowl increase water surface elevations above the elevation of the weir (estimated at 4-feet NAVD88 by San Francisco Airport staff), particularly as the capture devices collect trash and convey less flow. Airport staff have noted that, in certain instances of reported Landing Lane flooding, the Lomita Canal was not surcharged, suggesting that the increased flood hazard identified by the model may be present under a variety of conditions. In addition, the channel just upstream of Landing Lane Bowl appears to present a constriction that causes upstream backwater. Space is limited in this area to make improvements. It is recommended that the City consider alternatives to enhance conveyance at this location. One option is to install additional capture devices to increase hydraulic conveyance through the weir and Landing Lane Bowl. Given the total flow area out of Landing Lane Bowl is nearly 76 square feet, provided by 6 48-inch culverts, it would be appropriate to match this conveyance through the weir and trash collection system in a high flow event. In addition, the City should ensure trash removal at regular intervals, particularly prior to rain events.

Street flooding is expected in this watershed during the 100-year, 24-hour event, around Landing Lane Bowl, which therefore has insufficient freeboard, as shown on Figure 5-5. In addition, street flooding in excess of the performance criteria may be present along Magnolia Avenue in the vicinity of Green Hills Park. Since the flood hazard at this location is driven by excessive depth, it is likely that surcharges would escape the right-of-way toward the Marymount Greenhills Retirement Center under the existing condition.

5.5.3 Central Millbrae Watershed

The Central Millbrae Watershed provides drainage for nearly 50 percent of the total area of the City from its northwest corner east, to the head of Highline Canal, just west of the BART tracks. The shed covers an area as far south as Hillcrest Boulevard at its western edge and is drained by three major sub-systems.

A series of lines west of the Greenhills Country Club flow across the Country Club in an open channel and re-enter the storm drain system at the split between the 42-inch line that enters South Lomita Creek Watershed and the 48-inch line that turns south toward Anita Drive. This line takes on flow from the northern portion of the watershed at several locations and increases to a 60-inch line at Laurel Avenue.

It is joined near El Camino Real by a 48-inch line that drains everything from Richmond Drive in the north to Taylor Boulevard in the south and westward to the City limits. This line crosses the tracks at Hermosa Avenue and collects drainage from the Hillcrest Pump Station before discharging just east of the BART tracks.

The third major sub-system runs down Taylor Boulevard, ultimately in a 39-inch line that joins a large box culvert near Broadway, which has its outfall at the upstream end of the Highline Canal, just west of the BART tracks.

As shown on Figure 5-4, this watershed is expected to experience significant areas of surcharging during the 10-year, 24-hour event. In the upper watershed, surcharging is driven by high runoff on steep slopes, often at transitions to more gradual slopes. Further down, the trunk system is generally under-sized to maintain flows within the existing storm drain lines. Surcharges in excess of 6-inches in depth were identified along the line that runs west to east south of the Greenhills Country Club in the vicinity of Richmond Drive, in the area around the Hillcrest pump station, and at the crossing of the BART tracks, where an existing 18-inch line presents a constriction in flow.

There are five locations where depth may exceed 0.5 feet during the 10-year, 24-hour event. Two lie along the line connecting Tioga Drive to Geraldine Drive, where both significant inflows and downstream surcharging are exacerbated by the change in slope. A second location is at the intersection of Library Avenue and Magnolia Avenue, where the surcharge depth is expected to just exceed the performance criteria.

Model results suggest that during large storm events, there may also be localized flooding at the Hillcrest undercrossing of the BART tracks. Although the Hillcrest Pump Station has two pumps, City staff have indicated that they are not able to run at the same time, but instead provide redundancy in case of failure or maintenance. However, inflows to the pump station may exceed the capacity of a single pump. The City should consider re-operating the pump station to allow both pumps to operate simultaneously. This may necessitate a second 18-inch discharge line under the BART tracks.

The City has indicated that there is an 18-inch line under the BART tracks connecting Hemlock to the 33-inch line under the canal. This could not be verified during field inspections, but has been modeled according to the City's information. This location represents a hydraulic pinch point between two larger-diameter lines, and may cause flooding in the area upstream of the tracks. The depth of flooding is unclear, as a floodplain mapping was not performed during the modeling. It is recommended that the City verify the size of this line and upgrade it.

During the 100-year event there is significant and wide spread street flooding through the Central Millbrae Watershed, as shown on Figure 5-5. There are also numerous locations where the hazard to pedestrians may be a concern. Locations of flood hazard concern in the Central Millbrae Watershed include the following:

- In the upper watershed, from Helen Drive to Greenhills Country Club, flood hazards are greater than 6.0 with street velocities as high as 10.6 feet per second.

- Flood hazards above 6.0 were also present in Taylor Boulevard from the limit of the modeling at Ashton Avenue all the way to Broadway, with street velocities as high as 7.5 feet per second.
- Flood hazards in excess of 6.0 are also present along the length of Tioga Drive, emptying into the neighborhood between Anita Drive and Helen Drive with street velocities as high as 14 feet per second in this steep area.

In areas where street flood hazard is noted in the lower elevations, there are more opportunities for flow to spread over multiple streets. While modeling was performed along one alignment for each instance of 100-year surcharge, overall depths could be lower during an actual event. Areas where flood hazard were observed, but further analysis with two-dimensional modeling should be considered to better characterize the extent and the risk include:

- In the neighborhood along Anita Drive, including Helen Drive,
- Along the Anita Drive, Michael Lane, Richmond Drive alignments all the way down to Broadway,
- Along La Cruz Avenue from Magnolia Avenue to Broadway,
- Along Broadway from La Cruz Avenue to Hillcrest Boulevard.

In addition, open channels, including those at Greenhills Country Club and Highline Canal have insufficient freeboard, as shown on Figure 5-5. Should a 100-year, 24-hour event occur at the same time as a 100-year high tide, as modeled, Highline Canal would be expected to overtop in locations where the canal banks are lower than the tide elevation of 10.28 feet NAVD88. This situation would be exacerbated in a situation where sea level rise to 11.2 feet NAVD88 is considered, but the likelihood of the two events occurring at the same time is low and the results are advisory, rather than guaranteed.

5.5.4 Murchison Drive Watershed

This watershed contains two major sub-sheds. The Murchison Drive sub-watershed collects flows from southwestern Millbrae via a series of storm drains that increase in size toward El Portal Canal. It is joined by flows from the Mills Estate Watershed re-entering Millbrae from the City of Burlingame at the head of the El Portal Canal, just east of the tracks.

Millbrae Creek is the primary drainage for the upper portion of the Murchison Drive Watershed, collecting flows from the western edge of the City to Ashton Avenue. At this point, the channel enters a 48-inch culvert to cross Ashton Avenue. The culvert changes to an irregularly sized box culvert that continues under a series of structures paralleling Millbrae Avenue, reducing in cross sectional area until it daylights across the Avenue from Laurel Avenue in a natural channel section, with a small, rectangular low flow channel. This section coveys flow to a 24-inch storm drain near the northwestern corner of Mills High School that conveys flow south to the 54-inch line in Murchison Drive near Sequoia Avenue.

The Murchison Drive watershed storm system is expected to perform fairly well in a 10-year, 24-hour storm event, with minor surcharging below 6-inches in depth along Murchison Drive, due to the large areas that enter the storm drain system at the top of the shed.

Street flooding is expected along Murchison Drive during the 100-year, 24-hour event, where the street gradient is likely to encourage flows to follow the right-of-way, exposing pedestrians to potentially high velocities, as shown on Figure 5-5. The flood hazard exceeds the performance criteria of 6.0, with street velocities as high as 13.5 feet per second in this steep portion of the watershed, if flow does not find alternate paths. However, Mills Creek appears to have sufficient freeboard during the 100-year 24-hour event.

5.5.5 Millbrae Station Area Specific Plan Watershed

The flow in the Millbrae Station Area drains southeast to the corner of Camino Millenium and Aviador Avenue, where flow turns south in a 30-inch line that crosses Millbrae Avenue near the Highway 101 Freeway interchange. Flow crosses the interchange eastward as an open ditch, with culvert crossings at roadways, and then south through a system of culverts underneath the Aloft Hotel property into the Cowan pump station. The Cowan pump station discharges into the El Portal Canal.

The Millbrae Station Area drainage system consists mainly of smaller-diameter pipes that were not modeled. However, there is no indication of any surcharging in the watershed during the 10-year, 24-hour storm event, or any street flooding during the 100-year event. However, the shed is bordered by both the Highline Canal and the El Portal Canal, which have insufficient freeboard in a 100-year event and may be subject to overtopping in the event of sea level rise.

5.5.6 Mills Estates Watershed

This watershed drains the southwestern corner of the City through a 45-inch line in Trousdale Boulevard that passes through the City of Burlingame, collecting a limited amount of drainage from Burlingame and rejoining the Millbrae system as an open channel just east of the BART tracks that empties into the upstream end of the El Portal Canal.

While the surcharging during the 10-year, 24-hour event is less than 6-inches in depth, as shown on Figure 5-4, there may be significant flood hazard during the 100-year event due to the steep gradient of the watershed, which causes high velocities, as shown on Figure 5-5.

In the lower portion of Mills Estates Watershed, as runoff enters the City of Burlingame, street flooding exceeding performance criteria is expected during the 100-year event along Trousdale Boulevard from approximately South Ashton Avenue to Magnolia Avenue, with velocities as high as 9.3 feet per second. Data received from the City of Burlingame was incomplete along the portion of the alignment along Trousdale, and it was assumed that the transition between pipe diameters was located at the farthest upstream end of the missing data. Flood hazard modeling also indicated a high hazard potential through the neighborhood around Spring Valley Elementary School, but it is likely that flooding would be dispersed over multiple paths and broad, shallow sheet flow is more likely. Further analysis with two-dimensional modeling should be considered to better characterize the extent of the flood hazard.

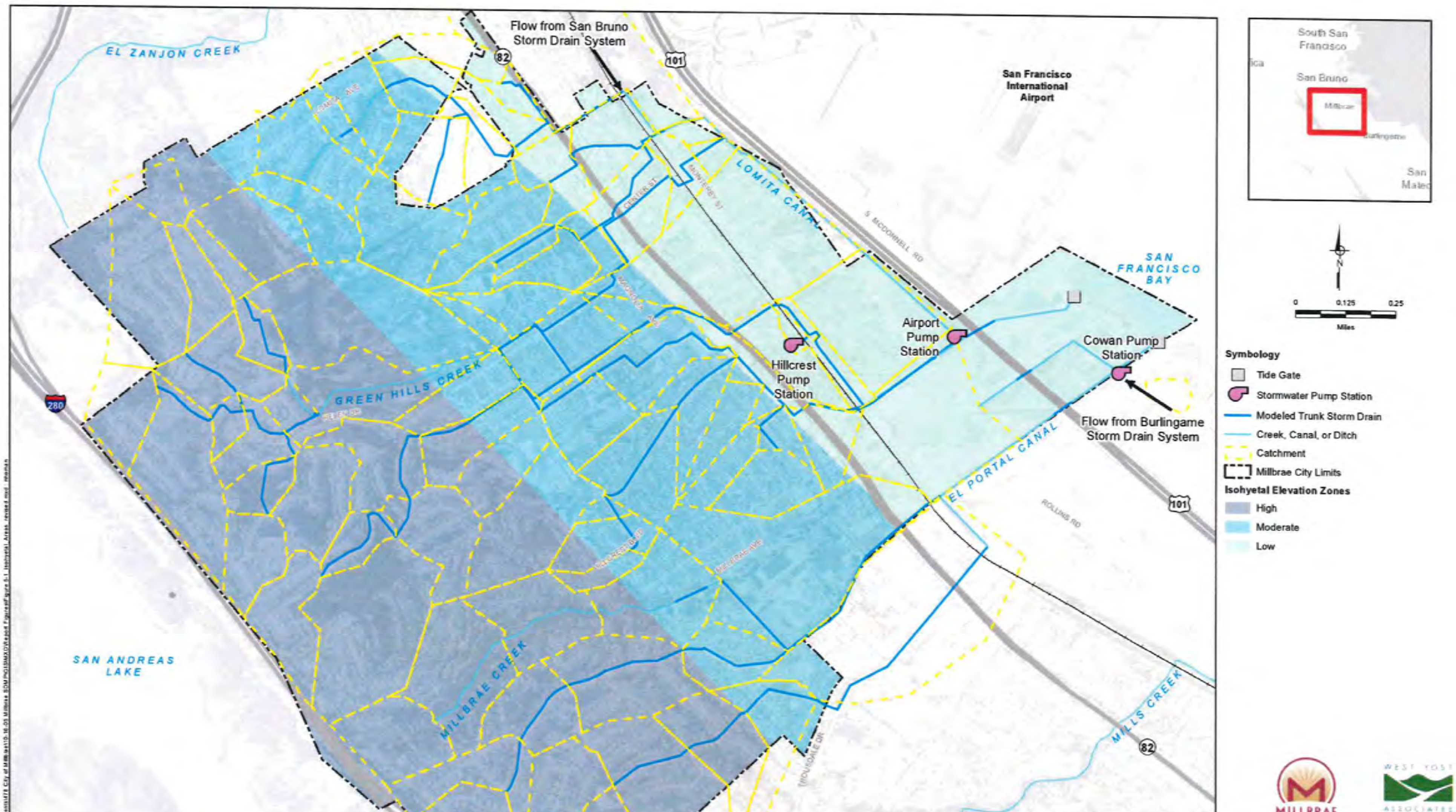


Figure 5-1

Spatial Distribution of Rainfall by Elevation Across Millbrae

City of Millbrae
Storm Drain Master Plan

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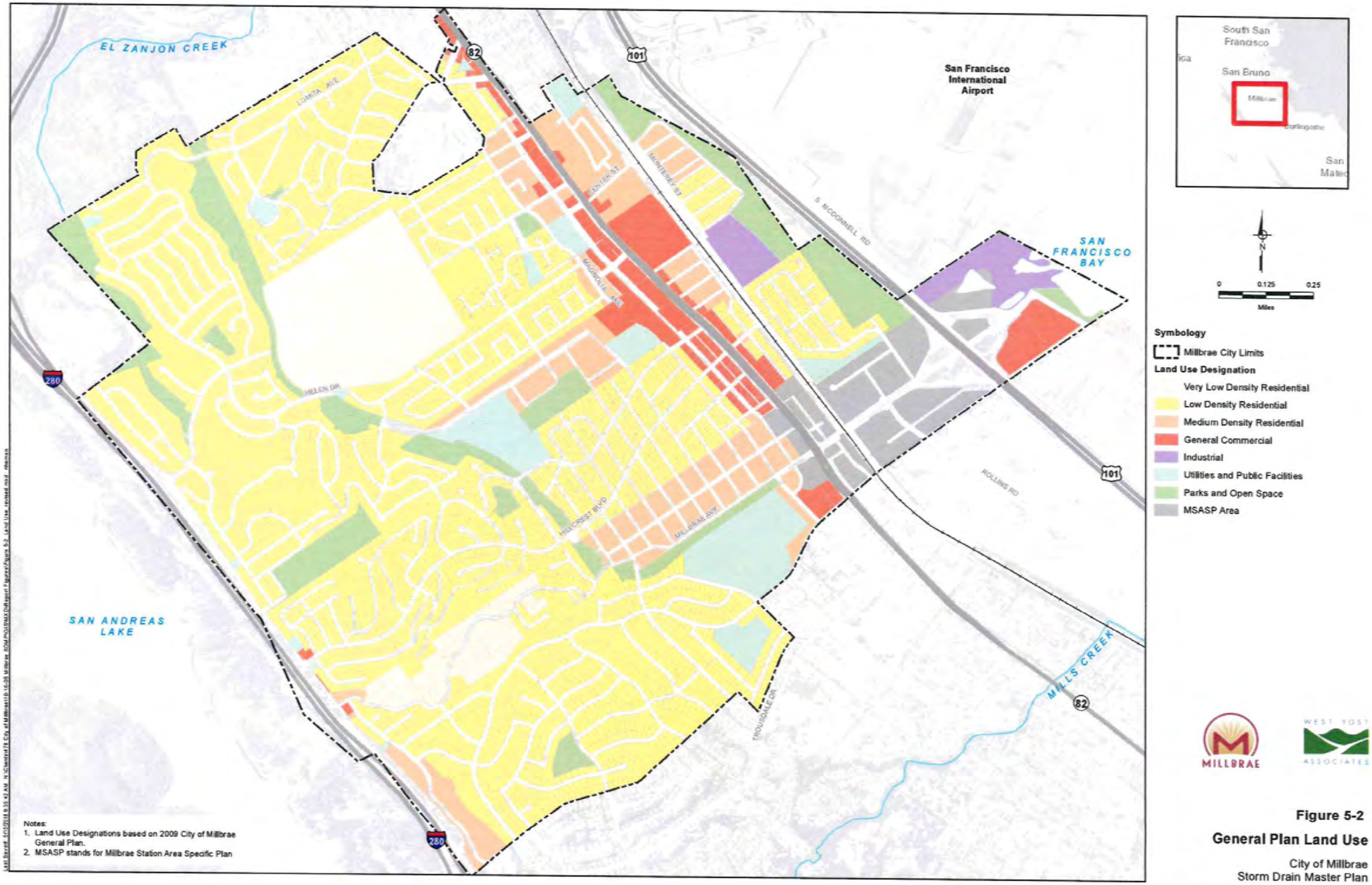

Notes:
1. Land Use Designations based on 2009 City of Millbrae General Plan.
2. MSASP stands for Millbrae Station Area Specific Plan

Figure 5-2

General Plan Land Use

City of Millbrae
Storm Drain Master Plan

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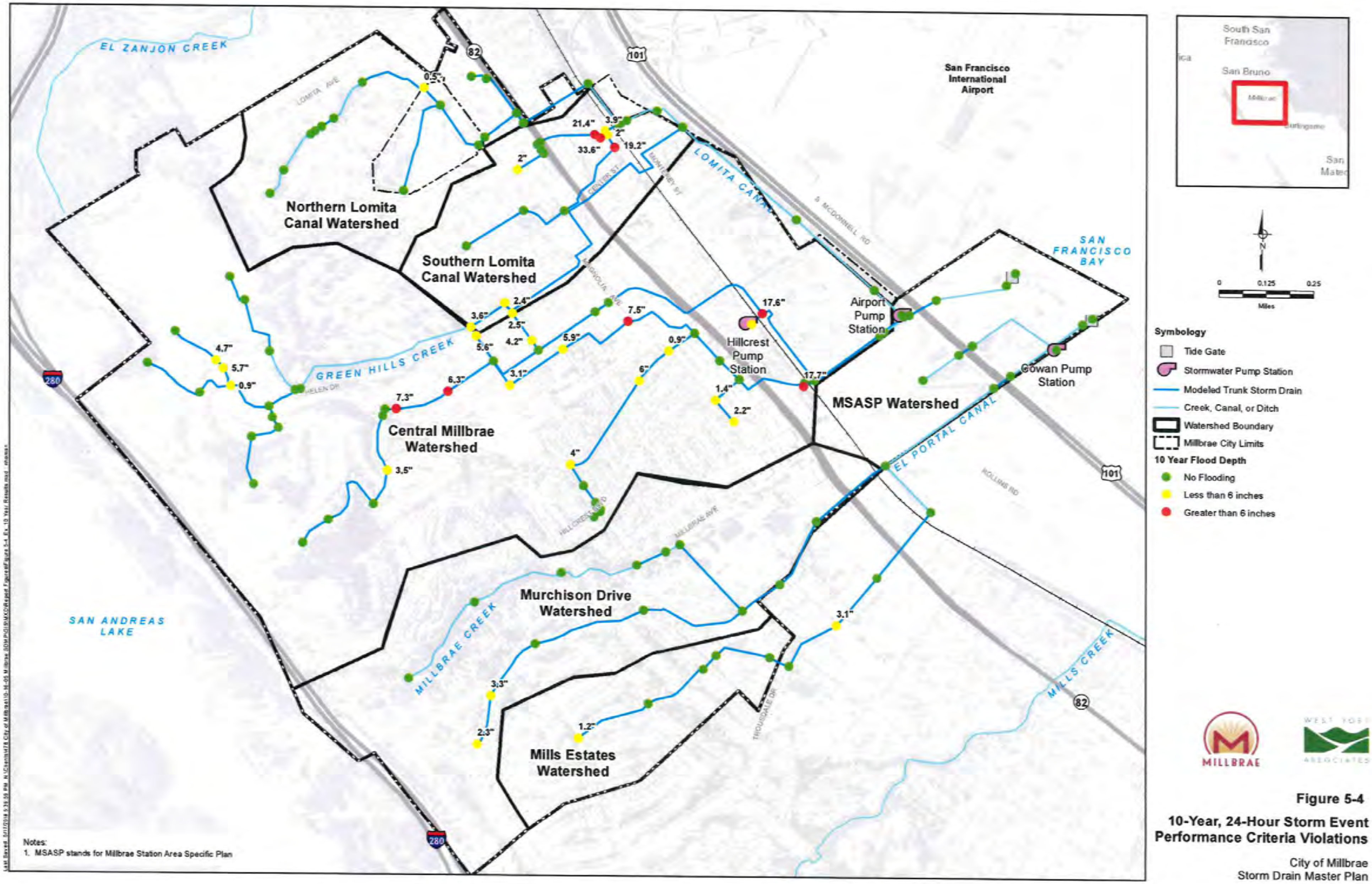

Notes:
1. MSASP stands for Millbrae Station Area Specific Plan

Figure 5-4

10-Year, 24-Hour Storm Event Performance Criteria Violations

City of Millbrae
Storm Drain Master Plan

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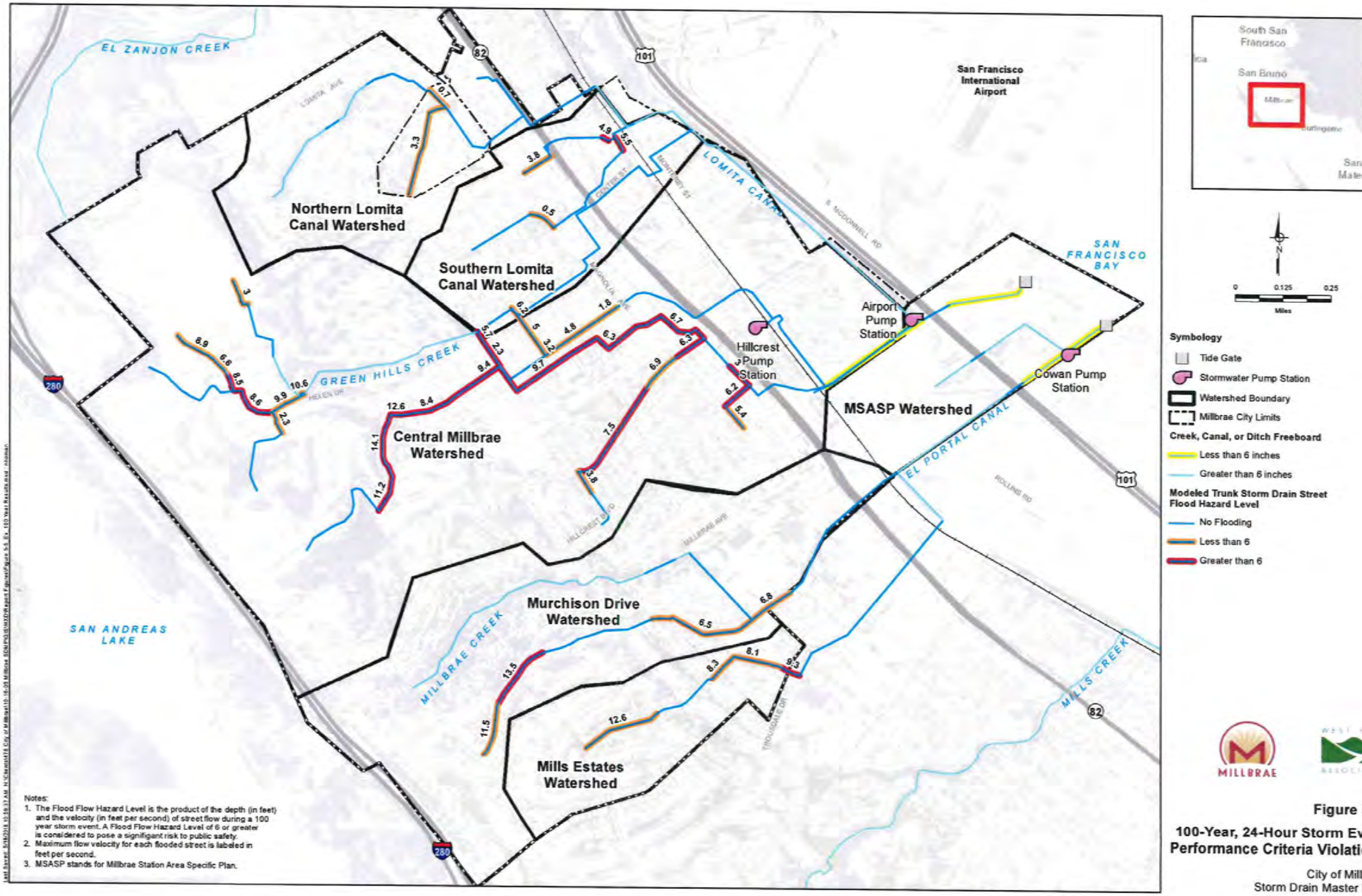

Notes:

1. The Flood Flow Hazard Level is the product of the depth (in feet) and the velocity (in feet per second) of street flow during a 100 year storm event. A Flood Flow Hazard Level of 6 or greater is considered to pose a signifigant risk to public safety.
2. Maximum flow velocity for each flooded street is labeled in feet per second.
3. MSASP stands for Millbrae Station Area Specific Plan.

Figure 5-5

100-Year, 24-Hour Storm Event Performance Criteria Violations

City of Millbrae
Storm Drain Master Plan

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CHAPTER 6
Recommended Stormwater Conveyance Improvements

This chapter of the SDMP presents the recommended improvements to mitigate the system deficiencies identified by the combined hydrologic and hydraulic model, as well as additional recommendations identified through review of previous studies, field investigation, and discussion with City staff.

6.1 CITY WIDE MODEL RESULTS WITH RECOMMENDED IMPROVEMENTS

Based on the results of West Yost's hydraulic modeling of the City's stormwater collection system, performance criteria were violated during both the 10-year, 24-hour and 100-year, 24-hour events. The 10-year event was modeled to evaluate the depth of flow at each model node, and the 100-year event was modeled to assess the capacity of open channels, as well as the depth and velocity of street flooding, which contribute to the flood hazard, as discussed in Chapter 4.

While it appears that much of the backbone system has sufficient capacity to convey stormwater from the 10-year, 24-hour design storm event, there are areas that are predicted to surcharge and locations that fail to meet the performance criteria. In the past, the City has observed several locations of nuisance flooding during larger storm events, as noted in Chapter 1. During the 10-year event, the modeling does predict surcharging at most of these locations, as discussed in Chapter 5. A second location near the intersection of Ashton and Hillcrest was indicated to be a problem where a single residence was constructed below street elevation. It is possible that nuisance flooding will persist at this location, due to overland flows, as sites below drainage inlets cannot discharge into the system.

Recommended improvements for the modeled pipelines that were predicted to surcharge above the curb height during the 10-year, 24-hour event are identified in Table 6-1. These improvements are also shown on Figure 6-1. Although there are a number of locations with minor surcharging, only 8 locations exceeded the depth performance criteria identified in Chapter 4. It should be noted that two segments of Capital Improvement Project (CIP) 5.1, 5.2 and 5.6 not only allow the improvement to meet the 10-year, 24-hour design criteria for surcharging, but also reduce critical flood hazards in the 100-year, 24-hour event.

The City's storm drain system was not designed for a 100-year, 24-hour storm. Therefore, during the 100-year event, significant street flow is expected throughout the City. Recommended improvements where model surcharging resulted in a violation of the depth performance criteria are noted in Table 6-1 as being designed to a "10-year standard", while flood hazards greater than 6.0 required improvements to be designed to a "100-year standard", as noted in Table 6-1. "Tier 1 Improvements" and "Tier 2 Improvements" identify CIPs where the flood hazard risk is more significant, while "Tier 3 Improvements" identifies CIPs where it is likely that any flooding would disperse over multiple flow paths, thus reducing the true risk. These CIPs should be further investigated to determine whether the benefits would be worth the investment. Based on City recommendations, CIPs with a combined cost estimate less than $2 million (M) were given the highest priority for implementation. Although components of some "Tier 2 Improvements" are well below this threshold, the desired outcomes will not be achieved by partially completing a CIP and the costs for all segments should be considered the cost of the CIP.

Table 6-1. Recommended Improvements

CIP ID	Link ID	Location Summary	Diameter, Inches		Design Criteria	Cost Estimate Dollars
			Existing	Proposed		
Tier 1 Improvements						
CIP 1	SOA301-NDA303	Landing Lane Bowl	Triple 24	Remove	10-year standard	$ 50,000
CIP 3	CDC402-CJC401	Inlet to line under Highline Canal	18	30	10-year standard	$ 399,000
CIP 6	CMC312-CMD301	Taylor Middle School Drainage	-	24	City proposed (10-year standard)	$ 1,146,000
CIP 7.1	CMD203-CDC204	Tioga Drive	30	36	100-year standard	$ 1,330,000
CIP 7.2	CDC204-CDC207	Tioga Drive	30	36	100-year standard	$ 166,000
CIP 7.3	CDC207-CMC204	Tioga Drive to Anita Lane	30	36	100-year standard	$ 255,000
					Tier 1 Improvements Subtotal	$ 3,346,000
Tier 2 Improvements						
CIP 2.1	CPC401-CMC406	Hillcrest Pump Station (PS)	Alternating	Two Together	10-year standard	$ 10,000
CIP 2.2	CPC401-CMC406	Hillcrest PS Discharge	12	Double 12	10-year standard	$ 116,000
CIP 2.3	CMC406-CMC404	Hillcrest PS to Highline Canal	66	Double 66	10-year standard	$ 4,043,000
CIP 4	MMC501-MPC502	Relocate inlet to Cowan PS	-	Double 48	City proposed (10-year standard)	$ 9,082,000
CIP 5.1/7.4	CMC204-CDC208	Tioga Drive to Geraldine Drive	36	48	100-year standard	$ 1,706,000
CIP 5.2/7.5	CDC208-CMC306	Geraldine Drive to Lincoln Circle	36	48	100-year standard	$ 2,587,000
CIP 5.3	CMC306-CMC309	Richmond Drive	42	48	10-year standard	$ 1,984,000
CIP 5.4	CMC309-CMC302	Richmond Drive	42	54	10-year standard	$ 2,823,000
CIP 5.5	CMC302-CMC304	Magnolia Avenue to Taylor Boulevard	-	Double 48	10-year standard	$ 3,236,000
CIP 5.6/10.2	CMC304-CMC401	Taylor Boulevard	39	Triple 39	100-year standard	$ 1,570,000
CIP 8.1	CMC102-CMC104	Helen Drive	30	36	100-year standard	$ 450,000
CIP 8.2	CMC104-CMC201	Helen Drive	42	48	100-year standard	$ 1,573,000
CIP 8.3	CMC201-CDC205	Helen Drive	42	48	100-year standard	$ 1,107,000
					Tier 2 Improvements Subtotal	$ 30,287,000
Tier 3 Improvements						
CIP 9	SDB302-SDB303	Magnolia Avenue to Broadway	18	24	100-year standard	$ 344,000
CIP 10.5	CMC403-CMC407	Behind Broadway to Highline Canal	(2) 48 x 68 Box	Add (2) Parallel 48	100-year standard	$ 3,222,000
CIP 10.4	CDC401-CMC403	Behind Broadway to Highline Canal	(2) 48 x 68 Box	Add (2) Parallel 49	100-year standard	$ 1,669,000
CIP 10.3	CMC401-CDC401	Behind Broadway to Highline Canal	(2) 48 x 68 Box	Add (2) Parallel 50	100-year standard	$ 2,299,000
CIP 10.1	CMC303-CMC304	Taylor Boulevard	36	42	100-year standard	$ 1,140,000
					Tier 3 Improvements Subtotal	$ 8,674,000
					Total	**$ 42,307,000**

In addition, there were violations of the freeboard performance criteria along many of the City's open channels, including at Landing Lane, Highline Canal and El Portal Canal. Much of the open channel performance is driven by tidal conditions in the Bay. With a high tide of just over 9 feet represented in the existing conditions model, and canal heights around 9 feet, these channels have very little additional capacity to convey flood flows. Even if improvements are made to the storm drain system, freeboard is expected to decrease when considering sea level rise, as modeled in the improvement designs. The lack of freeboard cannot be addressed by improving system capacity alone, and should instead be managed with improved isolation of the City from the Bay, coupled with either 1) enhanced pumping in the future or 2) increases in canal embankment height at an appropriate time in the future.

Many of the improvements described in the sections below are recommended to address potential flooding in areas that do not have a history of recurring flooding. This might be because the model's computation of localized depth at each surcharged node does not represent lateral spread that would occur during an actual flooding event. The same is true for many instances of flood hazard exceeding performance criteria. Typical street flow will select a broader flow area than a single street. However, the point depths and street velocities, as modeled, represent an important indicator of potential issues and hazards.

6.1.1 General Recommendations

In addition to the modeled results, there are several improvements to the storm drain system that have been identified based on the findings of previous studies where improvements have not yet been implemented, based on changing conditions, or based on common practice. The locations of these improvements are shown on Figure 6-1, but designs and cost estimates have not been prepared to address these issues.

West Yost conducted a series of site visits to photograph and document important facilities, as well as to verify the City's storm drainage network configuration and obtain invert elevations at model nodes. For a number of locations where West Yost could not access the drainage system to perform measurements, City staff provided follow up information to clarify needed data. However, not all locations could be accessed, even by the City, and the site visits focused on the trunk system. Therefore, additional verification and measurements should be performed in the future to complete the update of the City's existing storm drain system map.

During field investigations, a number of maintenance issues were identified that suggest a routine CCTV inspections program should be implemented to avoid underperformance during storm events. Collapsed pipes, blockages, sedimentation, and trash are concerns and increased routine inspections will help identify such issues before they become a problem. There are several areas of the City's system where access is not available, and the City should consider uncovering or adding manholes in the following locations:

- The 42-inch line draining from Green Hills Creek to Lomita Canal is sealed for its entire length. As the line is surcharged in significant storm events, it is important that it remain sealed to prevent flood waters from escaping. However, with no access for maintenance or inspection, it may be appropriate to install one or more sealed manholes that can be unbolted for inspection purposes.

- The 15-inch line under Magnolia Avenue between Ludeman Lane and Green Hills Drive that drains to Center Street has a sealed manhole. As the line is surcharged in significant storm events, it is important that it remain sealed to prevent flood waters from escaping. However, with no access for maintenance or inspection, it may be appropriate to uncover the existing sealed manhole for inspection and maintenance purposes.
- In the back yard of 15 Evergreen Court, there is a manhole that has been recently covered by a deck, constructed by the resident. This manhole provides access to a junction in the system and should be uncovered for future maintenance and inspection.
- The 33-inch line under Highline Canal has been sealed. Historically, the Canal was leaking into the line and causing the system to underperform. However, a sealed manhole could be considered for access and maintenance.

City staff have indicated that flooding has occurred in the past in the Aviador Area, particularly when there has been a failure at the Airport Lift Station. At the present time, the Airport Lift Station relies on a single 125 horsepower pump. Based on discussions with City staff, the existing Airport Lift Station would require modifications to the wet well and a separate discharge pipeline to accommodate a second pump. This recommendation is noted on Figure 6-1 as general recommendation (GR) 1.

The existing flap gates at the outlet of Highline Canal do not close completely and, during high tide events in the San Francisco Bay, allow water from the Bay to enter the Highline Canal. This raises the water level in the canal and reduces system storage. Considering the potential for sea level rise to an elevation of 11.20 feet NAVD88 by 2050, as suggested by the Sea Level Rise & Overtopping Analysis for San Mateo County's Bayshore, Final Report, May 2016 (see Chapter 2), without repair, the Highline Canal would be overtopped even without high runoff. It is important to note that modeling of improvements assumed the tide gate at this location was repaired. Failure to repair this problem will impact the ability of other improvements to function as designed. This recommendation is noted on Figure 6-1 as GR2.

In anticipation of future sea level rise, the City may wish to consider increasing the height of the Highline Canal and El Portal Canal embankments, which, due to differential settlement since construction, vary in height with elevations as low as 9 feet. These protective levees could be overtopped during high flow, high tide events, even without sea level rise. In addition, canal seepage during high flows is a concern, having been observed along the Highline Canal, and should be addressed with lining repair, a cutoff wall, or other measures. This recommendation is noted on Figure 6-1 as GR3.

The City has indicated that there is a history of flooding in the vicinity of Landing Lane. A significant component of this problem may be an excess of vegetation built up in the Lomita Canal that has been driven by difficulty in Airport maintenance crews obtaining permits to use equipment in the channel, where endangered species are present at times. Excess vegetation may cause a backwater condition in the upper portion of Lomita Canal that impairs drainage of the City at the Landing Lane Bowl. However, the City has recently installed a trash capture device in the Landing Lane Bowl that may also create a hydraulic impact at lower flows. Improvements were modeled in Landing Lane Bowl and are discussed in Section 6.3. This recommendation is noted on Figure 6-1 as GR4.

GR4 Is Recommended to Address Known Issue Number 1 – Flooding of Landing Lane Area

During field inspections, City staff performed a confined-space entry of the culvert where Mills Creek crosses Ashton Avenue. This culvert passes under several structures in a combination of circular, concrete box, and mixed concrete/corrugated metal construction and was found to be failing, which could endanger the structures above it. Although this location was not found to cause a hydraulic constriction, it is recommended for immediate repair and replacement, as the change in alignment and shape have caused significant scour, which is anticipated to further degrade in subsequent storm events. This recommendation is noted on Figure 6-1 as GR5.

The City has also noted that the lines in Taylor Boulevard and Center Street are subject to sedimentation that necessitates periodic sediment removal. The sedimentation was not modeled, and could represent a significant impact to system performance, if not cleaned regularly, particularly prior to the start of flood season. This recommendation is noted on Figure 6-1 as GR6.

6.1.2 Capital Improvement Projects

A suite of ten capital improvement projects were modeled in accordance with the design criteria in Chapter 4. The final configurations shown on Figure 6-1 meet the 10-year and 100-year design criteria, as shown on Figures 6-2 and 6-3, respectively, with the exception of the freeboard criteria in the 100-year, 24-hour event for open channels. As discussed, future sea level rise prevents the freeboard criteria from being met in any configuration of the storm drain system without increases in channel height.

6.1.2.1 Capital Improvement Project One

Improvements are needed at the Landing Lane Bowl to increase hydraulic capacity, as discussed in Chapter Five, and shown on Figure 6-1 as CIP 1. The recommended improvements include removing and the trash capture devices and the low flow weir to maximize conveyance through Landing Lane Bowl under the tracks. It may be necessary to identify an alternate design or location for trash capture in the future. This improvement will reduce backup in the systems that drain to the Bowl, but should be coupled with vegetation removal in Lomita Canal to achieve optimum results. It is assumed that vegetation control will be managed by the San Francisco Airport maintenance staff.

CIP1 Is Recommended to Address Known Issue Number 1 – Flooding of Landing Lane Area

6.1.2.2 Capital Improvement Project Two

This project includes two components: reoperation of the Hillcrest Pump Station to make use of both pumps during high flow storm events (CIP 2.1), and adding a discharge line that crosses the tracks and upgrading the downstream conveyance to Highline Canal by adding a second, parallel 66-inch line on the east side of the BART tracks to accommodate the additional pump discharge (CIP 2.2). The 66-inch line also alleviates existing performance issues upstream. Since both pumps are already in place, the bulk of the cost of this improvement is in the additional discharge and new large-diameter line. The City may also wish to consider a third pump as back-up for large storm events, but this would require extensive re-design of the pump station and is not included in the cost estimates at this time.

6.1.2.3 Capital Improvement Project Three

This project increases the conveyance under the BART tracks at the head of the 33-inch line under the Highline Canal that leads to the Airport Pump Station. This location is currently a hydraulic constriction, according to available drawings that indicate the line is 18-inches in diameter. In the improvements modeling, the size of the line was increased to 2.5-feet to achieve the design criteria. This was recommended, as opposed to a second, parallel line, as the additional width needed to install a line parallel could create the potential for additional utility conflicts.

6.1.2.4 Capital Improvement Project Four

The drainage channel connecting the Millbrae Station Area Specific Plan Watershed to Cowan Pump Station runs through the southern portion of the Highway 101 Interchange, from west to east. The channel, and its culverts crossing the Highway, have historically been difficult to maintain, and the City would like to relocate the alignment outside the Caltrans right-of-way to improve access and maintenance. This Improvement Project reflected the City's desire to facilitate future maintenance, rather than alleviate modeled performance problems.

CIP4 Addresses Known Issue Number 2 – Flooding of the MSASP Area

The cost and difficulty of implementing this project is not fully understood at this time. The preliminary alignment selected for the new dual 48-inch pipelines in a new right-of-way (as shown on Figure 6-1 as CIP 4.1) crosses private property along the 101 Freeway interchange and the El Portal Canal, where there is a large parking lot serving a hotel. While it does not appear that structures would be impacted, an easement would be necessary to assure long-term accessibility and the costs of land and permitting were not included in the preliminary cost estimate in Section 6.3. The cost estimate does not include decommissioning the culverts under the interchange and Highway 101, as it is assumed these will be disconnected, but may be needed for Highway drainage (CIP 4.2).

6.1.2.5 Capital Improvement Project Five

Due to the significant number of performance criteria violations, and the relatively flat terrain in the Central Millbrae Watershed, local improvements alone failed to produce sufficient reduction in flooding during the 10-year and 100-year events. The suite of components included in Improvement Project 5 are designed to achieve a reduction in flood depths for three locations that violated the performance criteria for depth during the 10-year event, as well as significant reaches of high velocity flood hazard along Tioga Drive. The proposed improvements also contribute to the improvement of widespread lower risk flood hazards throughout downtown.

CIP5 Addresses Known Issue Number 3, In Addition to Other Problems

Improvements include:

- Increasing pipe diameters all the way from Tioga Drive to Magnolia (CIPs 5.1-5.4) by 0.5 feet to 1.0 feet in diameter, depending on location;
- Relocating the connection of this line to the line in Taylor Boulevard (CIP 5.5) to allow additional parallel facilities to be added within street rights-of-way. This improvement includes capping the upstream end of the existing 4-foot diameter segment of storm drain (CIP 5.7); and
- Increasing pipe size just before the Taylor Boulevard line empties into the box culvert under Broadway to accommodate the additional flow (CIP 5.6).

The cost and difficulty of implementing this project is not fully understood at this time. The preliminary alignment selected for the new right-of-way was chosen to make use of City streets, but the extent of conflict with existing utilities is unknown and may impact the practicality of implementing this improvement.

6.1.2.6 Capital Improvement Project Six

The City has indicated that past flooding has occurred at Taylor School, and requested that a connection between the existing valley gutter at the school and the storm drain system be made to accommodate runoff from this area. This improvement was modeled as a new 24-inch storm drain connecting at Ashton and Taylor (CIP 6). The improvement did not have a discernable impact on system performance.

CIP6 Addresses Known Issue Number 5 – Flooding at Taylor Middle School

6.1.2.7 Capital Improvement Project Seven

The improvement projects along Tioga Drive were designed to alleviate flood hazard, where velocities are expected to be up to 14 feet per second during the 100-year, 24-hour event (CIP 7.1-7.5). The 6-inch increase to the existing 30- and 36-inch lines increase capacity to carry high flows underground, rather than in the street. Achieving the recommended amount of cover over the new pipe installations should be undertaken with care, as preliminary analysis suggests that there is less than 2-feet of cover available. It is reasonable to assume that adjustments in new pipe inverts can be made to obtain sufficient cover. CIPs 7.3 - 7.5 overlap with the improvements to address 10-year flood depths proposed in CIPs 5.1 and 5.2, but since the Tier 3 flood hazard improvements may be less cost effective to implement, they are not recommended without further study.

6.1.2.8 Capital Improvement Project Eight

The increases in pipe size along Helen Drive proposed by CIPs 8.1 - 8.3 reduce flood hazards, where velocities in the 100-year event are expected to be as high as 10.6 feet per second under the existing condition. While the improvements do not eliminate street flooding during the 100-year, 24-hour event, the flood hazard is expected to decrease below the design criteria.

6.1.2.9 Capital Improvement Project Nine

The improvement recommended along Center Street at CIP 9 was proposed because the existing condition 100-year, 24-hour model indicated a large amount of overflow at the downstream end of this link. Flood hazard was under 6 without improvement since velocity is only expected to be 0.48. It is likely that overland flow would distribute, reducing the overall depth of flooding, but the depth is still excessive and can be alleviated with a 6-inch increase in diameter. Although this is considered a Tier 3 improvement, the cost of the improvement was included in the total cost estimate of Table 6-1. For this proposed improvement, less than 2-feet of cover is available at both the upstream and downstream ends of the segment and care should be used in design to address this issue. Prior to the implementation of this improvement, the connection of this system with Center Street should be verified. During field investigations, the City indicated it does not connect to the 42-inch line from Greenhills Park, but it is possible that a connection exists that could not be located.

6.1.2.10 Capital Improvement Project Ten

CIPs 10.1 – 10.5 represent a significant investment to alleviate street flooding that may be less severe than predicted by the one-dimensional XPSWMM model. Flooding in the areas upstream of this location could not be reduced below a flood hazard of 6.0 without adding a second box culvert in Magnolia Drive, which receives flows from both Taylor and Richmond. The downstream culvert passing through the new Transit-Oriented Development near the BART station has already proposed to increase and relocate the existing box culvert connection to Highline Canal, which contributes to the success of this improvement at achieving its intended result. Obtaining sufficient cover to construct the proposed 3.5-foot circular pipe and the large box culverts may be a concern, particularly at the lower end near El Camino Real. It is reasonable to assume that minor adjustments to inverts in the installation of the improvements will be sufficient over the length of the installation to address this concern. While the cost estimates for these improvements are shown in Table 6-1, they are not reflected in the total for the proposed improvements.

6.1.3 Additional Considerations

In the past, the City has considered whether the storm drainage system could continue to perform if the City's side of the Airport Pump Station were taken off-line and the 33-inch line under Highline Canal was allowed to drain to the Bay by gravity. In the existing conditions modeling, even with the pump station on-line there were performance challenges in the 33-inch line, which is well below the tide level a significant amount of the time. This line should not be expected to be able to fully gravity drain during any tide event higher than -3.6 feet NAVD88. With future projected high tides of 11.2 feet NAVD88, such a re-operation is not advised.

6.2 COST ESTIMATES

Cost estimates for the proposed improvements were based on available information from recent Caltrans bids within the region, as well as a bid received by the City for a recently constructed storm drain in the vicinity of Ashton Avenue and Taylor Boulevard. Material costs for new or upsized storm drains were based on the cost per pipe diameter per linear foot of pipe included in the Ashton Avenue and Taylor Boulevard project bid. Other project costs (mobilization, traffic control, other material costs, etc.) were estimated by scaling up the pipeline material costs based on the ratio of pipeline material costs to other project costs used in the Ashton Avenue and Taylor Boulevard project bid. Costs for abandoning storm drains were based on an average CalTrans estimate of $300 per linear foot of abandoned pipeline.

Cost estimates are highly dependent on location, and the preliminary cost estimates provided do not reflect individual site costs that may be applicable, such as the purchase of easements or permitting. It is also unknown whether there are any potential utility conflicts that may impact the ultimate improvement design. Costs were driven by the hydraulic capacity needed to achieve design criteria and the available depth of cover alone. Utility conflict analysis during detailed design may suggest that a single, larger improvement be constructed instead of a second, parallel line, chosen based on cost of pipe construction alone. Table 6-1 presents preliminary cost estimates for the proposed improvements discussed above.

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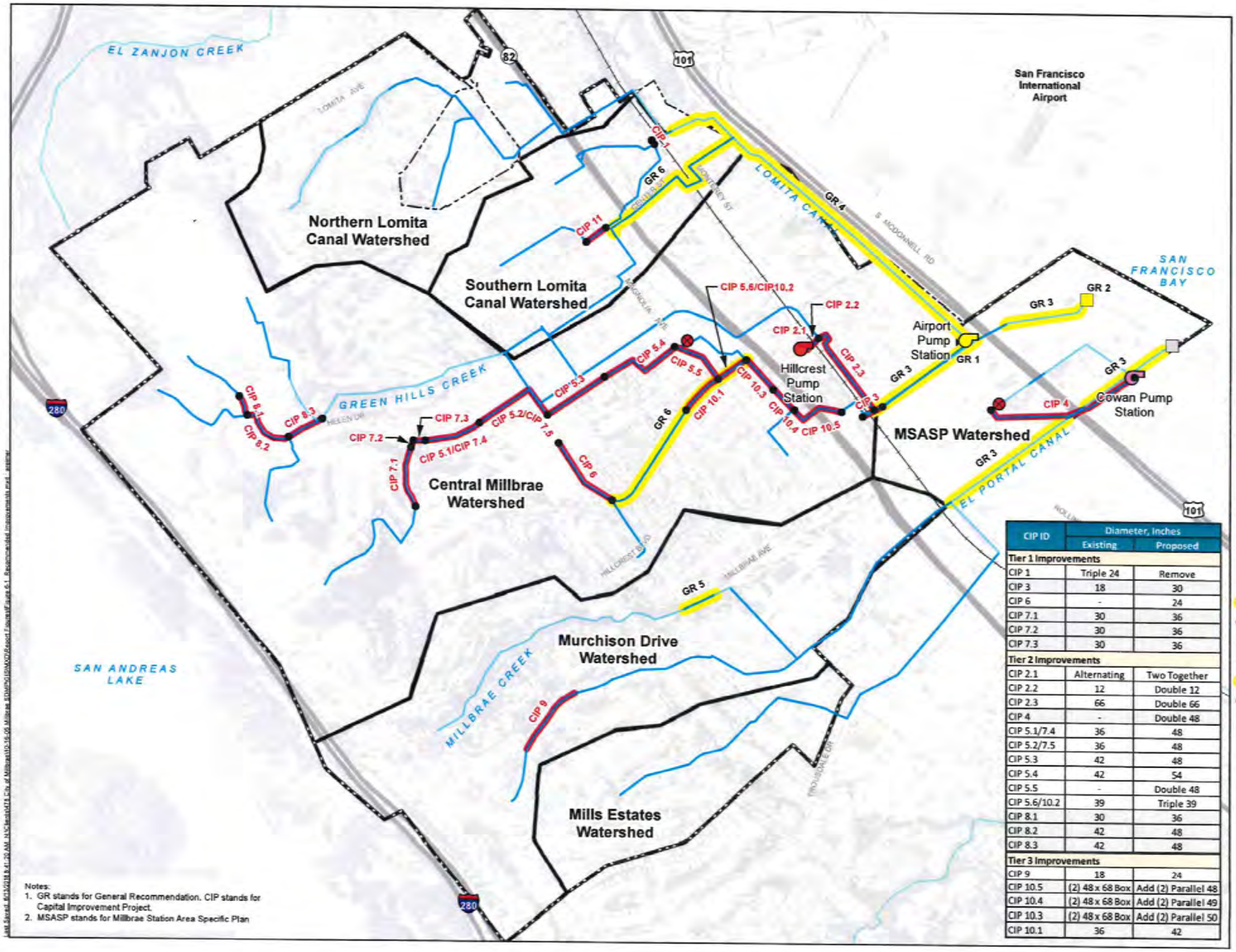

CIP ID	Diameter, Inches Existing	Diameter, Inches Proposed
Tier 1 Improvements		
CIP 1	Triple 24	Remove
CIP 3	18	30
CIP 6	-	24
CIP 7.1	30	36
CIP 7.2	30	36
CIP 7.3	30	36
Tier 2 Improvements		
CIP 2.1	Alternating	Two Together
CIP 2.2	12	Double 12
CIP 2.3	66	Double 66
CIP 4	-	Double 48
CIP 5.1/7.4	36	48
CIP 5.2/7.5	36	48
CIP 5.3	42	48
CIP 5.4	42	54
CIP 5.5	-	Double 48
CIP 5.6/10.2	39	Triple 39
CIP 8.1	30	36
CIP 8.2	42	48
CIP 8.3	42	48
Tier 3 Improvements		
CIP 9	18	24
CIP 10.5	(2) 48 x 68 Box	Add (2) Parallel 48
CIP 10.4	(2) 48 x 68 Box	Add (2) Parallel 49
CIP 10.3	(2) 48 x 68 Box	Add (2) Parallel 50
CIP 10.1	36	42

Notes:
1. GR stands for General Recommendation. CIP stands for Capital Improvement Project.
2. MSASP stands for Millbrae Station Area Specific Plan

Figure 6-1

Millbrae Storm Drain System Recommended Improvements

City of Millbrae
Storm Drain Master Plan

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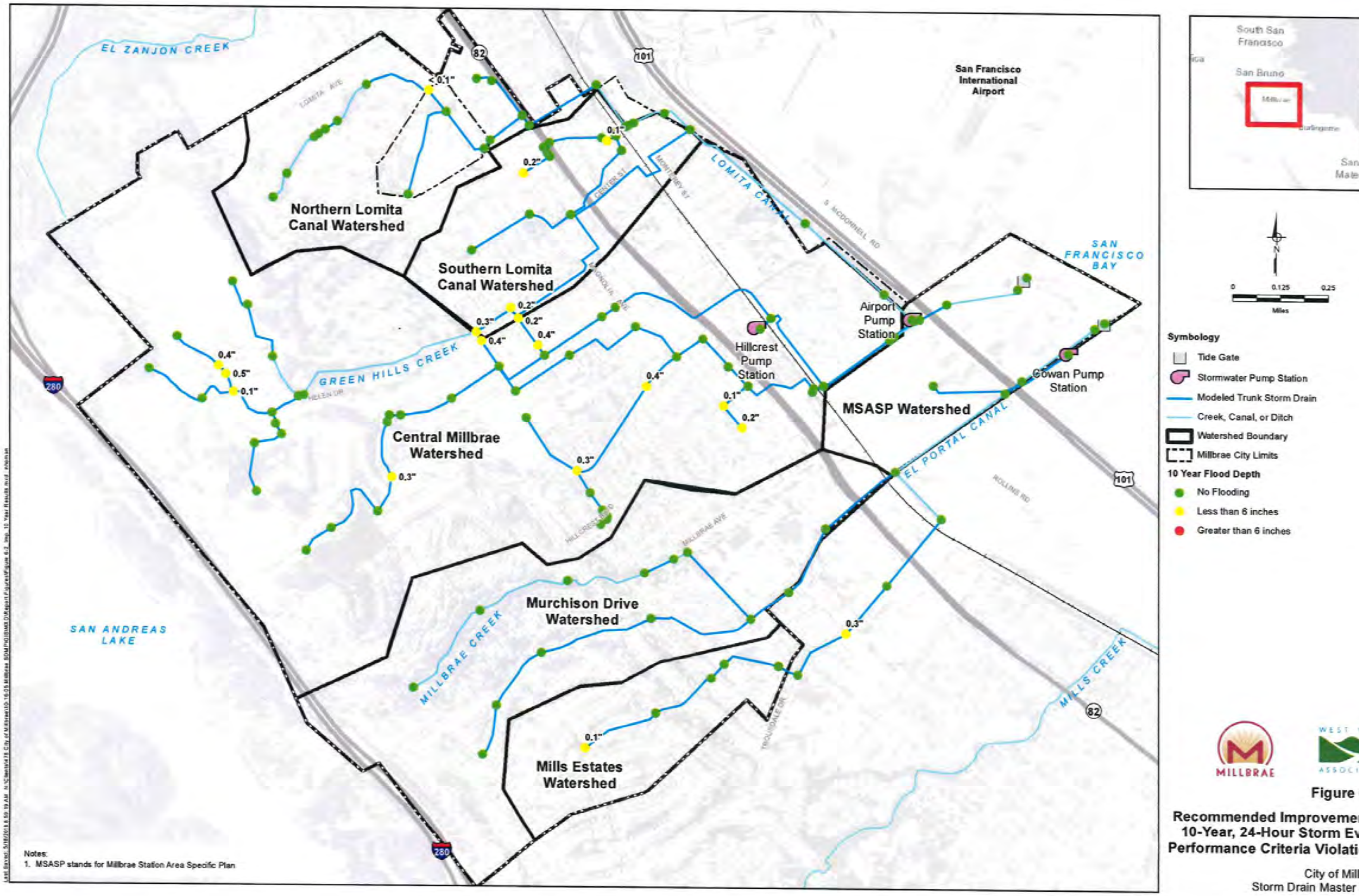

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Figure 6-2

Recommended Improvements: 10-Year, 24-Hour Storm Event Performance Criteria Violations

City of Millbrae
Storm Drain Master Plan

Notes:
1. MSASP stands for Millbrae Station Area Specific Plan

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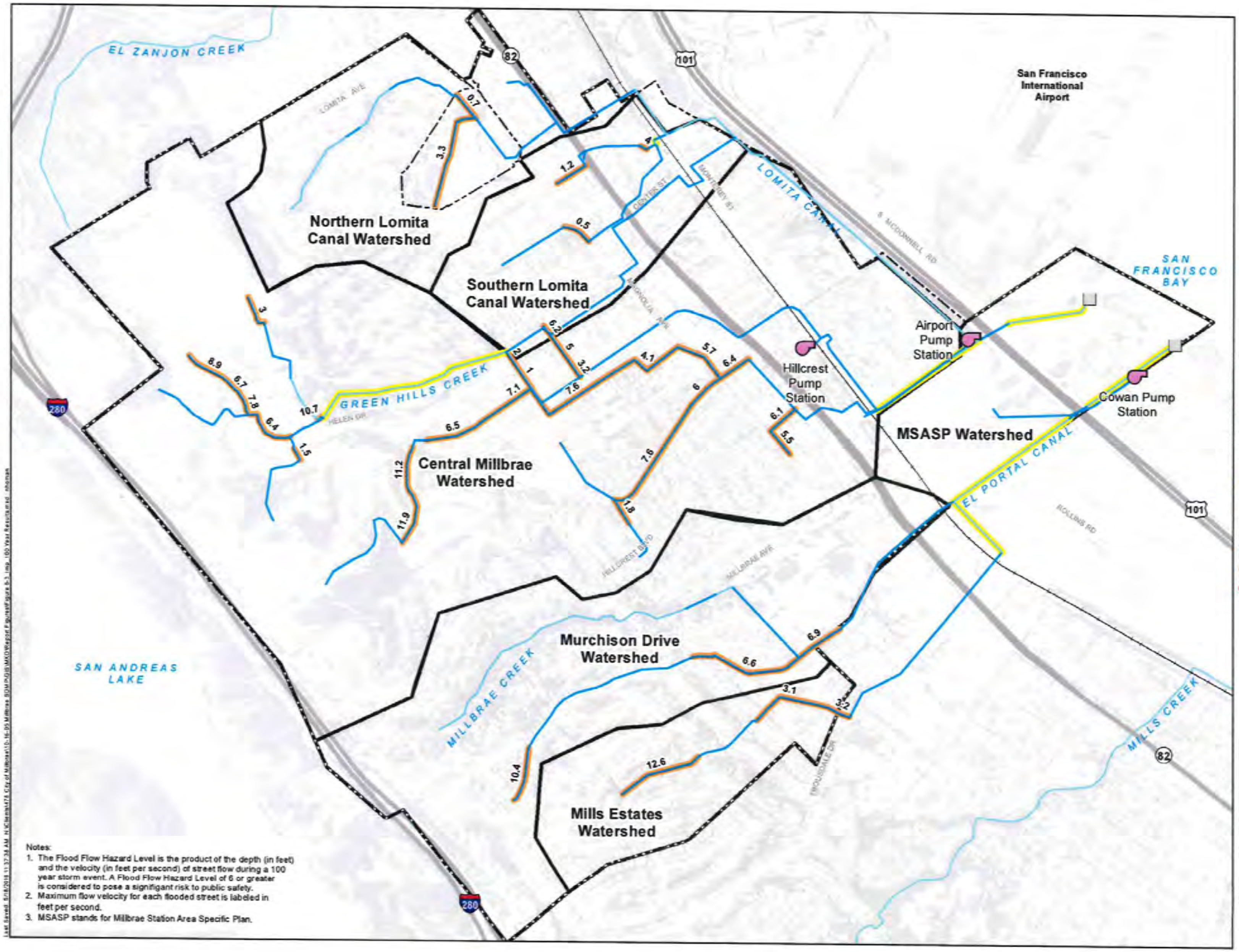

Notes:
1. The Flood Flow Hazard Level is the product of the depth (in feet) and the velocity (in feet per second) of street flow during a 100 year storm event. A Flood Flow Hazard Level of 6 or greater is considered to pose a signifigant risk to public safety.
2. Maximum flow velocity for each flooded street is labeled in feet per second.
3. MSASP stands for Millbrae Station Area Specific Plan.

Figure 6-3

Recommended Improvements: 100-Year, 24-Hour Storm Event Performance Criteria Violations

City of Millbrae
Storm Drain Master Plan

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CHAPTER 7
Conclusions and Recommendations

This chapter summarizes the conclusions and recommendations of this SDMP.

7.1 CONCLUSIONS

Existing information about the City's storm drain system was reviewed in Chapter 2, and field data was collected to more accurately describe the system, as discussed in Chapter 3. A hydrologic and hydraulic model was developed in XPSWMM based on regional climate data, topography, and the City's drainage system layout, as discussed in Chapter 5. The peak flow rates predicted by the hydrologic component of the model for selected catchments were compared with the peak flow rates calculated for those catchments using the City's Rational Method. The hydrologic model was calibrated to minimize differences between the City's method and the modeling by adjusting the computed watershed widths in XPSWMM. The sum of all differences was minimized to less than 0.33 cfs/acre for the new 10-year and 100-year rainfall distributions presented in Table 5-2.

Hydraulic model geometry was generally limited to major drainage channels and portions of the system greater than 18-inches in diameter. The hydraulic model accurately predicted flooding at all locations noted by the City to have experienced flooding during previous significant storm events, with the exception of MSASP flooding, historically caused by blocked drain inlets (Known issue number 2).

West Yost worked with the City to develop performance criteria and design criteria that provide a reasonable level of protection from future flooding. The combined hydrologic and hydraulic model was then used to identify 8 areas of the existing storm drain system that did not meet the performance criteria during the 10-year, 24-hour storm event, as well as a number of areas that may cause nuisance flooding without exceeding the performance criteria. Significant areas of street flooding were predicted during the 100-year, 24-hour storm event. The City's storm drain system was not designed for a storm of this size, and thus significant street flow is expected through the City during the 100-year event.

In addition to improvements suggested by the model, the City suggested improvements to improve two problems that were not modeled: a drainage line serving Taylor Middle School to address known issue number 5 and relocation of the line connecting MSASP to Cowan Pump Station to improve maintenance access and address known issue number 2. The City has already implemented an improvement to address known issue number 4, although nuisance flooding may persist at this location, as sites below drainage inlets cannot discharge into the system without ponding.

7.2 RECOMMENDATIONS

Ten (10) capital improvement projects were designed and modeled per the design standards of Chapter 4. Four projects have an estimated cost under $2M each, and are designated as "Tier 1 Improvements", with a total estimated cost of $3.3M. At the time of completion of this SDMP, the City had initiated work on CIP6, drainage of Taylor Middle School.

Four projects for a total of $30.3M are designated as "Tier 2 Improvements" to alleviate 10-year performance criteria violations or areas of significant 100-year flood hazard, but where the CIP costs were estimated to exceed $2M.

Two projects for a total of $8.7M were designed to a 100-year standard, per the design standards of Chapter 4, but are located in areas where further investigation should be performed prior to design and implementation. These are designated as "Tier 3 Improvements". See Chapter 6 for a detailed list of these CIPs. In addition to these recommended CIPs, West Yost identified several other recommended improvements during review of existing information, site visits conducted to gather data for the model, and through discussions with City staff.

- A routine CCTV inspections program should be implemented to identify and resolve maintenance issues such as collapsed pipes, blockages, and trash before they become a problem.
- Areas of the City's system where access is not available should be uncovered or have manholes added.
- A second pump should be added at the Airport Lift Station to provide reliability.
- The flap gates at the outlet of Highline Canal should be repaired so that they can close completely.
- The City may wish to consider increasing the height of the Highline and El Portal Canal embankments to guard against future sea level rise.
- Excess vegetation in the Lomita Canal should be removed to reduce the chance of continued flooding in this area.
- The culvert where Mills Creek crosses Ashton Avenue should be immediately repaired and replaced to prevent harm to the structures it passes under.

At this time of completion of this SDMP, the City had initiated design of a culvert realignment to address the Mills Creek crossing of Ashton Avenue.

In addition to the infrastructure improvements listed above and detailed in Chapter 6, West Yost recommends further hydrologic and hydraulic modeling using a 2D model to provide a more refined evaluation of localized flood risk that can be used to develop more detailed design and cost estimates of improvements prior to construction.

CHAPTER 8
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APPENDIX A

Mapbook

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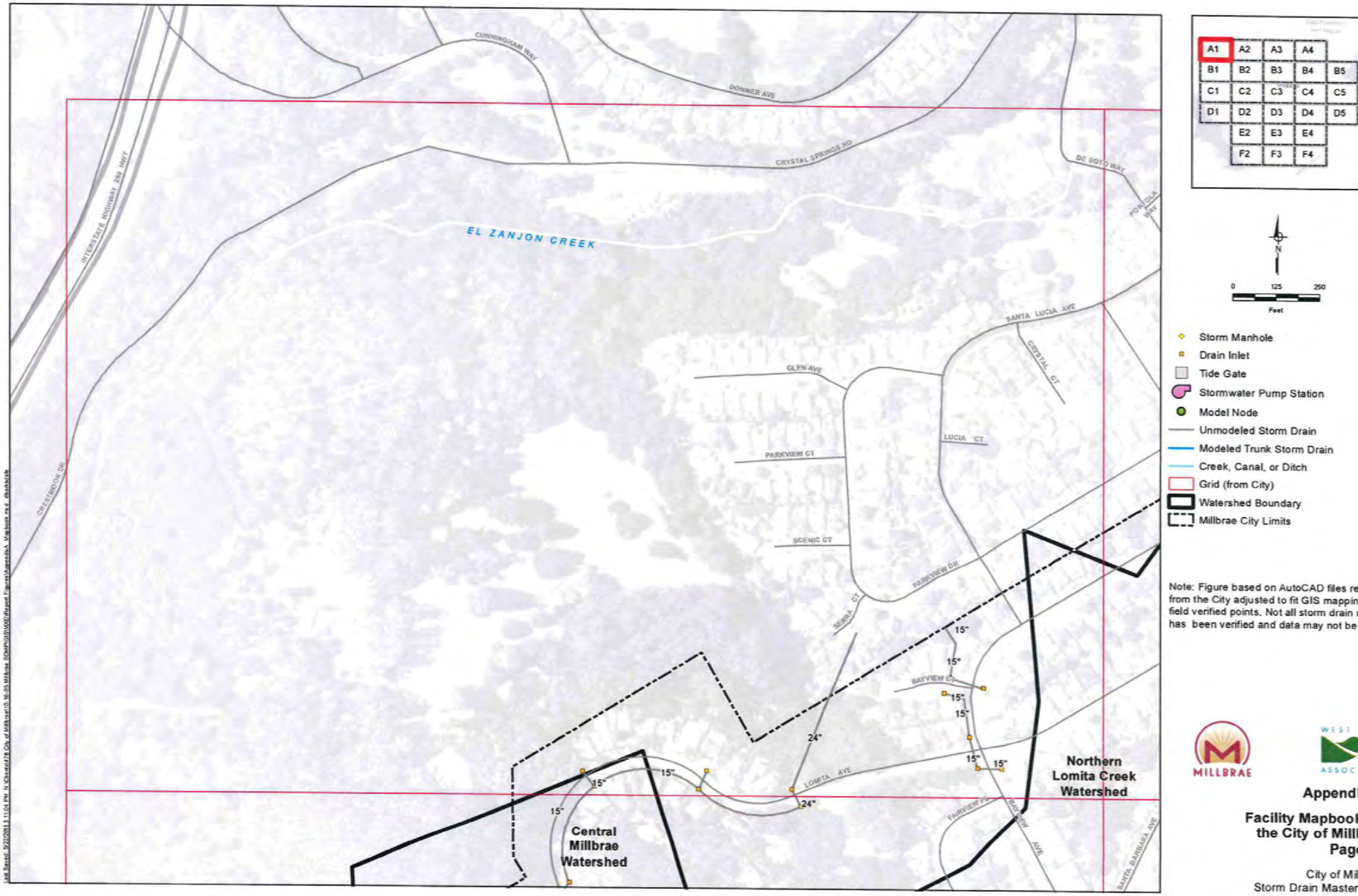

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
- Unmodeled Storm Drain
- Modeled Trunk Storm Drain
- Creek, Canal, or Ditch
- Grid (from City)
- Watershed Boundary
- Millbrae City Limits

Note: Figure based on AutoCAD files received from the City adjusted to fit GIS mapping and field verified points. Not all storm drain mapping has been verified and data may not be accurate.

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Appendix A

Facility Mapbook for the City of Millbrae Page A1

City of Millbrae
Storm Drain Master Plan

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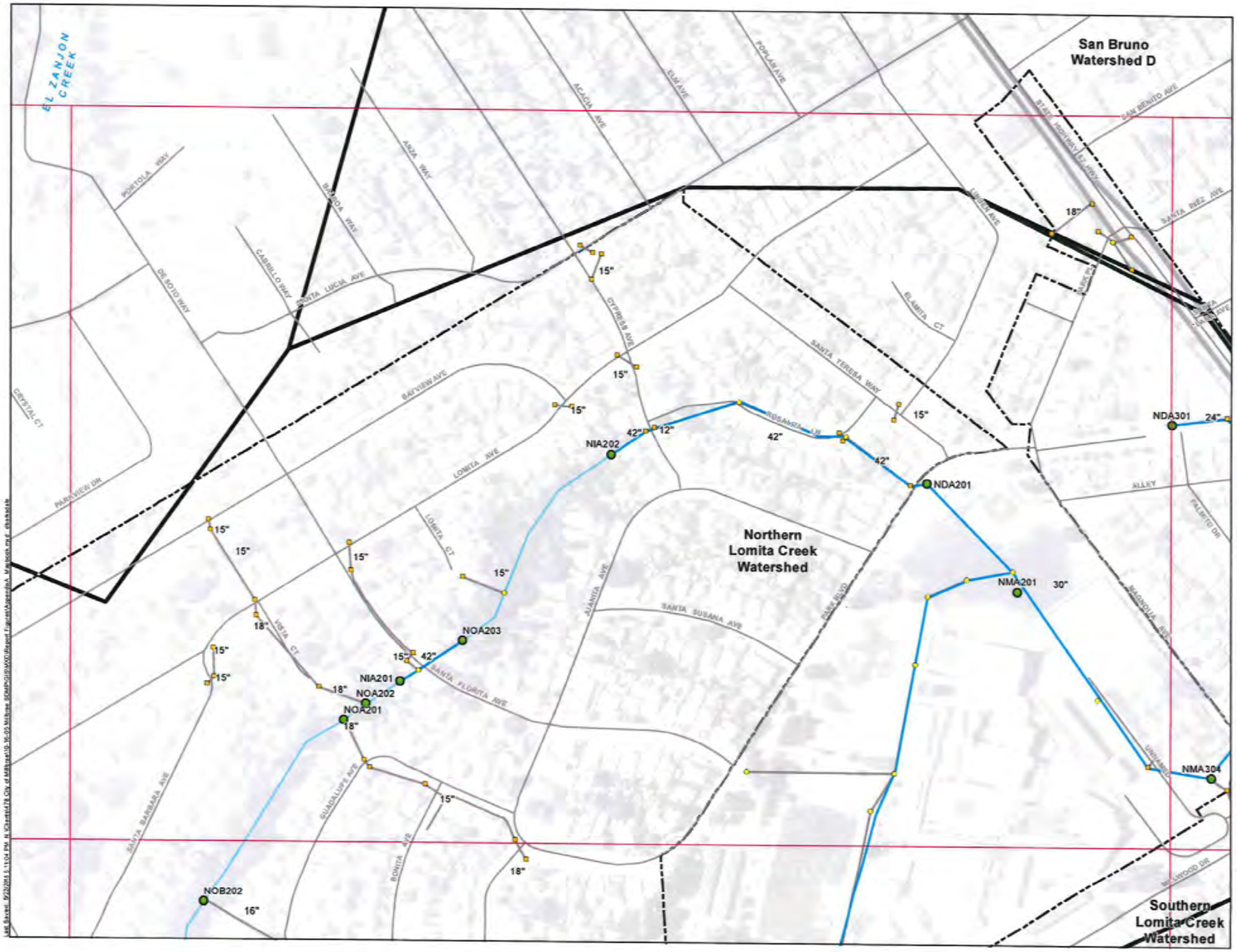

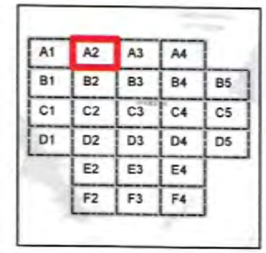

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Feet

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
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Appendix A

Facility Mapbook for the City of Millbrae Page A2

City of Millbrae
Storm Drain Master Plan

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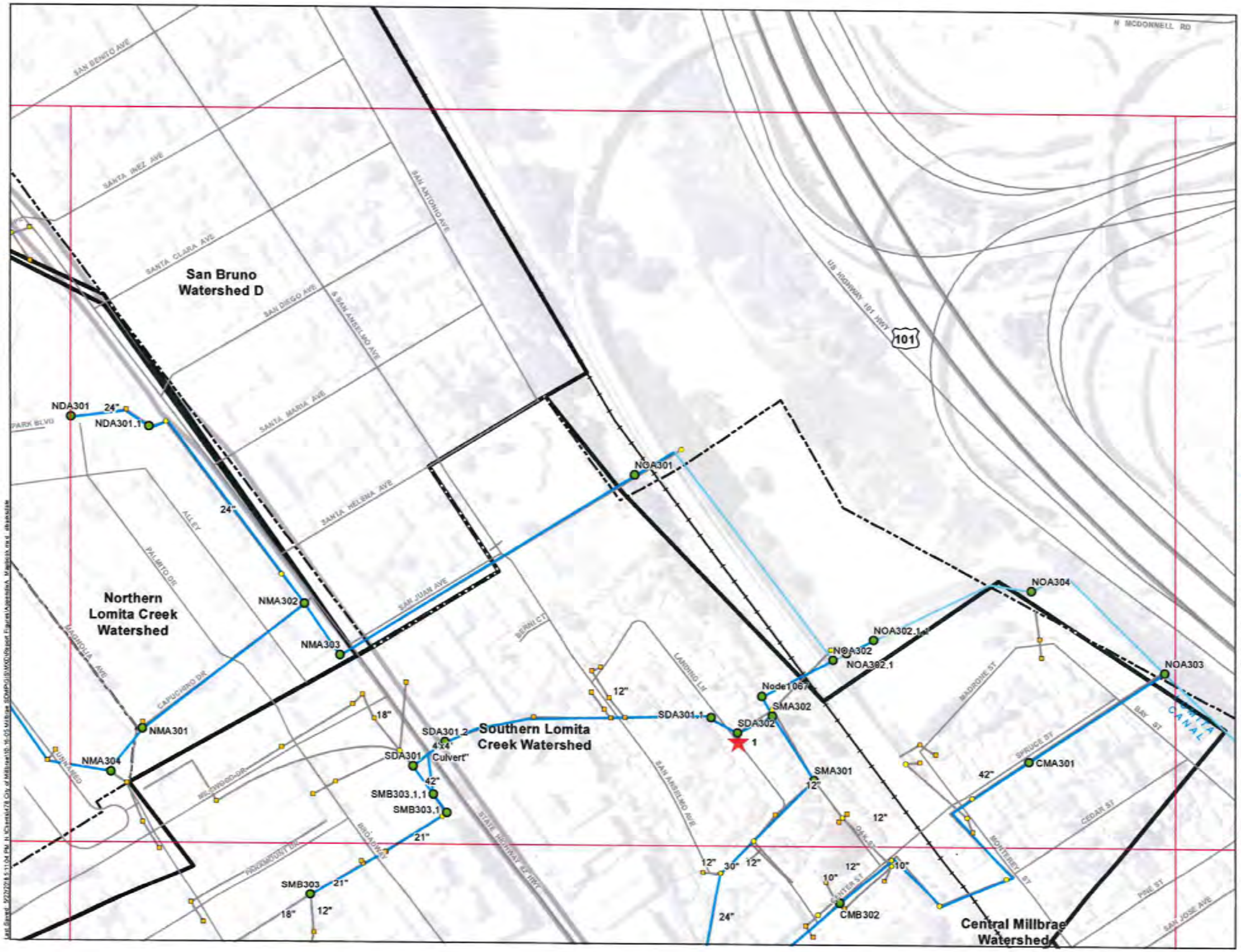

- Storm Manhole
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Appendix A

Facility Mapbook for the City of Millbrae Page A3

City of Millbrae
Storm Drain Master Plan

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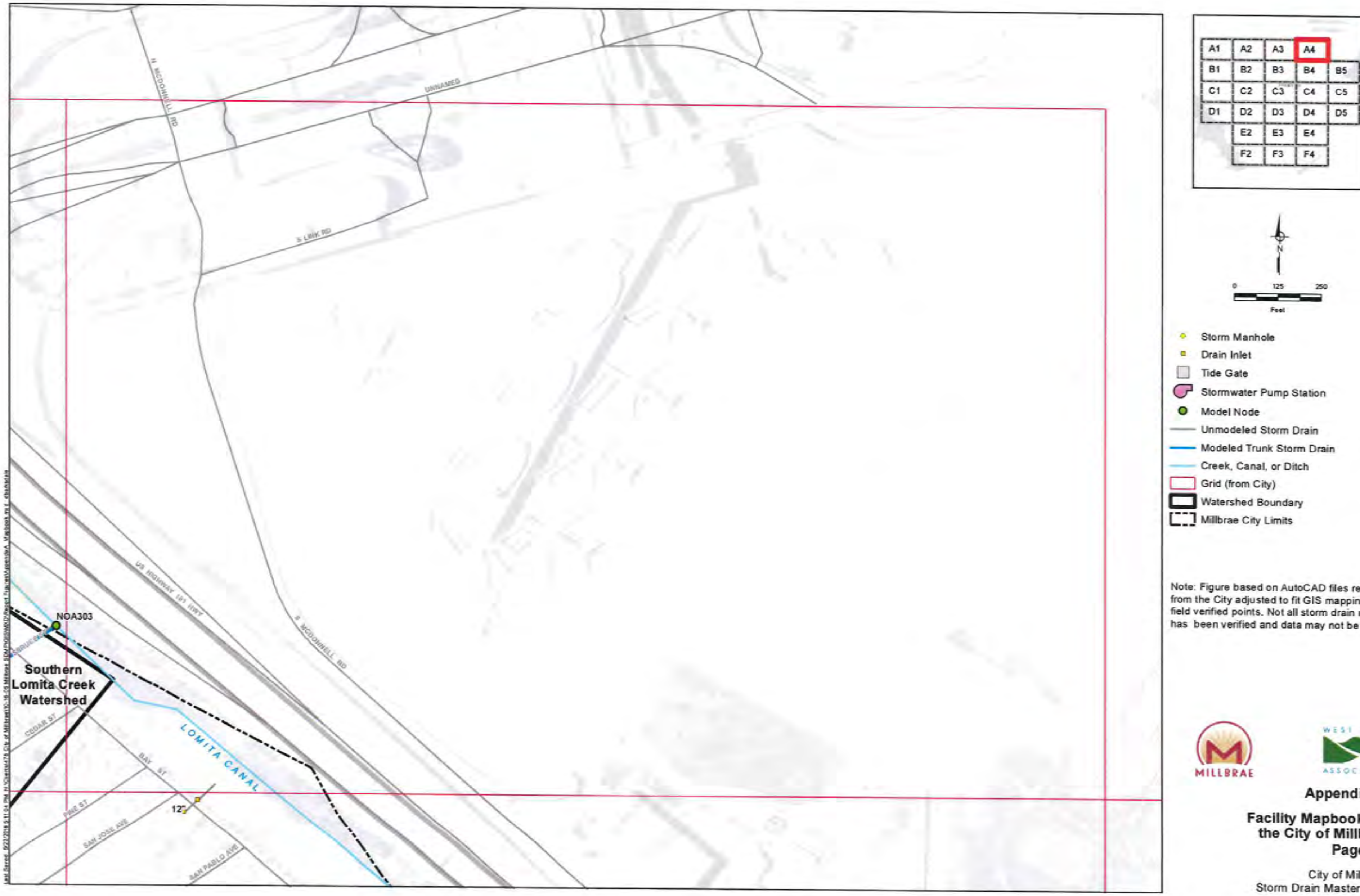

Note: Figure based on AutoCAD files received from the City adjusted to fit GIS mapping and field verified points. Not all storm drain mapping has been verified and data may not be accurate.

MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page A4

City of Millbrae
Storm Drain Master Plan

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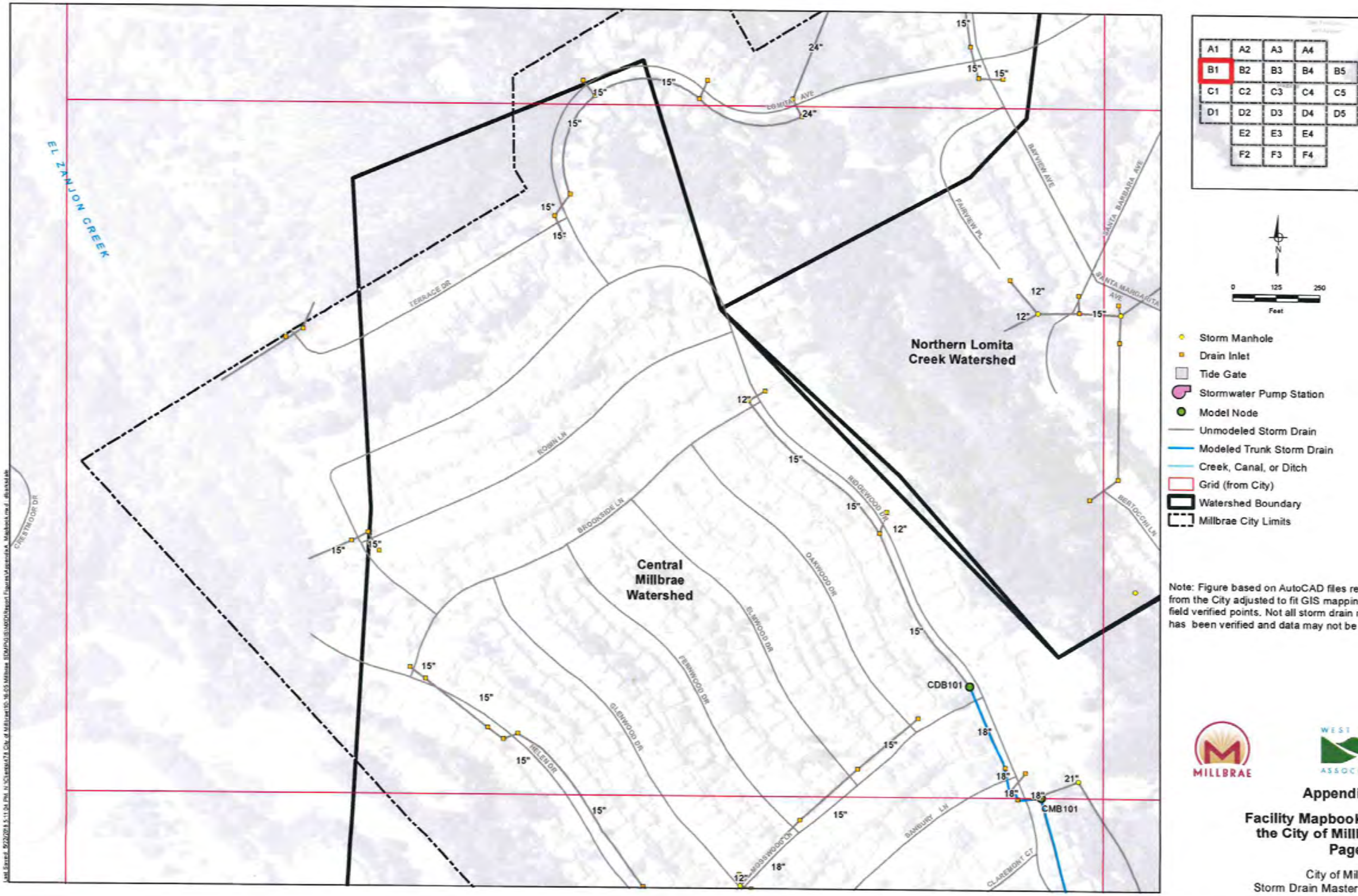

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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page B1

City of Millbrae
Storm Drain Master Plan

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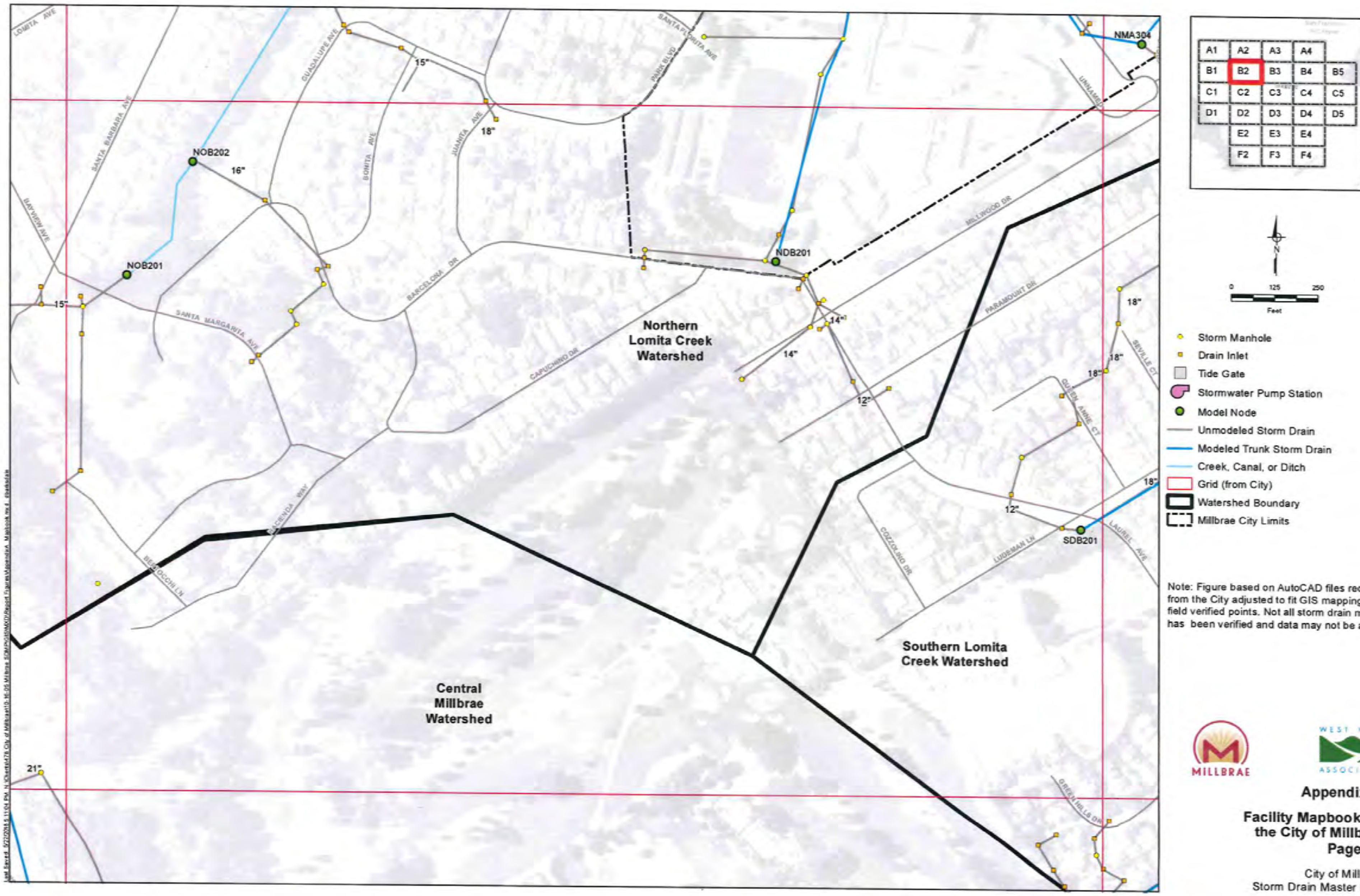

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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page B2

City of Millbrae
Storm Drain Master Plan

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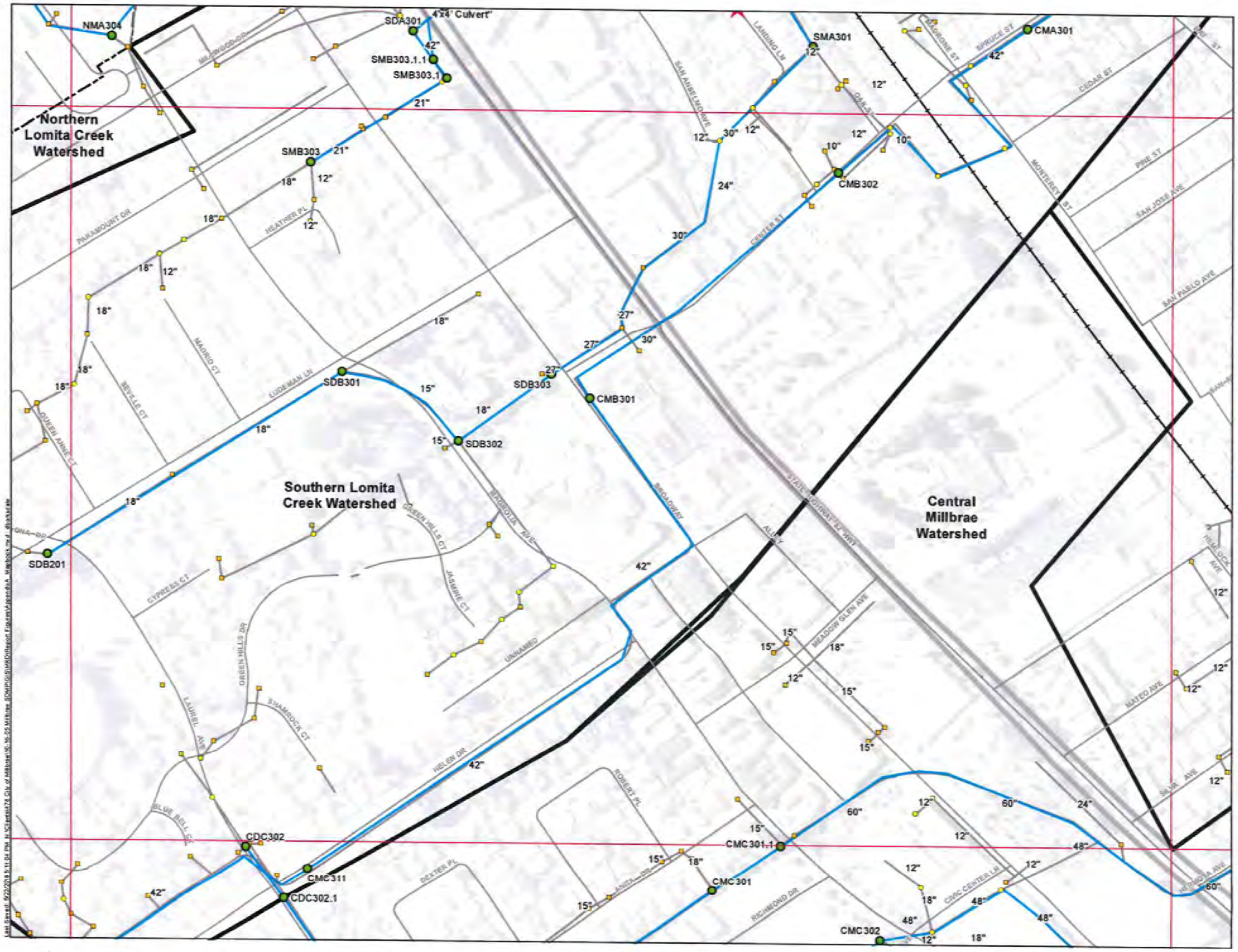

Storm Manhole
Drain Inlet
Tide Gate
Stormwater Pump Station
Model Node
Unmodeled Storm Drain
Modeled Trunk Storm Drain
Creek, Canal, or Ditch
Grid (from City)
Watershed Boundary
Millbrae City Limits

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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page B3

City of Millbrae
Storm Drain Master Plan

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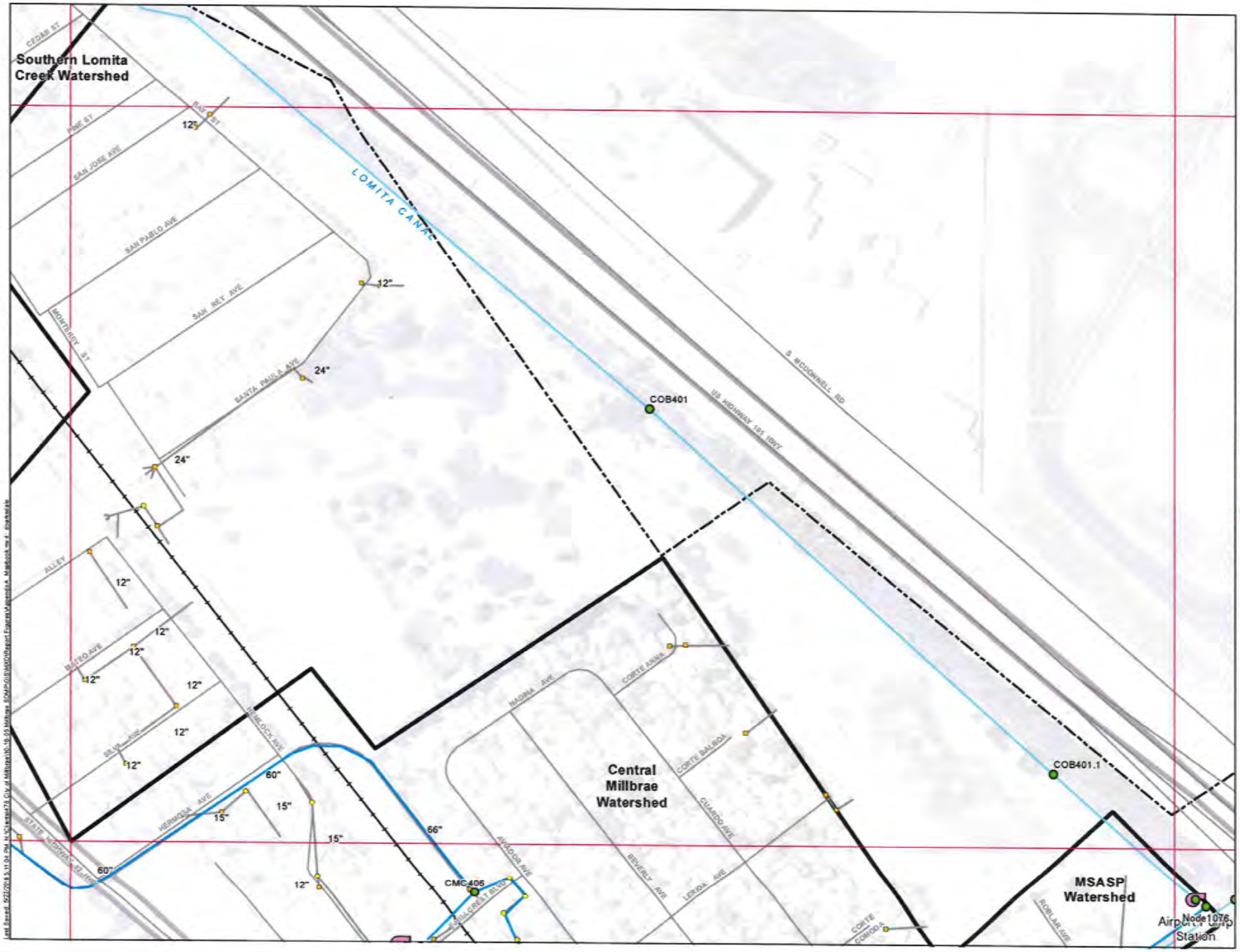

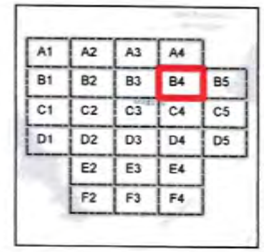

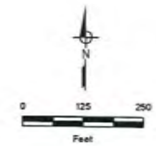

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
- Unmodeled Storm Drain
- Modeled Trunk Storm Drain
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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page B4

City of Millbrae
Storm Drain Master Plan

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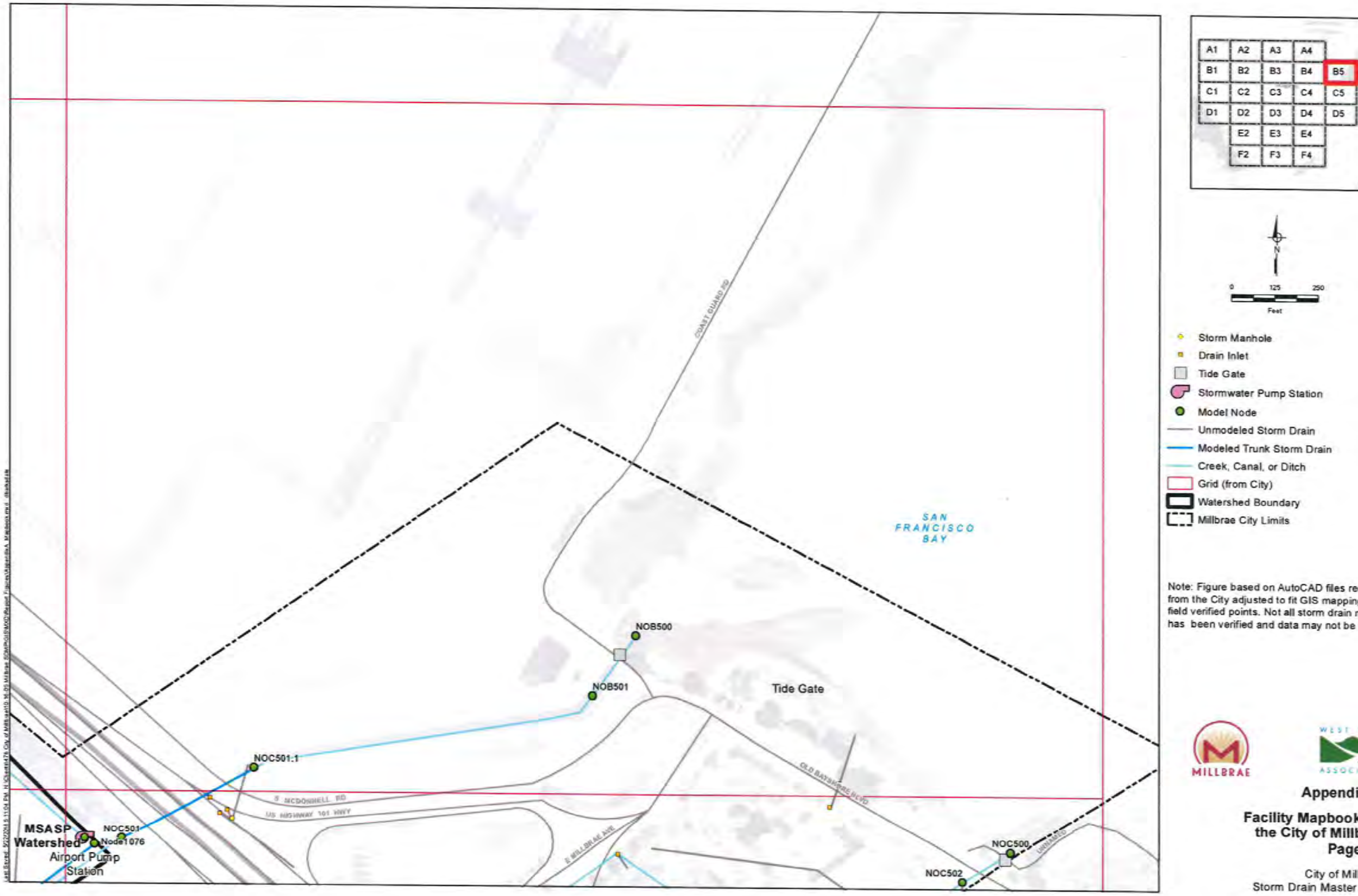

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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page B5

City of Millbrae
Storm Drain Master Plan

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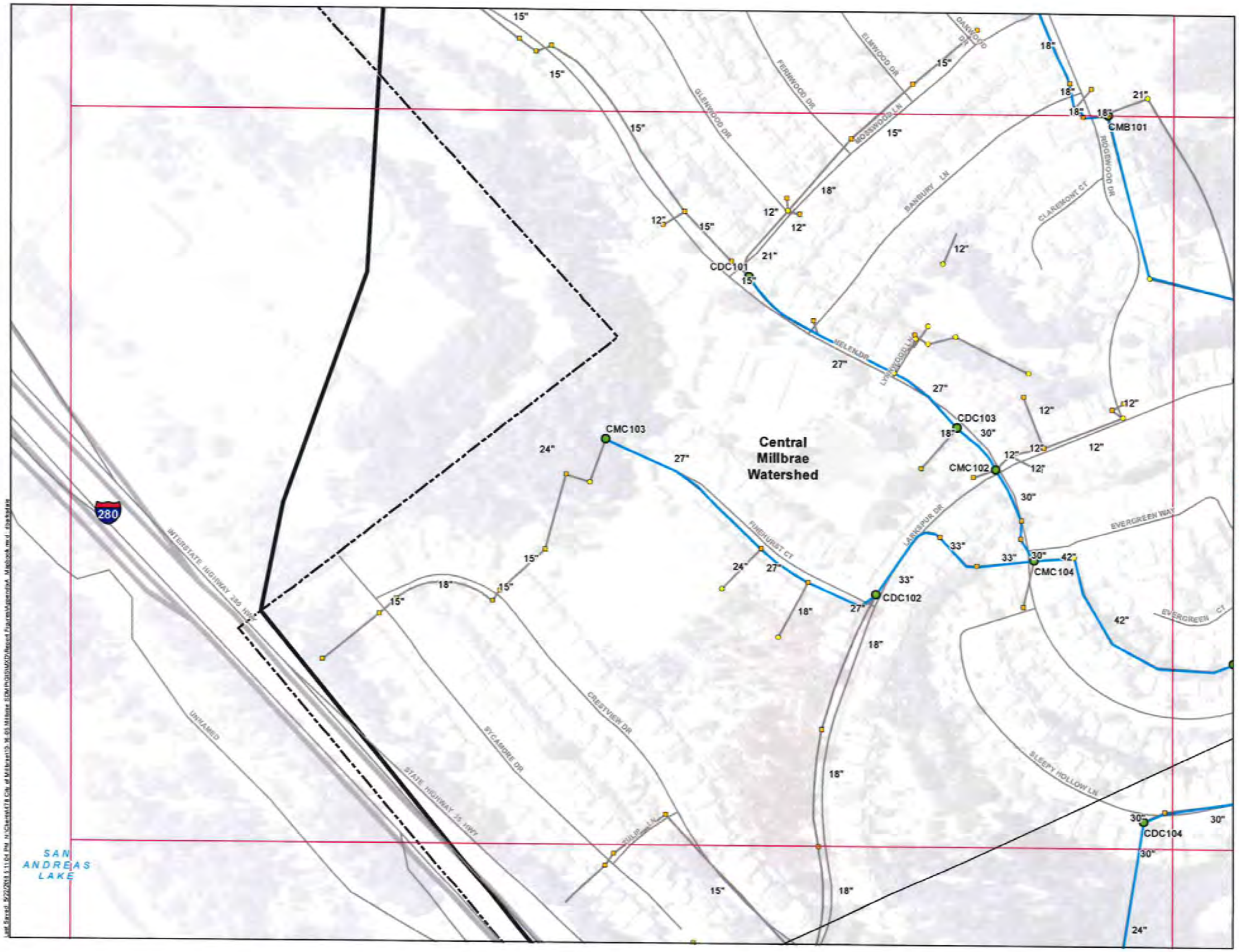

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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page C1

City of Millbrae
Storm Drain Master Plan

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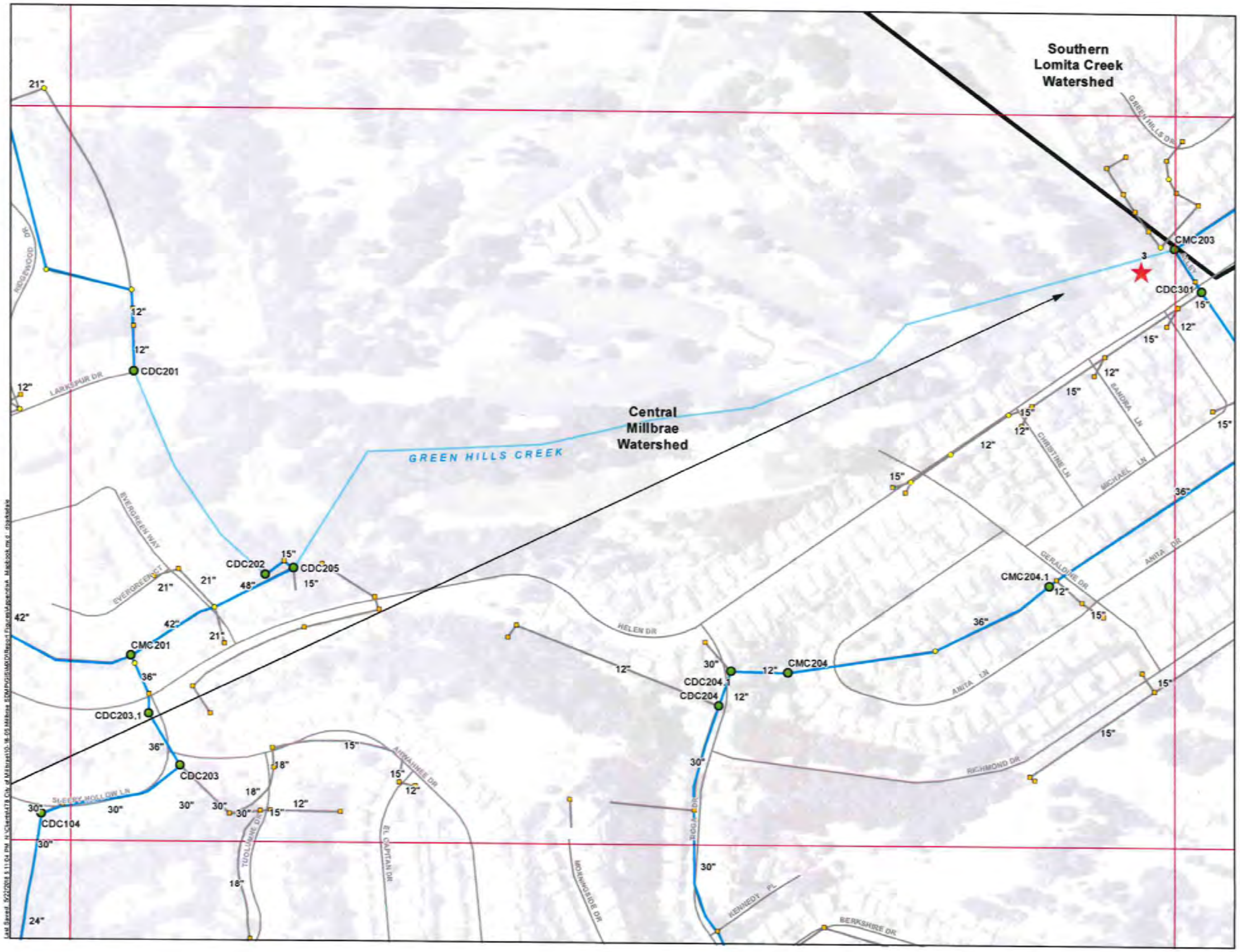

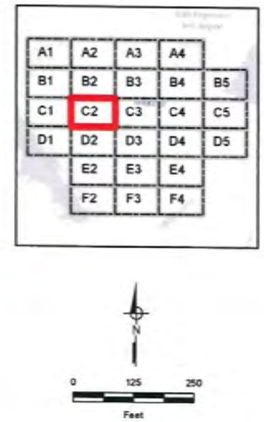

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
- Unmodeled Storm Drain
- Modeled Trunk Storm Drain
- Creek, Canal, or Ditch
- Grid (from City)
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- Millbrae City Limits

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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page C2

City of Millbrae
Storm Drain Master Plan

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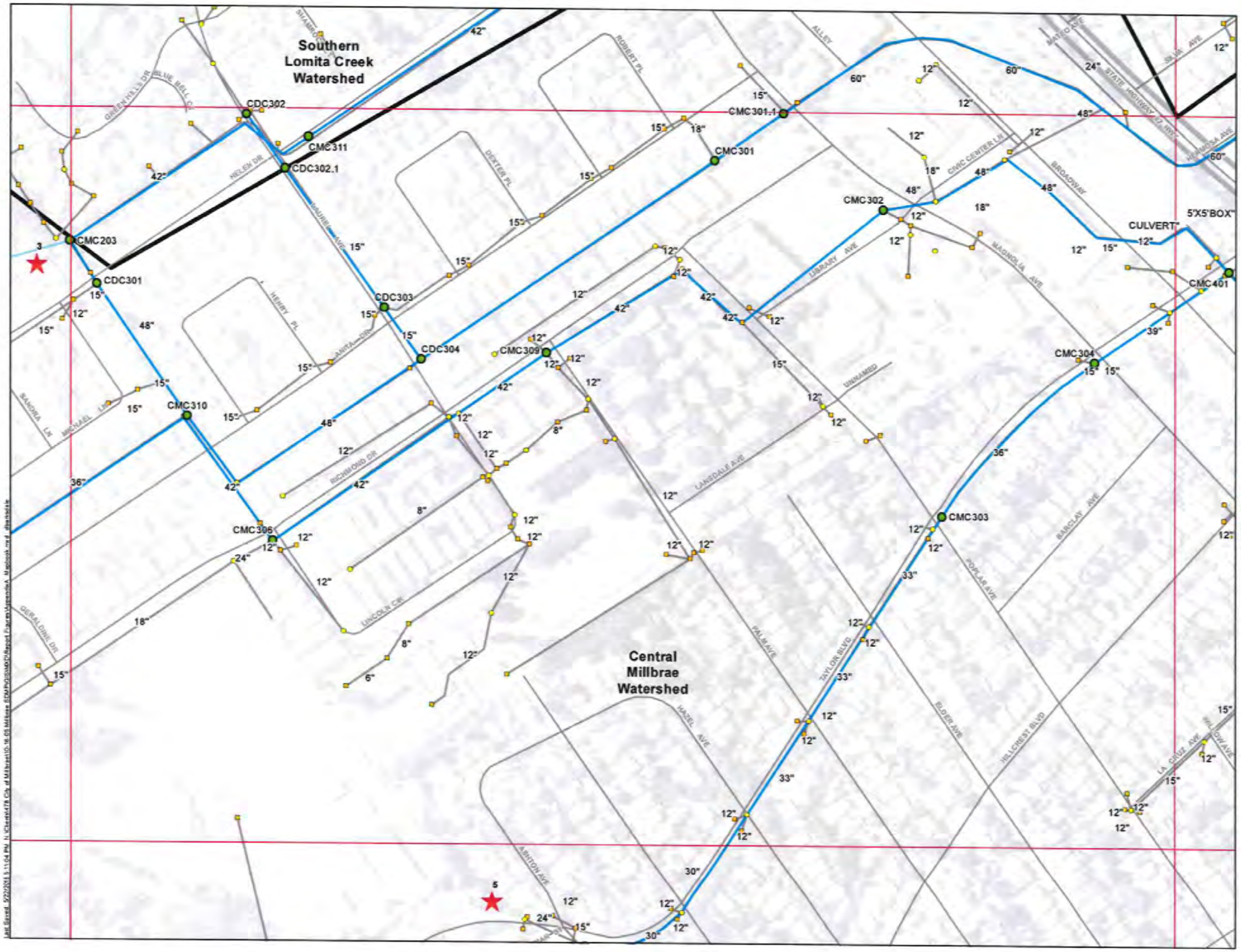

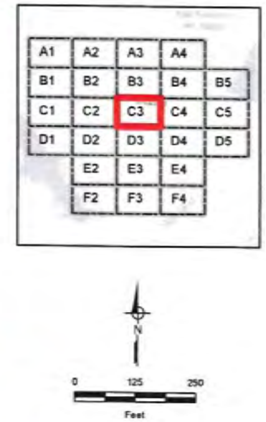

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
- Unmodeled Storm Drain
- Modeled Trunk Storm Drain
- Creek, Canal, or Ditch
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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page C3

City of Millbrae
Storm Drain Master Plan

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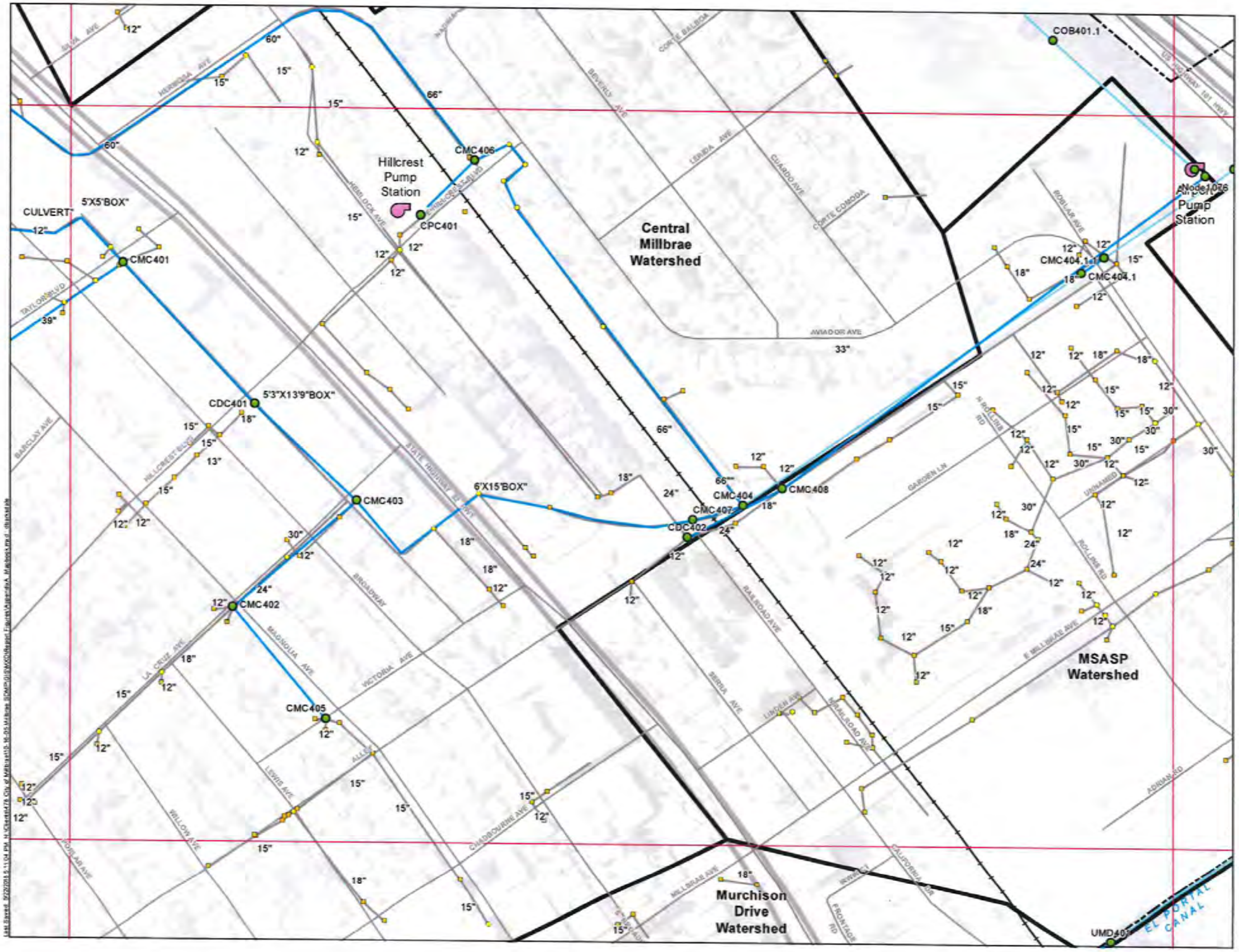

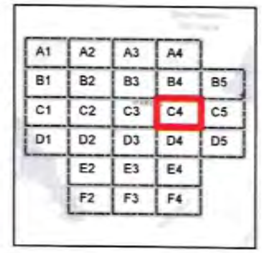

0 125 250
Feet

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
- Unmodeled Storm Drain
- Modeled Trunk Storm Drain
- Creek, Canal, or Ditch
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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page C4

City of Millbrae
Storm Drain Master Plan

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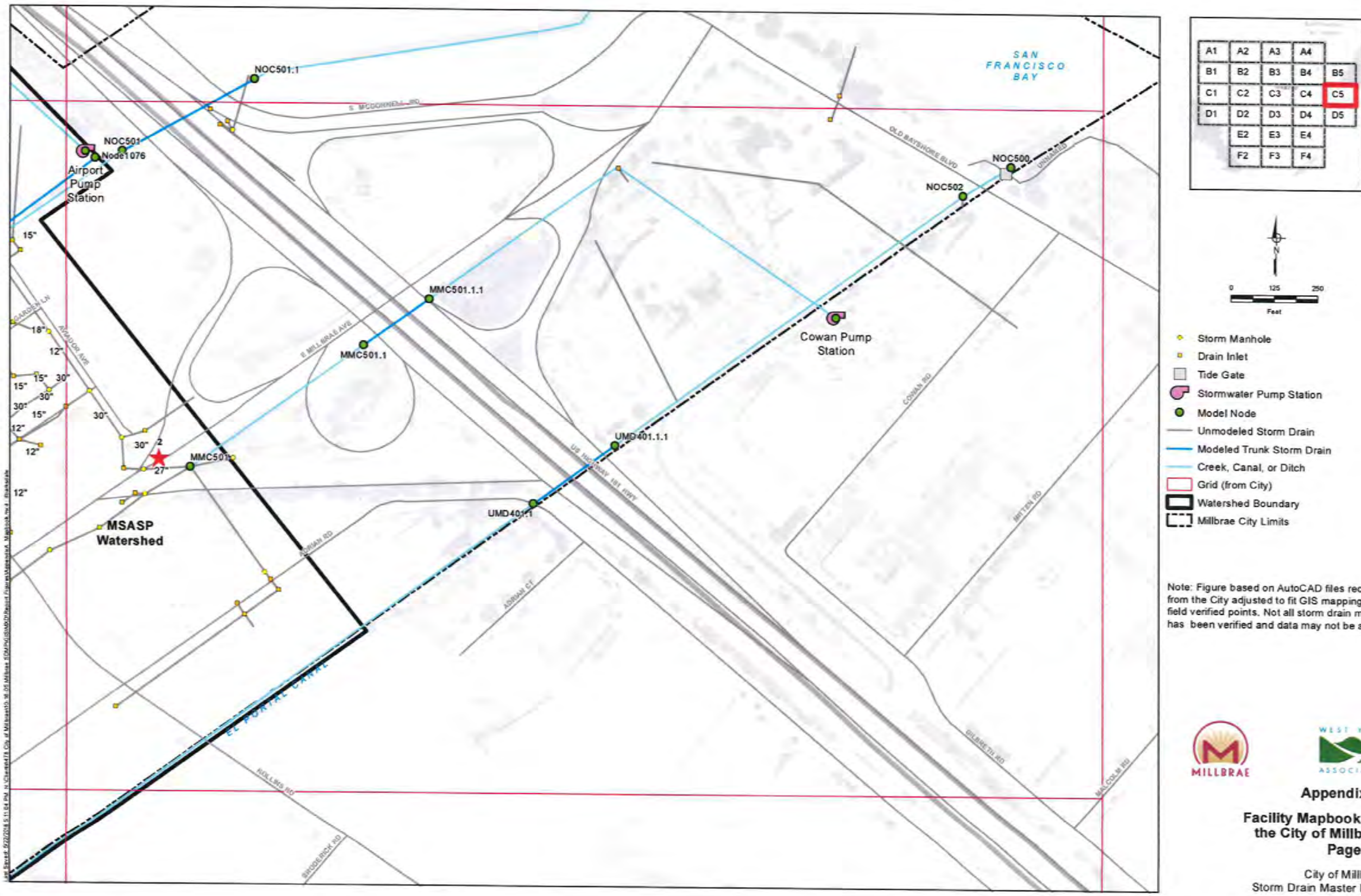

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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page C5

City of Millbrae
Storm Drain Master Plan

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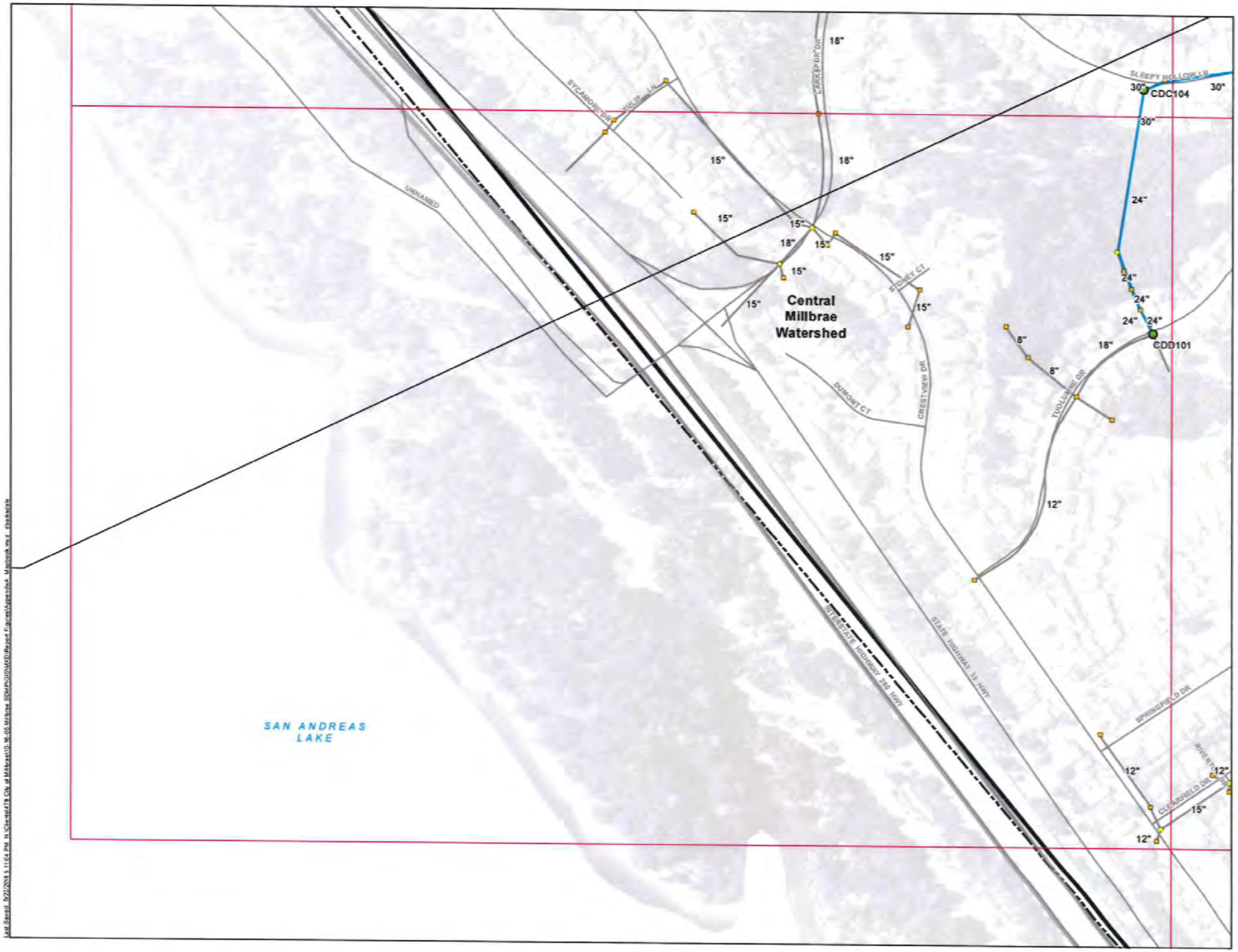

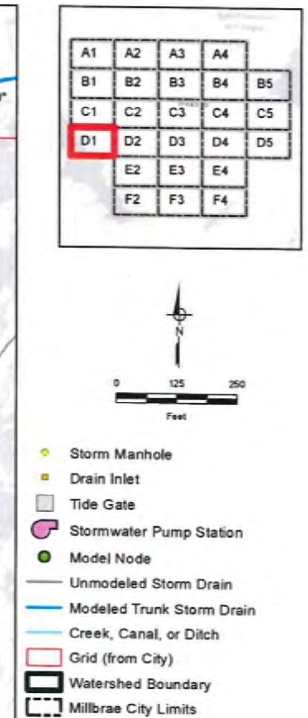

Note: Figure based on AutoCAD files received from the City adjusted to fit GIS mapping and field verified points. Not all storm drain mapping has been verified and data may not be accurate.

Appendix A

Facility Mapbook for the City of Millbrae Page D1

City of Millbrae
Storm Drain Master Plan

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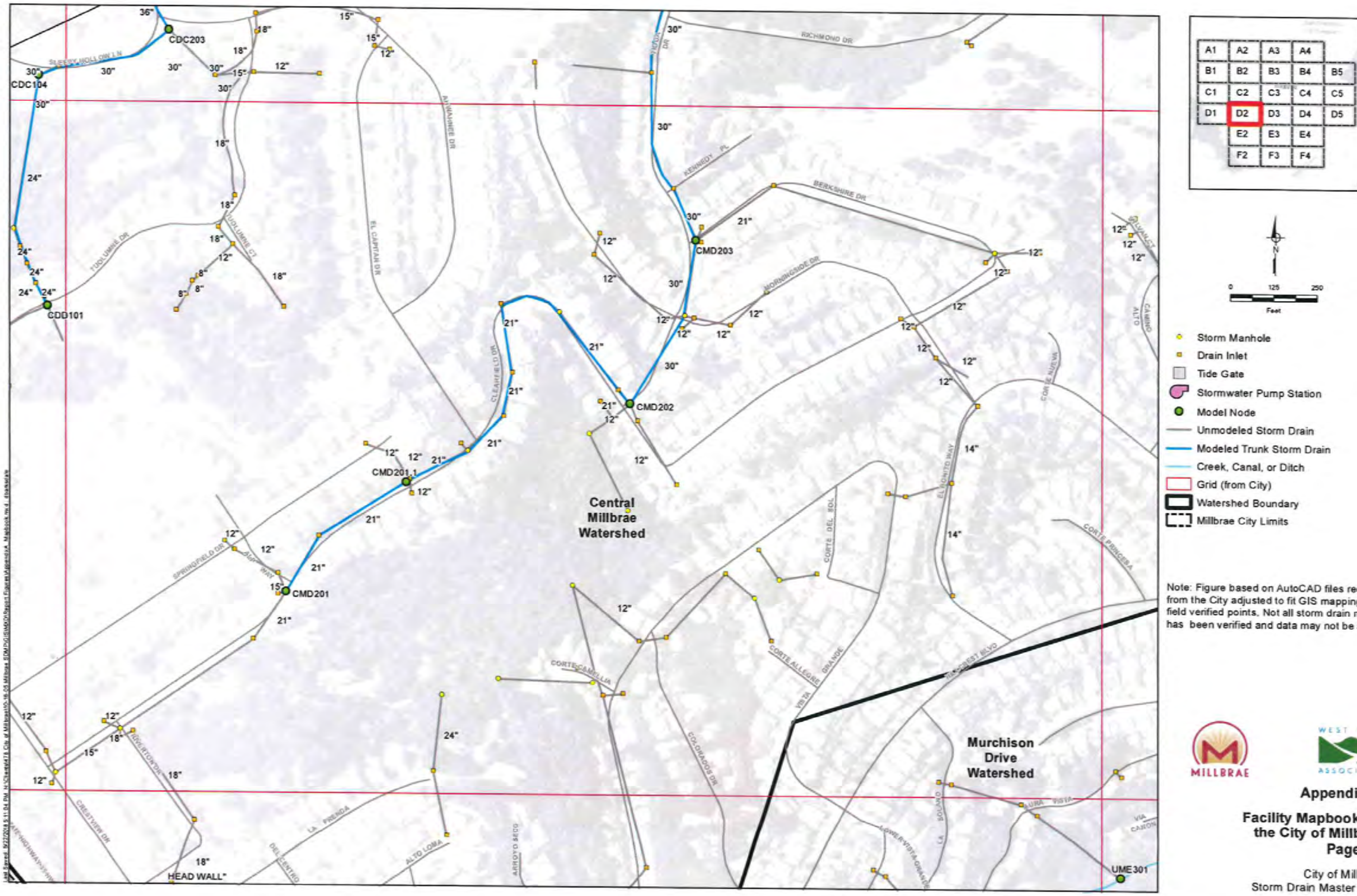

Note: Figure based on AutoCAD files received from the City adjusted to fit GIS mapping and field verified points. Not all storm drain mapping has been verified and data may not be accurate.

MILLBRAE

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Appendix A

Facility Mapbook for the City of Millbrae Page D2

City of Millbrae
Storm Drain Master Plan

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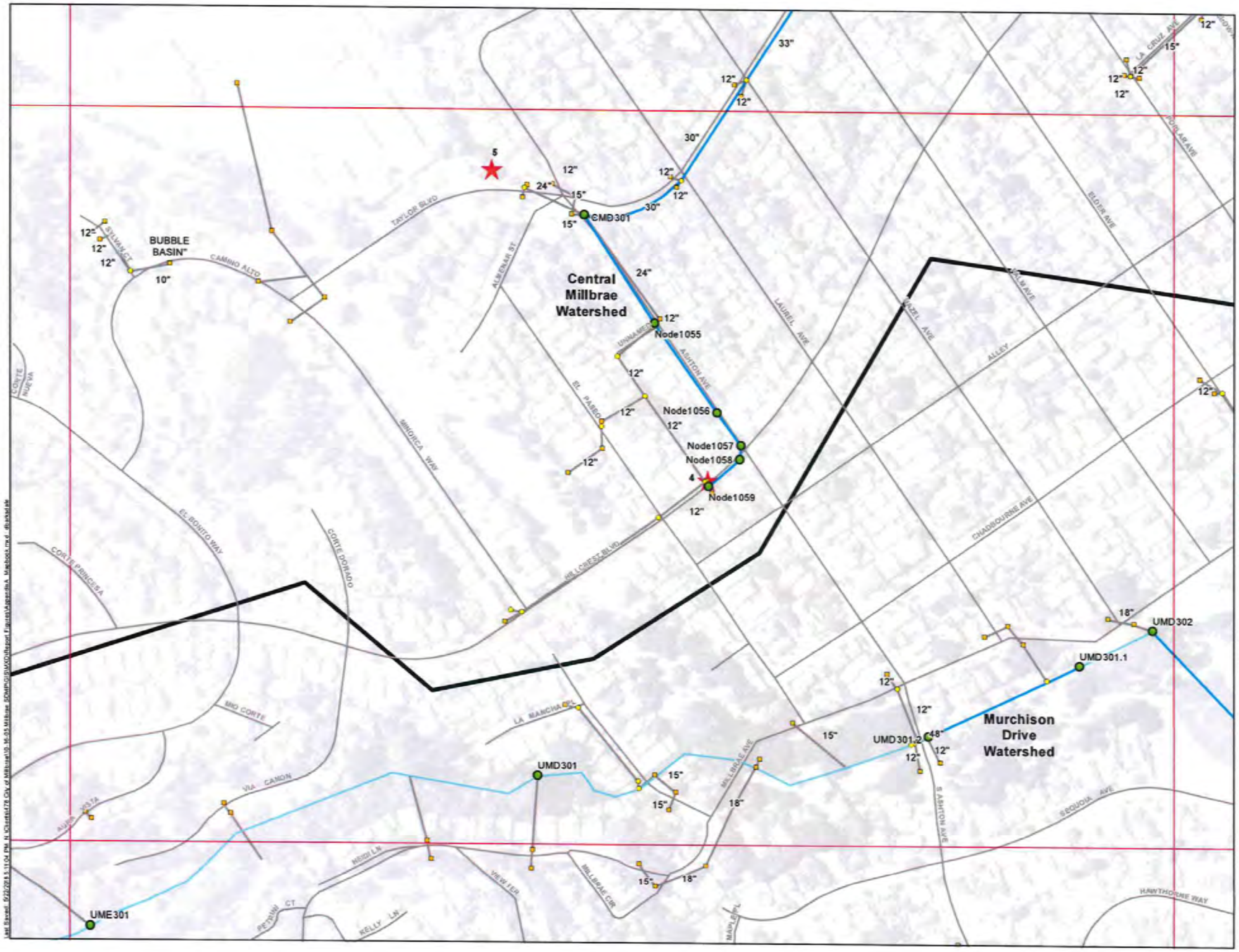

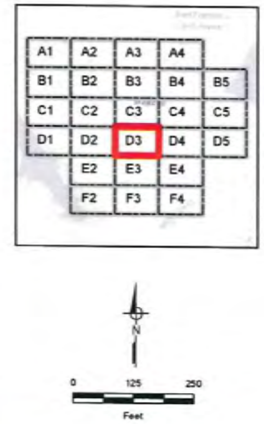

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
- Unmodeled Storm Drain
- Modeled Trunk Storm Drain
- Creek, Canal, or Ditch
- Grid (from City)
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- Millbrae City Limits

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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page D3

City of Millbrae
Storm Drain Master Plan

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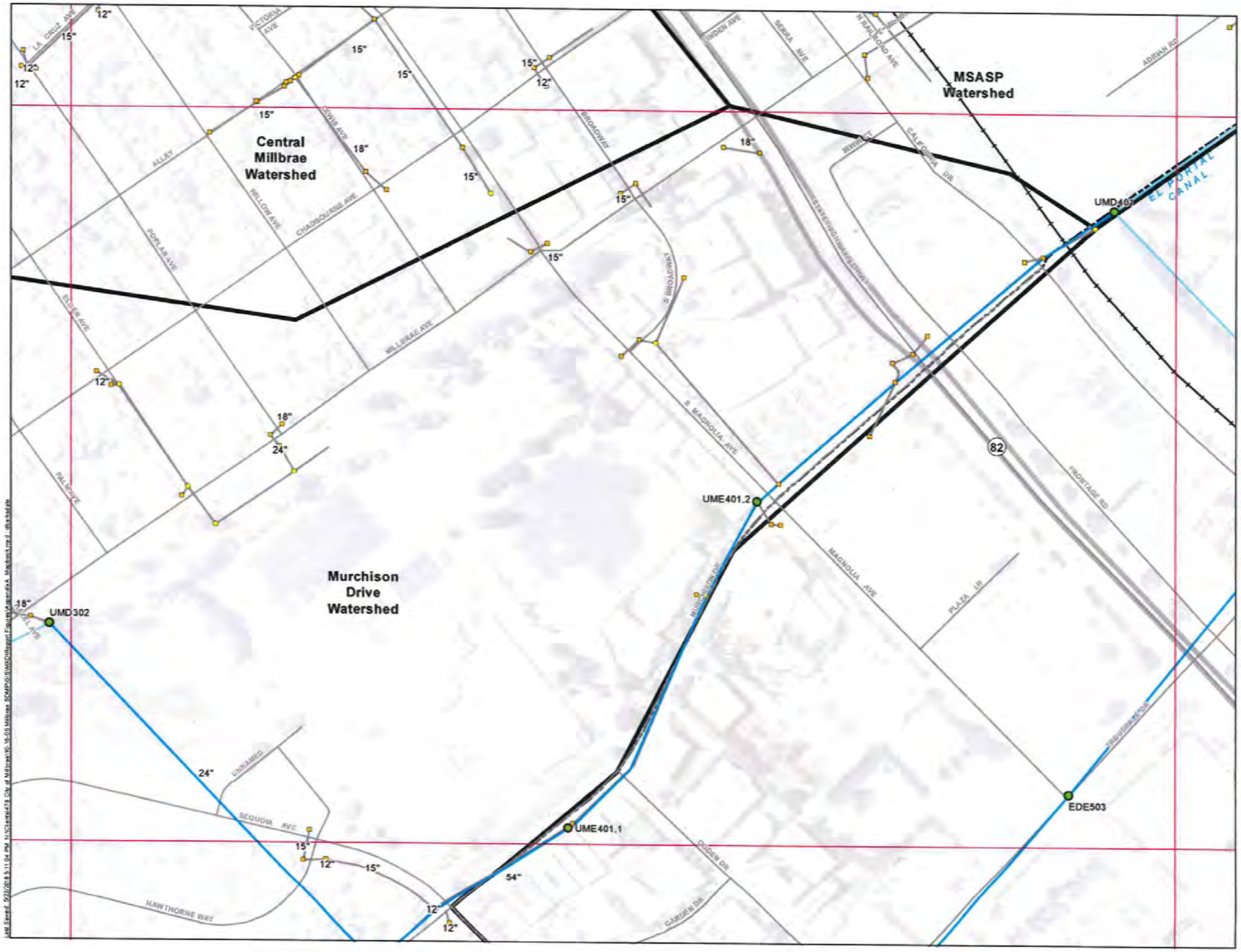

A1 A2 A3 A4
B1 B2 B3 B4 B5
C1 C2 C3 C4 C5
D1 D2 D3 D4 D5
E2 E3 E4
F2 F3 F4

N

0 125 250
Feet

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
- Unmodeled Storm Drain
- Modeled Trunk Storm Drain
- Creek, Canal, or Ditch
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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page D4

City of Millbrae
Storm Drain Master Plan

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Note: Figure based on AutoCAD files received from the City adjusted to fit GIS mapping and field verified points. Not all storm drain mapping has been verified and data may not be accurate.

Appendix A

Facility Mapbook for the City of Millbrae Page D5

City of Millbrae
Storm Drain Master Plan

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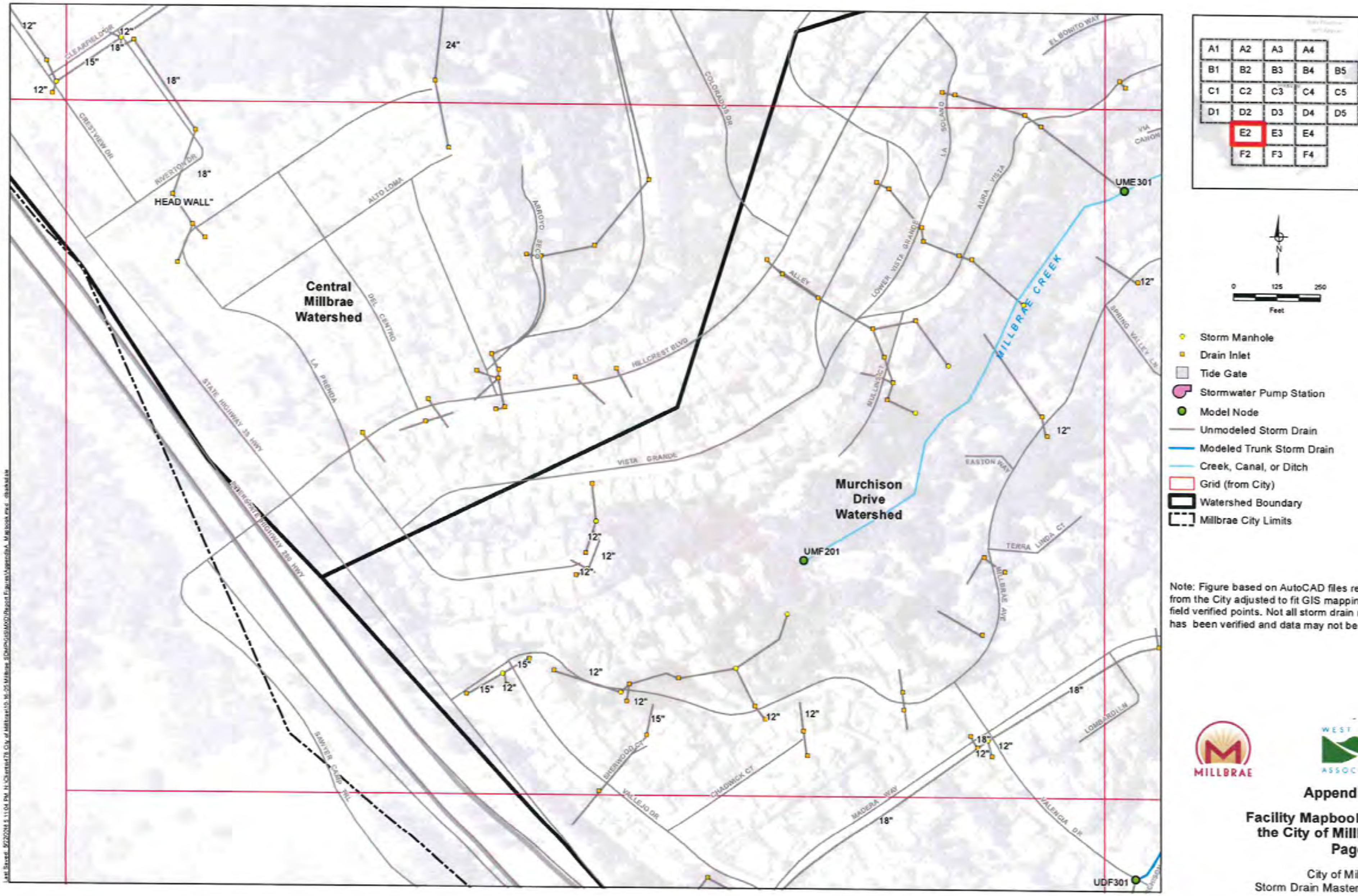

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
- Unmodeled Storm Drain
- Modeled Trunk Storm Drain
- Creek, Canal, or Ditch
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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page E2

City of Millbrae
Storm Drain Master Plan

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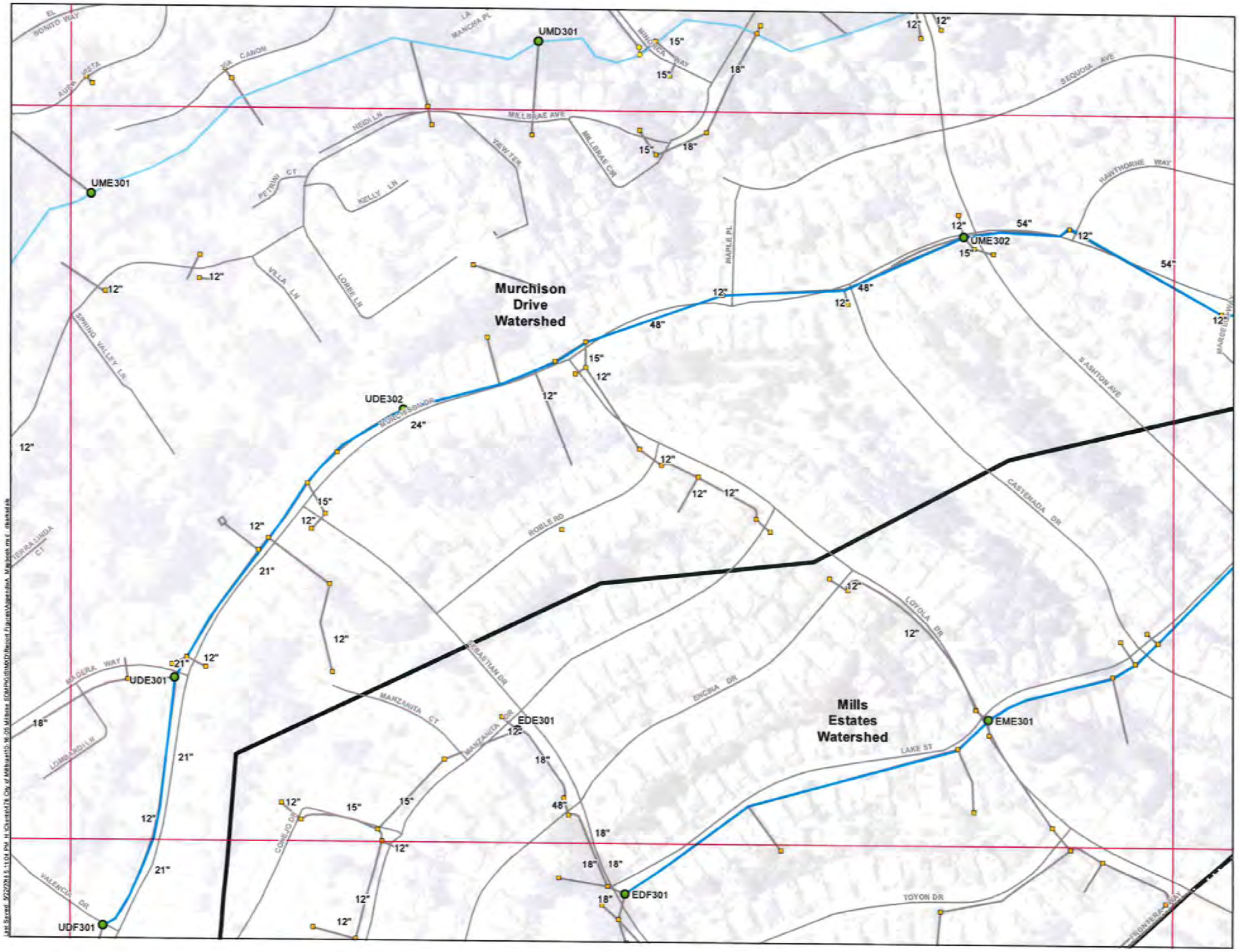

A1 A2 A3 A4
B1 B2 B3 B4 B5
C1 C2 C3 C4 C5
D1 D2 D3 D4 D5
E2 E3 E4
F2 F3 F4

0 125 250
Feet

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
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- Modeled Trunk Storm Drain
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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae
Page E3

City of Millbrae
Storm Drain Master Plan

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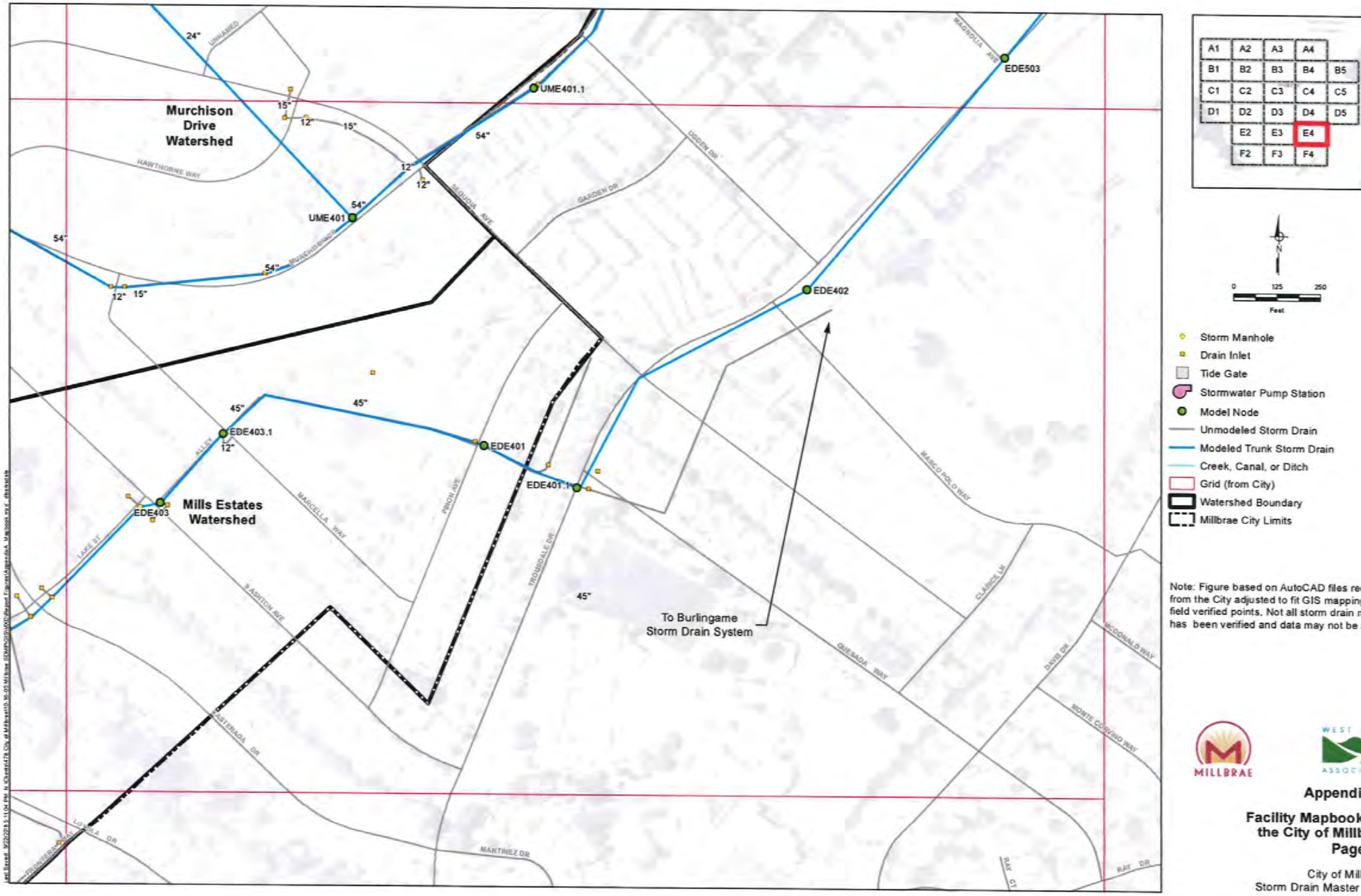

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Appendix A

Facility Mapbook for the City of Millbrae Page E4

City of Millbrae
Storm Drain Master Plan

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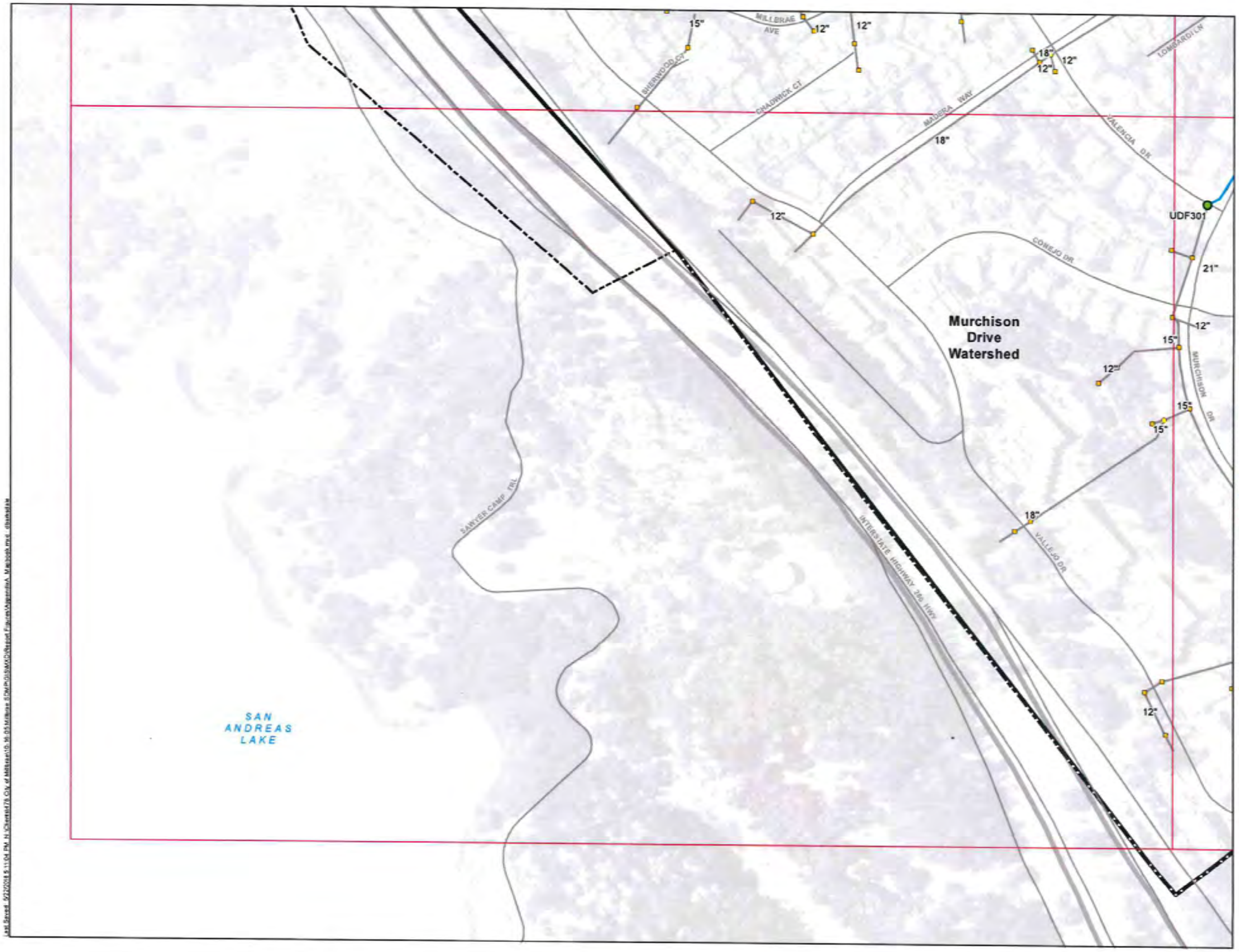

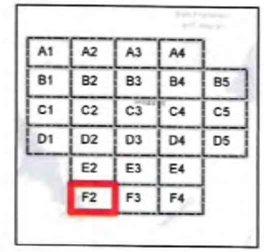

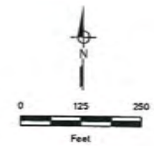

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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page F2

City of Millbrae
Storm Drain Master Plan

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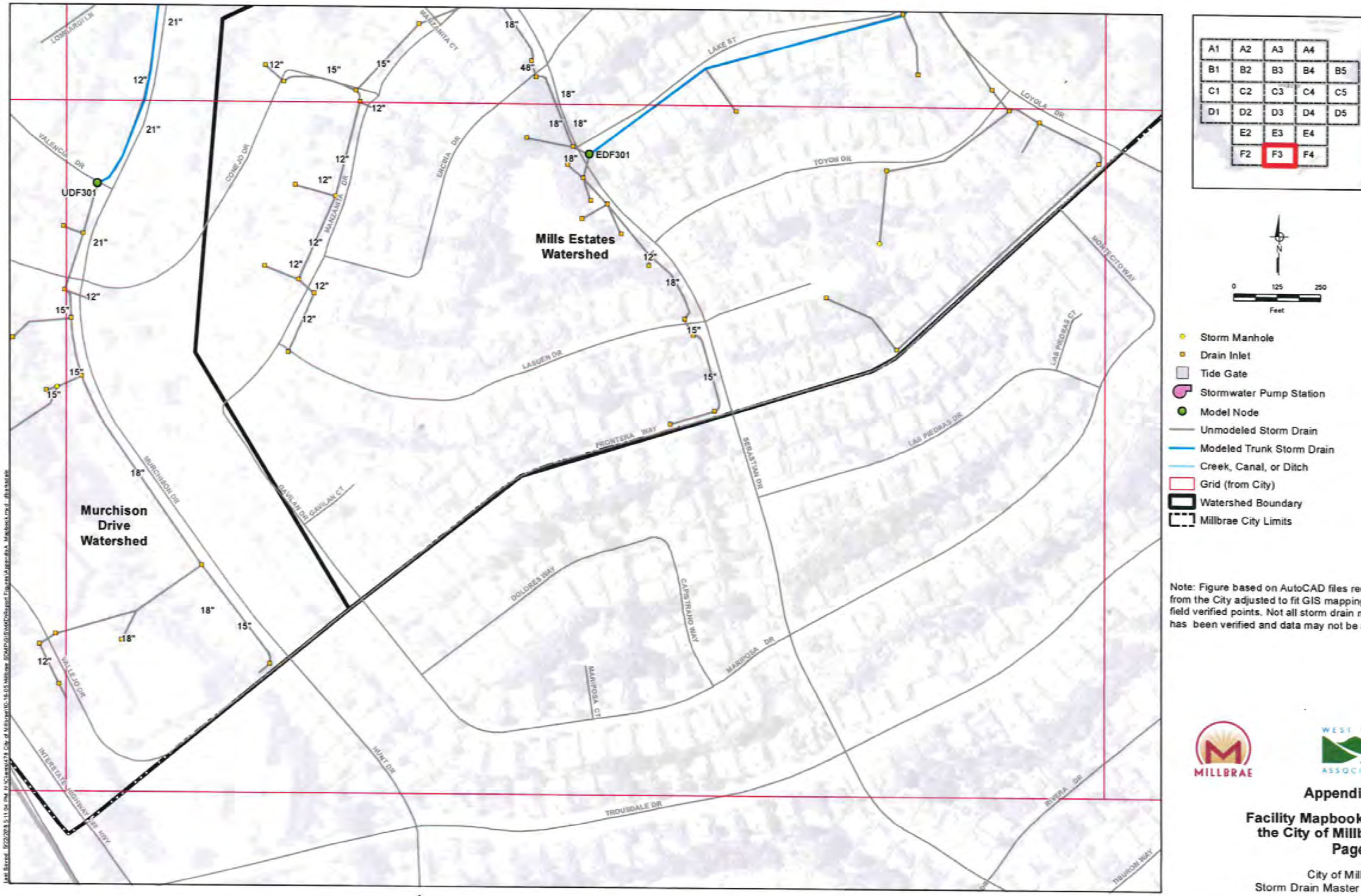

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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page F3

City of Millbrae
Storm Drain Master Plan

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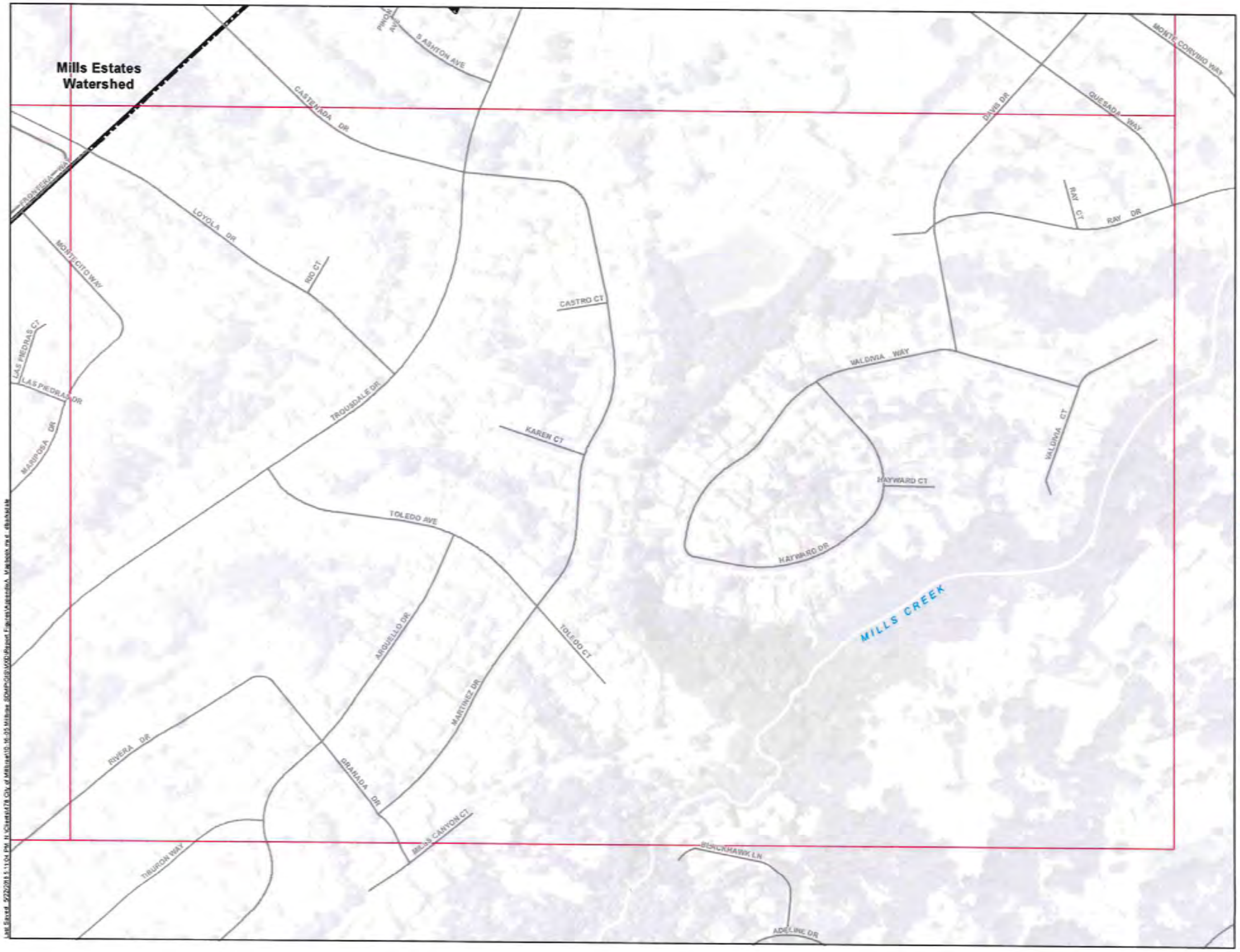

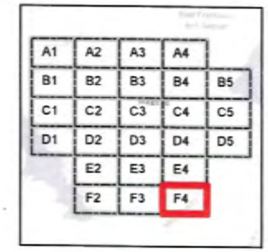

N

0 125 250
Feet

- Storm Manhole
- Drain Inlet
- Tide Gate
- Stormwater Pump Station
- Model Node
- Unmodeled Storm Drain
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MILLBRAE

WEST YOST ASSOCIATES

Appendix A

Facility Mapbook for the City of Millbrae Page F4

City of Millbrae
Storm Drain Master Plan

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APPENDIX B

Rainfall Depths by Catchment

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Appendix B-1. Existing Model Catchment Inputs and Runoff Results

Node Name	Area acre	Width feet	Soil Type	Impervious Percentage	Slope	10-year Existing Catchment Max Flow cfs	10-year Existing Peak Unit Runoff Ratio cfs/acre	100-year Existing Catchment Max Flow cfs	100-year Existing Peak Unit Runoff Ratio cfs/acre
NDA201	14.2	594.0	Group C	40	0.067	14	1.0	23	1.6
NDB201	31.9	995.2	Group C	30	0.098	25	0.8	44	1.4
NDA301	14.8	607.6	Group C	43	0.021	14	0.9	23	1.5
NMA301	11.6	520.6	Group C	46	0.075	13	1.1	21	1.8
NMA301	15.3	619.8	Group C	70	0.098	24	1.6	40	2.6
NMA302	5.7	331.5	Group C	68	0.067	9	1.6	15	2.6
NIA202	19.2	719.4	Group C	37	0.100	18	1.0	32	1.7
NOB201	27.3	900.6	Group C	33	0.235	25	0.9	45	1.6
NOB202	19.4	724.8	Group C	28	0.118	15	0.8	27	1.4
NOA203	8.8	437.1	Group C	39	0.074	9	1.0	16	1.8
NOA202	28.0	915.6	Group C	37	0.063	26	0.9	44	1.6
NOA302	10.7	494.3	Group C	80	0.012	17	1.6	28	2.6
NOA302	20.7	753.8	Group C	59	0.011	25	1.2	41	2.0
NOA302	152.0	2702.8	Group C	70	0.080	197	1.3	321	2.1
NOA303	4.4	279.7	Group C	43	0.024	4	1.0	7	1.7
NMA201	26.4	882.2	Group C	55	0.143	34	1.3	57	2.1
CMC103	21.1	764.1	Group C	35	0.180	21	1.0	39	1.8
SMB303	22.8	803.2	Group C	43	0.080	23	1.0	38	1.7
EME301	48.4	1299.0	Group C	58	0.140	71	1.5	118	2.4
CMD202	11.5	518.1	Group C	60	0.220	19	1.7	33	2.9
CMD202	65.7	1580.0	Group C	35	0.110	61	0.9	104	1.6
CMD203	27.4	902.8	Group C	53	0.115	38	1.4	64	2.3
CMD201	25.4	859.9	Group C	55	0.040	33	1.3	55	2.2
CMC201	14.2	592.0	Group C	48	0.110	18	1.3	32	2.2
CDC302	13.4	571.8	Group C	63	0.050	20	1.5	32	2.4
CMC309	26.3	880.2	Group C	58	0.030	33	1.3	54	2.0
CMC301	34.9	1049.3	Group C	60	0.025	43	1.2	70	2.0
CMC102	24.5	840.2	Group C	58	0.060	35	1.4	58	2.4
CMC104	6.3	353.9	Group C	45	0.110	8	1.3	14	2.3
CMC310	18.9	712.7	Group C	70	0.050	30	1.6	49	2.6
CMC203	68.6	1623.7	Group C	14	0.065	26	0.4	48	0.7
CMC203	31.9	994.3	Group C	10	0.060	9	0.3	19	0.6
CMC204	25.5	861.8	Group C	40	0.180	29	1.1	51	2.0
CMC306	33.3	1033.4	Group C	46	0.050	36	1.1	60	1.8
CMD301	43.4	1209.6	Group C	56	0.140	59	1.4	98	2.3
CMD301	3.3	233.4	Group C	50	0.020	4	1.2	7	2.0
CMC405	19.7	730.5	Group C	67	0.050	30	1.5	49	2.5
CMC402	10.5	487.9	Group C	60	0.060	15	1.5	25	2.4
CMC404	9.5	459.1	Group C	70	0.070	15	1.6	25	2.6
CMC401	19.0	800.8	Group C	69	0.030	27	1.4	44	2.3
UMD401	96.3	2018.8	Group C	71	0.020	105	1.1	172	1.8
UMD401	112.6	2018.1	Group C	80	0.020	132	1.2	218	1.9
UMD302	36.1	1076.4	Group C	45	0.060	39	1.1	64	1.8
UME301	42.7	1198.4	Group C	45	0.120	51	1.2	86	2.0
UMD301	31.1	979.9	Group C	48	0.150	40	1.3	68	2.2
UMF201	27.2	897.7	Group C	50	0.160	37	1.4	63	2.3
UME302	39.3	1137.3	Group C	55	0.120	56	1.4	93	2.4
MMC501	63.9	1553.3	Group C	95	0.010	76	1.2	125	1.9
UME401	19.1	717.6	Group C	60	0.020	24	1.3	39	2.1
SOA301	23.4	802.0	Group C	65	0.029	36	1.6	59	2.5
CDC101	45.3	1245.1	Group C	50	0.050	54	1.2	90	2.0
CDC101	15.2	618.1	Group C	60	0.050	23	1.5	38	2.5
CDB101	8.2	415.6	Group C	58	0.032	12	1.4	20	2.4
CDC102	44.5	1231.3	Group C	35	0.150	43	1.0	75	1.7
CDC301	18.7	707.3	Group C	60	0.050	26	1.4	43	2.3
CMC302	18.3	697.3	Group C	55	0.020	22	1.2	35	1.9
CMC303	29.0	935.2	Group C	55	0.030	34	1.2	57	2.0
CMC403	7.1	381.8	Group C	81	0.040	12	1.7	20	2.8
SDB303	7.4	408.5	Group C	72	0.069	12	1.6	20	2.7
SDB302	13.5	574.5	Group C	41	0.065	14	1.0	24	1.8
SDB301	6.9	374.0	Group C	45	0.032	8	1.1	13	1.9
SDB201	4.6	289.0	Group C	69	0.065	8	1.7	13	2.8
SDA301	17.2	670.5	Group C	90	0.075	32	1.9	52	3.0
UDE301	24.7	845.3	Group C	58	0.130	37	1.5	63	2.5
UDF301	47.0	1275.3	Group C	53	0.100	63	1.3	104	2.2
EDF301	14.8	609.6	Group C	45	0.170	19	1.3	33	2.2
EDF301	26.7	888.5	Group C	59	0.100	40	1.5	67	2.5
EDE403	28.0	916.2	Group C	60	0.100	40	1.4	67	2.4
EDE401	23.5	741.8	Group C	58	0.040	30	1.3	49	2.1
CDC203	11.3	513.5	Group C	18	0.230	7	0.6	16	1.4
CDC203	26.4	882.6	Group C	48	0.210	35	1.3	60	2.3
CDD101	19.2	720.1	Group C	55	0.110	28	1.5	47	2.5
NOA304	4.1	265.6	Group C	25	0.030	3	0.7	5	1.3
UDE302	24.0	829.9	Group C	55	0.120	35	1.5	58	2.4
CDC205	9.9	469.5	Group C	55	0.110	15	1.5	25	2.6
CDC201	10.3	481.4	Group C	58	0.040	15	1.5	25	2.4
CDC401	12.4	544.5	Group C	69	0.055	19	1.5	31	2.5
COB401	93.4	1977.2	Group C	63	0.020	94	1.0	155	1.7
CPC401	3.4	236.3	Group C	85	0.015	6	1.8	10	3.0
MPC502	100.0	2067.5	Group C	30	0.050	66	0.7	109	1.1
CDC402	17.8	684.7	Group C	80	0.008	22	1.2	36	2.0
CDC402	15.0	614.3	Group C	90	0.040	27	1.8	43	2.8
CMC407	22.5	795.0	Group C	90	0.017	33	1.5	54	2.4
COB402	47.5	1284.2	Group C	48	0.035	46	1.0	76	1.6
CMD302	15.8	633.9	Group C	50	0.050	19	1.2	32	2.0
CMD306	6.7	365.5	Group C	50	0.130	9	1.3	15	2.3
CMD306	6.7	365.5	Group C	50	0.130	9	1.3	15	2.3

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APPENDIX C

XPSWMM Hydraulic Model Inputs

- Existing Link Inputs 10-year and 100-year
- Improvements Inputs 10-year
- Improvements Inputs 100-year
- Inputs for Nodes

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Existing Link Inputs 10-year and 100-year

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Appendix C-1. Existing Link Input Data

Link Name	Shape	Diameter, feet	Width, feet	Length, ft	Upstream Invert Elevation, ft	Downstream Invert Elevation, ft	Conduit Slope, percent	Main Channel Manning's n	Left Overbank Manning's n	Right Overbank Manning's n
CMD303-CMD302	Circular	2	0	279	105.7	82.5	8	0.014		
CMD302-CMD301	Circular	2	0	360	82.5	75.5	2	0.014		
CMD302-CMD301	Natural	0	0	360	91.8	82.4	3	0.015	0.035	0.035
CMD304-CMD303	Circular	2	0	126	108.8	105.7	2	0.014		
CMD305-CMD304	Circular	2	0	38	109.8	108.8	3	0.014		
CMD306-CMD305	Circular	2	0	122	113.6	109.8	3	0.014		
NIC501-NOC501	Rectangular	8	15	300	0.8	0.0	0	0.014		
NIC501-NOC501	Rectangular	8	15	300	0.8	0.0	0	0.014		
NIC501-NOC501	Rectangular	8	15	300	0.8	0.0	0	0.014		
NIC501-NOC501	Rectangular	8	15	300	0.8	0.0	0	0.014		
CDB101-CMB101	Circular	1.5	0	431	313.7	301.6	3	0.014		
CDB101-CMB101	Natural	0.05	0	365	319.4	306.7	3	0.015	0.035	0.035
CDC101-CDC103	Circular	2.25	0	708	284.5	245.7	5	0.014		
CDC101-CDC103	Natural	0	0	708	289.6	249.9	8	0.015	0.035	0.035
CDC102-CMC104	Circular	2.75	0	556	262.4	230.6	6	0.014		
CDC102-CMC104	Natural	0	0	743	271.8	240.4	4	0.015	0.035	0.035
CDC104-CDC203	Circular	2.5	0	410	229.1	219.1	2	0.014		
CDC103-CMC102	Circular	2.5	0	157	245.7	241.6	3	0.014		
CDC103-CMC102	Natural	0.05	0	157	249.9	247.1	2	0.015	0.035	0.035
CDC201-CDC202	Trapezoidal	1	2	667	239.8	189.7	8	0.014		
CDC202-CDC205	Circular	1.25	0	94	189.7	160.7	31	0.014		
CDC202-CDC205	Natural	0.05	0	80	193.8	169.0	31	0.015	0.035	0.035
CDC203-CDC206	Circular	3	0	171	216.9	215.1	1	0.014		
CDC203-CDC206	Natural	0.05	0	171	221.6	222.4	0	0.015	0.035	0.035
CDC206-CMC201	Circular	3	0	163	215.1	213.4	1	0.014		
CDC206-CMC201	Natural	0.5	0	163	222.4	223.1	0	0.015	0.035	0.035
CDC204-CDC207	Circular	2.5	0	101	168.1	150.1	18	0.014		
CDC204-CDC207	Natural	0.05	0	101	173.2	156.8	16	0.015	0.035	0.035
CDC207-CMC204	Circular	2.5	0	155	150.1	122.5	18	0.014		
CDC207-CMC204	Natural	0	0	155	156.8	130.5	17	0.015	0.035	0.035
CDC205-CMC203	Natural	0	0	2679	160.7	75.0	3	0.05	0.035	0.035
CDC301-CMC310	Circular	4	0	435	73.8	73.2	0	0.014		
CDC301-CMC310	Natural	0	0	435	81.5	82.5	0	0.015	0.035	0.035
CDC302-CDC305	Circular	1.25	0	181	85.7	79.6	3	0.014		
CDC302-CDC305	Natural	0.05	0	181	90.0	83.5	4	0.015	0.035	0.035
CDC305-CDC303	Natural	0.05	0	645	83.5	67.0	3	0.015	0.035	0.035
CDC305-CDC303	Circular	1.25	0	464	79.6	63.9	3	0.014		
CDC303-CDC304	Circular	1.25	0	172	63.9	61.1	2	0.014		
CDC303-CDC304	Natural	0.05	0	172	67.0	66.1	1	0.015	0.035	0.035
CDC304-CMC301	Circular	4	0	967	61.1	37.3	2	0.014		
CDC304-CMC301	Natural	0	0	967	66.1	46.7	2	0.015	0.035	0.035
CDC401-CMC403	Rectangular	4	5.7	381	14.2	13.8	0	0.014		
CDC401-CMC403	Rectangular	4	5.7	381	14.2	13.8	0	0.014		
CDC401-CMC403	Natural	0	0	381	20.2	20.6	0	0.015	0.035	0.035
CDC402-CJC401	Circular	1.5	0	292	1.0	-2.2	1	0.014		
CDD101-CDC104	Circular	2	0	691	396.0	229.1	24	0.014		
CJA301-NOA303	Circular	3.5	0	444	0.9	0.1	0	0.014		
CMB101-CDC201	Circular	1.75	0	915	301.6	239.8	7	0.014		
CMJ301-CMJ302	Circular	3.5	0	978	14.1	3.0	1	0.014		
CMJ302-CJA301	Circular	3.5	0	1087	3.0	0.9	0	0.014		
CMC102-CMC104	Circular	2.5	0	274	241.6	230.6	4	0.014		
CMC102-CMC104	Natural	0	0	269	247.1	240.4	2	0.015	0.035	0.035
CMC103-CDC102	Circular	2.25	0	891	314.3	262.4	6	0.014		
CMC104-CMC201	Circular	3.5	0	718	230.6	213.4	2	0.014		
CMC104-CMC201	Natural	0.05	0	800	240.4	223.1	2	0.015	0.035	0.035
CMC201-CDC205	Circular	3.5	0	505	213.4	160.7	10	0.014		
CMC201-CDC205	Natural	0	0	505	223.1	169.0	11	0.015	0.035	0.035
CMC203-CDC301	Circular	4	0	138	75.0	73.6	1	0.014		
CMC203-CDC301	Natural	0	0	138	83.0	81.5	1	0.015	0.035	0.035
CMC203-CJC301	Circular	3.5	0	768	75.0	37.6	5	0.014		
CMC204-CDC208	Circular	3	0	778	122.5	101.0	3	0.014		
CMC204-CDC208	Natural	0.05	0	1010	130.5	113.0	2	0.015	0.035	0.035
CDC208-CMC306	Circular	3	0	1180	101.0	66.5	3	0.014		
CDC208-CMC306	Natural	0	0	1086	113.0	86.5	2	0.015	0.035	0.035
CMC301-CDC306	Circular	5	0	243	37.3	34.6	1	0.014		
CMC301-CDC306	Natural	0.05	0	242	46.7	44.0	1	0.015	0.035	0.035
CDC306-CMC406	Circular	5	0	2606	34.6	5.9	1	0.014		
CMC302-CMC401	Circular	4	0	1112	30.6	19.6	1	0.014		
CMC302-CMC401	Natural	0.05	0	1138	37.8	25.3	1	0.015	0.035	0.035
CMC303-CMC304	Circular	3	0	594	33.8	20.9	2	0.014		
CMC303-CMC304	Natural	0.05	0	594	39.0	30.8	1	0.015	0.035	0.035
CMC304-CMC401	Circular	3.25	0	441	20.9	19.6	0	0.014		
CMC304-CMC401	Natural	0	0	441	30.8	25.3	1	0.015	0.035	0.035
CMC306-CMC309	Circular	3.5	0	905	68.5	51.2	2	0.014		
CMC306-CMC309	Natural	0	0	905	86.5	60.4	3	0.015	0.035	0.035
CMC309-CMC302	Circular	3.5	0	1145	51.2	30.6	2	0.014		
CMC309-CMC302	Natural	0	0	1042	60.4	37.3	2	0.015	0.035	0.035
CMC310-CDC304	Circular	4	0	833	73.2	61.1	1	0.014		
CJC301-CMJ301	Circular	3.5	0	1974	37.6	14.1	1	0.014		
CMC401-CDC401	Rectangular	4	5.7	524	19.6	14.2	1	0.014		
CMC401-CDC401	Rectangular	4	5.7	524	19.6	14.2	1	0.014		
CMC402-CMC403	Circular	2	0	447	22.7	13.8	2	0.014		
CMC402-CMC403	Natural	0	0	447	31.4	20.6	2	0.015	0.035	0.035
CMC403-CMC407	Rectangular	4	5.7	1045	13.8	5.4	1	0.014		
CMC403-CMC407	Rectangular	4	5.7	1045	13.8	5.4	1	0.014		
CMC404-MIC401	Natural	0	0	1134	4.3	1.9	0	0.035	0.035	0.035
MIC401-MOC401	Rectangular	8	15	76	1.9	1.7	0	0.035	0.035	0.035
MOC401-NIC501	Natural	0	0	415	1.7	0.8	0	0.035	0.035	0.035
CMC405-CMC402	Circular	1.75	0	395	26.5	22.7	1	0.014		
CMC405-CMC402	Natural	0.05	0	395	40.1	31.4	2	0.015	0.035	0.035
CMC406-CMC404	Circular	5.5	0	1341	5.9	4.3	0	0.014		
CMC407-CMC404	Circular	4.5	5.7	142	5.4	4.3	1	0.014		
CJC401-MPC502	Circular	2.75	0	1424	-2.2	-18.0	1	0.014		
CMD201-CDD201	Circular	1.75	0	500	493.0	422.7	14	0.014		
CMD201-CDD201	Natural	0	0	500	500.3	438.4	12	0.015	0.035	0.035
CDD201-CMD202	Circular	1.75	0	1175	422.7	257.3	14	0.014		
CMD202-CMD203	Circular	2.5	0	523	257.3	235.8	4	0.014		
CMD202-CMD203	Natural	0.05	0	523	292.3	243.8	9	0.015	0.035	0.035
CMD203-CDC204	Circular	2.5	0	809	235.8	168.1	8	0.014		
CMD203-CDC204	Natural	0	0	809	243.8	173.2	9	0.015	0.035	0.035
CMD301-CMC303	Circular	2.5	0	1594	72.9	33.8	2	0.014		
CMD301-CMC303	Natural	0	0	1594	82.4	39.0	3	0.015	0.035	0.035
COB401-COB402	Natural	0	0	1494	0.0	-13.5	0	0.04	0.05	0.05
COB402-MPC501	Natural	0	0	500	-13.5	-18.0	0	0.04	0.05	0.05
EDE301-EDF301	Circular	1.5	0	581	385.6	359.4	5	0.014		
EDE301-EDF301	Natural	0.05	0	580	394.3	367.9	5	0.015	0.035	0.035
EDE401-EME402	Circular	3.75	0	245	85.7	77.5	3	0.014		
EDE401-EME402	Natural	0	0	245	89.6	81.8	3	0.015	0.035	0.035
EME402-EME403	Natural	0	0	913	81.8	57.0	3	0.015	0.035	0.035
EME402-EME403	Circular	3.75	0	913	77.5	52.0	3	0.014		
EME403-EME404	Circular	3.75	0	770	52.0	34.8	2	0.014		
EME403-EME404	Natural	0.05	0	766	57.0	41.0	2	0.015	0.035	0.035
EDE403-EME401	Circular	3.75	0	272	110.6	104.4	2	0.014		
EDE403-EME401	Natural	0	0	272	119.1	111.7	3	0.015	0.035	0.035
EME401-EDE401	Circular	3.75	0	815	104.4	85.7	2	0.014		
EME401-EDE401	Natural	0	0	815	111.7	89.6	3	0.015	0.035	0.035
EME404-EOD501	Circular	5	0	1245	34.8	7.0	2	0.014		

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Appendix C-1. Existing Link Input Data

EDD501-UMD401	Trapezoidal	6	10	236	7.0	5.9	0	0.014		
EDF301-EME301	Circular	1.7	0	1127	359.4	201.6	14	0.014		
EDF301-EME301	Natural	0	0	1127	367.9	210.1	14	0.015	0.035	0.035
EME301-EDE403	Circular	3.75	0	944	201.6	110.6	10	0.014		
MMC501-MIC501	Natural	0	10	629	0.0	-3.2	1	0.05	0.035	0.035
MIC501-MOC501	Circular	3	10	236	-3.2	-4.5	1	0.05	0.035	0.035
MOC501-MPC502	Natural	0	10	1418	-4.5	-11.8	1	0.05	0.035	0.035
NDA201-NMA201	Circular	4	0	383	31.2	30.5	0	0.014		
NDA201-NMA201	Natural	0.05	0	383	36.1	35.7	0	0.03	0.03	0.03
NDA301-NDA302	Circular	2	0	229	35.7	29.7	3	0.014		
NDA301-NDA302	Natural	0	0	212	38.8	38.0	1	0.015	0.035	0.035
NDA302-NMA302	Natural	0	0	870	38.0	27.9	1	0.015	0.035	0.035
NDA302-NMA302	Circular	2	0	870	29.7	12.3	3	0.014		
NDB201-NMA201	Circular	2	0	1383	77.3	33.1	3	0.014		
NDB201-NMA201	Natural	0	0	1383	85.6	35.7	4	0.015	0.035	0.035
NMA201-NMA304	Circular	4	0	789	30.5	17.8	2	0.014		
NMA201-NMA304	Natural	0.05	0	730	35.7	25.1	1	0.03	0.03	0.03
NIA201-NOA203	Circular	3.5	0	203	73.0	68.0	2	0.014		
NIA202-NDA201	Circular	3.5	0	958	51.2	31.2	2	0.014		
NMA301-NMA302	Circular	3.5	0	558	16.3	12.3	1	0.014		
NMA302-NMA303	Circular	3.5	0	170	12.3	8.0	3	0.014		
NMA303-NOA301	Rectangular	5	8	1086	8.0	3.0	0	0.014		
NMA304-NMA301	Rectangular	2	5	145	17.8	16.3	1	0.014		
NMA304-SDA301	Natural	0	0	1096	17.8	11.3	1	0.015	0.035	0.035
NOA201-NOA202	Natural	0	0	75	77.0	75.0	3	0.05	0.035	0.035
NOA202-NIA201	Natural	0	0	112	75.0	73.0	2	0.05	0.035	0.035
NOA203-NIA202	Natural	0	0	676	68.0	51.2	2	0.05	0.035	0.035
NOA301-NOA302	Natural	0	0	713	3.0	0.5	0	0.05	0.035	0.035
NOA302-NIA301	Natural	0	0	44	0.5	0.5	0	0.05	0.035	0.035
NIA301-NOA305	Rectangular	4	8	85	0.5	0.4	0	0.05	0.035	0.035
NOA305-NOA304	Natural	0	0	458	0.4	0.3	0	0.05	0.035	0.035
NOA303-COB401	Natural	0	0	2072	0.1	0.0	0	0.05	0.035	0.035
NOA304-NOA303	Natural	0	0	475	0.3	0.1	0	0.05	0.035	0.035
NOB201-NOB202	Natural	0	0	407	115.0	92.0	6	0.025	0.025	0.025
NOB202-NOA201	Natural	0	0	646	92.0	77.0	2	0.05	0.035	0.035
NOC502-NOC500	Circular	8	0	80	0.6	-2.0	4	0.015		
NOC502-NOC500	Circular	8	0	80	0.6	-2.0	4	0.015		
NOC502-NOC500	Trapezoidal	1	0	80	9.6	9.5	0	0.035		
NOB501-NOB500	Trapezoidal	1	100	80	10.0	9.9	0	0.035		
NOB501-NOB500	Rectangular	15	15	60	-2.0	-2.0	0	0.015		
NOB501-NOB500	Rectangular	15	15	60	-2.0	-2.0	0	0.015		
SDA301-SJA301	Rectangular	4	4	111	11.3	10.2	1	0.014		
SDA305-SDA302	Natural	0.5	0	80	6.9	6.0	1	0.015	0.035	0.035
SDA305-SDA302	Rectangular	4	4	78	2.8	2.0	1	0.014		
SJA301-SDA305	Rectangular	4	4	738	10.2	2.8	1	0.014		
SDA302-SOA301	Rectangular	4	6	115	2.0	1.5	0	0.014		
SDB201-SDB301	Circular	1.5	0	946	97.8	69.5	3	0.014		
SDB301-SDB302	Circular	1.25	0	382	69.5	37.4	8	0.014		
SDB301-SDB302	Natural	0.5	0	382	72.7	41.2	8	0.015	0.035	0.035
SDB302-SDB303	Circular	1.5	0	314	37.4	20.0	6	0.014		
SDB303-SMA301	Circular	3	0	1211	20.0	2.8	1	0.014		
SMA301-SOA301	Rectangular	2.4	3.3	224	2.6	1.5	0	0.05	0.035	0.035
SOA301-NDA303	Circular	2	15	60	1.5	1.5	0	0.6		
NDA303-NOA302	Circular	4	0	214	1.5	0.5	0	0.014		
NDA303-NOA302	Circular	4	0	214	1.5	0.5	0	0.014		
NDA303-NOA302	Circular	4	0	214	1.5	0.5	0	0.014		
NDA303-NOA302	Circular	4	0	214	1.5	0.5	0	0.014		
NDA303-NOA302	Circular	4	0	214	1.5	0.5	0	0.014		
NDA303-NOA302	Circular	4	0	214	1.5	0.5	0	0.014		
SOA301-NDA303	0	0	0	0	0.0	0.0	0	0		
SMB303-SDA303	Circular	1.75	0	441	17.0	12.9	1	0.014		
SMB303-SDA303	Natural	0	0	441	21.5	17.5	1	0.015	0.035	0.035
SDA303-SDA304	Natural	0.5	0	63	17.5	16.0	2	0.015	0.035	0.035
SDA304-SDA301	Natural	0.5	0	105	17.5	16.0	1	0.015	0.035	0.035
SDA303-SDA304	Circular	1.75	0	63	12.9	12.3	1	0.014		
SDA304-SDA301	Circular	1.75	0	105	12.3	11.3	1	0.014		
SDA304-SJA301	Circular	3.5	0	108	12.3	10.2	2	0.014		
UDE301-UDE302	Circular	2	0	981	350.4	248.9	10	0.014		
UDE301-UDE302	Natural	0.05	0	983	354.2	257.2	10	0.015	0.035	0.035
UDE302-UME302	Circular	3.7	0	1616	248.9	96.8	9	0.014		
UDF301-UDE301	Circular	1.75	0	731	426.5	350.4	10	0.014		
UDF301-UDE301	Natural	0.05	0	722	431.5	354.2	11	0.015	0.035	0.035
UMD301-UID301	Natural	0	0	1178	136.3	101.4	3	0.04	0.05	0.05
UOD301-UMD302	Natural	0	0	213	88.1	81.8	3	0.04	0.05	0.05
UID301-UOD301	Rectangular	3	4	450	101.4	88.1	3	0.04	0.05	0.05
UMD302-UME401	Circular	2	0	1283	81.8	74.9	1	0.014		
UMD401-MIC502	Natural	0	0	1985	5.9	2.9	0	0.05	0.035	0.035
MIC502-MOC502	Rectangular	8	15	300	2.9	2.5	0	0.05	0.035	0.035
MOC502-NOC502	Natural	0	0	1283	2.5	1.0	0	0.05	0.035	0.035
UME301-UMD301	Natural	0	0	1384	223.0	136.3	6	0.04	0.05	0.05
UME302-UME401	Circular	4.2	0	1520	96.8	65.3	2	0.014		
UME302-UME401	Natural	0	0	1502	109.0	77.5	2	0.015	0.035	0.035
UME401-UDD401	Circular	4.5	0	665	65.3	51.3	2	0.014		
UME401-UDD401	Natural	0.05	0	650	77.5	63.1	2	0.015	0.035	0.035
UDD401-UDD402	Circular	4.5	0	893	51.3	32.5	2	0.014		
UDD401-UDD402	Natural	0	0	893	63.1	42.2	2	0.015	0.035	0.035
UDD402-UMD401	Circular	4.5	0	1260	32.5	5.9	2	0.014		
UMF201-UME301	Natural	0	0	1487	383.3	223.0	11	0.04	0.05	0.05
NOC501-NOB501	Natural	0	0	1568	0.8	0.0	0	0.05	0.035	0.035

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Improvements Inputs 10-year

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Appendix C-2. 10-year Improvements Link Input Data

Link Name	Shape	Diameter feet	Width feet	Length ft	Upstream Invert Elevation ft	Downstream Invert Elevation ft	Conduit Slope percent	Main Channel Manning's n	Left Overbank Manning's n	Right Overbank Manning's n
CMD303-CMD302	Circular	2	0	279	105.7	82.5	8	0.014		
CMD302-CMD301	Circular	2	0	360	82.5	75.5	2	0.014		
CMD302-CMD301	Natural	0	0	360	91.8	82.4	3	0.015	0.035	0.035
CMD304-CMD303	Circular	2	0	126	108.8	105.7	2	0.014		
CMD305-CMD304	Circular	2	0	38	109.8	108.8	3	0.014		
CMD306-CMD305	Circular	2	0	122	113.6	109.8	3	0.014		
NIC501-NOC501	Rectangular	8	15	300	0.8	0.0	0	0.014		
NIC501-NOC501	Rectangular	8	15	300	0.8	0.0	0	0.014		
NIC501-NOC501	Rectangular	8	15	300	0.8	0.0	0	0.014		
NIC501-NOC501	Rectangular	8	15	300	0.8	0.0	0	0.014		
CDB101-CMB101	Circular	1.5	0	431.11	313.7	301.6	3	0.014		
CDB101-CMB101	Natural	0.05	0	365	319.4	306.7	3	0.015	0.035	0.035
CDC101-CDC103	Circular	2.25	0	707.75	284.5	245.7	5	0.014		
CDC101-CDC103	Natural	0	0	707.75	289.6	249.9	6	0.015	0.035	0.035
CDC102-CMC104	Circular	2.75	0	555.64	262.4	230.6	6	0.014		
CDC102-CMC104	Natural	0	0	743	271.8	240.4	4	0.015	0.035	0.035
CDC104-CDC203	Circular	2.5	0	410.35	229.1	219.1	2	0.014		
CDC103-CMC102	Circular	2.5	0	157.34	245.7	241.6	3	0.014		
CDC103-CMC102	Natural	0.05	0	157.34	249.9	247.1	2	0.015	0.035	0.035
CDC201-CDC202	Trapezoidal	1	2	666.73	239.6	189.7	8	0.014		
CDC202-CDC205	Circular	1.25	0	94.09	189.7	160.7	31	0.014		
CDC202-CDC205	Natural	0.05	0	80	193.6	169.0	31	0.015	0.035	0.035
CDC203-CDC206	Circular	3	0	171.2	216.9	215.1	1	0.014		
CDC203-CDC206	Natural	0.05	0	171.2	221.6	222.4	0	0.015	0.035	0.035
CDC206-CMC201	Circular	3	0	163.02	215.1	213.4	1	0.014		
CDC206-CMC201	Natural	0.5	0	163.02	222.4	223.1	0	0.015	0.035	0.035
CDC204-CDC207	Circular	2.5	0	101.05	168.1	150.1	18	0.014		
CDC204-CDC207	Natural	0.05	0	101	173.2	156.8	16	0.015	0.035	0.035
CDC207-CMC204	Circular	2.5	0	155	150.1	122.5	18	0.014		
CDC207-CMC204	Natural	0	0	155	156.8	130.5	17	0.015	0.035	0.035
CDC205-CMC203	Natural	0	0	2678.64	160.7	75.0	3	0.05	0.035	0.035
CDC301-CMC310	Circular	4	0	434.54	73.8	73.2	0	0.014		
CDC301-CMC310	Natural	0	0	434.54	81.5	82.5	0	0.015	0.035	0.035
CDC302-CDC305	Circular	1.25	0	180.9	85.7	79.6	3	0.014		
CDC302-CDC305	Natural	0.05	0	180.9	90.0	83.5	4	0.015	0.035	0.035
CDC305-CDC303	Natural	0.05	0	644.62	83.5	67.0	3	0.015	0.035	0.035
CDC305-CDC303	Circular	1.25	0	463.72	79.6	63.9	3	0.014		
CDC303-CDC304	Circular	1.25	0	171.81	63.9	61.1	2	0.014		
CDC303-CDC304	Natural	0.05	0	171.81	67.0	66.1	1	0.015	0.035	0.035
CDC304-CMC301	Circular	4	0	966.91	61.1	37.3	2	0.014		
CDC304-CMC301	Natural	0	0	906.91	66.1	46.7	2	0.015	0.035	0.035
CDC401-CMC403	Rectangular	4	5.7	380.72	14.2	13.8	0	0.014		
CDC401-CMC403	Rectangular	4	5.7	380.72	14.2	13.8	0	0.014		
CDC401-CMC403	Natural	0	0	380.72	20.2	20.8	0	0.015	0.035	0.035
CDC402-CJC401	Circular	2.5	0	291.57	1.0	-2.2	1	0.014		
CDD101-CDC104	Circular	2	0	690.81	396.0	229.1	24	0.014		
CJA301-NOA303	Circular	3.5	0	443.95	0.9	0.1	0	0.014		
CMB101-CDC201	Circular	1.75	0	914.66	301.6	239.6	7	0.014		
CJB301-CJB302	Circular	3.5	0	978.19	14.1	3.0	1	0.014		
CJB302-CJA301	Circular	3.5	0	1066.9	3.0	0.9	0	0.014		
CMC102-CMC104	Circular	2.5	0	273.75	241.6	230.6	4	0.014		
CMC102-CMC104	Natural	0	0	268.77	247.1	240.4	2	0.015	0.035	0.035
CMC103-CDC102	Circular	2.25	0	690.52	314.3	262.4	6	0.014		
CMC104-CMC201	Circular	3.5	0	717.66	230.6	213.4	2	0.014		
CMC104-CMC201	Natural	0.05	0	800	240.4	223.1	2	0.015	0.035	0.035
CMC201-CDC205	Circular	3.5	0	504.94	213.4	160.7	10	0.014		
CMC201-CDC205	Natural	0	0	504.94	223.1	169.0	11	0.015	0.035	0.035
CMC203-CDC301	Circular	4	0	137.77	75.0	73.8	1	0.014		
CMC203-CDC301	Natural	0	0	137.77	83.0	81.5	1	0.015	0.035	0.035
CMC203-CJC301	Circular	3.5	0	768.19	75.0	37.6	5	0.014		
CMC204-CDC208	Circular	3.5	0	778.35	122.5	101.0	3	0.014		
CMC204-CDC208	Natural	0.05	0	1010	130.5	113.0	2	0.015	0.035	0.035
CDC208-CMC306	Circular	3.5	0	1180.16	101.0	68.5	3	0.014		
CDC208-CMC306	Natural	0	0	1086	113.0	86.5	2	0.015	0.035	0.035
CMC301-CDC306	Circular	5	0	242.76	37.3	34.6	1	0.014		
CMC301-CDC306	Natural	0.05	0	242	48.7	44.0	1	0.015	0.035	0.035
CDC306-CMC406	Circular	5	0	2606.43	34.6	5.9	1	0.014		
CMC302-CMC304	Circular	4	5.7	738.11	30.6	20.9	1	0.014		
CMC302-CMC304	Natural	0	0	675	37.8	30.8	1	0.015	0.035	0.035
CMC302-CMC401	Circular	4.5	0	1112.4	30.6	19.6	1	0.014		
CMC302-CMC401	Natural	0.16	0	1138	37.8	25.3	1	0.015	0.035	0.035
CMC303-CMC304	Circular	3	0	594.23	33.8	20.9	2	0.014		
CMC303-CMC304	Natural	0.05	0	594.23	39.0	30.8	1	0.015	0.035	0.035
CMC304-CMC401	Circular	3.25	5.7	440.65	20.9	19.6	0	0.014		
CMC304-CMC401	Natural	0	0	440.65	30.8	25.3	1	0.015	0.035	0.035
CMC304-CMC401	Circular	4.5	5.7	440.65	20.9	19.6	0	0.014		
CMC306-CMC309	Circular	4	0	905.03	68.5	51.2	2	0.014		
CMC306-CMC309	Natural	0	0	905.03	86.5	60.4	3	0.015	0.035	0.035
CMC309-CMC302	Circular	4.5	0	1144.97	51.2	30.6	2	0.014		
CMC309-CMC302	Natural	0	0	1041.56	60.4	37.3	2	0.015	0.035	0.035
CMC310-CDC304	Circular	4	0	832.76	73.2	61.1	1	0.014		
CJC301-CJB301	Circular	3.5	0	1973.76	37.6	14.1	1	0.014		
CMC312-CMD301	Circular	2	0	1045.76	78.5	72.9	1	0.014		
CMC401-CDC401	Rectangular	4	5.7	524.42	19.6	14.2	1	0.014		
CMC401-CDC401	Rectangular	4	5.7	524.42	19.6	14.2	1	0.014		
CMC402-CMC403	Circular	2	0	446.6	22.7	13.8	2	0.014		
CMC402-CMC403	Natural	0	0	446.6	31.4	20.6	2	0.015	0.035	0.035
CMC403-CMC407	Rectangular	4	5.7	1045.07	13.8	5.4	1	0.014		
CMC403-CMC407	Rectangular	4	5.7	1045.07	13.8	5.4	1	0.014		
CMC404-MIC401	Natural	0	0	1133.81	4.3	1.9	0	0.035	0.035	0.035
MIC401-MOC401	Rectangular	8	15	76	1.9	1.7	0	0.035	0.035	0.035
MOC401-NIC501	Natural	0	0	415	1.7	0.8	0	0.035	0.035	0.035
CMC405-CMC402	Circular	1.75	0	394.95	26.5	22.7	1	0.014		
CMC405-CMC402	Natural	0.05	0	394.95	40.1	31.4	2	0.015	0.035	0.035
CMC406-CMC404	Circular	5.5	0	1341.37	5.9	4.3	0	0.014		
CMC407-CMC404	Circular	4.5	5.7	142.26	5.4	4.3	1	0.014		
CJC401-MPC503	Circular	2.75	0	1424.09	-2.2	-18.0	1	0.014		
CMD201-CDD201	Circular	1.75	0	500	493.0	422.7	14	0.014		
CMD201-CDD201	Natural	0	0	500	500.3	438.4	12	0.015	0.035	0.035
CDD201-CMD202	Circular	1.75	0	1175.2	422.7	257.3	14	0.014		
CMD202-CMD203	Circular	2.5	0	522.96	257.3	235.8	4	0.014		
CMD202-CMD203	Natural	0.05	0	522.96	292.3	243.8	9	0.015	0.035	0.035
CMD203-CDC204	Circular	2.5	0	809.35	235.8	168.1	8	0.014		
CMD203-CDC204	Natural	0	0	809.35	243.8	173.2	9	0.015	0.035	0.035
CMD301-CMC303	Circular	2.5	0	1593.53	72.9	33.8	2	0.014		
CMD301-CMC303	Natural	0	0	1593.53	82.4	39.0	3	0.015	0.035	0.035
COB401-COB402	Natural	0	0	1493.74	0.0	-13.5	0	0.035	0.035	0.035
COB402-MPC501	Natural	0	0	500	-13.5	-18.0	0	0.035	0.035	0.035
EDE301-EDF301	Circular	1.5	0	580.68	385.8	359.4	5	0.014		
EDE301-EDF301	Natural	0.05	0	580	394.3	367.9	5	0.015	0.035	0.035
EDE401-EME402	Circular	3.75	0	245.32	85.7	77.5	3	0.014		
EDE401-EME402	Natural	0	0	245.32	89.6	81.6	3	0.015	0.035	0.035
EME402-EME403	Natural	0	0	913.41	81.8	57.0	3	0.015	0.035	0.035
EME402-EME403	Circular	3.75	0	913.41	77.5	52.0	3	0.014		
EME403-EME404	Circular	3.75	0	770	52.0	34.8	2	0.014		
EME403-EME404	Natural	0.05	0	766	57.0	41.0	2	0.015	0.035	0.035
EDE403-EME401	Circular	3.75	0	271.73	110.6	104.4	2	0.014		
EDE403-EME401	Natural	0	0	271.73	119.1	111.7	3	0.015	0.035	0.035
EME401-EDE401	Circular	3.75	0	815	104.4	85.7	2	0.014		
EME401-EDE401	Natural	0	0	815	111.7	89.6	3	0.015	0.035	0.035
EME404-EOD501	Circular	5	0	1245	34.8	7.0	2	0.014		

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Appendix C-2. 10-year Improvements Link Input Data

Link Name	Shape	Diameter (feet)	Width (feet)	Length ft	Upstream Invert Elevation ft	Downstream Invert Elevation ft	Conduit Slope (percent)	Main Channel Manning's n	Left Overbank Manning's n	Right Overbank Manning's n
EOD501-UMD401	Trapezoidal	6	10	236	7.0	5.9	0	0.014		
EDF301-EME301	Circular	1.7	0	1127.47	359.4	201.6	14	0.014		
EDF301-EME301	Natural	0	0	1127.47	367.9	210.1	14	0.015	0.035	0.035
EME301-EDE403	Circular	3.75	0	944.32	201.6	110.6	10	0.014		
MMC501-MPC502	Circular	4	0	2071.73	0.0	-11.6	1	0.014		
MMC501-MIC501	Natural	0	10	629.46	0.0	-3.2	1	0.05	0.035	0.035
MIC501-MOC501	Circular	3	10	235.54	-3.2	-4.5	1	0.05	0.035	0.035
MOC501-MPC502	Natural	0	10	1417.74	-4.5	-11.6	1	0.05	0.035	0.035
NDA201-NMA201	Circular	4	0	383.23	31.2	30.5	0	0.014		
NDA201-NMA201	Natural	0.05	0	383	36.1	35.7	0	0.03	0.03	0.03
NDA301-NDA302	Circular	2	0	229.06	35.7	29.7	3	0.014		
NDA301-NDA302	Natural	0	0	212	38.8	36.0	1	0.015	0.035	0.035
NDA302-NMA302	Natural	0	0	669.58	36.0	27.9	1	0.015	0.035	0.035
NDA302-NMA302	Circular	2	0	669.58	29.7	12.3	3	0.014		
NDB201-NMA201	Circular	2	0	1382.84	77.3	33.1	3	0.014		
NDB201-NMA201	Natural	0	0	1382.84	85.6	35.7	4	0.015	0.035	0.035
NMA201-NMA304	Circular	4	0	768.96	30.5	17.8	2	0.014		
NMA201-NMA304	Natural	0.05	0	730	35.7	25.1	1	0.03	0.03	0.03
NIA201-NOA203	Circular	3.5	0	203.42	73.0	68.0	2	0.014		
NIA202-NDA201	Circular	3.5	0	958.44	51.2	31.2	2	0.014		
NMA301-NMA302	Circular	3.5	0	557.89	16.3	12.3	1	0.014		
NMA302-NMA303	Circular	3.5	0	170.1	12.3	8.0	3	0.014		
NMA303-NOA301	Rectangular	5	8	1066.01	8.0	3.0	0	0.014		
NMA304-NMA301	Rectangular	2	5	145.37	17.8	16.3	1	0.014		
NMA304-SDA301	Natural	0	0	1096	17.8	11.3	1	0.015	0.035	0.035
NOA201-NOA202	Natural	0	0	75.23	77.0	75.0	3	0.05	0.035	0.035
NOA202-NIA201	Natural	0	0	112.27	75.0	73.0	2	0.05	0.035	0.035
NOA203-NIA202	Natural	0	0	675.96	68.0	51.2	2	0.05	0.035	0.035
NOA301-NOA302	Natural	0	0	707.06	3.0	0.5	0	0.05	0.035	0.035
NOA302-NIA301	Natural	0	0	44.302	0.5	0.5	0	0.05	0.035	0.035
NIA301-NOA305	Rectangular	4	6	84.738	0.5	0.4	0	0.05	0.035	0.035
NOA305-NOA304	Natural	0	0	457.85	0.4	0.3	0	0.035	0.035	0.035
NOA303-COB401	Natural	0	0	2072.24	0.1	0.0	0	0.035	0.035	0.035
NOA304-NOA303	Natural	0	0	475.18	0.3	0.1	0	0.035	0.035	0.035
NOB201-NOB202	Natural	0	0	406.76	115.0	92.0	6	0.025	0.025	0.025
NOB202-NOA201	Natural	0	0	645.55	92.0	77.0	2	0.05	0.035	0.035
NOC502-NOC500	Circular	8	0	60	0.6	-2.0	4	0.015		
NOC502-NOC500	Circular	6	0	60	0.6	-2.0	4	0.015		
NOC502-NOC500	Trapezoidal	1	0	60	9.6	9.5	0	0.035		
NOB501-NOB500	Trapezoidal	1	100	60	10.0	9.9	0	0.035		
NOB501-NOB500	Rectangular	15	15	60	-2.0	-2.0	0	0.015		
NOB501-NOB500	Rectangular	15	15	60	-2.0	-2.0	0	0.015		
SDA301-SJA301	Rectangular	4	4	110.93	11.3	10.2	1	0.014		
SDA305-SDA302	Natural	0.5	0	80	6.9	6.0	1	0.015	0.035	0.035
SDA305-SDA302	Rectangular	4	4	78	2.8	2.0	1	0.014		
SJA301-SDA305	Rectangular	4	4	738.04	10.2	2.8	1	0.014		
SDA302-SOA301	Rectangular	4	6	115.19	2.0	1.5	0	0.014		
SDB201-SDB301	Circular	1.5	0	945.75	97.8	69.5	3	0.014		
SDB301-SDB302	Circular	1.25	0	382.42	69.5	37.4	8	0.014		
SDB301-SDB302	Natural	0.5	0	382.42	72.7	41.2	8	0.015	0.035	0.035
SDB302-SDB303	Circular	1.5	0	313.88	37.4	20.0	6	0.014		
SDB303-SMA301	Circular	3	0	1210.94	20.0	2.6	1	0.014		
SMA301-SOA301	Rectangular	2.4	3.3	223.84	2.6	1.5	0	0.05	0.035	0.035
SOA301-NOA303	Natural	4.5	6	60	1.5	1.5	0	0.05	0.035	0.035
NDA303-NOA302	Circular	4	0	213.69	1.5	0.5	0	0.014		
NDA303-NOA302	Circular	4	0	213.69	1.5	0.5	0	0.014		
NDA303-NOA302	Circular	4	0	213.69	1.5	0.5	0	0.014		
NDA303-NOA302	Circular	4	0	213.69	1.5	0.5	0	0.014		
NDA303-NOA302	Circular	4	0	213.69	1.5	0.5	0	0.014		
NDA303-NOA302	Circular	4	0	213.69	1.5	0.5	0	0.014		
SMB303-SDA303	Circular	1.75	0	440.53	17.0	12.9	1	0.014		
SMB303-SDA303	Natural	0	0	440.53	21.5	17.5	1	0.015	0.035	0.035
SDA303-SDA304	Natural	0.5	0	62.57	17.5	16.0	2	0.015	0.035	0.035
SDA304-SDA301	Natural	0.5	0	104.93	17.5	16.0	1	0.015	0.035	0.035
SDA303-SDA304	Circular	1.75	0	62.57	12.9	12.3	1	0.014		
SDA304-SDA301	Circular	1.75	0	104.93	12.3	11.3	1	0.014		
SDA304-SJA301	Circular	3.5	0	108.34	12.3	10.2	2	0.014		
UDE301-UDE302	Circular	3.5	0	980.83	350.4	246.9	10	0.014		
UDE301-UDE302	Natural	0.05	0	983	354.2	257.2	10	0.015	0.035	0.035
UDE302-UME302	Circular	3.7	0	1616.49	246.9	96.8	9	0.014		
UDF301-UDE301	Circular	2	0	731.24	426.5	350.4	10	0.014		
UDF301-UDE301	Natural	0.05	0	722	431.5	354.2	11	0.015	0.035	0.035
UMD301-UID301	Natural	0	0	1175.34	136.3	101.4	3	0.04	0.05	0.05
UID301-UOD301	Rectangular	3	4	454	101.4	88.1	3	0.04	0.05	0.05
UOD301-UMD302	Natural	0	0	211.67	88.1	81.8	3	0.04	0.05	0.05
UMD302-UME401	Circular	2	0	1282.54	81.8	74.9	1	0.014		
UMD401-MIC502	Natural	0	0	1984.55	5.9	2.9	0	0.05	0.035	0.035
MIC502-MOC502	Rectangular	8	15	300	2.9	2.5	0	0.05	0.035	0.035
MOC502-NOC502	Natural	0	0	1263.37	2.5	1.0	0	0.05	0.035	0.035
UME301-UMD301	Natural	0	0	1364.03	223.0	136.3	6	0.04	0.05	0.05
UME302-UME401	Circular	4.2	0	1520.45	96.8	65.3	2	0.014		
UME302-UME401	Natural	0	0	1502	109.0	77.5	2	0.015	0.035	0.035
UME401-UDD401	Circular	4.5	0	664.931	65.3	51.3	2	0.014		
UME401-UDD401	Natural	0.05	0	650	77.5	63.1	2	0.015	0.035	0.035
UDD401-UDD402	Circular	4.5	0	892.910	51.3	32.5	2	0.014		
UDD401-UDD402	Natural	0	0	892.919	63.1	42.2	2	0.015	0.035	0.035
UME401-UMD401 2.1	Circular	4.5	0	1259.98	32.5	5.9	2	0.014		
UMF201-UME301	Natural	0	0	1487.47	383.3	223.0	11	0.04	0.05	0.05
NOC501-NOB501	Natural	0	0	1567.79	0.8	0.0	0	0.05	0.035	0.035

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C3

Improvements Inputs 100-year

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Appendix C-3. 100-year Improvements Link Input Data

Link Name	Shape	Diameter, feet	Width, feet	Length ft	Upstream Invert Elevation ft	Downstream Invert Elevation ft	Conduit Slope, percent	Main Channel Manning's n	Left Overbank Manning's n	Right Overbank Manning's n
NIC501-NOC501	Rectangular	8	15	300	1	0	0	0.014		
NOC501-NOB501	Natural	0	0	1567.79	1	0	0	0.05	0.035	0.035
CMD303-CMD302	Circular	2	0	279	106	82	8	0.014		
CMD302-CMD301	Circular	2	0	360	82	75	2	0.014		
CMD302-CMD301	Natural	0	0	360	92	82	3	0.015	0.035	0.035
CMD304-CMD303	Circular	2	0	126	109	106	2	0.014		
CMD305-CMD304	Circular	2	0	38	110	109	3	0.014		
CMD306-CMD305	Circular	2	0	122	114	110	3	0.014		
NIC501-NOC501	Rectangular	8	15	300	1	0	0	0.014		
NIC501-NOC501	Rectangular	8	15	300	1	0	0	0.014		
NIC501-NOC501	Rectangular	8	15	300	1	0	0	0.014		
CDB101-CMB101	Circular	1.5	0	431.11	314	302	3	0.014		
CDB101-CMB101	Natural	0.05	0	365	319	307	3	0.015	0.035	0.035
CDC101-CDC103	Circular	2.25	0	707.75	285	246	5	0.014		
CDC101-CDC103	Natural	0	0	707.75	290	250	6	0.015	0.035	0.035
CDC102-CMC104	Circular	2.75	0	555.64	262	231	6	0.014		
CDC102-CMC104	Natural	0	0	743	272	240	4	0.015	0.035	0.035
CDC104-CDC203	Circular	2.5	0	410.35	229	219	2	0.014		
CDC103-CMC102	Circular	2.5	0	157.34	246	242	3	0.014		
CDC103-CMC102	Natural	0.05	0	157.34	250	247	2	0.015	0.035	0.035
CDC201-CDC202	Trapezoidal	1	2	666.73	240	190	8	0.014		
CDC202-CDC205	Circular	1.25	0	94.09	190	161	31	0.014		
CDC202-CDC205	Natural	0.05	0	80	194	169	31	0.015	0.035	0.035
CDC203-CDC206	Circular	3	0	171.2	217	215	1	0.014		
CDC203-CDC206	Natural	0.05	0	171.2	222	222	0	0.015	0.035	0.035
CDC206-CMC201	Circular	3	0	163.02	215	213	1	0.014		
CDC206-CMC201	Natural	0.5	0	163.02	222	223	0	0.015	0.035	0.035
CDC204-CDC207	Circular	3	0	101.05	168	150	18	0.014		
CDC204-CDC207	Natural	0.05	0	101	173	157	16	0.015	0.035	0.035
CDC207-CMC204	Circular	3	0	155	150	123	18	0.014		
CDC207-CMC204	Natural	0	0	155	157	131	17	0.015	0.035	0.035
CDC205-CMC203	Natural	0	0	2678.64	161	75	3	0.05	0.035	0.035
CDC301-CMC310	Circular	4	0	434.54	74	73	0	0.014		
CDC301-CMC310	Natural	0	0	434.54	82	82	0	0.015	0.035	0.035
CDC302-CDC305	Circular	1.25	0	180.9	86	80	3	0.014		
CDC302-CDC305	Natural	0.05	0	180.9	90	84	4	0.015	0.035	0.035
CDC305-CDC303	Natural	0.05	0	644.62	84	67	3	0.015	0.035	0.035
CDC305-CDC303	Circular	1.25	0	463.72	80	64	3	0.014		
CDC303-CDC304	Circular	1.25	0	171.81	64	61	2	0.014		
CDC303-CDC304	Natural	0.05	0	171.81	67	66	1	0.015	0.035	0.035
CDC304-CMC301	Circular	4	0	966.91	61	37	2	0.014		
CDC304-CMC301	Natural	0	0	966.91	66	47	2	0.015	0.035	0.035
CDC401-CMC403	Rectangular	4	5.7	380.72	14	14	0	0.014		
CDC401-CMC403	Rectangular	4	5.7	380.72	14	14	0	0.014		
CDC401-CMC403	Circular	4	0	380.72	14	14	0	0.015	0.035	0.035
CDC402-CJC401	Circular	2.5	0	291.57	1	-2	1	0.014		
CDD101-CDC104	Circular	2	0	690.81	396	229	24	0.014		
CJA301-NOA303	Circular	3.5	0	443.95	1	0	0	0.014		
CMB101-CDC201	Circular	1.75	0	914.66	302	240	7	0.014		
CJB301-CJB302	Circular	3.5	0	978.19	14	3	1	0.014		
CJB302-CJA301	Circular	3.5	0	1086.9	3	1	0	0.014		
CMC102-CMC104	Circular	3	0	273.75	242	231	4	0.014		
CMC102-CMC104	Natural	0	0	268.77	247	240	2	0.015	0.035	0.035
CMC103-CDC102	Circular	2.25	0	890.52	314	262	6	0.014		
CMC104-CMC201	Circular	4	0	717.66	231	213	2	0.014		
CMC104-CMC201	Natural	0.05	0	800	240	223	2	0.015	0.035	0.035
CMC201-CDC205	Circular	4	0	504.94	213	161	10	0.014		
CMC201-CDC205	Natural	0	0	504.94	223	169	11	0.015	0.035	0.035
CMC203-CDC301	Circular	4	0	137.77	75	74	1	0.014		
CMC203-CDC301	Natural	0	0	137.77	83	82	1	0.015	0.035	0.035
CMC203-CJC301	Circular	3.5	0	788.19	75	38	5	0.014		
CMC204-CDC208	Circular	4	0	778.35	123	101	3	0.014		
CMC204-CDC208	Natural	0.05	0	1010	131	113	2	0.015	0.035	0.035
CDC208-CMC306	Circular	4	0	1180.16	101	68	3	0.014		
CDC208-CMC306	Natural	0	0	1086	113	86	2	0.015	0.035	0.035
CMC301-CDC306	Circular	5	0	242.76	37	35	1	0.014		
CMC301-CDC306	Natural	0.05	0	242	47	44	1	0.015	0.035	0.035
CDC306-CMC406	Circular	5	0	2606.43	35	6	1	0.014		
CMC302-CMC304	Circular	4	5.7	738.11	31	21	1	0.014		
CMC302-CMC304	Natural	0	0	675	38	31	1	0.015	0.035	0.035
CMC302-CMC401	Circular	4.5	0	1112.4	31	20	1	0.014		
CMC302-CMC401	Natural	0.16	0	1138	38	25	1	0.015	0.035	0.035
CMC303-CMC304	Circular	3.5	0	594.23	34	21	2	0.014		
CMC303-CMC304	Natural	0.05	0	594.23	39	31	1	0.015	0.035	0.035
CMC304-CMC401	Circular	3.5	5.7	440.65	21	20	0	0.014		
CMC304-CMC401	Natural	0	0	440.65	31	25	1	0.015	0.035	0.035
CMC306-CMC309	Circular	4	0	905.03	68	51	2	0.014		
CMC306-CMC309	Natural	0	0	905.03	86	60	3	0.015	0.035	0.035
CMC309-CMC302	Circular	4.5	0	1144.97	51	31	2	0.014		
CMC309-CMC302	Natural	0	0	1041.56	60	37	2	0.015	0.035	0.035
CMC310-CDC304	Circular	4	0	832.76	73	61	1	0.014		
CJC301-CJB301	Circular	3.5	0	1973.78	38	14	1	0.014		
CMC312-CMD301	Circular	2	0	1045.78	79	73	1	0.014		
CMC401-CDC401	Rectangular	4	5.7	524.42	20	14	1	0.014		
CMC401-CDC401	Rectangular	4	5.7	524.42	20	14	1	0.014		
CMC401-CDC401	Circular	4	0	524.42	20	14	1	0.014		
CMC402-CMC403	Circular	2	0	446.6	23	14	2	0.014		
CMC402-CMC403	Natural	0	0	446.6	31	21	2	0.015	0.035	0.035
CMC403-CMC407	Rectangular	4	5.7	735.07	14	9	1	0.014		
CMC403-CMC407.1	Rectangular	4	16	395	9	5	1	0.014		
CMC403-CMC407	Rectangular	4	5.7	735.07	14	9	1	0.014		
CMC403-CMC407	Circular	4	0	735.07	14	9	1	0.014		
CMC404-MIC401	Natural	0	0	1133.81	4	2	0	0.035	0.035	0.035
MIC401-MOC401	Rectangular	8	15	76	2	2	0	0.035	0.035	0.035
MOC401-NIC501	Natural	0	0	415	2	1	0	0.035	0.035	0.035
CMC405-CMC402	Circular	1.75	0	394.95	26	23	1	0.014		
CMC405-CMC402	Natural	0.05	0	394.95	40	31	2	0.015	0.035	0.035
CMC406-CMC404	Circular	5.5	0	1341.37	6	4	0	0.014		
CMC407-CMC404	Circular	4.5	5.7	142.26	5	4	1	0.014		
CJC401-MPC503	Circular	2.75	0	1424.09	-2	-18	1	0.014		
CMD201-CDD201	Circular	1.75	0	500	493	423	14	0.014		
CMD201-CDD201	Natural	0	0	500	500	438	12	0.015	0.035	0.035
CDD201-CMD202	Circular	1.75	0	1175.2	423	257	14	0.014		
CMD202-CMD203	Circular	2.5	0	522.96	257	236	4	0.014		
CMD202-CMD203	Natural	0.05	0	522.96	292	244	9	0.015	0.035	0.035
CMD203-CDC204	Circular	3	0	809.35	236	168	8	0.014		
CMD203-CDC204	Natural	0	0	809.35	244	173	9	0.015	0.035	0.035
CMD301-CMC303	Circular	2.5	0	1593.53	73	34	2	0.014		
CMD301-CMC303	Natural	0	0	1593.53	82	39	3	0.015	0.035	0.035
COB401-COB402	Natural	0	0	1493.74	0	-13	0	0.035	0.035	0.035
COB402-MPC501	Natural	0	0	500	-13	-18	0	0.035	0.035	0.035
EDE301-EDF301	Circular	1.5	0	580.68	366	359	5	0.014		
EDE301-EDF301	Natural	0.05	0	580	394	368	5	0.015	0.035	0.035
EDE401-EME402	Circular	3.75	0	245.32	86	78	3	0.014		
EDE401-EME402	Natural	0	0	245.32	90	82	3	0.015	0.035	0.035
EME402-EME403	Natural	0	0	913.41	82	57	3	0.015	0.035	0.035
EME402-EME403	Circular	3.75	0	913.41	78	52	3	0.014		

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Appendix C-3. 100-year Improvements Link Input Data

Link Name	Shape	Diameter feet	Width feet	Length ft	Upstream Invert Elevation ft	Downstream Invert Elevation ft	Conduit Slope percent	Main Channel Manning's n	Left Overbank Manning's n	Right Overbank Manning's n
EME403-EME404	Circular	3.75	0	770	52	35	2	0.014		
EME403-EME404	Natural	0.05	0	766	57	41	2	0.015	0.035	0.035
EDE403-EME401	Circular	3.75	0	271.73	111	104	2	0.014		
EDE403-EME401	Natural	0	0	271.73	119	112	3	0.015	0.035	0.035
EME401-EDE401	Circular	3.75	0	815	104	86	2	0.014		
EME401-EDE401	Natural	0	0	815	112	90	3	0.015	0.035	0.035
EME404-EOD501	Circular	5	0	1245	35	7	2	0.014		
EOD501-UMD401	Trapezoidal	6	10	236	7	6	0	0.014		
EDF301-EME301	Circular	1.7	0	1127.47	359	202	14	0.014		
EDF301-EME301	Natural	0	0	1127.47	368	210	14	0.015	0.035	0.035
EME301-EDE403	Circular	3.75	0	944.32	202	111	10	0.014		
MMC501-MPC502	Circular	5	0	2071.73	0	-12	1	0.014		
MMC501-MIC501	Natural	0	10	629.46	0	-3	1	0.05	0.035	0.035
MIC501-MOC501	Circular	3	10	235.54	-3	-4	1	0.05	0.035	0.035
MOC501-MPC502	Natural	0	10	1417.74	-4	-12	1	0.05	0.035	0.035
NDA201-NMA201	Circular	4	0	383.23	31	31	0	0.014		
NDA201-NMA201	Natural	0.05	0	383	36	36	0	0.03	0.03	0.03
NDA301-NDA302	Circular	2	0	229.06	36	30	3	0.014		
NDA301-NDA302	Natural	0	0	212	39	36	1	0.015	0.035	0.035
NDA302-NMA302	Natural	0	0	669.58	38	28	1	0.015	0.035	0.035
NDA302-NMA302	Circular	2	0	669.58	30	12	3	0.014		
NDB201-NMA201	Circular	2	0	1382.64	77	33	3	0.014		
NDB201-NMA201	Natural	0	0	1382.64	86	36	4	0.015	0.035	0.035
NMA201-NMA304	Circular	4	0	788.96	31	18	2	0.014		
NMA201-NMA304	Natural	0.05	0	730	36	25	1	0.03	0.03	0.03
NIA201-NDA203	Circular	3.5	0	203.42	73	68	2	0.014		
NIA202-NDA201	Circular	3.5	0	958.44	51	31	2	0.014		
NMA301-NMA302	Circular	3.5	0	557.89	16	12	1	0.014		
NMA302-NMA303	Circular	3.5	0	170.1	12	8	3	0.014		
NMA303-NOA301	Rectangular	5	8	1086.01	8	3	0	0.014		
NMA304-NMA301	Rectangular	2	5	145.37	18	16	1	0.014		
NMA304-SDA301	Natural	0	0	1096	18	11	1	0.015	0.035	0.035
NOA201-NOA202	Natural	0	0	75.23	77	75	3	0.05	0.035	0.035
NOA202-NIA201	Natural	0	0	112.27	75	73	2	0.05	0.035	0.035
NOA203-NIA202	Natural	0	0	675.95	68	51	2	0.05	0.035	0.035
NOA301-NOA302	Natural	0	0	707.05	3	1	0	0.05	0.035	0.035
NOA302-NIA301	Natural	0	0	44.302	1	0	0	0.05	0.035	0.035
NIA301-NOA305	Rectangular	4	6	84.738	0	0	0	0.05	0.035	0.035
NOA305-NOA304	Natural	0	0	457.85	0	0	0	0.035	0.035	0.035
NOA303-COB401	Natural	0	0	2072.24	0	0	0	0.035	0.035	0.035
NOA304-NOA303	Natural	0	0	475.18	0	0	0	0.035	0.035	0.035
NOB201-NOB202	Natural	0	0	406.76	115	92	6	0.025	0.025	0.025
NOB202-NOA201	Natural	0	0	645.56	92	77	2	0.05	0.035	0.035
NOC502-NOC500	Circular	8	0	60	1	-2	4	0.015		
NOC502-NOC500	Circular	8	0	60	1	-2	4	0.015		
NOC502-NOC500	Trapezoidal	1	0	60	10	10	0	0.035		
NOB501-NOB500	Trapezoidal	1	100	60	10	10	0	0.035		
NOB501-NOB500	Rectangular	15	15	60	-2	-2	0	0.015		
NOB501-NOB500	Rectangular	15	15	60	-2	-2	0	0.015		
SDA301-SJA301	Rectangular	4	4	110.93	11	10	1	0.014		
SDA305-SDA302	Natural	0.5	0	80	7	6	1	0.015	0.035	0.035
SDA305-SDA302	Rectangular	4	4	78	3	2	1	0.014		
SJA301-SDA305	Rectangular	4	4	738.04	10	3	1	0.014		
SDA302-SOA301	Rectangular	4	6	115.19	2	2	0	0.014		
SDB201-SDB301	Circular	1.5	0	945.75	98	70	3	0.014		
SDB301-SDB302	Circular	1.25	0	382.42	70	37	8	0.014		
SDB301-SDB302	Natural	0.5	0	382.42	73	41	8	0.015	0.035	0.035
SDB302-SDB303	Circular	2	0	313.88	37	20	6	0.014		
SDB303-SMA301	Circular	3	0	1210.94	20	3	1	0.014		
SMA301-SOA301	Rectangular	2.4	3.3	223.84	3	2	0	0.05	0.035	0.035
SOA301-NDA303	Natural	4.5	6	60	2	2	0	0.05	0.035	0.035
NDA303-NOA302	Circular	4	0	213.69	2	1	0	0.014		
NDA303-NOA302	Circular	4	0	213.69	2	1	0	0.014		
NDA303-NOA302	Circular	4	0	213.69	2	1	0	0.014		
NDA303-NOA302	Circular	4	0	213.69	2	1	0	0.014		
NDA303-NOA302	Circular	4	0	213.69	2	1	0	0.014		
NDA303-NOA302	Circular	4	0	213.69	2	1	0	0.014		
SDA304-SJA301	Circular	3.5	0	108.34	12	10	2	0.014		
SMB303-SDA303	Circular	1.75	0	440.53	17	13	1	0.014		
SMB303-SDA303	Natural	0	0	440.53	22	18	1	0.015	0.035	0.035
SDA303-SDA304	Natural	0.5	0	62.57	18	16	2	0.015	0.035	0.035
SDA304-SDA301	Natural	0.5	0	104.93	18	16	1	0.015	0.035	0.035
SDA303-SDA304	Circular	1.75	0	62.57	13	12	1	0.014		
SDA304-SDA301	Circular	1.75	0	104.93	12	11	1	0.014		
UDE301-UDE302	Circular	3.5	0	980.63	350	249	10	0.014		
UDE301-UDE302	Natural	0.05	0	983	354	257	10	0.015	0.035	0.035
UDE302-UME302	Circular	3.7	0	1616.49	249	97	9	0.014		
UDF301-UDE301	Circular	2	0	731.24	427	350	10	0.014		
UDF301-UDE301	Natural	0.05	0	722	432	354	11	0.015	0.035	0.035
UMD301-UID301	Natural	0	0	1175.34	136	101	3	0.04	0.05	0.05
UID301-UOD301	Rectangular	3	4	454	101	88	3	0.04	0.05	0.05
UOD301-UMD302	Natural	0	0	211.67	88	82	3	0.04	0.05	0.05
UMD302-UME401	Circular	2	0	1282.54	82	75	1	0.014		
UMD401-MIC502	Natural	0	0	1964.55	6	3	0	0.05	0.035	0.035
MIC502-MOC502	Rectangular	8	15	300	3	2	0	0.05	0.035	0.035
MOC502-NOC502	Natural	0	0	1263.37	2	1	0	0.05	0.035	0.035
UME301-UMD301	Natural	0	0	1364.03	223	136	6	0.04	0.05	0.05
UME302-UME401	Circular	4.2	0	1520.45	97	65	2	0.014		
UME302-UME401	Natural	0	0	1502	109	78	2	0.015	0.035	0.035
UME401-UDD401	Circular	4.5	0	664.931	65	51	2	0.014		
UME401-UDD401	Natural	0.05	0	650	78	63	2	0.015	0.035	0.035
UDD401-UDD402	Circular	4.5	0	892.919	51	32	2	0.014		
UDD401-UDD402	Natural	0	0	892.919	63	42	2	0.015	0.035	0.035
UME401-UMD401 2.1	Circular	4.5	0	1259.86	32	6	2	0.014		
UMF201-UME301	Natural	0	0	1487.47	383	223	11	0.04	0.05	0.05

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C4

Inputs for Nodes

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Appendix C-4. XPSWMM Node Inputs

Node Name	Invert Elevation, feet	Ground Elevation, feet	Ponding Type
NDA201	31	38	Allowed
NDB201	77	88	Allowed
NDA301	36	39	Allowed
NMA301	16	21	Allowed
NMA302	12	28	Allowed
NMA303	8	22	Allowed
NIA202	61	70	Allowed
NOB201	115	156	Allowed
NOB202	92	133	Allowed
NIA201	73	81	Allowed
NOA201	77	104	Allowed
NOA203	68	87	Allowed
NOA202	75	86	Allowed
NOA301	3	20	Allowed
NOA302	1	16	Allowed
NOA303	0	12	Allowed
NIC501	1	11	Allowed
NOB501	-2	13	Allowed
NMA201	31	36	Allowed
NMA304	18	25	Allowed
CMC103	314	317	Allowed
SMB303	17	22	Allowed
EME301	202	210	Allowed
CMD202	287	292	Allowed
CMD203	236	244	Allowed
CMD201	493	500	Allowed
CMC201	213	223	Allowed
SMA301	3	7	Allowed
CDC302	86	90	Allowed
CMC309	51	60	Allowed
CMC301	37	47	Allowed
CMC406	6	15	Allowed
CMC102	242	247	Allowed
CMC104	231	240	Allowed
CMC310	73	82	Allowed
CMC203	75	83	Allowed
CMC204	123	131	Allowed
CMC306	68	88	Allowed
CMD301	73	82	Allowed
CMC405	26	40	Allowed
CMC402	23	31	Allowed
CMC404	4	14	Allowed
CJC401	-4	4	Sealed
CMC401	20	25	Allowed
CMC304	21	31	Allowed
UMD401	6	15	Allowed
UMD302	82	114	Allowed
UME301	223	316	Allowed
UMD301	136	230	Allowed
UMF201	383	432	Allowed
UME302	97	100	Allowed
MMC501	0	7	Allowed
UME401	65	76	Allowed
SOA301	2	9	Allowed
CDC101	285	290	Allowed
CDB101	314	319	Allowed
CDC103	249	250	Allowed
CDC102	262	272	Allowed
CDC204	168	173	Allowed
CDC301	74	82	Allowed
CDC303	64	67	Allowed
CDC304	61	66	Allowed
CMC302	31	38	Allowed
CMC303	34	39	Allowed
CMC403	14	21	Allowed
SDB303	20	24	Allowed
SDB302	37	41	Sealed
SDB301	70	73	Allowed
SDB201	98	100	Allowed
SDA301	11	16	Allowed
UDE301	350	354	Allowed
UDF301	427	432	Allowed
EDE301	386	394	Allowed
EDF301	356	368	Allowed
EDE403	111	119	Allowed
EDF401	86	90	Allowed
CDC203	217	222	Allowed
CDC104	229	233	Allowed
CDD101	396	400	Allowed
NOC502	1	11	Allowed
NOA304	0	10	Allowed
SDA302	2	6	Allowed
EME403	53	57	Allowed
UDE302	249	257	Allowed
CDC202	190	194	Allowed
CDC205	161	169	Allowed
CDC201	240	243	Allowed
CMB101	302	307	Allowed
CDC401	14	20	Allowed
CDB401	0	13	Allowed
CPC401	-15	15	Allowed
MPC501	-18	11	Allowed
MPC502	-12	8	Allowed
CDC402	0	0	0
NOB500	-4	13	Allowed
NOC500	-2	11	Allowed
NOC501	0	12	Allowed
CJC301	38	48	Sealed
CJB301	14	30	Sealed
CJB302	3	14	Sealed
CJA301	1	16	Sealed
CMC407	5	14	Allowed
EME401	104	112	Allowed
CDC208	101	113	Allowed
CDC206	215	222	Allowed
CDC305	80	84	Allowed
CDC207	150	157	Allowed
UDD401	51	63	Allowed
CDD201	423	438	Allowed
CDC306	35	44	Allowed
NDA302	30	38	Allowed
EME404	35	41	Allowed
EOD501	7	15	Allowed
COB402	-13	11	Allowed
CMD302	82	94	Allowed
CMD303	108	117	Allowed
CMD304	109	123	Allowed
CMD305	110	122	Allowed
CMD306	114	120	Allowed
MIC501	-3	6	Allowed
MOC501	-4	6	Allowed
MIC502	3	12	Allowed
MOC502	2	12	Allowed
MIC401	2	12	Allowed
MOC401	2	12	Allowed
NDA303	2	8	Allowed
SDA303	13	18	Allowed
SDA305	3	7	Allowed
EME402	78	82	Allowed
NIA301	0	17	Allowed
NOA305	0	16	Allowed
SDA304	12	19	Allowed
SJA301	10	17	Allowed
MPC503	-18	11	Allowed
UDD402	32	42	None
CMC312	79	90	None
UID301	101	156	Allowed
UOD301	88	138	Allowed
CMC408	9	14	None

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APPENDIX D

XPSWMM Hydraulic Model Results

- Links
- Nodes

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D1

Links

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Appendix D-1. Modeled Link Results

NIC501-NOC501	208.3	1.7	-0.8	258	2.2	0.2	0.5	221.6	1.9	0.2	278.9	2.3	1.0	2.3
NOC501-NOB501	802.7	2.1	-1.5	1004	2.3	-0.4	-0.9	884.5	2.2	-0.4	1110.2	2.3	0.4	0.8
CMD303-CMD302	8.8	10.3	-4.9	15	13.0	-1.7	-22.5	8.8	10.3	-1.7	15.5	12.8	-1.8	-20.2
CMD302-CMD301	27.7	10.1	0.3	34	10.6	0.5	6.4	27.7	10.3	0.6	34.4	10.7	0.6	6.1
CMD304-CMD303	8.8	8.2	-11.2	15	9.7	-11.0	-107.4	8.8	8.2	-11.0	15.5	9.7	-11.0	-107.5
CMD305-CMD304	8.8	8.8	-11.3	15	10.2	-11.0	-112.9	8.8	8.8	-11.0	15.5	10.2	-11.0	-112.9
CMD306-CMD305	8.8	9.6	-5.4	15	11.2	-5.2	-57.8	8.8	9.6	-5.2	15.5	11.2	-5.2	-57.8
NIC501-NOC501	208.3	1.7	-0.8	258	2.2	0.2	0.5	221.6	1.9	0.2	278.9	2.3	1.0	2.3
NIC501-NOC501	208.3	1.7	-0.8	258	2.2	0.2	0.5	221.6	1.9	0.2	278.9	2.3	1.0	2.3
NIC501-NOC501	208.3	1.7	-0.8	258	2.2	0.2	0.5	221.6	1.9	0.2	278.9	2.3	1.0	2.3
MPC501-NIC501	118.0	0.0	-0.8	118	0.0	0.2	0.0	118.0	0.0	0.2	118.0	0.0	1.0	0.0
MPC501-NIC501	118.0	0.0	-0.8	118	0.0	0.2	0.0	118.0	0.0	0.2	118.0	0.0	1.0	0.0
COB101-CMB101	11.7	9.1	-4.4	18	10.2	0.1	0.9	11.7	9.1	0.1	17.8	10.2	0.1	0.9
CDC101-CDC103	88.5	18.5	0.4	88	18.4	0.6	11.9	88.5	18.5	0.6	89.4	18.9	0.6	12.2
CDC101-CDC103	5.1	3.7	0.4	57	8.9	0.6	5.7	5.3	3.8	0.6	57.0	8.9	0.6	5.7
CDC102-CMC104	83.7	18.2	0.1	114	19.4	0.8	15.9	83.7	18.2	0.8	115.8	20.8	0.5	10.5
CDC104-CDC203	27.7	11.9	-2.0	47	11.9	2.3	27.0	27.7	11.9	2.3	47.0	12.2	1.5	17.9
CDC103-CMC102	56.6	13.5	0.5	57	13.8	0.7	10.0	56.7	13.5	0.7	76.0	16.5	0.6	10.0
CDC103-CMC102	23.2	4.8	0.5	75	6.8	0.7	4.8	23.5	4.8	0.7	74.2	6.7	0.6	4.3
CDC201-CDC202	26.2	16.7	-2.2	43	17.5	0.1	2.2	26.2	16.7	0.1	43.5	17.5	0.1	2.2
CDC202-CDC205	26.2	26.8	3.3	34	29.2	0.1	3.6	26.2	26.8	0.1	34.4	29.3	0.1	3.7
CDC203-CDC206	64.8	10.3	2.0	86	13.4	2.3	28.0	66.8	10.3	2.3	87.2	12.3	1.5	18.1
CDC206-CMC201	68.8	10.8	-4.6	129	18.1	1.5	20.0	68.9	10.8	1.5	97.0	13.7	-1.9	-26.5
CDC204-CDC207	145.4	36.3	3.2	186	38.2	0.4	16.0	144.5	36.9	0.4	243.4	41.1	-2.7	-112.9
CDC207-CMC204	145.4	33.5	0.6	158	32.2	1.0	30.7	144.4	35.5	1.0	243.1	38.3	0.6	24.0
CDC205-CMC203	263.1	6.3	0.3	376	6.4	1.4	8.7	263.5	6.4	1.4	428.0	6.5	1.7	11.3
CDC301-CMC310	148.5	11.8	0.5	192	13.1	2.9	34.7	149.2	11.8	2.9	190.9	12.3	2.9	35.5
CDC302-CDC305	12.0	10.0	0.2	13	10.1	0.3	3.4	12.0	10.0	0.3	12.8	10.0	0.3	3.4
CDC302-CDC305	8.1	4.9	0.2	21	6.2	0.3	2.1	8.1	4.9	0.3	20.8	6.2	0.3	2.1
CDC305-CDC303	7.4	3.6	0.4	20	5.0	0.5	2.6	7.4	3.6	0.5	20.2	5.0	0.5	2.6
CDC305-CDC303	11.5	9.6	0.4	11	9.5	0.5	5.0	11.5	9.7	0.5	11.5	9.5	0.5	4.9
CDC303-CDC304	9.8	7.9	0.4	10	7.9	0.5	4.1	9.8	7.9	0.5	9.8	7.9	0.5	4.1
CDC303-CDC304	9.9	2.5	0.4	25	3.3	0.5	1.7	9.9	2.5	0.5	25.6	3.3	0.5	1.9
CDC304-CMC301	181.3	18.3	-2.1	215	18.6	0.3	6.2	181.3	18.3	0.3	203.6	18.7	0.1	2.4
CDC401-CMC403	170.6	7.6	-1.6	207	9.1	2.2	19.7	186.3	8.3	2.2	188.0	8.2	-0.1	-0.8
CDC401-CMC403	170.6	7.6	-1.6	207	9.1	2.2	19.7	186.3	8.3	2.2	188.0	8.2	-0.1	-0.8
CDC402-CJC401	22.2	12.4	1.9	23	12.8	2.3	29.5	48.1	9.7	2.3	50.0	10.1	5.5	55.8
CDD101-CDC104	27.9	25.5	-2.9	47	29.0	-2.2	-65.1	27.9	25.5	-2.2	47.1	29.1	-2.3	-66.7
CJA301-NOA303	117.7	12.1	Sealed	118	12.1	Sealed		117.9	12.1	Sealed	116.7	12.2	Sealed	
CMB101-CDC201	11.8	13.6	-2.2	19	15.3	-1.9	-28.8	11.6	13.6	-1.9	19.0	15.4	-1.9	-28.6
CJB301-CJB302	117.8	11.7	Sealed	118	11.8	Sealed		118.0	11.7	Sealed	118.8	11.8	Sealed	
CJB302-CJA301	117.8	11.8	Sealed	118	11.9	Sealed		118.0	11.8	Sealed	118.7	11.8	Sealed	
CMC102-CMC104	84.3	17.2	0.5	85	17.2	0.8	14.1	84.3	17.2	0.8	126.4	18.9	0.6	11.8
CMC102-CMC104	43.9	6.7	0.5	122	8.5	0.8	7.0	44.2	6.7	0.8	61.9	7.9	0.6	4.9
CMC103-CDC102	21.0	13.8	-1.9	39	16.5	-1.4	-22.8	21.0	13.8	-1.4	38.7	16.5	-1.5	-25.5
CMC104-CMC201	170.4	18.0	0.1	175	18.2	0.8	14.9	170.5	18.0	0.8	247.8	18.9	0.5	9.9
CMC104-CMC201	0.8	2.1	0.1	146	8.6	0.8	7.0	1.0	2.3	0.8	44.6	6.4	0.5	3.1
CMC201-CDC205	256.8	34.9	3.5	326	39.5	0.3	9.5	257.0	34.9	0.3	414.0	38.8	-4.0	-158.8
CMC203-CDC301	133.6	10.7	0.5	141	11.1	2.9	31.8	137.1	10.8	2.9	148.0	11.6	2.9	33.5
CMC203-CDC301	10.0	3.1	0.5	228	8.7	2.9	18.3	4.0	1.0	2.9	221.5	2.0	2.9	5.7
CMC203-CJC301	134.3	21.3	23.7	144	21.8	24.8	538.6	139.9	21.4	24.8	145.6	21.9	25.0	544.2
CMC204-CDC208	116.2	16.4	0.8	117	16.5	1.0	15.7	166.6	18.5	1.0	221.1	19.7	0.6	12.4
CMC204-CDC208	60.2	6.4	0.8	190	8.4	1.0	8.1	0.0	0.0	1.0	69.0	6.5	0.6	4.1
CDC208-CMC306	109.9	18.3	0.5	110	18.9	0.9	13.8	164.1	18.2	0.9	203.3	18.6	0.5	10.2
CDC208-CMC306	54.6	7.0	0.5	176	9.5	0.9	8.2	0.0	0.0	0.9	58.0	7.1	0.5	3.6
CMC301-CDC306	216.2	14.3	-0.5	267	14.4	0.5	7.8	216.3	14.5	0.5	298.1	14.6	0.3	4.7
CDC306-CMC406	214.9	12.8	1.5	293	12.9	3.1	39.8	215.8	13.7	3.1	297.6	13.5	0.3	4.5
CMC302-CMC304			0.6			1.2		232.7	10.4	1.2	282.6	10.8	0.8	8.4
CMC302-CMC304			0.6			1.2		0.0	0.0	1.2	68.9	5.7	0.8	4.5
CMC302-CMC401	151.8	12.4	0.6	150	12.8	1.6	20.7	198.1	12.9	1.6	197.4	12.3	0.8	9.5
CMC302-CMC401	59.4	5.2	0.6	206	6.7	1.6	10.9	18.1	3.8	1.6	0.0	0.0	0.8	0.0
CMC303-CMC304	86.0	13.7	0.5	83	12.7	0.8	10.6	88.1	13.5	0.8	110.7	14.3	0.8	11.2
CMC303-CMC304	39.8	5.1	0.5	121	6.9	0.8	5.7	28.2	4.7	0.8	70.9	6.0	0.8	4.7
CMC304-CMC401	109.5	13.3	0.1	111	13.4	1.6	21.6	105.4	13.7	1.6	408.0	14.2	0.8	11.2
CMC304-CMC401	0.7	1.6	0.1	104	6.3	1.6	10.1	0.0	0.0	1.6	100.6	6.6	0.8	5.0
CMC306-CMC309	181.3	16.4	0.5	182	16.4	0.8	13.5	187.0	18.7	0.8	230.6	18.0	0.5	9.4
CMC306-CMC309	12.6	4.3	0.5	156	9.7	0.8	8.0	0.0	0.0	0.8	88.1	7.6	0.5	3.9
CMC309-CMC302	138.1	14.2	0.6	150	14.3	1.2	17.7	215.5	16.9	1.2	267.3	16.9	0.8	13.1
CMC309-CMC302	84.4	4.5	0.6	221	6.3	1.2	7.8	0.0	0.0	1.2	69.0	4.1	0.8	3.2
CMC310-CDC304	166.7	14.4	-2.1	204	16.3	1.9	31.1	165.6	14.4	1.8	169.4	15.2	0.1	1.6
CJC301-CJB301	117.9	11.6	Sealed	119	11.7	Sealed		118.1	11.7	Sealed	118.9	11.7	Sealed	
CMC401-CDC401	163.5	10.6	-1.6	255	11.1	2.2	24.3	179.0	10.8	2.2	176.7	10.6	-0.1	-0.8
CMC401-CDC401	163.5	10.6	-1.6	255	11.1	2.2	24.3	179.0	10.8	2.2	176.7	10.6	-0.1	-0.8
CMC401-CDC401			-1.6			2.2		#N/A	#N/A	2.2	186.5	9.5	-0.1	-0.7
CMC402-CMC403	39.1	13.2	0.1	40	12.9	1.4	17.2	38.6	12.1	1.4	40.7	12.8	0.4	5.4
CMC402-CMC403	2.3	2.9	0.1	35	6.2	1.4	8.6	2.7	3.1	1.4	32.4	6.1	0.4	2.6
CMC404-MIC401	592.2	2.9	-1.5	763	2.8	-0.4	-1.3	692.1	3.1	-0.4	827.6	2.8	0.3	0.9
MIC401-MOC401	592.8	1.2	-1.4	771	1.6	-0.3	-0.5	631.6	1.3	-0.3	836.1	1.7	0.4	0.7
MOC401-NIC501	569.4	1.9	-0.8	774	2.1	0.2	0.5	617.0	2.0	0.2	841.1	2.0	1.0	2.0
CMC405-CMC402	24.7	9.9	0.2	25	10.0	0.4	4.3	24.6	9.9	0.4	24.6	9.9	0.4	4.1
CMC405-CMC402	5.4	3.6	0.2	25	5.4	0.4	2.4	5.4	3.6	0.4	26.6	5.5	0.4	2.3
CMC406-CMC404	186.2	8.3	1.5	222	9.2	3.1	26.7	226.0	4.7	3.1	292.4	5.5	0.3	1.8
CMC407-CMC404	416.5	3.2	-2.7	558	4.4	-1.6	-7.0	458.0	3.6	-1.6	551.0	4.3	-1.0	-4.2
CJC401-MPC503	25.3	7.6	Sealed	29	7.7	Sealed		47.6	7.9	Sealed	47.6	7.9	Sealed	
CMD201-CDD201	33.3	24.0	-8.3	55	25.6	-5.8	-149.5	33.3	24.0	-5.8	54.5	25.8	-5.8	-149.6
CDD201-CMD202	33.2	21.9	-8.5	53	23.4	0.4	9.8	33.3	22.0	0.4	52.6	23.4	0.4	9.8
CMD202-CMD203	112.7	21.6	0.3	123	23.3	0.6	13.7	112.7	21.6	0.6	133.6	25.2	0.4	10.6
CMD203-CDC204	117.6	25.6	0.3	117	25.6	0.6	15.0	118.2	25.6	0.6	190.5	28.6	0.4	11.4
CMD203-CDC204	27.9	9.4	0.3	134	14.1	0.6	8.3	27.0	9.3	0.6	55.3	11.2	0.4	4.4
CMD301-CMC303	63.8	13.6	0.5	64	13.2	0.8	11.0	63.8	13.6	0.8	66.5	13.9	0.7	9.2
CMD301-CMC303	20.1	5.2	0.5	81	7.5	0.8	6.2	13.3	4.7	0.8	70.4	7.6	0.7	5.1
COB401-COB402	425.7	3.4	-9.5	581	3.8	-5.1	-19.2	475.8	4.2	-5.1	696.1	4.6	-5.2	-23.6
COB402-MPC501	304.0	1.9	-11.0	331	1.6	-4.9	-8.6	326.1	2.1	-4.9	378.2	2.0	-4.6	-8.6
MPC502-NOC502	23.3	0.0	-1.5	23	0.0	-0.1	0.0	23.3	0.0	-0.1	23.3	0.0	3.6	3.0
MPC502-NOC502	20.7	0.0	-1.5	21	0.0	-0.1	0.0	23.3	0.0	-0.1	23.3	0.0	3.6	0.0
MPC502-NOC502	51.7	0.0	-1.5	52	0.0	-0.1	0.0	57.2	0.0	-0.1	57.2	0.0	3.6	0.0
EDE301-EDF301	24.3	13.5	0.3	24	13.5	0.3	4.4	24.3	13.5	0.3	24.3	13.5	0.3	4.4
EDE301-EDF301	14.8	6.3	0.3	15	6.3	0.3	2.0	14.8	6.3	0.3	14.8	6.3	0.3	2.0
EDE401-EME402	191.4	20.2	-0.2	208	20.7	0.7	15.0	191.4	20.7	0.7	210.3	20.7	1.0	21.5
EME402-EME403	188.3	18.8	0.3	191	18.5	0.7	13.9	187.4	18.5	0.7	190.6	18.8	0.7	13.2
EME403-EME404	172.9	17.2	0.3	181	17.1	0.7	12.8	172.6	17.2	0.7	180.7	17.2	0.7	12.1
EME403-EME404	10.6	4.5	0.3	116	8.0	0.7	6.0	9.9	4.2	0.7	99.5	7.7	0.7	5.4
EDE403-EME401	166.1	17.5	-4.3	208	16.7	0.6	12.0	164.1	17.5	0.6	207.5	18.6	1.1	19.7
EME401-EDE401	164.8	17.4	-0.8	187	17.5	0.7	11.8	163.3	17.5	0.7	186.4	17.2	1.0	17.6
EME404-EDD501	183.0	16.7	-2.3	298	19.2	-0.9	-17.4	181.9	16.6	-0.9	360.2	18.9	-0.7	-12.7
EDD501-UMD401	176.7	1.8	-2.0	288	1.7	-0.6	-0.9	175.8	1.6	-0.6	279.4	1.5	-0.3	-0.5
EDF301-EME301	54.6	25.5	0.1	54	25.5	0.3	8.5	54.6	25.6	0.3	54.3	25.5	0.3	8.3
EDF301-EME301	3.9	6.3	0.1	44	12.7	0.3	4.1	1.0	3.6	0.3	43.6	12.7	0.3	4.1
EME301-EDE403	126.8	26.0	-5.6	214	30.9	0.6	19.9	123.8	25.8	0.6	214.0	30.9	1.1	32.8
MMC501-MPC502			-4.8			-4.0		72.6	5.7	-4.0	73.5	6.3	3.9	24.3
CPC401-CMC406	4.0	0.0	1.5	4	0.0	25.7	0.0	4.0	0.0	25.7	4.0	0.0	0.3	0.0
CPC401-CMC406			1.5			25.7		4.0	0.0	25.7	4.0	0.0	0.3	0.0
MPC503-NIC501	44.0	0.0	-0.8	44	0.0	0.2	0.0	44.0	0.0	0.2	44.0	0.0	1.0	0.0
MMC501-MIC501	74.0	2.3	-4.6	116	2.4	-4.0	-9.3	74.0	2.2	-4.0	74.0	2.2	2.8	5.1
MIC501-MOC501	62.3	8.9	-6.1	79	11.6	-4.3	-49.9	62.2	8.9	-4.3	63.2	8.9	-6.1	-54.1
MOC501-MPC502	57.8	1.0	-8.9	78	1.1	-6.6	-9.4	57.8	1.0	-6.6	57.8	1.0	3.9	3.9
NDA201-NMA201	86.5	7.7	0.0	105	8.4	0.3	2.7	86.4	7.7	0.3	104.9	8.4	0.3	2.7
NDA201-NMA201	1.8	0.1	0.0	75	0.7	0.3	0.2	1.8	0.1	0.3	75.5	0.7	0.3	0.2
NDA301-NDA302	13.6	10.2	-2.2	23	11.5	-1.9	-21.8	13.6	10.2	-1.9	22.6	11.5	-1.9	-21.8
NDA302-NMA302	13.5	9.0	-5.4	22	10.8	-5.1	-54.8	13.5	9.0	-5.1	22.3	10.8	-5.1	-54.8
NDB201-NMA201	24.3	12.5	-0.9	41	13.3	0.1	1.4	24.3	12.5	0.1	40.5	13.2	0.1	1.4
NMA201-NMA304	141.3	13.2	-0.9	145	13.3	0.1	1.2	141.3	13.2	0.1	144.9	13.3	0.1	1.2
NIA201-NOA203	62.8	14.5	-6.4	112	16.6	-5.6	-93.1	62.8	14.5	-5.6	111.7	16.6	-5.6	-93.1
NIA202-NDA201	86.5	13.8	0.0	136	15.1	0.3	4.5	86.5	13.8	0.3	135.6	15.1	0.3	4.8
NMA301-NMA302	60.4	9.0	-2.6	72	9.4	-2.3	-21.7	60.4	9.0	-2.3	72.3	9.4	-2.3	-21.7
NMA302-NMA303	82.7	15.2	-12.6	106	16.5	-12.3	-203.3	82.7	15.2	-12.3	105.4	16.5	-12.3	-202.4
NMA303-NOA301	61.8	6.6	-12.6	107	7.0	-12.3	-86.1	61.8	6.8	-12.3	107.3	7.2	-12.3	-88.5
NMA304-NMA301	31.8	5.6	-2.6	41	6.1	-2.3	-14.1	31.7	5.6	-2.3	40.5	6.1	-2.3	-14.1
NMA304-SDA301	95.0	3.0	-2.3	127	3.0	-1.6	-4.7	95.8	3.0	-1.6	127.0	3.0	-1.6	-6.3
NOA201-NOA202	37.8	3.5	-8.8	70	4.1	-8.2	-34.0	37.8	3.5	-8.2	69.5	4.1	-8.2	-34.0
NOA202-NIA201	82.7	4.3	-6.4	112	5.2	-5.6	-29.1	62.7	4.3	-5.6	111.6	5.2	-5.6	-29.1
NOA203-NIA202	69.8	4.3	-16.7	124	4.7	-14.2	-66.1	69.8	4.3	-14.2	123.8	4.7	-14.2	-66.2
NOA301-NOA302	59.5	0.7	-11.7	90	0.7	-10.8	-7.5	62.7	0.8	-10.8	90.8	0.8	-11.3	-9.1
NOA302-NIA301	353.2	1.8	-11.2	477	2.0	-10.2	-20.9	401.2	2.5	-10.2	583.4	2.6	-10.7	-28.5
NIA301-NOA305	351.1	7.3	-10.2	475	9.9	-9.5	-93.9	400.1	5.8	-9.5	581.1	8.1	-9.8	-79.1
NOA305-NOA304	334.9	1.9	-4.1	458	2.2	-3.5	-7.6	384.4	2.4	-3.5	561.7	2.9	-3.8	-10.8
NOA303-COB401	386.7	1.8	-6.3	509	2.1	-5.6	-11.6	432.6	2.4	-5.6	615.4	2.6	-5.8	-15.1
NOA304-NOA303	300.4	1.6	-4.1	424	1.8	-3.5	-6.5	354.1	2.1	-3.5	530.2	2.5	-3.8	-9.4
NOB201-NOB202	24.2	6.2	-38.6	45	7.3	-39.4	-289.5	24.2	6.2	-38.4	44.7	7.3	-39.4	-289.5
NOB202-NOA201	37.8	3.8	-25.8	70	4.6	-25.3	-117.1	37.8	3.8	-25.3	69.7	4.6	-25.3	-117.1
NOC502-NOC500	299.8	10.1	-1.5	427	12.9	-0.1	-1.7	316.6	10.3	-0.1	323.2	13.1	0.7	8.8
NOC502-NOC500	299.8	10.1	-1.5	427	12.9	-0.1	-1.7	316.6	10.3	-0.1	323.2	13.1	0.7	8.8
NOC502-NOC500	0.0	0.0	-1.5	85	1.3	-0.1	-0.2	0.0	0.0	-0.1	301.8	1.4	0.7	0.9
NOB501-NOB500	0.0	0.0	-3.9	7	0.2	-2.7	0.0	0.0	0.0	-2.7	112.0	0.6	-1.8	-1.0
NOB501-NOB500	403.9	2.4	-3.9	505	4.8	-2.7	-13.1	434.3	2.6	-2.7	617.7	4.0	-1.8	-7.2
NOB501-NOB500	405.9	2.4	-3.9	503	4.8	-2.7	-13.1	434.3	2.6	-2.7	617.7	4.0	-1.8	-7.2
SDA301-SJA301	86.7	8.3	-2.3	107	8.9	-1.6	-14.0	93.8	10.2	-1.6	121.5	10.4	-1.8	-18.4
SDA305-SDA302	181.6	5.2	2.8	187	4.9	4.1	19.9	0.0	0.0	4.1	40.0	4.0	1.2	4.6
SDA305-SDA302	-77.9	-4.9	2.8	-78	-4.7	4.1	-19.2	109.9	7.8	4.1	137.8	8.6	1.2	10.3
SJA301-SDA305	104.6	9.2	1.8	132	9.4	3.2	29.6	100.5	10.7	3.2	144.5	11.0	0.8	6.1
SDA302-SOA301	100.3	4.2	2.8	127	5.3	4.1	21.3	110.3	4.6	4.1	145.9	8.1	1.2	7.2
SDB201-SDB301	7.8	6.9	-1.7	13	10.0	0.2	1.9	7.8	6.9	0.2	13.0	10.0	0.2	1.9
SDB301-SDB302	15.4	15.0	2.6	17	16.0	10.6	158.9	15.4	15.0	10.6	18.4	15.8	0.2	2.5
SDB302-SDB303	26.5	14.7	Sealed	32	17.0	Sealed		26.4	14.7	Sealed	49.3	17.3	Sealed	
SDB303-SMA301	38.1	9.4	1.6	49	10.0	2.8	27.6	37.9	9.6	2.8	66.1	10.9	0.8	5.3
SMA301-SOA301	33.7	4.2	1.9	44	5.5	2.8	15.2	37.7	4.8	2.8	55.8	7.0	0.8	5.3
SOA301-NDA303			0.5			1.3		186.2	2.5	1.3	214.5	2.5	0.9	2.2
NDA303-NOA302	21.5	1.7	0.3	25	2.0	1.2	2.5	27.5	2.1	1.2	35.3	2.8	0.9	2.8
NDA303-NOA302	21.5	1.7	0.3	25	2.0	1.2	2.5	27.5	2.1	1.2	35.3	2.8	0.9	2.6

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Appendix D-1. Modeled Link Results

NDA303-NDA302	21.5	1.7	0.3	25	2.0	1.2	2.5	27.5	2.1	1.2	35.3	2.8	0.9	2.5
NDA303-NDA302	21.5	1.7	0.3	25	2.0	1.2	2.5	27.5	2.1	1.2	35.3	2.8	0.9	2.5
NDA303-NDA302	21.5	1.7	0.3	25	2.0	1.2	2.5	27.5	2.1	1.2	35.3	2.8	0.9	2.5
NDA303-NDA302	21.5	1.7	0.3	25	2.0	1.2	2.5	27.5	2.1	1.2	35.3	2.8	0.9	2.5
SDA304-SJA301	20.8	7.2	-3.9	32	7.4	-2.7	-19.8	21.8	7.3	-2.7	31.8	7.6	-3.3	-25.2
SMB303-SDA303	15.9	7.8	0.2	19	7.8	0.4	3.3	19.0	7.8	0.4	19.0	7.8	0.7	5.1
SMB303-SDA303	2.6	2.2	0.2	21	3.8	0.4	1.6	1.0	0.6	0.4	13.0	1.2	0.7	0.8
SDA303-SDA304	21.2	6.8	-2.7	38	15.0	-0.2	-2.9	18.9	6.6	-0.2	30.2	12.7	-1.3	-16.1
SDA304-SDA301	-8.4	4.2	-2.3	-11	-4.8	-1.6	7.5	-5.8	4.2	-1.6	-10.2	4.4	-1.8	-7.8
UDE301-UDE302	68.8	23.4	0.3	69	23.3	0.5	11.4	98.7	27.3	0.5	163.1	31.1	-2.0	-61.4
UDE301-UDE302	26.2	9.7	0.3	93	13.5	0.5	6.6	0.0	0.0	0.5	0.0	0.0	-2.0	0.0
UDE302-UME302	127.4	26.1	-6.7	218	31.0	0.5	16.5	132.5	26.4	0.5	220.7	31.1	0.5	17.0
UDF301-UDE301	48.4	21.8	0.3	48	21.6	0.5	10.8	62.0	23.9	0.5	78.5	24.3	0.3	7.2
UDF301-UDE301	13.0	7.7	0.3	55	11.5	0.5	5.7	0.0	0.0	0.5	31.1	10.4	0.3	3.1
UMD301-UID301	118.5	6.3	-52.5	187	7.7	-49.4	-354.7	118.5	6.3	-46.4	197.8	7.6	-48.3	-352.4
UID301-UOD301	108.6	3.3	-28.0	-311	5.3	-18.3	-60.3	118.8	15.2	-18.3	169.9	16.0	-18.2	-291.2
UOD301-UMD302			-14.8			-4.8		142.9	3.3	-4.8	-269.0	3.3	-4.8	-15.8
UMD302-UME401	29.4	9.0	-9.0	36	10.5	0.5	5.7	29.4	9.0	0.5	35.5	10.5	0.6	5.8
UMD401-MIC502	561.1	2.7	-2.0	872	3.1	-0.6	-1.7	559.5	2.7	-0.6	874.6	2.9	-0.3	-0.9
MIC502-MOC502	531.9	1.2	-2.0	866	1.8	-0.6	-1.0	535.4	1.3	-0.6	909.9	1.8	0.0	0.0
MOC502-NOC502	528.7	2.1	-1.5	858	2.8	-0.1	-0.3	528.2	2.1	-0.1	872.3	2.4	0.7	1.8
UME301-UMD301	81.8	4.2	-91.1	139	5.4	-90.8	-489.2	81.8	4.2	-90.8	139.1	5.4	-90.8	-489.2
UME302-UME401	179.3	17.4	-9.0	245	17.5	0.5	9.4	184.6	17.5	0.5	244.6	17.5	0.6	9.6
UME302-UME401	0.0	0.0	-9.0	52	6.5	0.5	3.5	0.0	0.0	0.5	55.2	6.6	0.6	3.7
UME401-UDD401	227.9	18.7	-8.6	309	19.2	0.5	10.3	233.8	18.8	0.5	287.8	18.7	0.6	10.3
UME401-UDD401	0.0	0.0	-8.6	55	6.8	0.5	3.5	0.0	0.0	0.5	56.1	6.9	0.6	3.8
UDD401-UDD402	227.7	18.7	-6.4	281	18.5	2.0	37.0	233.3	18.7	2.0	279.2	18.5	2.0	37.0
UDD401-UDD402	0.0	0.0	-6.4	43	2.8	2.0	5.6	0.0	0.0	2.0	45.7	2.7	2.0	5.4
UME401-UMD401.2.1	226.3	17.5	-2.0	285	18.0	2.0	35.9	231.8	17.6	2.0	283.9	17.9	2.0	35.8
UMF201-UME301	35.6	5.5	-49.2	61	6.8	-48.0	-325.1	35.6	5.5	-48.0	61.1	6.8	-48.0	-325.1

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Nodes

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Appendix D-2. Model Node Results

Node Name	Ground Elevation, ft NAVD88	Invert Elevation, ft	Existing: 10-year Max Water Elevation, ft	Existing: 10-year Existing Freeboard (ft)	Existing: 100-year Max Water Elevation, ft	Existing: 100-year Freeboard (ft)	Future: 10-year Max Water Elevation, ft	Future: 10-year Freeboard (ft)	Future: 100-year Max Water Elevation, ft	Future: 100-year Freeboard, ft
CDB101	319.4	313.7	314.8	4.6	319.5	-0.1	319.5	-0.1	319.5	-0.1
CDC101	290.1	284.5	289.8	0.4	290.1	0.1	290.1	0.1	290.1	0.1
CDC101	290.1	284.5	289.8	0.4	290.1	0.1	290.1	0.1	290.1	0.1
CDC102	271.8	262.4	263.9	7.9	270.4	1.4	270.4	1.4	270.1	1.7
CDC103	249.9	245.7	250.3	-0.4	250.6	-0.6	250.8	-0.6	250.6	-0.8
CDC104	233.2	229.1	230.3	2.9	231.0	2.2	231.0	2.2	230.9	2.3
CDC201	242.8	239.8	240.5	2.2	240.9	1.9	240.9	1.9	240.9	1.9
CDC202	193.8	189.7	190.5	3.3	193.9	-0.1	193.9	-0.1	193.9	-0.1
CDC203	221.6	216.9	219.6	2.0	223.8	-2.3	223.8	-2.3	223.0	-1.5
CDC203	221.6	216.9	219.6	2.0	223.8	-2.3	223.8	-2.3	223.0	-1.5
CDC204	173.2	168.1	169.9	3.2	173.6	-0.4	173.6	-0.4	170.4	2.7
CDC205	169.0	160.7	163.5	5.5	164.0	5.0	164.0	5.0	164.1	4.9
CDC206	222.4	215.1	217.7	4.6	223.8	-1.5	223.8	-1.5	220.4	1.9
CDC207	156.8	150.1	152.4	4.5	157.3	-0.4	157.3	-0.4	153.5	3.3
CDC208	113.0	101.0	113.5	-0.5	113.9	-0.9	113.9	-0.9	113.6	-0.6
CDC301	81.5	73.8	82.0	-0.5	84.4	-2.9	84.4	-2.9	84.4	-2.9
CDC302	90.0	85.7	90.2	-0.2	90.3	-0.3	90.3	-0.3	90.3	-0.3
CDC303	67.0	63.9	67.3	-0.4	67.5	-0.5	67.5	-0.5	67.5	-0.5
CDC304	66.1	61.1	64.0	2.1	66.4	-0.3	66.4	-0.3	66.2	-0.1
CDC305	83.5	79.6	83.7	-0.2	83.8	-0.3	83.8	-0.3	83.8	-0.3
CDC306	44.0	34.6	38.5	5.5	44.5	-0.5	44.5	-0.5	44.3	-0.3
CDC401	20.2	14.2	18.6	1.6	22.4	-2.2	22.4	-2.2	20.1	0.1
CDC402	12.0	1.0	13.5	-1.5	14.3	-2.3	14.3	-2.3	13.4	-1.4
CDC402	12.0	1.0	13.5	-1.5	14.3	-2.3	14.3	-2.3	13.4	-1.4
CDD101	399.9	396.0	396.7	3.2	396.9	3.0	396.9	3.0	396.9	3.0
CDD201	438.4	422.7	423.6	14.7	429.9	8.5	429.9	8.5	430.1	8.3
CMB101	306.7	301.6	302.3	4.4	302.5	4.2	302.5	4.2	302.5	4.2
CMC102	247.1	241.6	247.6	-0.5	247.8	-0.7	247.9	-0.7	247.8	-0.6
CMC103	317.1	314.3	315.2	1.9	315.5	1.6	315.5	1.6	315.5	1.6
CMC104	240.4	230.6	240.5	-0.1	241.3	-0.8	241.3	-0.8	240.9	-0.5
CMC201	223.1	213.4	215.9	7.2	223.4	-0.3	223.4	-0.3	216.5	6.6
CMC203	83.0	75.0	83.3	-0.3	84.4	-1.4	84.4	-1.4	84.7	-1.7
CMC203	83.0	75.0	83.3	-0.3	84.4	-1.4	84.4	-1.4	84.7	-1.7
CMC204	130.5	122.5	131.1	-0.6	131.5	-1.0	131.5	-1.0	131.1	-0.6
CMC301	46.7	37.3	40.9	5.8	46.9	-0.2	46.9	-0.2	46.8	-0.1
CMC302	37.8	30.6	38.4	-0.6	39.0	-1.2	39.0	-1.2	38.6	-0.8
CMC303	39.0	33.8	39.5	-0.5	39.8	-0.8	39.8	-0.8	39.7	-0.7
CMC304	30.8	20.9	30.9	-0.1	31.6	-0.8	31.6	-0.8	31.6	-0.8
CMC306	86.5	68.5	86.7	-0.3	87.3	-0.8	87.3	-0.8	87.0	-0.5
CMC309	80.4	51.2	80.9	-0.5	81.2	-0.8	81.2	-0.8	80.9	-0.5
CMC310	82.5	73.2	76.8	5.7	84.4	-1.9	84.4	-1.9	80.9	1.5
CMC401	25.3	19.8	22.2	3.1	26.9	-1.6	26.9	-1.6	22.7	2.6
CMC402	31.4	22.7	31.5	-0.1	31.8	-0.4	31.8	-0.4	31.8	-0.4
CMC403	20.6	13.8	17.0	3.5	21.9	-1.4	21.9	-1.4	18.3	2.3
CMC404	13.5	4.3	10.8	2.7	11.9	1.6	11.9	1.6	12.5	1.0
CMC405	40.1	26.5	40.3	-0.2	40.5	-0.4	40.5	-0.4	40.5	-0.4
CMC406	14.6	5.9	16.0	-1.5	17.7	-3.1	17.7	-3.1	14.9	-0.3
CMC407	14.0	5.4	11.3	2.7	12.1	1.9	12.1	1.9	12.7	1.3
CMD201	500.3	493.0	494.0	6.3	494.5	5.8	494.5	5.8	494.5	5.8
CMD202	292.3	257.3	285.8	6.5	292.7	-0.4	292.7	-0.4	292.7	-0.4
CMD202	292.3	257.3	285.8	6.5	292.7	-0.4	292.7	-0.4	292.7	-0.4
CMD203	243.8	235.8	244.1	-0.3	244.4	-0.6	244.4	-0.6	244.2	-0.4
CMD301	82.4	72.9	82.6	-0.3	83.0	-0.6	83.0	-0.6	83.0	-0.6
CMD301	82.4	72.9	82.6	-0.3	83.0	-0.6	83.0	-0.6	83.0	-0.6
CMD302	93.8	82.5	88.9	4.9	92.0	1.7	92.0	1.7	92.2	1.6
CMD303	117.4	105.7	106.2	11.2	106.4	11.0	106.4	11.0	106.4	11.0
CMD304	123.0	108.6	109.6	13.4	109.8	13.1	109.8	13.1	109.6	13.1
CMD305	121.8	109.6	110.5	11.3	110.7	11.0	110.7	11.0	110.7	11.0
CMD306	119.7	113.6	114.3	5.4	114.5	5.2	114.5	5.2	114.5	5.2
COB401	12.0	0.0	2.7	9.3	6.2	5.8	6.2	5.8	6.1	5.9
COB402	11.3	-13.5	0.0	11.2	6.1	5.1	6.1	5.1	6.1	5.2
CPC401	15.0	-15.0	15.5	-0.5	40.7	-25.7	40.7	-25.7	11.9	3.1
EDE301	394.3	385.8	394.6	-0.3	394.6	-0.3	394.6	-0.3	394.6	-0.3
EDE401	89.6	85.7	88.8	0.8	90.3	-0.7	90.3	-0.7	90.7	-1.0
EDE403	119.1	110.6	113.6	5.5	119.7	-0.6	119.7	-0.6	120.1	-1.1
EDF301	367.9	359.4	368.0	-0.1	368.3	-0.3	368.3	-0.3	368.3	-0.3
EDF301	367.9	359.4	368.0	-0.1	368.3	-0.3	368.3	-0.3	368.3	-0.3
EME301	210.1	201.6	203.2	6.9	203.8	6.4	203.8	6.4	203.8	6.4
EME401	111.7	104.4	107.4	4.3	112.3	-0.6	112.3	-0.6	112.6	-0.9
EME402	81.8	77.5	81.6	0.2	82.5	-0.7	82.5	-0.7	82.5	-0.7
EME403	57.0	52.0	57.3	-0.3	57.7	-0.7	57.7	-0.7	57.7	-0.7
EME404	41.0	34.8	37.3	3.6	38.4	2.6	38.4	2.6	38.2	2.7
EOD501	15.0	7.0	12.7	2.3	14.1	0.9	14.1	0.9	14.3	0.7
MIC401	11.8	1.9	10.2	1.5	11.3	0.4	11.3	0.4	12.1	-0.3
MIC501	6.2	-3.2	0.1	6.1	1.9	4.3	1.9	4.3	0.1	6.1
MIC502	12.4	2.9	10.0	2.4	11.5	0.9	11.5	0.9	12.1	0.3
MMC501	6.5	0.0	1.9	4.6	2.5	4.0	2.5	4.0	9.3	-2.8
MOC401	11.6	1.7	10.2	1.4	11.3	0.3	11.3	0.3	12.1	-0.4
MOC501	6.1	-4.5	-2.8	8.9	-2.5	8.6	-2.5	8.6	-2.8	8.9
MOC502	12.1	2.5	10.0	2.0	11.5	0.6	11.5	0.6	12.1	0.0
MPC501	11.0	-18.0	0.0	11.0	6.1	4.9	6.1	4.9	6.1	4.9
MPC502	5.5	-11.8	-4.3	9.8	-3.2	8.7	-3.2	8.7	9.4	-3.9
MPC503	11.0	-18.0	-3.2	14.2	-3.2	14.2	-3.2	14.2	-1.1	12.1
NDA201	38.1	31.2	36.2	0.0	36.5	-0.3	36.5	-0.3	36.5	-0.3
NDA301	38.8	35.7	36.6	2.2	36.9	1.9	36.9	1.9	36.9	1.9
NDA302	36.0	29.7	30.6	5.4	30.9	5.1	30.9	5.1	30.9	5.1
NDA303	6.0	1.5	6.3	-0.3	7.2	-1.2	7.2	-1.2	6.9	-0.9
NDB201	85.6	77.3	78.5	7.1	85.7	-0.1	85.7	-0.1	85.7	-0.1
NIA201	81.0	73.0	74.6	6.4	75.4	5.6	75.4	5.6	75.4	5.6
NIA202	70.0	51.2	53.3	16.7	55.8	14.2	55.8	14.2	55.8	14.2
NIA301	17.4	0.5	6.3	11.2	7.2	10.2	7.2	10.2	6.7	10.7
NIC501	11.0	0.8	10.2	0.8	11.2	-0.2	11.2	-0.2	12.0	-1.0
NMA201	35.7	30.5	34.9	0.9	35.8	-0.1	35.8	-0.1	35.8	-0.1
NMA301	21.3	16.3	18.6	2.6	19.0	2.3	19.0	2.3	19.0	2.3
NMA301	21.3	16.3	18.6	2.6	19.0	2.3	19.0	2.3	19.0	2.2
NMA302	27.9	12.3	14.3	13.6	14.7	13.3	14.7	13.3	14.7	13.3
NMA303	22.0	8.0	9.4	12.6	9.7	12.3	9.7	12.3	9.7	12.3
NMA304	25.1	17.8	18.8	6.3	19.0	6.0	19.0	6.0	19.0	6.0
NOA201	104.0	77.0	78.2	25.8	78.7	25.3	78.7	25.3	78.7	25.3
NOA202	86.0	75.0	77.2	8.8	77.8	8.2	77.8	8.2	77.8	8.2
NOA203	87.0	68.0	69.5	17.5	70.0	17.0	70.0	17.0	70.0	17.0
NOA301	20.0	3.0	6.3	13.7	7.2	12.8	7.2	12.8	6.8	13.2
NOA302	18.0	0.5	6.3	11.7	7.2	10.8	7.2	10.8	6.7	11.3
NOA302	18.0	0.5	6.3	11.7	7.2	10.8	7.2	10.8	6.7	11.3
NOA302	18.0	0.5	6.3	11.7	7.2	10.8	7.2	10.8	6.7	11.3
NOA303	12.0	0.1	5.7	6.3	6.4	5.6	6.4	5.6	6.2	5.8
NOA304	10.0	0.3	5.9	4.1	6.5	3.5	6.5	3.5	6.2	3.8
NOA305	16.2	0.4	6.0	10.2	6.7	9.5	6.7	9.5	6.4	9.8
NOB201	156.0	115.0	115.7	40.3	115.9	40.1	115.9	40.1	115.9	40.1
NOB202	133.0	92.0	93.2	39.8	93.6	39.4	93.6	39.4	93.6	39.4
NOB500	13.0	-4.0	9.1	3.9	10.3	2.7	10.3	2.7	11.2	1.8
NOB501	13.0	-2.0	9.1	3.9	10.3	2.7	10.3	2.7	11.2	1.8
NOC500	10.6	-2.0	9.1	1.5	10.3	0.3	10.3	0.3	11.2	-0.6
NOC501	11.6	0.0	10.1	1.5	11.2	0.4	11.2	0.4	12.0	-0.4
NOC502	10.6	0.6	9.1	1.5	10.5	0.1	10.5	0.1	11.3	-0.7
SDA301	16.0	11.3	13.7	2.3	14.4	1.6	14.4	1.6	14.3	1.8
SDA302	6.0	2.0	8.8	-2.8	10.1	-4.1	10.1	-4.1	7.2	-1.2
SDA303	17.5	12.9	14.8	2.7	17.3	0.2	17.3	0.2	16.3	1.3
SDA304	19.0	12.3	13.4	5.5	13.8	5.1	13.8	5.1	13.8	5.1
SDA306	6.9	2.8	8.7	-1.8	10.0	-3.2	10.0	-3.2	7.4	-0.6
SDB201	100.2	97.8	98.5	1.7	98.8	1.4	98.8	1.4	98.8	1.4
SDB301	72.7	69.5	70.5	2.2	72.9	-0.2	72.9	-0.2	72.8	-0.2
SDB303	24.1	20.0	21.5	2.5	21.9	2.2	21.9	2.2	22.5	1.6
SJA301	16.8	10.2	12.9	3.9	14.1	2.7	14.1	2.7	13.5	3.3
SMA301	7.2	2.6	8.7	-1.6	9.9	-2.8	9.9	-2.8	7.9	-0.8
SMB303	21.5	17.0	21.7	-0.2	21.9	-0.4	21.9	-0.4	22.2	-0.7
SOA301	8.5	1.5	8.7	-0.2	9.8	-1.3	9.8	-1.3	6.9	1.6
UDD401	63.1	51.3	54.5	8.6	63.6	-0.5	63.6	-0.5	63.6	-0.5
UDD402	42.2	32.5	35.8	6.4	44.2	-2.0	44.2	-2.0	44.2	-2.0
UDE301	354.2	350.4	354.5	-0.3	354.7	-0.5	354.7	-0.5	352.2	2.0
UDE302	257.2	248.9	250.5	6.7	251.1	6.1	251.1	6.1	251.1	6.1
UDF301	431.5	426.5	431.7	-0.2	431.9	-0.4	431.9	-0.4	431.8	-0.3
UID301	155.8	101.4	103.3	52.5	109.4	46.4	109.4	46.4	109.5	46.3
UMD301	230.0	136.3	138.9	91.1	139.2	90.8	139.2	90.8	139.2	90.8
UMD302	114.0	81.8	99.4	14.6	109.2	4.8	109.2	4.8	109.2	4.8
UMD401	14.7	5.9	12.7	2.0	14.1	0.6	14.1	0.6	14.3	0.3
UMD401	14.7	5.9	12.7	2.0	14.1	0.6	14.1	0.6	14.3	0.3
UME301	316.0	223.0	223.8	92.2	224.1	91.9	224.1	91.9	224.1	91.9
UME302	109.0	96.8	99.7	9.3	109.5	-0.5	109.5	-0.5	109.5	-0.5
UME401	77.6	65.3	66.6	9.0	78.1	-0.5	78.1	-0.5	78.1	-0.8
UMF201	432.0	383.3	383.8	48.2	384.0	48.0	384.0	48.0	384.0	48.0
UOO301	127.4	88.1	99.4	28.0	109.2	18.3	109.2	18.3	109.2	18.2

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