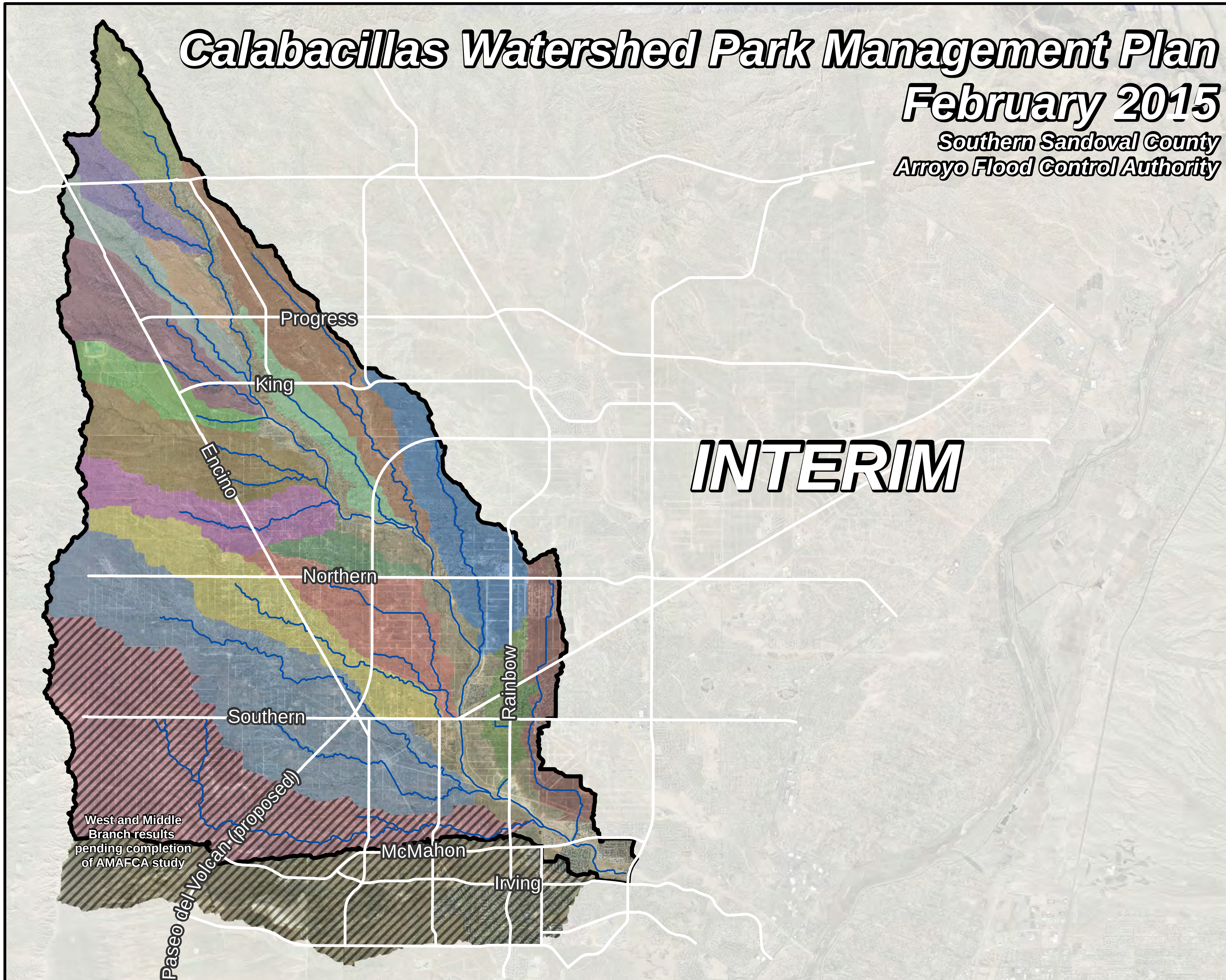
Calabacillas Watershed Park Management Plan

February 2015

Southern Sandoval County
Arroyo Flood Control Authority



INTERIM Calabacillas Watershed Park Management Plan (CAWMP)

Southern Sandoval County Arroyo Flood Control Authority

This plan is an interim document and is valid only for the upper portion of the Calabacillas Watershed located in Sandoval County and DOES NOT INCLUDE the West Branch and Middle Branch Tributaries. AMAFCA is working on developing the hydrology for the West Branch Tributary. Once completed, the results from that study will be incorporated into the overall watershed model, and the CAWMP will be re-published.

The INTERIM Calabacillas Watershed Park Management Plan was accepted by the SSCAFCA Board of Directors on ________________.

By: ______________________ Date: 2/20/15
Charles Thomas, P.E. (Executive Engineer)

By: ______________________ Date: 2/20/2015
James F. Fahey Jr. (Chair)

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This is a planning document. Nothing herein constitutes any commitment by SSCAFCA to construct any project, study any area, acquire any right of way or enter into any contract. This watershed park management plan does not obligate SSCAFCA in any way.

Drainage facility alignments, conveyance treatments, corridors, locations, rights-of-way and cost estimates are conceptual only, and may be altered or revised based upon future project analysis, changed circumstances or otherwise. Land uses included in this document were assumed for the basis of hydrologic modeling only. This document does not grant "free discharge" from any proposed development. Naturalistic channel treatments and piped storm drains are to be used for conveyance stabilization, unless otherwise authorized by SSCAFCA.

To ensure public health, safety and welfare, SSCAFCA develops and maintains the adopted "Master" regional hydrology for all watersheds within its jurisdiction. Updates and revisions are made and tracked by SSCAFCA, or their designee. A copy of the "Master" hydrology model is available for reference or use by others. Contact SSCAFCA to obtain copies of the model and see the SSCAFCA website for the Watershed Management Plan status. Use of electronic media provided by SSCAFCA is solely at the user's risk.

CALABACILLAS WATERSHED PARK MANAGEMENT PLAN (CAWMP) REVISION HISTORY

CURRENT THROUGH FEBRUARY 2015

Revision	Type	Title	Description of Changes	Prepared by	Effective Date/ Approval Date
v.1 2014	Initial Release, Interim Plan for the Upper Watershed not including the West Branch and Middle Branch Tributaries	Calabacillas Watershed Park Management Plan	n/a	SSCAFCA	

CALABACILLAS WATERSHED PARK
MANAGEMENT PLAN

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CALABACILLAS WATERSHED PARK MANAGEMENT PLAN
ABBREVIATIONS & DEFINITIONS

100-year Storm	-	A storm which has a 1% chance of being equaled or exceeded in any given year
ac	-	Acre
Ac-ft	-	Acre-feet (volume of water that covers one acre one foot deep)
AHYMO	-	**A**rid Lands **HY**drologic **MO**del
AMAFCA	-	Albuquerque Metropolitan Arroyo Flood Control Authority
Arroyo	-	Ephemeral stream in arid or semiarid southwestern U.S. typically with a flat floored channel and vertical or steeply cut banks that is usually dry.
Authority	-	See SSCAFCA
Blvd	-	Boulevard
CBC	-	Concrete Box Culvert
cfs	-	cubic feet per second – flow rate
cfs/ac	-	cubic feet per second per acre
CMP	-	Corrugated Metal Pipe
COA	-	City of Albuquerque
CoRR	-	City of Rio Rancho
USACE	-	United States Army Corps of Engineers
CY	-	Cubic yard
Dam	-	Facility intended for sediment, erosion, and flood control; (see also: "Jurisdictional Dam")
Design Q	-	The flow rate in cfs that the facility was designed for; this assumes that freeboard and other factors were included in the design; this is not the "bank full" capacity
Developed	-	Lot, parcel or area with structures or other man made construction
Detention	-	Collection, temporary storage and controlled release of runoff
DEVEXConditions Hydrology	-	Fully developed watershed, assuming existing platting, and only incorporating currently existing drainage infrastructure
DMP	-	Drainage Master Plan
DPM	-	SSCAFCA 2009 Development Process Manual Chapter 22
Drainage Basin	-	Area of land that drains to a specific location or drainage facility
Drainage Report	-	A document for the purpose of describing the existing drainage conditions, predicting the effects of land use or other changes and proposing solutions to drainage problems
du/ac	-	Dwelling unit per acre

Emergency Spillway	-	A spillway designed to convey excess water through, over or around a dam if the capacity of the dam and principal spillway are exceeded
EPA	-	Environmental Protection Agency
EXISTINGConditions Hydrology	-	Hydrology representing existing development and drainage infrastructure as of the date of the report
Facility	-	Any structure, levee, dike, diversion channel, storm drain, pond, pumping station, detention facility or dam, either natural or manmade, which has the function of conveying, containing, directing or storing stormwater runoff
Facility Name	-	The commonly referenced name for the facility
Facility Plan	-	A drainage study or design analysis of a specific facility, usually limited to a specific drainage basin or sub-basin
Failure	-	An incident resulting in the uncontrolled unintentional release or loss of control of stormwater
FEMA	-	Federal Emergency Management Agency
FIRM	-	Flood Insurance Rate Map
Flood	-	A general and temporary condition of partial or complete inundation of two or more acres of normally dry land or two or more properties from: - Overflow of inland or tidal waters - Unusual and rapid accumulation or runoff of surface waters from any source - Mud flow
Floodplain	-	That area above and alongside a river, an arroyo, floodway or channel, which is subject to inundation by out-of-bank flow
Floodway	-	The central channel or watercourse and the adjacent land area that is administered by FEMA and must be reserved in order to allow discharge of the base flood without increasing the water-surface elevation more than a designated height
fps	-	feet per second
Free Discharge	-	Runoff without peak flow and/or volume attenuation
Fully Developed	-	All areas are assumed to be completely developed (i.e. fully built out) based on existing platting, zoning and/or proposed development
GIS	-	Geographic Information System
Hard Lined Conveyance	-	Constructed channel or other conveyance system with non-pervious lining (concrete, soil cement, etc.)
HEC-HMS	-	Hydrologic Modeling System (HMS) developed and maintained by the US Army Corps of Engineers Hydrologic Engineering Center(HEC); software and manuals can be downloaded for free from the HEC website: http://www.hec.usace.army.mil/software/hec-hms/
Historic Runoff	-	Runoff based on "Pre-Development" conditions. For the purposes of this plan, historic runoff is interpreted as watershed conditions prior to significant human modifications

Jurisdictional Dam	-	Dam under the jurisdiction of the New Mexico Office of the State Engineer; Section 72-5-32 NMSA 19.25.12.7 D. (1) (a) NMAC-N, 3/31/2005, defines a jurisdictional dam as 25 feet or greater in height and storing more than 15 acre-feet or a dam that stores 50 AC-FT or greater and is 6 feet or more in height
Lateral Erosion Envelope (LEE)	-	An identified envelope boundary, inside of which development may be at increased risk from flooding or damage due to lateral migration of the arroyo or channel
MRCOG	-	Mid Region Council of Governments
MRGCD	-	Middle Rio Grande Conservancy District
Natural Arroyo	-	An ephemeral drainage way, typically having a sloping, movable bed with steep or vertical erodible banks, which has not been directly altered by human intervention
Naturalistic Arroyo	-	An ephemeral drainage way, typically having a sloping, movable bed with steep or vertical erodible banks, which has been directly altered by human intervention; and in which non-continuous or limited erosion protection measures have been installed to prevent damage to infrastructure while maintaining the natural bed and bank materials, with the objective of maintaining the natural character of the corridor to the maximum extent practicable such that it can continue to be used by wildlife and recreationist
NM	-	New Mexico
NM528	-	New Mexico Highway 528, also known as Pat D'Arco Highway
NMDOT	-	New Mexico Department of Transportation
NOAA	-	National Oceanic and Atmospheric Administration
NPDES	-	National Pollutant Discharge Elimination System (EPA permit program to reduce pollution in water of the US)
NRCS	-	Natural Resources Conservation Service
O&M	-	Operation and Maintenance
O&M Agency	-	The agency with primary operations and maintenance responsibility for a facility
OSE	-	Office of the State Engineer
PMF	-	Probable Maximum Flood
Pond	-	Facility intended for sediment, erosion, and flood control, which is constructed less than 25 feet in height and can store less than 50 AC-FT of water (see also "Jurisdictional Dam")
Principal spillway	-	The low-flow outlet from a dam, typically a pipe or box culvert
Probable Maximum Precipitation (PMP)	-	Theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location
Probable Maximum Flood (PMF)	-	The largest flood that may be expected at a point on a stream or water course resulting from the most severe combination of critical meteorological and hydrologic conditions possible in a particular watershed
Proposed Facility	-	A new recommended drainage facility
Q	-	Flow rate, in cfs
RCP	-	Reinforced Concrete Pipe
Regional Stormwater Detention Facility	-	See Major Facilities
ROW	-	Right-of-way
Retention	-	Collection and storage of runoff without release
SAD	-	Special Assessment District
SCS	-	Soil Conservation Service (previous name for NRCS)
Soft Lined Conveyance	-	Constructed channel, swale or other conveyance system with pervious lining, with or without erosion control measures (i.e. riprap, grass, natural soil, etc.)
SSCAFCA	-	Southern Sandoval County Arroyo Flood Control Authority
Sub-basin	-	Portion of a watershed; see also "drainage basin"
ULTIMATE Conditions Hydrology	-	Fully developed watershed including all existing drainage facilities along with anticipated future drainage infrastructure
USACE	-	United States Army Corps of Engineers
USGS	-	United States Geological Survey
Watershed	-	Drainage area usually incorporating several drainage basins or sub-basins, typically with an outfall directly to the Rio Grande or into an independent system which conveys the watershed runoff to the Rio Grande
Watershed Park Management Plan	-	A comprehensive study of the drainage characteristics of a watershed establishing the plan for managing drainage within the watershed
WC	-	Two letter identifier for the Willow Creek Watershed Park
CAWMP	-	Calabacillas Watershed Park Management Plan
WMP	-	Watershed Management Plan

I. INTRODUCTION

A. BACKGROUND

The Calabacillas Watershed Park Management Plan (CAWMP) was prepared by the Southern Sandoval County Arroyo Flood Control Authority (SSCAFCA) in cooperation with the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA). The main purpose of this study is to:

Research the hydrologic characteristics of the upper Calabacillas Watershed upstream of AMAFCA's Swinburne Dam

- Build rainfall-runoff models for existing conditions and anticipated future urban development (developed conditions) for the 100-year storm
- Model the Probable Maximum Flood (PMF) inflow into Swinburne Dam
- Identify major drainage deficiencies (areas at risk of flooding and erosion)
- Evaluate alternatives and propose solutions to solve drainage related problems

B. VISION AND GOALS

The goals presented in the CAWMP for the Calabacillas Watershed Park represent both the goals of SSCAFCA & AMAFCA, and goals specific to the watershed. These goals are:

- To provide flood protection up to the 100-year storm for the public health, safety and welfare of residents and properties within its boundaries.
- To recognize the value of the land purchased or controlled for floodways as areas with multi-use potential.
- To control sediment and erosion within the boundaries of the flood control authority.
- To assist other entities in the construction of flood control for the good of the public.
- To provide discharge guidelines for future development.
- Preserve the natural character of the arroyos where possible and propose improvements to mitigate the effect of developed flows.

II. WATERSHED OVERVIEW

A. STUDY AREA

The Calabacillas Watershed covers an area of approximately 97 square miles and drains to the Rio Grande just south of the Sandoval/Bernalillo county line. The area draining to AMAFCA's Swinburne Dam encompasses the upper 80 square miles of the watershed (see Figure 1, hatched area). SSCAFCA prepared the hydrologic models for the area highlighted in yellow; Models for the West Branch Tributary (purple) were prepared by Tetra-Tech for AMAFCA and incorporated into SSCAFCA's model. The Black and NM 528 Watersheds both discharge to the Calabacillas Arroyo below Swinburne Dam and were therefore not included in this study. The area studied by SSCAFCA will be referred to as the "**Upper Calabacillas**"; the AMAFCA study area will be identified as "**West Branch Tributary**" in this plan.

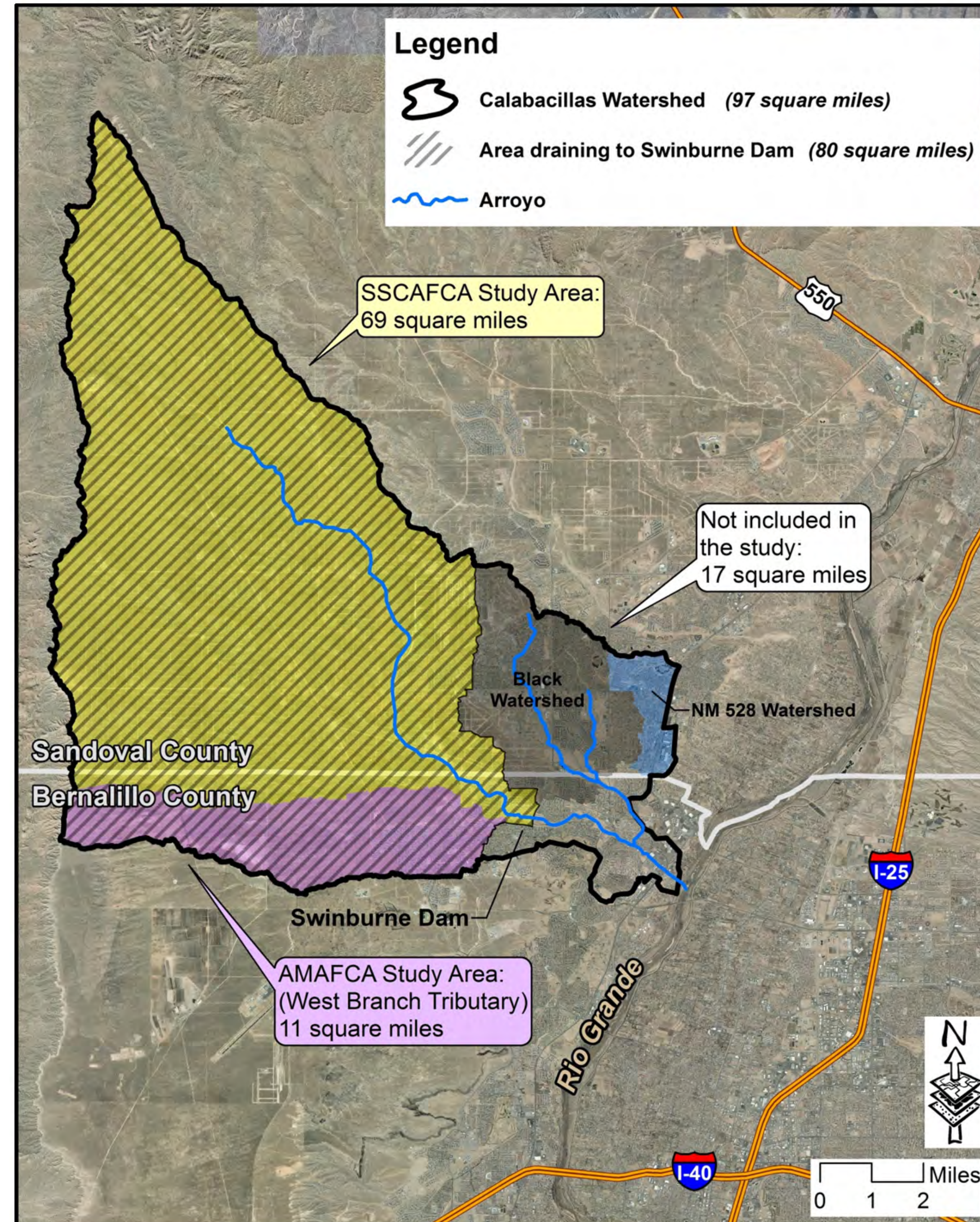


Figure 1: Map showing the area draining to Swinburne Dam (striped) within the overall Calabacillas Watershed Park.

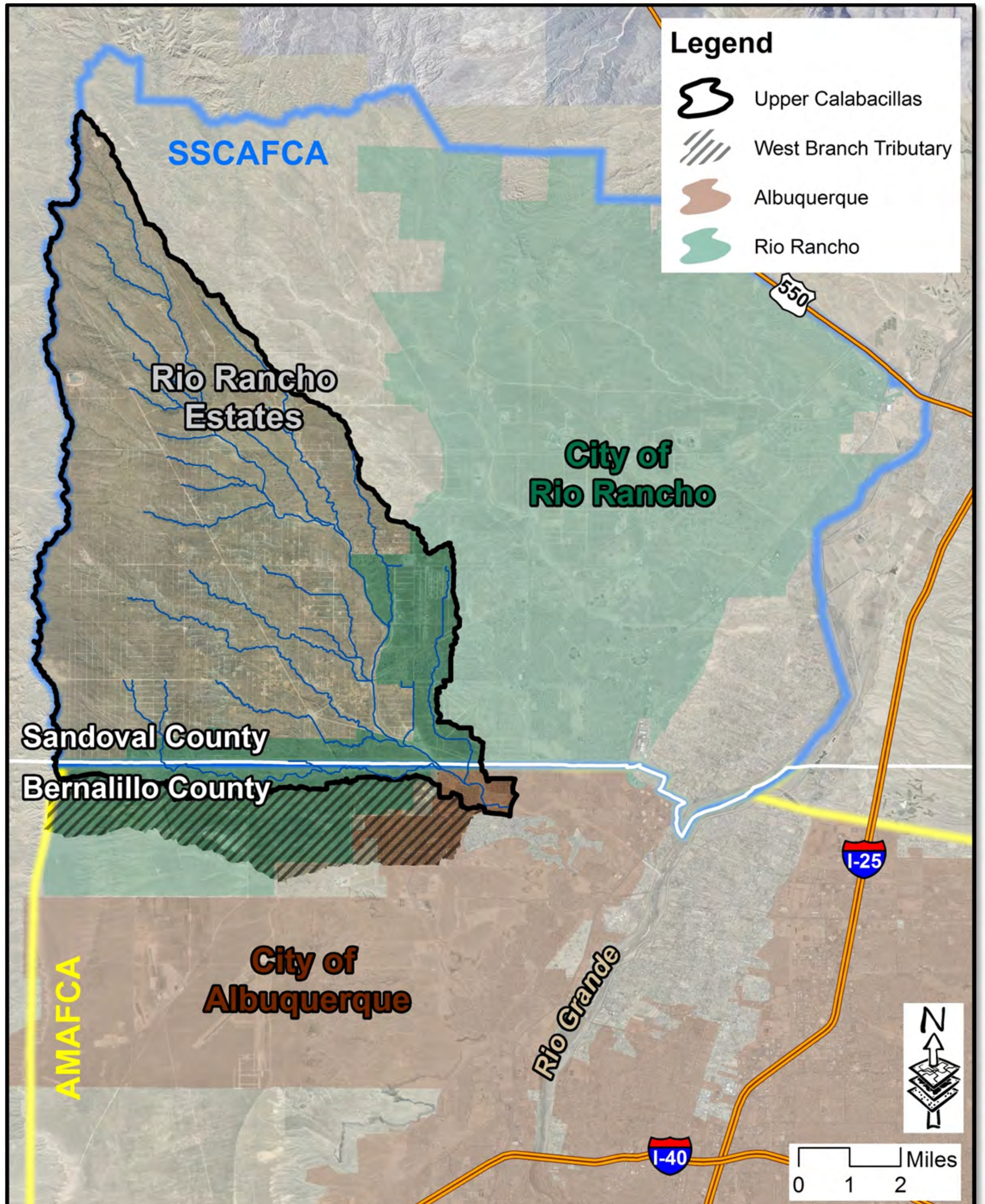


Figure 2: Map of the Calabacillas Watershed upstream of Swinburne Dam and local jurisdictions.

B. JURISDICTIONS

Most of the study area (65 square miles or 81 percent) lies within Sandoval County and SSCAFCA's jurisdiction. The southern portion (19 percent of the study area) is located in Bernalillo County and falls within AMAFCA's jurisdiction. Portions of the watershed are within the Rio Rancho and Albuquerque city limits, but the majority of the upper watershed falls within the Rio Rancho Estates area (see Figure 2), which is unincorporated Sandoval County.

C. REFERENCES

Available reports and plans for existing and proposed developments and drainage facilities within the watershed were assembled and reviewed and have been included in the development of the CAWMP. All reference documents are listed in Section VI and are available for review at the SSCAFCA office.

D. WATERSHED CHARACTERISTICS

All descriptions contained in this section of the report refer to the Upper Calabacillas only (see Figure 2); for a discussion of characteristics of the West Branch Tributary, please refer to the West Branch DMP (Tetra Tech, 2013).

1. Vegetation

With elevations ranging from 6,656 feet at the headwaters to about 5,260 feet at Swinburne Dam, the Calabacillas Watershed Park falls into the Pinon-Juniper belt. While Pinon trees are absent from the watershed, clusters of junipers are abundant in the higher elevations and often grow in depressed areas or gullies that concentrate runoff and provide slightly more moisture. Commonly found shrubs are Sagebrush (*Artemisia tridentata*) and Four-Wing Saltbush (*Atriplex canescens*).

Photo 1: Left: Typical vegetation found in the Calabacillas Watershed Park with Junipers in the background and Sagebrush and Four-Wing Saltbush in the foreground. Right: Claret cup cactus in full bloom.

2. Calabacillas Arroyo Main Stem

The main stem of the Calabacillas Arroyo between King Blvd. and Unser Blvd. is approximately 12 miles in length; the arroyo ranges from 40 to over 300 feet in width, with an average width of about 130 feet.

Photo 2: Calabacillas Arroyo looking upstream form 29th Ave; the width of the arroyo in this location is approximately 70 feet.

3. Major Tributaries and Their Basins

Figure 3 shows the 19 major tributaries and their respective basins that drain to the Calabacillas Arroyo. Only three of the tributaries are currently named: AMAFCA's West Branch Tributary (WB), the Middle Branch Tributary (MB) and the Rainbow Tributary (RA). All other tributaries were assigned letter designations (B through Q). Areas adjacent to the main stem of the Calabacillas Arroyo are designated with the letter "A". Tributary basins range in size from less than one square mile to almost twelve square miles (see Table 1).

Table 1: List of major tributaries to the Calabacillas Arroyo

Tributary	*Area (mi²)*
A (Main Stem)	7.2
B	10.7
C	4.4
D	3.2
E	1.0
F	2.8
G	3.8
H	1.6
I	3.4
J	1.8
K	0.7
L	1.5
M	2.0
N	4.5
O	1.7
P	3.8
Q	1.2
MB (Middle Branch)	11.6
RA (Rainbow Tributary)	2.1
WB (West Branch, AMAFCA study)	11.1
TOTAL:	**80.3**

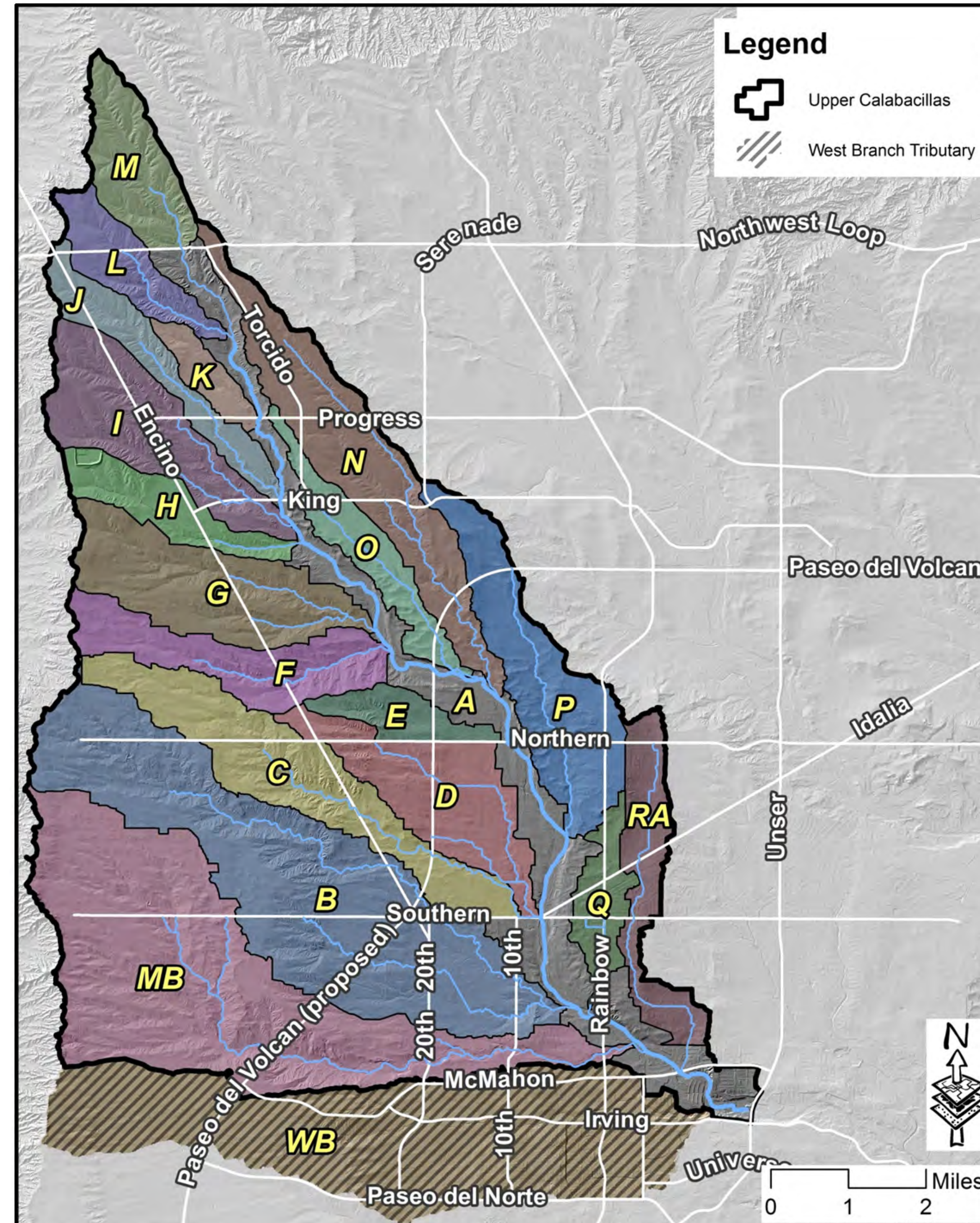


Figure 3: Map of the Calabacillas Watershed, major tributaries, and their basins.

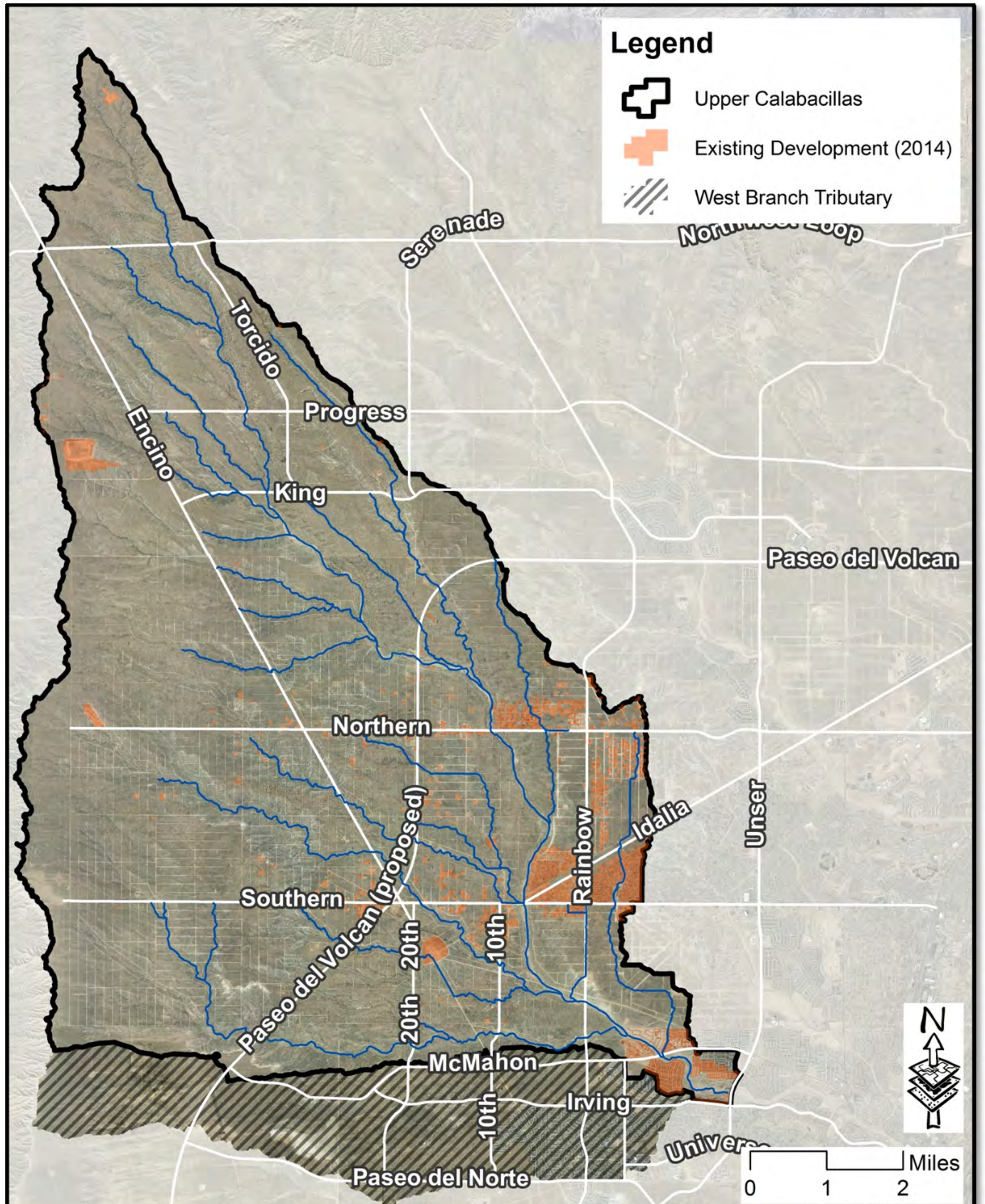


Figure 4: Map showing existing urban development and graded roads in the Calabacillas Watershed Park.

Photo 3: Picture showing a graded dirt road in the Calabacillas Watershed acting as a channel after a small storm event in August of 2013.

4. Urban Development

Most of the urban development is limited to the eastern edge of the study area, and is concentrated around Northern Blvd, Southern Blvd and McMahon. Under EXISTING (2014) conditions, less than two percent of the Upper Calabacillas is covered by impervious surfaces (paved roads, rooftops, driveways, etc.); please note that this figure does not include the West Branch Tributary.

Most of the watershed is still in its natural state, with the exception of a network of graded dirt roads that cross the Rio Rancho Estates area. Photo 3 shows how graded roads can alter the natural flow path by acting as channels that intercept and convey stormwater runoff.

5. Soils

The soils in the Upper Calabacillas are predominantly sandy loams and fine sandy loams, with some loamy fine sands along the main stem of the Calabacillas Arroyo and in the south-western portion of the study area. Soil data was obtained from the NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service).

Table 2: Soils found in the Upper Calabacillas

	Map Unit Symbol	*Description*	*Hydrologic Soil Group*	*% of Upper Calabacillas*
Sandoval County	41	Dune land	A	<1%
	142	Grieta fine sandy loam, 1 to 4 percent slopes	B	25%
	143	Clovis fine sandy loam, 1 to 4 percent slopes	B	23%
	145	Grieta-Sheppard loamy fine sand, 2 to 9 percent slopes	B	4%
	183	Sheppard loamy fine sand, 8 to 15 percent slopes	A	2%
	190	Zia-Skyvillage-Rock outcrop complex, 5 to 40 percent slopes	B	<1%
	191	Sheppard loamy fine sand, 3 to 8 percent slopes	A	13%
	211	Zia-Clovis association (sandy loam), 2 to 10 percent slopes	B	27%
Bernalillo County	Bb	Bluepoint fine sand, hummocky	A	<1%
	BCC	Bluepoint loamy fine sand, 1 to 9 percent slopes	A	3%
	BKD	Bluepoint-Kokan association, hilly	A	2%
	LtB	Latene sandy loam, 1 to 5 percent slopes	B	<1%
	MaB	Madurez loamy fine sand, 1 to 5 percent slopes	B	1%
	PAC	Pajarito loamy fine sand, 1 to 9 percent slopes	B	<1%

In general, soils found throughout the Upper Calabacillas can be characterized as highly erosive. Photo 4 shows roots of a juniper that were recently exposed when flood waters moving through the Calabacillas Arroyo eroded several feet of bank.

Photo 4: Bank erosion along the Calabacillas Arroyo.

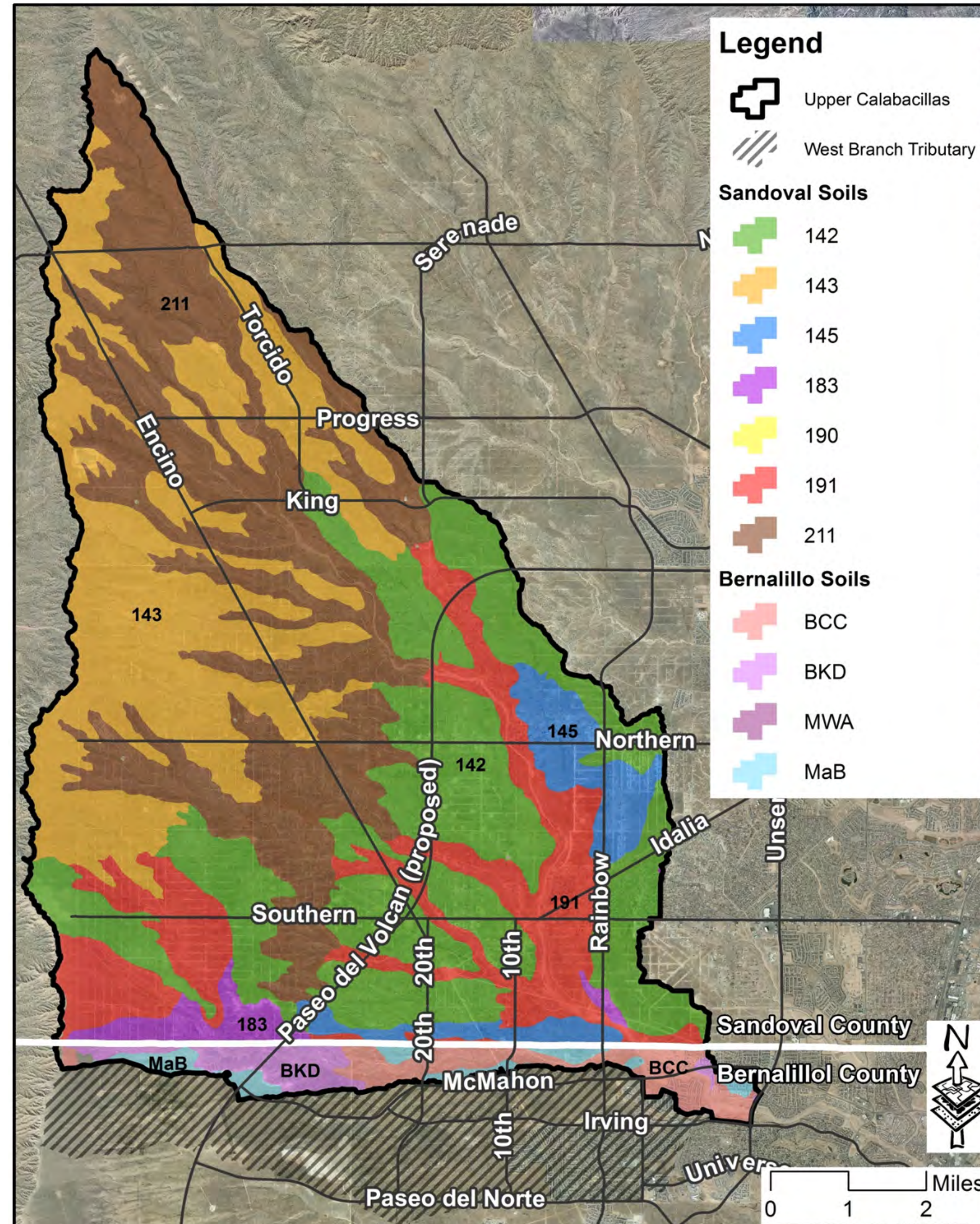


Figure 5: Map of soils found in the Upper Calabacillas; only soils that cover one percent or more of the study area are shown.

E. MAJOR EXISTING DRAINAGE FACILITIES

Details of existing drainage facilities are shown on the tiled maps in Appendix A. Each facility is assigned a unique identification number. Technical data pertaining to each existing facility is summarized in the table on the page adjacent to each map.

Under Existing (2014) conditions, minimal drainage infrastructure exists in the watershed; existing facilities include:

- **Ponds and Dams**

  Swinburne Dam. Located at the downstream end of the Upper Calabacillas where Unser Blvd crosses the Calabacillas Arroyo, Swinburne Dam was built by AMAFCA in 1990. The dam embankment has a maximum height of 34 feet, and the roadway (Unser Blvd) acts as the emergency spillway. The principal spillway consists of a trapezoidal soil cement channel with a bottom width of 12 ft. At the emergency spillway crest, the dam has a storage capacity of approximately 920 acre-feet.

  No other major stormwater detention facilities exist in the Upper Calabacillas to date; for drainage infrastructure in the West Branch Tributary, please refer to the West Branch DMP (Tetra Tech, 2013).

Photo 5: Swinburne Dam, looking upstream at the outlet structure.

- **Storm Drain**

  The Saltillo storm drain captures all runoff from the Rainbow Tributary north of the Sandoval/Bernalillo county line and conveys it through approximately 2000 feet of 102" reinforced concrete pipe to the Calabacillas Arroyo just downstream of McMahon Blvd.

Photo 6: Inlet to the Saltillo storm drain.

- **Road Crossings**

  Most roads in the Upper Calabacillas are unpaved dirt roads and cross arroyos at grade. Only two crossing structures exist along the main stem of the Calabacillas Arroyo upstream of Swinburne Dam:

  McMahon Blvd crosses the arroyo over a bridge, and Southern Blvd features a set of five 8ft W x 6ft H concrete box culverts. Some smaller culvert crossings exist along Northern Blvd and Southern Blvd, and within the Rainbow Tributary between Tulip Rd and Southern Blvd.

Photo 7: Typical at-grade road crossing (King Blvd & Calabacillas Arroyo, looking upstream)

Photo 8: McMahon Blvd Bridge crossing of the Calabacillas Arroyo, looking upstream.

Photo 9: Concrete box culverts at Southern Blvd, looking downstream.

F. STOCK PONDS

Stock ponds typically consist of an earthen berm that has been constructed across the flow path of an arroyo to retain water for livestock use. At least ten stock ponds were identified on private land in the Upper Calabacillas. While most of the ponds are small in size (less than ten acre-feet of storage) and located in remote areas, they can become a hazard after an intense storm if the embankment breaches suddenly.

Photo 10 shows the stock pond just north of King Blvd on Tributary N. During the storm of August 4, 2013, the pond filled to the top of the earthen embankment, retaining an estimated 20 acre-feet of runoff. Several hours after the storm, the embankment failed and sent a flood wave down the arroyo.

Stock ponds were not included in the hydrologic model, but are identified on the detailed drainage map tiles in Appendix B.

Photo 10: Stock pond north of King Blvd in Tributary N; the breach in the embankment caused by the storm of August 4, 2013 is evident in the foreground.

G. PLAYAS

Playas are natural depressions that capture and retain runoff. More than 50 playas were identified in the Upper Calabacillas (see Figure 6). The six larges playas with estimated storage capacities between 13 and 30 acre-feet were included in the hydrologic model. All playas are identified on the detailed drainage map tiles in Appendix B.

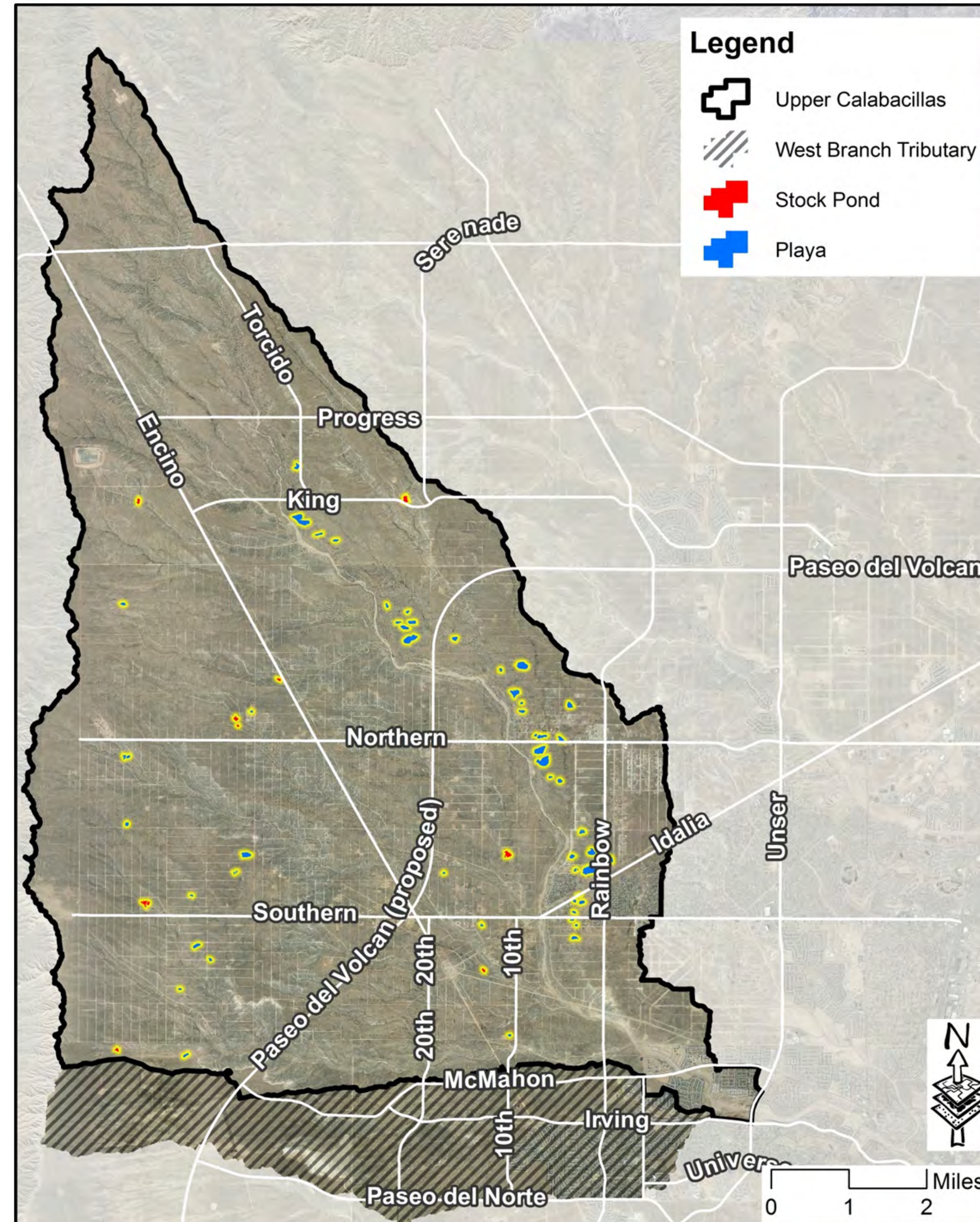


Figure 6: Map showing stock ponds and playas in the Upper Calabacillas.

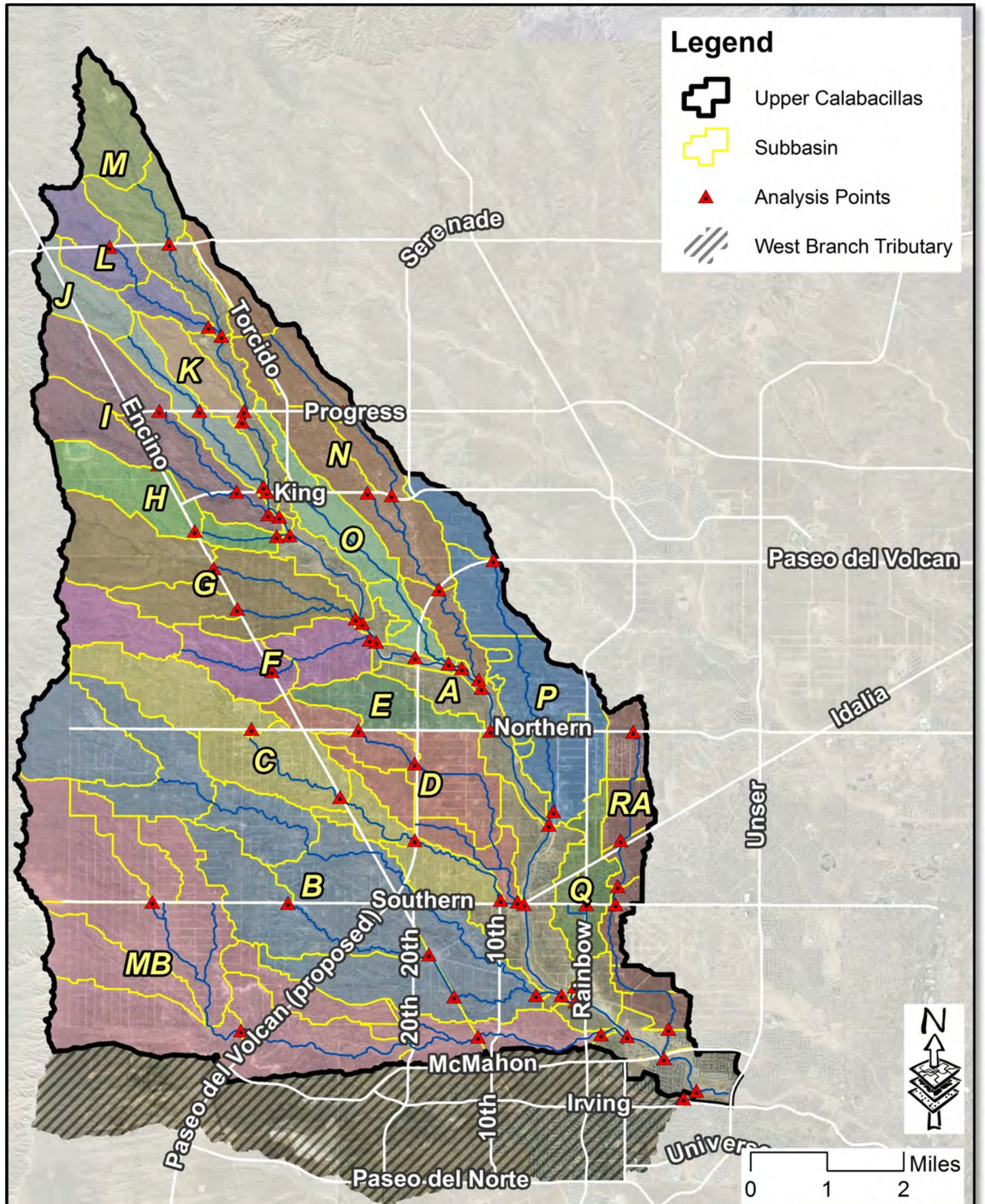


Figure 7: Map showing tributaries, subbasins and analysis points in the Upper Calabacillas.

III. HYDROLOGY

A. 1-PERCENT ANNUAL CHANCE STORM (100-YEAR STORM)

The methodologies utilized in this study are based on SSCAFCA's Development Process Manual (DPM), Chapter 22, Drainage, Flood Control and Erosion Control (Revised April 2010), and the HEC-HMS computer program version 3.5. All model parameters were computed in accordance with the DPM. Please refer to the West Branch DMP (Tetra Tech, 2013) for parameters used to develop the hydrology of the West Branch Tributary.

1. Mapping & Topography

Orthophotography used for this project consists of tiled images which depict color digital aerial photographs acquired in the spring of 2012 during leaf-off conditions. LiDAR-derived elevation data (2-foot contour interval, 2010) was used to delineate watersheds and sub-basins as well as for calculating hydrologic parameters. Both orthophotogarphy and elevation data are part of the *MRCOG Digital Orthophotography and Elevation Data Project*.

2. Analysis Points

Analysis points were selected for the following locations:

- Tributary confluences with the main stem of the Calabacillas Arroyo
- Major existing culverts
- Proposed major road crossings of main stem and tributaries (Northwest Loop, PDV, Northern, Southern)
- Major tributary crossings of high pressure gas line (Encino)
- Saltillo storm drain inlet
- Swinburne Dam

3. Subbasin delineation

Initial watershed and subbasin boundary delineation was accomplished using HEC Geo-HMS software with a digital elevation model (DEM) created from 2010 MRCOG LiDAR data. Basins were modified to accommodate desired analysis points and achieve basins sizes as uniform as possible. Wherever feasible, long narrow basins were split to achieve length-to-width ratios of 4:1 or less. All basin boundaries were checked based on 2010 2-ft elevation contours. Questionable boundaries were verified in the field, especially at existing culvert crossings, and at locations where graded roads influence flow paths, and a dominant flow path was not immediately obvious from 2-ft contours.

Major playas with a storage capacity of more than ten acre-feet were identified, and the area draining to each playa was mapped as a separate subbasin. All tributaries to the Calabacillas Arroyo within the study area were identified; Existing names were used where applicable (West Branch, Middle Branch, Rainbow Tributary), all other tributaries received letter abbreviations. Subbasin boundaries and flow paths for developed conditions were assumed to be identical to existing conditions, since patterns of future development are largely unknown.

4. Reach Routing

Routing reaches were delineated and slopes estimated in GIS; for each routing reach in the main branch of the Calabacillas Arroyo, a representative 8-point cross-section was developed. All other routing reaches were modeled using an idealized cross-section that most closely resembles the natural geometry of the reach (mostly trapezoidal, some triangular). Initially, roughness coefficients (Manning's n-value) were assigned in accordance with the SSCAFCA DPM. Based on model calibration results, n-values for sandy arroyos were later reduced from 0.055 to 0.025; n-values for overbank areas and vegetated, sinuous natural conveyances were reduced from 0.055 to 0.035 (see also Section III.B.1 below).

5. Rainfall

Each subbasin was assigned to one of six precipitation zones delineated in GIS using rainfall data based on the NOAA 14 Atlas (NOAA, 2014). Table 3 shows point precipitation depths for the 1-hour, 6-hour and 24-hours storms based on NOAA 14, and the adjusted values after applying the appropriate depth-area reduction factor for the 80 square mile watershed (Upper Calabacillas & West Branch Tributary).

Table 3: Point precipitation depths based on NOAA 14 (top), and adjusted depths for the Upper Calabacillas (bottom)

	Zone	*1*	*2*	*3*	*4*	*5*	*6*
Point Precipitation Estimate	100-year 1-hour (P_{60})	1.90	1.87	1.84	1.81	1.77	1.73
	100-year 6-hour (P_{360})	2.47	2.42	2.38	2.32	2.29	2.25
	100-year 24-hour (P_{1440})	3.10	3.00	2.90	2.80	2.70	2.60
Adjusted Rainfall Depth	100-year 1-hour (P_{60})	1.42	1.40	1.38	1.36	1.33	1.30
	100-year 6-hour (P_{360})	2.23	2.19	2.15	2.10	2.07	2.03
	100-year 24-hour (P_{1440})	2.92	2.82	2.73	2.63	2.54	2.45

Point precipitation depths range from 3.1 inches at the headwaters of the Calabacillas watershed to 2.6 inches at the outlet of the study area. Based on the large watershed area, adjusted rainfall depths are significantly lower (see Table 3, highlighted).

Reduction factors are typically applied to point precipitation estimates to account for the size of a watershed. The larger a watershed, the more point rainfall has to be reduced in order to be representative of the entire basin. To analyze crossing structure capacities in small tributaries and for the conceptual design of ponds and dams, the model was run using modified or no depth-area reduction factors to account for the actual size of the area draining to the point of interest.

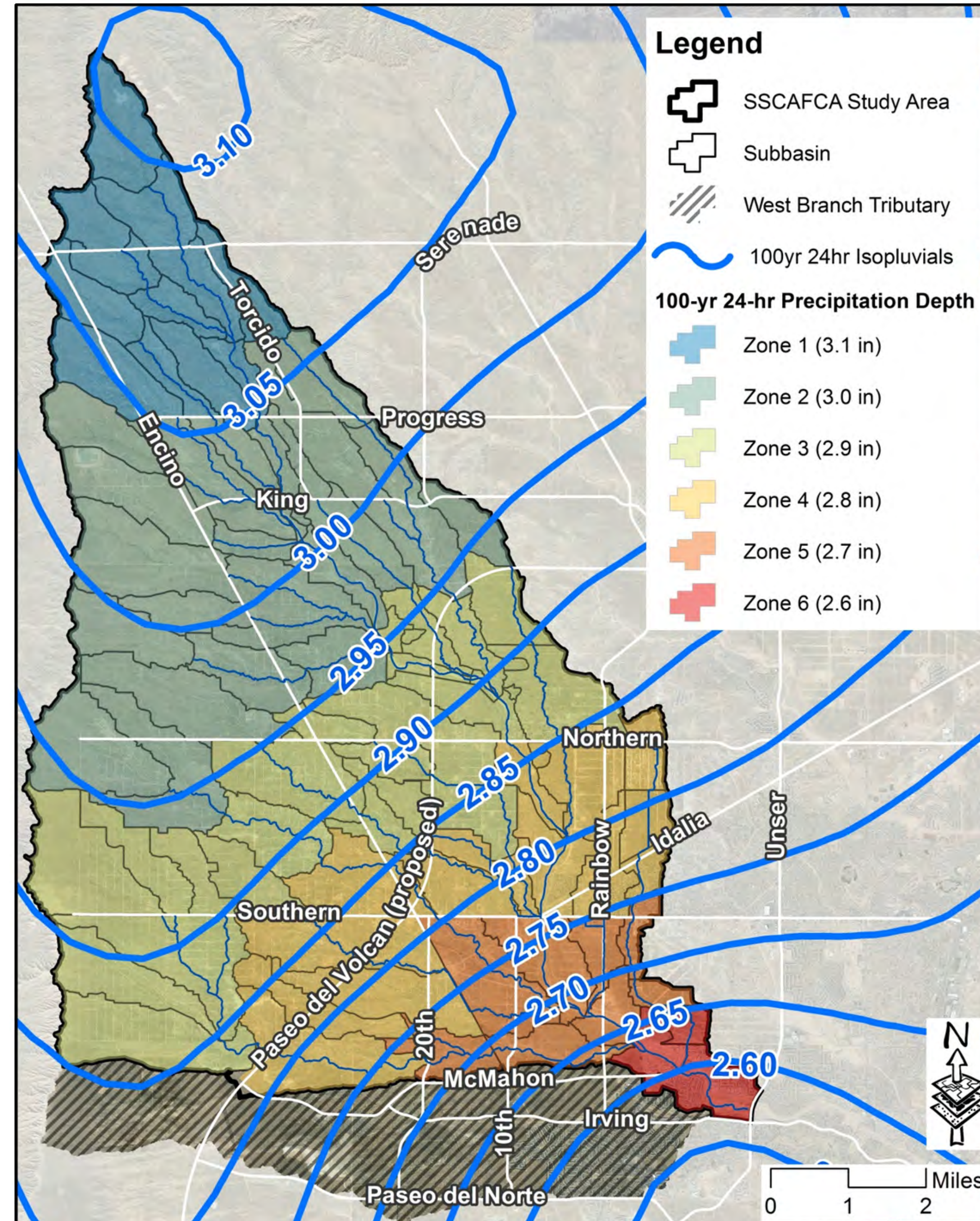


Figure 8: Map showing 100-year 24-hour point precipitation depths based on the NOAA 14 Atlas and values assigned to subbasins in the Upper Calabacillas.

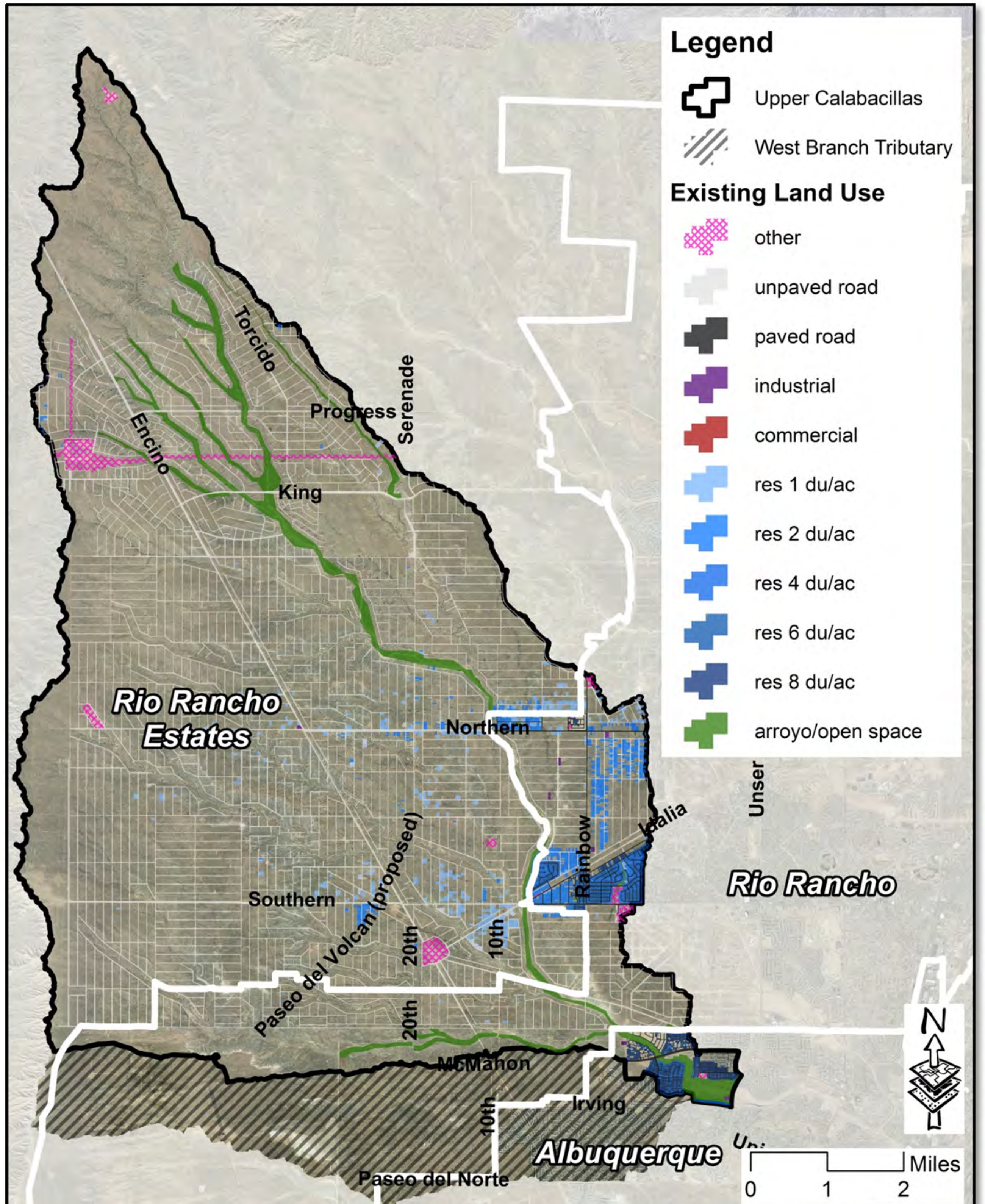


Figure 9: Map of the Upper Calabacillas showing existing conditions (2014) land use; most of the study area is undeveloped.

6. Land Use – Existing Conditions 2014

Existing land use information was obtained from GIS departments at the City of Albuquerque and the City of Rio Rancho. For the unincorporated Rio Rancho Estates area, existing land use was identified manually in GIS using the Sandoval County parcel coverage and 2012 digital orthoimagery.

Figure 9 shows that most of the study area is undeveloped under existing conditions. Some residential development (blue) exists between Southern and Northern Blvd east of the Calabacillas Arroyo, as well as at the downstream end of the study area. Noticeable are the unpaved roads that exist throughout the area.

Photo 11: Typical urban development in the Rio Rancho Estates Area.

7. Land Use – Developed Conditions

Land use under fully developed conditions was based on the following assumptions:

7.1. City of Albuquerque

Full development based on existing platting and zoning was assumed for the portion of the study area within the Albuquerque city limits.

7.2. City of Rio Rancho

Full development based on existing platting and zoning was assumed within the Rio Rancho city limits, with two exceptions:

- Developed land use in the Quail Ranch and Paradise West areas was based on approved master plans (see Figure 10).

- The area north of the county line and west of 20th Street was assumed to develop similar to the Rio Rancho Estates area (see below).

7.3. Unincorporated Rio Rancho Estates Area

According to the Draft Water Resources Planning Study for the Rio Rancho Estates area (Souder, Miller & Associates, 2013), only 8600 acre-feet of groundwater per year is available for development. Based on projected water usage, this would allow for development of approximately 18,000 of the 41,000 residential lots. Based on limited water availability, the following assumptions were made with respect to land use types and development densities:

Potential Master Planned Communities

The Rio Rancho Estates area was assessed for locations with the potential for master planned communities similar to Northern Meadows or North Hills. Three areas were identified with a large accumulation of lots under AMREP ownership (see Figure 10, label "A"). All three areas were assumed to be developed as residential subdivisions at a density of 8 dwelling units per acre, corresponding to a total of 6,600 dwelling units.

Areas with High Potential for Development

Other areas with a high potential for development were identified based on

- Existing development patterns and
- Proximity to existing development and utilities (Figure 10, label "B")
- Proximity to existing arterials (Southern and Northern Blvd.) and along the planned Paseo del Volcan corridor (Figure 10, label "C")

Those areas were assumed to be fully developed according to existing platting and zoning; currently undeveloped lots adjacent to Northern and Southern Blvd. were assigned commercial development. A total of 6,100 lots fell into this category.

All Other Areas

Based on the above assumptions, 5,300 additional dwelling units could be supported in the remaining area based on available water resources; those 5,300 dwelling units were distributed evenly over the remaining 28,660 empty lots, corresponding to a development density of approximately 18% (Figure 10, label "D"). Lots were assumed to be developed according to existing platting and zoning (single family residential, with the majority of lots sizes ranging from 0.5 to 1 acre).

The narrow strip of incorporated City of Rio Rancho land between the Rio Rancho Estates area to the north and the Bernalillo/Sandoval County line to the south was included in all land use assumptions for the Rio Rancho Estates area.

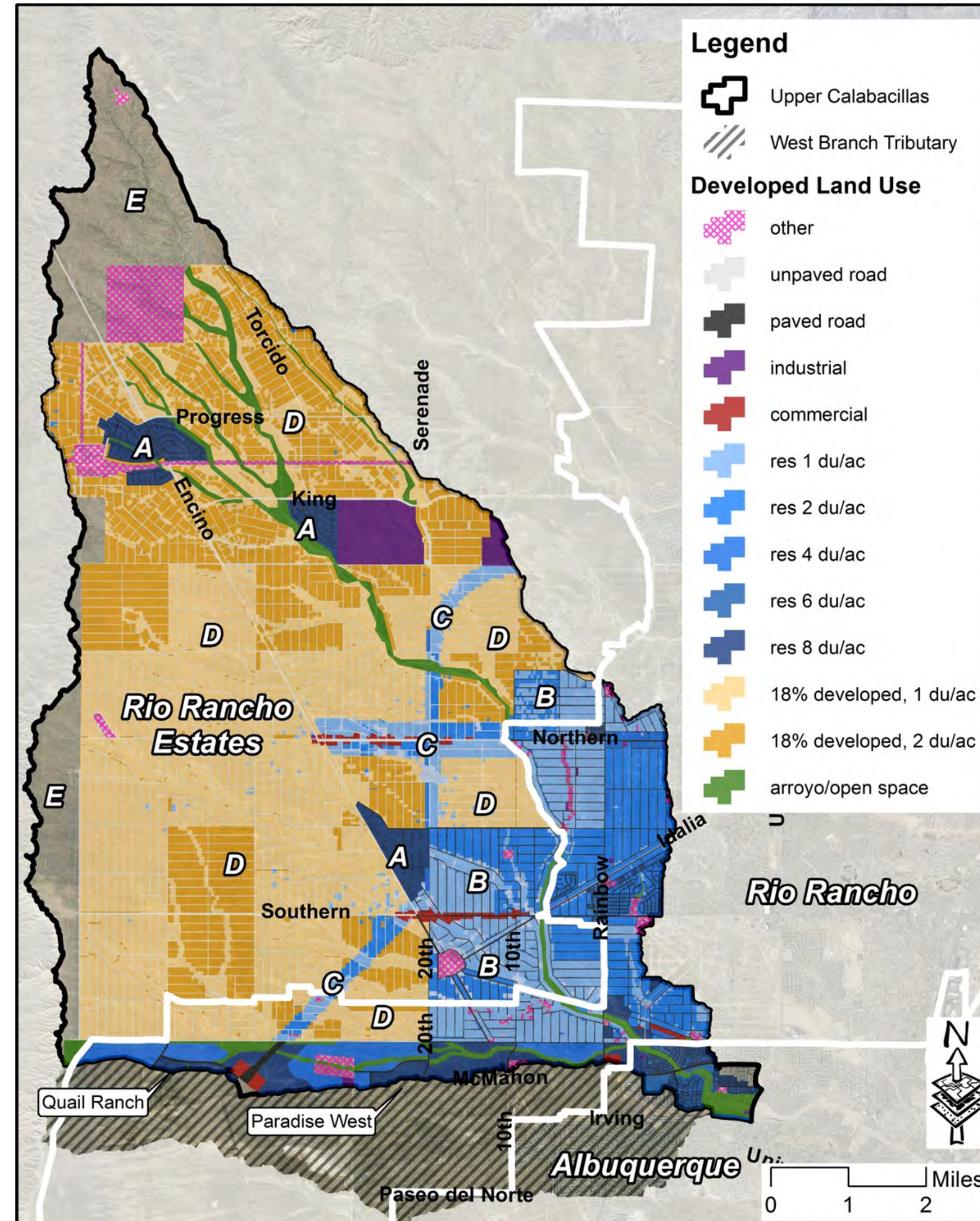


Figure 10: Map showing assumptions for developed land use in the Upper Calabacillas.

8. Rainfall Loss Methodology

Per SSCAFCA DPM (SSCAFCA, 2010), the *Initial and Constant* loss methodology was utilized in HEC-HMS to compute rainfall loss and rainfall excess for each subbasin. Initial abstraction accounts for losses due to depression storage, interception by vegetation and high initial infiltration rates and ranges from 0.35 inches to 0.65 inches; infiltration rates range from 0.83 inches/hour to 1.67 inches/hour. Area-average values of initial abstraction and infiltration rates were calculated for each subbasin based on existing and predicted land use. Percent impervious surface for each subbasin was estimated based on typical values for different land use types and verified using aerial photography. For model parameters used in the West Branch Tributary, please refer to the West Branch DMP (Tetra Tech, 2013).

Table 4: Rainfall loss parameters for typical land use types.

Cover Type/Land Use	Initial Abstraction	Constant Infiltration Rate	Impervious
	(in)	(in/hr)	%
Arroyo	0.65	1.67	0%
Open Space	0.65	1.67	0%
Residential 1du/ac	0.45	1.13	17%
Residential 2du/ac	0.34	0.83	27%
Residential 4du/ac	0.25	0.61	42%
Residential 8du/ac	0.13	0.31	70%
Road - unpaved	0.47	1.17	0%
Road - paved	0.04	0.08	90%
Commercial	0.05	0.12	85%
Industrial	0.13	0.31	70%
Undeveloped	0.65	1.67	0%
Residential 1 du/ac, 18% developed	0.61	1.57	3%
Residential 2 du/ac, 18% developed	0.59	1.52	5%

Detailed tables containing model parameters for all subbasins and model scenarios are contained in Appendix C.

9. Transform Methodology

The *Clark Unit Hydrograph* method was used in HEC-HMS to transform excess precipitation into runoff hydrographs. Times of concentration (Tc) and storage coefficients (R) for each subbasin were initially estimated according to the procedures outlined in the DPM (SSCAFCA, 2010). Based on model calibration results, both Tc and R for all subbasins were reduced by 25 percent (see also section III.B.1 below).

10. Sediment Bulking Factors

Sediment bulking factors of 18 percent for undeveloped areas and six percent for developed areas were added as flow ratios to the clearwater discharge in HEC-HMS to account for the increase in runoff volume due to suspended sediment in storm flows. Area averaged bulking factors were used for subbasins containing both developed and undeveloped areas.

Photo 12: Sediment-laden stormwater runoff in the Calabacillas Arroyo downstream of Swinburne Dam (left), and a graduated cylinder showing the amount of sediment in a stormwater sample (right).

11. Hydrologic Model Scenarios

Three hydrologic models were developed to identify drainage related problems:

- The *EXISTING CONDITIONS* model assumes existing development and existing drainage facilities as of the date of this report; it is used to identify current drainage related problems and deficiencies.
- The *DEVELOPED CONDITIONS – EXISTING FACILITIES* (DEVEX) model assumes full development of the watershed, based on the assumptions discussed in section 7 above, with existing drainage facilities; it is used to identify potential future problems and deficiencies.
- The *ULTIMATE CONDITIONS* (ULTIMATE) model assumes full development of the watershed as well as the implementation of all facilities and improvements recommended in the CAWMP.

B. RESULTS

1. Model Calibration

After completion of the preliminary hydrology, an effort was undertaken to compare model results to measured storm flows. Discharge data was obtained from a stream gauging station located at the outlet structure of Swinburne Dam (see Photo 13), at the downstream end of the Upper Calabacillas. The gauging station has been in operation since 1991. Between 1991 and 2011, the site was equipped with a crest-stage gauge located in a 2-inch galvanized steel housing. Crest-stage gauges record only the peak stage of a flow event; they provide no information regarding the timing of the peak or the rest of the hydrograph and therefore have limited usefulness for model calibration efforts. In 2011, the site was retrofitted with a pressure transducer. The probe measures stage (or depth of flow) in 5-minute increments; stage measurements are converted to discharge by using a rating curve developed for the location of the gauge.

Photo 13: Stream gauging station at the outlet structure of Swinburne Dam; the gauge is located in the 2-inch galvanized steel pipe on the right.

Table 5 shows the five highest recorded flow rates at Swinburne Dam during the 21-year period of record of the gauge. By far the largest flow occurred on September 13, 2013. The gauge measured a peak stage of 9.69 feet, which is equivalent to a discharge of 1,321 cfs. This storm was also the only major event that occurred after installation of a pressure transducer in 2011, and therefore the only storm for which a full hydrograph was available. For all the above reasons, model calibration was primarily based on the storm of September 12/13, 2013.

Table 5: Highest flow rates measured at Swinburne Dam during the 21-year gauge record (1991-2013)

Date	*Peak Flow @ Swinburne Dam (cfs)*	*Type of Gauge*
10/4 -5/2004	392	Crest-Stage (peak flow only)
8/1/2006	626	
8/5/2006	432	
8/23/2007	561	
9/12-13/2013	1,321	Pressure Transducer (full hydrograph in 5-minute increments)

The storm of September 12/13, 2013 began during the night of September 12 (approximately 20:00 local time) and had a total duration of approximately 14 hours. It was characterized by two main periods of intense rainfall (20:00-23:00 on 9/12 and 6:00-10:00 on 9/13, see Figure 11) with an intermittent period of light to moderate rainfall.

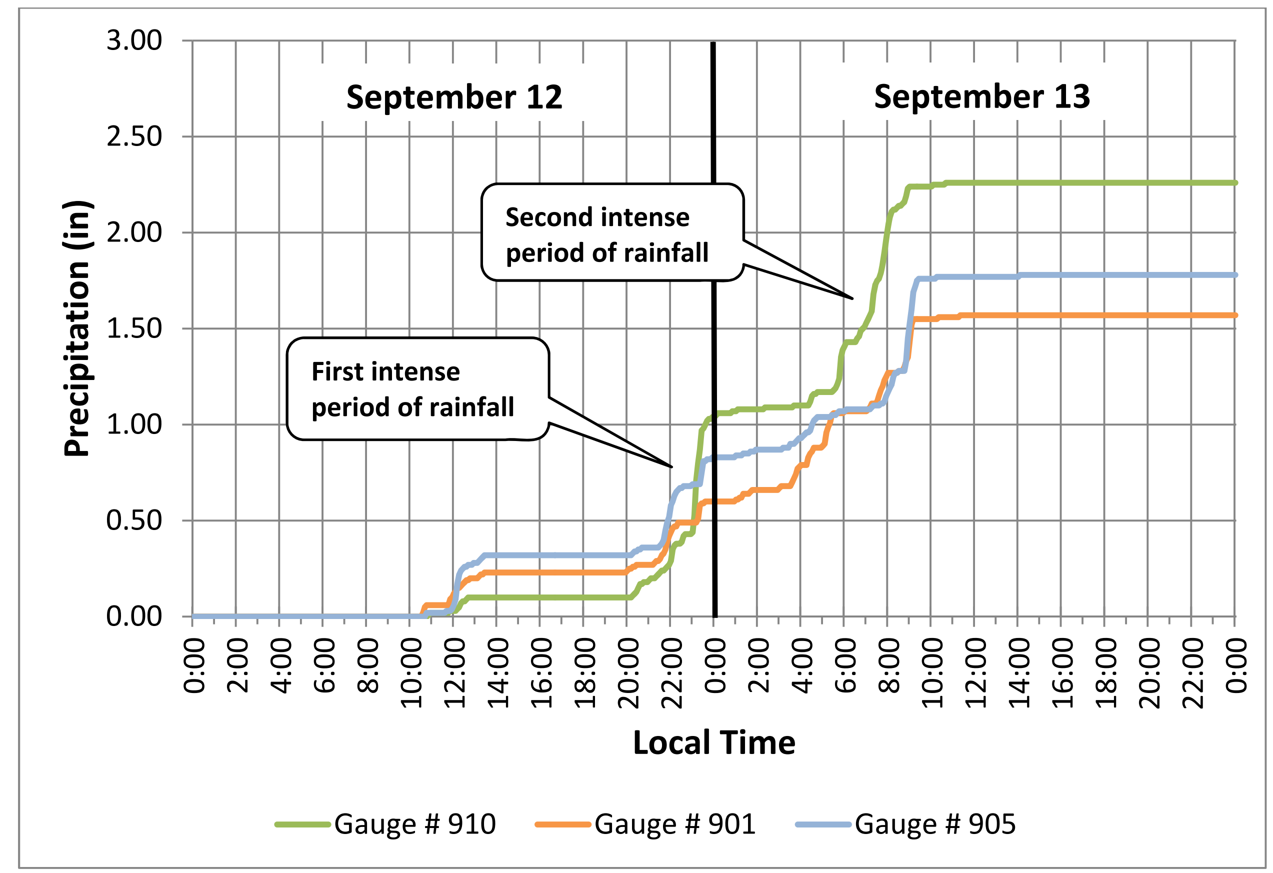


Figure 11: Cumulative rainfall curves measured by three data logging rain gauges for the storm of September 12/13, 2013.

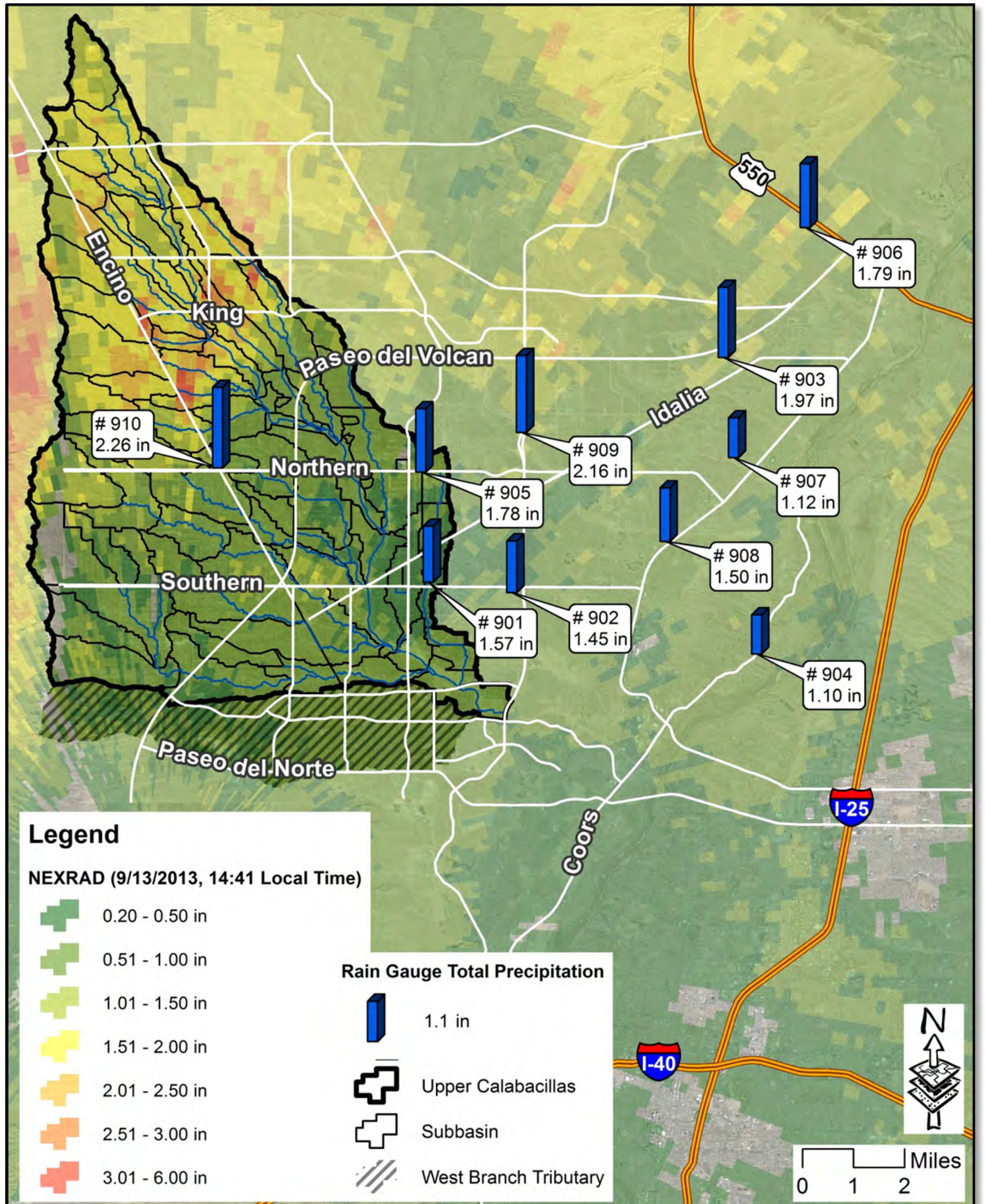


Figure 12: Radar and rain gauge data for the storm of September 13, 2013.

Two types of rainfall data were utilized in the calibration effort:

- Radar data (Next Generation Weather Radar or NEXRAD) from the National Climatic Data Center provides a grid of precipitation estimates for the entire watershed; reflectivity measured by the radar is converted to rainfall based on an algorithm; the resulting rainfall grid can have a significant bias and has to be adjusted using rain gauge measurements. Rainfall estimates are usually provided in time increments of 4 minutes; individual time steps, however, are not always uniform and can range from four to ten minutes.
- Data logging rain gauges (DLRG) maintained by SSCAFCA measure precipitation in increments of 0.01 inches.

Figure 12 shows that the storm of September 13, 2013 covered all of SSCAFCA's jurisdictional area with rain gauge records ranging from 1.10 to 2.26 inches overall. Radar data for the storm event indicates that the upper Calabacillas watershed received the highest total precipitation as indicated by yellow to red colors. Figure 12 shows cumulative precipitation at 2:41 pm local time on 9/13/2013 since the beginning of the storm event on 9/12/2013.

Rain gauge data was compared to the corresponding radar grid cell value for each gauge at 1:45 local time (after the first period of intense rainfall, see Figure 11) and after the end of the storm at 14:40 local time. Ratios were calculated by dividing gauge data and NEXRAD estimates (see Table 6).

Table 6: Point comparisons of rain gauge and radar data for the September 12/13 storm event.

	9/13/2013 1:45 Local Time			9/13/2013 14:40 Local Time		
Gauge #	***Rain Gauge Data (in)***	***NEXRAD (in)***	***Ratio (Gauge/NEXRAD)***	***Rain Gauge Data (in)***	***NEXRAD (in)***	***Ratio (Gauge/NEXRAD)***
901	0.66	0.26	2.54	1.57	0.33	4.76
902	0.57	0.22	2.59	1.45	0.51	2.84
903	0.62	0.30	2.07	1.97	0.99	1.99
904	0.70	0.44	1.59	1.10	0.69	1.59
905	0.86	0.26	3.31	1.78	1.23	1.45
906	0.86	0.68	1.26	1.79	1.17	1.53
907	0.60	0.28	2.14	1.12	0.57	1.96
908	0.81	0.44	1.84	1.50	0.81	1.85
909	0.28	0.28	1.00	1.69	0.96	1.76
910	1.08	0.60	1.80	2.26	0.84	2.69
	Median Ratio		***1.95***	***Median Ratio***		***1.91***
				Overall Median Ratio		***1.91***

Computed ratios ranged from 1.00 to 4.76; median ratios were almost identical at 1:45 and 14:40 indicating that the radar data consistently underestimated measured precipitation. The overall median ratio of 1.91 was used to ground-truth the radar data.

Only the tributaries in the upper watershed (tributaries F, G, H, I, J, K, L, M, N, O) contributed significant flow to the Calabacillas Arroyo during the storm. This was confirmed by field investigation following the storm and is consistent with the radar data. For all contributing tributaries, subbasin-average rainfall values for each time step were computed from the radar grid in GIS. Each time step was then multiplied by the ratio of 1.91 to adjust for the bias in the radar data. Based on this data, a separate hyetograph (rainfall distribution over time) was prepared for each subbasin and input into HEC-HMS.

The measured hydrograph at Swinburne Dam indicated that the large peak resulted from the second period of intense rainfall that occurred in the morning of September 13 (see Figure 13). Only the period between approximately 7:30 and 9:30 was therefore modeled in HEC-HMS.

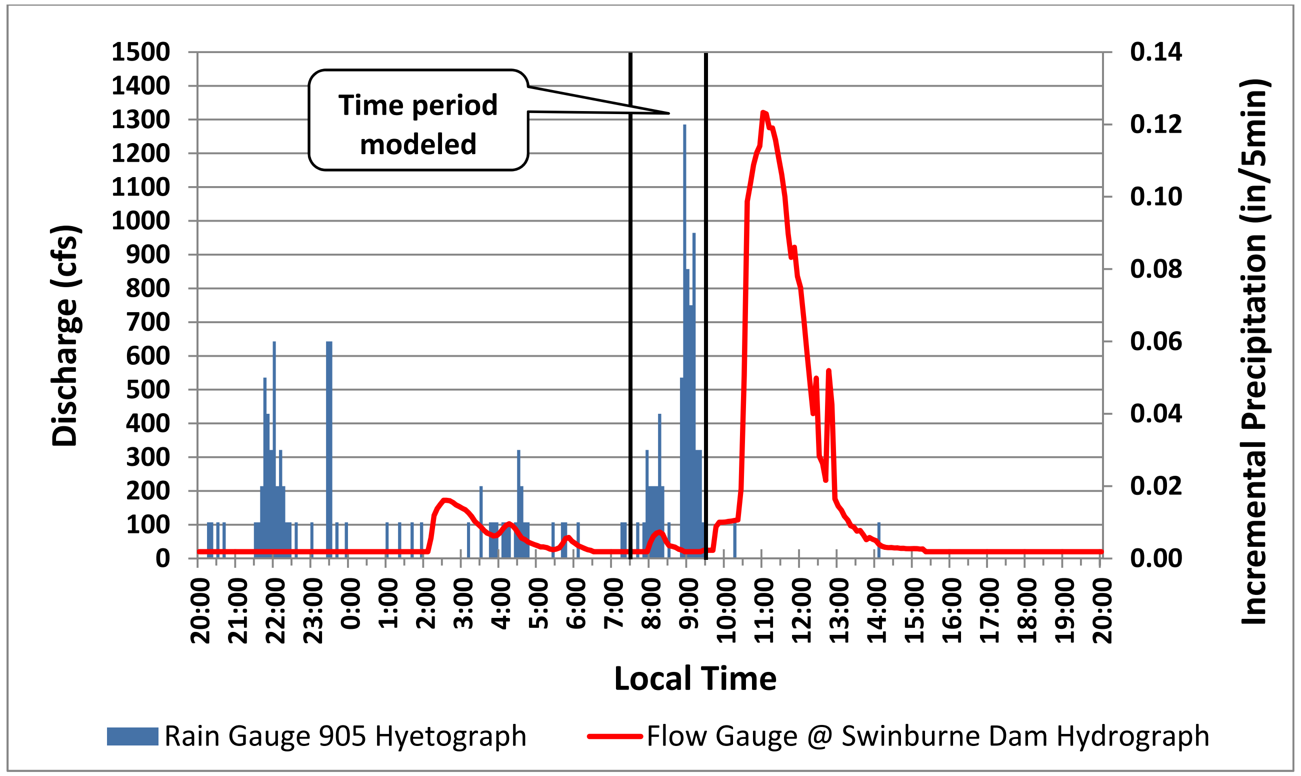


Figure 13: Comparison of timing of rainfall intensity measured by rain gauge # 905 and flow at Swinburne Dam for the September 12/13, 2013 storm.

In the baseline hydrology model, initial abstraction values for subbasins in the upper watershed are on average 0.64 inches. Initial abstraction accounts for losses that occur during the initial period of a storm, such as storage in small surface depressions ("puddles") and interception by vegetation. Since antecedent rainfall exceeded the initial abstraction amount for all subbasins that contributed runoff to the Calabacillas arroyo, initial abstraction values for those subbasins were set to zero.

Figure 14 shows the comparison of the measured hydrograph (solid red) and the baseline model simulation (dotted black). Most noticeably, the simulated peak lags behind the measured peak by approximately two hours. The simulated peak is also approximately 40 percent lower than the measured peak flow, and the falling limb of the simulated hydrograph is less steep.

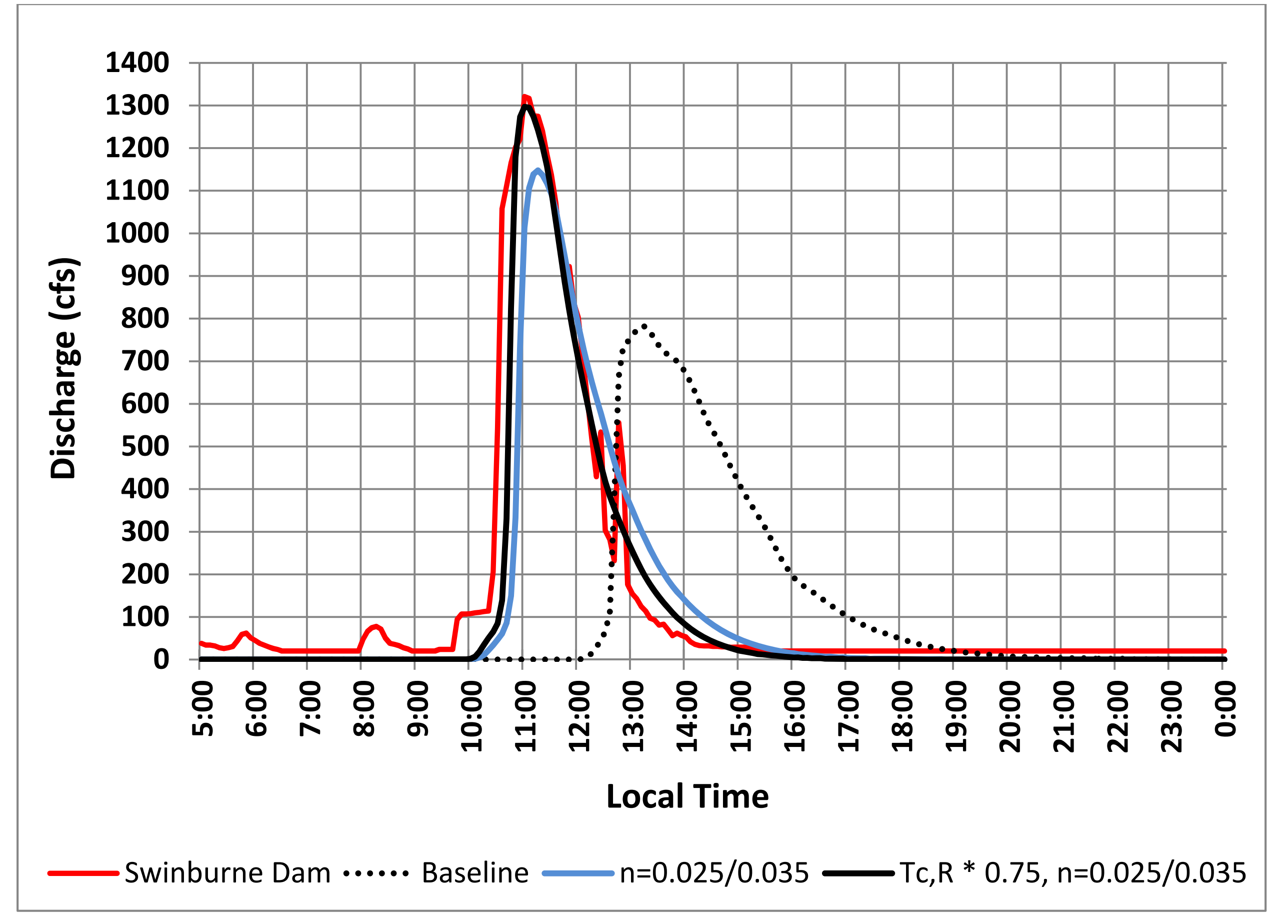


Figure 14: Comparison of measured hydrograph (red) and model simulations for the September 12/13, 2013 storm event.

Based on these observations, the Manning's roughness coefficients (n-values) for routing reaches were adjusted (see Table 7) to achieve a better fit in the timing of the hydrograph.

Table 7: Adjusted Manning's n-values based on model calibration efforts.

Reach description	DPM n-value	Adjusted n-value
Major arroyo (flat, sandy bottom)	0.055	0.025
All other arroyos (high sinuosity, vegetated) and overbank areas	0.055	0.035

The solid blue line in Figure 14 shows that the modification of roughness coefficients drastically improved the fit of the simulated hydrograph. An even better fit was achieved by additionally reducing the unit hydrograph parameters, time of concentration (Tc) and storage coefficient (R): Both parameters were reduced by 25 percent for all subbasins. The resulting simulated hydrograph (solid black line, Figure 14) is almost identical to the measured hydrograph.

The changes to n-values and unit hydrograph parameters were adopted for all model scenarios of the CAWMP.

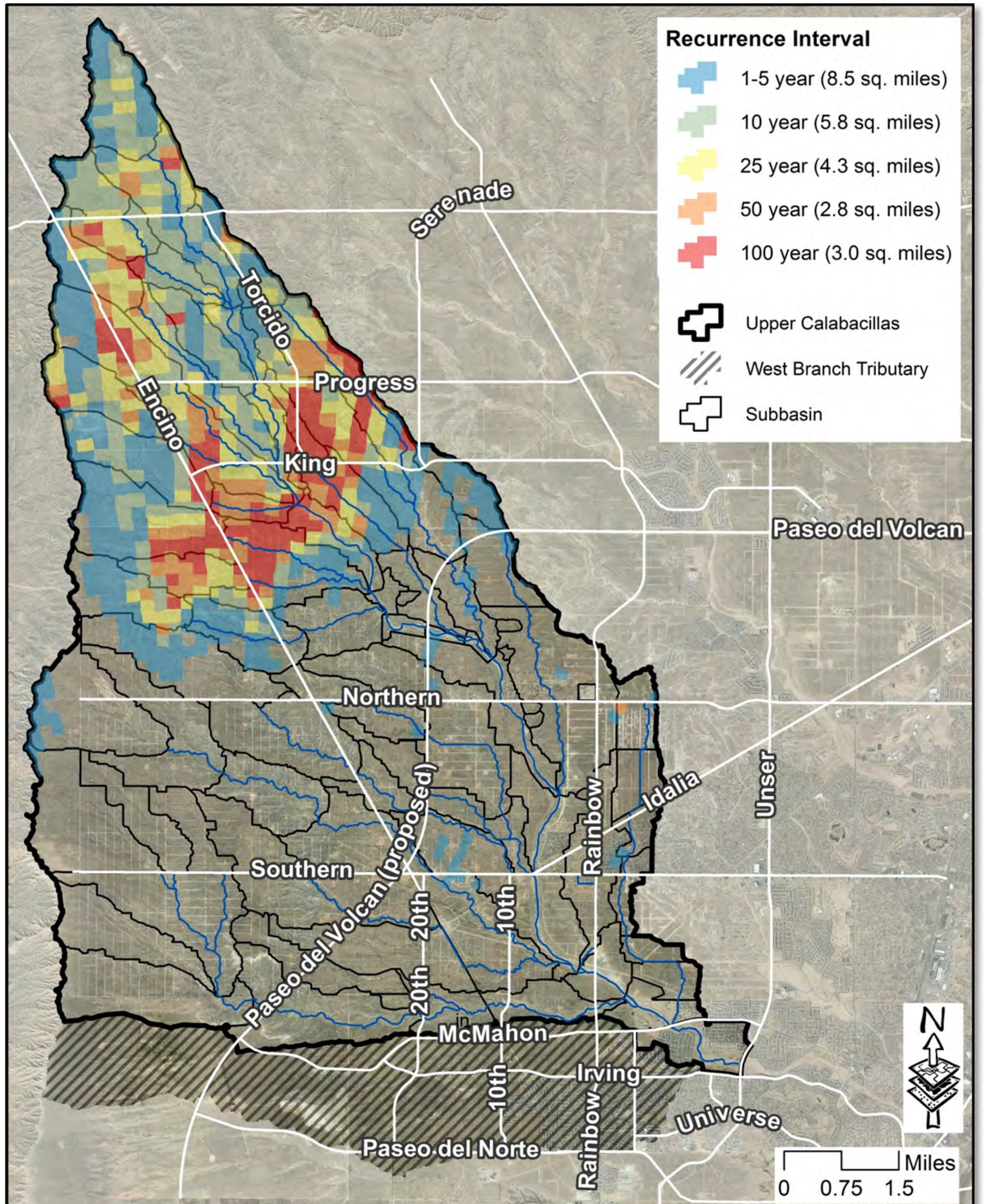


Figure 15: Map showing estimated recurrence intervals for the storm of September 13, 2013 for the 2-hour time period 7:30-9:30am, local time.

Figure 15 shows the estimated recurrence interval for the two hour period that was used for model calibration (7:30-9:30 am local time, September 13, 2013). The recurrence interval calculations were based on ground-truthed radar data (see above) and point-precipitation estimates for the storm location from the NOAA Precipitation Frequency Data Server (NOAA, 2014). In the upper Calabacillas Watershed, approximately two inches of rain in a 2-hour period constitute the 1-percent (or 100 year) storm. Rainfall data indicates that during the 2-hour period in question, two inches of rainfall were exceeded over an area of three square miles in the Upper Calabacillas Watershed (see Figure 15, red shading). The total storm coverage was approximately 24 square miles. Although the September 13 storm only covered a portion of the watershed, using it to calibrate the hydrologic model is justified for the following reasons:

- A portion of the storm equaled or exceeded the 100-year rainfall
- The Calabacillas Watershed is fairly uniform with respect to soil types, vegetation, and slopes
- Most of the watershed is undeveloped

Therefore, calibration based on a storm that covered only part of the watershed are expected to be valid for the entire drainage basin.

2. Model Peer Review

Peer review of the hydrologic models and of the document was performed by following entities:

- US Army Corps of Engineers – Albuquerque District (informal review)
- High Mesa Consulting Group on behalf of AMAFCA (see Appendix E)

All comments were addressed and incorporated into the document as appropriate.

3. Model Results - 100-year 24-hour Design Storm

Table 8 compares SSCAFCA's calibrated hydrology model results with peak flow rates and runoff volumes from the Unser Bridge/Calabacillas Arroyo Detention Basin Report (1989) by Resource Consultants Inc. (RCI). The RCI report served as the basis for the design of Swinburne Dam. Please note that the results reported in Table 8 include flows from the West Branch Tributary; the hydrologic model for the West Branch was developed by TeraTech for AMAFCA and incorporated into SSCAFCA's model.

Table 8: Comparison of hydrology results at Swinburne Dam

	*% Impervious **		*Peak Discharge (cfs)*		*Runoff Volume (ac-ft)*	
Development Scenario	***RCI (1989)***	***SSCAFCA (2014)***	***RCI (1989)***	***SSCAFCA (2014)***	***RCI (1989)***	***SSCAFCA (2014)***
EXISTING Conditions	2%	3%	12,300	11,281	3,046	2,133
Future 2036 (RCI)/ DEVEX (SSCAFCA)	25%	*tbd*	16,700	*tbd*	3,828	*tbd*
Fully Developed	44%	n/a **	25,600	n/a **	4,157	n/a **

** Impervious surface including West Branch Tributary*
*** None of SSCAFCA's model scenarios is comparable to the Fully Developed RCI scenario; under DEVEX conditions, only about 20 percent of the watershed is estimated to be impervious in SSCAFCA's model. For more explanation, please see discussion below*

The comparison shows that for EXISTING conditions, peak flows and runoff volumes modeled in this study are slightly lower than the RCI results, even though the 2014 EXISTING conditions model includes slightly more impervious areas than the 1989 EXISTING conditions model due to development that has since occurred in the watershed (see Table 8). In addition, the size of the overall watershed has increased by approximately 1.7 square miles due to the diversion of flows captured by AMAFCA's Las Ventanas Dam into the West Branch Tributary (Tetra Tech, 2013).

The "Future 2036" scenario model by RCI simulated projected development as of the year 2036 and assumed partial development of the watershed with approximately 25 percent of the watershed comprised by impervious surface. The 2036 scenario compares most closely to SSCAFCA's DEVEX scenario, which assumes that 20 percent of the watershed will be impervious.

A study commissioned by Sandoval County indicates that there are insufficient groundwater resources to develop the entire Calabacillas watershed (DRAFT Water Resources Planning Study, 2013). Based on that study, SSCAFCA's DEVEX scenario assumes that only about half of all lots in the Rio Rancho Estates area will be developed. Following this rationale, SSCAFCA did not compile a scenario that would compare with RCI's "Fully Developed" model run.

Table 10 shows the 100-year 24-hour peak flow rates and runoff volumes at selected analysis points for EXISTING and DEVEX conditions. For a summary of all model results, please consult Appendix B.

Depth-Area Reduction Factor Analysis

Please note that all results reported in Table 10 are based on numerous model runs with rainfall depth-area reduction factors appropriate for the area draining to each analysis point. Sizing of drainage facilities (channels, culverts, ponds) needs to be based on an analysis appropriate for the size of the contributing drainage area so as to not underestimate peak flows and runoff volumes.

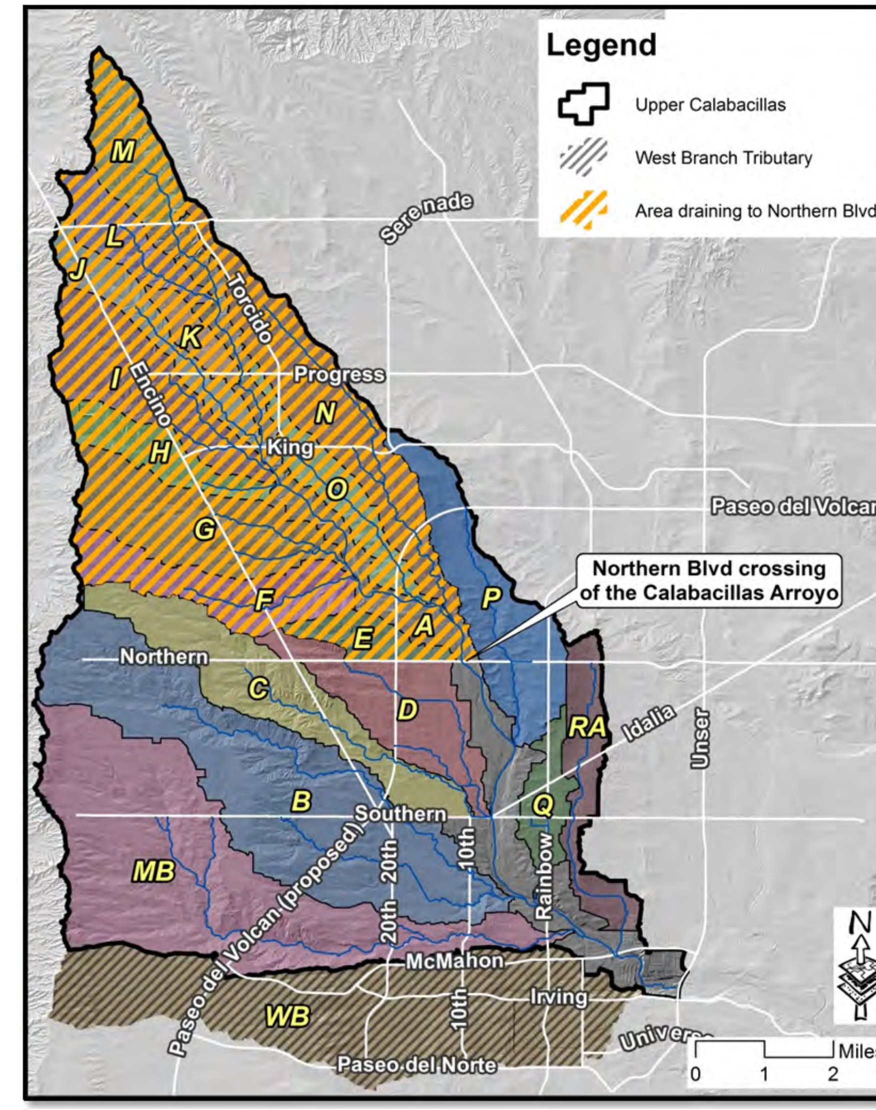


Figure 16: Map outlining the portion of the Upper Calabacillas draining to Northern Blvd.

<u>**Example**</u>:

Table 9 shows differences in model results for the Calabacillas Arroyo at Northern Blvd if depth-area reduction factors are applied for the entire 80 square mile area draining to Swinburne Dam, as opposed to the actual drainage area of 28 square miles at this location (orange). Using reduction factors for the entire watershed leads to significantly lower peak flow rates and runoff volume. This example illustrates the importance of selecting appropriate reduction factors so as to not underestimate storm flows at discrete locations in a large watershed model.

Table 9: Differences in model results at the Northern Blvd crossing of the Calabacillas Arroyo based on depth-area reduction factors for 80 square miles (blue) and 28 square miles (orange).

	Depth-area reduction factors for 80 square miles		Depth-area reduction factors for 28 square miles	
	Qp (cfs)	Vol (AC-FT)	Qp (cfs)	Vol (AC-FT)
EXISTING conditions	5227	695	6421	826
DEVEX conditions	8135	1020	9914	1170

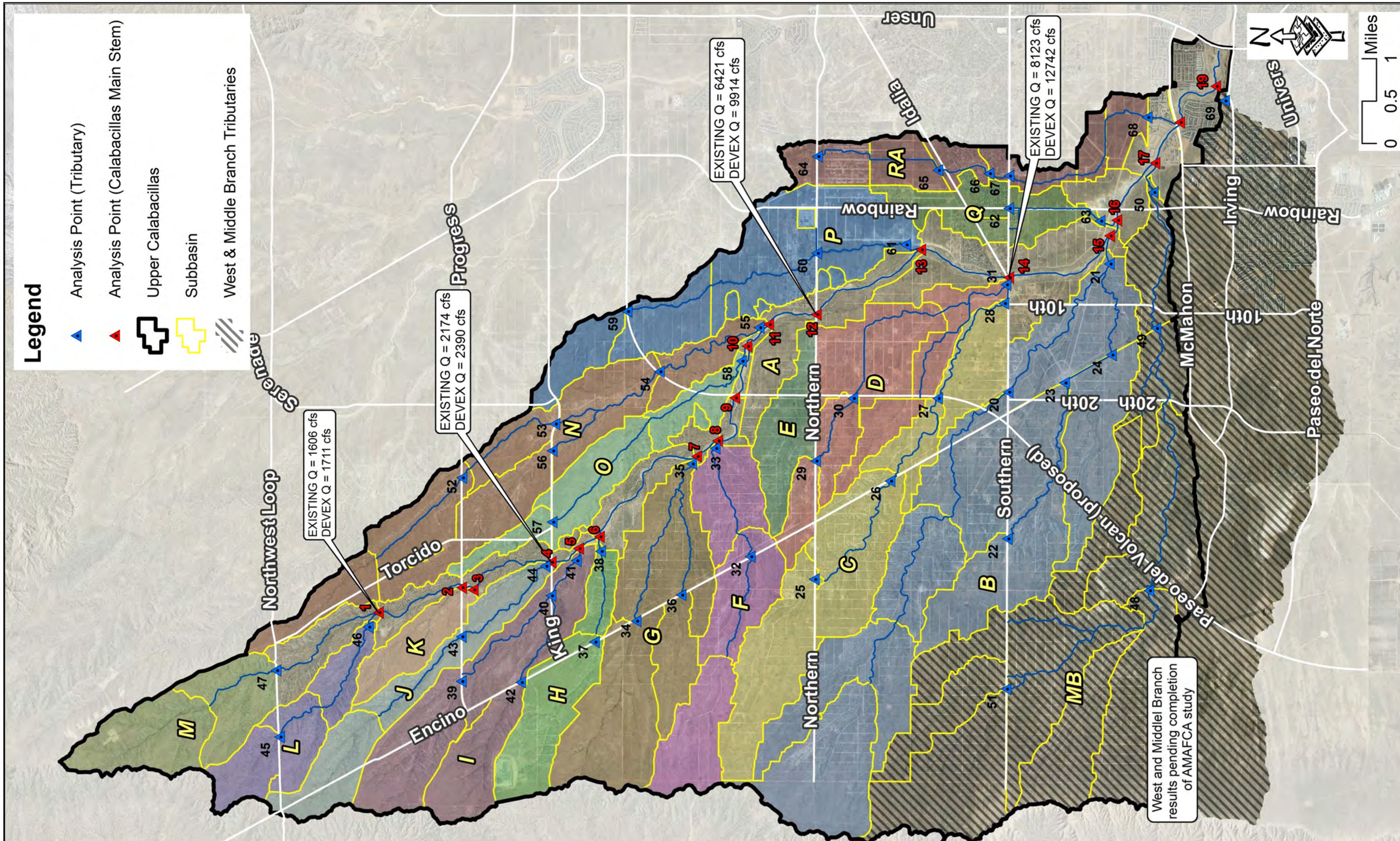
Table 10: EXISTING and DEVEX Flows for selected analysis points; results are based on model runs with depth-area reduction factors based on the size of the area draining to each analysis point.

Analysis Point	Tributary	HEC-HMS Element	Drainage Area (mi^2)	EXISTING 100-year peak flow (cfs)	EXISTING 100-year runoff volume (AC-FT)	DEVEX 100-year peak flow (cfs)	DEVEX 100-year runoff volume (AC-FT)
1	Calabacillas Main Stem (A)	A_101_J	4.2	1606	142	1711	158
2		A_102_J	4.6	1577	153	1687	170
3		A_103_J1	5.3	1694	178	1772	202
4		A_103_J2	7.4	2174	244	2390	279
5		A_104_J1	10.7	2850	349	3988	463
6		A_104_J2	12.4	3237	407	4998	542
7		A_105_J	16.9	4410	525	6727	690
8		A_106_J	19.8	5307	614	7929	794
9		A_107_J	19.9	5279	618	7896	798
10		A_108_J	21.7	5571	670	8562	925
11		A_109_J	26.3	6232	775	9671	1096
12		A_110_J	27.9	6421	826	9914	1170
13		A_111_J	32.1	7113	962	11100	1404
14		A_112_J	40.6	8123	1157	12742	1764
15		A_113_J1	52.3	10158	1468	15566	2241
16		A_113_J2	53.5	10213	1532	15685	2335
17		A_114_J	65.7	*tbd*	*tbd*	*tbd*	*tbd*
18		A_115_J	68.3	*tbd*	*tbd*	*tbd*	*tbd*
19		A_116_J	80.1	*tbd*	*tbd*	*tbd*	*tbd*
20	B	B_104_J	5.5	1823	178	2427	216
21		B_105_J2	10.7	2547	325	3475	462
22		B_201	0.8	391	25	569	30
23		B_202_J	2.4	830	77	1217	100
24		B_301_J	3.7	1117	115	1918	162
25	C	C_101	1.6	663	54	965	61
26		C_102_J	3.1	1048	102	1481	119
27		C_103_J	3.6	1103	118	1636	163
28		C_104_J	4.4	1179	145	1730	226
29	D	D_101	0.4	305	14	487	23
30		D_102_J	0.9	577	30	924	50
31		D_104_J2	3.2	1338	106	2178	181
32	F	F_102_J	1.9	845	66	1187	77
33		F_103_J	2.8	997	94	1360	109
34	G	G_101	1.7	846	59	1245	69
35		G_102_J2	3.8	1586	128	2268	150
36		G_201	0.6	375	22	536	25

Analysis Point	Tributary	HEC-HMS Element	Drainage Area (mi^2)	EXISTING 100-year peak flow (cfs)	EXISTING 100-year runoff volume (AC-FT)	DEVEX 100-year peak flow (cfs)	DEVEX 100-year runoff volume (AC-FT)
37	H	H_101	1.2	732	50	1130	67
38		H_102_J	1.6	868	62	1334	81
39	I	I_101	1.2	657	43	948	50
40		I_102_J1	2.1	1155	77	1955	120
41		I_102_J2	3.4	1565	117	2717	197
42		I_201	0.9	522	33	1041	70
43	J	J_102_J	1.3	650	44	801	54
44		J_103_J	1.8	759	62	893	74
45	L	L_101	0.5	390	18	397	18
46		L_103_J	1.5	812	53	957	66
47	M	M_102_J	2.0	970	71	970	71
48	Middle Branch (MB)	MB_101_J	7.7	*tbd*	*tbd*	*tbd*	*tbd*
49		MB_103_J2	10.9	*tbd*	*tbd*	*tbd*	*tbd*
50		MB_104_J	11.6	*tbd*	*tbd*	*tbd*	*tbd*
51		MB_301	1.7	*tbd*	*tbd*	*tbd*	*tbd*
52	N	N_102_J	1.4	657	50	906	59
53		N_103_J	1.9	730	67	981	78
54		N_104_J2	3.9	1235	132	1829	197
55		N_105_J	4.5	1262	150	1851	219
56		N_201	1.0	479	36	725	43
57	O	O_101	0.3	228	11	312	13
58		O_103_J	1.7	644	56	1584	132
59	P	P_101	0.6	350	19	656	38
60		P_103_J	2.7	1092	104	1699	164
61		P_104_J	3.7	1524	139	2290	233
62	Q	Q_101	0.5	656	39	780	50
63		Q_102_J	1.2	1170	72	1551	104
64	Rainbow Tributary (RA)	RA_101	0.2	210	8	307	14
65		RA_103_J	1.0	723	41	1144	80
66		RA_104_J	1.2	892	61	1400	105
67		RA_105_J	1.3	969	72	1495	116
68		RA_108_J	2.1	1052	98	1753	176
69	West Branch (WB)	WB_SWINBURNE_INFLOW	11.1	*tbd*	*tbd*	*tbd*	*tbd*

- All peak flow rates and runoff volumes in this table are for selected locations in the corresponding HEC-HMS models. For more details, please consult Appendix C.
- The peak flow at a confluence is not necessarily the sum of the peak flows from corresponding tributaries.

Figure 17: Map showing analysis points along the main stem of the Calabacillas Arroyo (red) and along major tributaries (blue).



4. Lateral Erosion Envelope

The Lateral Erosion Envelope (LEE) for the Calabacillas Arroyo and major tributaries was delineated in accordance with the procedures described in SSCAFCA's Sediment and Erosion Design Guide. The LEE represents the maximum lateral migration distance of the arroyo that can be expected over the next 30 to 50 years, and identifies a corridor where properties and infrastructure are potentially at risk from erosion.

Figure 18 shows the extent of lateral migration of the upper Calabacillas Arroyo between King Blvd. and the proposed Paseo del Volcan (PDV) alignment. The red lines represent the Arroyo banks in 1952; the blue shaded area indicates the location of the arroyo in 2012.

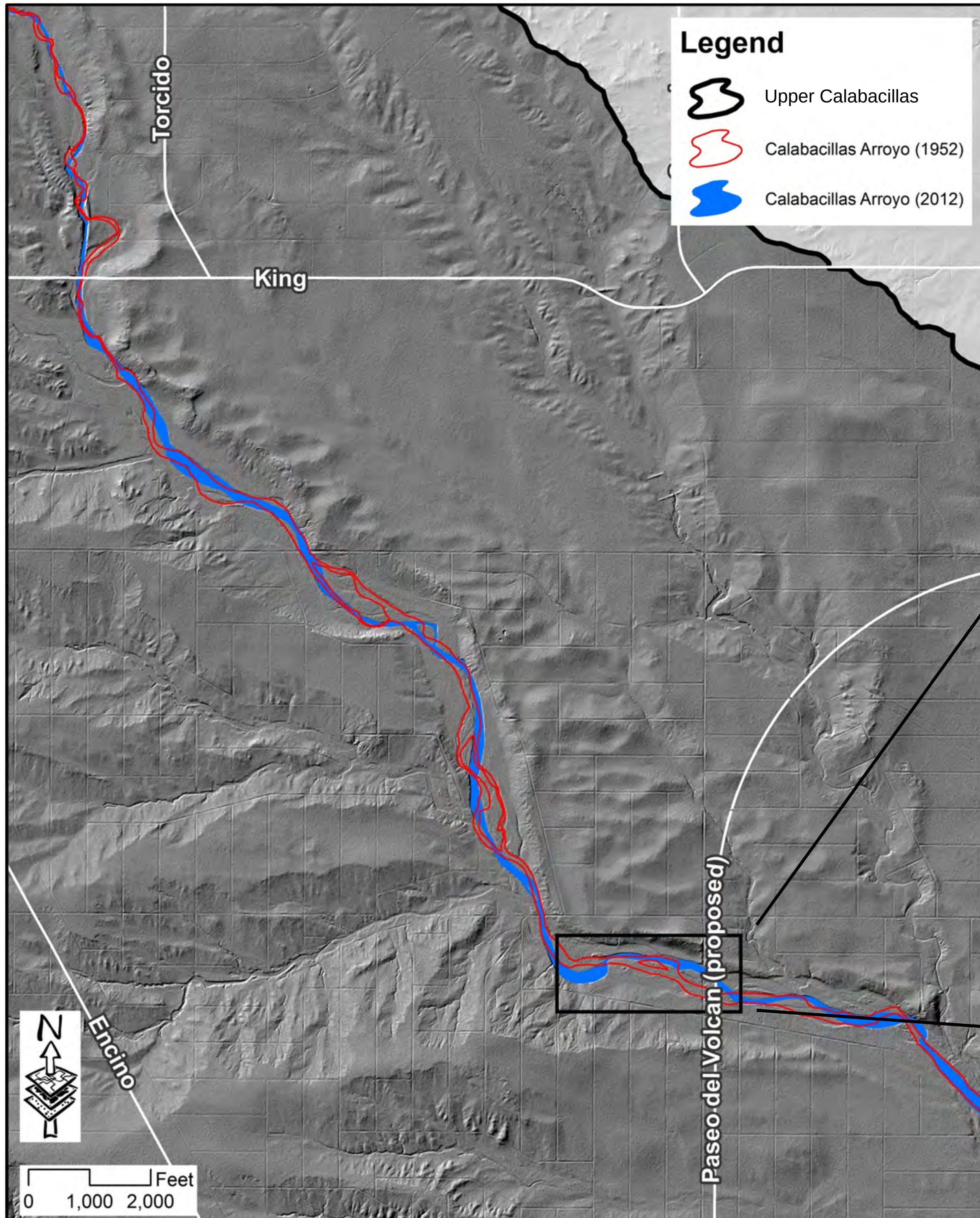


Figure 18: Map showing the extent of lateral migration of the upper Calabacillas Arroyo between 1952 (red) and 2012 (blue).

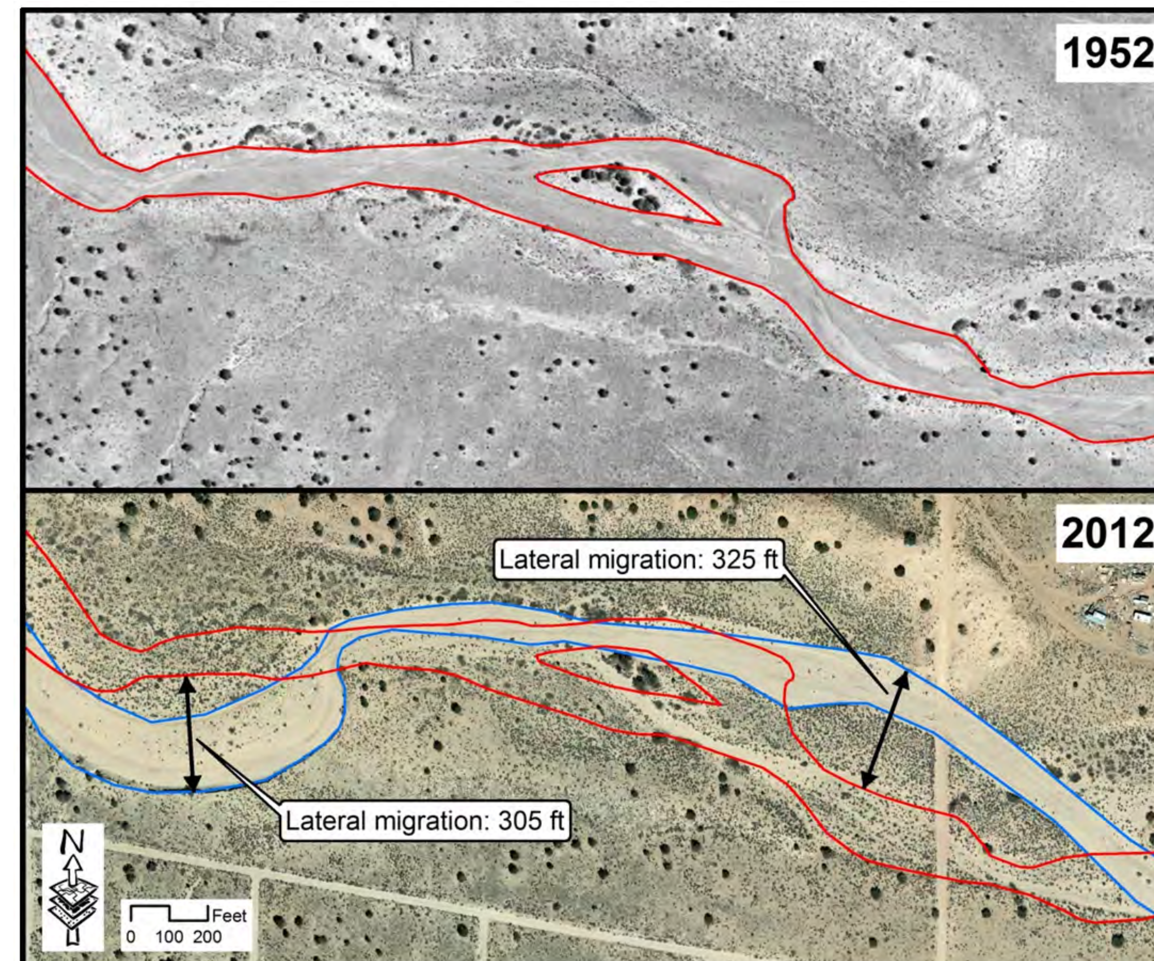


Figure 19: Detailed view of lateral arroyo migration west of the proposed PDV alignment.

The detailed view (Figure 19) illustrates the need for a lateral erosion envelope: through this reach, the banks of the Calabacillas Arroyo have moved more than 300 feet in the 60-year period between 1952 and 2012.

The Lateral Erosion Enveloped was mapped in GIS by calculating the expected maximum lateral erosion distance for each arroyo reach, and applying a buffer zone of corresponding width on either side of the existing arroyo bank (see Figure 20).

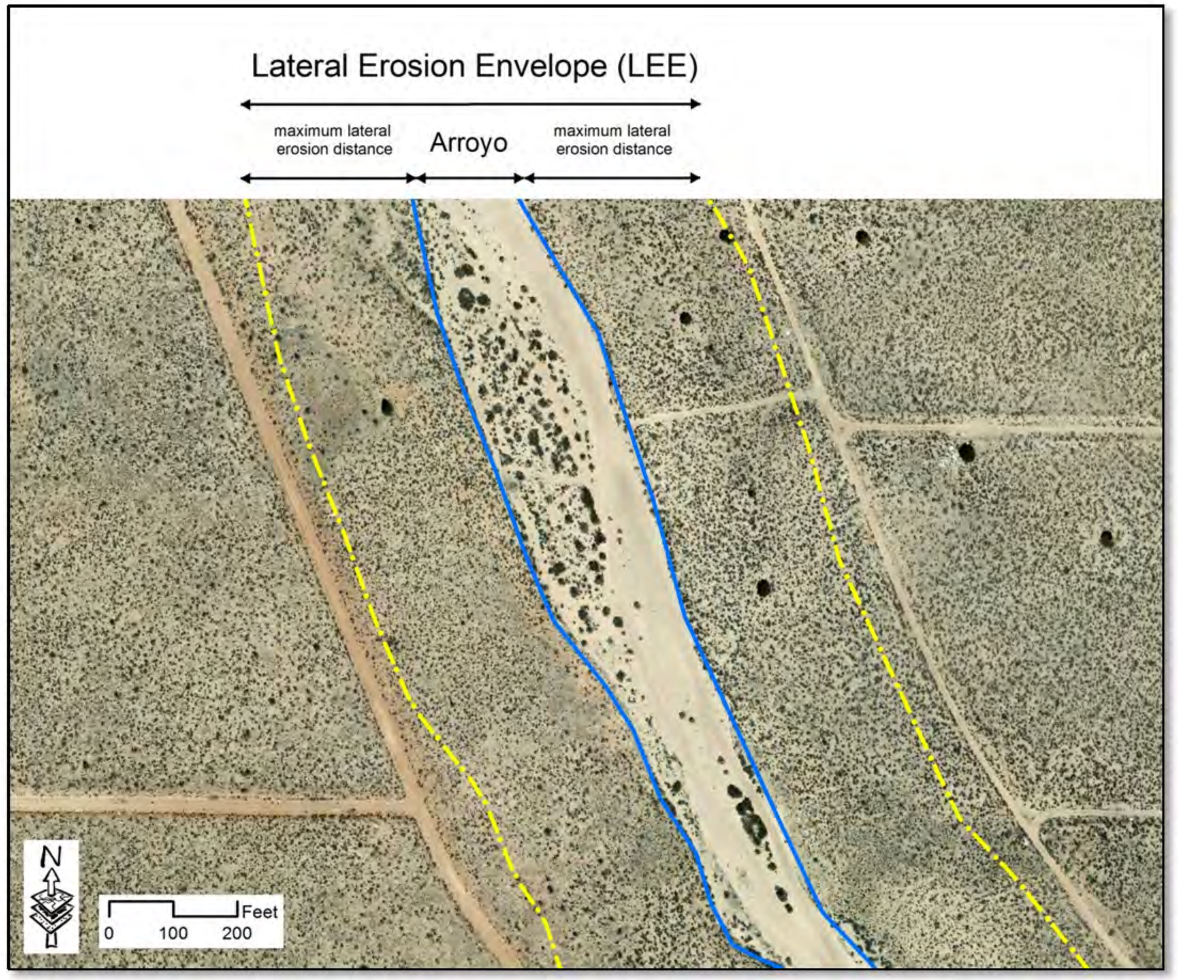


Figure 20: Example of LEE delineation on a typical reach of the Calabacillas Arroyo.

The Lateral Erosion Envelope does not predict the future course of the arroyo, nor does it guarantee that the arroyo will remain within its limits. The purpose of the LEE is to identify an area in the proximity of major arroyos that is at higher risk from damage caused by erosion. Detailed maps showing the lateral erosion envelopes of the Calabacillas Arroyo and major tributaries are contained in Appendix A. Please note that there may be other areas at risk that are not identified in this document, particularly in the upper reaches of tributaries and along smaller arroyos.

Photo 14 shows a house built adjacent to the Calabacillas Arroyo and within the Lateral erosion Envelope. In less than three hours, the flood of September 13, 2013 eroded approximately 40 feet of bank on the south side of the arroyo.

Photo 14: House built within the lateral erosion envelope of the Calabacillas Arroyo (looking east towards the Sandia Mountains in the background).

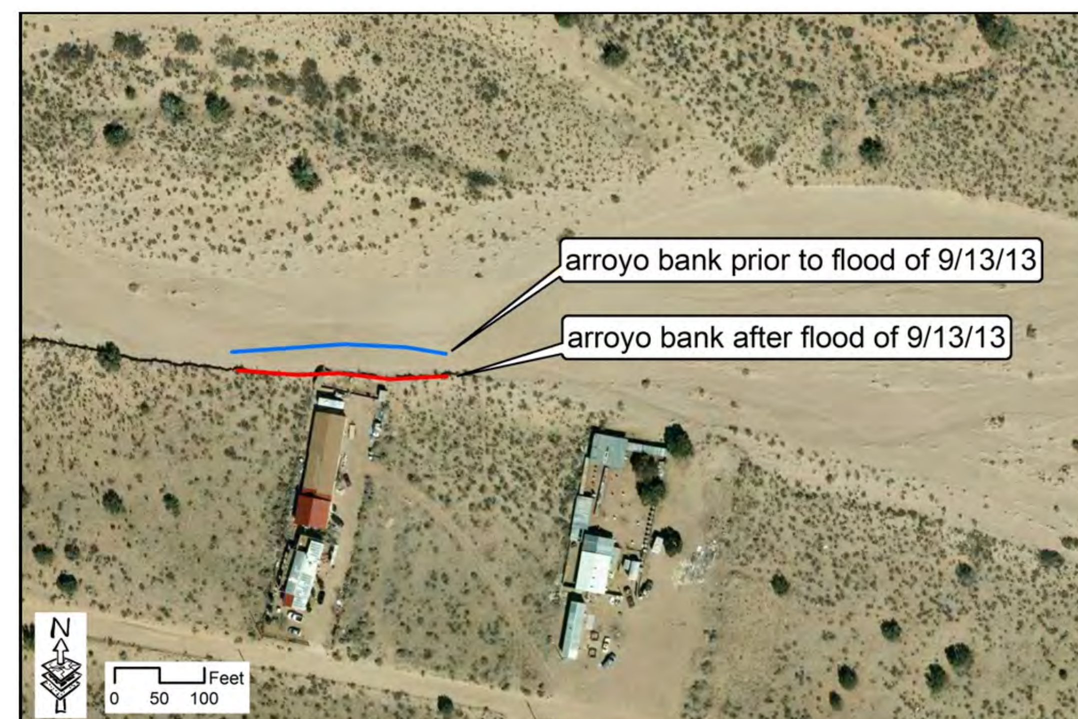


Figure 21: Aerial photograph of the area depicted in Photo 14; the flood of 9/13/2013 moved the bank of the Calabacillas Arroyo approximately 40 feet to the South.

IV. HYDRAULICS/FLOODPLAIN ANALYSIS

HEC-RAS, the River Analysis System software developed by the USACE Hydrologic Engineering Center, was used to perform steady-state hydraulic modeling along approximately 11.5 miles of the Main Branch of the Calabacillas Arroyo from Swinburne Dam to the confluence of the Calabacillas Main Branch and Tributary H. Model version 4.1.0 was used as described in this section to determine water surface elevations along the subject reach and RAS Mapper was utilized to produce the existing conditions floodplain boundaries.

To obtain a copy of the most recent version of the HEC-RAS model, please contact the SSCAFCA office.

A. HEC-RAS GEOMETRY

Topographic Data. Contours built from the MRCOG 2010 LiDAR mapping were used to establish the geometric properties of the cross sections. The contours were created using the Digital Elevation Model (DEM) provided by the MRCOG 2010 flight data. All topographic-related analysis was completed in ArcGIS 10.1 with Spatial and 3D Analyst extensions. The vertical datum for all topographic data is NAVD 88.

Cross Sections. The existing conditions cross sections, along with downstream reach lengths, were extracted from HEC-geoRAS in ArcGIS 10.1 from the DEM. All cross sections were inspected using the X-Y-Z Perspective Plot tool in HEC-RAS to confirm that the cross sections adequately represent channel and overbank geometry.

Roughness Values. The roughness (Manning's n) value used for the channel along the arroyo centerline was 0.035, representing an earthen channel with some stones and brush (Chow, 1959). This was determined reasonable due to the fairly sandy bottom and vegetated "islands" located throughout the subject reach. Roughness values used for the overbank areas were 0.045, representing a floodplain with scattered brush and heavy weeds (Chow, 1959).

Ineffective Flow Areas. Ineffective flow areas were established based on an evaluation of the topographic information generated from the DEM, which included backwater areas in side channels where ponding would occur but would not represent active conveyance.

Levees. The arroyo does not contain any constructed levee-like features, however the levee function was used in the model. In many cases, the cross section layout extended further on either side than the main channel banks in order to ensure containment of the target peak flow rate. In this case, several cross sections were unnecessarily over-extended and, since HEC-RAS applies the calculated WSEL uniformly across the entire cross section, it would be incorrect to model flow outside of the main channel when overtopping of the main channel bank(s) did not occur. In these cases, a levee was inserted to prevent flow from being considered in these areas.

Bridges. The existing conditions model contains two bridge crossings: the Southern Boulevard concrete box culvert (CBC) and the McMahon Boulevard bridge. Site specific details for each crossing are included below.

Southern Boulevard Crossing – A 5-cell 8'H x 6'W CBC. This crossing is oriented perpendicular to flow, therefore no skew/roadway geometry adjustments were included. Photo 8 (see page 7 of this report) shows a photo of this structure.

McMahon Boulevard Crossing – The bridge spans approximately 212 feet and includes 2 piers approximately 3.5 feet wide. This crossing is skewed approximately 27 degrees to flow, so bridge skew was addressed in the upstream and downstream cross sections by manually adjusting the cross section to accurately reflect a perpendicular-to-flow situation under the bridge. The piers are continuous through the bridge section and are oriented parallel to flow, so no skew adjustments were made.

B. STEADY FLOW DATA/BOUNDARY CONDITION

The peak discharges used in the hydraulic model are discussed in Section III.B.3 above. Table 11 below shows the flow change locations (HEC-RAS model cross sections) and their corresponding HEC-HMS ID.

Table 11: HEC-RAS Flow Change Locations

HEC-RAS XS	HEC-HMS ID	EXISTING Q (cfs)	HEC-HMS ID Description
59870.4	A_104_RAS	2843	Downstream end of basin A_104 prior to junction with Trib. H
51426.1	A_105_RAS	3276	Downstream end of basin A_105 prior to junction with Trib. G
49773.2	A_106_RAS	4418	Downstream end of basin A_106 prior to junction with Trib. F
42682.8	A_108_RAS	5235	Downstream end of basin A_108 prior to junction with Trib. O
39947.8	A_109_RAS	5557	Downstream end of basin A_109 prior to junction with Trib. N
36966.6	A_110_RAS	6278	Downstream end of basin A_110 prior to junction with Trib. E
28791.6	A_111_RAS	6433	Downstream end of basin A_111 prior to junction with Trib. P
22919.9	A_112_RAS	7117	Downstream end of basin A_112 prior to junction with Trib. C&D
15539.8	A_113_RAS	8081	Downstream end of basin A_113 prior to junction with Trib. B&Q
10377.4	A_114_RAS	10189	Downstream end of basin A_114 prior to junction with Trib. MB
6746.1	A_115_RAS	10770	Downstream end of basin A_115 prior to junction with Saltillo SD
2612.6	A_116_RAS	11014	Downstream end of basin A_116 prior to junction with WB

The downstream boundary condition utilized in the existing conditions model was based on the 100-yr maximum WSEL (5280.10) in Swinburne Dam, as provided in the HEC-HMS model and as reported in Appendix A in the Stormwater Detention Facilities table.

C. INUNDATION MAPPING

Inundation/Floodplain mapping was completed using the RAS Mapper tool within HEC-RAS 4.1.0. The Terrain input was based on the most recent LiDAR data available from MRCOG (2010), which was converted from a DEM to float (.flt) format, as required by RAS Mapper, using ArcMap 10.1. Results from the inundation mapping are shown in Appendix A.

D. RESULTS

This hydraulic analysis was conducted for the purpose of delineating the area of inundation resulting from the 100-yr rainfall event in order to identify potential flooding hazards along the main stem of the Calabacillas Arroyo. The results from this analysis are shown in Appendix A.

There are some important factors to consider when evaluating the results of this mapping:

Extremely Erosive Soils. As discussed in Section II.D.5 above, the Calabacillas Arroyo contains extremely erosive soils in both the channel and overbanks. When the arroyo experiences large runoff events, significant erosion occurs both along the arroyo bed and banks, which changes the overall geometry and alignment of the arroyo. Due to this fact, accurate delineation of the floodplain and especially water surface elevation determination is really only applicable for the time frame between when the underlying topographic data was collected and when the following significant runoff event occurs. The hydraulic analysis and inundation mapping presented in this report was completed using the most recent LiDAR data available from MRCOG, which was produced in 2010.

Lateral Migration/Bank Erosion. Following the 2013 monsoon season, SSCAFCA determined (based on a comparison of pre- and post-monsoon aerial imagery) that some banks along the main stem of the Calabacillas Arroyo moved in excess of 70 feet. An example of how lateral migration has affected semi-developed areas, see Figure 22 and Figure 23. The arroyo bank migrated approximately 50 feet at this location as a result of just one monsoon season. For additional information on lateral migration & erosion, see Section III.B.4 above.

It is important to understand that this arroyo system is very dynamic and that runoff events, however minor, have the potential to change the arroyo geometry and thus the floodplain boundaries. Floodplain boundary/inundation maps are an effective tool for watershed management and they should be re-evaluated periodically (especially following large runoff events) or as required in order to provide a more realistic perspective of what the flooding hazards in the area may be and to assist the public in identifying potential hazards both to existing structures and to future site developments.

Existing FEMA FIRMs. There are no immediate plans to revise the published FIRMs and this analysis was not intended to replace the existing FEMA Zone A floodplain along the Calabacillas Arroyo, only to identify potential flooding hazards. The existing FEMA Panel IDs for the Calabacillas Arroyo are: 35043C1875D, 35043C1888D, 35043C2100D & 35043C2101D.

Figure 22: Partially developed area just north of Northern Blvd 2012.

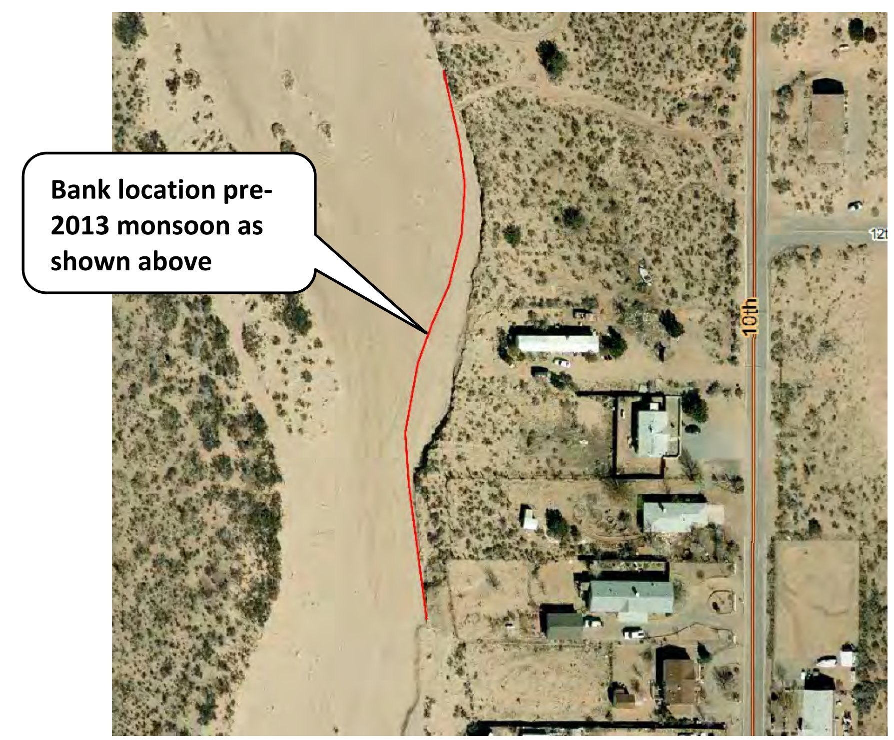


Figure 23: Same perspective shown in Figure 22 after the 2013 monsoon season.

V. DRAINAGE DEFICIENCIES AND RECOMMENDATIONS

Based on the development scenarios described in the previous section, drainage deficiencies were identified and potential solutions evaluated. Figure 24 shows an overview map of the Calabacillas Watershed Park. Areas with major drainage deficiencies are numbered in yellow; the numbers correspond to the detailed discussion of deficiencies and recommended improvements in Section V.A below.

Proposed improvements are shown in red, and effects of those improvements on the hydrology are reflected in the ULTIMATE conditions flow rates. Only flow rates for selected model junctions are shown on Figure 24. For more details, please consult the discussion below or the watershed maps in Appendix A. Please note that the peak flow rates reported in Figure 24 stem from model runs using rainfall input without depth-area reduction factors, since the contributing drainage area is less than two square miles in size (see also discussion in Section III.A.5 above).

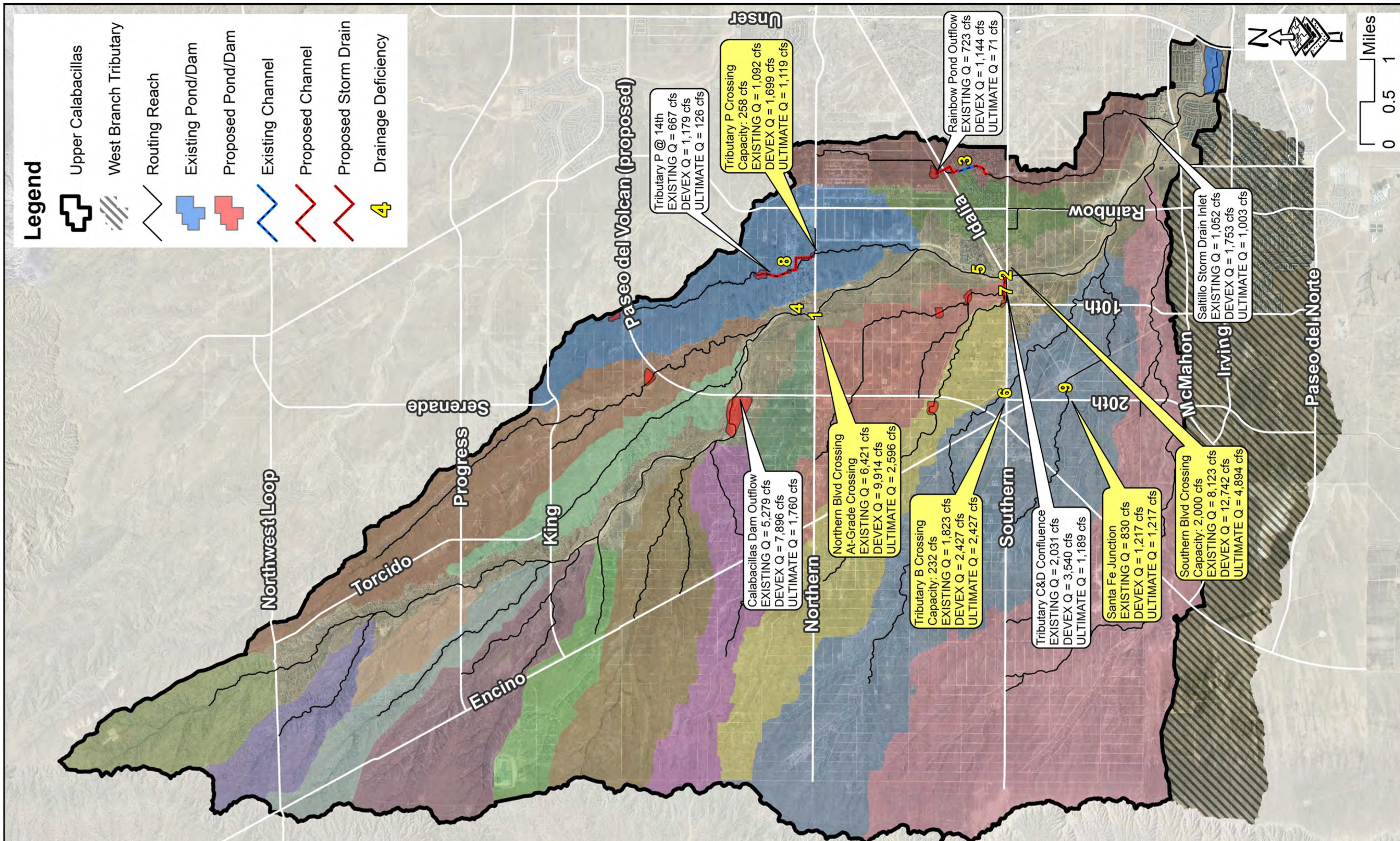
Callouts with yellow shading (see Figure 24) indicate locations where proposed regional drainage improvements do not solve all drainage issues, and local improvements will be necessary.

Photo 15: Flood waters crossing Northern Blvd during the storm of September 13, 2013 (Source: KOB News).

Photo 16: Storm flows in the Calabacillas Arroyo overtopping Southern Blvd during the September 13, 2013 storm (Source: KOAT News).

Photo 17: Extent of flooding upstream of Southern Blvd during the storm of September 13, 2013 (Source: KOAT News).

Figure 24: Overview map of drainage deficiencies and major flow rates; locations numbered in yellow refer to detailed discussion of deficiencies and recommended improvements in Section V.A below.



A. DEFICIENCIES AND EVALUATION OF ALTERNATIVES

1. Northern Blvd Crossing of the Calabacillas Arroyo

Issues:

Northern Blvd crosses the Calabacillas Arroyo at grade. Any storm flows in the arroyo have to cross the roadway, and no signage currently exists to warn motorists of the potential dangers of crossing flowing water. Storm flows also frequently cause damage to the road surface as can be seen in Photo 18 and Photo 19. Scour on the downstream side of the crossing undermined the asphalt, which subsequently collapsed.

The 100-year peak discharge at this location is 6,421 cfs under EXISTING conditions and 9,914 cfs under DEVEX conditions. Please note that these peak flow rates stem from model runs using rainfall input with depth-area reduction factors appropriate for the 28 square mile drainage basin upstream of the road crossing (see also discussion in Section III.A.5 above).

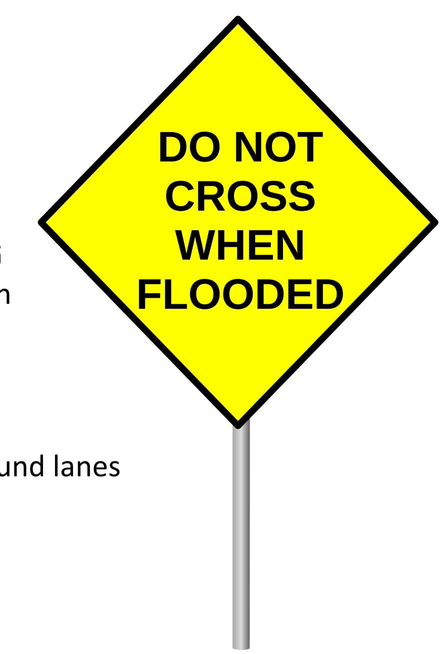
Under ULTIMATE conditions with the Calabacillas Dam upstream in place (see Section V.B.2 below); peak discharge at Northern Blvd would be reduced to 2,596 cfs during the 100-year storm.

Photo 18: Damage to Northern Blvd caused by the August 4, 2013 storm.

Photo 19: The south lane of Northern Blvd is partially undermined following the storm of September 13, 2013.

Proposed Improvements:

Construct a crossing structure (bridge or concrete box culverts) designed to be able to pass at least the 100-year peak flow rate. If the crossing structure is constructed prior to construction of the Calabacillas Dam upstream, it should be designed for the EXISTING conditions peak flow rate of 6,421 cfs. With the Calabacillas Dam in place, the structure would only need to convey 2,547 cfs. The crossing should be designed to resist clogging by debris and sediment.



In the meantime, signs should be posted on both east and westbound lanes warning drivers not to cross the arroyo when water is present.

2. Southern Blvd Crossing of the Calabacillas Arroyo

Issues:

The road crossing of the Calabacillas Arroyo at Southern Blvd consists of a five 8-ft wide by 6-ft high concrete box culverts (see Photo 20).

Photo 20: Southern Blvd. Crossing of the Calabacillas Arroyo, looking upstream.

The 100-year peak discharge at this location is 8,123 cfs under EXISTING conditions and 12,742 cfs under DEVEX conditions. Under ULTIMATE conditions with the proposed upstream Calabacillas Dam in place, peak flow would be reduced to 4,894 cfs (see Section V.B.2 below). Please note that these peak flow rates stem from model runs using rainfall input with depth-area reduction factors appropriate for the 40 square mile drainage basin upstream of the road crossing (see also discussion in Section III.A.5 above).

Photo 21: Debris accumulated on the upstream side of the Southern Blvd crossing following the 9/ 13/ 2013 flood.

Under ideal conditions, the existing crossing structure has an estimated capacity of 2,000 cfs. The effective capacity may be significantly lower due to sediment accumulation in the culvert. During large storm events, the debris getting caught at the entrance to the culvert can further reduce the capacity of the crossing (see Photo 21).

Following the storm of September 13, 2013, storm flows overtopped Southern Blvd (see Photo 22). This resulted in localized flooding upstream of the crossing structure due to the ponding effect of the road embankment, and to erosion downstream of the crossing.

The flow gaging station further downstream at Swinburne Dam indicated peak flows of approximately 1,300 cfs during the storm event. The crossing at Southern Blvd likely overtopped due to a combination of sediment accumulation in the culvert and debris caught on the upstream side.

Photo 22: Storm flows overtopping Southern Blvd during the flood of September 13, 2013. (Source: KOAT News).

Proposed Improvements:

Increase the capacity of the crossing structure to at least the EXISTING conditions 100-year peak flow rate of approximately 8,123 cfs. Although the proposed Calabacillas Dam upstream could ultimately limit peak discharge at Southern Blvd to 4,894 cfs, it is recommended to increase the crossing capacity to the higher EXISTING conditions flow rate, since the Calabacillas Dam will likely take years to complete. Crossing structure improvements should be designed to resist clogging by debris and sediment.

3. Rainbow Tributary between Tulip Road and Southern Blvd

Issues:

The *Drainage Management Plan- Rainbow Tributary of the Calabacillas Arroyo* (ASCG Inc., 2004) identified a number of drainage related deficiencies in the upper Rainbow Tributary. None of the proposed solutions have been implemented to date, and several proposed solutions have been rendered obsolete by ongoing single family residential development occurring within the proposed detention facility footprints. Following is a summary of the regional deficiencies; for a more in-depth analysis of this area including local drainage problems, please refer to the original report.

The Rainbow Tributary upstream of Tulip Road (approximately one square mile) drains to a shallow playa just north of Tulip Road; runoff then cross the road through a set of three 18-inch corrugated metal pipes (CMP) which daylight south of the road and transition into one 18-inch CMP culvert; this pipe in turn daylights upstream of Vancouver Road. Stormwater runoff exiting the pipe crosses Vancouver Road and flows into an existing earthen channel.

The drainage infrastructure between Tulip Road and the start of the channel is grossly inadequate to convey the 100-year peak flows, both under EXISTING and DEVEX conditions. Flood waters will overtop Tulip Road and surface-flow south to Vancouver Road, potentially causing damage to houses and other private property located in the flow path. The area in question is designated as a 100-year FEMA floodplain (see Figure 25). Please note that the peak flow rates reported in Figure 25 stem from model runs using rainfall input without depth-area reduction factors, since the contributing drainage area is less than two square miles in size (see also discussion in Section III.A.5 above).

Photo 23: Looking south from Tulip Road. Except for one 18" CMP culvert, no drainage infrastructure exists between Tulip and Vancouver Roads.; apartment buildings on both sides are in the 100-year floodplain

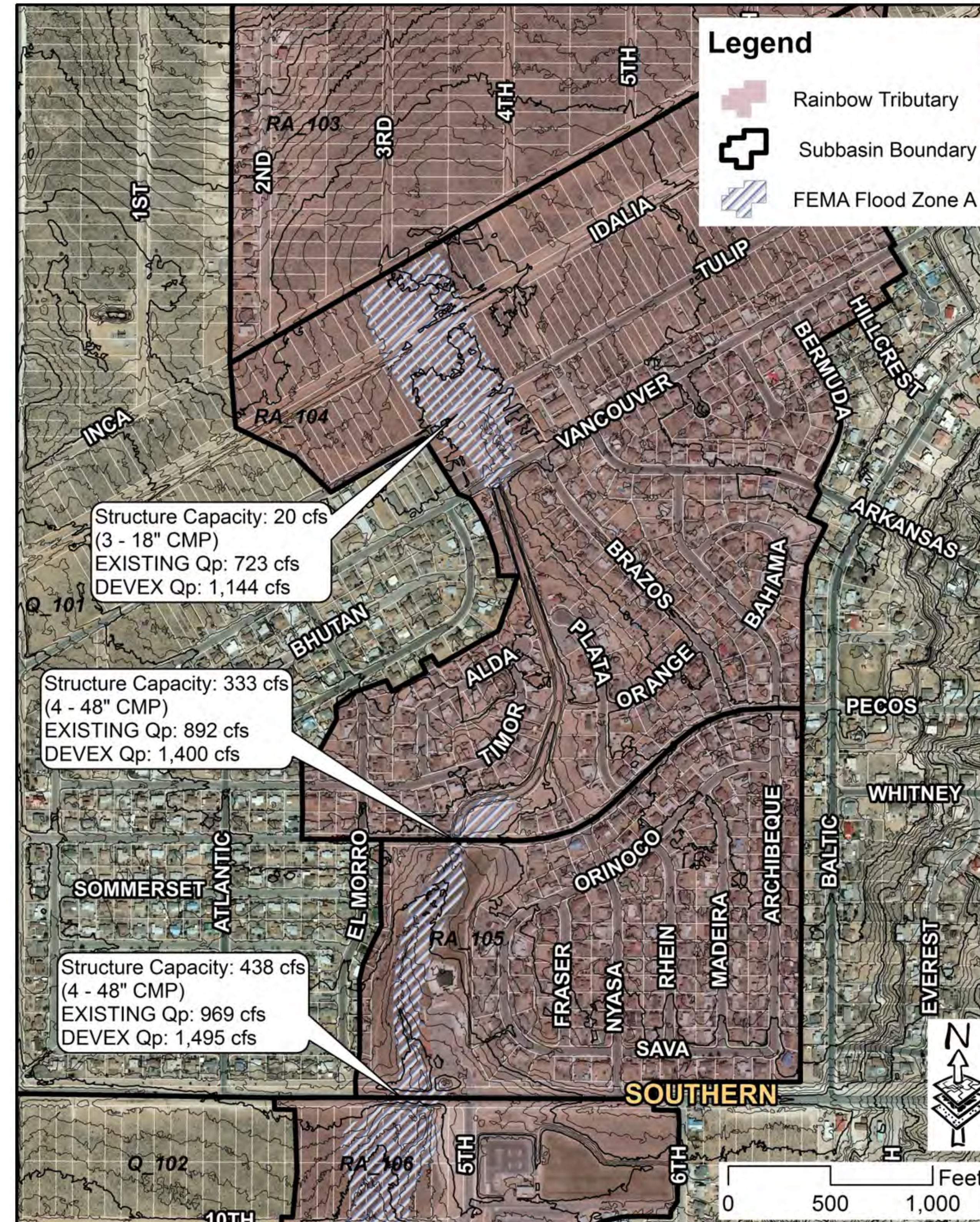


Figure 25: Map showing drainage deficiencies in the Rainbow Tributary.

The crossing structures further downstream at Pecos Loop and Southern Blvd are also undersized for EXISTING and DEVEX conditions and could lead to localized flooding due to temporary ponding upstream of the road crossings.

Photo 24: Rainbow Tributary crossing at Pecos Loop (4 – 48" CMP, capacity ≈ 333 cfs).

Photo 25: Rainbow Tributary crossing at Southern Blvd (4 – 48" CMP, capacity ≈ 438 cfs).

Please note that EXISTING and DEVEX peak flow rates on Figure 25 are based on model was runs using rainfall input without depth-area reduction factors due to the small size of the upstream drainage basin (see also discussion in Section III.A.5 above).

Proposed Improvements:

The proposed solution is a regional pond just upstream of Inca Road (CA_12P). During the 100-year storm, the pond would store approximately 58 AC-FT of runoff and reduce the peak discharge from 1,144 cfs to 71 cfs (a 94 percent reduction!). Although the storage capacity of the pond exceeds 50 AC-FT, the facility would not fall under OSE jurisdiction, since most of the storage would be below grade and the embankment height would not exceed six feet.

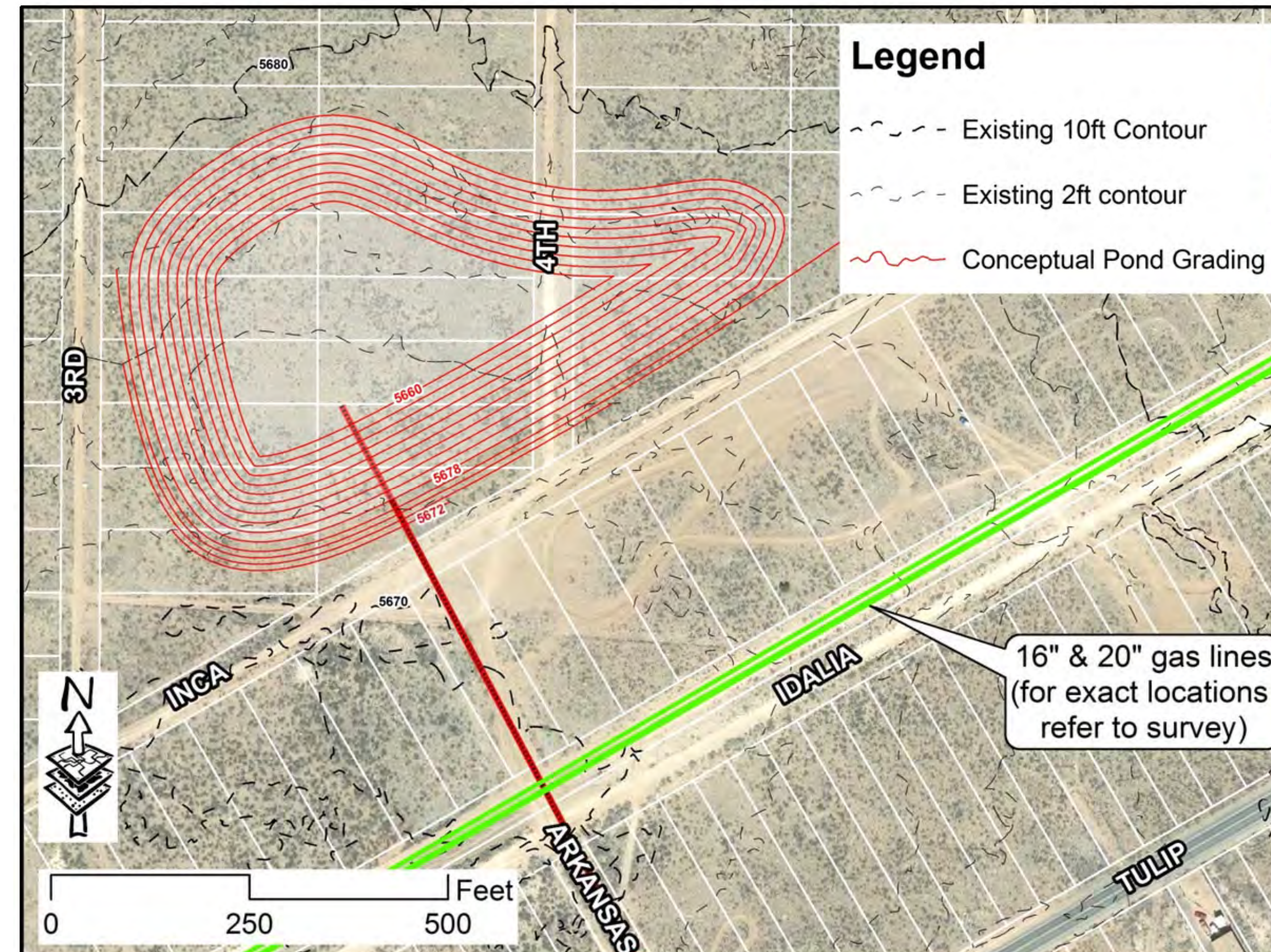


Figure 26: Conceptual grading of proposed pond CA_12P.

The outfall storm drain will cross underneath two high pressure gas lines (16" and 20", respectively) running parallel to Idalia Road. Exact locations and elevations of the gas lines were obtained by survey (potholing).

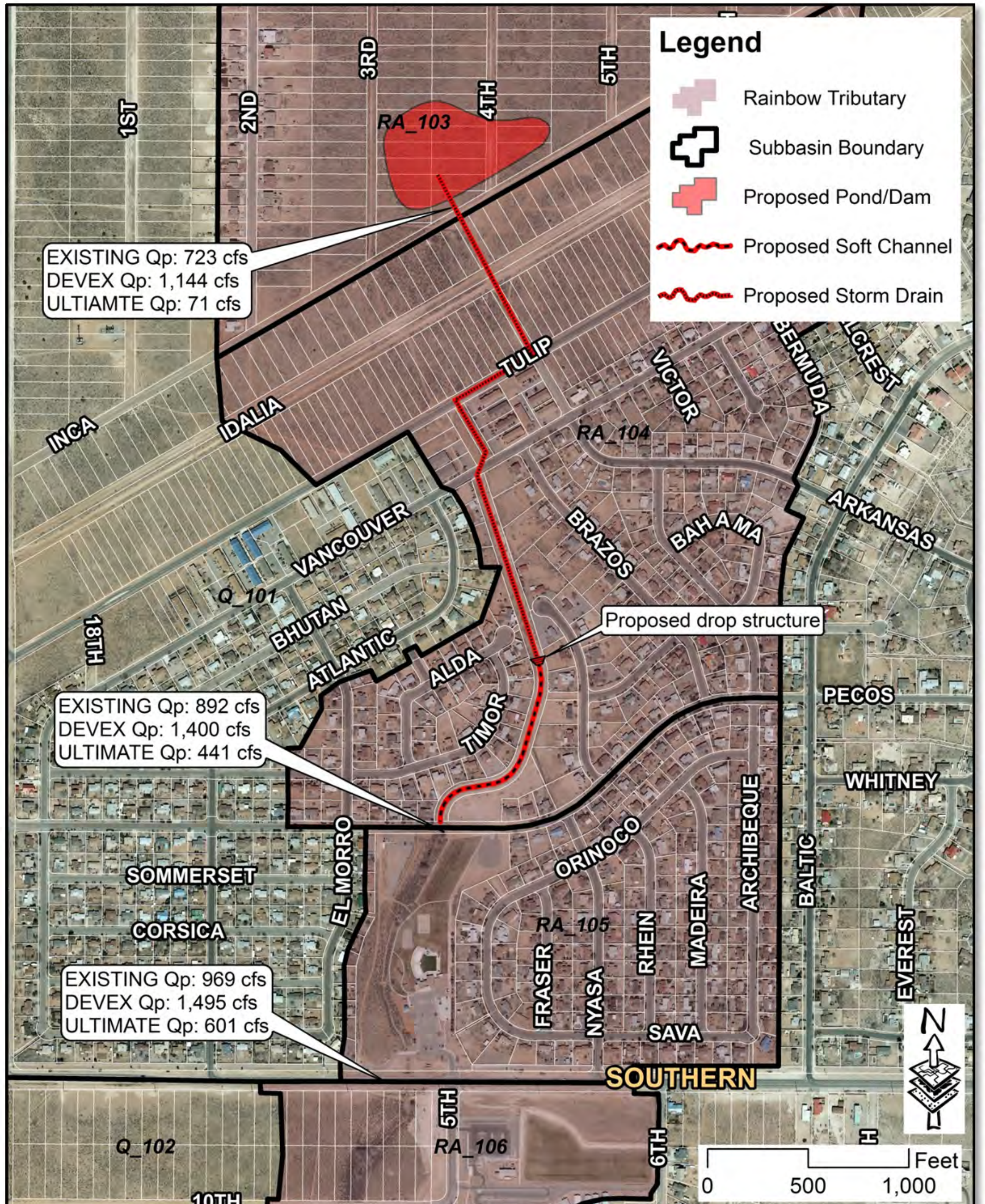


Figure 27: Map of proposed drainage improvements in the Rainbow Tributary.

The 36-inch outfall storm drain (see Figure 27) would convey outflow from the facility to the existing channel south of Vancouver Road. The storm drain would follow the channel for approximately 1,000 feet (below the grade of the existing channel) and terminate in a new drop structure. The estimated total length of the storm drain is 2,800 feet.

At the proposed drop structure, the existing channel has to be lowered approximately 4-6 feet to accommodate the invert elevation of the storm drain outlet. This will require regarding of the channel between the drop structure and Pecos Loop. The upper portion of the channel can remain unchanged and will serve to drain local flows from subbasin RA_104. I could also be used as a trail corridor and open space.

Even with all modifications in place, the proposed storm drain only has a slope of approximately 0.8 percent, and velocities in the pipe may be low; the flat slope is dictated by the slope of the terrain and the playa north of Tulip Road. The proposed pond will effectively remove sediment from storm flows, but sediment deposition in the pipe may become an issue if runoff from undeveloped areas is introduced to the storm drain through inlets located downstream of the pond. Special consideration should be given to this issue during design.

Photo 26: Looking south from Vancouver Road down the existing earthen channel.

4. Bank Erosion/Flooding at Northern Blvd

Issues:

At least 21 developed residential properties along the Calabacillas Arroyo and Northern Blvd are either partially in the 100-year flood plain, threatened by bank erosion, or both. Please note that the hatched area in Figure 28 represents the official FEMA floodplain; the area shaded in blue is the floodplain delineated based on the hydraulic model compiled as part of this study using EXISTING conditions peak flow rates. The differences between FEMA and SSCAFCA flood plain limits are likely a result of more detailed topographic data available for this study, as well as differences in peak discharge rates.

The hydraulic analysis (see Section IV above) indicates that, during the 100-year event, a portion of the flow will move east along Northern Blvd to approximately Hondo Road, before it turns south and rejoins the Calabacillas Arroyo further downstream. This can cause flooding to existing houses along Northern Blvd between 10th Street and Hondo Road.

Proposed Improvements:

Construct bank protection along the east bank of the Calabacillas to keep the arroyo from moving further to the east and causing erosion damage to developed properties. Construction of a crossing structure at Northern Blvd (see section V.A.1 above) can solve the flooding issues east of the arroyo along Northern Blvd by keeping storm flows from flowing east along Northern Blvd and inundating the depressed area north of the roadway. It is imperative that the structure be designed with sufficient capacity; if the crossing is undersized, it has the potential to exacerbate the upstream flooding due to water backing up behind the road embankment. When implemented, the proposed regional stromwater detention facilities upstream (see section V.B below) will also help by reducing peak flow rates through this reach.

Photo 27: House near the east bank of the Calabacillas Arroyo upstream of Northern Blvd.

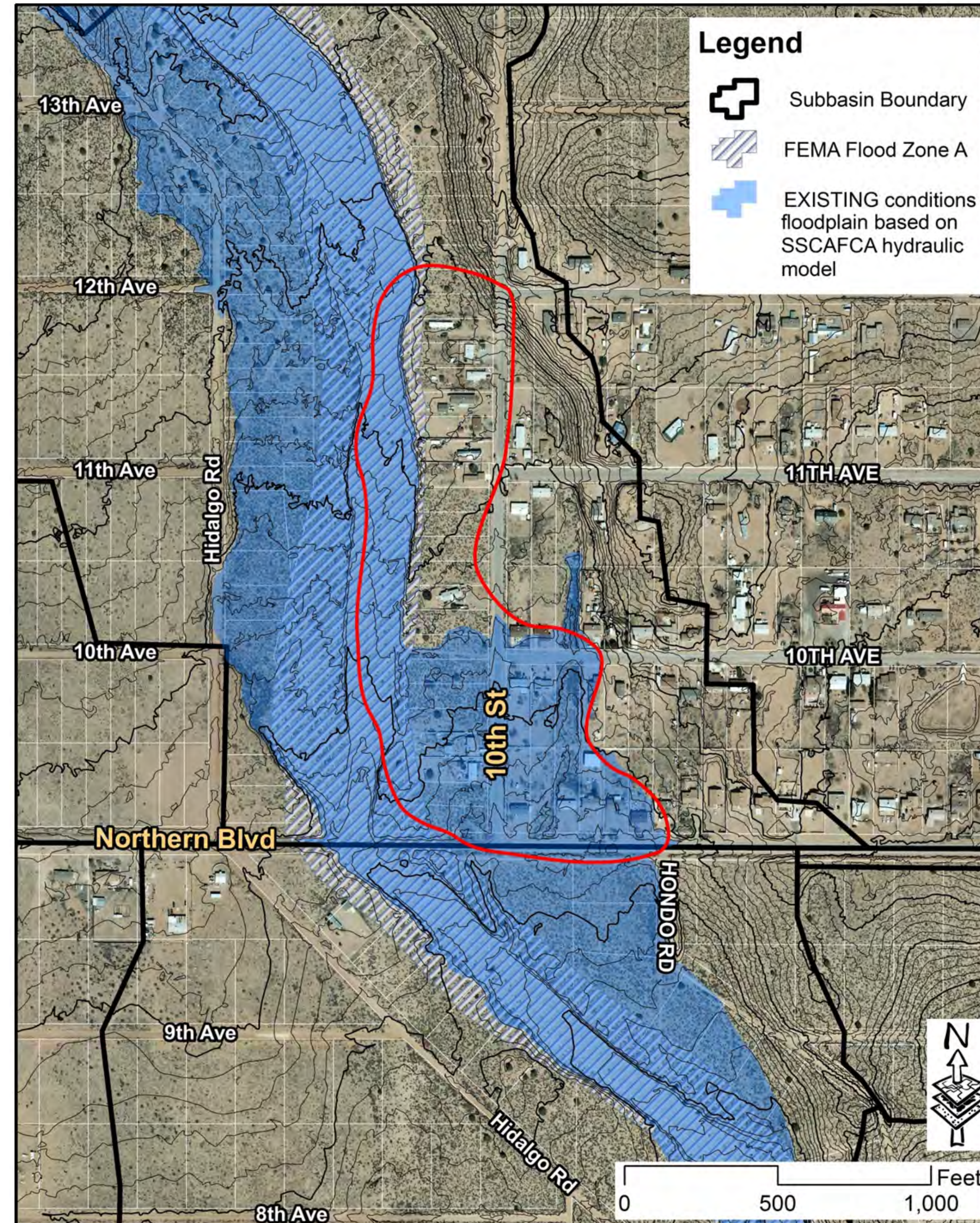


Figure 28: Residential properties along the Calabacillas Arroyo north of Northern Blvd at risk from flooding and erosion.

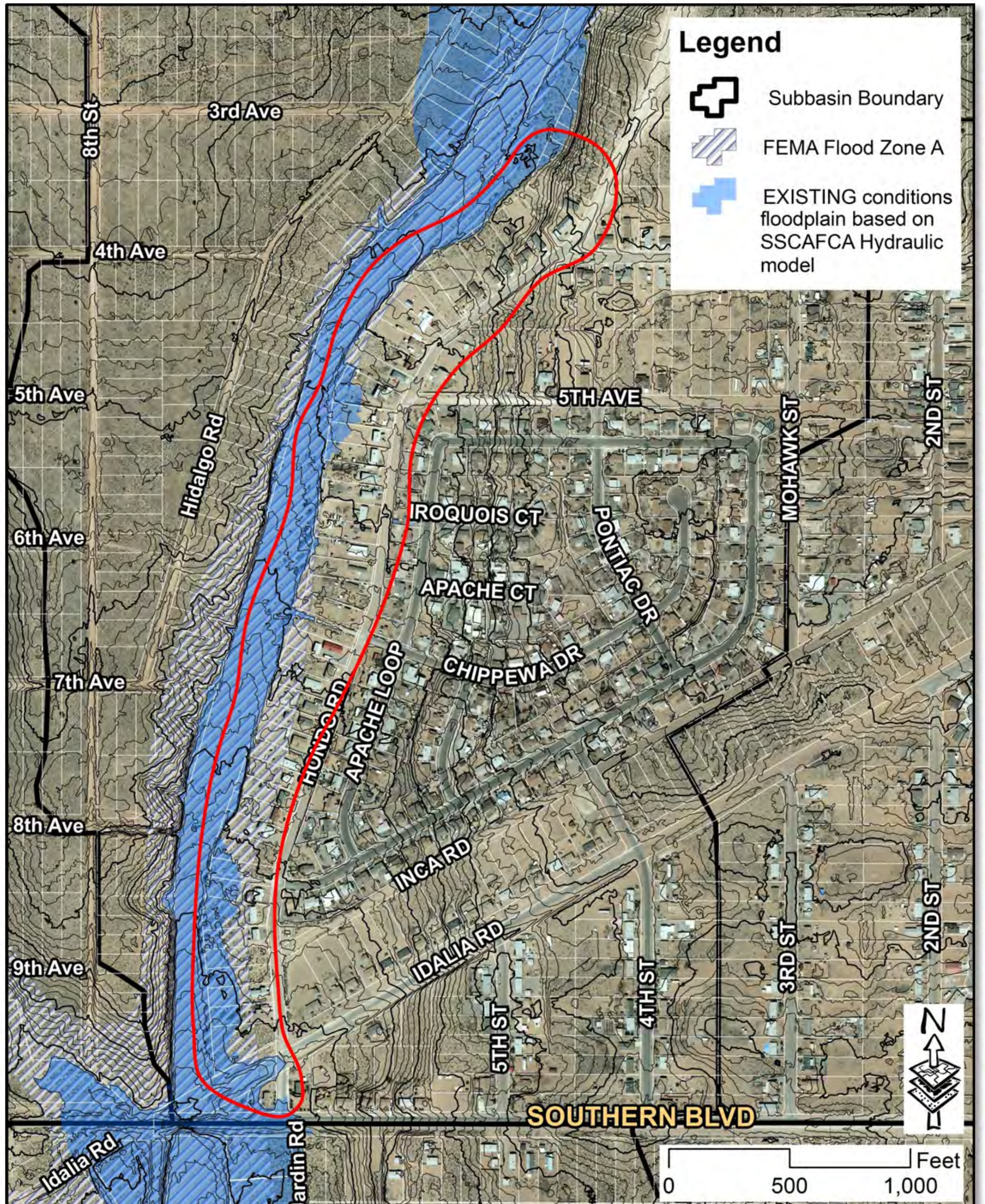


Figure 29: Residential properties along the Calabacillas Arroyo north of Southern Blvd at risk from flooding and erosion.

5. Bank Erosion/Flooding at Southern Blvd

Issues:

At least 41 developed residential properties along the Calabacillas Arroyo north of Southern Blvd are partially in the 100-year flood plain and threatened by bank erosion (see Figure 29). Insufficient capacity of the crossing structure at Southern Blvd causes ponding upstream of the road embankment and flooding of private properties at Southern Blvd and Hondo Rd.

Please note that the hatched area in Figure 29 represents the official FEMA floodplain; the area shaded in blue is the floodplain delineated based on the HEC-RAS hydraulic model compiled as part of this study using EXISTING conditions peak flow rates (see Section IV above). The differences between FEMA and SSCAFCA flood plain limits are likely a result of more detailed topographic data available for this study, as well as differences in peak discharge rates.

Photo 28: Houses on the east bank of the Calabacillas Arroyo north of Southern Blvd threatened by bank erosion.

Proposed Improvements:

Construct bank protection along the east bank of the Calabacillas to keep the arroyo from moving further to the east and causing erosion damage to developed properties. Upgrading the crossing structure at Southern Blvd (see section V.A.2 above) will solve the local flooding issues upstream of the road crossing. When implemented, proposed regional stormwater detention facilities upstream (see section V.B below) will also help by reducing peak flow rates through this reach.

6. Southern Blvd Crossing of Tributary B

Issues:

The upper portion of Tributary B (containing approximately 6 square miles) crosses Southern Blvd through a set of four corrugated metal pipes between 20th St and Gallup Rd. The hydrologic model indicates that peak flow rates at the road crossing are 1,823 cfs under EXISTING conditions and 2,427 cfs under DEVEX and ULTIMATE conditions (no upstream improvements are proposed in this basin, therefore DEVEX and ULTIMATE flow rates are identical). To determine structure deficiencies, the model was run using rainfall input with depth-area reduction factors appropriate for the 6 square mile drainage basin upstream of the crossing (see also discussion in Section III.A.5 above).

Photo 29: Tributary B crossing at Southern Blvd (4 – 48" CMP, capacity ≈ 232 cfs).

The crossing structure has an estimated capacity of 232 cfs, and is therefore undersized under EXISTING, DEVEX, and ULTIMATE conditions. Flows in excess of the culvert capacity will overtop the roadway, and a portion of the runoff may flow eastward along Southern Blvd, causing erosion along the road and exacerbating the conveyance deficiency that already exists downstream (see Section V.A.7 below).

Proposed Improvements:

Increase the capacity of the crossing structure to at least the EXISTING conditions 100-year peak flow rate of 1,823 cfs.

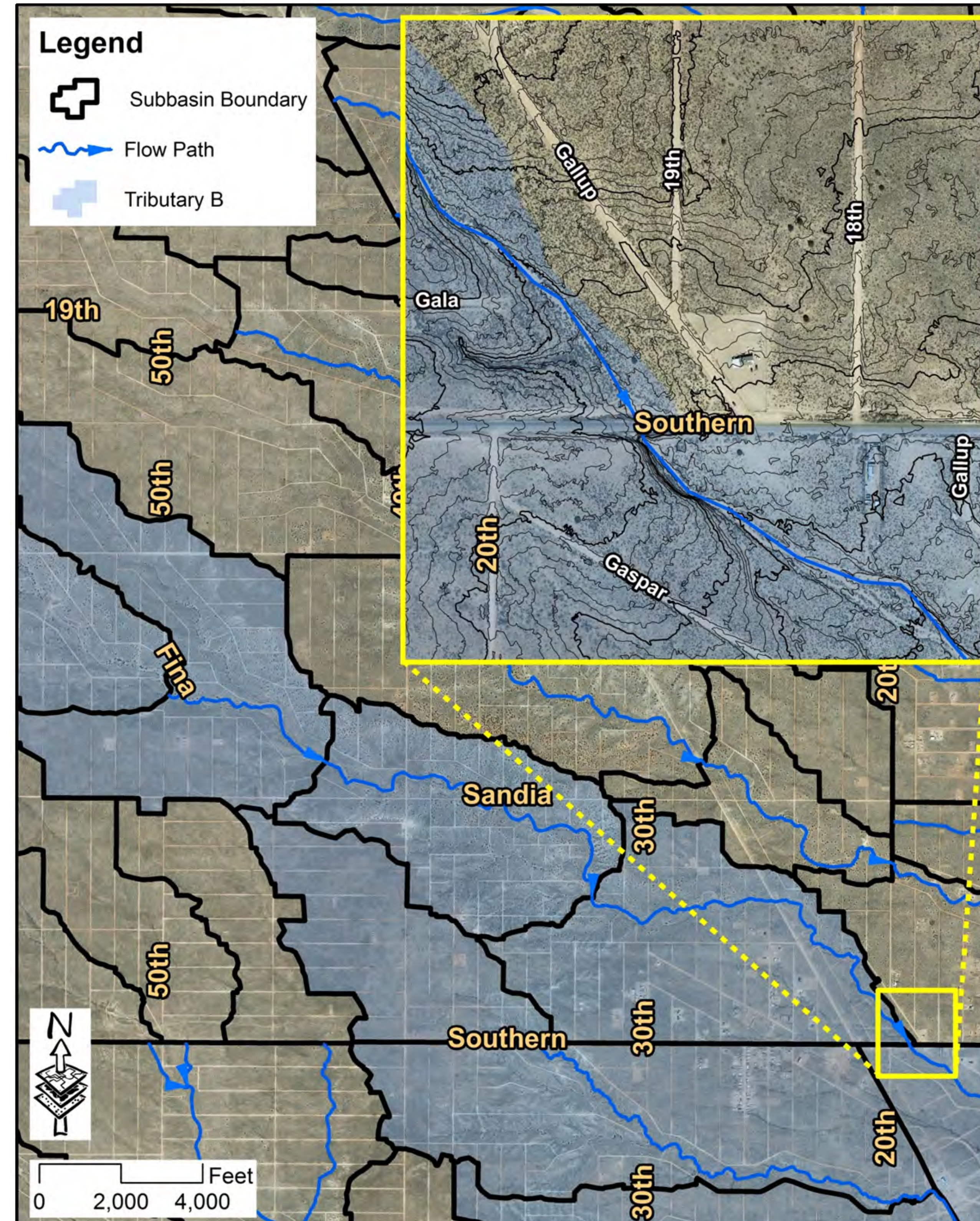


Figure 30: Southern Blvd crossing of Tributary B.

7. Southern Blvd Crossing of Tributaries C and D

Issues:

The historic flow path of Tributary C has been cut off by Southern Blvd; culverts that used to convey some flows under Southern are now completely filled with sediment (Photo 30). Additionally, houses have been constructed in the former flow path south of Southern. Runoff from Tributary C will now flow eastward along Southern Blvd for approximately 1,500 feet to the Calabacillas Arroyo; during large storm events, some flow may cross the roadway and cause flooding and erosion downstream.

Photo 30: Culverts at Southern Blvd & Tributary C filled completely with sediment (capacity = 0 cfs).

Tributary D intersects Southern Blvd just west of the Calabacillas Arroyo; the crossing structure has a capacity of 24 cfs and is therefore grossly undersized to convey the EXISTING or DEVEX conditions peak flows (2,031 cfs and 3,540 cfs, respectively). Runoff in excess of the culvert capacity will flow east into the Calabacillas Arroyo. Please note that these peak flow rates stem from model runs using rainfall input with depth-area reduction factors appropriate for the area of Tributary C (4 square miles) and Tributary D (3 square miles) upstream of Southern Blvd (see also discussion in Section III.A.5 above).

Photo 31: Culverts at Southern Blvd & Tributary D (2 – 24" CMP, capacity ≈ 24 cfs).

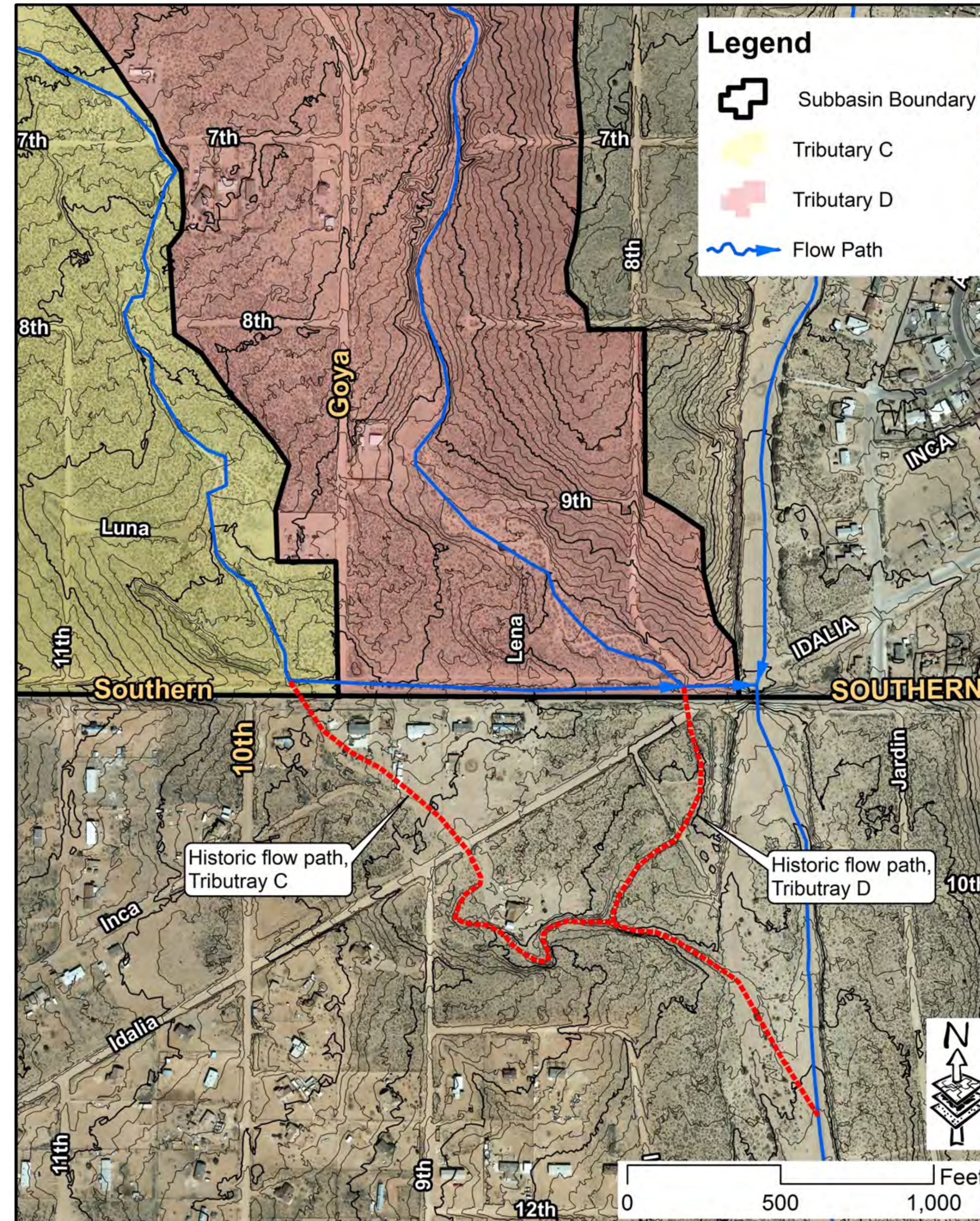


Figure 31: Map illustrating how Southern Blvd cut off the historic flow paths of Tributaries C and D.

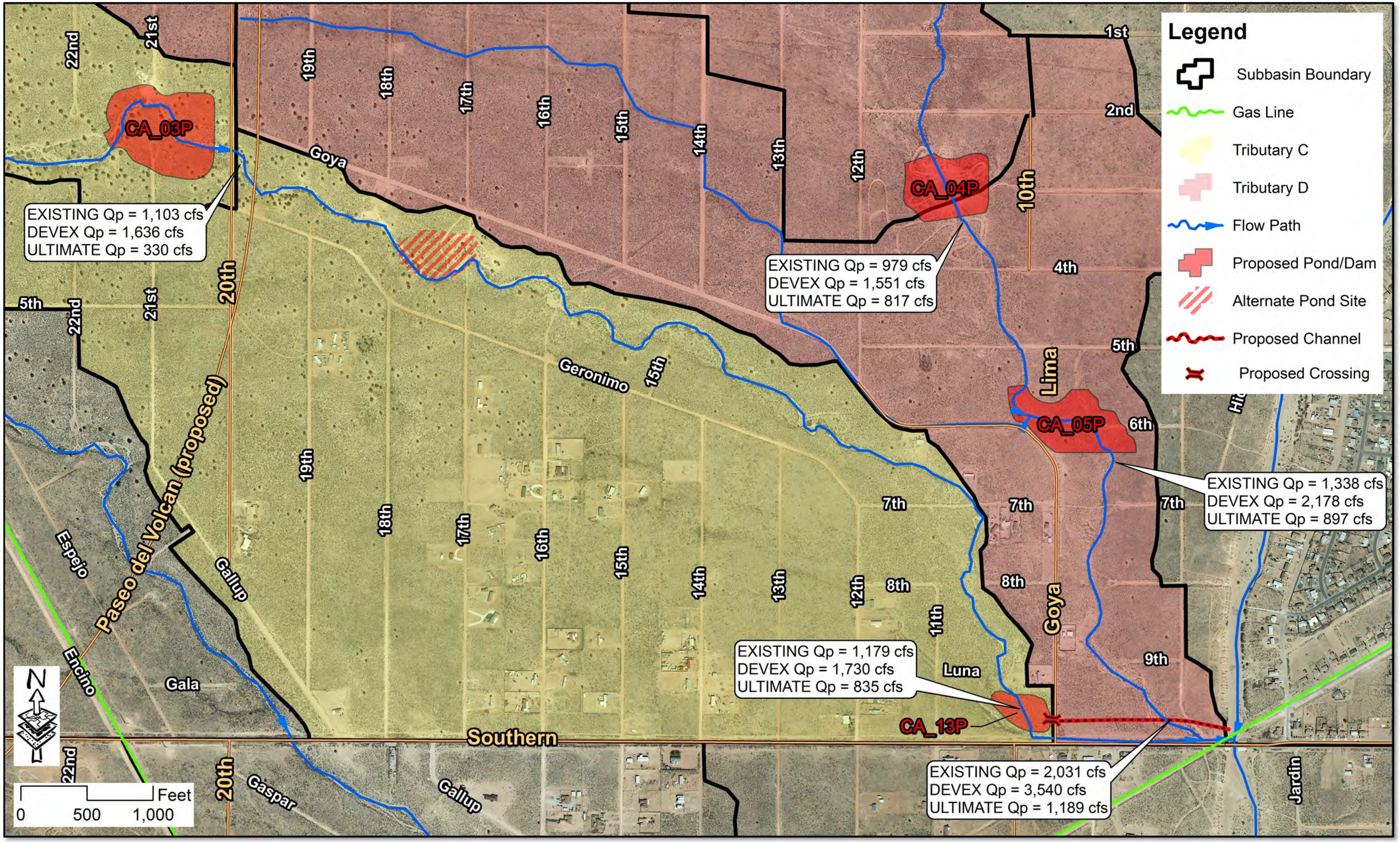


Figure 32: Map showing proposed ponds and channel in Tributaries C and D north of Southern Blvd.

Proposed Improvements:

The proposed solution to address the conveyance issue along Southern Blvd is a combination of four regional ponds, as well as a hardened channel along the north side of Southern Blvd. The ponds would reduce peak discharge from Tributaries C and D, and the channel would intercept storm flows at Southern Blvd and safely convey them to the Calabacillas Arroyo. Figure 32 shows an overview of all proposed improvements and their impact on peak flow rates. Please note that the results reported in Figure 32 stem from model runs using rainfall input with depth-area reduction factors appropriate for the size of the drainage basin upstream of each point of interest (see also discussion in Section III.A.5 above).

The upper pond in Tributary C (CA_03P, see Figure 33) is located immediately west of the proposed Paseo del Volcan (PDV) alignment and utilizes the road embankment as the dam. During the 100-year storm under ULTIMATE conditions, the pond would store 102 AC-FT of runoff and reduce the peak inflow from 1,636 cfs to 330 cfs.

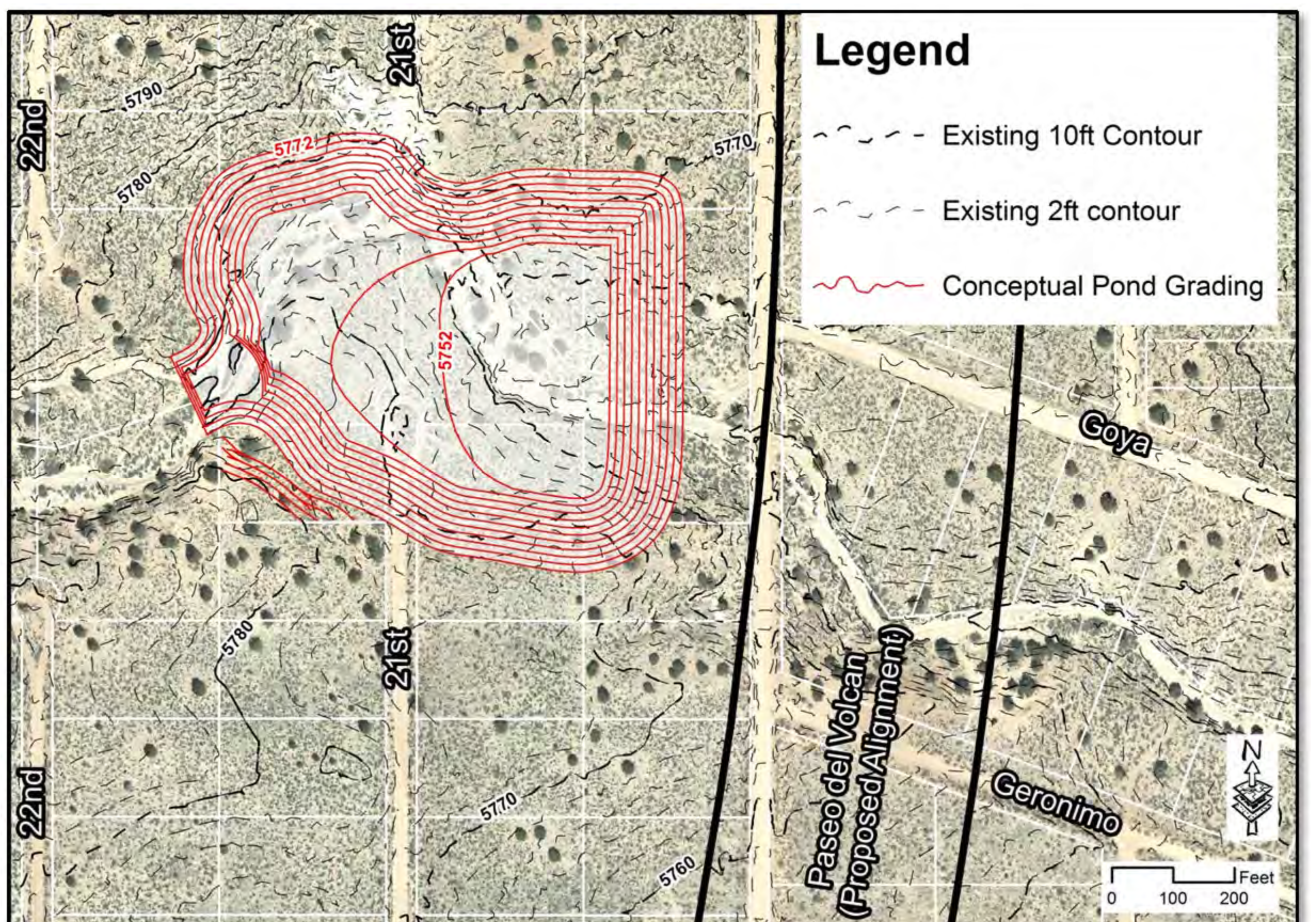


Figure 33: Conceptual grading of proposed pond CA_03P.

The upper pond in Tributary D (CA_04P, see Figure 34) is located on a 9-acres parcel of land that currently features a privately owned stock pond. During the 100-year storm under ULTIMATE conditions, the pond would store 46 AC-FT of runoff and reduce the peak discharge to 817 cfs.

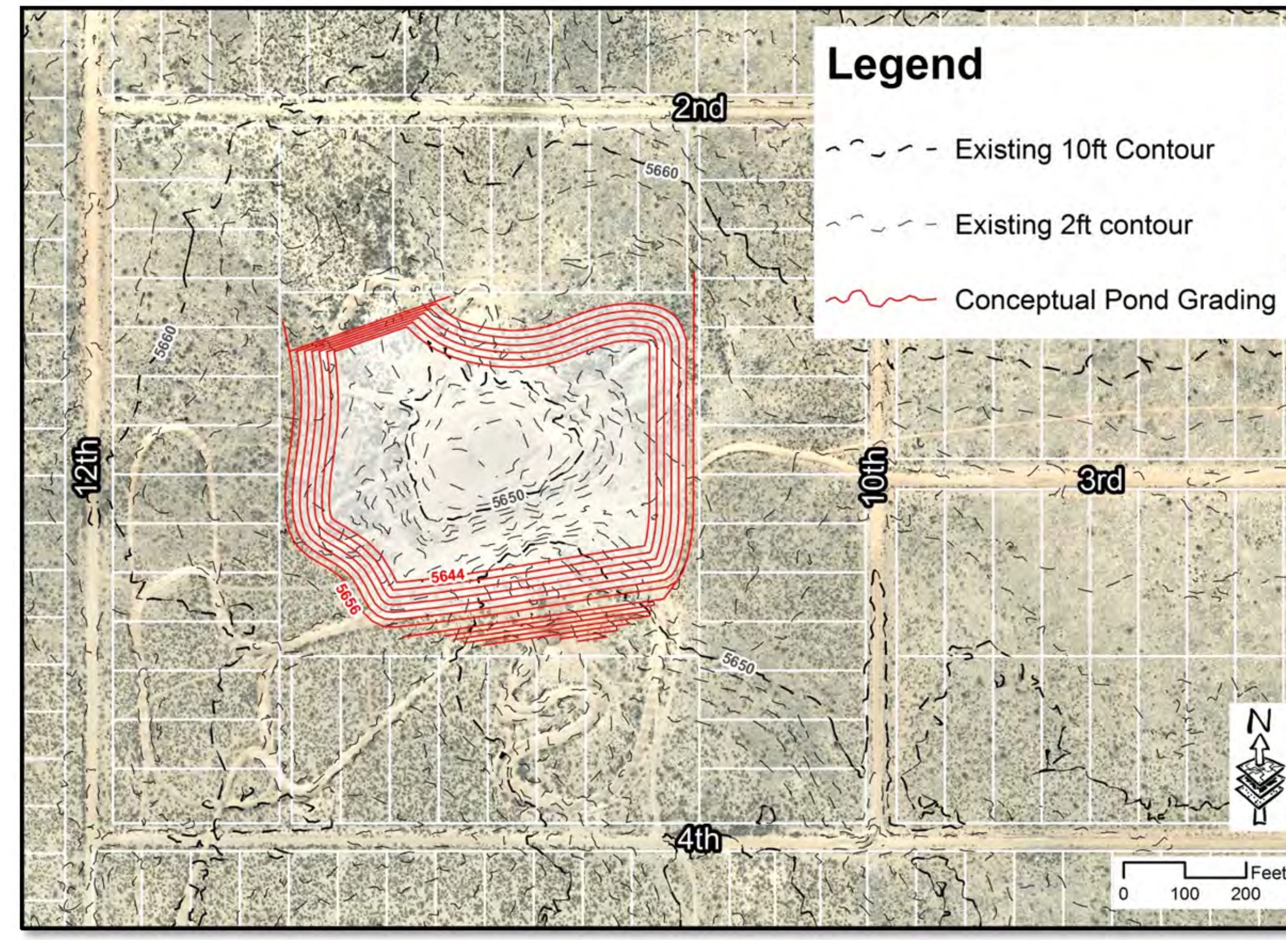


Figure 34: Conceptual grading of proposed pond CA_04P.

The lower pond in Tributary D (CA_05P, see Figure 35) would store 42 AC-FT of runoff and reduce the inflow peak from 1320 cfs to 897 cfs during the 100-year storm under ULTIMATE conditions.

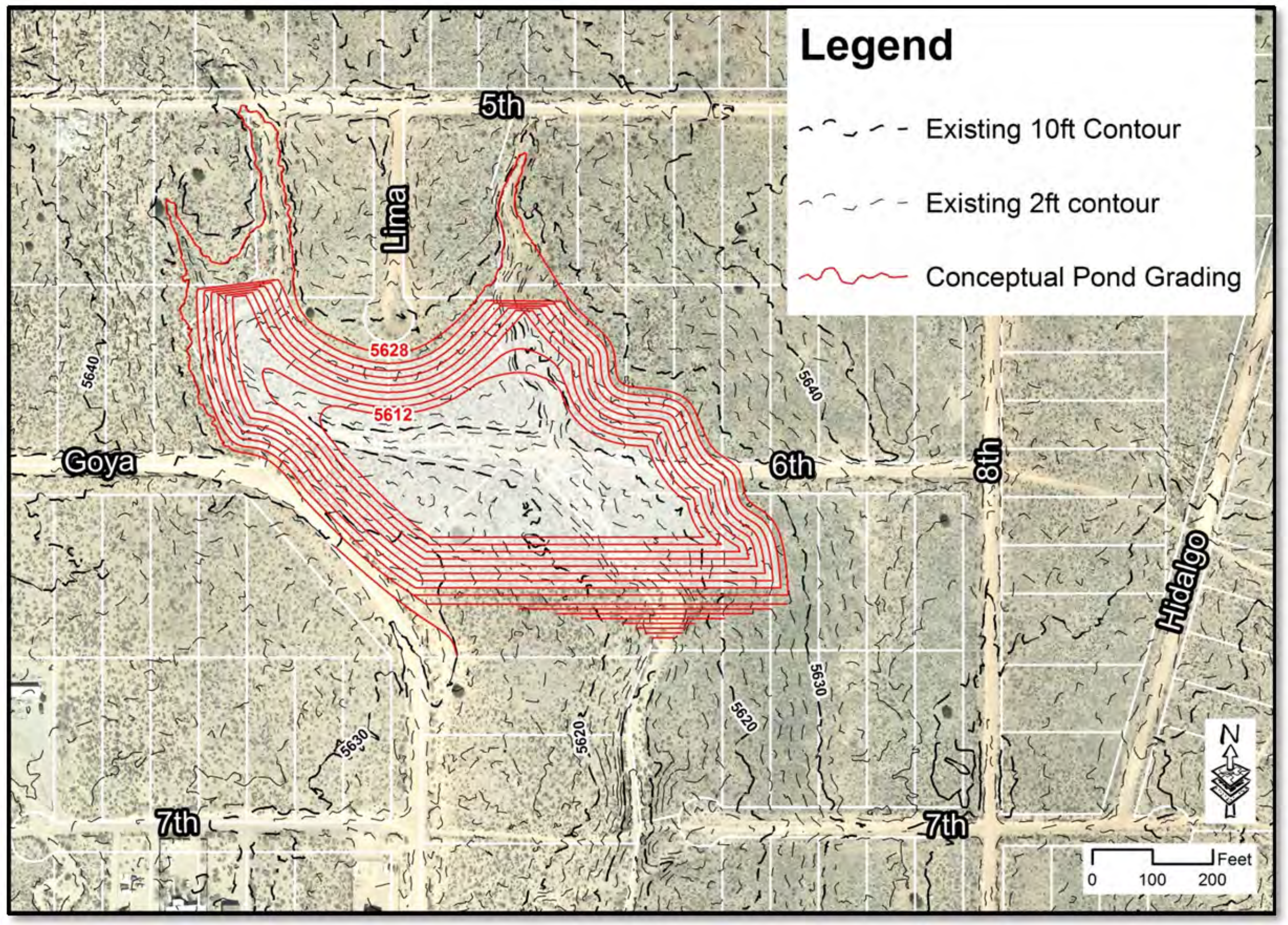


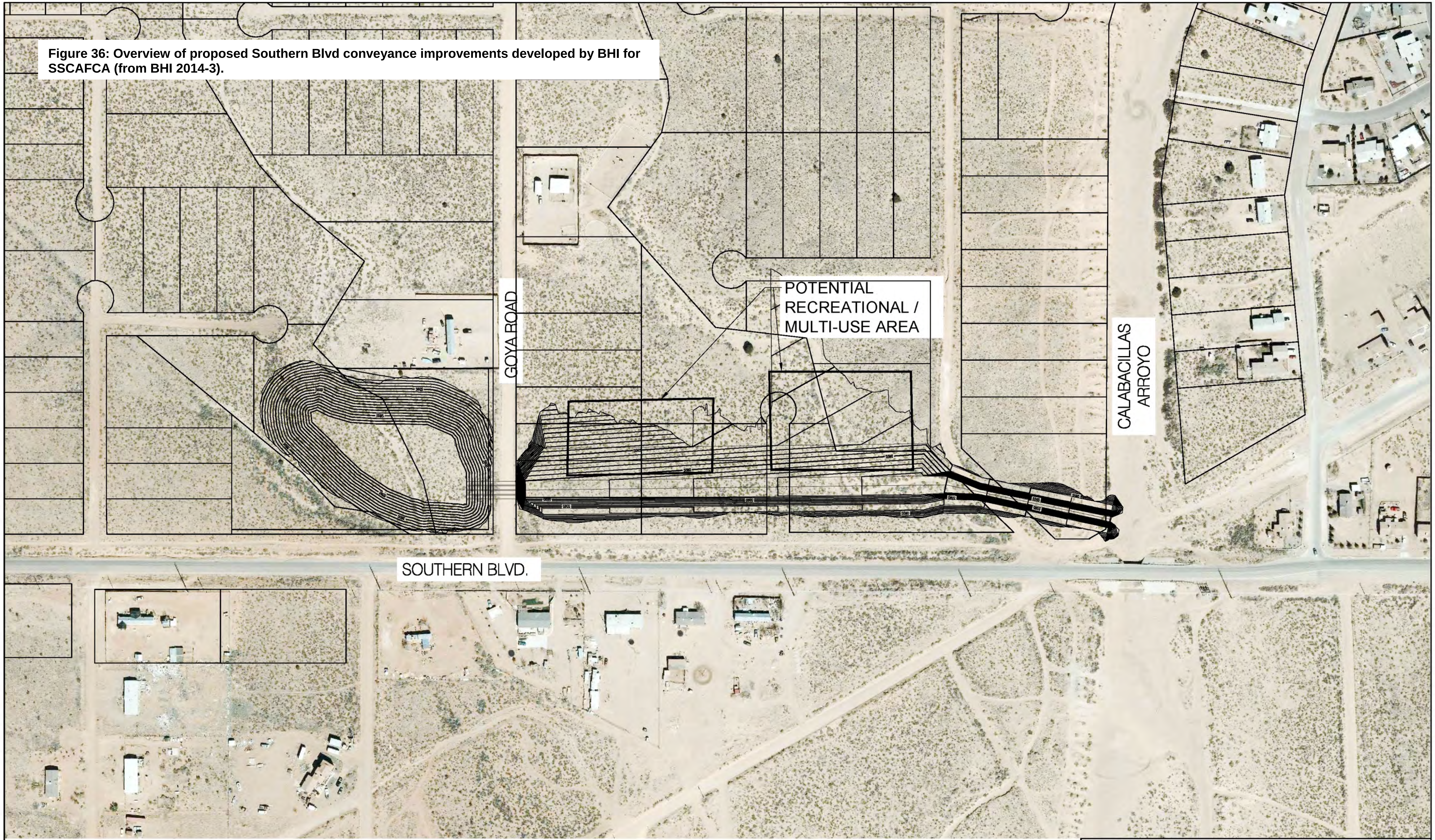
Figure 35: Conceptual grading of proposed pond CA_05P.

The conceptual design of the proposed conveyance improvements along Southern Blvd was completed by Bohannan Huston Inc. (BHI) and is contained in a report titled “Conceptual Design Report for Calabacillas Southern Blvd Conveyance Study” (BHI, 2014-3). The report evaluates alternatives for safely conveying storm flows from Tributaries C and D to the Calabacillas Arroyo. The following major constraints were addressed in the analysis:

- High flow rates from Tributaries C and D at Southern Blvd, even with regional ponds in place (see Figure 32)
- Undersized crossing structures at the intersection of Tributaries C and D with Southern Blvd (see above)
- Residential development south of Southern Blvd in the historic flow path of Tributary C (see above)
- Two regional gas pipelines crossing the Calabacillas at the Southern Blvd (see Figure 32 and Figure 38)

BHI analyzed a range of options, including various combinations of increased detention storage in Tributaries C and D upstream, and diversions to the Calabacillas Arroyo along different alignments north of Southern Blvd (BHI, 2014-3). The recommended alternative consists of a small pond located at the north-west corner of Goya Rd and Southern Blvd (CA_13P, see Figure 32). The pond, with a total volume of approximately 7 ac-ft, would intercept storm flows from Tributary C and redirect them to the east (see Figure 36 for conceptual pond grading). Under ULTIMATE conditions, peak outflow from the pond (835 cfs) would cross Goya Rd via four 5 ft by 8 ft concrete box culverts and discharge into a diversion channel on the north side of Southern Blvd. The diversion channel was conceptually designed as an earthen channel with a 7-ft tall, rip-rap protected berm along Southern Blvd. Just west of 8th St, storm flows from Tributary D would combine with diverted runoff from Tributary C to a combined peak discharge of 1,189 cfs under ULTIMATE conditions. At this point, the channel would transition into a 10 ft wide, 7 ft tall concrete channel, which would convey the combined flow to the Calabacillas Arroyo north of Southern Blvd and upstream of the gas lines (see Figure 38).
The proposed project would protect public safety as well as existing public and private infrastructure. It would furthermore provide the opportunity to combine a flood control facility with recreational amenities in an area where few public parks and sports fields exist.

Figure 36: Overview of proposed Southern Blvd conveyance improvements developed by BHI for SSCAFCA (from BHI 2014-3).



Bohannan Huston
www.bhinc.com 800.877.5332

CALABACILLAS SOUTHERN BLVD. OPTIONS STUDY	
OVERALL MAP	
DRAWN BY: LSM	DATE: 10/15/14
CHECKED BY: BCP	PROJECT NO. 20150091 SHEET NO.

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Overall

Figure 37: Proposed Southern Blvd conveyance improvements – detail 1 (from BHI 2014-3).

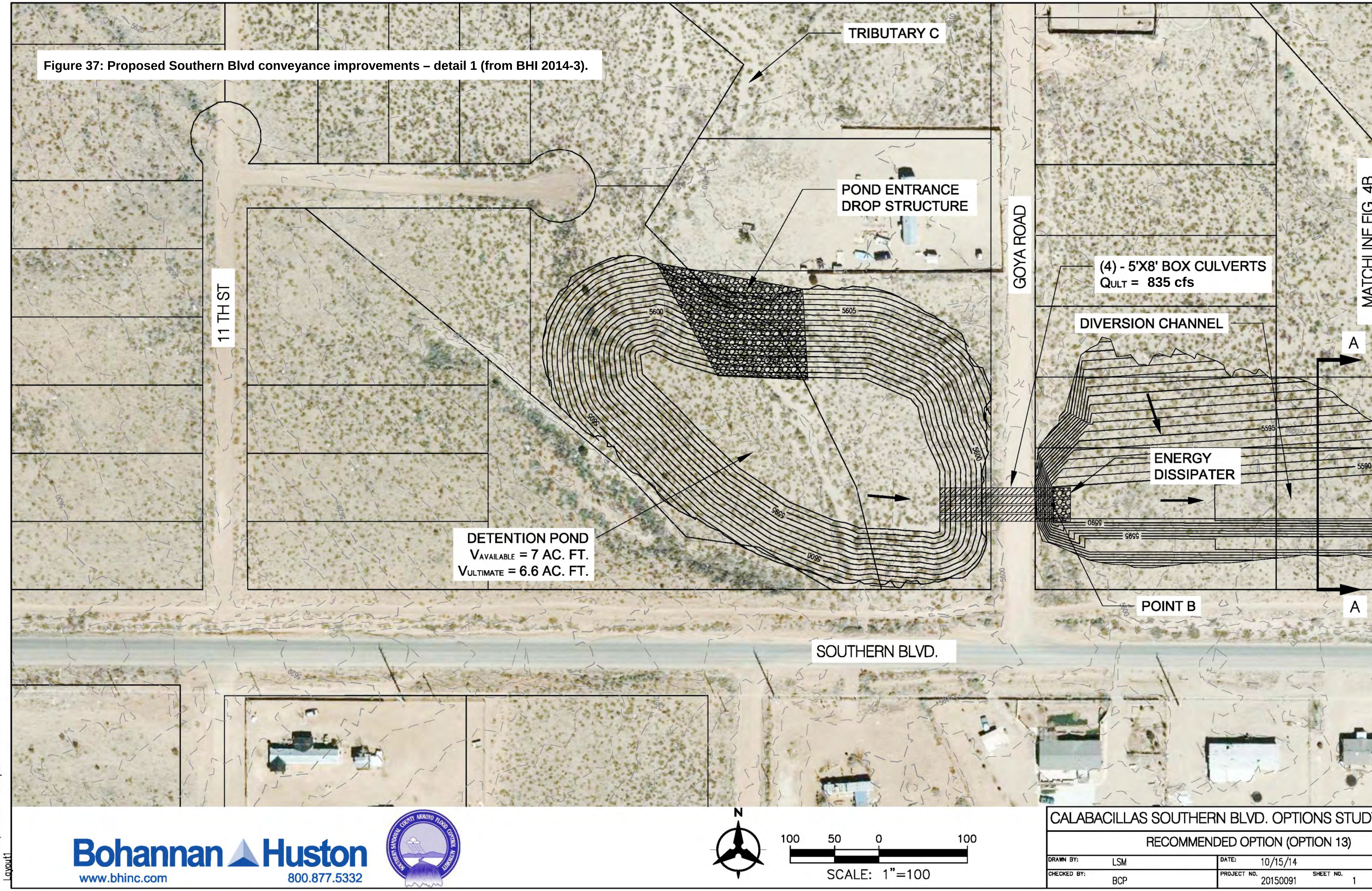
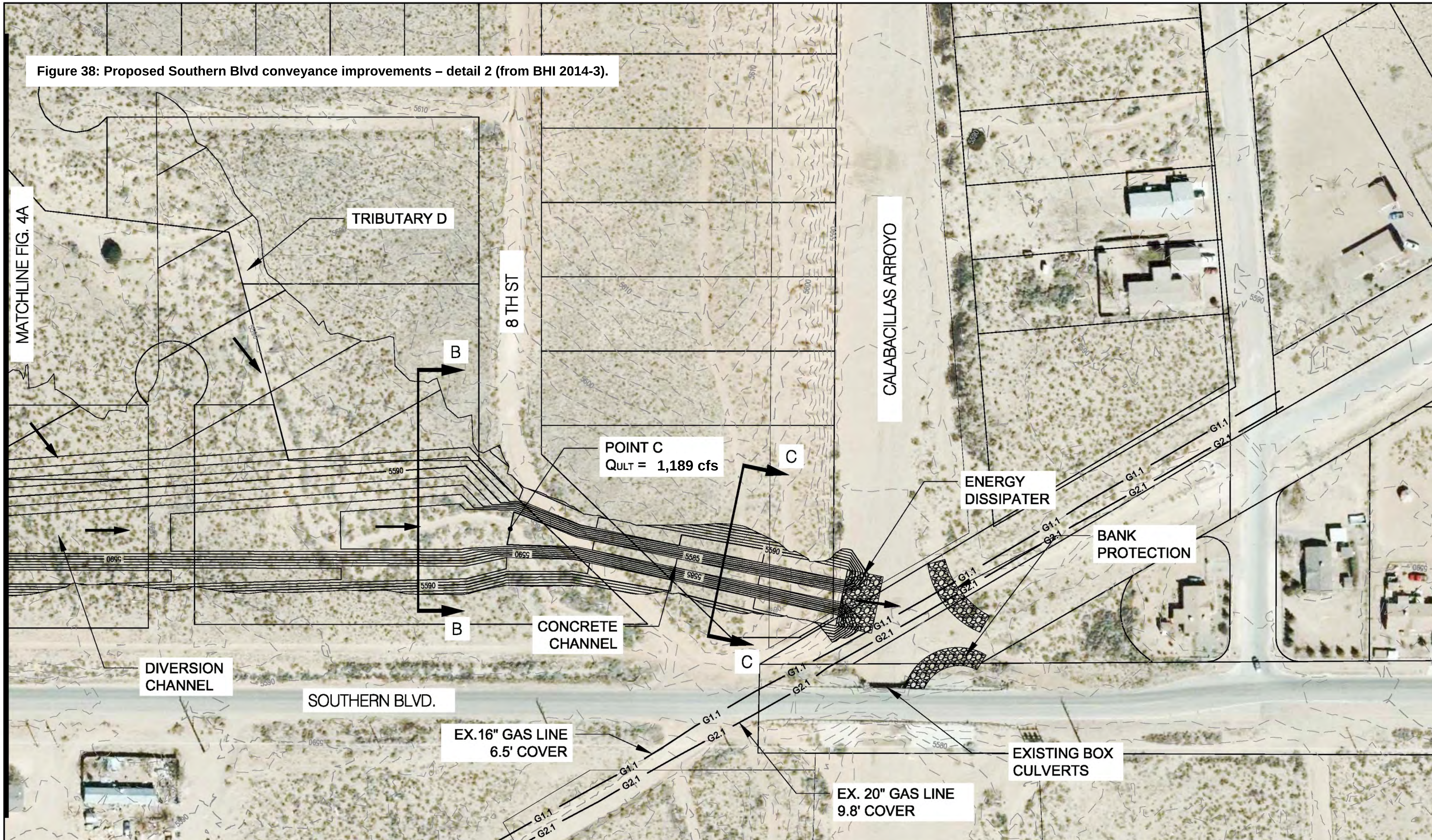


Figure 38: Proposed Southern Blvd conveyance improvements – detail 2 (from BHI 2014-3).



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CALABACILLAS SOUTHERN BLVD. OPTIONS STUDY			
RECOMMENDED OPTION (OPTION 13)			
DRAWN BY: LSM		DATE: 10/15/14	
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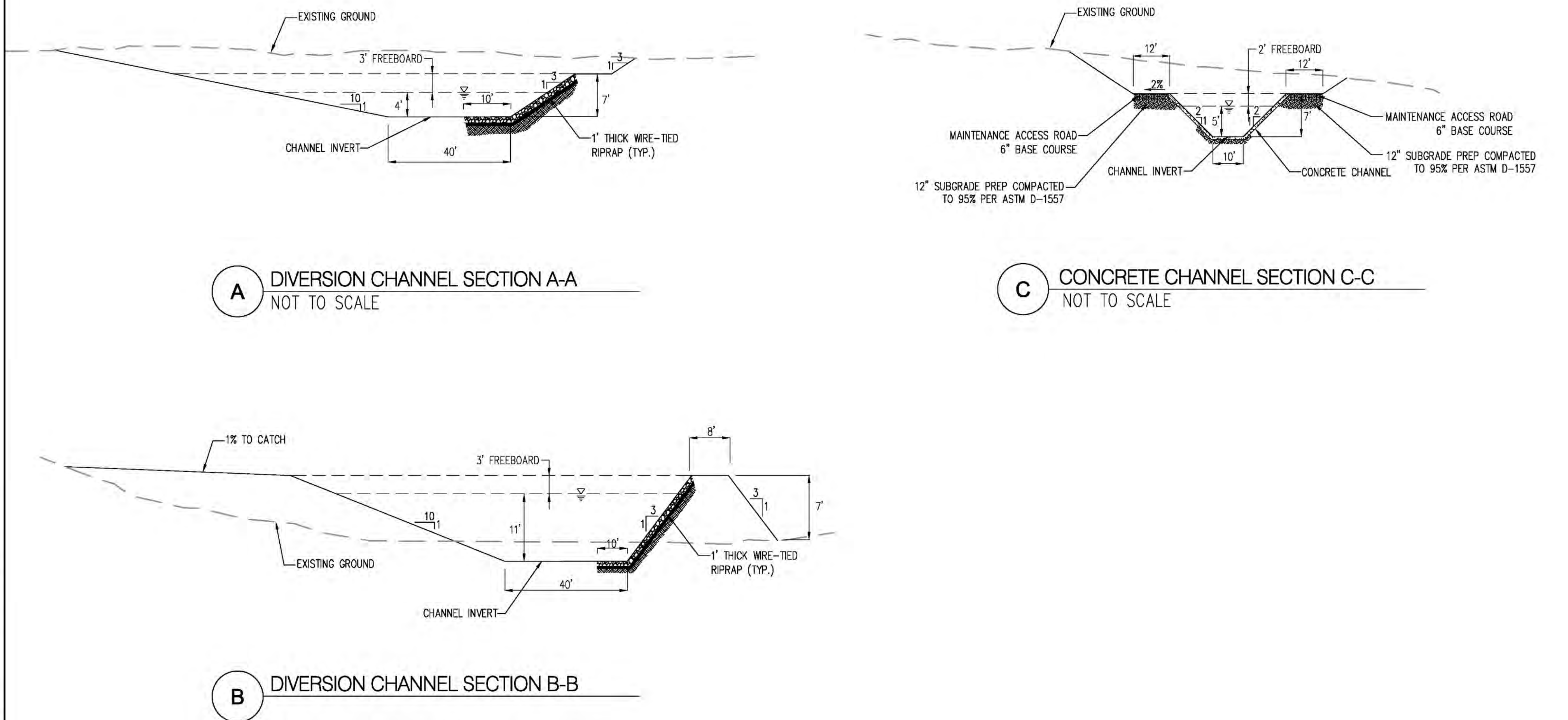
Figure 39: Proposed Southern Blvd conveyance improvements – detail 3 (from BHI 2014-3).



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Arroyo Sections

CALABACILLAS SOUTHERN BLVD. OPTIONS STUDY			
CHANNEL CROSS-SECTIONS			
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8. Tributary P North of Northern Blvd

Issues:

The upper portion of Tributary P (approximately 2 square miles) drains south towards the intersection of Northern Blvd and 5th Street (see Figure 40). While the upstream area is undeveloped, a fairly dense cluster of residential development exists around Northern Blvd.

The flow path of Tributary P can be identified as a valley on a topographic map, but no incised channel is evident in the field. This is probably due to the fact that no large storm has occurred in the area in the recent past. The lack of an incised arroyo, however, does not allow the conclusion that this is a minor drainage. Due to the significant size of the upstream drainage basin, the hydrologic model indicates that peak flows of 667 cfs must be expected at the upper end of the developed area under EXISTING conditions during the 100-year 24-hour storm. For DEVEX conditions, peak flows at the same location are 1,179 cfs. Please note that the peak flow rates reported in Figure 40 stem from model runs using rainfall input without depth-area reduction factors, since the contributing drainage area is less than two square miles in size (see also discussion in Section III.A.5 above).

In the lower portion of the reach between approximately 13th Ave and Northern Blvd, a number of residential homes have been built in the flow path (see Photo 32 and Photo 33). This poses a danger for properties and residents, potentially even from storms much smaller than the 100-year event.

Photo 32: Looking south from 10th Ave: the flow path of Tributary P crosses residential properties.

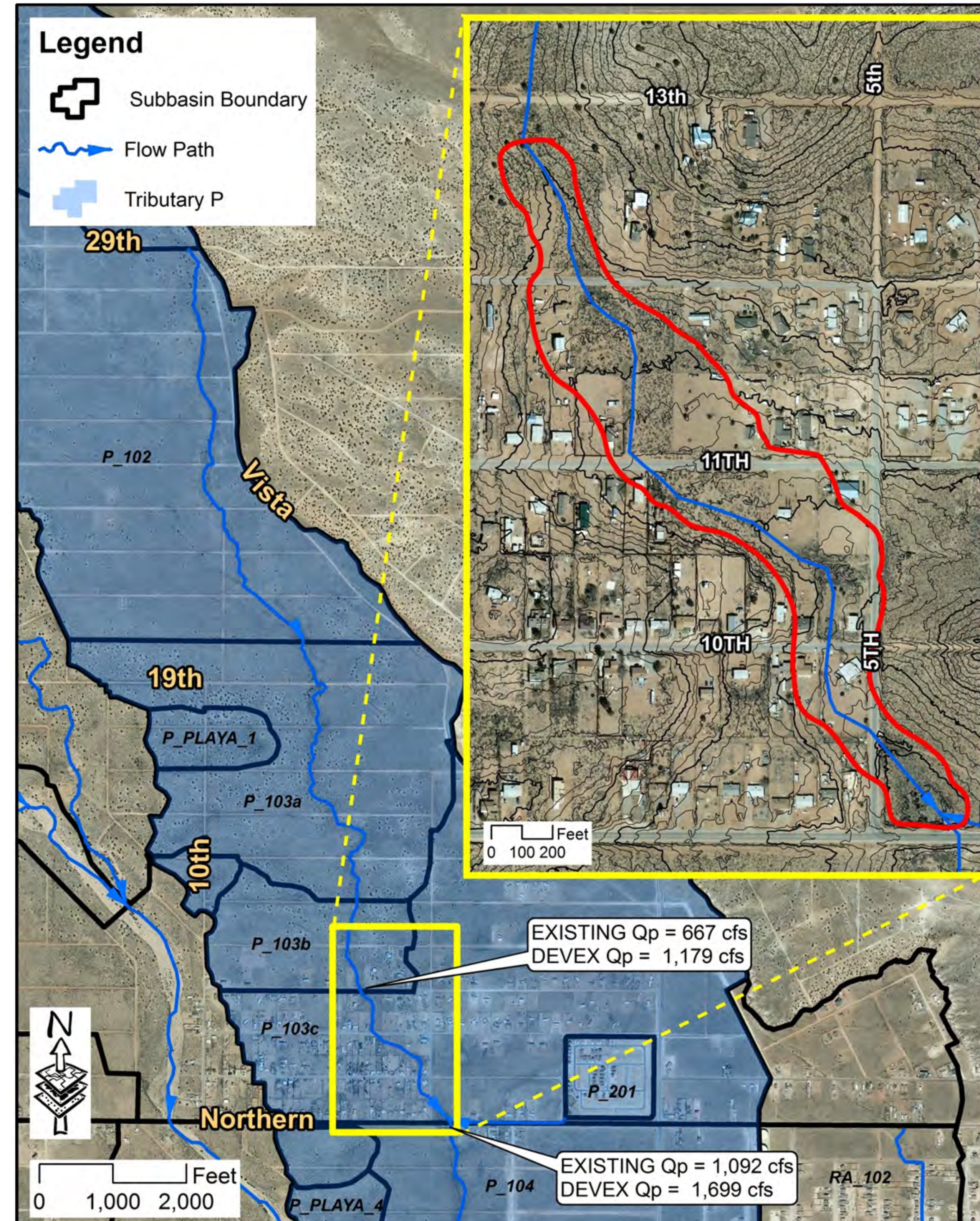

Figure 40: Map showing conveyance issues in Tributary P.

Photo 33: Looking south from 11th Ave: the flow path of Tributary P crosses residential properties.

The crossing of Tributary P and Northern Blvd consists for three 48" corrugated metal pipes (see Photo 34 and Figure 41). Under ideal conditions, the estimated total capacity of the crossing is 258 cfs. The actual capacity may be significantly less due to heavy vegetation at the inlet of all three pipes. Even under ideal conditions, the crossing structure is insufficient to convey the EXISTING or DEVEX conditions flows (1,092 cfs and 1,699 cfs, respectively).

The result will be overtopping of the roadway and ponding upstream of the road embankment, with potential flooding of adjacent residential structures (see Figure 41).

Photo 34: Looking upstream at the Tributary P crossing at Northern Blvd (3 – 48" CMP, capacity ≈ 258 cfs).

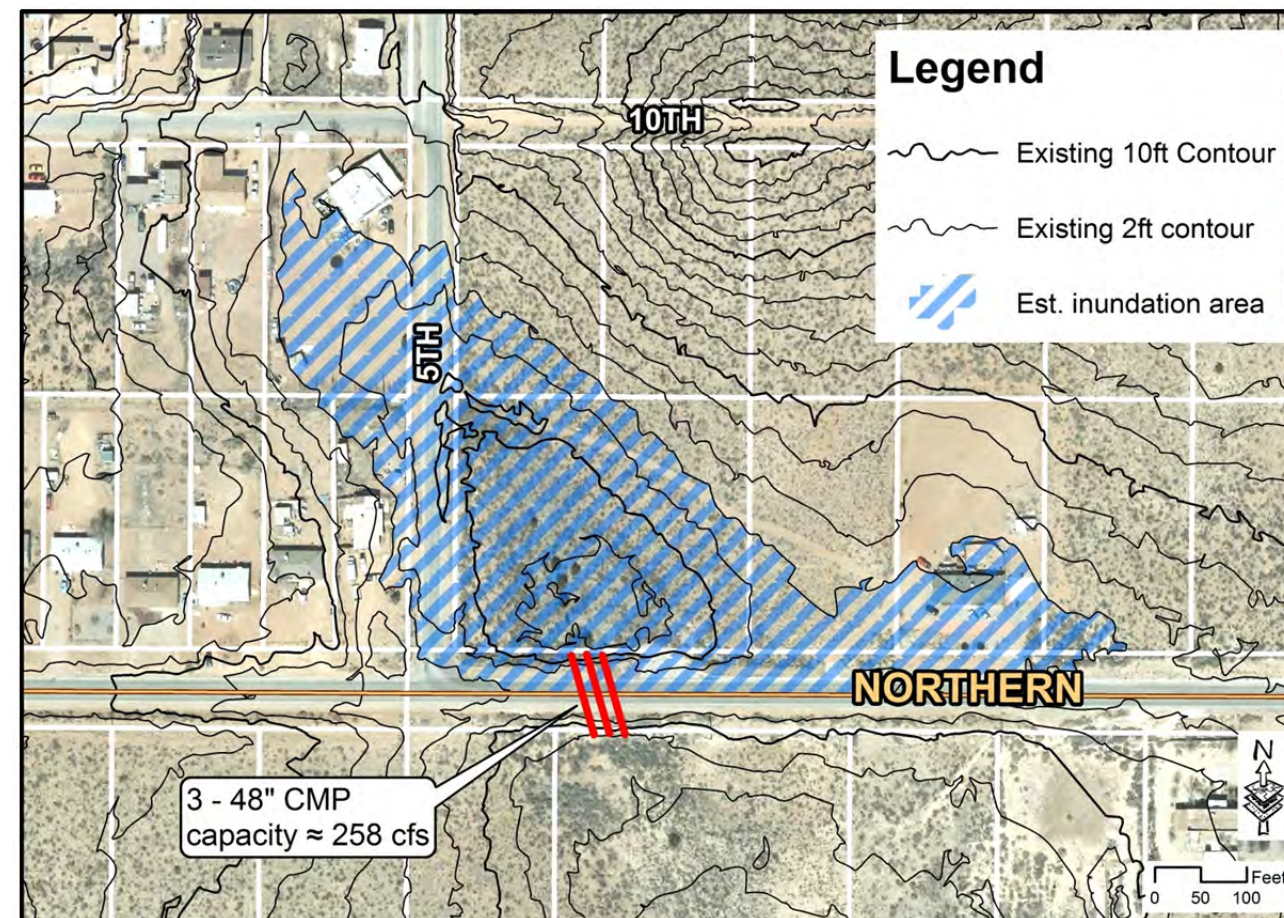

Figure 41: Map showing estimated inundation area north of Northern Blvd due to ponding upstream of the road embankment.

Proposed Improvements:

The proposed solution to address the conveyance issues north of Northern Blvd is a combination of ponds and conveyance improvements.

1. The first pond (CA_08P) is located just upstream of the proposed PDV alignment and would intercept flows from the upper-most subbasin in Tributary P. Under ULTIMATE conditions during the 100-year storm, the pond would store 28 AC-FT of runoff and reduce the peak flow from 656 cfs to 30 cfs.

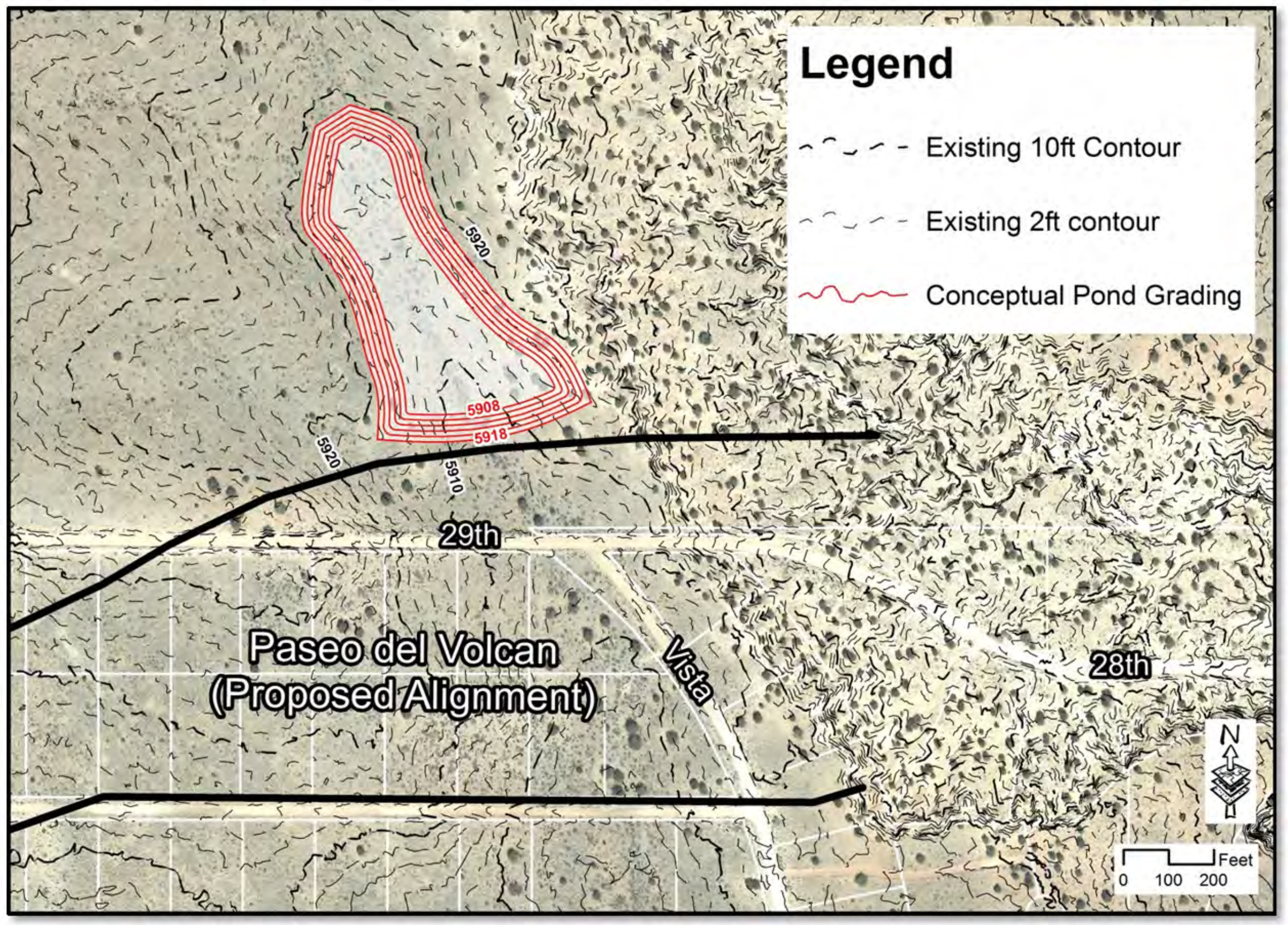

Figure 42: Conceptual grading of proposed pond CA_08P.

The pond would dramatically reduce peak discharge from the 100-year storm (95% reduction), thereby protecting the downstream reach and reducing the size of the culvert needed to convey runoff under the proposed PDV roadway.

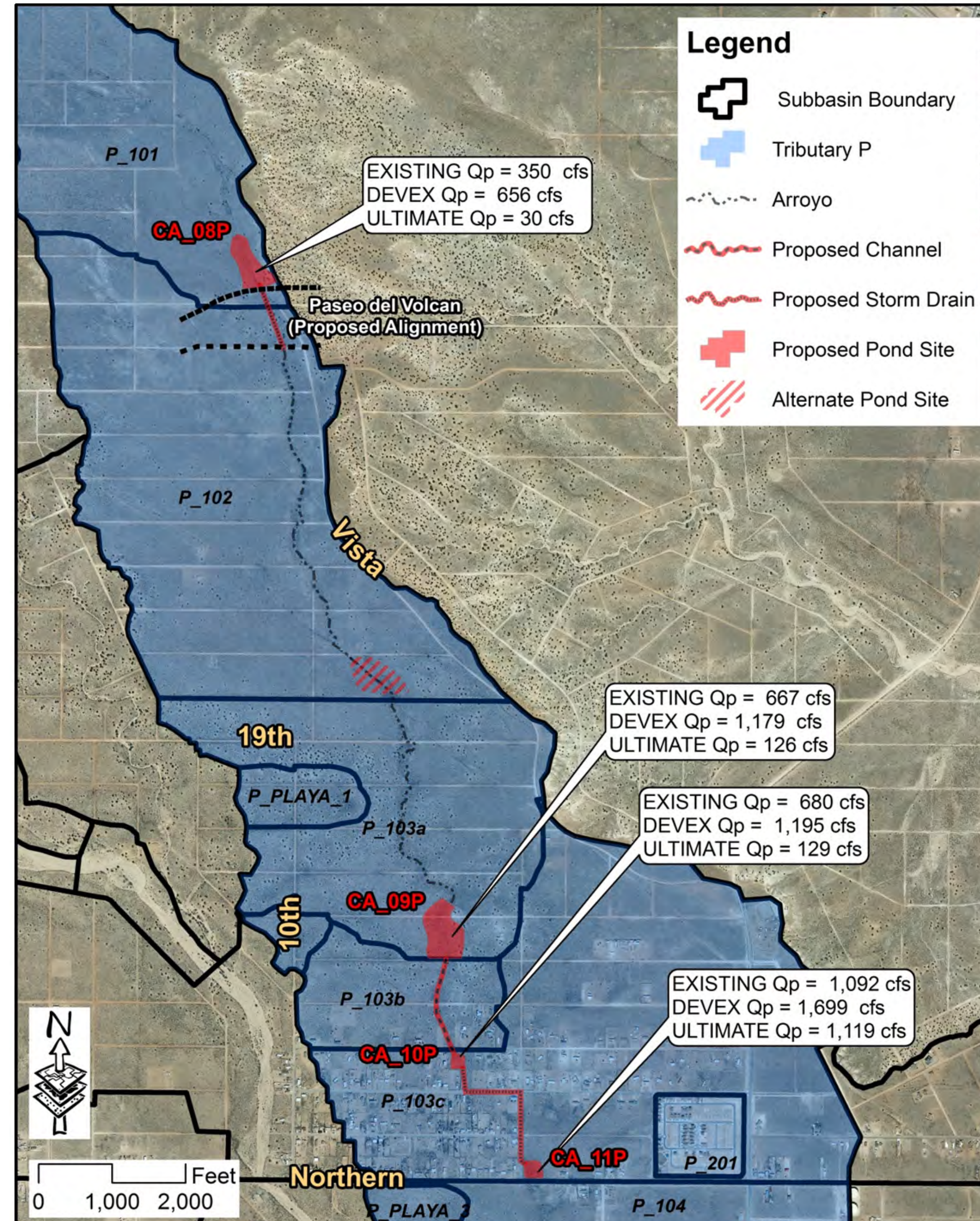

Figure 43: Map showing proposed drainage improvements in Tributary P.

2. The second proposed pond in tributary P is located just upstream of 14th Ave (CA_09P, see Figure 44). The pond would extend north past 15th Ave and require that a portion of the roadway be vacated. Under ULTIMATE conditions, the pond would store 42 AC-FT of runoff and reduce the peak flow to 126 cfs.

Photo 35: Looking west along 14th Ave towards the site of proposed pond CA_09P.

Outflow from pond CA_09P would then flow south in an improved conveyance (earthen channel, CA_01C) to a small pond (CA_10P, approximately 4 AC-FT) just south of 12th Ave. This pond would serve as the inlet to a storm drain (CA_01S), which in turn would convey runoff to an outlet pond at the north-east corner of Northern Blvd. and 5th St (CA_11P).

Detailed design of the conveyance system will be required to determine storm drain sizes, as well as the exact size and configuration of the inlet and outlet ponds (CA_10P & CA_11P). Based on a peak flow of 129 cfs at the storm drain inlet, the estimated minimum pipe size would be 60 inches.

All improvements proposed above would drastically reduce the 100-year peak discharge from the upper portion of Tributary P. The ULTIMATE flow at Northern Blvd (1,119 cfs), however, would still exceed the culvert capacity of approximately 258 cfs due to local flow contributions from subbasins P_103c and P_201 (see Figure 43). To avoid flooding of properties upstream of the road embankment, it is therefore recommended to increase the capacity of the crossing to accommodate the ULTIMATE flow rate of 1,119 cfs.

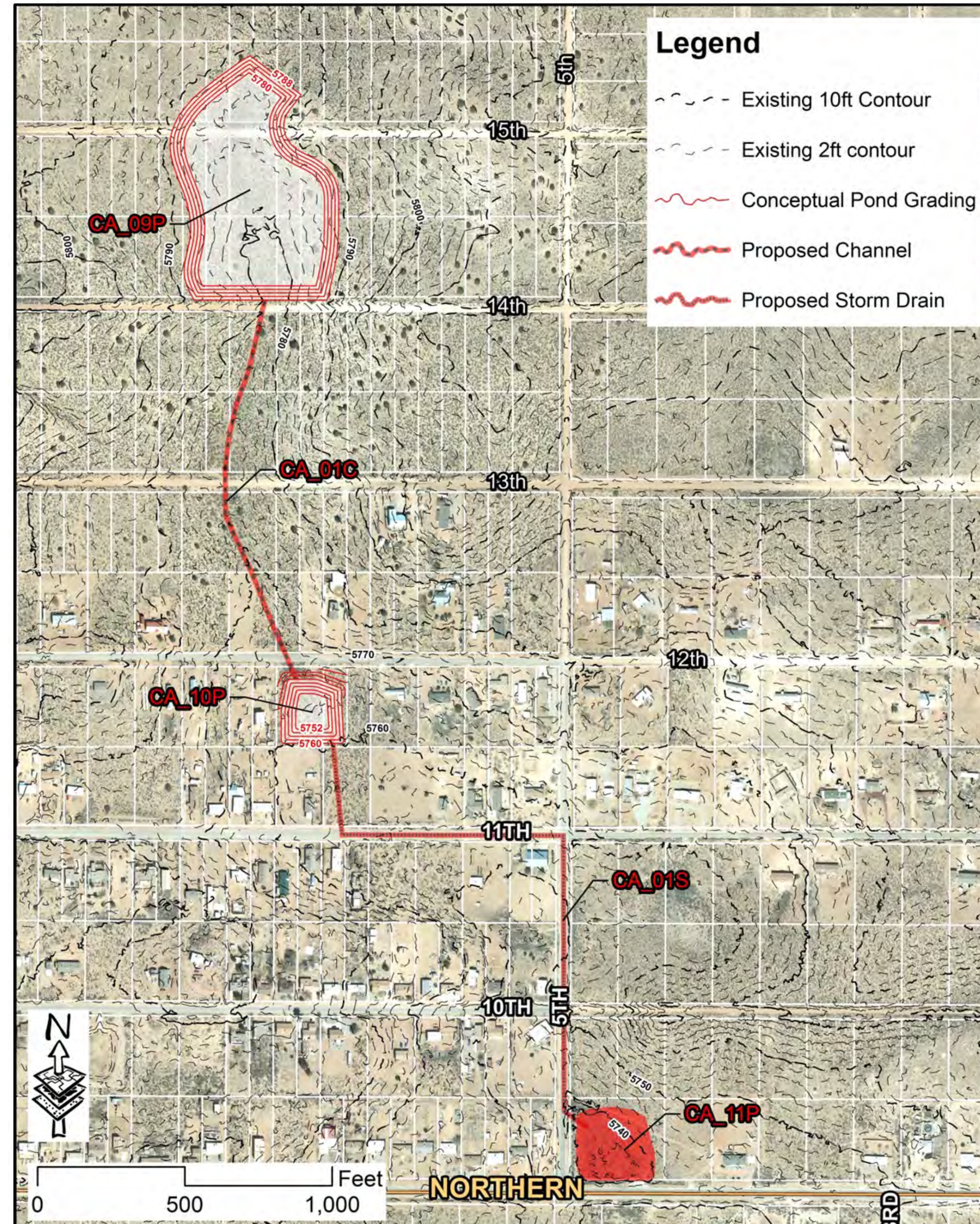

Figure 44: Proposed ponds and conveyance improvements in Tributary P north of Northern Blvd.

9. Drainage Deficiencies at the Santa Fe Junction

Issues:

The Santa Fe Junction, a facility owned and operated by the New Mexico Gas Company, is located at the intersection of Encino Rd and Idalia Rd in Tributary B. The facility, which compresses and delivers natural gas to the entire State of New Mexico, has been constructed in the former flow path of an arroyo with an upstream drainage area of approximately 2 square miles (see Figure 46). The facility is also partially located within FEMA Flood Zone A.

Figure 45: Looking east along the arroyo toward the Santa Fe Junction (source: Google Earth).

The hydrologic model indicates that, just upstream of the Santa Fe Junction, the 100-year storm will result in peak flows of 830 cfs under EXISTING conditions and 1,217 cfs under DEVEX conditions. Please note that these peak flow rates stem from model runs using rainfall input with depth-area reduction factors appropriate for the size of the upstream drainage basin (see also discussion in section III.A.5 above). No structures currently exist to protect the facility from flooding and erosion during a large storm event.

Proposed Improvements:

Given the importance of the Santa Fe Junction, it is strongly recommended to design and construct improvements to safely convey stormwater runoff around the facility without causing flooding or erosion damage. Improvements should be designed to accommodate the DEVEX conditions peak discharge rate of 1,217 cfs.

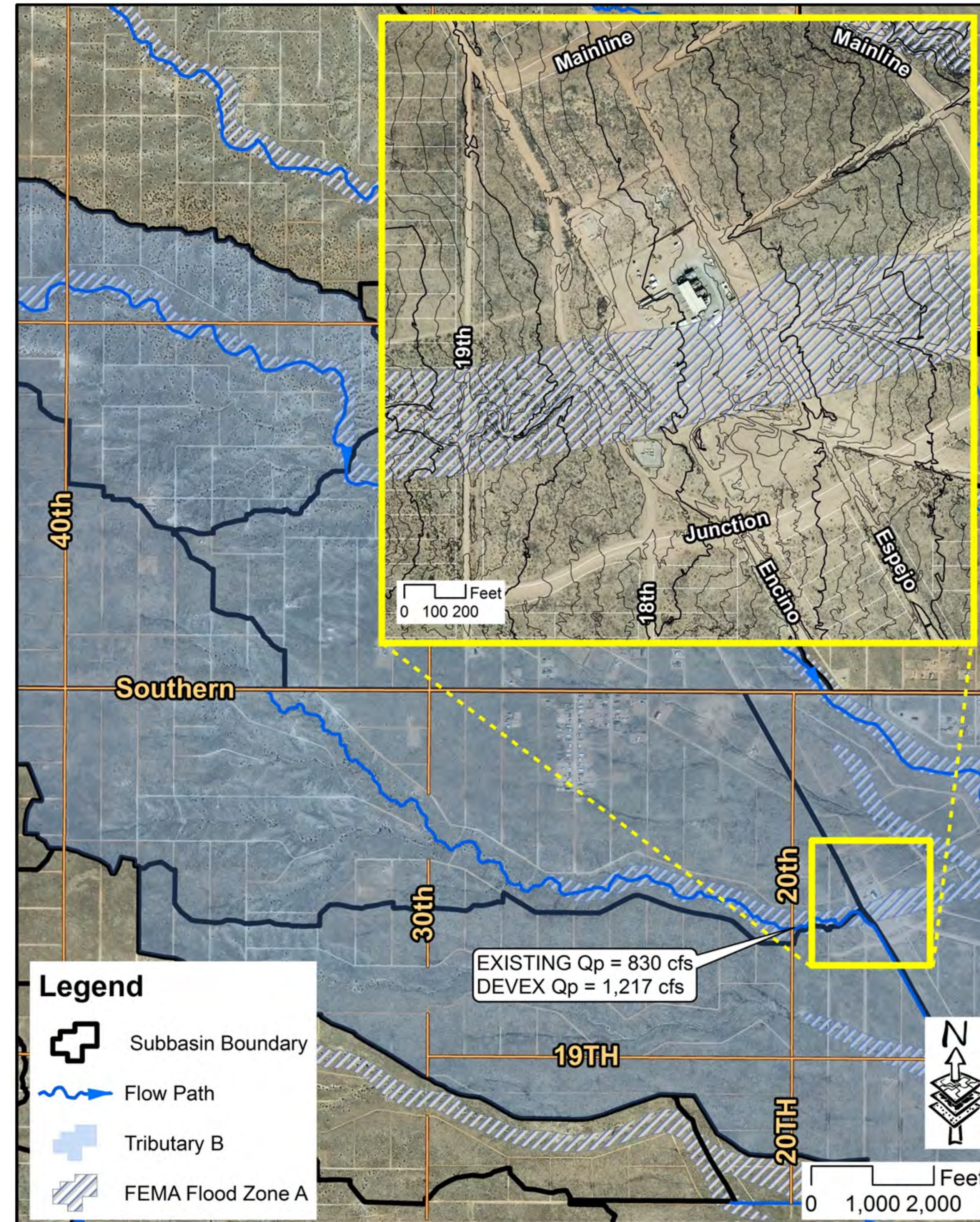

Figure 46: Map showing drainage deficiencies at the natural gas facility in Tributary B.

B. PROPOSED REGIONAL STORMWATER DETENTION FACILITIES

In addition to the proposed improvements discussed above, two regional stormwater detention facilities are recommended to reduce peak flow rates in the Calabacillas Arroyo. Both sites are located along the future alignment of PDV and would utilize the road embankment as the dam.

1. Tributary N Dam

The dam in Tributary N (CA_06P, see Figure 48) is located immediately upstream of the proposed Paseo del Volcan (PDV) alignment as it crosses through Tributary N. During the 100-year storm, the dam would store approximately 105 AC-FT of runoff and reduce the peak flow from 1829 cfs to 649 cfs.

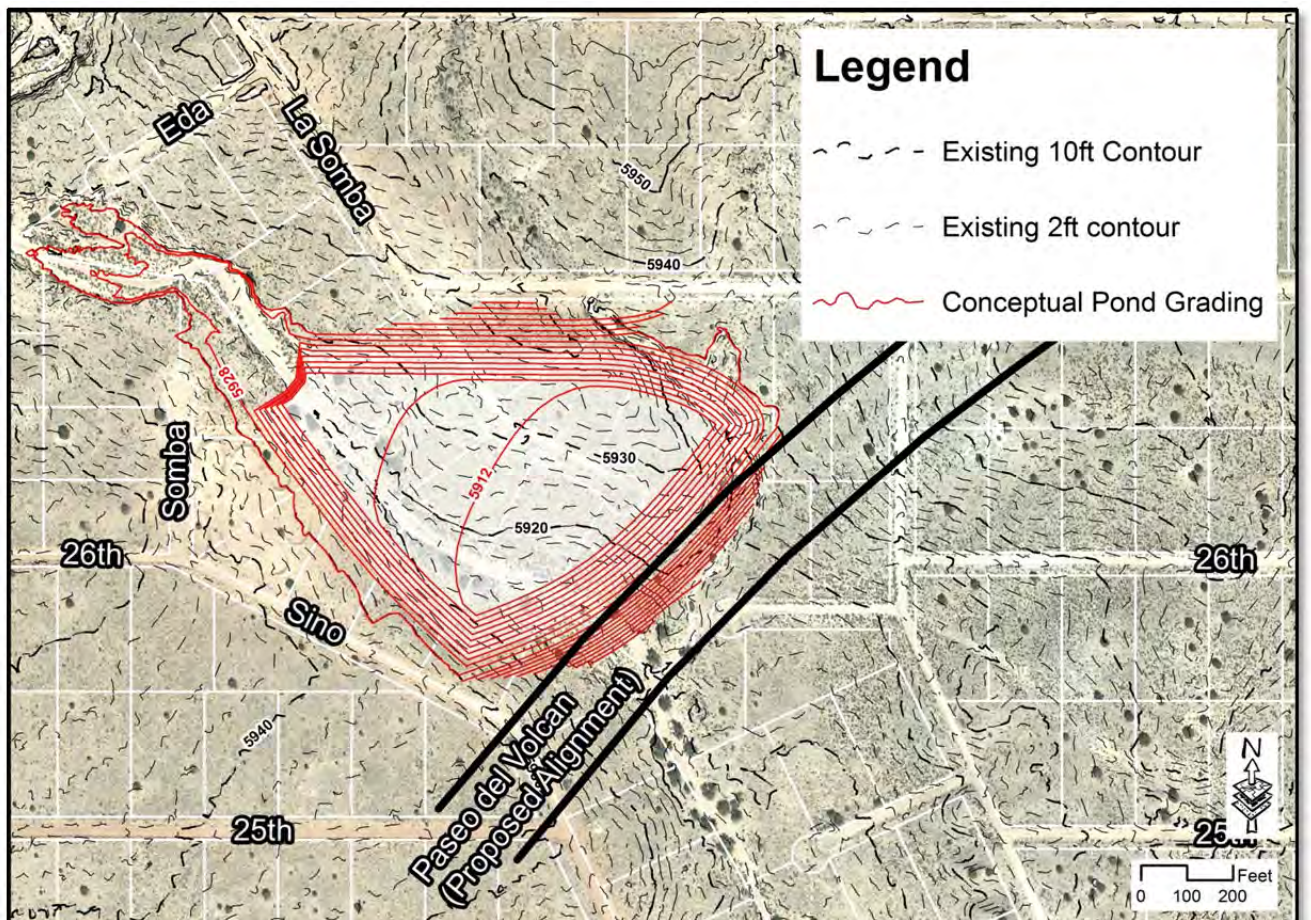

Figure 47: Conceptual grading of proposed dam CA_06P.

This facility would fall under OSE jurisdiction and require an emergency spillway sized for the PMF. A PMF analysis was not performed as part of this study, but should be completed in conjunction with conceptual design of the facility. Approximately five feet of freeboard were left between the 100-year water surface elevation (5,925 ft) and the approximate top of dam (5,930 ft) to accommodate the future PMF spillway.

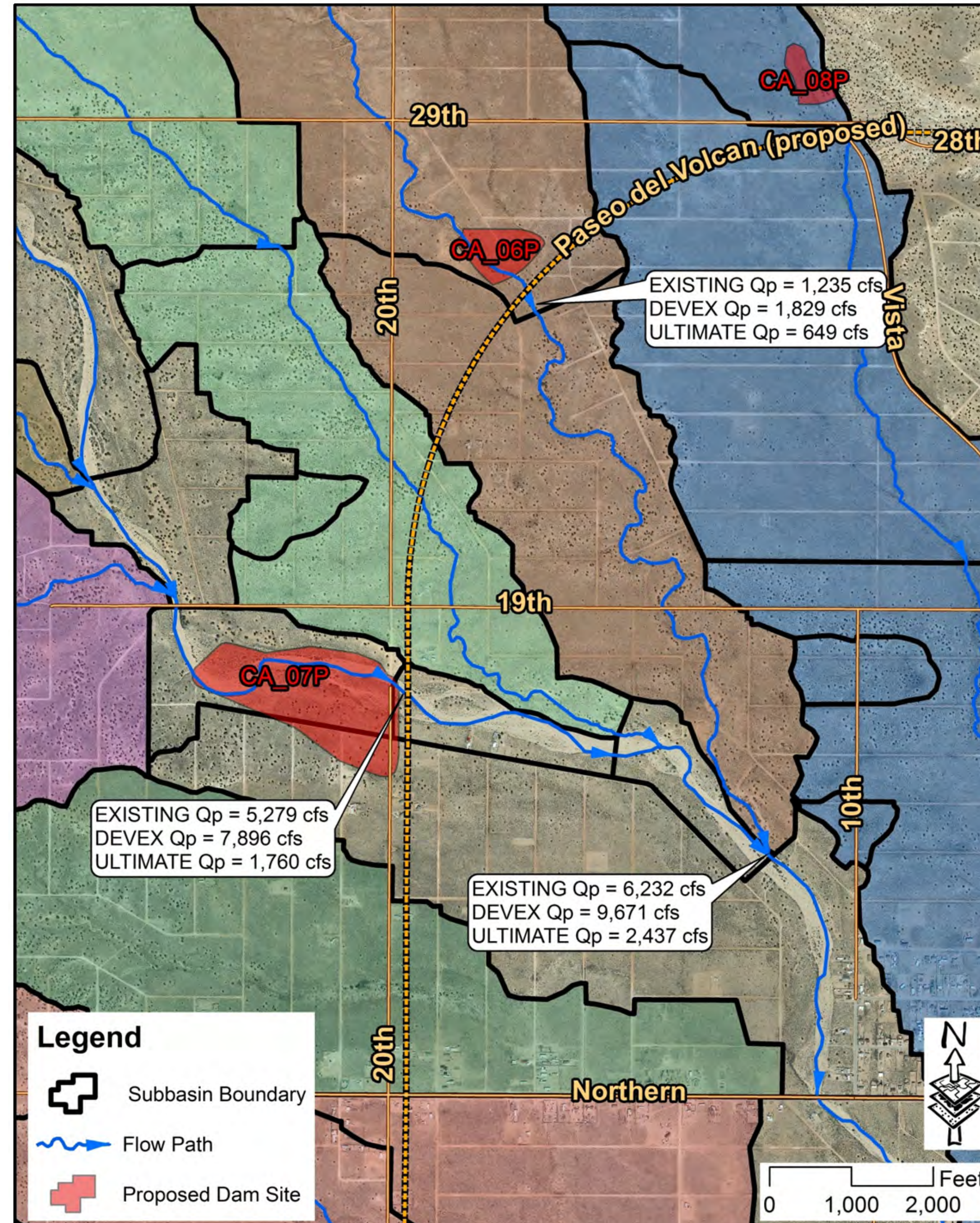

Figure 48: Proposed regional stormwater detention facilities on the Calabacillas main stem and in Tributary N.

2. Calabacillas Dam

The proposed Calabacillas Dam (CA_07P) is located on the main stem of the Calabacillas Arroyo just upstream of the proposed PDV alignment (see Photo 36). Conceptual design of the Calabacillas Dam was completed by Bohannan Huston Inc. (BHI) and is contained in a report titled "Conceptual Design Report for Calabacillas PDV Dam" (Bohannan Huston Inc., 2014-2).

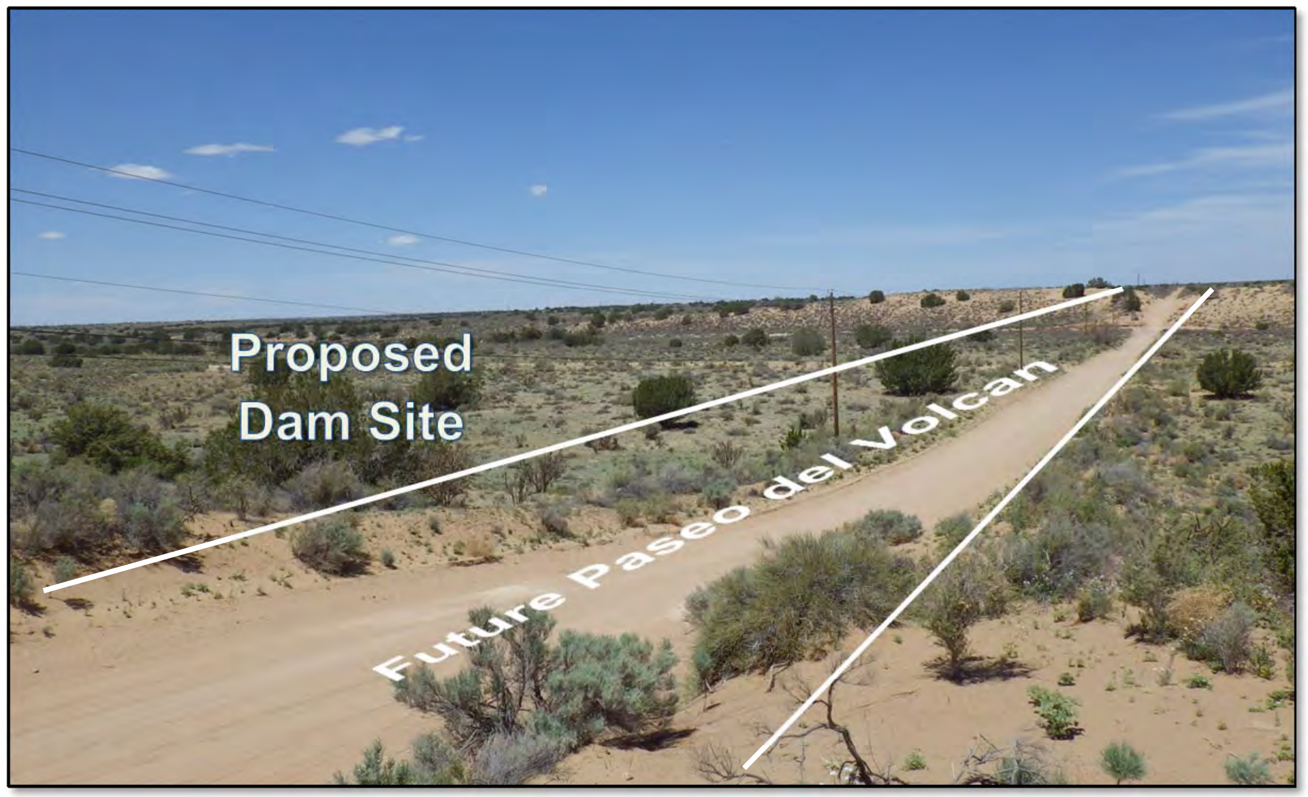

Photo 36: Looking north across the Calabacillas Arroyo along 20th Street; the approximate alignment of PDV and the proposed dam site are indicated in the photo.

Table 12 lists properties of the proposed dam. Please note that 100-year peak flow rates and the size of the principal spillway differ slightly from the BHI report; final model calibration increased the peak inflow resulting from the 100-year storm, and minor adjustments to the principal spillway were necessary.

Table 12: Properties of the proposed Calabacillas Dam.

Drainage area	20 square miles
Pond invert elevation	5,866 ft
Emergency spillway elevation (low point)	5,883 ft
Storage at emergency spillway crest	528 AC-FT
ULTIMATE conditions 100-year peak inflow	7,897 cfs
ULTIMATE conditions 100-year peak outflow	1,760 cfs
ULTIMATE conditions peak storage	476 AC-FT
ULTIMATE conditions 100-year WSEL	5,882 ft
Principal Spillway	1 – 12ft W x 10ft H CBC
Emergency Spillway	Roadway
PMP design rainfall	12.5 inches in six hours
PMF peak inflow into dam	76,000 cfs
PMF WSEL	5,894 ft

The dam would intercept flows from the upper 20 square miles of the watershed and reduce the peak discharge by 78 percent – from 7,897 cfs to 1,760 cfs. With a total storage volume of more than 500 acre-feet, the dam would fall under OSE jurisdiction and require an emergency spillway sized for the PMF event.

The conceptual design assumes that the proposed PDV roadway would form the dam embankment and emergency spillway (see Figure 49). Close coordination with the New Mexico Department of Transportation (NMDOT) will therefore be necessary during every step of planning and design of the facility. This project provides a unique opportunity to achieve significant peak discharge reduction while conserving resources by combining a major roadway and drainage project. For more detail, please consult the conceptual design report.

The conceptual design of the proposed Calabacillas Dam was based on the DEVEX conditions hydrology, which assumes urban development of the area upstream of the dam based on available water resources (see section III.A.7 above). Under EXISTING conditions, the area is almost entirely undeveloped, and development is expected to take decades. It is therefore recommended to build the facility in phases. Under a phasing approach, the embankment, principal spillway and emergency spillway would be constructed in accordance with ultimate design. Excavation of the flood pool would be phased based on the upstream development. Phasing the project has several potential benefits: it reduces the initial capital cost for the facility, and ensures that the storage volume is in step with the need for peak flow attenuation based on upstream development. If excavation of the flood pool coincides with urban development, there may also be an opportunity for usage of excavated material by developers.

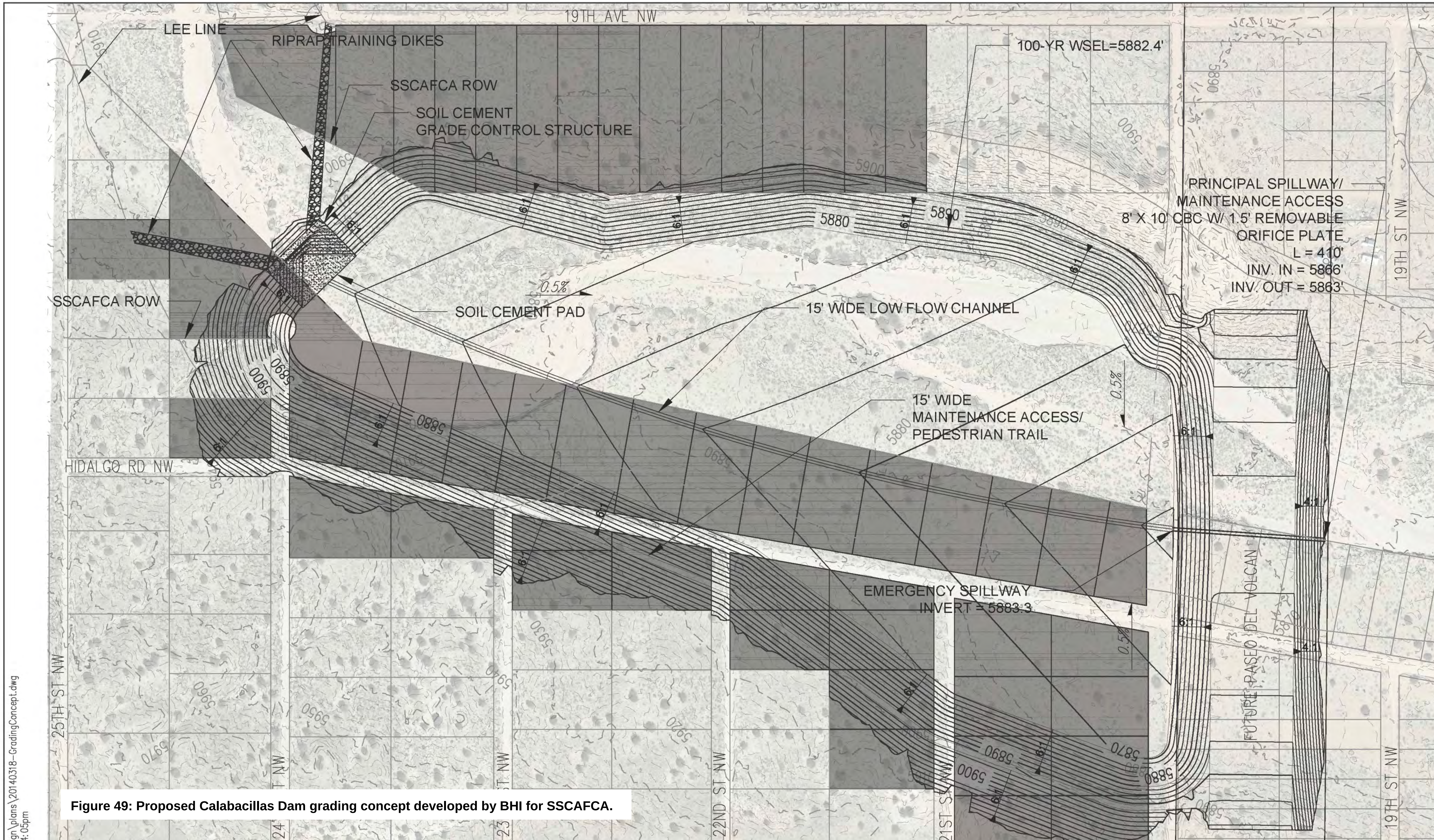

Figure 49: Proposed Calabacillas Dam grading concept developed by BHI for SSCAFCA.

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CALABACILLAS PDV DAM

GRADING CONCEPT

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C. STORMWATER QUALITY

1. Background

It is widely recognized that as land use changes due to urbanization, stormwater runoff quality is adversely impacted. Nearly all of the associated water quality issues result from one underlying cause: loss of the water-retaining and evapotranspiration functions of the soil and vegetation in the urban landscape. Increases in impervious cover result in increased runoff volume and frequency, transporting ever greater quantities of pollutants and sediment to the arroyos and the Rio Grande in short, concentrated bursts of high discharge. When combined with the introduction of pollutant sources from urbanization (such as lawns, motor vehicles, domesticated animals, and industries), these changes in hydrology have led to water quality and habitat degradation in many urban streams.

The Federal Clean Water Act contains provisions to address control of pollution in stormwater through promulgation of the National Pollutant Discharge Elimination System (NPDES). Under this program, entities responsible for the discharge of municipal stormwater runoff to waters of the United States are regulated through an NPDES permit issued by the Environmental Protection Agency. Under the conditions of the NPDES permit, each entity must conduct stormwater quality management activities that seek to reduce pollutant levels in stormwater runoff to the maximum extent practicable. The pollutants of concern are established by the New Mexico Environment Department and are indicated as impairments to the Rio Grande when the state-established water quality standard is exceeded.

Stormwater quality management has not historically been a formal part of the mission of SSCAFCA. The importance of SSCAFCA's facilities in the management and conveyance of water resources in the region and SSCAFCA's dedication to watershed stewardship along with the increasing regulatory attention to water quality management, have expanded the role of SSCAFCA to include water quality. This reinforces elements of SSCAFCA's overall mission to preserve the natural character of the arroyos, provide multi-use and quality-of-life opportunities for lands controlled by SSCAFCA, and to control sediment transport and erosion. The Rio Grande is also viewed as a valuable resource for residents of the jurisdiction including the flora and fauna of these riparian and arroyo corridors.

SSCAFCA, along with the City of Rio Rancho and Sandoval County, were identified as regulated entities under the NPDES in 2006. SSCAFCA submitted a Stormwater Management Plan (SWMP) on May 24, 2007. Under the permit, SSCAFCA is requested to:

- Reduce the discharge of pollutants to the "maximum extent practicable" (MEP);
- Protect water quality; and
- Satisfy the appropriate water quality requirements of the Clean Water Act.

These requirements are accomplished through six minimum control measures:

- Public Education and Outreach
- Public Participation/Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Runoff Control
- Post-Construction Runoff Control
- Pollution Prevention/Good Housekeeping

Details of the requirements and activities completed by SSCAFCA under the permit can be found on our website, www.sscafca.org.

2. Application in the Calabacillas Watershed Park

Many permanent regional best management practices are planned in this watershed park management plan to help reduce potential sediment and pollutants in stormwater runoff, including:

- Water quality treatment mechanisms will be incorporated in the design of all regional stormwater detention facilities (see Photo 37).
- SSCAFCA, in cooperation with the CoRR, has implemented a policy that requires residential, commercial and industrial developments to provide operation and maintenance of on-site stormwater quality facilities to treat the runoff from a 0.6", 6-hour storm event prior to discharge to a public facility. See the SSCAFCA/CoRR Development Process Manual.
- Naturalistic channel treatments (unlined channels, stabilized with bank protection and drop structures where necessary) will be utilized wherever feasible to slow down the velocity of stormwater runoff and promote infiltration into the soil.

Photo 37: Water Quality outlet structure in one of SSCAFCA's flood control dams; the ports in the standpipe let water drain, but filter out floatable debris.

3. Using Natural Arroyos to Improve Water Quality

In their original state, watersheds in the Middle Rio Grande area drain stormwater runoff through a network of natural stream channels or arroyos. Historically, flood control strategies have focused on the most efficient ways to convey stormwater runoff through populated areas, resulting in the conversion of many arroyos to hard-lined channels. Due to the increasing cost of traditional construction and concerns for the environment, SSCAFCA has long considered and implemented stormwater management approaches that preserve arroyos in as natural a state as possible, taking advantage of naturally high infiltration rates in arroyos and their potentially beneficial effect on water quality. The main challenges of natural stream channels in the arid Southwest are erosion and sediment deposition. This is of particular concern in the SSCAFCA area due to the highly erosive nature of local soils. However, keeping arroyos natural has many benefits such as lower cost (compared to building and maintaining a hard-lined channel), increased quality of life by preserving open space, as well as environmental benefits.

The Calabacillas Watershed Park is the largest drainage basin in SSCAFCA's jurisdiction. Most of the watershed is undeveloped, and the Calabacillas Arroyo and its mayor tributaries have not been lined or modified (see Photo 38).

Photo 38: Calabacillas Arroyo, looking upstream from King Blvd.

Unlined, sandy bottom arroyos have naturally high infiltration rates. The Albuquerque Bernalillo County Water Utility Authority (ABCWUA) is utilizing an unlined arroyo for groundwater recharge. Water is discharged into the Bear Canyon Arroyo in the City of Albuquerque and infiltrates into the arroyo bed. ABCWUA and their consultant, Daniel B. Stephens & Associates Inc. (DBS&A), have successfully demonstrated that water reaches the water table (approximately 550 feet below the land surface) in less than 50 days (Moore, 2008). The effective infiltration rate – i.e. the average infiltration rate with respect to time over the entire wetted reach – in the Bear Canyon Arroyo was found to be approximately 1.5 inches per hour (DBS&A, personal communications). The National Engineering Handbook (NRCS, 2007) specifies a range of infiltration rates of 0.75-0.88 inches per hour for loose sandy soils and 0.88-1.25 inches per hour for gravelly sandy soils.

The geometry of the Calabacillas Arroyo is characterized by cross-sections that are almost flat at the bottom and range in width from 40 feet to over 300 feet. The reach segment shown in Figure 50 is approximately ½ mile long and has an average width of 112 feet. The total channel bottom area available for infiltration is approximately 10 acres. Assuming an average infiltration rate of 1 inch/hour, this reach has an infiltration potential of 10 cubic feet per second (or about 4,500 gallons per minute). In other words, if the inflow into the reach at the upstream end is 10 cfs or less, all water will infiltrate, and there should be no outflow at the lower end of the reach.

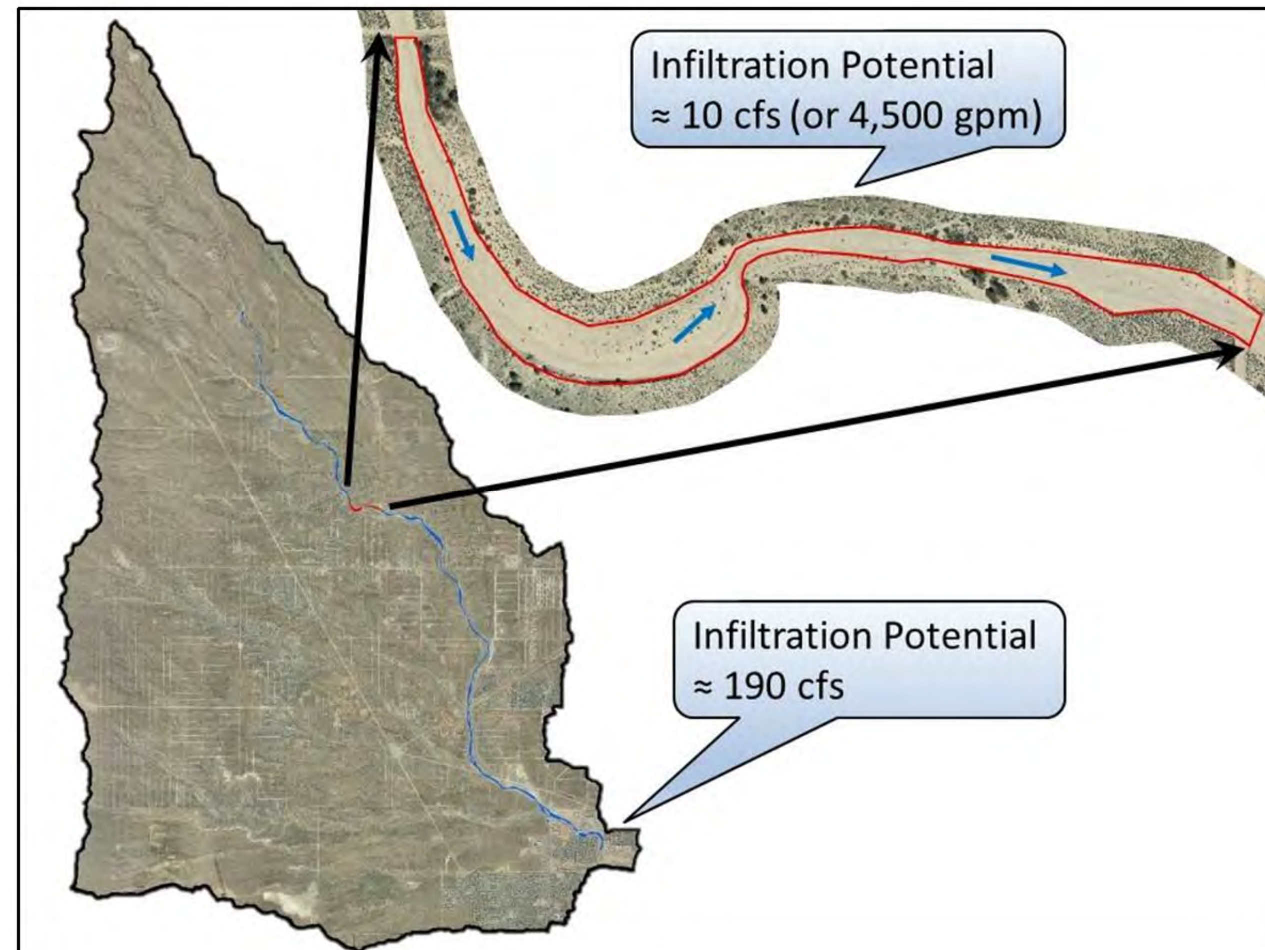

Figure 50: Infiltration potential of the Calabacillas Arroyo.

Using the same rationale, the Calabacillas main stem between Progress Blvd and Swinburne Dam (13 miles long, 186 acres of channel bottom area) has an infiltration potential of 188 cfs.

Transmission losses (or infiltration into the arroyo bed as a flood wave moves downstream) can explain some of the discrepancies that have been observed between predicted and measured flow in the Calabacillas Arroyo. Figure 51 shows rain gauge (blue bars) and radar data (colored background) for a storm that occurred late on August 4, 2013. Most of the precipitation fell in a brief period of about one hour; the most intense rainfall was limited to a relatively small area in the upper reaches of the watershed, as indicated by yellow, orange and red colors.

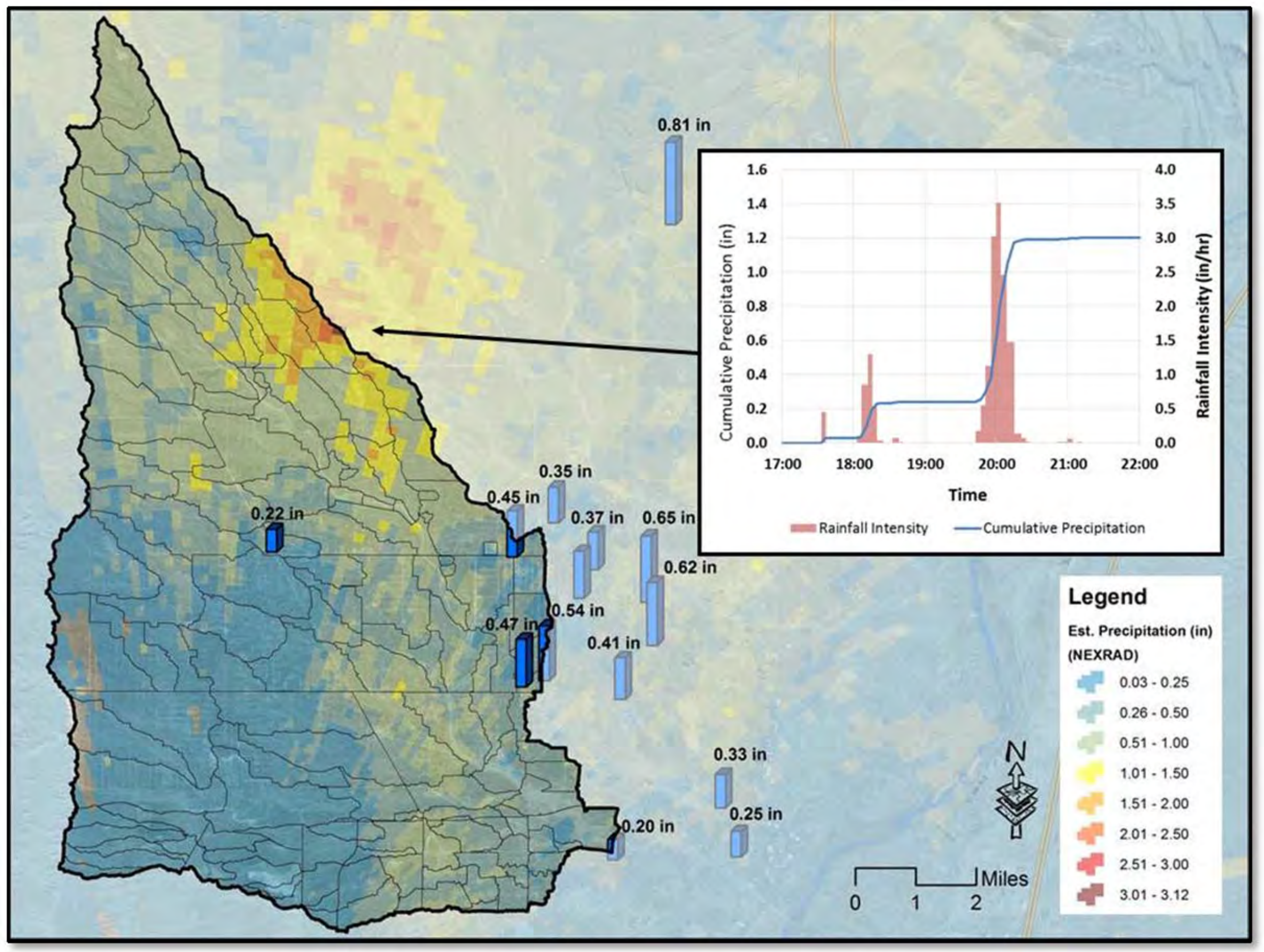

Figure 51: Map showing rainfall data for the storm of August 4, 2013.

The hydrologic model was run using rainfall input data from the storm event; model results were compared to the hydrograph measured by the stream gauging station located at Swinburne Dam (see Figure 52). The red line in Figure 52 represents the measured hydrograph (please note that the gauging station has a dry reading of 17 cfs). The black and blue lines represent model runs with and without accounting for transmission losses, respectively.

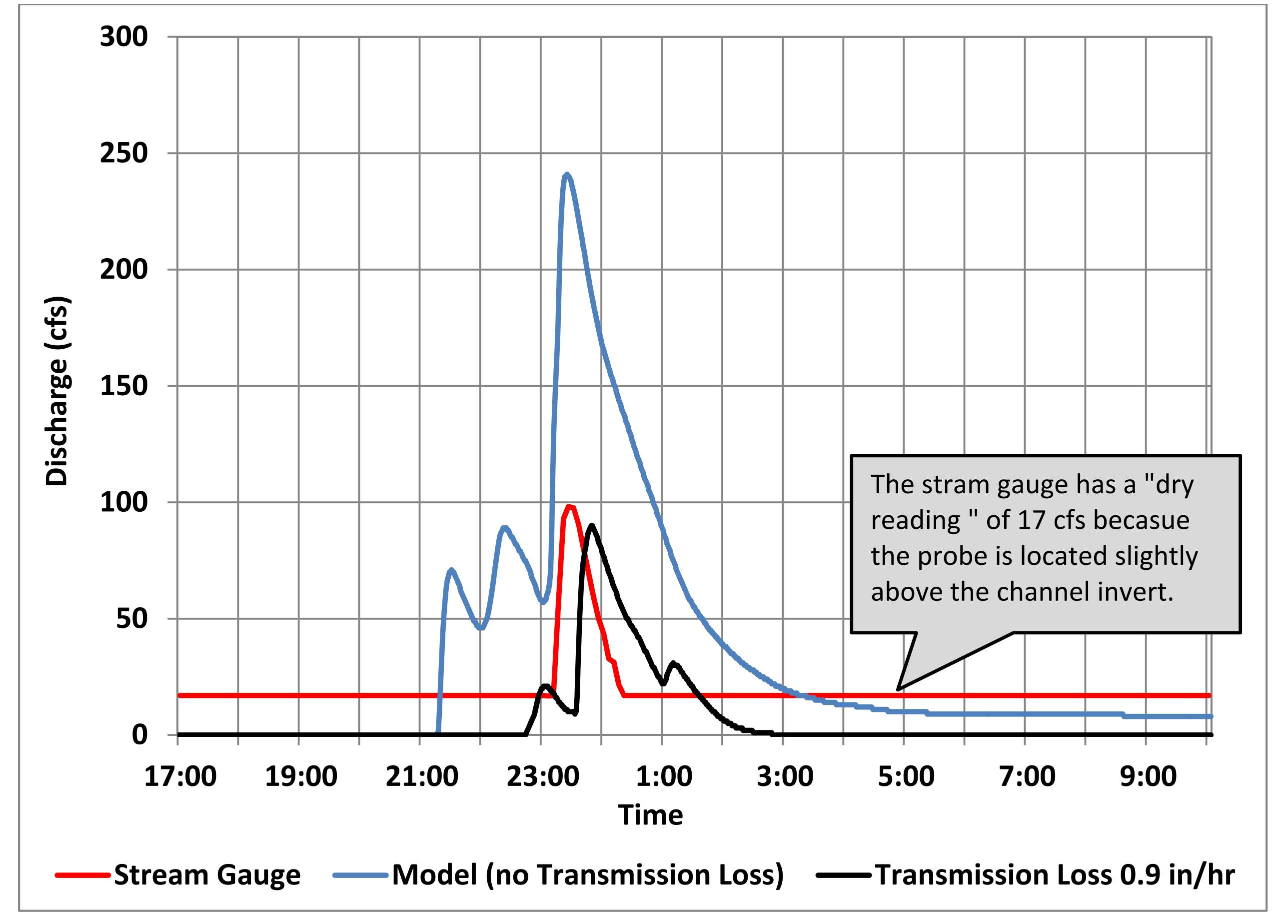

Figure 52: Comparison of measured flow at Swinburne Dam (red) and hydrologic model results without transmission losses (blue), and with transmission losses (black).

The comparison shows that the model run without transmission losses over-predicted peak flow more than 2-fold, and predicted runoff volume was seven times higher than that measured at the gauging station (see Table 13). By including transmission losses of 0.9 inches per hour into the hydrologic model, the results improve dramatically, and the predicted hydrograph closely resembles the measured data with respect to hydrograph shape, peak flow, and runoff volume.

Table 13: Comparison of measured and predicted peak flow rates and runoff volumes at Swinburne Dam for the storm of August 4, 2013.

	Peak Discharge (cfs)	Runoff Volume (ac-ft)
Stream Gauge	**98**	**6**
Model (no Transmission Losses)	**241**	**42**
Model (Transmission Loss 0.9 in/hr)	**90**	**8**

Another example for documented transmission losses is the South Pino Arroyo in Albuquerque (see Figure 53). From October 1996 to September 1997, the United States Geological Survey (USGS) simultaneously maintained two stream gauges separated by a 1-mile reach of natural, unlined arroyo.

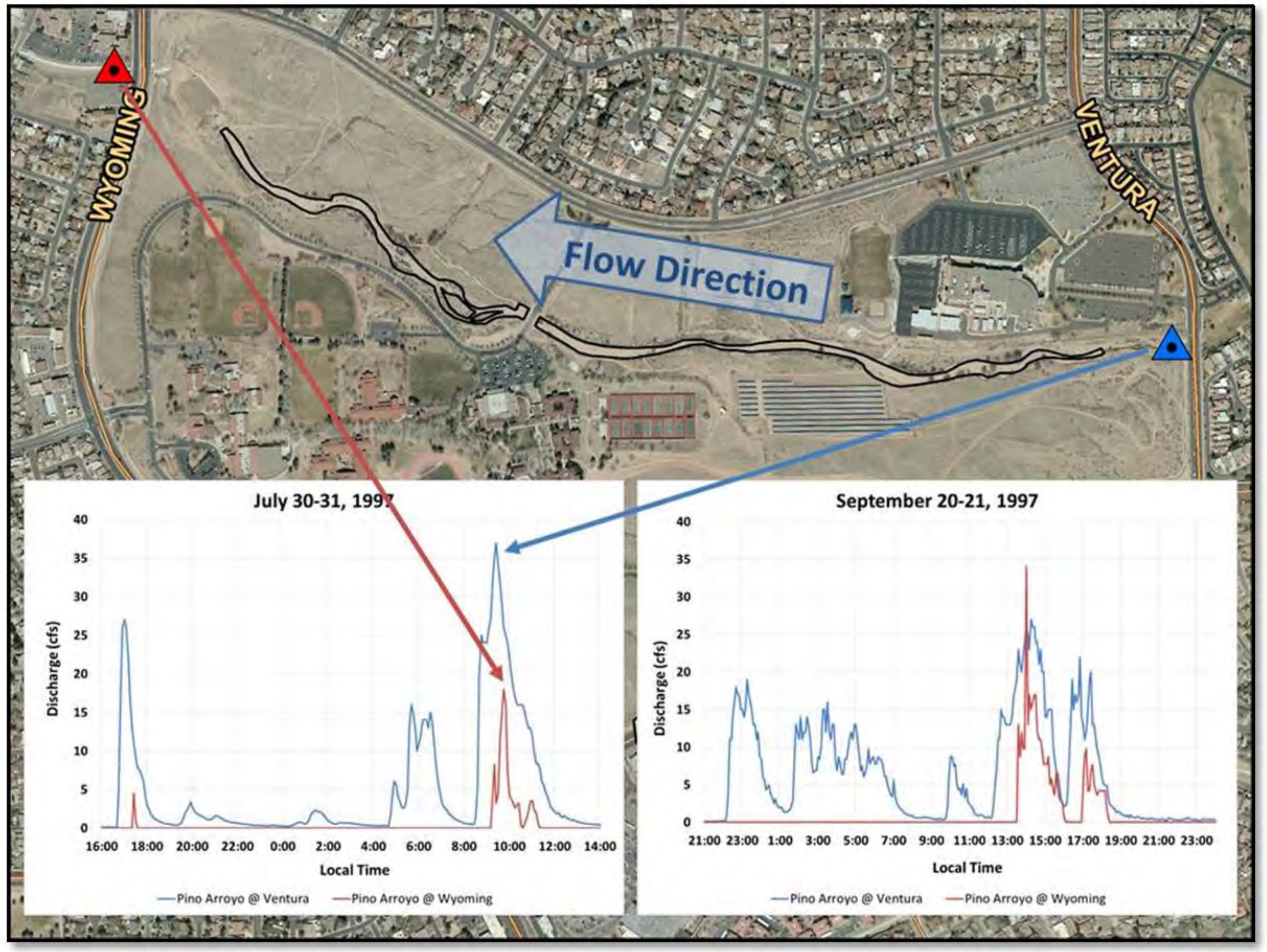

Figure 53: Flow gauge data for the South Pino Arroyo at Ventura Rd and Wyoming Blvd in Albuquerque.

During the one year period, eight storm events resulted in flow at both gauging stations. Two examples are displayed in Figure 53 and show hydrographs for the storms of July 30-31 and September 20-21, 1997. For every recorded event, the downstream gauge (red) recorded significantly less flow than the upstream gauge (blue). If flows upstream were less than approximately 15 cfs, no flow was recorded at the downstream gauging station. Based on the flow data and the channel bottom area, the estimated average infiltration rate for this reach was 2 inches per hour. During the documented one-year period, 80 percent of all runoff measured at the upstream gauge infiltrated before it reached the downstream gauging station.

Data from the Calabacillas, Bear Canyon, and Pino Arroyos show that unlined conveyances have the potential to infiltrate a significant portion of runoff from small storm events before it reaches the Rio Grande. The rainfall frequency curves in Figure 54 illustrate that most of the storms that occur in the Albuquerque/Rio Rancho area are small: 90 percent of all storm events have a rainfall total of less than 0.5 inches.

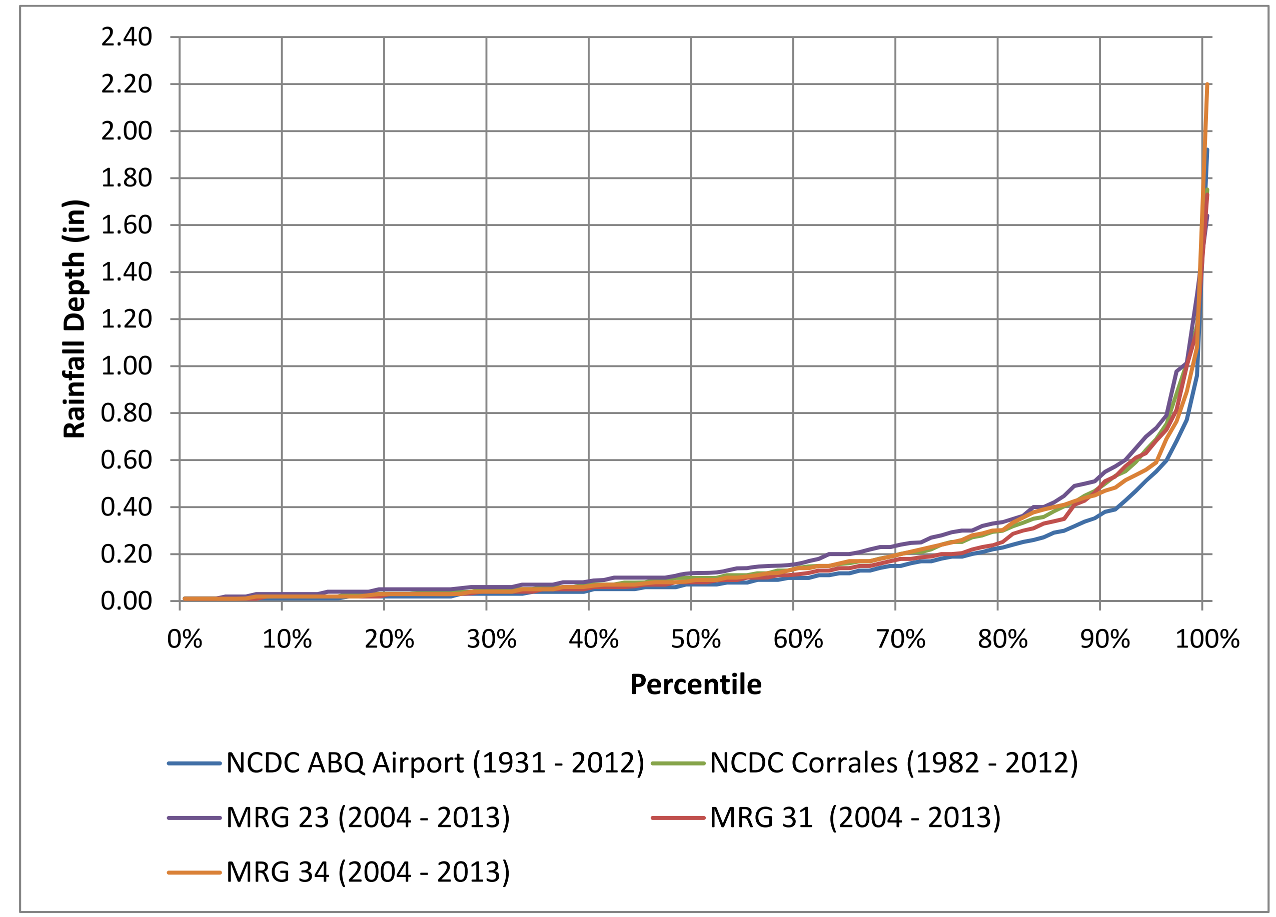

Figure 54: Rainfall frequency curves for five rain gauges in the Albuquerque/Rio Rancho area.

The increase of impervious coverage in a watershed due to urbanization not only leads to higher runoff volumes for a given storm event, but also increases the frequency of small runoff events. Since pollutants in urban stormwater runoff are a major concern for the receiving water body, transmission losses can be a valuable tool for protecting water quality. SSCAFCA's strategy of maintaining conveyances in a natural, unlined state in itself is an important measure to protect water quality in the Rio Grande.

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