CITY OF REDLANDS

MASTER PLAN OF DRAINAGE (MPD)

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A Baker Company

TECHNICAL APPENDIX B.4

XP-SWMM Analysis

- Model Methodology & Procedures
- Regional Alternative Exhibits
- Downtown Local Storm Drain Tables

XP-SWMM

The main calculation engine (SWMM) was developed by U.S. Environmental Protection Agency. This study uses an enhanced version of SWMM from the XP Solutions, appropriately named XP-SWMM, to analyze the city-wide drainage system. The program is a dynamic unsteady flow model (utilizing the St. Venant Equations) that allows for effects of storage and backwater in conduits and surface flows, and the timing of the hydrographs to yield a true representation of the water surface elevation at any point in space and time. The program includes a two-dimensional (2D) surface flow analysis module that can be linked to the subsurface facilities creating an interactive two-layered model.

XP-SWMM calculates the hydraulics of the subsurface drainage system using a dynamic wave analysis, which incorporates the volume and timing of each inflow/catch basin hydrograph. Dynamic wave analysis allows for backwater or reversal of flow directions, including reversal of flows out of the catch basins/manhole into the streets when downstream hydraulics governs. In this situation, the flows are conveyed back into the streets and modeled using the two-dimensional (TUFLOW) module

TUFLOW is the computational engine incorporated in XP-SWMM that provides two-dimensional and one-dimensional solutions of the free-surface flow equations to simulate flood propagation. TUFLOW is based on the Stalling finite difference, alternating direction implicit (ADI) scheme that solves the full 2D free surface shallow water flow equations. This module was used to calculate water surfaces and hydraulics within the streets. Collector street intersections where four possible directions exist for flow, the model has the ability to split flows and route them in multiple directions simultaneously, while linking them dynamically to the subsurface drainage system.

The XP-SWMM two-dimensional model analysis uses the digital terrain model (DTM) to route surface flows. Where the surface intersects the catch basins, a dynamic interaction exists between the surface flows and the subsurface flow network.

Three (3) scenarios were considered for the 2D modeling; existing conditions, project conditions, and project conditions with the local improvements structure.

Existing Conditions

Existing models were performed for two (2) areas within the City of Redlands;

1. Model #1 - Downstream of I-10 (Downtown Redlands)
2. Model #2 - Upstream of I-10 (Adjacent to University of Redlands)

Topography:

Model #1 - The 1-foot Digital Terrain Model (DTM) was developed by Vertical Mapping on January 14, 2014 for the downtown area and supplemented with San Bernardino County provided LiDAR and the 5-foot contours provided by the City of Redlands on the fringes of the study area. The combined topography was sufficient for the 2D XP-SWMM modeling of Zanja Creek and the surrounding downtown area.

Model #2 - County of San Bernardino provided LiDAR topography for City of Redlands. The data was in the form of Digital Elevation Model (DEM and was converted to shapefile points in GIS). It was noted that the bridge over Zanja Creek, University St and Church Street was not well defined in the LiDAR data. Civil 3D 2013 was used to add breaklines and adjust the data in those locations. This topography was used for the upstream of 1-10 (Adjacent to University of Redlands) Xp-SWMM 2D model.

The topographic information was imported into XP-SWMM as a 3-dimensional surface. The program reads this information and creates a grid of computational cells for the analysis.

Geometry: As-Built data obtained from the City was used to model the storm drain system. All invert elevations were converted to NAVD 88 datum. In areas where As-built information was missing, field reconnaissance was performed. In few areas the top of conduits were assumed to be 3-ft below existing ground surface.

Zanja Creek – Railroad crossing

Zanja Creek – Church Street

Looking Upstream	Looking Upstream

Discharges: The City of Redlands Master Plan of Drainage (MPD) was used to develop the Unit hydrographs for regional sub-watersheds and Small Area Hydrographs for the local area. These hydrographs were used for the 2D modeling. The hydrographs for the following concentration (Node) points were used:

Hydrology Node	Watershed	Tributary Area	Peak Discharge (Qp)
		(ac.)	(cfs)
20939	Regional	1000.8	1409.07
20454	Regional – Zanja	5454.9	3835.98
20852	Regional	2992.9	3171.2
20955	Local		85.06
20971	“	2.4	8.63
20972	“	3.2	10.8
20973	“	3.6	12.3
20974	“	3.7	12.32
20975	“	3.7	12.49
20976.5 - 20965	“	5.4	16.08
20977 - 20965	“	4.5	17.49
20968	“	12.9	43.59
21093	“	7.4	24.79
21084	“	20.3	48.39
21087	“	14.6	27.37
21097	“	66.2	160.15
21044	“	220.8	352.5
21045	“	25.6	68.69

Note: Node 20939 hydrograph was divided into 2 (for Node 20924 & 20938)

It is understood that Zanja Creek is well undersized and some of the runoff escapes the channel and floods the street and surrounding areas. In order to account for this Model #2 is used as the boundary condition (for discharge) into Model #1 for regional flows only. Such modeling allowed a better estimation of runoff into the downtown area.

2D Model

Grid Size

Model #1: The study area was divided into multiples of 13.5’ x 13.5’ cells.
Model #2: The study area was divided into multiples of 10’ x 10’ cells.
Both model study surface area consists of over 99,000 cells.

Computational Time Step

The computational time step is very important for 2D modeling. Courant Number (Cr) is calculated to determine a range of time-step that could be used for modeling. Cr is typically around 5 seconds for most real-world applications (Syme 1991). For this study a time-step of 1-second was used. This lower time-step allows all the peak of the flood hydrographs to be captured since the inflow hydrograph are in 1-second increments.

Head Boundary Conditions

Surface boundary conditions were set for the 2-D analysis along the western boundary of the study area. The boundary conditions were set at the ground elevations.

Proposed Conditions

Project Condition

Geometry: Two alternatives was analyzed in the project conditions:

Alternative 1 (Redlands Boulevard Alignment)

1. Addition of single-cell culvert next to existing Redlands Boulevard storm drain from Citrus Avenue to downstream of Texas Street.
2. Increase capacity of Zanja inlet at 9th Street to the Redlands Boulevard storm drain.
3. Improve Oriental storm drain from I-10 to Redlands Boulevard.
4. Improve Zanja channel from 9th Street to I-10.

Alternative 2 (Bypass Alignment)

- Redirection of Zanja from 9th Street to downstream of Texas Street (eliminate 9th Street Zanja inlet).
- Construct a diversion pipe in the Reservoir Canyon storm drain from 9th Street/Redlands Boulevard to the bypass structure to alleviate surcharged Redlands Boulevard storm drain.
- Improve Oriental storm drain from I-10 to Redlands Boulevard.
- Improve Zanja channel from 9th Street to I-10.

Project conditions with the local improvements

The calculations for the downtown local storm drains (storm drains other than Redlands Boulevard main line) were based on the Regional Alternative 1 alignment. In XP-SWMM, all storm drains and laterals were evaluated in one comprehensive model. Since the goal of the downtown is to minimize flooding, these facilities were sized for the 100-year storm event.

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Source:

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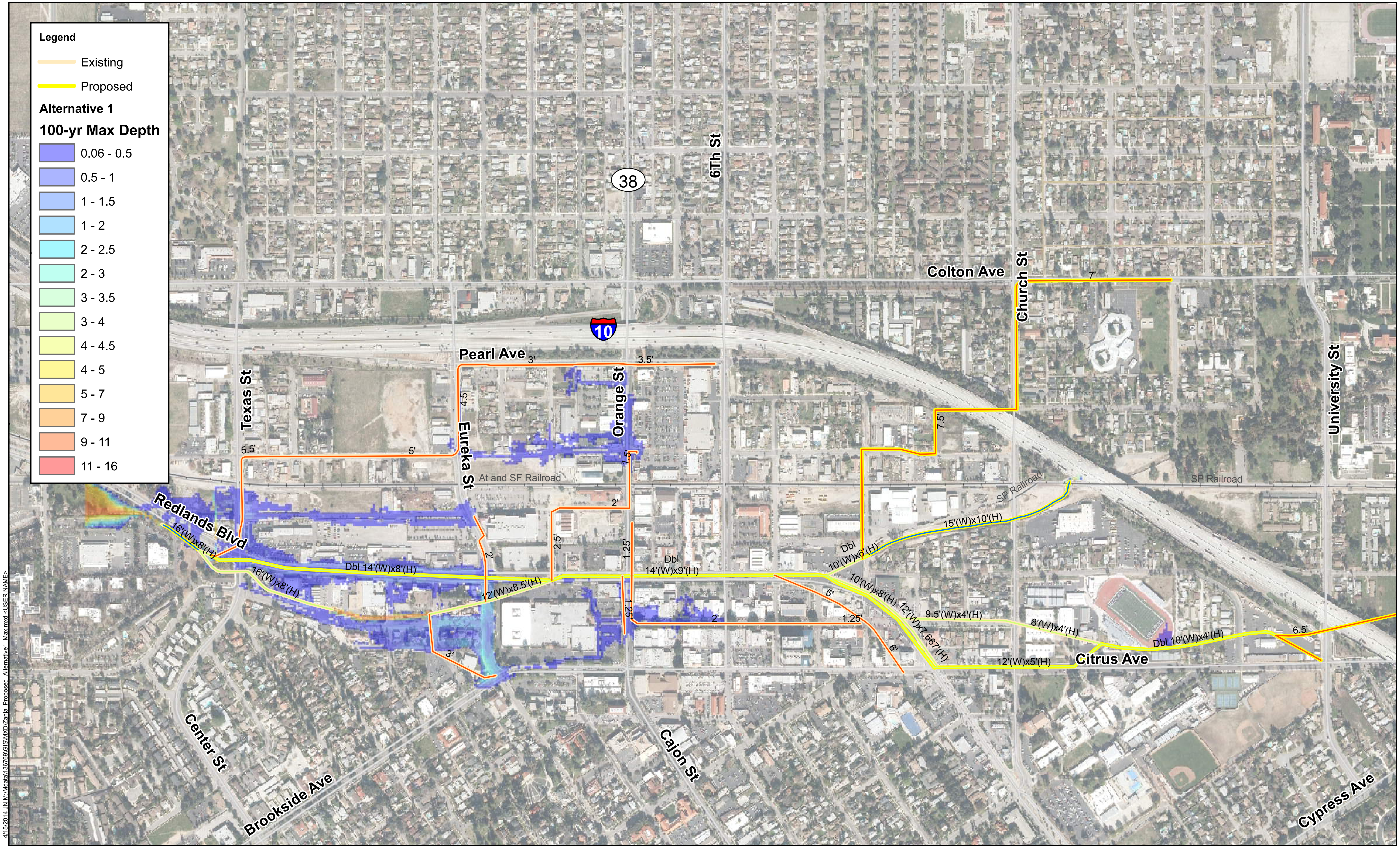
Existing Condition

Exhibit 2A



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0 300 600 1,200 Feet

Source:

CITY OF REDLANDS

Proposed Condition (Alternative 1)

Exhibit X