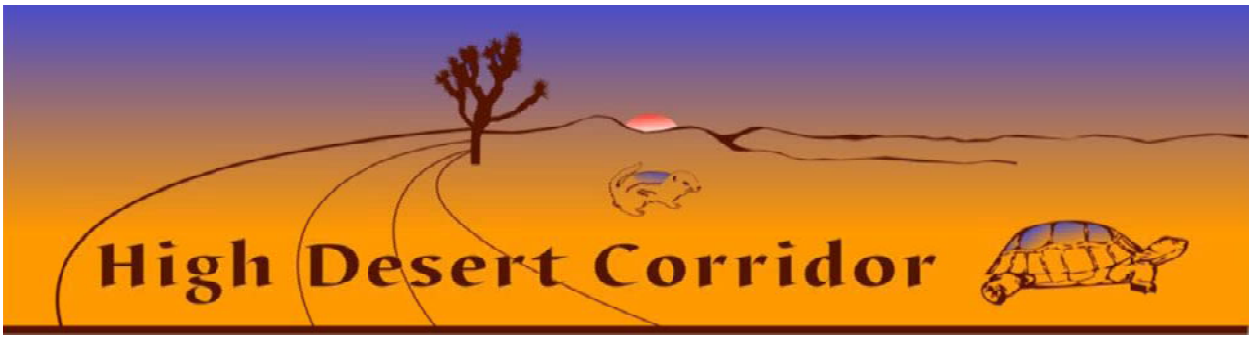
# Preliminary Hydrology and Hydraulics Report




## High Desert Corridor
## Palmdale to Apple Valley (State Route 14 to State Route 18)

January 2016

**PARSONS**
Parsons Transportation Group Inc.
100 West Walnut Street
Pasadena, CA 91124

Contract No.: 07A2912
Caltrans Project No.: 0700000080 (EA: 16720)

Caltrans

Metro

# Hydrology and Hydraulics Report

# High Desert Corridor (HDC) Project

LOS ANGELES and SAN BERNARDINO COUNTIES, CALIFORNIA
District 07 -LOS ANGELES -NEW 138 - PM 42.4 to PM 74.9
District 08 - SAN BERNARDINO -NEW 138 - PM 0.0 to PM 35.0
Caltrans Project No.: 0700000080 (EA: 16720)

## January 2016

STATE OF CALIFORNIA
Department of Transportation


Prepared By: Portia Gonzalez Date: January 29, 2016

Portia Gonzalez PE, Lead Author
Parsons
2201 Dupont Dr. Suite 200
Irvine, CA 92612

Approved By: Valenton Date: APRIL 28, 2016

Nestor L. Valenton
Division of Design
California Department of Transportation
District 7
Los Angeles, CA 90012

Approved By: STE(S) Date: APRIL 29, 2016.

Dave Bhalla
Division of Design
California Department of Transportation
District 7
Los Angeles, CA 90012

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# 1 PROJECT DESCRIPTION

The California Department of Transportation (Caltrans), in cooperation with the Los Angeles County Metropolitan Transportation Authority (Metro), proposes construction of the High Desert Corridor (HDC) as a new transportation facility in the High Desert region of Los Angeles and San Bernardino counties. The proposed 63-mile-long west-east facility would provide route continuity and relieve traffic congestion between State Route (SR) 18 and United States Highway 395 (US 395) in San Bernardino County with SR-14 in Los Angeles County and SR-18 and Interstate 15 (I-15) in San Bernardino County. The project would be comprised of one or more of the following major components, including highway, rail transit, bikeway, and recommendation for green energy facilities.

Figures 1-1 and 1-2 are project vicinity and location maps, respectively.

## 1.1 Purpose and Need

The purpose of the proposed action is to improve east-west mobility through the High Desert region of southern California by addressing present and future travel demand and mobility needs within the Antelope and Victor valleys. The proposed project is intended to achieve the following objectives:

- Increase capacity of west-east transportation facilities to accommodate existing and future transportation demand
- Improve travel safety and reliability within the High Desert region
- Improve the regional goods movement network
- Provide improved access and connectivity to regional transportation facilities, including airports and existing and future passenger rail systems (which include the proposed California high-speed rail (HSR) system and the proposed XpressWest HSR system)
- Contribute to state greenhouse gas (GHG) reduction goals by supporting future plans for green energy features along the corridor

The specific needs to be addressed by the proposed action include:

- Recent and future planned population growth within the High Desert region
- Limited and unreliable west-east connectivity within the High Desert region
- Regional demands for goods movement to support the growth of the regional economy
- Future demands for the use of green energy, including sustainability and green energy provisions in State law and policy

**Figure 1-1. Project Vicinity Map**

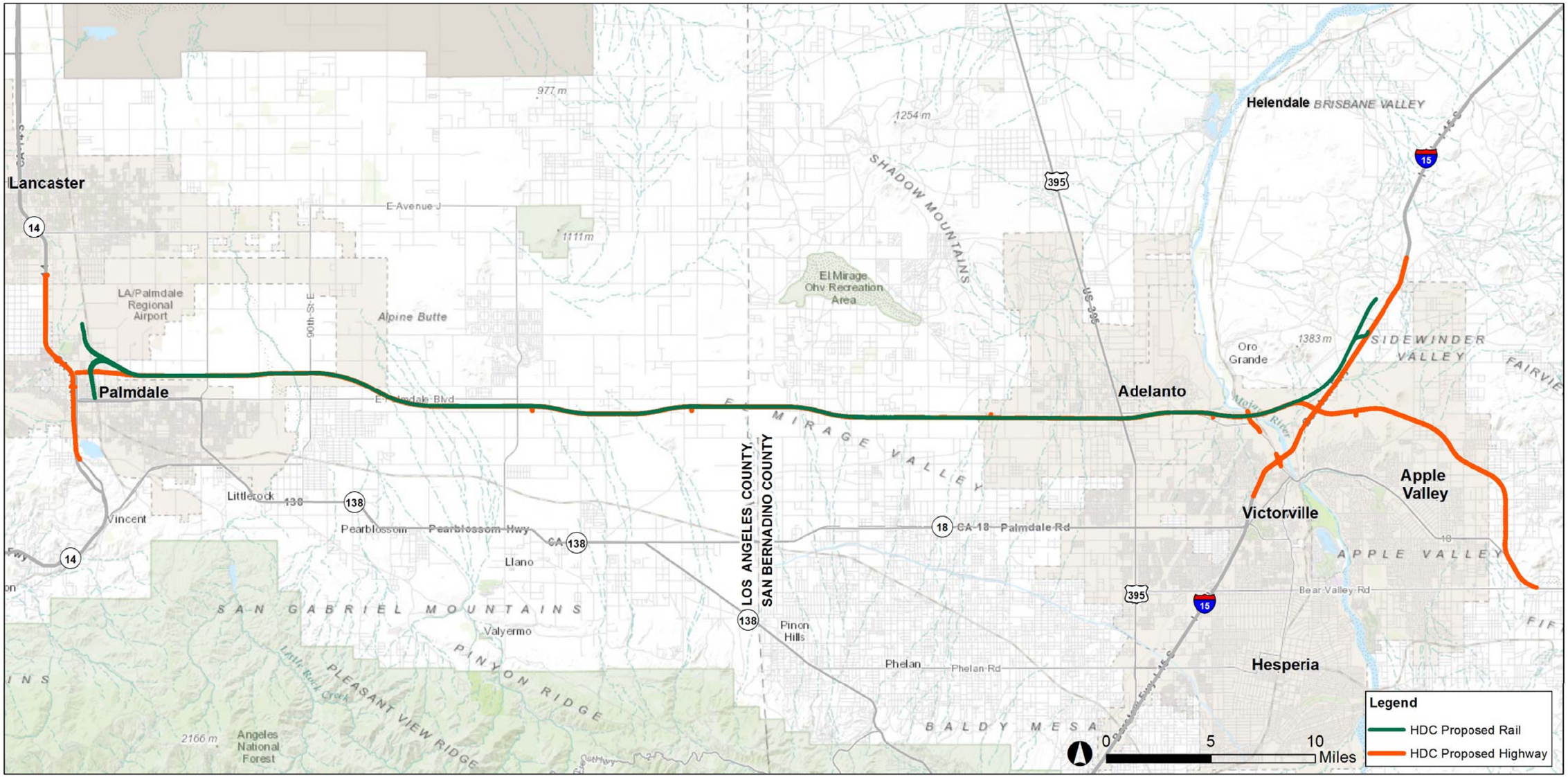


Figure 1-2. Project Location Map

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## 1.2 Project Alternatives

Several project alternatives and design variations have been considered and evaluated. A No Build Alternative and four build alternatives were selected for detailed evaluation in the Draft Environmental Impact Report/Environmental Impact Statement.

### NO BUILD ALTERNATIVE

Under the No Build alternative, no new transportation infrastructure would be built within the project area to connect Los Angeles and San Bernardino Counties aside from existing SR-138 safety corridor improvements in Los Angeles County and SR-18 corridor improvements in San Bernardino County. Traffic circulation and congestion currently experienced on Palmdale Boulevard, Air Expressway, and Happy Trails Highway (existing SR-18) would remain. The no action alternative functions as a baseline to compare against all of the proposed build alternatives.

### FREEWAY/EXPRESSWAY ALTERNATIVE (AVENUE P-8, I-15, AND SR-18)

This alternative would consist of a combination of a controlled-access freeway and an expressway. It generally would follow Avenue P-8 in Los Angeles County and just south of El Mirage Road in San Bernardino County. This alternative then extends east to Air Expressway Road near I-15 and curves south, terminating at Bear Valley Road. The incorporation of green energy technologies and a bike path along segments of the alternative would also be considered.

Four physical alignment variations are being considered, including:

- Variation A: Near Palmdale, the freeway/expressway would dip slightly south of the main alignment, approximately between 15th Street East and Little Rock Wash.
- Variation B: East of the county line, the freeway/expressway would flare out slightly south of the main alignment between Oasis Road and Coughlin Road. Variation B1 would be at the same location, but it would flare out a little less and pass through the Krey airfield.
- Variation D: Near the community of Lake Los Angeles, the freeway/expressway would dip slightly south of the main alignment, just south of Avenue R approximately between 180th Street East and 230th Street East.
- Variation E: Near Adelanto and Victorville, the freeway/expressway would dip south of the federal prison.

### FREEWAY/TOLLWAY ALTERNATIVE (AVENUE P-8, I-15, AND SR-18)

This alternative would follow the same physical alignment as the Freeway/Expressway Alternative (including Variations A, B, D, and E), but it would have a section between 100$^{th}$ Street East and US 395 operate as a tollway. Details of this operating feature are being evaluated as part of an ongoing P3 analysis. The incorporation of green energy technologies and a bike path would also be considered.

### FREEWAY/EXPRESSWAY ALTERNATIVE WITH HIGH-SPEED RAIL (HSR) FEEDER/CONNECTOR SERVICE

This alternative would be the same as the Freeway/Tollway Alternative except that it would also include an HSR Feeder/Connector Service between the cities of Palmdale and Victorville. The HSR Feeder/Connector Service would utilize proven steel wheel-on-steel track technology and have a design speed of 180 miles per hour (mph) with an operating speed of 160 mph. Additional details of this operating feature, including the type of train technology (i.e., electric versus diesel-electric), its location in relation to the HDC (median-running alignment), and its connections to existing and proposed rail stations, are being evaluated as part of an ongoing Rail Alternatives Analysis. The incorporation of green energy technologies and a bike path would also be considered.

### FREEWAY/TOLLWAY ALTERNATIVE WITH HIGH-SPEED RAIL FEEDER/CONNECTOR SERVICE

This alternative would be the same as the Freeway/Expressway Alternative except that it would also include an HSR Feeder/Connector Service between the cities of Palmdale and Victorville. The incorporation of green energy technologies and a bike path would also be considered.

## 1.2 Preferred Project Alternative

Through a collaborative process between Caltrans, Metro, and the HDC Joint Powers Authority (local Cities of the High Desert, and the Counties of Los Angeles and San Bernardino), a Preferred Alternative has been preliminarily identified by the multi-agency Project Development Team (PDT). The Preferred Alternative has been developed to provide broad geographic coverage and regional transportation benefits based on community desires and planning goals. The project has actively sought the wide participation of stakeholders, including, most recently, upon circulation of the draft environmental document for which four public hearings were conducted during November 2014 in the affected desert communities.

The preferred project alternative as shown in Figure 1-3 consists of the following elements:

- The Freeway/Tollway with High Speed Rail Alternative (including Variations D and B1)
- HSR Option 1C to connect to the Palmdale Transportation Center
- HSR main alignment to connect to the Victorville XpressWest rail station
- Bike path between US-395 and 20th Street East (with funding to provide an extension along local streets to the Palmdale Transportation Center)
- Green energy production and transmission facilities within study area footprint

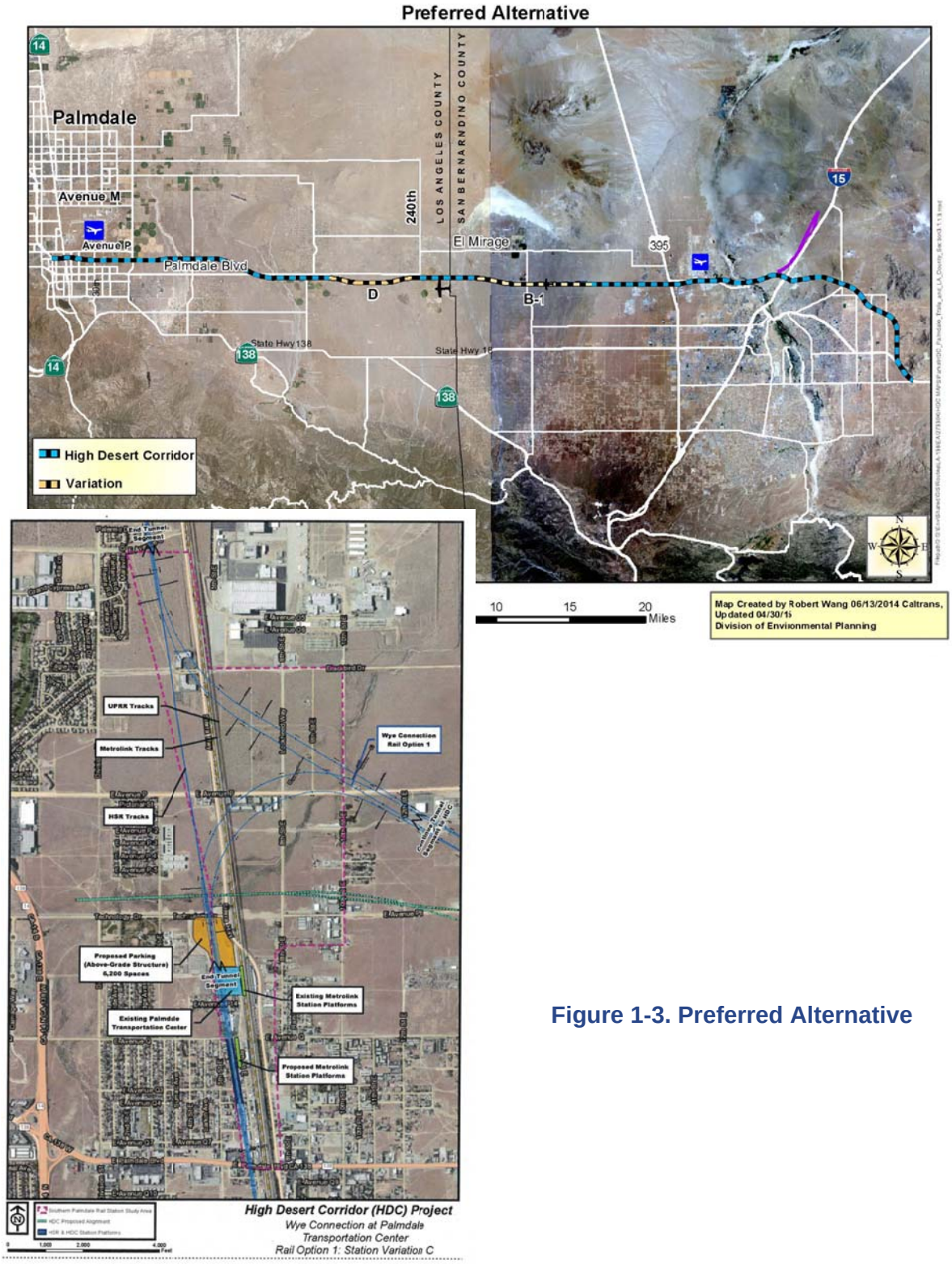


**Figure 1-3. Preferred Alternative**

These elements are discussed in more detail below.

Freeway/Tollway Element: The alignment, combining a controlled-access freeway and an expressway, will generally follow Avenue P-8 in Los Angeles County and just south of El Mirage Road in San Bernardino County, then extend east to Air Expressway Boulevard near I-15, and finally curve south, ending at Bear Valley Road. Right-of-way to accommodate up to four lanes of travel in each direction will be protected, with the number of initial lanes constructed at opening based on the traffic analysis and funding availability. The toll section would begin at 100th Street East in Palmdale and end at US 395 in Victorville. The preferred project would incorporate two variations, D and B1. These selected variations are:

- Variation D – Near Lake Los Angeles, the freeway/tollway would dip south of the main alignment, just south of Avenue R, approximately between 180th Street East and 230th Street East.
- Variation B1 – East of the county line, the freeway/tollway would flare out slightly south of the main alignment between Oasis Road and Coughlin Road and pass through Krey Field.

**High Speed Rail Feeder Service Element:** HSR Feeder/Connector Service is recommended between the cities of Palmdale and Victorville. The HSR Feeder/Connector Service would utilize steel wheel-on-steel track technology with a design speed of 180 mph and optimal operating speed of 125 mph. Two rail connections would be constructed, one at the future Victorville XpressWest Station in San Bernardino County and another one at the existing Palmdale Transportation Center in Los Angeles County.

Out of the six Palmdale Rail Connection options evaluated in the draft environmental document, Rail Option 1C is preferred. Although it would require relocation of the Palmdale Transportation Center, it would have fewer community impacts overall and would avoid conflicts with park (4(f)), UPRR and Plant 42 property.

The preferred project alternative would connect at its eastern terminus with the XpressWest station. Of the two XpressWest connection options evaluated in the draft environmental document, the Main Alignment option is preferred over the Variation E alignment. The preferred Main Alignment variation would entail only one crossing of the Mojave River, and would leave the HDC approximately 1.8 miles after that crossing. After leaving the HDC, the HSR design speed would be reduced to 150 mph for compatibility with XpressWest. Bicycle Path Element: The HDC Project would include bicycle facilities, extending 39 miles along the corridor from US 395 in Adelanto to 20th Street East in Palmdale. The bike facility would be designed to complement the proposed freeway/expressway and HSR feeder service. In addition, the necessary funding to provide bike lane(s) as specified in the City's general plan, along 20th Street East and Avenue Q, in its entirety to the Palmdale Transportation Center or future High Speed Rail station, will be provided by Metro as a project mitigation cost.

**Green Energy Corridor Element:** The green and renewable energy component would contribute to greenhouse gas reductions and reduce energy costs. Due to the ongoing development of new green and renewable energy technologies, the selection of specific

technologies, including funding, construction, and operation, would be done through a PPP or utility company.

**Rationale:**
This multimodal preferred project alternative would meet the project's Purpose and Need. The alternative would improve traffic operations along the entire length of the corridor, maintain mobility/accessibility and enhance mode choice while accommodating planned growth in the Antelope and Victor Valleys. The preferred project alternative would also help reduce the potential for head on crashes and increase safety by introducing more gentle and gradual curves, wider lanes, and other geometric engineering improvements. The preferred project alternative would provide a connection to existing and future passenger rail systems, including the California HSR system and the proposed XpressWest HSR system. The proposed bike path would provide a continuous linkage between Los Angeles and San Bernardino counties and would be built by Caltrans and local planning authorities or through a public private partnership (PPP) program. The green and renewable energy component would contribute to a reduction in greenhouse gas emissions and reduce energy costs.

The rationale for supporting the Preferred Project Alternative includes:

- The Preferred Project Alternative, with its variations, would have fewer impacts to sensitive environmental resources, including two protected avian species - the State and federally-listed southwestern willow flycatcher and the least bell's vireo - than would other build alternatives.
- The Preferred Project Alternative, with its variations, would have fewer projected residential displacements than would other build alternatives.
- Comments received from both the general public and local agencies during the Draft EIR/EIS public review period showed positive support for multi-modal options.
- Given the uncertainty of future federal and state government funds for surface transportation improvements, and pending other financial options, the use of Tolled Express Lanes is consistent with and is included as part of SCAG's 2012-2035 Regional Transportation Plan/Sustainable Communities Strategy.
- With the implementation of a FasTrak system as part of the tolling facility, the Preferred Project Alternative would be implemented faster and, upon construction and opening, would continue to foster a more efficient and coherent transportation network for the motoring public.
- The HSR feeder service recommended between Palmdale and Victorville provides an additional mode choice that would complement the HDC and has the potential to connect the San Francisco, Central Valley, Los Angeles, Las Vegas, and San Diego regions.
- The Preferred Project Alternative would add capacity to the transportation system to accommodate the immense projected growth in international freight and goods movement. It also has the potential as a bypass of the greater Los Angeles urban area.
- The Preferred Project Alternative would provide improved access and linkages between various desert residential communities, businesses, and facilities.
- The Preferred Project Alternative is consistent with the community planning goals of the various affected local jurisdictions as framed by their respective general plans.

- The Preferred Project Alternative is expected to support local economic development efforts in the High Desert. It would have little or no effect on the major development plan expansion projects already underway or on regional development trends in general.
- The Preferred Project Alternative can be built with minimal disruption to current east west traffic flow in the desert making it inherently easier to construct.
- The Preferred Project Alternative will help achieve smart growth goals required by SB 375 in that it may help foster higher-density and mixed-use developments, especially near the proposed HSR rail stations in Palmdale and Victorville.
- Community character and livability would be enhanced as a result of incorporating the proposed bike path/lane. Incorporation of a bike path would provide the community with an additional transportation option.
  The green and renewable energy component would contribute to greenhouse gas and energy cost reductions. The green energy production and transmission facilities would be constructed within the study area footprint, thus resulting in no additional impacts to environmental resources.

# 2 HYDROLOGY

## 2.1 Existing Watershed Characteristics

The west portion of the project area is located in the Antelope Valley watershed, as shown in Figure 2-1. This watershed encompasses approximately 1,220 square miles within Los Angeles County and 143 square miles in San Bernardino County. Numerous streams originating in the mountains and foothills flow across the valley floor and eventually pond in several dry lakes to the north, including Rosamond Lake and Rogers Lake.

The east portion of the project area is located in the Mojave River Watershed, contributing flow to the river at the "Narrows" where the water body has perennial flow. In general, the hydrologic regime along the entire corridor exhibits the characteristics of an alluvial fan, with several incised streams and channels that cross the project alignment including Mojave River, Bell Mountain Wash, Fremont Wash, Mescal Wash, Big Rock Creek, and Little Rock Creek. These are considered the largest waterways within the project area and, with the exception of Bell Mountain Wash, generally flow northerly across the project site. The Mojave River includes perennial low flow channels along the stream bed, and it supports extensive riparian vegetation along its banks and adjacent areas.

The corridor traverses the northern side of the City of Palmdale. Palmdale has developed a Drainage Master Plan (DMP; 1996) that incorporates a network of storm drains and detention facilities for flood control. It is anticipated that HDC construction will occur prior to the proposed improvements identified in the city's DMP. Specifically, the HDC proposes to place culverts to accommodate the existing off-site runoff under current conditions. In addition, storm drains proposed in the city's DMP that cross the corridor will be constructed within the HDC right-of-way limit. After establishment of a Cooperative Agreement between the City of Palmdale and Caltrans, the HDC infiltration basins within the city's area of service would be connected to the drainage network, which would then facilitate the discharge of runoff in a more efficient manner. Coordination between Caltrans and the city on the timeline and connection of the DMP is anticipated to occur during the plans, specifications, and estimate (PS& E) phase. Excerpts of the DMP are provided in Appendix B.

The Antelope Valley and Mojave River watersheds are further delineated into Hydrologic Unit Code (HUC) subwatersheds. These subwatersheds are displayed in Figure 2-2. The subwatersheds within the County of Los Angeles include Upper Amargosa Creek, Anaverde Creek, Lower Amargosa Creek, Lake Palmdale, Brainard Canyon-Little Rock Wash, Rock Creek, Big Rock Wash, Lovejoy Springs, Grandview Canyon, Mescal Creek, Jesus Canyon, Le Montaine Creek, and Eller Slough. The subwatersheds within the County of San Bernardino include Black Mountain-Frontal El Mirage Lake, El Mirage Lake, Sheep Creek, Horse Canyon-Fremont Wash, Manzanita Wash, Shadow Hills-Fremont Wash, Burkhardt Lake, Oro Grande Wash, Bell Mountain Wash, Desert Knolls Wash, Apple Valley Dry Lake, Deadman Hills, and Isabelle Spring.

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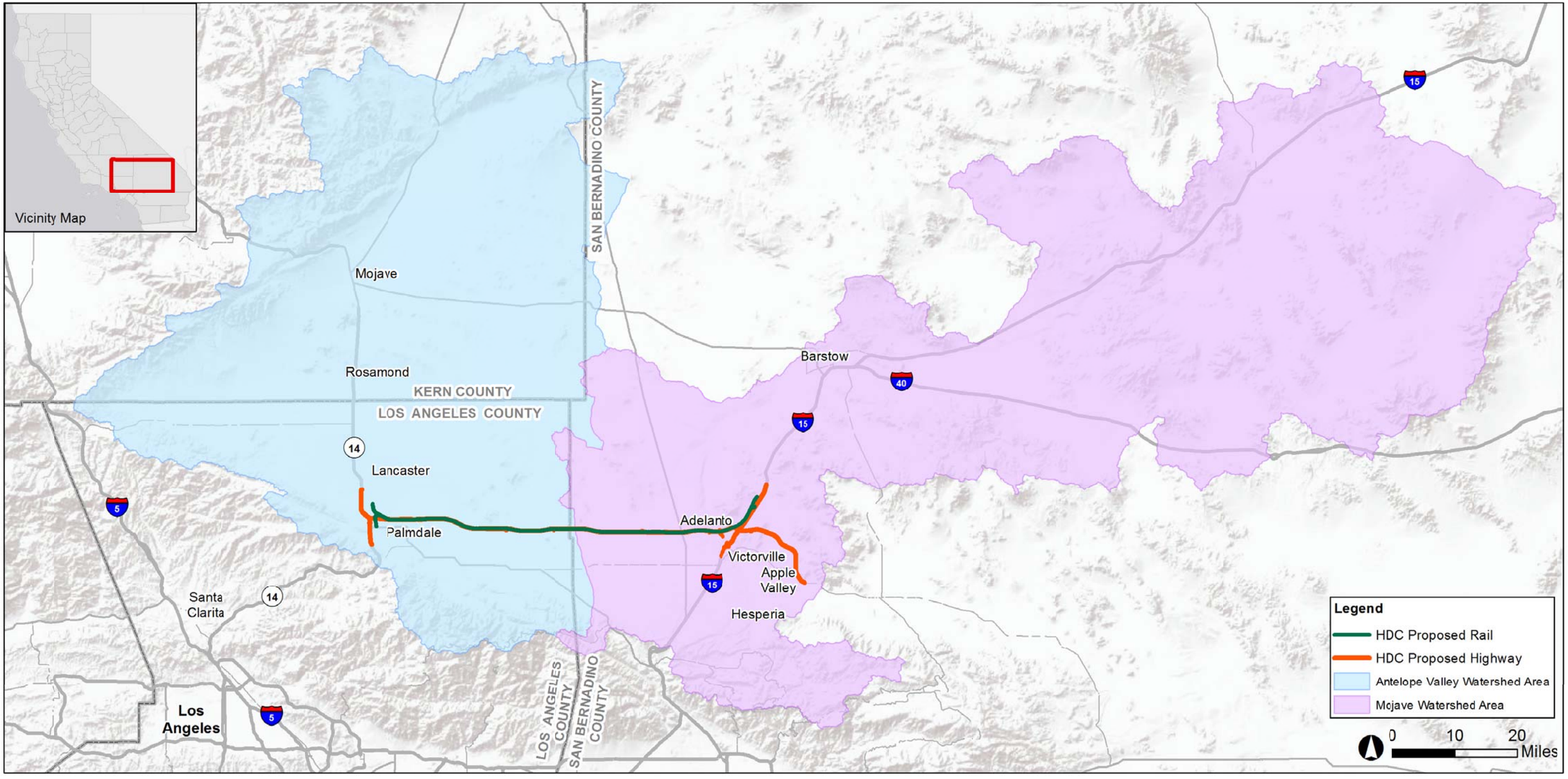


Figure 2-1. HDC Corridor and Watersheds

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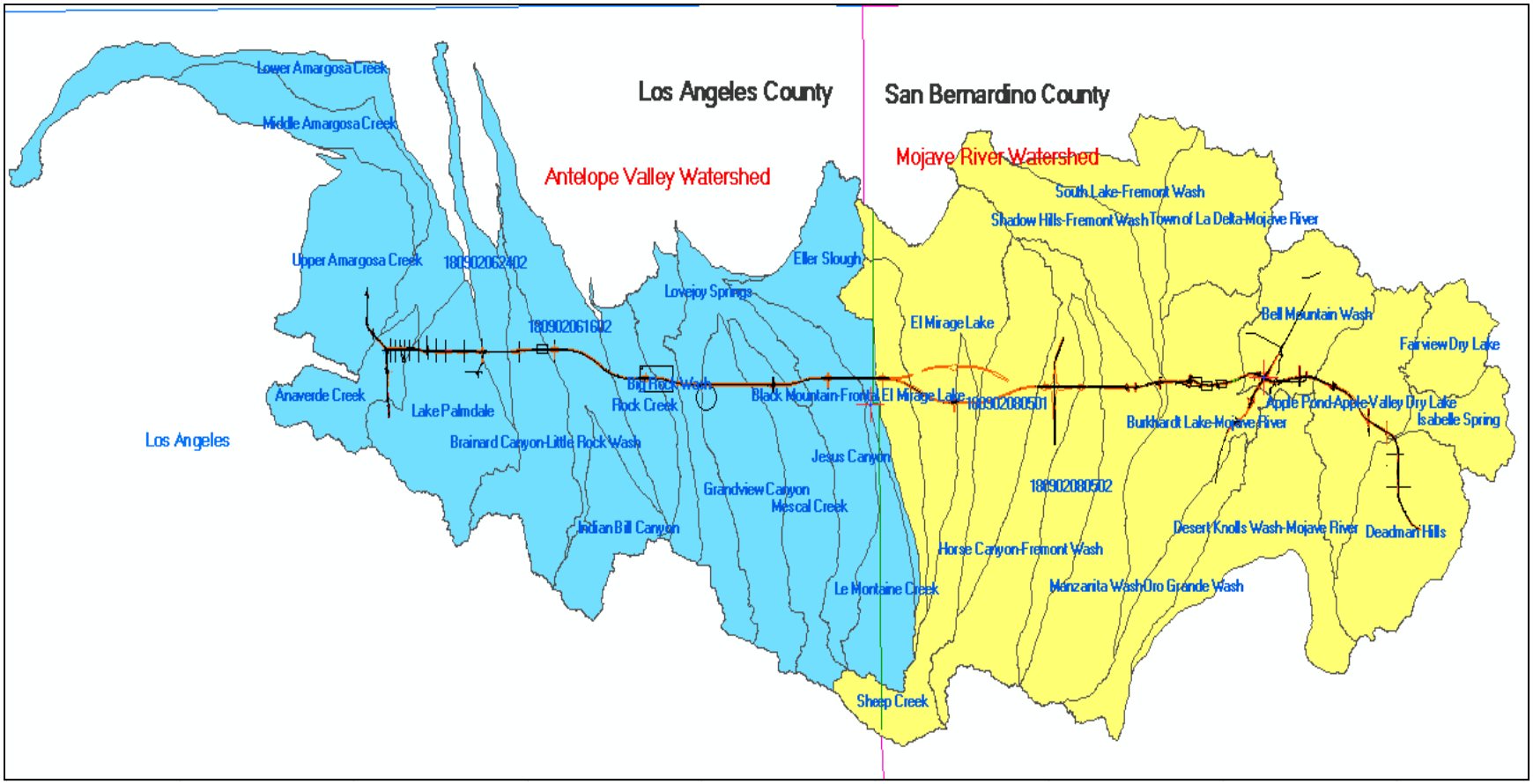


**Figure 2-2. HUC Subwatersheds**

## 2.2 Rainfall Characteristics

The project area has a high-desert type climate, characterized by long, dry, hot summers and cold and windy winters. According to the Caltrans Water Quality Planning Tool (WQPT), the proposed project crosses the following hydrologic areas/hydrologic subareas: Lancaster/626.50, Rock Creek/626.80, El Mirage/628.10, and Upper Mojave/628.20.

**Table 2-1. Average Annual Precipitation per Hydrologic Area**

| Hydrologic Unit | ANTELOPE | ANTELOPE | MOJAVE | MOJAVE |
|---|---|---|---|---|
| Hydrologic Area | Lancaster | Rock Creek | El Mirage | Upper Mojave |
| Hydrologic Subarea | 626.50 | 626.80 | 628.10 | 628.20 |
| Watershed Area (acres) | 557,620 | 265,344 | 106,382 | 556,821 |
| Average Annual Rainfall (inches) | 7.3 | 13.3 | 7.9 | 12 |

The average annual rainfall within these hydrologic areas is displayed in Table 2-1. Most of the precipitation occurs between October and May. Primarily, precipitation occurs as rainfall, with snow common in the high mountains. Precipitation frequency estimates were obtained from the National Oceanic and Atmospheric Administration (NOAA) for various locations within the watersheds that are traversed by the corridor. Tables showing the various precipitation distributions are provided in Appendix C. Flow rates for the sections east of Fremont Wash were obtained from the Caltrans District 8 Preliminary Hydrology Report for the HDC. Flows for Fremont Wash were obtained from the City of Adelanto DMP (1992). Excerpts from the Caltrans Preliminary Hydrology Report are provided in Appendix A, and excerpts from the City of Adelanto DMP and the Palmdale DMP can be found in Appendix B.

## 2.3 Soil and Groundcover Characteristics

Lands within the project watersheds are largely undeveloped, and most of the terrain is brush-covered, as shown in Figure 2-3. Some of the undeveloped land is used for rangeland or agricultural purposes. Another common use of land is for residential and office commercial purposes, especially in the vicinity of cities and towns. Sand and gravel deposits are found extensively in floodplains and stream channels located north of the San Gabriel Mountains in the Little Rock and Big Rock Wash areas.

**Figure 2-3. Typical Ground Cover**

The soil map generated from Natural Resource Conservation Service's Web Soil Survey is shown in Appendix D. In Los Angeles County, the soils within the project alignment include CcA2 (Cajon loamy fine sand), HgA (Hesperia loamy fine sand), HkA (Hesperia fine sand), and CaA (Cajon loamy sand). Within San Bernardino County the major soils crossed are 105 (Bryman loamy fine sand), 112 and 113 (Cajon sand), 118 (Cajon-Arizo Complex), 132 (Helendale loamy sand), 133 (Helendale-Bryman loamy fine sand), 144 (Manet Coarse sand), and 149 (Mirage-Joshua Complex). Based on these criteria, soils were further classified into four hydrological soil groups: A, B, C, and D, where Type A is the most pervious with low runoff potential (such as sand and gravel), and Type D is the least pervious with high runoff potential (such as clay soils). In the project area, types A and B generally follow the alluvial deposits along the creeks and along the alluvial fan of major streams such as Little Rock Wash, Big Rock Wash, and the Mojave River. Types C and D are generally located along the hillsides, in the upper watersheds of Little Rock, Big Rock, Mescal, and Fremont washes and in the vicinity of the Mojave River. Along the alignment, most of the soil is characterized as type A or B.

## 2.4 Floodplain Characteristics

There are several locations along the project with floodplain impacts from longitudinal or transverse encroachments by the project. This section identifies the locations where the project may affect a floodplain. Preliminary recommendations for mitigation and further study are also provided.

FEMA designates Special Flood Hazard Areas (SFHAs) according to Zones. The Base Flood Elevation (BFE) is the water-surface elevation of the 1% annual chance of flood. The zones are described as:

**Zone A** – Corresponds to the 100-year floodplains that are determined in the Flood Insurance Study (FIS) by approximate methods. No BFEs or depths have been determined.

**Zone AE** – Corresponds to the areas of 100-year floodplains that are determined in the FIS by detailed methods. In most instances, BFEs have been derived from detailed hydraulic analyses and are shown in this zone.

**Zone AH** – Corresponds to the areas of 100-year shallow flooding with a constant water-surface elevation. Flood depths of 1-foot (0.3-meter) to 3 feet (0.9-meter) (usually areas of ponding); BFEs are derived from detailed hydraulic analyses and are shown at selected intervals in this zone.

**Zone AO** – Corresponds to the areas of 100-year shallow flooding. Flood depths of 1-foot (0.3-meter) to 3 feet (0.9-meter) (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.

**Zone AR** – Depicts areas protected from flood hazards by flood control structures such as levees that are being restored.

**Zone X** (dotted) – Other flood areas. Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1-foot (0.3-meter) or with drainage areas less

than 1 square mile (2.5 square kilometers [km]); and areas protected by levees from 1% annual chance flood.

**Zone X** – Areas determined to be outside the 0.2% annual chance floodplain.

An overview of the SFHA located along the entire project alignment is provided in Appendix E. The following are detailed discussion of 100-year flood hazards along the alignment:

As shown in Figure 2-4, near the western terminus of the project, portions of the proposed roadway and proposed rail corridor are located in Flood Zone AO. Specifically, this zone extends from approximately Division Street to Sierra Highway, and between Avenue P-4 and Avenue P-8 Here, the project alignment would be elevated more than 6 feet above grade.

The alignment between SR 14 and Division Street is located within Zone X. The alignment from Sierra Highway east to 53rd Street E also traverses Zone X.

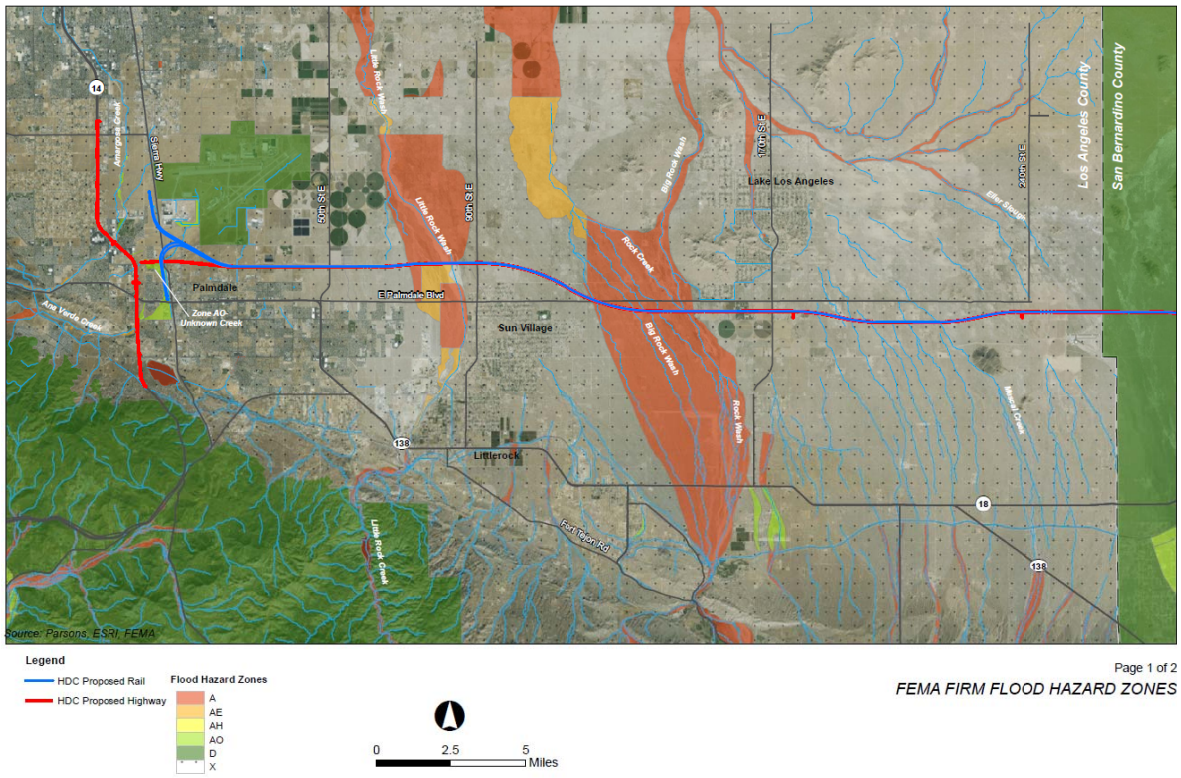


**Figure 2-4. Flood Map- Los Angeles County**

According to Figure 2-4, the proposed roadway and proposed rail corridors between 70th Street E and east of Little Rock Wash are within Flood Zone A (an area inundated by 100-year flooding, for which no base flood elevations [BFEs] have been established). The proposed project is located within Zone X from east of Little Rock Wash to 90th Street E.

According to Figure 2-4, the proposed project alignment extending east from south of E Palmdale Boulevard to Big Rock Wash is located within Zone A.

According to Figure 2-5, the area where the proposed rail and proposed highway corridors cross both  Turner Wash and Ossum Wash is located in Zone D. Where the alignment crosses the Mojave River is labeled Zone AE (a Special Hazard Area inundated by 100-year flooding, for which BFEs have been established).

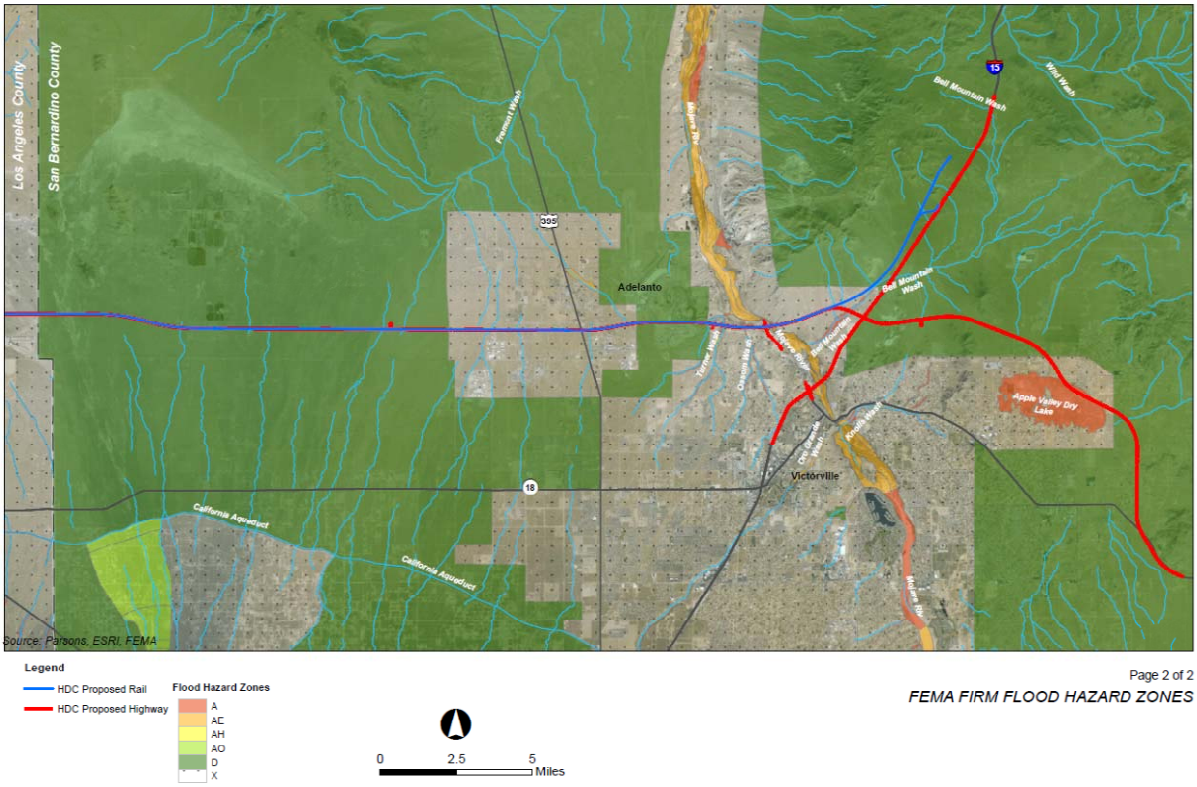


**Figure 2-5. Flood Map – San Bernardino County**

As shown in Figure 2-5, the project alignment across the Bell Mountain Wash to the west of I-15 is within Zone A.

Figure 2-5 shows  the proposed project alignment along the I-15 where direct connectors would be constructed as part of the proposed freeway-to-freeway interchange. The alignment crosses the Mojave River within Zone AE in the vicinity of I-15.

According to Figure 2-5, the alignment from south of S Road to Candlewood Road (west of Joshua Road) is within Zone A.

## Floodplain Mitigation and Risk

It is the intention of this project to minimize floodplain impacts. The HDC profiles were set to protect the roadway from the 100-year storm. For future design considerations, no bridge abutments or embankment would encroach on a regulatory floodway.

The proposed HDC project will adhere to all policies for floodplain management associated with federal, state, and local agencies. Some basic guidelines are:

- Minimize impacts that adversely affect base floodplains;
- Restore and preserve the natural and beneficial floodplain values that are adversely affected;
- Avoid support of incompatible floodplain development; and
- Be consistent with the intent of the Standards and Criteria of the NFIP.

## 2.5 Existing Drainage Pattern

### *2.5.1 Off-site Drainage Crossings*

The off-site drainage pattern crossing the corridor generally flows in a northerly direction. The more-detailed flow pattern is presented in Figures 2-6 through 2-8, which are referred to as Hydrology Maps 1, 2, and 3, respectively.

Off-Site Hydrology Map 1 (Figure 2-6) shows the western portion of the project alignment. As shown, the tributary area within the City of Palmdale (from SR 14 to Little Rock Wash) drains in a northerly direction across the project alignment. The off-site watershed depicted in this area has been divided into 11 subwatersheds, labeled as drainage areas 1 through 11.

As depicted in Map 1 (Figure 2-6), the watershed area from Little Rock Wash to Big Rock Wash drains northwesterly through the Antelope Valley in an alluvial fan formation toward the Rosamond and Rogers dry lakes. This watershed area has been divided into 10 drainage areas, labeled as Drainage Areas 12 through 21.

As shown in Maps 1 and 2 (Figures 2-6 and 2-7), the tributary area from Big Rock Wash to Fremont Wash drains northerly across the project alignment. East of Big Rock Wash, there are numerous streams traversing the project alignment and tributary to Mescal Creek, which flows northwesterly to a dry lake referred to as Lake Los Angeles. Drainage Areas contributing flow to Mescal Creek include Drainage Areas 22 through 43. Farther east, the runoff generally flows in a northeasterly alignment to Fremont Wash within the City of Adelanto. Drainage Areas contributing flow to this stream include those labeled 44 through 55. This wash eventually drains to the Mojave River, as depicted in Figure 2-8.

As depicted in Map 2 (Figure 2-7), from Fremont Wash to I-15, the off-site drainage areas flow to larger streams such as Turner Wash (Drainage Area 56) and Ossum Wash (Drainage Area 57), which both drain to the Mojave River farther to the north. The Mojave River (Drainage Area 58) also flows northerly across the alignment.

Map 3 (Figure 2-8) shows that runoff generated east of I-15 is conveyed to Bell Mountain Wash (Drainage Areas 59 and 60), which flows southerly across the alignment to the Mojave River. Finally, at the east end of the project site, the off-site drainage flows in a southwesterly to westerly direction across the project alignment to Apple Valley Dry Lake (Drainage Areas 61 to 64).

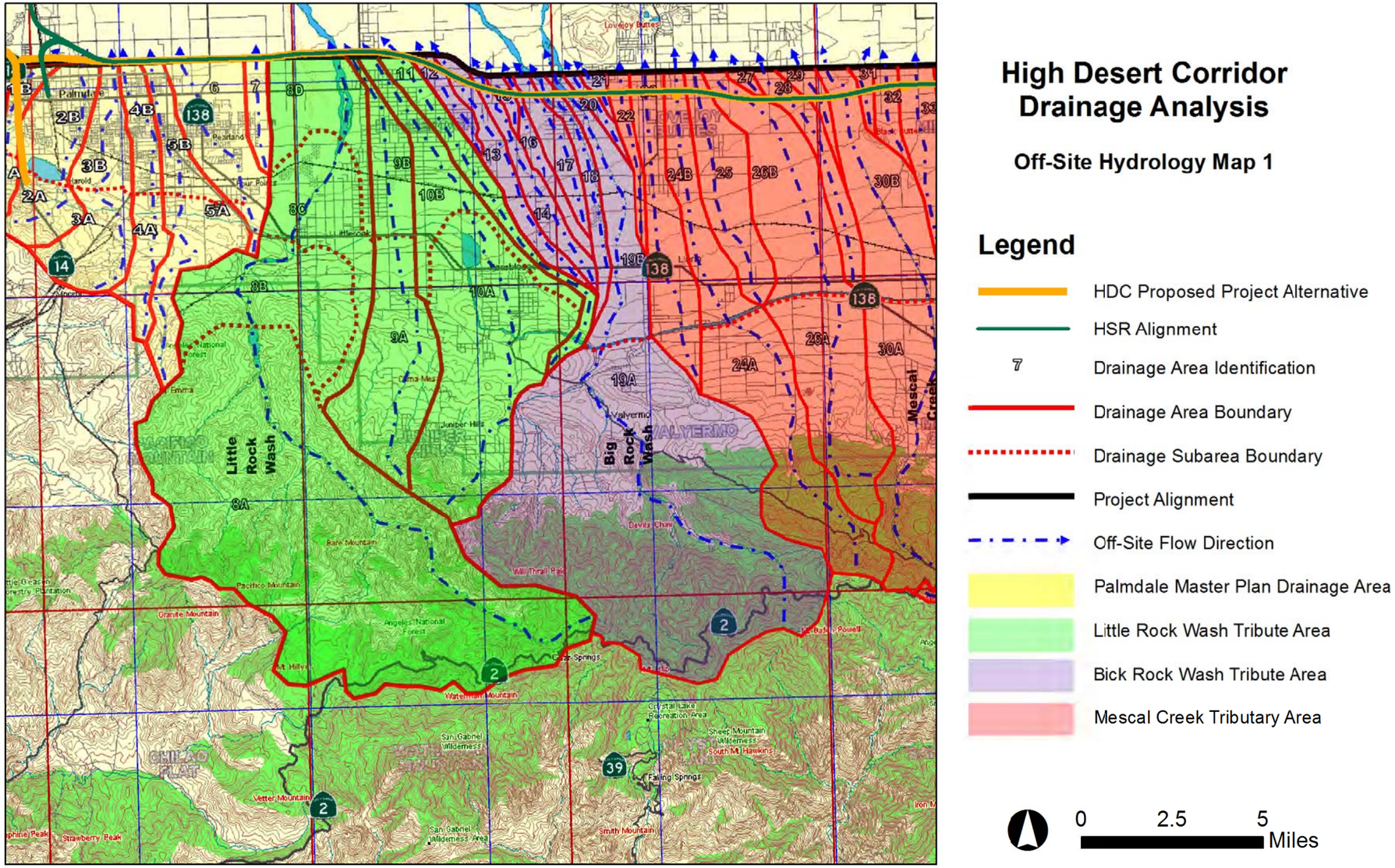


Figure 2-6. Off-Site Hydrology Map 1 – Drainage Pattern West Segment of Project

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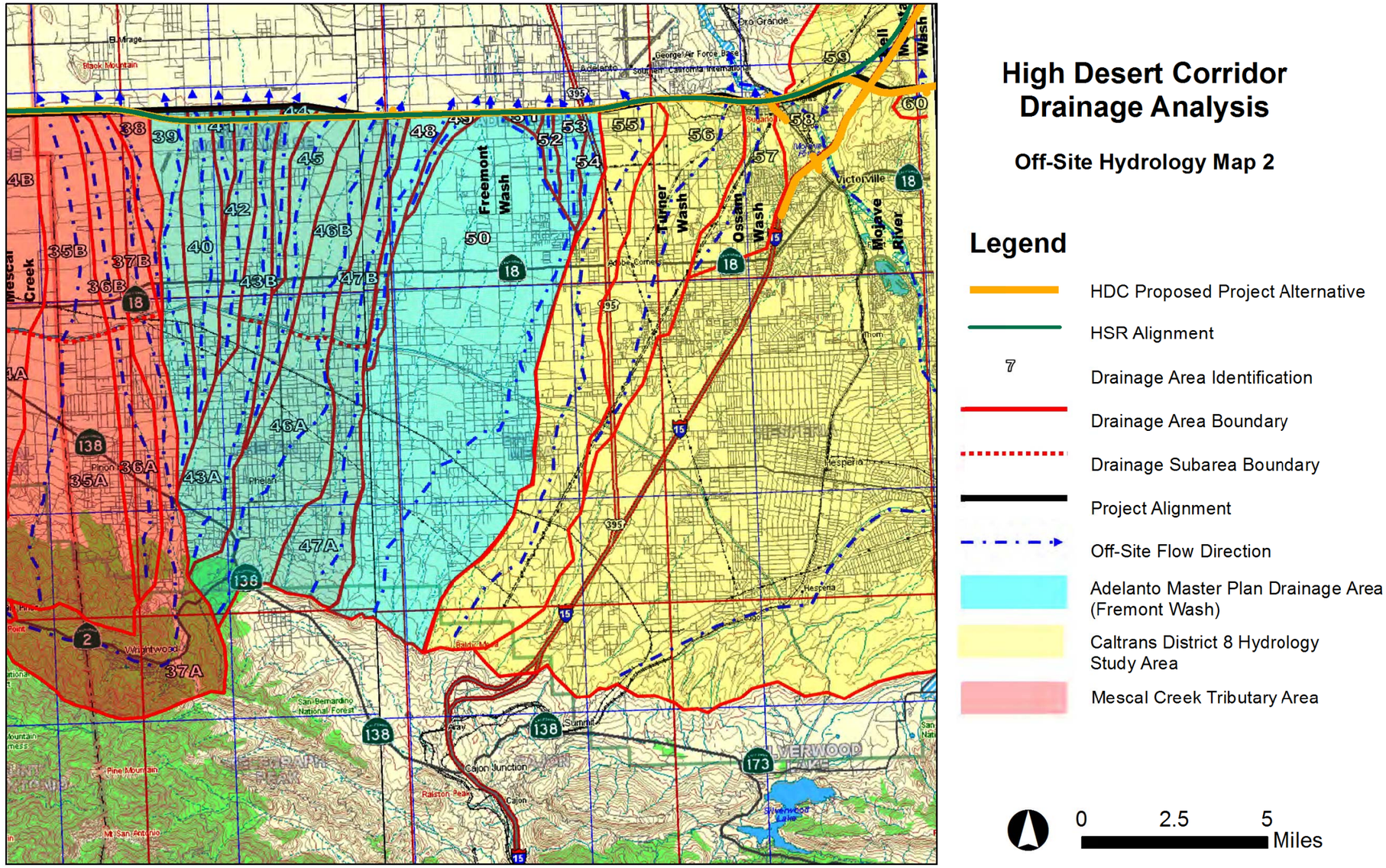


Figure 2-7. Off-Site Hydrology Map 2 – Drainage Pattern Central Segment of Project

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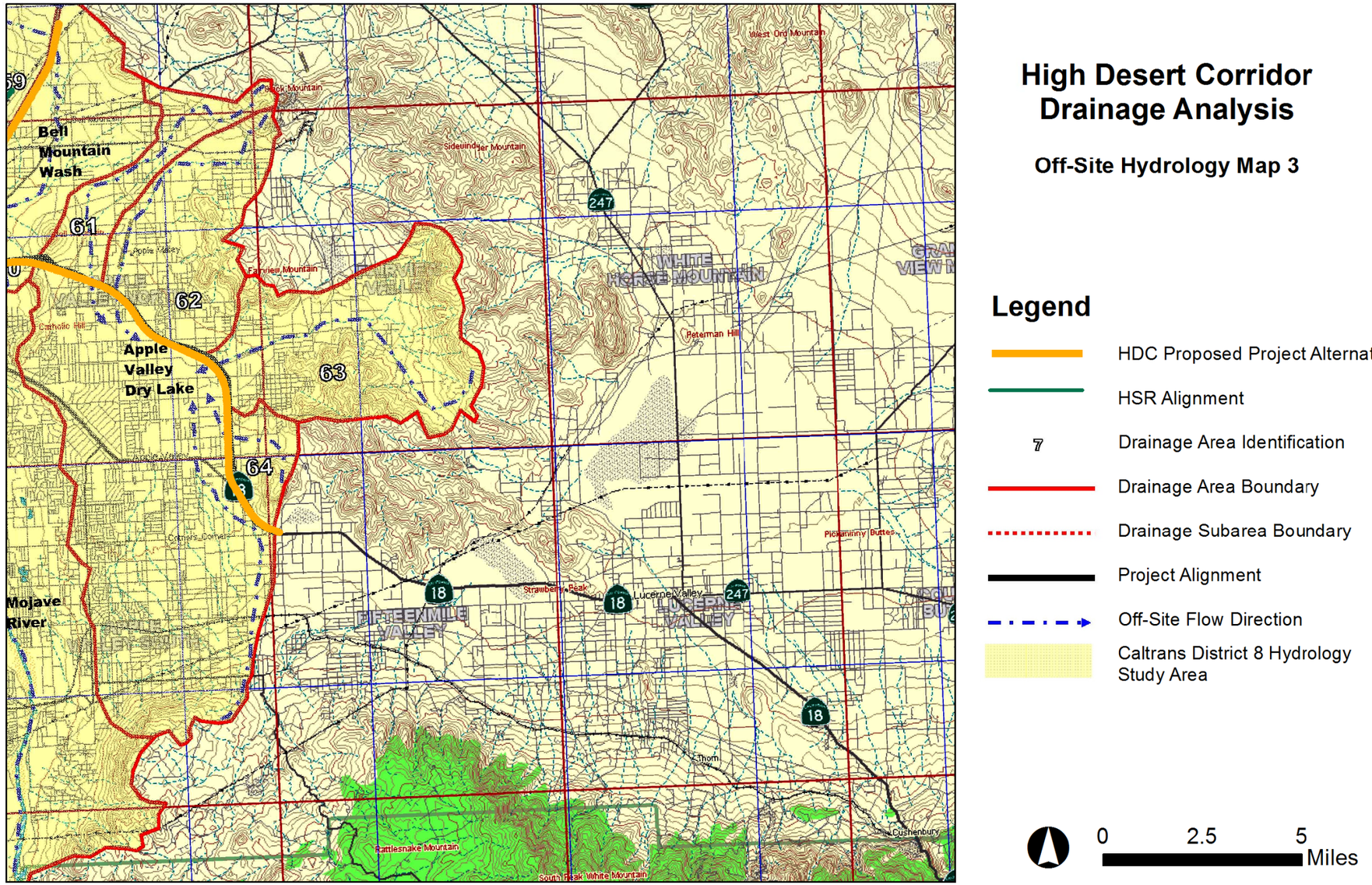


Figure 2-8. Off-Site Hydrology Map 3 – Drainage Pattern East Segment of Project

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**Figure 2-9. Crossings over California Aqueduct near Little Rock Wash**

## 2.5.2 Major Streams

**Little Rock Wash**

The project alignment across Little Rock Wash is located approximately 5 miles downstream of the California Aqueduct (Figure 2-9). The California Aqueduct was built such that there was no interference with the natural flow path of Little Rock Wash in the area just west of 72nd Street E, as well as in the area near Magda Street.

Runoff in Little Rock Wash is generated from the San Gabriel Mountains and its northern foothills that outlet into the Antelope Valley. The wash conveys flow to a closed basin at Rosamond Lake. Northeast of Rosamond Lake is Rogers Lake, which is also a closed basin located east of Rosamond Lake in the northern part of Antelope Valley.

A hydraulic feature associated with Little Rock Wash is the Little Rock Dam. The Little Rock Dam, with a tributary drainage area of 49.2 square miles, is located 8 miles upstream of the alignment and 3 miles south of the California Aqueduct. The Little Rock Dam plays a role in reducing peak flows, as well as serving as a storage feature in the watershed.

**Big Rock Wash**

The proposed alignment would cross Big Rock Wash east of Little Rock Wash. The alignment curves to the northeast past Lovejoy and Alpine buttes, and it eventually forms a common hydrologic system with its sister drainage, flowing to the Rosamond and Rogers Dry Lake Basin. Big Rock Wash is approximately 7.5 miles downstream of the California Aqueduct. Figure 2-10 displays the SR 138 Bridge over Big Rock Wash, 5 miles south of the alignment.

Figure 2-10. Big Rock Wash near SR 138

## Turner Wash

The proposed alignment would cross Turner Wash east of Phantom E, before it drains to the Mojave River, as depicted in Figure 2-11.

## Ossum Wash

Ossum Wash crosses the alignment east of Turner Wash before it drains to the Mojave River, as also shown in Figure 2-11.

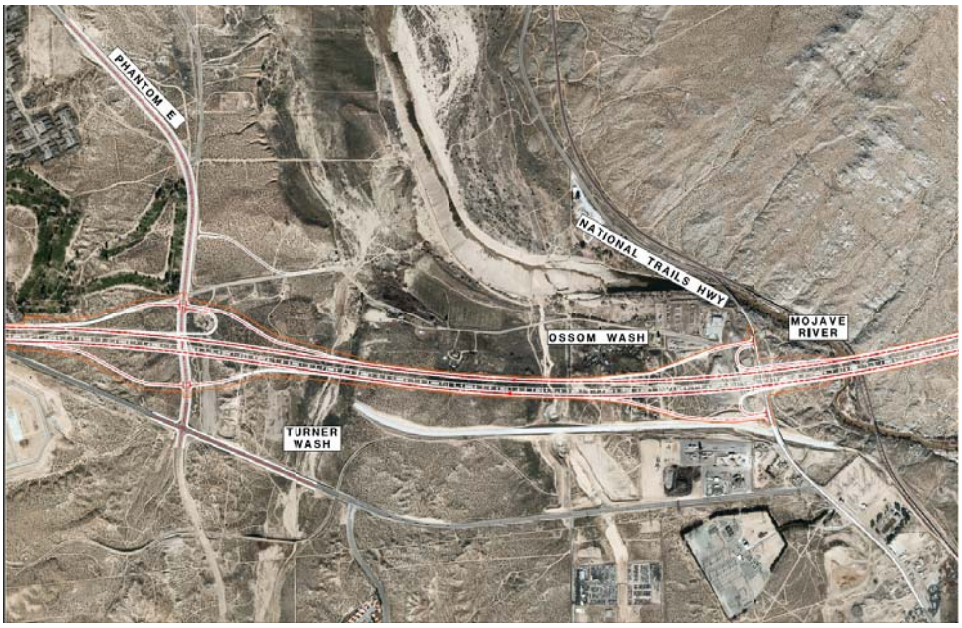


Figure 2-11. Turner Wash, Ossum Wash, and Mojave River

## Mojave River

The Mojave River is, for the most part, an intermittent river that conveys runoff northerly from the eastern San Bernardino Mountains into the Mojave Desert in San Bernardino County. The Mojave River is the largest drainage system in the Mojave Desert. A small section of the river, referred to as the "Narrows," is a perennial stream where groundwater outcrops in the narrow valley adjacent to Victorville throughout the entire year. This is the location of the proposed

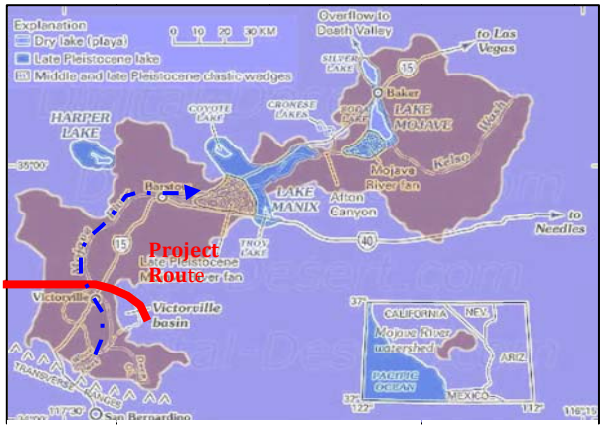


Figure 2-12. Mojave River

crossing of the HDC, as shown in Figure 2-11.

Figure 2-13 shows the bridge over the Mojave River on SR 18 (D Street) near I-15, 1.2 miles south of the alignment.

**Bell Mountain Wash**

Bell Mountain Wash crosses the alignment just west of I-15, east of Turner Wash, before it drains to the Mojave River, as depicted in Figure 2-14.

Figure 2-13. Mojave River at SR 18

Figure 2-14. Bell Mountain Wash at I-15

## 2.6 Hydrologic/Hydraulic Methodology

To evaluate the hydrology of the drainage area within the project site, the HEC-1 hydrologic computer model was employed to develop flow rates used for hydraulic modeling and for sizing of flood control and flow conveyance facilities described in later sections of this report. The HEC-1 program is designed to simulate the surface runoff response of a watershed to precipitation by representing the watershed as an interconnected system of hydrologic and hydraulic components. The hydrologic methodology is based on the U. S. Natural Resource Conservation Service (NRCS) curve number method, which requires the following inputs:

- The tributary area for each drainage basin. Section 2.6.1 explains how the tributary areas are obtained;
- Use of precipitation frequencies to develop a hypothetical storm distribution derived from NOAA, as listed in Appendix C. Because rainfall characteristics vary considerably between the mountainous and foothill sections of the watersheds, storm distributions from Palmdale easterly to Fremont Wash were estimated for each location using the NOAA distributions and were incorporated into the hydrologic models accordingly;

- A curve number (CN), which is a parameter that evaluates precipitation loss within the drainage area through infiltration and storage based on soil type, land use, antecedent moisture condition, and hydrologic condition. The calculation of CN is further discussed below in Section 2.6.2; and

- The time of concentration ($T_C$) for each drainage sub-basin. $T_C$ within Los Angeles County is calculated using the Time of Concentration Calculator provided by the County of Los Angeles as part of their Hydrology Manual. $T_C$ within San Bernardino County is calculated by using the Kerby Equation. The $T_C$ calculation is explained below in Section 2.6.3.

The hydraulic component of this model is based on the kinematic wave equation for hydraulic routing of flows through the downstream sub-basins. The variables include: (1) the cross section of the concentrated flow path, (2) the slope of the flow path, and (3) the roughness coefficient of the flow path. The parameter table is shown in Appendix G, HEC-1 Input Parameters, Undeveloped Drainage Area $T_C$ Calculations, and Composite CNs.

### 2.6.1 Sub-Basin Delineation

Drainage sub-basins were delineated using United States Geological Survey (USGS) topographic mapping superimposed on aerial photogrammetric mapping provided for the HDC Project area. Flow areas and flow paths are shown in Figures 2-6 through 2-8. A total of 77 sub-basins were delineated, each showing areas that cross the proposed alignment corridor at different locations. Note that hydrologic calculations were only conducted for the sub-basins west of Fremont Wash. Flow rates for the sections east of Fremont Wash were obtained from the Caltrans District 8 Preliminary Hydrology Report for the HDC (Appendix A) and the Adelanto DMP (Appendix B).

The California Aqueduct is located between approximately 10 miles south on the east end of the HDC alignment to about 3 miles south on the west end. A photograph of the aqueduct is shown in Figure 2-15.

**Figure 2-15. California Aqueduct near Sierra Highway**

As shown in Appendix F, portions of the watershed tributary to the HDC are located upstream of the California Aqueduct, which traverses along the south side of the Antelope Valley. This facility is generally placed above grade, which causes it to act as a dam to some of the flows generated upstream. During the assessment of the sub-basin areas, however, it was determined that sufficient culvert and channel crossings under the aqueduct (and railroad tracks) exist to prevent flow diversions and impeded flows within the sub-basins. Therefore, the hydrology calculations will

disregard the physical impacts of the California Aqueduct. The locations of the various crossings within the vicinity of the project area are provided in Appendix F.

### 2.6.2 Curve Numbers

Curve numbers for the sub-basins were estimated based on the land use type and the hydrologic soil group (HSG). Most of the upper watersheds were characterized as undeveloped, and in HSG Types B, C, or D, while the lower watersheds were characterized as residential districts with average lot size larger than 2 acres, or as undeveloped in HSG Types A and B along the concentrated flow paths. In general, undeveloped areas within the project vicinity were best characterized as rangeland or open brush in poor to fair condition. The CNs used for characterizing the various land uses throughout the watersheds, and for different HSG types, were obtained from State of California Highway Design Manual, as shown in Table 2-2.

**Table 2-2. NRCS Curve Numbers Used for Hydrologic Analysis**

| Land Use/ Hydrologic Condition | Hydrologic Soil Group | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Range or Open Brush – Poor Condition | 68 | 79 | 86 | 89 |
| Range or Open Brush – Fair Condition | 49 | 69 | 79 | 84 |
| Range or Open Brush – Good Condition | 39 | 61 | 74 | 80 |
| Low-Density Residential (2-acre lots) | 48 | 66 | 78 | 83 |
| Farmsteads | 59 | 74 | 82 | 86 |
| Roads (Hard Surface) | 74 | 84 | 90 | 92 |

Source: State of California Highway Design Manual, 2012.

A composite CN was used for basins with multiple land uses. The composite CN was calculated using an area-weighted average for each CN associated with each land use. The CNs for various sub-basins are provided in Appendix G.

### 2.6.3 Time of Concentration

$T_C$ for the areas within Los Angeles County was computed using the $T_C$ Calculator provided in the County of Los Angeles Hydrology Manual. This calculator includes the following input parameters: (1) Tributary Area, which could be obtained by the method described in Section 2.6.2; (2) Impervious Percentage (percent impervious, which varied from 1 to 20 percent within the watershed); (3) Soil Type from the Isohyet Maps obtained from the Hydrology Manual as shown in Appendix G; (4) Rainfall Isohyet found in Appendix G; (5) Flow Path Length; and (6) Flow Path Slope.

$T_C$ for the areas east of Little Rock Creek in San Bernardino County were estimated using the Kerby Equation, which solves for the $T_C$ given flow path length, slope, and a retardance roughness coefficient dependent on land use.

The results range from 0.9 to 5.1 hours for the various sub-basins. Calculations are provided in Appendix G.

### 2.6.4 Results

The input parameters used in the HEC-1 hydrologic model are provided for each sub-basin in Appendix G. The output results for the hydrologic modeling are provided in Appendix H. Hydrologic maps showing the flow rates used for all the drainages crossing the alignment are also provided in Appendix H.

As a check, the flow rates obtained from the HEC-1 models were compared with preliminary flow rates computed by District personnel and were found to vary, in most cases, by only 0 to 5 percent. This level of accuracy between two different hydrologic modeling techniques is very good.

# 3 HYDRAULICS

## 3.1 Overview of Hydraulic Structures

### 3.1.1 Off-Site System

In general, the roadway would be constructed on fill, and the proposed alignment would be elevated approximately 5 to 6 feet above grade. In Palmdale, the alignment would pass the floodplain at the connection with SR 14, as shown in Figure 2-5. Within this area, as shown in the Drainage Layout Plans in Appendix N, the roadway profile is significantly higher than 6 feet above grade. Infiltration basins, earthen and concrete channels, bridges, cross culverts, storm drain pipelines and inlets, riprap energy dissipation devices, and other forms of erosion protection will be constructed so that runoff will be intercepted and conveyed along and across the roadway alignment without the need of pump stations, while minimizing erosion potential. In most cases, these facilities will be placed at or above grade, though in some instances, the facilities may be constructed in cut as long as gravity flow conditions are maintained downstream. Existing slopes are relatively flat, less than 2 percent on average. Proposed slopes will generally follow existing grade. Swales and channels will be constructed as flat as possible to minimize erosive flow velocities while maintaining appropriate conveyance capacities. Embankment slopes shall not be steeper than 2:1 (horizontal to vertical) and will be constructed at 4:1 or flatter to the maximum extent practicable.

### 3.1.2 Design Methodology

As discussed in Section 2.5, runoff generally crosses the proposed project corridor in a northerly direction. Facilities would be designed for the 100-year storm event to prevent flooding of the proposed roadway and potential flooding upstream and downstream of the roadway. Two alternatives enabling flood flows to cross the freeway are to: (1) mimic existing flow conditions by placing cross culverts at existing flow concentration points along the alignment and, where applicable, construct infiltration basins upstream to reduce runoff through the culvert; or (2) place longitudinal channels along the alignment to divert existing flow to crossings. Because flow diversion would exacerbate downstream flooding conditions and cause associated erosion, the first alternative was chosen as the recommended concept for flood and erosion control along most of the project alignment.

Culverts were sized for the 100-year storm flow without producing objectionable backwater effects (maximum headwater of approximately 5 feet) and placed at slopes that would minimize downstream velocities[1]. They were sited at concentrated flow paths along the alignment as dictated by topography. At this preliminary level, culverts were generally assumed to be reinforced concrete box construction with a minimum height of 3 feet to reduce clogging potential due to sediment buildup. The culverts were placed such that a minimum of 2 feet of cover over each culvert could be maintained. The cross culverts were

[1] Hydrologic and hydraulic calculations for each culvert are provided in a separate document.

placed to intercept flow at the upstream toe of embankment and convey the flow perpendicularly across the road to the downstream toe of embankment. Culvert lengths were estimated assuming embankment slopes of 4:1. Each culvert was equipped with inlet/outlet headwalls and downstream energy dissipaters in the form of riprap pads. Numerous channels and ditches will also be placed at the edge of right-of-way along the alignment to convey off-site flows to the proposed bridge crossings and cross culverts. Certain culverts are also being used as wildlife crossings requiring heights varying from 3-ft to 6-ft in various areas along the alignment and minimum widths of 7-ft. Wildlife corridors are shown in Appendix J.

### 3.1.3 On-Site System

Based upon the Preferred Alternative, the total impervious surface area for the proposed 63-mile corridor is estimated at approximately 1,660 acres. The proposed project would replace sections of roadway along SR 18 in the town of Apple Valley at the east end of the proposed project corridor and sections of roadway within the City of Palmdale at the west end of the corridor. The existing impervious surface along the entire 63-mile corridor was estimated to be approximately 220 acres; hence, the proposed additional impervious surface area for the Preferred Alternative was estimated as 1,440 acres. Therefore, as a result of the increased impervious area, an increase in runoff will be exhibited within the various watersheds traversed by the corridor. Because the soils are relatively pervious and groundwater is relatively deep, the installation of infiltration basins is practical. The on-site drainage systems along the alignment will therefore incorporate flow control devices, such as infiltration basins, to mitigate the potential increase in flow that could occur due to increases in impervious surface areas. Infiltration basins are proposed at most of the interchanges to treat stormwater runoff generated from impervious surfaces and for flow control so that flow rates will mimic existing conditions for both high and low flows. An estimate of quantities and cost for the on-site drainage systems is provided in Appendix O.

HSR facilities would be constructed within the HDC ROW. It is assumed that the hydrologic modeling analysis conducted for the Freeway/Expressway Alternative would also apply to the proposed HSR Feeder/Connector Service alternative. Similarly, the drainage facilities (e.g., bridges, cross-culverts, infiltration basins) and BMPs proposed would also address potential hydrology and hydraulic impacts associated with construction and operation of the Preferred Alternative.

The impact of a HSR Feeder/Connector Service option, as it relates to drainage facilities, was analyzed as a part of this report. Cross -culvert locations, infiltration basin sizes, and roadway crossings were modified to accommodate the HSR Feeder/Connector Service. Culverts were designed with concrete bottoms in order to withstand structural and vibratory issues related to the HSR Feeder/Connector Service. Conceptual drawings of drainage facilities for the HSR Feeder/Connector Service are included in Appendix N.

### 3.1.4 HSR Drainage Facilities

Seven drainage conveyance scenarios have been identified for the HSR:

- Aerial Structure – Would cross large water bodies. Columns would typically be located outside the floodway. Deck drains would collect runoff from the bridge deck.
- Culvert Crossings – Would convey drainage across the tracks by pipes or reinforced concrete box structures.
- Tunneling under Water Bodies – Would minimize impacts to existing water bodies.
- Drainage Channels/Ditch – Would convey longitudinal flows and onsite flows to a cross drainage.
- Under Drains – Would capture flows under the ballasts at retained sections and restrained areas.
- Pump Stations – Would dispose of drainage at cut section, trench section, tunnels, and roadway sag areas if gravity flow cannot be achieved.
- Retention/Detention Basins – Would be utilized as necessary to attenuate peak flows and/or infiltrate flows.

#### AERIAL SEGMENTS

Bridges are proposed to cross major rivers as shown in Figure 3-1. A 2 feet minimum freeboard would be provided between the 100-year water surface elevation and lowest bridge soffit elevation.

The bridge deck drainage system includes the bridge deck, bridge gutters, inlets, pipes, downspouts, and bridge end collectors. A longitudinal drainage system would be provided along the deck to minimize standing water on the bridge structure.

Where the drainage ditches are not feasible or if the runoff exceeds the available capacity of the ditches, deck drainage design may include a sufficient number of inlets, pipes, and downspouts to collect, convey and drain the entire deck. Inlets would be provided at intervals to collect the flow into the storm drainage system.

Where the elevated guideway passes over developed urban corridors with existing impervious surfaces, rainwater would be collected via inlets and conveyed down support columns to the existing storm drainage system with approval from jurisdictional authorities. An analysis of the receiving drainage system must be carried out to assure there is adequate capacity. Where sufficient capacity to accommodate project runoff is found to be lacking, additional capacity would need to be added. Alternatively, onsite retention/ detention could be pursued if adequate right-of-way exists.

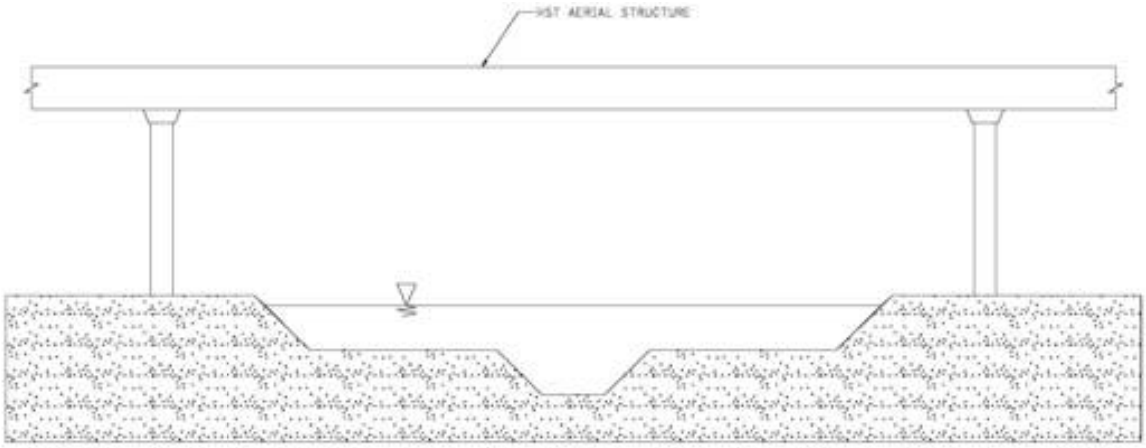


**Figure 3-1 Example of Aerial Structures over Water Bodies**

## AT-GRADE SEGMENTS

The at-grade track would be ballasted. Depending on local topography, the ballast may be placed in the form of an embankment having a typical height ranging approximately 4 to 10 feet (1.2 to 3 m). Rainfall would percolate through the rail ballast, and it would likely flow laterally out from the subballast and into a ditch or under drain system.

The onsite storm drainage system would consist of open ditches and/or under drains placed at the outer sides of the track bed. The main focus in designing an open ditch for this project is to provide hydraulic capacity for the storm runoff while maintaining freeboard between the 100-year base flood elevation and the subballast. Trackside ditches are typically a minimum 4-foot flat bottom trapezoidal shape and would be deep enough and sized for handling the design runoff anticipated while allowing the subgrade to drain.

The use of under drain pipes would be utilized in retained sections or constrained areas where ditches cannot be constructed.

Water from the open ditches and under drains would either enter the local storm drain system or directly enter into the offsite drainage systems. The use of ditches, as shown in Figure 3-2, is preferred rather than under drain systems for at-grade sections.

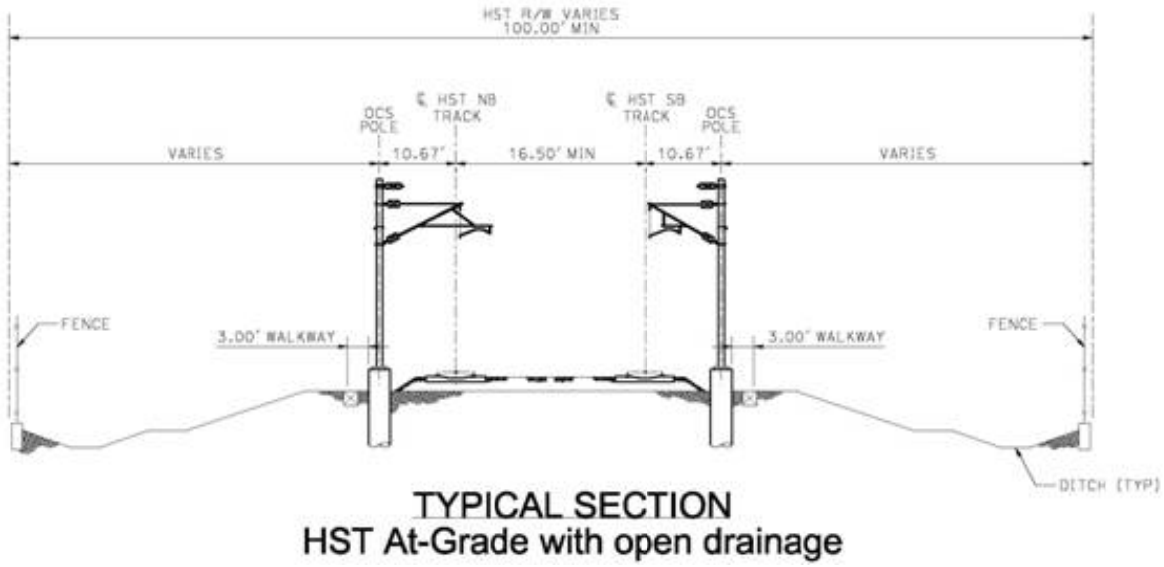


Figure 3-2 Drainage Ditch Adjacent to Track

## TRENCH SEGMENTS

The trench segments would be below grade and have trench walls to retain the earth behind them (Figure 3-3) and with concrete slabs connecting the walls. Rainfall would be carried through a drainage system on or within the concrete slab and discharge to a sump at the low point of the trench and will be pumped out from the sump to a drainage system outside the trench. Longitudinal ditches along the top of the retaining wall would be required to intercept and collect offsite drainage away from the trench section. Note that there are no trench segments in the current design.

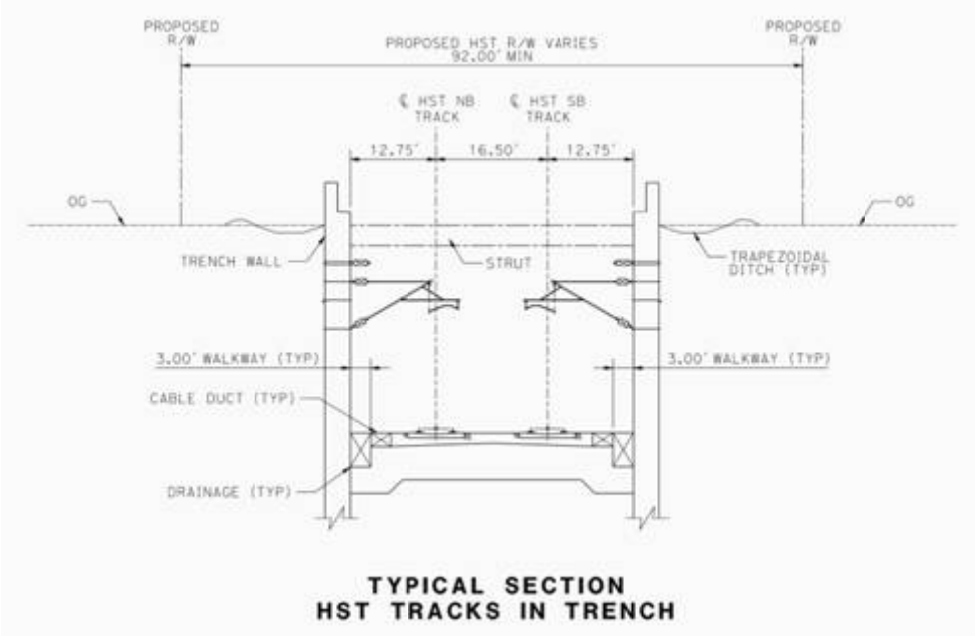


Figure 3-3 Trench Typical Section

### TUNNEL SEGMENTS

Tunnel segments do not typically encounter surface runoff as in other segments shown above. Tunnels, however, would require a means of collecting and disposing of water should it enter the tunnel via groundwater, upstream track way leading to the tunnel, or potential fire extinguishing activities inside the tunnel. Tunnel segments would be direct fixation.

## 3.2 Bridge Hydraulics

Bridges are proposed over the deeper streams, such as Little Rock Wash, Big Rock Wash, Turner Wash, Ossum Wash, and Mojave River. These major streams were discussed in Section 2.5.2. Cross culverts are proposed at the other waterways traversed by the project alignment, including Grandview Canyon Creek, Graham Canyon Creek, Mescal Creek, Fremont Wash, and Bell Mountain Wash.

### *3.2.1 Bridge Design Methodology*

The bridges would be designed to minimize impacts to the upstream and downstream water surface elevations, flow velocities, and overall streambed and embankment configurations. To analyze the impacts to these washes from the proposed project, the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) model was used. The goal of using the HEC-RAS model for this application was to: (1) analyze how the proposed project would affect the flow of the major streams and (2) provide hydraulic data required for bridge design.

Bridge hydraulic analysis was conducted for the 100-year storm event flow ($Q_{100}$) for the bridges crossing Little Rock Wash, Big Rock Wash, Turner Wash, Ossum Wash, and Mojave River for a minimum distance of 500 feet upstream and downstream of the proposed improvements (Table 3-1). The 100-year flow rates were obtained from the HEC-1 model output, as shown in Appendix H.

**Table 3-1. Q100 Flow Rates from HEC-1 Output**

| Stream Name | $Q_{100}$ (cfs) |
|---|---|
| Little Rock Wash | 22,944 |
| Big Rock Wash | 17,268 |
| Turner Wash | 5,299 |
| Ossum Wash | 2,178 |
| Mojave River | 27,484 |
| Bell Mountain Wash | 10,704 |
| Stream at Coughlin Road and Off-ramp* | 2,238 |
| Stream at Koala* | 1,250 |
| Stream at Bellflower* | 146 |
| Stream US 395* | 87 |
| Joshua Wash* | 2,169 |

*HEC-RAS Hydraulic Analysis were not performed for these minor streams. Bridges are assumed to span over these washes.

Within the upstream and downstream study reach limits, the boundary conditions were assumed to be normal depth within the streams. The HEC-RAS model geometric cross-sections input and hydraulic output results are listed in Appendix I. A baseline HEC-RAS hydraulic model of the study reach was first created to represent the existing conditions of each water course, with cross sections taken from recent topographic mapping including aerial and field surveys. A post-project conditions model was then generated to analyze the proposed conditions by inserting the proposed bridge to the baseline model. Ineffective flow areas were added both upstream and downstream of the bridge to model the flow transitions. All models were run in the mixed-flow condition. The resulting water surface elevation from each cross section was then plotted and the roadway profile adjusted to maintain the Caltrans freeboard criterion of 2 feet. The HEC-RAS model results show that construction of the bridges will impose no significant rise in the BFEs. The flow rates, bridge configurations, flow velocities, and flow depths at each location are described below.

### 3.2.2 Little Rock Wash

A roughness coefficient of 0.05 was used for the entire floodplain in this area, which is indicative of floodplains with light to medium brush, as found in the project area. A 15-span, 3,000-foot-long bridge with vertical faced abutments (skewed 20 degrees to follow the alignment of the creek) and a pier width of 7 feet has been proposed for crossing the waterway.

For a 100-year flood event, the flow rate ($Q_{100}$) was determined to be 22,944 cfs; the flow velocity ($V_{100}$) ranges from 2 to 4 feet per second (fps), exhibiting little to no scour potential; the flow depth ranges from 2 to 4 feet; and the maximum rise in water surface elevation is 0.97-foot upstream of the bridge at Station 1079+00, which is within the acceptable limits of the Federal Emergency Management Agency (FEMA) guidelines. The comparison table is shown in Appendix K.

**Impact of Little Rock Creek Dam**

The Little Rock Creek Dam, with a tributary drainage area of 49.2 square miles, is located approximately 8 miles upstream of the HDC and 3 miles south of the California Aqueduct. The dam's effectiveness in reducing peak flows was evaluated using HEC-1 modeling software.

Incorporating the Little Rock Creek Dam into the hydrologic model for the Little Rock Wash reduced the peak 100-yr flow rate to 20,000 cfs; down from 22,944 cfs when the model is run without the dam. Given that the dam is also used as a reservoir, the availability of the total storage capacity cannot be guaranteed. At this level of design it would be more prudent to remain somewhat conservative in the bridge design. Therefore, a separate HEC-RAS model with reduced flow rates was not prepared for this condition.

The HEC-1 model incorporating the Little Rock Creek Dam is included in Appendix H

### 3.2.3 Big Rock Wash

The overbanks were modeled with a Manning's roughness coefficient of 0.04 to simulate slightly less vegetative growth than at Little Rock Wash. A 9-span, 1,800-foot-long bridge

with vertical faced abutments (skewed to follow the alignment of the creek) with a pier width of 7 feet has been proposed for crossing the waterway.

For a 100-year flood event, the $Q_{100}$ was computed as 17,268 cfs; the $V_{100}$ ranges from 4 to 5 fps; the flow depth is approximately 2 feet; and the maximum rise in water surface elevation is 0.2-foot. A roughness coefficient of 0.03 was used for the main channel because field observations indicate that this area is more channelized than Little Rock Wash. Relatively well-graded sandy soils and much less vegetation growth is exhibited within the channel.

### 3.2.4 Turner Wash

A roughness coefficient of 0.04 was used for the main channel and 0.065 for the overbanks because field observations indicate that the channel is fairly well defined with some light brush, while the overbanks include much taller vegetation. A single-span, 180-foot-long bridge is proposed at approximately Station 1049+30.

The $Q_{100}$ was computed as 5,299 cfs; the $V_{100}$ ranges from 9 to 13 fps (higher scour potential than Little Rock Wash and Big Rock Wash); the flow depth ranges from 2 to 3 feet; and the maximum rise in water surface elevation is approximately 0.2-foot.

### 3.2.5 Ossum Wash

A roughness coefficient of 0.04 was used for the main channel and 0.065 for the overbanks because field observations indicate that the channel is fairly well defined with some light brush, while the overbanks include much taller vegetation. A single-span, 100-foot-long bridge is proposed at approximately Station 1081+50.

The $Q_{100}$ was computed as 2,178 cfs; the $V_{100}$ ranges from 9 to 10 fps at the bridge (higher scour potential than Little Rock Wash and Big Rock Wash); the flow depth ranges from 4 to 7 feet; and the maximum rise in water surface elevation is approximately 0.7-foot.

### 3.2.6 Mojave River

A roughness coefficient of 0.04 was used for the main channel and 0.065 for the overbanks because field observations indicate that the channel is very well defined, characterized by short vegetation along the bottom and toe of slope, with rock outcroppings along the upper embankment and along the overbanks. A 3-span (80-foot, 150-foot, and 90-foot each), 320-foot-long bridge with vertical faced abutments and a pier width of 7 feet is proposed approximately at Station 1124+00.

The $Q_{100}$ was calculated as 27,484 cfs; the $V_{100}$ ranges from 6 to 7 fps; the flow depth ranges from 17 to 20 feet; and the maximum rise in water surface elevation is approximately 0.2-foot.

# 3.3 Cross Culverts

## 3.3.1 Cross Culvert Design Methodology

The proposed HDC alignment is at least 5 to 6 feet above grade and acts as a dam to upstream runoff. Cross culverts are placed to minimize flow diversions and to mimic existing flow conditions along the project alignment. The culverts would enable runoff to cross the freeway without inundating the paved surface and without flooding upstream and downstream properties. Each culvert would be designed with inlet/outlet headwalls. Energy dissipaters, in the form of vegetated riprap pads, would be incorporated at the downstream ends of the cross culverts to slow flows to non-erosive levels where necessary. In general, cross culvert slopes are flat enough (on the order of 0.2 to 0.5 percent slope) to prevent velocities from rising too high. To address agency concerns regarding establishment of vegetation where riprap is to be used, construction of such energy dissipation devices should include placement of 1-foot of topsoil above the riprap that will be "flood compacted" to fill the voids within the underlying riprap. The flood compacting will cause the fill soil to enter the interstices of the riprap, thus allowing vegetation to grow.

The hydraulic analysis for sizing each cross culvert was conducted using the CulvertMaster program and the summary output from this model is provided in Appendix K. CulvertMaster by Bentley Corporation is a culvert hydraulic software that uses the energy equation and laws of hydraulic continuity to analyze and design culverts. Table 3-2 provides a synopsis of the proposed cross culverts located throughout the alignment. Note that at this preliminary level, only concrete box culverts and reinforced concrete pipe culverts have been evaluated. Culverts were designed with concrete bottoms in order to withstand structural and vibratory issues related to the HSR Feeder Service Alternative.

If soft bottoms are required, the allowance for a small amount of silt buildup in the culvert floor has been incorporated into the design, though silt buildup beyond one foot should not be allowed. The minimum height for each culvert is 3 feet. This will ensure maintainability of the culverts if silt buildup occurs and enable small wildlife to cross the alignment. At certain locations, culverts were increased in height by 5- and 6-feet in order to allow for larger wildlife to cross the HDC. The wildlife corridor used in the design for the culvert heights is shown in Appendix J. Hydraulics for each cross-culvert are shown in Appendix K.

Cross culverts have been sized to accommodate the 100-year storm event flow without inundating the freeway or causing objectionable flooding outside the freeway right-of-way. The flow rates were taken from the flows generated by the HEC-1 model provided in Hydrology Maps 1, 2, and 3, which are included in Appendix H. In some cases, several culverts were sited along the corridor at the outlet of a sub-basin. In these instances, the flow rates shown for the sub-basin were divided into the number of culverts conveying flow across the freeway for the particular sub-basin. These sub-divided flows were then used for the sizing of the culverts. Approximately 140 cross culverts are proposed along the corridor. The cross culverts are shown in the Drainage Layout Plans provided in Appendix N. An estimate of quantities and cost for the cross-culverts is provided in Appendix O.

Cross culverts located beneath the HSR require a minimum cover of 6-feet. For the most part, cross culverts shown in the non-HSR alternative were also able to meet the HSR requirement in the HSR alternative; those that did not were relocated to more suitable areas. A separate hydrologic analysis, reflecting the relocated culverts, was not performed as a part of this study. It is assumed that the capacity of the overall cross-culvert system will not change as a result of these modifications.

## 3.4 Infiltration Basins

The design criterion for infiltration basins in an urban area is to size the basin to contain the runoff generated by two 10-year frequency storms of 24-hour duration. Ideally, all basins should have 2 feet of freeboard. Within the clear recovery area, the basin water depth is limited to 3 feet. If the water is deeper than 3.6 feet, then basin fencing is required. The preferred side slope is 1:4 or flatter. If the slope is greater than 1:4, concurrence from Maintenance is required. The preferred bottom width or length is a minimum of 45 feet. For side ditches or longitudinal basins along the side of the travel way, the depth of water is limited to 3 feet. No freeboard is necessary, but if the basin overtops, the roadway cannot be flooded. In all cases, damage as a result of basin overtopping must be evaluated; therefore, it is prudent to provide a spillway to permit excess runoff to safely drain from the basin.

**Table 3-2. Proposed Culvert Crossings**

| Station | Description | Flow (cfs) | Station | Description | Flow (cfs) | Station | Description | Flow (cfs) |
|---|---|---|---|---|---|---|---|---|
| 270+75 | (4) 7'x3' RCB | 314 | 966+20 | (3) 7'x3' RCB | 500 | 1884+00 | (1) 8'x6' RCB | 271 |
| 276+00 | (1) 12'x8' RCB | 1215 | 1015+50 | (1) 7'x3' RCB | 77 | 1904+00 | (1) 8'x6' RCB | 100 |
| 287+50 | (3) 7'x3' RCB | 284 | 1049+55 | (1) 10'x5' RCB | 100 | 1928+00 | (2) 8'x6' RCB | 700 |
| 329+39 | (4) 7'x3' RCB | 338 | 1068+05 | (1) 10'x5' RCB | 97 | 1942+00 | (2) 7'x3' RCB | 300 |
| 330+04 | (1) 6'x6' RCB | 254 | 1093+49 | (1) 7'x3' RCB | 110 | 1965+00 | (1) 8'x6' RCB | 326 |
| 330+89 | (4) 7'x3' RCB | 340 | 1109+53 | (1) 10'x5' RCB | 360 | 2030+00 | (1) 8'x6' RCB | 136 |
| 349+00 | (4) 7'x3' RCB | 308 | 1144+54 | (2) 8'x6' RCB | 900 | 2055+00 | (1) 8'x6' RCB | 330 |
| 352+50 | (4) 7'x3' RCB | 291 | 1159+76 | (3) 10'x8' RCB | 1979 | 2076+00 | (2) 10'x6' RCB | 835 |
| 365+00 | (4) 7'x3' RCB | 345 | 1164+55 | (3) 10'x8' RCB | 1729 | 2096+00 | (3) 10'x6' RCB | 1536 |
| 383+50 | (7) 7'x3' RCB | 687 | 1176+49 | (2) 8'x6' RCB | 1200 | 2157+76 | (1) 8'x4' RCB | 200 |
| 385+00 | (4) 7'x3' RCB | 261 | 1183+44 | (3) 8'x6' RCB | 1100 | 2215+76 | (1) 6'x6' RCB | 246 |
| 399+39 | (4) 7'x3' RCB | 336 | 1189+00 | (3) 8'x6' RCB | 410 | 2235+87 | (7) 10'x8' RCB | 4725 |
| 403+00 | (4) 7'x3' RCB | 336 | 1200+00 | (1) 8'x6' RCB | 763 | 2251+16 | (6) 12'x7' RCB | 4350 |
| 408+65 | (1) 8'x6' RCB | 1718 | 1216+00 | (2) 8'x6' RCB | 763 | 2301+24 | (1) 7'x3' RCB | 60 |
| 414+93 | (1) 8'x6' RCB | 43 | 1220+00 | (2) 8'x6' RCB | 700 | 2305+44 | (1) 5'x3' RCB | 40 |
| 420+79 | (4) 7'x3' RCB | 279 | 1225+00 | (3) 8'x6' RCB | 1035 | 2311+04 | (1) 8'x6' RCB | 40 |
| 439+19 | (3) 7'x3' RCB | 127 | 1265+00 | (1) 6'x6' RCB | 131 | 2328+76 | (1) 7'x3' RCB | 146 |
| 456+67 | (4) 10'X6' RCB | 859 | 1285+00 | (1) 6'x4' RCB | 131 | 2553+00 | (1) 7'x3' RCB | 100 |
| 464+07 | 48" RCP | 80 | 1305+00 | (1) 6'x6' RCB | 131 | 2772+53 | (9) 12'x8' RCB | 10704 |
| 473+50 | (1) 7'x3' RCB | 85 | 1311+00 | (1) 7'x3' RCB | 104 | 1569+55 | (4) 7'x3' RCB | 726 |
| 507+79 | (1) 7'x3' RCB | 85 | 1320+00 | (1) 7'x3' RCB | 104 | 1581+19 | (4) 7'x3' RCB | 726 |

**Table 3-2. Proposed Culvert Crossings**

| Station | Description | Flow (cfs) | Station | Description | Flow (cfs) | Station | Description | Flow (cfs) |
|---|---|---|---|---|---|---|---|---|
| 518+05 | (1) 10'x9' RCB | 1032 | 1360+00 | (2) 10'x6' RCB | 924 | 1585+00 | (3) 10'x5' RCB | 1238 |
| 519+19 | (1) 7'x3' RCB | 85 | 1364+00 | (3) 10'x8' RCB | 2100 | 1590+00 | (2) 10'x6' RCB | 726 |
| 532+49 | (1) 7'x3' RCB | 85 | 1377+00 | (3) 8'x6' RCB | 900 | 1592+52 | (4) 7'x3' RCB | 726 |
| 570+31 | (4) 7'x3' RCB | 428 | 1385+00 | (3) 8'x6' RCB | 900 | 1599+00 | (4) 7'x3' RCB | 697 |
| 573+33 | (4) 7'x3' RCB | 428 | 1397+00 | (1) 7'x3' RCB | 100 | 1606+41 | (4) 7'x3' RCB | 697 |
| 691+00 | (5) 10'x5' RCB | 1470 | 1428+00 | (1) 6'x6' RCB | 198 | 1610+00 | (4) 7'x3' RCB | 697 |
| 694+00 | (5) 10'x5' RCB | 1470 | 1435+00 | (1) 6'x6' RCB | 46 | 1615+00 | (4) 7'x3' RCB | 697 |
| 696+67 | (5) 10'x5' RCB | 1470 | 1473+00 | (1) 6'x6' RCB | 46 | 1620+00 | (4) 7'x3' RCB | 697 |
| 699+31 | (5) 10'x5' RCB | 1470 | 1507+86 | (2) 7'x3' RCB | 277 | 1623+82 | (4) 7'x3' RCB | 697 |
| 701+97 | (5) 10'x5' RCB | 1470 | 1543+89 | (2) 8'x6' RCB | 722 | 1633+21 | (4) 7'x3' RCB | 697 |
| 704+64 | (5) 10'x5' RCB | 1470 | 1567+89 | (2) 8'x6' RCB | 700 | 1640+75 | (4) 7'x3' RCB | 697 |
| 707+32 | (5) 10'x5' RCB | 1470 | 1598+95 | (3) 10'x8' RCB | 1732 | 1650+11 | (4) 7'x3' RCB | 697 |
| 710+43 | (4) 7'x3' RCB | 451 | 1611+89 | (2) 10'x6' RCB | 950 | 1655+00 | (3) 7'x3' RCB | 559 |
| 717+69 | (4) 7'x3' RCB | 451 | 1621+89 | (2) 10'x6' RCB | 950 | 1660+00 | (3) 7'x3' RCB | 559 |
| 722+87 | (4) 7'x3' RCB | 451 | 1629+95 | (4) 10'x6' RCB | 1800 | 1666+25 | (3) 7'x3' RCB | 559 |
| 728+55 | (1) 10'x5' RCB | 451 | 1643+92 | (3) 8'x6' RCB | 1048 | 1770+24 | (3) 7'x3' RCB | 559 |
| 760+96 | (2) 10'x5' RCB | 651 | 1667+91 | (4) 8'x4' RCB | 800 | 1774+40 | (3) 7'x3' RCB | 559 |
| 772+62 | (5) 7'x3' RCB | 651 | 1683+11 | (2) 10'x8' RCB | 1237 | 1776+45 | (3) 7'x3' RCB | 559 |
| 780+23 | (5) 7'x3' RCB | 651 | 1691+53 | (2) 10'x8' RCB | 1237 | 1787+00 | (3) 7'x3' RCB | 559 |
| 804+16 | (1) 10'x5' RCB | 247 | 1706+00 | (2) 10'x8' RCB | 1237 | 1893+52 | (3) 7'x3' RCB | 559 |
| 848+09 | (1) 10'x5' RCB | 247 | 1719+00 | (2) 8'x6' RCB | 800 | | | |
| 903+19 | (1) 10'x5' RCB | 126 | 1746+00 | (1) 8'x6' RCB | 208 | | | |
| 921+09 | (1) 10'x5' RCB | 181 | 1777+00 | 96" RCP | No Data in MP | | | |
| 933+14 | (2) 7'x3' RCB | 185 | 1858+00 | (1) 8'x6' RCB | 238 | | | |

Infiltration basins are proposed at most intersections within the ROW to treat and partially contain the on-site pavement runoff of the roadway. The infiltration basins treat runoff by retaining the water quality volume (WQV) and enough flow volume to ensure flow rates mimic existing conditions. Once the required volume has been retained, runoff shall outlet through spillways or pipe risers where the excess runoff will be conveyed to the natural flow path. Along the western portion of the alignment, the City of Palmdale has developed a Drainage Master Plan (DMP) that incorporates a network of storm drains and detention facilities for flood control within Palmdale. After construction of the DMP, the outflow from the infiltration basins would be tied to the proposed drainage network. In this way, installation of the infiltration basins would alleviate water quality and hydromodification impacts related to the roadway. The locations of the proposed infiltration basins are shown in Appendix L. An estimate of overall cost for the on-site infiltration basins is provided in Appendix O.

For projects in which new basins are being considered, the preliminary bottom area of the basin should be designed so that the WQV draws down within 24 hours. After the area has

been determined, Caltrans will determine during the Project Development phase if the 24-hour drawdown time is practical or if other vector control measures should be implemented.

## 3.5 Retention Basins

Due to clearance requirements for the HSR, the HSR Alternative and its variations would require local roads and US 395 to cross beneath the HDC. Local roads would be graded to allow positive drainage beyond the undercrossing. In a few locations, positive drainage is either not possible or infeasible. At these locations, construction of retention basins is recommended.

Retention basins were sized to accommodate the total rainfall volume produced during a 4-day storm period. Basins for local roads would provide sufficient storage to capture a 4-day 25-year storm; and basins for state highways would provide sufficient storage to capture a 4-day 50-year event. Rainfall data was obtained from the Los Angeles County Department of Public Works Hydrology Manual (2006) and the NOAA Atlas 14 Point Precipitation Frequency Estimates. A list of undercrossings with sump conditions, and retention basin calculations is provided in Table 3-2.

**Economic Analysis of Alternative Drainage Designs**

Another option considered was the use of sump pumps. Given that the proposed undercrossings are in undeveloped areas, however, the cost of developing the infrastructure to bring electricity to the sump pumps was determined to be infeasible. Furthermore, export material from the excavation of retention basins could be utilized as backfill for the proposed HDC; which would decrease the amount of import material.

**Table 3-3. Proposed Retention Basins**

| Location | Storm Day | Area (acres) | Frequency | Length (ft) | Isohyet (in.) | Volume (acre-ft) | Volume (cu.ft.) |
|---|---|---|---|---|---|---|---|
| 15th St. Basin | Day 4 | 2.34 | 25 | 1215 | 3.0 | 0.52 | 22651 |
| 15th St. Basin | Day 3 | 2.34 | 25 | 1215 | 1.0 | 0.18 | 7841 |
| 15th St. Basin | Day 2 | 2.34 | 25 | 1215 | 1.2 | 0.21 | 9148 |
| 15th St. Basin | Day 1 | 2.34 | 25 | 1215 | 0.3 | 0.05 | 2178 |
| 20th St. Basin | Day 4 | 2.52 | 25 | 1309 | 3.0 | 0.56 | 24394 |
| 20th St. Basin | Day 3 | 2.52 | 25 | 1309 | 1.0 | 0.20 | 8712 |
| 20th St. Basin | Day 2 | 2.52 | 25 | 1309 | 1.2 | 0.22 | 9583 |
| 20th St. Basin | Day 1 | 2.52 | 25 | 1309 | 0.3 | 0.06 | 2614 |
| **Basin @ 20th St.** | | | | | | | **87120** |
| 25th St. Basin - Alt 7 | Day 4 | 2.33 | 25 | 976 | 2.7 | 0.47 | 20473 |
| 25th St. Basin - Alt 7 | Day 3 | 2.33 | 25 | 976 | 1.0 | 0.16 | 6970 |
| 25th St. Basin - Alt 7 | Day 2 | 2.33 | 25 | 976 | 1.1 | 0.19 | 8276 |
| 25th St. Basin - Alt 7 | Day 1 | 2.33 | 25 | 976 | 0.3 | 0.05 | 2178 |
| 30th St. Basin | Day 4 | 3.10 | 25 | 1300 | 2.7 | 0.63 | 27443 |
| 30th St. Basin | Day 3 | 3.10 | 25 | 1300 | 1.0 | 0.22 | 9583 |
| 30th St. Basin | Day 2 | 3.10 | 25 | 1300 | 1.1 | 0.25 | 10890 |
| 30th St. Basin | Day 1 | 3.10 | 25 | 1300 | 0.3 | 0.06 | 2614 |
| **Basin @ 30th St.** | | | | | | | **88427** |
| 40th St. Basin | Day 4 | 3.61 | 25 | 1384 | 2.5 | 0.66 | 28750 |
| 40th St. Basin | Day 3 | 3.61 | 25 | 1384 | 0.9 | 0.23 | 10019 |
| 40th St. Basin | Day 2 | 3.61 | 25 | 1384 | 1.0 | 0.26 | 11326 |
| 40th St. Basin | Day 1 | 3.61 | 25 | 1384 | 0.2 | 0.07 | 3049 |
| 50th St. Basin | Day 4 | 4.94 | 25 | 1584 | 2.5 | 0.90 | 39204 |
| 50th St. Basin | Day 3 | 4.94 | 25 | 1584 | 0.9 | 0.31 | 13504 |
| 50th St. Basin | Day 2 | 4.94 | 25 | 1584 | 1.0 | 0.36 | 15682 |
| 50th St. Basin | Day 1 | 4.94 | 25 | 1584 | 0.2 | 0.09 | 3920 |
| **Basin @ 50th St.** | | | | | | | **125453** |
| 90th St. Basin | Day 4 | 3.81 | 25 | 1459 | 2.3 | 0.65 | 28314 |
| 90th St. Basin | Day 3 | 3.81 | 25 | 1459 | 0.8 | 0.23 | 10019 |
| 90th St. Basin | Day 2 | 3.81 | 25 | 1459 | 0.9 | 0.26 | 11326 |
| 90th St. Basin | Day 1 | 3.81 | 25 | 1459 | 0.2 | 0.06 | 2614 |
| **Basin @ 90th St.** | | | | | | | **52272** |
| Adelanto * | Days 1-4 | 2.8191 | 50 | 1228 | 4.2 | 0.88 | 34648 |
| US 395* | Days 1-4 | 7.25326 | 50 | 2548 | 4.2 | 2.27 | 89146 |
| **Basin @ US 395** | | | | | | | **123794** |

*50 yr rain totals obtained from NOAA. 24 hr 25-yr rainfall totals for undercrossing located in Los Angeles County were obtained from the LA County Hydrology Manual

## 3.6 Channels

A series of longitudinal channels placed at the edge of right-of-way to intercept and convey off-site flows to the culverts and bridges are proposed along the corridor. In most instances, where velocities allow it, these channels would be either earthen or vegetated. In some instances, velocities may be too high to allow channels of this type. Where flow velocities are too high for earthen or vegetated channels, other forms of erosion protection will be evaluated, including the use of concrete-lined conveyance systems. The channels have been designed using Manning's equation with flow depths ranging between 1 and 5 feet. Sample channel hydraulic calculations are provided in Appendix M. Locations of proposed ditches and channels are provided in the Drainage Layout Plans in Appendix N. An estimate of quantities and cost for the concrete lined channels is provided in Appendix O. FlowMaster was used to calculate normal depths for each channel. FlowMaster by Bentley Corporation uses the Manning Equation to calculate normal depth.

# 4 CONCLUSION

In support of the PA/ED work effort, this preliminary Hydrology and Hydraulics Report has been prepared to analyze and address hydrologic impacts associated with the proposed 63-mile-long HDC project. In this report, the preliminary placement and sizing of numerous drainage improvements (e.g., storm drains, infiltration basins, cross culverts) have been defined. Based on computer modeling, this report evaluates hydraulics for each proposed improvement with the intent of preventing flow diversions, flow rate changes, water quality degradation, and other potential hydromodification concerns associated with the project.

In an effort to maintain the existing off-site drainage flow pattern along the HDC, several bridges and cross culverts have been located along the alignment. The bridges are proposed over Little Rock Wash, Big Rock Wash, Turner Wash, Ossum Wash, and Mojave River for the conveyance of off-site flows across the proposed project alignment. Numerous channels and earthen ditches will be placed along the embankments of the highway where conveyance of off-site flow to the cross culverts or bridges is required.

Though the proposed corridor construction will create more impervious surface area and consequently generate additional runoff within the various watersheds crossed by the proposed highway, this increase in runoff will be mitigated through the use of infiltration basins located at most interchanges. The infiltration basins will treat and contain the flow from the on-site pavement runoff of the roadway. The Drainage Layout Plans in Appendix N show the locations of the proposed cross culvert, bridges, channels, and infiltration basins.

As described previously, the drainage pattern and flow rates within the project vicinity will remain unchanged due to controls proposed along the project alignment; therefore, no additional flow or flooding potential should be generated from construction of the HDC. In this way, the flow pattern, flow rates, overall water quality, and floodplains will not be significantly impacted within the watershed due to construction and operation of the proposed improvements.

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# 5 REFERENCES

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