1 Introduction

1.1 Purpose

The City of Redlands Master Plan of Storm Drainage covers the City and adjacent areas that are tributary to the major regional flood control facilities that traverse through the City. The purpose of the Master Plan is to:

- Provide comprehensive long-range planning for the implementation and development of drainage facility improvements in the area,
- Determine the cost of implementing the facilities, and
- Discuss funding priorities of the improvements.

Since the City of Redlands does not have a Design Manual for Drainage Facilities, the County of San Bernardino standards were used as a basis for the criteria used in this Master Plan of Drainage.

Figures 1-1 and 1-2 show the existing Regional Location Map and Project Location map, respectively.

1.2 Background

The City of Redlands does not currently have a Master Plan of Drainage (MPD) specifically devoted to their drainage system and City needs. The City uses the San Bernardino County Flood Control District's (SBCFCD) "Zone 3 Comprehensive Storm Drain Plan No. 4" (CSDP#4), and historical flood events to help identify current and future drainage improvement needs. Originally prepared in 1976, a later revision to the CSDP#4 hydrology section was prepared by the County in February of 2013. No updates have been performed for the hydraulics or facility sizing with the revision to the hydrology. The intent of this Master Plan is to use the County's latest hydrology to identify the appropriate drainage facility infrastructure to provide appropriate flood protection.

The City of Redlands has a long history of flooding during moderate to severe storm events. One of the main causes for flooding is the lack of conveyance capacity in the historical channel of Mission Zanja (Zanja). The Zanja, formerly known as the Mill Creek Zanja, is a surface channel that flows from the Crafton Hills area, west to 9th Street, near downtown Redlands, where it transitions into a box culvert. The Zanja was built by the natives in 1819 as a water-supply irrigation ditch, pulling flows from Mill Creek. Due to extensive flooding and development, the diversion of flow from Mill Creek was blocked. Nonetheless, the Zanja was never improved to convey local storm flows and the drainage area tributary to the 9th Street storm drain still produces flows that far exceed the capacity of the box culvert, causing extensive flooding through the downtown area. The City has secured funding for the implementation of a flood attenuation basin along the Zanja, at Opal Avenue (Opal Basin).

Another source of flooding comes from the Reservoir Canyon storm drain. Several previous studies have been completed to try and identify potential attenuation solutions, with no successful site location.

Other efforts to minimize the flooding in downtown Redlands include a proposed diversion pipe that would split flows from Zanja at 9th Street. As part of the effort to identify drainage facility sizing, this alternative will be reviewed.

In addition to the County's 1976 CDSP#4 and their hydrology update prepared in February 2013, other studies that were reviewed and used as reference in this study include the following:

- Crafton and Opal Detention Basins Feasibility Study, Volume 1 – 2009, SBCFCD
- City of Redlands Field Investigation Report – 2009, SBCFCD
- Mill Creek Zanja Detention Basin Study, SBCFCD – 1986, Williamson & Schmidt
- FEMA FIS Study Yucca Creek, The Zanja – 1976 (approximately), FEMA
- Mission Zanja Creek, City of Redlands San Bernardino County, 1986, USACE.

1.3 Existing Watershed Description

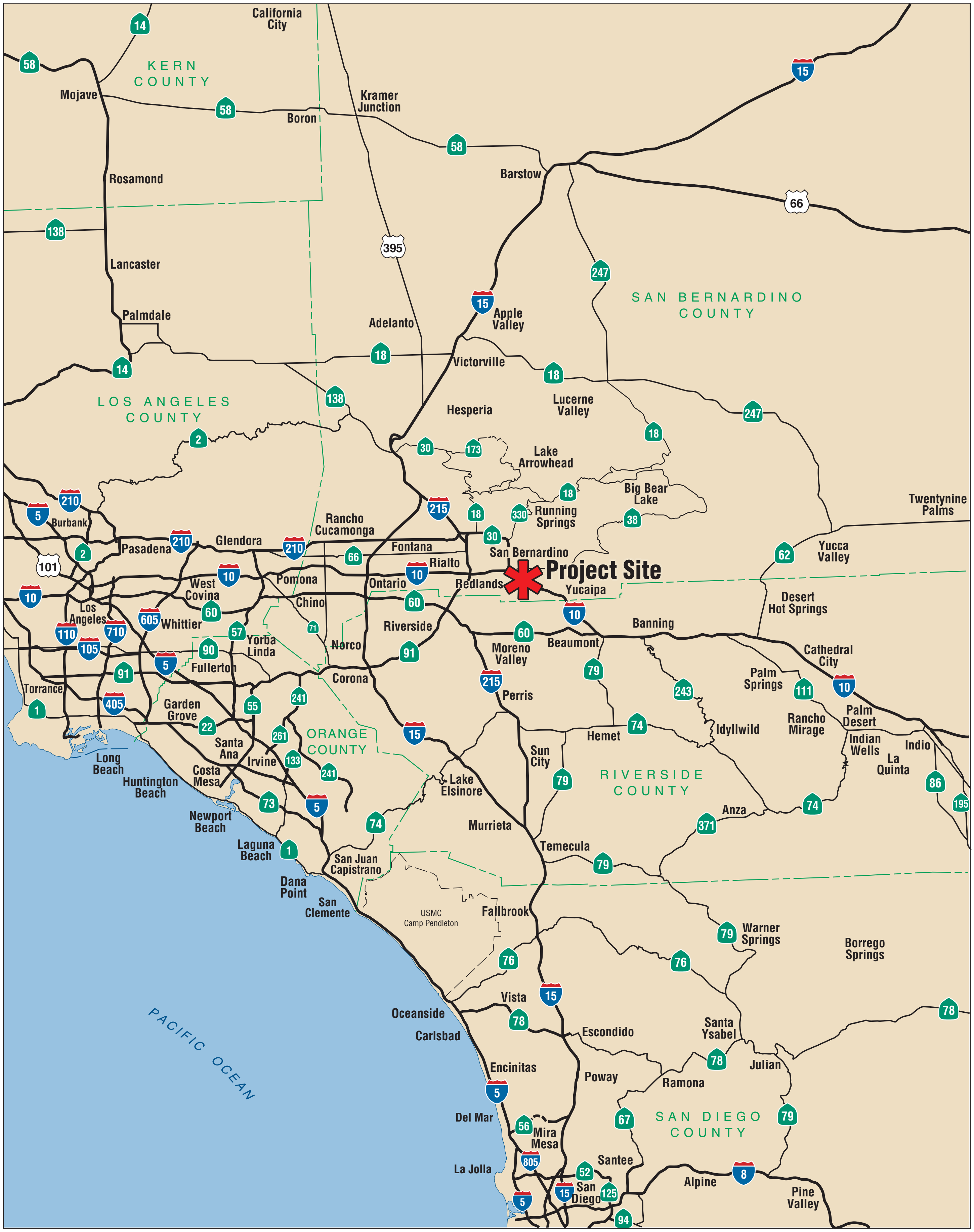
The City of Redlands generally drains from east to west to one of two main existing major flood control facilities. These facilities include the Santa Ana River and the San Timoteo Channel. Tributary to these major flood control facilities are several tributaries that run through the City of Redlands. Three of the largest named tributaries are: Mission Zanja, Reservoir Canyon Channel, and Mission Channel. The downtown area of the City of Redlands is located at the confluence of the historical Mission Zanja (Zanja) and the Reservoir Canyon Channel nears the east end. Downstream, at the northwest side of downtown, these flows combine with other local tributaries to form the Mission Channel.

Tributary to the downtown area, the Zanja consists of approximately 6,000 acres of drainage area. The Reservoir Canyon Channel consists of about 4,000 acres of drainage area tributary to the confluence with the Zanja at Redlands Boulevard. Other tributaries contribute to the downtown include the Oriental storm Drain (1000 acres) and the Carrot storm drain (543 acres).

This study is intended as a planning level investigation to determine current development and potential future redevelopment impacts to hydrology sizing of the proposed drainage infrastructure. The analyses were performed to cover the drainage areas within the City of Redlands. The Area designations or Regional Watershed Areas are listed below, and illustrated in Figure 1-3.

Table 1-1: Watershed Drainage Areas

Drainage Area Designation	Description
Mission Zanja	Covers drainage area tributary to Zanja to the confluence with Reservoir Canyon storm drain at Redlands Boulevard storm drain.
Reservoir Canyon	Covers the drainage area tributary to Reservoir Canyon storm drain to the confluence with Zanja at Redlands Boulevard storm drain.
Downtown	Covers local drainage area tributary to downtown (Redlands Boulevard) storm drain.
North City	Covers drainage area generally north of I-10 freeway, tributary to the Santa Ana River.
South City	Covers drainage areas in the far south of the City, tributary to Mission Creek and San Timoteo Creek.



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A Baker Company

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

Regional Vicinity

Figure 1-1

Source: Aerial Google Earth Pro.

RBF
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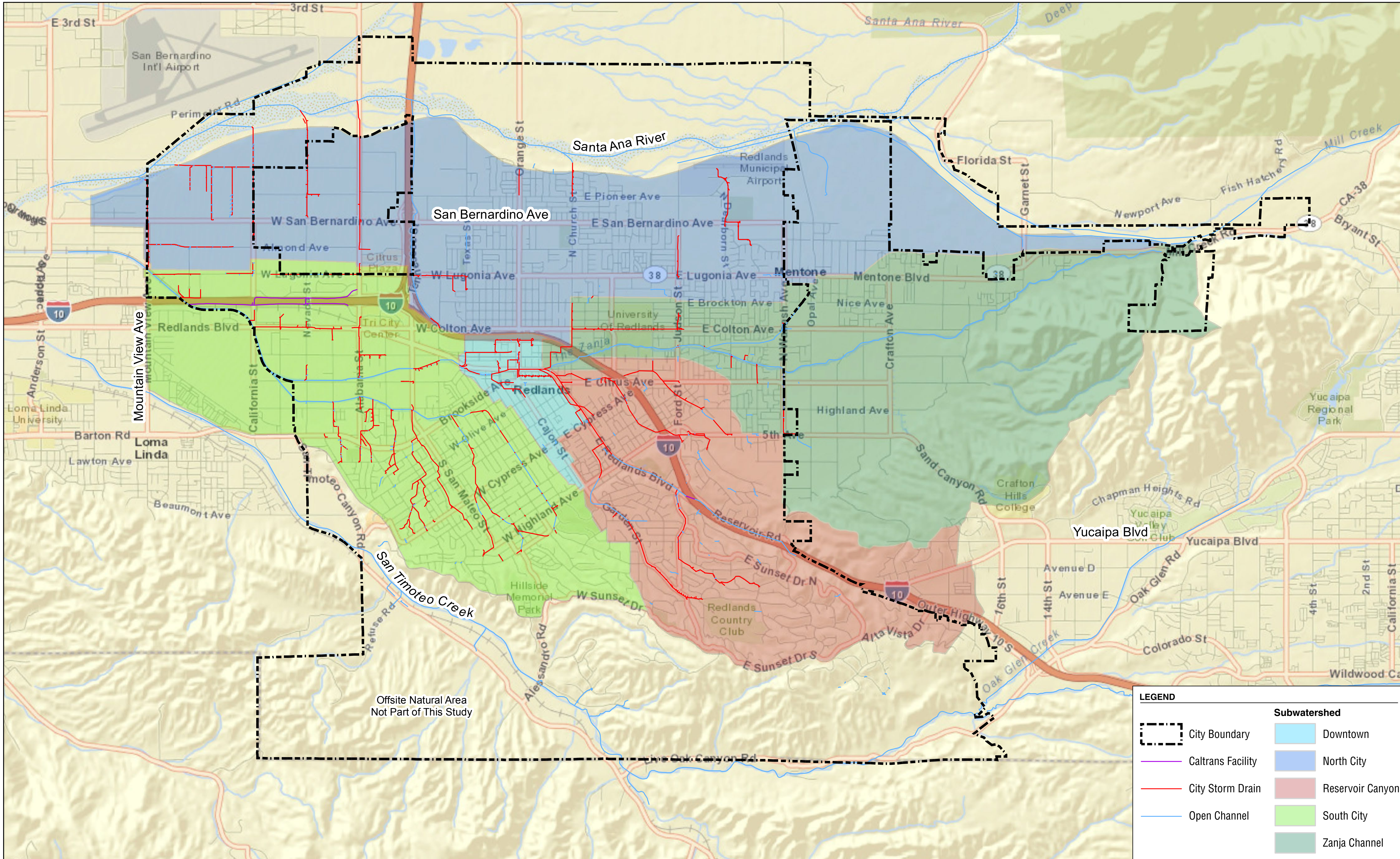
CITY OF REDLANDS MASTER PLAN OF DRAINAGE

Local Vicinity

Figure 1-2



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CITY OF REDLANDS MASTER PLAN OF DRAINAGE

Drainage Area Map

Figure 1-3

1.4 Background Facility Inventory

After compiling all available as-built data, GIS data, and reports, it was apparent that multiple information "gaps" existed in the local drainage system. Current as-built inventory covers approximately 30 percent of the existing city-wide drainage system. To improve accuracy of the hydraulic calculations and hydrologic boundary estimations, coordination with the City was necessary to acquire field verification of the existing storm drain facilities.

In some cases, these facilities were inaccessible, requiring engineering judgment to estimate approximate existing facility sizes, depths, and slopes. In most cases, upstream and downstream as-built plans were used to make determinations. If insufficient data existed, conduit slopes were estimated based on existing ground surface gradients.

Once the database was complete, the information was uploaded to GIS. The GIS database was used to help establish hydrologic drainage boundaries and to compile input data for hydraulic modeling of the existing storm drain capacities. The data collected in the field was used to back check the data from the as-builts, and the City's previous GIS database of the drainage facilities.

Table 1-2: Hydrology Background Information

Base Data	Source	Model Use
Topography	Flown 2014 (Downtown) Dated 2013 provided by SBCFCD (remaining City)	Primarily for elevations and slopes used in the XP-SWMM surface 2D models, AES rational and Unit Hydrograph analyses. Together with the As-built plans, provided the general slope of the area and was applied in determining tributary areas.
As-builts	City As-builts for storm drains and streets	Primarily for elevations and slopes of streets and storm drains hydraulics and also in hydrology to determine tributary areas.
Hydrologic Soil Types	SBCFCD CDSP#4 Updated Report (2013)	The soil data was used in the model was predominately Type "B" which has Moderate infiltration rates.
Land Use Data	SBCFCD CDSP#4 Updated Report (2013), verified w/ Aerial photo	Used as the basis for the land use determination. The data was then further refined with the aerial photography. The study area consists mainly of Commercial/Industrial and Residential land uses.
Aerial Photography	December, 2013	Used to further refine the City's Land Use Data into Land use types in accordance with the SBCFCD Hydrology Manual. Ex. Residential was refined into 5-7 dwelling units/acre (du), and apartments.

1.5 Water Quality and Recharge Initiatives

As part of this Master Plan of Drainage, water quality and water replenishment initiatives were evaluated. In accordance with the requirements of the Santa Ana RWQCB Permit No. R8-2010-0036, the City is to establish a review, approval and permitting process for new development and redevelopment occurring within its boundaries.

This MPD includes potential applications for redevelopment and retrofitting existing drainage facilities to accommodate water quality treatment and/or groundwater replenishment. Ten (10) locations have been identified for “Green Initiatives” based on location, soil type, land use, and tributary drainage area size.

Water quality facilities are designed to treat the “first flush”, or the smaller more frequent rainfall events. However, water quality facilities are not capable of treating or handing large flow events. Some volume based best management practices (BMPs) are capable of treating larger area, such as extended detention basins, retention basin, or large wetlands. Yet even these facilities cannot treat larger storm events. Combined flood control detention basins can be designed to treat water quality as well, but the treatment mechanism in the water quality portion of the basins will only treat the “first flush” storm events.

Low impact development (LID) strategies are encouraged in the NPDES Permit. The idea of disconnecting impervious surfaces leads to “first flush” or small storm partial infiltration. This could be beneficial for new development or redevelopment with respect to slowing the local drainage “Time of Concentration” to produce lower peak flows during small storm events. With respect to large storm events, generally over 2-year storm events, these “impervious” areas or water quality features are already at capacity and unable to accept any additional flows.

A comprehensive study of the City’s drainage areas has been performed to identify potential areas for Green Initiatives, or combined water quality/ground water recharge facilities. To maximize the facility benefits, large open space areas (for facility footprint) with a sizable drainage tributary area were evaluated. In some cases, smaller areas were also considered based on land use and potential to treat large paved or impervious areas.

2 Technical Criteria

2.1 Hydrologic Analysis

The County's updated CSDP#4 report used the original hydrologic boundaries from the 1975 CSDP#4 report. As a result, they were not updated based on the City's current storm drain system layout. These boundaries have been updated to match the existing and proposed storm drain system layout. However the regional boundaries identified from the updated CSDP#4 were used for this study.

The directive of this MPD is to use the updated County hydrology values where possible to identify appropriate flood control measures and drainage infrastructure to reduce flooding within the City. Consequently, the drainage facilities have been identified based on the previous CSDP#4 naming conventions.

Where new hydrology needed to be created, the hydrology analysis was achieved using the rational method model and multiple unit hydrograph method models for all concentration points where the total tributary area exceeds 640 acres. This was done for the 10-year, 25-year, and 100-year storm events, where the County's CSDP#4 report results were recalculated. The analysis was conducted per the SBCFCD Hydrology Manual and methods discussed below.

For the purpose of the advanced surface modeling within the downtown area, the County hydrology was used as a basis to develop peak flow hydrographs for the 100-year storm events. The local storm drain systems directly tributary to the Redlands Boulevard storm drain, were evaluated individually. Each local area required individual unit hydrograph development to appropriately evaluate flooding potential.

The updated County hydrology was reviewed to ensure appropriate hydrologic characteristics were used in the development of peak runoff. In one instance, the area tributary to the proposed Opal Basin was revised to include more realistic Manning's "n" values within the reaches of the Zanja. Using a Manning's "n" value that corresponded to "improved" channels sections, the County assumed this reach would be built out. Due to the historic value of this creek, it was assumed that existing, "natural" Manning "n" values would be more appropriate.

2.1.1 Hydrology Criteria for Street Capacity Calculations

The 10-year, 25-year, and 100-year peak flows were applied in street flooded width analysis to meet the following criteria for local streets and arterial highways:

Local Streets

1. The 10-year storm on sloped streets and 25-year storm for sump condition (where the area in question is at a low point, water surface elevation shall not exceed top of curb).
2. The 100-year water surface elevation shall not exceed the street right-of-way.

Arterial Highways (Major Roadways)

1. One travel lane (12-foot assumed if not determined) shall be free from inundation in each direction in a 10-year storm.
2. In a sump condition, one travel lane (12-foot assumed if not determined) shall be free from inundation in each direction in a 25-year storm.

3. The 100-year water surface elevation shall not exceed the street right-of-way.

Areas where recalculation of hydrology was necessary within the interior of the downtown region, the following SBCFCD Rational Method Guidelines, as outlined in their Hydrology Manual, were applied for the Rational Method analysis:

- Initial area maximum distance did not exceed 1,000' and was based on sheet flow only.
- Initial subareas were less than 10 acres.
- Subarea sizes increased gradually to satisfy the following conditions for 100-year calculations:
    - Travel Times increase by less than 3 minutes when TC is less than 30 minutes
    - Travel Times increase by less than5 minutes when TC is less than 60 minutes
    - Travel Times increase by less than10 minutes when TC is over 60 minutes

Most of the City streets are extremely flat, and in a few instances, this criterion was slightly exceeded. This was based on engineering judgment and eliminated breaking down the subareas and flow lengths further than necessary for this planning-level analysis.

Hydrologic routing for both rational and unit hydrograph analyses were performed utilizing the existing facility sizes provided by the City and Manning's "n" values were estimated based on San Bernardino County Flood Control Design Manual guidelines. AES Computer Software was used to estimate initial storm drain sizes, where existing system sizes were unknown or are non-existent.

The Rational Method times of concentrations were used to calculate lag times, while the land use and soil type parameters were applied in determining the sub-watershed and watershed loss rates. Both the lag times and loss rate are necessary for unit hydrograph analysis.

2.1.2 Precipitation

The precipitation values used in the County's CSDP#4 Hydrology Update in 2013 were in compliance with the 1986 Hydrology Manual. These values have changed since the previous 1976 CSDP#4 report. The hydrology models were performed using the 24-hour duration, 10-, 25-, and 100-year storm event precipitation values. For master planning purposes, the County used an Antecedent Moisture Condition value of 2 (AMC II). For detailed precipitation amounts, refer to the 2013 CSDP#4 Hydrology update, or the County's Hydrology Manual.

2.1.3 Land Use

Land Use designations were acquired from the County CDSP#4 report values. For local areas within downtown that required new hydrology to be calculated, CDSP#4 values were compared to General Plan values. In the downtown area, some of the CSDP#4 watershed had to be refined to adequately identify minor drainage area contributions to the main Redlands Boulevard storm drain.

2.1.4 Soil Types

The soil data used was consistent with those found in the County CSDP#4 calculations. The soil types within the City consisted predominantly of Type "B" which has moderate infiltration rates. The values in the CSDP#4 were developed based on the County Soils maps.

2.1.5 Watershed Descriptions

The watersheds tributary and within the City, were divided into five (5) areas; Mission Zanja (Zanja), Reservoir Canyon, Downtown, North City, and South City. The Zanja and Reservoir Canyon watersheds comprise of most of the area tributary to the City, and thus most of the flood source potential for the downtown area. Refer to Figure 1-3, "Regional Watershed Map."

The Zanja is the largest watershed tributary to the downtown area, consisting of 6,000 acres. The area includes the Crafton Hills area which is mostly flat agricultural lands and the area tributary to the Carrot storm drain, along Church Street. This area is mostly comprised of drainage area (approximately 4,000 acres) outside the City limit boundary. Consequently, this particular watershed has been extensively studied by the SBCFCD to identify possible flood control solutions. Current plans for flood control mitigation in this watershed include the implementation of the "Opal Basin." Another flood control project that has been identified is the construction of a diversion storm drain that would intercept flows at 9th Street and Zanja and route them west to Texas Street, where it would join Mission Creek, essentially bypassing the downtown area.

The Reservoir Canyon watershed is the second largest watershed area tributary to downtown Redlands (approximately 4,000 acres tributary to 9th Street). This area includes the Oriental storm drain tributary. Studies have been completed for this area to try and identify potential flood control mitigation efforts. The area is hilly, with relatively steep slopes. Consequently very little open space exists for potential detention/retention alternatives. Previous studies have shown no cost effective solutions for flood control attenuation is available for this area. This area is one of the main contributors to the historical flooding of the downtown area. With the proposed construction of the Opal Basin, and the planned diversion storm drain along the Zanja, it is expected that flows from this area will still cause extensive flooding in the downtown area.

The Downtown watershed consists of the local drainage systems in the downtown area, tributary to the Mission Creek channel at Alabama Street. Bound by the I-10 freeway to the north and Zanja and Reservoir Canyon to the east, and approximately Orange/Pine Avenue to the south, this area primarily consists of primarily dense residential and commercial development.

The North City watershed is the area north of the I-10 Freeway, and south of the Santa Ana River. This area is not tributary to the downtown area. This watershed is relatively flat, and is comprised of predominately agricultural and industrial land uses. The construction of Seven Oaks Dam has mitigated the flooding potential for the northern portion of this area, adjacent to the Santa Ana River. However, the Seven Oaks Dam does not affect the flooding potential of the downtown area.

The South City watershed consists of the drainage area south of downtown, tributary to Mission Creek. This area consists of hillside, residential, and open space. Existing storm drains and drainage courses in this area do not necessarily follow the alignments of the existing roads, but rather meander through the open space as "open channels." Areas tributary to San Timoteo Creek were not modeled as part of the Master Plan.

2.2 Hydraulic Analyses

The proposed improvements follow the CSDP#4 storm drain facility naming convention. The County referred to each system with a “project” number. This convention was used in this study.

Three different methods for hydraulic calculations were used to design the proposed system depending on the size and location of the facilities. For minor, or local systems, and street sections, normal depth calculations were performed using the Flowmaster (Bentley) computer program. The Los Angeles County’s Water Surface Pressure Gradient (WSPGW) program was used for evaluating proposed pipe sizes for main storm drains over 36-inches in diameter. WSPGW is a steady state hydraulic model that uses Bernoulli’s Equation (Energy Equation) for conduit calculations, and the Pressure/Momentum equation for junctions.

The downtown area, in addition to a portion of Zanja (upstream of the I-10), was modeled and sized using XP Software’s XP-SWMM, which is an improved version of the U.S. EPA’s Storm Water Management Model (SWMM). XP-SWMM is a dynamic wave model that solves the full St. Venant Equations. Dynamic modeling allows the effects of storage and backwater in conduits and floodplains and the timing of the hydrographs to yield a true representation of the hydraulic conditions. XP-SWMM can model the surface in 2-dimensions, while linking to the subsurface infrastructure, or storm drain system. The result is a comprehensive model that can communicate between the surface and subsurface facilities throughout the modeled design storm duration.

Hydraulic analyses were completed for both existing and proposed conditions for various design storm events. Existing condition analyses were performed to identify the capacity of a given drainage reach or system. This was completed by evaluating the capacity of the street sections, above the storm drain in addition to the storm drain capacity. Street capacities were evaluated by an Excel spreadsheet entitled StreetFlowCalcs+Existing.xlsx which considered pipe and roadway capacities to ultimately identify the level-of-protection necessary for each system. FlowMaster computations to model the hydraulic capacity of roadway sections were incorporated into the Excel spreadsheet. Depending on the size of the laterals or main storm drain lines, the sizes were calculated based on either normal depth or using a combination of energy equation and pressure and momentum.

For existing small open channels, a capacity analysis was performed using FlowMaster. If the facility failed, the proposed new facility was replaced with a reinforced concrete pipe (RCP). This was done for cost purposes. When these facilities are designed and built in the future, alternative conduits will be evaluated during the final design process.

Downtown Area (9th Street – Texas Street)

The downtown area required the use of a more advanced hydraulic model due to the large undersized regional drainage facilities tributary to it. This excess runoff requires an advanced surface model to identify flow quantity and direction as it moves through the downtown area. The City’s plans to construct a future “diversion storm drain”, in addition to the proposed Opal Basin, provided the basis to estimate their cumulative impacts on the current flood hazard within the downtown area. Traditional hydraulic modeling techniques can not accurately identify these facility impacts on the area. Using the advanced modeling techniques, hydraulic analyses were completed for both existing and proposed conditions using a linked 2-dimensional surface model, and 1-dimensional subsurface model (1D/2D) in XP-SWMM. The existing City storm drains were added to a 3-dimensional surface terrain model to understand the level of flooding, and to create the foundation for identifying appropriate future master planned facilities. Flows, or hydrographs, were added along the Zanja (near the I-10 underpass), Reservoir Canyon storm drain, Church Street storm drain, and near North University Street.

The main focus of this model is the Redlands Boulevard storm drain. All main lateral connections between 9th St. and Texas St. were modeled to identify their performance.

Regional Backbone Facility

Several studies have been completed to identify and alleviate the current flooding conditions in the downtown area. The 1986 U.S Army Corps (Corps) of Engineer's study provided the most detailed evaluation of multiple alternatives. At the time, the Corps used the steady-state flow model HEC-2 to evaluate the floodplain impacts of each alternative. Although the study did not provide technical calculations, alternatives included diverting flows from Zanja to Texas Street to increasing the capacity of the existing Redlands Boulevard storm drain. Their recommended alternative was the diversion structure. Even with this alternative, the Corps recognized that it was pointed out with the Zanja flows diverted, the 100-year flows from the Reservoir Canyon storm drain would still cause up to 1.5' of flooding in the downtown area.

RBF Consulting prepared several alternatives using the much more advanced hydraulic model, XP-SWMM, to identify the best regional drainage solution through the downtown area based on the SBCFCD revised CSDP#4 100-year hydrology. These alternatives included the planned future planned "diversion structure" and replacing the Redlands Boulevard storm drain. Alternatives were performed and compared to existing conditions to understand the levels of protection each alternative provided.

Section 3.3 discusses the model calculations and results.

2.2.1 Existing Conditions

The existing condition calculations were performed for the downtown area to identify existing street conveyance and storm drain deficiencies. Since the City of Redlands does not have published design criteria, the SBCFCD's criteria recommended in the CDSP#4 were used. The following sub-sections describe the methods used to analyze the existing condition hydraulics.

2.2.1.1 Downstream Water Surface Control Elevations

For the facilities that drain directly into large or regional facilities, criteria had to be estimated for the downstream tail water conditions. The depth of flow estimated in these large facilities greatly impact the hydraulic performances of the local facilities connecting to them.

Four different methods were used to determine the downstream water surface control elevation for the existing conditions hydraulic analyses:

1. Hydraulic grade lines from the As-built plans provided by the City of Redlands.
2. In areas where storm drains were tributary to other storm drains, water surface elevations were taken from the downstream models.
3. If no other information was available, the water surface elevation in large open channels was assumed to be three feet (3-ft) below the ground surface elevation at top of channel. The criteria were selected based on the County's "Earthen Channel Design Requirements (S.P. 100) for velocities over 8 feet per second. Since the MPD does not include bulked flows, this portion of the criteria was not used.

The majority of the models did not have as-built plans with HGLs, so methods 2 and 3 were predominantly used.

Table 2.1 below provides a summary of the street protection level discussed in section 2.1.1.

Table 2-1: Design Protection Levels for Streets

Type of Street	Storm Frequency	Maximum Allowable Flooding
Local	10-yr & 25-yr sump condition	Top of Curb
	100-yr	At adjacent pad elevation
Arterial Highway	10-yr & 25-yr sump condition	17 feet flooded width within road (or one dry lane in each direction)
	25-yr	Top of Curb
	100-yr	At lowest point in adjacent pad elevation

Each street type was designed based on its size and grade. Local streets are smaller two-lane facilities typically located within the residential and rural areas. Arterial highways consists of the larger multiple lane facilities that are typically located in high volume traffic areas.

The grade of the street can be described as either continuous or sump conditions. Continuous grades are street sections that do not have a low point, but rather slope in a continuous direction. Catch basins are typically designed in these facilities based on the allowable flow “spread” within the street. Sump locations within a street are low points, where excess runoff would generally pond. These locations typically create most of the local flooding during storm events as they are designed to capture the overflow runoff from upstream continuous grade inlets in addition to their respective tributary drainage area. Larger catch basin inlets are generally located at these locations.

The street capacity calculations were completed utilizing an excel spreadsheet developed for this study. Each drainage area was analyzed using the flow rates from the respective existing condition hydrology minus the existing storm drain capacities. The flow above the storm drain was assumed to be in the streets and normal depth was used to determine flow depths. If any of the above design protection levels were exceeded, the existing system was classified as deficient.

2.2.2 Proposed Conditions

The following sub-sections discuss the Proposed Condition Hydraulic analyses and the methods used. For subsurface storm drain infrastructure below streets, a proposed hydraulic grade line (HGL) of two feet (2-ft) below street surface was assumed. This would allow sufficient inlet conveyance capacity along the street sections to capture appropriate flows (as in Table 2.1).

2.2.2.1 Normal Depth Storm Drain Sizing (Local Storm Drains)

In order to determine the approximate required pipe size for the deficiency removals in areas outside major or main storm drain areas, an excel spreadsheet specifically developed for this study was used.

Normal depth was used to perform street flooded width analyses and calculate the proposed storm drain sizes. Each system was sized for the 10-, 25-, and 100-year storm events and then upsized if any of the Design Protection levels were still exceeded. Since normal depth calculations do not take into account downstream backwater conditions, the calculated pipe sizes were rounded up to the nearest 6 inches. The detailed procedure taken to complete this analysis, including discussions of how the calculation spreadsheet was constructed and what each of columns represent is included in Appendix B.

In cases where proposed systems discharge to existing regional facilities, a separate sensitivity analysis was performed on the facility size (determined based on normal depth). This was performed using the WSPGW hydraulic model, with the downstream control set based on the criteria in Section 2.2.1.1. The proposed facility size was upsized where necessary as determined by the WSPGW hydraulic calculation. A Storm Drain Facility ID Map is included as Exhibit 3.

The required sizes are discussed in detail in each drainage area (Sections 3).

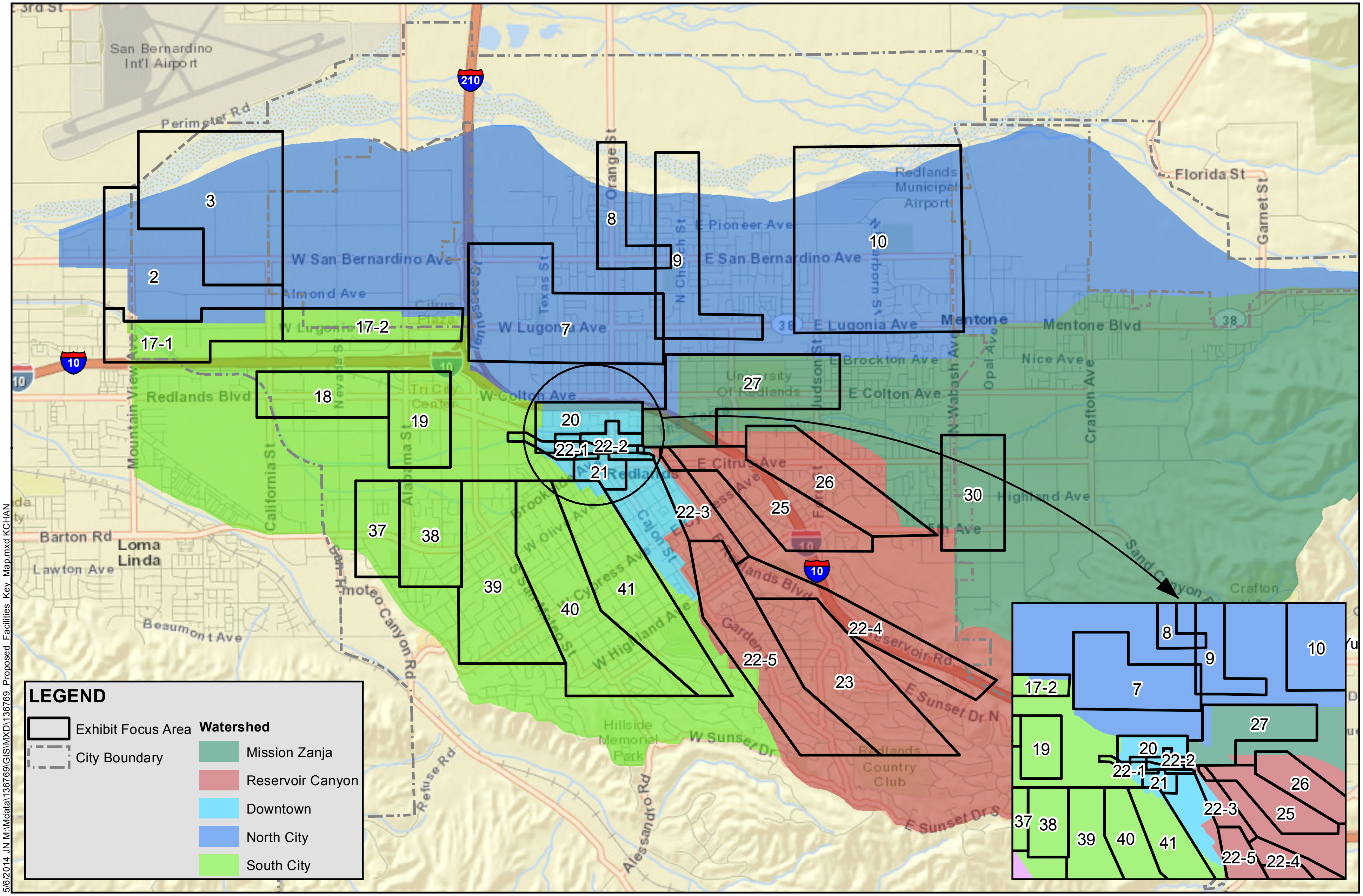
2.2.2.2 Main Lateral Storm Drain Sizing

For most subsurface storm drain systems 36-inch diameter and larger, WSPGW was used to analyze the systems. WSPGW models the impact of downstream tailwater conditions, and thus provides more accurate results than normal depth calculations.

For the downtown area of the MPD, XP-SWMM was used to size the proposed drainage facilities. As part of the regional model to evaluate Zanja and Reservoir Canyon Channel, the downtown local facilities that were connected to the Redlands Boulevard storm drain. Since these laterals were already a part of the regional model, it was more beneficial to size them in XP-SWMM.

2.2.2.3 Facility Naming Convention

The storm drain facilities were identified based on the CSDP#4 naming convention. For areas where new storm drains were recommended, the naming convention was sequentially increased for that particular storm drain or “project” as they are referred to in the CSDP#4. For the facilities key map, refer to Figure 3-1.



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Source: Base Map - Esri

CITY OF REDLANDS MASTER PLAN OF DRAINAGE

PROPOSED FACILITIES KEY MAP

Figure 2-1

2.3 Facility Priority Evaluations

A priority ranking has been developed based on the projects of greatest importance. A process has been prepared to determine which projects should be constructed first when funding becomes available. The three priorities are summarized below: Refer to Exhibit 4 for a map containing priority storm drains.

- **Priority 1a (*highest priority*)**
  - *Local Streets* – Existing streets and storm drain systems where flood depth is above the right-of-way in the 10-year storm event.
  - *Arterial Streets* - Existing streets and storm drain systems where flood depth is above the right-of-way in the 25-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 10-year flood protection AND overflows impact multiple adjacent local facilities.
- **Priority 1b**
  - *Local Streets* **–** Existing streets and storm drain systems where flood depth is above top of the curb in 10-year storm event.
  - *Arterial Streets* **-** Existing streets and storm drain systems where flood depth is above top of curb in the 25-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 25-year flood protection AND overflows impact multiple adjacent local facilities.
- **Priority 2**
  - *Arterial Streets* **-** Existing streets and storm drain systems where flooded width is greater than 17 feet in the 10-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 100-year flood protection AND overflows impact multiple adjacent local facilities.
- **Priority 3**
  - *Local Streets* **–** Existing streets and storm drain systems where flood depth is above the right-of-way in the 100-year storm event.
  - *Arterial Streets* **-** Existing streets and storm drain systems where flood depth is above the right-of-way in the 100-year storm event.
  - *Regional Facilities* – Existing storm drain systems do not achieve 100-year flood protection AND overflows impact multiple adjacent local facilities.

2.4 Cost Estimates

Cost estimates were created for the proposed condition of new or replacement storm drain systems. The unit prices were developed in cooperation with the City and current market values.

The calculated system costs estimates include costs for engineering, construction, SWPPP, surveying, construction management and contingencies. Any new storm drain construction within the City most likely will require utility relocation. This can be very costly especially considering the downtown area is highly urbanized and with infrastructure dating back over 100 years. The quantity and complexity of utility relocation is unknown and requires detailed site specific subsurface investigations.

Pipe costs are per linear foot and included costs for excavation, shoring, bedding, backfill, compaction, removal of excess material, and trench resurfacing.

Due to the fact that construction will take place over a number of years, the total cost of master plan implementation will vary from the numbers provided in this study. It is recommended that any future implementation plans take into account future construction unit costs prior to creating a funding program for the Master Plan of Drainage. The Engineering Construction Cost Index is 9750 as of this report.