City of Chico, California

STORM WATER MASTER PLAN

CITY OF CHICO
INC. 1872

December 2024

WOOD RODGERS

City of Chico

Storm Water Master Plan

Prepared by Wood Rodgers, Inc.

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City of Chico
Storm Water Master Plan – December 2024
Revision Log

Revisions – October 2025:

1. Replace page xiv – Add Appendix J to the List of Appendices.
2. Replace page ES-5 – Text added at the bottom of page ES-5: "Costs for improvements in the Esplanade and Garner Lane project area north of Mud Creek are included in Appendix J but are not included in Tables ES-1 and ES-2 or the funding analysis."
3. Replace Figure ES-2.
4. Replace pages 102 and 103 – Text added at the bottom of page 102, at the end of Section 9.1: "Deficiencies in the area of Esplanade and Garner Lane north of Mud Creek were evaluated separately from the rest of the SWMP and are presented in Appendix J." Page 103 replaced due to shift associated with text insertion.
5. Replace page 151 – Text added on page 151, right after Table 37: "The OPC for the Esplanade and Garner Lane project area is included in Appendix J."
6. Replace figures: 21, 22, 30, 31, 32 and 50.
7. Add Appendix J.

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ACRONYMS AND ABBREVIATIONS

Abbreviation/ Acronym	Full Name	First Usage (Section No.)
1D	One-dimensional	5.3.1
1987 SDMP	Preliminary Storm Drainage Master Plan	1.3
2010 Handbook	*Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities*	2.3.1.2
2D	Two-dimensional	6.3.3.1
A	Area	6.2.3.1
A	Airport	7.2.1
AB	Assembly Bill	2.3.1
ABS	Acrylonitrile-Butadiene-Styrene	6.3.2.1
AC	Airport Commercial	7.2.1
ACFC&WCD	Alameda County Flood Control & Water Conservation District	6.2.3.2
ACP	Asbestos Cement Pipe	6.3.2.1
AM	Airport Manufacturing	7.2.1
AP	Airport Public Facilities	7.2.1
BID	Business Improvement District	15.3.4
BIG	Big Chico Creek	10.4.3
BMPs	Best Management Practices	2.1.2
BPA	Basin Plan Amendment	4.1.5
BUC	Butte Creek	10.4.3
C	Runoff Coefficient	7.2.3.2
CASQA	California Stormwater Quality Association	15.2
CC	Community Commercial	7.2.1
CDEC	California Data Exchange Center	7.3.1
CFD	Community Financing District	15.3.4
CFR	Code of Federal Regulations	2.4.4
cfs	Cubic feet per second	2.4.2
Chico State	California State University Chico	1.2
CIP	Cast-in-place	6.3.2.1
CIP	Capital Improvement Program	14.4.3
City	City of Chico	1.1
CMC	City of Chico Municipal Code	3.0
CMP	Corrugated Metal Pipe	6.3.2.1
CN	Neighborhood Commercial	7.2.1
CN	Curve Number	7.2.3.2

Abbreviation/ Acronym	Full Name	First Usage (Section No.)
CONC	Concrete	6.3.2.1
C_p	Peaking Factor	6.2.3.2
CR	Regional Commercial	7.2.1
CRS	Community Rating System	3.2.1
CS	Services Commercial	7.2.1
CSR	Combined System Routing	2.3.6
CVFED	Central Valley Floodplain Evaluation and Delineation Program	1.3.1
CVFPP	Central Valley Flood Protection Plan	2.3.8
CVHS	Central Valley Hydrology Study	8.2.1.1
DEM	Digital Elevation Model	5.2
DHS	Dead Horse Slough	10.4.3
DN	Downtown North	7.2.1
DS	Downtown South	7.2.1
DWR	State of California Department of Water Resources	1.3.1
EAP	Emergency Action Plan	10.5.1
EIFD	Enhanced Infrastructure Financing District	15.3.4
EIR	Environmental Impact Report	2.1.3
EM	Engineering Manual	2.1.8
EPA	U.S. Environmental Protection Agency	4.3.2
ESRI	Environmental Systems Research Institute, Inc.	7.2.2
FCS	Full Capture Systems	4.1.3
FEMA	Federal Emergency Management Agency	1.3.1
FIER	Final Environmental Impact Report	2.1.2
FIRM	Flood Insurance Rate Map	2.4.3
FIS	Flood Insurance Study	2.4.3
GDR	Geotechnical Data Report	2.3.2
GER	Geotechnical Evaluation Report	2.3.5
GIS	Geographic Information System	1.1
GO	General Obligation	15.4.4.4
GOR	Geotechnical Overview Report	2.3.4
HDPE	High Density Polyethylene	6.3.2.1
HGL	Hydraulic Grade Line	9.4
HM	Hydromodification Management	3.1
hr	hour	6.2.2
HSG	Hydrologic Soil Group	7.1
i	imperviousness	7.2.3.2
ICM	Integrated Catchment Modeling	5.3.1

Abbreviation/ Acronym	Full Name	First Usage (Section No.)
IDF	Intensity-Duration-Frequency	3.3.1.2
IGP	Industrial General Permit	4.0
in	inches	6.2.2
IOMU	Industrial Office Mixed-Use	7.2.1
K	Headloss factor	6.3.2.1
K_b	Headloss factor for bends	6.3.2.1
Ksat	Saturated Hydraulic Conductivity	7.2.3.1
LBC	Little Chico Creek (model designation assigned in CVFED)	10.4.3
LCH	Lindo Channel	7.3.1
LFP	Longest Flow Path	6.2.3.1
LHMP	Butte County Local Hazard Mitigation Plan Update	2.2.2
LID	Low Impact Development	3.1
LID	Lindo Channel (model designation assigned in CVFED)	10.4.3
LiDAR	Light Detection and Ranging	1.1
MEP	Maximum Extent Practicable	4.1.1
MG	General Manufacturing	7.2.1
MIP	Monitoring Implementation Plan	4.1.2
ML	Light Manufacturing	7.2.1
MS4s	Municipal Separate Storm Sewer Systems	4.0
MUC	Mud Creek	10.4.3
MUSR RFMP	Mid & Upper Sacramento River Regional Flood Management Plan	2.3.5
NAVD 88	North American Vertical Datum of 1988	1.3.1
NFIP	National Flood Insurance Program	3.1
NGVD 29	National Geodetic Vertical Datum of 1929	1.3.1
NLCD	National Land Cover Dataset	7.2.2
NOAA	National Oceanic and Atmospheric Administration	6.2
NPDES	National Pollution Discharge Elimination System	1.1
NRCS	Natural Resources Conservation Service	6.2.1
NTC	Notice to Comply	4.1.6
NULE	Non-Urban Levee Evaluation	2.3.3
O&M	Operations and Maintenance	2.1.8
OC	Office Commercial	7.2.1
OR	Office Residential	7.2.1
OS1	Primary Open Space	7.2.1
OS2	Secondary Open Space	7.2.1
P	Perimeter	6.2.3.1
PAL	Provisional Accredited Levee	2.1.8

Abbreviation/ Acronym	Full Name	First Usage (Section No.)
PAL	Provisionally Accredited Levee	2.3.5
PCBs	Polychlorinated biphenyls	4.4
PCSP	Post-Construction Standards Plan	3.1
PLU	Priority Land Uses	4.1.3
PMC	Pacific Municipal Consultants	2.1.3
PQ	Public/Quasi Public Facilities	7.2.1
PV Ditch	Pleasant Valley Ditch	5.3.3
PVC	Polyvinyl Chloride	6.3.2.1
PZ	Precipitation Zone	6.2.1
R1	Low Density Residential	7.2.1
R1-10	Low Density Residential 10,000SF min	7.2.1
R1-15	Low Density Residential 15,000SF min	7.2.1
R2	Medium Density Residential	7.2.1
R3	Medium-High Density Residential	7.2.1
R4	High Density Residential	7.2.1
RCP	Reinforced Concrete Pipe	6.3.2.1
RMU	Residential Mixed Use	7.2.1
ROW	Right of Way	7.2.1
RS-1	Suburban Residential 1-acre min	7.2.1
RS-2	Suburban Residential 2-acre min	7.2.1
RS-20	Suburban Residential 20,000SF min	7.2.1
RS-3	Suburban Residential 3-acre min	7.2.1
RWQCB	Regional Water Quality Control Board	4.1.5
SB	Senate Bill	2.3.1
SCS	Soil Conservation Service	6.2
SDMP	Storm Drainage Master Plan	1.3
SDV	Stormwater Design Volume	7.2.3.2
SFE	Single Family Equivalent	16.4
SFHA	Special Flood Hazard Area	2.4.3
SHE	Sheep Hollow Creek	10.4.3
SOI	Sphere of Influence	2.1.2
SOPs	Standard Operating Procedures	4.1.3
SOS	Secondary Open Space	9.5.1
SPA	Special Planning Area	8.2.1.1
SPA	Special Planning Area	7.2.1
SPFC	State Plan of Flood Control	2.3.5
sq. mi.	square miles	2.4.3
SR	State Route	2.1.6

Abbreviation/ Acronym	Full Name	First Usage (Section No.)
SRR	Sacramento River Routing	2.3.6
SUDAD	Shasta Union Drainage Assessment District	2.2.1
SWMM	Storm Water Management Model	6.0
SWMP	Storm Water Management Program as used in the quotations from the General Plan	2.1.3
SWMP	Storm Water Master Plan (this document)	1.1
SWPPP	Storm Water Pollution Prevention Plan	4.1.2
SWRCB	State Water Resources Control Board	4.1.1
SWRP	Storm Water Resource Planning	4.0
SYC	Sycamore Creek	10.4.3
TMDL	Total Maximum Daily Load	4.3.2
TND	Traditional Mixed Use	7.2.1
TR-55	USDA NRCS Urban Hydrology for Small Watersheds	7.2.3.2
T_t	Travel Time	6.2.3.1
ULDC	Urban Levee Design Criteria	2.3.1.1
ULE	Urban Levee Geotechnical Evaluation	2.3.2
ULOP	Urban Level of Flood Protection	2.3.1.1
UPRR	Union Pacific Railroad	2.3.5
USACE	U.S. Army Corps of Engineers	2.1.8
USDA	United States Department of Agriculture	6.2.1
USGS	U.S. Geological Services	1.3
VCP	Vitrified Clay Pipe	6.3.2.1
WDR	Waste Discharge Requirement	4.0
WQ	Water Quality	4.1

Executive Summary

EXECUTIVE SUMMARY

A. Purpose

The purposes of this Storm Water Master Plan (SWMP) include providing a comprehensive report on the City of Chico's (City's) drainage systems within the Study Area shown on Figure ES-1 with recommendations for improvements that will be necessary to:

1. Alleviate existing deficiencies;
2. Support construction of curb and gutter;
3. Provide connections to capped systems, bubble-up drains and dry wells;
4. Accommodate future development; and
5. Meet storm water quality and floodplain management regulations.

The SWMP includes planning-level Opinions of Probable Construction Costs (OPCs). These costs provide a basis for capital improvement plan elements and financial analysis including storm drainage fee considerations.

Additional purposes of this SWMP include:

1. Summarizing past plans;
2. Recommending updates to the City's municipal code and design criteria;
3. Identifying measures to meet storm water quality requirements;
4. Updating the City's drainage system mapping; and
5. Presenting floodplain management information associated with the streams and channels.

B. Approach

Development of the SWMP involved:

1. Review of numerous plans and studies;
2. Use of recent topographic mapping;
3. Updates to the City's drainage system mapping;
4. Detailed modeling of the City's storm drainage system;
5. Comprehensive modeling of the Chico area streams;
6. Identification of drainage system deficiencies; and
7. Development of project recommendations and associated OPCs.

The City's drainage system mapping was updated and refined in order to provide a basis for evaluating existing system performance and developing recommendations for improvements. Extensive improvements to the City's drainage system mapping were made in order to create preliminary models of the existing drainage systems. Additional revisions to the drainage system

input data were made where inaccuracies were found to have caused the modeled flood results to be inconsistent with institutional knowledge. Final changes to the City's drainage system mapping were made where inaccuracies in the base data were identified during the process of developing project recommendations. The models of existing conditions were updated to be consistent with the refined drainage system mapping.

The storm drainage system models of existing conditions included extensive details of the existing system. Almost all of the City's catch basins, manholes, pipes, channels, detention basins, and other features were included in the existing models. An automated watershed delineation process was used to estimate areas tributary to the various model inflow points. Watershed boundaries were revised where issues with the automated delineation were identified that could have significant impacts on the SWMP recommendations. Runoff from the watersheds was computed using design rainfall based on National Oceanic and Atmospheric Administration (NOAA) Atlas 14 and appropriate hydrologic parameters. Hydrologic parameters were calibrated using local rainfall and Lindo Channel stream flow data. The results of the models were reviewed with the City, and models were refined until the results were determined to be sufficiently representative of observed conditions.

Storm drainage system deficiencies were identified and recommendations for improvements were developed. Deficiencies were identified using a combination of institutional knowledge, model results and system configuration data. Deficient systems included locations where relatively frequent flooding was known to have occurred and locations where inlet configurations were found to be inadequate. Areas of the City without curbs and gutters were also considered to be deficient for drainage. Some drainage systems within the City have features such as leaching trenches or dry wells to promote infiltration and were not connected to the City's storm drainage system that drains to the creeks. Some of the drainage systems with infiltration components were constructed with caps to facilitate future connections to the City's storm drainage systems. Some of the dry well locations were identified as drainage deficiencies due to known performance issues. Project recommendations were developed to alleviate known drainage deficiencies, to support future construction of curb and gutter street improvements, and to provide connections for capped systems, dry wells, and bubble-ups (bubble-ups are facilities that allow drainage contained in an underground pipe to surface at street level). Improvements to the drainage system should incorporate measures such as infiltration trenches and bioretention in order to reduce runoff and promote groundwater recharge.

The SWMP included a detailed analysis of the Chico area streams. The City's drainage system is tributary to a complex stream system that flows both around and through the City. Portions of the City have flood risks associated with the streams. Some of the streams have levees. Some of the levees are accredited by the Federal Emergency Management Agency (FEMA) to provide

100-year flood protection and others are not. The detailed analysis of the streams included updating models that were prepared by the California Department of Water Resources (DWR). The updates included the application of Central Valley Hydrology Study (CVHS) data to determine standard recurrence interval storm flows (such as the 100-year and 200-year flows). Flood profiles were computed and used to identify locations of freeboard deficiencies and areas at risk of flooding due to potential levee failures. Recommendations for follow-up actions to manage flood risks from stream flows are provided within this SWMP.

C. Results

The results of the SWMP include:

1. An updated storm drainage system Geographic Information System (GIS) integrated map with existing features and new facilities that comprise the SWMP recommendations;
2. A summary of a review of drainage system inlets;
3. A compilation of information about existing detention basins within the City;
4. An analysis to support recommendations for future detention basins and infiltration systems;
5. A detailed review of the existing streams and conveyance channels in the City that include 10-year, 50-year, 100-year, 200-year, and 500-year water surface profiles for the major streams, and a summary of known erosion sites;
6. Two-year, 10-year, and 100-year flooding and flow results from the existing drainage system models;
7. Two-year, 10-year, and 100-year flow results from the build-out drainage system models with recommendations for improvements;
8. Information about the FEMA levee accreditation process and 100-year floodplain mapping;
9. 200-year floodplain mapping; and
10. Data that facilitates selection of efficient locations to implement trash capture systems.

D. Recommendations

The SWMP provides recommendations for:

1. Updates to the Chico Municipal Code related to floodplain management, storm water quality, and drainage;
2. Updating the Post-Construction Standards Plan to address trash capture requirements;
3. Projects to address known drainage deficiencies;
4. Improvements to accommodate construction of curb and gutter improvements;
5. Correcting deficient storm drain inlet configurations;

6. Pipes to provide connections to the locations of capped systems and bubble-up storm drain configurations, as well as to provide overflow relief from dry wells;
7. Storm drainage system improvements to accommodate future development;
8. Incorporating projects that reduce runoff and achieve multiple benefits;
9. How to efficiently meet the objectives of the Trash Implementation Plan; and
10. Implement the high priority recommendations included in the City's Storm Water Resources Plan.

E. Opinions of Probable Cost

Storm drainage improvements were assigned to be in groups based on location. Twenty-three project areas were defined considering proximity to other planned capital improvement projects or areas within the City. The project grouping areas are presented on Figure ES-2 with schematic layouts representing the project features.

Opinions of probable costs (OPCs) for the storm drainage infrastructure improvements projects identified in this SWMP were developed for planning purposes. The quantities associated with identified projects are based on project concepts, and revisions should be expected as the projects progress through more advanced planning and design phases. A summary of project costs is listed in Table ES-1.

Each recommended improvement feature is assigned one or more project categories in order to facilitate prioritization of improvements. Five categories were defined as follows:

1. Improvements to alleviate existing deficiencies that the City has identified as high priority;
2. Improvements to accommodate areas with no curb and/or gutter;
3. Improvements to connect capped systems, dry wells, and bubble-ups to outfalls;
4. Improvements to accommodate new developments; and
5. Miscellaneous improvements to alleviate existing deficiencies that have not been identified by the City as high priority.

Significant capital improvements will be necessary to comply with the trash capture requirements mandated by the State Water Resources Control Board. It is estimated that more than 146 devices will need to be installed (not including 12 already installed or planned) at a planning level cost estimate of $45 million to achieve full trash capture from priority land use areas. Additional site-by-site (parcel-level) investigations will be required to identify cost-effective recommendations to meet trash capture requirements at some locations and it is anticipated that these investigations will identify multiple low-cost devices that will replace some high-cost systems that have been identified. Therefore, it is anticipated that more than 146 devices will be needed to achieve compliance within the planning-level budget.

Costs for improvements in the Esplanade and Garner Lane project area north of Mud Creek are included in Appendix J but are not included in Tables ES-1 and ES-2 or the funding analysis.

Table ES-1: Opinions of Probable Costs by Project Area (not including Trash Capture Systems)				
Project Area	**Base Construction**	**Easement/ Acquisition**	**Other Costs**	**Total Cost**
Barber	$ 1,387,749	$ 2,172	$ 693,874	$ 2,083,795
Bell-Muir	$12,922,919	$11,151,375	$ 6,461,460	$ 30,535,754
Bruce Humboldt	$ 387,530	$ 75,852	$ 193,765	$ 657,147
Chapman	$ 2,088,144	$ 119,369	$ 1,044,072	$ 3,251,586
East Streets	$ 2,737,975	$ 14,303	$ 1,368,987	$ 4,121,265
Eaton Road	$ 2,192,034	$ 900,081	$ 1,096,017	$ 4,188,132
Esplanade	$ 2,797,056	$ 200,751	$ 1,398,528	$ 4,396,336
Fair Street Area	$ 376,846	$ 49,321	$ 188,423	$ 614,590
Glenwood	$ 2,246,628	$ 1,000	$ 1,123,314	$ 3,370,942
Lindo	$ 999,591	$ 37,562	$ 499,796	$ 1,536,949
Lindo South	$ 71,044	$ -0-	$ 35,522	$ 106,565
Little Chico Creek - South	$ 717,370	$ 136,861	$ 358,685	$ 1,212,916
Mansion Park NE	$ 3,324,000	$ 1,422	$ 1,662,000	$ 4,987,421
Mansion Park SW	$ 7,232,156	$ 363,189	$ 3,616,078	$ 11,211,423
Mulberry	$ 413,679	$ 2,982	$ 206,839	$ 623,500
Nord Avenue	$ 1,850,880	$ 500	$ 925,440	$ 2,776,820
North Chico	$19,868,969	$ 6,281,670	$ 9,934,485	$ 36,085,124
Park Vista	$ 304,644	$ -0-	$ 152,322	$ 456,967
South Campus	$ 2,372,750	$ 83,325	$ 1,186,375	$ 3,642,449
South Entler	$ 4,243,652	$ 5,066,536	$ 2,121,826	$ 11,432,014
Stewart Avenue	$ 196,526	$ 907	$ 98,263	$ 295,696
SUDAD East	$ 771,649	$ 387,248	$ 385,824	$ 1,544,721
SUDAD West	$ 201,043	$ 80,764	$ 100,521	$ 382,328
Vallombrosa	$ 2,263,230	$ 112,332	$ 1,131,615	$ 3,507,177
Total	**$71,968,062**	**$25,069,521**	**$35,984,031**	**$133,021,614**

Table ES-2: Storm Drain Capital Improvement Costs by Project Groupings					
Project Category	**Base Construction**	**Easement /Acquisition**	**Other Costs**	**Total Cost**	**Future Development Cost Share**
Priority Deficiencies Requiring C&G	$ 1,695,902	$ 16,218	$ 847,951	$ 2,560,071	$ 36,925
Priority Deficiencies Not Requiring C&G	$ 5,199,319	$ 457,049	$ 2,599,659	$ 8,256,027	$ 269,036
Non-Priority C&G	$23,447,556	$ 2,315,480	$11,723,778	$ 37,486,814	$ 1,783,564
Relief from Infiltration Systems	$ 6,444,567	$ 548,727	$ 3,222,283	$ 10,215,577	$ 1,062,926
Accommodate Future Development	$33,771,817	$21,717,853	$16,885,908	$ 72,375,578	$ 60,672,089
Other Deficiencies	$ 1,408,902	$ 14,195	$ 704,451	$ 2,127,547	$ 3,050
Total	**$71,968,062**	**$25,069,521**	**$35,984,031**	**$133,021,614**	**$ 63,827,590**

F. Funding

a. Introduction to Funding Needs

The City, through its Public Works Department undertakes essential activities to prevent flooding, preserve surface water quality, and ensure compliance with all associated legal requirements. The complex storm drainage system is comprised of various facilities such as integrated storm drainage pipes, inlets, outfalls, culverts, creeks and channels, underground storm water conveyance, detention basins, access roads, and trash capture devices. Necessary activities include operations, maintenance, capital improvement master planning, infrastructure and green infrastructure construction, compliance with the Municipal Separate Storm Sewer Systems (MS4) Permit, and overall system management and administration.

Throughout the City's growth, up to the early 1990s, the City's storm water system was primarily viewed as a drainage system that collected rainwater and conveyed it away from developed areas. However, beginning in the early 1990s, the City was required to comply with newly enacted environmental laws that evolved over the past three decades into a comprehensive set of regulations. These regulations, embodied by the NPDES General Permit for Waste Discharge Requirements for Storm Water Discharges from Small MS4 Phase II Permit, and the NPDES General Permit for Storm Water Discharges Associated with Industrial Activities ("Industrial General Permit" or "IGP"). These permits have been renewed and updated several times; the MS4 was most recently in 2013, while the IGP was adopted in 2014 and amended in 2018. These Permits regulate storm water and non-storm-water discharges from the City's MS4 and requires implementation of key Best Management Practices (BMPs) and other

elements. Over the years, the scope and effort required to implement the storm water program have increased in response to the evolving regulatory requirements and community needs. To comply with the MS4 Permit, the City has prepared several compliance documents, including an MS4 Water Pollution Prevention & Monitoring Plan, a Post-Construction Standards Plan, and a wide range of BMPs. Together, these regulations have significantly changed how the City and private property owners approach land use decisions. This new paradigm has placed storm water management at the forefront of land use practices, on par with other community priorities such as transportation, housing, and major utility services. As a result, many municipalities across the state and nation are now considering storm water as a major utility.

As the scope of storm water management has expanded, so have the associated costs. Historically, storm water management of City facilities has been funded through the City's Gas Tax and general fund due to the connection between vehicular infrastructure and storm water management systems, unlike the City's other utilities (Cal Water, wastewater, and Waste Management and Recology) which rely on separate, dedicated user fees. The increasing cost of storm water management places greater stress on the General Fund, forcing it to compete with a wide range of other priorities such as public safety and community services.

The storm water operations side of the storm water program has also developed numerous activities to support clean water goals and maintain the City's aging infrastructure to protect neighborhoods and businesses from local flooding. On average, the industry-standard life expectancy of a storm drain system is approximately 60 years, or longer for concrete based systems. Much of the City is served by well-configured concrete systems that function effectively.

The City's complex storm drainage system has evolved to meet the unique needs dictated by the City's varied topography and location in the Sacramento Valley, regional watersheds, and the Sierra Nevada foothills on its eastern edge. Historically, the system has protected the City from flooding caused by local storm runoff. However, climate change is bringing new challenges with more frequent and intense storms. While the City's storm drainage system must adapt to these changes, it alone cannot provide all the solutions needed to address these climate change challenges. Therefore, funding options evaluated in this chapter will not fully address the impacts of climate change.

This financial analysis does not include the funding necessary to achieve levee accreditation for non-accredited levees, or the funding needed to maintain accreditation of those levees that are currently accredited.

Future tasks (not part of this work) include a Proposition 218 compliant Storm Water Fee Study.

b. Financial Review

The City's Public Works Department (Department) is organized into two sections: Operations and Maintenance, and Engineering. Each section consists of several divisions and perform various storm water program activities; however, no single section handles all storm-water-related activities. To conduct this analysis, a hypothetical storm water utility that would fund the City's resources required to conduct all necessary and beneficial storm water activities was created. Based on a review of the related financial accounts and discussions with supervisory staff, planning-level estimates of the costs and revenues required to fund the storm water utility were developed.

The financial review was conducted in three parts: 1) Establish current operating costs as a baseline; 2) Estimate additional operating needs; and 3) Amortize capital needs. For current operating costs, financial budgets across all City funding sources that support storm water activities were reviewed, resulting in estimated baseline operating costs at approximately $1.22 million for Fiscal Year 2024-25 (FY 25).

Next, potential additional operating needs were identified, including basic operations and regulatory compliance that should be included in a future utility structure. These additional operating needs comprise of work likely to be repeated periodically as additional capital projects are implemented. It was estimated that an additional $420,000 would be needed annually by FY 25. Combined with current baseline operating costs, the total revenue required for basic operations and maintenance of the storm water system is estimated to be $1.63 million for FY 25.

Finally, the capital costs identified by the SWMP were incorporated. The results were compiled into a single Capital Improvement Program (CIP) totaling $180 million. The largest capital project costs identified by the CIP are for future development and trash capture systems. Fees tied to future development will provide funding for a large portion of those project costs, while trash capture project costs are expected to be funded by their own, separate revenue source. After accounting for the share of costs projected to be funded by fees from future development and cost offsets from

alternative revenue streams such as General Obligation bonds and Gas Tax funding for specific projects, the total cost for CIP was adjusted to $32.8 million.

A summary of the financial analysis is shown in Table ES-3 below.

Table ES-3: Summary of Financial Analysis

Description	**FY 25 ($1,000s)**
Baseline Costs	$ 1,221
Additional Needs	$ 405
Subtotal Operating Costs	$ 1,626
Capital Improvement Program *	$ 2,082
Total Revenue Requirement	**$ 3,708**

** CIP is amortized over 30 years*

c. Storm Water Utility Finding Source

A storm water utility can be viewed as a fully self-supporting entity similar to most municipal water and sewer utilities, where all the services and programs are funded primarily by a user fee. In municipal financial parlance, the funding model is also called an enterprise fund and ensures all services and programs are financially independent. However, unlike water and sewer service, storm water fees are subject to Proposition 218, which requires voter approval.

Storm water fees are based on annual revenue requirements and a fair-share apportionment of costs to all properties based on the amount of their impervious surface. Revenue requirements were estimated using a 30-year forecasting tool ("model") that included various escalation factors, a 30 percent operating reserve balance, and, for some scenarios, allowances for debt costs (annual debt service, finance charges, and a debt reserve). The model looked at various budget scenarios sufficient to support estimated on-going operating costs and to fund the CIP over a 30-year planning horizon.

The initial revenue requirement of $3.55 million, translates to a user fee of approximately $7 per month for the average residential parcel. Fees for other types of parcels vary based on the amount of impervious surface. This planning-level estimate could fluctuate by 10% to 20%; however, it serves as a reliable basis for a community survey and planning purposes.

d. Roadmap Forward and Recommendations

Establishing a storm water utility involves a series of critical steps, with the final ones mandated by Proposition 218. However, before reaching that stage, extensive groundwork is recommended before those final procedural steps are taken. Because of the ballot requirement, engagement with stakeholders, community opinion surveys, and other forms of community engagement should introduce the storm water fee concept early in the process. Simultaneously, the City must clearly define services objectives, perform a rigorous needs analysis, and, finally, undertake a thorough rate study. Only then can a municipality make a compelling case to the community through a Proposition 218 ballot measure.

Analysis reveals that the annual full cost of the storm water program is approximately $3.55 million (current value). A typical rate structure would require a fee as high as $7 per month (or $86 per year) for the average home to fund such a program – a rate relatively high compared to other municipalities statewide. Strategies for right-sizing the rate to as low as $5 per month are discussed in the SWMP.

The following next steps are recommended:

- Launch a comprehensive community engagement program
- Conduct a community survey to ascertain the community's values and priorities, messaging focal points, and ultimately their willingness to pay such a fee
- Prepare a rigorous rate study
- Proceed with a Proposition 218 ballot measure using the proposed rates

This multifaceted process will likely span at least 18 months, potentially up to two years, contingent upon community engagement levels. Due to the anticipated high level of financial need with its resulting rate levels, the full cost of the storm water utility might not be fully funded by storm water fees alone. Thus, alternative funding sources to supplement the storm water fee should be explored.

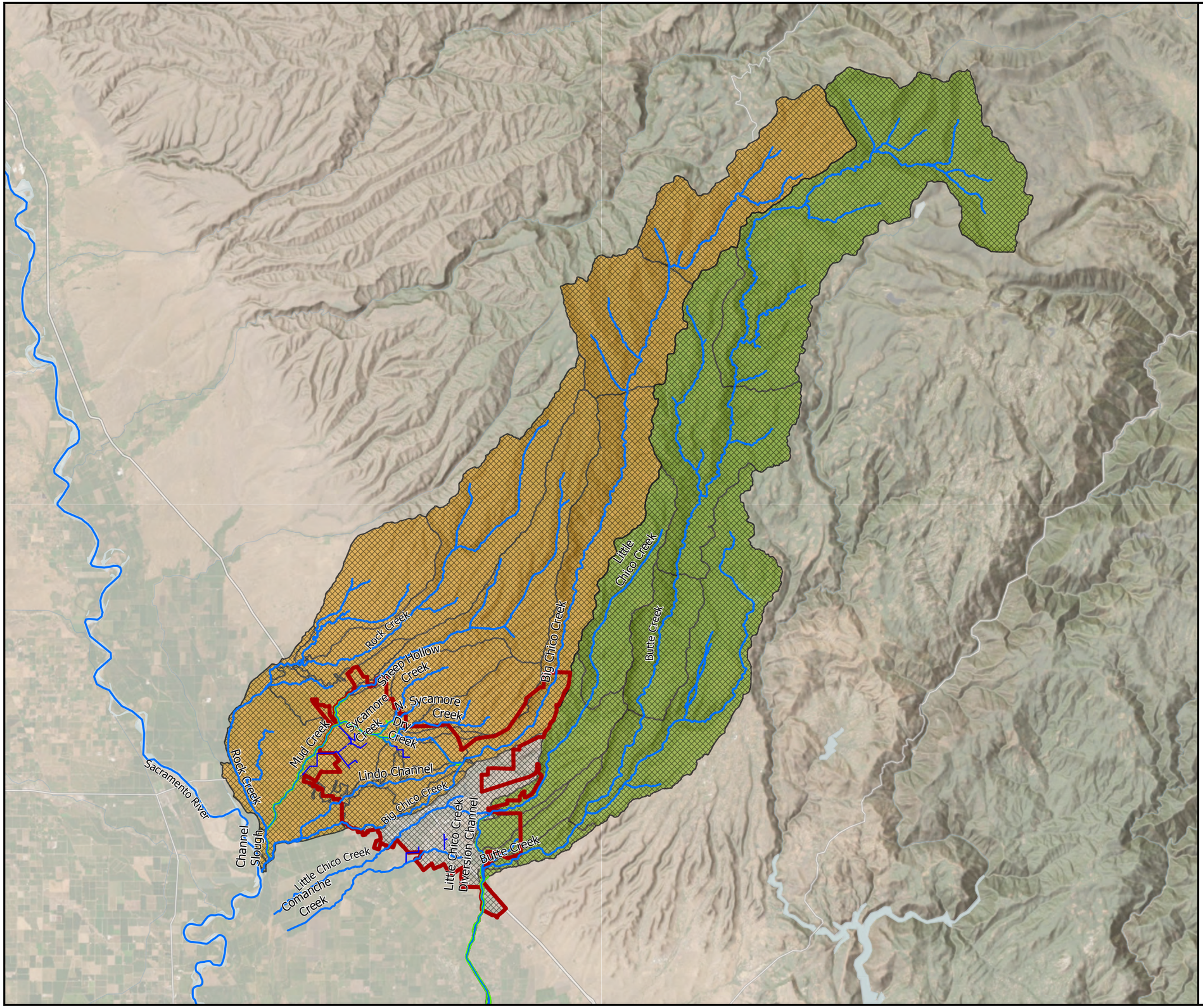
In summary, storm water utility funding is a substantial process involving planning, engineering, rate analysis, ballot proceedings, and community engagement. Successfully executing this roadmap will not only provide a funding source for important storm water services, but also present an opportunity to enhance the quality of life for residents and businesses within the City.

STUDY AREA

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024



NORTH

0 10,000 20,000 40,000

Feet

Legend

- Streams
- In-City Tributaries
- SPFC Levees
- Sphere of Influence
- Little Chico Creek and Butte Creek Watersheds
- Big Chico Creek, Mud Creek, and Rock Creek Watersheds
- Study Area Regional Watersheds

SOURCES:
Stream Lines:
Central Valley Hydrology Study (CVHS), Central Valley Floodplain Evaluation and Delineation Program (CVFED), Chico SWMP

Watersheds:CVHS

WOOD RODGERS

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FIGURE ES-1

STORM DRAIN CIP GROUPINGS

STORM WATER MASTER PLAN

CITY OF CHICO

OCTOBER 2025

NORTH

0 2,500 5,000 10,000

Feet

- Proposed Manhole
- Proposed Drop Inlet
- Proposed Outfall
- Remcve/ Replace Inadequate Drop Inlet
- Proposed Pump
- Proposed Pipe
- Remcve/Replace Inadequate Pipe
- Existing Pipe
- Proposed Detention Basin
- City Limits
- Sphere of Influence

Project Groups

- Barber
- Bell-Muir
- Bruce/ Humboldt
- Chapman
- East Streets
- Eaton Road
- Esplanade
- Fair Street Area
- Glenwood
- Lindo
- Lindo - South
- Little Chico Creek - South
- Mansion Park NE
- Mansion Park SW
- Mulberry
- Nord Avenue
- North Chico
- Park Vista
- SUDAD - East
- SUDAD - West
- South Campus
- Stewart Avenue
- South Entler
- Vallombrosa
- Garner Lane/Esplanade

NOTES:

1. Barber Yard Basin and Outlet are shown, but associated costs for these facilities are not included in the SWMP planning costs.

2. Basins proposed to accommodate future development are conceptual. Alternative configurations of regional basins, and/or project-specific basins, could be constructed in order to meet the objective of the SWMP.

WOOD RODGERS

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FIGURE ES-2

1.0
Introduction

1.0 INTRODUCTION

1.1 Purpose

The purpose of this Storm Water Master Plan (SWMP) is to provide an updated plan that consolidates information from numerous documents, develops new and updated technical analyses, and provides a comprehensive resource to support future drainage system operations, planning, and development within the city of Chico and its sphere of influence, Butte County, California. The last Storm Drainage Master Plan was adopted by the City of Chico (City) in 2001 and was an amended plan that had been prepared in 1987. Numerous studies have been completed since 2001 and there are tremendous amounts of data and new technologies that have become available that will facilitate drainage studies. High resolution Light Detection and Ranging (LiDAR) topographic mapping data and advanced hydrologic modeling software provide the foundation for detailed analysis and user-friendly presentation of results that are useful to identify drainage issues and prepare comprehensive city general plans. The various hydrologic modeling tools and associated Geographic Information System (GIS) applications with model input and output capability are valuable tools for a wide range of planning purposes.

Key elements of this SWMP include reviews of:

1. Catch basins, in order to identify locations where existing catch basins are inadequate;
2. Detention basins, in order to evaluate performance and potential opportunities for improvements; and
3. Creeks and channels, in order to identify capacity, erosion, and sedimentation issues.

The SWMP evaluated the existing drainage system in order to simulate drainage deficiencies that require improvements. Locations that lack effective storm drainage, such as intersections with low points that do not drain and streets where curb and gutter improvements will be constructed, were identified as locations for future storm drains. Hydrology based on General Plan build-out conditions was used as a basis for developing drainage system improvement recommendations. The SWMP provides information about National Pollutant Discharge Elimination System (NPDES) compliance and also gives updated recommendations for meeting trash capture requirements. The significance and impacts of existing deficiencies, future development and other capital improvement projects were considered in order to prioritize improvements.

The SWMP includes opinions of probable cost for the recommended drainage system improvements. Development impact fee recommendations and additional financial analyses are also provided.

1.2 Study Area

The City of Chico is located in the Sacramento Valley, approximately 90 miles north of the City of Sacramento, and it is the largest city in Butte County (as shown in **Figure 1**). The Study Area for the SWMP covers the watershed's tributary to the City's Sphere of Influence (as shown in **Figure 2**). The Sierra Nevada mountain range lies to the east of the City, while the Sacramento River is located approximately five miles to the west. The City's terrain is generally flat, but it rises into the foothills at the City's eastern edge. The incorporated area of the City has grown to approximately 33 square miles, with a Department of Finance 2020 estimated population of 110,326. Chico is a mixed residential and commercial properties community, with a multimodal transportation network. The largest land use in the City is residential, comprised of single-family and multi-family housing options. Chico supports a diverse range of industries including agriculture, recreation, tourism, education, medical, and manufacturing. Chico is also the home of California State University, Chico (Chico State), the second oldest institution in the California State University system, enrolling approximately 14,000 students. The City is protected by streams, channels, and levees to divert flows from the foothills and carry waters away from the City to the Sacramento River.

The hydrologic setting of the City is quite complex with numerous streams crossing through it, generally from the northeast to the southwest. As shown on Figure 2, from northwest to southeast the major streams crossing the City are Mud Creek, Lindo Channel, Big Chico Creek, Little Chico Creek, Comanche Creek and Butte Creek. High flows in Big Chico Creek are largely diverted into Sycamore Creek, a tributary connected to Mud Creek by flow control structures that limit flows into the portions of Big Chico Creek and Lindo Channel that pass through highly developed areas of the City. Similarly, high flows in Little Chico Creek are largely diverted into Butte Creek. The City's storm drainage systems include pipes and channels that have outfalls into the streams.

Due to the City's location at the downstream end of a relatively long watershed, high stream flows resulting from runoff originating within the City are not expected to be coincident with much higher flows resulting from precipitation in the hills to the northeast. **Exhibit 1** (below) illustrates typical Lindo Channel flows resulting from a rainfall event by plotting rainfall at the Chico State rain gage and observed stream discharges. At first, a small amount of precipitation does not result in runoff at the stream gage; then, additional rainfall generates runoff, and peak runoff occurs just slightly after peak local rainfall. There is a lag of approximately 24 hours from peak rainfall in the hills to the northeast of Chico until the peak discharge within City limits that results from runoff originating in the watershed upstream of the City.

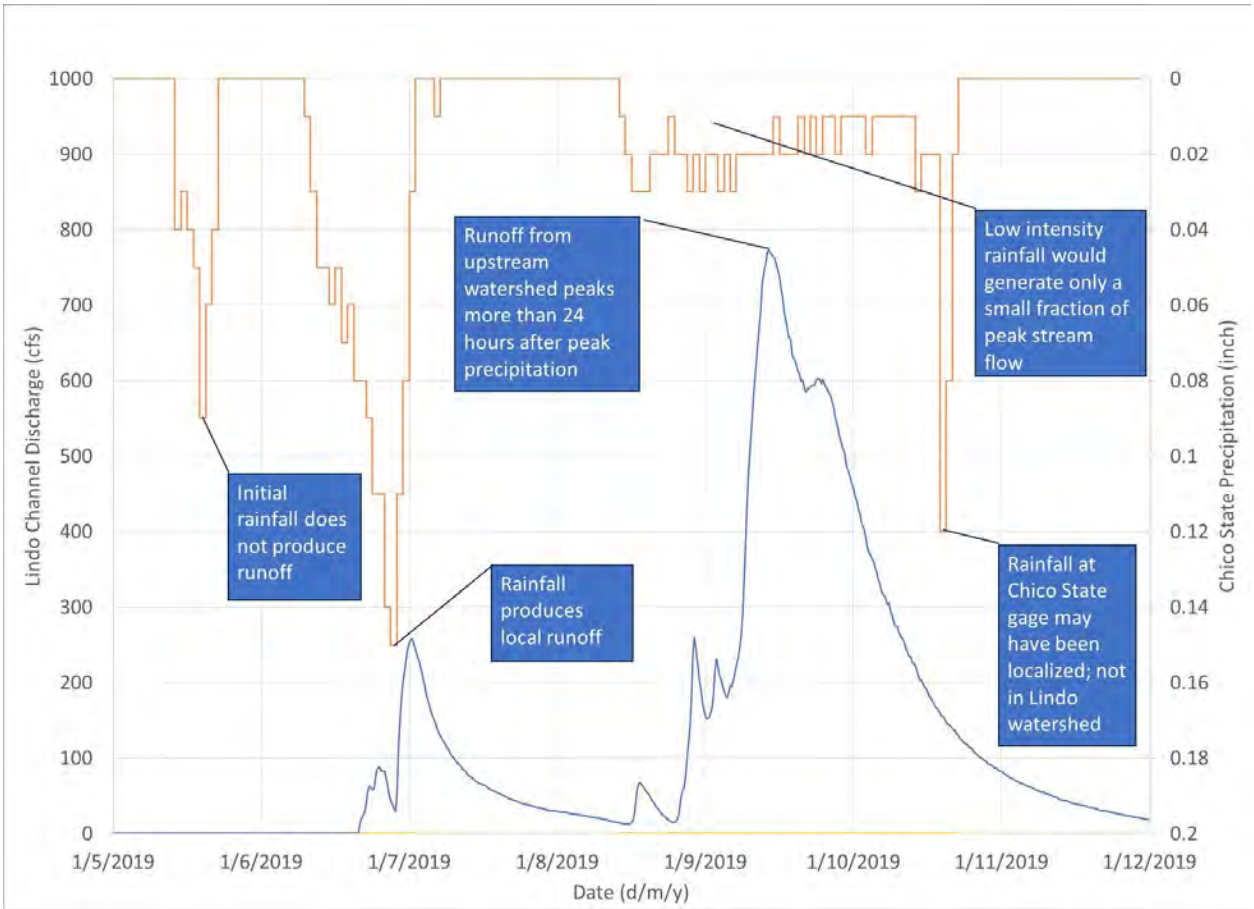


Exhibit 1: Typical Lindo Channel Response to Precipitation

1.3 Topography

The topographic mapping used in the development of this SWMP is a major change from previous drainage studies prepared for the City. The topographic data impacts the accuracy and resolution of the analysis and presentation of the results. It allows for an approach that uses the impacts of flows that are not contained within the storm drainage system pipes and channels to develop recommendations for prioritized improvements rather than assuming that pipe capacity should be added if existing pipes do not have capacity based on design standards. Topographic data defines the ground surface that is used to delineate watershed boundaries and evaluate surface flow paths in the SWMP. The *Preliminary Storm Drainage Master Plan* [1] (1987 SDMP) used U.S. Geological Services (USGS) topographic mapping with a 5-foot contour interval and the storm drainage system layout as the basis for watershed delineations. The USGS topographic mapping transitions to a 20-foot contour interval in the steeper areas of the watersheds tributary to the streams that drain toward the City. The USGS topographic mapping provides a useful reference

with which to view the regional topography and is presented in **Figure 3**. This SWMP uses LiDAR-based topographic mapping.

The LiDAR topographic data used to prepare this SWMP is much more accurate than the USGS topographic mapping. Due to the resolution of the LiDAR data, it is not practicable to present the entire Study Area at the level of detail that is available. Instead, the following series of exhibits is provided to illustrate the detail that is available. **Exhibit 2** show the overall topographic relief of the City. **Exhibit 3** shows topographic features such as roads and streams. Note that, typically, bridges are removed from the terrain in a process called "hydro-enforcing" in order for the surface flow paths to be reflected in the data. As shown, some of the bridges have not been removed. Generally, stream cross sections can be cut from the terrain data, although care must be taken because vegetation and/or water that obscures the ground may be present. Information about channel modeling, stream cross sections and surveys is presented in Section 10.5.

Exhibit 4 shows the detail available in the topographic data. Flow patterns along streets, including low points where catch basins are likely to be found, can be seen in the terrain data. Capacities of detention basins were extracted from the terrain data. Elevation data from as-built drawings was used to establish conduit elevations for drainage system modeling at critical locations. Pipe invert elevations were estimated or interpolated based on known elevations and constraints where precise invert elevation data would not impact the plan.

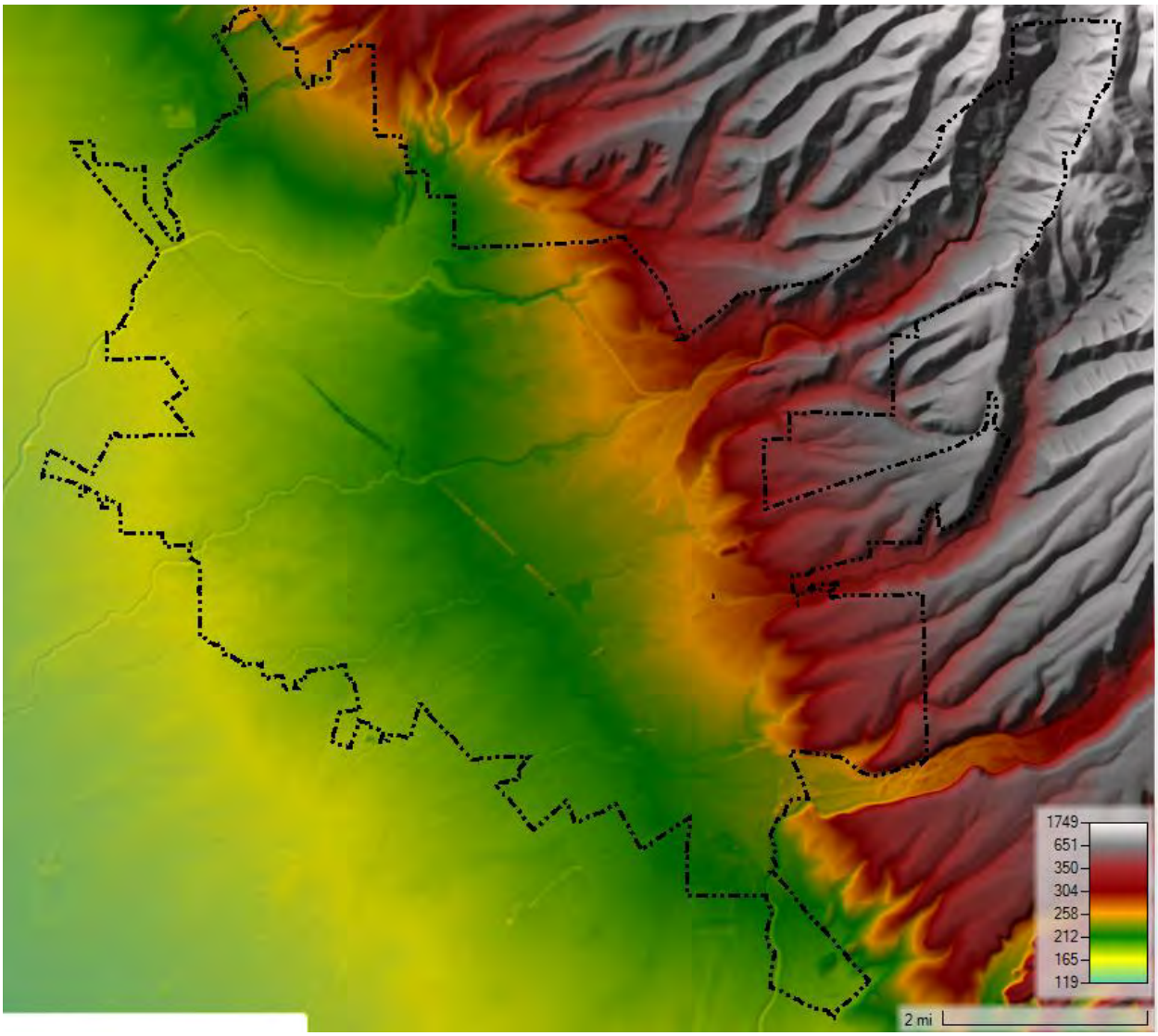


Exhibit 2: Citywide Topography Showing General Relief

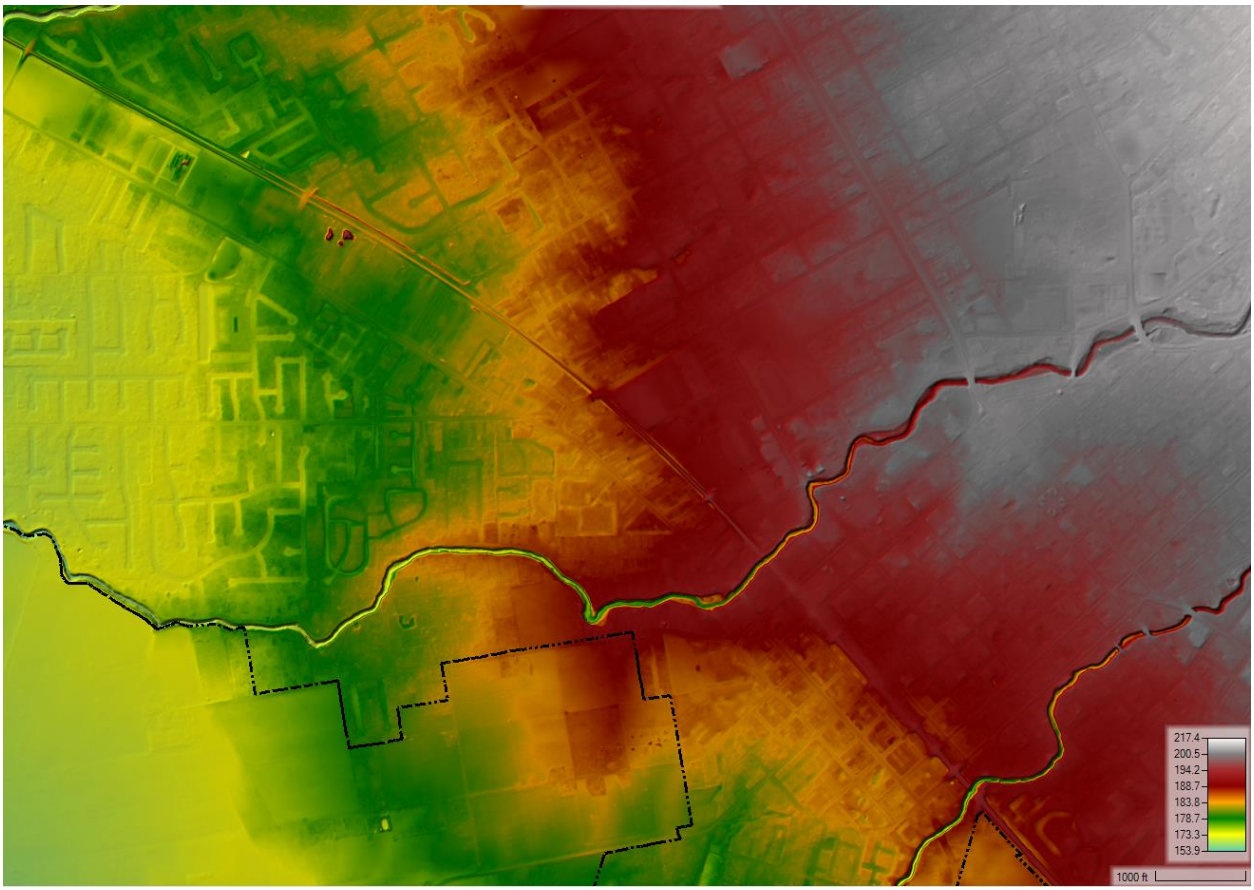


Exhibit 3: Topographic Features

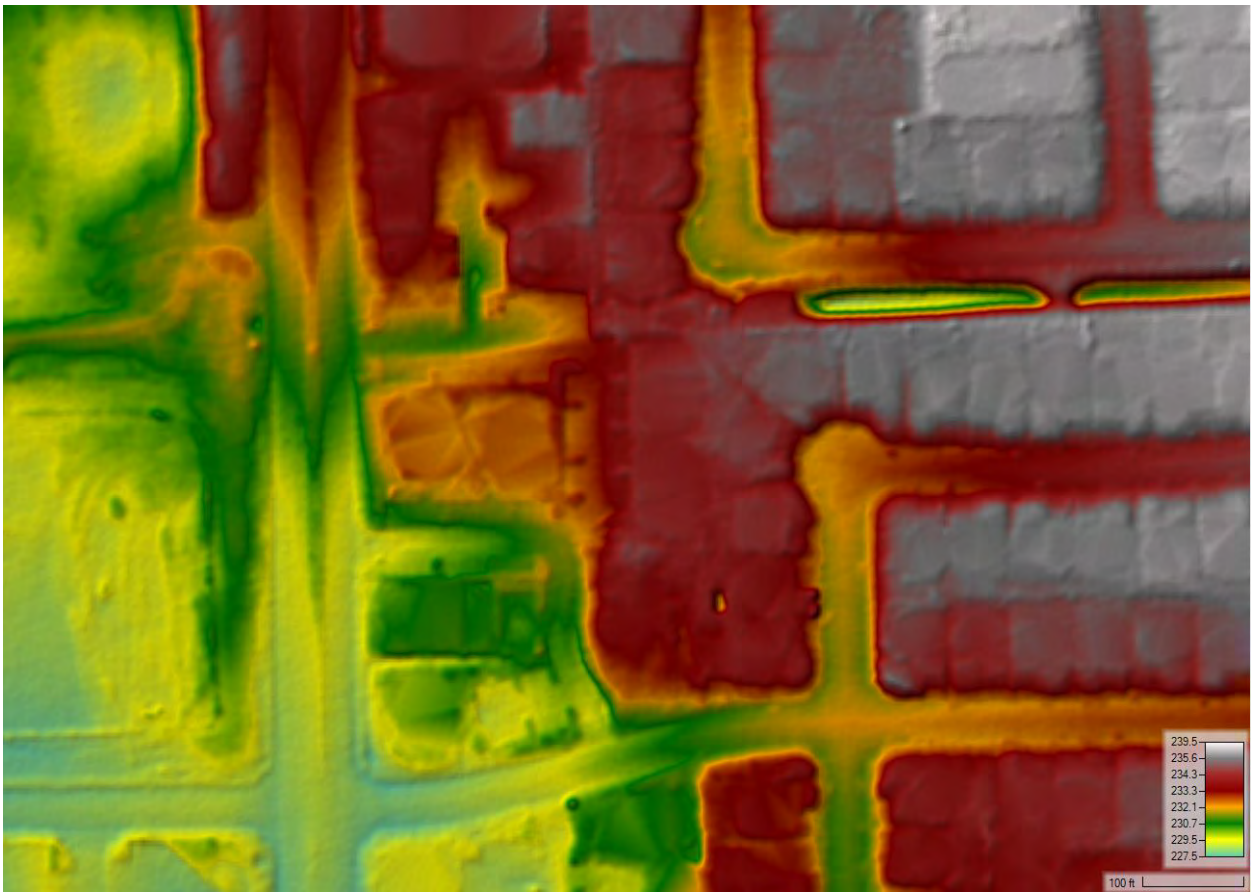


Exhibit 4: Topographic Details

1.3.1 Vertical Datum

Elevations in this report are presented in North American Vertical Datum of 1988 (NAVD 88). Elevations on various plan sets and some other data were on National Geodetic Vertical Datum of 1929 (NGVD 29). The conversion between NAVD 88 and NGVD 29 used for the SWMP is 2.35 feet, with NAVD 88 presenting the higher value. This is the conversion factor used for all of Butte County by the Federal Emergency Management Agency (FEMA) [2].

1.3.2 LiDAR Data Sources

Multiple sources of LiDAR data were available within the Study Area. In 2007, the California Department of Water Resources (DWR) acquired LiDAR data as part of the Central Valley Floodplain Evaluation and Delineation Program (CVFED). The CVFED data was collected in 2007 and processing was completed in 2013. The USGS collected LiDAR data in May of 2017 and published it in 2018. The 2017 USGS LiDAR data is referenced as "USGS Lidar Point Cloud CA FEMA-R9-Keefer 2017." The USGS collected additional LiDAR data from July 2018 through February 2019 and published this data in January of 2020 as "USGS Lidar Point Cloud CA NoCAL Wildfires B2 2018." None of the data sets covers the entire Study Area, but there is complete

coverage using all three sources, and they appear to be vertically consistent where the ground surface has not changed. The most recent data was used for locations where multiple data sets are available. **Figure 4** presents the extents of the three LiDAR data sets.

All three data sets contained useful information. A comparison between the 2007 data and the 2017 data was made to help identify locations of erosion and sedimentation along channels. Comparisons between the data sets were also used to identify which one appeared to have the best data in some stream cross sections where vegetation may have impacted the data more in one data set than in another.

2.0
Summary of Past Plans

2.0 SUMMARY OF PAST PLANS

The SWMP ties many existing plans that the City has in support of the storm drain system into a single document. The various plans are summarized in this section of the SWMP which is organized into City, County, State, and Federal sub-sections based on the agency responsible for plan development.

2.1 Summary of City Plans

2.1.1 Preliminary Storm Drainage Master Plan (1987)

The 1987 SDMP was prepared by Brown and Caldwell, consultants to the City of Chico and Butte County. The purpose of the 1987 SDMP was to establish and determine, at a conceptual level, the ultimate storm drainage collection system needs under ultimate build-out of a major portion of the urban area.

The 1987 SDMP focused on the major pipes and improved channels of the urban area storm drain system and their ability to adequately convey storm runoff. It did not address improvement needs associated with the major waterways that pass through the City while receiving runoff from the urban area storm drain systems.

The 1987 SDMP Study Area included all of the area within the Chico Sphere of Influence as defined by the September 1985 Chico General Plan, with the exception of those areas south of Comanche Creek, the Louisiana Pacific property located west of the terminus of West 16th Street, and the Elmer Street neighborhood located between Little Chico Creek and Dayton Road. The SDMP Study Area was assumed to be fully built out in accordance with the 1985 General Plan.

The 1987 SDMP established design criteria to be used for the 1987 SDMP, proposed capacity improvements for major pipes and ditches, estimated improvement costs, and recommended improvement priorities.

The SDMP Study Area was divided into 122 tributary subareas, one for each storm drain outfall that discharged into one of the major waterways that pass through the City. The need for major storm drain capacity improvements was evaluated for each subarea.

An approximate high-water surface elevation was estimated in the major waterways at the outfall discharge points, and 11 subareas were identified as requiring storm drain pumping stations.

2.1.2 Final Environmental Impact Report (1992)

Jones & Stokes Associates Inc. prepared a "*Final Environmental Impact Report on the Chico Urban Area Draft Sanitary Sewer and Storm Drainage Master Plan, Northwest Annexation and General Plan Amendments North of Lindo Channel*" [3] dated December 1992.

Of the four "projects" covered by this certified Final Environmental Impact Report (FEIR), only the 1987 SDMP was not adopted by the City Council. The FEIR recognized that the 1987 SDMP did not address improvement needs associated with the major waterways that pass throughout the City while receiving runoff from the urban area storm drain system. To correct this omission, the FEIR required the following:

- Incorporate measures for controlling peak runoff into project designs in the Sphere of Influence (SOI);
- Implement a regional approach for controlling peak runoff in the SOI;
- Incorporate measures for channel stabilization into project designs in the SOI; and
- Implement a combination of best management practices (BMPs) to reduce pollutant loads in urban runoff, i.e., provide for water quality treatment.

2.1.3 Chico 2030 General Plan

The Chico 2030 General Plan was prepared by Pacific Municipal Consultants (PMC), adopted April 2011, and amended March 2017 [4]. Section 9, *Parks, Public Facilities, and Services*, of the Chico 2030 General Plan states:

> "*Consistent with the 1994 General Plan and the City's 2000 Storm Drain Master Plan Integrated Document, new development must incorporate storm water quality and quantity mitigations into their designs. As required by the Clean Water Act, the City has an established Storm Water Management Program (SWMP) in compliance with its National Pollution Discharge Elimination System (NPDES) permit. The City's NPDES permit controls water pollution by regulating point sources that discharge pollutants into local waters. The SWMP addresses storm water quality issues in the areas of construction and post-construction Best Management Practices, municipal operations, and community involvement.*"

The following goal, policies and actions related to storm water drainage facilities are included in Section 9 of the Chico 2030 General Plan:

- *Goal PPFS-6: Provide a comprehensive and functional storm water management system that protects people, property, water quality, and natural aquifers.*
    - *Policy PPFS-6.1 (Storm Drainage Master Plan) – Address current and future storm drainage needs in a Storm Drainage Master Plan.*
        - *Action PPFS-6.1.1 (Update the Storm Drainage Master Plan) – Update, adopt and implement an updated Storm Drainage Master Plan that identifies areas with infrastructure deficiencies and establishes a program to address the deficiencies. Address drainage issues on a basin or sub-basin scale. Identify opportunities to increase infiltration, based on factors such as existing infrastructure, geology, the hydrology and hydraulics of the receiving waters, and planned land uses.*

- *Action PPFS-6.1.2 (Development Fees) – Update the development fee program as needed to ensure that storm water drainage development fees are equitable and adequate to pay for the storm water drainage infrastructure needed for future development.*

- *Policy PPFS 6.2 (Storm Water Drainage) – Continue to implement a storm water drainage system that results in no net increase in runoff.*
  - *Action PPFS-6.2.1 (Storm Water Drainage Standards) – Regularly update storm water drainage standards to include all current best management practices and ensure water quality and quantity standards governing the discharge of storm water drainage to downstream receiving waters conform with State and Federal regulations.*
  - *Action PPFS-6.2.2 (Expand Storm Water Infrastructure) – As funding allows, continue installation of storm water drainage infrastructure in areas not served.*
- *Policy PPFS-6.3 (Storm Water Drainage BMPs) – To protect and improve water quality, require the use of Best Management Practices for storm water drainage infrastructure suited to the location and development circumstances.*
  - *Action PPFS-6.3.1 (Alternative Storm Water Infrastructure) – Continue to develop engineering standards and guidelines for the use of alternative storm water infrastructure in order to minimize impervious area, runoff and pollution, and to maximize natural storm water infiltration wherever feasible.*
- *Policy PPFS-6.4 (Water Runoff) – Protect the quality and quantity of water runoff that enters surface waters and recharges the aquifer.*
  - *Action PPFS-6.4.1 (Storm Water Management Program) – Continue to implement the City's Storm Water Management Program (SWMP) and enforce storm water provisions in the City's Municipal Code.*
- *Policy PPFS-6.5 (Flood Control) – Manage the operation of the City's flood control and storm drainage facilities and consult with local and state agencies that have facilities providing flood protection for the City.*
  - *Action PPFS-6.5.1 (Flood Management) – Consult with Butte County and other flood control agencies to ensure that all possible actions are taken to prevent floodwaters from entering the City.*
  - *Action PPFS-6.5.2 (Natural Watercourses) – Utilize natural watercourses and existing developed flood control channels as the City's primary flood control channels when and where feasible.*
  - *Action PPFS-6.5.3 (Flood Impacts) – Require that new development not increase flood impacts on adjacent properties in either the upstream or downstream direction.*

        - *Action PPFS-6.5.4 (Flood Zones) – Require new development to fully comply with State and Federal regulations regarding development in flood zones.*

The following goal, policy and actions related to water supply and water quality are included in Section 10, *Open Space and Environment*, of the Chico 2030 General Plan:

- *Goal OS-3: Conserve water resources and improve water quality.*
    - *Policy OS-3.1 (Surface Water Resources) – Protect and improve the quality of surface water.*
        - *Action OS-3.1.1 (Comply with State Standards) – Comply with the California Regional Water Quality Control Board's regulations and standards to maintain, protect, and improve water quality and quantity.*
        - *Action OS-3.1.2 (Runoff from New Development) – Require the use of pollution management practices and National Pollutant Discharge Elimination System permits to control, treat, and prevent discharge of polluted runoff from development.*
        - *Action OS-3.1.3 (Discharge Enforcement) – Continue enforcement of illegal discharges to Chico's creeks.*
        - *Action OS-3.1.4 (Clean Creeks Project) – Continue implementation of the Chico USA Clean Creeks Project which provides community-wide education regarding storm water runoff, pollution management practices, and the importance of clean creeks.*
        - *Action OS-3.1.5 (Water Quality Monitoring) – Monitor water quality in Big Chico Creek (above and below Sycamore Pool) daily between Memorial Day and Labor Day and monthly during the balance of the year.*
        - *Action OS-3.1.6 (Teichert Ponds Restoration) – Seek funding to implement the Teichert Ponds Restoration Habitat Development Plan, which will enhance storm water quality, wildlife habitat, public access, and education at the Teichert Ponds stormwater facility.*
        - *Action OS-3.1.7 (Five-Mile Operation) – Work with the Butte County Public Works Department to improve operation and maintenance of the Five-Mile flood control system to enhance flow and sediment management and thereby enhance water quality, fisheries habitat, and flood capacity*.

The following goal, policy and actions related to flooding are included in Section 12, *Safety*, of the Chico 2030 General Plan:

- *Goal S-2: Minimize the threat to life and property from flooding and inundation.*
    - *Policy S-2.1 (Potential Flood Hazards) – When considering areas for development, analyze and consider potential impacts of flooding.*
        - *Action S-2.1.1 (Flood Hazard Analysis) – As part of project review, analyze potential impacts from flooding and require compliance with appropriate*

building standards and codes for structures subject to 200-year flood hazards.

- *Action S-2.1.2 (Flood Hazard Management) – Continue efforts to work with the Federal Emergency Management Agency and state and local agencies to evaluate the potential for flooding, identify areas susceptible to flooding, accredit the flood control levees in the City, and require appropriate measures to mitigate flood related hazards.*
- *Action S-2.1.3 (200-Year Flood Protection) – Cooperate with local, regional, state, and federal agencies to seek funding for the provision of 200-year flood protection.*
- *Action S-2.1.4 (Floodplain Hazard Materials) – Provide materials to the community regarding Federal Emergency Management Agency and California Department of Water Resources flood mapping*.

2.1.4 SDMP Addendum (1997)

Based on the findings of the 1992 Environmental Impact Report (EIR) and the Chico General Plan Update, in 1997 the City prepared an amendment to the 1987 SDMP to address omissions by incorporating additional project elements to address the following:

- Peak Flow in Comanche Creek and Little Chico Creek;
- Channel stabilization in all waterways passing through the urban area;
- BMPs throughout the urban area; and
- Design and data collection projects that are a necessary precursor to the above projects, the future Storm Water Management Program and water quality monitoring.

It was further determined that projects addressing the following concerns should not be incorporated into the Addendum:

- Peak flow in Big Chico Creek, Lindo Channel and Sycamore/Mud Creeks; and
- Storm runoff volume reduction.

2.1.5 Environmental Impact Report for the Storm Drainage Master Plan (2000)

EIP Associates prepared the *Environmental Impact Report for the Storm Drainage Master Plan* [5] dated October 2000. The Program EIR describes the environmental resources that exist within the Chico Urban Area, including the SDMP Study Area, and analyzes the potential impacts on those resources resulting from implementation of the 1997 SDMP Addendum. The Program EIR evaluated the following:

- land use;
- growth inducement;
- erosion and channel stabilization;
- drainage patterns;

- drainage flows;
- channel capacity;
- water quality;
- biological resources; and
- cultural resources.

The Program EIR made every reasonable attempt to define impacts and to identify existing City policies and actions to mitigate those impacts.

2.1.6 Sandy Gulch (Lindo Channel) Resource Inventory (2001)

The Sandy Gulch Resource Inventory [6] was prepared for the City Parks Department by Geo Environmental Management. The development of GIS data from Sycamore Bypass to approximately 600 feet west of State Route 32 (SR 32) was documented. **Exhibit 5** is Figure 1.3 from the Sandy Gulch Resource Inventory (which was obtained from the DWR) that shows the layout of the Chico, Mud and Sandy (Lindo Channel) Project Diversion Structures.

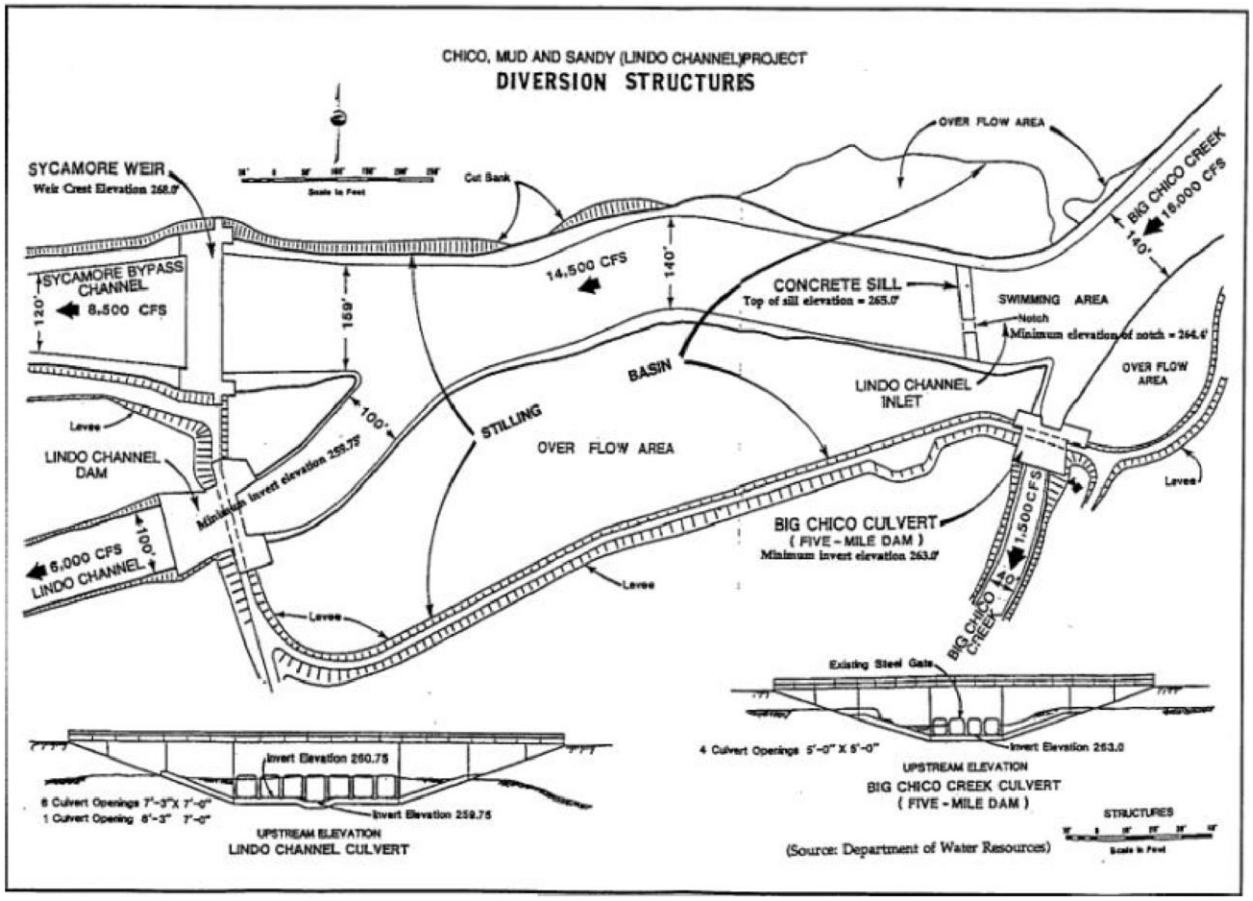


Exhibit 5: Figure 1.3 from Sandy Gulch Resource Inventory

2.1.7 Teichert Ponds Restoration Habitat Development Plan (2008)

The *Teichert Ponds Restoration Habitat Development Plan* [7] was prepared by Restoration Resources for the City of Chico. It is a guidance document for the restoration of Teichert Ponds with the goals of enhancing storm water detention capacity and improving water quality, as well as creating high-quality wetland and riparian habitats. The plan has not been implemented.

2.1.8 Provisional Accredited Levee Report (2011)

The Provisional Accredited Levee (PAL) [8] Report was prepared by Lumos and Associates, Inc. for the City. The PAL Report includes photographs of the culvert drainage facilities that penetrate the levees along Mud and Sycamore Creeks. The PAL Report documents freeboard analysis, embankment erosion, foundation stability and seepage, embankment settlement, and interior drainage. Geotechnical boring logs are included. The document includes copies of:

1. Chico and Mud Creeks and Sandy Gulch General Design;
2. U.S. Army Corps of Engineers (USACE) Engineering Manual (EM) 1110-2-1913, Design and Construction of Levees;
3. Operation and Maintenance (O&M) Manual for Chico and Mud Creeks and Sandy Gulch;
4. Butte County Levee Inspection Report (2010); and
5. USACE improvement plans.

2.2 Summary of County Plans

2.2.1 North Chico Area Storm Drainage Study, January 1985

The *North Chico Area Storm Drainage Study* [9] was prepared by Rolls, Anderson & Rolls, Inc. for Butte County. The purpose of the North Chico Areas Drainage Study was to develop a plan for an area covering 1,338 acres, of which 1,204 acres were north of Lindo Channel and 134 acres were south of the channel. The study was completed shortly after and included a sewer study for the same area in order to develop planning information for drainage if undeveloped portions of the area were to develop. Information about the Shasta Union Drainage Assessment District (SUDAD) facilities is provided. The study provided a plan for a backbone storm drainage system sized to convey 100-year runoff.

The Bell Muir Area is within the area covered by the North Chico Area Storm Drainage Study. This SWMP provides a new approach for drainage improvements within the Bell Muir Area in Section 9.5.1.

2.2.2 Butte County Local Hazard Mitigation Plan Update, October 2019

The Butte County Local Hazard Mitigation Plan Update (LHMP) was prepared by Foster Morrison Consulting, Ltd. For Butte County. [10] The LHMP includes Annex B-1 that covers the City of Chico and presents a range of information from Butte County GIS. Information contained in the LHMP that relates to drainage and flooding includes impacts of potential dam failures; 100-year, 200-year and 500-year flooding; vulnerability to localized flooding; and levee failure. Hazard

information is presented using a GIS analysis of available data sets to identify risks. Specific information about actual events that have caused damages was not provided.

2.3 Summary of California Department of Water Resources Plans

2.3.1 Urban Level of Flood Protection Criteria, November 2013

The California Legislature passed Senate Bill 5 (SB 5) in 2007 that requires all new projects or reconstruction projects constructed in urban areas within the Sacramento-San Joaquin Valley to achieve an urban level of flood protection by 2025. An urban level of flood protection is defined as the level of flood protection necessary to withstand flooding that has a 1-in-200 chance of occurring in any given year. SB 5 and Assembly Bill 162 (AB 162), as amended by SB 1278, also requires cities and counties to amend their General Plans and Zoning Ordinances by no later than July 2, 2016 in order to address 200-year flooding by requiring that certain findings be made as part of the development review process. The intent of the legislation was to strengthen the link between flood management and land use. The following two sections of the SWMP explain the 2007 flood legislation's key requirements.

2.3.1.1 Senate Bill 5 Requirements

Senate Bill 5 establishes a requirement that "urban areas" and "urbanizing areas" begin applying a 200-year return period storm level of flood protection standard (urban level of flood protection) to new development no later than July 2, 2016 [thirty-six (36) months after the Flood Protection Plan was adopted by the state]. "Urban area" is defined as a developed area in which there are 10,000 residents or more; therefore, the City would currently be classified as an "urban area". According to SB 5, the 200-year standard will only be required to be applied to floodplain areas mapped by FEMA. The DWR has also published maps that depict "Preliminary 100- and 200-Year Floodplains Based Upon Best Available Data." The CVFED produced floodplain maps based on levee failure scenarios associated with streams located in the Chico area. Senate Bill 5 also authorized the DWR to develop criteria for an urban level of flood protection. In May 2012, DWR issued the Urban Levee Design Criteria (ULDC) that provides technical criteria for designing, constructing, operating, and maintaining a levee or floodwall for protection against a flood with a 1-in-200 annual chance of occurrence (i.e., a 200-year flood). In November 2013, DWR issued the Urban Level of Flood Protection (ULOP) criteria, which are procedural criteria for developing findings related to 200-year flood protection.

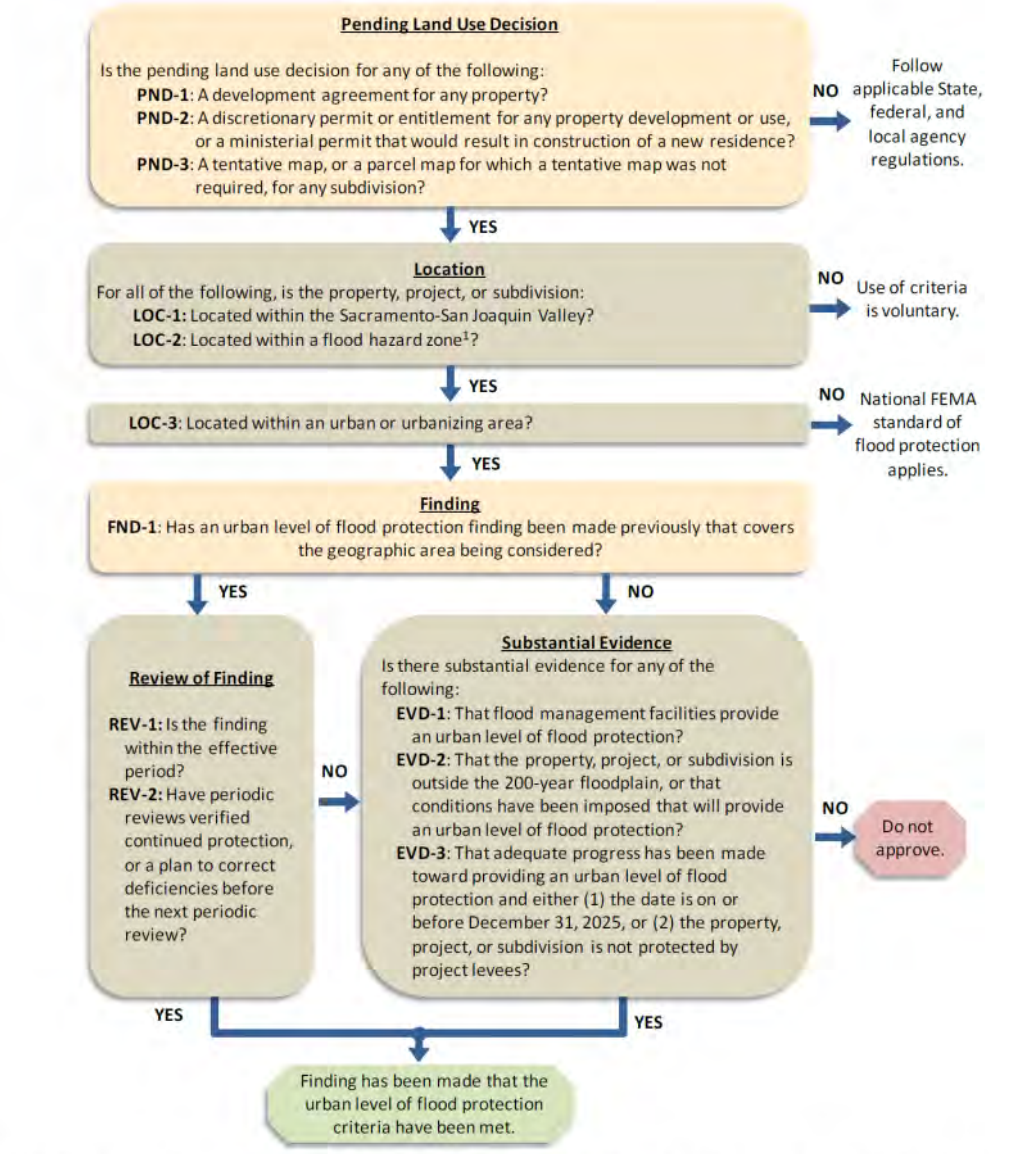
The ULOP criteria requires that cities and counties (land use decision-making entities) make a finding related to an urban level of flood protection before approving development in urban and urbanizing areas. Developed areas that have, or are projected to have, populations of 10,000 persons or more within ten (10) years must either have a 200-year level of flood protection or have adequate progress toward a 200-year level of flood protection. The California Code of Regulations Sections 65865.5, 65962, and 66474.5 require that cities and counties make a finding related to flood protection before making development decisions after July 2, 2016.

Documentation needed for compliance with the ULDC criteria include:

1. Design Water Surface Elevation (ULDC Section 7.1)
2. Minimum Top-of-Levee (ULDC Section 7.2)
3. Soil Sampling, Testing and Logging (ULDC Section 7.3)
4. Slope Stability for Intermittently Loaded Levees (ULDC Section 7.4)
5. Under-Seepage for Intermittently Loaded Levees (ULDC Section 7.5)
6. Frequently Loaded Levees (ULDC Section 7.6)
7. Seismic Vulnerability (ULDC Section 7.7)
8. Levee Geometry (ULDC Section 7.8)
9. Interfaces and Transitions (ULDC Section 7.9)
10. Erosion (ULDC Section 7.10)
11. Right-of-Way (ULDC Section 7.11)
12. Encroachments (Excluding Penetrations, Closure Structures, and Levee Vegetation) (ULDC Section 7.12)
13. Penetrations (ULDC Section 7.13)
14. Floodwalls, Retaining Walls, and Closure Structures (ULDC Section 7.14)
15. Animal Burrows (ULDC Section 7.15)
16. Levee Vegetation (ULDC Section 7.16)
17. Wind Setup and Wave Run-up (ULDC Section 7.17)
18. Security (ULDC Section 7.18)
19. Sea Level Rise (ULDC Section 7.19)
20. Emergency Actions (ULDC Section 7.20)
21. Operations, Maintenance, Inspection, Monitoring, and Remediation of Poor Performance (ULDC Section 8.0)

As outlined below in **Exhibit 6**, before approving any affected land use decisions, cities and counties are required to make a finding related to an ULOP or the national FEMA Guidelines and Policy Standards for flood protection based on the substantial evidence in the record for one of the following:

1. EVD-1 that the flood management facilities provide an urban level of flood protection.
2. EVD-2 that the property, project, or subdivision is outside the 200-year floodplain; or that conditions have been imposed that will provide an urban level of flood protection.
3. EVD-3 that adequate progress has been made toward providing an urban level of flood protection.



1. "Flood hazard zone" means an area subject to flooding that is delineated as either a special hazard area or an area of moderate hazard on an official flood insurance rete map issued by the Federal Emergency Management Agency (California Government Code Section 65007(d)).

Exhibit 6: Flowchart for Making Findings Related to Urban Level of Flood Protection

2.3.1.2 Assembly Bill No. 162 Requirements

AB 162 (2007) requires every city and county in the state to review and amend, as appropriate, the land use (California Government Code §65302(a)), conservation (California Government Code §65302(d)), and safety (California Government Code §65302(g)) elements of its general plan for the consideration and incorporation of information regarding flood hazards; mapping; and the establishment of flood risk management goals, policies, objectives, and feasible implementation

measures to help protect their communities from the effects of flooding. Cities and counties should refer to the publication, *Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities* [11] (2010 Handbook) for the best available information on the AB 162 (2007) statutory requirements. Assembly Bill 162 requires that community general plan updates include at least the following additions:

1. The conservation element shall identify rivers, creeks, streams, flood corridors, riparian habitats, and lands that may accommodate floodwater for purposes of groundwater recharge and storm water management.
2. The safety element shall identify information regarding flood hazards; establish a set of comprehensive goals, policies and objectives based on the identified flood hazard information for the protection of the community from the unreasonable risks of flooding; and establish a set of feasible implementation measures designed to carry out the goals, policies and objectives.
3. Each applicable county or city shall submit the draft element of, or draft amendment to, the safety element to the Central Valley Flood Protection Board and to every local agency that provides flood protection to territory in the county or city.

2.3.2 Geotechnical Data Report (GDR) Chico North Study Area

The *Geotechnical Data Report (GDR) – Final, Chico North Study Area* was prepared by the DWR in association with URS Corporation (URS) and dated October 2010. The 2010 GDR was part of DWR's Urban Levee Geotechnical Evaluation (ULE) Program. The 2010 GDR includes portions of the left banks of Sycamore, Mud, and Dry Creeks, and the Sycamore Creek Diversion Channel. Mud Creek upstream from Sycamore Creek is not included because this is not an urban levee.

2.3.3 Geotechnical Data Report (GDR), North NULE Project Study Area

The *Geotechnical Data Report (GDR), North NULE Project Area* report prepared by URS and dated November 2012 provides information about the Non-Urban Levee Evaluation (NULE). Volume 1 of the GDR provides an overview and Volume 10 focuses on the Chico Area.

2.3.4 Geotechnical Overview Report Volume 1, Existing Conditions

The *Geotechnical Overview Report, Volume 1, Existing Conditions, Chico North and South Study Area Levee Segments 104, 263, 274, 381, and 45* (GOR) dated August 2014 and prepared by URS describes the scope of the NULE and the results of the assessment. Segment 274 is the right bank of the Little Chico Butte Creek Diversion Canal, Segment 263 is the right bank of Butte Creek, and Segment 45 is the right bank of Mud Creek upstream from Sycamore Creek. The GOR discusses potential issues and information on a reach-by-reach basis along each segment.

2.3.5 Mid & Upper Sacramento River Regional Flood Management Plan, November 10, 2014

The Mid & Upper Sacramento River Regional Flood Management Plan [12] (MUSR RFMP) identifies the city of Chico as the only urban area within the coverage area of the document. The Chico Urban Area was assumed to be the City of Chico sphere of influence together with directly-adjacent, developed unincorporated areas. Section 8.3.2, Levee System Description, states, *"The levees are maintained by the Butte County Department of Public Works, and the channels and diversion structures are maintained by DWR."*

The MUSR RFMP provides the following concise description of the regional drainage system associated with the State Plan of Flood Control (SPFC). Figures 8-3 and 8-4 from the MUSR RFMP, taken from the *Operation and Maintenance Manual for Chico and Mud Creeks and Sandy Gulch* (O&M Manual SAC504) [13] and *Operation and Maintenance Manual for Upper Butte Creek – Part No. 2 from Little Chico Creek Diversion Structure Down Stream 9.3 Miles* [14] (O&M Manual SAC516)[1], show the SPFC levees associated with the Chico area streams and are included as **Exhibit 7** and **Exhibit 8**.

> *The Chico urban area relies on a system of existing levees, bypasses and control structures for its flood protection. The Big Chico Diversion and the Sycamore and Mud Creek levee systems are located north of Chico, CA and were designed by the United States Army Corps of Engineers (USACE) in the 1960's to protect Chico from flooding during major storm events. The levees are maintained by the Butte County Department of Public Works, and the channels and diversion structures are maintained by DWR.*
>
> *The Mud Creek/Big Chico Creek watershed covers portions of northwest Butte County and southeast Tehama County. The watershed originates at the headwaters of Big Chico Creek and Mud Creek located in Chico Meadows and Cohasset Ridge, respectively. The watershed drains approximately 209 sq. miles and contains four main streams: Big Chico Creek, Mud Creek, Sycamore Creek, and Rock Creek. Big Chico Creek and Mud Creek are the principal streams of the watershed. Rock Creek and Sycamore Creek are the primary tributaries to Mud Creek. A number of smaller tributary creeks enter Sycamore Creek including Dry Creek and Sycamore Creek Spike (Sheep Hollow) along with a number of other small creeks.*
>
> *There are two flood control diversion structures and one diversion bypass channel in the watershed. The first diversion structure is the Big Chico Creek gates. The Big Chico gates limit the flow in Big Chico Creek through the City of Chico to the channel design capacity of 1,500 cfs. The second diversion structure is the Lindo Channel gates located just downstream of the Big Chico gates. The Lindo Channel gates limit the flow in the Lindo Channel to the design capacity of 6,000 cfs, diverting excess flows over the Sycamore Weir into the Sycamore Creek Diversion. The Sycamore Creek Diversion has a design capacity of 8,500 cfs and conveys diverted flood flows around the City of Chico through Sycamore Branch, Sycamore*

[1] DWR prepared these figures using GIS in order to provide updated location maps based on those in the O&M Manuals.

Creek to Mud Creek before finally flowing to the Sacramento River. SPFC levees provide flood protection along the Sycamore Creek Diversion and along portions of Dry, Sycamore, and Mud creeks. Failure or overtopping of these structures could result in flooding of portions of the City of Chico.

Floodwaters from Little Chico Creek to the south are also diverted away from the city of Chico into Butte Creek by a diversion structure and diversion channel. While these streams rise rapidly and generally flow high for a limited duration, a prolonged storm event could potentially create an extended flow situation which would greatly increase the flood threat on this system.

Figure 8-3 shows an overview of the Big Chico Creek system, and Figure 8-4 shows an overview of the Little Chico Creek System.

The Butte Creek/Little Chico Creek watershed is located southeast of the Mud Creek/ Big Chico Creek watershed and northwest of the Feather River. The watershed is located primarily in Butte County with small portions of the watershed located in Tehama and Plumas counties. The watershed drains approximately 185 sq. miles and contains two main streams: Butte Creek and Little Chico Creek. Butte Creek originates in Jonesville Basin (Lassen National Forest) and flows to the Butte Slough before eventually entering the Sacramento River. Butte Creek enters the Sacramento River at two locations: through Butte Slough and through the Sutter Bypass. Little Chico Creek originates north of Butte Creek, and enters Butte Creek through the Little Chico Creek Diversion. The Little Chico Creek Diversion provides flood protection to the City by diverting flood flows in excess of 3,000 cfs to Butte Creek by way of the diversion weir and diversion channel. SPFC levees provide flood protection along portions of the Little Chico Creek Diversion and Butte Creek.

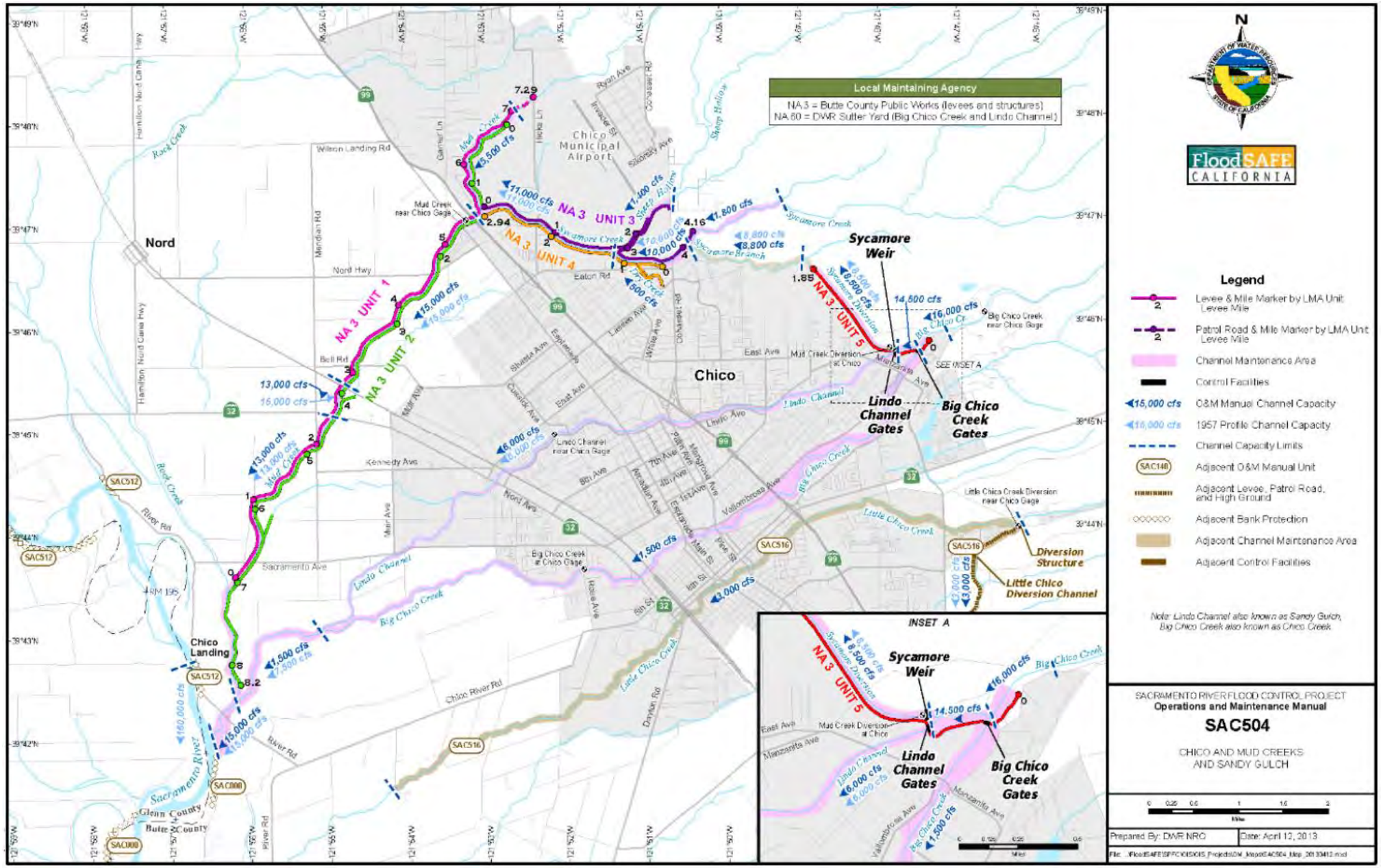


Exhibit 7: Figure 8-3 from the MUSR RFMP, Overview of the Big Chico Creek Levee System

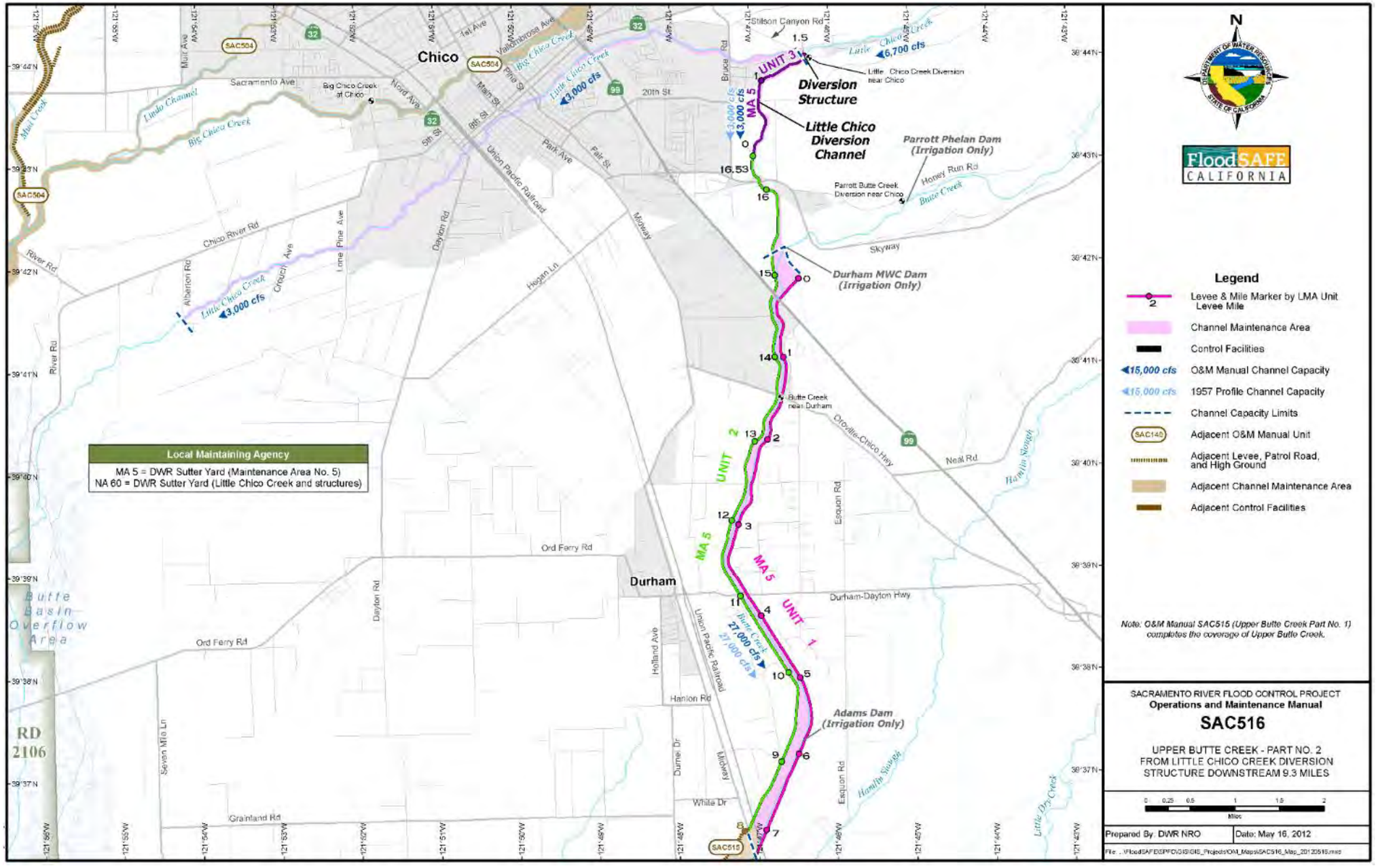


Exhibit 8: Figure 8-4 from the MUSP MFMP, Overview of the Little Chico Creek Levee System

The MUSR RFMP describes the FEMA Provisional Accredited Levee (PAL) program, the State Urban Levee Design Criteria, the State Urban Level of Protection Criteria, and DWR's ULE and NULE programs. The MUSR RFMP refers to a forthcoming Geotechnical Evaluation Report (GER) for the ULE and a forthcoming GOR for NULE. Draft results from the GER and GOR that identify some areas of levee deficiencies were presented.

Section 10.5 describes channel hydraulic analysis with updated hydrology that was completed as part of this SWMP to update and refine levee freeboard analysis that is more accurate than that included in the MUSR RFMP.

Limitations of DWR's 200-Year Floodplain Mapping are presented in Section 8.5.1 of the MUSR RFMP. The MUSR RFMP concluded that the informational maps prepared in 2013 as part of the CVFED program may need to be substantially refined before using them to make ULOP findings for the Chico Urban Area.

The MUSR RFMP describes maintenance issues and provides information about potential improvements. Key recommendations include:

1. Development of an enhanced channel maintenance program;
2. Investigation of a potential Sheep Hollow Off-Stream Storage Area;
3. Mud Creek Union Pacific Railroad (UPRR) Bridge crossing improvements; and
4. Early flood warning system improvements.

2.3.6 Sacramento River Basin System-Wide Hydraulic Routing Model – Technical Report

The Sacramento River Basin System-Wide Hydraulic Routing Model – Technical Report [15] (SRR Report), December 31, 2014, prepared by Wood Rodgers for DWR, documents the development of the Sacramento River Routing (SRR) model that added 196 stream miles to the Combined System Routing (CSR) model. The goals of the SRR model included support of flood forecasting, maintenance of SPFC facilities, emergency preparedness and response planning, and regional plan formulation. The SRR Report references Lindo Channel model geometry data from a previously prepared DWR Northern Regional Office study. The Chico area streams had been included in the CSR model. Numerous refinements to the Chico area streams were made in the development of the SRR model from the CSR model. These refinements were documented in the SRR Report.

2.3.7 Geotechnical Evaluation Report (GER), Chico North Study Area

The *Geotechnical Evaluation Report (GER), Chico North Study Area* (dated March 2015) was prepared by DWR in association with URS. The GER was prepared as part of the ULE and focused on the portions of the left banks of Mud Creek and Sycamore Creek, the left and right banks of Dry Creek, and the portions of the Sycamore Diversion Channel that are closest to the more populated areas of the city of Chico. The GER presents an evaluation of the existing conditions of the following areas: 1) approximately 2.7 miles of the SPFC levee along the left bank of Mud Creek between its confluence with Sycamore Creek to the north and the Union Pacific Railroad tracks to the south; 2) 2.1 miles of the SPFC levee along the left bank of Sycamore Creek between

its confluence with Mud Creek to the west and its intersection with East Eaton Road to the east; 3) 0.6 mile of SPFC levees along both left and right banks of Dry Creek; and 4) 1.4 miles of SPFC levee along the left bank of Sycamore Diversion Channel from where it connects to Lindo Channel in Bidwell Park (to the northwest) to where the levee ends and merges with high ground. These levees are referred to as being located in the Chico North Study Area in Butte County, California.

The GER identified freeboard deficiencies along Dry Creek, on Sycamore Creek upstream from Dry Creek, and along Mud Creek in the vicinity of Bell Road. Details of the various evaluations are provided in the GER.

2.3.8 Sacramento River System Study Area Report

The *Sacramento River System Study Area Report* [16] dated May 29, 2015, was prepared by Wood Rodgers for DWR to provide documentation for the Refine/Calibrate Combined Sacramento River and San Joaquin River Systems (Refine/Calibrate) task. The Refine/Calibrate task was a system-wide effort to improve the HEC-RAS models that were prepared under Task Order No. 34 of the CVFED Program. Flood events from 1997 and 2006 were used in the calibration effort. Specific sections of the Sacramento River System Study Area Report relevant to the City of Chico are Section 4.1.2.5, Little Chico Butte Creek Diversion Channel Model Refinement, and Section 5.1.1, Chico Area Streams (Mud Creek, Big Chico Creek, Sycamore Creek and Lindo Channel).

It should be noted that a review of Section 4.1.2.5 in the Refine/Calibrate Report revealed that the model improvements described were not included in the 2017 Central Valley Flood Protection Plan (CVFPP) model provided by DWR.

Section 4.3.1 and Exhibit 19 within the Refine/Calibrate Report provide detailed information about the availability of gage data for the study events and the methods for setting event inflows. Based on available data, it was concluded that the Sycamore Bypass gate operation rules were not followed during the 1997 event. The Refine/Calibrate Report relied upon stage data and model rating curves rather than on reported gage rating curves.

2.3.9 State Plan of Flood Control Descriptive Document Update

The *State Plan of Flood Control Descriptive Document Update* [17] (dated August 2017) is intended to serve as a reference for flood management planners. The 2017 SPFC Descriptive Document Update works with the 2010 SPFC Descriptive Document Update. Table 3-3 of the 2017 SPFC Descriptive Document Update lists the O&M Manuals and maintaining agencies for various SPFC facilities. The Big Chico Creek Gates (Diversion Control Structure), the Lindo Channel Gates (Control Structure), and the Sycamore (Lindo Channel Diversion) Weir are shown as being maintained by Butte County Public Works and covered by the SAC504 O&M Manual. The Little Chico Creek Diversion Structure is listed as being maintained by the DWR Sutter Maintenance Yard and covered by the SAC516 O&M Manual.

2.3.10 Chico Final Central Valley Hydrology Study Hydrology Review

The *Chico Final Central Valley Hydrology Study* (CVHS) *Hydrology Review* [18] dated May 14, 2013 (Rev.) was prepared by CH2M Hill for DWR as part of Task Order 32 of the CVFED Program. The Chico Final CVHS Hydrology Review documents the 200-year and 500-year flows for the Chico area streams including Butte Creek and Butte Creek Diversion. Tables listing peak flows and plots of hydrographs were included. The Big Chico Creek and Lindo Channel inflow-diversion functions are provided.

2.4 Summary of Federal Plans

2.4.1 Chico and Mud Creeks and Sandy Gulch General Design

The *Chico and Mud Creeks and Sandy Gulch General Design* [19] document dated June 21, 1961 is the U. S. Army Corps of Engineers' design memorandum covering the subject streams. It establishes design flows, describes flood control improvements that existed prior to the project, and presents the design of the proposed system. A flood damage reduction benefit was computed that supported a benefit-to-cost ratio greater than 1.

2.4.2 Operation and Maintenance Manual for Chico and Mud Creeks and Sandy Gulch

The Operation and Maintenance Manual for Chico and Mud Creeks and Sandy Gulch [13] dated May 1965 identifies the City of Chico as being responsible for the operation and maintenance of the diversion structures on Big Chico Creek near its bifurcation with Sandy Gulch and on Lindo Channel one-quarter mile downstream from its bifurcation with Chico Creek, as well as the concrete sill at the head of Lindo Channel near the Big Chico Creek Culvert. The City maintenance obligation has since been terminated and is now the responsibility of Butte County The DWR is responsible for semi-annual reporting to USACE.

A detailed list of design flows in cubic feet per second (cfs) is provided below in **Table 1**.

Table 1: Project Design Flows

Stream	Discharge (cfs)
Big Chico Creek (upper)	16,000
Diversion Channel	8,500
South Sycamore Creek	8,800
Sycamore Creek (Sta 365+39 – Sta 447+40)	11,000
Sycamore Creek (Sta 449+79 – Sta 499+65)	10,000
Mud Creek (Sta 222+90 – Sta 361+25)	15,000
Mud Creek (Sta 206+02 – Sta 222+90) Channel	13,000
Mud Creek (Sta 206+02 – Sta 222+90) Levees	15,000
Mud Creek (Sta 9+56 – Sta 206+02)	13,000
Big Chico Creek Lower	15,000
Lindo Channel	14,500
Mud Creek (extended)	5,500
Sheep Hollow	1,400
Dry Creek	500
North Sycamore Creek	1,800
Big Chico Creek – Unimproved (Mud Creek to Diversion Works)	1,500
Sandy Gulch – Unimproved (Lindo Channel)	6,000

The O&M Manual provides maintenance procedures for the above streams. Locations of drainage and irrigation penetrations through the levees are also identified.

2.4.3 FEMA Revised Countywide Flood Insurance Study

The latest revision of the *Flood Insurance Study Butte County, California and Incorporated Areas* [2](FIS) is dated January 6, 2011. The FIS investigated the existence and severity of flood hazards in the geographic area of Butte County and included revising and updating previous FIS/Flood Insurance Rate Maps (FIRMs). The FIS also describes the FEMA hydrology and hydraulic analysis that is unchanged since the original FIS dated June 8, 1998. The FIS provides the results of the analysis with flooding summaries, hydraulic profiles, base flood elevations, the associated map of the FEMA Special Flood Hazard Areas (SFHAs) presented on **Figure 5**, and the following Summary of Peak Discharges (**Table 2**) with flows stated in cfs and tributary areas listed in square miles (sq. mi.).

Table 2: Summary of Peak Discharges						
Flooding Source	**Location**	**10YR (cfs)**	**50YR (cfs)**	**100YR (cfs)**	**500YR (cfs)**	**Drainage Area (sq. mi.)**
Big Chico Creek	Upstream of Big Chico Creek Diversion Structure			11,000		73.65
Big Chico Creek	Downstream of Diversion Structure (Upstream of Manzanita)			1,400		73.65
Big Chico Creek	Road Bend at Bidwell Ave.			1,730		75.56
Big Chico Creek Diversion Channel	Upstream of Confluence with Sycamore Creek			6,070		4.69
Big Chico Creek Diversion Channel	Downstream of Confluence with Sycamore Creek			5,600		
Comanche Creek	Approximately one mile above Midway	300	550	6,300	16,800	
Comanche Creek	Approximately 1,500 feet above Midway	300	550	3,000	3,000	
Comanche Creek	At Midway	300	550	2,300	2,300	
Comanche Creek	At Union Pacific Railroad	400	800	2,100	2,100	
Dead Horse Slough	At confluence with Little Chico Creek	750	1,500	1,900		5.36
Lindo Channel	Upstream of confluence with Channel Slough/ Sandy Gulch (0.6 mi. downstream of SR 32)			4,600		5.25
Lindo Channel	Downstream of Big Chico Creek Diversion Structure			4,000		
Little Chico-Butte Creek Diversion Channel	At Diversion Structure	700	2,200	3,100	4,900	
Little Chico Creek	Below Diversion Structure	2,300	4,400	5,600	7,800	
Little Chico Creek	At Forest Avenue	1,500	2,000	2,200	2,500	
Little Chico Creek	At State Route 99 (SR 99)	2,100	3,400	3,700		
Little Chico Creek	Approximately 100 feet above Bruce Street	2,100	3,400	3,500	3,700	
Little Chico Creek	At Bruce Street	2,200	3,100	3,100	3,100	
Little Chico Creek	At Mills Street (Location?)	2,200	2,800	2,800	2,800	
Little Chico Creek	At Crouch Road (Avenue)	2,200	2,500	2,500	2,500	

Figure 6 presents the locations of the flow rate changes listed in Table 2.

2.4.4 FEMA Levee Certification Letter, May 12, 2011

The FEMA Certification Letter [20] references PAL documentation and found that the south side of the Sycamore-Mud Creek Levee System meets the minimum criteria in the Code of Federal Regulations (CFR) 65.10.

2.4.5 Central Valley Hydrology Study: Mud Creek/Big Chico Creek Watershed Hydrologic Analysis

The *CVHS: Mud Creek/Big Chico Creek Watershed Hydrologic Analysis* [21] dated March 1, 2013 documents the process used to develop flow-frequency estimates for streams within the Chico area that have peak flows controlled by runoff coming from the Mud Creek and Big Chico Creek Watersheds, generally to the north of the City. Design storm peak flows were established at various analysis points for standard recurrence intervals from 10-year to 500-year events. The process used to develop and calibrate the watershed hydrology is also presented.

2.4.6 Central Valley Hydrology Study: Butte Creek Watershed Hydrologic Analysis

The *CVHS: Butte Creek Watershed Hydrologic Analysis* [22] dated March 12, 2013 documents the process used to develop flow-frequency estimates for streams within the Chico area that have peak flows controlled by runoff coming from the Butte Creek and Little Chico Creek Watersheds, generally to the northeast of the City. Design storm peak flows were established at various analysis points for standard recurrence intervals from 10-year to 500-year events. The process used to develop and calibrate the watershed hydrology is also presented.

3.0
Municipal Code Update Recommendations and Design Criteria

3.0 MUNICIPAL CODE UPDATE RECOMMENDATIONS AND DESIGN CRITERIA

Design criteria related to storm water cover, storm water quality, floodplain regulation and storm drainage are promulgated in the City's Municipal Code (CMC). Recommendation for updates to the CMC were developed as part of the SWMP. **Appendix A** contains markups of applicable sections from the CMC with comments and recommended changes.

CMC sections related to FEMA floodplain requirements, DWR ULOP, NPDES and local drainage requirements were reviewed. The specific CMC sections that were reviewed are:

1. CMC–- 15.50 Storm Water Management
2. CMC–- 16 Floodplain Regulation
3. CMC–- 18R_08_050 Storm Drainage

3.1 Storm Water Quality

A comprehensive discussion of storm water quality elements is provided in Section 4.0.

The recommended changes to *CMC–- 15.50 Storm Water Management* focus on improving consistency between the CMC, the Phase II Municipal Permit, and the Post-Construction Standards Plan [23] (PCSP). Additional changes to the CMC will be needed when the PCSP is updated to address the Trash Amendment to the Phase II Municipal Permit in order to maintain consistency. Recommended changes to *CMC–- 15.50 Storm Water Management* are included in **Appendix A-1**.

Low Impact Development (LID) and Hydromodification Management (HM) measures have the potential to impact the rate and volume of runoff from development projects during more frequent storm events. LID and HM criteria are detailed in the Post-Construction Standards. The effectiveness of existing LID and HM measures at reducing existing conditions storm water discharges have been included in the SWMP analysis to the extent that features, such as surface detention basins and underground facilities, have been incorporated into the model. A more generalized approach that applies a reduction in effective impervious area to future development was used to evaluate expected build-out conditions. The build-out conditions model assumes that the requirements of the Post-Construction Standards Plan will be met and that the hydrologic benefits of LID and HM described in **Section 7.2.3** will be achieved.

3.2 Floodplain Regulations

The stated objectives of CMC–- 16 Floodplain Regulation include preventing increases in flood heights and velocities, minimizing private and public losses due to flood conditions, and meeting National Flood Insurance Program (NFIP) requirements in order to make it so that flood insurance can be made available at reasonable rates.

The proposed revisions to the City's Floodplain Regulations are intended to comply with the ULOP Criteria presented in **Section 2.3.1**.

The City's Floodplain Regulations call for structures to be elevated to a minimum of the base flood elevation. It is recommended that buildings be elevated to a minimum of one foot above the base flood elevation in order to address uncertainties in determining flood risks.

Recommended changes to *CMC–- 16 Floodplain Regulations* are included in **Appendix A-2**.

The models of streams, floodplains and storm drainage systems prepared as part of the SWMP could be used to update the floodplain maps that cover the City's sphere of influence. **Section 10.0, Review of Creeks and Channels**, describes how the models were used to prepare floodplain mapping and stream profiles for various storm events.

3.2.1 Community Rating System

According to the FEMA website [24]:

The Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management practices that exceed the minimum requirements of the National Flood Insurance Program (NFIP). Over 1,500 communities participate nationwide.

In CRS communities, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from the community's efforts that address the three goals of the program:

1. *Reduce and avoid flood damage to insurable property*
2. *Strengthen and support the insurance aspects of the National Flood Insurance Program*
3. *Foster comprehensive floodplain management*

Annex B to the Butte County Local Hazard Mitigation Plan Update [10] summarizes information about the NFIP in the City. The City joined the NFIP on June 11, 1997; however, the City is not a participant in the CRS program. Participating in the CRS could help the City better achieve its objective of making flood insurance available at reasonable rates. CRS participation can result in discounts of up to 45 percent on flood insurance premiums.

3.3 Storm Drainage

The recommended changes to CMC–- 18R_08_050 Storm Drainage are intended to address inconsistencies, improve definitions, provide flexibility, and update outdated information.

3.3.1 Rational Method

The City's design criteria are based on Rational Method. The Rational Method calculates discharge as the product of a runoff coefficient, rainfall intensity and contributing area.

3.3.1.1 Runoff Coefficients

The table of runoff coefficients referenced in the CMC is included as **Table 3**.

Table 3: Runoff Coefficients	
Land Use	**C**
Landscaped area	0.25
Residential	
Rural (up to 2 units/acre)	0.35
Low-density (2+ to 6 units/acre)	0.50
Medium-density (6+ to 14 units/acre)	0.60
High-density (14+ units)	0.75
Public	0.40 - 0.70
Schools, Hospitals	0.35 - 0.70
Commercial	0.70 - 0.90
Industrial	0.70 - 0.90
Highway	0.80 - 0.90

The runoff coefficients included in the CMC are typical for the indicated land uses and are appropriate for computing peak discharge rates that can be appropriately estimated using average rainfall intensity for a duration equal to the time of concentration for the contributing area. The table of runoff coefficients does, however, provide ranges of values for various land uses which can cause uncertainty in the process of selecting an appropriate coefficient. The uncertainty in selecting runoff coefficients can be limited by specifying that the coefficients shall not be less than the area-weighted averages of 0.2 for pervious areas and 0.9 for impervious areas.

In many cases, the contributing area may include detention basins or systems that promote infiltration. Detention basins and infiltration systems cause peak runoff rates to be less than the rates calculated using the Rational Method. Hydrograph routing methods should be used to compute runoff rates and volumes for conditions that are not consistent with the underlying assumptions of the Rational Method.

3.3.1.2 Rainfall Intensity from Current Standards

The City's Standards include a set of intensity-duration-frequency (IDF) curves (included below as **Exhibit 9**) that were adopted in 1981 and were based on data published in 1976.

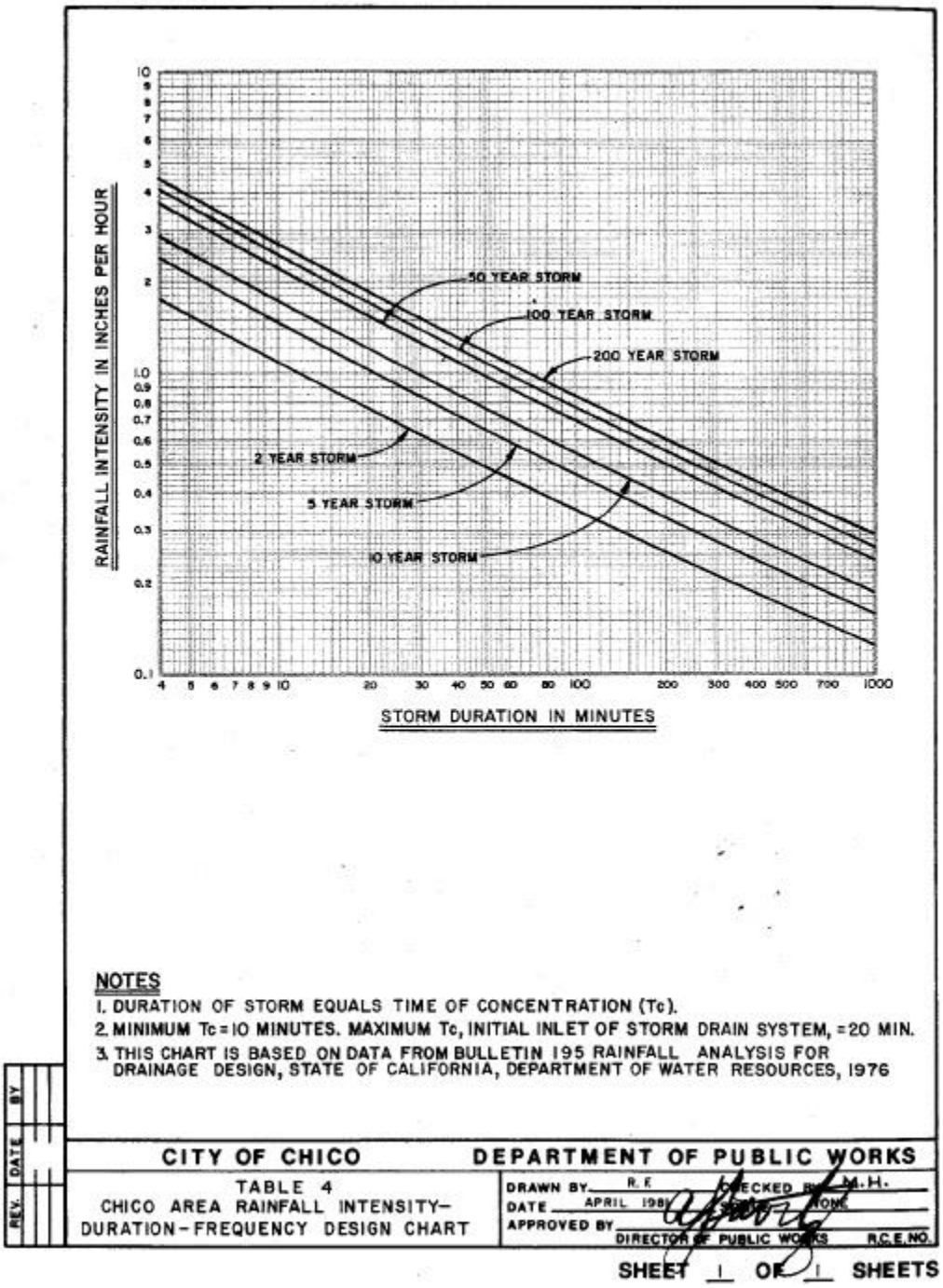


Exhibit 9: Current Intensity-Duration-Frequency Curves

The current IDF curves were determined to match an equation in the form of:

$$i = \frac{a}{t^b}$$

Where the "i" in the formula above is the precipitation intensity in inches per hour for a duration of "t" in minutes. The coefficient "b" was determined to be 0.492. The coefficient "a" was determined to be 3.44, 5.36, and 7.59 inches per hour for the 2-year, 10-year, and 100-year storm events, respectively.

Rather than continue to use outdated precipitation data, an alternative approach that uses precipitation zones to assign design precipitation values is recommended. The recommended approach is described in **Section 6.2.1**. As presented below in **Exhibit 10**, the recommended precipitation intensities in the lowest recommended precipitation zone are higher than those based on the current CMC.

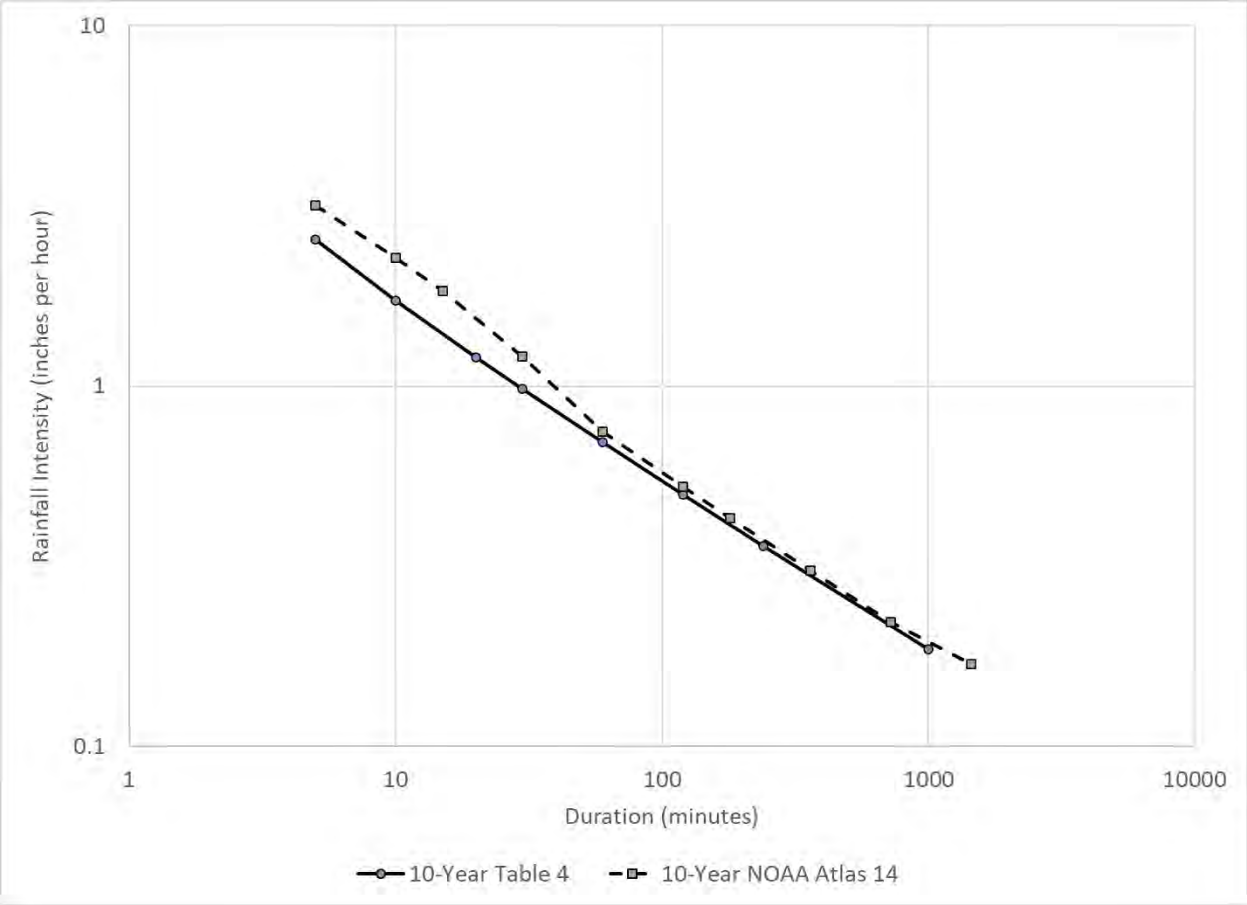


Exhibit 10: Comparison of 10-Year Precipitation Intensity from CMC to NOAA Atlas 14

Recommended changes to *CMC–- 18R_08_050 Storm Drainage* are included in **Appendix A-3**.

4.0
Storm Water Quality

4.0 STORM WATER QUALITY

The objective of this section of the SWMP is to provide information necessary for the SWMP to be consistent with, and assist in addressing, the regulatory requirements and other related planning and implementation programs pertaining to storm water quality, pollutant load reductions, and implementation of treatment controls, that include the following:

- NPDES General Permit for Waste Discharge Requirements (WDRs) for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) (Phase II MS4 Permit); [25]
- NPDES General Permit for Storm Water Discharges Associated with Industrial Activities (Industrial General Permit or IGP);
- Amendments to the Water Quality Control Plan for the Ocean Waters of California to Control Trash and Part 1 Trash Provisions of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California (Statewide Trash Amendments);
- Amendments to Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California—Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions (Statewide Mercury Provisions);
- Amendment to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Pyrethroid Pesticide Discharges (Pyrethroid Control Program);
- Salt and Nitrate Control Programs for the Central Valley Region (Salt Control Program); and
- Storm Water Resource Planning (SWRP) consistent with SB 985, the Storm Water Management Planning Act of 2014.

4.1 Regulatory Requirements and Implementation

This section summarizes the key regulatory requirements for the storm water program as they pertain to the focus of the SWMP – implementation of storm water projects and treatment controls and the operation and maintenance of the storm water drainage infrastructure.

4.1.1 Phase II MS4 Permit

The Phase II MS4 Permit (Water Quality (WQ) Order 2013-0001-DWQ[2]) was adopted by the State Water Resources Control Board (SWRCB) in February 2013 and it expired in July 2018 (although it has been administratively extended until the permit is reissued[3]). Consistent with the Clean

[2] As amended by Orders 2015-0133-EXEC, 2016-0069-EXEC, 2017-XXXX-DWQ, 2018-0001-EXEC, and WQ 2018-0007-EXEC

[3] Reissuance of the Phase II MS4 Permit is underway as of the writing of this report. (https://www.waterboards.ca.gov/water_issues/programs/stormwater/docs/remediated_phase2ms4permit_v2.pdf) The schedule published by the State Water Board anticipates release of the draft Order in 2024. Reissuance would follow the formal public comment period.

Water Act, this permit requires the City to implement a wide range of BMPs to reduce pollutants from the MS4 to the maximum extent practicable (MEP).[4] The specific provisions that are most related to the SWMP are summarized in **Table 4**, below.

Table 4: NPDES Phase II Permit Sections Applicable to the SWMP

Phase II Permit Section		Description
D.	Receiving Water Limitations	The City must describe the BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce pollutants that are identified as causing or contributing to exceedances of water quality standards. *The City implements a wide range of BMPs to reduce pollutants in the discharges and modifies them as needed.*
E.11	Pollution Prevention/ Good Housekeeping	The City must inventory and map City-owned or operated facilities and include the storm drains receiving discharges from the facility and the outfalls and receiving water that the drainage flows to (E.11.b). The City must prevent or reduce the amount of pollutant runoff from Permittee operations including: (d) Storm Water Pollution Prevention Plan (f) Storm Drain System Assessment and Prioritization (g) Maintenance of Storm Drain System (i) Incorporation of Water Quality and Habitat Enhancement Features in New Flood Management Facilities *The City has assessed and prioritized the storm drain system maintenance, maintained the storm drain system, and incorporated water quality and habitat enhancement features in new facilities as applicable. In addition, the City has developed an MS4 Water Pollution Prevention & Monitoring Plan for the Municipal Service Center.*
E.12	Post Construction	The City must regulate public and private development projects to ensure that site design, source control, and low impact design standards are incorporated to reduce the volume of runoff, treat storm water, and provide baseline hydromodification management. Additionally, the City must regulate larger projects to ensure full hydromodification management. The City must inventory and assess the maintenance condition of structural post-construction BMPs (including BMPs used for flood control). E.12.h requires that the City implement an operations and maintenance verification program. E.12.i requires that the City inventory and assess the maintenance condition of the structural post-construction BMPs. *The City has developed a Post-Construction Standards Plan* [23] *(March 2017) to guide project proponents and municipal plan checkers through the post construction requirements. The volumetric and flow-based design criteria are specified in Sections 5.4.2 and 5.4.3 of the City's Post-Construction Standards Plan.*
E.13	Water Quality Monitoring	Consistent with E.13.d.1, the City must conduct receiving water monitoring. *The City conducts receiving water monitoring in Big Chico Creek (see **Section 3.3**).*

[4] Defined in Phase II MS4 Permit, Attachment I

The City submits an annual report every October 15th summarizing the activities completed for each program element.

Although draft permit language has not yet been released, preliminary discussions with SWRCB staff indicate that the Phase II MS4 Permit may include new requirements relevant for the SWMP planning process, including:

- Pollutant load reduction assessments and plans as a compliance pathway for Permit Section D (Receiving Water Limitations)
    - This may include a requirement for pollutant load reduction assessments and/or modelling to demonstrate attainment of the water quality objectives over a specific timeframe based on the best management practices that are implemented.

- Asset management as a part of Permit Section E.11 (Pollution Prevention/Good Housekeeping)
    - This may include a focus on assets related to storm water quality that could be used within an overall asset management approach such as:
        - Inventory and mapping of storm water conveyance systems, inlets, and/or outfalls to receiving waters;
        - Information based on inventories and mapping completed for installed structural treatment controls (publicly owned and operated);
        - Information based on the inspections, operations and maintenance of the storm water conveyance system and structural treatment controls; and
        - Information on and identification of opportunities that may have been evaluated through long-term storm water program planning documents.

- Implementation of the Statewide Trash Amendments
    - This may include updates to jurisdictional maps and priority land uses areas, specific implementation milestones, demonstration of full capture system O&M, and/or monitoring and reporting requirements.

4.1.2 Industrial General Permit

The IGP (Order 2014-0057-DWQ) was adopted on April 1, 2014 and became effective on July 1, 2015. It was subsequently amended in 2015 and again in 2018. Although the Order expired on June 30, 2020, it has been administratively extended until it is renewed, which is anticipated to occur before the end of 2026. The Chico Municipal Airport is subject to the IGP and, therefore, has developed and is implementing a Storm Water Pollution Prevention Plan (SWPPP) and a Monitoring Implementation Plan (MIP).

The SWPPP identifies and includes facility-specific information such as site maps, industrial materials handled/stored on-site, potential pollutant sources, the best management practices that are implemented, and the inspections and monitoring that occurs. The SWPPP specifically

identifies Advanced BMPs that are implemented on-site (Section 8.2), which primarily include exposure minimization, storm water containment, and discharge reduction BMPs. If treatment control BMPs are desired or necessary in the future, they would need to be designed to a standard that is consistent with Section X.H.6 of the IGP (Design Storm Standards for Treatment Control BMPs – Volume-Based or Flow-Based BMPs).

The MIP summarizes the monitoring that occurs and that is consistent with the IGP and includes a description of the visual observation procedures and locations as well as the sampling procedures, locations, and methods. Visual observations are generally focused on floating and suspended materials, oil and grease, discolorations, turbidity, odors, and trash and debris. Water quality monitoring is also conducted for total suspended solids, oil and grease, and pH.

It should be noted that the pollutants of concern, BMP design criteria, and operations and maintenance requirements that are required pursuant to the IGP, SWPPP, or MIP are only applicable to SWMP projects that would occur on-site at the airport (or within the area that is regulated by the IGP).

4.1.3 Statewide Trash Amendments

On April 7, 2015, the SWRCB adopted the Proposed Final Amendment to the Water Quality Control Plan for Ocean Waters of California (Ocean Plan) and the Proposed Final Part 1 Trash Provisions of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California [26] (Statewide Trash Amendments). The goal of the Statewide Trash Amendments is to address the impacts of trash to the surface waters of California through the establishment of a statewide narrative water quality objective and implementation requirements to control trash, including a prohibition against the discharge of trash. The Statewide Trash Amendments became effective on December 2, 2015; full compliance with the Trash Amendments is required by December 2, 2030.

Subsequently, the SWRCB staff issued a California Water Code Section 13383 Order on June 1, 2017, for all Phase II permittees (including the City) requiring selection of a compliance track and additional supporting information. The City selected Track 1, which requires the installation, operation, and maintenance of full capture systems[5] (FCS) for all storm drains that capture runoff from the priority land uses (PLUs) within the City's jurisdiction. PLUs, as defined in the Statewide Trash Amendments, include high-density residential, industrial, commercial, mixed urban, and public transportation stations.

In September 2018, the City developed a Trash Master Plan that consisted of an Implementation Plan and an O&M Plan. The Implementation Plan used a prioritized, phased approach for the verification of existing, and installation of, new FCS. New FCS installations were classified as

[5] A treatment control, or series of treatment controls, including, but not limited to, a multi-benefit project or a low-impact development control that traps all particles that are 5 mm or greater, and has a design treatment capacity that is either: a) of not less than the peak flow rate, Q, resulting from a one-year, one-hour, storm in the subdrainage area; or b) appropriately sized to, and designed to carry at least the same flows as, the corresponding storm drain.

"small, medium, and large" devices depending on tributary area. Criteria for these classifications include:

- Small Distributed FCS = 6- (or sometimes less) to 30-acre drainage area
- Medium Regional FCS = 30- to 100-acre drainage area
- Large Regional FCS = > 100-acre drainage area.

The phasing for the installation of new FCS was planned as indicated in **Table 5**, below:

Table 5: Phasing for Installation of Full Capture Systems

Calendar Year	Planning	Regional FCS	Distributed FCS
2019-22	Planning for FCS in SWRP areas, downtown, and areas draining to Bidwell Park	Installation of 8 small, 5 medium, and 3 large FCS in SWRP and downtown areas	Installation of 3 FCS in SWRP areas; installation of 27 FCS in areas downtown and areas draining into Bidwell Park or northwestern areas
2023-26	Planning for FCS in central, western, and northwestern areas	Installation of 12 small, 8 medium, and 8 large FCS in downtown, Bidwell Park, central, and northwestern areas	Installation of 50 FCS in areas draining into Bidwell Park and central area, western or northwestern areas
2027-30	Planning for FCS in northern and southern areas	Installation of 9 small, 8 medium, and 8 large FCS in western, northern, and southern areas	Installation of 52 FCS in western, northern, and southern areas

This SWMP recognizes that the City has not met the original phasing plan for implementation of FCS but does include an updated phasing plan that takes advantage of the data collected for the SWMP to refine the recommended locations for FCS and for the prioritization of implementation.

The O&M Plan provides general guidance to the City staff regarding the protocols necessary to ensure that the operation and maintenance of the FCS installed meets the SWRCB's requirements. Key attributes include the following:

- Inspect the FCS devices a minimum of twice per year; once prior to the wet season (April 15-October 15) and once during the wet season (October 15-April 15).
- Standard Operating Procedures (SOPs) were developed for debris separating baffle boxes, inlet filters, connector pipe screens, skimmer boxes, and hydrodynamic separators (O&M Plan, Attachment F). The SOPs additionally discuss access to the FCS by mosquito vector control personnel for observation and mosquito treatment.
- The SWRCB created Fact Sheets for the multi-benefit treatment systems, [27] which include specific O&M requirements. Regular maintenance is required to retain adequate trash capture capacity and to ensure that trapped trash does not migrate off-site from bioretention, capture and use systems, detention basins, infiltration trenches and ditches, and media filters. The City's maintenance schedule is based on site-specific factors, including the size of the BMP, the storm frequency, and the characterization of upstream trash and vegetation accumulation.

The trash provisions will ultimately be implemented through the Phase II MS4 Permit when it is reissued (see Section **4.1.1**).

It is recommended that the City update the Post-Construction Standards so that the requirements of the Statewide Trash Amendments are considered and incorporated during the design process for new development and redevelopment projects. This recommendation is included because the Statewide Trash Amendments were adopted by the SWRCB subsequent to the City's development and adoption of the Post-Construction Standards Plan. The Statewide Trash Amendments require agencies with regulatory authority over PLUs to comply with the prohibition of trash discharges to receiving waters. This recommendation would proactively ensure that City would be in compliance with the Statewide Trash Amendments for newly developed and redeveloped PLU areas.

4.1.4 Statewide Mercury Provisions

On May 2, 2017, the SWRCB adopted Resolution 2017-0027, which approved *Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California—Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions.* Resolution 2017-0027 provides a consistent regulatory approach throughout the state by setting mercury limits to protect the beneficial uses associated with the consumption of fish by both people and wildlife. [28]

These provisions will ultimately be implemented through the Phase II MS4 Permit when it is reissued (see Section 4.1.1) and will include a combination of source control measures to reduce total mercury or methylmercury discharges (e.g., thermometer exchange and fluorescent lamp recycling programs, public education and outreach to residents and auto dismantlers, and internal surveys and procedures for eliminating the use of products that contain mercury).

4.1.5 Pyrethroid Control Program

On June 8, 2017, the Central Valley Regional Water Quality Control Board (RWQCB) adopted Resolution R5-2017-0057, which adopted the Basin Plan Amendment (BPA) for the Control of Pyrethroid Pesticide Discharges. This BPA established measurable pyrethroid concentration goals and an implementation program for the control of pyrethroid pesticides that are impacting, or could potentially impact, aquatic life in surface waters in the Sacramento River and San Joaquin River watersheds of the Central Valley. [29]

These provisions will ultimately be implemented through the Phase II MS4 Permit when it is reissued (see Section 2.1). The City submitted a revised Pyrethroid Baseline Monitoring Report to the RWQCB on October 28, 2022. On November 1, 2022, the RWQCB approved the Report, determined that the City demonstrated attainment of the pyrethroid trigger limits, and also determined that the City's discharge is not causing or contributing to exceedances of the narrative objectives for toxicity. This fulfilled the City's responsibilities under July 13, 2020 13267/13383 Order. [30]

4.1.6 Salt Control Program

In May 2018, the RWQCB adopted Resolution RS-2018-0034, approving new Salt and Nitrate Control Programs. The Salt Control Program was developed to address salt accumulation issues in surface water and groundwater throughout the Central Valley Region. Under the new Salt Control Program, the RWQCB will impose new permit requirements to protect surface waters and groundwater from salts in wastewater. Notices to Comply (NTC) were issued in January 2021 and they require the City to choose between new salinity permitting options established under the new Salt Control Program including Conservative Salinity Permitting Approach and an Alternative Salinity Permitting Approach by July 2021. The City received Notices to Comply for the Sycamore Pool Operations and Greenwaste Composting Facility.

- Sycamore Pool Operations - The City received a Notice to Comply for the Sycamore pool operations with a deadline of July 15, 2021. On May 4, 2021 the RWQCB received an exemption request from the City, and on September 2, 2021 the RWQCB granted the exemption to the City since the permit for the pool operations is for annual cleaning of sediment and debris from the creek channel and monitoring of bacteria in Big Chico Creek. [31]

- Chico Greenwaste Composting Facility - In December 2021, the RWQCB determined that the Chico Greenwaste Composting Facility is no longer required to be enrolled under the Composting General Order and, therefore, is not subject to the Salt Control Program. [32]

4.2 Storm Water Resource Planning

Senate Bill 985, the Storm Water Management Planning Act of 2014, requires a Storm Water Resources Plan as a condition of receiving grant funds for storm water and dry weather runoff capture projects from any bond approved by voters after January 2014. [33] The intent of SB 985 is to encourage the use of storm water and dry weather runoff as a resource to maximize water supply, water quality, flood management, and environmental and other community benefits within the watersheds of the planning areas.

The City completed a Storm Water Resources Plan [34] in August 2018 (2018 SWRP) as a comprehensive document that identifies, prioritizes, and schedules storm water projects within the Planning Area Watersheds, including Big Chico Creek, Rock Creek, Sycamore Creek, Mud Creek, Little Chico Creek, and Comanche Creek. The City used a metrics-based analysis to identify, prioritize and rank the top 17 projects, which are summarized below in **Table 6** (**bolded projects** were identified as the highest priority).

Table 6: Storm Water Resources Plan Implementation Schedule	
SWRP Project	**Project Schedule, Year**
I: Trash Reduction Master Plan and Specific Implementation Projects	2018
G: Storm Water Monitoring for compliance with MS4 permit	2018-2038
59: Routine Community Creek Clean Up Project (Program)	2018-2038
65: Laxson South Bioswale	**2019-2020**
40: Parking Lot #4 Rehabilitation, Project 50019	2019-2020
77: Revised Low Impact Development and Green Infrastructure Implementation Program for Butte County Schools	**2019-2041**
44: 5 Mile and Lindo Channel Diversion Structures Study	2027
85: Chapman Mulberry Rain Garden	**2021-2022**
Q: Teichert Ponds Improvement Project	2021
R: Fair Street Detention Basin Improvement Project	2023
N: Little Chico Creek 2^{1st} Century Management Plan	2024-2026
O: Comanche Creek Management Plan	2024-2026
73: Bidwell Avenue/Grape Way Storm Water Protection and Restoration Project	2027
M: Big Chico Creek 2^{1st} Century Management Plan	2028-2031
16 and 68: Channel Stabilization and Create Hydrologic Floodplains on Streams	2032
P: Updating the City's Storm Water Master Plan and Policies	2035
33: Mud and Rock Creek Flood Protection Project	To Be Determined

Implementation of the SWRP projects would reduce pollutants across multiple pollutant categories (e.g., pesticides, trash, heavy metals) in storm water discharges; and would increase infiltration/ groundwater recharge, improve flood control, and protect water quality in receiving waters. These objectives will be accomplished by employing an array of appropriate non-structural, structural, regional, and green infrastructure BMPs to reduce runoff volume, velocity, and erosion and sediment transport; maximize the use of green infrastructure for catchment, infiltration, and treatment; and by conducting public outreach and education. [34]

The schedule for implementation of the projects identified in the SWRP and presented in **Table 6** was obtained from the SWRP. The actual implementation schedule will depend on funding of the various projects.

4.3 Water Quality

This section summarizes the water quality priorities and the results of the monitoring that is conducted by City.

4.3.1 Watersheds and Waterbodies

The City is within the Big Chico Creek and Little Chico Creek watersheds, with approximately 65 percent of the City draining to the Big Chico Creek watershed and 35-percent draining to the Little Chico Creek watershed. The primary waterbodies within each of the watersheds to which the City drains include the following:

- Big Chico Creek Watershed
  - Big Chico Creek
  - Mud Creek
  - Sycamore Creek
- Little Chico Creek Watershed
  - Little Chico Creek
  - Comanche Creek

4.3.2 303(d) Listed Waterbodies and Total Maximum Daily Loads

Section 303(d) of the Clean Water Act requires the state to identify water bodies that do not meet, or are not expected to meet, water quality standards (i.e., impaired water bodies). [35] The pollutant-water body combination is placed on the 303(d) List, prioritized, and ultimately addressed through a regulatory program or Total Maximum Daily Load (TMDL). The SWRCB combines the 303(d) List of Impaired Waters and the 305(b) Water Quality Assessment Report into a single Integrated Report with the most current report developed in 2014-2016. These lists are periodically updated.

The 2014-2016 Integrated Report was approved by the U.S. Environmental Protection Agency (EPA) in 2018. The pollutant-water body combinations for the waterbodies to which the City drains within the Big Chico Creek and Little Chico Creek Watersheds are summarized in **Table 7**, below.

Table 7: Waterbodies on Section 303(d) List

Waterbody	Pollutant/Stressor	TMDL Required?
Mud Creek (Butte County)	Toxicity (source unknown)	Yes
Big Chico Creek (Butte and Tehama Counties)	Mercury (source unknown)	Yes

The 2020-2022 Integrated Report was finalized in March 2022. There are numerous additional listings for Big Chico Creek (aluminum, bifenthrin, chromium, indicator bacteria, nickel, dissolved oxygen, pyrethroids, toxicity, and pH) and Little Chico Creek (pH).

4.3.3 Water Quality Monitoring and Studies

Consistent with Section E.13.d of the Phase II MS4 Permit, the City conducted Special Studies (in 2017) and Receiving Water Monitoring (in 2019 and 2020). The receiving water monitoring in Big Chico Creek was conducted to evaluate water quality trends at two locations: a) an upstream site at an urban/rural interface adjacent to Bidwell Park Golf Course; and b) a downstream site within an urbanized area at the Warner Street Bridge. The constituents that are monitored are listed in **Table 8**, below; however, the list varies from year to year.

Table 8: Water Quality–- Monitored Constituents

Field Parameters	Nutrients (Nutrient-Related)	Other
Temperature	Nitrate as N	E. Coli (Indicator Bacteria
pH	Nitrogen, Ammonia as N	Pyrethroids
Electrical Conductivity	Nitrate-Nitrite	Chlorpyrifos
Dissolved Oxygen	Total Kjeldahl Nitrogen	Diazinon
Turbidity	Organic Nitrogen	Total Organic Carbon
	Total Phosphorus as P	Dissolved Organic Carbon
	Ortho Phosphorus as P	Total Suspended Solids
	Chlorophyll A	Bioassessment
		Physical Habitat

Key observations from the 2019 and 2020 Annual Reports [36] included the following:

A. Field Parameters
   - Receiving water quality has remained consistent between the monitoring periods, which show low electrical conductivity, low turbidity, relatively high natural pH (generally higher in the upstream location), and variable temperatures;
   - Flow measurements from the monitoring periods show great variability in flow velocity and discharge, probably due to the frequency and intensity of precipitation events; and
   - Dissolved oxygen concentrations showed variations between the monitoring periods.

B. Laboratory Analyses
   - Concentrations of Chlorophyll A, total suspended solids, and nutrients show that levels of nutrients at both locations are relatively low, and dissolved oxygen concentrations also indicate low nutrient levels.

In general, a comparison of the upstream (at Golf Course Bridge) and downstream (at Warner Street Bridge) monitoring locations showed that receiving water quality is similar in both locations.

4.4 Storm Water Quality Element Summary

As noted above, the SWMP will be consistent with, and assist in, addressing the regulatory requirements and other related planning and implementation programs including:

- Phase II MS4 Permit;
- Industrial General Permit;
- Statewide Trash Amendments;
- Statewide Mercury Provisions;
- Pyrethroid Control Program; and
- Storm Water Resource Plan.

Considerations for the SWMP that would support the implementation of these programs are summarized below.

A. Projects that address the ***priority water quality constituents*** and requisite load reductions should be considered as a part of the SWMP. The priority water quality constituents include:
   - Sediment;
   - Pathogens – Indicator Bacteria;
   - Toxic Chemicals – Polychlorinated biphenyls (PCBs);
   - Trash;
   - Mercury/Methylmercury; and
   - Pesticides/Pyrethroids.

B. Both the Phase II MS4 Permit and the Statewide Trash Amendments include ***design criteria*** that need to be considered as a part of the SWMP:
   - Statewide Trash Amendments – Full Capture Systems must trap all particles that are 5 mm or greater, and a design treatment capacity that is either: a) of not less than the peak flow rate, Q, resulting from a one-year, one-hour storm in the subdrainage area; or b) appropriately sized and designed to carry at least the same flows as the corresponding storm drain.
   - Phase II MS4 Permit, Post-Construction Standards Plan volumetric and flow-based criteria.
   - Industrial General Permit volumetric and flow-based criteria (to the extent that projects may occur on-site at the Chico Municipal Airport).
   - Phase II MS4 Permit, E.11 Water Quality and Habitat Enhancement Features in New Flood Management Facilities – requires the consideration and design of water quality and habitat enhancement features in new and rehabilitated flood management facilities.

C. Both the Phase II Permit and the Statewide Trash Amendments include ***operations and maintenance protocols*** that need to be considered as a part of the SWMP. Aspects of the operations and maintenance that should be considered are:
   - Site-specific requirements that may apply in certain areas of the City (IGP for the Municipal Airport);
   - Assessment, prioritization, inspection, and clean-out frequencies for the storm drain system maintenance (Phase II Permit, E.11.f-g);
   - Operations and maintenance requirements for the proprietary and public domain full capture systems (Statewide Trash Amendments).

D. The type of ***projects that should be considered/prioritized*** as a part of the SWMP include projects that:
   - Retain or treat the urban and storm water runoff so that there is an overall volume and/or pollutant load reduction;
   - Meet the requirements for full capture systems (especially for projects prior to December 2030); and/or
   - Have been deemed a high-priority, multi-benefit project within the SWRP.

E. ***Anticipate future requirements:***
   - Phase II Permit – The SWMP should consider the future need for tracking and inventorying drainage system assets as part of an asset management program. Such needs might include:
     - GIS mapping and inventory of the storm drainage system including catch basins, pollutant priority areas, trash PLUs, outfalls, storm water treatment systems, hydromodification management systems, flood management facilities; and
     - O&M and inspection tracking systems.

IGP – The SWMP should consider the future need for full capture system trash control implementation within the footprint of the airport that is regulated by the IGP.

5.0
Update Current GIS Mapping

5.0 UPDATE CURRENT GIS MAPPING

5.1 Mapping Provided by the City

On April 28, 2021, Chico State provided the City's GIS data sets to Wood Rodgers. The data was provided in the form of a geodatabase and included the following feature classes:

- Storm Nodes
- Storm Drains
- GP 2030 Chico Major Streets
- Hydrology Line
- Streets Geocode
- City Limits
- Plan Area
- Sphere of Influence

The Storm Nodes and Storm Drains datasets were identified as the critical feature classes for modeling purposes. These datasets contained large amounts of information. There were 11,508 features in the Storm Nodes dataset and 10,797 features in the Storm Drains dataset. The Storm Nodes data included node type information, such as whether the point represented a drop inlet, a manhole, or outlet, and 92 percent of the points include a reference to the data source. The Storm Drain data included pipe size and material information for many of the features, and 91 percent of the conduits include a reference to the data source. Partial connectivity information (from and to nodes) and some elevation information was included in the Storm Drain data. The City Storm Nodes dataset also included some BMP locations.

The data provided by the City required extensive review and refinement in order to develop a dataset that was accurate enough for the SWMP. Critical inaccuracies included missing features, incorrect dimensions, and erroneous horizontal configurations. Elevation data was incomplete and lacked reference to datum. The following section describes the effort to improve the drainage system GIS to support drainage system modeling.

5.2 System Map Review and Revision Process

The drainage system map review and revision process was an extensive collaborative effort between City staff and the City's Consultant. The process involved reviewing the data, finding areas where additional data was needed, obtaining the data and incorporating it into the GIS. Numerous locations of the storm drains in the GIS had discontinuities or configurations that did not appear correct. Record drawings were reviewed and changes to the GIS were made where needed for modeling purposes. Additionally, pond nodes for the detention basins that would be modeled as one-dimensional elements were added. Break nodes were added to provide connections in the model that do not represent a physical feature (see Section 6.3.3.2 for more

information about break nodes). ArcGIS Online was used to directly integrate City staff's efforts to fill data gaps in the GIS Mapping.

The review of the existing GIS datasets was an eight-part process. Each part of the process involved multiple steps. The review process was iterative because it was conducted before, during, and, to a limited extent, after the modeling process when potentially significant issues with the original GIS data were identified. The process involved:

1. Identifying existing assets that were missing critical attributes;
2. Locating small data gaps in the GIS inventory;
3. Finding relatively large, developed areas without features in the GIS inventory;
4. Determining where the storm drains were not in the correct horizontal location;
5. Detecting where the configuration in the GIS inventory appeared to be inaccurate;
6. Investigating where the model results showed unrealistic flooding resulting from inaccurate definition of the storm drainage system in the GIS inventory;
7. Correcting the existing configuration in the GIS inventory when inaccuracies were found in the process of reviewing water quality features; and
8. Refining the GIS inventory where inaccuracies were found in the process of developing project recommendations and finalizing the GIS and figures for presentation.

The first part of the process was to filter the data to identify the assets missing critical attributes, such as pipe size and material. Data collection was prioritized in order to focus on entering data that would be critical to the modeling. Pipe sizes are critical to the modeling process. Pipe elevations at key locations such as detention basins that are critical to the modeling process were researched and entered into the GIS. Non-critical elevations were assumed where they were necessary to provide reasonable pipe profiles.

The second part of the process was to identify data gaps in the existing inventory. This was done by visually tracing each storm drain system to ensure continuity from the upstream inlet to the outfall. Locations of data gaps were identified. Additionally, pipe systems were reviewed to find locations where downstream pipes were smaller than upstream pipes. This process resulted in finding errors in the data, finding locations where multiple barrel systems were present but not identified as such in the GIS, and confirming locations where pipe size reductions actually do occur.

The third part of the process was to identify locations where storm drain inventory was missing from the existing dataset. These locations were typically identified by sump locations with no storm drain assets or large urban drainage areas contributing to a single inlet. A GIS process was used to map the sump locations throughout the City and to cross reference those locations with the Storm Nodes and Storm Drains in order to identify sumps without assets. Many sump locations within the City are associated with private drainage systems that are not included in the GIS. Some of the private systems that are included in the GIS inventory were not included in the models.

The fourth part of the process was to identify locations where the storm drains were not close enough to the correct horizontal location. Sump locations and storm drain alignments were

visually reviewed relative to the aerial imagery and the digital elevation model (DEM). Feature locations were adjusted where they were necessary to support adequate watershed delineations and connections to inlets in order to support the modeling.

The fifth part of the process involved determining where storm drain configurations appeared to be incorrect based on engineering judgements made during the model development process. This included areas where the GIS inventory was outdated based on observed development and locations where storm drainage system features in the GIS were digitized incorrectly.

The sixth part of the GIS inventory refinement process occurred during the model development process. After the GIS inventory was deemed adequate to support preliminary existing conditions modeling, initial versions of the existing conditions models were completed and run, and the results were reviewed. Additional data collection was conducted during the process of investigating locations where the model results showed unrealistic flooding. The existing conditions models were deemed to be essentially complete when the results were found to be reasonably consistent with the City's expectations based on institutional knowledge.

The seventh part of the process included a detailed review of the existing BMPs' inventory that included vault interceptors, infiltration leach trenches, and detention basins. During the process of reviewing as-built drawings, BMP data was added and modifications to the existing storm drain system were implemented as inconsistencies were found. Some of the BMPs were included in the GIS inventory but were excluded from the model because the BMPs were not expected to significantly impact the system capacity analysis.

The eighth part of the process involved making corrections to the GIS inventory where inaccuracies were identified during the process of developing project recommendations. For example, some locations of existing drainage system inlets were found during the process of determining proposed project configurations.

5.3 SWMP Storm Drainage System GIS

The SWMP storm drainage system GIS includes both modeled and non-modeled existing drainage system features and proposed features. Proposed features were included in the build-out condition models. Attributes are provided that define the status of each feature in both the existing condition models and the build-out condition models. Two-year, 10-year, and 100-year model results for each of the modeled features are also provided. This section focuses on the data related to the existing drainage system. Features from the original dataset that were found to be inconsistent with the existing drainage system are not included in the final database for the SWMP.

The SWMP includes a file geodatabase deliverable that includes multiple features classes with data used in the process of developing the drainage system models. The key feature classes are Nodes, Links, Watersheds, and Detention Basins. The data fields include information provided by the City, information added by Wood Rodgers, the actual system data used in the models, and results from the models. Some of the data includes a Modeled Status of "Not Modeled." Not Modeled features in the GIS include some data for private systems that were not incorporated in

the model. Not Modeled features also include some features from the data provided by the City that did not represent the actual storm drainage system but did not get removed from the GIS. The Not Modeled data is not presented in the SWMP. It may be useful to view the Not Modeled data during the detailed analysis of specific locations in order to determine if there is potentially useful data for that specific location. However, most of the Not Modeled data has been superseded by a more accurate representation of the current system in the modeled system data.

5.3.1 Links

The Links feature class includes numerous fields populated with attributes that define what each link represents. The attributes include object identifiers unique to each link and to the object identifiers of the upstream and downstream nodes connected to it. Links are used to simulate many different types of features in InfoWorks Integrated Catchment Modeling (ICM), and the "Link Type" attribute is used to distinguish between the various modeled features. The various link types are described in **Table 9**, below.

Table 9: Link Types in GIS

Link Type	No. of Links	Description
One-dimensional (1D) Channel	143	Segments of existing channels that are modeled as one-dimensional features.
Collector	5	These are channel/conduit links used in the Airport area build-out model to convey runoff into the master-planned detention basin for the North Chico SPA.
Conduit	11,726	Pipes, arches and box culverts features that are modeled. Additional attributes are used to define which ones exist and which ones are part of the master-planned improvements.
Future New Conduit	916	Of the 11,711 modeled conduits, 916 are part of the master-planned proposed drainage system.
Culvert Outlet	99	A modeling convention link to connect a culvert to a one-dimensional channel.
Flap Gate	36	A link that restricts flow to one directional in the adjacent conduit for existing conditions.
Non-Modeled Conduit	632	Features from the original City GIS that were found to not be accurate or not represent a feature appropriate for inclusion in the models.
Orifice	29	Orifice links are used to simulate restrictions, typically controlling discharges from detention basins.
Proposed Channel	6	Proposed ditch modeled as a one-dimensional channel.
Proposed Flap Gate	1	A link that restricts flow to one direction in the adjacent conduit for proposed conditions.
Proposed Pump	3	These links are used to simulate master-planned pumps that would serve the North Chico SPA.
Pump	1	This link represents an existing pump system that serves a small area west of SR 99 just south of Sycamore Creek.
User Control	15	User control links provide estimated performance of infiltration from features where a specific expected infiltration rate was simulated.
Weir	28	Weirs are links that control detention basin overflow onto adjacent overland flow areas simulated with two-dimensional mesh.
Total	12,724	

A shape identifier is used for conduits to show the modeled shape as circular, rectangular, or arch. (Elliptical conduits are modeled as a circular conduit with a pipe diameter that provides equivalent conveyance.) Attributes are also provided for the Manning's n-value (based on pipe material), pipe length, number of parallel conduits, modeled upstream and downstream invert elevations, and entrance and exit loss coefficients. Peak flow results are provided for most conduits. For locations where the simulations show any reverse flow, a negative flow rate for the peak reverse flow is reported. Additional attributes are included in the feature class in order to store the data populated by the City and comments and other data added by Wood Rodgers. References to as-built drawings are included where available.

The existing conditions models contain 11,070 GIS links and 10,732 represent conduits. Of these, 10,698 conduit links represent circular or elliptical pipes, 7 represent arches, and 27 represent box culverts. The 10,732 conduit links represent 10,892 pipe connections considering each barrel of multiple-barrel elements separately. The buildout conditions models include 12,034 GIS links. Of these, 11,669 represent conduit links. Details of the proposed improvements are listed in **Section 11.0**. Quantities (in feet) of the sizes of various existing conduits are summarized below in **Table 10**. The total length of conduit is approximately 264 miles. The metal pipe lengths are listed in a separate column because the metal pipes are more likely to require replacement due to material deficiencies than are the plastic or concrete pipes.

Table 10: Lengths of Existing Conduits					
Shape	**Height/Diameter**	**Width**	**Plastic/Concrete**	**Metal**	**Total**
	(inches)	**(inches)**	**(feet)**	**(feet)**	**(feet)**
Arch	24	35		1,151	1,151
Arch	36	58	580	90	670
Circular	4		68	-	68
Circular	6		2,520	108	2,628
Circular	8		39,283	275	39,673
Circular	10		99,666	27	99,693
Circular	12		254,870	417	255,836
Circular	14		4,668	-	4,668
Circular	15		201,650	298	202,668
Circular	16		2,905	-	2,905
Circular	18		217,719	1,440	219,538
Circular	20		679	-	679
Circular	21		44,626	-	44,626
Circular	24		150,071	1,012	151,119
Circular	27		17,155	1,994	19,148
Circular	30		96,164	357	96,521
Circular	33		8,378	-	8,378
Circular	34		312	-	312
Circular	36		78,153	778	78,932
Circular	39		1,397	-	1,397
Circular	42		63,243	-	63,243
Circular	44		-	95	95
Circular	48		50,611	127	51,158
Circular	54		25,129	53	25,181
Circular	60		12,826	129	12,925
Circular	66		677	-	677
Circular	72		7,846	-	7,674
Circular	95		570	-	570
Circular	98		112	-	112
Rectangular	30	48	283		283
Rectangular	36	60	423		777
Rectangular	36	72	-		412
Rectangular	48	60	-		407
Rectangular	48	72	-		544
Rectangular	48	84	-		422
Rectangular	48	96	-		549
Rectangular	48	108	-		22
Rectangular	48	120	-		240
Rectangular	60	60	-		74
Rectangular	60	72	-		33
Rectangular	72	96	-		50
Total			**1,382,585**	**8,350**	**1,390,935**

5.3.2 Nodes

The Nodes feature class includes numerous fields with attributes that define what each node represents. The "Node ID" attribute provides unique identifiers assigned for modeling purposes. The "MH" attribute provides the original node identifiers included in the City's data. There were 10,827 nodes with identifiers assigned by the City, but 146 of these were not unique. The "Model Node Type" attribute provides the modeled node type as described in **Section 6.3.3**. The "Physical Type" attribute provides a description of the actual feature such as manhole, drop inlet, or outlet. The "Break" Physical Type is used for modeled nodes that do not represent a structural feature. The "WR Classification" attribute is used to identify which features are proposed by the SWMP using names such as "Future DI," "Future Outfall," and "Future MH." The various WR Classifications for existing features are related to the model development process and are not significant moving forward except for the classification of "EX to be Removed/Replaced." This classification is for inadequate inlet configurations where the same node is used for the inlet in the existing conditions and build-out models; however, the replacement inlet needs to be included in the capital improvement recommendations. Quantities of major node types are listed below in **Table 11**. The "Infiltration System" attribute is assigned to nodes associated with dry wells and leach trenches, and it includes information about whether or not the system is modeled. (See **Sections 6.3.3.5, Outfalls**, and **8.1.2, Dry Wells**, for additional information.) Additional attributes are included to provide the data populated by the City and the comments and other data added by Wood Rodgers, including information about nodes that represent BMPs. References to as-built drawings are included where available.

Table 11: Quantities of Major Node Types

Node Description/Type	Drop Inlet (DI)	Manhole (MH)	Outfall/Outlet (interchangeable)
Existing to Remain	8117	1842	520
Existing to be Replaced	127	4	1
Proposed New	623	153	32

Some of the fields in the Nodes feature class provide data generated by the models and GIS processes. The Nodes feature class includes model results for the maximum HGL at each location for the various modeled storms. Results of the analysis that was prepared to evaluate potential locations for full trash capture systems is included. The data includes how much area, PLU area, and impervious area is tributary to each node. Impervious tributary area is provided for both existing and build-out conditions in order to provide a basis or attributing costs to future development. It should be noted that tributary areas associated with some nodes overlap due to split flow/diversion systems. Information about overlapping watersheds tributary to specific outfalls is provided in the following section.

The existing conditions modeled drainage system is presented in a map series included as **Figure 7**.

5.3.3 Watersheds

The Watersheds feature class lists hydrologic parameters used in the modeling and classifications that can be used to display groupings of watersheds. Classification data is used to associate watersheds with model domains. The model domains are presented on **Figure 8**. A detailed discussion of the hydrologic data developed for each watershed is included in **Sections 6.1** and **6.2**. The watershed GIS includes 8,088 areas for which runoff hydrographs were computed within the ICM models. Watersheds were delineated for the areas tributary to nearly all existing and master-planned public drainage inlets. The watersheds that are tributary to California Park Lake and Dead Horse Slough are included in the GIS because these areas were modeled in ICM. The large watersheds tributary to the major streams that were included in the Chico Area Streams HEC-RAS model are provided in a separate feature class. A summary of watersheds, listed by model domain, is provided in **Table 12**, below.

Table 12: Watershed Summary by Model Domain

Model Domain	Model Domain Area (sq. mi.)	Number of Watersheds	Existing Conditions Imperviousness	Build-out Conditions Imperviousness	Change in Imperviousness
Airport	3.82	193	0.21	0.53	0.32
Big Chico	1.90	642	0.45	0.45	0.00
Comanche	5.93	928	0.36	0.46	0.10
Little Chico	9.49	2,019	0.28	0.32	0.04
Lower Lindo	2.05	743	0.43	0.46	0.03
PV[6] Ditch	1.54	755	0.49	0.51	0.02
South Sycamore	0.77	365	0.49	0.56	0.07
SUDAD	5.92	1,373	0.34	0.40	0.06
Upper Lindo	3.39	1,080	0.47	0.48	0.00
Total	**34.83**	**8,098**	**0.35**	**0.42**	**0.08**

5.3.4 Trace Analysis

Trace analysis was performed in order to associate cumulative watershed data with the nodes in the drainage system. Trace analysis is a GIS process that was used to create a list associated with each node (typically a manhole, catch basin or outfall) of each node upstream from it based on connectivity through conduits. The list for each furthest upstream node (typically a catch basin)

[6] PV Ditch is an abbreviation for Pleasant Valley Ditch as identified on City of Chico map of Storm Drain Tributary Areas dated January 2002. The PV Ditch drains to the leveed channel referred to as Dry Creek in the SPFC documents.

only includes one node. Outfall nodes have lists that include all of the nodes associated with the storm drains connected to it. Watersheds are associated with nodes and a list of watersheds upstream from each node was prepared. Cumulative drainage area, cumulative PLU area, and cumulative impervious area for both existing conditions and build-out conditions were computed based on the lists of watersheds associated with each node.

One complicating factor in the trace analysis is split flow conditions. In typical storm drainage system configurations, each node has only one pipe draining away from it. There are occasionally interconnected parallel pipes with split flow conditions at their upstream end and at equalizing junctions. In general, parallel pipe systems are only a minor complication because there is a unique watershed tributary to nodes downstream of the parallel pipe system. Split flow conditions are more complicated where flows from a junction drain to multiple outfalls. The complication of drainage configurations with multiple outfalls is that some watersheds drain to multiple outfall locations. This causes those watersheds that are tributary to some outfall locations to be overlapped. **Figure 9** illustrates the cumulative drainage area to each outfall location from build-out storm drainage networks. Overlapping watersheds are illustrated with hatching to show where watersheds drain to multiple outfalls.

The primary purpose of the trace analysis was to provide the information that is necessary for the selection of appropriate locations for FCS. As noted above, a cumulative PLU area was computed for each node. The ratio of PLU area to total tributary area was also computed which can be used to consider the efficiency of siting a FCS at a particular location. Additionally, the impervious area within the tributary area at each node was computed and can be used to determine a runoff coefficient for use in calculating the 1-hour, 1-year runoff design discharge rate for the FCS. Information about siting and sizing FCS is provided in **Section 11.4**.

5.3.5 Detention Basins and Water Quality Features

The Detention Basins feature class stores the general data for each detention basin as detailed in **Section 8.2**. The detention basins that have PLU areas within their tributary area could be cost-effective locations to install FCS. The existing detention basin locations are shown on **Figure 10**, as well as their tributary areas and PLU areas. Figure 10 also shows the locations of other existing storm water quality BMPs that are included in the GIS.

5.3.6 Limitations of GIS Mapping

The GIS mapping of the storm drainage system was refined sufficiently to be able to prepare models that provide results that can be used to support the recommendations contained in this SWMP. However, there are limitations associated with the GIS data. These limitations include missing features, and horizontal and vertical inaccuracy.

Most of the missing features are parts of private drainage systems. Locations of many inlets and storm drain pipes within areas such as apartment complexes and commercial and industrial parcels

were not included in the GIS. The accuracy of watershed delineations could be improved by adding private drainage system details and adjusting drainage area boundaries, accordingly. Other drainage system boundary refinements could be made by reviewing the delineations with imagery and parcel boundaries in order to determine where the boundaries resulting from the automated delineation process could be improved. In some cases, it may be necessary to investigate private drainage systems to validate assumptions used to size trash capture systems and verify what priority land use areas would be treated by a device at a specific location.

The horizontal accuracy of the drainage system GIS varies because many inlet nodes were shifted to topographic low points where necessary in order to evaluate deficiencies and the effectiveness of proposed improvements. The horizontal accuracy of features that were not found to be critical to the SWMP results were not refined. Future refinement of the horizontal accuracy of the drainage system features would improve the accuracy of the modeling and utility mapping. The vertical accuracy of the data was reviewed and refined at some locations, such as detention basins where the elevations are critical to system performance. In many locations, system elevations were set to be reasonable based on known constraints. The pipe elevations in the GIS should not be used for the design of system improvements.

Numerous existing inlets were found and added to the City's GIS. The connections from most of these inlets to known drainage pipes were determined based on as-built drawings. Some were determined to drain dry wells without a piped connection to an outfall. Some of the inlets were assumed to connect to nearby storm drains. Assumed connections to pipes and dry wells are noted as being assumed in the GIS. The GIS should be reviewed in order to consider how much effort may be needed to confirm existing system configurations for design-level studies. Design-level studies may include incorporation of data associated with private drainage systems and surveys of drainage systems. The GIS refined for the SWMP is adequate for most uses with the exception of design-level studies. Therefore, additional refinement of the storm drainage system GIS in areas that do not have known problems and where no projects are being planned would not provide a significant benefit.

6.0
Hydrologic and Hydraulic Modeling

6.0 HYDROLOGIC AND HYDRAULIC MODELING

The InfoWorks Integrated Catchment Modeling (ICM) computer program that is based on the EPA's Storm Water Management Model (SWMM) program was selected for the SWMP because it is a state-of-the-art platform capable of providing a basis for master planning and/or design of drainage improvements. Application of this SWMM-based modeling approach provides the flexibility to simulate varying levels of detail within a single model in order to support master planning, project planning, and design-level analysis in a consistent manner. The advantages of employing the ICM system instead of alternative software include:

1. GIS integration;
2. A single program for both hydrology and hydraulic analysis;
3. Simultaneous analysis of overland surface, channelized, and piped flows;
4. Dynamic modeling that allows downstream water levels to influence upstream flows; and
5. A flexible two-dimensional mesh that simulates storage, flows in streams and along streets, and other overland flow conditions.

6.1 Hydrologic Modeling

Hydrologic modeling is the process that generates the inflows at the drainage system inlets and other selected locations through the Study Area. A summary of hydrologic input data is provided in **Appendix B** - Drainage System Data and **Appendix C** - Precipitation Intensity Values. The model files, in addition to the GIS files that include the Appendix B geodatabase, were provided to the City.

6.1.1 Watershed Delineation

The watersheds for the ICM model were delineated using a semi-automated GIS process. The process relies on the terrain and creates flow accumulation lines based on identifying the direction of flow from each elevation pixel to its adjacent pixels. Watersheds are delineated by identifying the area that drains to locations called "pour points."

Identifying appropriate pour points is key to the development of reasonable watersheds. The pour points are typically storm drain inlets. However, not every inlet is included in the model. Numerous inlets with relatively small tributary areas and within some areas of private development were not included in the model in order to simplify model development and shorten model run times. Flows from the inlets that are not assigned as pour points are included in the watershed tributary to the next node downstream that is assigned as a pour point.

Quality control review is critical to the watershed delineation process and edits are necessary to obtain an adequate set of watersheds for the models. Many locations where the initial delineations were not adequate were revised by adding and moving pour points. Many of the adjustments were necessary due to inaccuracies in the storm drainage system GIS. Inaccuracies included missing

pipes and inlets and locations where inlets were not located directly on topographic low points. Once the revisions were determined to provide adequate watersheds, hydrologic parameters for the updated watersheds were computed.

The regional watersheds are presented on Figure 2.

The ICM model domain watersheds are presented on Figure 8.

The detailed watershed delineations for each of the modeled pour points is presented on Figure 10.

6.2 Precipitation Depths from NOAA Atlas 14

Precipitation depth, duration, frequency, and distribution data appropriate for standard recurrence interval design storms is available in [National Oceanic and Atmospheric Administration, (NOAA)] *NOAA Atlas 14, Volume 6, Version 2*, (2014). [37] *NOAA Atlas 14, Volume 6, Version 2* provides gridded results from an analysis of many precipitation gages for frequencies from 1 year to 1,000 years and durations from five minutes to 60 days. Both partial duration and annual maximum values are provided. Partial duration series results are appropriate for drainage master planning because these include multiple significant events in the same year, and this can be significant in the determination of appropriate depths for more frequent events such as the 10-year return period storm. Precipitation depths for the 90-percent confidence limits around each expected value are also listed. For the purposes of the SWMP, expected values based on the partial duration series data were used.

Isohyetal lines for 2-, 10- and 100-year storm events for durations of 1 hour and 24 hours are presented in **Figure 11** through **Figure 16**.

6.2.1 Precipitation Zones

The development of design rainfall distributions for the SWMP is consistent with methodology described in the document, "*Design Rainfall Distributions based on NOAA Atlas 14 Rainfall Depths and Durations*," published by the US Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) engineers in 2015. [38] This reference document discusses how the legacy Soil Conservation Service (SCS) distributions are being replaced by the *NOAA Atlas 14* data. The new USDA NRCS approach uses a curve fitting process to match 60-minute and 24-hour precipitation depths. For the SWMP, a curve fitting process was used that matches the 60-minute and 24-hour precipitation depths and also limits differences at other durations. The curve fitting process was performed using data for locations that are representative of bands of similar precipitation statistics. **Figure 17** shows five Precipitation Zones (PZs) that were used to assign appropriate precipitation distributions to each study watershed. To apply the NOAA Atlas 14 based precipitation, the curve-fit data for each watershed was determined by the PZ that contains the centroid of the watershed being evaluated.

Table 13 (below) provides a summary of 1-hour and 24-hour precipitation depths for 2-year, 5-year, 10-year, and 100-year storms for each of the five PZs.

Table 13: 1-Hour and 24-Hour Precipitation Depths								
PZ	**2-Year**		**5-Year**		**10-Year**		**100-Year**	
	1-Hour	**24-Hour**	**1-Hour**	**24-Hour**	**1-Hour**	**24-Hour**	**1-Hour**	**24-Hour**
	(in.)	**(in.)**	**(in.)**	**(in.)**	**(in.)**	**(in.)**	**(in.)**	**(in.)**
1	0.51	2.64	0.64	3.45	0.75	4.06	1.11	5.96
2	0.54	2.81	0.68	3.69	0.79	4.36	1.17	6.42
3	0.60	3.17	0.76	4.14	0.88	4.90	1.33	7.28
4	0.67	3.70	0.86	4.81	1.00	5.69	1.53	8.53
5	0.72	4.05	0.92	5.26	1.08	6.22	1.65	9.37

Exhibit 11 through **Exhibit 20** provide Intensity-Duration-Frequency Charts and Cumulative Precipitation Charts for each of the five PZ. Appendix C contains tabulated precipitation intensity values that were used in the models and tabulated intensity-duration values that could be used for Rational Method applications.

Numerous curve-fitting equations were tested in the process of selecting one that would provide a reasonable match to NOAA Atlas 14 data. The typical equation format for intensity (i in inches per hour) as a function of time (t in minutes) is:

$$i = \frac{a}{t^b}$$

The equation format above was used for durations longer than 90 minutes. Other terms were added to the typical equation for shorter durations using the following equation:

$$i_{t\leq 90} = vt^{-4} + wt^{-3} + xt^{-2} + yt^{-1} + z$$

The values for the variables (a, b, v, w, x, y, and z) were determined using a sum of least-squares depth error minimization process for each recurrence interval for each PZ. The values for the variables are tabulated in Appendix C.

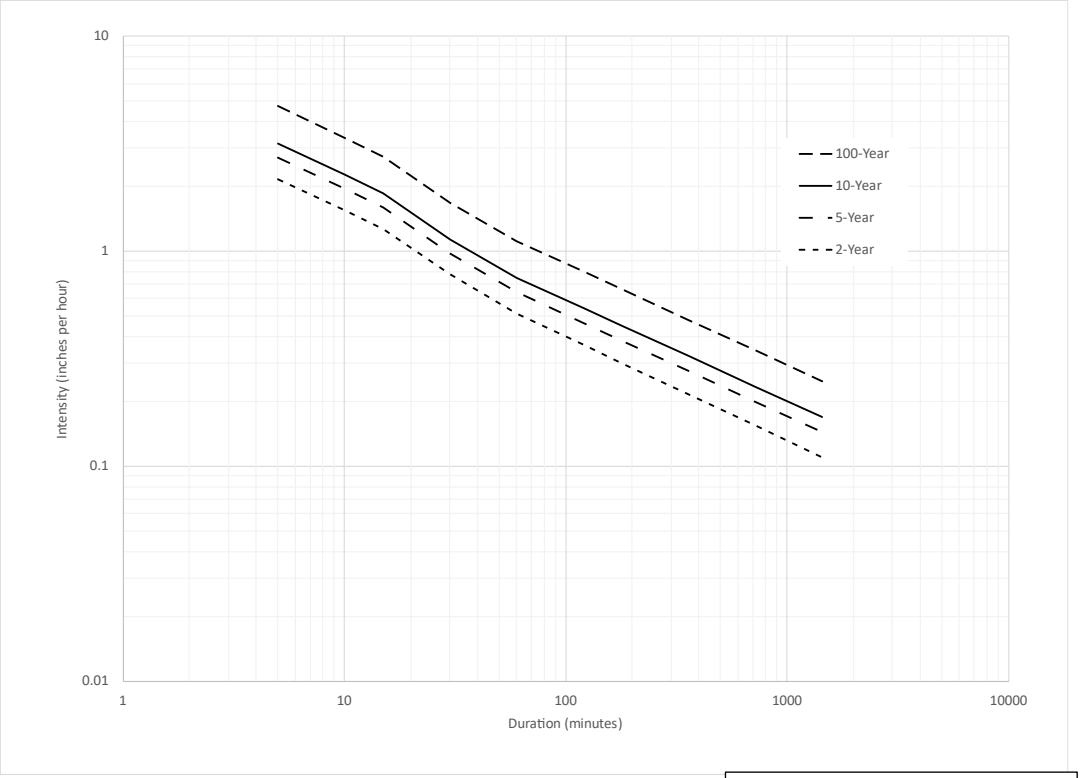


Exhibit 11: Intensity-Duration-Frequency Chart for PZ 1

Link to Figure 17: Design Precipitation Zones

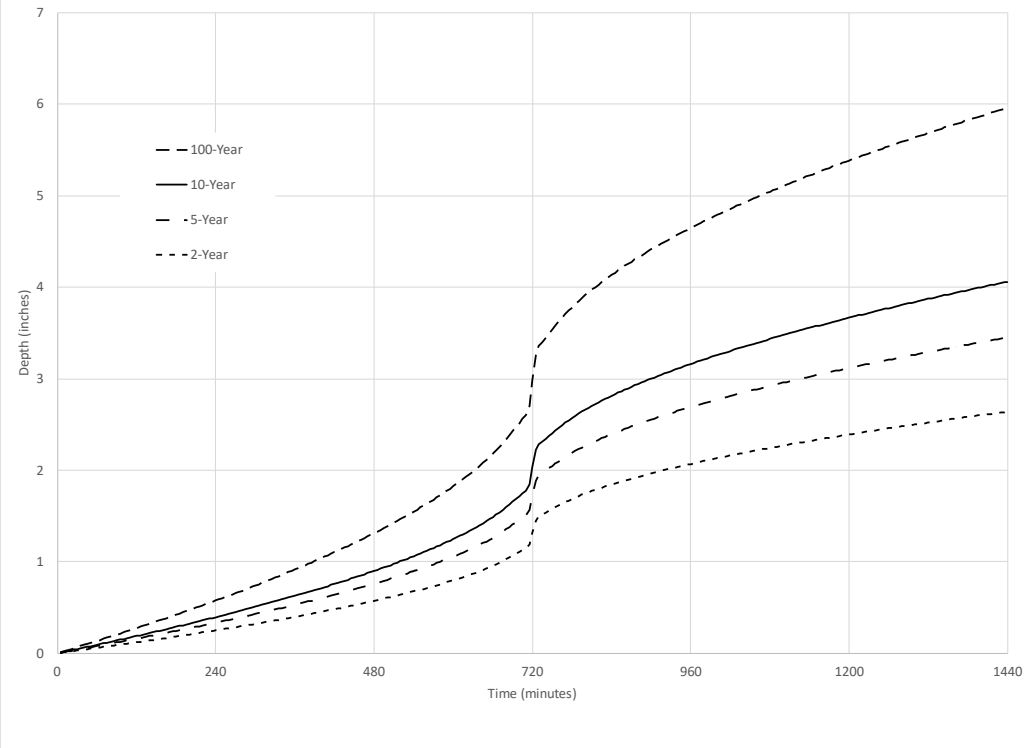


Exhibit 12: Cumulative Precipitation Chart for PZ 1

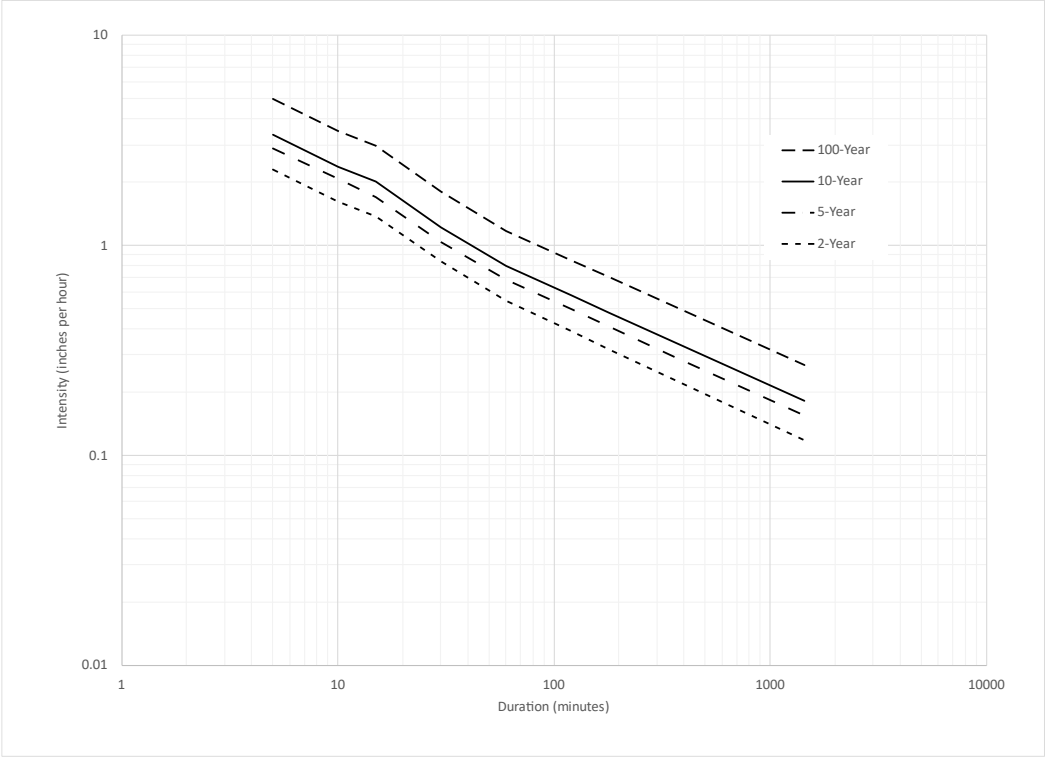


Exhibit 13: Intensity-Duration-Frequency Chart for PZ 2

Link to Figure 17: Design Precipitation Zones

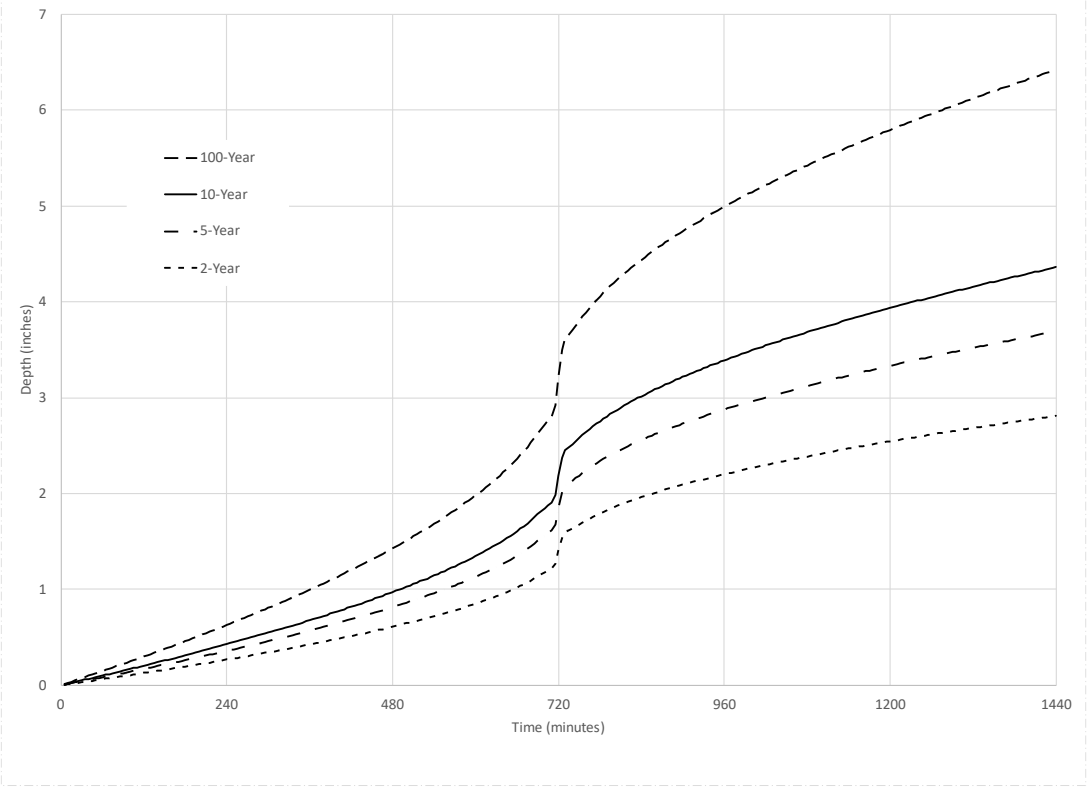


Exhibit 14: Cumulative Precipitation Chart for PZ 2

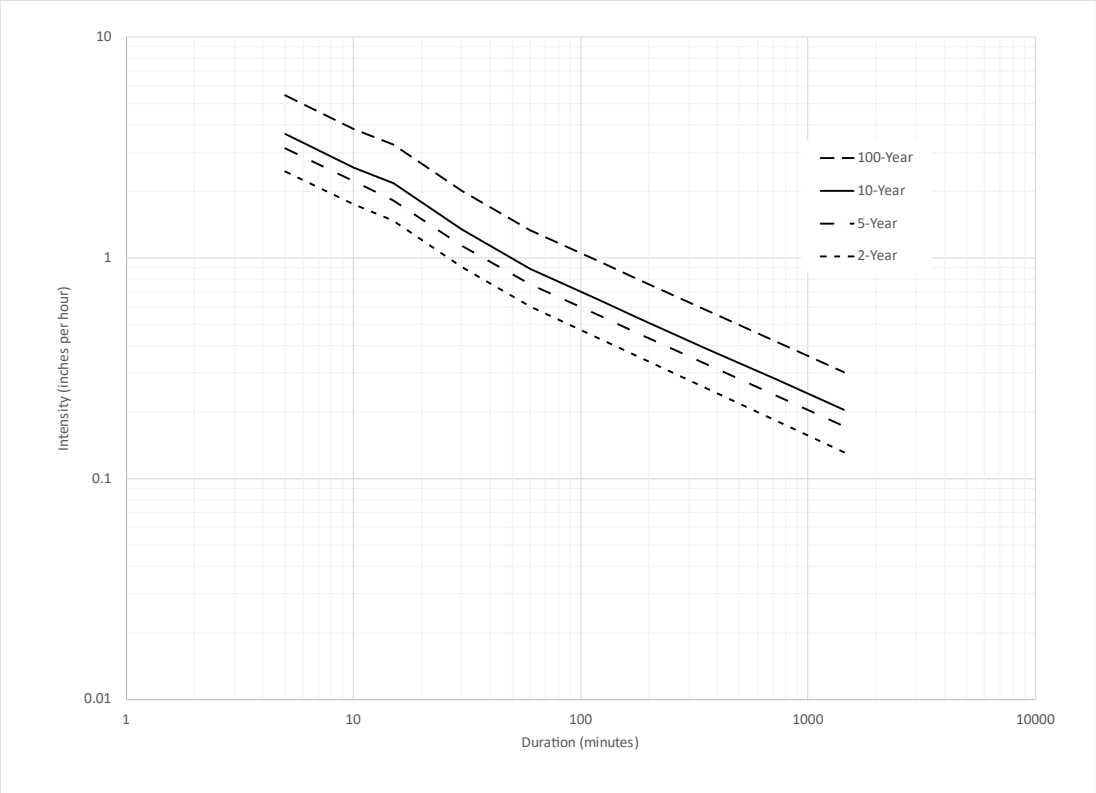


Exhibit 15: Intensity-Duration-Frequency Chart for PZ 3

Link to Figure 17: Design Precipitation Zones

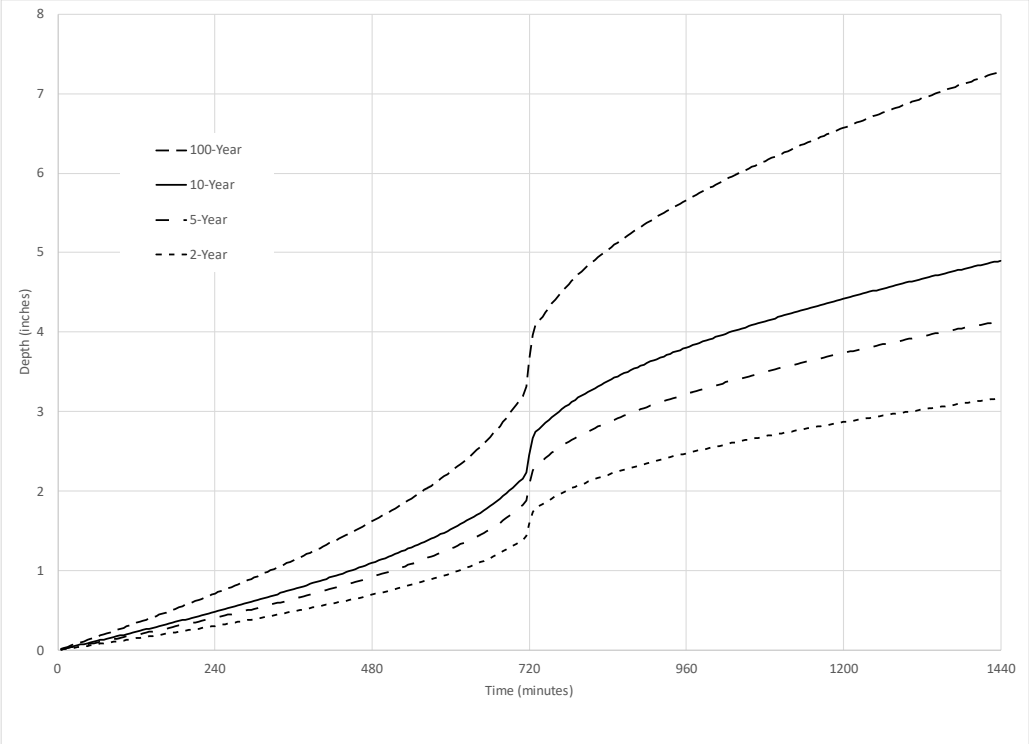


Exhibit 16: Cumulative Precipitation Chart for PZ 3

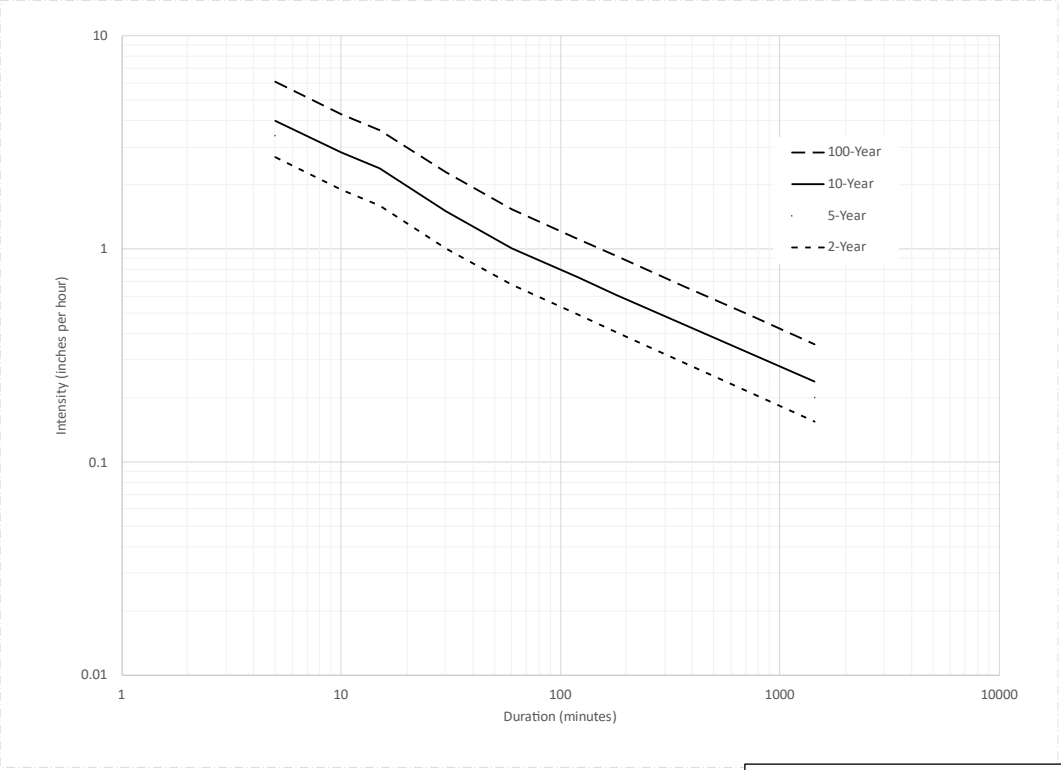


Exhibit 17: Intensity-Duration-Frequency Chart for PZ 4

Link to Figure 17: Design Precipitation Zones

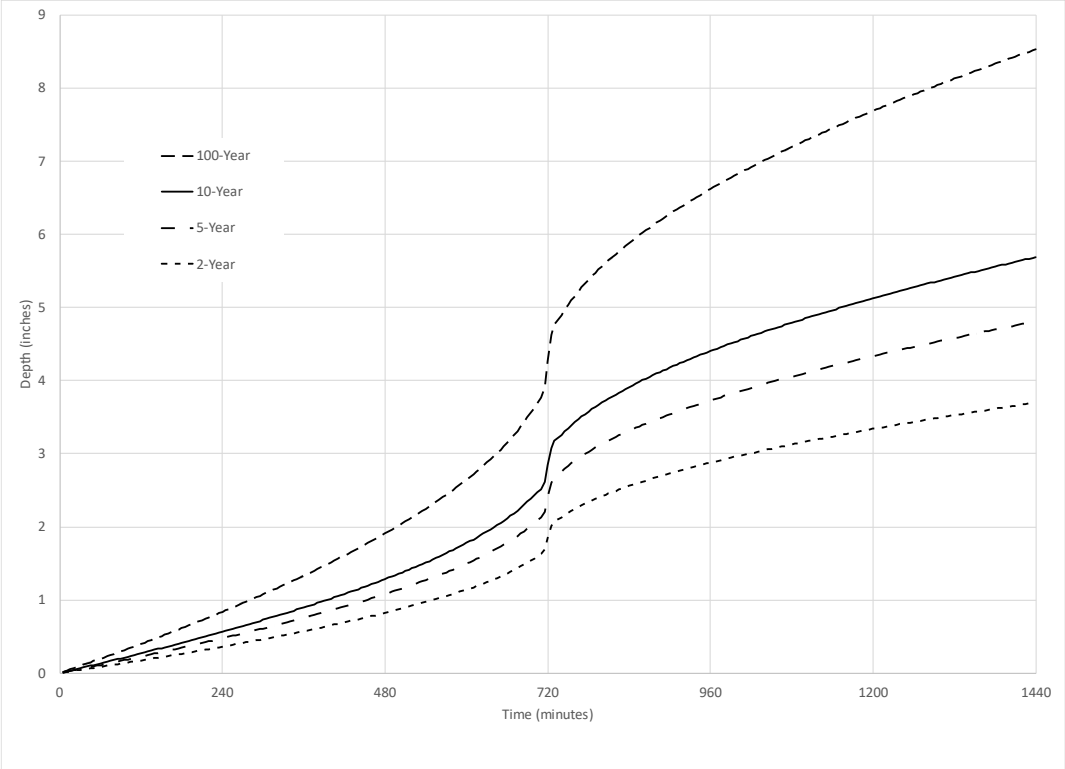


Exhibit 18: Cumulative Precipitation Chart for PZ 4

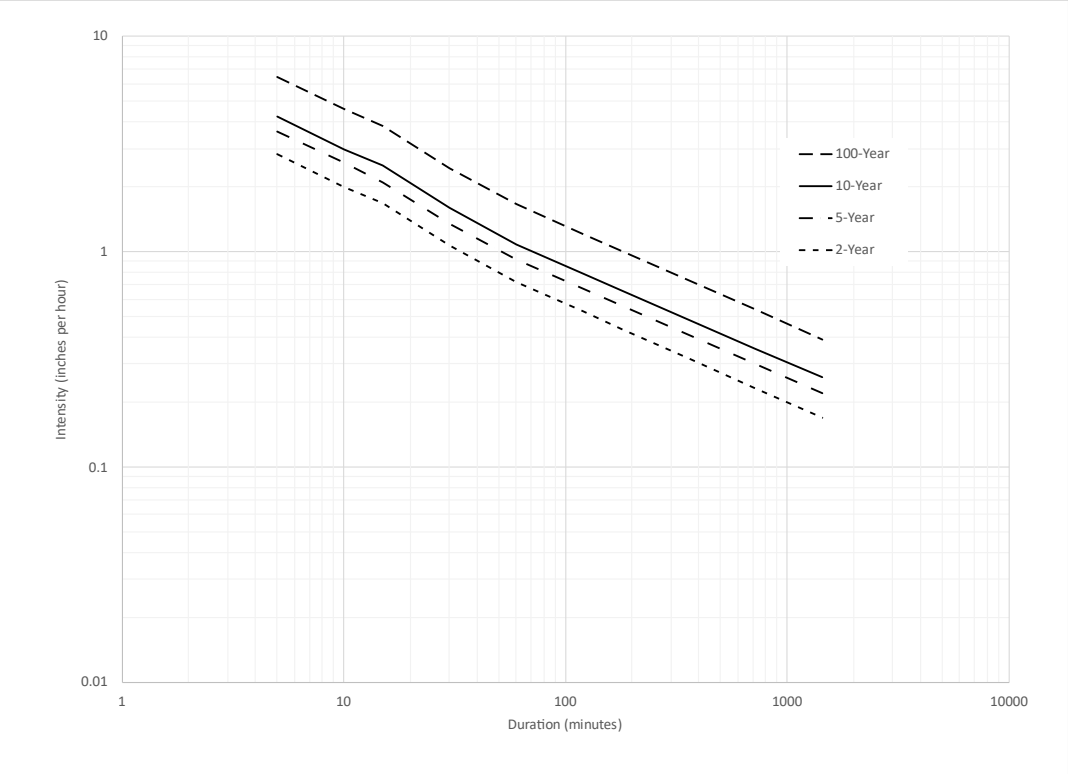


Exhibit 19: Intensity-Duration-Frequency Chart for PZ 5

Link to Figure 17: Design Precipitation Zones

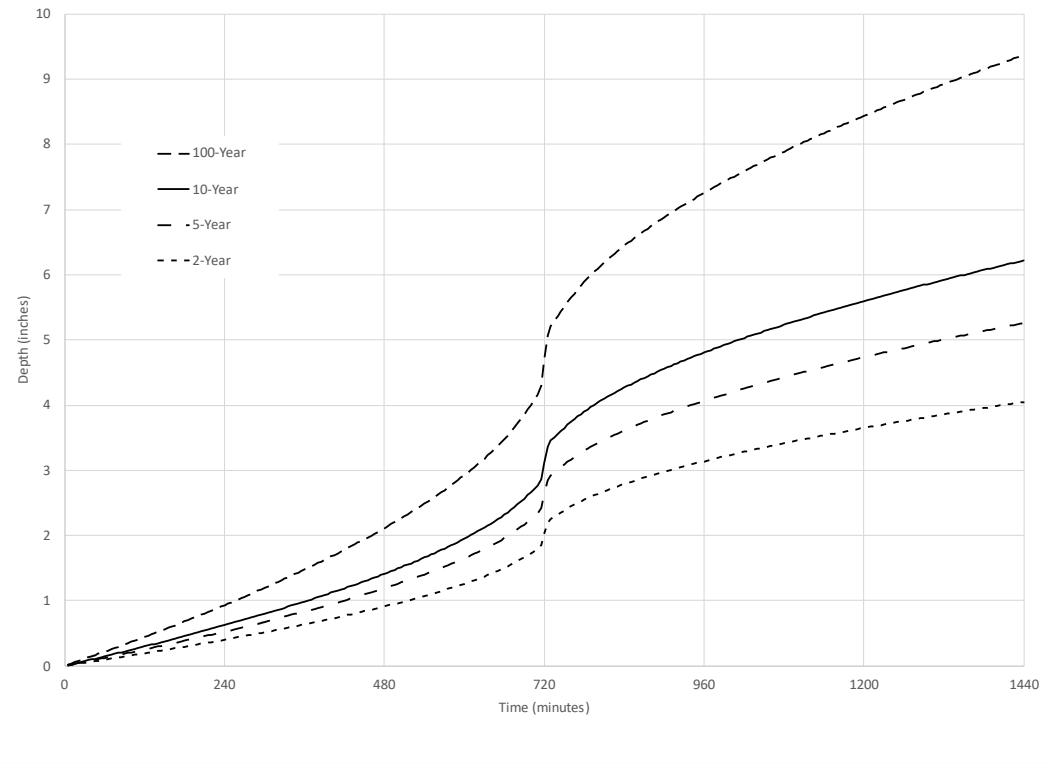


Exhibit 20: Cumulative Precipitation Chart for PZ 5

6.2.2 Loss Rates

Loss rates control how much of the rainfall incident to pervious areas (areas that are not effective impervious areas) becomes runoff. The Modified Horton Method described in Section 4.3 of the U.S. Environmental Protection Agency's *Storm Water Management Model Reference Manual, Volume 1 – Hydrology (Revised)* [39] was applied. The Modified Horton Method adjusts the potential infiltration rate during the storm using a function of minimum and maximum infiltration capacities, rainfall and coefficients that control how the infiltration rate changes over time. Typical parameters used with the Modified Horton Method are listed below in **Table 14**. The parameters used in the ICM models prepared for this SWMP were set as part of a calibration process presented in Section 7.3.3.

Table 14: Modified Horton Method Loss Equation Parameters

Hydrologic Soil Group	Max. Infiltration Rate Range (in/hr)	Min. Infiltration Rate Range (in/hr)	Decay Constant Range (1/hr)	Drying Time Range (days)
A	5 - 10	>= 0.45	2 - 7	2 - 14
B	4 - 8	0.30 - 0.15	2 -7	2 - 14
C	3 - 6	0.15 - 0.05	2 -7	2 - 14
D	1 - 2	0.00 - 0.05	2 - 7	2 - 14

6.2.3 Runoff Routing

Runoff routing is the process of transforming effective rainfall (rainfall that becomes runoff after loss rates are applied) to the runoff hydrograph at the watershed concentration point. The Snyder Unit Hydrograph Routing Model was selected for this analysis. In ICM, the Snyder method requires user inputs of Lag Time in minutes, as well as the Peaking Coefficient.

6.2.3.1 Lag Time

For this analysis, lag time was calculated as a fraction of the time of concentration. The lag time was set to 60 percent of the Time of Concentration.

The Time of Concentration was determined using the methodology described in USDA-NRCS Conservation Engineering Division's "*TR-55, Urban Hydrology for Small Watersheds*". [40] Factors affecting the Time of Concentration include surface roughness, channel shape, flow length, and land slope.

The following process was used to compute the Time of Concentration:

- The maximum and minimum elevation points, areas, and perimeters of each watershed were obtained using GIS.

- The length of the Longest Flow Path (LFP) was estimated based on a function of area (A) and perimeter (P): LFP ≈ [P-2.4(A/P)]/2.
- The length of sheet flow path was determined using the following assumptions:
    - If the area has imperviousness greater than 75 percent, assume that the sheet flow is 50 feet.
    - If the imperviousness is between 45 percent and 75 percent, assume that the sheet flow length over grass varies from 50 to 100 feet (longer distance for lower imperviousness).
    - If the imperviousness is less than 45 percent, the distance is assumed to vary from 100 to 300 feet.
- The slope was determined by taking the difference between minimum and maximum point elevations in the watershed and dividing this by the length of the LFP.
- An estimate for the Manning's roughness coefficient for sheet flow was obtained using the following process:
    - Where the imperviousness was greater than 80 percent, it was assumed that sheet flow would most likely be over pavement, and an n-value of 0.011 was used per TR-55 Table 3-1 included as **Table 15**, below.

Table 15: Table 3-1 Roughness Coefficients for Sheet Flow from TR-55

Table 3-1 Roughness coefficients (Manning's n) for sheet flow

Surface description	n [1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses [2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1] The n values are a composite of information compiled by Engman (1986).
[2] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3] When selecting n , consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

  - Otherwise, it was assumed that the sheet flow would be on grass with an n-value of 0.24.

- Precipitation depths for 2-year, 24-hour rainfall events were obtained from NOAA Atlas 14 data and are listed in **Table 9**. This parameter is used in the calculation of sheet flow travel time.

- For sheet flow path lengths less than 300 feet, the Manning's kinematic solution [41] was used to compute travel time (T_t) of sheet flow.

- The length of the concentrated flow path was calculated by subtracting the length of the sheet flow path from the length of the LFP.

- Effective velocity for shallow concentrated flow was estimated using the following assumptions:

  - The effective velocity varied based on the imperviousness.

  - Where the imperviousness was greater than 45 percent, then the paved velocity was used.

- Where the imperviousness was less than 45 percent, then effective velocity was determined by interpolating between the paved velocity and the unpaved velocity.
- The shallow concentrated flow travel time was determined based on the effective velocity and the length of the concentrated flow path.

- Time of Concentration assumptions:
  - Time of Concentration was calculated by adding both the shallow concentrated flow travel time and the sheet flow travel time. The minimum Time of Concentration was set as five (5) minutes.

6.2.3.2 Peaking Coefficient

The Snyder Unit Hydrograph basin peaking factor (C_p) affects the shape of the runoff hydrograph. C_p can range from 0.4 to 0.8. A C_p of 0.6 was applied to all of the watersheds in the Study Area, except for the large watersheds that are located upstream of the California Park Lake. The C_p values for these watersheds were calculated in accordance with the Alameda County Flood Control and Water Conservation District's (ACFC&WCD Hydrology and Hydraulics Manual 2016 [42] using the equation described in **Exhibit 21**, below. The ACFC&WCD Hydrology and Hydraulics Manual is referenced because it provides exceptional explanations of procedures to follow for the application of the Snyder Unit Hydrograph Method.

EQUATION 14 BASIN PEAKING FACTOR

$$C_p = 0.6e^{0.06(S_o/A)} \quad (14)$$

where:

C_p = *basin peaking factor* $(C_p \leq 0.85)$
S_o = *average watershed slope (percent from* ***Attachment 10****)*
For $S_o \leq 5\%$, $C_p = 0.6$
A = *drainage area* (mi^2; *if* $A < 5mi^2$, *use* $A = 5mi^2$)

Exhibit 21: Peaking Factor

6.3 Hydraulic Modeling

6.3.1 Overview of ICM

ICM provides the ability to model the complete natural and engineered above-ground and below-ground drainage systems including sewers, overland flow, rivers, and floodplains. The system

provides a master database for storing model and hydraulic data, with all the tools necessary to create, edit and manage that data. The software solves the St. Venant Equations for one-dimensional hydraulics and the Shallow Water Equations for two-dimensional hydraulics.

The various types of model elements are discussed in the following sections. Rather than tabulate all of the data for all of the elements in the model, a geodatabase with data for each modeled element has been provided to the City. The ICM model files have also been provided to the City.

6.3.2 Links

6.3.2.1 Closed Conduits

Closed conduits include all modeled culverts and pipes. Parameters associated with closed conduits include shape and size, invert elevations, roughness coefficients, and entrance and exit loss coefficients.

A Manning's n-value of 0.013 was assigned to the concrete pipes [cast-in-place (CIP), concrete (CONC), and reinforce concrete pipe (RCP)], a value of 0.011 was assigned to the plastic pipes [high density polyethylene (HDPE), polyvinyl chloride (PVC), and acrylonitrile-butadiene-styrene (ABS)], vitrified clay pipe (VCP), and asbestos cement pipe (ACP), and a value of 0.025 was assigned to corrugated metal pipe (CMP). **Table 16** includes the pipe material and its assigned n-value.

Table 16: Manning's n-values for Pipes

Pipe Material	n-value
CIP/CONC/RCP	0.013
ACP/VCP	0.011
HDPE/PVC/ABS	0.011
CMP	0.025

The modeling software has limitations in defining nonstandard pipe shapes such as an elliptical pipe. An equivalent round size was used to model the elliptical pipes. The GIS contains an attribute that provides the elliptical pipe dimensions and another attribute with the equivalent circular pipe size.

Junction head loss coefficients are used to account for energy losses through junctions such as manholes. Junction head loss coefficients were computed using the parameters listed in the ACFC&WCD Hydrology and Hydraulics Manual and summarized in **Table 17**. The head loss coefficients (K_b factors) for each pipe upstream from each junction were calculated based on the angle between the upstream and downstream pipe and this K_b factor was applied at the downstream end of the upstream pipe. The upstream head loss coefficient was set to NONE for most pipes in order to prevent double-counting the losses. Flap gates were assigned a loss coefficient of 1.0

because cast iron flap valves are typical. Pipes that discharge to a channel also used a K factor of 1.0. The entrance and exit loss coefficients of culverts were assigned as 0.5 and 1.0, respectively.

Table 17: Energy Loss Coefficients due to Flow Direction Change	
Structure Configuration	**K_b shaped**
Manhole straight run = 0°	0.05
Manhole Θ = 30°	0.15
Manhole Θ = 45°	0.29
Manhole Θ = 60°	0.48
Manhole Θ = 90°	1.02

6.3.3 Nodes

6.3.3.1 Manholes

Manholes are typical locations where pipes join. Catch basins are also frequently used as pipe junction locations. Within ICM, inlets are modeled as manholes. One of the model parameters associated with manholes is "Flooding Type." Most of the manholes in the model are defined with a Flooding Type of "2D" that allow an exchange of flow with the mesh. The exchange of flow between the 2D manhole and the 2D mesh is calculated using weir equations assuming a weir crest level at the node ground level, and a crest length equal to the node shaft circumference.

6.3.3.2 Break Nodes

Break nodes are generally used to connect links where no manhole or inlet is present. Break nodes are used to connect river reaches, pipes to culverts, and culverts and pipes to river reaches. The model set up for some special features, such as flap gates and orifices, include break nodes. Break nodes create a closed junction and can be used to model changes in slope or dimension in a conduit. The only parameter required for break nodes is ground level.

6.3.3.3 Pond Nodes

A pond node defines a volume that supports the simulation of infiltration into the ground from the sides and the base of the pond. The detention basins in the model are represented by pond nodes. Each pond node includes an array of areas corresponding to depths. This information is used by ICM for calculations of the storage volume. The parameters required for pond nodes are: ground level, vegetation and liner levels (if used to vary infiltration rate), and infiltration rate. Infiltration was not needed for the modeled detention basins.

6.3.3.4 Storage Nodes

Storage nodes are used to define storage area shapes using level-area pairs. Storage nodes were used for modeled underground detention systems with infiltration. Infiltration from underground storage systems was included by using outfalls with a stage versus discharge relationships.

6.3.3.5 Outfalls

Outfall nodes are used for discharge points where flows leave the modeled system. Outfalls are assigned a boundary condition that controls the starting water surface elevation or hydraulic grade line at the discharge point. The 50-year water surface elevation from HEC-RAS was used for the starting elevation for the 100-year pipe analysis for locations where storm drainage systems discharge to creeks that are not modeled in ICM. Similarly, the 10-year water surface elevations from HEC-RAS were used as the downstream boundary condition for both the 10-year and 2-year pipe system analysis. The 50-year water surface at the creek was assumed for the 100-year pipe evaluation because peak 100-year conditions in the pipe would not be coincident with peak 100-year conditions in the receiving channel.

Some dry wells and leach trenches were modeled using outfalls. Small dry wells and leach trenches that are part of the drainage systems that are connected to creeks via pipes and channels were not modeled because their typical intended purpose was assumed to be for storm water quality. Generally, larger infiltration systems were modeled in detail based on available storage and an assumed infiltration rate using storage nodes and an outfall node that receives the infiltration losses. However, the infiltration systems within capped systems that receive runoff from drainage inlets and small drainage systems were assumed to be adequate to manage all local runoff in the existing system analysis and were modeled using outfalls. The outfalls at capped systems and other inlets with dry wells in the existing conditions model were not included in the build-out drainage system model.

6.3.3.6 Two-dimensional Outfalls

Two-dimensional outfalls are nodes where there are flows directly from or to the two-dimensional zone from the one-dimensional model features. Two-dimensional outfalls were used as inlets for crossing culverts rather than manhole features because two-dimensional outfalls allow for the node ground invert to be set equal to the conduit invert without generating instability.

6.3.3.7 Two-dimensional Point Source

Two-dimensional point sources are points where the subcatchments' discharges flow directly into the two-dimensional zone. These were used in locations where a subcatchment does not discharge flow directly into a manhole (manholes are used as inlets); instead, flow exits the subcatchment as overland flow. These points were also used to discharge flow from subcatchments that drain directly to a two-dimensional outfall. In an existing conditions model, watersheds discharge to a

two-dimensional point source where a proposed drop inlet is located. This shows the overland flow where there are improvement projects in the buildout conditions model.

6.3.4 Two-dimensional Mesh

Two-dimensional mesh zones are used to simulate flooding through streets, across open ground, and along some of the streams within the Study Area. The ICM mesh consists of triangles of various sizes that cover the ground. Each triangle approximates the ground with a single elevation and roughness. The program derives elevation values from the terrain surface that is imported into the model. Mesh roughness values were assigned using roughness zone polygons. Roughness zones for the roadways were determined using land use and parcel data.

ICM allows for the use of areas with different ranges of mesh sizes. Model runs were first performed using a relatively coarse mesh in order to determine where finer mesh is required. The typical coarse mesh element size is 1,000 square feet. Though this mesh size is not small enough to capture details of curb and gutter geometry, it is adequate to convey the flows that are not contained within the storm drain system. Areas with significant flows along streets and areas with channels are modeled with a finer mesh to better simulate concentrated flow conditions. The finer mesh elements are smaller than 50 square feet. There are transition zones within the areas of coarse mesh where mesh sizes are gradually varied in order to come into alignment with the finer mesh. The areas with finer mesh and roughness zones are shown in **Figure 18**.

The maximum water surface elevation at each mesh element is determined in ICM. A digital surface is then generated using the ICM results. A GIS process is used to map the flood surface onto the terrain DEM. The process of mapping the model results to the terrain produces a more precise depiction of potential flooding than that which would result from the direct presentation of model results.

7.0
Baseline Hydrology and Calibration

7.0 BASELINE HYDROLOGY AND CALIBRATION

Baseline hydrology is the process of determining the flow rates that will be used to evaluate the performance of the existing drainage system. The baseline also provides a reference for comparison to identify impacts of potential changes. For the purposes of storm water master planning, information about existing conditions is used to determine the rate and timing of runoff from rainfall. The existing physical drainage system is discussed in Section 5.0, Update Current GIS Mapping. The amount of rainfall that becomes runoff is a function of the amount of rainfall, soil types, vegetation, and imperviousness. The timing of runoff is dependent on surface roughness, slope, flow line lengths and channelization. This section of the SWMP presents the development of hydrologic model parameters used to calibrate the model and establish standard recurrence interval (2-year, 10-year, and 100-year) storm flows.

The focus of this section of the SWMP is on the hydrology used for the evaluation of the urban drainage system. The sources of hydrology used for the evaluation of the Chico Area Streams are discussed in **Sections 2.4.5** and **2.4.6**. The process for applying the hydrology to the hydraulic models of the streams is included in **Section 6.0 Hydrologic and Hydraulic Modeling**.

7.1 Soils

Soil characteristics factor into how much rainfall becomes runoff. The USDA-NRCS produces data that describes various soil characteristics. One of the characteristics that is commonly used to estimate runoff from rainfall is the hydrologic soil group (HSG).

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The soils in the United States are assigned to four groups (A, B, C and D) and three dual classes (A/D, B/D and C/D). The dual classes are not present within this Study Area. The groups are defined as follows:

Group A – Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well-drained to excessively-drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B – Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of soils that are moderately deep or deep, or moderately well-drained or well-drained, and that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C – Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water, or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D – Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

The latest soil data available from the USDA-NRCS Soil Survey for Butte County is Version 18, dated September 2021. There is a high degree of variability in the HSG classifications within the Study Area. The HSG map for the Study Area is included as **Figure 19**. [43]

7.2 Imperviousness

Imperviousness is a key parameter used in the process of computing runoff. In highly-developed areas, nearly all rainfall that is incident to impervious surfaces such as pavement and rooftops[7] becomes runoff. Runoff from some rooftop and pavement areas is directed onto pervious surfaces and some runoff flows directly into the storm drain system. Only a fraction of the runoff directed from impervious surfaces onto pervious surfaces reaches the storm drain system. Many factors influence how much of the rainfall incident to impervious surfaces will reach the storm drain system. For the SWMP hydrologic analysis, imperviousness for existing conditions was estimated. Then, the estimates of actual imperviousness were adjusted to assign effective imperviousness values used in the calculation of runoff.

General Plan land use data was used with aerial imagery and available estimates of imperviousness and building footprint data in a process used to estimate the existing imperviousness of each parcel and the roadway right-of-way within the Study Area. The parcel-by-parcel imperviousness estimates were used to compute an existing condition imperviousness value for each drainage area in the storm drainage system model.

7.2.1 General Plan Land Use

General Plan land use data does not provide a direct correlation to existing conditions imperviousness or buildout conditions imperviousness. However, it is useful to consider zoning during the process of evaluating existing and potential imperviousness. The General Plan land use is illustrated in **Figure 20**. The table of land use zoning was obtained from: https://gicwebsrv.csuchico.edu/gicarcsrv01/rest/services/City_of_Chico/GeocortexMap_Public/MapServer/26 (link not available as of February 2024), is available at City of Chico (arcgis.com) in March 2024 by viewing parcel legend data, and is included as **Table 18**.

[7] Exceptions include green roofs and pervious pavement.

Table 18: General Plan City Zoning/Pre-zoning	
Land Use	**Land Use Description**
A	Airport
AC	Airport Commercial
AM	Airport Manufacturing
AP	Airport Public Facilities
CC	Community Commercial
CN	Neighborhood Commercial
CR	Regional Commercial
CS	Services Commercial
DN	Downtown North
DS	Downtown South
IOMU	Industrial Office Mixed-Use
MG	General Manufacturing
ML	Light Manufacturing
OC	Office Commercial
OR	Office Residential
OS1	Primary Open Space
OS2	Secondary Open Space
PQ	Public/Quasi Public Facilities
R1	Low Density Residential
R1-10	Low Density Residential 10,000SF min
R1-15	Low Density Residential 15,000SF min
R2	Medium Density Residential
R3	Medium-High Density Residential
R4	High Density Residential
RMU	Residential Mixed Use
ROW	Right-of-Way
RS-1	Suburban Residential 1-acre min
RS-2	Suburban Residential 2-acre min
RS-20	Suburban Residential 20,000SF min
RS-3	Suburban Residential 3-acre min
SPA	Special Planning Area
TND	Traditional Mixed Use

7.2.2 National Land Cover Database and Building Footprints

The National Land Cover Database (NLCD) provides 30-meter resolution raster data for ground cover and urban imperviousness. Upon detailed inspection, it was found that the NLCD data varies in accuracy, depending on various circumstances and that other available

data could be used to assign more precise estimates on a parcel-by-parcel basis. Rather than relying solely on NLCD data for estimates of imperviousness, the analysis for the SWMP included a review of other data in order to aid in the estimation of impervious cover. The data available to estimate imperviousness for existing conditions included 2019 NLCD imperviousness data, as well as building outlines from https://github.com/Microsoft/USBuildingFootprints and Environmental Systems Research Institute, Inc. (ESRI) world imagery from https://services.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer. During the review of these sources, both the weighted average NLCD imperviousness and the fraction of building coverage within each parcel were computed and analyzed.

In some instances, the NLCD was effective in capturing the impervious cover, but in other cases it was not. For example, the parcel in **Exhibit 22** (below) is in an area with commercial land use designation. The weighted average of 72-percent imperviousness from the NLCD appears to be reasonable based on the examination of the imagery for this parcel. In some instances, however, the NLCD does not accurately capture the existing impervious cover. The most common discrepancies were observed for R1, R2 and R3 zoning that, together, make up about 80 percent of the parcels and 25 percent of the land area in the City's sphere of influence. **Exhibit 23** (below) shows a parcel that is 53-percent imperviousness based on the NLCD. Based on a detailed review of the imagery, it was determined that this is an overestimation of imperviousness that may have been due to a lack of vegetation on bare earth. There are many other examples that show the NLCD overestimating imperviousness, but there are also many parcels for which the NLCD underestimates the impervious cover.

Exhibit 22: Community Commercial (CC) Land Use Consistent with NLCD Imperviousness

Exhibit 23: Low Density Residential (R1) Land Use Inconsistent with NLCD Imperviousness

To provide better estimates of imperviousness for the parcels with R1, R2, and R3 land use designations, building footprint data was incorporated into a process for estimating the imperviousness of each parcel by taking the following steps:

1. Preliminary screening was applied to parcels that were outliers. Parcels with irregular shapes, parcels with only portions of building footprints, and parcels without building footprints were screened and assumed to have an estimated imperviousness equal to the NLCD weighted average. Smaller parcels that lie directly on buildings or portions of buildings were all assumed to have an estimated imperviousness equal to 95 percent. In

both cases the imagery was used to confirm that the values are reasonable. Steps 2-6 (below) were used to estimate existing conditions imperviousness for the remaining parcels.

2. An amplified building footprint was computed by multiplying the building footprint area by 1.2 to account for driveways and other impervious surfaces.
3. If the difference between the NLCD imperviousness area and the amplified building footprint area was less than one (1) percent, then the NLCD data would govern as the imperviousness estimate because the sources of data were consistent.
4. If the amplified building footprint was greater than the NLCD imperviousness area, then the amplified building footprint would govern as the imperviousness estimate. In these cases, it was concluded that the NLCD typically underestimated imperviousness based on a review of aerial imagery.
5. If the amplified building footprint was less than the NLCD imperviousness area, then the lesser of the NLCD and the doubled building footprint was used as the imperviousness estimate.
6. For R2 and R3 land uses, an additional condition statement was added to provide better estimates for parcels with large differences between the NLCD imperviousness and the amplified building footprint area. For these situations, the NLCD imperviousness was used in place of the amplified building footprint if the NLCD imperviousness area minus the amplified building footprint was more than 50 percent of the parcel area.

7.2.2.1 National Land Cover Database and Imagery

For many of the other land use categories (other than R1, R2 and R3), the NLCD data provided a more reliable estimate of imperviousness than the building footprint ratio. In high-density areas such as commercial and manufacturing, the parcels are typically larger, allowing for the 30-meter raster pixels to better represent the existing imperviousness condition. The driveways and parking spaces make up a varying portion of the impervious area which complicates the use of building footprints for estimation. The NLCD was also deemed accurate for special, low-density residential, high-density residential and suburban residential parcels. For these land uses, the NLCD-based imperviousness values were used after being reviewed and compared to the imagery for verification of reasonableness. All land uses were examined to identify parcels with significantly low or high imperviousness values and manual corrections were made to reflect what was seen in the imagery.

Airport, Open Space and Traditional Mixed Use land uses required manual entry to replace the NLCD imperviousness weighted averages. The manual correction was required to rectify discrepancies between the data and the imagery.

7.2.2.2 Active Development

A map and list of active development sites[8] was provided by the City. The map is included as **Exhibit 24**, below. The imperviousness for the parcels in these areas was manually updated to reflect the estimated built-out imperviousness for the corresponding type of development (residential, commercial, multi-family). Imperviousness values were assigned to active development parcels based on typical values observed in NLCD data and imagery for more recently developed similar land uses.

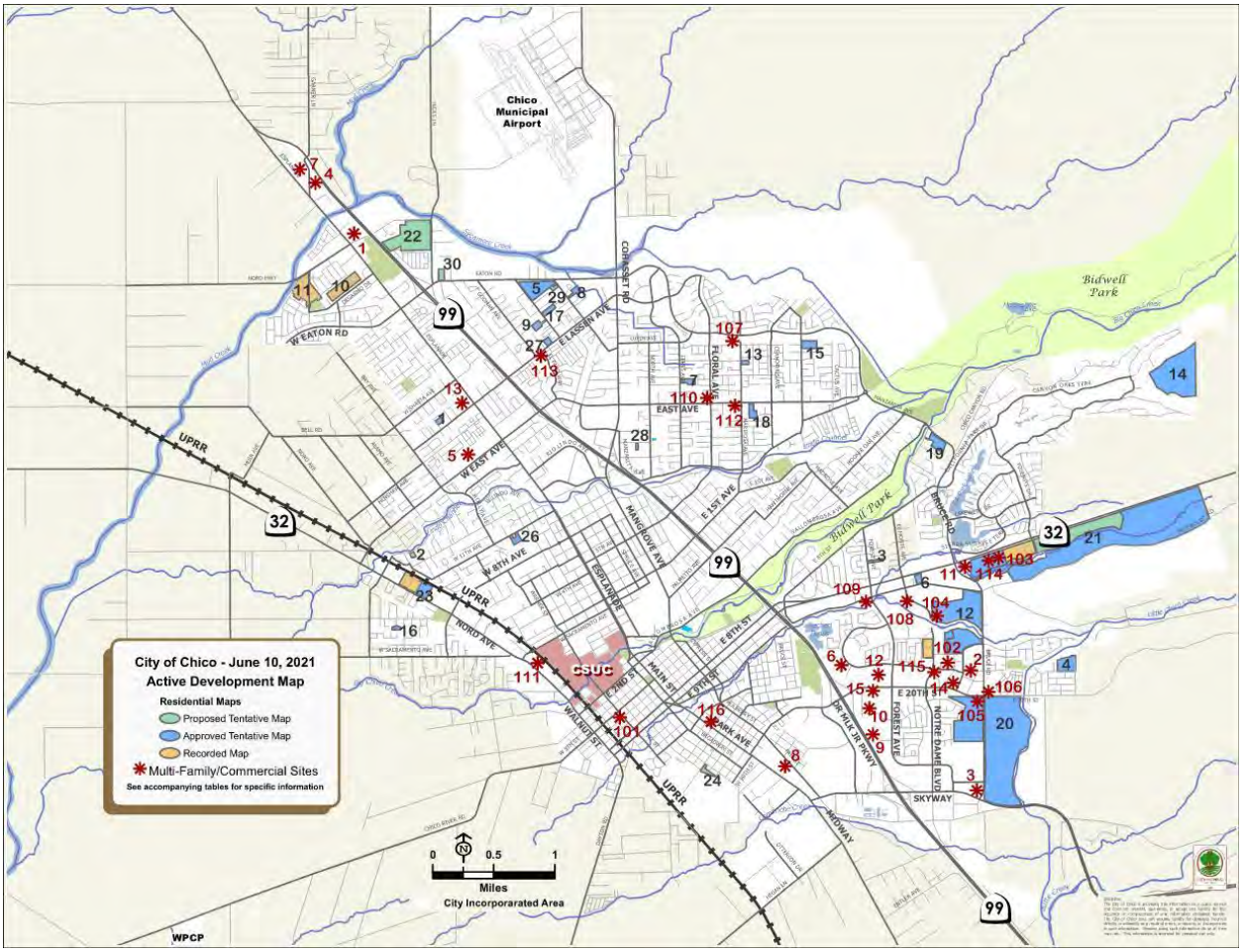


Exhibit 24: Active Development Locations

7.2.2.3 Roadway Imperviousness

The approach used to assign an impervious cover percentage to roadways involved analyzing the imagery and approximating a typical value. For the majority of the roadways, a value of 80-percent imperviousness was assigned, because approximately 20 percent of these areas are

[8] Email from City titled, "RE: Baseline existing conditions hydrology and drainage system," dated November 15, 2021.

covered by planters, medians, and lawns. A typical example of roadway is presented below in **Exhibit 25** where there are landscaped areas along the road. For SR 99, a value of 55-percent imperviousness was assigned to account for the larger percentage of pervious surfaces. **Exhibit 26** illustrates a typical area of the highway where nearly half of the road's right-of way is made up of pervious surfaces.

Exhibit 25: Typical Roadway Section in a Medium Density (R2) Land Use Area

Exhibit 26: Typical SR 99 Section with Merging Ramps and Overpass

Figure 21 presents the estimates of actual imperviousness used for existing conditions analysis.

The process for assigning imperviousness for build-out conditions is described in **Section 9.3**.

7.2.3 Effects of LID Measures on Effective Imperviousness

Determination of appropriate imperviousness values for buildout conditions can be significant to storm drainage master planning. Imperviousness is the key variable that causes runoff rates and volumes as areas develop. Imperviousness values are typically correlated to land use assumptions for the purpose of storm drainage master planning. Adjustments to actual imperviousness are often used as a generalized approach to account for the flow reduction benefits that result from non-directly-connected impervious areas (**Section 7.3.4**) and incorporation of LID measures. The LID measures are sustainable infrastructure principles that include the use of disconnected roof drains, amended soils, bioretention and other design features to reduce the rate and volume of storm water runoff.

7.2.3.1 Infiltration Rates and Bioretention

LID measures generally rely on soil permeability to reduce runoff volume. The effectiveness of LID measures at reducing runoff volume is highly dependent on the infiltration capacity of the soil. Higher infiltration rates make LID measures more effective. Other factors, including precipitation quantities, imperviousness of the tributary area, and design details also affect the effectiveness of LID measures at reduction runoff. The Web Soil Survey provides values for saturated hydraulic conductivity (Ksat) that provide a measure of the permeability of the soil. Although there are some relatively small locations of other Ksat values, the vast majority of the City is underlain with soils that have reported Ksat values from 0.06 to 7.0 inch per hour. In the absence of other information, it is reasonable to use half of the reported Ksat value for soils below the surface layer as the infiltration rate for planning studies in order to account for variability and long-term degradation of infiltration rates under bioretention facilities. **Figure 22** presents the saturated hydraulic conductivity values from the NRCS soil database.

The NRCS soil database includes depth ranges and various Ksat values for each depth range. For cases where the deepest indicated depth is 152 centimeters (cm) or less, the Ksat – Representative Value for the deepest depth available was selected. For cases where the deepest indicated depth is greater than 152 cm, the minimum Ksat – Representative Value for depths greater than 152 cm was selected. The Ksat values listed in the NRCS database are in units of micrometer per second. These values were converted to inches per hour for presentation in the SWMP.

7.2.3.2 Evaluation to Quantifying the Benefit of LID Measures

In practice, implementing a LID approach can involve the use of many measures throughout a development rather than centralized detention, retention, or infiltration basins. LID measures include stream setbacks and vegetated buffers, soil quality improvements, tree planting and preservation, porous pavement, green roofs, vegetated swales, rain harvesting and reuse, bioretention basins, rain gardens, infiltration trenches, flow-through planters and tree wells.

The Phase II Permit (Provision E.12.e.(f)) identifies bioretention as the standard storm water treatment control measure unless: 1) an alternative treatment control measure that is equivalent to bioretention is proposed and demonstrated (Provision E.12.e.(g)); or 2) a specified exemption applies (Provision E.12.e.(i)). In order to have a relatively straightforward approach to account for the effectiveness of implementing LID principles at reducing runoff volume, analysis was performed based on a standard design approach for bioretention basins.

LID measures are intended to reduce the volume of runoff relative to that which would have occurred using traditional approaches to land development. Additionally, the Phase II Permit requires certain projects to meet hydromodification management requirements that regulated discharge rates. However, the benefits of LID and hydromodification management on flows in the storm drainage system and the creeks to which they drain are difficult to quantify. Highly variable site conditions. primarily related to the timing of peak discharges from the site relative

to the timing of peak discharges in receiving waterways. cause the need for evaluating project-specific peak flow impacts on a case-by-case basis when this information is required.

Bioretention basins can be highly effective at reducing peak discharges from relatively high-intensity, low-volume storms of short duration that are typically responsible for peak discharges from small areas. Storms with low peak rainfall intensities but high total rainfall volumes can cause bioretention basins to overflow, at which point runoff rates can increase significantly over pre-Project conditions. This SWMP assumes that it is reasonable to simulate runoff from future areas that will incorporate LID measures based on an effective reduction in the impervious area expected from the incorporation of bioretention basins.

The effective reduction in the impervious area resulting from the incorporation of a bioretention basin depends on the design of the bioretention basin; the infiltration rate of the soils below the basin; the precipitation and the soil, ground cover, and actual imperviousness of the tributary area. The design parameters that affect the performance of a bioretention basin include its area and effective depth, in addition to any underdrain that has been included. For the purposes of the SWMP, the effective reduction in imperviousness for a 100-year storm was evaluated for each of the five precipitation zones (PZs) defined in Section 6.2.1. Though the effective reduction in imperviousness would be higher for more frequent storm events, it would be impracticable to use different effective impervious values for different storm events. The evaluation was performed for each of the four HSGs using a typical curve number (CN) and infiltration rate for each, except for HSG D for which two infiltration rates were evaluated. The infiltration rates were selected by using typical saturated conductivity values divided by 2. Actual imperviousness (i) was varied from 0.1 to 0.9. Site runoff into the bioretention basins was calculated using TR-55 [40]. **Table 19** lists the CN and values and infiltration rates used in the bioretention basin evaluation.

Table 19: Typical Precipitation and Runoff Depths

HSG	CN	Infiltration Rate (inches/hour)
A	39	3.5
B	61	0.6
C	74	0.3
D	80	0.1
D	80	0.03

The design of bioretention basins is a function of the mean annual runoff-producing rainfall depth (P_6) of 0.55 inch.[9] The design procedures call for this value to be multiplied by a regression constant (a) of 1.963 (for a 48-hour drawdown time) and the runoff coefficient (C) to determine the unit storm water volume (Maximized Detention Volume, P_0) that is used to

[9] Consistent with the Appendix 6 Volumetric BMP Sizing Tool referenced in the City's Post Construction Standard Plan

calculate the storm water design volume (SDV). For the purposes of calculating the SDV, the runoff coefficient (C) was computed using the equation: $C = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$.

The required bioretention basin bottom surface area (A) is computed by dividing the SDV by the effective depth of the facility. The effective depth of 1.25 feet was determined by adding 0.5 foot of surface storage, 1.5 feet of planting media with a porosity of 0.26, and 1.0 foot of gravel with a porosity of 0.36. **Table 20** lists the bioretention basin sizes assumed in the runoff reduction evaluation. The sizes of the basins are a function of the imperviousness of the tributary area.

Table 20: Bioretention Sizing for Runoff Reduction Evaluation

Imperviousness	Runoff coefficient	Unit storm water volume (inches)	SDV (ft^3/acre)	Area (ft^2/acre)	Bioretention area (% of watershed)
i	C	P_0	SDV	A	
0.1	0.11	0.12	433	346	0.8%
0.2	0.17	0.18	668	534	1.2%
0.3	0.23	0.24	882	706	1.6%
0.4	0.28	0.30	1096	877	2.0%
0.5	0.34	0.37	1330	1064	2.4%
0.6	0.41	0.44	1603	1282	2.9%
0.7	0.49	0.53	1936	1549	3.6%
0.8	0.60	0.65	2349	1879	4.3%
0.9	0.73	0.79	2862	2290	5.3%

The bioretention basins in areas of HSGs C and D were assumed to have underdrains located at the top of the gravel layer.

The results of the runoff reduction analysis for PZ 3 are presented in **Exhibit 27**. The marker symbols are assigned by infiltration rate as indicated in the legend. The values presented in the chart are computed as the difference between the actual imperviousness and the effective imperviousness divided by the actual imperviousness.

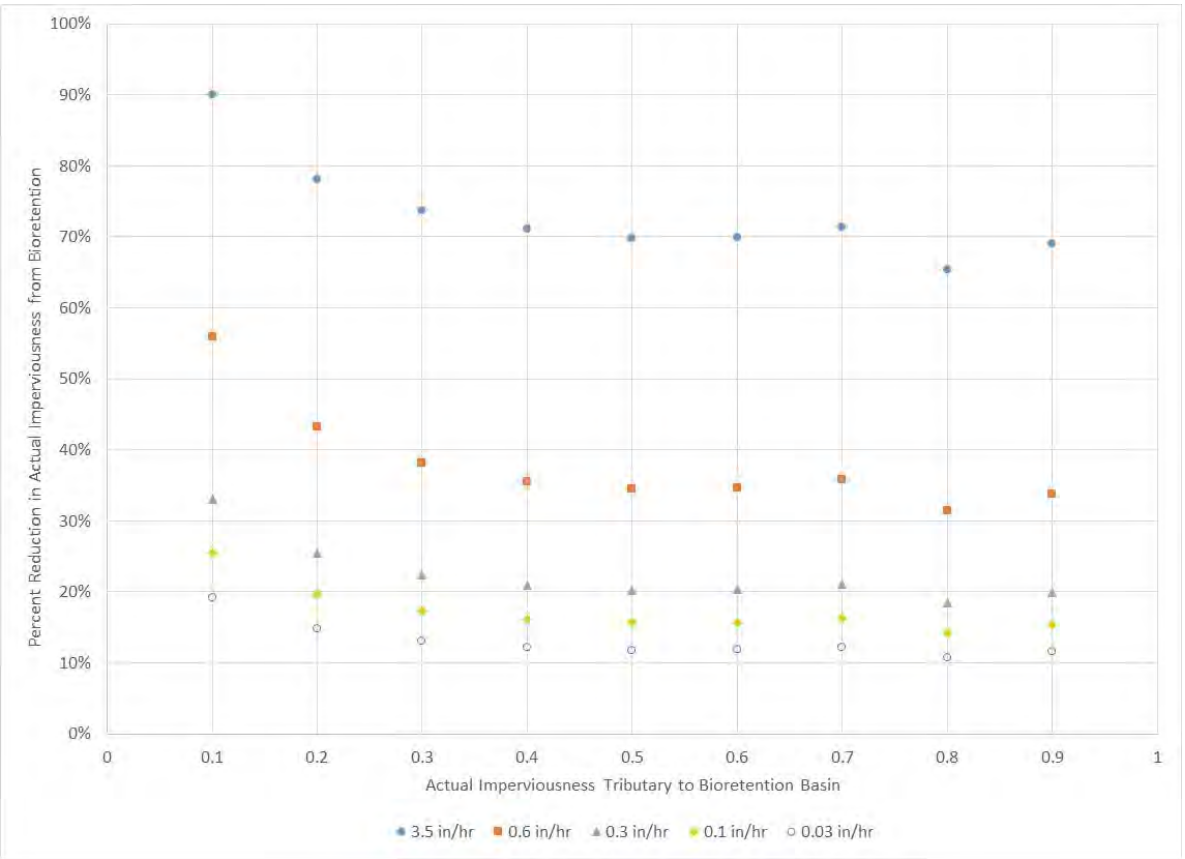


Exhibit 27: LID Runoff Reduction Credit for Precipitation Zone 3

Exhibit 28 (below) illustrates the results of the runoff reduction analysis for a design infiltration rate of 0.3 inch per hour. This chart shows that there is a relatively small variation in effectiveness between the five PZs. There is also only a relatively small variation in effectiveness for actual imperviousness between 0.3 to 0.9. Similar charts were prepared for each of the infiltration rates being evaluated. Most development will have imperviousness between 0.3 and 0.9. Therefore, for the sake of simplicity, it is reasonable to use one imperviousness reduction factor for each infiltration rate. The reduction factor was assigned based on one-half of the average saturated hydraulic conductivity below the surface soils of each parcel extracted from the USDA NRCS Soil Survey data. The reduction factors listed in **Table 21** were applied to new development based on the assumption that LID measures that provide runoff reduction that is as effective as bioretention will be incorporated into future projects.

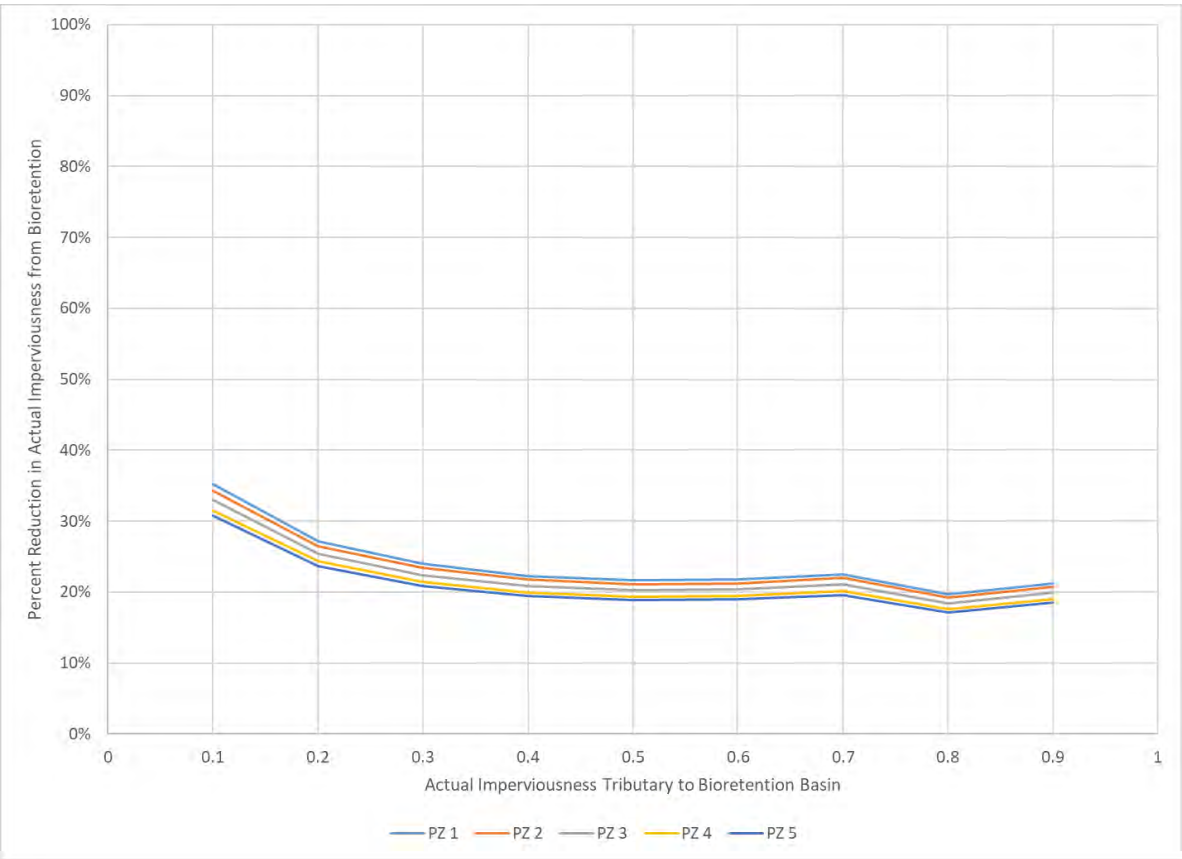


Exhibit 28: LID Runoff Reduction Credit for Design Infiltration Rate of 0.3 in/hr

Table 21: Percent Reduction in Effective Imperviousness from Bioretention	
One-half of Ksat (in/hr)	**Reduction in Effective Imperviousness**
3.5	70%
0.6	34%
0.3	20%
0.1	16%
0.03	12%

See **Section 9.3 Build-out Hydrology** for additional information about how LID effectiveness was applied to future conditions analysis.

7.3 Calibration

Hydrologic model calibration is the process of adjusting model parameters while comparing model results to measured flow rates in order to improve confidence that the model produces reasonable results. Model calibration was performed using available stream flow records for a gage on Lindo Channel at Cussick Avenue. The process involves applying measured precipitation to the model

and adjusting parameters such as loss rates and roughness factors. One critical aspect of calibrating the local storm drainage system model using the Lindo Channel stream gage is the selection of a storm event with flows that result from runoff originating within the City as opposed to the Big Chico Creek Watershed upstream from the City. Maximum Lindo Channel flows include diversions out of the Big Chico Creek – Sycamore Creek flood control system that manages runoff that originates outside of the City.

There are numerous challenges associated with model calibrations. There are periods when stream gages are not functioning or are producing suspect readings. There are also issues with the availability of precipitation data. For the SWMP, the Western Weather Group provided precipitation data. In order to have the most available precipitation records, the SWMP calibration effort focused on events from 2018 through 2021.

7.3.1 Stream Data

Stream gage data for Lindo Channel near Chico (Station ID: LCH) was downloaded from the California Data Exchange Center (CDEC) [44]. Stream data for Big Chico Creek (Station ID: BIC) upstream from the diversion systems was also downloaded. Stream data is also available for Mud Creek (Station ID: (MUC), but Mud Creek flows were not useful in the storm drainage system model calibration effort because it was not possible to isolate the urban contribution to runoff from the large contributing drainage area. The stream gage locations are shown below on **Exhibit 29**. When there are flows in Lindo Channel but not in Big Chico Creek upstream from the diversion systems, the flows in Lindo Channel result from local inflows and can potentially be used for calibration.

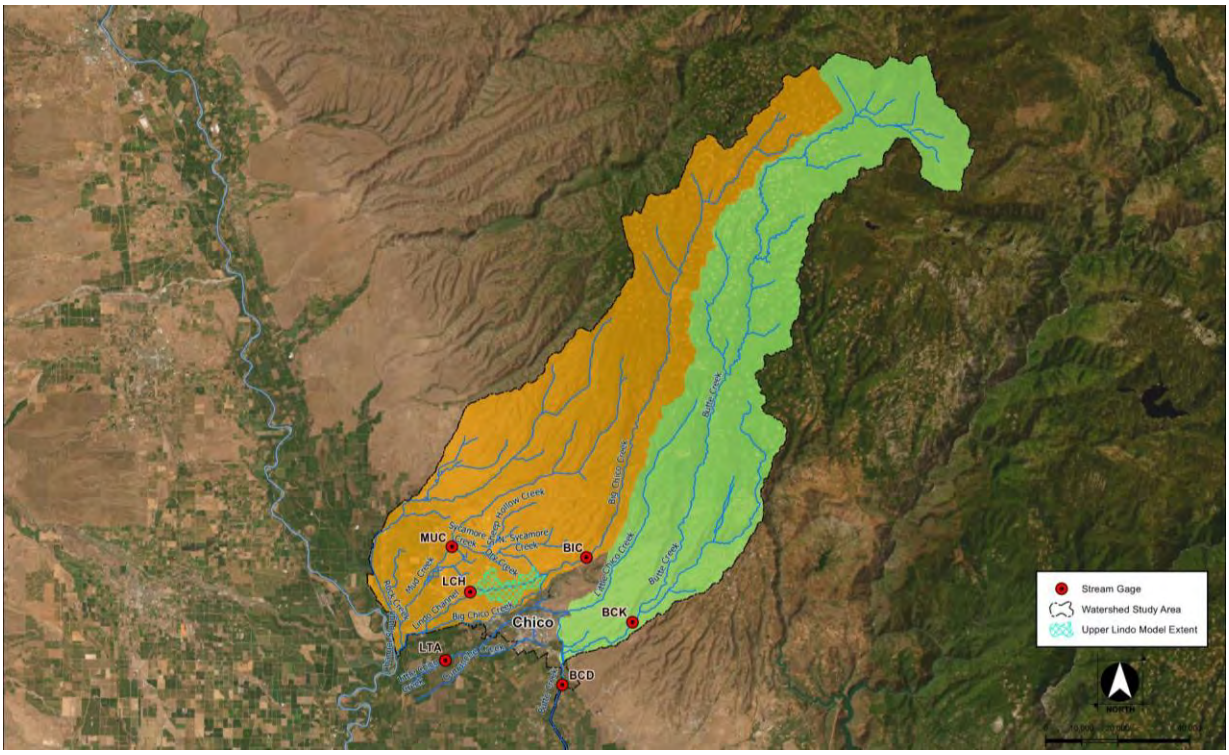


Exhibit 29: Streamflow Gage Locations

A rainfall event on April 16, 2018 was selected for calibration. Although there were flows of up to 400 cfs in Big Chico Creek during this event, the flows were contained to Big Chico Creek and were not being diverted into Lindo Channel.

7.3.2 Precipitation Data for Calibration

Precipitation data is a key component of the calibration process. The runoff from a watershed that generates stream flows is caused by spatially varied precipitation. Although radar rainfall can provide spatially accurate precipitation distributions, the effort to obtain, validate and apply radar rainfall for model calibration was not anticipated to be worthwhile and was not included in the Scope of Services for the SWMP. Rain gage data was available at multiple locations around the City and the rain gage data was used for the calibration. Precipitation gage locations are shown below in **Exhibit 30**.

On April 16, 2018, the Chico State Farm precipitation gage recorded 0.59 inch, the Chico-North gage recorded 0.78 inch, the Central gage recorded 1.18 inches, and the Chico-Northeast gage recorded 1.4 inches. These measurements show considerable spatial variability in the rainfall. The Chico-North gage precipitation was applied to the entire Upper Lindo Creek Watershed Model because it produced the most reasonable results.

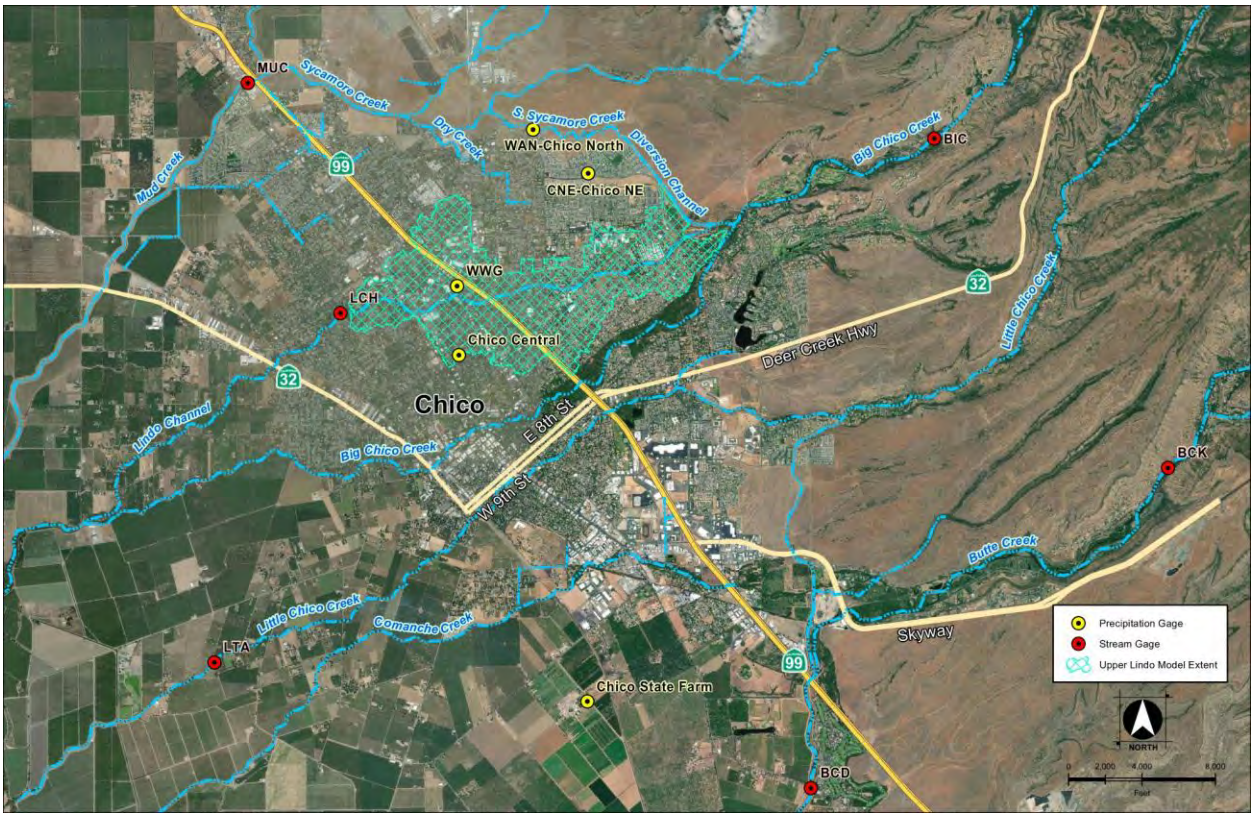


Exhibit 30: Precipitation Gage Locations

7.3.3 Loss Rate Parameters

Part of the calibration process establishes model loss rate parameters. The model results were generally producing more runoff than indicated by the stream gage. Therefore, relatively high loss rates were applied in order to improve how well the model would match runoff rates and volumes. Losses from the Lindo Channel were not included in the analysis. **Table 22** presents the loss rate parameters selected for drainage system modeling based on the model calibration process.

Table 22: Calibrated Modified Horton Method Parameters

Hydrologic Soil Group	Initial Infiltration Rate (in/hr)	Limiting Infiltration Rate (in/hr)	Decay Constant (1/hr)	Drying Time (days)
A	12	0.45	1	2
B	9	0.30	1	2
C	6	0.25	1	2
D	4	0.09	1	2

7.3.4 Effective Imperviousness Reduction from Non-directly Connected Impervious Areas

As part of the calibration process, the concept of effective imperviousness resulting from a non-directly-connected impervious area was applied in order to reduce the modeled imperviousness from the estimated actual imperviousness. In areas with relatively low densities of development, runoff from much of the off-street impervious area has an opportunity to flow across pervious areas before reaching a storm drainage system. However, in areas that have dense development, essentially all runoff from impervious surfaces drains directly into the storm drainage system. In order to approximate how much impervious area would effectively contribute to runoff, a multiplier of 0.6 was applied to the estimated imperviousness of each drainage area, with estimated imperviousness less than 0.25 and a multiplier of 1.0 was applied to the estimated imperviousness of each drainage area with an estimated imperviousness greater than 0.85. The multiplier was varied linearly between 0.6 and 1.0 as the estimated imperviousness varied from 0.25 to 0.85. The relationship between estimated and effective imperviousness is presented below in **Exhibit 31**.

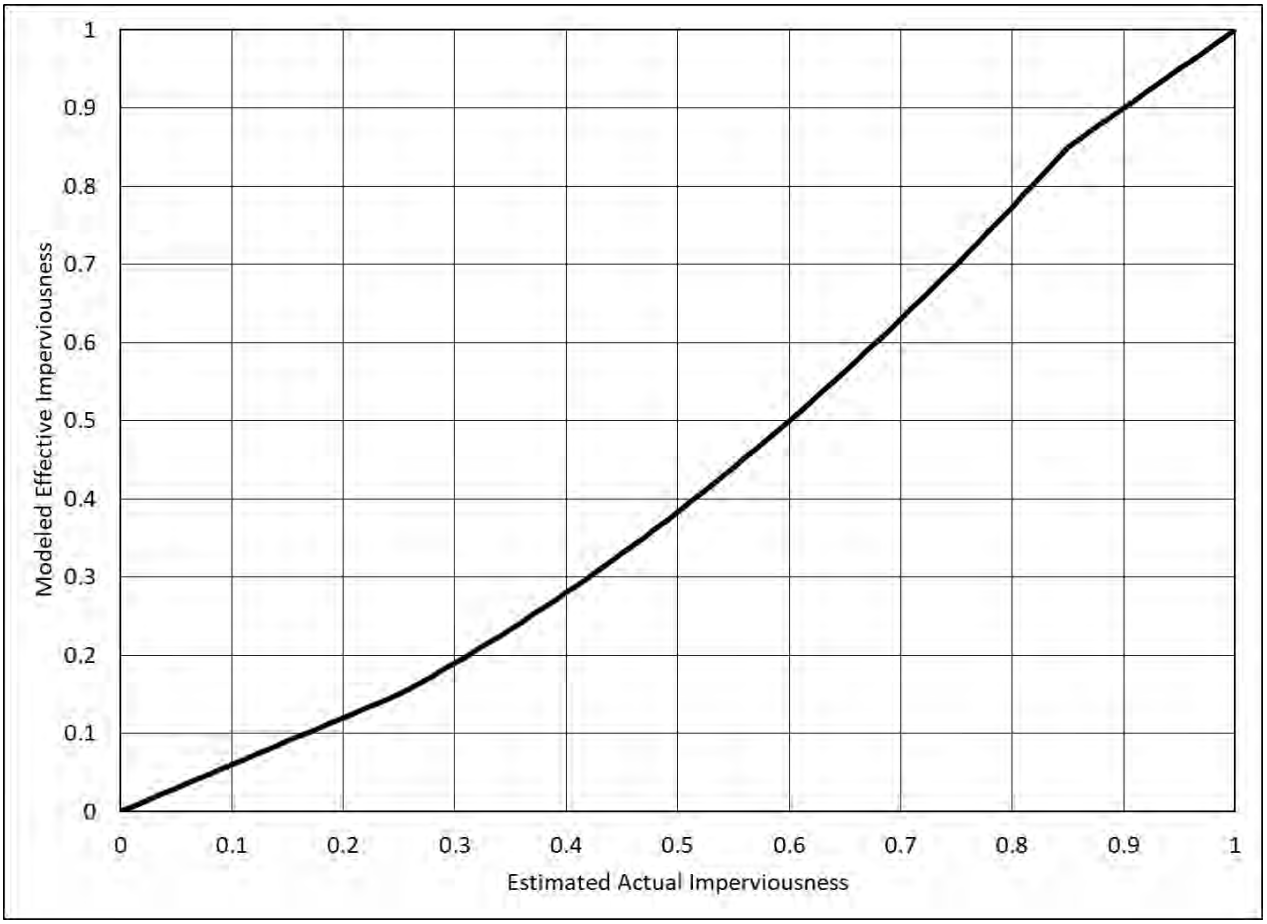


Exhibit 31: Effective Imperviousness as a Function of Estimated Imperviousness

7.3.5 Calibration Results Summary

Although there is uncertainty regarding the average precipitation across the model watershed, comparison of the estimated rainfall volume to modeled and measured runoff volumes can support a determination as to whether or not the model is producing reasonable results. The Upper Lindo Creek Watershed Model covers 2,144 acres with an effective imperviousness ratio of 0.54. The rainfall depth of 0.78 inch equates to 139 acre-feet for the entire model watershed. The model results show the watershed producing 65 acre-feet of runoff, whereas the stream gage data indicates 60 acre-feet of runoff. The stream gage measured a stage that corresponds to a peak flow rate of 245 cfs and the model results showed a peak flow of 241 cfs. The calibration results are summarized graphically in **Exhibit 32** (below).

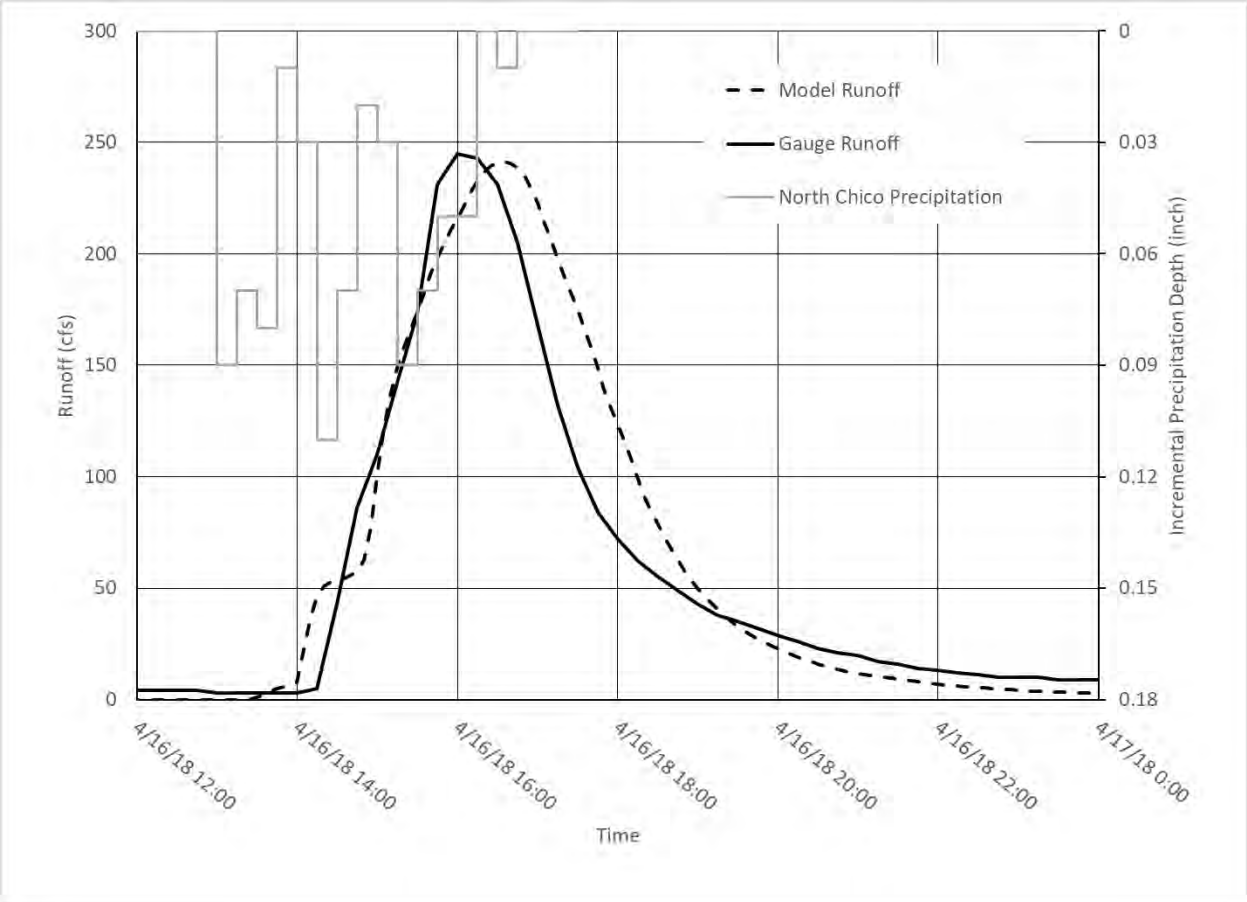


Exhibit 32: April 16, 2018 Calibration Hydrographs

7.3.6 Model Validation

One approach to model validation is to simulate an event other than the calibration event to see if the model results are consistent with observed conditions. Other rainfall events were reviewed and evaluated in addition to the one on April 16, 2018.

One of the other events that was modeled took place on December 16, 2018. The model results showed higher runoff than those measured at the stream gage, although the timing of the modeled stream flows was similar to the measured results. One possible explanation for the difference is that the rain gage data did not reflect typical conditions over the watershed. Another possibility is that there was an issue with the stream gage. The jaggedness of the second peak and the abruptness of the falling limb reaching zero flow are potential evidence of there being an issue with the measured flow. It is also possible that infiltration from the streambed into the underlying soils accounts for significantly less flow at the gage than flow that discharges from the storm drains. The modeled and measured flows for the December 16, 2018 rainfall event are presented below in **Exhibit 33**.

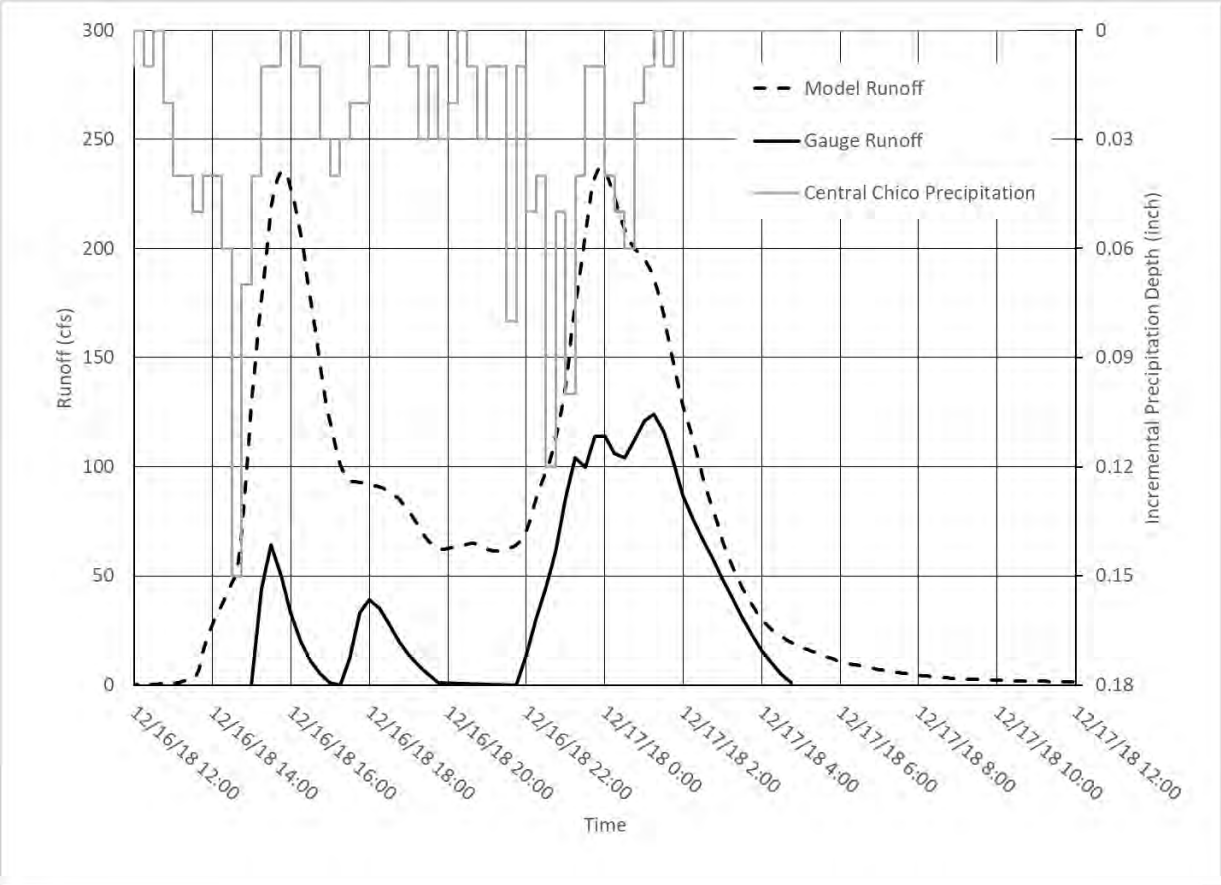


Exhibit 33: December 16, 2018 Validation Hydrographs

Additional validation is not needed at this time because: 1) the model calibration run provides reasonable results; 2) other storms that were reviewed indicate that the model does not underestimate discharges; and 3) the loss rates that were used are at the high end of what is considered to be reasonable. Use of radar rainfall can help with model calibration and validation, but it was not included in the scope of the SWMP. The model results can be considered adequate for drainage master planning without the use of radar rainfall data and further calibration.

8.0
Review of Catch Basins and Detention Basins

8.0 REVIEW OF CATCH BASINS AND DETENTION BASINS

8.1 Review of Catch Basins

The objectives of the review of catch basins were to determine where new catch basins are recommended in order to alleviate drainage deficiencies and to determine where catch basin inserts could be used to meet trash capture requirements. New catch basins are recommended where:

1. The existing drainage inlet physical configuration is inadequate;
2. New inlets are needed to support curb and gutter improvements or gutter improvements; and
3. It would be beneficial to retrofit developed areas with improved drainage, primarily at intersection corner low points that currently lack a storm drainage system (many of which result from the retrofit construction of pedestrian ramps).

In most cases, storm drainage pipeline improvements would be needed to accommodate the flows from new catch basins. Schematic layouts of drainage system improvements were created in order to develop opinions of probable cost and to identify potential Project extents. There are potential alternative system alignments that could be evaluated. The alignments of potential drainage system improvements can be considered relative to other capital improvement plans in order to determine if any opportunities exist to address drainage system needs with other projects.

Catch basins and other drainage system improvements can provide opportunities to incorporate measures to improve storm water quality and that could potentially be used to meet trash amendment requirements. Similarly, locations where improvements are needed to meet trash amendment requirements can be reviewed to determine if those improvement measures should be designed to work with a future drainage system configuration.

8.1.1 Physical Configuration

A partial review of storm drainage inlet configurations was performed. This review focused on identifying locations where inlets should be added or replaced. This review found that the vast majority of drainage inlets in the City are effective combination inlets (grate with curb opening). Some of the combination inlets are smaller than the current standard that calls for Caltrans Type GO inlets, but many of the smaller combination inlets appear to be adequate. There are some very small cast-iron inlets, such as the one shown below in **Exhibit 34**, that are highly susceptible to clogging. Other intersections have unusual curb openings that may be associated with bubble-up systems that convey flows under roadway crowns or flow-through openings along gutter flow paths that might have been obstructed as part of accessibility projects. Examples of unusual configurations that appear to be inadequate are shown in **Exhibit 35** and **Exhibit 36**. In some cases, unusual inlet configurations may be connected to the storm drainage system. The locations found to have grate openings without curb openings on the street were assumed to be inadequate because they are highly susceptible to clogging. **Figure 23** presents the locations where non-standard catch basins and inlets were found, and it identifies which of the non-standard

configurations appear to be inadequate. Locations with drainage deficiencies that do not have drop inlets, such as flow-through configurations, are discussed in **Section 9.1**.

Exhibit 34: Drainage Inlet at Broadway Street and W 20th Street

Exhibit 35: Unusual Drainage Inlet at Broadway Street and W 14th Street

Exhibit 36: Unusual Drainage Inlet at Broadway Street and W 15th Street

8.1.2 Dry Wells

Figure 23 also shows the locations that were identified where inlets are connected to dry wells. The term "dry well" is used in the SWMP to refer to various underground infiltration systems including pits and trenches filled with rocks as well as trenches with pipes surrounded by rocks. Dry wells can be relatively small and these are intended to meet water quality requirements; or they can be relatively large and intended to infiltrate 100-year storm runoff on a temporary, or sometimes permanent, basis. Some dry wells that are intended to manage all runoff on a temporary basis are connected to capped systems. Capped systems are drainage system features that are not connected to the City's drainage system. Modeled "outfalls" as described in **Section 6.3.3.5** are used at the capped systems in order to cause runoff into the capped systems to leave the model based on the assumption that the infiltration system has sufficient capacity to infiltrate the runoff that drains to it. The SWMP calls for connections from the capped drainage systems to the creeks in order to provide relief when the capacity of the infiltration systems has been reached. This is because the performance of dry wells typically degrades over time as the systems become clogged

with sediment and debris. Infiltration systems should be incorporated into new projects, redevelopment projects, and retrofit projects to the extent feasible. It is recommended that infiltration systems be constructed with an upstream filtration chamber that is maintainable in order to enhance the long-term performance and increase the service life of the infiltration systems.

Infiltration trenches and basins can be used as FCS. However, the facilities need to be designed, constructed, and maintained in accordance with the requirements of the SWRCB to be counted as FCS. The requirements are specified in a SWRCB fact sheet titled, "Infiltration Trench or Basin Multi-Benefit Full Capture Systems" [45], dated June 2023. In order to qualify as an FCS, an infiltration trench would need to include a screen and/or a bypass that meets the specified criteria.

Numerous inlets within the City are connected to dry wells. Most of the stand-alone catch basins (those not connected to storm drains leading to outfalls) were verified to be connected to dry wells. Many private systems contain inlets that are connected to dry wells. The SWMP mapping on Figure 10 shows where digital data was available to identify private catch basins connected to dry wells or infiltration trenches. The mapping for the SWMP does not include all private catch basins or all private catch basins that are connected to dry wells.

8.1.3 Storm Water Quality Measures at Inlets

Catch basin inserts are being used as part of the process to meet Trash Capture Requirements. Catch basin inserts are most effectively used where trash capture is necessary and cannot be achieved using downstream systems that manage trash from a relatively large watershed at a single location. Only nine catch basin inserts[10] have been installed by the City as of January 2024, and their locations are shown on Figure 10.

8.2 Review of Detention Basins

Numerous storm water detention basins are included in the City's storm drainage system, and other detention and water quality basins are included in private drainage systems within the City. Some detention basins are used to meet storm water quality treatment requirements, some are used to limit flows to the capacity of existing storm drains, and other basins receive runoff from relatively large areas to meet flood control objectives. Figure 10 shows the locations of the 33[11] surface and seven underground (pipe storage) detention basins that are included in the ICM models and the areas tributary to them. Figure 10 also shows the locations of basins that were not modeled. Basins that were not modeled include basins that do not have a drainage function and private storm water quality basins. **Table 23** summarizes key information about the modeled basins based on existing conditions hydrology. The detention basin information is provided as part of a master-planning level assessment of basin function. Site-specific, detailed analyses would be required to support any design modifications.

[10] Email from City with the subject "RE: Trash Capture Devices" dated April 28, 2023 and confirmed in 2024
[11] One of the 33 surface basins is actually 10 small basins in series and is referred to as B47a through B47j.

Detention basins are typically excavated features that store water above ground. Some detention basins are off-line, meaning that they only fill when the hydraulic grade line in the conveyance system reaches a set stage. Most detention basins are on-line and have pipes that drain into them as well as an outlet that regulates the discharge from it. Storage within an on-line basin starts to become utilized even with low flows from upstream. Off-line basins are more efficient than on-line basins at attenuating peak discharges given the same storage volume. Some detention basins are completely underground with storage provided in oversized pipes or various chamber systems. Some underground detention basins are configured to promote infiltration, while other underground facilities are designed to keep storm water from contacting the surrounding soils.

Promoting infiltration into underlying soils is a significant function of some detention and retention basins. Detention basins have outlet pipes, whereas retention basins empty only by infiltration and evaporation. Terminal infiltration facilities include dry wells and infiltration chambers. Some infiltration systems are designed to retain runoff volume up to a relief elevation and are connected to a storm drainage system in order to manage runoff when the retention volume is full.

Table 23: Detention Basin Summary				
ID	**Location/Name**	**1D/2D**	**Tributary Area (ac)**	**100-Year Volume (ac-ft)**
Surface Basins				
B01	Windrose Court	1	12.3	0.19
B02	Royal Glen Lane	1	20.8	0.85
B03	Newport Drive	1	48.2	0.78
B04	Silver Lake Drive	1	50.5	0.98
B05	Crater Lake Drive[12]	1	78.0	0.99
B06	Baltar Loop	1	18.4	0.20
B07	Penzance Avenue	1	98.6	6.19
B08	Abbott Circle	1	290.1	32.29
B09	Aspen Glen Drive @ Esplanade	1	19.9	0.63
B10	Aspen Glen Drive @ Esplanade	1	13.7	0.30
B12	Floral Avenue @ Whitewood Way	1	26.4	0.12
B13	Floral Avenue @ Pauletah Place	1	3.2	0.00
B14	Tierra Rose Lane	1	3.1	0.04
B15	Ceanothus Avenue @ Brenni Way	1	2.5	0.00
B16	Marilyn Court	1	2.8	0.03
B17	Kona Drive	1	5.3	0.10
B18	Marigold Avenue	1	5.4	0.02
B19	Maddie Court[13]	1	59.2	0.09
B20	Arch Way @ Marigold Avenue	1	38.3	0.08
B21	Mariposa Avenue @ Admiral Lane	1	18.4	0.19
B22	Ravenshoe Way @ Cabaret Drive	1	11.3	0.14
B23	Private Facility near Eaton Road	1	11.3	0.12
B25	Viceroy Lane @ Swallowtail Lane	1	38.1	0.82
B26	Nob Hill	1	33.1	2.91
B27	Stirling Oaks	1	33.6	1.75
B28	Humboldt Road	1	118.4	0.23
B29	California Park Lake	2	2,613.2	NC[14]
B30	Teichert Ponds	2	363.7	NC
B37	Fair Street Basin[15]	1	534.8	31.57
B38a	Marilyn Drive	1	14.8	0.01
B38b	Marilyn Drive	1	15.4	0.09
B38c	Marilyn Drive	1	15.8	0.11

[12] Tributary areas of B09 and B10 are included in the total tributary area due to pass through flows.
[13] Tributary areas of S04 are included in the total tributary area due to pass through flows.
[14] Some data associated with basins modeled in the two-dimensional mesh is not readily available from the model results and was not computed (NC) because it was not material to the SWMP.
[15] Tributary areas of B38a, B38b, B38c and S08 are included in the total tributary area due to pass through flows.

Table 23: Detention Basin Summary				
ID	**Location/Name**	**1D/2D**	**Tributary Area (ac)**	**100-Year Volume (ac-ft)**
B41	Home Depot	1	11.6	0.17
B42	Private facility near Fair Street	2	12.3	NC
B43	Private Facility at County Drive & Fair St.	2	NC	NC
B46	Butte College	2	NC	NC
B47a-j	Chain of Lakes	2	NC	NC
Underground Storm Water Storage				
S01	Lobelia Court	1	2.6	0.023
S02	Elisha Court	1	4.1	0.023
S03	Daylily Lane	1	1.4	0.034
S04	Cactus Avenue	1	6.7	0.203
S05	Overseer Court	1	1.9	0.010
S06	Rubicon Court	1	1.7	0.024
S07	Marci Way	1	1.5	0.014
S08	E 20th Street	1	13.4	1.358

There are multiple ways to model detention basins. Many detention basins are modeled as one-dimensional point features with tables of associated data for storage and infiltration parameters. Some surface detention basins are modeled in the two-dimensional mesh. Underground detention facilities are modeled by including the storage elements such as oversized pipes, and flow control elements such as weirs and orifice controls, using one-dimensional model elements that directly simulate the physical configuration. User-defined discharge curves are used to simulate infiltration from the modeled underground detention systems that were designed to promote infiltration. The selection of a modeling method depends on location-specific conditions.

8.2.1 Evaluating Impacts of Local Detention Basins on Regional Flows

Detention basins can impact the timing of peak discharges in receiving waterways. In many circumstances the impact of a detention basin on peak discharges is beneficial, and in other cases the impact may be negligible or even detrimental. In general, storm water detention in the upper part of a watershed delays the peak runoff, allowing downstream runoff to drain before the upstream release which, thereby, results in a net reduction in peak discharge. However, the opposite can hold true for storm water detention in the lower part of a watershed. If not designed carefully, detention basins in the downstream portions of a watershed can delay peak discharges to the point that the basin increases the rate of release at the time of peak discharge from the upstream watershed. Care must be taken to ensure that detention storage that is incorporated into the downstream portion of a watershed does not result in negative impacts. Qualitative factors to consider when planning detention within the watersheds of local channels within the City are

discussed in Section 10.9. Local channels include the Pleasant Valley Ditch, Comanche Creek, BD Channel, and SUDAD Channel.

Detention for storm water quality that would be incorporated into projects in order to meet NPDES Phase II bioretention and hydromodification management requirements is necessary for projects in and around the City, regardless of a project's location in the watershed. Detention for storm water quality is typically designed for relatively small storm events (i.e., storms that are expected to have precipitation depths that are equaled or exceeded at least once every two years). Detention for drainage and flood control purposes is typically designed for storms with precipitation depths that are expected to be exceeded once every 10 years and/or once every 100 years, depending on the objectives of the particular facility. It should be noted that detention designed for relatively frequent storms can impact discharges from relatively severe storms. Detention for storm water quality typically involves capturing the increase in runoff volume that is expected to occur with added impervious area. Systems designed to capture runoff volume can be highly effective at reducing runoff from high-intensity, short-duration storm events. However, systems designed to capture a relatively small volume of runoff would be expected to become full and then release runoff during storms that have a high volume of runoff, even if the rainfall occurs at a relatively low intensity.

Stream gage and model data illustrate why delaying runoff in the lower portion of a watershed can increase peak discharges in the lower portions of a stream system. As illustrated (above) in Exhibit 32 for the calibration evaluation, peak runoff from the City portion of the Lindo Channel Watershed occurs within two hours of the time of peak rainfall intensity. A plot of the streamflow and rainfall data for the storm on December 15, 2016 (selected because it is larger than a 10-year storm and good streamflow data was available) shows that Big Chico Creek flows at the BIC gage peak approximately five hours after peak rainfall. It takes approximately two hours for peak flows to propagate from the BIC gage location to the LCH gage location for which Lindo Channel flows are presented. Additionally, Big Chico Creek and Lindo Channel flows remain high for more than 12 hours.

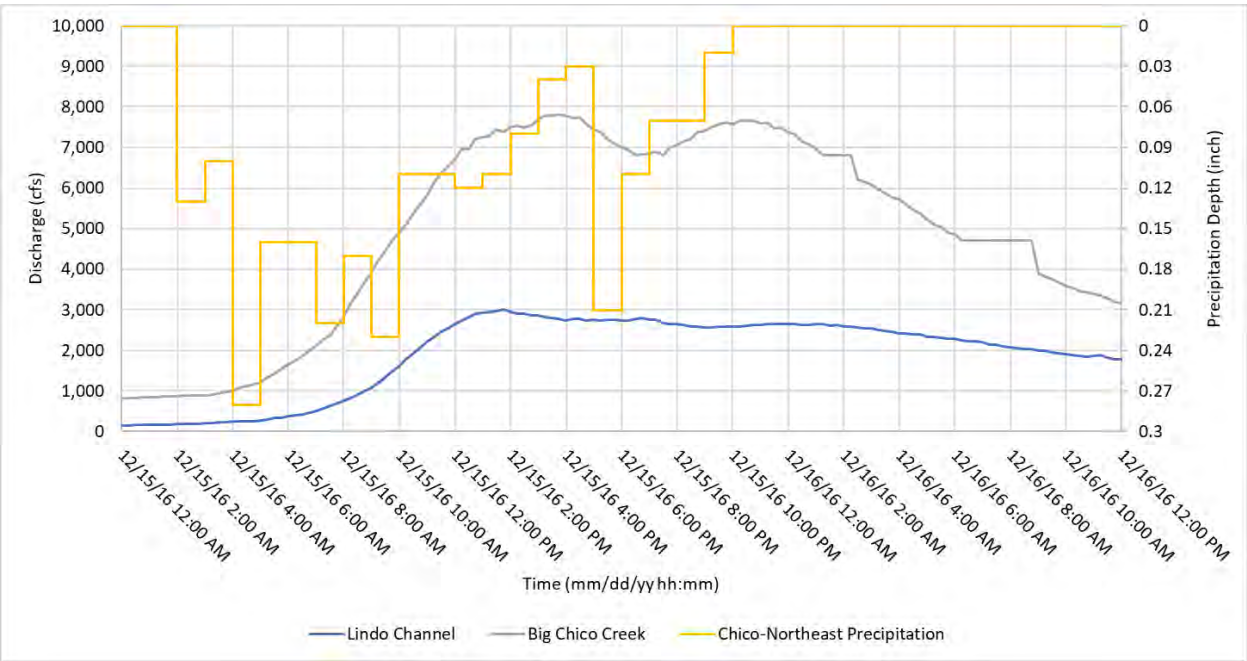


Exhibit 37: Streamflow and Precipitation Data for December 15, 2016

In this example of Lindo Channel and Big Chico Creek flows, the Lindo Channel peak flow resulting from local runoff is higher than the later flows resulting from diversions out of Big Chico Creek. In this case, therefore, detention in the lower watershed would not cause a negative impact. However, there are times when the peak generated by flows diverted from Big Chico Creek would be higher than flows resulting from the Lindo Channel Watershed runoff.

The Little Chico Creek-Butte Creek Watershed is similar to the Big Chico Creek-Mud Creek Watershed. Therefore, there are similar concerns about the detention basins in and around the City in the Little Chico Creek and Butte Creek Watersheds having the potential to cause increases in peak discharges in the channels by changing the timing of flows. Where detention must be used, the peak release rate (at the time the upstream peak flow passes the proposed detention basin site) must be lower than the runoff from the site at the time of peak discharge from the upstream watershed under pre-project conditions.

It should be noted that, contrary to determinations of flood flows, overestimating discharges does not result in a conservative detention basin design. By overestimating pre-project flow rates, a detention basin designed to release post-project runoff at pre-project rates would be undersized, with an outlet control that is too large to meet the design objectives. In order to evaluate the impacts development causes within a small watershed near the downstream end of a large watershed, the contribution of the runoff from the small watershed on the peak flow that is predominantly controlled by runoff from the large watershed must be considered. In addition to timing of runoff, the application of areal reduction factor methodology (as described in *Hydrometeorological Report No. 59, Probable Maximum Precipitation for California* [46]) is also

appropriate. Areal reduction factors are necessary for determining design runoff from large watersheds using rainfall to runoff transformations because the point rainfall statistics provided by NOAA Atlas 14 are applicable to points, and not to averages over large areas.

8.2.1.1 Detention within the Doe Mill/Honey Run Special Planning Area

The Doe Mill/Honey Run Special Planning Area (SPA) described in the 2030 General Plan covers approximately 1,441 gross acres located in the lower foothills at the eastern end of E. 20th Street, east of Potter Road, and north of Honey Run Road and Skyway.

Solutions to the drainage challenges associated with the Doe Mill/Honey Run SPA will need to be identified by the developer of this area. Information about the potential impacts of increased runoff from the Doe Mill/Honey Run SPA are presented in this SWMP in order to illustrate potential issues with detention in this area so that future evaluations can focus on determining how to mitigate for the potential impacts that have been identified. The four-day storm from the Central Valley Hydrology Study (CVHS) is used for this example. The design storm starts at a time of 24 hours. It uses hourly rainfall values, and the peak hour of rainfall is from hour 72 to hour 73 in the modeled simulation. The Doe Mill/Honey Run SPA overlaps portions of the 2.46-square-mile watershed identified as "Sub_BUT-43_8" and the 4.00 square mile watershed identified as "Sub_BUT-43_2." within the Butte Watershed HEC-HMS model. The 100-year peak discharge from Sub_BUT-43_8 combined with Sub_BUT-43_2 is 1,355 cfs at time 75.0 hours, which is 2.5 hours after the midpoint of the hour of peak rainfall (the flow results are reported in 15-minute intervals). The main Little Chico Creek Watershed upstream from Sub_BUT-43_8 covers 25.5 square miles and has a 100-year peak discharge of 5,400 cfs at time 76.5 hours, which is 1.5 hours after the combined peak discharge of the watersheds that drain through the Doe Mill/Honey Run SPA. However, most of the flows from Little Chico Creek are diverted into Butte Creek, which has a tributary area of over 150 square miles and a 100-year peak discharge of 29,000 cfs at time 78.5 hours. Butte Creek controls the timing of the peak flow of 32,330 cfs, and the combination of Sub_BUT-43_8 and Sub_BUT-43_2 contributes 998 cfs to this peak. Flow hydrographs are provided below in **Exhibit 38**. Therefore, for detention within the Doe Mill/Honey Run SPA to be effective, the peak discharge from Sub_BUT-43_8 would need to be less than 998 cfs, using build-out hydrology consistent with CVHS methodology, in order to mitigate for the impacts of increased runoff on peak discharge in Butte Creek downstream from the Doe Mill/Honey Run SPA.

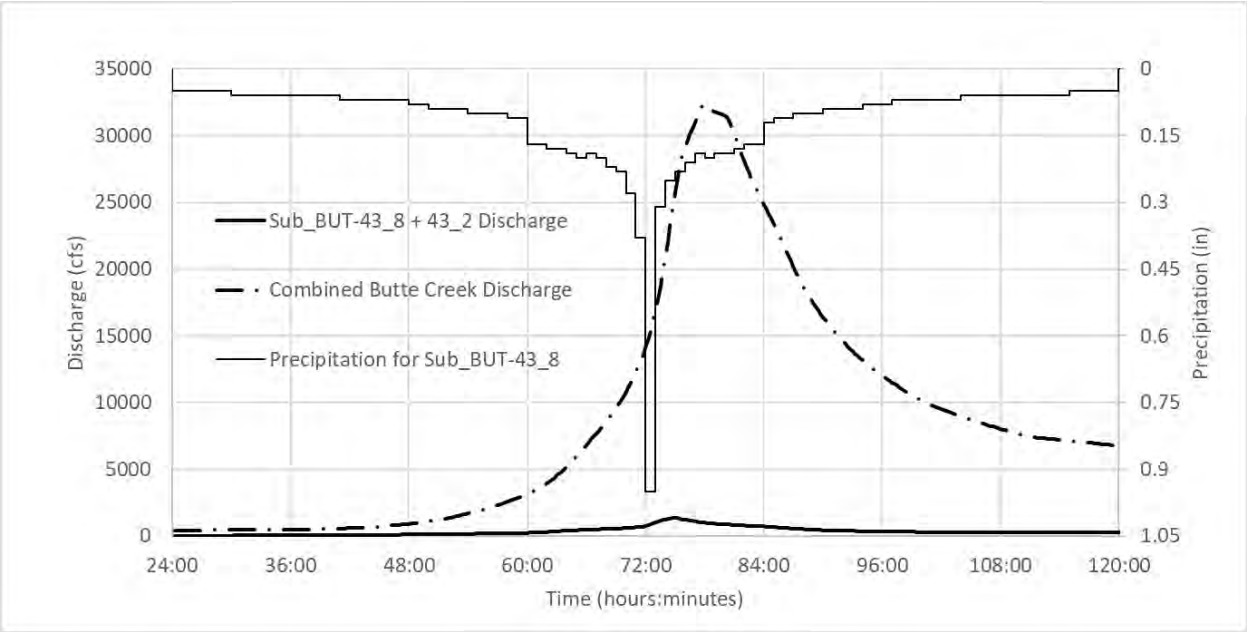


Exhibit 38: Relative Timing of Doe Mill/Honey Run SPA and Butte Creek Discharges for 100-Year Storm

In order to address ULOP criteria along the Butte Creek levees, impacts on discharges for storms that would cause less than three feet of freeboard along the Butte Creek levee, and impacts to the 200-year discharges would need to be evaluated in addition to 100-year discharges.

8.2.1.2 Development Area between Little Chico Creek and Humboldt Road

Development in the area north of Little Chico Creek and south of Humboldt Road has the potential to cause an increase of discharges into Little Chico Creek that could exacerbate downstream flooding. Detention basins could help mitigate for the impact of increased runoff from this area for those times when the downstream flooding results from runoff originating within the City. However, detention basins could delay runoff such that it could add to the flows originating from the upstream Little Chico Creek Watershed. Therefore, it is recommended that development in this area be conditioned to include detention that is regulated by a new stream gage on Little Chico Creek. As part of the planning process, an analysis will be needed to determine the conditions under which discharge should be stopped, as well as to determine the storm water storage volume needed for mitigation.

9.0
Analysis of System
(Current, Future, Pipework, and Capacity)

9.0 ANALYSIS OF SYSTEM (CURRENT, FUTURE, PIPEWORK, AND CAPACITY)

9.1 Identification of Existing Deficiencies

Existing drainage deficiencies were identified using the City's knowledge, model results and review of the existing drainage system and topography. ICM model results for 2-year, 10-year, and 100-year storms were used to prepare the maps of potential flood depths presented on **Figure 24**, **Figure 25**, and **Figure 26**, respectively. These ICM model results are primarily intended for the evaluation of local drainage systems with the exception of Little Chico Creek. The ICM model for the area that includes Little Chico Creek includes all of the channel details and flow hydrographs for runoff originating outside of the City. Evaluation of flooding generated by runoff originating outside of the City was prepared separately from the analysis of local flooding issues using HEC-RAS as described in Section 10.5. A complete picture of potential flood risks identified by the modeling would involve overlaying results from both the HEC-RAS and ICM models.

The ICM and HEC-RAS floodplain results associated with Little Chico Creek flows for 10-year and 100-year floods are presented in **Figure 27** and **Figure 28**, respectively. As expected, the ICM results show extensive street flooding due to local inflows, and the HEC-RAS model shows flooding that results from overtopping of the right bank of the Little Chico Creek Diversion Channel.

The results from the ICM drainage system models include time series data for each modeled element. This provides the user with the ability to review the flow hydrograph through each pipe and channel cross section and flood stage hydrographs at each inlet, manhole, and two-dimensional mesh element. This allows the user to review the duration of flooding that cannot be considered solely through the use of static inundation mapping. Maximum water surface elevation data is mapped to the terrain in order to provide a graphical representation of potential flooding depths that is consistent with the resolution of the terrain data. Although there are limitations associated with any modeling and terrain data, the flood depth results provide information that can be used to identify locations that may have drainage deficiencies. The duration of inundation also needs to be considered in the process of evaluating the significance of deficiencies identified from inundation mapping.

Existing drainage deficiencies include:

1. Areas without curb, gutter, and storm drain;
2. Areas without curb and gutter;
3. Locations with insufficient conveyance capacity;
4. Locations with inadequate catch basin configurations; and
5. Locations that require excessive maintenance.

Initially, a list of 15 known locations of drainage deficiencies were provided by City staff, and then additional locations were subsequently identified by the City in emails and during meetings to review model results. Some of the locations were noted as maintenance issues. Deficiency locations identified by the City are presented on **Figure 29** and listed in **Table 24**. Additional deficiencies were identified during the various reviews conducted as part of this SWMP. For example, many intersections have curb ramps with inadequate flow-through drainage configurations. Flow-through drainage configurations are the small conduits along gutters below curb ramps that frequently become clogged with debris. However, only a few intersections (which may be the most problematic locations) were identified by the City. The SWMP included a review of topography and the existing drainage system in order to identify other intersections that would benefit from drainage improvements due to inadequate, or complete lack of, storm drainage.

Table 24: City Identified Deficiency Locations

ID	Issue	Location
1S	Inlet Deficiencies/insufficient capacity	Porter Way
2S	Insufficient capacity	Park Vista Drive and Carol Avenue
3S	Inlet Deficiencies/insufficient capacity	West 1st Avenue and Warner Street
4S	Inlet Deficiencies	West 1st Avenue and Cherry Street
5S	Insufficient capacity	Fair Street
6S	Inlet Deficiencies/insufficient capacity	West Sacramento Avenue and Warner Street
7S	Flow-through inlets that backup	West 3rd Street and Ivy Street
8S	Flow-through inlets that backup	West 4th Street and Ivy Street
9S	Flow-through inlets that backup	West 4th Street and Cherry Street
10S	Flow-through inlets that backup	West 6th Street and Cherry Street
11S	Lack of curb and gutter and storm drains	Pomona Avenue
12S	Lack of curb and gutter and storm drains	Pomona Avenue
13S	Insufficient capacity	Cohasset Road and Pillsbury Road
14S	Bubble up	Memorial Way and East Side Drive
15S	Tailwater	Alamo Avenue Silverado Estates Court
16S	Bubble up	West 5th Street and Normal Avenue
17S	Dry well	Palmetto Avenue and Toyon Way
18S	Dry well	811 West 2nd Avenue
19S	City noted root issue, also capacity issue	East Lincoln and East Side Drive
20S	Dry well	1502 North Cherry Street
21S	Dry well	East 3rd Avenue and Sunset Avenue
22S	Dry well	Vallombrosa Avenue and Sheridan Avenue
23S	Tailwater	Bruce Rd at bus stop N. of Sierra Sunrise Tr.
24S	Tailwater	Meadowhawk Court (off of Lakoda Court)
25M	Root issue	962 Yosemite Drive and Blue Oak Park
26S	Lack of curb and gutter and storm drains	W. 7th St. and Almond St. near Pomona Ave.
27S	Dry well	183 East 8th Avenue
28M	Root issue	E. Frances Willard Ave. and E. Side Dr.
29S	Insufficient capacity	West 8th Avenue and Jetta Court

The Existing Deficiencies Map, Figure 29, also shows locations where curb and gutter improvements (or, in some cases, gutter improvements where curbs are already present) are needed to improve drainage. Locations where new inlets are recommended to support curb and gutter construction are shown. Figure 29 also shows where new inlets are recommended in order to eliminate flow-through configurations under curb ramps. Locations of inadequate drop inlets are also shown.

Deficiencies in the area of Esplanade and Garner Lane north of Mud Creek were evaluated separately from the rest of the SWMP and are presented in Appendix J.

9.2 Improvement Recommendation Development Process

The SWMP provides recommendations for projects to both correct existing drainage deficiencies and to accommodate build-out. The development of improvement recommendations involved determining where storm drainage system capacity would be needed to alleviate known deficiencies and to receive runoff from the new inlets necessary to alleviate existing deficiencies and accommodate new curb and gutter improvements. Potential storm drain locations were identified to connect the identified new and replaced inlet locations, and public inlets that are currently connected to bubble-up and infiltration systems, as well as to outfalls. Additionally, a backbone pipe layout was developed for the Bell Muir Area. Pipe sizes and detention basin capacities were determined as necessary to accommodate build-out hydrology as discussed in the following sections.

The SWMP provides layouts for improvements to drainage systems that consider where there is available capacity in the existing drainage system and also where there are routes along public rights-of-way to potential new outfall locations. Challenges with potential utility conflicts were not evaluated in the development of project recommendations. Analysis that includes consideration of potential conflicts with existing utilities will be needed to advance from the SWMP to design. It is expected that improvement alignments that are different than those shown in the SWMP will be evaluated in some locations as part of the design process, and that better options than those included in the SWMP may be identified. Systems to divert runoff away from areas with insufficient capacity are proposed where diversions appear to be more feasible than downstream capacity improvements. The planning-level opinions of probable cost recognize that it is challenging to retrofit storm drainage improvements into a built environment where existing utilities need to be avoided or relocated.

In most areas of the City, build-out will not significantly increase discharges into the storm drainage system. It is anticipated that the cost share of projects attributable to new development will be determined using a process that considers added impervious areas of new development relative to the total imperviousness at build-out.

9.3 Build-out Hydrology

Build-out hydrology defines the process of determining runoff rates and volumes under General Plan build-out conditions. The most significant factor that increases runoff volume is added impervious area. Mitigation measures such as detention basins and implementing LID measures in project planning typically reduce, but do not eliminate, the impacts of added impervious area.

9.3.1 Identification of Non-Built-Out Parcels

The first step in computing runoff rates and volumes for build-out conditions is to identify the areas where new development and redevelopment are expected to add impervious area during the timeframe covered by the SWMP. Most of the City was evaluated on a parcel-by-parcel basis. The existing conditions estimated imperviousness of each parcel was considered in the process of determining if it would change within the planning timeframe. Threshold values were assigned to each land use description. If the existing imperviousness of a parcel was estimated to be at or above the threshold value, the parcel was assumed to be built-out and the imperviousness at build-out was assumed to remain the same as it is in the existing conditions. If the existing imperviousness was estimated to be below the threshold value, it was assumed that the imperviousness of the parcel would increase according to the value assigned to the land use description. The build-out imperviousness threshold and build-out imperviousness value for each land use description is listed below in **Table 25**. The build-out imperviousness values were assigned based on a review of aerial imagery of relatively recent developments with the indicated land use.

Table 25: Build-Out Imperviousness Thresholds and Values			
Land Use Type	**Land Use Description**	**Build-out Imperviousness Threshold**	**Build-out Imperviousness Value**
A	Airport	NA	NA
AC	Airport Commercial	50%	85%
AM	Airport Manufacturing	50%	90%
AP	Airport Public Facilities	10%	45%
CC	Community Commercial	45%	90%
CN	Neighborhood Commercial	50%	90%
CR	Regional Commercial	45%	90%
CS	Services Commercial	40%	90%
DN	Downtown North	NA	NA
DS	Downtown South	NA	NA
IOMU	Industrial Office Mixed-Use	45%	90%
MG	General Manufacturing	40%	75%
ML	Light Manufacturing	40%	90%
OC	Office Commercial	45%	85%
OR	Office Residential	40%	75%
OS1	Primary Open Space	NA	NA
OS2	Secondary Open Space	NA	NA
PQ	Public/Quasi Public Facilities	10%	80%
R1	Low Density Residential	12%	65%
R1-10	Low Density Residential 10,000-SF min.	12%	60%
R1-15	Low Density Residential 15,000SF min.	NA	NA
R2	Medium Density Residential	15%	80%
R3	Medium-High Density Residential	25%	85%
R4	High Density Residential	50%	90%
RMU	Residential Mixed Use	30%	80%
ROW	Right of Way	NA	NA
RS-1	Suburban Residential 1-acre min.	6%	40%
RS-2	Suburban Residential 2-acre min.	6%	30%
RS-20	Suburban Residential 20,000 SF min.	12%	50%
RS-3	Suburban Residential 3-acre min.	6%	20%
SPA	Special Planning Area	Varies	Varies
TND	Traditional Mixed Use	15%	85%

9.3.2 Build-out Imperviousness

Imperviousness values listed in Table 25 were assigned to most parcels based on the parcel's General Plan land use description if the existing imperviousness was estimated to be less than the threshold value listed in Table 25. Areas with land used descriptions that have "NA" in the corresponding threshold value column maintained the same imperviousness at build-out as was

estimated for the existing conditions analysis. Imperviousness values for build-out conditions within SPAs (except for Doe Mill/Honey Run[16] SPA) were assigned based on information in Appendix C to the Chico 2030 General Plan. Specifically, it was assumed that the Barber Yard and North Chico SPAs will become 76-percent impervious, that the Bell Muir Area will become 58-percent impervious, and that the South Entler SPA will become 71-percent impervious. The imperviousness values for the Doe Mill/Honey Run SPA were not assigned as part of the SWMP because detailed drainage plans for it are being prepared by others; additionally, the systems planned for it will not impact other improvements proposed within this SWMP because this area drains into Butte Creek, and not into the City's storm drainage system.

The modeled imperviousness at build-out is the same as the modeled imperviousness with existing conditions for parcels that do not have added impervious areas. For parcels with added impervious areas, the effective imperviousness computed as the maximum of the existing effective imperviousness value and the build-out imperviousness value (taking into account the LID adjustment factor determined using the methodology described in Section 7.2.3.2, Evaluation to Quantifying the Benefit of LID Measures). **Figure 30** illustrates the build-out conditions imperviousness determined for this SWMP, and **Figure 31** illustrates the change in imperviousness from existing conditions to build-out conditions.

9.4 Projects to Alleviate Existing Deficiencies

Existing deficiencies are presented in Section 9.1.

Most of the improvements recommended in this SWMP are intended to accommodate curb and gutter retrofit projects as well as to improve drainage at existing intersections with poor drainage. The recommended projects will improve safety and also meet the needs of infill and redevelopment projects. Pipe size recommendations were developed using runoff for build-out conditions. **Figure 32** illustrates recommended improvements. The allocation of project costs between future projects and existing development is discussed in **Section 12.1**.

The process used to develop SWMP recommendations encompassed multiple steps to develop, review, and refine proposed project configurations. The first step involved developing a preliminary layout of proposed improvements. The second step involved estimating required pipe sized for the improvements. The third step was to model the proposed improvements and to review the model results. The model results were reviewed by comparing existing conditions to build-out conditions based on the HGL elevations. The proposed system configuration and pipe sizes were refined until it was demonstrated that the projects would provide a significant reduction in flooding at locations of known deficiencies without generating new significant deficiencies. The system used to identify locations of potential impacts is illustrated on **Figure 33**.

[16] The Doe Mill/Honey Run SPA is the VESPA described in Section 8.2.1 Evaluating Impacts of Local Detention Basins on Regional Flows.

Locations where Figure 32 shows a red dot are locations where the build-out model results indicate an increase in maximum flood level where there is an apparent deficiency (based on the model results). These locations were reviewed to determine whether or not the proposed system as modeled would be considered to be adequate. In most cases, the red dots show locations where there is a very short duration modeled flood condition and the increase in flood depth was on the order of hundredths of a foot. For example, improvements are recommended to reduce flooding in the vicinity of Manzanita Avenue and Cohasset Road. Although the results indicate a momentary trivial increase in peak flooding, the stage hydrographs presented in **Exhibit 39** demonstrate that the proposed improvements would be expected to provide a net reduction in flooding.

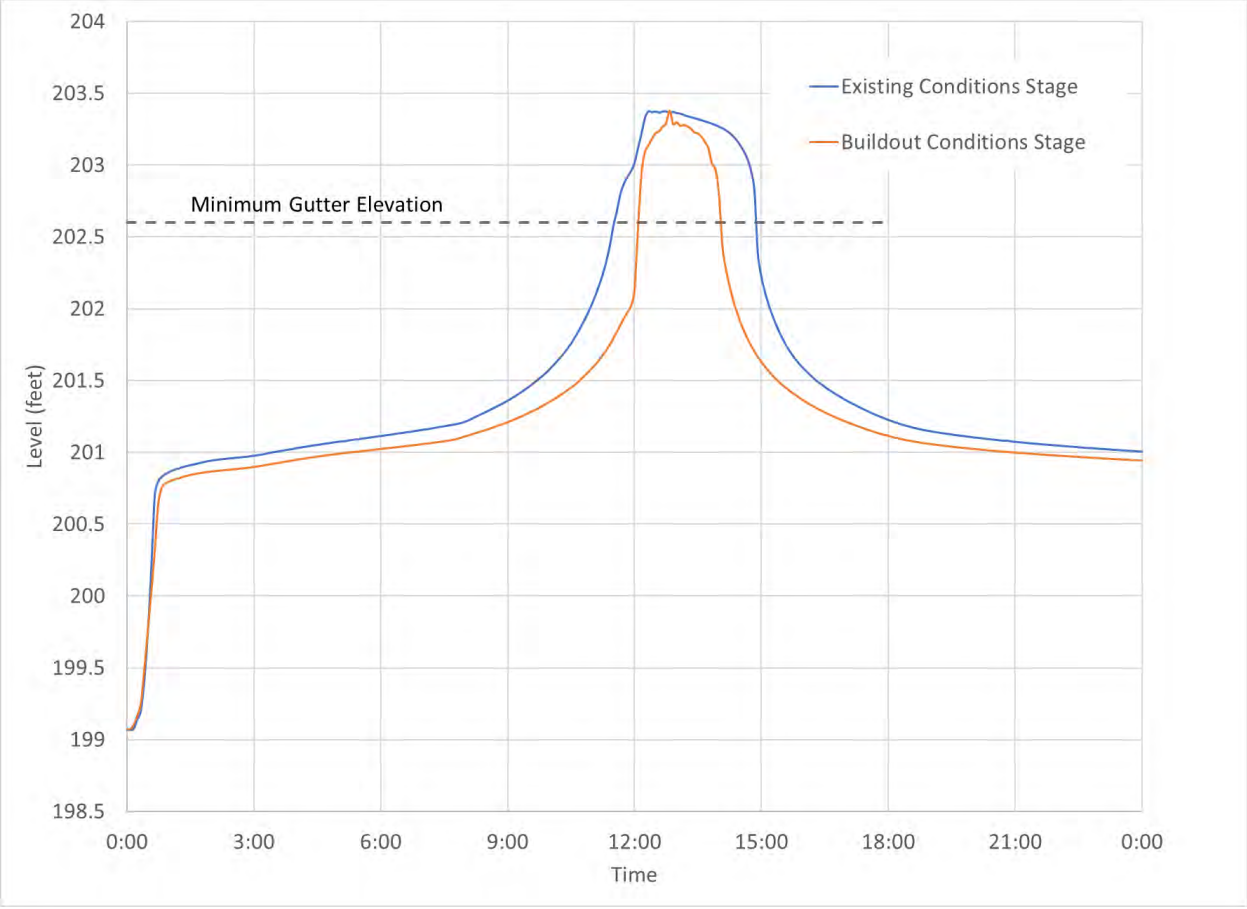


Exhibit 39: 10-Year Storm Stage Hydrographs at Manzanita Avenue and Cohasset Road

Various measures are needed in order for the City to comply with the Statewide Trash Amendments. Some of these measures could be included as a part of the projects to alleviate existing drainage deficiencies.

9.5 Projects to Accommodate Future Development

In general, large infill development projects will incorporate detention basins to mitigate for impacts on the local drainage system to which the project will drain. Project-specific analysis is recommended to design detention basin systems in order that proposed projects would not cause increases in flooding during the 2-year, 10-year, or 100-year storm based on the modeling developed as part of this SWMP and any subsequent model improvements.

The projects to accommodate future development that are included in this SWMP focus on SPAs identified in Appendix C to the 2030 General Plan. The General Plan describes the five SPAs shown on Figure 31. Subsequent to completion of Appendix C, the SPA designation was removed from the Bell Muir Area.

The five SPAs as shown in Appendix C are:

- Bell Muir Area
- Barber Yard SPA
- Doe Mill/Honey Run SPA
- North Chico SPA
- South Entler SPA

Drainage solutions for the Doe Mill/Honey Run SPA are not included in this SWMP. Information about the challenges associated with mitigating for the impacts of increased runoff from the Doe Mill/Honey Run SPA are discussed in Section **8.2.1.1**. Increased runoff from the Doe Mill/Honey Run SPA has the potential to increase the likelihood of levee failures along Butte Creek. Drainage improvements by the developers the of Doe Mill/Honey Run SPA should be required to demonstrate that the potential project impacts identified in this SWMP have been adequately mitigated.

The SWMP considered the potential impacts of infill development by using build-out hydrology to size recommended improvements. The recommended improvements are presented on Figure 32.

9.5.1 Future Drainage within the Bell Muir Area

The Bell Muir Area is located immediately to the west of the City, within the City's Sphere of Influence. It is bounded by Muir Avenue to the west and Bell Road and Alamo Avenue to the north and northeast, respectively, and covers approximately 398 acres. The southern boundary is along the UPRR corridor west of W. East Avenue. The primary roadway alignments that cross

the Bell Muir Area run southeast to northwest and include Rodeo Avenue, Nord Avenue, and Guynn Avenue. Current land uses are primarily agricultural, with some residential areas.

Soil types, topography, and planned land uses influence potential drainage solutions. There are no well-defined drainage paths within the Bell Muir Area. The ground slopes downward from east to west, with high ground at an elevation of 175 feet near W. East Avenue and low ground at 155 feet near Muir Avenue. The average slope is approximately 0.3 percent. The area drains to the SUDAD Channel on the north side of the UPRR. The Bell Muir Area is in an area predominantly covered by HSG B. The saturated hydraulic conductivity of underlying soils at a depth of five feet is 1.4 inches per hour according to USDA NRCS soil data. The General Plan shows areas of Secondary Open Space (SOS or OS2) for community gardens and small agriculture scattered throughout the Bell Muir Area. These areas could potentially be designed to become multi-objective detention basins. It can be more cost-effective to have multiple, spatially distributed detention basins rather than a single, or small number of, detention basins because it reduces the size of pipes and channels necessary to convey flows to the detention basins. The detention basins could also promote infiltration of storm water. This SWMP includes four detention basins within the Bell Muir Area to accommodate future development. The required storage could be further subdivided and implemented on a project-by-project basis. Detention implemented on a project-by-project basis would need to be reviewed and approved by the City in order to ensure that designs will meet functional and maintenance requirements.

The Bell Muir area had been evaluated in the North Chico Storm Drainage Study by Rolls Anderson & Rolls (dated January 1985). The drainage concept that was proposed in 1985 was to use large-diameter storm drains to convey peak flows to an improved open channel that would connect to the SUDAD Channel. This SWMP considers the need to mitigate for impacts caused by increased runoff into the SUDAD Channel. Additionally, use of distributed detention basins that promote infiltration can be utilized to meet NPDES LID requirements. This SWMP would supersede the 1985 North Chico Storm Drainage Study.

9.5.2 Future Drainage from the Barber Yard SPA

The Barber Yard SPA is bounded by the Union Pacific Railroad tracks to the south and west, Chestnut Street and Normal Avenue to the northeast, and Estes Road to the east and covers approximately 150 acres. The planning area is relatively flat and generally slopes east to west from an elevation of approximately 198 feet down to an elevation of approximately 189 feet. However, the railroad track forms an embankment that could impound runoff originating from both on-site and off-site sources up to an elevation of 192.5 feet. The implication of the on-site flood potential was presented in a Technical Memorandum, *Potential Flood Conditions at Barber Yard* dated June 7, 2022 and attached as **Appendix D**.

The SWMP modeling included a preliminary concept for the Barber Yard detention basin. The final storm water management system for the Barber Yard area will be designed by the developers

and reviewed and approved through a process separate from the SWMP. The costs for Barber Yard drainage improvements are not included in the SWMP.

9.5.3 Future Drainage within the North Chico SPA

The North Chico SPA is located north of the City between SR 99 and the Chico Municipal Airport. It is bounded by Hicks Lane to the east, Sycamore Creek to the south and Mud Creek to the north and west and covers approximately 484 acres. Current land uses are primarily agricultural with one residential area along Caballo Way.

The topography and the levees along Mud Creek and Sycamore Creek are the primary factors influencing potential drainage solutions for the North Chico SPA. The area slopes downward from northeast to southwest. It has some defined drainage courses, including ditches through the Caballo Way neighborhood. High ground at the northern end of the SPA is at an elevation of approximately 220 feet, and low ground is at an elevation of approximately 175 feet near the confluence of Mud Creek and Sycamore Creek. The average slope is approximately 0.8 percent. The area drains to Sycamore Creek via culverts that penetrate through the levee. The culverts include flap gates to prevent water from backing up from the creek into the SPA.

The North Chico SPA is in an area predominantly covered by HSG C. The saturated hydraulic conductivity of underlying soils at and below a depth of five feet varies from near zero inches to 20 inches per hour according to USDA NRCS soil data. Site geotechnical information would be needed to determine if it would be feasible to use infiltration systems to manage some of the North Chico SPA runoff. The projects for the North Chico SPA proposed in this SWMP do not include infiltration.

The FEMA SFHA mapping (see Figure 5) in the North Chico SPA shows a floodplain along the Mud Creek levee. Any flooding resulting from a levee breach or overtopping along the left (south or east) bank of Mud Creek into the North Chico SPA would pool along the Sycamore Creek levee; however, the FEMA SFHA does not reflect potential pooling of breach flows behind the Sycamore Creek levee. Interior drainage in excess of culvert capacity that can be limited by tailwater conditions also has the potential to be impounded by the Sycamore Creek levee and the southern portion of the Mud Creek levee. Although the FEMA SFHA does not show flooding along the Sycamore Creek levee, such flooding is shown in the models developed for this SWMP and must be addressed as a part of the drainage improvements to support the North Chico SPA. Levee improvements and/or fill would be required to provide 200-year ULOP for areas at risk of flood depths in excess of three feet due to flows originating from Mud Creek or Sycamore Creek.

The North Chico SPA will require a pump station, or pump stations, to manage runoff. The required capacity of the pump station will depend on the volume of detention that is used. Including a large amount of detention would allow for the use of a relatively small pump station. Conversely, a large capacity pump station would be required to manage runoff with a relatively

small volume of detention. The detention basin and pump station would need to be sized for the minimum of a 100-year design storm. There may be some benefit to include additional detention basin capacity in order to plan for stopping pump flows during periods of peak discharge in Mud Creek. However, the pump rates would be small compared to the Mud Creek discharge rates, and the potential benefit of stopping the pump when Mud Creek levels are high would be small. The optimum sizing of the detention basin and pump station depend on costs, including land values and excavation costs that can vary over time. Therefore, the facility sizing recommendations included in this SWMP should be considered to be for planning purposes with the understanding that design-level studies may result in different recommendations.

This SWMP provides planning-level guidance for managing runoff from the North Chico SPA through the use of storm water detention and pumping. Internal drainage system planning within the North Chico SPA is not part of this SWMP. A channel is included in the ICM model of the North Chico SPA in order to deliver flows to the modeled detention basin. However, this channel is not included in the proposed improvements for the North Chico SPA because the developers of the area will be responsible for its design and implementation.

9.5.4 Future Drainage within the South Entler SPA

The South Entler SPA is located within the southeastern portion of the City's Sphere of Influence. It is bounded by SR 99 and Entler Avenue to the northeast, Butte Creek to the east, Entler Avenue at the northern corner, Marybill Ranch Road to the south, and the Sphere of Influence limit to the west, and it covers approximately 300 acres. Current land uses include commercial, manufacturing, warehousing, ballfields, and open space.

The topography in the South Entler SPA slopes from an elevation of approximately 220 feet at the northern end of the planning area to a low point at approximately 200 feet at its southwestern corner. There are no significant natural drainage features with the SPA. There are, however, some manmade ditches and retention basins.

This SWMP recommends the use of infiltration systems to manage runoff from the South Entler SPA because the expected infiltration capacity would support this approach. More than half of the South Entler SPA is covered by HSG A and the remainder is covered by HSG C. According to USDA NRCS soil data, the saturated hydraulic conductivity of underlying soils at and below a depth of five feet varies from 3.6 inches per hour to 21 inches per hour. The SWMP includes four storm water retention basins to serve the South Entler SPA. The basins were sized using a spreadsheet system and are not included in the build-out modeling.

10.0
Review of Creeks and Channels

10.0 REVIEW OF CREEKS AND CHANNELS

10.1 Purposes of the Streams and Channels Evaluation

The purpose of this section of the SWMP is to document known and potential issues with the creeks and channels related to drainage and flood control within the City. Known and potential issues were identified by reviewing information provided by the City, by making comparisons of various topographic data sources to identify locations of erosion and sedimentation, and by considering the results of updated computer models of the streams.

Figure 2 illustrates the major streams and their watersheds in and around the City. It also shows the streams and channels within the City's sphere of influence.

Preparation of the HEC-RAS Chico Area Streams Model (HEC-RAS Model) was a key component of the evaluation of known and potential issues with the creeks and channels. The Model includes a one-dimensional channel representation of the streams and channels that were included in the CVFED Combined Sacramento River System model. The key features in the HEC-RAS Model are presented in **Figure 35**. The purposes of the Model include:

1. Reviewing stream capacities by comparing standard recurrence interval water surface profiles to top-of-levee and top-of-bank elevations.
2. Providing reasonable tailwater elevations to use as boundary conditions for storm drain system modeling using ICM.
3. Analysis of the expected performance of the flow control structures on Little Chico Creek, Big Chico Creek, Lindo Channel and the associated bypass channels.
4. Providing a base model that could be used for simulating levee breaches and the resulting flooding.
5. Modeling and mapping of levee breach conditions for 200-year flows.
6. Modeling and mapping of 100-year flood conditions based on levee removal scenarios in order to estimate potential SFHAs that could be mapped if levees are not accredited by FEMA the next time that the FIRMs are updated. See **Appendix E**. The mapped potential 100-year flood areas are intended for informational purposes only. The information on the maps can be used to aid in the determination of the importance of maintaining levee accreditation. The maps can also be used to aid in the determination of the potential benefit of achieving levee accreditation for those levees that are not currently accredited.

Streams and channels that were not included as one-dimensional features in the HEC-RAS Chico Area Streams Model were also evaluated as part of the SWMP. One-dimensional channel models of other streams and channels were prepared in HEC-RAS in order to facilitate import into the ICM models.

10.1.1 Floodplain Mapping

The City benefits from updated floodplain maps for numerous reasons. Updated floodplain maps provide information about potential flood hazards that is better than information that could be found either in existing FEMA floodplain maps (that are intended for flood insurance purposes) or in the City's 200-year floodplain map prepared by DWR (that was based on coarse modeling and stream profiles that are not consistent with the latest modeling). SB 5 requires cities and counties within the Sacramento Valley and the San Joaquin Valley to make findings related to an ULOP before approving land-use decisions. Updated floodplain mapping would aid in determining where ULOP criteria are applicable. Additionally, updated floodplain mapping results could be used to estimate the costs of damages from potential storm events. The costs of potential damages can be used to justify costs for improvement projects to reduce flooding.

The SWMP provides various floodplain maps. The 100-year flood maps prepared as part of this SWMP are for informational purposes only and are not intended to replace FEMA regulatory flood maps. The SWMP models and mapping could be used to help identify locations where improvements to FEMA regulatory flood maps might be appropriate. Additional analysis, review and refinement of the results would be necessary to generate work products consistent with FEMA requirements. The SWMP provides 200-year flood mapping intended to be used by the City during the process of making findings associated with ULOP criteria.

ULOP refers to the level of protection that is necessary to withstand flooding that has a 1-in-200 chance of occurring in any given year using criteria developed by DWR. ULDC are part of ULOP Criteria where levees are used to provide flood protection. A finding related to ULOP is required for development projects when all of the following conditions (summarized from DWR documents) are met:

1. It is located in an urban area (10,000 residents or more).
2. It is in a FEMA moderate or special flood hazard zone.
3. It is in the Sacramento Valley-San Joaquin Valley area.
4. It is in an area of potential flood depth above 3.0 feet.
5. It is in a watershed with a contributing area encompassing more than 10 square miles.

Conditions 1 and 3 apply to the entire City and adjacent areas of Butte County. Most, but not all, of the area of concern could be impacted by flooding from a watershed that covers more than 10 square miles. Regarding the FEMA flood hazard zones (Condition 2), large portions of the City are covered by either moderate (0.2% annual chance) or special (1% annual chance) flood hazard zones (as shown below in **Exhibit 40,** and in more detail in Figure 5). Although not relevant to whether or not ULOP determinations are required, there may be areas of the City with a significant risk of flooding that are not within the FEMA flood hazard zones. For example, in some areas there is no 0.2% annual chance flood hazard zone immediately outside of the 1% annual chance flood, even though the 0.2% flood would be expected to be deeper than the 1% chance flood. DWR suggests that communities use 200-year flood depths to determine if Condition 4 applies.

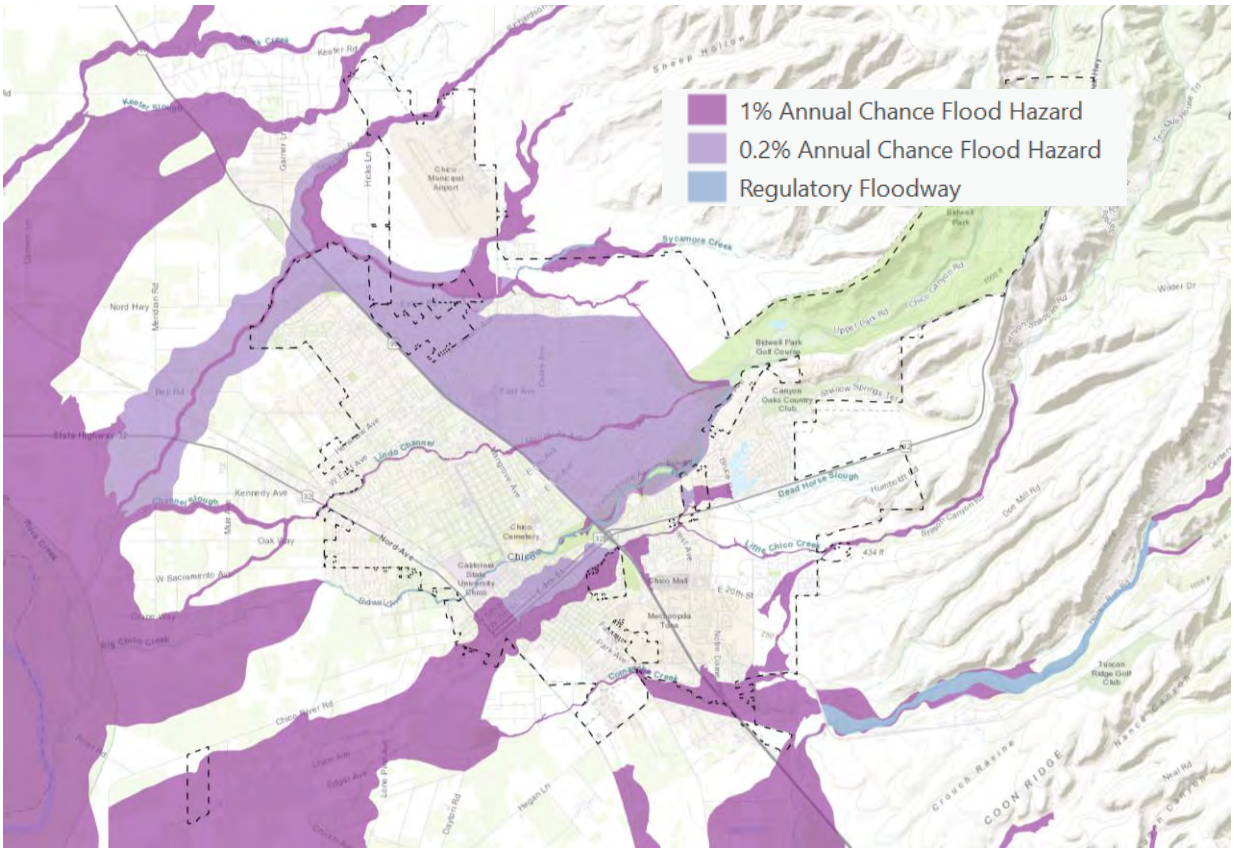


Exhibit 40: FEMA Flood Hazard Zones

The previously available 200-year floodplain mapping for the City was prepared as part of DWR's CVFED Project and is shown below in **Exhibit 41**. It was developed using coarse FLO-2D models for which one ground elevation was used and one depth was computed for each grid with a side length of approximately 325 feet. Flows based on selected levee breach scenarios were applied to the model. However, the stream flows used to compute breach flows were selected prior to the final results of the CVHS becoming available.

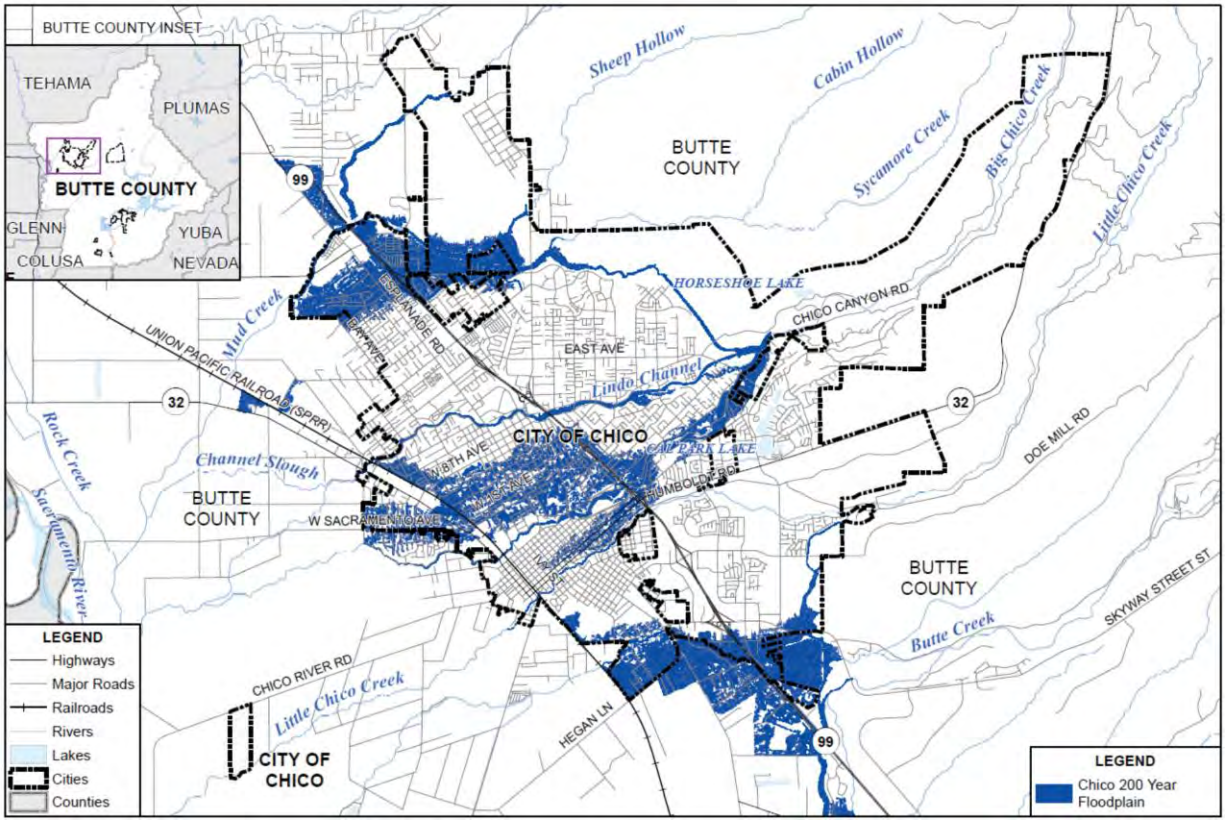


Exhibit 41: Existing 200-Year Floodplain Map developed by DWR

The 200-year floodplain mapping used to make ULOP findings must include major sources of potential flooding in addition to levee breach flows. The DWR 200-year floodplain map includes levee breach flows, but it does not include flooding associated with Little Chico Creek or Dead Horse Slough. Little Chico Creek and Dead Horse Slough needed to be included in the 200-year analysis because they are part of the regional drainage system and are not considered to be a local drainage system that would be exempted from 200-year flood requirements. Local flooding from rainfall within the City (that was evaluated by the detailed drainage system modeling prepared as part of the SWMP) is excluded from ULOP requirements. The DWR models used as a starting point for the Chico Area Streams HEC-RAS modeling for the SWMP included Little Chico Creek flows, but it did not include Dead Horse Slough flows. Flows from Dead Horse Slough needed to be considered for the 200-year floodplain mapping because these flows can contribute to flooding along Little Chico Creek where the tributary area is greater than 10 square miles. However, ULOP criteria do not apply to the area along Dead Horse Slough upstream from its confluence with Little Chico Creek where the contributing watershed area is less than 10 square miles.

The SWMP provides the City with a 200-year floodplain map that considers all major sources of flooding, uses CVHS flow results, and identifies where the 200-year flood depth is greater than 3.0 feet. Areas where ULOP criteria are required to be applied include locations where the mapping indicates flooding that measures more than 3.0 feet deep and where the contributing area is more than 10 square miles.

The 200-year floodplain maps developed as part of this SWMP for the evaluation of ULOP criteria include flooding from levee breaches that would be triggered once the 200-year flood level rises above the levee reliability height, as described in the Levee Breach Analysis section and based on DWR's ULE and NULE Projects. The results of the Chico Area Streams HEC-RAS model developed for the SWMP do not show extensive out-of-bank flooding along Big Chico Creek downstream from the Sycamore Creek Diversion Channel in the 200-year event. However, the 200-year floodplain map that was prepared using the CVFED model does show extensive out-of-bank flooding along Big Chico Creek. The differences are due to updated model geometry and flow rates.

10.2 Stream and Channel Modeling Approach

The approaches used to model the streams and channels in the City vary as determined to be appropriate for the purposes of the SWMP and depend on the function of the stream or channel in the system. Some of the channels have peak flow conditions that are controlled by runoff from the watersheds located upstream of the City, and others have peak flows that are generated by runoff originating from within the City. The streams and channels that have peak flows that result from runoff originating within the City were modeled using ICM. Multiple ICM models were used because it was determined that it would be more efficient to have generally independent areas modeled separately. The HEC-RAS Chico Area Streams Model is the primary tool for evaluating the streams and channels that have peak flows originating from watersheds located upstream of the City.

The Lindo Channel is included as a one-dimensional channel in the HEC-RAS Chico Area Streams Model, but it is also partially included as a one-dimensional channel in the ICM model. Although peak flows along the Lindo Channel originate from the Big Chico Creek watershed upstream of the City, part of the Lindo Channel is included in ICM model in order to model the City watershed that is upstream of a stream gage on the Lindo Channel. The stream gage sometimes measures flows that are independent from the upstream Big Chico Creek watershed. The Lindo Channel drainage area ICM model was used for model calibration based on Lindo Channel flows from the runoff originating entirely from within the City. The Lindo Channel gage location and the layout of streams included in the ICM models are presented in **Figure 36**.

A combination of one-dimensional and two-dimensional modeling is used to evaluate other streams within the City's sphere of influence. All of the streams that are not modeled as one-dimensional features in the HEC-RAS Chico Area Streams Model are included within the two-dimensional model regions in the HEC-RAS model. However, the accuracy of two-dimensional stream model results can be lower than one-dimensional stream model results unless steps are taken to ensure that topographic conditions and significant bridge and culvert features are represented at an appropriate level of detail. The ICM models include more details along the channels in the two-dimensional flow areas within the HEC-RAS Chico Area Streams Model because the ICM models include the local drain systems. HEC-RAS geometry files for the SUDAD Channel, Pleasant Valley (Dry Creek), Little Chico Creek, and the BD Channel were prepared in order to facilitate modeling of these channels as one-dimensional features in ICM.

Peak flooding along Little Chico Creek originates from its watershed upstream of the City and it was modeled within the two-dimensional flow area in HEC-RAS. Dead Horse Slough was also modeled within the two-dimensional flow area in HEC-RAS.

A HEC-RAS one-dimensional geometry file was prepared for Little Chico Creek and Comanche Creek within the City's sphere of influence using the FEMA model data provided by the City. The FEMA geometry data was georeferenced in an approximate manner using bridge locations for reference. The Little Chico Creek geometry was refined based on survey data, and then was imported into an ICM model. The refined one-dimensional cross sections along Little Chico Creek were used to build a terrain surface that was incorporated into the two-dimensional mesh zone in HEC-RAS in order to improve the accuracy of the HEC-RAS model. Comanche Creek was included in ICM using two-dimensional mesh with some terrain modifications to improve the digital elevation data that had been impacted by water.

10.3 Flow Control Systems

10.3.1 Little Chico Creek Flow Control

The Operation and Maintenance Manual for Upper Butte Creek – Part No. 2 from Little Chico Creek Diversion Structure Down Stream 9.3 Miles (SAC516 O&M) states, *"The project design flow for Little Chico Creek upstream from the diversion structure is estimated at 6,700 cubic feet per second and downstream from the diversion structure the flow in Little Chico Creek is limited to 2,200 cubic feet per second, which is the non-damaging capacity of the creek through the City of Chico. The remaining 4,500 cubic feet per second of flow is diverted over the concrete weir and through the diversion channel to Butte Creek. The project design flow for this diversion with a freeboard of 3 feet is 3,000 cubic feet per second, however, a flow of 4,500 cubic feet per second can pass down this channel with zero freeboard. The adopted freeboard for the levees on Butte Creek downstream from its junction with the diversion channel is such that it will contain the standard project flood of 40,000 cubic feet per second with no freeboard, or that it will contain the project design flow of 27,000 cubic feet per second with 3 feet of freeboard, whichever results in the higher levee."*

Section 4-05 of the SAC516 O&M Manual states, *"A concrete diversion structure is located on Little Chico Creek at the head of the Little Chico Creek to Butte Creek Diversion Channel as shown on the Location Map, Exhibit A-1 and drawings of Exhibit B. The portion of the diversion structure which controls the flow downstream to Little Chico Creek consists of a reinforced concrete structure with four openings each 4 feet wide by 9 feet high and invert at streambed. This structure passes all upstream low water flows (up to about 900 c.f.s.) downstream to Little Chico Creek. The portion of the diversion structure which controls the flow downstream to the diversion channel consists of an ungated concrete ogee weir 100 feet long with crest 4 feet above the upstream streambed. Baffle blocks are provided on the downstream concrete apron to reduce velocities before the water enters the diversion channel. Wing walls on each end of the diversion structure tie the structure to high ground. During the project design flow of 6,700 c.f.s. in Little Chico Creek upstream from the structure, the flow downstream into Little Chico Creek is controlled to a non-damaging flow of 2,200 c.f.s. and the remainder of the flow of 4,500 c.f.s.*

passes over the ogee weir downstream to the diversion channel. A freeboard of 2.5 feet is provided at the concrete structure and 3.0 feet at the wing levees. Stop log slots, 7 inches wide, are provided in the two end openings of the Little Chico Creek portion of the diversion structure. However, stop logs are not to be used unless, during the project design flow, the distribution of flow downstream to Little Chico Creek exceeds the estimated 2,200 c.f.s. and then only sufficient stop logs will be used to control the flow to 2,200 c.f.s."

Analysis of the Little Chico Creek diversion system determined that less flow would be expected to be conveyed through the gates than the flow rates stated in the SAC516 O&M. The elevations of the weir and gate structures were surveyed and added to the HEC-RAS model based on the CVFED model. The model results showed 335 cfs continuing along Little Chico Creek before diversions would begin, and that 1,630 cfs would flow through the gate structure into Little Chico Creek when the upstream discharge reaches 6,700 cfs. The modeled flows are presented below in **Exhibit 42**.

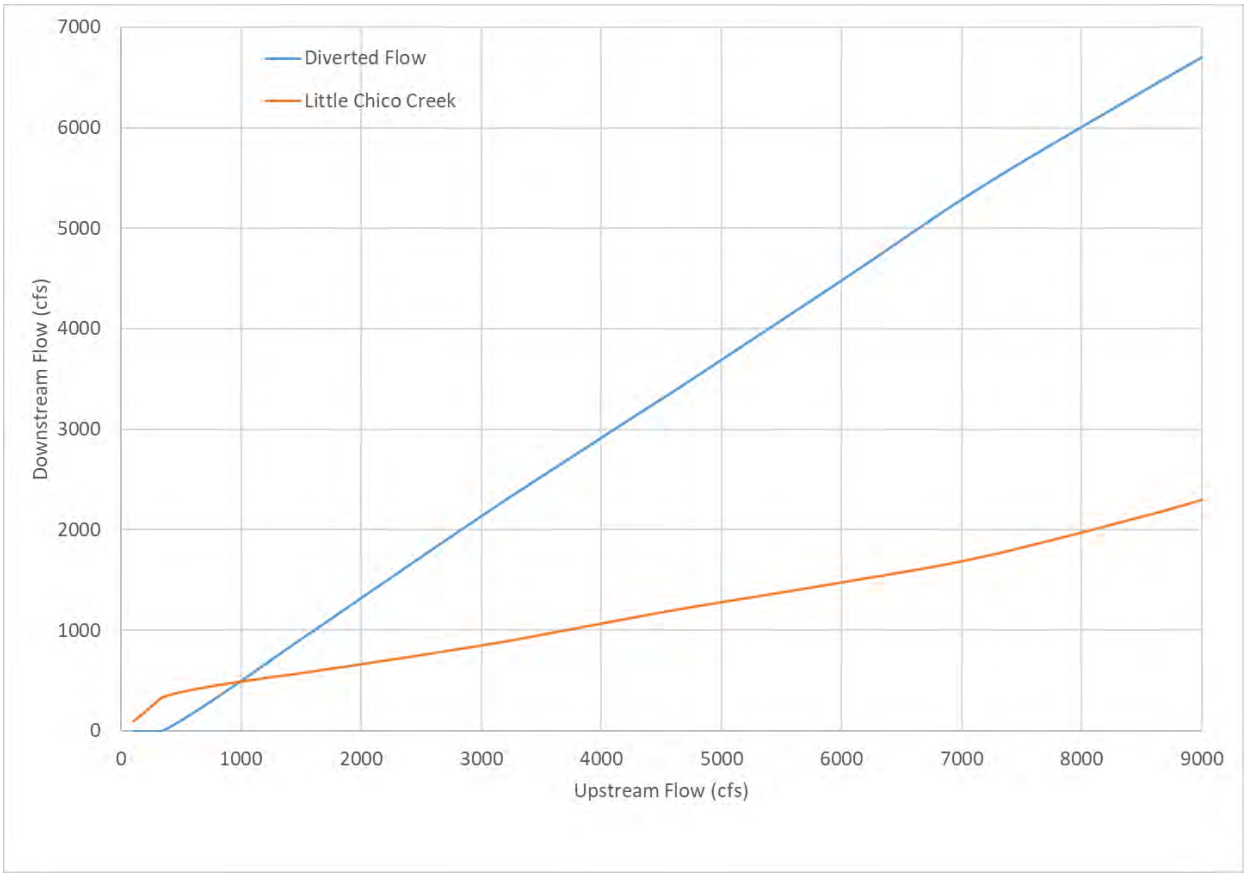


Exhibit 42: Modeled Flow at Little Chico Creek Diversion

10.3.2 Big Chico Creek Flow Control

The Operation and Maintenance Manual for Chico and Mud Creeks and Sandy Gulch[17] (SAC504 O&M) states, *"For the project design levee grade, at least 3 feet of freeboard has been provided over the project design flood plane."*

Section 4-05 of the SAC504 O&M provides descriptions of the diversion structures and their operations. No operations at the facilities are intended to occur during flood conditions. The flashboards are removed and the gates are fully open from October 15 to April 15. The following discussion of the flow control facilities is provided:

"A Diversion Structure to be operated and maintained by local interests located on Chico Creek near its bifurcation with Sandy Gulch consists of a 4-barreled reinforced concrete culvert, each barrel 5 feet square with related headwalls and wing walls designed to carry a roadway 12 feet wide. A slide headgate with pedestal lift has been provided for one barrel, and slots have been provided for stop logs at the other three openings."

"A Diversion Structure to be operated and maintained by local interests located on Sandy Gulch about one-quarter mile downstream from its bifurcation with Chico Creek consists of a 7-barreled concrete culvert, with six barrels 7 feet-3 inches high by 7 feet wide and the center barrel 8 feet-3 inches high by 7 feet wide with related headwalls and wing walls. Slots have been provided for stop logs at the heads of the culvert openings."

"A Concrete Ogee Weir to be operated and maintained by local interests, 178 feet long with a crest at elevation 268.25 feet and related wingwalls is located at the beginning of the diversion channel one-quarter mile downstream from the Sandy Gulch bifurcation with Chico Creek, just northerly of the 7-barreled Sandy Gulch diversion structure."

Analysis of the Big Chico Creek diversion system shows that 1,500 cfs would be expected to be conveyed down Big Chico Creek when the upstream total discharge is 16,000 cfs, consistent with the SPFC documents. However, the model results show that slightly less flow - 5,500 cfs rather than 6,000 cfs - would flow into Lindo Channel under these conditions, than was indicated in the SPFC documents. This difference would leave slightly more flow - 9,000 cfs rather than 8,500 cfs - flowing into the Sycamore Creek system which drains into Mud Creek. The modeled flows are presented below in **Exhibit 43**.

[17] Sandy Gulch and Lindo Channel are synonymous.

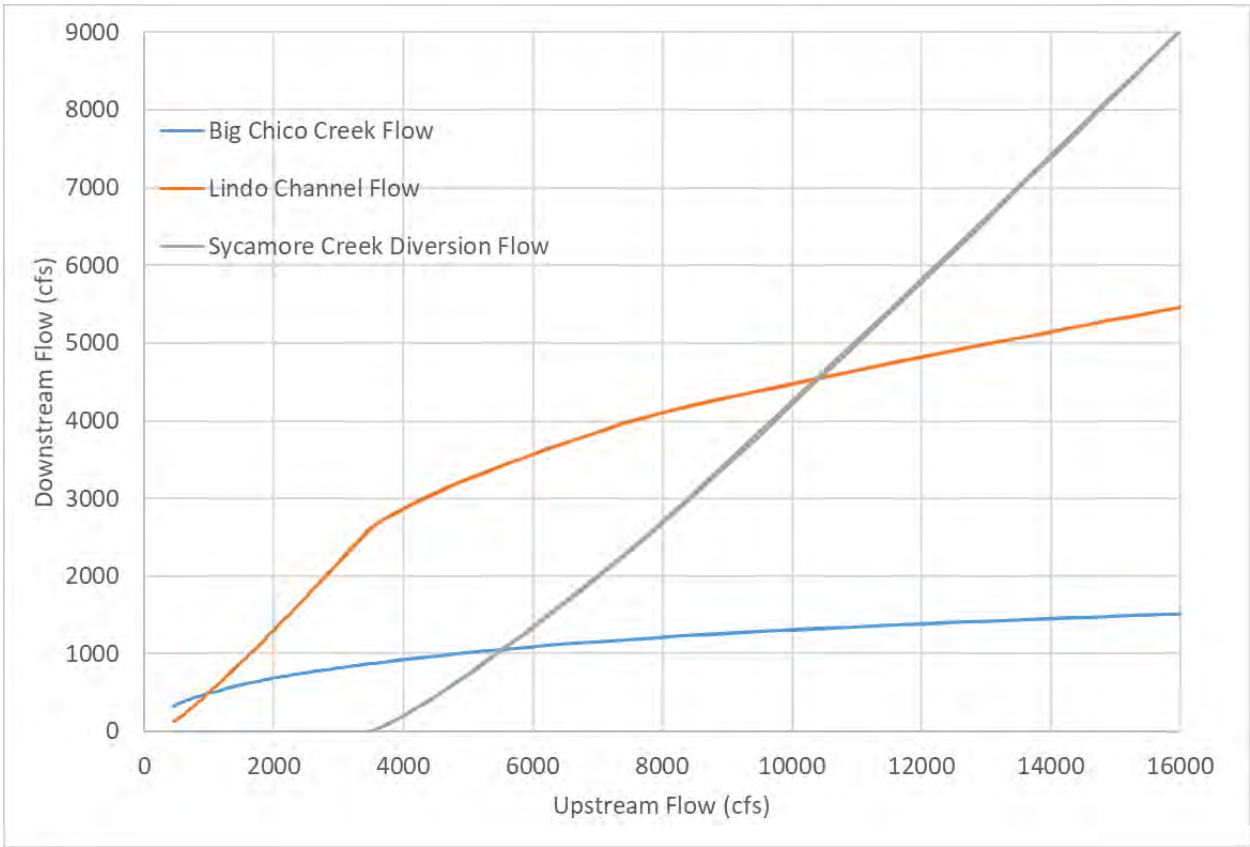


Exhibit 43: Modeled Flow at Big Chico Creek and Lindo Channel Diversion

10.4 Standard Recurrence Interval Flow Rates

Standard recurrence interval flow rates are the 10-, 50-, 100-, 200- and 500-year average recurrence interval storms. These are also called the 0.10, 0.02, 0.01, 0.005, and 0.002 annual exceedance probability storm events. Storm conditions can refer to peak flows or average flows (or volumes) for specific durations. For the Chico SWMP, peak flows are used.

The CVHS developed standard recurrence interval peak flows for the watersheds that drain to the SPFC facilities that protect the City. Two reports were prepared by David Ford Consulting Engineers (Draft Reports dated March 12, 2013) to document the model calibration process. One is titled *Mud Creek/Big Chico Creek Watershed Hydrologic Analysis* [21] and the other is titled *Butte Creek Watershed Hydrologic Analysis* [22]. The Butte Creek analysis included Little Chico Creek. The HEC-HMS models used for these studies are included with the referenced reports and other reference information provided to the City. The CVHS provides the best available peak flow information for the major streams draining towards the City where flows enter the flood control system.

Determination of standard recurrence interval flows at the upstream end of the flood control system requires the selection of appropriate precipitation depths, routing parameters, areal reduction factors and other parameters as described in the CVHS documentation of the HEC-HMS models.

The flows within the flood control system may not be accurately determined in the HEC-HMS models because the diversion parameters in the HEC-HMS models do not precisely reflect how the physical flood control system operates. The HEC-HMS model for Big Chico Creek and Mud Creek has various scenarios for different tributary areas in order to provide flow rates based on different areal reduction factors. The correct scenario must be selected in order to obtain flow rates for specific locations.

An additional potential complication is that design conditions do not necessarily reflect current conditions. For example, sediment accumulation upstream from the flow control weir that directs water into the bypass from Big Chico Creek into Sycamore Creek has reduced the efficiency of the weir. The water level upstream from the weir at a given flow rate would, therefore, be higher than the design level. The higher upstream water levels would tend to cause the flows going into Lindo Channel (which are dependent on this level) to be higher than the design flows. However, a detailed analysis concluded that other factors cause less flow to be directed into Lindo Channel than was shown in the planning documents.

10.4.1 Little Chico Creek Flows

The CVHS HEC-HMS model for Butte Creek included only one set of precipitation distributions based on a tributary area of 183.11 square miles. However, the area tributary to Little Chico Creek at the diversion structure is only 25.5 square miles. Precipitation patterns based on a tributary area of 24.4 square miles had been included in the Mud Creek /Big Chico Creek HEC-HMS model, and these precipitation patterns were used to compute standard recurrence interval peak flows for the location of the diversion structure on Little Chico Creek. Based on a review of similar precipitation depths, it was determined that the precipitation zones used in the Mud Creek/Big Chico Creek model were not the same as the precipitation zones used in the Butte Creek model. Precipitation Zone 2 in the Mud Creek/Big Chico Creek model corresponds to Precipitation Zone 3 in the Butte Creek model, and the other zones were similarly shifted to apply the precipitation parameters available in the Mud Creek/Big Chico Creek HEC-HMS model to the Butte Creek HEC-HMS model.

10.4.2 Dead Horse Slough Flows

The Dead Horse Slough Watersheds were delineated using CVHS watershed boundaries and LiDAR topographic data. Two watersheds were delineated for Dead Horse Slough: the upper 4-square-mile watershed that drains to California Park Lake, and the lower 1.3-square-mile watershed which drains to the Dead Horse Slough confluence with Little Chico Creek. The watershed delineations are shown in **Exhibit 44**.

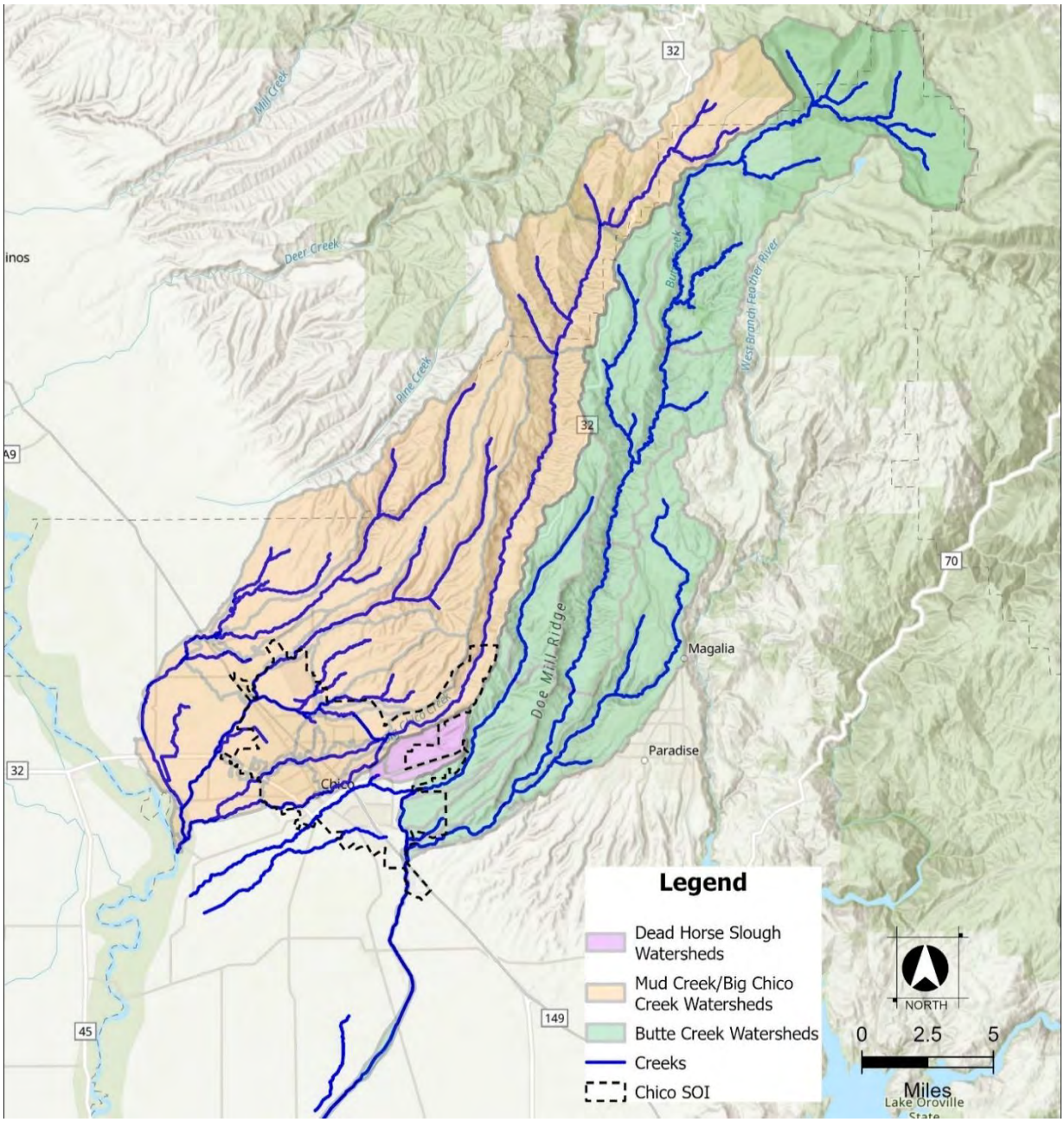


Exhibit 44: HEC-HMS Model and Dead Horse Slough Watersheds

The Dead Horse Slough Watersheds were added to the CVHS Mud Creek/Big Chico Creek Watershed HEC-HMS model because that model contains hydrology for an areal reduction factor of 2.8 square miles. The Dead Horse Slough Watersheds are 4.0 square miles and 1.3 square miles; therefore, application of an areal reduction factor for 2.8 square miles is reasonable. The same loss, transformation, and baseflow methods were utilized as described in the *Mud Creek/Big Chico Creek Watershed Hydrologic Analysis*. The percentage of impervious area was calculated using the methodology described in Section 7.2.

10.4.3 Inflow Locations

The HEC-RAS Chico Area Streams Model that was used to produce channel flood profiles uses twelve hydrograph inflow locations. Peak flows for these twelve inflow locations were obtained from nine HEC-HMS elements in the CVHS models plus two output hydrographs that were created within elements added to the Mud Creek/Big Chico Creek HEC-HMS model in order to provide flows into California Park Lake and Dead Horse Slough. The flows from one of the HEC-HMS elements was divided by two in order to split the flows from the S. Sycamore Creek watershed into two inflow locations in the HEC-RAS model. The inflow descriptions, HEC-RAS inflow locations, and the HEC-HMS element peak flow source are listed below in **Table 26**.

Table 26: HEC-RAS Inflow Locations and Peak Flow Sources

Inflow Description	HEC-RAS Location	HEC-HMS Element
Big Chico Creek upstream of Sycamore Bypass	XS SYC R03 6.113	BCC-10
Trib. to S. Sycamore Ck below Sycamore Creek Div Ch.	XS SYC R03 4.899	Sub_BCC-13_1
S. Sycamore Creek inflow point	XS SYC R03 4.001	Sub_MUD-D_1
Area below S. Sycamore Creek inflow point	XS SYC R03 3.088	Sub_MUD-D_1
N. Sycamore Creek inflow point	XS SYC R03 2.6	Sub_MUD-D_2
Sheep Hollow Creek inflow point	SA CHI-05	Sub_MUD-E_1
Upstream end of Mud Creek Levees	XS MUC R02 10.34	MUD-8
Channel serving northwest Chico, SUDAD Channel	XS MUC R01 5.078	Sub_MUD-4_1
Butte Creek	XS BUC R02 45.399	BUT-43
Little Chico Creek	XS LBC R01 2.897	Little Chico Ck Div
California Park Lake	Cal_Park_Lake	Upper DHS
Dead Horse Slough	DHS_Inflow_Alignment	Sub_Lower_DHS

A steady-state HEC-RAS plan was used to compute the water surface profiles for Mud Creek (MUC) upstream from Sycamore Creek (SYC) and for Sheep Hollow Creek (SHE). **Table 27** provides the peak flows for the standard recurrence interval storms for the upstream end of MUC and SHE.

Table 27: Mud Creek and Sheep Hollow Creek Inflows

Inflow Location	Reduction Area	Average Recurrence Interval				
		10-Year	50-Year	100-Year	200-Year	500-Year
	(mi^2)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
Mud Creek	24.4	2,494	3,909	4,539	5,186	6,062
Sheep Hollow Creek	2.8	1,789	2,428	2,703	2,987	3,363

For the Mud Creek/Big Chico Creek system, the HEC-RAS Chico Area Streams Model uses scaling factors applied to the design storm used in the CVFPP HEC-RAS model in order to set the peak inflows to match the target peak flows from the CVHS model results. Peak flows computed using precipitation depths for different areal reduction factors that are based on the tributary area at key locations in the CVHS HEC-HMS models were used to establish the peak flows for the HEC-RAS model runs for the standard recurrence interval water surface profiles. Flow rates based

on an areal reduction factor for 24.4 square miles were used to compute water surface profiles for the Mud Creek system upstream of the confluence of Sycamore Creek with Mud Creek. Flow rates based on an areal reduction factor for 74 square miles were used to compute water surface profiles for the system located upstream from the confluence of Sycamore Creek with Mud Creek, and they are presented below in **Table 28**. Flow rates based on an areal reduction factor for 124.3 square miles were used to compute water surface profiles for Mud Creek at a location downstream from the confluence of Sycamore Creek, and they are presented below in **Table 29**. The locations where the various areal reduction factors were applied are shown on **Figure 37**.

Table 28: Inflows for Big Chico Creek, Lindo Channel and Sycamore Creek

Inflow Location	Average Recurrence Interval				
	10-Year (cfs)	50-Year (cfs)	100-Year (cfs)	200-Year (cfs)	500-Year (cfs)
Big Chico Creek	6,782	10,528	12,225	13,982	16,357
S. Sycamore Creek Trib.	267	359	397	436	487
S. Sycamore Creek 1	84	114	126	137	153
S. Sycamore Creek 2	84	114	126	137	153
N. Sycamore Creek	1,397	1,904	2,117	2,344	2,637
Sheep Hollow Creek	1,370	1,865	2,082	2,302	2,590

Table 29: Inflows for Mud Creek Profile below Sycamore Creek

Inflow Location	Average Recurrence Interval				
	10-Year (cfs)	50-Year (cfs)	100-Year (cfs)	200-Year (cfs)	500-Year (cfs)
Big Chico Creek	6,306	9,897	11,524	13,196	15,471
S. Sycamore Creek Trib.	224	302	335	367	410
S. Sycamore Creek 1	79	107	118	129	143
S. Sycamore Creek 2	79	107	118	129	143
N. Sycamore Creek	1,255	1,711	1,909	2,109	2,374
Sheep Hollow Creek	1,370	1,865	2,082	2,302	2,590
Mud Creek	1,863	3,058	3,591	4,140	4,883
Mud Creek-Sycamore Creek Confluence	325	436	483	530	593
SUDAD Channel	311	468	539	609	703

Hydrographs obtained from the HEC-HMS result were used for the Butte Creek and Little Chico Creek areas rather than scaling the hydrographs in the CVFPP HEC-RAS model. Direct use of HEC-HMS results rather than scaled hydrographs ensured that the storms would have appropriate volumes where flood routing is significant for the Little Chico Creek area that is impacted by flows through California Park Lake. The peak flow rates computed for Butte Creek and Little Chico Creek are listed below in **Table 30**. The areal reduction factor for 24.4 square miles was used to compute peak conditions at the diversion weir and along Little Chico Creek. The areal reduction factor for 183.11 square miles is appropriate for areas where Butte Creek controls peak flood conditions. Peak flows computed for Dead Horse Slough were also computed using an areal

reduction factor for a tributary area of 2.8 square miles in order to provide flows for comparison to FEMA flow rates for Dead Horse Slough. The FEMA FIS lists a 10-year flow of 750 cfs, a 50-year flow of 1,500 cfs, and 100-year flow of 1,900 cfs for Dead Horse Slough at its confluence with Little Chico Creek, The rounded sums of the California Park Lake and Dead Horse Slough flows listed in Table 30 are 1,300 cfs, 1,700 cfs, and 1,900 cfs for the 10-year, 50-year and 100-year flood conditions, respectively.

Table 30: Butte Creek and Little Chico Creek Inflows

Inflow Location	Reduction Area	Average Recurrence Interval				
		10-Year	50-Year	100-Year	200-Year	500-Year
	(mi^2)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
Butte Creek	183.11	16,144	27,263	32,331	37,589	44,791
Little Chico Creek	183.11	3,145	4,713	5,389	6,084	7,014
Little Chico Creek	24.4	4,193	6,115	6,960	7,828	9,004
California Park Lake	24.4	942	1,267	1,395	1,535	1,712
California Park Lake	2.8	986	1,327	1,465	1,607	1,793
Dead Horse Slough	24.4	285	381	419	459	510
Dead Horse Slough	2.8	298	399	439	481	534

ICM results are used for illustrating potential flooding from local rainfall within the City limits. The hydrology prepared for the CVHS was not intended to provide accurate flows from the urbanized area of the City. The topographic data used for the CVHS provided reasonable watershed delineations in the upper watershed, but did not provide an accurate basis for delineating drainage boundaries within the City. Flows from Dry Creek within the City are not expected to contribute significantly to the peak conditions along the Sycamore Creek Bypass, and a small inflow was used for HEC-RAS modeling purposes. Discharges for the Dry Creek/Pleasant Valley Watershed were computed using detailed ICM. The resulting 100-year discharge of 220 cfs is significantly lower than Dry Creek's rated capacity of 500 cfs as stated in the SPFC Descriptive Document. Considering the relatively low flow from the tributary watershed that would be expected at the time of peak discharge in Sycamore Creek and the Dry Creek channel capacity, it would be reasonable to evaluate the adequacy of the Dry Creek Levees based on backwater flooding from Sycamore Creek. SUDAD Channel inflows to Mud Creek based on CVHS hydrology were included in the Mud Creek analysis. A detailed analysis for the SWMP provides different flows for the SUDAD Channel tributary area than CVHS hydrology. The SWMP flows for SUDAD Channel do not need to be used for Mud Creek analysis because the peak flows from the City would not be coincident with the peak flows in Mud Creek.

10.4.4 Comparison of SWMP and FEMA Standard Recurrence Interval Flows to Stated Capacity

Some of the creeks and channels have capacity information stated in the SPFC. Figure 3-2 in the *SPFC Descriptive Document Update* (dated August 2017) shows the capacities listed below in **Table 31.** (See Exhibit 7, Figure 8-3 from the MUSR RFMP, which also presents the stated channel capacities.) The text on Figure 3-2 states, *"The capacities depicted on this map are from the 1957 Design Profile and Operation and Maintenance Manuals and do not represent existing system capacities. The capacities shown on this map represent only those pertaining to leveed channel systems. These capacities represent an estimate made at a specific time with limited resources. The existing system capacities, in some cases, may differ substantially."*

Table 31 provides a comparison of stated channel capacities with FEMA flow rates (where available) and the updated 100-year and 200-year flows based on the HEC-HMS and HEC-RAS modeling described in the previous sections.

Unlike the FEMA FIS models, the HEC-RAS Chico Area Streams Model provides a fully dynamic unsteady-state simulation. The unsteady-state simulation routes inflow hydrographs through the system rather than assigning constant flows by location as in the FEMA FIS. Flows downstream from the inflow points are obtained from the HEC-RAS model results.

Table 31: Comparison of Updated and FEMA Standard Recurrence Interval Flows to Stated Capacity				
Location	**Stated Capacity (cfs)**	**FEMA 100-Year Flow (cfs)[18]**	**Updated 100-Year Flow (cfs)**	**Updated 200-Year Flow (cfs)**
Little Chico Ck. above Div.[19]	6,700	5,600	7,000	7,800
Little Chico Ck. below Div.	3,000[20]	2,200	1,700	1,900
Little Chico Ck. Div. Channel	3,000	3,100	5,300	5,900
Butte Creek	27,000	25,000[21]	35,300	40,600
Big Chico Creek above Div.	16,000	11,000	12,300	14,000
Big Chico Creek below Div.	1,500	1,400	1,400	1,500
Lindo Channel above Div.	14,500[22]		10,800	12,500
Lindo Channel[23] below Div.	6,000	4,000	4,900	5,100
Sycamore Bypass	8,500	5,600	6,000	7,400
S. Sycamore Creek	8,800	6,070	6,500	8,000
SYC from above SHE	10,000	7,080	8,600	10,100
Sheep Hollow Creek	1,400		2,700	3,000
SYC from SHE to MUC	11,000	8,100	10,600	12,400
MUC above SYC	5,500		4,500	5,200
MUC below SYC	15,000	10,410	13,700	15,900

10.5 HEC-RAS Model Development and Application

The DWR provided the 2017 CVFPP Sacramento River System HEC-RAS model that included the "1997_80-95" hydrology. The 2017 CVFPP HEC-RAS model was based on the CVFED Task Order No. 34 Enhanced System Model (TO 34 Model). Subsequent to the TO 34 Model, further refinements had been made as documented in the *Refine/Calibrate Combined Sacramento River and San Joaquin River Systems, Sacramento River System Study Area Report* dated May 29, 2015. Key changes that had been made in the Refine/Calibrate Model were incorporated into the 2017 CVFPP model for the HEC-RAS Chico Area Stream Model for the SWMP.

The Chico Area Streams region of the 2017 CVFPP Model was extracted to provide a base model that could be used more efficiently than the entire Sacramento River model. Key changes from the Refine/Calibrate model (specifically Manning's n-values, hydraulic property tables, and the configuration of the LBC-BUC confluence) were integrated into the HEC-RAS Chico Area Streams model. The model was updated to HEC-RAS version 6.3.1, the lateral structures were georeferenced, and the areas of the City that had been covered by one-dimensional storage areas were updated to be covered by two-dimensional flow areas. Other adjustments to the model were

[18] Not all of the locations are listed in the Flood Insurance Study.
[19] The location "Below Diversion Structure" listed in the FIS is actually above the Diversion Structure as confirmed in the HEC02 input file 2LCMB01.DAT
[20] The indicated capacity of 3,000 cfs appears to conflict with the SAC516 O&M that indicates that the capacity of Little Chico Creek is limited to 2,200 cfs.
[21] Listed discharge at Skyway
[22] Flow rate not included on Figure 3-2 but listed in SAC504 O&M.
[23] Sandy Gulch

made to achieve model stability. The Little Chico Creek weir and gate structures were added based on information in the Operations and Maintenance Manual. The elevations of these structures were surveyed because these structures had not been included in the CVFED or FEMA models. Modifications to how the control systems of Big Chico Creek and Lindo Channel had been simulated in the DWR models were made in order to improve model accuracy. These modifications were implemented in order to better match information in the Operations and Maintenance Manual and to allow the physical system to control the flow splits rather than using rating curves or rules that had been applied in the previous model versions.

Recommendations for field surveys were developed based on a detailed review of modeled cross sections and available sources of topographic data. In some cases, it was determined that the cross sections should be updated based on available topographic data. Development of the recommendations for field surveys and cross section modifications are included in **Appendix F**. The recommended survey was completed between December 2021 and February 2022; following the completion of the survey, the cross sections were updated using survey data and available topographic data as determined to be appropriate.

10.5.1 200-year Floodplain Analysis Model Development

The HEC-RAS model used for the SWMP was further refined and updated to conduct the 200-year floodplain analysis. Areas to the west of Mud Creek and east of Butte Creek that had been covered by one-dimensional storage areas were updated to be covered by two-dimensional flow areas, and culverts with diameters measuring 24 inches and larger and that cross through levees were added to lateral structures based on City storm drain system data. Most culverts have flap gates that prevent flow from leaving the creeks through the culverts.

California Park Lake and its associated storage, dam, and spillway were added based on information in the *Emergency Action Plan (EAP): California Park Dam*. California Park Lake is modeled as a one-dimensional storage area, and the dam and spillway are modeled as a lateral structure that spills to a two-dimensional flow area. The initial water surface elevation of the storage area is set to the elevation of the spillway of 259 feet, which assumes that the lake is full at the beginning of the storm.

Upper Dead Horse Slough inflows are applied as a lateral inflow to the California Lake Park storage area. Dead Horse Slough downstream of the spillway is modeled as a two-dimensional flow area. Lower Dead Horse Slough inflows are applied upstream of the confluence with Little Chico Creek.

Several additional refinements were made to the model to improve the accuracy of the two-dimensional flow areas. Additional breaklines were added along roadway embankments, banks of channels not being modeled as one-dimensional features, and other grade breaks significant to the floodplain. Two-dimensional flow areas were updated with detailed roughness coefficients (Manning's n-values) to represent roadways, buildings, and channels. Roadways are assigned a Manning's n-value of 0.016, building footprints are assigned a value of 0.25, and an n-value of

0.060 was used for the remainder of the Study Area (except for a corridor along the bottom of Little Chico Creek that used 0.03). Manning's n-values are shown in **Exhibit 45**.

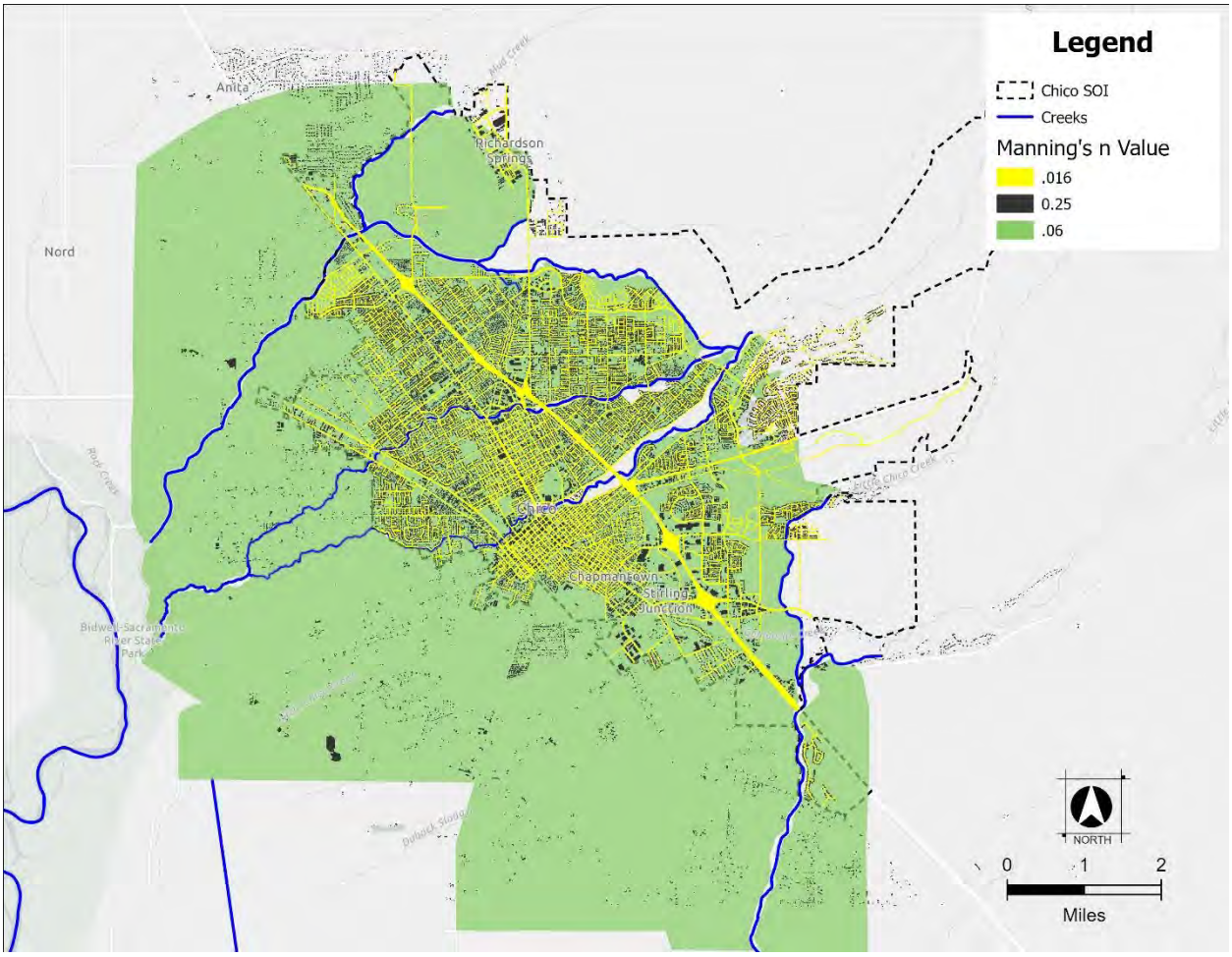


Exhibit 45: Manning's n-Values

10.6 Levee Breach Analysis

Thorough analyses were conducted on 50 levee breach locations by utilizing breach data spreadsheets and shapefiles that were developed as part of the CVFED. Each breach was evaluated independently[24] using the appropriate areal reduction factor to determine the flow rate. The breach locations labeled with river stationing are shown in **Figure 38**.

To properly define a levee breach in HEC-RAS, physical and temporal parameters for the initiation, propagation, and completion of the breach opening process during hydraulic simulation are required. This process includes specifying the final breach bottom width and elevation, the breach center location, side slopes, breach coefficient, and the breach formation time. The HEC-RAS User's Manual outlines two methods for defining the formation time: 1) a linear progression;

[24] Some model runs included two independent breaches.

and 2) a user-defined curve to create variable changes in breach width during the formation period. In order to initiate a breach during simulation, a breach trigger must be defined; this could be an elevation input, an elevation plus duration, or a simple duration. This feature allows the program to delay breach initiation if geotechnical parameters require additional saturation time on the levee before failure occurs. The duration-only input may be used to simulate a historical breach that occurred at a specific time during a measured flood event. A user-defined breach formation time is used for this analysis.

The breach analysis for this analysis follows guidance for levee breach parameters for input into the HEC-RAS models that was finalized by DWR in March 2012. This guidance includes the following direction related to establishing levee breach parameters:

- Breach formation time is assumed to be six hours;
- Breach side slopes are assumed to be vertical;
- Breach opening width shall be estimated as 50 times the height of the levee above the landside toe; and
- Breach formation shall be triggered by violating the reliable levee elevation. The reliable levee elevation considers both the geotechnical levee reduction height and the hydraulic freeboard elevation. The geotechnical levee reduction heights for levees of the SPFC were determined by DWR as part of the ULOP Program's evaluation of Urban and Non-Urban levees (ULE and NULE Projects).

Breach information provided in the CVFED spreadsheets and shapefiles include the breach locations and the reliable levee elevations. Breach data is tabulated below in **Table 32**. Six of the listed breach locations were removed from the analysis based on detailed reviews of the model and topography leading to the conclusions that these locations were not appropriate for inclusion. The previously identified breach locations that were removed are shaded. One breach location was added to evaluate potential flooding that could result from a breach located along the north side of Sycamore Creek east of Mud Creek.

Table 32: Breach Data											
River	**Reach**	**River Station**	**Breach Station**	**Levee Top Elev.**	**Bottom Elev.**	**Levee Height**	**Breach Width**	**Reduction Height**	**Reduction Levee (Triggered Elev.)**	**Hydrology Multiplier**	**HEC-RAS Plan Name**
MUC	R02	9.246	1095.0	201.486	198.73	2.76	137.8	3	198.49	24.4	200-Year_for_SycCk_18_M9.246
MUC	R02	9.026	83.5	200.625	197.66	2.96	148.0	3	197.66	24.4	200-Year_for_SycCk_18_M9.026
MUC	R02	8.773	116.0	193.996	189.39	4.61	230.5	3	191.00	24.4	200-Year_for_SycCk_18_M8.773
MUC	R02	8.696	95.0	192.401	188.66	3.74	187.0	3	188.66	24.4	200-Year_for_SycCk_18_M8.696
MUC	R02	8.290	1480.0	186.208	177.58	8.63	431.5	3	183.21	24.4	200-Year_for_SycCk_18_M8.290
SYC	R01	2.240	460.5	194.113	189.74	4.38	219.0	4	190.11	74	200-Year_for_SycCk_18_S2.240_L2.159
SYC	R01	1.888	671.6	192.560	186.96	5.60	280.0	4	188.56	74	200-Year_for_SycCk_18_S1.888_L1.649
SYC	R01	1.594	642.1	191.020	184.35	6.67	333.5	4	187.02	74	200-Year_for_SycCk_18_S1.594_L1.131
SYC	R01	1.320	469.6	190.100	181.87	8.23	411.5	4	186.10	74	200-Year_for_SycCk_18_S1.320_L0.931
SYC	R01	0.996	290.0	188.999	179.90	9.10	455.0	4	185.00	74	200-Year_for_SycCk_18_S0.996_L0.501
SYC	R01	0.698	920.0	187.161	179.40	7.76	388.0	4	183.16	74	200-Year_for_SycCk_18_S0.698_B44.123
SYC	R01	0.504	205.0	187.141	178.99	8.15	407.5	4	183.14	74	200-Year_for_SycCk_18_S0.504_B44.002
SYC	R01	0.214	226.0	185.790	176.79	9.00	450.0	4	181.79	74	200-Year_for_SycCk_18_S0.214_B43.741
MUC	R01	7.860	127.4	185.327	176.37	8.96	252.7	4	181.33	124.3	200-Year_for_SycCk_18_M7.860_B43.501
MUC	R01	7.794									
MUC	R01	7.780	223.5	183.404	178.64	4.76	238.0	4	179.40	124.3	200-Year_for_SycCk_18_M7.780_B43.742
MUC	R01	7.612	1707.4	178.160	172.73	5.43	271.5	4	174.16	124.3	200-Year_for_SycCk_18_M7.612_B43.135
MUC	R01	7.256	779.2	175.037	168.29	6.75	337.5	4	171.04	124.3	200-Year_for_SycCk_18_M7.256_B43.242
MUC	R01	7.256									
MUC	R01	7.002	2225.0	170.008	165.22	4.78	239.0	4	166.01	124.3	200-Year_for_SycCk_18_M7.002_B42.551
MUC	R01	6.610	495.0	168.627	162.45	6.18	308.9	4	164.63	124.3	200-Year_for_SycCk_18_M6.61_B42.550
MUC	R01	6.456	2605.0	161.990	155.54	6.45	322.5	4	157.99	124.3	200-Year_for_SycCk_18_M6.456_B42.177
MUC	R01	5.940	1795.0	157.850	151.88	5.97	298.5	4	153.85	124.3	200-Year_for_SycCk_18_M5.940_B42.156
MUC	R01	5.532	156.3	157.450	152.85	4.60	230.0	4	153.45	124.3	200-Year_for_SycCk_18_M5.532_B41.675
MUC	R01	5.380	531.4	155.220	151.03	4.19	209.5	4	151.22	124.3	200-Year_for_SycCk_18_M5.380_B41.676
MUC	R01	5.220	91.3	156.427	154.93	1.50	75.0	3	154.93	124.3	200-Year_for_SycCk_18_M5.220_B41.111
MUC	R01	4.992	156.0	154.347	148.18	6.17	308.5	3	151.35	124.3	200-Year_for_SycCk_18_M4.992_B41.150
MUC	R01	4.886	685.0	153.124	146.80	6.32	316.2	3	150.12	124.3	200-Year_for_SycCk_18_M4.886
MUC	R01	4.766	939.9	151.671	144.78	6.89	344.5	3	148.67	124.3	200-Year_for_SycCk_18_M4.766
MUC	R01	4.420	999.7	150.309	142.34	7.97	398.5	3	147.31	124.3	200-Year_for_SycCk_18_M4.420
MUC	R01	4.036	215.0	149.940	141.45	8.49	424.5	3	146.94	124.3	200-Year_for_SycCk_18_M4.036
MUC	R01	3.928	1290.0	148.298	1369.10	9.20	459.9	3	145.30	124.3	200-Year_for_SycCk_18_M3.928
MUC	R01	3.646	1640.0	145.939	137.54	8.40	420.0	3	142.94	124.3	200-Year_for_SycCk_18_M3.646
MUC	R01	3.240	2262.4	144.095	134.50	9.60	479.8	3	141.10	124.3	200-Year_for_SycCk_18_M3.24
LBC	R01	2.875									
LBC	R01	2.159	1407.62	262.785	261.92	0.87	43.3	3	259.79	74	200-Year_for_SycCk_18_S2.240_L2.159
LBC	R01	1.883									
LBC	R01	1.649									

Table 32: Breach Data											
River	**Reach**	**River Station**	**Breach Station**	**Levee Top Elev.**	**Bottom Elev.**	**Levee Height**	**Breach Width**	**Reduction Height**	**Reduction Levee (Triggered Elev.)**	**Hydrology Multiplier**	**HEC-RAS Plan Name**
LBC	R01	1.131	568.0	242.937	236.40	6.54	326.9	3	239.94	74	200-Year_for_SycCk_18_S1.594_L1.131
LBC	R01	0.931	2137.2	243.101	234.31	8.79	439.6	7.22	235.88	74	200-Year_for_SycCk_18_S1.320_L0.931
LBC	R01	0.501	658.4	235.572	233.09	2.48	124.2		233.09	74	200-Year_for_SycCk_18_S0.996_L0.501
BUC	R01	44.123	1197.0	227.213	221.39	5.82	291.2	7.22	221.06	74	200-Year_for_SycCk_18_S0.698_B44.123
BUC	R01	44.002	1484.6	225.734	221.22	4.51	225.7	3	222.73	74	200-Year_for_SycCk_18_S0.504_B44.002
BUC	R01	43.741	852.8	220.500	215.30	5.20	260.0	4.5	216.00	74	200-Year_for_SycCk_18_S0.214_B43.741
BUC	R01	43.501	749.7	216.410	213.47	2.94	147.2	4.5	213.47	124.3	200-Year_for_SycCk_18_M7.860_B43.501
BUC	R01	43.742	1584.6	216.804	209.95	6.86	342.8	3	213.80	124.3	200-Year_for_SycCk_18_M7.780_B43.742
BUC	R01	43.135	1851.0	205.494	199.81	5.68	284.2	4.5	200.99	124.3	200-Year_for_SycCk_18_M7.612_B43.135
BUC	R01	43.242	1984.2	205.684	201.17	4.52	225.9	3	202.68	124.3	200-Year_for_SycCk_18_M7.256_B43.242
BUC	R01	42.551	1624.8	197.209	191.05	6.16	308.0	4.5	192.71	124.3	200-Year_for_SycCk_18_M7.002_B42.551
BUC	R01	42.550	1194.0	198.510	190.70	7.81	390.5	3	195.51	124.3	200-Year_for_SycCk_18_M6.61_B42.550
BUC	R01	42.177	207.3	195.829	188.04	7.79	389.5	4.5	191.33	124.3	200-Year_for_SycCk_18_M6.456_B42.177
BUC	R01	42.156	221.5	196.295	187.44	8.86	442.8	3	193.30	124.3	200-Year_for_SycCk_18_M5.940_B42.156
BUC	R01	41.675	2696.0	182.994	175.32	7.67	383.7	4.5	178.49	124.3	200-Year_for_SycCk_18_M5.532_B41.675
BUC	R01	41.676	2561.0	183.463	172.90	10.56	528.2	3	180.46	124.3	200-Year_for_SycCk_18_M5.380_B41.676
BUC	R01	41.111	184.8	182.243	174.85	7.39	369.6	4.5	177.74	124.3	200-Year_for_SycCk_18_M5.220_B41.111
BUC	R01	41.150	274.5	182.303	171.90	10.40	520.2	3	179.30	124.3	200-Year_for_SycCk_18_M4.992_B41.150

10.7 HEC-RAS Model Results

Water surface profiles were computed for the channels within the City's sphere of influence that were included in the HEC-RAS Chico Area Streams Model. The water surface profiles for "no breach" conditions are included as **Figure 39** through **Figure 45**. Locations where the analysis shows less than three feet of freeboard are presented for both the 100-year and 200-year profiles. Locations where there is less than three feet of freeboard based on the 200-year water surface profile are identified by showing the levee profile in red instead of green for the right-side levee (looking downstream), and in orange for the left-side levee. Additionally, pink fill covers the area between the levee and the water surface profiles where there are freeboard deficiencies revealed by this analysis. Where there is less than three feet of freeboard based on the 100-year water surface profile, the pink fill extends down to the 100-year water surface profile instead of only to the 200-year water surface profile. **Table 33** summarizes the length of the levee with various degrees of height deficiencies. Additional information about potential levee deficiencies are provided in Appendix E. **Figure 46** illustrates the geographic locations of the levees with freeboard deficiencies.

Table 33: Summary of Levee Freeboard Deficiencies by Height Ranges (feet)										
River	**Side**	**Event**	**Lower Sta**	**Upper Sta**	**0<D <0.1**	**0.1<D <0.25**	**0.25<D <0.5**	**0.5<D <1**	**1<D <2**	**2<D**
BUC	Left	100	42.3	44	200	319	1079	1437	1757	2067
BUC	Right	100	42.3	44	71	127	495	1075	2925	3359
LBC	Right	100		2	440	601	445	685	927	-
DRC	Left	100			8	23	15	-	-	-
DRC	Right	100			16	27	-	-	-	-
SYC	Left	100		3	399	534	159	-	-	-
SYC	Right	100		3	411	660	422	404	359	-
MUC	Left	100	4	7.9	171	473	1102	1712	969	251
MUC	Right	100	4	7.9	184	224	1119	2567	1109	-
MUC	Left	100	7.9	10	72	144	185	44	166	172
MUC	Right	100	7.9	10	95	197	273	886	717	-
SHE	Left	100		1	261	472	714	938	1438	-
SHE	Right	100		1	25	255	1048	702	783	384
Total					**2353**	**4056**	**7056**	**10451**	**11151**	**6232**
BUC	Left	200	42.3	44	31	27	16	312	2891	4091
BUC	Right	200	42.3	44	-	6	-	289	1377	6732
LBC	Right	200		2	148	147	81	934	3702	1034
DRC	Left	200			141	249	362	160	18	-
DRC	Right	200			191	255	330	245	7	-
SYC	Left	200		3	385	783	1527	3153	94	-
SYC	Right	200	0	3	808	939	1392	2550	895	349
MUC	Left	200	4	7.9	55	88	106	756	2816	2069
MUC	Right	200	4	7.9	77	107	222	709	3410	2228
MUC	Left	200	7.9	10	133	134	193	338	194	172
MUC	Right	200	7.9	10	59	108	252	510	1403	91
SHE	Left	200	0	1	8	48	98	1098	2372	577
SHE	Right	200	0	1	15	5	15	347	2496	403
Total					**2051**	**2898**	**4594**	**11400**	**21675**	**17746**

The following list identifies the stream profile included on each figure:

Figure 39: Big Chico Creek Profile

Figure 40: Butte Creek Profile

Figure 41: Little Chico Creek Diversion Channel Profile

Figure 42: Lindo Channel Profile

Figure 43: Mud Creek Profile

Figure 44: Sheep Hollow Creek Profile

Figure 45: Sycamore Creek and Bypass Profile

Floodplain inundation results from the HEC-RAS model runs that have no levee breaches are presented on **Figure 47**. These results only represent the floodplains of the HEC-RAS Chico Area Streams Model with levee overtopping, but no levee failures. These maps do not show flooding from local rainfall within the City. Flooding that would be expected from local rainfall is presented separately based on the results of modeling that includes detailed storm drain systems. ICM model results provide more accurate information than the HEC-RAS results for Little Chico Creek through the City as well as other small channels that were modeled with more detail in ICM than in HEC-RAS.

10.7.1 200-year Floodplain Mapping

The 200-year floodplain is developed based on a composite of the model results for each breach location. Two 200-year floodplain maps have been developed. Each map shows the studied streams, levees, City limit, City sphere of influence, Study limits, and shaded areas indicating that the portion of the floodplain formed by a contributing watershed is less than 10 square miles. The two floodplain maps are:

- A map of the 200-year floodplain including shallow depths (provided in **Figure 48**).
- A map of the 200-year floodplain showing only depths greater than three feet (provided in **Figure 49**).

10.8 Channel Erosion Issues

10.8.1 Big Chico Creek Erosion

The City identified locations along Big Chico Creek where erosion is problematic. To address these problems, the City is pursuing bank stabilization measures. It is not surprising that erosion is localized along Big Chico Creek based on the channel velocities computed in HEC-RAS. **Exhibit 46** (below) shows the main channel velocities calculated from the CVFED HEC-RAS model. There are a number of locations with velocities above six feet per second that would probably be erosive. The plotted velocities are the calculated average velocities in the main channel portion of each cross section at the time of peak stage. Local velocities at the erosion locations could be significantly higher, especially along the outer side of channel bends.

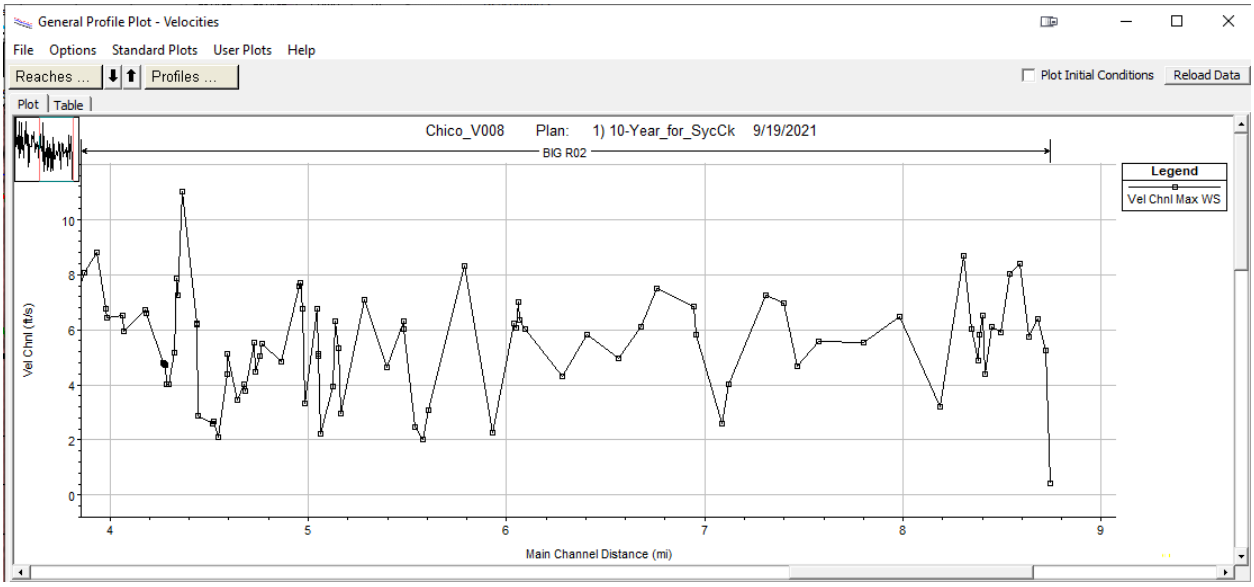


Exhibit 46: 10-Year Flow Velocities along Big Chico Creek

Two approaches were used for the investigation of changes to stream channel geometry that could result from erosion or sedimentation. A review of the cross sections along Big Chico Creek revealed some interesting issues, but this review was not useful for identifying areas of erosion. However, a review of the differences in elevation between the LiDAR data collected in 2007 and the LiDAR data collected in 2017 does reveal locations where erosion is, or may be, an issue. In **Exhibit 47** (below), shades of red were used to indicate where the 2017 LiDAR shows elevations that are lower than the 2007 LiDAR. Elevation differences of two feet or more are indicated by the same shade of red. Differences in elevations may be caused by erosion, accuracy issues on steep slopes, water levels and vegetation.

Exhibit 47 shows red areas on both banks of Big Chico Creek between Camellia Way and Esplanade. Exhibit 47 also shows a relatively small area of erosion at Location 9 (as identified by the City).

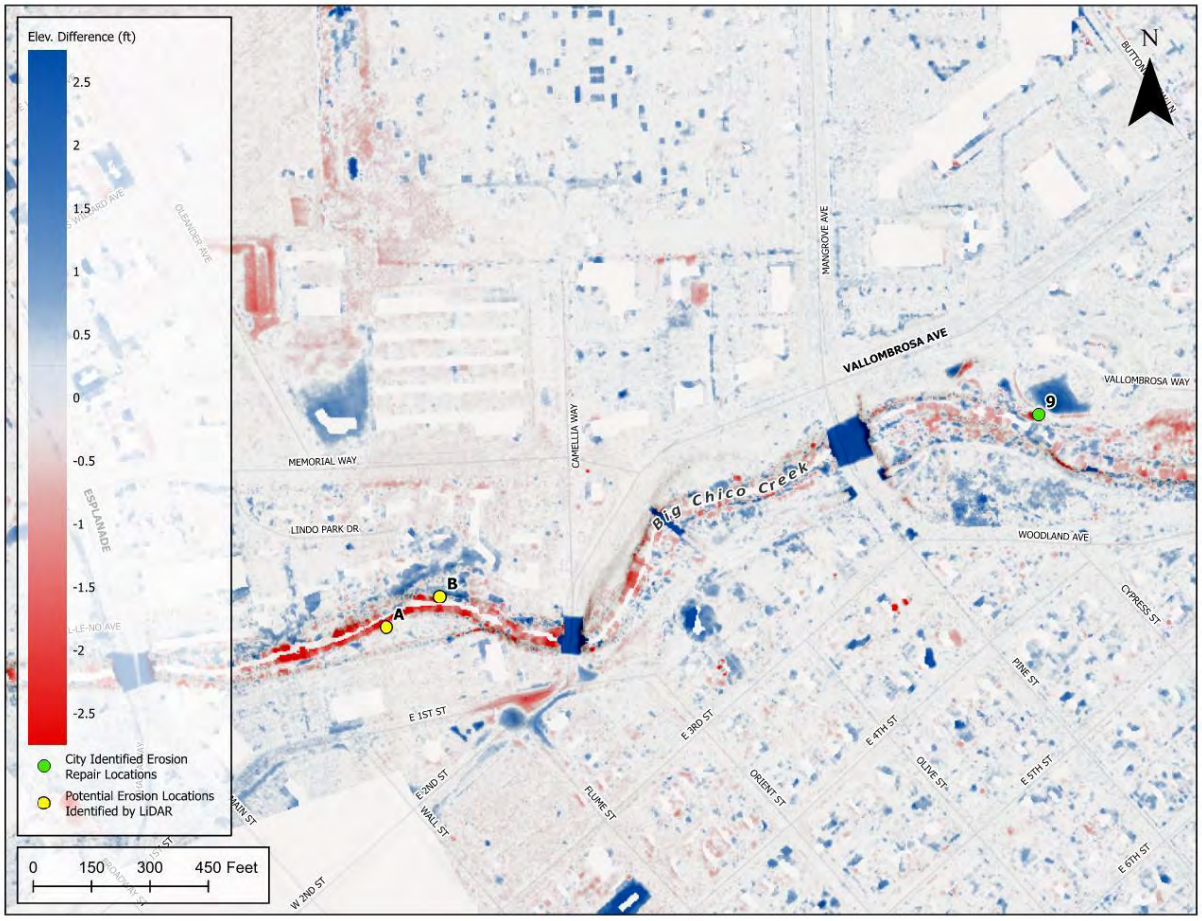


Exhibit 47: Potential Erosion between Camellia Way and Esplanade

Exhibit 48 (below) shows an area between a pedestrian bridge and Camellia Way where the differences in terrain surfaces indicate possible bed erosion. However, differences in accounting for water levels may generate the elevation difference. Note that no elevation difference is shown (the white areas) where the 2017 LiDAR surface did not include elevations.

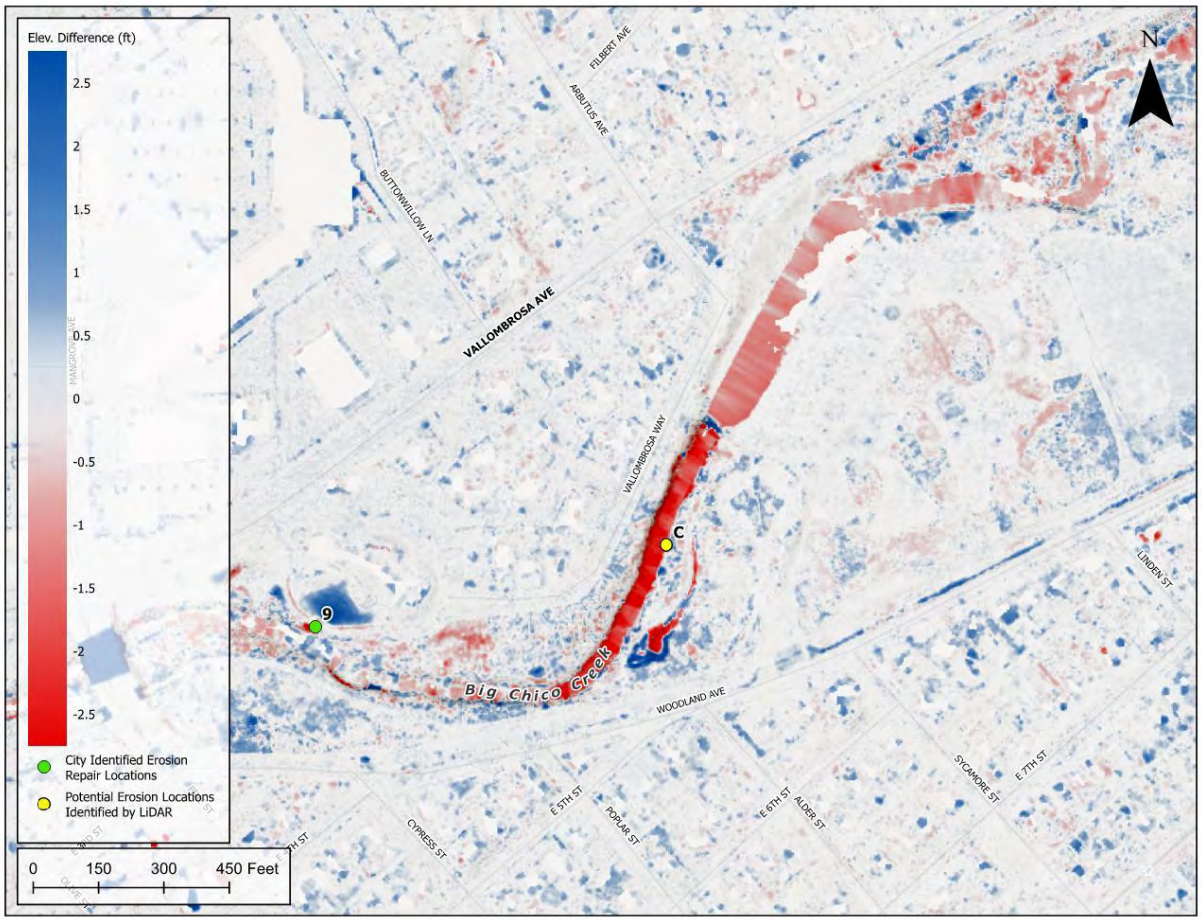


Exhibit 48: Potential Bed Elevation Change between Pedestrian Bridge and Camellia Way

Exhibit 49 (below) shows Locations 1 and 2 where the City identified erosion issues. The LiDAR data at these locations does not show any changes between 2007 and 2017. The erosion may have occurred before 2007.

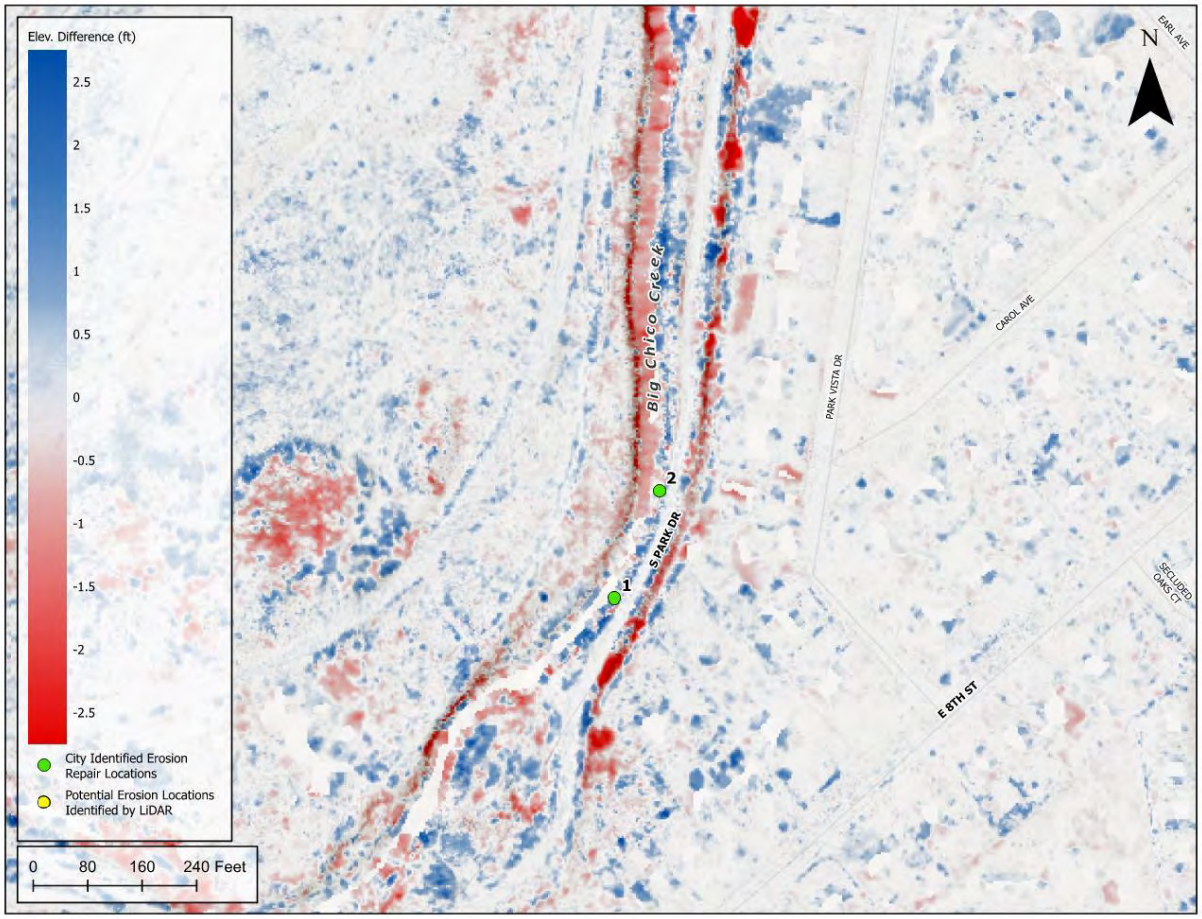


Exhibit 49: Locations 1 and 2 Identified by the City

Exhibit 50 (below) shows Locations 3 and 4 where the City identified erosion issues. The LiDAR data indicates erosion at points D and E, near Locations 3 and 4.

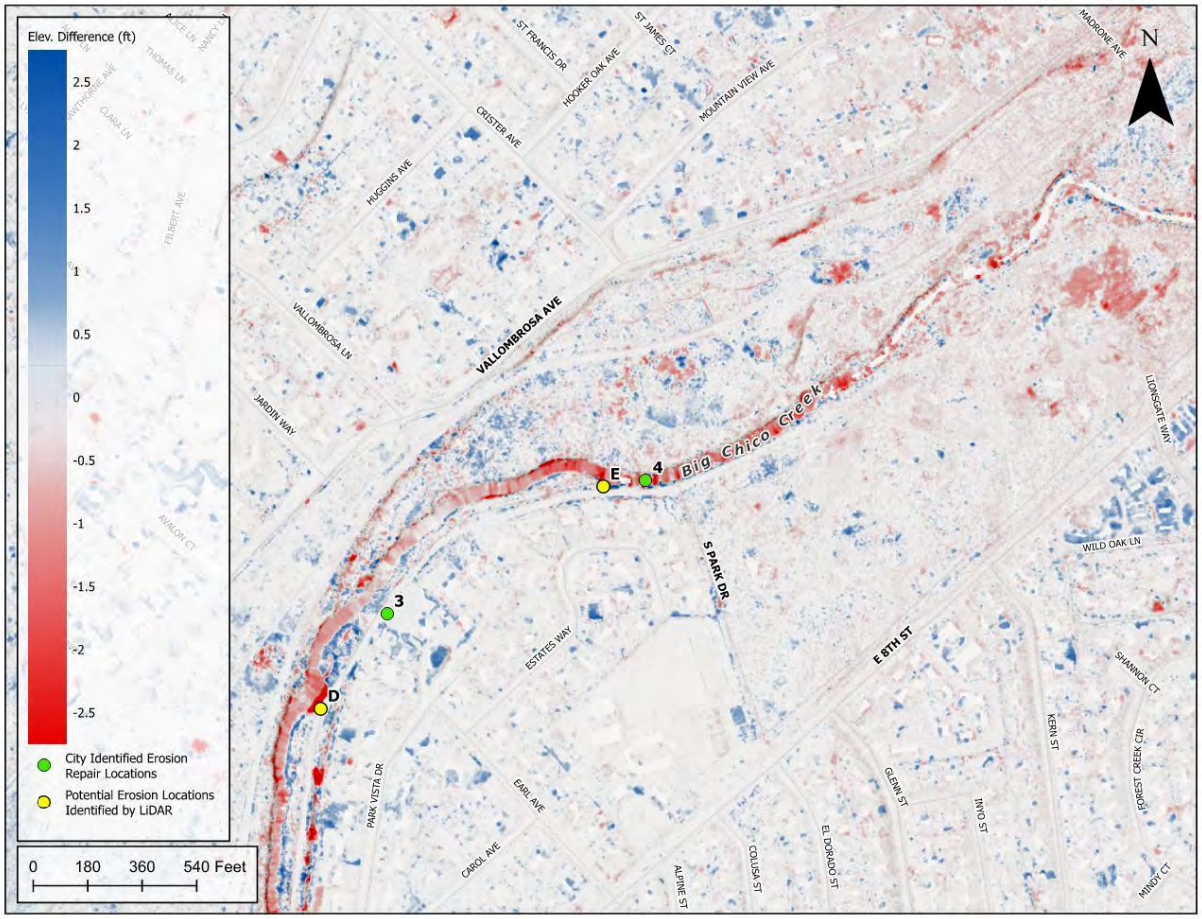


Exhibit 50: Locations 3 and 4 Identified by the City

Exhibit 51 (below) shows a location along Big Chico Creek near El Monte Avenue where the LiDAR data indicates potential erosion.

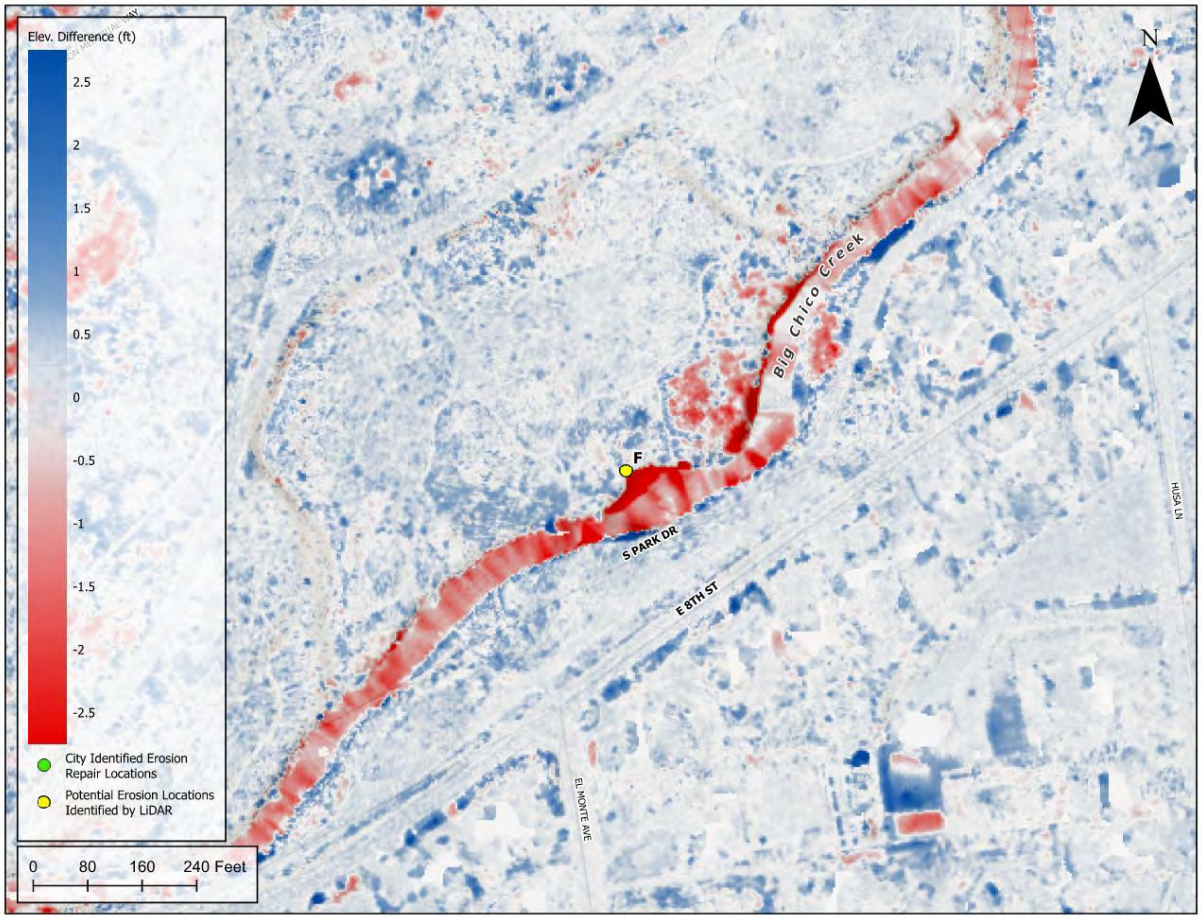


Exhibit 51: Point F near El Monte Avenue

Exhibit 52 (below) shows Locations 5, 6, 7 and 8 where the City identified erosion issues. The LiDAR data indicates recent erosion near Locations 6 and 7 and a small amount of erosion near Location 8. The erosion near Location 5 may have occurred before 2007.

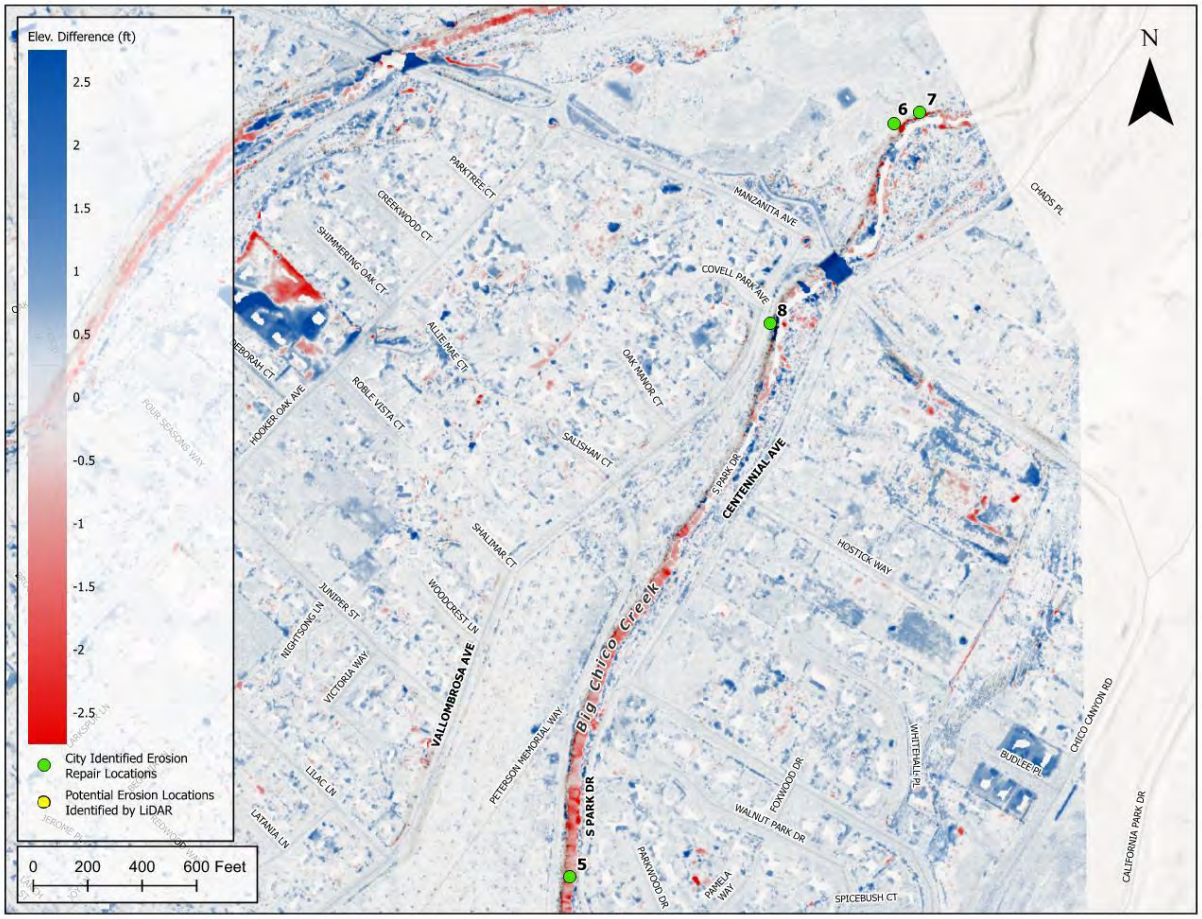


Exhibit 52: Locations 5, 6, 7 and 8 Identified by the City

10.8.2 Big Chico Creek, Sycamore Creek and Dry Creek Erosion and Sedimentation

Sediment mobilized by erosion within the Big Chico Creek and Sycamore Creek Watersheds created deposits upstream from the Sycamore Weir and along Sycamore Creek in the vicinity of Cohasset Road. Major sediment removal maintenance along Sycamore Creek was performed in 2011 that excavated sediment from the creek and placed it in a fill pile on the north side of the creek. The changes in elevation between 2007 and 2018 are presented below in **Exhibit 53.** Most of the area shown in red along Sycamore Creek indicates where maintenance activities removed sediment and placed it in the blue area immediately to the west of Cohasset Road on the north side of Sycamore Creek. Stream monitoring is needed to determine where erosion conditions necessitate the implementation of stream bed and bank stabilization measures, and also to determine when sediment accumulation necessitates additional sediment removal to reestablish channel capacity.

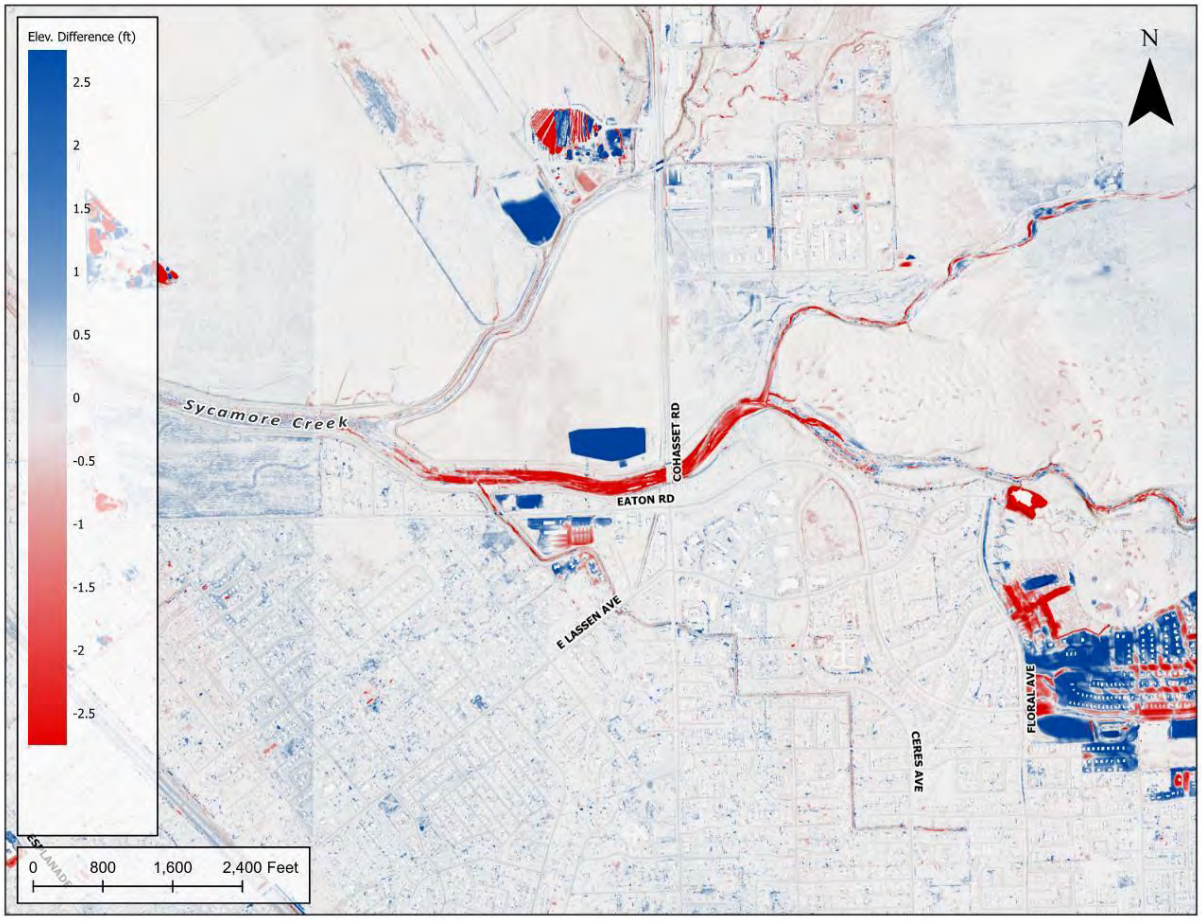


Exhibit 53: Elevation Changes along Sycamore Creek

10.9 Miscellaneous Channel Notes

10.9.1 SUDAD Channel

The SUDAD Channel originates in the west side of the City near W. Shasta Avenue and the city limit. It flows to the northwest along the city limit where it turns to the southwest along Catherine Court The SDMP ICM modeling shows that the SUDAD Channel has sufficient capacity to convey the existing conditions 100-year flows without inundating any developed areas. There are ten existing detention basins in the SUDAD Channel tributary area that help regulate discharges to the capacity of the channel.

Storm water detention for future development in the Bell Muir Area that drains to the SUDAD Channel is recommended for two objectives that required more capacity than that needed to meet the criteria in the Post-Construction Standards Plan. One objective is to not increase flooding upstream of the railroad tracks. Another objective is to reduce the cost of the overall drainage system considering the trade-offs between detention and conveyance costs. The master plan improvements also consider grade constraints associated with conveying runoff to the SUDAD Channel upstream from the railroad tracks.

Storm water detention requirements should be reviewed on a case-by-case basis to ensure that site-specific factors may be considered. Based on the SWMP proposed conditions model and all of the assumptions and estimates that went into the SWMP effort, the Bell Muir basin that would serve the area near Nord Avenue and Henshaw Avenue would have a capacity of 0.4366 acre-feet per each impervious acre that is added within its tributary watershed. Each added impervious acre would be allotted a peak 100-year discharge of 0.373 cfs. The unit storage volume of 0.4366 acre-feet per impervious acre is 88 percent of the 100-year 24-hour precipitation depth. The impervious area would consider roads, driveways, walkways, paved patios, and roof tops. Underground storage could be used. The City could verify the adequacy of proposed improvements by simulating specific proposed conditions and reviewing impacts.

10.9.2 Pleasant Valley Ditch

The PV Ditch is located in the northern part of the City east of Cohasset Road. It drains along a zigzag path to the west and to the north in the vicinity of Glenshire Lane and Ceres Avenue. There are many small detention basins throughout the PV Ditch watershed. These basins are effective at keeping flows within the capacity of the storm drains between the basins and the PV Ditch, as well as within the capacity of the PV Ditch itself. Infill development should include detention to keep flows within the capacity of the storm drainage systems between the development and the PV Ditch. The PV Ditch model could be used to evaluate specific improvements. It is recommended that specific improvements and associated detention requirements be evaluated on a case-by-case basis due to complex flow timing issues associated with the system and how changes in flows may impact the function of existing detention basins.

10.9.3 BD Channel

The BD Channel conveys runoff from the southern limits of the SR 99 interchange at E. 20th Street to the Fair Street Detention Basin. The BD Channel derives its name from a watershed designation assigned in the 1987 SDMP. The ICM modeling prepared for this SWMP indicates that the BD Channel does not currently have sufficient capacity to contain all of the runoff from a 100-year storm. However, a comparison between the ICM modeling and BD Ditch hydrologic and hydraulic calculations performed by Rolls Anderson & Rolls, Inc. in 1988 [47] showed that the capacity deficiency results from accumulation of sediment and debris in addition to vegetation. These factors reduce the channel cross-sectional area and increase channel roughness, thereby reducing channel conveyance. A photograph of the BD Channel is presented in **Exhibit 54**. Therefore, it is anticipated that maintenance of the BD Channel could restore adequate channel capacity. If it is determined that it is not feasible to maintain the channel clear of sediment and vegetation, a short (non-regulatory) floodwall could be constructed along the right (west) bank of the channel in order to add capacity and reduce the frequency of required maintenance.

Exhibit 54: Photograph of BD Channel

Detention requirements for new development within the BD Channel watershed should be evaluated on a case-by-case basis. Delaying runoff in the lower parts of the watershed could cause the increased runoff to add to peak flows originating from upstream. It may be preferrable to have the runoff from the downstream areas discharge into the BD Channel and flow to the Fair Street Detention Basin ahead of runoff from further upstream. Runoff volume reduction measures required by the Post-Construction Standards Plan would need to be incorporated, regardless of any requirements for peak flow attenuation.

10.9.4 Comanche Creek

Within the city limits, Comanche Creek drains from east to west across the southern portion of the City. The portion of Comanche Creek east of the City is intercepted by the Little Chico Creek Diversion Channel and diverted into Butte Creek. The BD Channel is tributary to Comanche Creek. The ICM model results indicate some localized flooding along Comanche Creek. However, the accuracy of the modeling is limited due to standing water in the creek. Some approximate adjustments to the terrain were made to account for some conveyance below the waterline. Bathymetric data and a survey through dense vegetation would need to be collected and incorporated into the modeling if it is determined to be necessary to improve model accuracy along Comanche Creek. A photograph of Comanche Creek is included as Exhibit 55.

Exhibit 55: Photograph of Comanche Creek

As with other areas, it is not appropriate to provide a one-criterion-fits-all requirement for detention basins within the Comanche Creek watershed. Detention would be recommended for the upstream portion of the watershed and anywhere within the watershed where storm drain conveyance between the development and Comanche Creek is limited. For major projects, the watershed model can be used to calculate potential project impacts for the design storm scenarios and to develop a site-specific basis for detention basin design.

10.9.5 Crouch Ditch

A portion of Crouch Ditch to the east of the Fairgrounds is now intercepted by the BD Ditch. The portion of the Crouch Ditch that is east of the Little Chico Creek Diversion Channel is not relevant to the SWMP because it is no longer connected to the portion that connects to the BD Channel. Crouch Ditch had been an irrigation channel. Some parts have been intercepted, cutoff, or undergrounded and rerouted.

11.0
Potential Projects and Costs

11.0 POTENTIAL PROJECTS AND COSTS

11.1 Basis for Construction Unit Costs

The costs presented in this section should be considered only as planning-level Opinions of Probable Costs (OPCs) using 2024 dollars. Actual unit costs for individual projects may vary considerably.

The construction cost values used for unit costs listed below are for retrofit storm drainage projects. The costs were developed from tabulations of similar work in California and data available from Caltrans. Costs for typical bid items that are not listed (such as mobilization, pavement removal and replacement, traffic control, erosion control, etc.) are included in the costs that are listed. Actual storm drain installation costs will vary substantially depending on pipe depth, complexities associated with existing utilities, and other factors. The construction costs for specific groupings of improvements are summarized in **Section 11.3**.

Contingency, planning and design, construction management, and administration were combined and applied as a percentage of the total construction cost for the project groups in **Section 11.2**. The basis for estimates for easements and land acquisition are included in Section 11.1.4.

11.1.1 Pipes and Channels

Pipe and channel costs are included using unit cost estimates per linear foot of improvement. End structures, such as headwalls and energy dissipation measures, were added as separate costs. Pipe costs listed in **Table 34** are for RCP. Only one new channel is proposed in this SWMP. It is included in the Bell Muir area in order to provide a connection to existing surface drainage where elevation constraints preclude the use of underground storm drains.

Table 34: Unit Cost Data for Pipes	
Pipe Diameter (inches)	**RCP Pipe Cost ($/foot)**
12	155
15	189
18	223
24	297
30	377
36	465
42	559
48	659
54	767
60	882
66	1,002
72	1,130
78	1,265
84	1,420

11.1.2 Inlets and Manholes

Catch basins and manholes were included based on concept level project layouts. For some long storm drain projects, assumptions of typical spacing were made based on factors specific to the location. Actual costs for manholes and inlets will vary depending primarily on depth. Costs of $5,000 per new inlet and $5,500 per replacement inlet were assumed. Manhole costs vary by size. Sizes were estimated based on connected pipe size and junction angles. Actual required sizes will be determined as part of the detailed design. Unit costs for manholes are listed in **Table 35**. Unit costs for outfalls based on the size of the pipe connected to it are listed in **Table 36**.

Table 35: Unit Costs for Manholes	
Manhole Diameter (inches)	**Cost ($/Each)**
48	12,500
60	16,000
72	21,000

Table 36: Unit Costs for Outfalls	
Outfall (pipe diameter, inches)	**Cost ($/Each)**
12	8,000
15	16,000
18	21,000
24	30,000
30	37,000

11.1.3 Detention Basins and Channel

Detention basins costs were estimated based on excavation volumes, surface area and perimeter. Excavation costs were estimated at a rate of $22 per cubic yard ($35,000 per acre-foot). Actual excavation costs will depend on haul distances. Costs for erosion control and general landscaping are included in a rate of $25,000 per acre. An addition $200 per foot of perimeter is included for maintenance access, perimeter landscaping and fencing.

Only one new channel is proposed in this SWMP. It is included in the Bell Muir area in order to provide a connection to existing surface drainage where elevation constraints preclude the use of underground storm drains. The cost for the channel was estimated using the unit costs for the detention basins. However, the perimeter was taken as the length of the channel rather than two times the length of the channel because it was assumed that access along one side of the channel would be sufficient to address maintenance requirements.

11.1.4 Easements and Land Acquisition

The SWMP calls for some drainage improvements to be made outside of the existing public ROW in order to alleviate drainage deficiencies within the public ROW. These improvements include pipes, a channel, and some detention basins. It has been assumed that the City will need to acquire easements or ownership for drainage improvements on areas that are currently private property.

For the purposes of this SWMP, it has been assumed that drainage easements and land acquisition would cost $10 per square-foot[25] ($453,600 per acre). The required easement areas were calculated by multiplying the project length on private property times the assumed width that would be required. It was assumed that a 15-foot-wide easement would be required for pipes and that 12 feet in addition to the estimated channel top width would be required for the open channel. The length of pipe requiring easement was estimated by intersecting the proposed pipe length with parcels that had land use codes indicating something other than public ownership. For example, no ROW was assumed to be required where pipes cross areas zoned for parks or open space. In some cases, the SWMP shows alignments that are near and parallel to the limits of an existing public ROW. In some cases, it may be possible to align the pipe to be within the public ROW where the SWMP shows it outside of the public ROW. In other cases, the SWMP may show a proposed improvement just inside the public ROW, but a permanent or temporary construction easement could end up being required. Therefore, there is significant uncertainty in the quantity of easement or land acquisition that will ultimately be needed.

11.2 Miscellaneous Project Costs

Miscellaneous project costs (also referred to as "soft costs") associated with many aspects of project implementation are typically included in planning-level cost estimates as percentages of construction costs. The appropriateness of specific multipliers depends on the complexity and scale of projects. For example, it can take as much effort to design an 18-inch-diameter pipeline as it takes to design a 48-inch-diameter pipeline. However, the 48-inch pipeline may cost four times more than the 18-inch pipeline costs to construct. Therefore, if it would be appropriate to use a 10-percent factor for the design of a 48-inch pipeline, it would be appropriate to use a 40-percent factor for the design of an 18-inch pipeline. However, for the purposes of planning-level cost estimates in the SWMP, a single factor was used. Miscellaneous project costs include:

1. *Contingency* – Contingency costs are included in planning estimates for project funding to account for uncertainty in a project's ultimate cost. Contingency costs are reduced as the planning for a project becomes more advanced. For example, it is typical to use a 30-percent contingency at a master plan level, a 20-percent contingency at a preliminary design level, and a 10-percent contingency at the final design stage. A 25-percent contingency cost is included in this SWMP because the costs presented herein are for

[25] Per email from the City with the subject line: "FW: SWMP input for project costs," dated February 15, 2024.

concept level layouts; however, the basis of the project plans (model results) are more accurate than those typically available for planning studies.

2. *Planning and Design* – Planning and design includes:
   a. Alternatives analysis;
   b. California Environmental Quality Act (CEQA) studies;
   c. Geotechnical investigations;
   d. Design-level surveys; and
   e. Plans, specifications, and estimate (PS&E).

   A 15-percent factor is recommended for planning and design costs.
3. *Construction Management* – Construction management covers the cost of the sampling and testing of materials, as well as site inspections during construction. A 5-percent factor is appropriate for construction management.
4. *Program Administration* – Program administration includes the City's internal costs for the various projects such as management of consultant agreements, CEQA processing, permits, financing expenses, and legal review. A 5-percent factor has been applied to account for program administration.

Based on the factors described above, a 50-percent factor was applied to account for the various miscellaneous costs that are not included in the base construction costs. The base construction costs include a factor for mobilization and other construction costs (such as Water Pollution Control and Traffic Control) that might be in various line items in a bid other than those listed as part of the Opinions of Probable Cost (OPCs).

11.3 Project Groupings

Storm drainage improvements were assigned to be in groups based on location. Twenty-three project areas were defined considering proximity to other planned capital improvement projects or areas within the City. In the case of the Bell Muir project group, the area was delineated considering the area that would be served by the drainage system for the area previously defined as a SPA. The project grouping areas are presented on **Figure 50** with schematic layouts representing the project features. The project details are presented in Figure 32.

11.3.1 Estimated Infrastructure Costs

OPCs for the storm drainage infrastructure improvements projects identified in this SWMP were developed for planning purposes. The quantities associated with identified projects are based on project concepts, and revisions should be expected as the projects progress through more advanced planning and design phases. The quantities and costs associated with each project grouping are presented in **Appendix G**. The Engineering News Record Construction Cost Index value for San Francisco of 13,518 should be used as a basis for escalating the OPCs. Therefore, it is important that the cost estimates be updated annually to allow the funding mechanisms to be adjusted in order to account for changes in construction and land acquisition costs. A summary of project costs is listed in **Table 37**.

Table 37: Project OPC Summary				
Project Area	**Base Construction**	**Easement/ Acquisition**	**Other Costs**	**Total Cost**
Barber	$1,387,749	$2,172	$693,874	$2,083,795
Bell-Muir	$12,922,919	$11,151,375	$6,461,460	$30,535,754
Bruce Humboldt	$387,530	$75,852	$193,765	$657,147
Chapman	$2,088,144	$119,369	$1,044,072	$3,251,586
East Streets	$2,737,975	$14,303	$1,368,987	$4,121,265
Eaton Road	$2,192,034	$900,081	$1,096,017	$4,188,132
Esplanade	$2,797,056	$200,751	$1,398,528	$4,396,336
Fair Street Area	$376,846	$49,321	$188,423	$614,590
Glenwood	$2,246,628	$1,000	$1,123,314	$3,370,942
Lindo	$999,591	$37,562	$499,796	$1,536,949
Lindo South	$71,044	$-	$35,522	$106,565
Little Chico Creek - South	$717,370	$136,861	$358,685	$1,212,916
Mansion Park NE	$3,324,000	$1,422	$1,662,000	$4,987,421
Mansion Park SW	$7,232,156	$363,189	$3,616,078	$11,211,423
Mulberry	$413,679	$2,982	$206,839	$623,500
Nord Avenue	$1,850,880	$500	$925,440	$2,776,820
North Chico	$19,868,969	$6,281,670	$9,934,485	$36,085,124
Park Vista	$304,644	$-	$152,322	$456,967
South Campus	$2,372,750	$83,325	$1,186,375	$3,642,449
South Entler	$4,243,652	$5,066,536	$2,121,826	$11,432,014
Stewart Avenue	$196,526	$907	$98,263	$295,696
SUDAD East	$771,649	$387,248	$385,824	$1,544,721
SUDAD West	$201,043	$80,764	$100,521	$382,328
Vallombrosa	$2,263,230	$112,332	$1,131,615	$3,507,177
Total	$71,968,062	$25,069,521	$35,984,031	$133,021,614

The OPC for the Esplanade and Garner Lane project area is included in Appendix J.

11.4 Trash Full Capture Approach and Potential Locations

This section describes the evaluation performed to develop a planning-level cost estimate for trash capture devices to meet the water quality requirements described in **Section 4.1.3**. The evaluation was completed by:

1. Reviewing the designated PLU areas within the City's jurisdiction;
2. Taking into account locations of existing and planned FCS;
3. Conducting a desktop analysis to identify potential locations for the installation of FCS;
4. Removing some of the potential FCS locations where data discrepancies caused inappropriate locations to be considered;
5. Revising the data to eliminate significant discrepancies that were discovered;

6. Identifying the device category expected to be used at each location;
7. Tabulating information about pipe sizes, flow rates and configurations that would influence construction costs; and
8. Assigning planning-level costs to the FCS locations.

Planning-level costs were estimated by reviewing cost data associated with the FCS material, installation, as well as the operation and maintenance costs for each device category.

11.4.1 Methodology For FCS Site Selection

11.4.1.1 Full Capture System Types

The approach used for this desktop analysis started with determining where regional FCS would be necessary and/or efficient. There are some locations where regional FCS are necessary because of the physical drainage system configuration, such as where FCS need to be located near multiple outfalls to capture trash originating from within overlapping drainage areas. Other regional FCS are efficient because a large amount of PLU area is tributary to a single system. After the PLU areas that are expected to be treated by regional FCS were determined, preliminary locations for distributed FCS to treat the remaining PLU areas were identified.

The types of FCS included in the assessment were:

- Certified Trash FCS (Proprietary Devices) – A full list of the certified, approved FCS has been developed by the SWRCB[26] and is updated periodically. The general categories of FCS assessed in this evaluation were selected from the approved types of devices included in the most recent SWRCB list. Proprietary devices include various catch basin inserts, hydrodynamic separators, and screen filters.
- Categorically Certified Multi-Benefit Trash Treatment Systems (Public Domain Best Management Practices) - A full list of the categorically certified multi-benefit trash treatment systems has been developed by the SWRCB[27] and is updated periodically. Existing multi-benefit treatment systems that qualify, or could qualify with minor modifications, as FCS were accounted for within this analysis. Multi-benefit systems include bioretention systems, infiltration trenches, media (such as sand) filters, capture and use systems, and detention basins. Multi-benefit systems must be designed and maintained to meet FCS requirements.

FCS device locations were categorized based on whether the FCS would be underground or on the surface. Underground installations are expected on existing pipes that range in size from 8 inches to 60 inches. It has been assumed that installations along systems with pipe sizes equal to or less

[26] https://www.casqa.org/resources/water-quality-priorities/trash/certified-trash-full-capture-systems-available-to-the-public
[27] https://www.casqa.org/resources/water-quality-priorities/trash/certified-multi-benefit-trash-treatment-systems

than 18 inches in diameter would be retrofitted with screens designed to be installed into existing catch basins. There are 32 locations where relatively inexpensive retrofit screen systems are expected to be used. Retrofit screen systems are sometimes used where pipes larger than 18 inches in diameter are connected to inlets. However, for the purposes of this SWMP, it has been assumed that new underground vaults will be used along existing 18-inch-diamemeter and smaller pipes at 13 locations due to system configurations. There are 66 underground FCS locations where the connecting pipe sizes are greater than 18 inches in diameter. Most of the identified surface FCS locations are along drainage channels near existing culverts. There are 18 FCS locations at existing culverts with sizes ranging from 12 inches to 72 inches in diameter, two of which have double barrel culverts. Screen devices can generally be installed downstream from existing culverts. Both underground and surface FCS locations can cause increases in upstream flooding. Devices can also be categorized based on the level of concern related to potential increased flood levels in order to account for additional costs for FCS that incorporate expensive bypass features.

There are some identified FCS locations that require special consideration. These include:

1. A floating screening device for California Park Lake;
2. Four small detention basins that can be retrofitted with screens;
3. Eighteen locations for new catch basin inserts on existing catch basins; and
4. Multiple locations where the SWMP identified a regional system for a relatively small amount of tributary PLU area and multiple distributed FCS would likely be more cost-effective, but would require additional parcel-level investigations.

Treatment capacities of FCS are used to establish a design flow rate at and below which all trash larger than 5 mm in size would be captured without bypass. The treatment capacities were calculated for each of the given drainage areas using the Rational Equation with a rainfall intensity (I) of 0.39 inches/hour[28] and a runoff coefficient (C) calculated using the Urban Runoff Quality Management Approach[29] that computes a runoff coefficient as a function of the imperviousness of the tributary area. The Rational Method flows can overestimate the required treatment flow rate for some large areas, detention basins discharges, and locations where multiple outfalls serve overlapping drainage areas. (Use of alternative methods for calculating flows is included in the SWRCB document titled "Detention Basins – Multi-Benefit Full Capture Systems" dated 2023. [48]) The two-year flow rate from the drainage system models were used to determine treatment flow requirements where the modeled peak two-year flow was determined to be appropriate. Modeled conditions were also used to identify locations where high bypass flow requirements should be considered in the planning-level costs.

[28] One-year one-hour storm for Chico https://svctenvims.dot.ca.gov/basinsizer/
[29] See Section 5.5.1 of the California Stormwater BMP Handbook, January 2003, $C=0.858i^3-0.78i^2+0.774i+0.04$, where i is build-out imperviousness.

The SWMP provides an updated approach from that used in previous planning studies to estimate costs for FCS for the City. Previous planning studies used generalized categories of FCS devices, applied conservative estimates of design treatment flow rates, and did not consider existing pipe sizes or design peak flow rates and allowable increases in hydraulic grade lines.

11.4.1.2 Evaluation of Full Capture System Locations

Various steps, as outlined below, were taken to develop recommendations for FCS to treat runoff from PLU areas.

1. **Review of Existing Categorically Certified Multi-benefit Treatment Devices**: The City has 22 storm water detention basins with PLU areas within the detention basin's tributary area. However, they have not all been assessed to determine if they meet the multi-benefit treatment system design requirements[30]. For this analysis, they were conservatively assumed to not be designed to meet the multi-benefit requirements because none of the ones that were reviewed were confirmed to meet FCS requirements. In the process of developing recommendations for treatment locations, four (4) of the existing detention basins were found to be at beneficial locations for FCS. It has been assumed that these basins could be modified with the installation of relatively low-cost screens in order to meet FCS requirements.

2. **Review of Existing Certified Trash Full Capture System Devices**: The City has nine small drop inlet (DI) devices installed. Together these devices treat 11 acres of PLU. The City also has 22 Jensen Precast interceptors. Jensen Deflective Separators are certified treatment devices. The existing interceptors would need field-verification to determine if they meet the requirements necessary to be considered FCS. After developing recommendations for treatment locations, it was determined that only one of the existing interceptors is at a location where a FCS is recommended.

3. **Review of FCS Installed on Private Property**: Available information on existing private BMPs showed that the existing systems do not meet FCS requirements or that compliance could not be verified. Therefore, private BMPs were not counted as FCS.

4. **Planned Certified Trash Full Capture System Devices**: The City has three large, planned devices[31] that should be installed in September 2024[32]. These three large devices together will treat 69 acres of PLU. The planned large FCS devices are in an area with some divergent storm drains where the areas tributary to some outfalls overlap. FCS at additional recommended locations will be needed to complete treatment of the tributary area.

[30] https://www.casqa.org/resources/water-quality-priorities/trash/certified-multi-benefit-trash-treatment-systems
[31] Device Location Maps, City of Chico.
[32] Email correspondence with the City of Chico. Email January 31, 2024.

5. **Potential Large Regional FCS**: Using detailed storm drain line and watershed area information, locations of storm drainage system that receive runoff from significant areas covered by PLUs were identified. This analysis identified locations for treatment devices downstream of storm drain trunklines that capture flow from PLUs where no additional PLUs drain to the system downstream from the selected locations. Some areas of the City have split storm flow. In those cases, treatment devices were placed along each divergent storm drain trunkline downstream of PLUs. Some of the identified locations are along drainage ditches, and other locations are along pipelines. The evaluation distinguishes between installations along ditches from those requiring underground vaults in order to provide a better basis for the cost estimates. It should be noted that it is recognized that some of these locations may need to be moved once a feasibility analysis is undertaken to determine the best location to install each device.

6. **Small Distributed FCS and Assorted Regional FCS**: All of the locations of PLUs that would not be treated at the potential large regional FCS locations were reviewed to determine efficient locations to place FCS to capture the runoff from the PLUs not treated by large regional systems. This detailed review included some investigations into private drainage system configurations and review of watershed delineations in order to provide a more refined assessment than could have been provided during prior planning studies. Appropriate FCS locations capable of treating runoff from otherwise untreated PLU areas were identified. The locations where the location is a catch basin with no connecting pipes from PLU areas were identified as locations for catch basin inserts. Locations where pipes drain through catch basins and the pipe sizes are 18-inches in diameter and less were identified as locations for retrofit screen systems. It is anticipated that vault systems will be need at the other locations that are along pipelines, except where the treatment location is at-grade at an outfall or other surface location. The City is not required to install FCS on private drainage systems that do not drain into the City's storm drainage system.

11.4.1.3 Limitations of the Analysis

The FCS location identification process and basis for cost estimation is intended to take advantage of data developed for this SWMP in order to provide more refined recommendations than were available for previous trash capture studies, but the analysis has significant limitations. These limitations are primarily due to details in the data. The SWMP focused on providing recommendations for improvements to alleviate existing drainage deficiencies and to accommodate future development. Limited effort was expended to refine drainage system data accuracy in areas that would not impact the capacity improvement recommendations. As a result, there are limitations in the accuracy of parcel-level drainage area delineations. The limitations are due to missing and/or inaccurate private drainage system data and the accuracy of terrain data where it is impacted by filtering out vegetation, buildings, vehicles, and other non-ground features. As a result, there are many locations where, in reality, an entire PLU parcel drains to one storm

drainage systems, but the SWMP data will show small portions of the PLU parcel draining to different systems. The following steps would be necessary to advance from the SWMP FCS analysis to design level analysis:

1. **Storm Drain Infrastructure Information**: The configurations of the private and public drainage systems in the vicinity of the FCS being designed need to be verified based on as-built drawings and field verification in order to ensure that key feature locations, generally inlets and manholes, are mapped accurately.

2. **Watershed Refinement:** Watersheds need to be re-delineated in order to be consistent with the refined drainage system data and parcel-by-parcel review of the SWMP delineations.

3. **Flow Rate Updates**: Drainage system flow rates for FCS design need to be recalculated based on the refined watersheds. The treatment flow rate can typically be recalculated using the Rational Method. Depending on the significance of watershed refinements on modeled flow rates, 10-year and, in some cases, 100-year flow rates may be needed to provide the information necessary to design bypass systems for the FCS. Maximum allowable upstream hydraulic grade line conditions need to be established in order to design each FCS location to pass high flows, even when the systems are loaded with trash, without unacceptable impacts to potential flood conditions.

4. **Utility Conflict and Supplemental Field Verification**: Each potential treatment device location needs reviewed based on utility data and field-verification of various factors that could impact design and construction. In some cases, potholing will be required in order to provide information for design. In some cases, utility data can result in a determination that alternative locations need to be considered.

5. **FCS Specification and Site Design**: After the design parameters and constraints have been established, alternative proprietary approved FCS can be reviewed to determine what systems could cost-effectively meet the requirements of the specific location. Maintenance considerations also need to be addressed in the system and site configuration process. The City may have options for how to procure FCS. One option would be to use the traditional design-bid-build approach. Alternatively, it may be feasible to develop specifications for installation performance that could permit the use of a design-build approach. Due to the wide range of proprietary systems available to meet FCS requirements and alternatives that could be used to meet design hydraulic grade line constraints, a design-build approach may produce more cost-effective solutions than the traditional design-bid-build approach.

11.4.2 Full Capture System Quantities and Locations

The City has 2,585 acres of PLU (3,654 parcels). The locations of the PLU parcels and identified FCS locations are shown on **Figure 51**. Additional investigations will be needed to identify less expensive distributed FCS locations to replace regional systems that are not cost-effective.

During the GIS placement analysis, 153 potential FCS locations were identified. Seven of these FCS locations are on proposed drainage improvements, rather than existing systems, and would only need to be implemented when the master planned improvements are constructed. The breakdown of potential FCS categories is shown below in **Table 38**. The accuracy of the listed values of PLU areas that are treated by the potential devices is limited by the accuracy of drainage areas delineations and the overlapping drainage areas due to split flows.

Table 38: Potential Full Capture System Quantities by Type

Device Type	Quantity	Area of PLUs Treated (Acres)	Fraction of Total PLU Area(%)
Existing Drop Inlet Device	9	11	0.4
Planned Vault Device	3	69	3
Potential Catch Basin Insert (Surface)	20	21	0.8
Potential Culvert/Outfall Screen	15[33]	425	16
Potential Detention Basin Screen	4	41	2
Potential Vault	77[34]	1,757	68
Potential Catch Basin Screen (Underground)	35[35]	113	4
Potential California Parks Lake Screen	1	50	2
Potential Public Interceptor Retrofit	1	2	0
Potential Sum:	**153**	**2,489**	96%
City of Chico Total:	**165**	**2,585**	--

11.4.3 Recommended Approach to Plan Implementation of Full Capture Systems

It is recommended that the City expedite additional efforts to identify areas to begin device installation based on design and engineering costs and the areas with the highest need for treatment based on the current trash generation rates. The SWMP does not provide information about site specific trash generation rates. The SWMP does include an approximate value for the area of PLU tributary to each of the identified potential FCS locations. This data can be used to select FCS locations that would treat the largest amount of PLU area. Additionally, the SWMP includes master-plan level opinions of probable cost for the identified FCS and this information has been

[33] The total incudes 14 devices on the existing storm drain system and 1 device on future improvements.
[34] The total includes 73 devices on the existing storm drain system and 3 devices on future improvements.
[35] The total includes 32 devices on the existing storm drain system and 3 devices on future improvements.

used to estimate the relative cost effectiveness of the FCS locations. Consideration of cost-effectiveness can be used to prioritize implementation of FCS at the most cost-effective locations.

Meeting trash amendment requirements in Chico will be challenging due to the complexity of the drainage system and the wide distribution of PLUs. These factors preclude use of a small number of centralized treatment locations and will necessitate construction of a large number of distributed FCS. The FCS implementation plan should include parallel tasks of design and installation of high-priority improvements while also refining data and investigating alternatives to achieve trash capture objectives in areas where the options identified in the SWMP are cost prohibitive. It is recommended that the City adopt an annual budget for a six-year FCS implementation program that would be adjusted for inflation. The implementation program would focus on construction of the most cost-effective locations first in order to maximize the PLU areas treated during the early phases of the plan. Data will be collected and design level investigations following the steps described in Section 11.4.1.3 will be conducted. It is anticipated that more cost-effective options will be identified for treatment of the least cost-effective locations. At some locations, use of large numbers of small, distributed FCS at private catch basins would be more cost-effective than retrofitting existing storm drains with FCS in vaults. However, public-private partnerships, or development of an ordinance to require retrofit installations, may be required to implement the more cost-effective solution involving installations on private drainage systems.

11.5 Estimated Cost of Full Capture Systems

The estimated costs for installation of different types of FCS devices were gathered based on review of vendor information, factsheets, cost estimates conducted for previous trash evaluations, and construction bid data for multiple installations. There is a broad range of costs, which depend on many factors including, but not limited to, the type of device selected, the treatment capacity, bypass flow and measures necessary to mitigated for impacts on drainage system capacity, depth and sizes of inlet and outlet pipes, utility relocations, presence of groundwater, traffic control, system maintainability and trash capture storage volume.

There are numerous device configurations including hydrodynamic separators that are installed in deep, circular vaults and screen systems installed in rectangular vaults. Some rectangular vaults are designed to store captured debris below the outlet pipe invert and others are designed such that the bottom of the vault is flush with the pipe invert. FCS vary in terms of how much trash they store, the level of effort needed for maintenance, and the impact of the FCS on hydraulic grade lines. The size of FCS is often controlled by the size of the pipe draining into it. In many cases, the FCS can be installed directly along the existing storm drain, in which case the FCS size may be dictated by the size of the existing pipeline. In some cases, FCS are installed in-line with the existing storm drain and a bypass pipeline is constructed to limit impacts on hydraulic grade lines. In other cases, low flows can be diverted into FCS sized for the required treatment flow rate thereby allowing smaller pipe connections to the FCS, which may result in smaller FCS. In areas that are very sensitive to increases in hydraulic grade lines, special weirs can be used that automatically lower to pass more flow as the water level exceed a preset elevation. Therefore, there are three

options for bypass systems: one that only uses weirs that are internal to the FCS, a fixed external weir system, and self-adjusting (elevation-maintaining) weir systems.

Estimating the costs for installation of FCS is challenging because the installation costs vary dramatically depending on the configuration. In cases where installations are straightforward with vaults being installed along the existing storm drain alignment, the total costs can be three to five time the cost of the treatment unit itself. If the installations are complex with challenging hydraulic, groundwater and existing utility issues, the total cost of implementation can exceed ten times the cost of the device itself. Fortunately, the factors that lead to the most expensive installations are not expected to be present in the City.

The planning level opinions of probable cost for FCS included in this SWMP are intended to strike a balance between recognizing that there is significant uncertainty in what FCS will be selected for each location and how specific FCS installations will need to be configured while also taking advantage of details available from the SWMP data to determine costs for budgetary and priority planning.

The cost estimation process included assigning a device type for each identified FCS location. The following generalized device types were considered:

1. Catch basin inserts were used for locations where all of the runoff from the PLU area tributary to the device enters through the surface grate of the catch basin.
2. Catch basin screens were used for locations where it is anticipated that it will be feasible to retrofit the catch basin with a screen device that captures trash upstream from the outlet pipe. These systems may be applicable where PLU areas drain into the catch basin through upstream pipes, but where the total trash load and hydraulic impacts are expected to be acceptable for the configuration.
3. Detention basin screens were used on existing detention basins to satisfy the SWRCB requirements to have detention basins categorically approved as FCS.
4. Underground vaults were used at locations along underground storm drain lines where it was concluded that catch basin screens would not be appropriate. Bypass and weir systems can be required due to hydraulic constraints.
5. Surface systems were used where the FCS location is along an open channel or at an outfall into a channel. These systems can include baskets or nets and may be installed within new culverts and may include separate weir, wingwalls, or other features. However, because the surface systems are not as deep as underground vaults, construction costs for similarly sized FCS would be lower.

In addition to the generalized types, two unique devices were included. One device would add a floating screen near the overflow from California Park Lake to manage all of the PLUs upstream from the lake. The other unique installation will be a retrofit of an existing vault so that it becomes a FCS.

The costs for underground vaults and surface systems are largely dependent on the size of the pipes connected to it. There are minimum sizes for devices and some devices can fit a range of pipe sizes. In general, large pipe sizes are associated with deeper and more expensive installations. Although some smaller system installations may cost more than some larger systems due to site-specific conditions, it is expected that, generally, FCS on larger pipes will cost more than FCS on smaller pipes. Underground vault material costs were assigned for five vault sizes associated with pipe diameters of 30 inches and less, 36 inches, 42 to 48 inches, 54 to 66 inches and 72 inches. Based on a review of construction bid data for some vault FCS, it was determined that it would be reasonable to lump construction costs into parameters associated with excavation area, excavation perimeter (shoring costs are a major factor in retrofit construction), excavation volume and fixed costs (such as mobilization and traffic control). Unit rates were varied to obtain results that are reasonably consistent with bid totals. For surface systems, device costs from manufacturers were used along with bid data for concrete structures similar to those necessary for installation in order to develop cost estimates. Based on these estimates, it was determined that 50 percent of the unit cost (from a manufacturer) would be a reasonable estimate of the cost of installation for the surface systems. Hydraulic model results were used to identify locations where it was apparent that weir systems would be needed to limit energy losses, and a 30 percent factor was added to the base total construction costs for these locations. A factor of 50 percent was used for miscellaneous project costs described in Section 11.2. Opinions of probable costs for the identified FCS are summarized in **Table 39**.

Table 39: FCS Opinions of Probable Costs (2024 dollars)

Description	No.	Add weir	Unit Material Cost ($)	Unit Install. Cost ($)	Unit Const. Cost ($)	Unit Cost for Weir ($)	Total Const. Cost ($)	Misc. Proj. Costs ($)
Retrofit								
Inlet Inserts[36]	20		1,000	300	1,300		26,000	13,000
Catch Basin Pipe Screens	32		2,000	1,000	3,000		96,000	48,000
Detention Basin Screens	4		5,000	2,000	7,000		28,000	14,000
Vault for 12-inch pipe	4		60,320	239,940	300,260		1,201,040	600,520
Vault for 15-inch pipe	3		60,320	243,150	303,470		910,410	455,205
Vault for 18-inch pipe	5	1	60,320	246,360	306,680	92,004	1,625,404	812,702
Vault for 21-inch pipe	2	1	60,320	249,570	309,890	92,967	712,747	356,374
Vault for 24-inch pipe	7	1	60,320	252,430	312,750	93,825	2,283,075	1,141,538
Vault for 27-inch pipe	2		60,320	255,640	315,960		631,920	315,960
Vault for 30-inch pipe	14	1	60,320	258,850	319,170	95,751	4,564,131	2,282,066

[36] One of the inlet insert locations is on a private drainage system.

Table 39: FCS Opinions of Probable Costs (2024 dollars)								
Description	**No.**	**Add weir**	**Unit Material Cost ($)**	**Unit Install. Cost ($)**	**Unit Const. Cost ($)**	**Unit Cost for Weir ($)**	**Total Const. Cost ($)**	**Misc. Proj. Costs ($)**
Vault for 36-inch pipe	12	2	102,960	327,680	430,640	129,192	5,426,064	2,713,032
Vault for 42-inch pipe	5	1	172,640	427,310	599,950	179,985	3,179,735	1,589,868
Vault for 48-inch pipe	7	2	172,640	455,200	627,840	188,352	4,771,584	2,385,792
Vault for 54-inch pipe	7	1	267,800	553,690	821,490	246,447	5,996,877	2,998,439
Vault for 60-inch pipe	3		267,800	586,460	854,260		2,562,780	1,281,390
Vault for 66-inch pipe	1		267,800	620,410	888,210		888,210	444,105
Vault for 72-inch pipe	1		346,320	738,670	1,084,990		1,084,990	542,495
Vault for 2x54-inch pipe	1		267,800	620,410	888,210		888,210	444,105
Surface FCS for 12-in pipe	1		99,000	49,500	148,500		148,500	74,250
Surface FCS for 18-in pipe	3		99,000	49,500	148,500		445,500	222,750
Surface FCS for 24-in pipe	3		100,000	50,000	150,000		450,000	225,000
Surface FCS for 42-in pipe	1		118,000	59,000	177,000		177,000	88,500
Surface FCS for 48-in pipe	1		142,000	71,000	213,000		213,000	106,500
Surface FCS for 60-in pipe	1		198,000	99,000	297,000		297,000	148,500
Surface FCS for 72-in pipe	1		255,000	127,500	382,500		382,500	191,250
Surface FCS for 2x24-in pipe	1		132,000	66,000	198,000		198,000	99,000
Surface FCS for 2x36-in pipe	1		196,000	98,000	294,000		294,000	147,000
Surface FCS for 3x48-in pipe	1		396,000	198,000	594,000		594,000	297,000
Interceptor retrofit	1		25,000	10,000	35,000		35,000	17,500
California Parks Lake	1		200,000	10,000	210,000		210,000	105,000
Subtotal for retrofit FCS	*146*	*10*					*40,321,677*	*20,160,839*
New								
Catch Basin Pipe Screens	3		2,000	1,000	3,000		9,000	4,500
Vault for 10-inch pipe	1		60,320	239,940	300,260		300,260	150,130
Vault for 24-inch pipe	1		60,320	252,430	312,750		312,750	156,375

Table 39: FCS Opinions of Probable Costs (2024 dollars)								
Description	**No.**	**Add weir**	**Unit Material Cost ($)**	**Unit Install. Cost ($)**	**Unit Const. Cost ($)**	**Unit Cost for Weir ($)**	**Total Const. Cost ($)**	**Misc. Proj. Costs ($)**
Vault for 42-inch pipe	1		172,640	427,310	599,950		599,950	299,975
Surface system for 15-inch pipe	1		99,000	49,500	148,500		148,500	74,250
Subtotal for new SD FCS	7						*1,370,460*	*685,230*

Using the information presented in Table 39, total construction costs plus miscellaneous project costs are estimated at $63 million; $61 million for retrofits into existing storm drainage systems and $2 million of installations that would be constructed as part of the future drainage improvements included in this SWMP. The costs for FCS in future drainage improvements are generally associated with new outfalls that would receive runoff from existing PLUs in order to alleviate existing drainage deficiencies. It is anticipated that FCS for future PLUs will be provided as part of those development projects. Some of the FCS locations selected to develop the costs presented in Table 39 were determined to be cost-prohibitive. It is anticipated that some of the cost-prohibitive public retrofit locations will be replaced by sets of screens and inserts and will likely involve coordination with owners of private property. An estimated total program for FCS cost of $47 million, rather than $63 million is recommended based on expected refinements to the solutions as FCS implementation advances from master planning to design.

12.0
Prioritized Capital Improvement Recommendations

12.0 PRIORITIZED CAPITAL IMPROVEMENT RECOMMENDATIONS

12.1 Project Categories

One or more project categories were assigned to each proposed drainage feature in order to facilitate prioritization of improvements. Five categories were defined as follows:

1. Improvements to alleviate existing deficiencies that the City has identified as high priority;
2. Improvements to accommodate areas with no curb and/or gutter;
3. Improvements to connect capped systems, dry wells, and bubble-ups to outfalls;
4. Improvements to accommodate new developments; and
5. Miscellaneous improvements to alleviate existing deficiencies that have not been identified by the City as high priority.

The highest priority is implementation of remedies for the City's existing deficiencies known to cause relatively frequent flooding. Implementation of other improvements will depend on funding and the timing of new development. The costs of projects summarized by project category are summarized in **Table 40**. Project priorities may change over time. For example, proposed features that would convey flows to an outfall from an effective dry well would be a low priority. However, the priorities of the improvements would increase if the dry well's performance was to degrade to the point where surface flooding became a problem.

The categories of the proposed improvements are illustrated on **Figure 52**. The purpose of Figure 52 is to generally illustrate the extents of the proposed improvements that fall into the various categories. Many of the proposed improvements fall into more than one category. Multiple line thicknesses and colors are used in order to illustrate the various project categories for each feature. Some of the details are not distinguishable due to the to the scale of the figure. Users will need to refer to GIS data to use all of the detailed information developed for this SWMP.

Table 40: Project Category Cost Summary					
Project Category	**Base Construction**	**Easement /Acquisition**	**Other Costs**	**Total Cost**	**Future Development Cost Share**
Priority Deficiencies Requiring C&G	$ 1,695,902	$ 16,218	$ 847,951	$ 2,560,071	$ 36,925
Priority Deficiencies Not Requiring C&G	$ 5,199,319	$ 457,049	$2,599,659	$ 8,256,027	$ 269,036
Non-Priority C&G	$ 23,447,556	$ 2,315,480	$ 11,723,778	$ 37,486,814	$ 1,783,564
Relief from Infiltration Systems	$ 6,444,567	$ 548,727	$ 3,222,283	$ 10,215,577	$ 1,062,926
Accommodate Future Development	$ 33,771,817	$21,717,853	$ 16,885,908	$ 72,375,578	$ 60,672,089
Other Deficiencies	$ 1,408,902	$ 14,195	$ 704,451	$ 2,127,547	$ 3,050
Total	**$ 71,968,062**	**$25,069,521**	**$ 35,984,031**	**$133,021,614**	**$ 63,827,590**

12.2 Storm Water Quality Projects

Storm water quality project include FCS and SWRP projects. Implementation of FCS should be prioritized in order to construct those treatment systems that are most cost effective at treating runoff from PLU areas. The highest priority projects identified in the SWRP are summarized in Table 6.

12.2.1 Phased Implementation

Analysis of costs for individual FCS locations and their associated FCS revealed that some of the identified locations are inefficient from a capital cost perspective. It is recommended that the installation of FCS be phased to start with the most cost-effective locations followed by increasingly less cost-effective locations. Cost effectiveness has been calculated as the estimated construction cost divided by the PLU areas treated by the device in acres. The accuracy of the calculation of cost-effectiveness is impacted by the various limitations discussed in this SWMP and should be continuously updated as more accurate information is developed. Therefore, the order of installation of FCS locations should be updated to take advantage of new data. By focusing on the most cost-effective locations first, the City will maximize the rate of completion based on a uniform rate of expenditures.

The Statewide Trash Amendments require that full compliance occurs by December 2, 2030 and that the municipalities meet interim milestones that demonstrate progress to full implementation. As such, this analysis assumes a phased approach to the installation of FCS, beginning in FY 2024-25 and continuing incrementally through FY 2029-30. The City is budgeting for implementation based on a uniform budget for each of the six years.

To account for this phased approach, the installation of the new FCS is distributed over the 6-year period. This phased approach anticipates the potential Trash Reduction Milestone requirements that are anticipated for the Phase II permit reissuance, which may require a 30%, 70% and 100%

achievement of the trash reduction milestone in 2026, 2028, and 2030, respectively. The SWMP recommends a prioritized sequence of installations starting with the most cost-effective FCS in terms of PLU area treated in order to achieve the trash reduction milestones.

It is recommended that the City budget for $7.5 million per year in 2024 dollars for FCS implementation, including the design, construction management and contingency. Although it is recognized that $45 million would fall far short of the $61 million discussed in the previous section, the phased implementation based on installation efficiency indicates that over 90 percent of the City's PLU area could be treated for $37.5 million, which is 83 percent of the of the recommended budget of $45 million. It is anticipated that more cost-effective means to treat the runoff from some of the PLU areas than those used in this SWMP will be identified during the process of site-by-site investigations.

The phased implementation plan focuses on the 146 retrofit FCS locations summarized in Table 39. Therefore, the $45 million budget does not include $2 million for FCS that would need to be incorporated into master planned drainage projects to alleviate existing deficiencies. However, the timing of when the drainage improvements will occur has not been determined and the associated FCS are only required when the projects are constructed. The cost-effectiveness of each of the 146 retrofit FCS locations was ranked and the cumulative cost of implementation was computed. An implementation year was assigned to each location based on the annual budget of $7.5 million. Figure 53 color codes the FCS for years one through five and indicates the other locations as either requiring value engineering or being one of the seven FCS locations that are along proposed storm drains. This phased implementation plan calls for construction of 107 of the 146 identified FCS locations to be implemented by 2029 anticipating that this would treat runoff from over 90 percent of the City's PLU acreage.

12.2.2 Cost Estimate of Track 1 Implementation

The cost schedule for the phased implementation of Track 1 for the City is shown in **Table 41**, below. Implementation is being planned based on level annual funding, prioritizing design and construction of the most cost-effective FCS in parallel with more detailed planning to improve the overall efficiency of achieving full trash capture.

Table 41: Expected Range of FCS Implementation									
Fiscal Year	**FCS Funded**							**Progress to Complete Compliance[37]**	**Budget Cost in 2024 $1,000**
	CB Insert	**CB Pipe Screen**	**DB Screen**	**Surface**	**Vault**	**Other**	**Total**		
FY 24-25	16	28	4	6	5	1	60	44%	7,500
FY25-26	1	1	0	1	8	1	12	67%	7,500
FY26-27	1	0	0	0	9	1	11	79%	7,500
FY27-28	1	2	0	0	9		12	87%	7,500
FY28-29	1	0	0	1	10		12	93%	7,500
FY29-30	0	1	0	5	33		39	100%	7,500
TOTAL	**20**	**32**	**4**	**13**	**74**	**3**	**146**	**100%**	**45,000**

It would be beneficial to review and update this annually as additional information is gained in order to refine the plan for the future needs until 2030.

[37] Completion is stated based on percentage of PLU acreage treated by funded devices being implemented according to the phased implementation plan. The Draft Phase II permit anticipated trash reduction milestones of 30% by 2026, 70% by 2028, and 100% by 2030.

13.0
O&M Annual Maintenance Plan and Cost

13.0 O&M ANNUAL MAINTENANCE PLAN AND COST

13.1 Big Chico Creek Erosion Repair

As described in **Section 10.8.1**, Big Chico Creek has existing erosion damage at several locations along its alignment that will require repair. As these repairs are not capital improvement projects, the work would probably be classified as O&M activities. Some erosion locations are more critical than others based on how fast erosion is progressing and whether or not any structures or pavement are threatened. It is anticipated that the repairs will be implemented over a period of years. It is also anticipated that other erosion sites will develop. Therefore, it would be prudent to budget for erosion repairs on an annual basis.

An analysis of the erosion-damaged areas discussed in this report was presented in a memorandum prepared by Dokken Engineering in July of 2022, entitled *Draft Hydraulic Assessment and Conceptual Design Memorandum* [49] (see **Appendix H**). The Dokken study analyzed the hydraulic conditions present at the erosion sites, developed a high-level repair alternative, and prepared preliminary cost estimates for each of the ten erosion sites. The total estimated cost to repair all of the sites was $3.3 million (in 2022 dollars). Using USACE cost indices for bank stabilization work, this cost was escalated by approximately 11%, resulting in a total cost of $3.7 million in 2024 dollars.

It should be noted that, given the high level of the Dokken memorandum, it was limited to just a single repair alternative for each site, with the mitigation alternatives consisting of gabions for all locations except the one at Warner Street Bridge that utilized rock-slope protection (RSP). It is recommended that an alternatives analysis be performed to review other potential mitigation measures based on design-level topographic mapping before moving further into design. Mitigation measures such as geogrids, turf reinforcement mats, tied concrete block mats, and RSP, together with the gabion design, should be included in the analysis to weigh the advantages and disadvantages of each. The alternatives analysis would provide the City with the information necessary to determine which option would provide the best value for each circumstance.

13.2 O&M of Full Capture Systems

The annual O&M requirements for FCS were based on previous municipal studies and they estimate the need for three inspections with a clean out for the catch basin distributed devices and one inspection with a clean out for the other devices that include vaults and screen systems near culverts and outfalls. In general, the O&M cost estimates took into consideration the personnel cost of a crew to perform the cleaning as well as the cost of supplies and the purchase of a vactor truck to use for clean outs. It was assumed that a vactor truck costs approximately $500,000 and can perform 2,064 clean outs per year[38]. Device maintenance costs are summarized in **Table 42**.

[38] Stockton Urbanized Area (SUA)–Trash Amendments Compliance Analysis (LWA, 2017), San Deigo Full Capture Systems Workplan (LWA, 2021).

Table 42: Estimated O&M Costs Based on Device Category		
Device Type	**Assumptions & Costs**	
Estimated Cost Per Distributed Device (Category – Small)	O&M Clean Outs Per Year	3
	Cost Per Cleanout	$115[39]
	Total Annual O&M Cost	$400[40]
Estimated Cost Per Regional Device (Category – Medium and Large)	O&M Clean Outs Per Year	1
	Cost Per Cleanout	$3,000[41]

Based on a total of 165 FCS devices needed to treat all PLUs, including devices already installed or planned by the City and the devices that will be incorporated into the master-planned storm drainage system improvements, the total flat O&M cost estimate is summarized showing phased implementation in **Table 43**. It is estimated that, once all devices are installed, the annual cost of O&M will be approximately $329,000 in 2024 dollars.

Table 43: Estimated Total O&M Costs of Recommended Devices					
Fiscal Year	**FCS Installed**			**Cumulative Percent Progress Towards Full Installation[42]**	**Cumulative O&M[43]**
	Catch Basin Device	**Other Devices**	**Total**		
Completed	9	3	12	8%	$12,600
FY 24-25	44	16	60	46%	$78,200
FY 25-26	2	10	12	53%	$109,000
FY 26-27	1	10	11	60%	$139,400
FY 27-28	3	9	12	68%	$167,600
FY 28-29	1	11	12	75%	$201,000
FY 29-30	1	38	39	100%	$315,400
Non-programmed	3	4	7		$328,600
TOTAL	64	101	165	100%	$400,000

[39] The cost estimate is based on a previous municipal study which accounted for the personnel cost of a three-person crew (utility worker, supervisor, equipment operator), and purchase of a Vactor truck and fuel to perform the clean out. A Vactor truck is assumed to cost $500,000 upfront and can perform 2,064 cleanouts per year. The final number has been adjusted for inflation.
[40] The total cost has been rounded up.
[41] This clean out cost was estimated based on a previous municipal study which accounted for the personnel cost of a four-person crew (two utility workers, a supervisor, and an equipment operator), and the purchase of a Vactor truck and a 1.5-yard crew truck to perform the clean out. The final number has been adjusted for inflation.
[42] Percentages are indicated based on number of installations.
[43] O&M cost estimate includes a cleanout frequency of 3x for small FCS and 1x a year for medium and large FCS.

Due to the expectation that a larger number of less expensive devices will ultimately be used than had been identified in the SWMP in order to reduce the FCS capital costs identified in the SWMP, it is recommended that the City plan on a budget of $400,000 for maintenance of FCS devices once all of the devices have been installed.

14.0
Evaluation of Project Financial Needs

14.0 EVALUATION OF PROJECT FINANCIAL NEEDS

The City's Public Works Department (Department) is organized into two sections: Operations and Maintenance, and Engineering. Each section consists of several divisions and perform various storm water program activities; however, no single section handles all storm water-related activities. To conduct this analysis, the Project Team created a hypothetical storm water utility that would fund the City's resources required to conduct all necessary and beneficial storm water activities. Based on a review of the related financial accounts and discussions with supervisory staff, the Project Team developed planning-level estimates of the costs and revenues required to fund the storm water utility.

The financial review was conducted in three parts: 1) Establish current operating costs as a baseline; 2) Evaluate additional operating needs and associated costs; and 3) Amortize capital needs. These costs were then used to develop a 30-year forecasting tool, or model, that would enable the Team to create various cost/revenue scenarios and perform various analyses.

14.1 Baseline Operating Costs

For current operating costs, a review of financial budgets across City Funds that support storm water activities was performed. Baseline operating costs were estimated at approximately $1.22 million for Fiscal Year 2024-25 (FY 25).

14.2 Additional Future Operating Needs

The next step was to determine any additional needs for a future utility structure. This assessment was divided into two categories: Basic operations and MS4 compliance. Critical information and data points were gathered during the Master Plan update, configuring projects that will likely need to be repeated periodically. As additional capital projects are implemented, it will be essential to ensure compliance with state and federal clean water regulations, specifically the MS4 Permit. This includes ongoing erosion repair work, as repairs are finished, new issues can emerge requiring continuous monitoring and intervention of problem areas over time.

11 total sites for erosion repair work have been identified totaling $7.23 million. After accounting for the share of costs projected to be funded from alternative revenue streams such as the Parks Fund (funded by the General Fund) and grant funds, the total cost for erosion repair was adjusted to $6.3 million. Erosion repair work will be completed as ongoing maintenance as completed repairs reveal new areas of concern requiring continuous attention and intervention for effective management and mitigation. Estimated total costs are summarized in **Table 44** below.

Table 44: Adjusted Erosion Repair Costs	
Description	**Total Cost** (Costs shown in thousands)
Erosion repair projects total	$ 7,225
Estimated alternate funding*	$ 970
Adjusted erosion repair costs	$ 8,196

**Parks fund and grant funds*

To accommodate these projects as ongoing work, projections for the 11 project sites and their costs have been implemented over a 20-year period, including escalation factors. As additional trash capture devices are installed, the MS4 permit compliance work required increases as additional capital projects are implemented. The estimated annual costs for these additional operating needs for FY 25 are summarized as follows:

- $405,000 for Erosion Repair
- $82,400 for MS4 Trash Capture Compliance

Maintenance costs for all Full Capture System devices are estimated to total $400,000 over 5 years. Annually, this cost is estimated as an additional $82,400 plus 3% escalation for inflation each year for the four subsequent years until all devices are installed over the 5-year period.

The results of the additional needs analysis showed that approximately $405,000 in additional funding would be needed annually by FY 25. Combined with the baseline operating costs, this would bring the total FY 25 operating budget to $1.63 million. These amounts are summarized in **45** below.

Table 45: Summary of Estimated Operating Costs					
Program	**FY 24-25**	**FY 25-26**	**FY 26-27**	**FY 27-28**	**FY 28-29**
Total O & M	$ 1,221	$ 1,258	$ 1,296	$ 1,335	$ 1,375
Baseline Costs	$ 1,221	$ 1,258	$ 1,296	$ 1,335	$ 1,375
Additional Needs*	$ 405	$ 489	$ 574	$ 659	$ 744
Total Operating Costs	$ 1,626	$ 1,747	$ 1,870	$ 1,994	$ 2,119

**Annual 3% escalation plus additional trash capture maintenance*

14.3 Capital Improvement Program

Comprehensive system needs and associated capital costs identified by the Storm Water Master Plan have been compiled into a full Capital Improvement Program totaling $180 million, shown in **Table 46** below.

Table 46: Summary of Capital Needs	
Program Element	***Total Cost***
Priority Deficiencies Requiring C&G	*$ 2,560,071*
Priority Deficiencies w/o C&G	*$ 8,256,027*
Non-Priority C&G	*$ 37,486,814*
Relief from Infiltration Systems	*$ 10,215,577*
Accommodate Future Development	*$ 72,375,578*
Other Deficiencies	*$ 2,127,547*
Trash Capture Systems	*$ 45,000,000*
Deficiency Dependent Trash Capture	*$ 2,000,000*
Total Revenue Requirement	***$ 180,021,614***

14.4 Adjusted Capital Improvement Program

A thorough review of these capital projects, conducted in collaboration with senior City staff and the Project Team, identified three capital project categories suitable for funding from non-enterprise sources: priority requiring curb and gutter, non-priority deficiencies requiring curb and gutter, and trash full capture systems.

14.4.1 Curb and Gutter

Roadway-related projects were identified as appropriate for gas-tax funding when there is a connection between vehicular infrastructure and storm water management systems. Heavily travelled roadways are significant sources of surface runoff, which often carries pollutants such as oils, heavy metals, and debris into the storm drainage system. Curbs and gutters are essential components in effectively channeling this runoff into storm drains, thereby mitigating flooding, reducing erosion, and preventing water pollution. Gas tax revenues, generated from the users of these roadways, can be reinvested by municipalities into infrastructure that supports the integrity and functionality of the transportation network. This funding strategy ensures that the installation of curb and gutter storm water management systems is financially supported by the activities that create the need for them.

14.4.2 Trash Full Capture Systems

The most expensive project, by far, is the installation of trash full capture systems, programmed at $45 million, plus deficiency dependent trash capture of $2 million, for a total of $47 million. Funding the installation of trash full capture systems for storm water management through a general obligation bond is appropriate due to the compliance requirements of the MS4 permit and the substantial costs involved. The MS4 permit mandates municipalities to implement measures

that prevent trash and pollutants from entering waterways, necessitating the installation of full capture systems. These systems effectively filter out trash and debris from storm water, ensuring regulatory compliance and protecting water quality and the environment. However, the high capital costs of these installations strain municipal budgets.

By utilizing a general obligation bond, municipalities can take advantage of a typically lower interest rates compared to other debt mechanisms, and spread the financial burden over time, making it more manageable for taxpayers. This funding mechanism allows for the immediate implementation of necessary infrastructure improvements, avoiding an imbalance in debt service to user fee revenue, which would occur if user fees were programmed to serve as the repayment source.

14.4.3 Adjusted Capital Improvement Program Tiers

After accounting for the share of costs projected to be funded by fees from future development and the cost offsets from alternative revenue streams such as General Obligation bonds and projects identified as appropriate for gas-tax funding, the total cost for the Capital Improvement Program (CIP) was adjusted to $32.8 million.

The adjusted CIP shown in **Table 47** includes three tiers of projects. Tier 1 ($8.1 million) includes current high priority projects identified in the SWMP and projected to be shared by the City. Tier 2 ($23 million) includes costs associated with potential future development projected to be shared by the City, infiltration system relief, and other deficiencies not identified as high priority. Tier 3 ($1.8 million) includes non-priority project costs projected to be shared by the City.

Table 47: Adjusted Capital Improvement Program

Program Element	*Cost*	Tier 1	Tier 2	Tier 3
Priority Deficiencies Requiring C&G	*$ 126,157*	$ 126,157		
Priority Deficiencies w/o C&G	*$ 7,986,991*	$ 7,986,991		
Non-Priority C&G	*$ 1,785,163*			$ 1,785,163
Relief from Infiltration Systems	*$ 9,152,651*		$ 9,152,651	
Accommodate Future Development*	*$11,703,489*		$ 11,703,489	
Other Deficiencies	*$ 2,124,497*		$ 2,124,497	
Total Revenue Requirement	***$32,878,948***	**$ 8,113,148**	**$ 22,980,637**	**$ 1,785,163**

** This is the City's share of project costs for future development. Total costs are estimated at $72,375,578*

15.0
Evaluation of Potential Funding Sources

15.0 EVALUATION OF POTENTIAL FUNDING SOURCES

15.1 Review of Utility Fee Structures and Proposition 218 Requirements

Many municipalities operate utilities such as water, wastewater, and solid waste as enterprises, providing services to properties within their jurisdiction that are primarily supported financially through user fees. Historically, storm water management has not been treated as a municipal utility. However, there is a rapidly growing trend nationwide to establish storm water management as a utility.

Currently, the City does not have a separate storm water revenue fund supported by a user fee system. The legal requirements for establishing and increasing municipal utility fees are governed by Proposition 218. Fees for water, sewer, refuse collection (or solid waste), and storm water services are defined as property-related fees. Notably, while voter approval is not required for the first three types of fees, it is required for storm water fees. This voter approval requirement poses a significant barrier for municipalities trying to establish storm water fees. Consequently, municipalities often seek alternative, non-balloted funding options to support storm water activities. Several such options are reviewed below.

15.2 Summary of Funding Options

A variety of options exist for funding a storm water program, which can be categorized into ongoing funding, one-time funding, or debt financing (one-time funds repaid over time). It is crucial to distinguish between balloted and non-balloted funding sources, as those requiring a ballot measure inherently present more challenges and risks. The matrix below categorizes these funding options along two axes and provides examples of each.

	Sustainable / Ongoing	One-Time	Long-Term Debt
Balloted	Taxes, Fees & Assessments		GO Bonds *
Non-Balloted	Regulatory Fees Re-Alignment Developer Fees	Grants	COPs ** Revolving Fund

** General Obligation Bonds; ** Certificates of Participation*

Exhibit 56: Funding Option Matrix

Appendix I is a Stormwater Funding Matrix [50] developed by the California Stormwater Quality Association (CASQA). It provides a summary matrix of funding options and includes pros and cons for each option.

15.2.1 Legal Landscape

New sources of revenues for municipalities typically come in the form of taxes, fees, assessments and other charges, which are governed by two voter-approved initiatives: Propositions 218 and 26.

Proposition 218 requires all taxes, fees, and assessments be approved through a ballot measure, except for user fees for water, sewer, and refuse collection services, and a few other types of user fees specified in Proposition 26. Securing voter or property owner approval through a ballot measure can be challenging, often making many revenue mechanisms difficult to implement.

15.2.1.1 Proposition 218

Proposition 218, approved by California voters in 1996, addresses taxes, fees, and assessments, with taxes and fees being pertinent to this Study. Most storm water revenue mechanisms in the State are considered to be property-related fees under Proposition 218 (Article XIIID, Section 6). This category includes fees for water, sewer, and refuse collection services, which must meet certain criteria to be in compliance:

Revenues derived from the fee shall not exceed the funds required to provide the property-related service.

Revenues derived from the fee shall not be used for any purpose other than that for which the fee was imposed.

The amount of a fee upon any parcel or person as an incident of property ownership shall not exceed the proportional costs of the service attributable to the parcel.

No fee may be imposed for a service unless that service is actually used by, or immediately available to, the owner of the property in question. Fees based on potential or future use of service are not permitted. Standby charges, whether characterized as charges or assessments, shall be classified as assessments and shall not be imposed without compliance with the assessment section of the code.

No fee may be imposed for general governmental services including, but not limited to, police, fire, ambulance, or library services where the service is available to the public at large in substantially the same manner as it is to the property owners.

Proposition 218 imposes certain procedural requirements for imposing or increasing property-related fees. There are two distinct steps:

A protest period that begins with a notice of the fee mailed to each property owner and a 45-day period where property owners may file a written protest culminating in a public hearing. If the owners of a majority of the parcels affected by the rates file a written protest, the agency cannot impose the fee. If a majority protest is not formed, the agency may move to the second step.

A ballot proceeding where the agency submits the fees to the electorate consisting of the owners of the affected properties. Based on each parcel counting as a vote, a fee is approved if more votes are cast for the fee than against it. Alternately, the agency may submit to the registered voters in the area affected in which case a two-thirds majority is required for passage.

Proposition 218 goes on to exempt fees for water, sewer, and refuse collection from the second step. While there was no mention of storm water fees in that list of exemptions, some municipalities considered storm water (sometimes called "storm sewers") to be in the category of sewers. The City of Salinas was one of these municipalities and moved ahead with a storm water fee in 1999 without submitting it to a ballot proceeding. In 2002, a subsequent lawsuit was decided by the Sixth Appellate District against the City, which established a legal requirement to submit storm water fees to a ballot proceeding.

15.2.1.2 Proposition 26

Proposition 26, approved by California voters in 2010, tightened the definition of regulatory fees. It defined a special tax to be "any levy, charge, or exaction of any kind imposed by a local government" with certain exceptions. Pursuant to law, all special taxes must be approved by a two-thirds vote of the electorate.

Regulatory fees are thus defined through the cited exceptions to the broad, all-encompassing assertion that all levies are taxes. The pertinent exception is "a charge imposed for the reasonable regulatory costs to a local government for issuing licenses and permits, performing investigations, inspections, and audits, enforcing agricultural marketing orders, and the administrative enforcement and adjudication thereof." Hence, it seems that a portion of the City's storm water costs (e.g., plan checks and inspections) may be funded through regulatory fees.

The other pertinent exception is, "assessments and property-related fees imposed in accordance with the provisions of Article XIIID." The Proposition goes on to state that, "the local government bears the burden of proving by a preponderance of the evidence that a levy, charge, or other exaction is not a tax, that the amount is no more than necessary to cover the reasonable costs of the governmental activity, and that the manner in which those costs are allocated to a payor bear a fair or reasonable relationship to the payor's burdens on, or benefits received from, the governmental activity."

15.3 Overview of Storm water Funding Options: Balloted versus Non-Balloted

In accordance with the legal requirements above, funding mechanisms are traditionally divided into two categories: balloted and non-balloted. Balloted approaches are generally less desirable due to the additional costs of the balloting and community outreach, the inherent risk voter rejection, and the limitations on revenue associated with proposing a politically viable rate. Hence, non-balloted approaches generally should be researched, pursued, and employed first as long as they meet legal, administrative, and other political requirements – unfortunately, California law requires balloted funding mechanisms in most cases. Additionally, there are also other special financial mechanisms that are worth considering.

15.3.1 Balloted Mechanisms

There are two primary types of balloted measures suitable for storm water funding: property-related fees and special taxes. Although successfully implemented balloted approaches can provide significantly and reliable funding for storm water management, they are often challenging to enact. The key to a successful ballot measure is proposing a project or program that the voting community perceives as offering value commensurate with the tax or fee. The two greatest challenges are crafting a measure that meets this threshold and then effectively communicating its benefits to the community.

Since balloted funding mechanisms tend to be the most comprehensive, flexible, sustainable, and defensible, they often form the backbone of an agency's entire program. They can directly fund services or projects and create a dedicated and sustainable revenue stream that can be leveraged to secure grants, loans, partnerships, and many other opportunities. Without such a dedicated revenue stream, these opportunities are often missed. Ballot-based measures include:

- Property-related fees for storm water services are similar to fees imposed for water, sewer, and solid waste services. The distinct difference is that storm water fees require approval through a ballot measure in accordance with Proposition 218, requiring a simple 50% majority for passage (with one parcel equating to one vote). Otherwise, they are identical to the other utility fees: they require a fair-share apportionment of costs to ratepayers as detailed in a rate study or other cost of service analysis; they cannot charge more than the proportionate cost of service (e.g., discounts or exemptions cannot be subsidized by other ratepayers); and all revenues must exclusively be spent on the storm water services. Property-related fees are the most common sustainable revenue mechanism employed by municipalities for storm water management services.

  Property-related fees are subject to the requirements of Articles XIIIC and D of the State Constitution, which were approved by voters in 1996 through Proposition 218, as well as the Proposition 218 Omnibus Implementation Act (Government Code Sections 53750 – 53758).

Any property-related fee must comply with the requirements of Article XIIID, Section 6, as described above.

Proposition 218 mandates a two-step process for implementing new or increased property-related fees: 1) a 45-day public protest period culminating in a public hearing, and 2) a ballot proceeding requiring approval by a 50% simple majority of property owners (or a two-thirds supermajority of registered voters). However, fees for water, sewer, and refuse collection are exempt from the second step.

Following the passage of Proposition 218, there was uncertainty regarding whether storm water fees qualified as a type of sewer fee, potentially exempting them from the ballot proceeding

requirement. The ambiguity was resolved in 2002 when the California Sixth Appellate District Court ruled that storm water fees do not qualify as a type of sewer fee, thereby necessitating ballot approval for new or increased fees.

This voter approval requirement creates a significant barrier for municipalities attempting to set storm water fees, prompting many to seek non-balloted funding options to support storm water activities. Despite these barriers, property-related fees remain the most common dedicated, sustainable funding source for storm water utilities across the state and country. Other balloted mechanisms often require a higher approval threshold, such as a two-thirds majority. While non-balloted funding mechanisms are worth pursuing but are typically considered as supplement funding sources since they can rarely generate the level of revenue required to support a full enterprise.

- Special taxes are decided by registered voters and require a two-thirds majority for approval. Special taxes are well known to Californians and are utilized for all manner of services, projects, and programs. They are usually legally stout and flexible and can support debt issuance of debt with most loans or bonds. Among the various types of special taxes, parcel taxes are the most commonly used for storm water services. Other special taxes include sales, business licenses, vehicle licenses, utility users, and transient occupancy taxes. These taxes can also be implemented as a general (not special) tax, which require only a simple 50% majority for passage. However, to qualify as a general tax, the revenue must be allocated to the agency's general fund without specific restrictions. In this case, storm water services must compete for funding with other general funded services such as police, fire, and parks. Although a general tax requires only a simple majority, voters tend to favor special taxes that explicitly identify their purpose.

- General Obligation (GO) bonds are well-known to the voting public and require a two-thirds majority for approval. These bonds are issued to raise funds upfront and are repaid through a tax levied against property on the annual property tax bill. A primary restriction on GO bonds is that they can only be used for capital projects, including land acquisition, planning, design, and construction. However, costs for maintenance and operations cannot be paid from bond proceeds.

Challenges with balloted approaches extend beyond the requirement for voter approval; they include a lack of familiarity among storm water professionals, the need for extensive community engagement and education, and a certain amount of political strategizing. Over the past 15 years, fewer than three dozen community-wide measures for storm water have been attempted throughout California, with a success rate of just over 50 percent.

	Property-Related Fee	Special Tax
Who Pays	Property Owners	Property Owners
Who Votes	Property Owners	Registered Voters
Vote Threshold	50%	66.70%
Votes When	Any Time	Established Voting Dates
Fairness of Rates	Strict Fairness Requirements	No Fairness Requirements
Other Features	* Tenants excluded from vote * No exemptions or discounts for low-income or seniors * Government and non-profit must pay * Each parcel gets a vote, unweighted	* Out-of-town owners excluded from vote * Exemptions or discounts allowed for low-income or seniors * Tax-exempt properties do not pay * Exemptions cut into revenues

Exhibit 57: Balloted Approach Matrix

15.3.2 Non-Balloted Mechanisms

Non-balloted funding mechanisms include regulatory fees, developer impact fees, and other opportunistic approaches. While these funding methods do not require voter approval, they still impact various segments of the community and therefore subject to local political forces.

Of these mechanisms, regulatory fees and realignment are the most applicable to the City for compliance with the MS4, which is primarily a set of operational tasks rather than capital improvement projects.

- Regulatory fees are those which recover the actual cost of "issuing licenses and permits, performing investigations, inspections and audits, and the administrative enforcement and adjudication thereof."[44] In terms of the City's storm water activities, this might include development plan checks and inspections, commercial and industrial inspections, and compliance with Senate Bill 205 requirements.

- Realignment is the term applied to reorganizing the internal workflow and/or financial tracking of revenues and expenditures of certain storm water management activities that support other non-balloted fee structures (water, sewer, and refuse collection). The most common examples are street sweeping and trash capture.

    - The MS4, as a storm water pollutant reduction permit, requires the City to implement a trash load reduction plan. However, collecting trash/litter is a function of a community's solid waste collection system, whose fees do not require voter approval for increases. Therefore, the City could charge all of its trash capture

[44] Proposition 26, California Constitution, Article XIIIC, Section 1 (e)(3).

expenses (capital, operations and maintenance, and administrative) directly to properties that contribute to the trash burden through an existing or new solid waste fee.

- Although street sweeping is no longer required by the MS4, the City continues this important function. Since street sweeping costs are already embedded into the City's solid waste rates, no realignment is necessary.

15.3.3 Grants and Loans

Grants and loans are typically one-time funds from an outside source. Due to their one-time nature, they are best suited for finite projects or programs rather than ongoing and recurring operational and maintenance programs. Grants do not require repayment whereas loans must be repaid, usually with interest. Both require an agency to submit an application, which can be time-consuming and costly, and are usually competitive.

While grants and loans cannot be relied upon for the backbone funding for storm water activities, they should be considered as supplemental funding options to enhance other funding sources whenever opportunities arise.

15.3.4 Special Financing Districts

Special financing districts are financial structures created by local agencies for the purpose of levying taxes, fees, or assessments for specific improvements and/or services provided. While most special financing districts require registered voter or property owner approval, they are often used in new development projects where a single entity (the developer) controls all properties and votes. In such cases, the balloting becomes an administrative function with a predictable outcome. To create a special financing district in established areas or neighborhoods is much more politically challenging, as it involves a true ballot measure.

There are four basic types of special financing districts that apply to MS4 activities: Benefit assessments; community financing districts (CFDs, or Mello-Roos); business improvement districts (BIDs); and enhanced infrastructure financing districts (EIFDs). Each of these can be used to support debt service and are explored in more detail below:

- Benefit assessments are relatively restrictive in that they must account for any general benefit to property outside the district, which in turn cannot be included in the assessment calculation for the properties. With storm water, the general benefits could be considerable thereby diluting the funding potential for this option. This option requires a simple 50% majority (with ballots weighted by the amount of the assessment), and public or tax-exempt properties cannot be exempted. Since storm water services are typically considered necessary rather than simply beneficial, they are usually viewed as a utility with user fees instead of an optional service that benefits property. Thus, benefit assessments have not been widely used to fund storm water costs.

- CFDs utilize a tax (not an assessment) and are the most flexible. There is no "general benefit" restriction, and there is flexibility in exempting various types of properties (e.g., government, tax-exempt, etc.). As a special tax, a two-thirds majority is required for approval. As with benefit assessments, these are most often used in new developments where the only voter is the developer.
- BIDs are limited to business districts and can sometime include a specified residential area/district. They can be used to assess property owners and/or business owners for certain improvements and services. Storm water features can function as aesthetic improvements popular with business districts (e.g., permeable pavers on streets, bioswale bulb-outs, and rain gardens). A notable example of a BID in relation to storm water activities is the "Green Benefits District," successfully pioneered by the City of San Francisco/SFPUC. Because BIDs are limited to business areas or local neighborhoods, they are usually viewed as supplemental funding sources.
- EIFDs are a form of tax increment financing that captures the increase in property tax as properties within the district are developed to a higher assessed value (similar to the now-defunct redevelopment agencies). This is a relatively new mechanism (signed into law in 2014) and has only been implemented a handful of times statewide. The proceeds are intended for enhancing the properties within the district, usually through infrastructure improvements, which in turn, fuels the property assessment increase. The most common infrastructure enhancements have been in the areas of transportation and parks, but utilities have also benefited. There is a potential for using this mechanism for storm water infrastructure, although it has not been a successfully implemented in this context yet. One challenge is that EIFD funds cannot be used for operations and maintenance activities.

15.3.5 Development

Storm water funding opportunities from the development community arise primarily through Impact fees and/or in-lieu fees. Both methods are heavily influenced by MS4 requirements and have the potential to become significant revenue streams in a growing community like Chico. They are discussed below.

- Impact fees must be crafted carefully to comply with AB 1600 with a rigorous nexus between the type of development and the fee assessed. For storm water, most significant development is governed by the Statewide Phase 2 NPDES MS4 Permit, which mandates most new development to incorporate limited low impact development features on-site. This has the effect of mitigating some impacts of development projects, however drainage infrastructure is still needed and long term design performance cannot be ensured.

  In-lieu fees can be imposed either on a case-by-case basis or through an adopted program. These fees are used when developments cannot mitigate their impacts or meet their conditions of approval on-site. Instead, developers contribute financially to the City's project or program that meets those requirements on their behalf. An in-lieu program must be based on a City-sponsored project or program capable of meeting these requirements for certain development projects, with impacts monetized accordingly.

15.3.6 Partnerships

By teaming up with other entities, an agency may not generate additional funding directly, but partnerships offer many other benefits that can aid in delivering storm water projects and programs. These benefits can include economy-of-scale savings or multi-benefit projects that can achieve multiple goals for a single price. Strategies include the following:

- Multi-agency Partnerships: Collaborating with other agencies can create economies of scale, provide access to additional funding, and leverage other resources, enhancing the overall effectiveness and efficiency of storm water projects.
- Transportation Opportunities: Multi-benefit projects can deliver more outcomes cost-effectively. In some cases, transportation projects can fully fund the storm water elements. Transportation project funding is expected to provide significant cost offsets for identified storm water deficiencies, as described later in this chapter.
- Public-Private-Partnerships (P3): P3s typically require a dedicated revenue stream to finance the projects, but they can create cost efficiencies and bring in needed expertise and other resources. These partnerships can be particularly valuable in managing complex or large-scale storm water projects.
- Volunteers and Not-for-Profits: Certain storm water tasks, such as trash capture and minor watershed stewardship, can be effectively performed by outside groups. These tasks often come at little or no cost, aside from supervisory expenses. When not-for-profit organizations charge for their skilled labor, the costs are typically lower than market rates.

15.4 Optimal Approaches for the Program

The funding needs of the City's storm water program are a blend of operational, regulatory, and capital costs. Therefore, not all potential funding approaches listed above are practical for every aspect of the program. Some funding approaches align well with certain aspects of the program, while others are harder to match to appropriate funding mechanisms. This section identifies the most practical approaches and identifies the pros and cons of each.

15.4.1 Balloted Property-Related Fee – Primary Options

The premise of this financial analysis is to create a hypothetical storm water utility (or enterprise fund). In general, a municipal utility is a self-supporting government enterprise that provides services to the public for a fee. The City currently has enterprise funds established for wastewater service and a special fund for solid waste services, both of which rely primarily on user fees categorized under Proposition 218 as property-related fees. These user fees are not only the most common funding source but also recognized as legitimate by ratepayers, flexible in funding all enterprise-related costs, legally stout, and sustainable for future needs.

For storm water management, a property-related fee must be approved by voters as noted above. While this requirement increases the difficulty and risk of enacting such a fee, it remains the most

common and sustainable dedicated funding source used by storm water utilities throughout the state and country. Other balloted mechanisms typically require a higher approval threshold (i.e., two-thirds majority), and non-balloted funding mechanisms rarely generate the necessary revenue.

For these reasons, it is recommended that the balloted property-related fee be considered as the primary option to move forward. However, other options should not be discarded. Establishing additional revenue sources can lessen the burden on ratepayers, making a portfolio approach with multiple revenue sources the most practical strategy.

Features

- Requires ballot proceeding. A 50% majority is required, with each parcel equal to a vote.
- Must allocate costs in a fair manner, usually documented in a cost of allocation analysis or fee study.
- Revenues can be used for all storm water program costs, including operations, maintenance, capital improvements or equipment, and administration.

Pros

- Common fee mechanism.
- Legally stout.
- Flexible, applicable to any or all storm water expenses.
- Can be used to secure debt.

Cons

- Must be approved in a ballot measure.
- Requires significant community outreach effort.
- Increasing or adding to existing fees is unpopular with property owners.
- Proposition 218 ballot process is unfamiliar to property owners.

15.4.2 Re-alignment

Realignment is the term used to describe how non-balloted-fee revenue can pay for certain storm water functions. This can be achieved through an interpretation of Proposition 218, where property-related fees can pay for all associated activities that support the services provided under those fees. Realignment is most effective when both participating utilities fall within the City's jurisdiction.

The two most common opportunities for realignment involve trash or solid waste collection: Trash load reduction (MS4 Phase 2 Permitting mandate) and street sweeping. The latter is already funded through the City's solid waste fees. Trash load reduction has two cost elements: capital costs for purchasing and installing trash capture devices, and annual maintenance of those devices. The capital costs should be funded through alternative sources, as described above, but the annual maintenance presents a prime opportunity for realignment.

These ongoing maintenance costs to keep trash capture devices clear and operational will be substantial. These costs can justifiably be embedded into the existing solid waste fee mechanism or can be the basis for a stand-alone fee. For example, currently funded positions working to prevent litter throughout the City through various programs and activities benefit the storm water system by keeping debris out and allowing storm water to flow cleanly and properly. These activities are considered refuse collection, and therefore, a fee to fund these activities would not require a ballot measure but would follow same process as the existing solid waste fees.

Similarly, within the sewer fund, City staff perform crucial tasks for both the storm water system and the sanitary system. Environmental Compliance Inspectors educate and work with local businesses and property owners to ensure proper sanitary sewer discharges and protect storm water from contaminants. Inspectors also help eliminate sanitary sewer overflows by identifying and correcting illicit connections to both storm water and sanitary sewer systems. Maintenance workers prepare for wet weather by cleaning creeks and storm drains to prevent clogs and ensure storm water does not flow into the sanitary sewer system. Additionally, staff maintain storm drainage conveyance systems to help prevent flooding and keep storm water out of the wastewater collection system.

These activities are also considered refuse collection, and therefore a fee to fund them would not require a ballot measure but would be subject to the same process as the existing solid waste fees. This realignment approach ensures that critical storm water management activities receive sustainable funding without necessitating voter approval, thereby streamlining operations and enhancing service delivery.

Features

- If costs are added to the existing solid waste fee mechanism, they could be included at the next rate setting process.
- If costs are the basis for a stand-alone fee, rate setting must follow the same Proposition 218 process as the existing solid waste including the following:
    - Mailed notice of public hearing to all rate payers.
    - Conduct public hearing on proposed rates.
    - A majority protest can stop the rate setting process.
- Revenues can be used for all associated trash load reduction costs, including operations, maintenance, capital improvements or equipment, and administration.

Pros

- Common fee mechanism (similar to water and sewer rate setting).
- Balloting not required for refuse collection enterprise.
- Legally sound.
- Flexible, applicable to any or all expenses.
- Can be used to secure debt.

Cons

- Increasing or adding to existing fees is unpopular with property owners.
- Requires significant community outreach effort.
- Likely limited to only funding trash-related activities.
- Few examples of a stand-alone fee for trash and litter in waterways.

15.4.3 Regulatory Fees

Regulatory fees are charged for specific services requested by the public and typically appear in a city's master fee schedule. In context to storm water activities, these fees generally cover plan reviews, plan checks, site inspections, and related administrative and enforcement activities. Under Proposition 26, regulatory fees are limited to cost recovery only. This means that fee amounts must correspond directly to the actual cost of providing the service; they cannot be used to cover other operations, maintenance, or capital expenses. Therefore, conducting a rigorous cost-of-service study is recommended. Municipalities should closely examine all costs associated with regulating private properties under the MS4 program, such as plan checks, construction inspections, and ongoing certification of structural BMPs.[45]

A review of the City's Comprehensive Fee Schedule revealed that fees for construction inspections, annual inspections for MS4 compliance, and storm water plan review and plan checks for new development and encroachment activities are already in place. Since there is no actual storm water utility at this time, these fees may present a conflict between the source of the revenue and its allocation to the appropriate division. If a storm water utility were formed in the future, care should be taken to ensure that revenues for these activities are allocated to the appropriate divisions that pays for the resource.

Features

- A cost-of-service study is recommended to validate the amount of the fees and compliance with Proposition 26.
- Adoption by governing board.
- Usually included in a municipality's master fee schedule.
- Limited to cost recovery only.

Pros

- Balloting not required.
- Legally stout.

[45] BMP is an acronym that stands for best management practices. In the context of the MS4 Permit, BMPs are specific measures set forth in the permit and various guidance documents. Structural BMPs refer to permanent treatment controls such as bioswales, rain gardens, and retention/detention facilities.

Cons

- Can only cover the cost of regulation; cannot cover costs of operations, maintenance, or capital expenses.
- Collecting inspection fees for post-project structural BMPs is difficult as the property owner has no more permits to obtain.

15.4.4 Opportunistic Options

There are two primary types of opportunistic options to watch for: grants and partnerships. While the City may not want to rely heavily on opportunistic options when designing a financial system or rate structure, staying informed about these opportunities and utilizing them as much as possible is beneficial.

15.4.4.1 Grants

Grant funding is typically applied to capital projects, although it can occasionally support other programmatic activities. Historically, grants for storm water projects have been rare but are becoming more common. It is worth noting that grants often come with other financial requirements such as matching funds or obligations for post-project maintenance. For these reasons, an underlying revenue stream (e.g., user fee) is crucial to leverage these opportunities effectively.

- Grants
    - As one-time money, they can be very useful for funding projects or programs as applicable or available.
    - They cannot be relied upon for dedicated and sustainable revenue.
    - They typically require matching funds and post-project obligations for additional operations and maintenance activities and costs.

15.4.4.2 Partnering

Partnerships, particularly in multi-benefit projects such as street improvements, are another valuable funding option. In such projects, transportation funding can help pay for storm water facilities such as pipeline upgrades or installation of green infrastructure. If storm water features cannot be paid for by the primary funding source, other efficiencies can make these storm water elements more cost-effective compared to stand-alone projects. These efficiencies can include avoiding costs related to project mobilization, management, demolition, surface restoration, or leveraging existing design and construction resources.

Partnering opportunities are most effective when the storm water elements are integrated at the project's inception – during the concept and planning phases. This requires storm water staff to be involved early and consistently during the CIP planning process. Below is a summary of why various funding mechanisms are not suitable for funding MS4 tasks. These are categorized into

two groups: those that may be applicable as opportunities arise and those that are not applicable or practical.

15.4.4.3 Development (Impact or In-Lieu Fees)

The City's fees include cost share projections for capital projects associated with new development. These fees and share of costs have been accounted for within the adjusted Capital Improvement Plan. Cost share from future development is estimated to account for $63.8 million of the full $180 million Capital Improvement Plan.

15.4.4.4 General Obligation Bonds

General Obligation (GO) bonds are well-known to the voting public and require a two-thirds majority for approval. These bonds are issued to raise funds upfront and are repaid through a tax levied against property on the annual property tax bill. A primary restriction on GO bonds is that they can only be used for capital projects, including land acquisition, planning, design, and construction. However, the costs for maintenance and operations cannot be paid from the bond proceeds.

The installation cost of trash full capture systems required for MS4 compliance is $47 million – a very substantial amount. Utilizing GO bonds for this purpose is appropriate as these bonds are limited to capital projects. GO bonds allow the City to take advantage of typically lower interest rates than other debt mechanisms, and spread the financial burden over time, making it more manageable for taxpayers. This funding mechanism allows for the immediate implementation of necessary infrastructure improvements, avoiding an imbalance in debt service to user fee revenue, if user fees were programmed to serve as the source of repayment.

However, repaying bonds require a dedicated and sustainable revenue stream equal to the cost of servicing the bonds. The extremely high cost burden mandated by the SWRCB requirements for timely installation of full trash capture system presents a very significant challenge to achieving the necessary two-thirds voter approval.

15.5 Other Revenue Mechanisms – Reasons for Not Considering

- Special Financing Districts (BID or CFD)
  - BIDs and CFDs are typically limited to local neighborhoods or new developments. These are usually formed to cover a variety of costs (not just storm water).
  - They should be considered on a case-by-case basis with storm water costs being part of the discussion.
- EIFD
  - EIFDs are not authorized to fund operations and maintenance activities.
  - The effort to study and implement an EIFD takes considerable resources.
  - An EIFD is geared toward self-improving an area, and MS4 tasks do not usually directly support that objective.

- If an EIFD is considered, MS4 activities including drainage and watershed management and green infrastructure should be included as appropriate.

15.5.1 Senate Bill 231

Senate Bill 231 (SB 231) could be a significant game-changer by eliminating the voter-approval requirement for storm water fees. SB 231, signed by Governor Brown in 2017, changed the Government Code by providing a definition for sewer that includes surface waters. In doing so, it opens the door to classifying fees for the storm water activities as a type of sewer fee and would therefore be exempt from voter approval. Based on that, a municipality could move forward to establish a storm water fee without a ballot measure.

However, classifying storm water activities as a sewer fee to avoid voter approval would involve significant risks. Prominent taxpayers' organizations object to the premise of SB 231 citing legislative limits on amending the State constitution (such as Proposition 218). As a result, any municipality that proceeds down that path can expect a legal challenge and possibly become a test case for the constitutionality of SB 231. In response to that likelihood, Senator Hertzberg (sponsor of SB 231) has created a working group to help interested municipalities move forward strategically in an effort to shape any test case in a way favorable to intent of SB 231.

Based on this, it is currently advised for municipalities, including the City, to not use the SB 231 path, but rather to move forward with a ballot measure.

15.5.2 Special Taxes

The two-thirds voter requirement for a Special Tax make this approach impractical for MS4-related activities.

15.5.3 Benefit Assessments

Any general benefits must be funded by other sources such as the General Fund. Storm water services are more suited for a property-related fee instead of benefit assessment.

16.0
Preliminary Rate Structure and Recommendations

16.0 PRELIMINARY RATE STRUCTURE AND RECOMMENDATIONS

Around the Country, a storm water utility is the term used to describe a governmental entity that provides a specific set of services within a defined geographical area, funded through a user fee structure. This is similar to water and sewer utilities, where the average property owner is accustomed to paying monthly or annual bills for those services. In California, municipalities often use the term "enterprise fund" to describe this setup, where revenues are kept separately from the municipality's general fund and other special funds, and user fees are used strictly for the designated services.

Proposition 218 provides additional clarity for such utility fees under Article XIIID, Section 6 of the California Constitution, which governs property-related fees. Key requirements include:

- Property-related fees must be used only for their stated purpose.
- Costs to be apportioned in a fair and reasonable manner.
- Municipalities cannot collect more revenues than necessary to provide the service.
- New or increased property-related fees must be approved by property owners through a ballot proceeding.

This ballot requirement has proven to be a significant hurdle throughout the State. Since 2002, fewer than 30 property-related fees have been submitted to voters with approximately one-third of those attempts have failed at the ballot box. **Table 48** lists recent examples of these attempts.

Table 48: Recent Stormwater Fee Ballot Measures

Agency	Year	Annual Amount	Type	Support Level
City of San Mateo	2024	$ 96	Fee	52%
City of Manhattan Beach	2024	$ 129	Fee	53%
City of Sacramento	2022	$ 207	Fee	52%
Vallejo Flood & Storm	*2022*	*$ 54*	*Fee*	*32%*
City of Davis	2021	$ 157	Fee	61%
City of San Bruno	*2021*	*$ 154*	*Fee*	*36%*
City of Alameda	2019	$ 129	Fee	57%
City of Cupertino	2019	$ 56	Fee	51%
City of Los Altos	*2019*	*$ 88*	*Fee*	*44%*
City of Berkeley	2018	$ 96	Fee	61%
Los Angeles County	2018	$ 83	Tax	69%
Town of Moraga	*2018*	*$ 120*	*Fee*	*48%*
City of Palo Alto	2017	$ 164	Fee	64%
City of Culver City	2016	$ 99	Tax	74%

NOTE: Brown font indicates a failed ballot measure

A storm water utility may also consider other revenue mechanisms, such as taxes. While taxes do not have the same strict requirements as property-related fees, they generally require a two-thirds majority voter approval.

In this section, the discussion will focus on the typical process required to establish a new storm water utility, estimating rate levels for the City's storm water program needs, looking at various funding options, discussing the importance of community involvement, and making recommendations for moving forward.

16.1 Process of Forming a Storm Water Utility

There are three primary procedural steps in forming a new storm water utility: 1) understanding your needs; 2) preparing a rigorous rate study; and 3) implementing a revenue mechanism. On a parallel track, community engagement and education steps are equally important. These two tracks run parallel and are illustrated in **Exhibit 58** below, with the procedural steps in green (left) and the community engagement in blue (right).

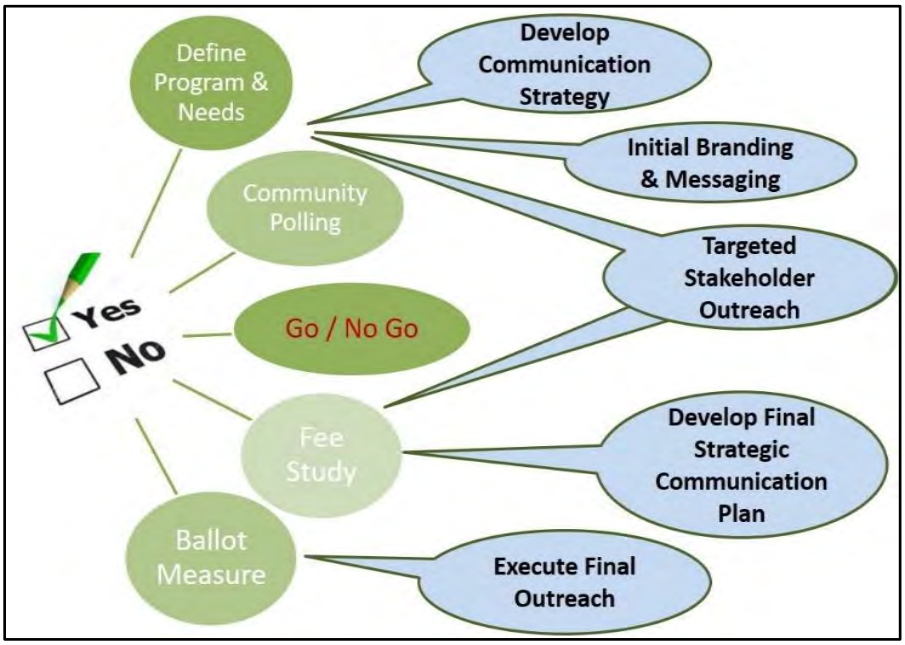


Exhibit 58: Parallel Tracks to form a Storm Water Utility

16.1.1 Understanding Your Needs - Overview

Any successful effort requires thorough preparation, including the following key components:

- Storm Drain Infrastructure Needs: Develop an up-to-date storm drain master plan, asset management plan, watershed management plan, and/or other needs analysis on the

capacity, condition, trouble spots, and projected needs for operations, maintenance, and capital projects.

- NPDES Permit Compliance: Evaluate the current and future needs of the City's NPDES Permit requirements.
- Organizational Review: Assess how the City's storm water program is structured within the organizational and financial frameworks. This review can identify areas for improvement and ensure alignment with the City's goals.
- Financial Analysis: Flowing from or included in a master plan or asset management plan, this analysis identifies costs required to meet infrastructure and regulatory needs.

Another important aspect of knowing your needs is engaging with the community. Since any revenue mechanism ultimately requires voter approval, it is important to assess community priorities early in the process. The four bullet points above will help define the City's needs, alignment with community priorities is essential for a successful ballot measure. Two early steps can help gauge community's priorities: stakeholder outreach and community-wide opinion survey.

The City of Chico's current effort to update its storm drain master plan is a major step in quantifying system needs and associated costs. The updated master plan ensures that known system needs are validated and all deficiencies have been identified to the extent possible. Given that NPDES Permit requirements have escalated significantly in the past 20 years, the updated master plan provides the City with a solid understanding of system costs in the current regulatory landscape. By completing the Capital Improvement Program and master plan update prior to bringing the funding proposal to the community, the City will bolster both its understanding of system needs and the community's confidence in the City's planning and preparation.

Completion of the master plan update and financial needs will enable the City to make informed decisions about which direction to proceed. These important steps demonstrate to the community that the City has done its "homework" by thoroughly understanding its needs and evaluating its options. This analysis provides a roadmap of how the City might navigate all the necessary steps toward establishing a storm water utility and includes specific recommendations to help it become prepared.

16.2 Process of Forming a Storm water Utility

To estimate user rates for a property-related fee mechanism, two main elements are considered: 1) Financial needs and revenue requirements; and 2) Apportionment of those costs across the various parcel types in compliance with Proposition 218.

Financial Needs and Revenue Requirements:

- Annual Revenue Calculation: Convert the financial needs into to an annual revenue requirement. This calculation must account for other revenue sources such as gas taxes, developer contributions, transfers from other internal funds, alternative revenue sources, and potential one-time contributions like grants.

- Capital Improvement Financing: Consider the financing method for large capital improvement needs. The two primary options are:
    - Pay-as-You-Go ("PayGo"): Projects are built as funds are accumulated.
    - Debt Financing: Funds are obtained upfront to build the projects early, with the debt paid off over time. In this case, the debt service payments replace actual CIP costs in the annual revenue requirement calculation.
    - Hybrid Approach: A blend of PayGo and debt financing can also be considered based on the specific needs and financial strategy of the City

Apportionment of Costs:

- Compliance with Proposition 218: Ensure that the apportionment of costs is fair and reasonable across the various types of parcels. Proposition 218 mandates that fees be used only for their stated purpose and that no more revenue is collected than necessary to provide the service.
- Cost Distribution: Apportion the costs in a manner that reflects the benefit received by each parcel type. This involves detailed analysis and equitable distribution methodologies to ensure compliance and fairness.

Additional Considerations:

- Engagement and Transparency: Engage with the community to explain the financial needs, proposed rates, and benefits of the storm water utility. Transparency in the calculation and apportionment process is crucial for gaining public support.
- Rate Study: Conduct a rigorous rate study to support the proposed fee structure. This study should include detailed financial analysis, cost distribution models, and compliance checks with Proposition 218.
- Flexibility in Planning: Be prepared to adjust the financial strategy based on feedback from stakeholders and changing circumstances. This might involve revisiting the PayGo versus debt financing decision or adjusting the apportionment methodology.

By following these steps and considering the outlined elements, the City can establish a storm water utility that meets financial needs, complies with legal requirements, and gains community support.

16.3 30-Year Revenue Model

Due to the relatively large CIP, a 30-year model was used. This planning horizon allows for evaluation of long-term debt options, which can help smooth the rate impacts while enabling timely delivery of major projects. The model was designed to include a utility fund reserve equal to 20-30% of the annual operating expenditures to ensure financial stability.

The goal of the model is to complete the full CIP within the 30-year period. Several scenarios were developed, incorporating all three tiers of the adjusted CIP (Table 4) and different balances of debt versus PayGo financing. Recent sensitivity analyses indicate that incorporating debt does not significantly increase rate levels, with increases of 2% to 3%.

The graphic below illustrates a 30-year projection of revenues (dark blue bars) against three types of expenditures: O&M, PayGo, and debt service. The depicted scenario in **Exhibit 59** below requires an initial revenue of $3.55 million and funds the $33 million CIP through a combination of $25 million in 30-year debt with the remainder through PayGo. A lower debt level would not decrease the overall expenditures significantly; it would primarily trade the debt service (light blue) area for the PayGo (green) area. The primary difference with a lower debt level would be a substantially slower delivery of capital projects.

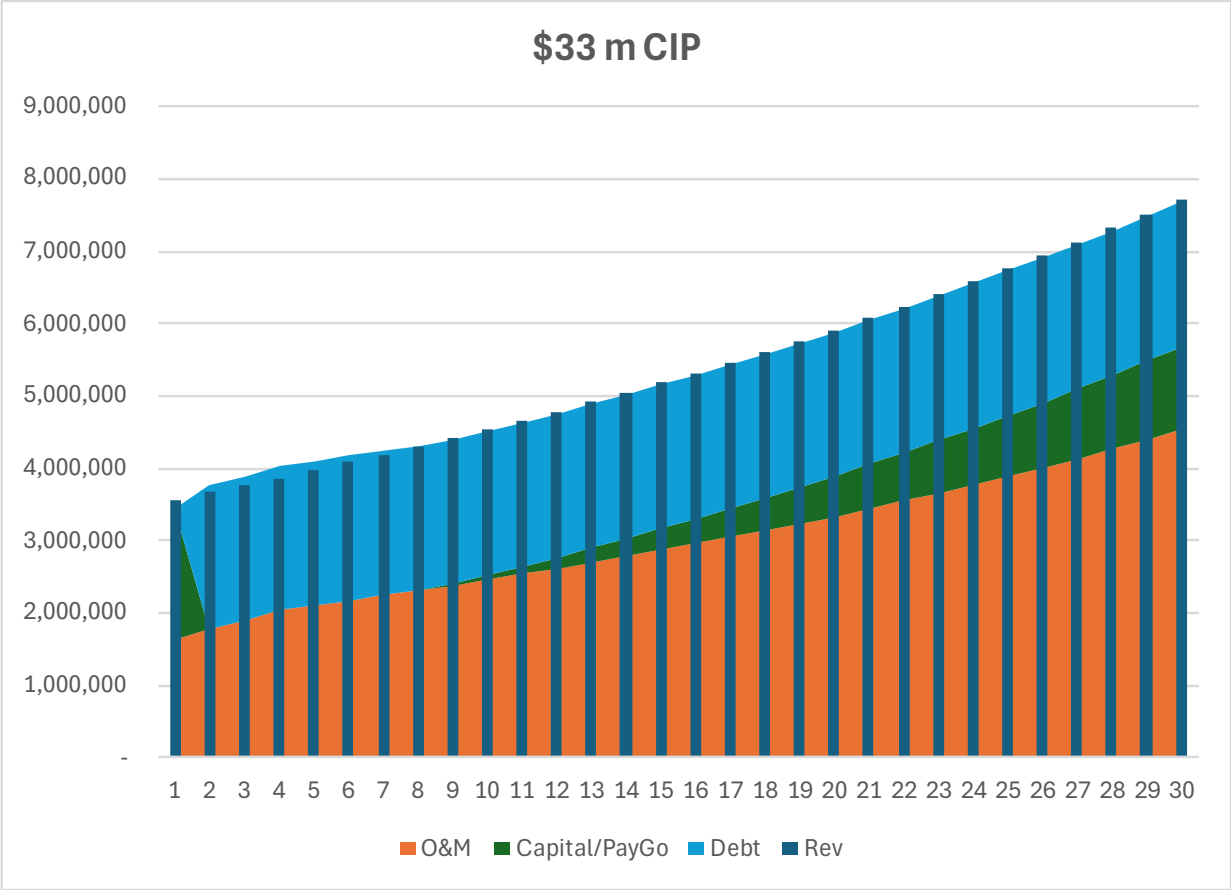


Exhibit 59: Revenue and Expenditures

Table 49 below shows the net costs – and revenue requirement – for FY 25, the initial year of the 30-year model.

Table 49: FY 25 Revenue Requirement	
Description	**FY 25 ($1,000s)**
Baseline Costs	$ 1,221
Additional Needs	$ 405
Subtotal Operating Costs	*$ 1,626*
Capital Improvement Program*	$ 2,082
Total Revenue Requirement	**$ 3,708**

**CIP is amortized over 30 years*

This revenue model makes several assumptions:

- Revenues are not ramped up in the early years; they are set only to escalate at a rate equal to the Consumer Price Index (assumed to average 2.7% annually).
- Expenses escalate at 3.1% annually.
- CIP project costs escalate 2.9% each year that they are not built (remaining balance on CIP).

16.4 Rate Calculation

Storm water utility rates are typically, and appropriately, based on average impervious area per property type of each parcel of land. While the specific approach and unique features can vary among municipalities and rate study professionals, the benchmark for user rates is the average single-family home, defined here as the single-family equivalent[46] (SFE). Other types of land uses are calculated based on a multiplier of the SFE. A rate study will sum the SFEs for all parcels within the municipality, and then divide the annual revenue requirement by that number to arrive at the SFE rate.

A preliminary survey of parcels in the City of Chico has been conducted and estimates the following:

- 31,327 parcels within the City and Special Planning Areas
- ~ 31,170 eligible to be charged a fee[47]
- ~ 41,500 SFEs

Assuming an annual revenue requirement of $3.55 million[48] , the annual SFE rate is expressed as:

[46] Other names for this metric are the equivalent residential unit (ERU) or drainage measurement unit (DMU).
[47] Some parcels may not be charged a fee based on the land use or conditions of the soil.
[48] Based on a five-year accumulative total escalating at 3% per year.

$$SFE\ Rate = \frac{Annual\ Revenue\ Req't}{Total\ SFEs}$$

$$= \frac{\$3,708,151}{41,500}$$

$$= \$89 \text{ per Year}$$
$$(= \$7 \text{ per Month})$$

This is a planning level estimate that could vary by 10% to 20%. It is worth noting that $89 per year (or $8 per month) is in the moderate range for municipalities in California. **Table 50** contains a list of adopted storm water rates for various cities in the State.

Table 50: Adopted Storm Water Rates

Municipality	Annual	Type of Fee
Alameda	$ 134	Property-Related Fee
Bakersfield	$ 200	Property-Related Fee
Culver City	$ 99	Special Tax
Davis	$ 85	Property-Related Fee
Elk Grove	$ 70	Property-Related Fee
Hayward	$ 29	Property-Related Fee
Los Angeles	$ 27	Special tax
Los Angeles County	$ 83	Special tax
Manhattan Beach	$ 129	Property-Related Fee
Palo Alto	$ 164	Property-Related Fee
Redding	$ 16	Property-Related Fee
Sacramento (City)	$ 136	Property-Related Fee
Sacramento (County)	$ 70	Property-Related Fee
San Bruno	$ 46	Property-Related Fee
San Clemente	$ 60	Property-Related Fee
San Jose	$ 92	Property-Related Fee
San Mateo	$ 96	Property-Related Fee
Santa Cruz	$ 109	Special Tax
Stockton *	$ 221	Property-Related Fee
Vallejo Sanitation and Flood	$ 24	Property-Related Fee
West Sacramento	$ 144	Property-Related Fee
Woodland	$ 6	Property-Related Fee

** This is the calculated average rate for the City of Stockton, which has 15 rate zones with rates ranging from $3.54 to $651.68 per year.*

Strategies for lowering the annual fee level closer to the $50 level should be considered. These could include continuing the financial support from the Gas Tax Fund, reducing CIP costs, or

phasing in the rates over a period of time. Evaluating these and other strategies will be discussed below.

16.5 Rate Calculation

As noted earlier, there are two parallel tracks recommended for a successful funding initiative: procedural and community engagement. A robust community engagement process is critical to the success of any storm water program for two basic reasons: community members often do not understand how their storm water infrastructure and pollution prevention program are important to their quality of life; and since a ballot measure will ultimately determine the success of the funding initiative, informing and involving the community from the beginning is crucial.

The California Stormwater Quality Association's website offers excellent resources on community engagement. Key highlights include the following:

- Start with "Why:" Clearly communicate the reasons for support and funding. Emphasize issues such as aging infrastructure with deferred maintenance, local flooding that can be addressed, and environmental concerns that resonate with the community.
- Branding: Educate the community about the storm water program's role and importance. Effective branding helps disseminate this message, ideally well BEFORE soliciting support for a funding initiative.
- Public Opinion Survey: Conduct opinion surveys as part of both the procedural and community engagement tracks. Opinion surveys can be conducted in multiple, iterative steps with early versions surveying for general community priorities (e.g., public safety, traffic, roads, and environmental issues) to understand where stormwater concerns rank. Later surveys can focus on specific storm water program elements and assess the community's willingness to pay.
- Stakeholder Outreach: Engage stakeholders and opinion leaders early in the process. Their feedback is valuable and makes them invested in the program's direction. Continued stakeholder involvement can reinforce support and strengthen community ties.
- Community Outreach: Implement general outreach efforts such as mailers, social media campaigns, and town hall meetings. These activities typically occur later in the process once the funding initiative is more defined, and fees are relatively set.

Any Proposition 218 process necessarily includes two direct mailings to the voting community at large: a notice of the proposed fees and public hearing; and a mailed ballot packet. These communications are essential and occur near the end of the process, often perceived as "bad news" because they request approval for a new fee. Therefore, it is advantageous if the community is already familiar with the storm water program, understands its community importance, and has had some objective interaction with the City before reaching this critical stage. Early and ongoing engagement helps build awareness and support, making the final request for approval more likely to succeed.

16.6 Recommendations and Next Steps

This analysis inventories the City's current levels of service and associated costs for a storm water utility. It then forecasts those costs using a 30-year model, leveraging information gathered from City staff and the consultant team's expertise in financial forecasting and MRP requirements. This analysis forms a solid foundation for the next step: developing a communication strategy and conducting a community opinion survey. These and subsequent steps should be conducted with a focus on the ultimate goal of forming a storm water utility and establishing a dedicated, sustainable revenue stream.

16.6.1 Communication Strategy

Prior to conducting a survey, the City should develop a strategic communication plan that includes several key elements:

- Identify Primary Stakeholders and Open a Dialogue: Early input from stakeholders can help formulate effective messaging strategies. This can range from selected individuals to existing groups to the formation of a blue-ribbon committee. This process could also include study sessions by the City Council or relevant committees.
- Begin Branding the Storm Water Program: Use existing media channels to inform the community about the extent and value of the storm water program. Branding is intended to raise awareness without discussing the potential revenue measure. This can be achieved through periodic articles in the newsletters and on the City's website and social media platforms.
- Develop Messaging Elements for Testing: Create messaging components that can be evaluated through a community opinion survey. Testing these elements will help refine the communication strategy and ensure it resonates with the community.

16.6.2 Community Opinion Survey

Most successful ballot measures are preceded by statistically valid opinion surveys. Well-crafted surveys can scientifically calibrate several key metrics simultaneously:

- Community values and priorities
- Effectiveness of messaging strategies
- Willingness to pay for various levels of service

As the nation recovers from the COVID-19 pandemic, measuring a community's position on all these elements is more important than ever. Public opinion may have shifted significantly, and what civic leaders previously understood may no longer be accurate in a post-COVID world. Conducting a survey not only provides the City with valuable insights but also serves as an opportunity to introduce and reinforce the storm water program's "brand" within the community, marking a crucial early step in the overall process.

16.6.3 Strategies for Right-Sizing the Rates

As noted above, storm water rates sufficient to fund the full cost of the program could be as high as $8 per month for the typical home – a moderate amount compared to other municipalities in the State. However, obtaining voter approval for this cost may be challenging. The community survey provides an opportunity to test the community's cost-indexed priorities. In other words, the survey could test multiple rate scenarios, each paired to their respective levels of service or improvements.

To assist in this exercise, the cost components are presented as scenarios based on the amount of CIP funding, as shown in **Table 51** below:

- Scenario 1 - the Full Enterprise includes operating costs, additional operating needs, and all capital projects in the Adjusted Capital Improvement Program from Table 4.
- Scenario 2 - the operating costs, additional operating needs, and high priority capital projects from Table 4.

The monthly rate components corresponding to each scenario are shown on the right side of the table.

Two rate scenarios have been developed and are summarized below.

- $7.13 per month – This scenario is the full rate that includes all identified costs and services.
- $4.81 per month – This scenario reduces the revenue requirement by eliminating the lower priority projects recommended in the 2024 Storm Drain Master Plan (Tier 2 & Tier 3)

Scenario 2 represents a reasonable level of service that can be responsibly recommended. It would fund current operations, additional operational needs, and high-priority capital projects while deferring non-priority and Tier 2 capital projects.

Table 51: Right-Sizing the Rates

Scenario	FY 25 Fee Revenue	Additional O&M Needs	Tier 1 CIP	Tier 2 CIP	Tier 3 CIP	FY 25 Total Budget	Monthly Rate
1 Full Enterprise	$ 3,548,250	$ 404,533	$ 8,113,148	$ 22,980,637	$ 1,785,163	$ 3,708,151	$ 7.13
2 O&M + High Priority	$ 2,396,625	$ 404,533	$ 8,113,148			$ 2,396,625	$ 4.81

Other strategies could include pursuing supplemental revenue streams as identified above. Most of these initiatives can (and should) move forward independently of the storm water utility funding initiative. Any additional revenue generated will help reduce the user rates needed to fund the storm water utility. These strategies include:

- Additional regulatory fees (plan review, inspections, etc.)
- Additional re-alignment opportunities
- Grants
- Partnering

16.6.4 Timeline

A detailed timeline cannot be formulated at this early stage. However, the City may want to allow for at least 18 months to complete the process. The preliminary timeline in **Exhibit 60** below shows an aggressive schedule, which could easily extend longer depending on factors such as time spent making policy decisions, additional public engagement, or calendar conflicts (e.g., general elections, holiday seasons).

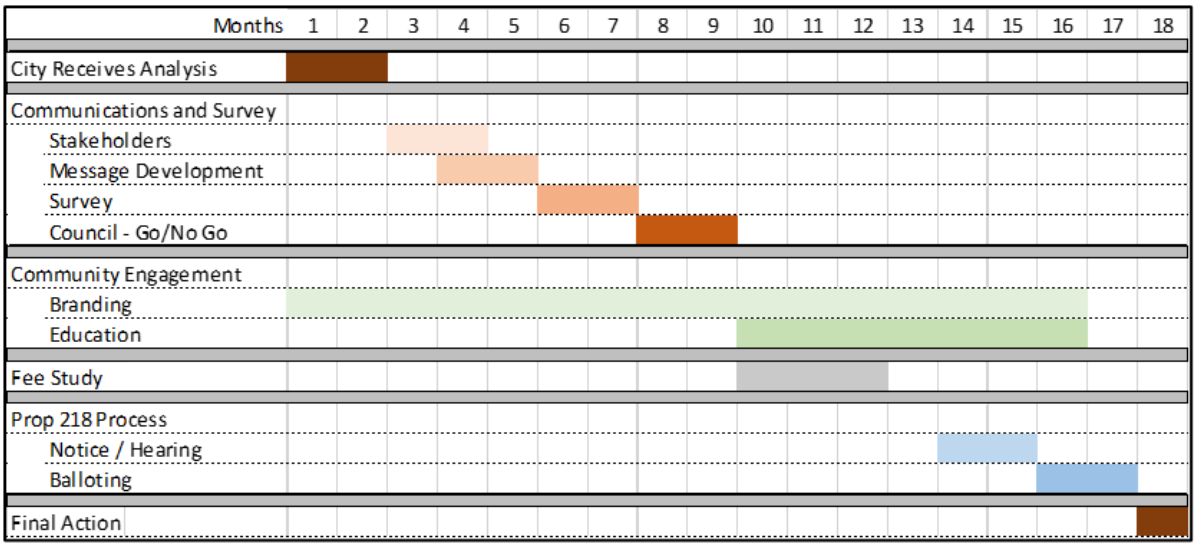


Exhibit 60: Generalized Proposition 218 Process Timeline

17.0
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Figures

VICINITY MAP

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 0.5 1 2

Miles

Legend

- NHD Flowline
- Watershed (HUC-12)
- City Limits

PROJECT LOCATION MAP

SOURCES:
Flowlines and Watersheds:
USGS National Hydrography Dataset (NHD)

Hydrological Unit Code (HUC)

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FIGURE 1

STUDY AREA

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 10,000 20,000 40,000

Feet

Legend

- Streams
- In-City Tributaries
- SPFC Levees
- Sphere of Influence
- Little Chico Creek and Butte Creek Watersheds
- Big Chico Creek, Mud Creek, and Rock Creek Watersheds
- Study Area Regional Watersheds

SOURCES:

Stream Lines:
Central Valley Hydrology Study (CVHS), Central Valley Floodplain Evaluation and Delineation Program (CVFED), Chico SWMP

Watersheds:CVHS

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FIGURE 2

USGS TOPOGRAPHIC MAPPING

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 3,000 6,000 12,000

Feet

Legend

Sphere of Influence

Chico

WOOD RODGERS

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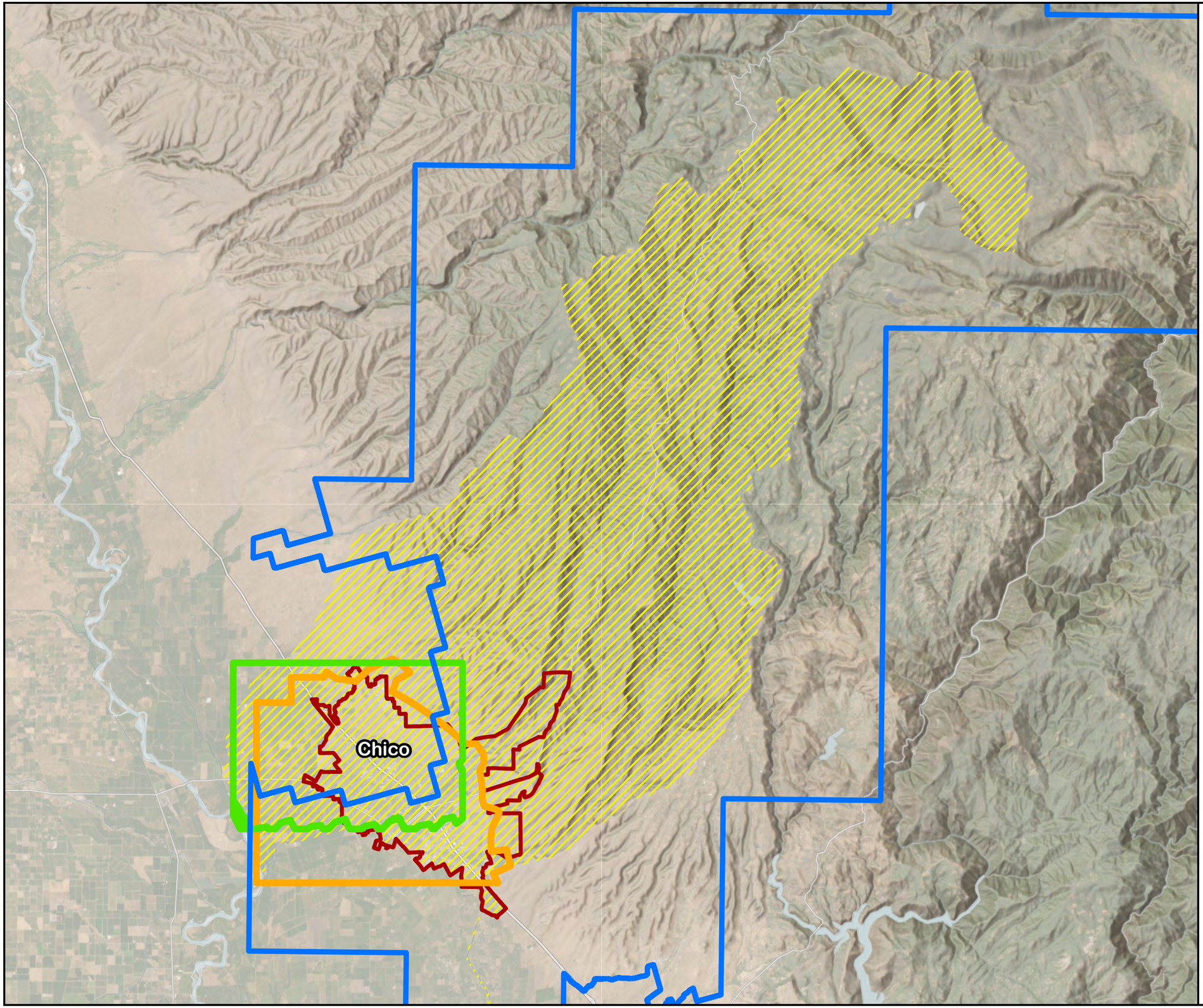
FIGURE 3

LIDAR DATA AVAILABILITY

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024



NORTH

0 10,000 20,000 40,000

Feet

Legend

- Sphere of Influence
- Study Area Regional Watersheds
- 2008 DWR CVFED LiDAR
- USGS Lidar Point Cloud CA FEMA-R9-Keefer 2017
- USGS Lidar Point Cloud CA NoCAL Wildfires B2 2018

SOURCES:
LiDAR Data: California Department of Water Resources/ Central Valley Flood Evaluation and Delineation Program, 2008; USGS LiDAR Point Cloud, 2017 and 2018

Watersheds: CVHS

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FIGURE 4

FEMA SPECIAL FLOOD HAZARD AREAS

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2,500 5,000 10,000

Feet

Legend

- Streams
- Levee
- City Limits
- Sphere of Influence

Flood Hazard Zone

- A
- AE
- AH
- AO
- Floodway

SOURCES:

Floodplains: National Flood Hazard

Layer Flowlines: NHD

WOOD RODGERS

Esri, NASA, NGA, USGS, FEMA, Maxar

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FIGURE 5

FEMA FLOW RATE CHANGE LOCATIONS

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2,500 5,000 10,000

Feet

Legend

- Flow Change Location
- Levee
- Stream Flowline

SOURCES:

Floodplains: National Flood Hazard Layer

Flowlines: NHD

WOOD RODGERS

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FIGURE 6

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

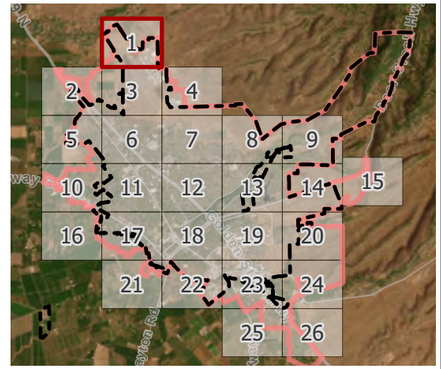
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
2. Many detention basins are modeled as points, but the basins are presented using polygons for illustrative purposes. Pipes cross basins in the schematic because the pipes connect to the point that represents the basin in the model.
3. The line segment lengths shown in the schematic do not necessarily match the modeled or actual pipe lengths.
4. Most storm water quality Best Management Practices (BMPs), such as treatment vaults and dry wells, were not modeled and are not shown on the modeled drainage system. Please refer to the figure presenting Watersheds and BMPs for BMP location information.
5. The 2D Point Sources represent locations where watershed runoff was applied to the drainage model at locations that were not modeled as 1D model points such as drop inlets and detention basins. In many cases, the 2D point sources are at topographic low points. In some cases, the 2D point sources are at drop inlets that are connected to infiltration systems that are not modeled.

FIGURE 7-1

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

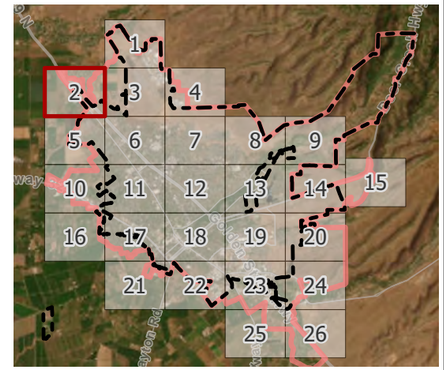
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
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FIGURE 7-2

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

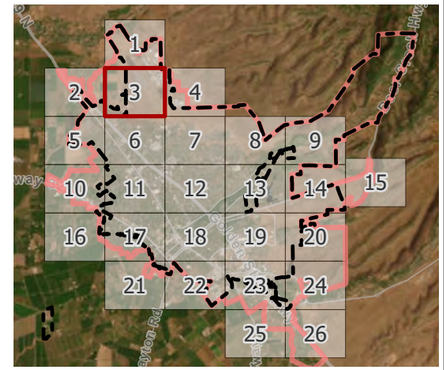
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
2. Many detention basins are modeled as points, but the basins are presented using polygons for illustrative purposes. Pipes cross basins in the schematic because the pipes connect to the point that represents the basin in the model.
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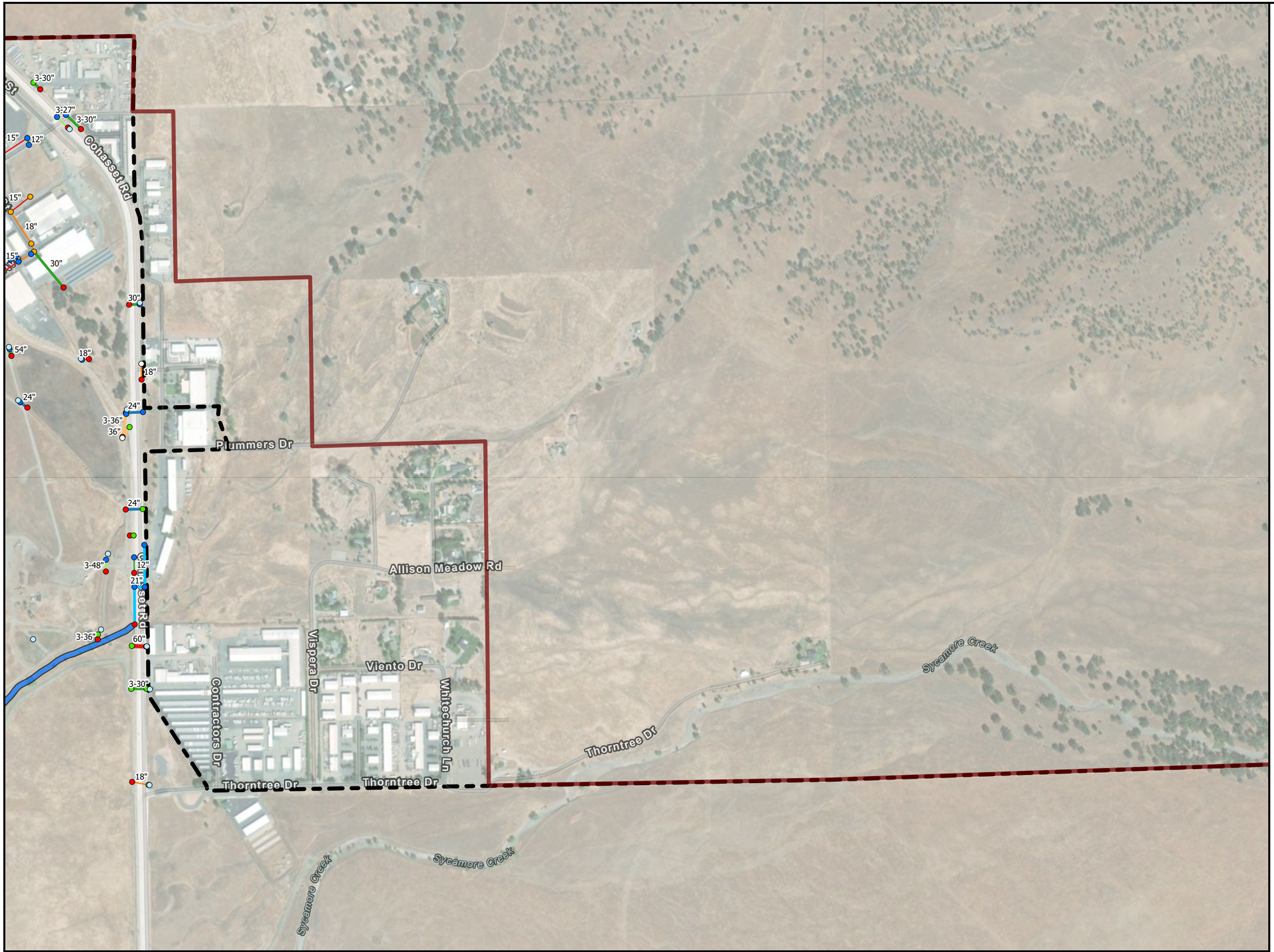
FIGURE 7-3

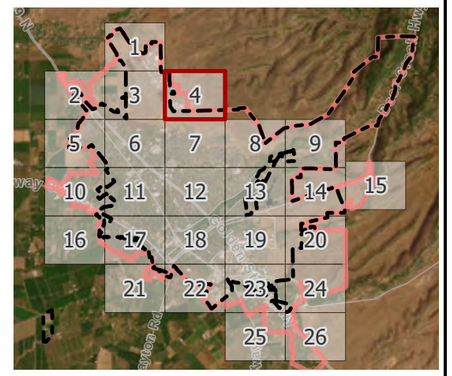
MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024





0 375 750 1,500

Feet

NORTH

- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
2. Many detention basins are modeled as points, but the basins are presented using polygons for illustrative purposes. Pipes cross basins in the schematic because the pipes connect to the point that represents the basin in the model.
3. The line segment lengths shown in the schematic do not necessarily match the modeled or actual pipe lengths.
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FIGURE 7-4

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

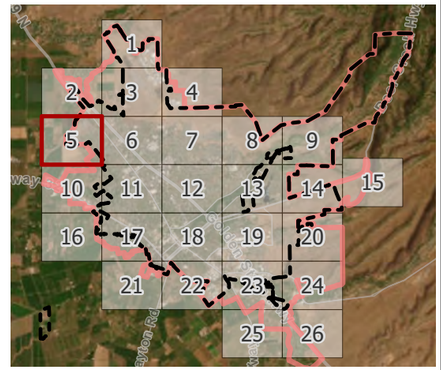
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
2. Many detention basins are modeled as points, but the basins are presented using polygons for illustrative purposes. Pipes cross basins in the schematic because the pipes connect to the point that represents the basin in the model.
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FIGURE 7-5

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

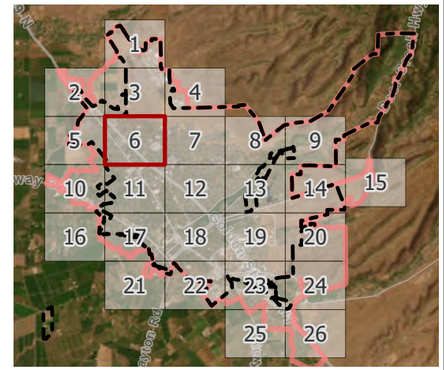
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
2. Many detention basins are modeled as points, but the basins are presented using polygons for illustrative purposes. Pipes cross basins in the schematic because the pipes connect to the point that represents the basin in the model.
3. The line segment lengths shown in the schematic do not necessarily match the modeled or actual pipe lengths.
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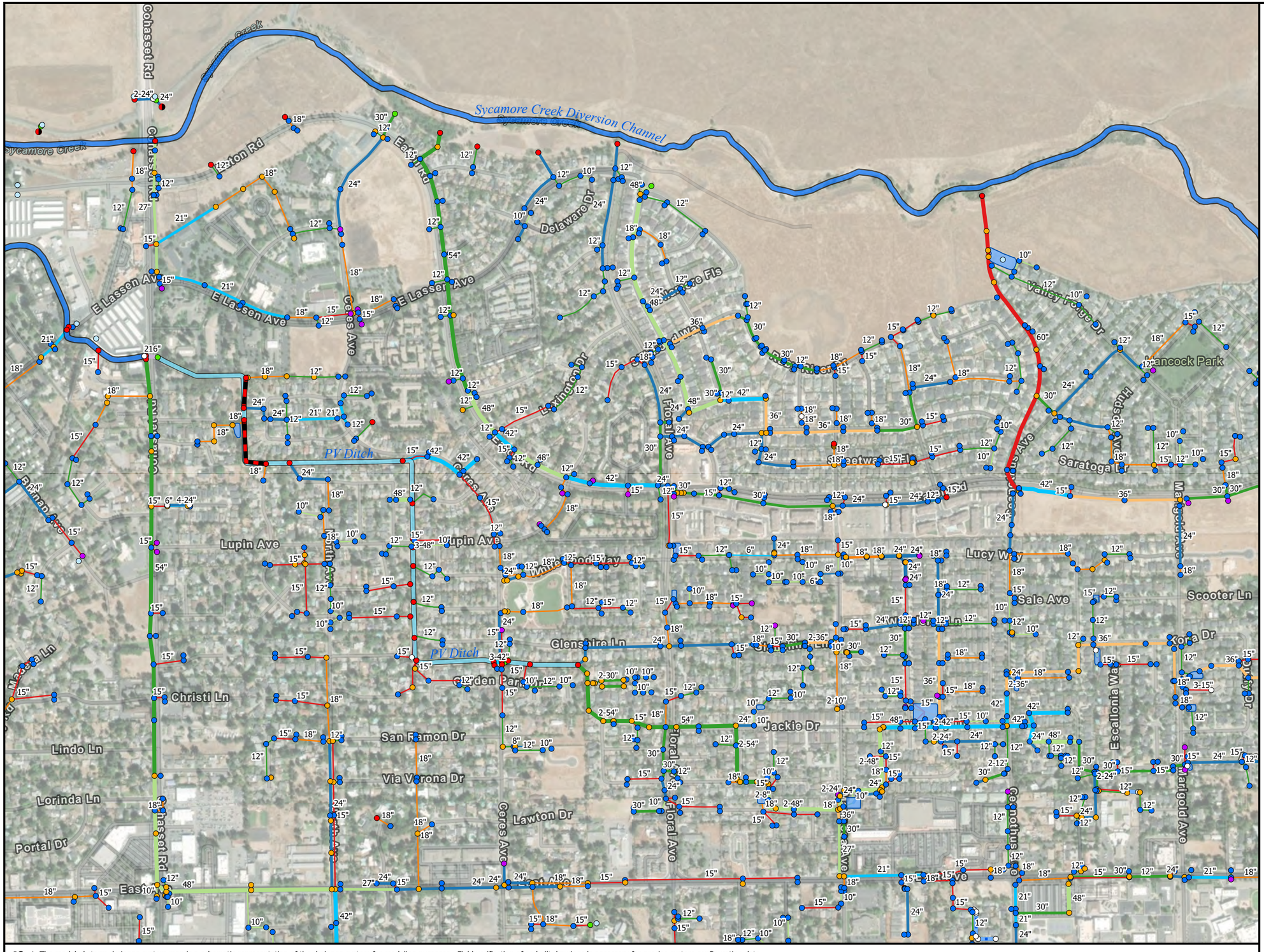
FIGURE 7-6

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

CITY OF CHICO

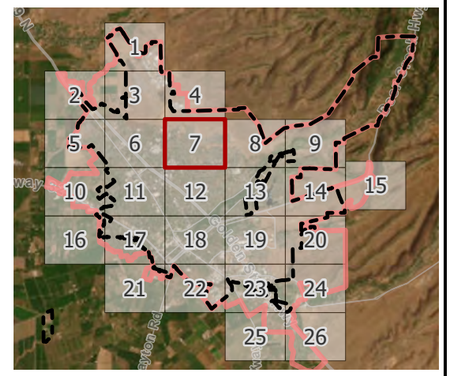
DECEMBER 2024



NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
2. Many detention basins are modeled as points, but the basins are presented using polygons for illustrative purposes. Pipes cross basins in the schematic because the pipes connect to the point that represents the basin in the model.
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FIGURE 7-7

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

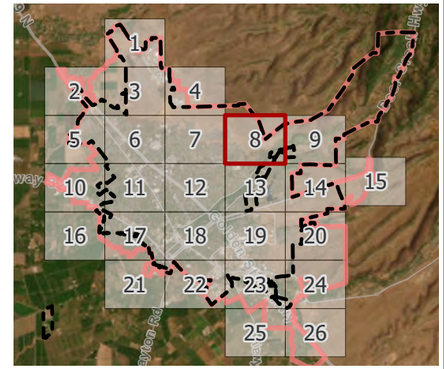
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
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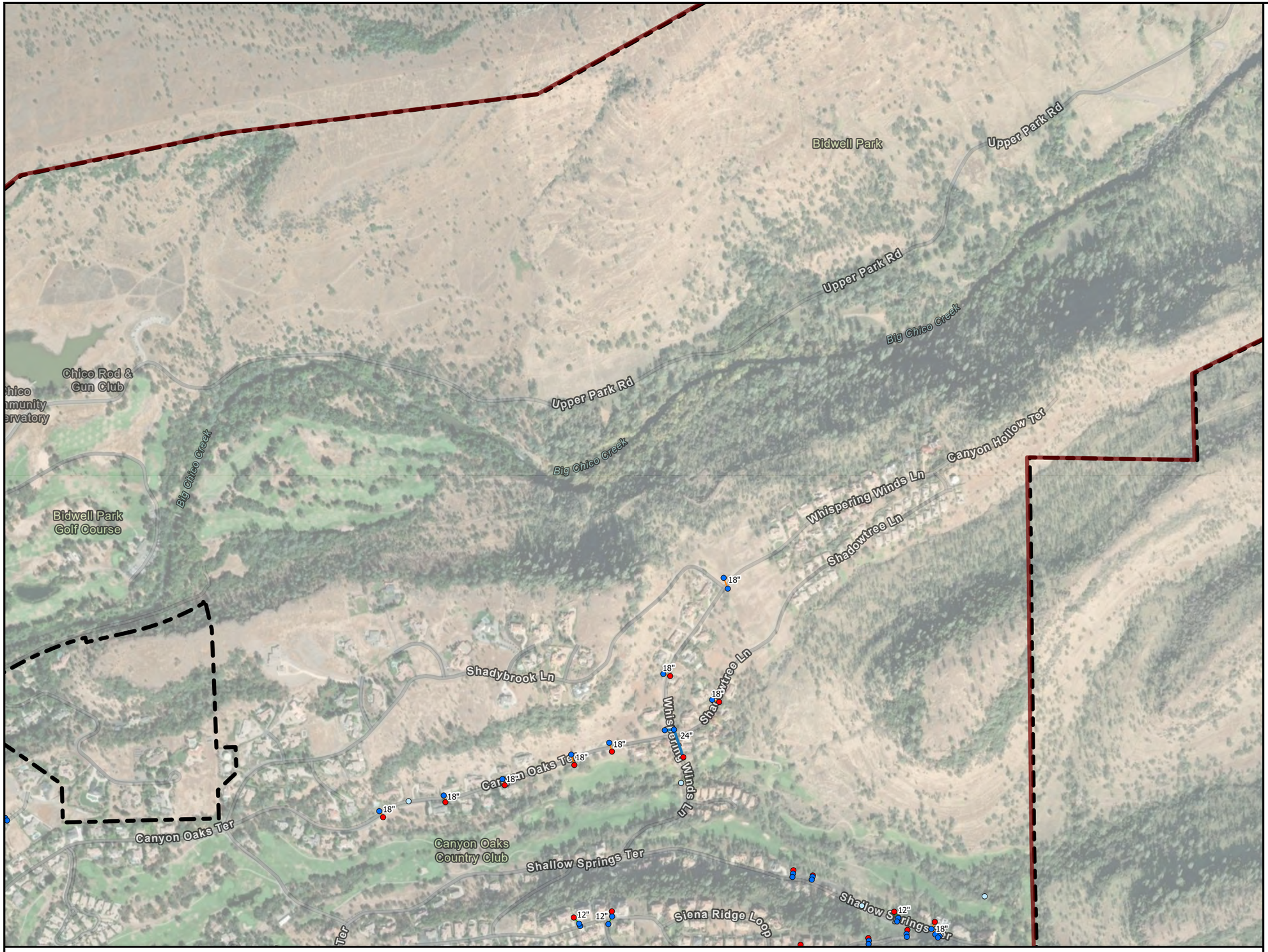
FIGURE 7-8

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

CITY OF CHICO

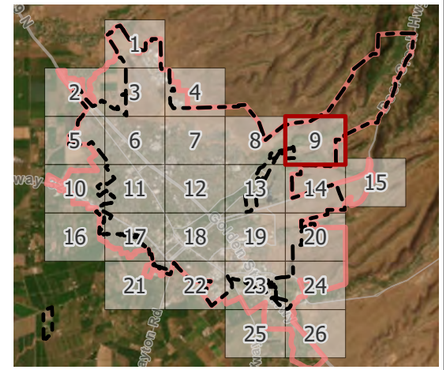
DECEMBER 2024



NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
2. Many detention basins are modeled as points, but the basins are presented using polygons for illustrative purposes. Pipes cross basins in the schematic because the pipes connect to the point that represents the basin in the model.
3. The line segment lengths shown in the schematic do not necessarily match the modeled or actual pipe lengths.
4. Most storm water quality Best Management Practices (BMPs), such as treatment vaults and dry wells, were not modeled and are not shown on the modeled drainage system. Please refer to the figure presenting Watersheds and BMPs for BMP location information.
5. The 2D Point Sources represent locations where watershed runoff was applied to the drainage model at locations that were not modeled as 1D model points such as drop inlets and detention basins. In many cases, the 2D point sources are at topographic low points. In some cases, the 2D point sources are at drop inlets that are connected to infiltration systems that are not modeled.

FIGURE 7-9

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

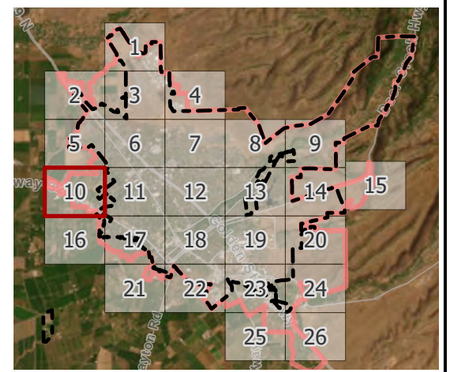
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

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J:\Jobs\8835_City_of_Chico\8835001_Chico_SWMP\GIS\ArcGISPro\SWMP_Project_Figures_20220725\SWMP_Project_Figures_MapSeries_26_SHT.aprx 4/30/2024 9:25 AM Mcedeno

FIGURE 7-10

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

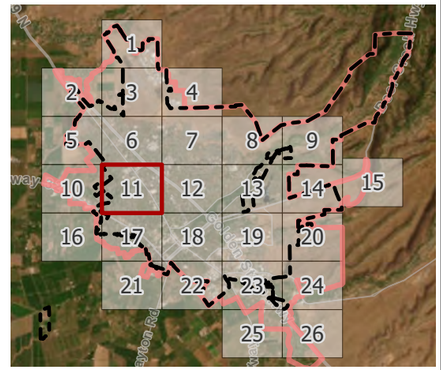
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

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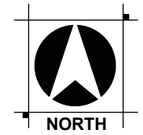
FIGURE 7-11

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

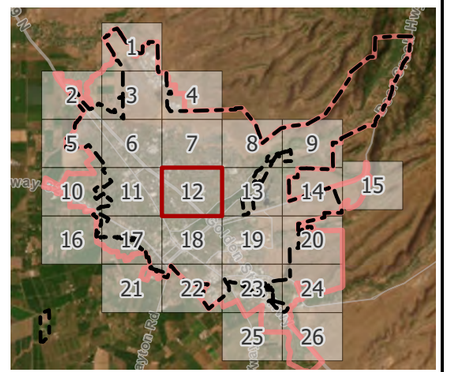
CITY OF CHICO

DECEMBER 2024



0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
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FIGURE 7-12

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

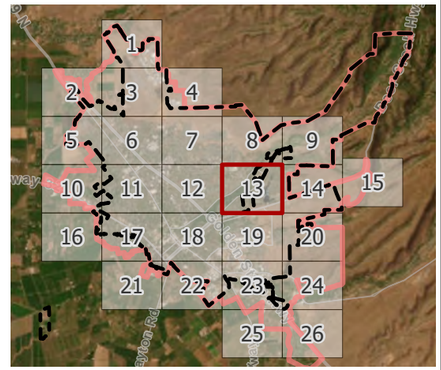
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
2. Many detention basins are modeled as points, but the basins are presented using polygons for illustrative purposes. Pipes cross basins in the schematic because the pipes connect to the point that represents the basin in the model.
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FIGURE 7-13

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

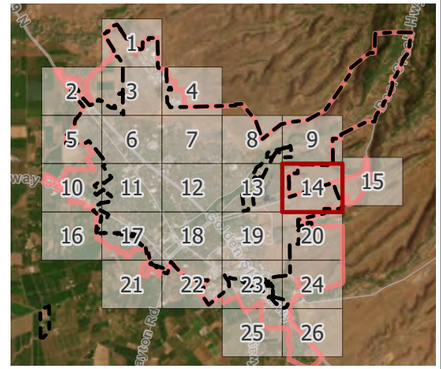
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
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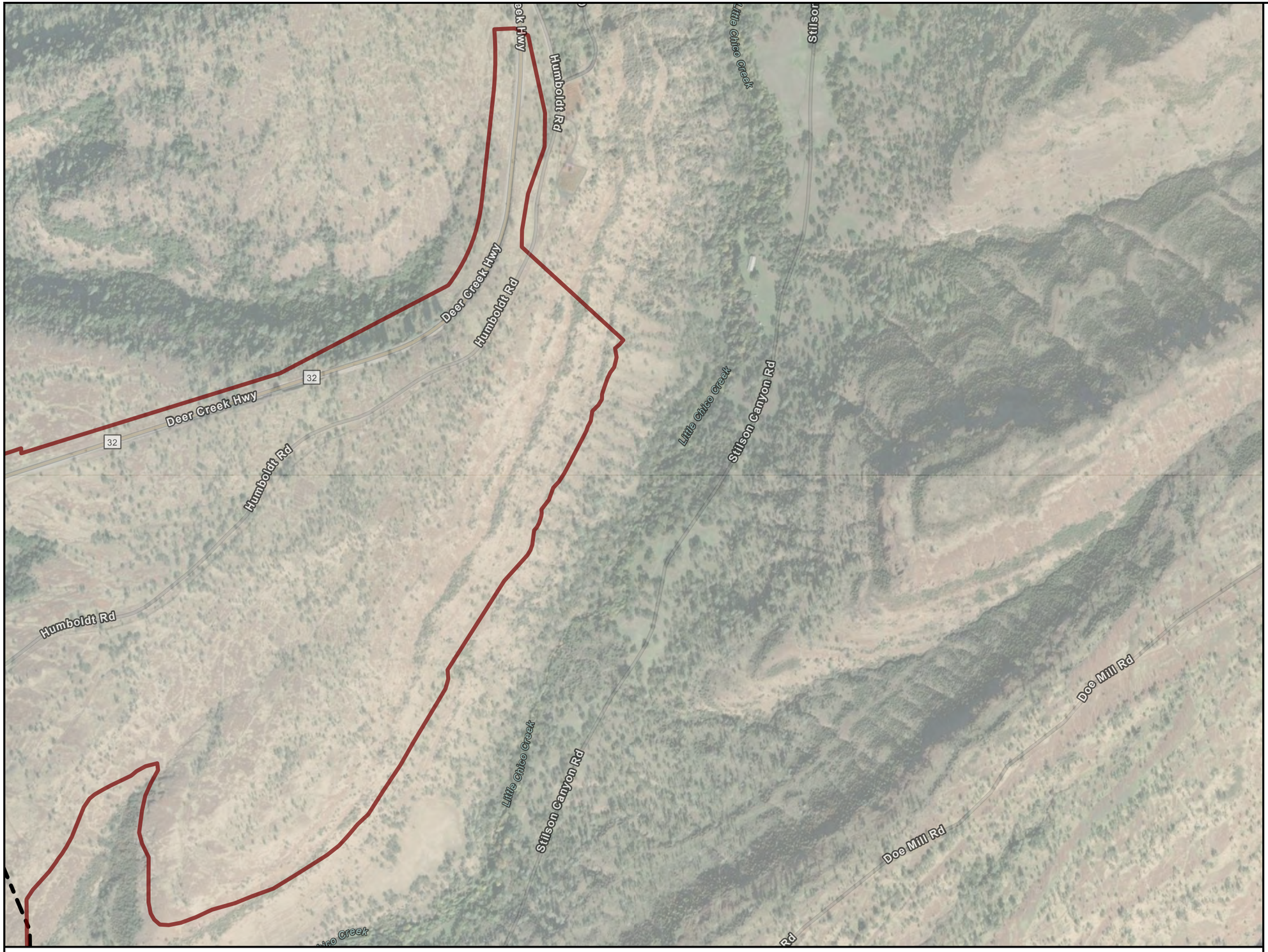
FIGURE 7-14

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

CITY OF CHICO

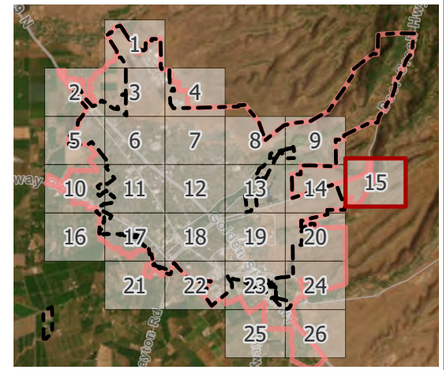
DECEMBER 2024



NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

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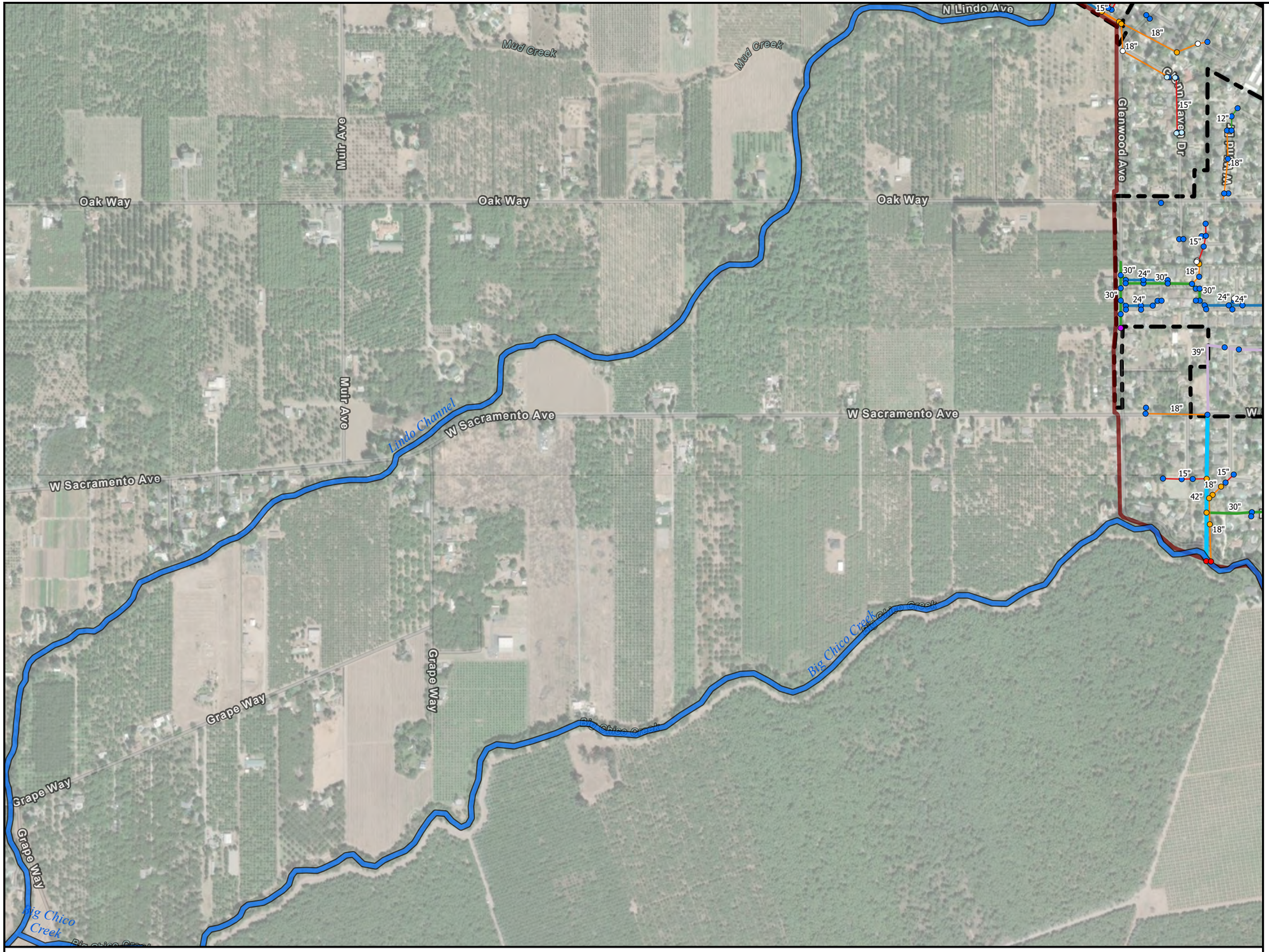
FIGURE 7-15

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

CITY OF CHICO

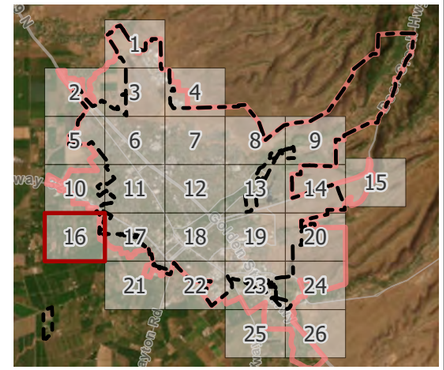
DECEMBER 2024



NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

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FIGURE 7-16

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

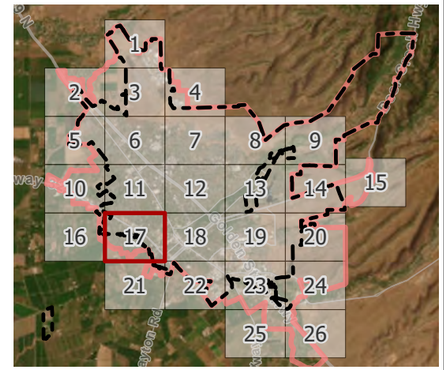
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

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FIGURE 7-17

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

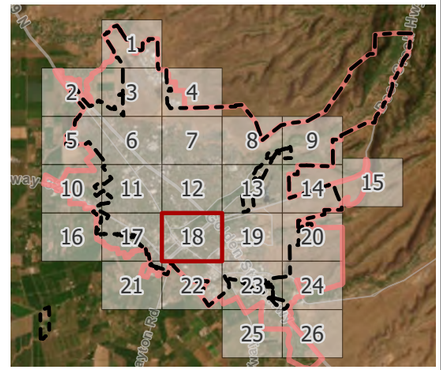
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
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FIGURE 7-18

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

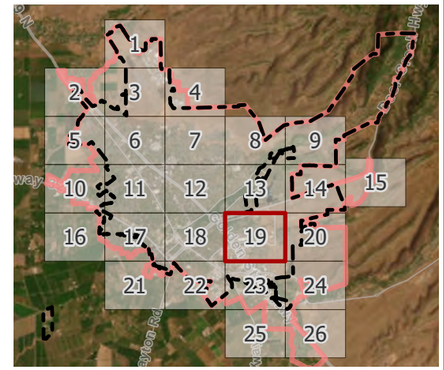
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
2. Many detention basins are modeled as points, but the basins are presented using polygons for illustrative purposes. Pipes cross basins in the schematic because the pipes connect to the point that represents the basin in the model.
3. The line segment lengths shown in the schematic do not necessarily match the modeled or actual pipe lengths.
4. Most storm water quality Best Management Practices (BMPs), such as treatment vaults and dry wells, were not modeled and are not shown on the modeled drainage system. Please refer to the figure presenting Watersheds and BMPs for BMP location information.
5. The 2D Point Sources represent locations where watershed runoff was applied to the drainage model at locations that were not modeled as 1D model points such as drop inlets and detention basins. In many cases, the 2D point sources are at topographic low points. In some cases, the 2D point sources are at drop inlets that are connected to infiltration systems that are not modeled.

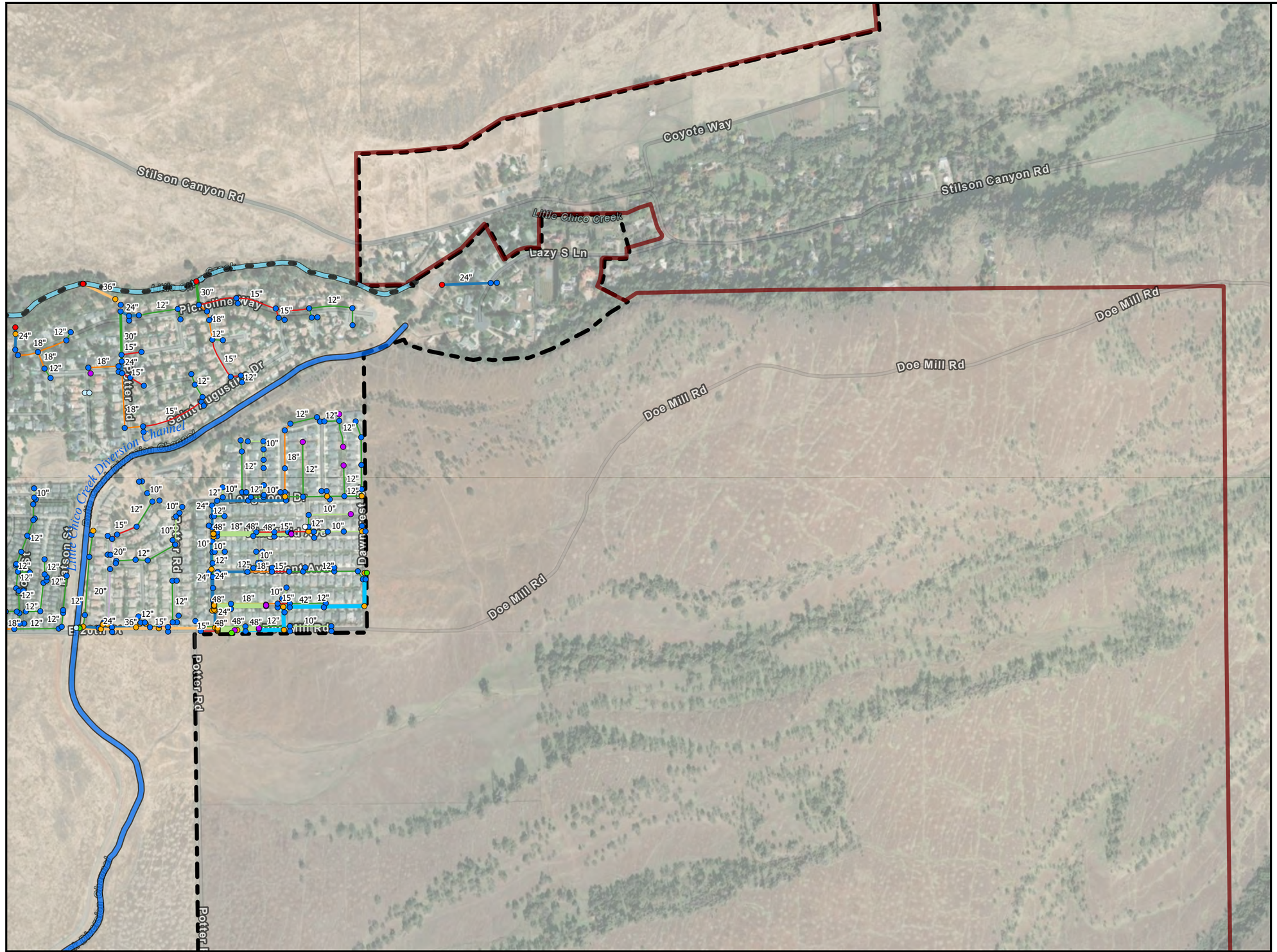
FIGURE 7-19

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024


Stilson Canyon Rd
Coyote Way
Stilson Canyon Rd
Little Chico Creek
Lazy S Ln
Doe Mill Rd
Doe Mill Rd
Doe Mill Rd
Doe Mill Rd
Pictoline Way
Saint Augustine Dr
Potter Rd
Potter Rd
Potter Rd
Dawn West Dr
Little Chico Creek Diversion Channel
Little Chico Creek
Lindo Channel
Lindo Channel
Lindo Channel

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

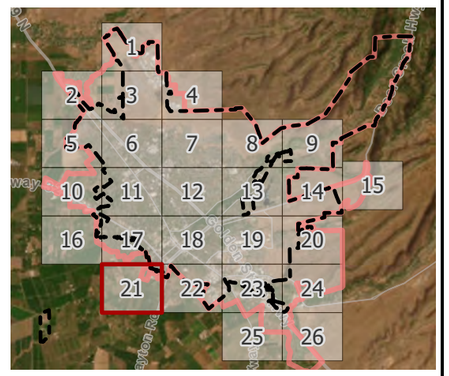
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
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FIGURE 7-21

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

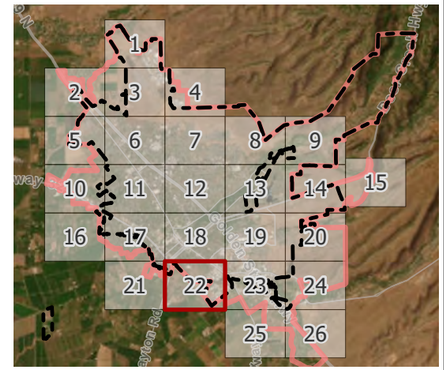
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The modeled storm drainage system map is a schematic representation of the drainage system for modeling purposes. Field verification of as-built drawings is necessary for precise system configuration data.
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FIGURE 7-22

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

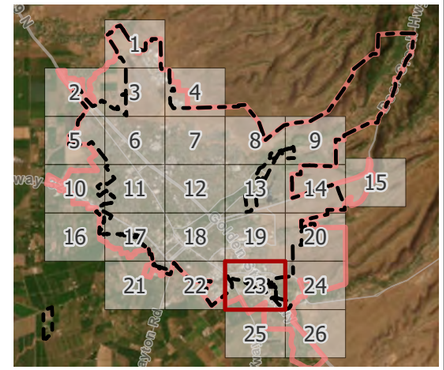
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

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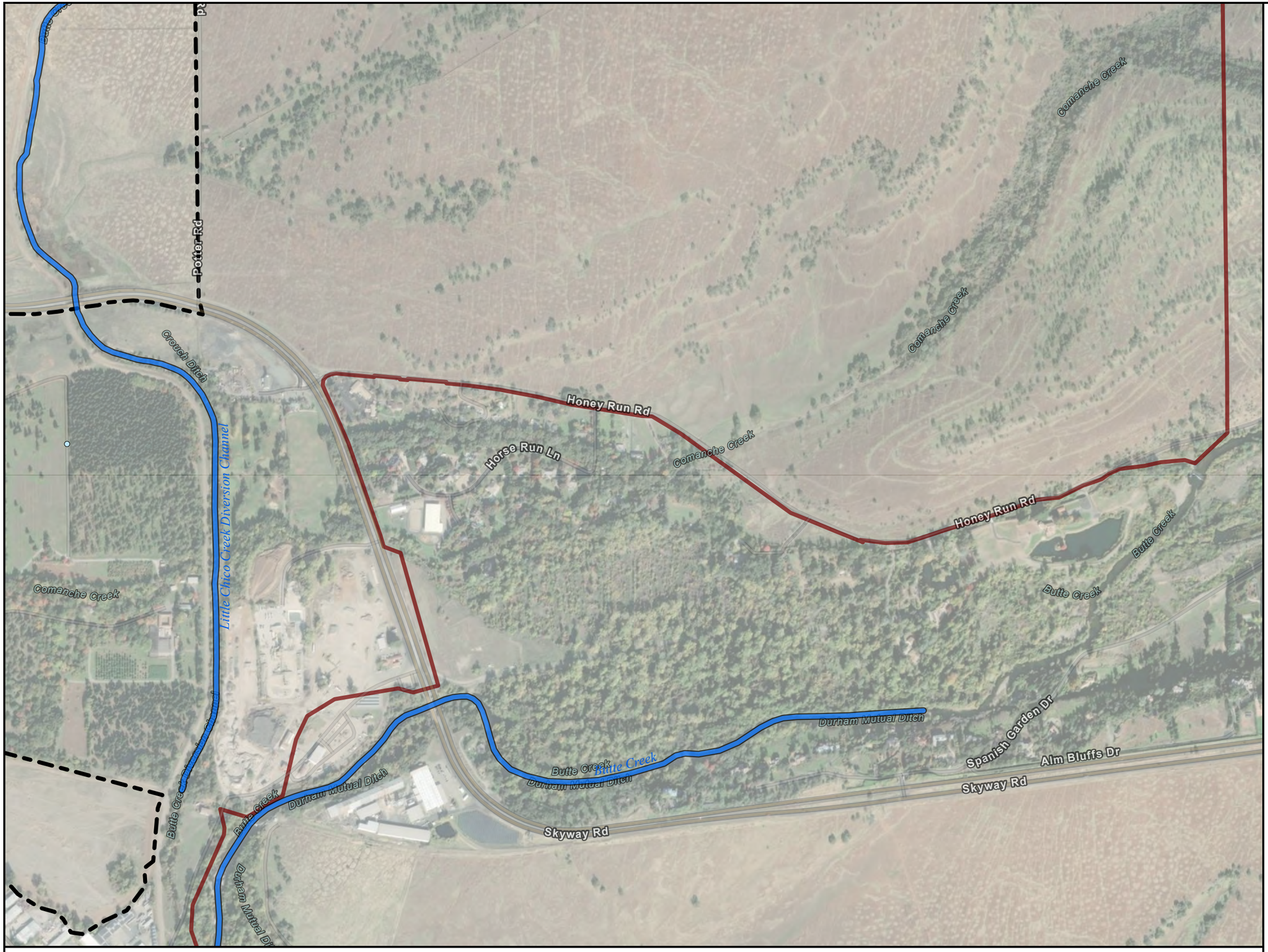
FIGURE 7-23

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

CITY OF CHICO

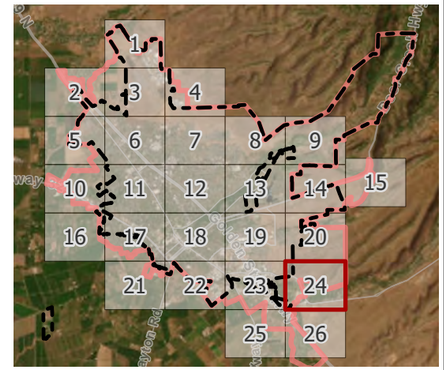
DECEMBER 2024



NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

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FIGURE 7-24

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

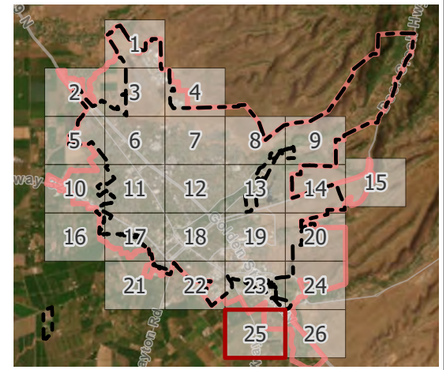
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
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WOOD RODGERS

NOTES

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FIGURE 7-25

MODELED STORM DRAINAGE SYSTEM

STORM WATER MASTER PLAN

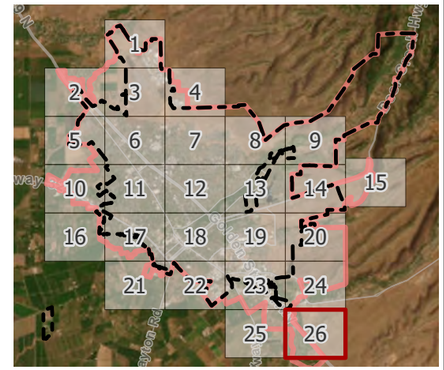
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



- 2D Point Source
- Capped End
- Drop Inlet
- Headwall/Culvert Entrance
- Manhole
- Outlet
- Outlet with Flap Gate
- Stub
- Not Classified

Stream/Channel Model Type

- 1-D ICM Modeled Channel
- 2-D ICM Modeled Channel
- 1-D HEC-RAS Modeled Channel

Pipe Diameter (inches)

multi-barrel pipes labeled x-x"

- <8
- 8
- 10
- 12
- 14
- 15
- 16
- 18
- 20
- 21
- 24
- 27
- 30
- 33
- 34
- 36
- 38
- 39
- 42
- 44
- 48
- 54
- 58
- 60
- 66
- 72
- >72
- Infiltration Trench
- Flap Gate
- Orifice
- Detention Basins
- Sphere of Influence
- Chico City Limits

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

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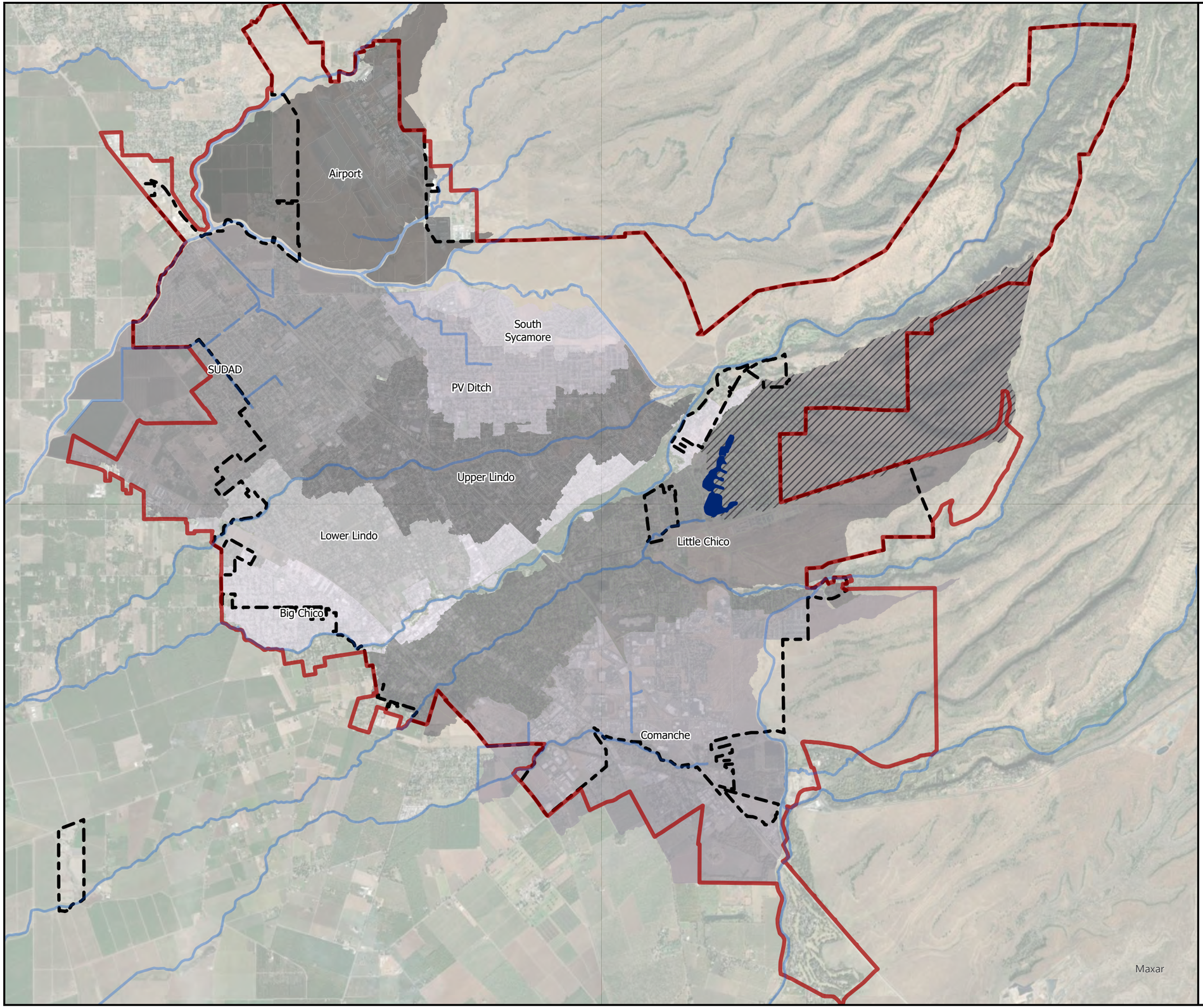
FIGURE 7-26

ICM MODEL WATERSHED OVERVIEW

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024



NORTH

0 2,500 5,000 10,000

Feet

Legend

- Streams/Channel
- California Park Lake
- California Park Lake Tributary Area
- Chico City Limits
- Sphere of Influence
- Airport
- Big Chico
- Comanche
- Little Chico
- Lower Lindo
- PV Ditch
- SUDAD
- South Sycamore
- Upper Lindo

WOOD RODGERS

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FIGURE 8

WATERSHEDS BY OUTFALL

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2,000 4,000 8,000

Feet

Legend

- Outfall
- Existing Conduits
- Proposed Conduits

Number of Overlaps

- 2
- 3
- 4
- 5
- 6
- Sphere of Influence
- Chico City Limits

WOOD RODGERS

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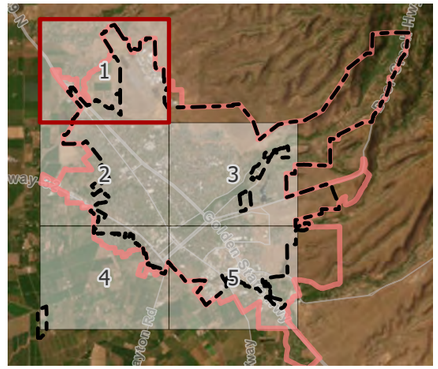
FIGURE 9

DETENTION BASINS AND WATER QUALITY FEATURES

STORM WATER MASTER PLAN
CITY OF CHICO
DECEMBER 2024

NORTH

0 875 1,750 3,500
Feet



- Modeled Links
- Modeled Watersheds
- Priority Land Use Area
- Modeled Detention Basin
- Non-modeled Detention Basin
- Sphere of Influence
- Chico City Limits
- Modeled Infiltration Trench Connected to System
- Infiltration Trench not Connected to System
- Tributary Area to DI Trash Capture Device
- Parcels with Surface BMP
- Parcels with Infiltration Trench

Types of BMP's
- BMP- Not Classsified
- Infiltration Trench Associated with Parcel
- Infiltration Trench Not Connected to System
- Infiltration Trench Connected to System
- Surface BMP
- BMP Interceptor
- FCS at Drop Inlet
- Underground Pipe Storage

Detention Basin Tributary Areas
- B01
- B02
- B03
- B04
- B05
- B06
- B07
- B08
- B09
- B10
- B12
- B13
- B14
- B15
- B16
- B17
- B18
- B19
- B20
- B21
- B22
- B23
- B25
- B26
- B27
- B28
- B29
- B30
- B37
- B41
- B42
- B43
- B66
- B69
- S01
- S02
- S03
- S05
- S06
- S07
- S08

Pass Through Areas
- B09
- B10
- B38a, B38b, B38c
- S04
- S08

WOOD RODGERS

NOTES

Pass Through Area - Flows from an area that pass through an underground storage or a detention basin then get routed to another detention basin

J:\Jobs\8835_City_of_Chico\8835001_Chico_SWMP\GIS\ArcGISPro\SWMP_Project_Figures_20220725\SWMP_Project_Figures_MapSeries_5_SHT_FIG_10.aprx 4/16/2024 11:00 AM Mcedeno

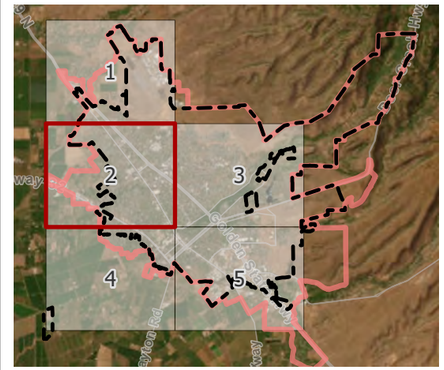
FIGURE 10-1

DETENTION BASINS AND WATER QUALITY FEATURES

STORM WATER MASTER PLAN
CITY OF CHICO
DECEMBER 2024

NORTH

0 875 1,750 3,500
Feet



- Modeled Links
- Modeled Watersheds
- Priority Land Use Area
- Modeled Detention Basin
- Non-modeled Detention Basin
- Sphere of Influence
- Chico City Limits
- Modeled Infiltration Trench Connected to System
- Infiltration Trench not Connected to System
- Tributary Area to DI Trash Capture Device
- Parcels with Surface BMP
- Parcels with Infiltration Trench

Types of BMP's
- BMP- Not Classsified
- Infiltration Trench Associated with Parcel
- Infiltration Trench Not Connected to System
- Infiltration Trench Connected to System
- Surface BMP
- BMP Interceptor
- FCS at Drop Inlet
- Underground Pipe Storage

Detention Basin Tributary Areas
- B01
- B02
- B03
- B04
- B05
- B06
- B07
- B08
- B09
- B10
- B12
- B13
- B14
- B15
- B16
- B17
- B18
- B19
- B20
- B21
- B22
- B23
- B25
- B26
- B27
- B28
- B29
- B30
- B37
- B41
- B42
- B43
- B66
- B69
- S01
- S02
- S03
- S05
- S06
- S07
- S08

Pass Through Areas
- B09
- B10
- B38a, B38b, B38c
- S04
- S08

NOTES

Pass Through Area - Flows from an area that pass through an underground storage or a detention basin then get routed to another detention basin

WOOD RODGERS

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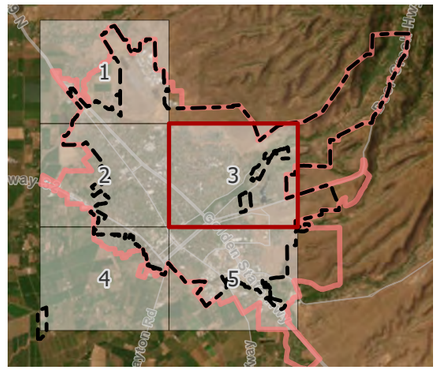
FIGURE 10-2

DETENTION BASINS AND WATER QUALITY FEATURES

STORM WATER MASTER PLAN
CITY OF CHICO
DECEMBER 2024

NORTH

0 875 1,750 3,500
Feet



- Modeled Links
- Modeled Watersheds
- Priority Land Use Area
- Modeled Detention Basin
- Non-modeled Detention Basin
- Sphere of Influence
- Chico City Limits
- Modeled Infiltration Trench Connected to System
- Infiltration Trench not Connected to System
- Tributary Area to DI Trash Capture Device
- Parcels with Surface BMP
- Parcels with Infiltration Trench

Types of BMP's

- BMP- Not Classsified
- Infiltration Trench Associated with Parcel
- Infiltration Trench Not Connected to System
- Infiltration Trench Connected to System
- Surface BMP
- BMP Interceptor
- FCS at Drop Inlet
- Underground Pipe Storage

Detention Basin Tributary Areas

- B01
- B02
- B03
- B04
- B05
- B06
- B07
- B08
- B09
- B10
- B12
- B13
- B14
- B15
- B16
- B17
- B18
- B19
- B20
- B21
- B22
- B23
- B25
- B26
- B27
- B28
- B29
- B30
- B37
- B41
- B42
- B43
- B66
- B69
- S01
- S02
- S03
- S05
- S06
- S07
- S08

Pass Through Areas

- B09
- B10
- B38a, B38b, B38c
- S04
- S08

WOOD RODGERS

NOTES

Pass Through Area - Flows from an area that pass through an underground storage or a detention basin then get routed to another detention basin

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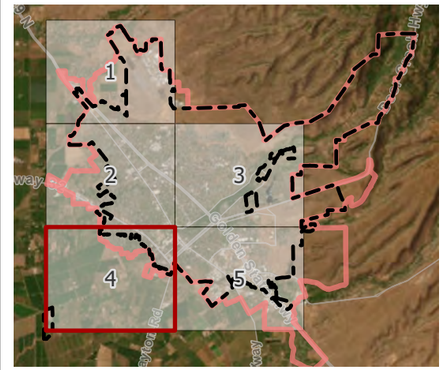
FIGURE 10-3

DETENTION BASINS AND WATER QUALITY FEATURES

STORM WATER MASTER PLAN
CITY OF CHICO
DECEMBER 2024

NORTH

0 875 1,750 3,500
Feet



- Modeled Links
- Modeled Watersheds
- Priority Land Use Area
- Modeled Detention Basin
- Non-modeled Detention Basin
- Sphere of Influence
- Chico City Limits
- Modeled Infiltration Trench Connected to System
- Infiltration Trench not Connected to System
- Tributary Area to DI Trash Capture Device
- Parcels with Surface BMP
- Parcels with Infiltration Trench

Types of BMP's

- BMP- Not Classsified
- Infiltration Trench Associated with Parcel
- Infiltration Trench Not Connected to System
- Infiltration Trench Connected to System
- Surface BMP
- BMP Interceptor
- FCS at Drop Inlet
- Underground Pipe Storage

Detention Basin Tributary Areas

- B01
- B02
- B03
- B04
- B05
- B06
- B07
- B08
- B09
- B10
- B12
- B13
- B14
- B15
- B16
- B17
- B18
- B19
- B20
- B21
- B22
- B23
- B25
- B26
- B27
- B28
- B29
- B30
- B37
- B41
- B42
- B43
- B66
- B69
- S01
- S02
- S03
- S05
- S06
- S07
- S08

Pass Through Areas

- B09
- B10
- B38a, B38b, B38c
- S04
- S08

NOTES

Pass Through Area - Flows from an area that pass through an underground storage or a detention basin then get routed to another detention basin

WOOD RODGERS

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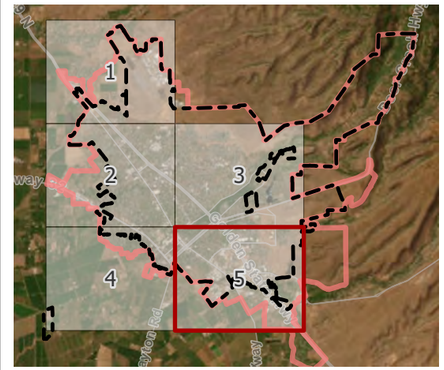
FIGURE 10-4

DETENTION BASINS AND WATER QUALITY FEATURES

STORM WATER MASTER PLAN
CITY OF CHICO
DECEMBER 2024

NORTH

0 875 1,750 3,500
Feet



- Modeled Links
- Modeled Watersheds
- Priority Land Use Area
- Modeled Detention Basin
- Non-modeled Detention Basin
- Sphere of Influence
- Chico City Limits
- Modeled Infiltration Trench Connected to System
- Infiltration Trench not Connected to System
- Tributary Area to DI Trash Capture Device
- Parcels with Surface BMP
- Parcels with Infiltration Trench

Types of BMP's
- BMP- Not Classsified
- Infiltration Trench Associated with Parcel
- Infiltration Trench Not Connected to System
- Infiltration Trench Connected to System
- Surface BMP
- BMP Interceptor
- FCS at Drop Inlet
- Underground Pipe Storage

Detention Basin Tributary Areas
- B01
- B02
- B03
- B04
- B05
- B06
- B07
- B08
- B09
- B10
- B12
- B13
- B14
- B15
- B16
- B17
- B18
- B19
- B20
- B21
- B22
- B23
- B25
- B26
- B27
- B28
- B29
- B30
- B37
- B41
- B42
- B43
- B66
- B69
- S01
- S02
- S03
- S05
- S06
- S07
- S08

Pass Through Areas
- B09
- B10
- B38a, B38b, B38c
- S04
- S08

WOOD RODGERS

NOTES

Pass Through Area - Flows from an area that pass through an underground storage or a detention basin then get routed to another detention basin

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FIGURE 10-5

2-YEAR 1-HOUR PRECIPITATION DEPTH

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2 4 8

Miles

Legend

- 2-year 1-hour Isohyetal (depth in inches)
- City Sphere of Influence
- City Limits
- Study Area Regional Watersheds

SOURCES:

Precipitation Data: NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 6 Version 2.3: California

https://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume6.pdf
ftp://hdsc.nws.noaa.gov/pub/hdsc/data/sw/

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FIGURE 11

2-YEAR 24-HOUR PRECIPITATION DEPTH

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2 4 8

Miles

Legend

- 2-year 24-hour Isohyetal (depth in inches)
- City Sphere of Influence
- City Limits
- Study Area Regional Watersheds

SOURCES:

Precipitation Data: NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 6 Version 2.3: California

https://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume6.pdf
ftp://hdsc.nws.noaa.gov/pub/hdsc/data/sw/

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FIGURE 12

10-YEAR 1-HOUR PRECIPITATION DEPTH

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2 4 8

Miles

Legend

- 10-year 1-hour Isohyetal (depth in inches)
- City Sphere of Influence
- City Limits
- Study Area Regional Watersheds

SOURCES:

Precipitation Data: NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 6 Version 2.3: California

https://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume6.pdf
ftp://hdsc.nws.noaa.gov/pub/hdsc/data/sw/

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FIGURE 13

10-YEAR 24-HOUR PRECIPITATION DEPTH

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2 4 8

Miles

Legend

- 10-year 24-hour Isohyetal (depth in inches)
- City Sphere of Influence
- City Limits
- Study Area Regional Watersheds

SOURCES:

Precipitation Data: NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 6 Version 2.3: California

https://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume6.pdf
ftp://hdsc.nws.noaa.gov/pub/hdsc/data/sw/

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FIGURE 14

100-YEAR 1-HOUR PRECIPITATION DEPTH

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2 4 8

Miles

Legend

- 100-year 1-hour Isohyetal (depth in inches)
- City Sphere of Influence
- City Limits
- Study Area Regional Watersheds

SOURCES:

Precipitation Data: NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 6 Version 2.3: California

https://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume6.pdf
ftp://hdsc.nws.noaa.gov/pub/hdsc/data/sw/

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FIGURE 15

100-YEAR 24-HOUR PRECIPITATION DEPTH

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2 4 8

Miles

Legend

- 100-year 24-hour Isohyetal (depth in inches)
- City Sphere of Influence
- City Limits
- Study Area Regional Watersheds

SOURCES:

Precipitation Data: NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 6 Version 2.3: California

https://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume6.pdf
ftp://hdsc.nws.noaa.gov/pub/hdsc/data/sw/

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FIGURE 16

DESIGN PRECIPITATION ZONES

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 3,000 6,000 12,000

Feet

Zone 1

Zone 2

Zone 3

Zone 4

Zone 5

Chico

PARADISE

Legend

Precipitation Zones:

- 1
- 2
- 3
- 4
- 5
- City Limits
- City Sphere of Influence

SOURCES:

Precipitation Data: NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 6 Version 2.3: California

https://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume6.pdf

ftp://hdsc.nws.noaa.gov/pub/hdsc/data/sw/

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FIGURE 17

ICM ROUGHNESS AND MESH ZONES

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2,500 5,000 10,000

Feet

Legend

- Building Polygon
- Mesh Zone

Roughness Zone (Manning's n)

- 0.02
- 0.03
- 0.035
- 0.06
- Chico City Limits
- Sphere of Influence

WOOD RODGERS

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FIGURE 18

HYDROLOGIC SOIL GROUPS

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 3,000 6,000 12,000

Feet

Legend

- Streams
- City Sphere of Influence
- City Limits

Soil Groups:

- A
- B
- C
- C/D
- D
- DATA GAP
- Water

SOURCES:
USDA-NRCS Soil Survey for Butte County, Version 18, September 2021

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FIGURE 19

GENERAL PLAN LAND USE

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 2,500 5,000 10,000

Feet

Legend

City Limits

City Sphere of Influence

Zoning:

RS-3	Suburban Residential 3 acre min.
RS-2	Suburban Residential 2 acre min.
RS-1	Suburban Residential 1 acre min.
RS-20	Suburban Residential 20,000 sq ft min.
R1-15	Low Density Residential 15,000 sq ft min.
R1-10	Low Density Residential 10,000 sq ft min.
R1	Low Density Residential
R2	Medium Density Residential
R3	Medium-High Density Residential
R4	High Density Residential
RMU	Residential Mixed Use
OR	Office Residential
OC	Office Commercial
CN	Neighborhood Commercial
CC	Community Commercial
DS	Downtown South
DN	Downtown North
CS	Services Commercial
CR	Regional Commercial
ML	Light Manufacturing
MG	General Manufacturing
IOMU	Industrial Office Mixed-Use
A	Airport
AP	Airport Public Facilities
AC	Airport Commercial
AM	Airport Manufacturing
TND	Traditional Mixed Use
SPA	Special Planning Area
PQ	Public/Quasi Public Facilities
OS1	Primary Open Space
OS2	Secondary Open Space
ROW	Right of Way

SOURCES:
Land Use Data: City of Chico Specific Zoning District Standards

https://chico.ca.us/sites/main/files/file-attachments/citywebmap_zoning20170901aug2017.pdf?1594054713

WOOD RODGERS

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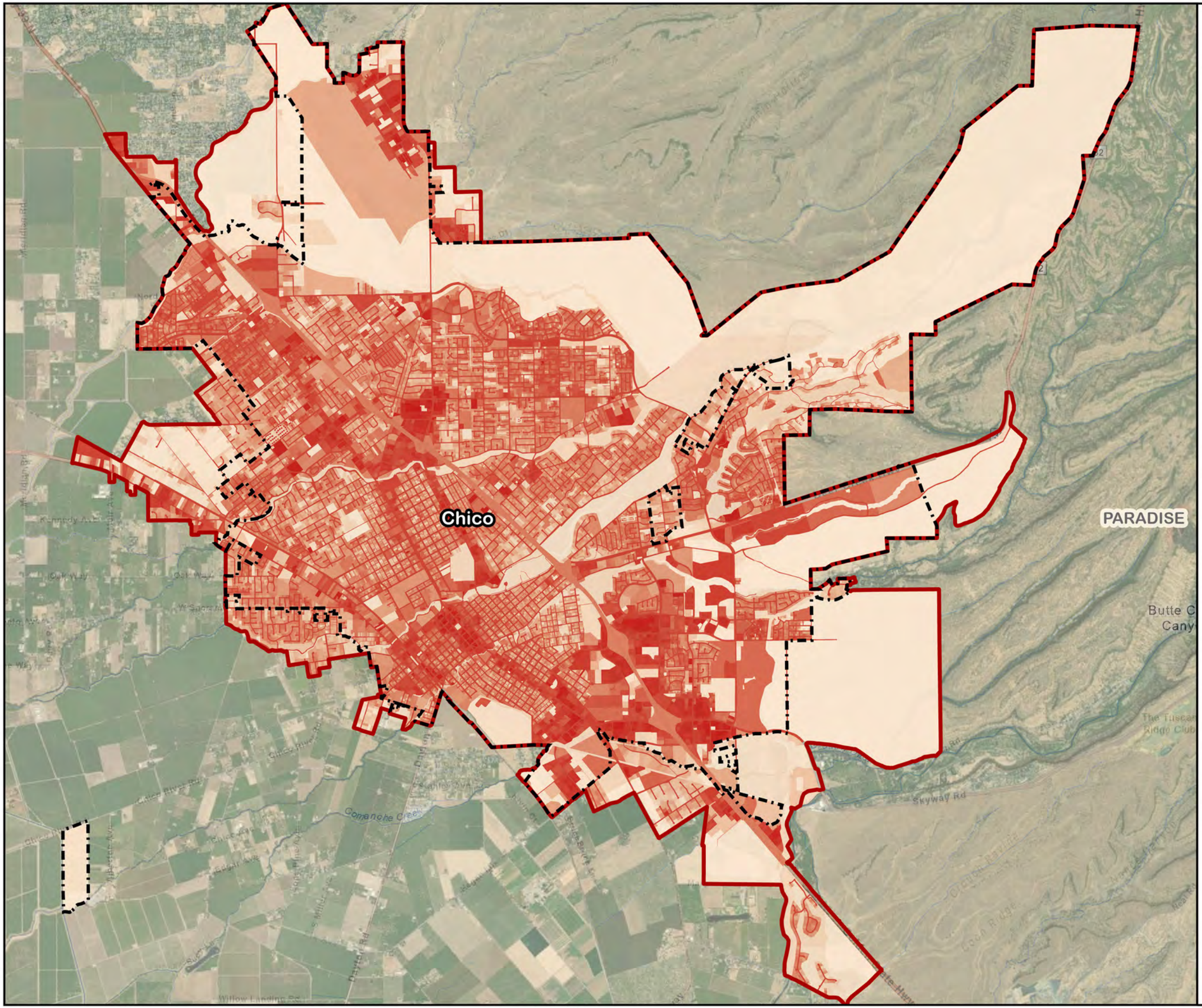
FIGURE 20

EXISTING CONDITIONS IMPERVIOUSNESS

STORM WATER MASTER PLAN

CITY OF CHICO

OCTOBER 2025



NORTH

0 2,500 5,000 10,000

Feet

Legend

City Limits

City Sphere of Influence

Percent Impervious

0.0

100

WOOD RODGERS

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FIGURE 21

SATURATED HYDRAULIC CONDUCTIVITY

STORM WATER MASTER PLAN

CITY OF CHICO

OCTOBER 2025

NORTH

0 3,000 6,000 12,000

Feet

- Streams
- Water
- City Sphere of Influence
- City Limits

Saturated Hydraulic Conductivity (Inches Per Hour)

- 0
- 0.0014
- 0.0085
- 0.068
- 0.18
- 0.2
- 0.26
- 0.43
- 0.45
- 0.57
- 0.64
- 0.71
- 0.85
- 1.4
- 1.8
- 2
- 2.1
- 2.6
- 2.8
- 3.6
- 4
- 4.3
- 8.5
- 13
- 20
- 21

SOURCES:
USDA-NRCS Soil Survey for Butte County, Version 18, September 2021

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FIGURE 22

CATCH BASIN DEFICIENCIES AND DRY WELL LOCATIONS

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024

NORTH

0 1,500 3,000 6,000

Feet

Legend

Catch Basin Condition

- Inadequate
- Dry Well
- Bubble-up Locations
- Modeled Pipe
- Stream
- City Limits
- Sphere of influence

WOOD RODGERS

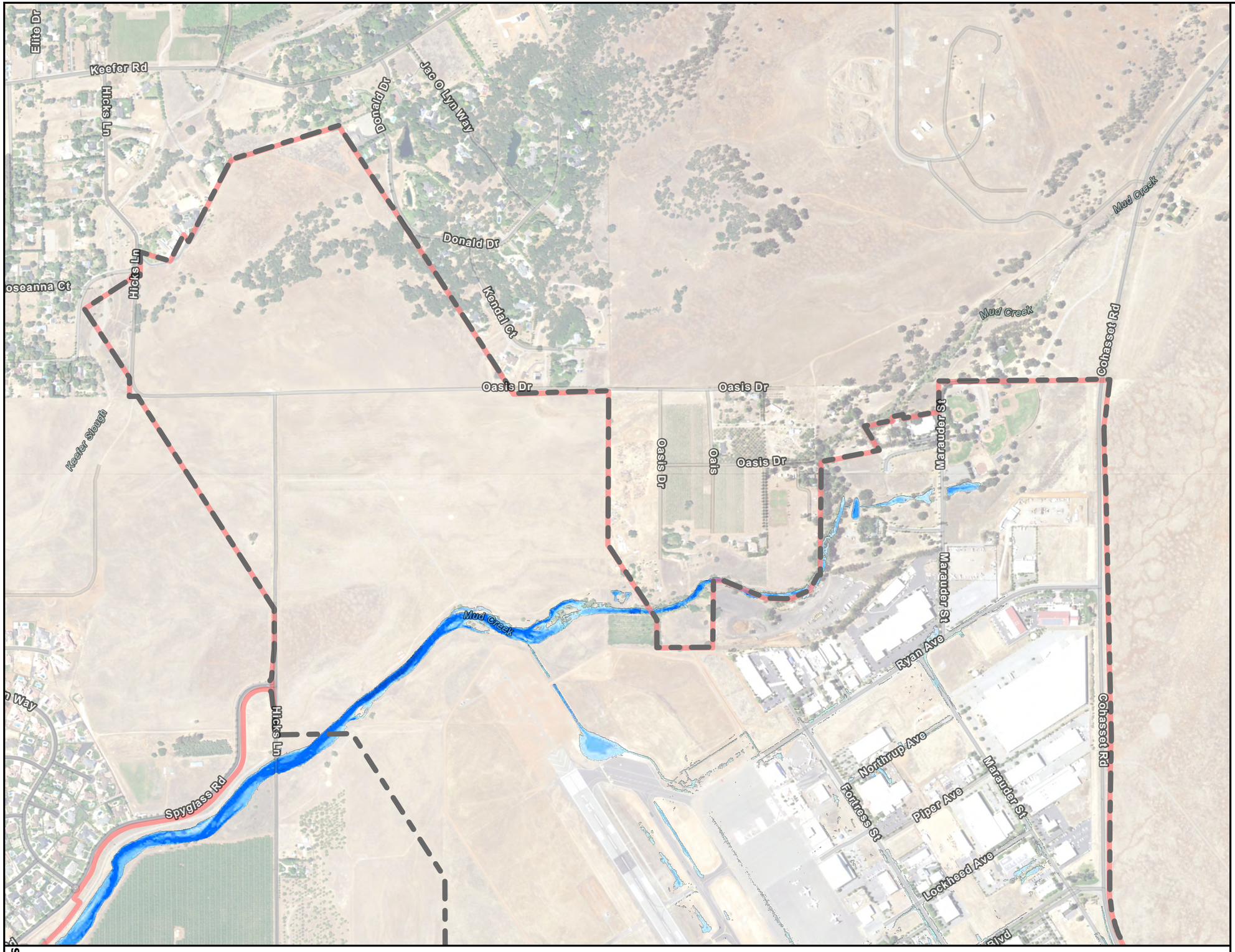
FIGURE 23

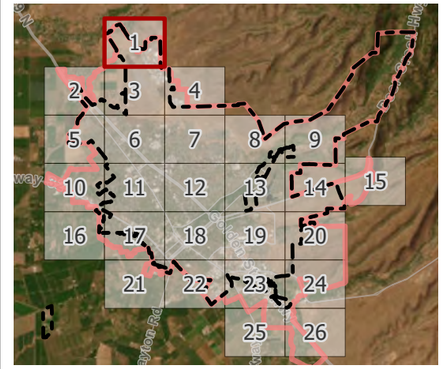
2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024





NORTH

0 375 750 1,500

Feet

Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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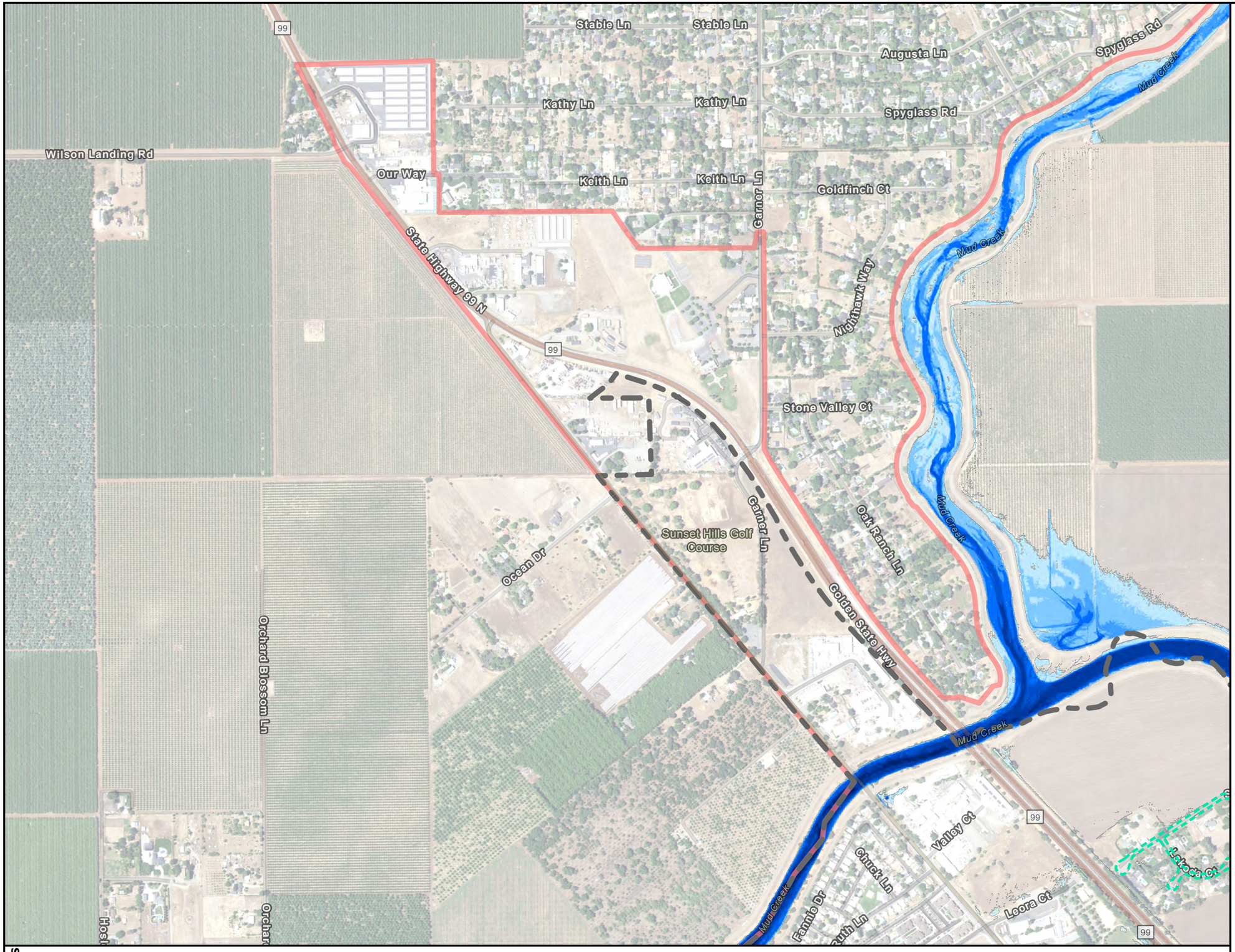
FIGURE 24-1

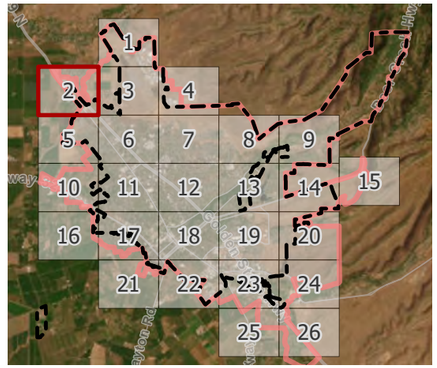
2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024





NORTH

0 375 750 1,500

Feet

Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
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WOOD RODGERS

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2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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FIGURE 24-2

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

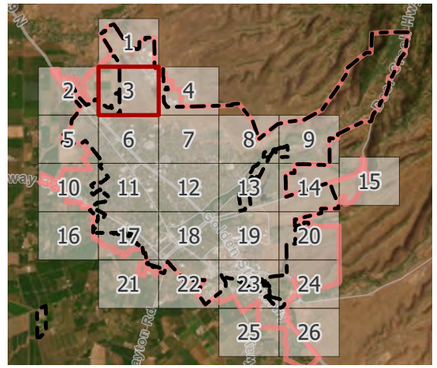
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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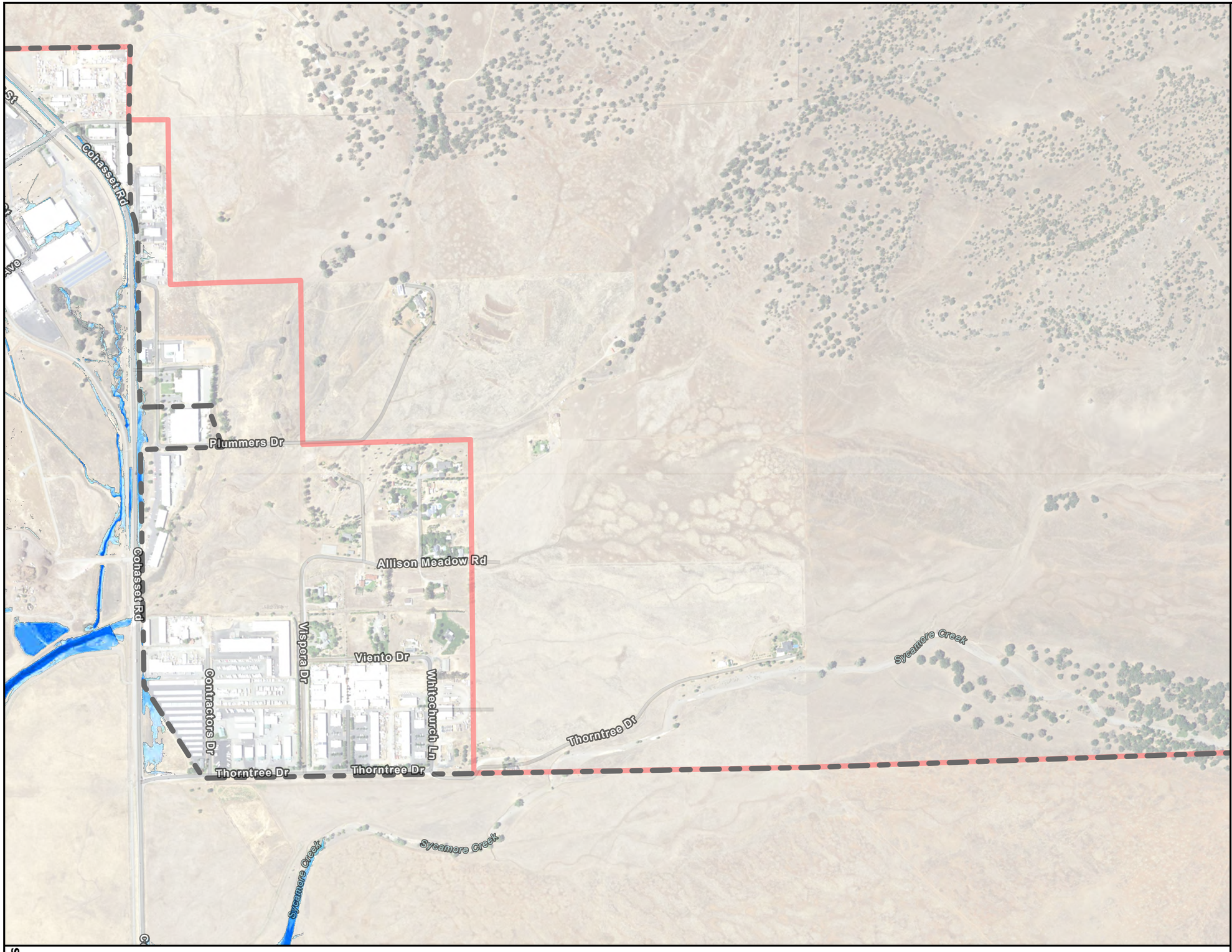
FIGURE 24-3

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

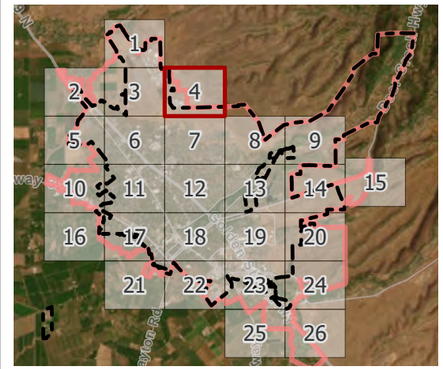
CITY OF CHICO
DECEMBER 2024



NORTH

0 375 750 1,500

Feet



Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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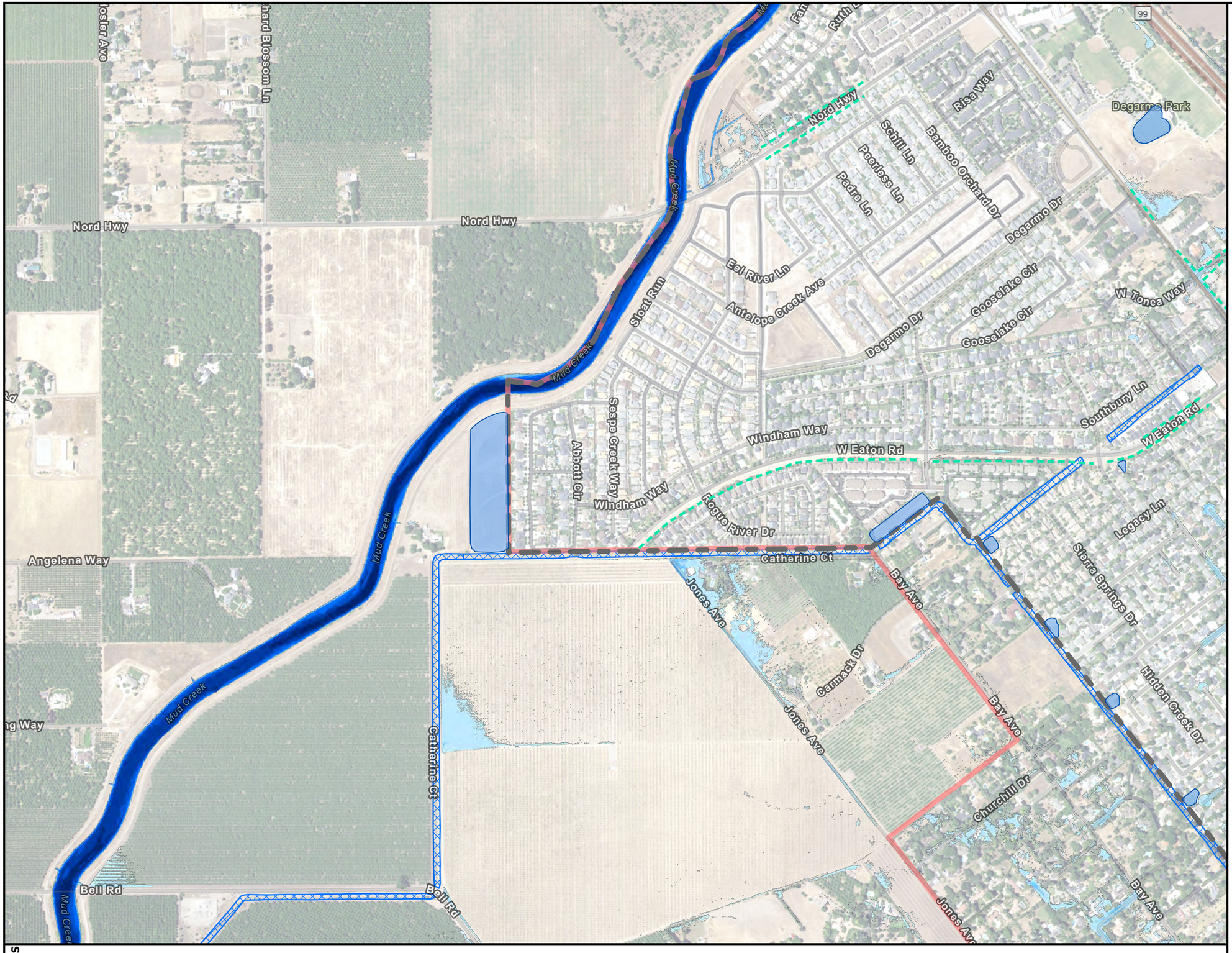
FIGURE 24-4

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

CITY OF CHICO

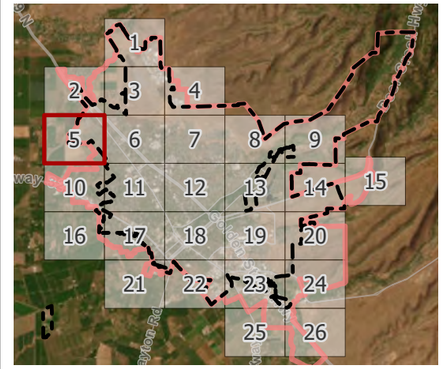
DECEMBER 2024



NORTH

0 375 750 1,500

Feet



Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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FIGURE 24-5

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

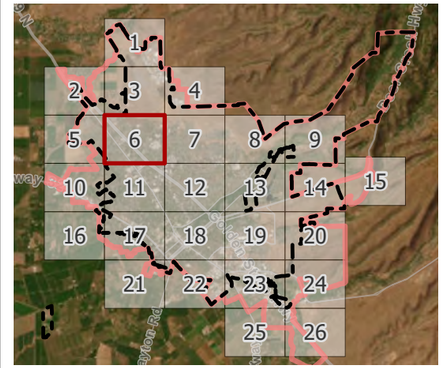
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
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FIGURE 24-6

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

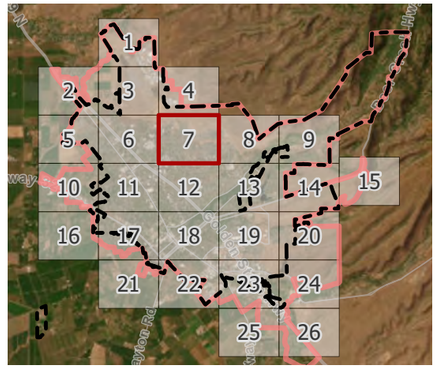
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

FIGURE 24-7

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

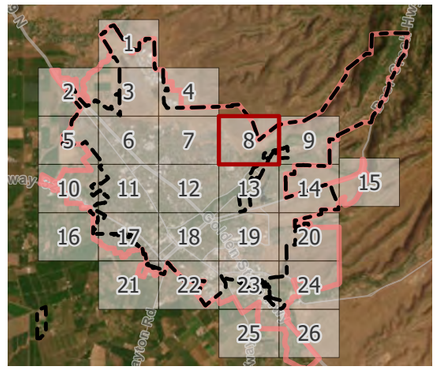
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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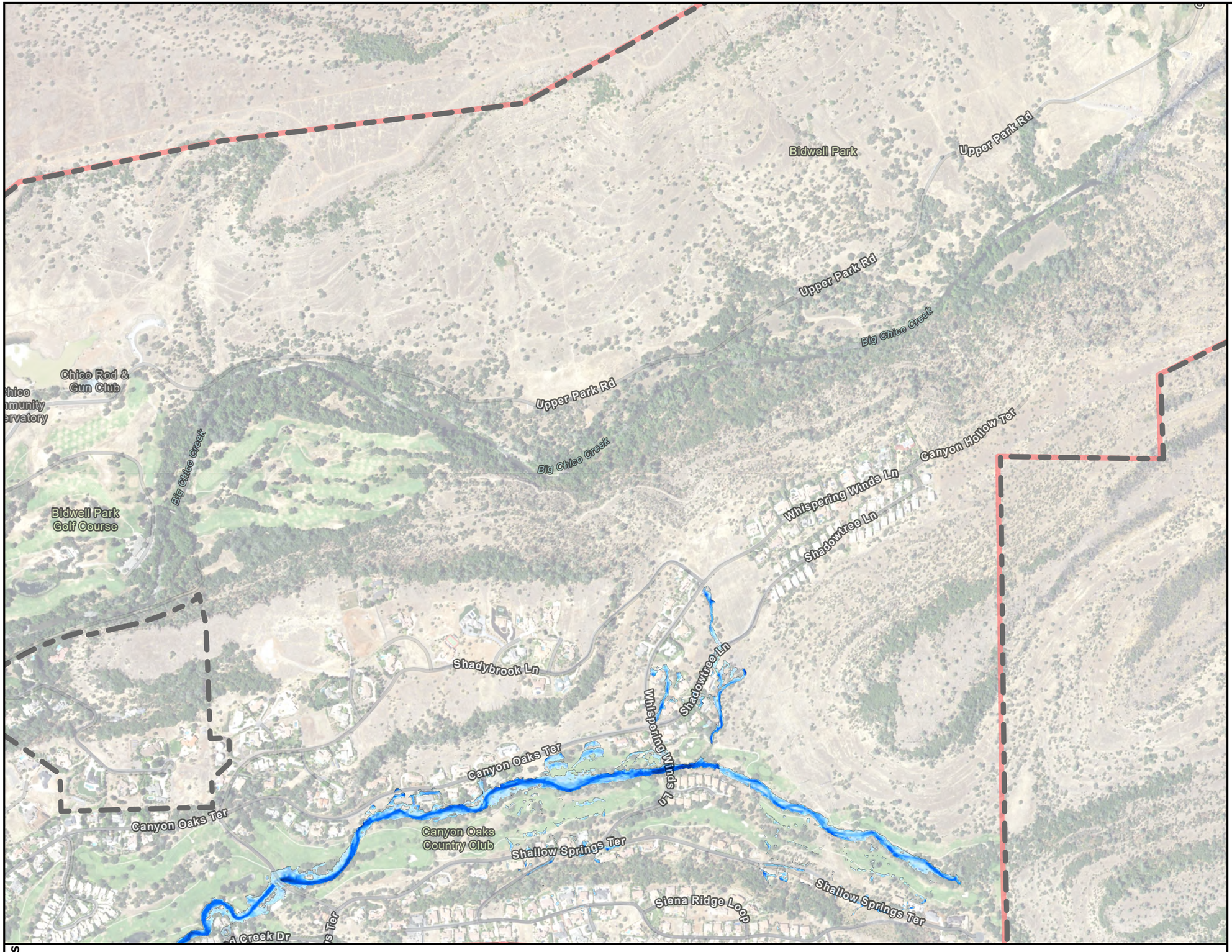
FIGURE 24-8

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

CITY OF CHICO

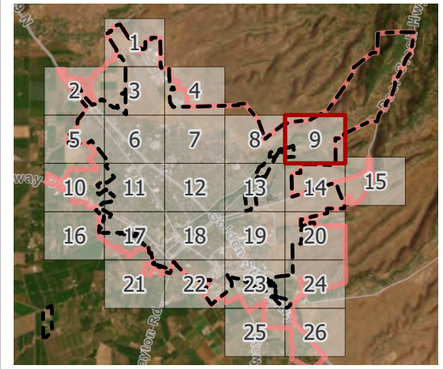
DECEMBER 2024



NORTH

0 375 750 1,500

Feet



Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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FIGURE 24-9

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

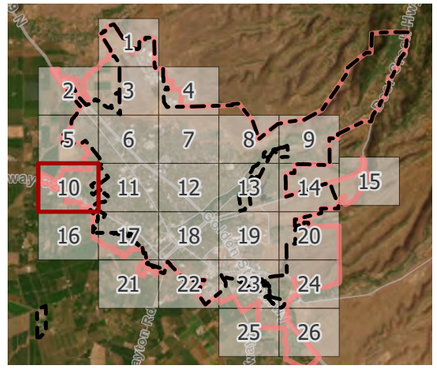
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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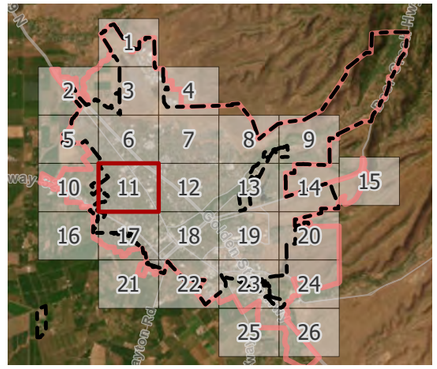
FIGURE 24-10

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

CITY OF CHICO

DECEMBER 2024



NORTH

0 375 750 1,500

Feet

Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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FIGURE 24-11

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

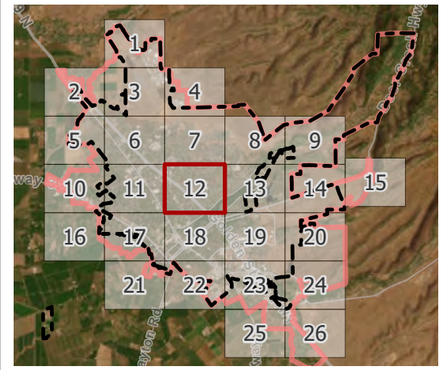
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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FIGURE 24-12

2-YEAR FLOODING FROM EXISTING DRAINAGE SYSTEM MODEL RESULTS

STORM WATER MASTER PLAN

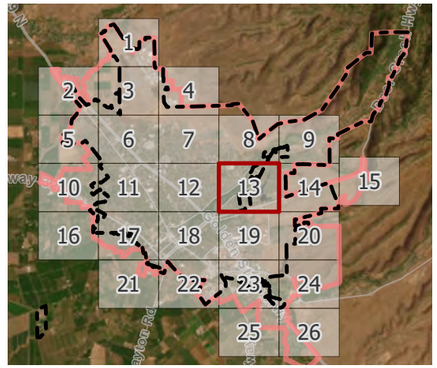
CITY OF CHICO

DECEMBER 2024

NORTH

0 375 750 1,500

Feet



Condition

- Lack of Curb and Gutter
- Lack of Gutter
- Detention Basins
- 1D Modeled Channel
- Chico City Limits
- Sphere of Influence

2-Year Model Results

- 0.25 foot - 1 foot
- 1 foot - 2 feet
- 2 feet - 3 feet
- 3 feet - 5 feet
- 5 feet - 7 feet
- 7 feet - 10 feet
- Greater than 10 feet

Source:
For layers used the sources of specific drainage feature information is available in the SWMP GIS

WOOD RODGERS

NOTES

1. The model results may show more flooding than may be expected in some areas due to limitations associated with drainage system data, terrain accuracy and infiltration systems that were not modeled.
2. Flooding along streams is shown based on 10-year flood depths above the terrain data obtained from HEC-RAS models and is provided for illustration purposes only.

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FIGURE 24-13