



# **APPENDIX 3**

## **TECHNICAL MEMORANDUM 3 – CONCEPTUAL DRAINAGE REPORT**



# Yuma Parkway Corridor Feasibility Study – Salome Highway to Palo Verde Road

Contract No.: 2010-055  
Project No.: TT005

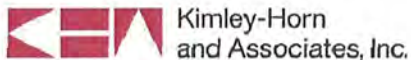
---

## FINAL Technical Memorandum 3 Conceptual Drainage Report



EXPIRES 3/31/2014

Prepared by:



August 2011  
091337133

Copyright © 2011 Kimley-Horn and Associates, Inc.



# TABLE OF CONTENTS

## CONCEPTUAL DRAINAGE REPORT

<b>1. INTRODUCTION .....</b>	<b>1</b>
<b>1.1 Background and Study Need.....</b>	<b>1</b>
<b>1.2 Study Area .....</b>	<b>1</b>
<b>1.3 Document Purpose and Scope.....</b>	<b>2</b>
<b>1.4 Design Drainage Criteria.....</b>	<b>2</b>
<b>2. EXISTING STUDIES AND OTHER DATA SOURCES.....</b>	<b>4</b>
<b>2.1 Summary of Drainage Studies .....</b>	<b>4</b>
<b>2.2 Summary of Other Documents and Data.....</b>	<b>7</b>
<b>3. WATERSHED FEATURES .....</b>	<b>9</b>
<b>3.1 Topography and Geology .....</b>	<b>9</b>
<b>3.2 Soils.....</b>	<b>12</b>
<b>3.3 Existing Land Use .....</b>	<b>14</b>
<b>3.4 Flooding Hazards .....</b>	<b>14</b>
<b>3.5 Existing Drainage Structures .....</b>	<b>20</b>
<b>4. EXISTING HYDROLOGY .....</b>	<b>22</b>
<b>4.1 Summary of Hydrology Methods.....</b>	<b>22</b>
<b>4.2 Offsite Hydrology Results.....</b>	<b>26</b>
<b>5. SUMMARY AND CONCLUSIONS.....</b>	<b>29</b>



# TABLE OF CONTENTS

## CONCEPTUAL DRAINAGE REPORT

### LIST OF FIGURES

Figure 1 – Study Area .....	3
Figure 2 – Area Drainage Studies .....	5
Figure 3 – Slope Analysis .....	10
Figure 4 – Hydrologic Soil Groups .....	13
Figure 5 – Regulatory Floodplains .....	16
Figure 6 – Offsite Hydrology Workmap .....	24

### LIST OF TABLES

Table 1 – Significant Offsite Drainage Crossings .....	23
Table 2 – Offsite Hydrology Results .....	28

### LIST OF APPENDICES

Appendix TM3-01:	Data Collection Summary
Appendix TM3-02:	Existing Geologic Mapping
Appendix TM3-03:	Subsidence and Earth Fissure Documentation
Appendix TM3-04:	Tonopah Uplift Documentation
Appendix TM3-05:	Drainage Field Photos
Appendix TM3-06:	Recommended Area Drainage Master Plan Improvements
Appendix TM3-07:	Recent Erosion and Sedimentation in Hassayampa River
Appendix TM3-08:	Existing Erosion Hazard Mapping
Appendix TM3-09:	Sand and Gravel Mining Documentation
Appendix TM3-10:	Existing Drainage Structure Documentation
Appendix TM3-11:	Existing Hydrology Results Excerpts

## 1. INTRODUCTION

Technical Memorandum 3 (TM 3), entitled *Conceptual Drainage Report*, identifies and summarizes the existing drainage conditions, features, and hydrologic characteristics for the *Yuma Parkway Corridor Feasibility Study – Salome Highway to Palo Verde Road* (hereafter referred to as “the study”). The purpose of TM 3 is to identify known drainage opportunities and constraints for developing feasible corridor alignments. Offsite concentration points and flow magnitudes prepared in previous studies and reports within the study area for the 100-year storm event were compiled and are presented in this report. TM 3 is based on a review of available existing information including previous drainage master plans and studies, floodplain delineation studies, roadway drainage reports, discussions with several stakeholders, and field observations. Additional detailed information about the study is included in the following companion documents: *Existing and Future Corridor Features* (TM 1), *Environmental Overview* (TM 2), *Development and Evaluation of Candidate Alternative Alignments* (TM 4), and *Detailed Preferred Alignment* (TM 5).

### 1.1 Background and Study Need

In July 2008, the Maricopa Association of Governments (MAG) completed the *Interstate 10/Hassayampa Valley Transportation Framework Study* (known as the Hassayampa Framework Study), that recommended a comprehensive roadway network to meet the future traffic demands that result when the area west of the White Tank Mountains is completely developed (hereafter referred to as buildout travel demand). This long-range regional transportation network includes the “Arizona Parkway” as a new facility type to supplement more traditional roadway classifications in meeting projected travel demand.

The Arizona Parkway utilizes a distinct intersection treatment that prohibits left turns at major cross-street intersections and controls intersection traffic movements with two-phased traffic signal control. Left-turn movements are made indirectly using directional left-turn crossovers in the median immediately downstream of cross-street intersections. The typical right-of-way width for an Arizona Parkway is 200 feet.

The Hassayampa Framework Study recommended Yuma Parkway as an “Arizona Parkway” to meet buildout travel demands and provide a continuous parkway network. Although today’s land development and travel demands in the study area do not warrant a major new high capacity roadway in the short-term, the buildout forecast for future land development and travel demands does warrant a major new high capacity roadway in the long-term future. Plans are already underway to convert some of the vacant lands within the study area to land uses that will generate future traffic.

The scope of work for this study includes the preparation of a corridor feasibility report that will provide Maricopa County, the Town of Buckeye, area property owners, developers, and other stakeholders with guidelines to preserve a 200-foot-wide right-of-way corridor to accommodate the typical Arizona Parkway design. This will require significant coordination with various governing bodies, other public agencies, development interests, and the general public.

### 1.2 Study Area

The Yuma Parkway study area is approximately 13 miles long and two miles wide and is generally centered on the Buckeye Road/Yuma Road section line, from one-half mile west of



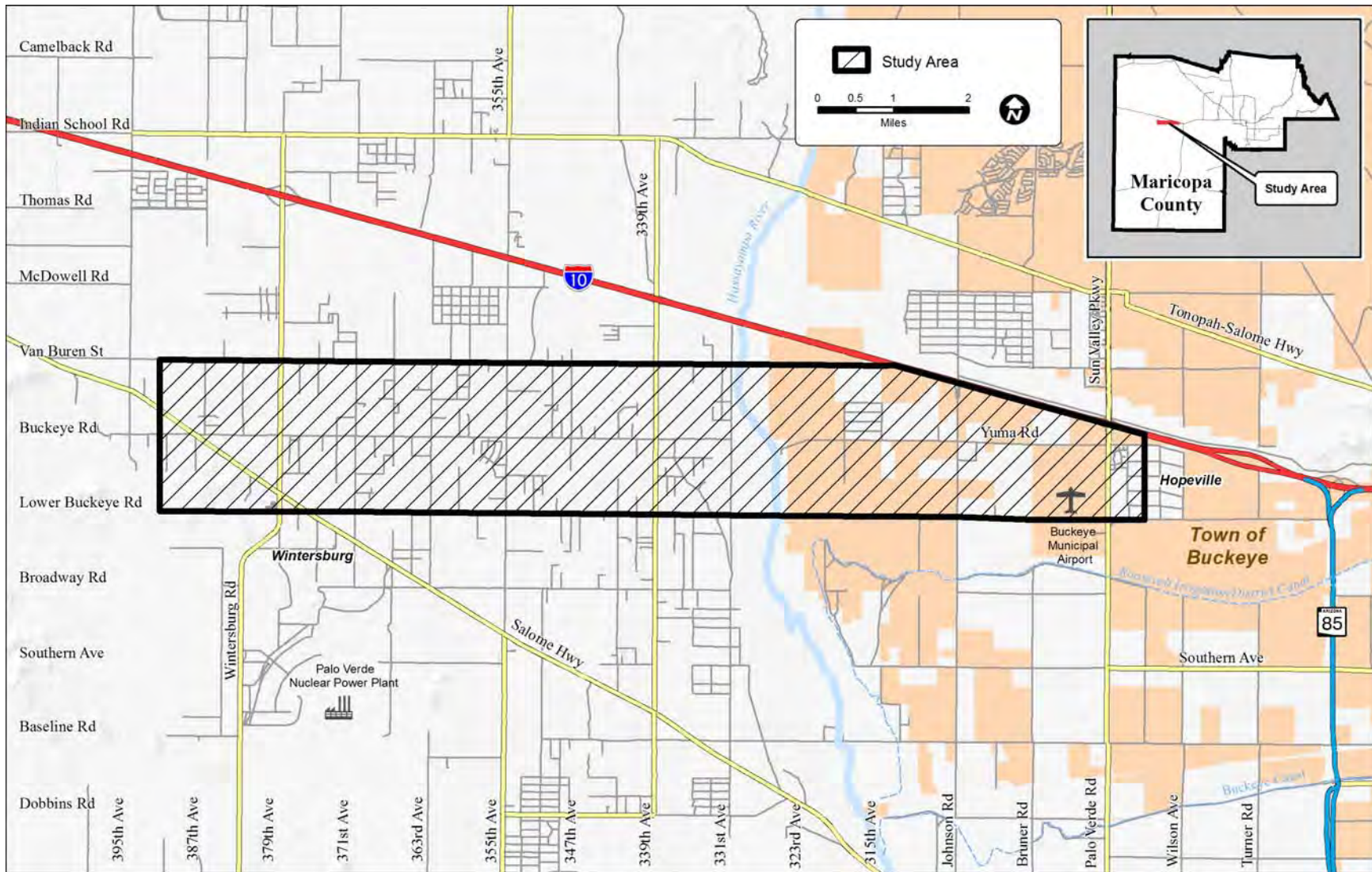
Salome Highway to one-half mile east of Palo Verde Road. The study area boundary is shown in **Figure 1**.

### **1.3 Document Purpose and Scope**

The purpose of the *Conceptual Drainage Report* is to describe the existing drainage conditions in the study area. The drainage study was limited to the collection and review of existing drainage reports and studies, existing geologic and groundwater mapping, limited discussion with stakeholders, and field observations of existing drainage patterns and structures included in and adjacent to the study area. Hydrologic information from previous drainage and floodplain studies was compiled to present watershed subbasins and previously determined peak flow rates draining to the study area. This information provides an overview of the physical features of the study area pertaining to drainage and will be used in the development of feasible alignment alternatives.

### **1.4 Design Drainage Criteria**

Drainage design for the proposed parkway will follow criteria outlined in the *Drainage Policies and Standards for Maricopa County, Arizona* (Maricopa County, 2007) and Chapter 4.7 of the *Roadway Design Manual* (Maricopa County, 2004). A draft version of an update to the *Drainage Policies and Standards for Maricopa County* was distributed by Maricopa County for public review and comment in July 2010.



**Figure 1 – Study Area**

## 2. EXISTING STUDIES AND OTHER DATA SOURCES

Numerous drainage, geologic, groundwater studies and other drainage-related documents have been prepared within or adjacent to the study area. A complete list of the existing documents reviewed is included in **Appendix TM3-01**. Summaries of the most relevant documents are provided in the following sections. The general order of presentation and discussion is from west to east.

### 2.1 Summary of Drainage Studies

A map depicting the major drainage studies that are in the general vicinity of the study area is provided as **Figure 2** at the end of this section. The drainage studies shown in **Figure 2** that have direct relevance to the Yuma Parkway study area are briefly discussed below. These drainage studies were reviewed for descriptions of existing hydrology, drainage features, and existing drainage patterns. Most of these drainage studies were completed for the Flood Control District of Maricopa County (FCDMC).

#### 2.1.1 *Palo Verde Watershed Detailed Floodplain Delineation Study Technical Data Notebook (Draft 2010)*

This FCDMC study aims to establish and refine 100-year flooding limits. The Palo Verde Watershed extends from the Big Horn Mountains to just east of Wickenburg Road. This study is a refinement of the 2003 Zone A Floodplain Delineation Study for the same watershed. The detailed study is not yet complete, but the draft hydrology report was available for review. Six of the studied washes cross the Yuma Parkway study area: Four Mile Wash, T1N-R6W-S17E, T1N-R6W-S08, T1N-R6W-S16, T1S-R6W-S27, and T1N-R6W-S22N.

#### 2.1.2 *Hydrologic Study Report for Luke Wash Zone AE Floodplain Delineation Study (2008)*

The purpose of this FCDMC study was to develop detailed 100-year hydrologic models to delineate 85 linear miles of Zone AE floodplains and floodways. The analysis focused on Luke Wash and nearby tributaries of the Hassayampa and Gila Rivers, with six washes that cross the Yuma Parkway study area: T1S-R5W-S17, Phillips Wash, Dickey Wash, Luke Wash, T1N-R5W-S22, and T1N-R5W-S15.

#### 2.1.3 *500 kV Electric Transmission Structures Hassayampa River Hydrologic Engineering Services (2010)*

The Salt River Project (SRP) initiated the *500kV Electric Transmission Structures Hassayampa River Hydrologic Engineering Services* (ETS report) in response to the January 2010 flood that exposed the foundations of transmission towers in the Yuma Parkway study area. The report included scour and lateral stream bank migration analyses for the Hassayampa River, and provided mitigation recommendations for the tower foundations.

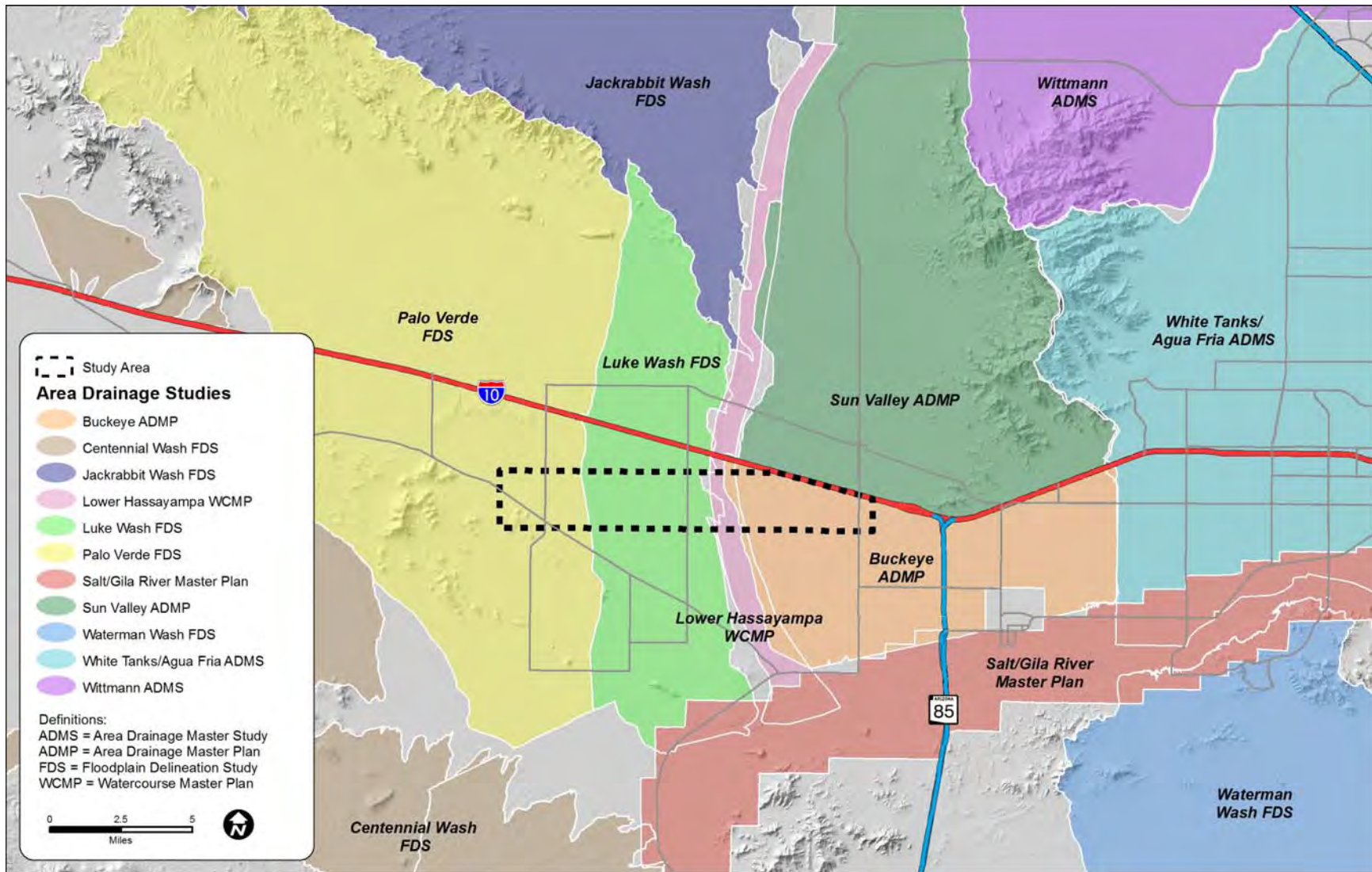


Figure 2 – Area Drainage Studies

#### *2.1.4 500 kV Electric Transmission Structures Hassayampa River Phase 3 Hydrologic Engineering Services (2011)*

This SRP report was completed after a single ring dike was chosen as the preferred alternative from the 2010 report. The ring dike would consist of a raised structure surrounding the power pole foundations and elevated above the floodplain. The ring dike would incorporate scour protection measures such as riprap, gabion mattresses or soil cement that would extend below the river bed to protect the tower foundations from scour and lateral migration of the river banks. This report provided additional hydraulic impacts and scour design for the selected option.

#### *2.1.5 FLUVIAL-12 Modeling of Sand Mining Impacts for Lower Hassayampa River (2009)*

This study was prepared to assist the FCDMC with managing erosion and flooding hazards due to sand and gravel mining in the Lower Hassayampa River. The study presents a sediment transport model that simulates river bed changes in the vertical and horizontal direction.

#### *2.1.6 Lower Hassayampa Watercourse Master Plan Phase 1 (2006)*

The FCDMC prepared Phase 1 of the Lower Hassayampa Watercourse Master Plan (LHWMP) to formulate technical guidance for managing flooding hazards, lateral migration of the watercourse, and cumulative impacts of existing and future development into the floodplain of the Hassayampa River. The river crosses the Yuma Parkway study area within River Reach 2, which extends from the Union Pacific Railroad (UPRR) Bridge to just downstream of Interstate 10 (I-10). Phase 1 is complete and contains seven volumes; Phase 2 is currently under development and should be made available in the near future. Volume 2 contains hydrologic documentation – an analysis of stream gage records, a simplified HEC-1 model, and multiple previous studies were compared to examine peak discharges for the river. Volume 5 contains river behavior analysis – compiled and presented historical and existing fluvial processes in the river.

#### *2.1.7 Hydrologic Analysis of the Hassayampa River in Maricopa County, Arizona (1988)*

This report was prepared for FEMA in order to estimate the 100-year discharge of the Hassayampa River for use in the corresponding FEMA Flood Insurance Re-Study. The study limits comprise approximately 53 stream miles from the Yavapai/Maricopa County line to the confluence with the Gila River. The Hassayampa River crosses the Yuma Parkway study area within this reach.

#### *2.1.8 Buckeye Flood Retarding Structure #1 Rehabilitation Project (Ongoing)*

This project is currently under development by FCDMC. Buckeye FRS #1 is located along the north side of I-10 for 7.1 miles, extending from approximately the Hassayampa River to Oglesby Road (287<sup>th</sup> Avenue). The planning phase was completed in 2008, with overall rehabilitation being selected as the alternative to move forward into final design.

### 2.1.9 *Buckeye/Sun Valley Area Drainage Master Study (2006)*

This FCDMC Area Drainage Master Study (ADMS) identified drainage, flooding, and erosion hazards within the Buckeye/Sun Valley area and developed preliminary guidelines for development to be used as a basis of stormwater management. The Buckeye/Sun Valley study limits extend from the Hassayampa River to approximately the White Tank Mountains and Dean Road alignment. This overall watershed was subdivided into four hydrologically distinct areas, with the Yuma Parkway study area falling within Area 1, named the Buckeye Area.

### 2.1.10 *Buckeye Area Drainage Master Plan Recommended Design Report (2009)*

This Area Drainage Master Plan (ADMP) was prepared for the FCDMC as a follow-up to the ADMS process described previously. The master plan study area extends from I-10 south to the Gila River, and from Airport Road west to the Hassayampa River. The Yuma Parkway study area crosses the ADMP study area. The ADMP provides regional drainage recommendations, including two proposed north-south channels: the Palo Verde Channel follows Palo Verde Road and the Johnson Channel follows an alignment ½ mile east of Johnson Road. However both of these proposed 100-year channels begin at the Roosevelt Irrigation District (RID) canal, which is located south of the Yuma Parkway study area. The ADMP also recommends constructing a regional retention basin one-half mile east of Johnson Road on the north side of the RID canal (outside the Yuma Parkway study area). The recommended master plan drainage improvements are shown in **Appendix TM3-06**.

## 2.2 **Summary of Other Documents and Data**

In addition to drainage studies, data sources such as geologic investigations and groundwater records were reviewed for information on other regional physical processes that could potentially impact the Yuma Parkway study area. A summary of the most relevant data sources is provided below.

### 2.2.1 *Geologic Map of the Wintersburg 7.5' Quadrangle, Maricopa County, Arizona (2006)*

The AZGS produced digital geologic mapping and descriptions of the Wintersburg 7.5' Quadrangle. This quadrangle encompasses the study area from 383<sup>rd</sup> Avenue to just west of the Hassayampa River. The descriptive map legend describes surficial and bedrock geology, geologic hazards and aggregate resources.

### 2.2.2 *Geologic Map of the Buckeye NW 7.5' Quadrangle, Maricopa County, Arizona (2004)*

The AZGS produced digital geologic mapping and descriptions of the Wagner Wash Well 7.5' Quadrangle. This quadrangle encompasses the study area from the Hassayampa River to Oglesby Road (287<sup>th</sup> Avenue).

### 2.2.3 *Earth Fissure Map of Maricopa County, Arizona (2009)*

The AZGS produced a map summarizing the earth fissure mapping that had been completed in Maricopa County. It presents a graphical overview of the eight areas that have been found to have active earth fissures.

### 2.2.4 *A New Earth Fissure near Wintersburg, Maricopa County, Arizona (2001)*

The AZGS produced a report on an earth fissure located approximately three miles south of the study area near Wintersburg. The report presents maps, photos, geologic setting, groundwater history, and discussion of the fissure formation.

### 2.2.5 *Additional Giant Desiccation Cracks near Wintersburg, Maricopa County, Arizona (2003)*

The AZGS produced a report on giant desiccation cracks located approximately one-half mile south of the study area near Wintersburg. The report presents maps, photos, and history of development of the cracks.

### 2.2.6 *Active Land Subsidence Areas in Arizona Based on ADWR InSAR Data (2009)*

This working document shows active land subsidence areas monitored by the Arizona Department of Water Resources (ADWR). Interferometric synthetic aperture radar (InSAR) technology is used to measure temporal elevation changes in the Earth's surface. The map covers the entire state of Arizona.

### 2.2.7 *Land Subsidence Areas in the Buckeye Area, Western Maricopa County (2008)*

This ADWR map shows subsidence in an area roughly bounded by Johnson Road and Miller Road. Some of the active subsidence area is within the Yuma Parkway study corridor. The exhibit presents InSAR measurements of land subsidence between February 2007 and April 2008.

### 2.2.8 *Uplift in the Vicinity of the Tonopah Recharge Facility (2010)*

This ADWR working document shows the extent of uplift, or elevation of the Earth's surface, caused by the Tonopah Desert Recharge Project. The recharge facility is located approximately nine miles northwest of the study area adjacent to the Central Arizona Project (CAP) Canal.

### 2.2.9 *Groundwater Site Inventory (GWSI) (2011)*

The GWSI is ADWR's primary repository for statewide groundwater data. It contains historical well levels and other background information for each well in the database, including the wells within the study area. The GWSI is an online product that is continuously updated as new field data is collected.

### 3. WATERSHED FEATURES

#### 3.1 Topography and Geology

Most of the study area is fairly flat, particularly west of the Hassayampa River and north of the Salome Highway. The Hassayampa River, which crosses the study area roughly between the 315<sup>th</sup> Avenue and 331<sup>st</sup> Avenue alignments, is surrounded by rolling terrain, particularly on the east side of the river. A land form slope analysis map is provided in **Figure 3**.

The region west of the Hassayampa River is described as Piedmont Alluvium in the *Geologic Map of the Wintersburg 7.5' Quadrangle, Maricopa County, Arizona* (AZGS, 2006). This piedmont contains areas of young deposits associated with active or recently active fluvial systems and areas of older intermediate deposits associated with extensive relic alluvial fans. Wash channels are typically located less than two meters (6.6 feet) below adjacent surfaces. These areas without much local relief are of particular concern because of the potential for widespread inundation and changes in channel positions during floods. In the southwest corner of the study area, south of the Salome Highway, basalt lava flows cap several hills known as the Palo Verde Hills. These hills represent the greatest local relief within the study area, but are not expected to influence the alignment of Yuma Parkway since the future roadway will tie into the Salome Highway.

The region around the Hassayampa River contains more undulating terrain and steeper slopes. The incised, sandy river channel width varies between approximately 500 feet to 2000 feet within the study area. The unit descriptions in the *Geologic Map of the Buckeye NW 7.5' Quadrangle, Maricopa County, Arizona* (AZGS, 2004) suggest that the current Hassayampa River channel is 15 to 20 meters (49 to 66 feet) below the terraces formed by the maximum aggradation of the river. These terrace surfaces are dissected by tributary drainages and have been substantially modified by erosion. Within the study area, the higher terraces are much more preserved on the east side of the Hassayampa River than on the west side.



**Undulating terrain near river**

The region east of the Hassayampa River is described as Piedmont Alluvium in the *Geologic Map of the Buckeye NW 7.5' Quadrangle*. This piedmont contains areas of young deposits associated with active or recently active fluvial systems and areas of older intermediate deposits associated with extensive relic alluvial fans. Local topographic relief varies from 0.5 m to 6 m (1.6 feet to 20 feet). The Arizona Geological Survey (AZGS) maps pertaining to the study area have been included as **Appendix TM3-02**.

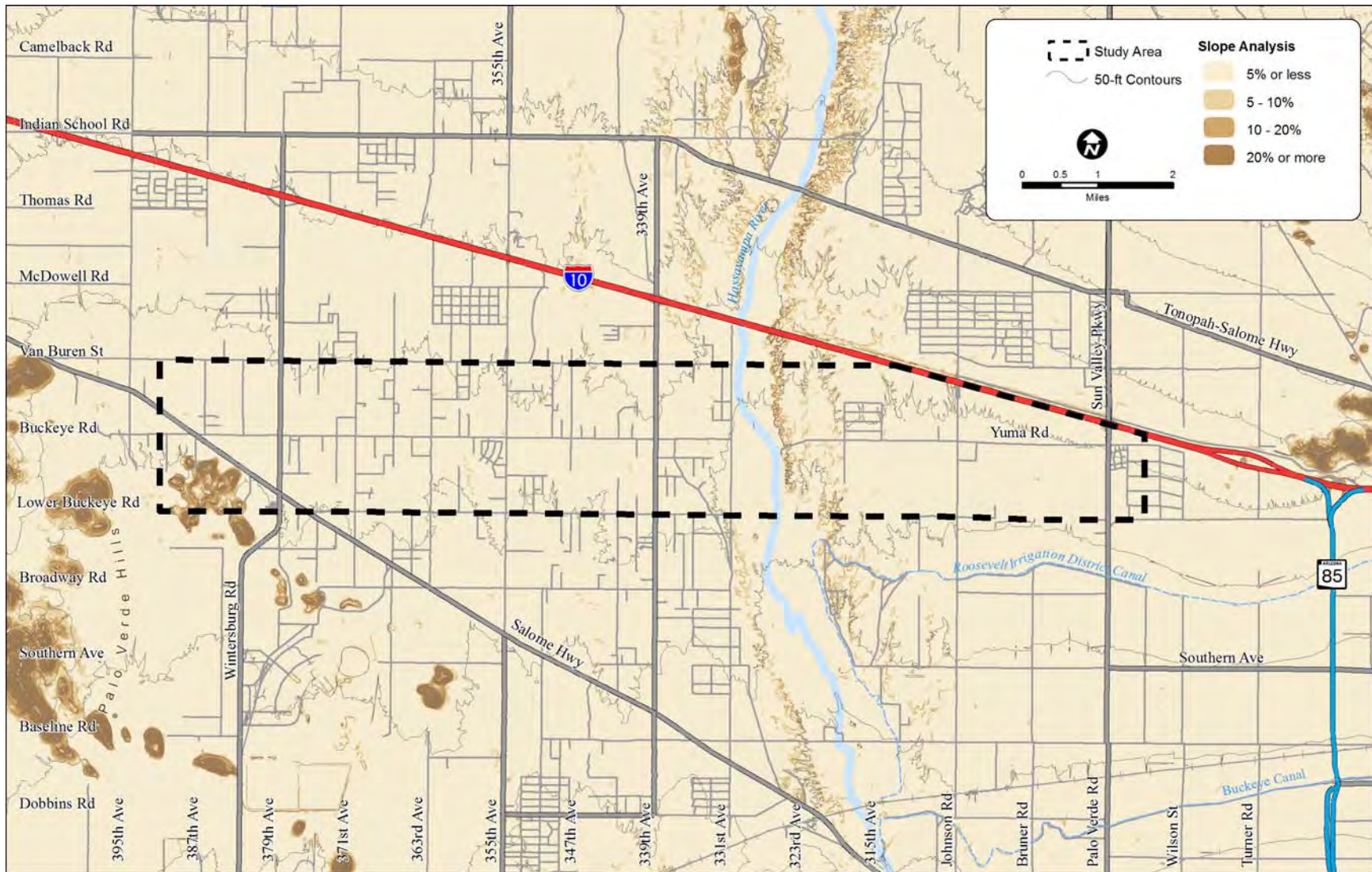


Figure 3 – Slope Analysis

### 3.1.1 Land Subsidence and Earth Fissures

ADWR has mapped an active land subsidence feature in the Buckeye Area based on measurements obtained between February 2007 and April 2008. The map entitled *Land Subsidence in the Buckeye Area, Western Maricopa County* (ADWR, 2008) indicates that there has been up to 0.5 cm (0.2 inches) of subsidence within the study area east of Palo Verde Road. South of the study area between Johnson Road and Palo Verde Road, up to three centimeters (1.2 inches) of subsidence has been documented. The extent of the land subsidence is included in **Appendix TM3-03**. Land subsidence in Arizona typically occurs due to groundwater drawdown. While subsidence is not considered to be a significant issue within the study area at this time, as water demand changes with future development, the increased potential for land subsidence (or uplift) should be considered when building infrastructure.

ADWR is also monitoring an active uplift area caused by the Tonopah Desert Recharge Project. The recharge facility is located adjacent to the CAP Canal approximately nine miles northwest of the study area. As of March 2010, the facility's groundwater plume and associated ground uplift had extended as far east as 355<sup>th</sup> Avenue and as far south as Buckeye Road. ADWR provided an exhibit called *Uplift in the Vicinity of the Tonopah Recharge Facility* (ADWR, 2010) that is included in **Appendix TM3-04**. This map shows that up to one centimeter (0.4 inches) of uplift occurred within the study area between 2006 and 2010. A review of recent well logs from the *Groundwater Site Inventory (GWSI)* (ADWR, 2011) did not indicate a marked increase in groundwater elevation within the study area. These hydrographs and a map showing the four well sites have been included in **Appendix TM3-04**. However, the plume may continue to expand as groundwater travels towards the Hassayampa River and Gila River. The recharge project will probably not impact the selection of a Yuma Parkway alternative, but uplift or subsidence in this area should be monitored in future design phases, especially if the Tonopah Desert Recharge Project modifies the rate of groundwater recharge.

The nearest documented earth fissure is located approximately three miles south of the study area near the intersection of the 363<sup>rd</sup> Avenue and Baseline Road alignments. Earth fissures are large cracks associated with differential basin subsidence, largely due to groundwater drawdown. Earth fissures pose a serious danger to roadways: extensive underground fissures can develop below the surface before anything is apparent on the surface, and filling exposed fissures is often only a temporary solution. A location map and photo of the fissure, where it crosses Baseline Road is included in **Appendix TM3-03**. More detailed information can be found in *A New Earth Fissure near Wintersburg, Maricopa, Arizona* (AZGS, 2001). No surface evidence of fissures has been found in the study area, but this does not guarantee that hidden or future earth fissures are not present.

Giant desiccation cracks have also been found in the area, with the closest documented features approximately one-half mile south of the study area immediately west of Wintersburg Road. A location map and photos of the cracks, excerpted from *Additional Giant Desiccation Cracks near Wintersburg, Maricopa County, Arizona* (AZGS, 2003), are included in **Appendix TM3-03**. Desiccation cracks are formed by the drying out of fine-grained soils. These cracks are not the same as earth fissures, but there is some evidence that desiccation cracks may significantly advance the development of nearby earth fissures. While no giant desiccation cracks have been identified within the study area, prolonged drought conditions may increase the probability for these cracks to occur within the area.

### 3.2 Soils

The National Resources Conservation Service (NRCS) assigns soil map unit components to hydrologic soil groups to broadly indicate soils groups that have similar runoff characteristics. These hydrologic soil groups are shown in **Figure 4**. Most of the study area falls within Group B: soils that have moderately low runoff potential when thoroughly wet. These areas typically have a large proportion of sands and allow unimpeded transmission of water through the soil. However, the land west of the Hassayampa River contains significant areas that fall within Hydrologic Group C: soils with moderately high runoff potential. Soils in Group C typically have between 20 to 40 percent clay and less than 50 percent sands. Water movement through the soil is expected to be somewhat restricted.

Three areas fall within Hydrologic Group D: soils with high runoff potential when thoroughly wet. One area is the exposed bedrock of the Palo Verde Hills southwest of the Salome Highway. The second area is the residential area bounded by Power Butte Road and 315<sup>th</sup> Avenue, and the third is a small area within the Buckeye Municipal Airport. Water movement in these soils is restricted or very restricted. Soils in Group D typically have greater than 40 percent clay or the depth to a water impermeable layer (such as rock) is less than 20 inches. Descriptions of the hydrologic soil groups were taken from Chapter 7 of the NRCS *National Engineering Handbook Part 630 Hydrology* (2007). Contributing watersheds that contain Hydrologic Group D soils should be carefully analyzed when designing downstream structures or roadways since precipitation events may result in very quick runoff responses.

The LHWMP *River Behavior Report* (FCDMC, 2006) documented soil pit analyses (average depth of 6.6 feet) that were taken from the Hassayampa River floodplain within the study area. Pit results indicated that sediments were alternating loamy sand and sand, with the lower profile more sandy. Gravel was less than 10% throughout the profile, and no clay was present. Evidence suggested a geologically young surface with historically frequent inundation and no resistance to lateral erosion. Soil borings in the same area were also taken for the ETS report (SRP, 2010). These borings showed more than 30 feet of refuse depth before encountering bedrock.

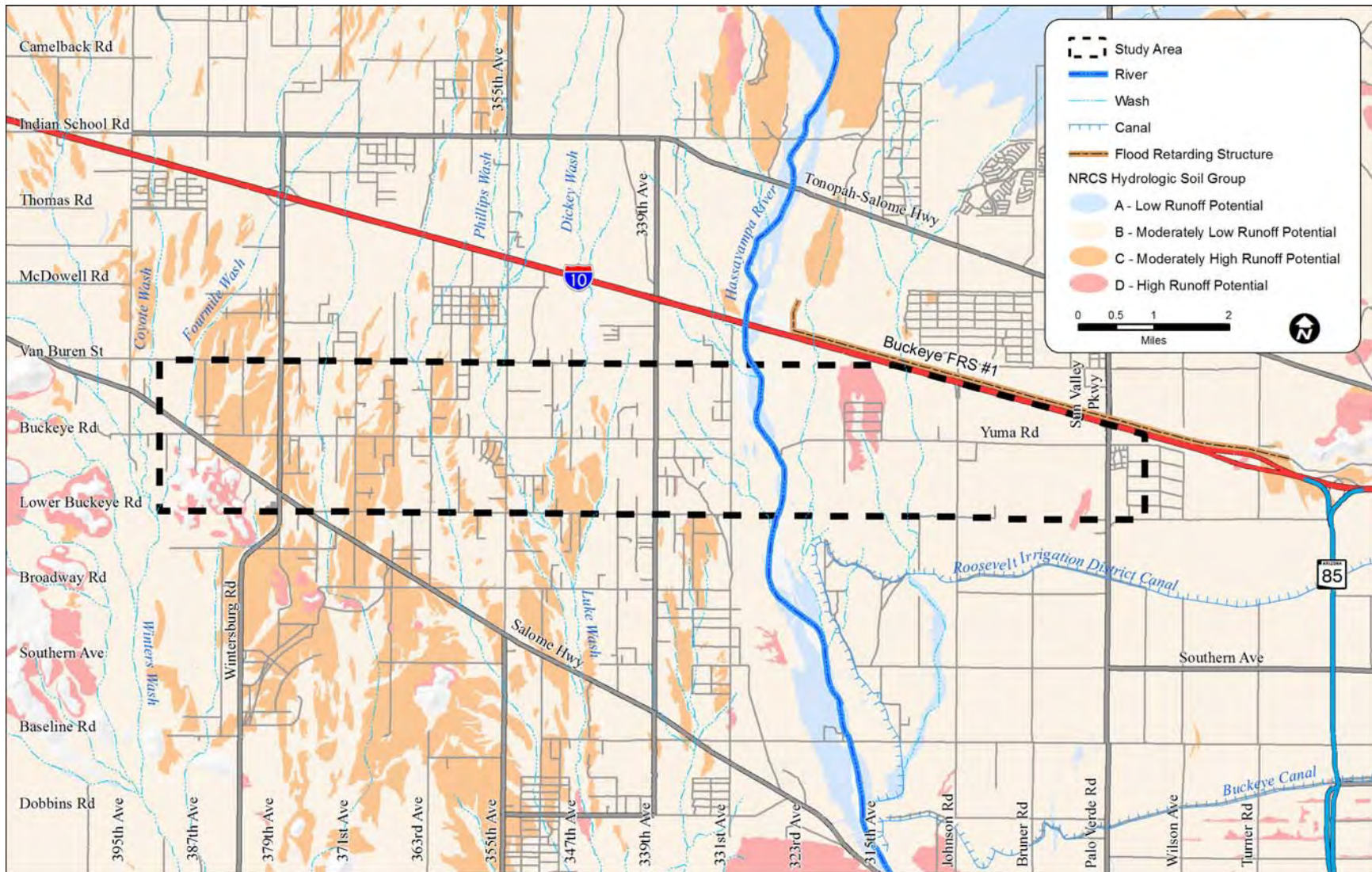


Figure 4 – Hydrologic Soil Groups

### 3.3 Existing Land Use

Technical Memorandum 1 (TM 1) presents a discussion of land ownership, zoning, existing land use, future land use, existing and planned developments, and existing and future transportation networks. The land use descriptions below are abbreviated versions of the TM 1 descriptions that pertain to drainage design.

#### 3.3.1 Existing Land Use

The predominant existing land use within the study area is natural desert open space, but there are large clusters of single family residential land uses west of the Hassayampa River. **Appendix TM3-05** provides photographs taken during field visits of the study area land uses and major drainage features. Photo 650 (in **Appendix TM3-05**) shows undeveloped desert landscape that is typical of the land around the Hassayampa River, and photo 687 shows typical low density residential development along Buckeye Road west of the river. A few clusters of agriculture use are also present, with a large dairy farm located east of Johnson Road. The Buckeye Municipal Airport is located near the southeast corner of the study area. A limited network of two-lane paved roadways and unpaved roadways serve the existing properties, but there is not an existing roadway that connects the east and west sides of the Hassayampa River within the study area.



Typical land use along Buckeye Road

#### 3.3.2 Future Land Use

According to Maricopa Association of Governments (MAG) general plan GIS data provided by Public Works of Maricopa County (May 2009), existing vacant land within the study area is anticipated to be converted to primarily residential land use at buildout. The land west of the Hassayampa River is primarily planned to have low density single family residential uses. The study area east of the Hassayampa River is planned to have more medium/high density residential and multi-family uses. There are large areas of retail, office, and industrial land uses planned at major intersections throughout the study area, particularly near the Town of Wintersburg and within the Buckeye Municipal Planning Area Boundary (east of the Hassayampa River). These future land use patterns incorporate the land use plans for the large master planned communities in the study area vicinity.

### 3.4 Flooding Hazards

#### 3.4.1 Regulatory Floodplains

Floodplain and floodway delineations were based on the *Flood Insurance Study, Maricopa County, Arizona and Incorporated Areas, FIS No. 04013CV001A* (Federal Emergency

Management Agency, 2005). Numerous FEMA floodplains drain through the study area. **Figure 5** provides a map of the 100-year floodplain areas and also displays the Flood Insurance Rate Map (FIRM) panels containing the effective floodplain mapping. Both FEMA effective and FCDMC (typically pending FEMA approval) floodplain limits are shown on this exhibit. The watercourses west of 371<sup>st</sup> Avenue drain south to Centennial Wash, which is a tributary of the Gila River. Washes between 363<sup>rd</sup> Avenue and 339<sup>th</sup>



**Hassayampa River floodplain**

Avenue drain south directly to the Gila River. Watercourses between 339<sup>th</sup> Avenue and Johnson Road drain to the Hassayampa River, which discharges into the Gila River. The study area east of Johnson Road does not contain any regulatory floodplains.

The study area contains 15 regulatory floodplains. Floodplain encroachment is a consideration for the parkway alternatives, especially when crossing major watercourses like the Hassayampa River. The Hassayampa River 100-year floodplain is approximately 3,000 feet wide at the section line. Detailed hydraulic and sediment transport studies will be necessary to develop appropriate crossing alternatives for this highly dynamic river.

The crossings of Four Mile Wash and the drainage system near 371<sup>st</sup> Avenue also deserve further attention when developing alignment alternatives because each has a very wide floodplain. The Four Mile Wash 100-year floodplain is approximately 3,300 feet wide. An eastern tributary of Four Mile Wash historically joined Four Mile Wash immediately north of the Palo Verde Hills, but the Salome Highway now acts as a partial barrier and forces the ponding of flood flows upstream of the elevated highway. This backwater flood zone is located at the intersection of Salome Highway and the Buckeye Road alignment, so it may be possible to avoid the floodplain with a Yuma Parkway alignment that ties into the Salome Highway further east (south of the section line).



**Four Mile Wash floodplain**

The regulatory 100-year floodplain of the drainage system near 371<sup>st</sup> Avenue is approximately 3,200 feet wide at the Buckeye Road alignment. There is little topographic relief in this area and the wash system may be distributary with multiple branching flowpaths.

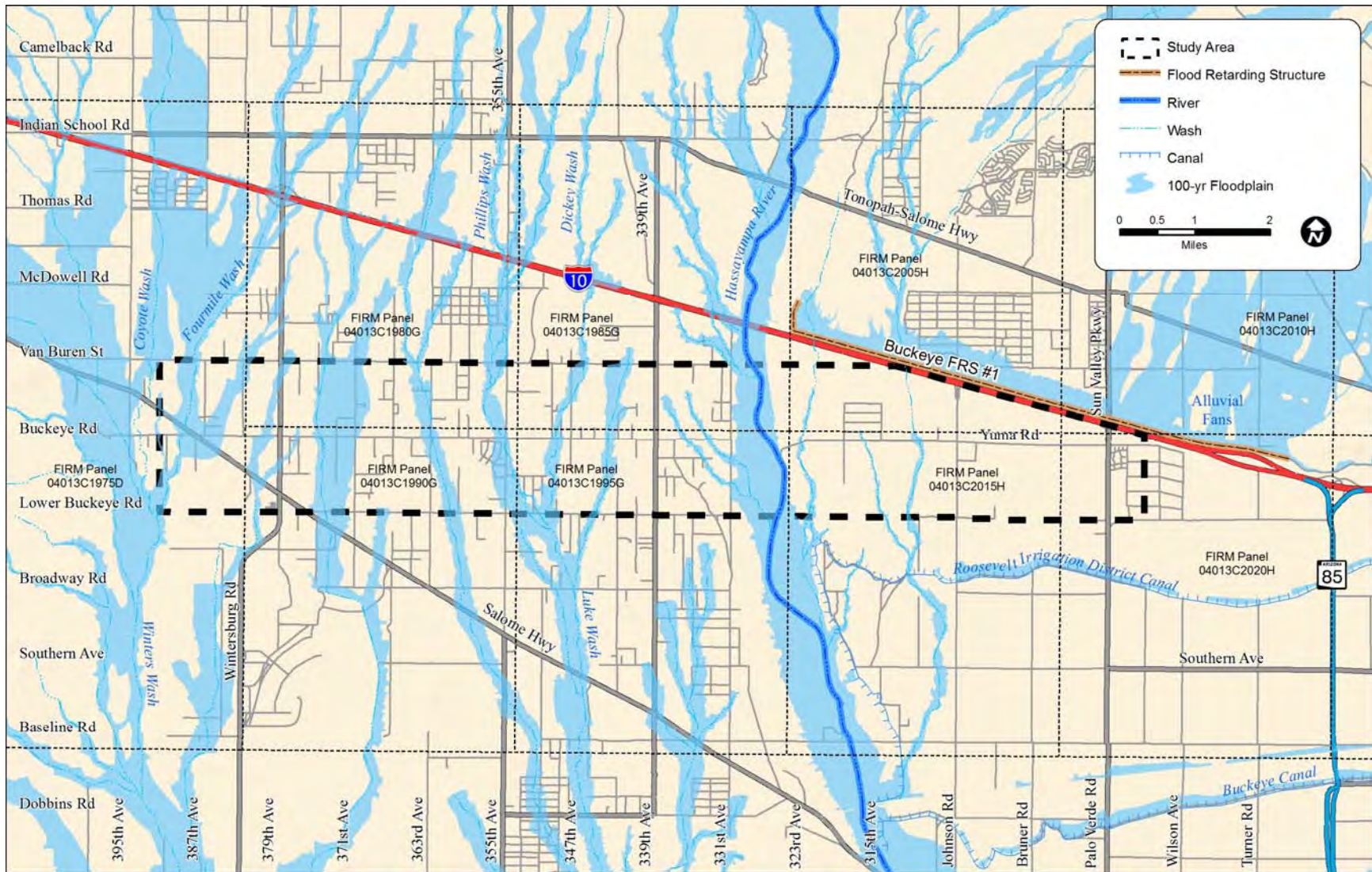


Figure 5 – Regulatory Floodplains

Per discussions with the FCDMC Project Manager for the Palo Verde Detailed Floodplain Delineation Study, which is currently being developed, there will be three mapped flooding sources at this location: the wash known as T1S-R6W-S25 and two split flows of this wash. The detailed delineation study may result in three distinct floodplains with islands in between the flood hazard areas; however, it may also result in a single very wide floodplain, as currently shown on FCDMC mapping.

### 3.4.2 *Alluvial Fans*

No active alluvial fans have been identified within the Yuma Parkway study area. Active alluvial fans are extensively documented north of I-10 near the White Tank Mountains, but the Buckeye Flood Retarding Structures effectively block the alluvial fans from extending south into the study area.

### 3.4.3 *Scour and Sedimentation*

Scour and sedimentation associated with the Hassayampa River was analyzed as part of the LHWMP *River Behavior Report* (FCDMC, 2006). The Yuma Parkway crossing occurs in Reach 2 of the Hassayampa River, which extends from just downstream of the I-10 Bridge to just upstream of the UPRR Bridge. Total scour (not including local scour) in Reach 2 was estimated to be approximately 10 feet for the 10-year event and 15 feet for the 100-year event. The largest component of calculated scour was bend scour due to the sharp bends in the active river channel. Degradation of the Hassayampa River channel bed was not expected to be limited by the development of an armored layer of larger materials. Scour was also calculated for the transmission lines crossing within the study area as part of the ETS report (SRP, 2010). The report stated a total estimated scour of 9.5 feet and 11 feet respectively for the 25- and 100-yr flood events.

A UPRR bridge located approximately four miles downstream of the study area is the nearest downstream bridge on the Hassayampa River. The LHCMP documented evidence of scour between one to three feet deep at the upstream face of three (of 12) piers, and no significant erosion of the abutments. The I-10 bridges located approximately 3,000 feet upstream of the study area are the nearest upstream bridges. The LHCMP found no evidence of scour at any of the 28 piers. The abutments were protected by rock riprap held in place by I-beam rails and chain link fencing, but a large scour hole on the east and a small cutbank on the west were encroaching on the upstream abutments. During the March 2010 field work conducted for the ETS report, some scour was observed around the west bridge abutment.

Despite the large amount of sediment moving through the Hassayampa River system, historical channel slopes have been relatively constant, suggesting that the system is near sediment balance equilibrium (FCDMC, 2006). This equilibrium could readily change in the future if sand and gravel mining in the river or other disturbances reduce the sediment supply. Increased pressure to mine the Hassayampa River channel for sand and gravel is likely as development occurs in the area. The LHWMP *River Behavior Report* plotted historical river profiles and found that Reach 2 showed net aggradation between 1988 and 2004. In contrast, a HEC-RAS sediment transport model that was completed for the ETS report suggested that the long-term river behavior tended towards degradation, with a maximum degradation of 1.4 feet over the entire simulation period. The authors noted that the one-dimensional HEC-RAS model does not account for horizontal erosion processes;

this is important in the Hassayampa River since lateral migration should tend to limit vertical erosion.

Sediment issues are expected to be a potential maintenance concern for any Yuma Parkway culvert, especially since very high sediment loads have been associated with the Hassayampa River. The FCDMC provided photos of a significant flood event that occurred in January of 2010. One of these photos showing sediment deposition of the Hassayampa River near the Tonopah-Salome Highway has been included in **Appendix TM3-07**. Water can be seen flowing through the main channel in the background of the photo, and the foreground shows the overbank where slowing flows deposited approximately six feet of sediment. Photo 722 in **Appendix TM3-05** shows the typical sedimentation that can be expected in Yuma Parkway culverts.

#### 3.4.4 *Sand and Gravel Mining*

Numerous active sand and gravel mining operations are present in the Hassayampa River. According to FCDMC records (2010), the nearest upstream mining permit is approximately 8,000 feet north of the Yuma Parkway study area near Indian School Road. The nearest downstream mining permit is along the southern boundary of the study area near the Lower Buckeye Road alignment. These and other active mining permits in the area are shown in an exhibit in **Appendix TM3-09**. Sand and gravel mines create deep pits in the flow channel – during a flood event sediment that is suspended in the water tends to deposit in the pits, leaving the water starved of sediment. This leads to degradation in the reaches downstream of large mining pits, such as the reach that passes through the study area. It is also possible that a headcut from the downstream pit along Lower Buckeye Road could propagate upstream during erosive flood events.

Results from the *FLUVIAL-12 Modeling of Sand Mining Impacts for Lower Hassayampa River (FCDMC, 2009)* further document that sand and gravel mines in the Hassayampa River have the potential to greatly impact the long-term channel bed. According to the FLUVIAL-12 study, the model that includes all approved pits exhibits a bed degradation that is one foot more than the existing conditions model during a single 100-year flood event, and eight feet more degradation during the long-term flood series. Both of these values were taken at river station 9.45, which is the closest cross section to the Yuma Road section line. Additional results and plotted bed profiles from the FLUVIAL-12 study are included in **Appendix TM3-09**. It is expected that as development occurs in the region, pressure to further mine the Hassayampa River will increase. Ultimate mining pit configurations should be carefully considered when determining toe-down depths of any structure, such as a bridge or culverts, in the Hassayampa River.

#### 3.4.5 *Lateral Erosion*

Bank erosion from flood events is a critical concern for potential Yuma Parkway infrastructure. The *LHWMP River Behavior Report (FCDMC, 2006)* concluded that rather than undergo significant vertical changes in bed elevation in response to changes in flow or sediment supply, the river tends to migrate laterally. Both the LHWMP and the ETS report provide detailed analyses of river morphology within the study area. The active channel in Reach 2 was listed as varying between 100 to 600 feet wide.



**Vertical cutbanks**

Vertical cutbanks within the limits of the study area, evidence of lateral migration, varied between two to eight feet at the time of the LHWMP field investigation. Cutbanks were typically located on the outside of large bends in the active channel. Bank materials in cutbanks were found to be composed of non-cohesive, highly erodible fine-grained alluvium. Photos 662 and 663 in **Appendix TM3-05** show wash banks in the study area that have recently eroded into near vertical cut banks. These banks are unstable and may continue to erode during successive flood events until a more resistant soil layer is encountered.

**Appendix TM3-07** presents photos and map exhibits showing the extent of bank erosion of the Hassayampa River during the recent January 2010 flood event. As shown in the map exhibit, the three SRP transmission line towers near the Yuma Road section line were originally built above the bank of the Hassayampa River. The bank of the river eroded approximately 265 feet during this single storm event, exposing the tower footings as shown in the photos and providing yet another indicator of the extremely erosive nature of the Hassayampa River. Analysis of historical lateral migration events in the ETS report indicate that internal forces such as pore water pressure likely played a larger factor in bank migration than external scour forces such as bend scour. Sloughed material at the toe of the banks, as seen in the photo at left, supports this conclusion.

Avulsions (when flows abandon a previously established channel in favor of a new drainage path) can unexpectedly form when some manmade or natural changes are made in the floodplain terrain. Yuma Parkway improvements should minimize changes to existing flow paths as much as possible, and provide adequate structural protection of the roadway at all wash crossing locations. Photo 700 in **Appendix TM3-05** shows an example of bank stabilization measures that have been constructed within the study area.

The LHWMP classified the Hassayampa River as having a naturally braided pattern, with the active channel pattern consisting mostly of a single channel within the study area. The river is subject to extreme rates of lateral erosion during small and large flood events. The active flow channel moves laterally on a frequent basis, except at confluences with major tributaries. The maximum reported change in channel position during a single storm event was 1,300 feet. The LHWMP included the delineation of Hassayampa River erosion hazard zones to safeguard future development from river bank movement. Existing erosion hazard maps and historical channel locations are shown in **Appendix TM3-08**. The ETS report redefined floodway and erosion hazard zones after the primary flow channel moved in the January 2010 storm event. These revised erosion hazard figures can be found in **Appendix TM3-07**.

Wherever possible, care must be taken to locate foundations and structures, such as proposed bridge abutments, outside of the erosion hazard zones that have been delineated for the Hassayampa River. This system is highly dynamic and has a history of rapidly

changing channels. If structures must be placed inside the erosion hazard zones, the ETS report provided some potential mitigation options: bank protection (such as soil cement), ring dikes, grade control structure or dumped riprap, training devices (such as bendway weirs), and detention ponds. The follow-up report, *500 kV Electric Transmission Structures Hassayampa River Phase 3 Hydrologic Engineering Services* (SRP, 2011) provided further technical analysis for the selected mitigation measure: a single ring dike around the three transmission towers. As the proposed Yuma Parkway will likely cross the Hassayampa River near these existing towers, any design improvements in the area will need to consider both the existing towers and any associated scour countermeasures.

### 3.5 Existing Drainage Structures

#### 3.5.1 Culverts

East of the Hassayampa River, the existing paved Yuma Road contains numerous cross culverts. These culverts are typically corrugated metal pipe (CMP) with concrete headwalls. The design storm of these culverts is not known, but based on field observations they are only capable of containing relatively small flows. Erosion protection at outlets was not observed; however, little evidence of inlet or outlet scour was seen in the field.



**Culvert near Palo Verde Road**

There are also twin reinforced concrete pipe (RCP) culverts at the Four Mile Wash crossing of the Salome Highway. These culverts appear to have grouted riprap instead of headwalls at the pipe inlet and outlet. At the present time, there is little evidence of scour. Sedimentation does appear to be a maintenance issue for culverts in this area.

#### 3.5.2 At-Grade Crossings

The existing Buckeye Road features at-grade dip crossings instead of culverts at the eight study crossing locations west of the Hassayampa River. The larger washes have concrete aprons on the upstream and downstream sides of the at-grade crossings. Evidence of downstream undercutting of this apron, as shown in the photo at right, was found at the Dickey Wash crossing.



**Dickey Wash crossing**

As the intent of drainage design for Yuma Parkway will be to maintain existing flow patterns to the extent feasible, it is expected that more detailed hydraulic calculations will

be required if culverts are proposed at a future date. Care must be exercised to avoid adverse flooding impacts on upstream adjacent properties if the proposed roadway is raised for a dry crossing, and to avoid adverse flooding impacts on downstream properties by concentrating sheet flows at crossing locations.

### 3.5.3 Channels

The only drainage channels observed during the field visit were at Stotz Dairy and Phillips Wash. An earthen channel has been constructed south of Yuma Road through the dairy property. This channel likely has been designed to convey both offsite flows and local onsite runoff from the dairy land. As with all the drainages east of the Hassayampa River, little offsite flow is expected due to the Buckeye FRS #1.



**Stotz Dairy channel**

The partial channelization of Phillips Wash occurs downstream of Buckeye Road. The wash bed is at the natural location, but a vertical gabion wall has been constructed along the east bank to protect 355<sup>th</sup> Avenue from lateral migration of the wash. This gabion wall is displayed in Photo 700 of **Appendix TM3-05**.

### 3.5.4 Buckeye Flood Retarding Structure #1

Buckeye Flood Retarding Structure (FRS) #1 is located immediately east of the Hassayampa River and north of I-10. This earthen embankment was constructed in 1974 to provide flood protection for the interstate and downstream properties. The embankment is approximately seven miles long and outlets west into the Hassayampa River. Yuma Parkway will not impact the Buckeye FRS #1, but the dam impacts offsite flows that reach the study area. The structure intercepts offsite flows that historically traveled south through the study area east of the Hassayampa River. This runoff is instead retained behind the dam; with excessive flows from large storm events being discharged directly to the Hassayampa River. If the earthen embankment were to fail when water is impounded, the entire study area east of the Hassayampa River could potentially be at risk of inundation. The potential inundation areas and flood depths/velocities from the *Emergency Action Plan for the Buckeye Structures* (FCDMC, 2007) are included in **Appendix TM3-09**.

The FCDMC is currently in the design phase of a rehabilitation project for Buckeye FRS #1. Overall rehabilitation has been chosen as the alternative to move forward into final design. Based on conversations with the FCDMC Project Manager (2011), this alternative does not represent a significant change from existing conditions. The principal spillway capacity is approximately 400 cfs, which is much less than flood flows within the Hassayampa River. The emergency spillway is utilized only for events greater than the 500-year flood.

## 4. EXISTING HYDROLOGY

Various hydrologic studies have been completed that together encompass the entire study area. These existing studies were not necessarily performed to the same level of detail. Some studies, typically those intended for planning purposes, focused on broad drainage trends, featuring large subbasins and a limited number of concentration points. On the other hand, studies intended for floodplain delineation purposes typically used small subbasins and a large number of concentration points. To present a consistent level of hydrologic analysis throughout this study, offsite flows were reported at each location where a regulatory 100-year floodplain or a United States Geological Survey (USGS) “blue line” stream crossed the study corridor centerline. Regulatory floodplains can be FEMA effective floodplains or 100-year floodplains that have been recognized by FCDMC. USGS “blue lines” refer to intermittent and perennial streams that are shown (in blue) on the commonly referenced USGS primary series quadrangle maps. **Table 1** presents an overview of the offsite hydrology concentration points examined for this report.

The location of each offsite drainage crossing is provided in **Figure 6**. Drainage crossings 1-9 are located in the region west of the Hassayampa River. Crossings 10-13 are in the Hassayampa River region and Crossings 14-18 are located in the region east of the Hassayampa River. Six named washes exist in the study area.

### 4.1 Summary of Hydrology Methods

Existing hydrology data for the study area was extracted for each of the 18 offsite concentration points from the following five studies:

- Palo Verde Watershed Detailed Floodplain Delineation Study Hydrology Study (FCDMC, Draft 2010);
- Hydrologic Study Report for Luke Wash Zone AE Floodplain Delineation Study (FCDMC, 2008);
- Hydrologic Analysis of the Hassayampa River in Maricopa County, Arizona (FEMA, 1988); and
- Buckeye Area Drainage Master Plan Existing Conditions Hydrology Update (FCDMC, 2008).

**Figure 6** shows the subbasins within each of these watersheds grouped by color. Concentration points in existing studies were used directly if located near the study corridor. If a crossing was not near a published concentration point, the peak flow was calculated as the contributing area weighted portion of the next downstream published value. The methodology used in each existing study is summarized as follows. The watersheds are discussed from a west to east direction.

#### 4.1.1 *Palo Verde Watershed*

The 100-year, 6-hour and 24-hour storm events were modeled for the Palo Verde Watershed using HEC-1 software, in conjunction with methods and procedures described by FCDMC. Drainage Design Management System for Windows (DDMSW) software was utilized to prepare the input parameters for the HEC-1 models. ArcGIS was utilized to prepare parameters for modeling purposes.

**Table 1 – Significant Offsite Drainage Crossings**

<b>Crossing ID</b>	<b>Watercourse Name</b>	<b>Nearest Cross Street</b>	<b>FEMA / FCDMC Regulatory Floodplain</b>	<b>USGS "Blue Line"</b>
1	Four Mile Wash	388 <sup>th</sup> Ave	Yes	Yes
2	T1N-R6W-S17E	387 <sup>th</sup> Ave	Yes	No
3	T1N-R6W-S08	379 <sup>th</sup> Ave	Yes	No
4	T1N-R6W-S16	377 <sup>th</sup> Ave	Yes	No
5	T1S-R6W-S27	376 <sup>th</sup> Ave	Yes	Yes
6	T1S-R5W-S17	363 <sup>rd</sup> Ave	Yes	Yes
7	Phillips Wash	355 <sup>th</sup> Ave	Yes	Yes
8	Dickey Wash	350 <sup>th</sup> Ave	Yes	Yes
9	Luke Wash	343 <sup>rd</sup> Ave	Yes	Yes
10	T1N-5W-S22	336 <sup>th</sup> Ave	Yes	Yes
11	T1N-5W-S15	333 <sup>rd</sup> Ave	Yes	Yes
12	Hassayampa River	N/A	Yes	Yes
13	Unnamed Tributary to Hassayampa River	Powers Butte Rd	Yes	Yes
14	Unnamed Tributary to Hassayampa River	315 <sup>th</sup> Ave	Yes	Yes
15	White Tanks Wash	309 <sup>th</sup> Ave	Yes	Yes
16	Unnamed Tributary to Gila River	Johnson Rd	No	Yes
17	Unnamed Tributary to Gila River	N/A	No	Yes
18	Unnamed Tributary to Gila River	Palo Verde Rd	No	Yes

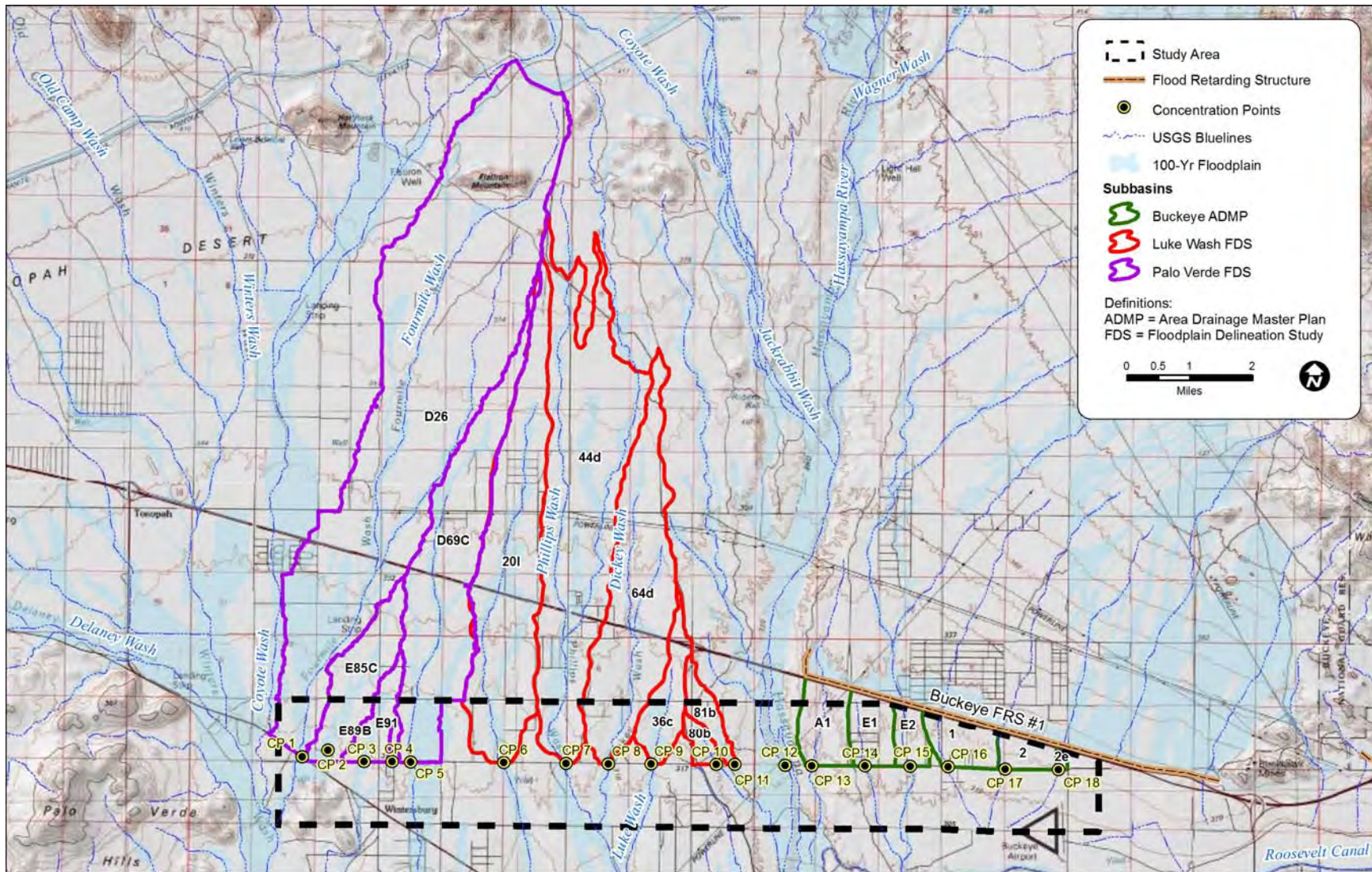


Figure 6 – Offsite Hydrology Workmap

National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall data was used to estimate the design rainfall depth for this study. FCDMC 6-hour local storm distributions for the 6-hour model and the SCS Type II precipitation distribution for the 24-hour model were used for HEC-1 rainfall distributions. The Green and Ampt infiltration equations were utilized for the estimation of rainfall losses. Topography used for the study consisted primarily of 10-foot contour interval mapping north of the CAP Canal and 2-foot contour interval data south of the CAP Canal. Aerial mapping (2008) was used to adjust subbasin delineations as appropriate.

Normal depth channel routing methodology was utilized in the hydrologic model to route surface runoff through subbasins, and the Modified Puls method with stage-storage-discharge relationships was used for storage routing. Rating tables to determine flow splits were based on normal depth hydraulic calculations. The longitudinal slopes were estimated with ArcGIS based on existing topography, and Manning's "n" values were based on field reconnaissance and aerial photography.

Events were modeled for two separate conditions: a "With Levee" scenario that accounts for the effects of structures such as the CAP Canal, I-10, Palo Verde Power Plant, and Salome Highway, and a "Without Levee" scenario that ignores the embankments (FCDMC, 2010). Of particular relevance to the Yuma Parkway study, the Salome Highway near Four Mile Wash is one of the non-certified levees that is modeled differently in the two scenarios. In the "Without Levee" models the full flow is routed directly across the highway, but in the "With Levee" models some of the flow is diverted east.

#### 4.1.2 Luke Wash Watershed

The 100-year, 6-hour and 24-hour storm events were modeled for the Luke Wash watershed using HEC-1 software, in conjunction with methods and procedures described by FCDMC. Watershed Modeling System (WMS) software was used to develop the preliminary subbasin boundary delineations. DDMSW software was utilized to prepare the input parameters for the HEC-1 models. ArcGIS was applied to transfer databases available from FCDMC to prepare parameters for modeling purposes. Surface runoff from the subbasins has the potential to concentrate at more than one point. It was assumed that the concentration point was located at the hydrologic low point of the subbasin (FCDMC, 2008).

NOAA 14 rainfall data was used to estimate the design rainfall depth for this study. FCDMC 6-hour local storm distributions for the 6-hour model and the SCS Type II precipitation distribution for the 24-hour model were used for HEC-1 rainfall distributions. The Green and Ampt Method was utilized for the estimation of rainfall losses. The S-Graph method was used for the development of unit hydrographs.

Normal depth channel routing methodology was utilized in the hydrologic model to route surface runoff through subbasins. An eight-point composite channel cross-section was developed to represent typical wash cross-section conveyance using 2-foot contour mapping. The longitudinal slopes were estimated based on general existing wash slopes, and Manning's "n" values were based on field reconnaissance estimates.

#### 4.1.3 *Hassayampa River*

Peak discharges at three existing stream gage locations were calculated using a Log-Pearson Type III statistical analysis of each site's gage records. Yuma Parkway is upstream of gage station 95170 (Arlington) and downstream of gage station 95165 (Morristown), which had 22 and 30 years of recorded data, respectively. The study recommended using a 100-year peak discharge of 74,100 cfs at the Arlington gage station and 61,600 cfs at the Morristown gage station. The original published discharge (FEMA, 1988) nearest the study area was the Hassayampa River at I-10 with a 100-year peak of 74,800 cfs. Flow rates for locations between the previously described reference stations were calculated by interpolation using an attenuation rate per stream mile.

#### 4.1.4 *Buckeye Area Watershed*

The 100-year and 10-year, 6-hour and 24-hour storm events were modeled for the Buckeye Area Watershed using HEC-1 software, in conjunction with methods and procedures described by FCDMC. DDMSW software was utilized to prepare the input parameters for the HEC-1 models. The primary goal of this hydrology update was to update existing land uses in the hydrologic model.

NOAA 2 rainfall data was used to estimate the design rainfall depth for this study. Rainfall distributions for the 6-hour storm were taken from the FCDMC *Hydrology Manual*. SCS Type II precipitation distributions were used for 24-hour models. The Green and Ampt Method was utilized for the estimation of rainfall losses. The S-Graph method was used for the development of unit hydrographs.

Normal depth channel routing methodology was used to route runoff through subbasins. An eight-point composite channel cross-section was obtained from field surveys to represent typical wash cross-section conveyance. Some routing channels were expanded if they were incapable of conveying the 100-year peak discharge. Retention basin information of existing developments was collected from drainage reports or estimated from Buckeye's 100-year, 2-hour retention requirement and accounted for in the storage routing.

## 4.2 **Offsite Hydrology Results**

Detailed hydrologic analysis was not performed as part of this study. The existing peak 100-year flows for each major wash crossing of the study area are listed in **Table 2**. The wash information presented previously is also included to provide a comprehensive summary of the offsite hydrology at each crossing. Note that the contributing basins shown in **Figure 6** have been trimmed at the section line, and the drainage areas reported in **Table 2** reflect these revised areas. **Table 2** indicates if the peak flow was taken directly from an existing study or if the discharge was calculated as a contributing area weighted portion of a published value. The concentration point or subbasin identification and storm duration used in each existing study are also presented. Excerpts from the original source documents of each respective hydrologic study are included in **Appendix TM3-10**.

The regional watercourse within the study area is the Hassayampa River (Crossing 12). The peak flows presented for these large crossings in **Table 2** reflect the effective FEMA discharges, but it should be noted that these values have been the subject of significant debate. A limited record of stream gage measurements were available when the peak flows were calculated for FEMA in



1988 and new statistical analyses continue to be performed as more gage data becomes available. An analysis completed for the FCDMC as part of the LHWMP *Hydrology Report* (FCDMC, 2005) presented peak discharges that were much lower than the effective peak discharges. For instance, the Hassayampa River 100-year flow rate at I-10 was calculated as 39,000 cfs. The 100-year flow presented in the original 1988 FEMA report was 74,100 cfs, and the most recent FEMA effective flow is 75,164 cfs at this location. The USGS is also conducting a statistical analysis of their Hassayampa River gage records and should present results soon. However, despite the varying results it is unlikely that FCDMC and FEMA will adopt different regulatory flows for these reaches in the near future. The recommended design flows for the Hassayampa Rivers is the FEMA effective flow shown in **Table 2**.

**Table 2 – Offsite Hydrology Results**

<b>Crossing ID</b>	<b>Watercourse Name</b>	<b>Nearest Cross Street</b>	<b>Drainage Area (mi<sup>2</sup>)</b>	<b>FEMA / FCDMC Regulatory Floodplain</b>	<b>USGS "Blue Line"</b>	<b>Calculation Method</b>	<b>Existing Study Name</b>	<b>Existing Study ID</b>	<b>Storm Duration</b>	<b>Peak 100-Year Flow (cfs)</b>
1	Four Mile Wash	388th Ave	17.92	Yes	Yes	published value	Palo Verde FDS	C760M	24-Hour	3,659
2	T1N-R6W-S17E	387th Ave	1.86	Yes	No	published value	Palo Verde FDS	C770C	24-Hour	1,674
3	T1N-R6W-S08	379th Ave	0.73	Yes	No	published value	Palo Verde FDS	S800A	6-Hour	800
4	T1N-R6W-S16	377th Ave	0.10	Yes	No	published value	Palo Verde FDS	S800B	6-Hour	360
5	T1S-R6W-S27	376th Ave	5.53	Yes	Yes	published value	Palo Verde FDS	C910J	24-Hour	848
6	T1S-R5W-S17	363rd Ave	6.03	Yes	Yes	published value	Luke Wash FDS	C20h	24-Hour	1,045
7	Phillips Wash	355th Ave	8.34	Yes	Yes	published value	Luke Wash FDS	C40c	24-Hour	2,107
8	Dickey Wash	350th Ave	4.98	Yes	Yes	published value	Luke Wash FDS	C60b	24-Hour	1,571
9	Luke Wash	343rd Ave	1.09	Yes	Yes	published value	Luke Wash FDS	36c	24-Hour	702
10	T1N-5W-S22	336th Ave	0.28	Yes	Yes	published value	Luke Wash FDS	80b	24-Hour	404
11	T1N-5W-S15	333rd Ave	0.51	Yes	Yes	published value	Luke Wash FDS	81b	24-Hour	495
12	Hassayampa River		1,450	Yes	Yes	published value	FEMA FIS	At I-10	6-Hour	75,164
13	Unnamed Tributary to Hassayampa River	Powers Butte Rd	1.07	Yes	Yes	partial area pro-rate	Buckeye ADMP	A1	6-Hour	1,040
14	Unnamed Tributary to Hassayampa River	315th Ave	0.83	Yes	Yes	partial area pro-rate	Buckeye ADMP	E1	6-Hour	774
15	White Tanks Wash	309th Ave	0.53	Yes	Yes	partial area pro-rate	Buckeye ADMP	E2	6-Hour	342
16	Unnamed Tributary to Gila River	Johnson Rd	0.87	No	Yes	partial area pro-rate	Buckeye ADMP	1	6-Hour	308
17	Unnamed Tributary to Gila River		0.50	No	Yes	partial area pro-rate	Buckeye ADMP	2	6-Hour	556
18	Unnamed Tributary to Gila River	Palo Verde Rd	0.07	No	Yes	partial area pro-rate	Buckeye ADMP	2	6-Hour	76

## 5. SUMMARY AND CONCLUSIONS

The purpose of TM 3 is to provide an overview of the existing drainage conditions and patterns, including peak flows, for the study area based on available studies and data. The findings of this memorandum will help determine the preferred alignment for the proposed Yuma Parkway. Drainage structures and features in and around the study area have been identified and should be considered during the design of the future parkway. Peak flows reported in this memorandum have been compiled for planning purposes only. Discharges should be evaluated based on FCDMC drainage criteria during final design of the parkway.

The impacts of crossing the numerous washes in the study area should be a significant consideration when developing and evaluating potential parkway alignment alternatives. Drainage structures, such as bridges and box culverts, necessary to convey flood flows under the proposed parkway will play a considerable role in both the cost and impacts of the project. Structures that are too large will result in unnecessary capital costs for the project; however, structures that are too small can cause substantial adverse impacts to adjacent properties and the environment and also result in increased maintenance costs. As a result, the two overarching goals of drainage design for Yuma Parkway are to minimize the impacts of the proposed parkway on existing drainage patterns, and to minimize the impacts of drainage on the parkway.

Four Mile Wash is a major wash crossing that may be avoided with an adjustment of the proposed alignment for Yuma Parkway. The Four Mile Wash floodplain is approximately 3,300 feet wide at the intersection of the Salome Highway and the Buckeye Road alignment. If the Yuma Parkway alignment were to tie into the Salome Highway further east (south of the section line), the crossing could be avoided completely.

Due to the nature of the study area, most wash crossings, unlike Four Mile Wash, are unavoidable regardless of the proposed alignment. At these locations, Yuma Parkway could cause incremental increases in inundation upstream of the road as well as increased flow velocities downstream of the road. As a result, the configuration and size of the drainage structures at these crossings are vital to avoiding adverse impacts to upstream and downstream properties. Avoiding adverse floodplain impacts are particularly important for the multiple drainage systems where flood flows are not contained in a well-defined channel, such as the drainage system near 371st Avenue. These watercourses typically have wide floodplains with shallow flow depths, and existing roadway crossings mainly consist of at-grade dip crossings. Concentrating flows to provide improved dry crossings of Yuma Parkway must be done carefully to avoid adverse impacts upstream and downstream of the project.

The most critical drainage crossing within the study corridor is at the Hassayampa River. In addition to floodplain impacts, the location and size of this proposed bridge crossing should take into account the highly dynamic nature of the watercourse. The river has demonstrated a significant potential for lateral migration of the river channel, especially within the Yuma Parkway study area, as evidenced by the January 2010 flood which eroded the river bank and exposed the footings of several SRP transmission line towers. If possible, proposed bridge abutments and other structures, should be located outside of the erosion hazard zones that have been delineated for the river. In addition, while the river appears to be in dynamic equilibrium (i.e., no trends toward significant aggradation or degradation) any potential changes to the sediment supply, such as increased sand and gravel mining operations, could cause long-term changes to river bed elevation and further impact the proposed bridge crossing.



Sedimentation is another factor that should be taken into account when designing proposed drainage structures. The high sediment loads associated with the Hassayampa River and its tributaries should be considered when sizing culverts. Undersized culverts can become easily clogged with sediment, which in turn can cause flooding problems upstream and possibly cause degradation downstream. Culverts should be sized appropriately to allow for the conveyance of sediment-laden flows, thereby maintaining the existing sediment continuity of the system.

In summary, the most important drainage issue to be considered during the alignment alternatives analysis is the location of crossings at the Hassayampa River and other major washes. The location, configuration and size of these crossings will play a substantial role in determining both the capital and long-term costs of the Yuma Parkway project as well as the impacts to existing conditions. If properly designed, the drainage structures will meet the two-fold goal of minimizing the impacts of Yuma Parkway on drainage and minimizing the impacts of drainage on Yuma Parkway.



# **APPENDIX TM3-01**

## **DATA COLLECTION SUMMARY**

**Summary Table of Documents Reviewed - Kimley-Horn and Associates**

AZGS = Arizona Geological Survey  
 ADOT = Arizona Department of Transportation  
 ADWR = Arizona Department of Water Resources  
 FCDMC = Flood Control District of Maricopa County  
 FEMA = Federal Emergency Management Agency  
 KHA = Kimley-Horn and Associates  
 MAG = Maricopa Associated Governments  
 MC = Maricopa County  
 MCDOT = Maricopa County Department of Transportation

**Yuma Parkway  
 Corridor Feasibility Study  
 Data Collection Summary**

**Drainage Document Inventory**

LIBRARY	ITEM				TRACKING			
KHA No.	Title	Description	Author	Date	Source	Format/ File Type	Collected By	Discipline
75	500 kV Electric Transmission Structures Hassayampa River Hydrologic Engineering Services	Examines hydraulics, scour, and sediment transport of Hassayampa River as it relates to the tower foundations along the banks. Also presents mitigation alternatives	WEST Consultants	Aug 2010	WEST	pdf	BML	Drainage
76	500 kV Electric Transmission Structures Hassayampa River Phase 3 Hydrologic Engineering Services	Describes ring dike scour protection measures for selected alternative at transmission tower foundations	WEST Consultants	Feb 2011	WEST	pdf	BML	Drainage
79	A New Earth Fissure near Wintersburg, Maricopa, Arizona	report, maps, geology, + photos on earth fissure and nearby giant desiccation cracks, Open-File Report 01-10	AZGS	Nov 2001	AZGS	pdf	BML	Geology
2	Active Land Subsidence Areas in Arizona Based on ADWR InSAR Data	map showing active subsidence areas	ADWR	Jul 2009	ADWR	pdf	BML	Water
80	Additional Giant Desiccation Cracks near Wintersburg, Maricopa County, Arizona	report, maps, + photos on cracks, Open-File Report 03-07	AZGS	Nov 2003	AZGS	pdf	BML	Geology
3	ADWR GIS Data CD-ROM	Shapefiles: recharge points, industry points, depth to water and water level elev (Phoenix AMA only), irrigation polygons, hardrock	ADWR	Mar 2009	ADWR	CD	BML	Water
7	As-Built Report Buckeye Site 1 Drain Maricopa County, Arizona	as-built inspection report for 4.5 miles of 17.5' deep embankment drain trench for Buckeye FRS #1, includes plans at end of document	ERTEC, Inc.	Mar 1981	FCDMC	pdf	BML	Drainage
68	Bridge Scour and Design of Corrective Measures for Old U.S. 80 Highway Bridge over Hassayampa River	presents 3 alternatives for scour countermeasures	INCA Engineers	Oct 1997	FCDMC	pdf	BML	Drainage
67	Bridge Scour Assessment Reports for 16 Maricopa County Bridges Volume II Structure Numbers 9427, 9588, 9999, 8038, 7818, 9154, 9142, 7553	assesses scour failure for superflood at Old US 80 Bridge over Hassayampa River	Cannon & Associates	Jul 1996	FCDMC	pdf	BML	Drainage
74	Buckeye Area Drainage Master Plan Existing Conditions Hydrology Update	updates HEC-1 models from ADMS with newer (existing) land use and limited retention basin information	Dibble Engineering	Mar 2008	FCDMC	pdf	BML	Drainage
8	Buckeye Area Drainage Master Plan Recommended Design Report	describes various plan components to manage runoff. Study area is south of I-10. Also includes Conceptual Design Plans for recommended channels and detention basins.	Dibble Engineering	Jun 2009	FCDMC	pdf	BML	Drainage
9	Buckeye Area Flood Delineation Study Hydrology Report	FEMA report to estimate 100-yr peak flows for floodplain delineation. Study area is south of I-10 so not esp. pertinent to NP.	McLaughlin Kmetty Engineers	Jul 1992	FCDMC	pdf	BML	Drainage
61	Buckeye Area Flood Delineation Study Public Notification and FEMA Forms RSD-1 Document	documentation notebook for detailed floodplains along RID Canal, SPRR, and Buckeye Canal embankments	FCDMC	Apr 1994	FCDMC	pdf	BML	Drainage

**Summary Table of Documents Reviewed - Kimley-Horn and Associates**

**AZGS** = Arizona Geological Survey  
**ADOT** = Arizona Department of Transportation  
**ADWR** = Arizona Department of Water Resources  
**FCDMC** = Flood Control District of Maricopa County  
**FEMA** = Federal Emergency Management Agency  
**KHA** = Kimley-Horn and Associates  
**MAG** = Maricopa Associated Governments  
**MC** = Maricopa County  
**MCDOT** = Maricopa County Department of Transportation

**Yuma Parkway  
 Corridor Feasibility Study  
 Data Collection Summary**

**Drainage Document Inventory**

LIBRARY	ITEM				TRACKING			
	KHA No.	Title	Description	Author	Date	Source	Format/ File Type	Collected By
84	Buckeye Flood Retarding Structure No. 1 Rehabilitation Project	study currently under development (in final design phase) to fully rehab embankment	FCDMC	pending	FCDMC	phone	BML	Drainage
66	Buckeye/Sun Valley Area Drainage Master Study Geomorphic Evaluation and Landform Stability Assessment	focuses on areas 3/4 -- not relevant	Ayres Associates	Jul 2005	FCDMC	pdf	BML	Drainage
64	Buckeye/Sun Valley Area Drainage Master Study Guidelines for Development	presents existing regulations, potential flooding/erosion impacts due to development, and proposed guidelines	PBS&J	Jan 2006	FCDMC	pdf	BML	Drainage
62	Buckeye/Sun Valley Area Drainage Master Study Technical Data Notebook Volume IV-B: Area 2 Hydrology, Hydraulics, and Floodplain Delineation Report	See title (Area 2 is from Hassayampa River to Johnson Rd)	PBS&J	Feb 2006	FCDMC	pdf	BML	Drainage
63	Buckeye/Sun Valley Area Drainage Master Study Technical Data Notebook Volume V-A2: Area 3 Hydrology Report	Area 3 is north of I-10, so probably not relevant	PBS&J	Feb 2006	FCDMC	pdf	BML	Drainage
65	Buckeye/Sun Valley Area Drainage Master Study Technical Memorandum T2.6.5 Delineation of Erosion Hazard Setbacks	short memos and erosion hazard setback mapping for area 2 and 3	Ayres Associates	May 2005	FCDMC	pdf	BML	Drainage
10	Buckeye/Sun Valley Area Drainage Master Study Volume I: Master Document Summary	overview of the project and the four areas included. References the other eight volumes	PBS&J	Jun 2006	FCDMC	pdf	AOM	Drainage
11	Buckeye/Sun Valley Area Drainage Master Study Volume III-A: Area 1 Hydrology Report	description of hydrologic methods and results for Area 1	PBS&J	Aug 2006	FCDMC	pdf	AOM	Drainage
12	Buckeye/Sun Valley Area Drainage Master Study Volume IV-B: Area 2 Floodplain Delineation Report	description of hydrologic and hydraulic methods and results for Area 2	PBS&J	Feb 2006	FCDMC	pdf	AOM	Drainage
13	D.W.R. Hydrologic Map Series Report No. 10	maps showing groundwater conditions in the Hassayampa Sub-basin of the Phoenix Active Management Area	ADWR	1982	ADWR	pdf	BML	Water
70	D.W.R. Hydrologic Map Series Report No. 12	maps showing groundwater conditions in the West Salt River, East Salt River, Lake Pleasant, Carefree and Fountain Hills Sub-basins of the Phoenix AMA	ADWR	1983	ADWR	pdf	BML	Water
14	D.W.R. Hydrologic Map Series Report No. 27	maps showing groundwater conditions in the Phoenix Active Management Area	ADWR	1992	ADWR	pdf	BML	Water
15	D.W.R. Hydrologic Map Series Report No. 35	maps showing groundwater conditions in the Phoenix Active Management Area	ADWR	Nov 2002-Feb 2003	ADWR	pdf	BML	Water
58	Data Collection and Modeling Approach for Selected River Mechanics Tasks of Phase II of the Lower Hassayampa Watercourse Master Plan	topo and hydraulic/sediment transport models, mining photos	FCDMC	Nov 2010	FCDMC	CD	BML	Drainage

**Summary Table of Documents Reviewed - Kimley-Horn and Associates**

AZGS = Arizona Geological Survey  
 ADOT = Arizona Department of Transportation  
 ADWR = Arizona Department of Water Resources  
 FCDMC = Flood Control District of Maricopa County  
 FEMA = Federal Emergency Management Agency  
 KHA = Kimley-Horn and Associates  
 MAG = Maricopa Associated Governments  
 MC = Maricopa County  
 MCDOT = Maricopa County Department of Transportation

**Yuma Parkway  
 Corridor Feasibility Study  
 Data Collection Summary**

**Drainage Document Inventory**

LIBRARY	ITEM				TRACKING			
KHA No.	Title	Description	Author	Date	Source	Format/ File Type	Collected By	Discipline
19	DI-05: Geologic Data for the Phoenix South 30' x 60' Quadrangle	1:100,000 digital map of OFR93-18, in jpg and shp formats	AZGS	Mar 2006	AZGS	CD	BML	Geology
82	Drainage Policies and Standards for Maricopa County, Arizona	drainage standards	FCDMC	Apr 2007	FCDMC	pdf	BML	Drainage
20	Earth Fissure Map of Maricopa County, Arizona	mapping of earth fissures	AZGS	Dec 2009	AZGS	pdf	BML	Geology
81	Earth Fissure Map of the Wintersburg Study Area: Maricopa County, Arizona	location map of nearest earth fissure, Digital Map Series-Earth Fissure Map 10	AZGS	Feb 2009	AZGS	pdf	BML	Geology
60	Emergency Action Plan for the Buckeye Structures	flowcharts and downstream inundation exhibits for frs #1, #2, #3	LTM Engineering	Jun 2007	FCDMC	CD	BML	Drainage
108	Flood Insurance Rate Map Maricopa County, Arizona and Incorporated Areas	effective FIRMs: panels 1980, 1985, 1990, 2005, 2010, 2015, and 2020	FEMA	Sep 2005	FEMA	jpg	BML	Drainage
22	Flood Insurance Study Maricopa County, Arizona and Incorporated Area	FIS No. 04013CV001A: description of general flooding issues in county, effective discharges, and flood profiles	FEMA	Sep 2005	KHA	pdf	BML	Drainage
109	FLUVIAL-12 Modeling of Sand Mining Impacts for Lower Hassayampa River	mobile boundary sediment transport model comparing existing conditions and scenario where all active mining permits are exercised	FCDMC	May 2009	FCDMC	pdf	BML	Drainage
17	Geologic Map of the Buckeye NW 7.5' Quadrangle, Maricopa County, Arizona	DGM-37	AZGS	Nov 2004	AZGS	CD	BML	Geology
18	Geologic Map of the Wintersburg 7.5' Quadrangle, Maricopa County, Arizona	DGM-47	AZGS	Mar 2006	AZGS	CD	BML	Geology
25	GWSI Database CD-ROM	Access database of Groundwater Site Inventory: well ownership, historic water levels, construction data, etc.	ADWR	Jul 2009	ADWR	CD	BML	Water
71	GWSI Hydrographs	historical groundwater levels at four sites: B-01-05 10BBC, 33254111, 33263411, and 33264811	ADWR	May 2011	ADWR	pdf	BML	Water
83	Hydrologic Analysis of the Hassayampa River in Maricopa County, Arizona	hydrology for jackrabbit wash and hassayampa river completed for FIS	FEMA	May 1988	FCDMC	pdf	BML	Drainage
27	Hydrologic Study Report for Luke Wash Zone AE Floodplain Delineation Study	Contains only the hydrology documentation (Section 4) of a larger study	Wood, Patel & Associates	Sep 2008	KHA	pdf	BML	Drainage
29	Hydrologic/Hydraulic Design Analysis of Proposed Sun Valley Parkway Crossing of the Buckeye Watershed Structure	summary of the analysis of the proposed improved interchange on the Buckeye FRS #1	Collar, Williams & White Engineering	Aug 1987	FCDMC	pdf	BML	Drainage
73	Land Subsidence in the Buckeye Area, Western Maricopa County 02/10/2007 to 04/05/2008	map showing 1.2 yr subsidence (0 to 3 cm)	ADWR	Apr 2008	ADWR	pdf	BML	Water

**Summary Table of Documents Reviewed - Kimley-Horn and Associates**

AZGS = Arizona Geological Survey  
 ADOT = Arizona Department of Transportation  
 ADWR = Arizona Department of Water Resources  
 FCDMC = Flood Control District of Maricopa County  
 FEMA = Federal Emergency Management Agency  
 KHA = Kimley-Horn and Associates  
 MAG = Maricopa Associated Governments  
 MC = Maricopa County  
 MCDOT = Maricopa County Department of Transportation

**Yuma Parkway  
 Corridor Feasibility Study  
 Data Collection Summary**

**Drainage Document Inventory**

LIBRARY	ITEM				TRACKING			
KHA No.	Title	Description	Author	Date	Source	Format/ File Type	Collected By	Discipline
72	Land Subsidence in the Buckeye Area, Western Maricopa County 02/25/2006 to 04/05/2008	map showing 2-yr subsidence (0 to 4 cm)	ADWR	Apr 2008	ADWR	pdf	BML	Water
31	Lower Hassayampa Watercourse Master Plan Phase I	seven technical reports intended to develop guidance for managing the river floodplain	FCDMC	Apr 2006	FCDMC	pdf	AOM	Drainage
28	Luke Wash Watershed Zone AE Floodplain Delineation Study Technical Data Notebook	4 volumes. Report, survey field notes, supporting documentation, and exhibits.	Wood, Patel & Associates	Mar 2009	FCDMC	pdf	BML	Drainage
32	Maricopa County Drainage Policies and Standards	drainage guidelines	MC	Jan 2007	KHA	pdf	BML	Drainage
38	National Engineering Handbook Part 630 Hydrology	Chapter 7 Hydrologic Soil Groups	NRCS	May 2007	NRCS	pdf	BML	Drainage
78	Palo Verde Watershed Detailed Floodplain Delineation Hydrology Draft GIS Subbasins	ArcGIS files showing hydrology schematics for With and Without Levee models	Entellus	Sep 2010	FCDMC	gdb	BML	Drainage
77	Palo Verde Watershed Detailed Floodplain Delineation Hydrology Study (DRAFT)	documents hydrology for palo verde watershed detailed study - includes report, exhibits, and DDMSW/HEC-1 files. Study is still open and this is not the final version	Entellus	Sep 2010	FCDMC	zip	BML	Drainage
39	Palo Verde Watershed Zone A Floodplain Delineation Study Technical Data Notebook	7 volumes. Hydrology, hydraulics, and floodplain delineation for approx. 400 miles of washes; Area C and Area D cover western portion of NP study area.	Entellus	May 2003	FCDMC	pdf	BML	Drainage
40	Phoenix Active Management Area	maps shows major infrastructure and grandfathered water rights	ADWR	Sep 2003	ADWR	pdf	BML	Water
47	Roadway Design Manual	guidelines for standard roadway design	MCDOT	Apr 2004	KHA	pdf	BML	Roadway
69	Special Provisions for Palo Verde Road T.I.	special provisions for bid document	ADOT	Jul 1987	FCDMC	pdf	BML	Roadway
57	Uplift in the Vicinity of the Tonopah Recharge Facility	map showing ground uplift from 2006 to 2010 due to recharge plume	ADWR	Mar 2010	ADWR	pdf	BML	Water



# **APPENDIX TM3-02**

## **EXISTING GEOLOGIC MAPPING**

# Geologic Map of the Wintersburg 7.5' Quadrangle, Maricopa County, Arizona

by Philip A. Peartree and Charles A. Ferguson and Raymond C. Harris  
Arizona Geological Survey Digital Geologic Map 47 (DGM-47), version 1.0  
March 2006

Citation for this map: Peartree, P. A., Ferguson, C. A., Harris, R. C., 2006. Geologic map of the Wintersburg 7.5' Quadrangle, Maricopa County, Arizona: Tucson, Arizona: Arizona Geological Survey Digital Geologic Map 47 (DGM-47), version 1.0, 1 CD-ROM with 1 Adobe Acrobat file (1 sheet, layout scale 1:24,000).

Not to be reproduced for commercial purposes

Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number #D40HAG0072. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

### Acknowledgments

The Flood Control District of Maricopa County provided high-resolution digital orthophotos that were used to accurately locate surficial geologic unit boundaries. Stevan Gyetvaly was the cartographer for version 1.0 of DGM-47.

### Introduction

The Wintersburg 7.5' quadrangle is located 40 to 50 miles (70-90 km) west of downtown Phoenix. The map area covers much of the piedmont between the Palo Verde Hills and the Hassayampa River and a 7 mile (11 km) reach of the Hassayampa River. The quadrangle includes a portion of the Palo Verde Nuclear Generating Station (PVNGS) and Interstate Highway 10. It has experienced some suburban development associated with the PVNGS and is currently on the outer fringe of the greater Phoenix metropolitan area, so more development is likely in the near future. The small bedrock units in the southeastern quarter of the quadrangle were mapped by Charles Ferguson in the spring of 2005. Surficial deposits that cover most of the quadrangle were mapped by Philip Peartree using color aerial photos from 1979, high-resolution digital color orthophotos provided by the Flood Control District of Maricopa County by CDMA, Inc. and topographic information. Field checking was done in the spring, summer and fall of 2005. This mapping was done in conjunction with geologic mapping of the Flatiron Mountain 7.5' quadrangle (Spencer et al., 2005) to the north, and this quadrangle map is one of eight 1:24,000 scale geologic maps covering most of the Hassayampa Valley that have been produced in 2004 - 2006. This mapping was completed under the joint State/USGS/CDMA program, as specified in the National Geologic Mapping Act of 1992.

### Surficial Geology

The Wintersburg quadrangle is almost entirely covered with surficial deposits laid down by the Hassayampa River and numerous smaller tributary stream systems. These surficial deposits were mapped primarily using stereo pairs of color aerial photos taken in 1979 for the Bureau of Land Management, high-resolution digital orthophotos provided by the FCDMC, and topographic information obtained from the 7.5' United States Geological Survey digital geologic map. Mapping interpretations were verified by field observations during the spring, summer and fall of 2005; unit characteristics were described and unit boundaries were spot-checked in the field. The physical characteristics of Quaternary alluvial surfaces (channels, alluvial fans, floodplains, stream terraces) evident on aerial photographs and in the field were used to differentiate their associated deposits by age and source. This mapping was completed over a digital orthophoto base from 2003 provided by the FCDMC. Mapping was done in a GIS format and the final linework was generated from the digital data.

Several characteristics evident on aerial photographs and on the ground were used to differentiate various alluvial surfaces and deposits associated with them by age and source. The color of alluvial surfaces is partly controlled by soil color, desert pavement development and rock varnish, and vegetation type and density. Significant soil development begins beneath an alluvial surface after it becomes isolated from active flooding and deposition (Gale et al., 1981; Birkeland, 1999). Holocene soils typically have relatively subtle soil profiles, and Pleistocene soils are more strongly developed. Dark brown or gray, relatively uniform soil horizons develop over thousands to tens of thousands of years. Typical soil horizons in Pleistocene alluvial sediments of Arizona are reddish brown argillic horizons (zones of clay accumulation) and white calcic horizons (zones of calcium carbonate and silica accumulation). In areas such as the lower Hassayampa Valley, clay accumulation and reddening associated with argillic horizon development tend to be relatively weak even on old alluvial surfaces. On color aerial photographs and on the ground, older alluvial surfaces characteristically appear slightly redder or distinctly yellower (on more eroded surfaces) than younger surfaces. Dark rock varnish and gravel pavements also develop with time on stable alluvial surfaces, so well-preserved older surfaces typically have a dark brown color. Differences in the drainage patterns between surfaces also provide clues to surface age. Young alluvial surfaces commonly display distributary (branching downstream) or anastomosing (branching and rejoining) channel patterns. Areas adjacent to active channels commonly have little channel development because unconfined shallow flooding predominates. Dendritic (draining downstream) drainage patterns are characteristic, where modern drainages are incised into older surfaces. Topographic relief between adjacent alluvial surfaces and the depth of entrenchment of channels can be determined using stereo-paired aerial photographs and topographic maps. Young surfaces are minimally dissected and are less than 1 m above channel bottoms. Active channels are entrenched 1 to 5 m below Pleistocene alluvial surfaces, and the older surfaces typically have been moderately to severely rounded by erosion. Ages of various surficial deposits of the map area were roughly estimated based on regional correlations to southern Arizona.

Variations in the distribution of surfaces of different ages and sources and concomitant variations in dissection across the quadrangle provide evidence regarding the recent geologic evolution of this area. Generally, areas along the Hassayampa River are moderately to deeply dissected. The highest terrace remnants of the Hassayampa River (unit Q<sub>1</sub>) are in the east. In the west, the youngest Quaternary (Q<sub>1</sub>) terrace cap a several hundred meter thick aggradational sequence that was deposited during late Pleistocene to Quaternary (units Q<sub>1</sub> and Q<sub>2</sub>) (Shoustra et al., 1979). Adjacent piedmont areas to the west and north were aggrading in the late Pleistocene and early Quaternary as well (unit Q<sub>1</sub>). At that time the river was probably depositing sediment across a fairly broad floodplain in the eastern part of the quadrangle, and alluvial fans on both sides of the river were interfingering with the floodplain. Since then the Hassayampa River has downsized to 10 to 15 m, with incision increasing slightly to the north. Pleistocene river terraces recording intermediate levels of the Hassayampa River in the west are poor. The valley bottom along the Hassayampa River consists almost entirely of modern channel deposits (unit Q<sub>1</sub>) and late Holocene floodplain deposits (Q<sub>1</sub>). Tributary washes immediately west and east of the Hassayampa River have downcut in response to incision of the river, and late Quaternary deposits are quite limited in extent along these drainages.

In the western 2/3 of the quadrangle, piedmont washes drain to the south to the Gila River or Centennial Wash, a sizable tributary of the Gila River. Much of this piedmont is mantled by Pleistocene to Quaternary (units Q<sub>1</sub>, Q<sub>2</sub>, or Q<sub>3</sub>) Older Pleistocene deposits have eroded into broadly rounded ridges. The relatively small tributary washes that drain this area are incised less than a few meters below adjacent Pleistocene alluvial surfaces. Even though the amount of net incision is modest, there is enough topographic coarsening of active floodplains and stream channels to suggest that late Pleistocene to Quaternary (units Q<sub>1</sub> and Q<sub>2</sub>) (Shoustra et al., 1979). Adjacent piedmont areas to the west and north were aggrading in the late Pleistocene and early Quaternary as well (unit Q<sub>1</sub>). At that time the river was probably depositing sediment across a fairly broad floodplain in the eastern part of the quadrangle, and alluvial fans on both sides of the river were interfingering with the floodplain. Since then the Hassayampa River has downsized to 10 to 15 m, with incision increasing slightly to the north. Pleistocene river terraces recording intermediate levels of the Hassayampa River in the west are poor. The valley bottom along the Hassayampa River consists almost entirely of modern channel deposits (unit Q<sub>1</sub>) and late Holocene floodplain deposits (Q<sub>1</sub>). Tributary washes immediately west and east of the Hassayampa River have downcut in response to incision of the river, and late Quaternary deposits are quite limited in extent along these drainages.

### Bedrock Geology

Basalt lava flows cap several hills in the southwest corner of the map area. The basalt is part of an extensive lava field known as the Palo Verde Hills lava field. The flows were sampled extensively in and around the PVNGS prior to its construction. The lava range in age from 16.3 to 20.7 Ma (Shoustra et al., 1976; Shaflighan et al., 1980). In general, the lavas are gently dipping, but locally, dips up to 70 degrees have been reported for lavas to the west of this map area (Shaflighan et al., 1980).

The westernmost hills, which lie directly north of the PVNGS, are divided into two map units. A gently north-south-trending contact between the units, concealed by cultivation, is interpreted to be present on the westernmost hill. The upper lava contains abundant mafic (pyroxene and/or olivine), and plagioclase phenocrysts (Tb<sub>1</sub>). The lower lava contains only mafic phenocrysts (Tb<sub>2</sub>). Similar units are found in the low hills just to the east. The interpretations are possible for the volcanic stratigraphy and structure of the area. The simplest interpretation, which is depicted on the map, shows the sequence of upper and lower lavas related by a southwest-dip-sloping normal fault with modest (50-100 m) displacement. An alternative interpretation is that there is no fault, but that the volcanic stratigraphy is more complex, with intertonguing flows of different composition.

The pair of hills lying to the east of the PVNGS are composed of amalgamated flows of mafic phenocrystophytic basaltic lava (Tb) that appear to dip moderately to the southwest. These lavas were interpreted by Shaflighan et al. (1980) to represent the oldest in the area. This sequence may correlate with the Td<sub>1</sub> map unit, but since there are no other types of lavas in the area, and since the flows dip in the opposite direction, these rocks are mapped as undifferentiated basalts (Tb). The difference in dip between the eastern and western hills implies that an intervening structure may exist.

### Geologic Hazards and Aggregate Resources

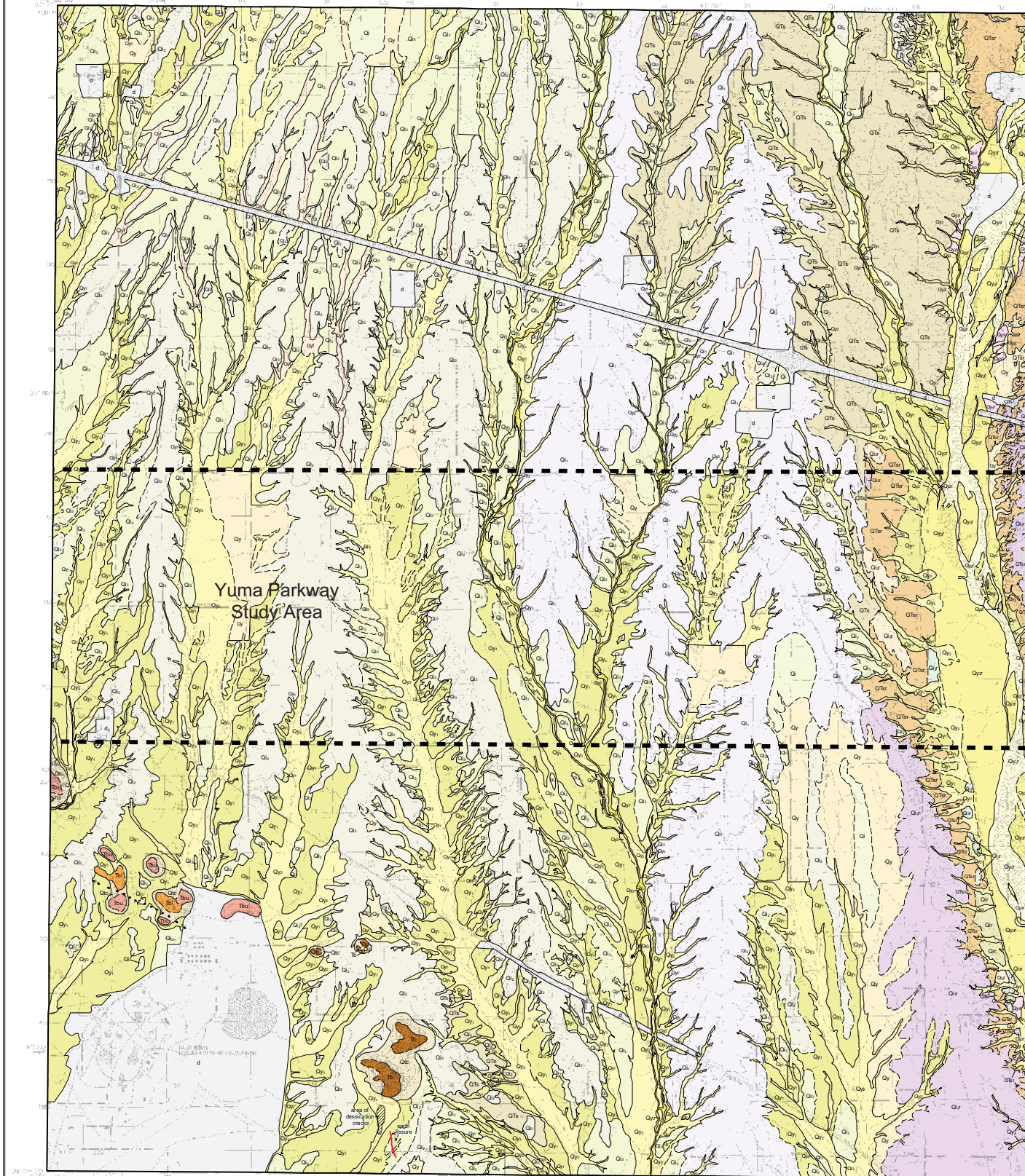
The geomorphology and surficial geology of the quadrangle provide clues to the extent and character of flood hazards and the availability of aggregate resources. Geologically young fluvial deposits (units Q<sub>1</sub>, Q<sub>2</sub>, and locally Q<sub>3</sub> along tributary washes and units Q<sub>1</sub>, Q<sub>2</sub>, and Q<sub>3</sub> along the Hassayampa River) record recent fluvial activity. The Hassayampa River is incised and floodplain is restricted to the valley bottom. The fact that the valley bottom is covered almost entirely by late Holocene deposits strongly suggests that the valley bottom in the floodplain, and all portions of it have been subjected to recent incision and deposition. Flooding is restricted to relatively narrow corridors along the incised tributary washes that drain directly to the Hassayampa. Flood-prone areas are somewhat more extensive in the western 2/3 of the quadrangle where incision is modest. Valley bottoms covered with young deposits but channels are quite small, implying that shallow sheet flooding and bank erosion along channels are the principal flood hazards. Although valley bottoms are fairly wide, there are no major distributary channel networks or active alluvial fans on the piedmont.

Aggregate resources were extracted from several small pits in piedmont surficial deposits near Interstate Highway 10, probably for construction of the highway. Two larger aggregate operations are currently active along the Hassayampa River north of Interstate Highway 10. These operations are apparently mining aggregates primarily from Holocene river deposits, but they may be drawing upon older river deposits as well. The potential for useful aggregate resources in older river deposits that flank the modern floodplain is not known because the thickness of these deposits is unknown.

Both earth fissures (Harris, 2001) and giant desiccation cracks (Harris, 2003) have been recognized in the southwestern portion of the quadrangle. A new earth fissure opened in the summer of 2000 about 3 miles (5 km) southeast of Wintersburg. The fissure trends nearly north-south and is about 1,150 ft (350 m) long. The fissure is very young, with narrow, steep sides and a highly irregular apparent depth ranging from <1 foot to >8 feet over short distances. In two locations the fissure is an echelon, with NW-SE steps. There is no discernible vertical offset across the fissure. The location of the fissure, at the edge of the Palo Verde basin and somewhat in line with the trend of a small fault, suggests that a shallow buried bedrock ridge may extend south of the hill beneath the trace of the fissure. If this scenario is correct, the crack may represent fissuring due to compaction and subsidence on either or both sides of the buried ridge. Adjacent to the new earth fissure is an area of giant desiccation cracks that opened at the same time as the earth fissure. Alignments of established vegetation in some portions of the polygonal desiccation crack network demonstrate that cracking has occurred periodically in the past. Additional areas of giant desiccation cracks were mapped by Harris (2003) immediately west and south of the Wintersburg quadrangle.

### References

Birkeland, Peter W., 1999. Soils and Geomorphology (3<sup>rd</sup> Ed.). New York: Oxford University Press, 429 p.  
Gale, L.H., Hawley, J.W., and Grossman, R.B., 1981. Soils and geomorphology in the basin and range area of southern New Mexico - a guidebook to the Desert Project. New Mexico Bureau of Mines and Mineral Resources Memoir 39, 222 p.  
Harris, R.C., 2001. A new earth fissure near Wintersburg, Maricopa County, Arizona. Arizona Geological Survey OFR 01-10, 23 p.  
Harris, R.C., 2003. Additional giant desiccation cracks near Wintersburg, Maricopa County, Arizona. Arizona Geological Survey OFR 03-07, 17 p.  
Machette, M.N., 1985. Calcic soils of the southwestern United States. In Waide, D.L., ed., Soils and geomorphology of the southwestern United States. Geological Society of America Special Paper 203, p. 1-21.  
Shaflighan, M., Damon, P.E., Lynch, D.J., Reynolds, S.J., Rahm, W.A., and Raymond, R.H., 1980. A volcanic geochronology and geologic history of southwestern Arizona and adjacent areas. In Ramberg, J.P. and Stone, C., eds., Studies in western Arizona. Arizona Geological Survey Digest 12, p. 201-242.  
Shoustra, J., Smith, J.L., Scott, J.D., Street, R.L., and Dull, D., 1976. Geology and geomorphology, and lithologic conditions and Appendix 20 (Radiometric age), in Palo Verde Nuclear Generating Stations 1, 2, and 3. Preliminary safety analysis report. Arizona Public Service Commission, v. no. 2, Section 2.5, v. 6, Appendix 20.  
Spencer, J.E., Youngberg, Ann, and Ferguson, C.A., 2005. Geologic map of the Flatiron Mountain 7.5' Quadrangle, Maricopa County, Arizona: Arizona Geological Survey Digital Geologic Map DGM 46, scale 1:24,000.



### Surficial Units

#### Piedmont Alluvium

Quaternary and late Tertiary piedmont deposits from the Belmont Mountains to the north cover the western 2/3 of the Wintersburg quadrangle. This alluvium was deposited primarily by larger tributary streams that flow to the north of the quadrangle; these larger streams and smaller streams that in this quadrangle have eroded and reworked some of these deposits. Clast lithologies include basalt and felsic volcanic rocks with lesser amounts of granite. Deposits range in age from modern to Pliocene. Abbreviations used are ka, thousands of years before present, and Ma, millions of years before present.

**Q<sub>1</sub> Modern stream channel deposits** - Active channel deposits composed of very poorly-sorted sand, pebbles, and cobbles with some boulders to moderately-sorted sand and pebbles. Channels are generally 0.5 to 2 m below adjacent Holocene terraces and alluvial fans, but may be incised as much as 4 m below adjacent Pleistocene deposits. Channel morphology generally consists of a single thread, relatively deep channel or multi-threaded smaller, shallower channels with gravel bars. Channels are extremely flood prone and are subject to deep, high velocity flow in moderate to large flow events. Areas adjacent to Q<sub>1</sub> deposits may be prone to lateral bank erosion.

**Q<sub>2</sub> Late Holocene alluvium** - Young, typically fine-grained deposits in floodplains, low terraces and small channels. Along the larger drainages, unit Q<sub>2</sub> sediment is generally poorly to very poorly sorted sand, silt, and small cobbles; floodplain and terrace surfaces typically are mantled with sand and finer sediment. On lower piedmont areas and in smaller tributary washes young deposits consist predominantly of moderately sorted sand and silt, with some pebbles and cobbles in channels. Soils are pale brown in color (10 YR), and soil development is very weak, consisting of slight carbonate accumulation. Channels generally are incised less than 1 m below adjacent young surfaces, but locally incision may be as much as 2 m. Channel morphologies generally consist of a single- or multi-threaded channels with gravel bars adjacent to low flow channels. Channels are flood prone and may be subject to deep, high velocity flows in large flow events. Substantial lateral bank erosion may occur in these deposits, and flood flows may significantly change channel morphology and flow paths. Local relief varies from fairly smooth channel bottoms to undulating bar-and-ridge topography that is characteristic of coarser deposits. Terraces have planar surfaces, but small channels are common.

**Q<sub>3</sub> Holocene alluvium** - Older Holocene terrace deposits found mostly along the margins of incised drainages throughout the map area. Q<sub>3</sub> surfaces are higher and less subject to modification than adjacent Q<sub>2</sub> surfaces. Q<sub>3</sub> terraces are generally planar but local surface relief may be up to 1 m where gravel bars are present. Q<sub>3</sub> surfaces are +2 m above adjacent active channels. Surfaces typically are sandy but locally have unvarnished, fine gravel lags or pebble and cobble deposits. Q<sub>3</sub> soils typically are brown in color (7.5 to 10 YR) with weakly developed stage I calcium carbonate accumulation (caliche). Note: for description of stages of calcium carbonate accumulation in soils.

**Q<sub>4</sub> Fine-grained Holocene alluvium** - Thin, fine-grained Holocene alluvial deposits formed in swales on ridges of mid-Pleistocene fan deposits. These deposits are very thin, typically less than 0.5 m thick, but locally may be 1 m or more thick. Typically is brown (7.5 YR) mainly silt and sand, with occasional deposits of open, unvarnished, fine gravel lag. Soil development is minimal, with substantial disseminated carbonates but little visible carbonate accumulation.

**Q<sub>5</sub> Holocene alluvial deposits, undifferentiated**

**Q<sub>6</sub> Late Pleistocene alluvium** - Unit Q<sub>6</sub> is composed of slightly dissected relict alluvial fans and terraces. Active channels are incised up to about 2 m below Q<sub>6</sub> surfaces, and Q<sub>6</sub> fans and terraces generally are lower in elevation than adjacent older surfaces. Q<sub>6</sub> deposits consist of pebbles, cobbles, and fine-grained sediment. Q<sub>6</sub> surfaces commonly are fairly smooth with weak bar and swale topography and loose to moderately packed pebbles and cobbles and generally are light-colored. Q<sub>6</sub> surfaces typically exhibit weak to moderate brown rock varnish but some surfaces in the northern part of the quadrangle that are mainly composed of fine-grained volcanics are more strongly varnished. Q<sub>6</sub> soils are moderately developed, with brown loamy (7.5 YR) near-surface horizons and stage II calcium carbonate accumulation.

**Q<sub>7</sub> Middle to late Pleistocene alluvium** - Unit Q<sub>7</sub> is composed of moderately dissected relict alluvial fans and terraces with moderate soil development. Q<sub>7</sub> surfaces are drained by broad swales and well-developed, moderately incised tributary channel networks; channels are typically 1-2 meters below adjacent Q<sub>7</sub> surfaces. Well-preserved, planar Q<sub>7</sub> surfaces are smooth with pebbles and cobble pavements; surface color is reddish brown, surface gravel clasts are moderately to strongly varnished. More eroded, rounded Q<sub>7</sub> surfaces are characterized by strongly varnished, scattered, cobble to pebble lags associated with planar, sandy to 7.5 YR, clay loam argillic horizons with clay coatings and subangular to subrounded blocky structure. Underlying soil carbonate development is typically stage III with areas to stage IV, and abundant carbonate through at least 1 in of the soil profile. In more eroded locations, argillic horizons have been removed and soils are calcic throughout.

**Q<sub>8</sub> Middle Pleistocene alluvium** - Unit Q<sub>8</sub> is composed of moderately dissected relict alluvial fans and terraces with moderate soil development. Q<sub>8</sub> surfaces are drained by broad swales and well-developed, moderately incised tributary channel networks; channels are typically 1-2 meters below adjacent Q<sub>8</sub> surfaces. Well-preserved, planar Q<sub>8</sub> surfaces are smooth with pebbles and cobble pavements; surface color is reddish brown, surface gravel clasts are moderately to strongly varnished. More eroded, rounded Q<sub>8</sub> surfaces are characterized by strongly varnished, scattered, cobble to pebble lags associated with planar, sandy to 7.5 YR, clay loam argillic horizons with clay coatings and subangular to subrounded blocky structure. Underlying soil carbonate development is typically stage III with areas to stage IV, and abundant carbonate through at least 1 in of the soil profile. In more eroded locations, argillic horizons have been removed and soils are calcic throughout.

**Q<sub>9</sub> Middle and late Pleistocene alluvial deposits, undifferentiated**

**Q<sub>10</sub> Early Pleistocene to Pliocene alluvium** - Unit Q<sub>10</sub> is composed of eroded alluvial fan deposits, locally overlain by younger Quaternary units. Q<sub>10</sub> deposits typically are poorly exposed on ridge slopes, in wash banks, and in channels as strath terraces. The thickness of Q<sub>10</sub> deposits is variable, but certainly is at least tens of meters (Shoustra et al., 1976). In the shallow subsurface, unit Q<sub>10</sub> includes an extensive clay-rich unit (the Palo Verde clay) that is older than 2 Ma (Shoustra et al., 1976). Surface exposures of Q<sub>10</sub> include poorly sorted, subangular to subrounded, carbonate cemented, tan, pebble to cobble conglomerates, moderately to well sorted, subangular to subrounded, moderately indurated, cross-bedded, red, pebbly sandstones, and buried paleosols.

**Hassayampa River Alluvium**  
Quaternary and late Tertiary piedmont deposits associated with the Hassayampa cover the eastern margin of the Wintersburg quadrangle. Clast lithologies are quite diverse, but are principally mixed fine-grained volcanic rocks and granites. Clasts range from well-rounded to subangular in shape. Deposits range in age from modern to Pliocene.

**Q<sub>11</sub> Active river channel deposits** - Moderately to poorly sorted sand, gravel and minor silt in recent active channels and light vegetated bars of the Hassayampa River. Gravel consists mainly of pebbles with some cobbles; clasts range from subangular to well-rounded.

**Q<sub>12</sub> Late Holocene floodplain deposits** - Sand, silt, and gravel deposits associated with the floodplain and low terraces along the Hassayampa River. Q<sub>12</sub> surfaces typically are smooth and are less than 2 m above the active channel. Terrace surfaces typically are covered with fine-grained floodplain deposits, but relict gravel bars and lenses are common.

**Q<sub>13</sub> Older Holocene river terrace deposits** - Sand, silt, and gravel deposits associated with slightly higher terraces along the Hassayampa River. Terrace surfaces typically are flat and rounded around their margins and are less than 3 m above the active channel. Terrace surfaces typically are covered with a fine gravel lag where well-preserved but are quite fine-grained where eroded.

**Q<sub>14</sub> Late Pleistocene river terrace deposits** - Deposits associated with low intermediate terraces about 3 m above the Holocene floodplain of the Hassayampa River. Deposits consist of sand, silt, and gravel, with weak to moderate soil carbonate (Stage II) accumulation. Terrace surfaces typically are smooth and are covered with fine-grained floodplain deposits, but relict gravel bars and lenses are found locally.

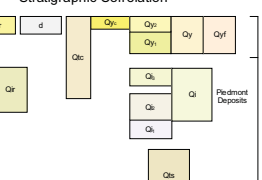
**Q<sub>15</sub> Middle Pleistocene river terrace deposits** - High intermediate terraces about 5 m above the Holocene floodplain of the Hassayampa River. Terrace surfaces typically are dissected by small tributary drainages but are smooth away from the drainages. Terrace deposits are a mix of river sand, gravel, and silt and clay, but surfaces typically are covered with relict gravel deposits. Terrace development is moderately strong, consisting primarily of stage II to III calcic horizons.

**Q<sub>16</sub> Early to middle Pleistocene river deposits** - Deposits associated with the highest terraces along the Hassayampa River that record the maximum aggradation of the river. Terrace surfaces are broadly rounded, and the deposits are moderately to deeply dissected by tributary drainages and the river and have been substantially modified by erosion. Exposures are poor, but subangular to well-rounded gravel is evident at the surface. Terrace surfaces are also typically covered with litter from underlying indurated stage IV petrocalcic soil horizons. Q<sub>16</sub> terrace surfaces are more extensive than any of the younger Pleistocene terrace deposits. Terrace surfaces range from about 10 to 15 m above the active river channel, and rise slightly to the north across the quadrangle.

**Q<sub>17</sub> Pleistocene river deposits, undifferentiated**

**Q<sub>18</sub> Pliocene to early Pleistocene river deposits** - A sequence of old river deposits of unknown thickness that underlies the Q<sub>16</sub> terrace deposits. These deposits consist of river sand, gravel and silt with a substantial component of tributary sand and gravel. Local zones of substantial carbonate accumulation may represent moderately to strongly developed buried soils.

### Stratigraphic Correlation



### Other Units

**d** Disturbed areas - Much of the quadrangle has been disturbed by human activities, particularly agricultural activities. This unit designation is used only in areas of substantial excavation or anthropogenic deposition, for example, major flood-control levees.

**Q<sub>19</sub>** Quaternary hillslope talus and colluvium - Thin, steeply to moderately sloping, weakly bedded hillside deposits mantling the middle and lower slopes of basalt hills. Deposits are locally defined and very poorly sorted, consisting of angular to subangular basalt cobbles and boulders with a matrix of sand, silt, and clay. Older hillside deposits have darkly varnished cobble and boulder mantles and relatively clay-rich soils.

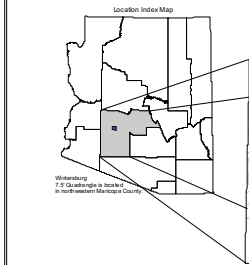
### Bedrock Units

**Tb<sub>1</sub>** Upper basalt - Basalt lava containing 3-7%, 1-2 mm mafic phenocrysts (pyroxene and/or iddingsite altered olivine), and 5-10% 1-4 mm plagioclase phenocrysts (samples: CAF-2-10637, 10638, 10639, 10643, 10649, 10650, 11343, 11344, 11345, 11346, and 11348).

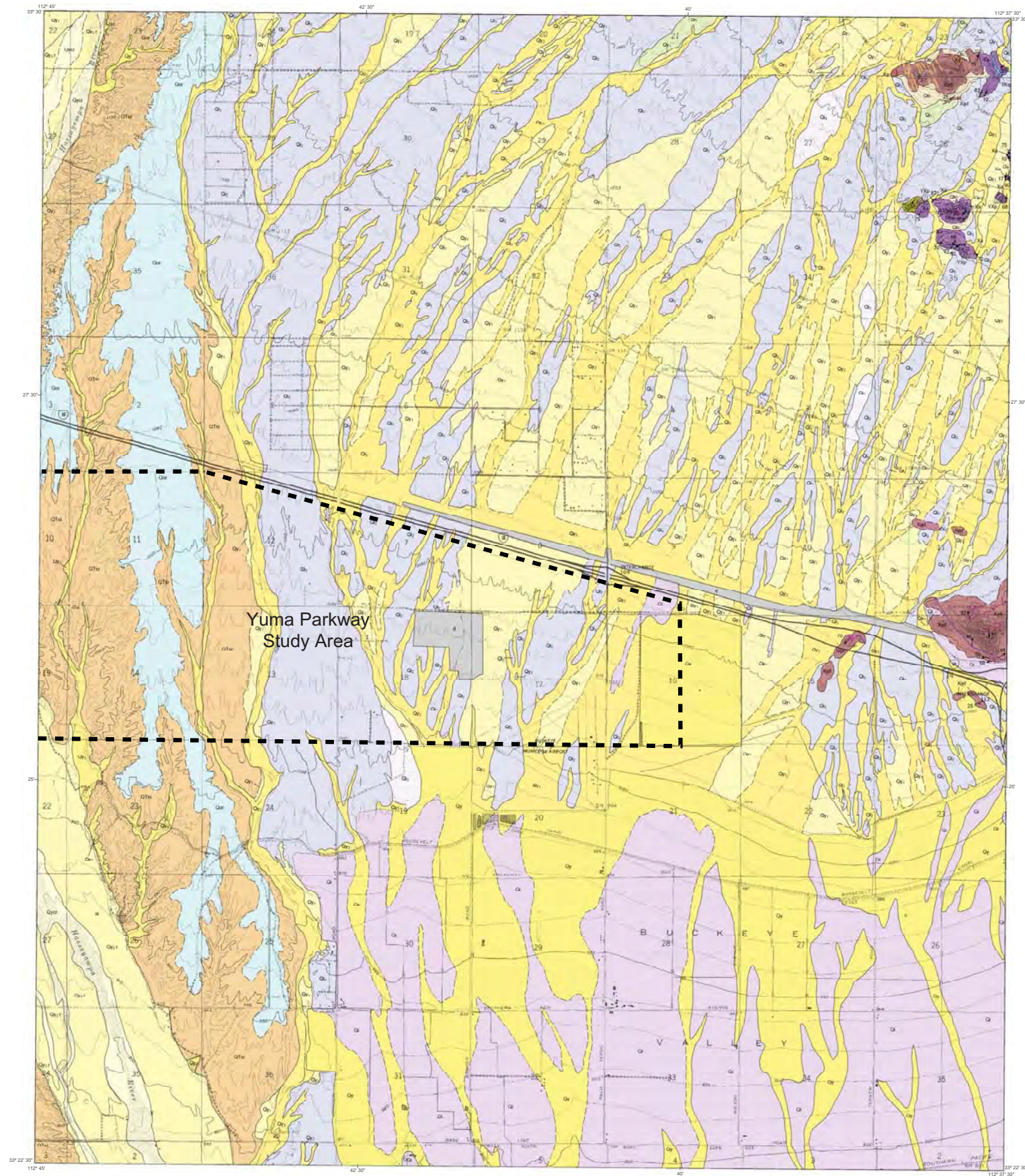
**Tb<sub>2</sub>** Lower basalt - Basalt lava containing 3-7%, 1-3 mm mafic phenocrysts (pyroxene and/or iddingsite altered olivine), and sparse 1-2 mm plagioclase phenocrysts (samples: CAF-2-10640, 10644, 10646, 10646).

**Td** Basalt lava, undifferentiated - Basalt lava containing 2-7%, 0.5-3 mm mafic phenocrysts (pyroxene and/or iddingsite altered olivine) with sparse plagioclase phenocrysts <2 mm (samples: CAF-2-10622, 10626, 10631, and 10635). Shaflighan et al. (1980) report a whole rock K/Ar age of 27 ± 0.8 Ma for this unit, making it the oldest known lava from the Palo Verde lava field.

Topographic base from USGS Wintersburg 7.5' quadrangle.  
Compiled from aerial photographs taken 1960.  
Projection: Transverse Mercator datum: NAD 27, UTM zone 12.  
Magnetic declination 117° east of true north.



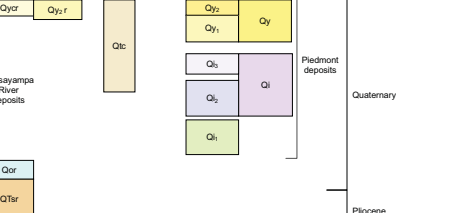
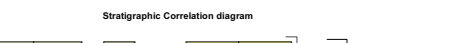
Arizona Geological Survey  
416 W. Congress Street, Suite 100  
Tucson, AZ 85701  
Telephone: 520-622-1000  
www.azgs.gov



Yuma Parkway  
 Study Area

**Unit Descriptions**

- Piedmont Alluvium**
- Qy** **Late Holocene deposits in active stream channels, low terraces, and alluvial fans** - Very young deposits associated with active or recently active fluvial systems. Channel deposits typically consist of sand and pebbles with some cobbles in middle and upper piedmont areas, and sand and some pebbles lower on the piedmont. Terrace and fan deposits typically consist of sand and silt with some gravel lenses. Fan and terrace surfaces typically are planar where deposits are fine and gently undulating where deposits are coarser, with gravel bars and fine-grained swales. Desert pavement development is minimal and rock varnish is very light or nonexistent. Soil development is weak. Surface dissection is minimal and is associated with channels that are incised up to 1.5 m below adjacent fans or terraces. Channel patterns are variable, including anastomosing or distributary linked channels and separate small tributary channels feeding into larger channels.
  - Qy** **Older Holocene deposits on alluvial fans and terraces** - Young deposits associated with recently active alluvial fans and terraces. In middle and upper piedmont areas, deposits are poorly sorted, consisting sand, silt, pebbles, and cobbles; in lower piedmont areas, deposits are typically sand and silt with minor gravel. Surface relief varies with particle size, with rict bar and swale topography where deposits are gravelly and relatively smooth surfaces where sand and silt predominate. Soil development is weak, with some soil structure and minor carbonate accumulation. Surfaces typically are brown to gray, with common gravel litter but minimal desert pavement and light brown rock varnish.
  - Qy** **Holocene alluvial deposits, undifferentiated, primarily in areas disturbed by agricultural activity**
  - Qa** **Late Pleistocene alluvial fan and terrace deposits** - Younger intermediate deposits associated with inactive alluvial fans and terraces along washes. Deposits typically are poorly sorted mixtures of silt, sand, pebbles and cobbles. Surfaces are moderately dissected by tributary drainages that head on the surfaces and through-going distributary channels. Local surface topographic varies from about 0.5 to 2 m. Soil development is moderate, with minimal clay accumulation and soil reddening and weak to moderate calcic horizon development. Rock varnish on surface clasts varies from light to dark brown.
  - Qa** **Middle Pleistocene alluvial fan deposits** - Older intermediate deposits associated with extensive rict alluvial fans. Deposits are poorly sorted, including sand, pebbles, cobbles, and small boulders with minor silt and clay. Surfaces are moderately to deeply dissected, with local topographic relief varying from about 0.5 to 6 m. Original depositional topography typically is not preserved, and surfaces are quite smooth where not eroded. Qa surfaces are dissected by extensive tributary drainage networks. Interfluvial areas between drainage vary from quite flat to broadly rounded. Soils have weak to moderate clay accumulation and slight reddening in the upper 30 cm beneath the surface, and calcic horizons show obvious calcic horizon development.
  - Qa** **Middle and late Pleistocene alluvial fan and terrace deposits, undifferentiated**
  - Qa** **Middle to early Pleistocene alluvial fan deposits** - Old rict alluvial fans with moderately strong soil development. Deposits are poorly sorted, including sand, pebbles, cobbles, and small boulders with minor silt and clay. Surfaces typically are moderately dissected with up to 6 m of local relief, but interfluvial surfaces are quite smooth and have dark, strongly developed pebble-cobble desert pavements. Soils have moderate clay accumulation and obvious reddening and abundant carbonate accumulation resulting in weak cementation.
- Hassayampa River Alluvium**
- Qyr** **Active river channel deposits** - Moderately to poorly sorted sand, gravel and minor silt in recently active channels and lightly vegetated bars of the Hassayampa River. Gravel includes subangular to well-rounded clasts of diverse lithology.
  - Qy,r** **Late Holocene to modern floodplain deposits** - Sand, silt, and gravel deposits associated with slightly higher terraces along the Hassayampa River. Terrace surfaces typically are smooth and are less than 3 m above the active channel. Terrace surfaces typically are covered with fine-grained floodplain deposits, but rict gravel bars and lenses are common.
  - Qor** **Early Pleistocene river deposits** - Deposits associated with the high terraces along the Hassayampa River that record the maximum aggradation of the river. Terrace surfaces are fairly flat or broadly rounded, but all terrace surfaces are moderately to deeply dissected by tributary drainages and the river and have been substantially modified by erosion. Exposures are poor, but well-rounded gravel is evident at the surface. Terrace surfaces are also typically covered with litter from underlying petrocalcic soil horizons. Terrace surfaces range from about 15 to 20 m above the active river channel, and rise slightly to the north across the quadrangle.
  - QTr** **Pliocene to early Pleistocene river deposits** - A moderately thick sequence of old Hassayampa River deposits that underlies the Qor terrace-fan deposits. These deposits consist of river sand, gravel and silt with a substantial component of tributary sand and gravel. Local zones of substantial carbonate accumulation may represent moderately to strongly developed buried soils.
- Other Units**
- Qtc** **Holocene and Pleistocene colluvium and talus** - Very poorly sorted, weakly stratified, hillslope deposits mantling bedrock slopes.
  - d** **Disturbed areas** - Much of the quadrangle has been disturbed by human activities, particularly agricultural activities. This unit designation is used only in areas of substantial excavation and anthropogenic deposition, for example, major flood-control levees.
- Bedrock map units**
- TKm** **Mafic dikes (Tertiary - Cretaceous)** - Dark-colored, fine-grained to very fine-grained dioritic dikes with sparse 1-4 mm plagioclase and mafic phenocrysts.
  - TKq** **Rhyolite porphyry (Cretaceous)** - Quartz-phyric rhyolite porphyry dikes and small intrusions with variable phenocryst content. The rhyolite porphyry is characterized by light gray, commonly flow-foliated aphanitic matrix and contains between 5% and 20% 1-6 mm quartz, potassium feldspar, and plagioclase phenocrysts with sparse biotite, hornblende, and other mafics. In general, grain size and the abundance of accessory mafic minerals increases with phenocryst content. The rhyolite porphyry correlates with the intrusive rocks (unit T1) of Reynolds et al. (2002).
  - YXp** **Pegmatite and leucogranite complex (Middle and Early Proterozoic)** - Medium- to coarse-grained pegmatite and heterogeneous texture, banded, muscovite leucogranite.
  - Xg** **Granite (Early Proterozoic)** - Weakly foliated, fine- to medium-grained 10-20% biotite granite or quartz monzonite (Xg) that appears to be younger than the granodiorite (Xgd).
  - Xgd** **Granodiorite (Early Proterozoic)** - Medium-grained, weakly to strongly foliated granodiorite to quartz monzonite containing between 15-40% mafics. The granodiorite correlates with the undifferentiated metamorphic rocks (Xm), granitic rocks and pegmatite (Xp), and tonalite (Xt) units of Reynolds et al. (2002).
  - Xa** **Amphibolite schist (Early Proterozoic)** - Fine- to medium-grained amphibolite schist and banded, mafic-rich orthogneiss with lesser amounts of biotite schist, sericite schist and psammite schist. The amphibolite schist correlates with the undifferentiated metamorphic rocks (Xm), and tonalite (Xt) units of Reynolds et al. (2002).
  - Xp** **Pinal Schist (Early Proterozoic)** - Fine- to medium-grained, light gray biotite schist, sericite schist, and psammite schist. The Pinal Schist map unit represents a zone of metamorphic rocks void of amphibolite schist.



# GEOLOGIC MAP OF THE BUCKEYE NW 7.5' QUADRANGLE, MARICOPA COUNTY, ARIZONA

by John J. Field, Philip A. Pearthree and Charles A. Ferguson  
 Arizona Geological Survey Digital Geologic Map 37 (DGM-37), version 1.0

November, 2004

Citation for this map: Field, J.J., Pearthree, P.A., and Ferguson, C.A., 2004, Geologic Map of the Buckeye NW 7.5' Quadrangle, Maricopa County, Arizona: Arizona Geological Survey Digital Geologic Map 37 (DGM-37), 1 sheet, scale 1:24,000.

Not to be reproduced for commercial purposes

Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award #03QAG0114. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government.

**Introduction**

The Buckeye NW 7.5' quadrangle is located approximately 35 miles (60 km) west of downtown Phoenix, Arizona. The map area covers the southwestern piedmont of the White Tank Mountains which merges to the south into Buckeye Valley and to the west into Hassayampa Plain. Bedrock was mapped in April, 2004, and Quaternary geology, modified from Field and Pearthree (1991), was supplemented with new mapping and aerial photograph interpretation using high-resolution digital images provided by the Flood Control District of Maricopa County. This map is one of six 1:24,000 scale geologic maps covering much of the Hassayampa Plain area that were produced for this study. Mapping was done as part of a multiyear mapping program directed at producing complete geologic map coverage for the Phoenix-Tucson metropolitan corridor, and was done under the joint State-Federal STATEMAP program, as specified in the National Geologic Mapping Act of 1992.

**Surficial Geology**

Surficial geology was mapped primarily using aerial photos taken in 1979 for the Bureau of Land Management. Unit boundaries were spot-checked in the field, and mapping was supplemented by field observations during the spring of 2004. The physical characteristics of Quaternary alluvial surfaces (channels, alluvial fans, floodplains, stream terraces) evident on aerial photographs and in the field were used to differentiate their associated deposits by age and source. This mapping was transferred to a digital orthophoto base from 2002 provided by the Flood Control District of Maricopa County. Mapping was completed in a GIS format and the final line work was generated from the digital data. Surficial deposits of the map area were then correlated with regional deposits to roughly estimate their ages. The mapping of Field and Pearthree (1991) was incorporated into this map with contacts modified extensively in some parts of the map based on reinterpretation of geologic relationships and the higher-quality digital aerial photo base that is currently available. Characteristics evident on aerial photographs and on the ground were used to differentiate and map various alluvial surfaces. The color of alluvial surfaces depicted on aerial photographs is primarily controlled by soil color, and to a lesser extent, rock varnish. Significant soil development begins on an alluvial surface after it becomes isolated from active flooding and depositional processes (Gile et al., 1981; Birkeland, 1990). Over thousands of years, distinct soil horizons develop. Two typical soil horizons in Pleistocene alluvial sediments of Arizona are reddish brown argillic horizons and white calcic horizons. As a result, on color aerial photographs older alluvial surfaces characteristically appear redder or whiter (on more eroded surfaces) than younger surfaces. Older surfaces have a dark brown color where dark brownish desert pavements are well preserved. Differences in the drainage patterns between surfaces provide clues to surface age and potential flood hazards. Young alluvial surfaces that are subject to flooding commonly display distributary (branching downstream) or braided channel patterns; young surfaces may have very little developed drainage if unconfined shallow flooding predominates. Dendritic tributary drainage patterns are characteristic of older surfaces that are not subject to extensive flooding. Topographic relief between adjacent alluvial surfaces and the depth of entrenchment of channels can be determined using stereo-paired aerial photographs and topographic maps. Young flood-prone surfaces appear nearly flat on aerial photographs and are less than 1 m above channel bottoms. Active channels are typically entrenched 1 to 10 m below older surfaces. Comparisons of calcic horizon development on the White Tank Mountains piedmont with other soil sequences in the western United States provide one of the few methods of estimating the ages of the different alluvial surfaces (Gile et al., 1981; Machette, 1985). Calcic horizon development varies from fine white filaments of calcium carbonate in young soils to soil horizons completely plugged with calcium carbonate (caliche) in very old soils.

Variations in the distribution of surfaces of different ages and sources and concomitant variations in dissection across the quadrangle provide evidence regarding the recent geologic evolution of this area and the distribution of flood hazards. Generally, areas near the Hassayampa River are moderately to deeply dissected, whereas dissection in middle piedmont areas varies substantially across the quadrangle. Very old terraces of the Hassayampa River (unit Qor) record the level of the river bed in the early Quaternary. Qor terraces cap a substantial aggradational sequence that was deposited during the late Tertiary to early Quaternary. At that time the river was not entrenched and probably was depositing sediment across a fairly broad floodplain in the western part of the quadrangle. Since then the Hassayampa River has downcut up to 20 m, with dissection increasing slightly to the north. The effects of this downcutting are expressed by incision of tributary drainages near the western margin of the quadrangle. In the eastern and southern part of the quadrangle, piedmont drainages turn to the southwest and south before eventually joining the Hassayampa or Gila rivers. Incision along these drainages generally is less than a few meters, and most drainages have mature, well-developed distributary channel networks and extensive, thin young deposits in the middle piedmont. These areas are of particular concern because of the potential for widespread inundation and changes in channel positions during floods (Field and Pearthree, 1992). The southern part of the map area is marked by relatively fine-grained Pleistocene and Holocene distal fan deposits that merge to the south with floodplain deposits of the Gila River (south of the quadrangle). Surfaces in this southern area have been profoundly modified by agriculture activity, and age estimates and mapping are based on interpretation of an NRCS soil survey (Hartman, 1977).

**Bedrock Geology**

Bedrock units are dominated by Early Proterozoic granodiorite (Xgd). The granodiorite intrudes amphibolite schist (Xa) and biotite sericite schist (Xp). Collectively, these rocks comprise a widespread metamorphic complex that is present throughout the White Tank Mountains (Reynolds et al., 2002; Ferguson et al., 2004). Other rocks include a small stock of pegmatite (YXp) that probably correlates with a series of Middle Proterozoic pegmatite stocks associated with a coarse-grained, potassium feldspar-bearing, biotite schist found to the north. A series of mostly north-striking mafic (TKm, TKq), intermediate (TKap), and quartz porphyry (TKq) dikes are correlated with similar dikes in the northerly adjacent Wagner Wash Quadrangle (Ferguson et al., 2004). The early to middle Tertiary (TK) and middle Tertiary (T1) ages for these rocks are based on cross-cutting relationships the dikes display with respect to a widespread granitic unit (T1) of the northerly adjacent map area in the northern White Tank Mountains that has been dated at 56.2 ± 1.4 Ma (U-Pb zircon, Spencer et al., 2003). Schistosity in Early Proterozoic supracrustal rocks (Xa, Xp) and a weakly developed foliation in the Early Proterozoic granodiorite (Xgd) is generally steeply dipping and northeast striking. These fabrics are cut by the Middle Proterozoic, and middle to early Tertiary stocks and dikes, and are therefore not considered to be related to middle Tertiary extensional deformation. At the southern edge of the bedrock exposures, however, a pervasive, gently southeast-dipping protomylonitic fabric is present in the granodiorite (Xgd). This fabric is similar to pervasive fabrics described in the eastern White Tank Mountains that cut middle Tertiary rocks (Brittingham, 1985), and is possibly related to middle Tertiary extension.

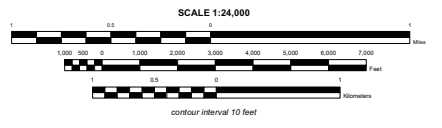
**Acknowledgments**

The authors would like to thank Steve Reynolds for introducing us to the bedrock geology of the White Tank Mountains. The Flood Control District of Maricopa County provided support for the initial surficial geologic mapping of this quadrangle (Field and Pearthree, 1991) and provided high-resolution digital orthophotos that were used to accurately locate surficial geologic unit boundaries. Erin M. Moore designed the map layout.

**References**

Birkeland, Peter W., 1990, Soils and Geomorphology (3<sup>rd</sup> Ed.), New York: Oxford University Press, 420 p.  
 Brittingham, P.L., 1985, Structural geology of a portion of the White Tank Mountains, central Arizona: Tempe, Arizona State University, unpublished M.S. thesis, 106 p.  
 Ferguson, C.A., Spencer J.E., Pearthree, P.A., Youberg, A., and Field, J.J., 2004, Geologic map of the Wagner Wash Well 7½' Quadrangle, Maricopa County, Arizona: Arizona Geological Survey Digital Geologic Map 38, 1 sheet, scale 1:24,000.  
 Field, J.J., and Pearthree, P.A., 1991, Surficial geology around the White Tank Mountains, central Arizona (Dagga Tank, White Tank Mts. NE, McKittrick Dam, Buckeye NW, White Tank Mts. SE, Waddell, Buckeye NW, Valencia, and Perryville 7.5' quadrangles): Arizona Geological Survey Open-File Report 91-08, 7 p., 9 sheets, scale 1:24,000.  
 Field, J.J., and Pearthree, P.A., 1992, Geologic mapping of flood hazards in Arizona - An example from the White Tank Mountains area, Maricopa County, Arizona: Arizona Geological Survey Open-File Report 91-10, 16 p., 4 sheets, scale 1:24,000.  
 Gile, L.H., Hawley, J.W., and Grossman, R.B., 1981, Soils and geomorphology in the basin and range area of southern New Mexico - guidebook of the Desert Project: New Mexico Bureau of Mines and Mineral Resources Memoir 39, 222 p., scale 1:20,000.  
 Hartman, G.W., 1977, Soil survey of Maricopa County, central part: Soil Conservation Service, USDA, 117 p., 131 sheets, scale 1:24,000.  
 Machette, M.N., 1985, Calcic soils of the southwestern United States, in: Weide, D.L., ed., Soils and Quaternary Geology of the Southwestern United States, Geological Society of America Special Paper 203, p. 1-21.  
 Reynolds, S.J., and Dewitt, Ed., 1991, Proterozoic geology of the Phoenix region, central Arizona, in: Karlstrom, K.E., ed., Proterozoic geology and mineral deposits of Arizona: Arizona Geological Society Digest 19, p. 237-246.  
 Reynolds, S.J., Woods, S.E., Pearthree, P.A., and Field, J.J., 2002, Geologic map of the White Tank Mountains, central Arizona: Arizona Geological Survey Digital Geologic Map 14, scale 1:24,000.  
 Spencer, J.E., Isachsen, C.E., Ferguson, C.A., Richard, S.M., Skotnicki, S.J., Woodon, J., and Riggs, N.R., 2003, U-Pb isotope geochronology data from 23 igneous rock units in central and southeastern Arizona: Arizona Geological Survey Open-File Report 03-08, 40 p.

Topographic base from USGS Buckeye NW 7.5' quadrangle, compiled from photogrammetric methods from aerial photos taken 1955 and by plane-table surveys 1958. UTM zone 12, NAD 83. Reprojected to NAD 83. Magnetic declination 1°3' east of true north. Contour interval 10 feet.

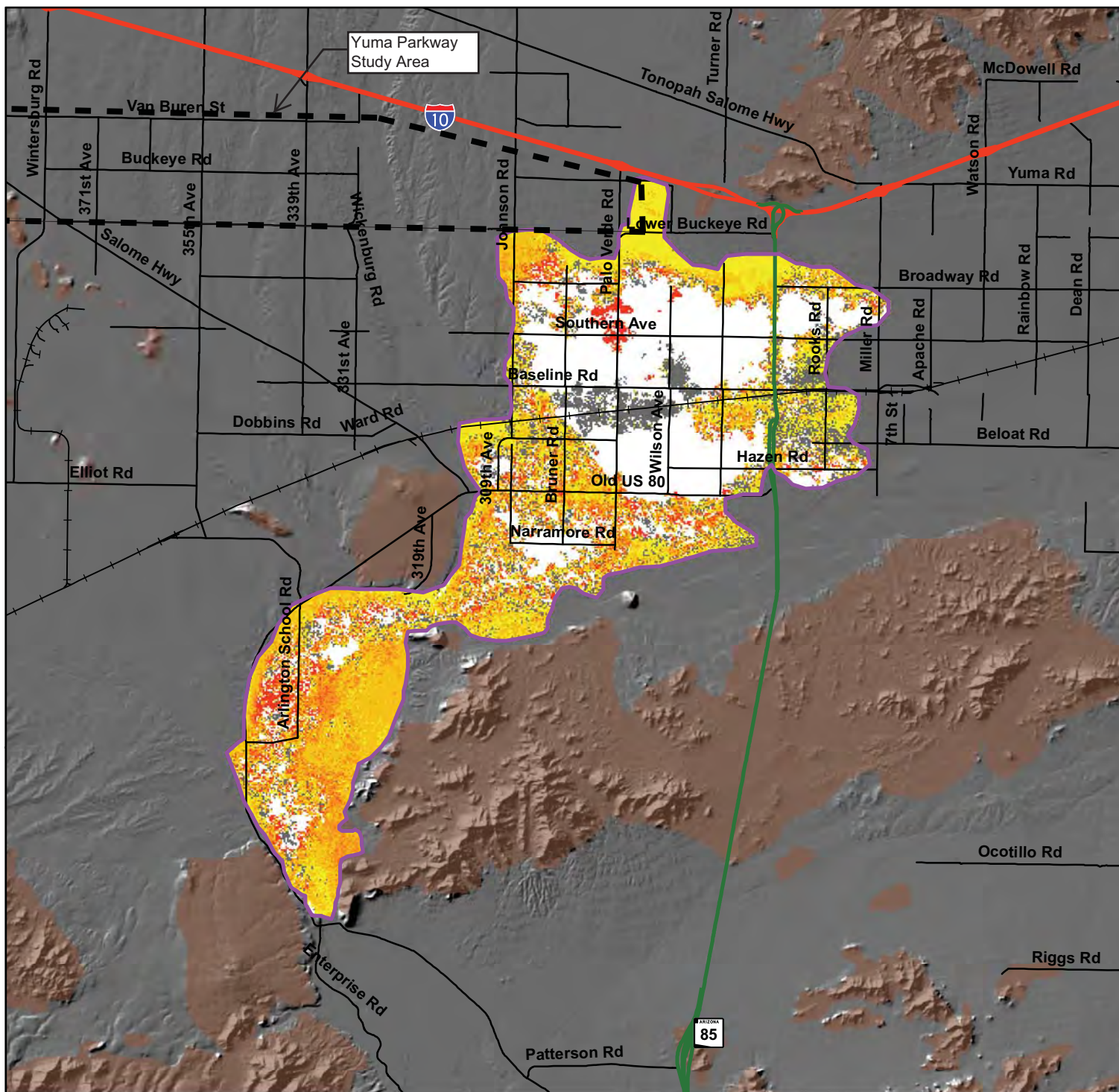


Arizona Geological Survey  
 416 W. Congress Street, Suite 100  
 Tucson, AZ 85701  
 (520) 770-3500  
 www.azgs.gov



# **APPENDIX TM3-03**

## **SUBSIDENCE AND EARTH FISSURE DOCUMENTATION**



Land Subsidence in the Buckeye Area, Western Maricopa County  
 Based on ADWR EnviSat Time-Series InSAR Data  
 Time Period of Analysis: 1.2 Years 02/10/2007 To 04/05/2008

© ESA 2007 - 2008

02/10/2007 To 04/05/2008

**Subsidence**

- Decorellation/No Data
- 2.0 To -3.0 cm
- 1.5 To -2.0 cm
- 1.0 To -1.5 cm
- 0.5 To -1.0 cm
- 0 To -0.5 cm

Subsidence Feature

Hardrock

CAP Canal

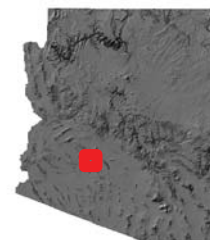
**Arizona Highways and Interstates**

- Interstate
- US
- State
- Railway
- Roads

1:173,025



0 1 2 4 6 8 Miles



Decorellation (white areas) are areas where the phase of the received satellite signal changed between satellite passes, causing the data to be unusable. This occurs in areas where the land surface has been disturbed (i.e. bodies of water, snow, agriculture areas, areas of development, etc).



A NEW EARTH FISSURE  
NEAR WINTERSBURG,  
MARICOPA COUNTY, ARIZONA

Arizona Geological Survey  
Open-File Report 01-10

Raymond C. Harris  
*Arizona Geological Survey*

November 2001

22 pages

## ARIZONA'S NEWEST EARTH FISSURE

A new earth fissure has been reported southeast of Wintersburg, about 75 km (50 miles) WSW of Phoenix (Figure 1). The fissure was reported to AZGS in early September and was visited several times through early November. Field mapping was done with a hand-held GPS. This fissure appeared over the past summer, probably during a heavy rainstorm in July. The earth fissure and adjacent desiccation cracks are plotted on a topographic base (Figure 2) and an aerial photo base (Figure 3).

The fissure is nearly north-south and is 307 m (1007 ft) long (Figure 4). The fissure is very young, with narrow, steep sides and a highly irregular apparent depth ranging from <1 foot to >8 feet over short distances. In two locations the fissure is en echelon (Figure 5), with NW-SE steps. There is no discernable vertical offset across the fissure.

At the time of the first visit in mid September, little material had sloughed off into the fissure, only enough to open a narrow trench. Erosional downcutting of 4-12 inches has created miniature badlands up to 10 feet wide on the uphill (east) side of the crack (Figure 6). At the time of a follow-up visit in early November, the edges of fissure were noticeably rounded off from a small rainstorm the previous day. Much of the fissure had been partially filled in but there had not been enough runoff to enlarged it.

Both ends of the fissure are characterized by a gradual fading of the trench to miniature grabens and then to a hairline crack. The final 50 feet of both ends are slightly curved. Typical segments of the fissure are shown in Figures 7 and 8.

It is common for earth fissures to seemingly appear "overnight" following severe rainfall. Heavy rain softens the surficial material, allowing it to cave into the underlying fissure. The surface expression of the fissure probably formed in response to heavy rain associated with a monsoon storm in July. At depth, the precursor fissure may have been forming for years or even decades.

The location of the fissure, at the edge of the basin and somewhat in line with the trend of a small hill, suggests that a shallow buried bedrock ridge may extend south of the hill beneath the trace of the fissure. If this scenario is correct, the crack may represent fissuring due to compaction and subsidence on either or both sides of the buried ridge. This mechanism of differential subsidence due to buried topography has been proposed for earth fissure development in other areas of the state (Jachens and Holzer, 1982).

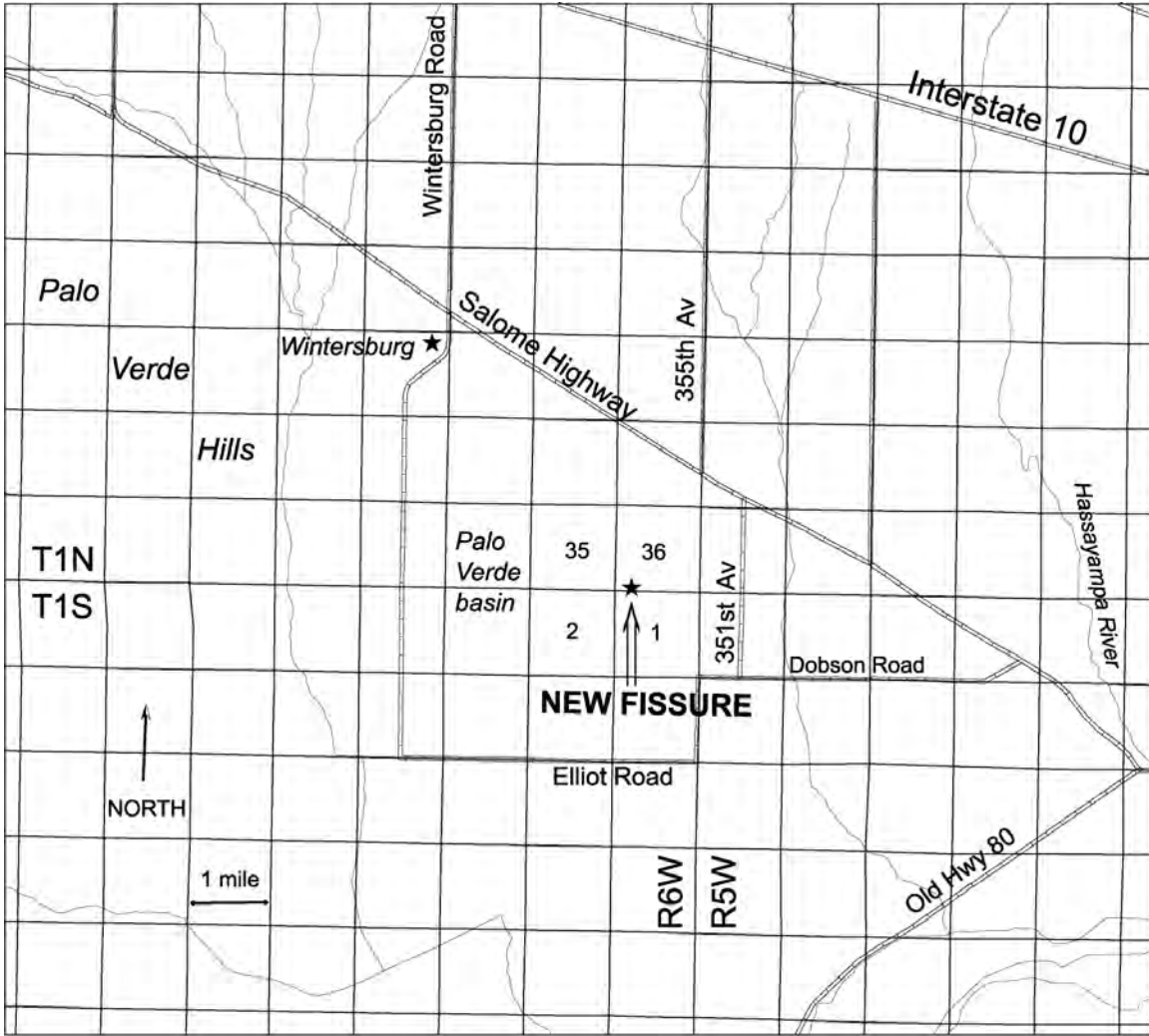


Figure 1. Location of new earth fissure near Wintersburg.

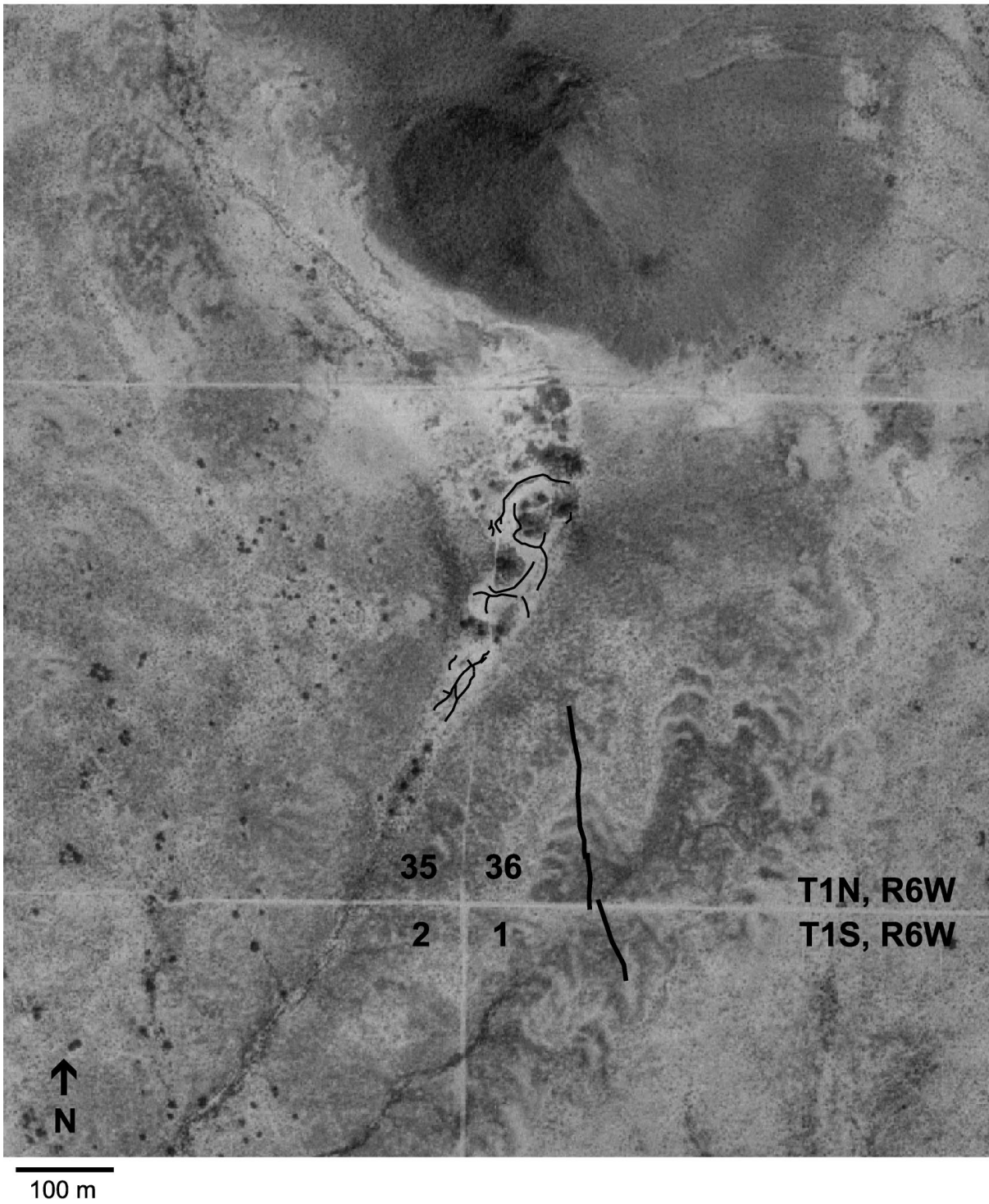


Figure 3. Aerial photo showing location of earth fissure and desiccation cracks.



Figure 5. En echelon section of earth fissure crossing Baseline Road, looking NW. Fissure is 6-12 inches wide here. Second earth fissure crosses road at far left (arrow).



Figure 6. Section of earth fissure north of Baseline Road, showing erosion on uphill (east) side. Fissure is 12-18 inches wide, 1-6 feet deep in this section.

ADDITIONAL GIANT DESICCATION  
CRACKS NEAR WINTERSBURG,  
MARICOPA COUNTY, ARIZONA

by  
Raymond C. Harris

Arizona Geological Survey  
**Open-File Report 03-07**

November 2003



Arizona Geological Survey  
416 W. Congress, Suite #100,  
Tucson, Arizona 85701

## AREAS OF ADDITIONAL GIANT DESICCATION CRACKS

Giant desiccation cracks have been discovered in two areas near the settlement of Wintersburg (Figure 1) on detailed aerial photos obtained from Maricopa County Flood Control District. One area is one mile southwest of Wintersburg. The second area is about one mile south-southeast of the intersection of Wintersburg Road (379th Ave.) and Elliot Road, about 6 miles south of Wintersburg.

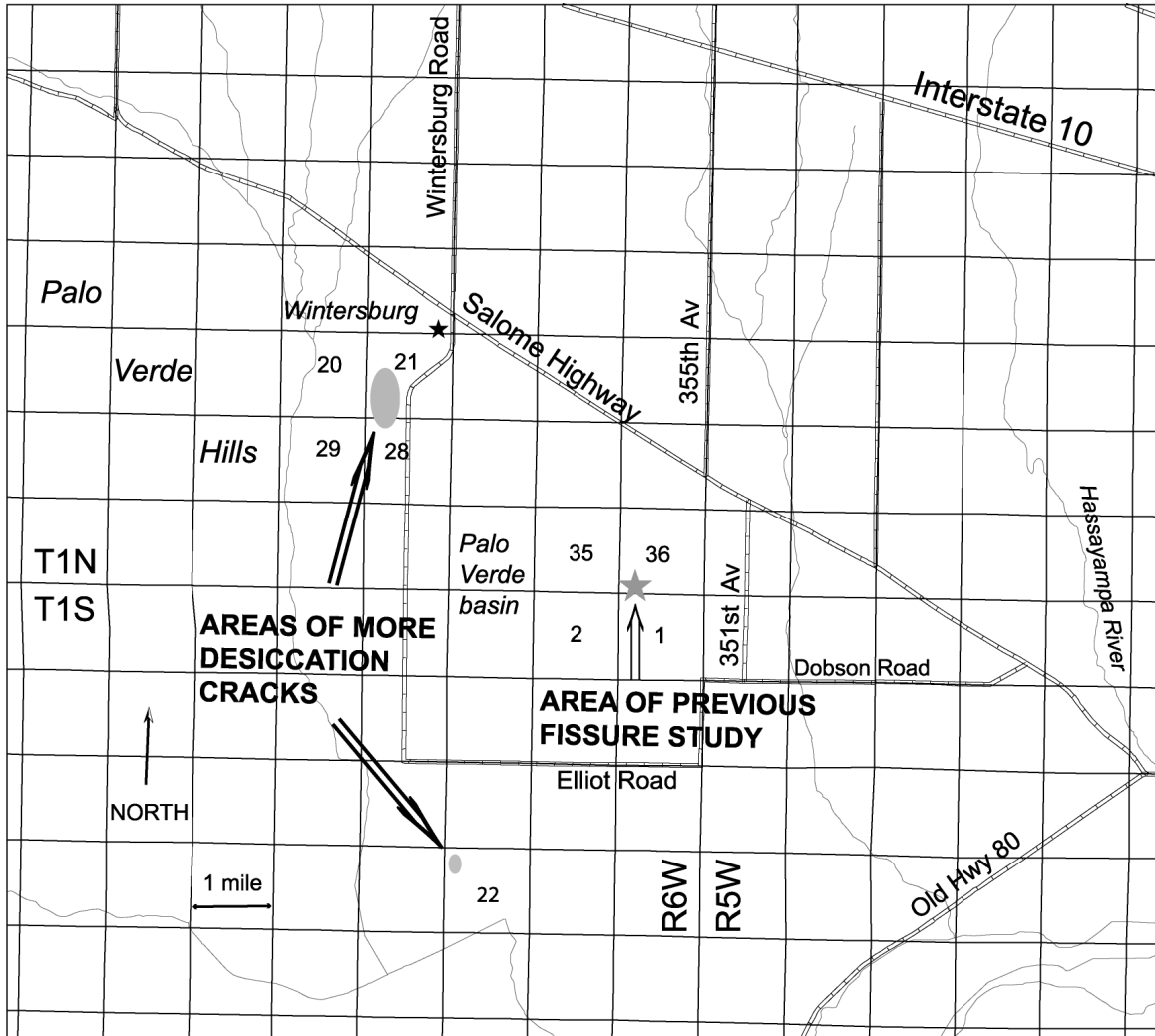


Figure 1. Location of additional giant desiccation cracks near Wintersburg.

## DESICCATION CRACKS SOUTHWEST OF WINTERSBURG

Giant desiccation cracks have been discovered one mile southwest of Wintersburg (Figure 1) on detailed aerial photos obtained from Maricopa County Flood Control District. These cracks are immediately west of Wintersburg Road and south of a small hill (Figures 2 and 3). Previously, a new earth fissure and nearby giant desiccation cracks were reported three miles southeast of Wintersburg in the late Summer 2001 (Harris, 2001).

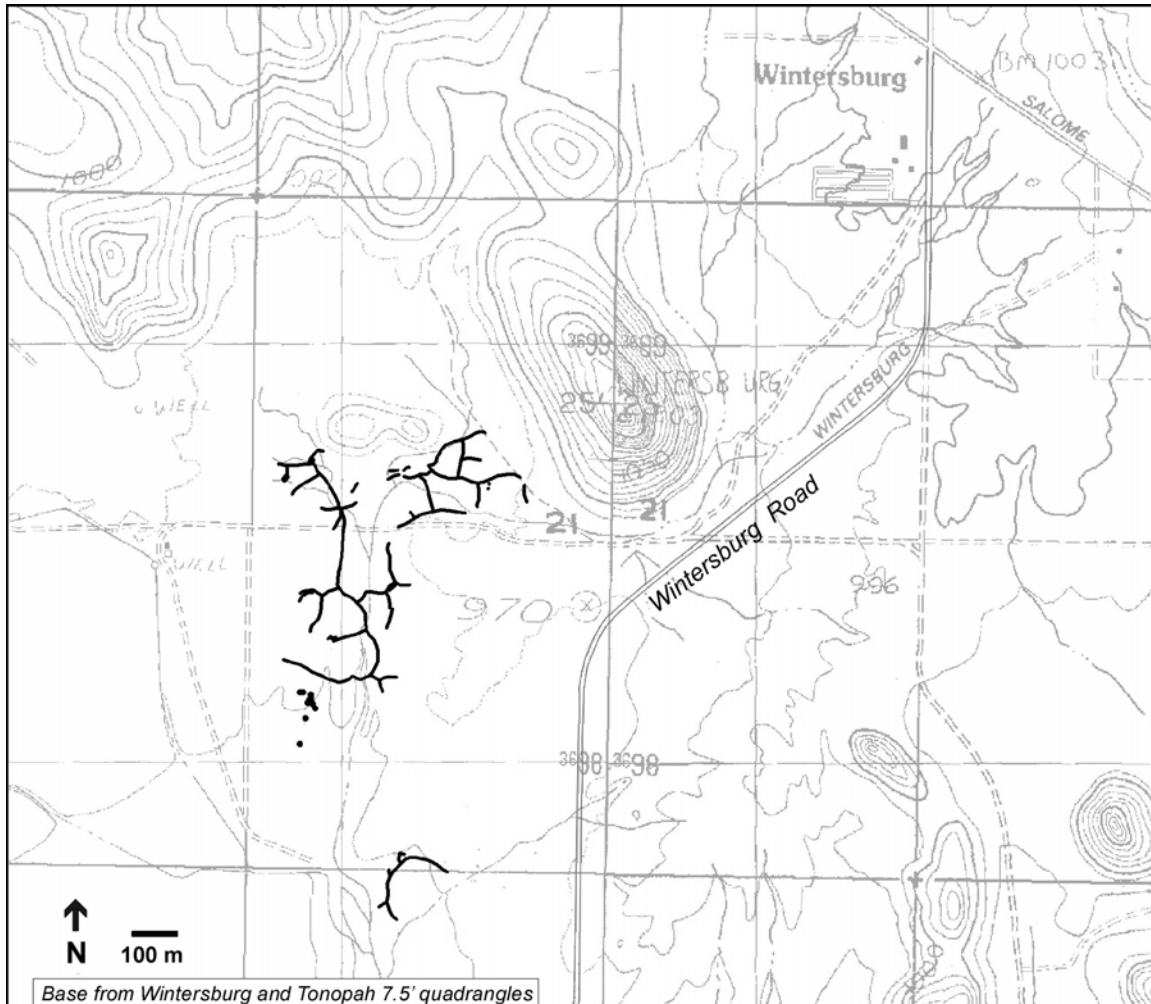


Figure 2. Location of desiccation cracks one mile southwest of Wintersburg.

Two clusters of cracks are present. The larger northern group (main cluster) extends from within a few ten of meters of a small outlier of the Palo Verde Hills southward nearly 700 meters. Another cluster, consisting of a single crack about 250 meters long, with minor splays, lies 400 meters south of the main cluster.



Figure 7. Intersection of cracks near northwestern end of main cluster, Winter 2002.



Figure 8. Crack near outcrop at northern end of main cluster, Winter 2002. This crack has multi-stage history, as shown by older vegetation in renewed crack.



Figure 9. Crack near northwestern end of main cluster displays highly variable width and depth along its course.

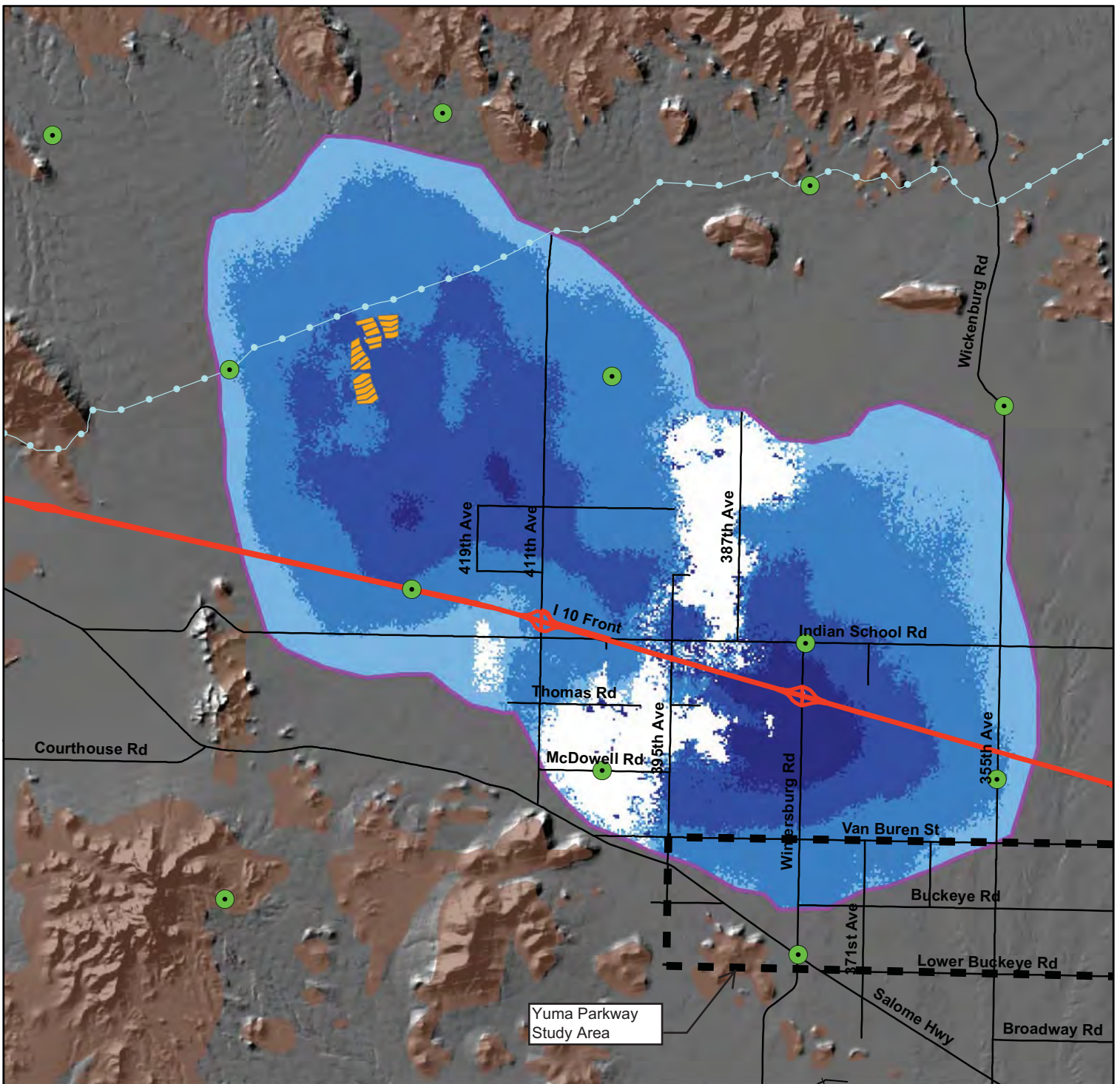


Figure 10. Typical crack, near north end of main cluster.



# **APPENDIX TM3-04**

## **TONOPAH UPLIFT DOCUMENTATION**



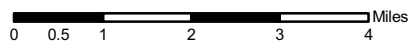
© ESA 2006 - 2010

**Uplift in the Vicinity of the Tonpah Recharge Facility**  
**Based on ADWR EnviSat Time-Series InSAR Data**  
**Time Period of Analysis: 2.8 Years 03/13/2006 To 03/06/2010**

- |                                 |                       |                       |                        |
|---------------------------------|-----------------------|-----------------------|------------------------|
|                                 | MCDOT GDACS Monuments |                       | Tonpah Recharge Basins |
|                                 | CAP Canal             |                       | Area of Uplift         |
|                                 | Hardrock              |                       |                        |
| <b>Highways and Interstates</b> |                       |                       |                        |
|                                 | Interstate            |                       |                        |
|                                 | US                    |                       |                        |
|                                 | State                 |                       |                        |
|                                 | Roads                 |                       |                        |
|                                 | Railway               |                       |                        |
|                                 | <b>Uplift</b>         |                       |                        |
|                                 |                       | Decorrelation/No Data |                        |
|                                 |                       | 0 To 1 cm             |                        |
|                                 |                       | 1 To 2 cm             |                        |
|                                 |                       | 2 To 3 cm             |                        |
|                                 |                       | 3 To 4 cm             |                        |

**03/13/2006 To 03/06/2010**

1:136,676

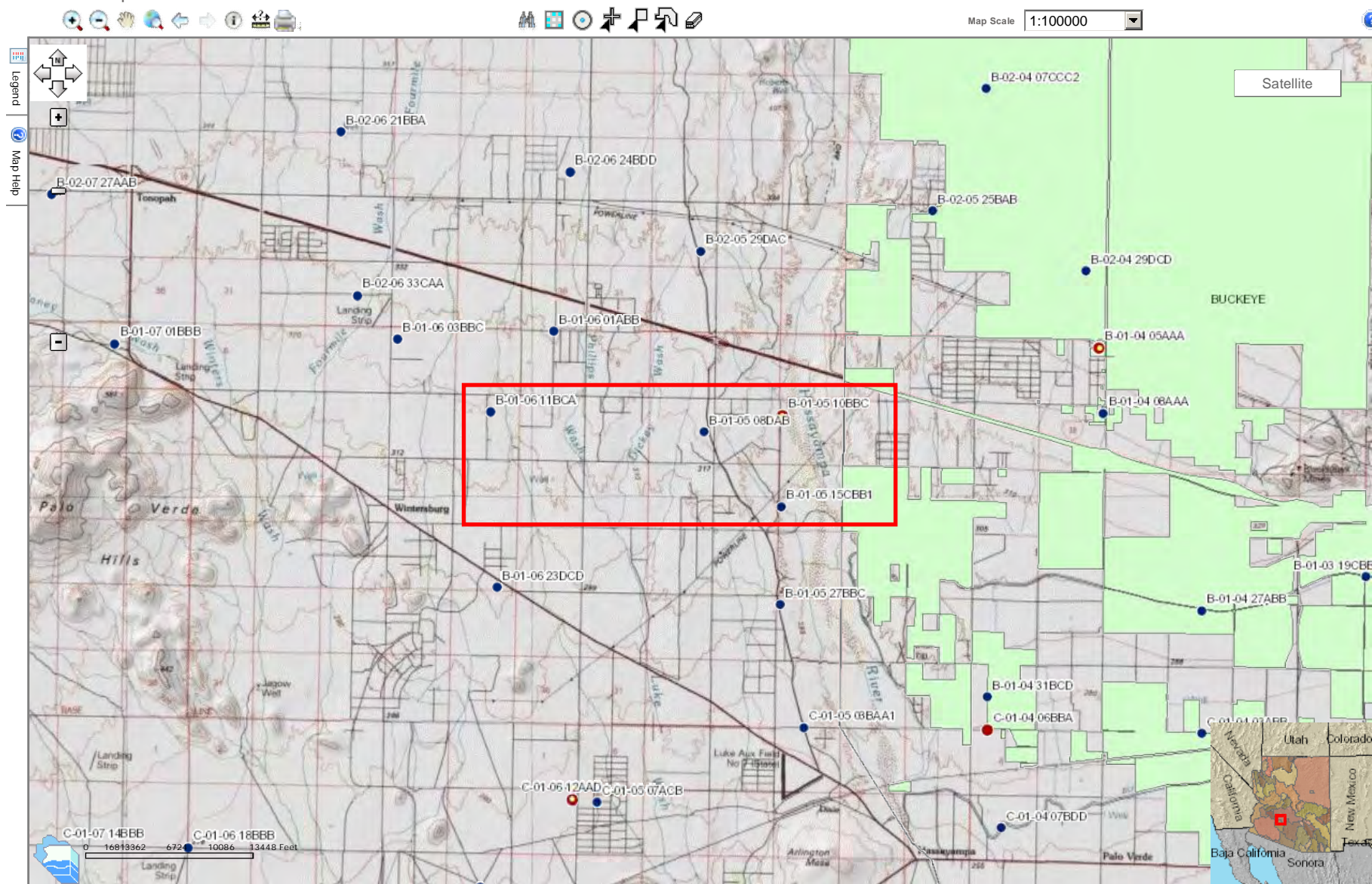


Decorrelation (white areas) are areas where the phase of the received satellite signal changed between satellite passes, causing the data to be unusable. This occurs in areas where the land surface has been disturbed (i.e. bodies of water, snow, agriculture areas, areas of development, etc).



Arizona Department of Water Resources - Groundwater Data

Water Resource Data | GIS Data | Map FAQs | ADWR | Feedback



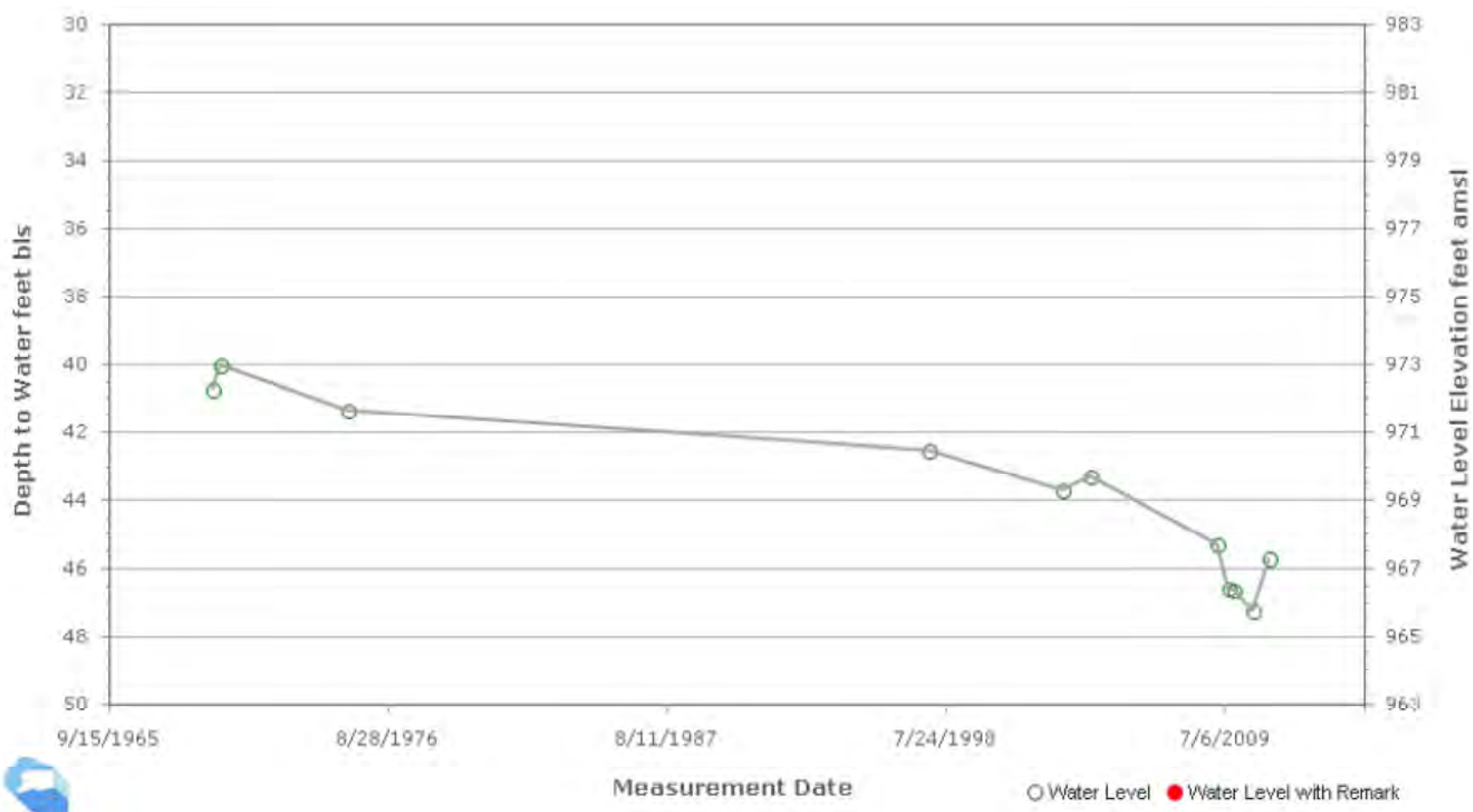
Hydrographs were printed for the four wells shown within the red box above.

Well Info Map Reset Graph Auto Site Hydrograph Email Help

### Arizona GroundWater Monitoring Site Hydrograph

Local ID	Site ID	Registry ID	Latitude NAD27	Longitude NAD27	Alt. (ft amsl)	Water Use	Well Depth (ft)	Case Dia. (in)	Drill Date	Latest WL Date	DTW (ft)	WL Elev. (ft)
B-01-05 10BBC	332648112454301	614389	33° 26' 47.5"	112° 45' 45.0"	1012.88	UNUSED	0	16		3/17/2011	45.67	967.21

Set x-axis  
Set y-axis  
Measurement Remarks



GWSI is ADWR's technical database of well locations, construction data, and water levels.

Created on 5/13/2011

Well Info Map Reset Graph Standard Hydrograph Email Help

### Arizona Automated GroundWater Monitoring Site Hydrograph

Local ID	Site ID	Registry ID	Latitude NAD27	Longitude NAD27	Alt. (ft amsl)	Water Use	Well Depth (ft)	Case Dia. (in)	Drill Date	Latest WL Date	DTW (ft)	WL Elev. (ft)
B-01-05 10BBC	332648112454301	614389	33° 26' 47.5"	112° 45' 45.0"	1012.88	UNUSED	0	16		3/17/2011	45.67	967.21

Set x-axis  
Set y-axis  
Measurement Remarks



GWSI is ADWR's technical database of well locations, construction data, and water levels.

Created on 5/13/2011

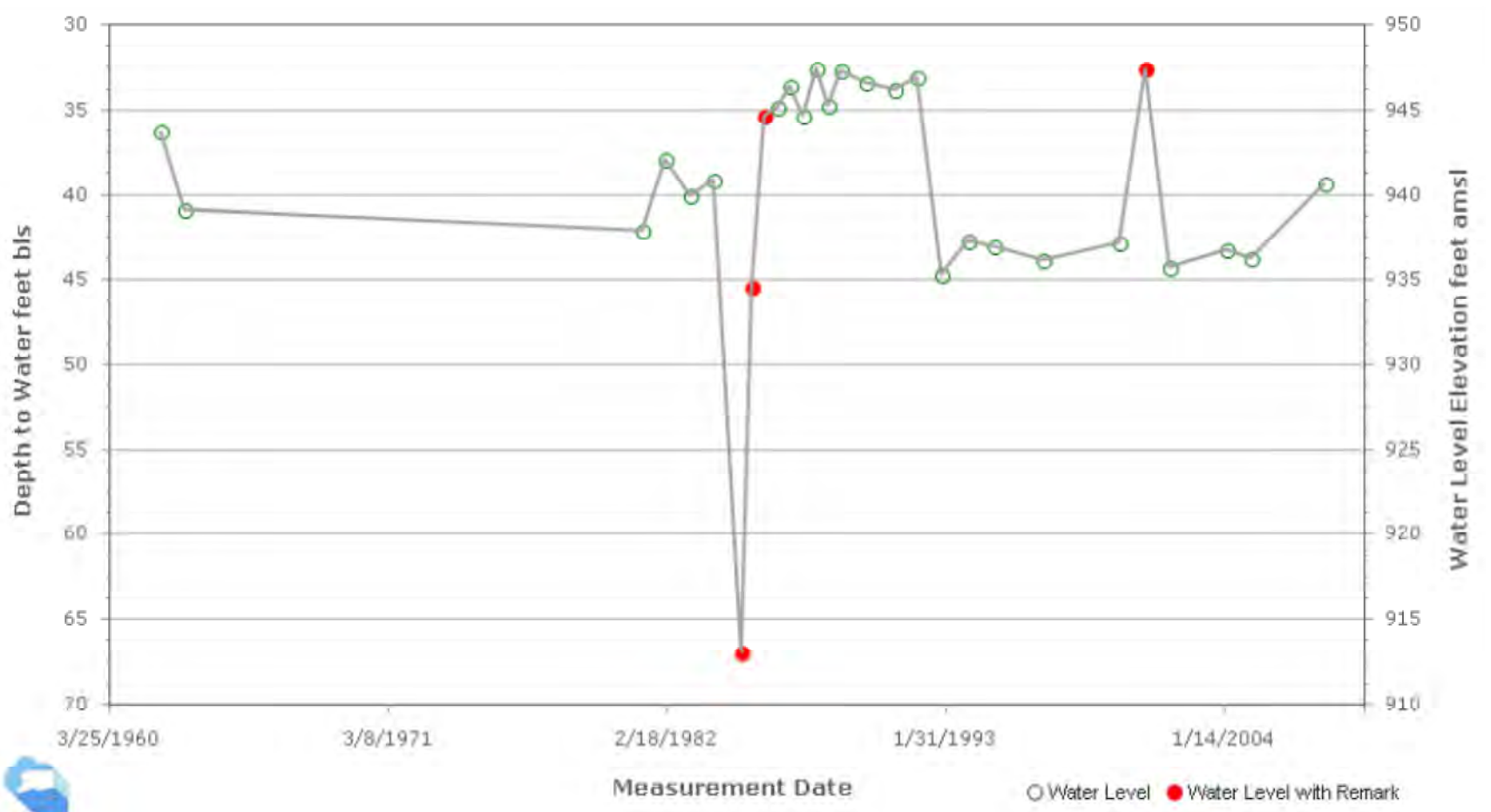
ResetGraph

Well Info Map Reset Graph Auto Site Hydrograph Email Help

### Arizona GroundWater Monitoring Site Hydrograph

Local ID	Site ID	Registry ID	Latitude NAD27	Longitude NAD27	Alt. (ft amsl)	Water Use	Well Depth (ft)	Case Dia. (in)	Drill Date	Latest WL Date	DTW (ft)	WL Elev. (ft)
B-01-05 15CBB1	332541112454501	636568	33° 25' 35.0"	112° 45' 44.3"	980	UNUSED	140	12		12/10/2007	39.3	940.7

Set x-axis  
Set y-axis  
Measurement Remarks



GWSI is ADWR's technical database of well locations, construction data, and water levels.

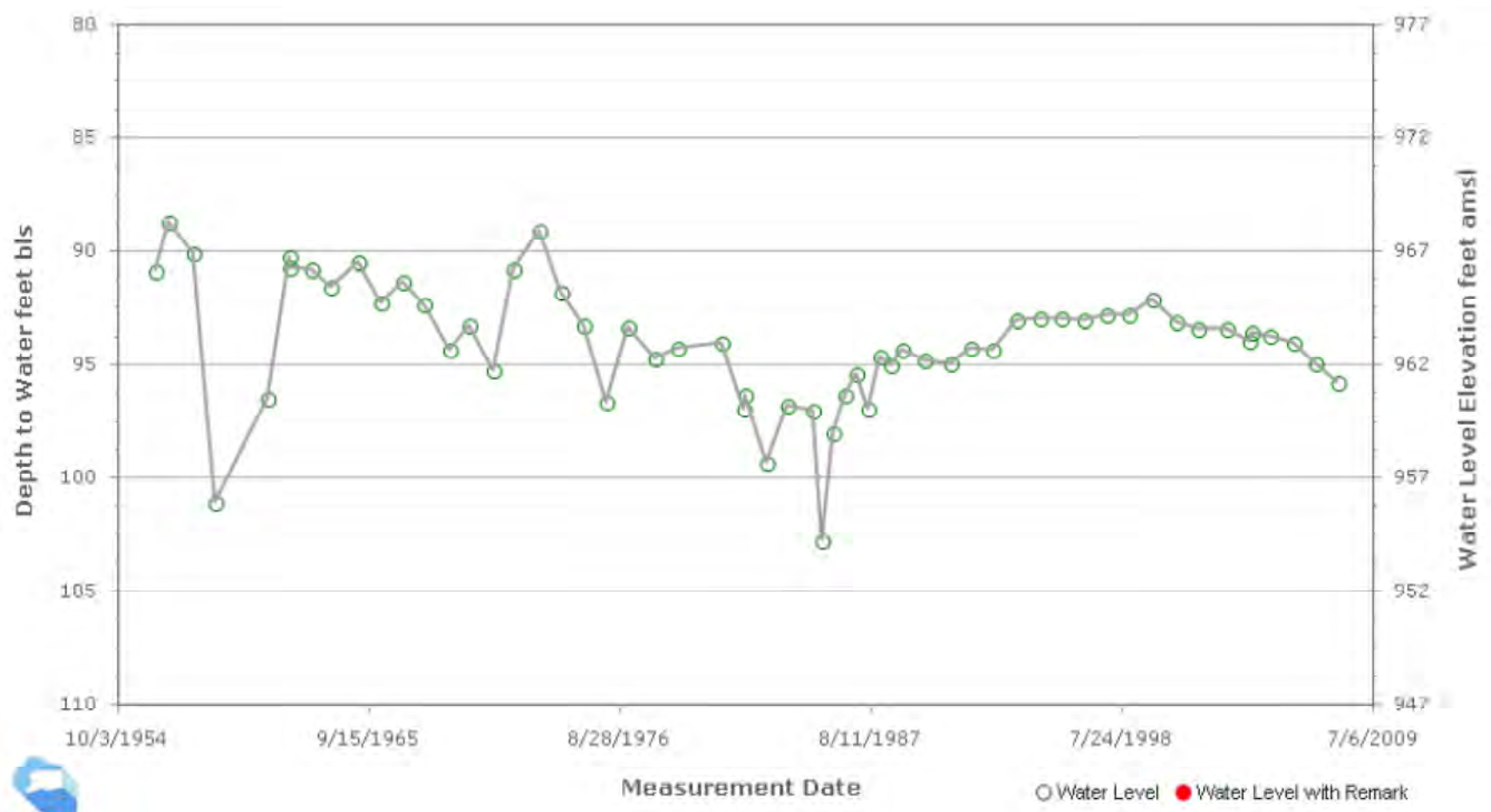
Created on 5/13/2011

Well Info Map Reset Graph Auto Site Hydrograph Email Help

### Arizona GroundWater Monitoring Site Hydrograph

Local ID	Site ID	Registry ID	Latitude NAD27	Longitude NAD27	Alt. (ft amsl)	Water Use	Well Depth (ft)	Case Dia. (in)	Drill Date	Latest WL Date	DTW (ft)	WL Elev. (ft)
B-01-05 08DAB	332634112470001	800303	33° 26' 33.6"	112° 46' 59.3"	1056.8	UNUSED	304	16	1/1/1956	12/10/2007	95.8	961

Set x-axis  
Set y-axis  
Measurement Remarks

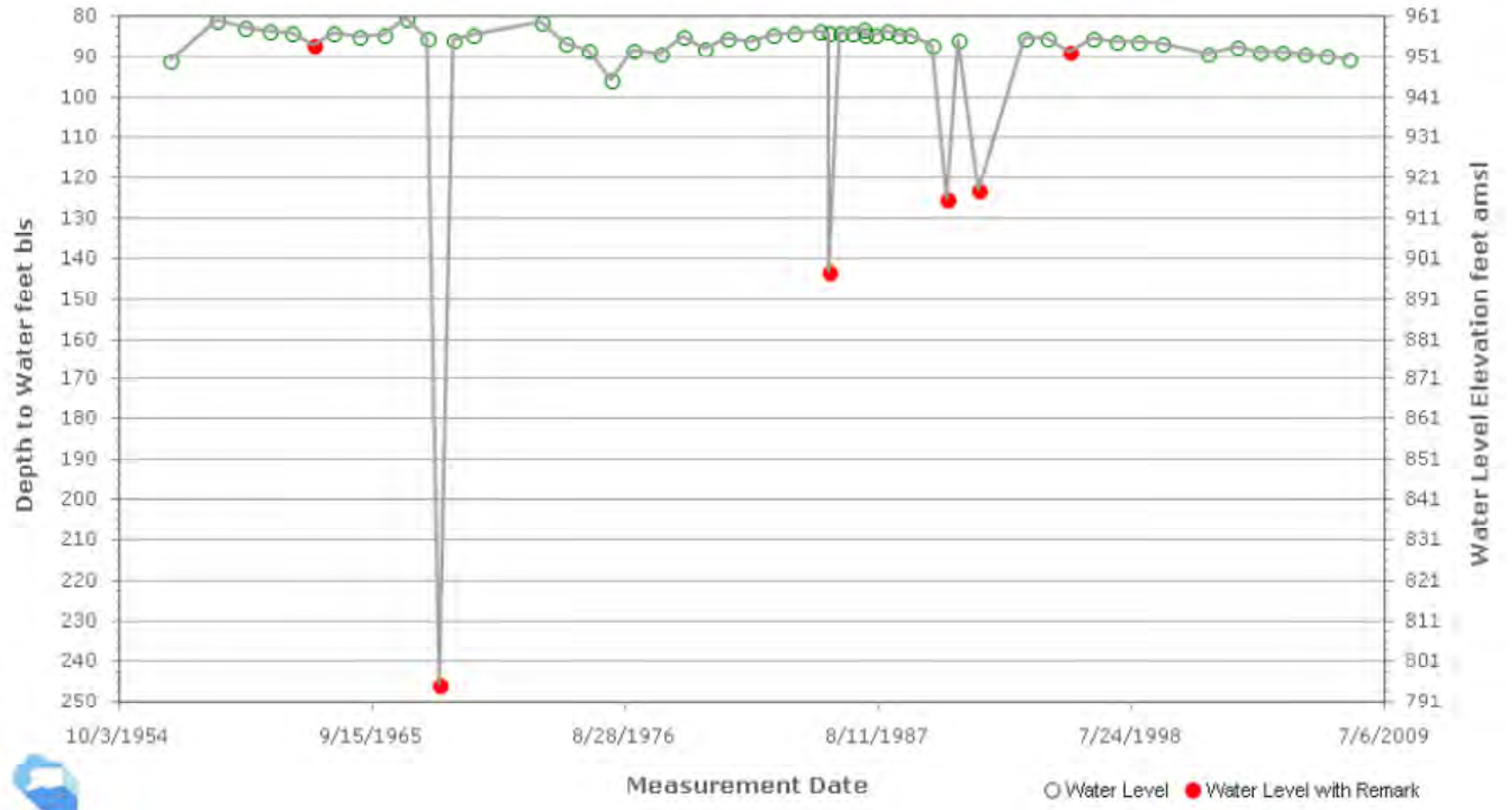


Well Info Map Reset Graph Auto Site Hydrograph Email Help

### Arizona GroundWater Monitoring Site Hydrograph

Local ID	Site ID	Registry ID	Latitude NAD27	Longitude NAD27	Alt. (ft amsl)	Water Use	Well Depth (ft)	Case Dia. (in)	Drill Date	Latest WL Date	DTW (ft)	WL Elev. (ft)
B-01-06 11BCA	332648112504401	629598	33° 26' 46.8"	112° 50' 44.0"	1040.69	IRRIGATION				12/10/2007	90.6	950.09

Set x-axis  
Set y-axis  
Measurement Remarks

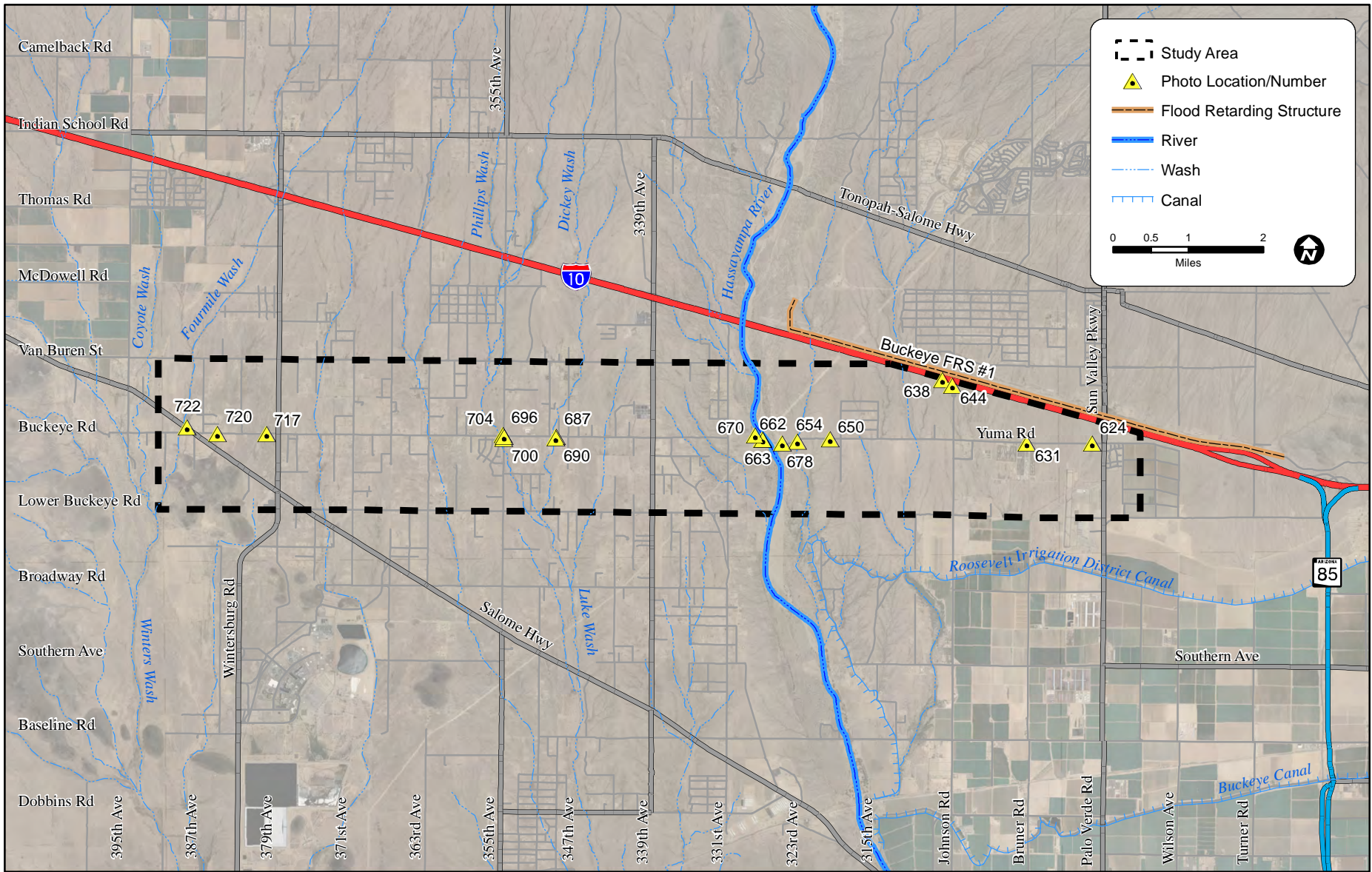


GWSI is ADWR's technical database of well locations, construction data, and water levels.

Created on 5/13/2011

# **APPENDIX TM3-05**

## **DRAINAGE FIELD PHOTOS**



**Kimley-Horn and Associates, Inc.**  
Right Road Right Time Right Cost

**MCDOT TRANSPORTATION**

**Yuma Parkway  
Corridor Feasibility Study**

**Maricopa County, Arizona**

**TM3-05 Drainage Field Photo Locations**



624: Culvert near Palo Verde Rd



631: D/S Channel through Stotz Dairy



638: U/S at I-10 Culvert



644: Erosion SE of Johnson Rd crossing of I-10



650: W towards Hassayampa River valley



654: D/S at Hassayampa River tributary



662: D/S along Hassayampa River R Bank



663: U/S along Hassayampa River R bank



670: D/S towards recent lateral migration of Hassayampa River



678: Hassayampa River floodplain



687: W towards Dickey Wash crossing



690: U/S at Dickey Wash crossing



696: D/S at Phillips Wash crossing



700: D/S at gabion lining along L Bank of Phillips Wash



704: U/S at Phillips Wash



717: U/S at wash crossing near Wintersburg Rd



720: D/S at tributary to Fourmile Wash crossing



722: D/S at Fourmile Wash culverts

# **APPENDIX TM3-06**

## **RECOMMENDED AREA DRAINAGE MASTER PLAN IMPROVEMENTS**



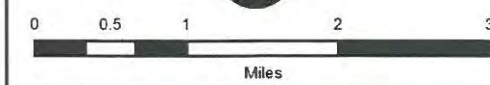
**Buckeye Area  
Drainage Master Plan**  
F.C.D. Contract No. 2004C058

**Legend**

- Buckeye ADMP Boundary
- RECOMMENDED BASINS
- RECOMMENDED STORM DRAIN
- ADOT CHANNEL
- RECOMMENDED CHANNEL SYSTEMS**
- Oglesby
- Palo Verde
- Rooks
- Watson
- White Tanks
- Canal
- Railroad

**Data Sources**

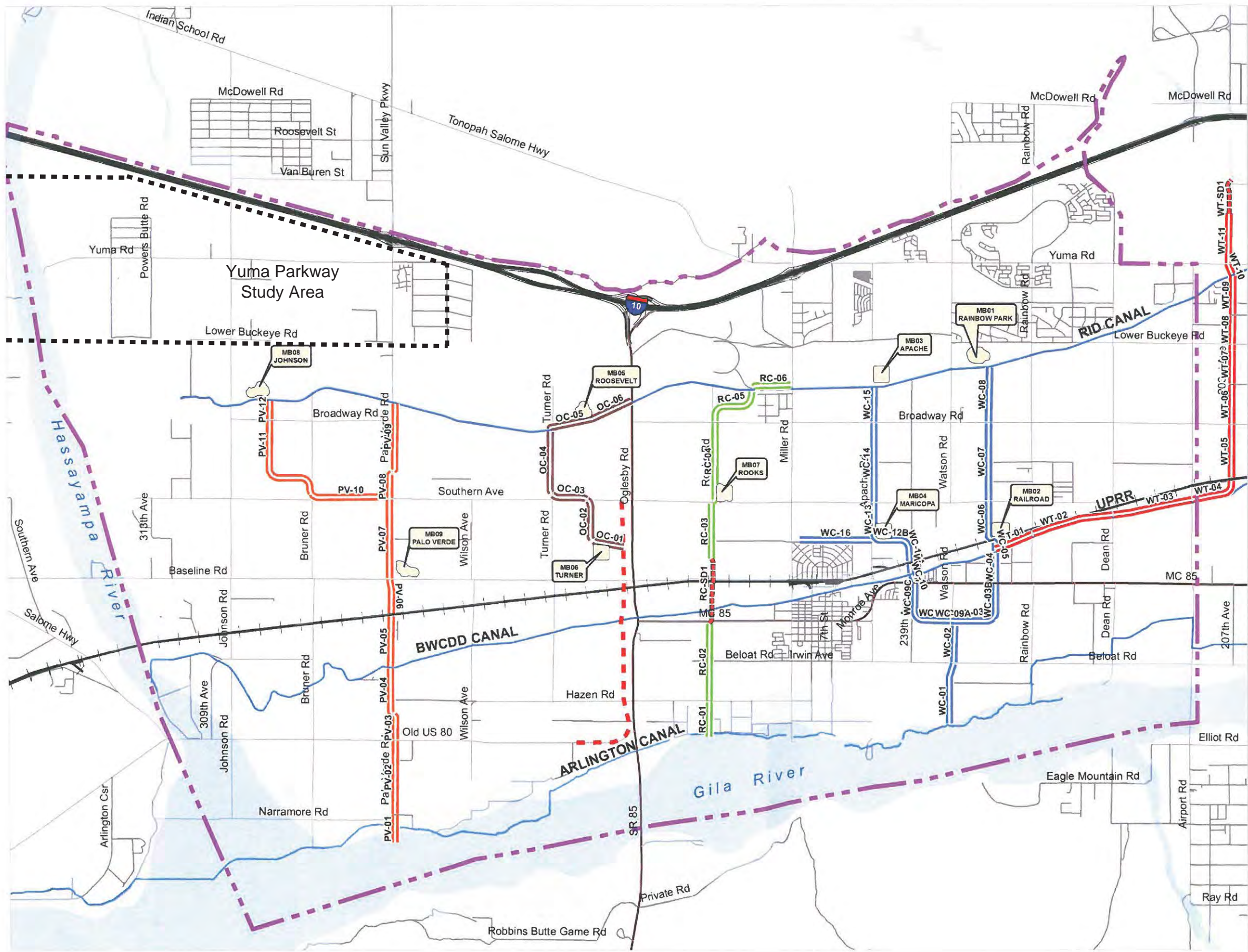
Base Map Data supplied by FCDMC



**Dibble  
Engineering**

**RECOMMENDED  
PLAN**

Figure VII-1 Recommended Plan





**APPENDIX TM3-07**  
**RECENT EROSION AND SEDIMENTATION IN HASSAYAMPA RIVER**  
**JANUARY 2010 STORM**



Overview of channel at SRP poles



Lateral bank migration at SRP poles



Photo courtesy of WEST Consultants

Channel erosion at SRP poles



Photo courtesy of WEST Consultants/SRP

Overview of SRP remedial fill



Sediment deposition at Tonopah Salome Highway



Bank erosion at Tonopah Salome Highway





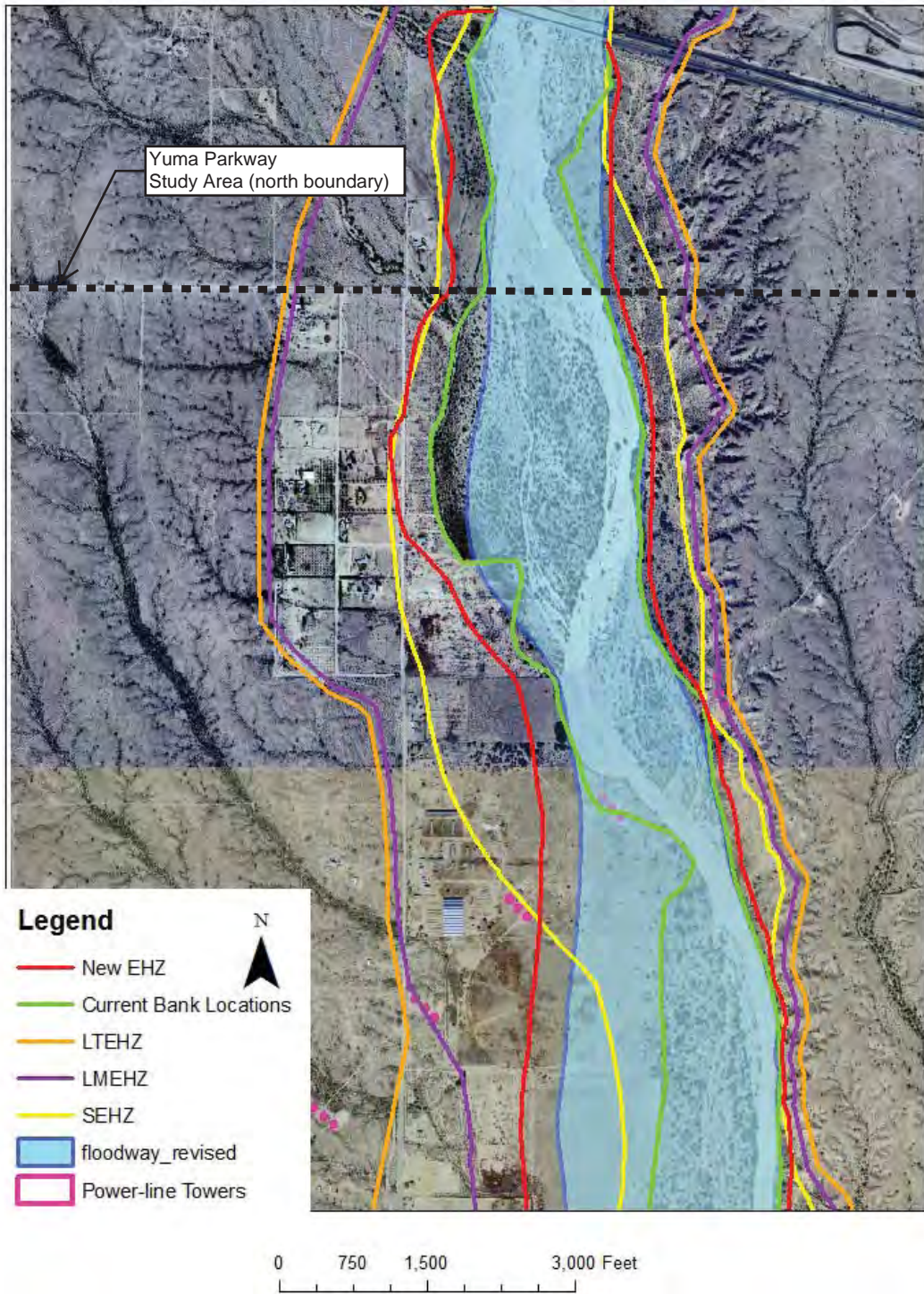
# 500 KV ELECTRIC TRANSMISSION STRUCTURES HASSAYAMPA RIVER HYDROLOGIC ENGINEERING SERVICES

Prepared for the Salt River Project

August 2010

Final Report





**Figure 8. Erosion Hazard Zones**

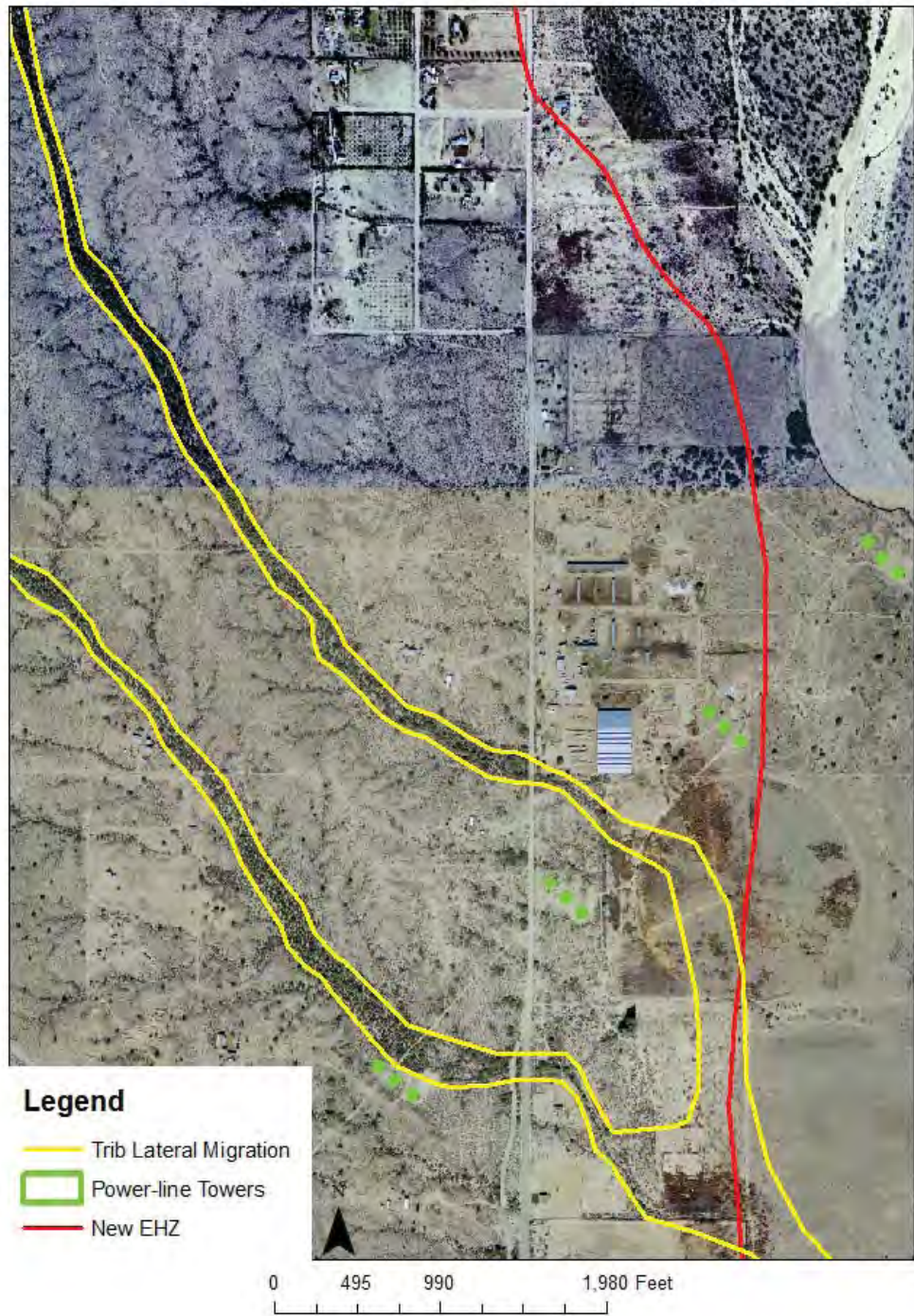


Figure 31. Erosion hazard zones around the tributaries

## 5 Site Conditions

On March 9, 2010, personnel from WEST conducted a field reconnaissance of the Hassayampa River near the electrical transmission towers. Several changes from the 2005 conditions under which the LHWCMF was developed were noted and summarized in Figure 32. The most obvious observation during the site visit was the lateral migration of the river and scour that had occurred around the foundations of electrical transmission lines (see Figure 33). There were several areas where vertical, unstable banks were present (see Figure 34 and Figure 35). In addition, a minor flow split north of the electrical transmission line crossing has now become a major conveyor of water. Finally, there was some scour observed around the right abutment of the I-10 Bridge (see Figure 36). The soil material present in the channel appeared to be similar to the material described in the sediment gradation curves for the sediment transport modeling of the LHWCMF. Thus, it was determined that no new soil analyses were needed for this study.



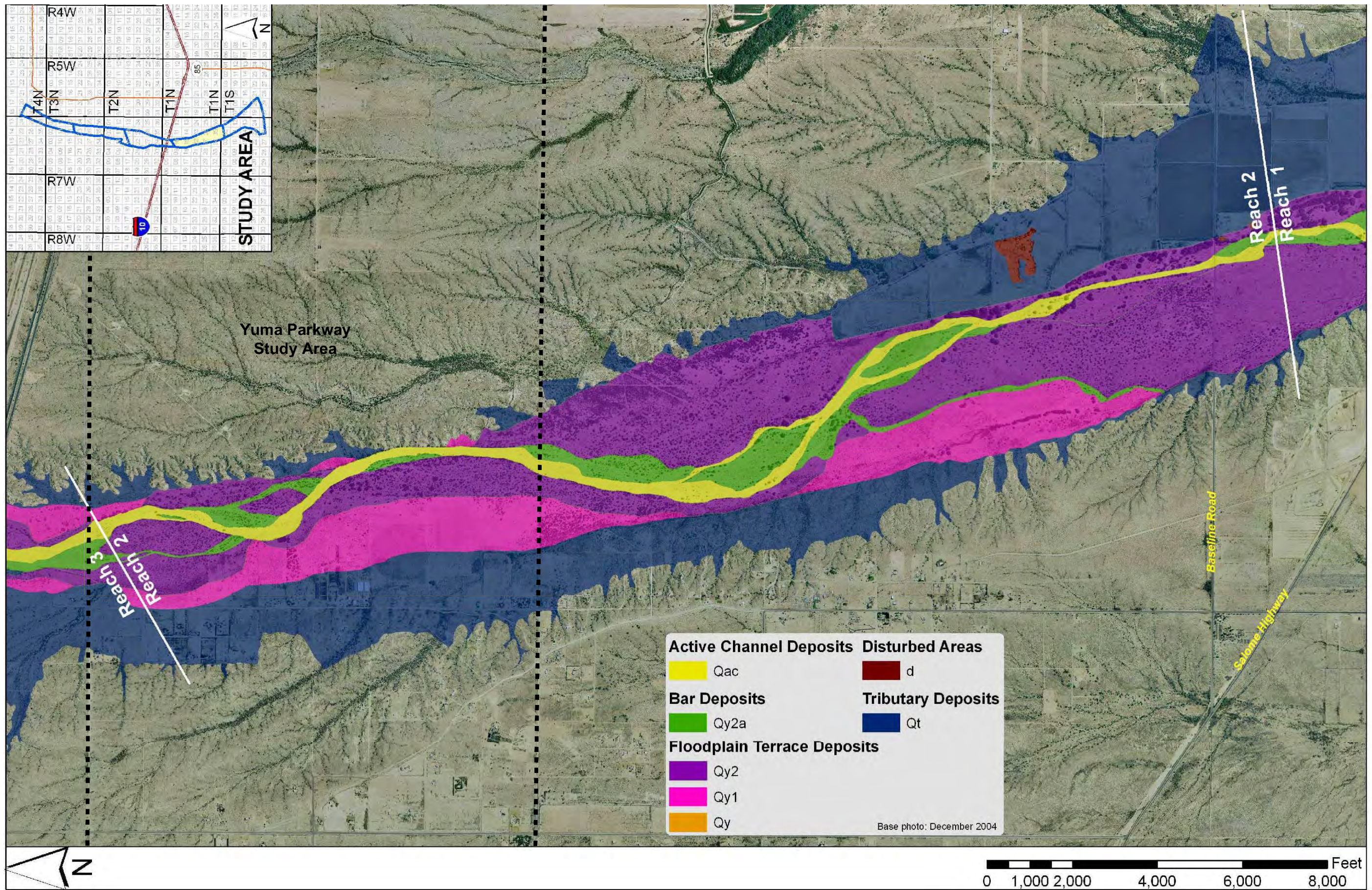
Figure 32. Areas of observed changes during the field visit



Figure 34. Areas along the Hassayampa River with observed vertical banks

# **APPENDIX TM3-08**

## **EXISTING EROSION HAZARD MAPPING**



Reach 2 mapped geomorphology

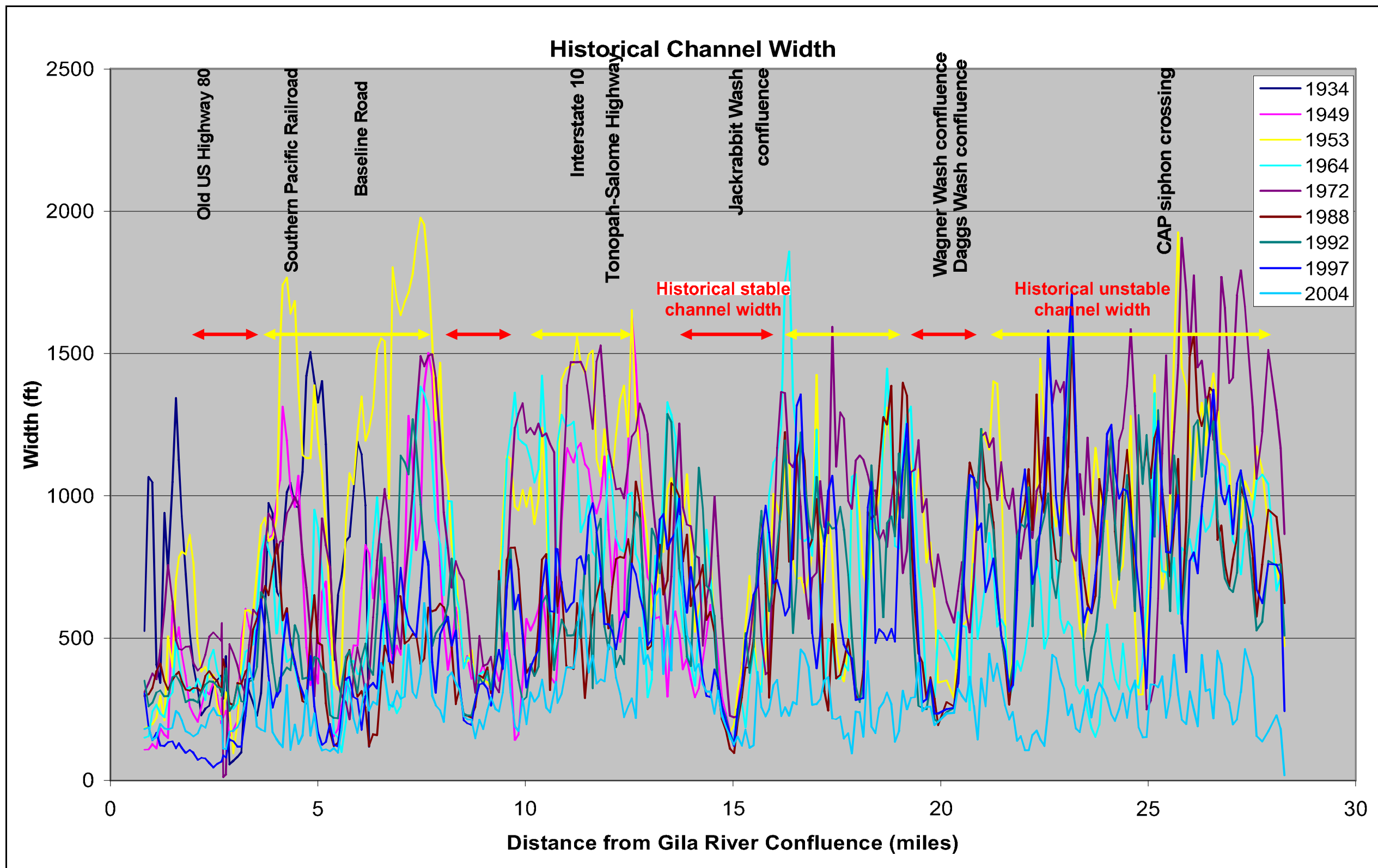


Figure 6-4. Width change analysis summary

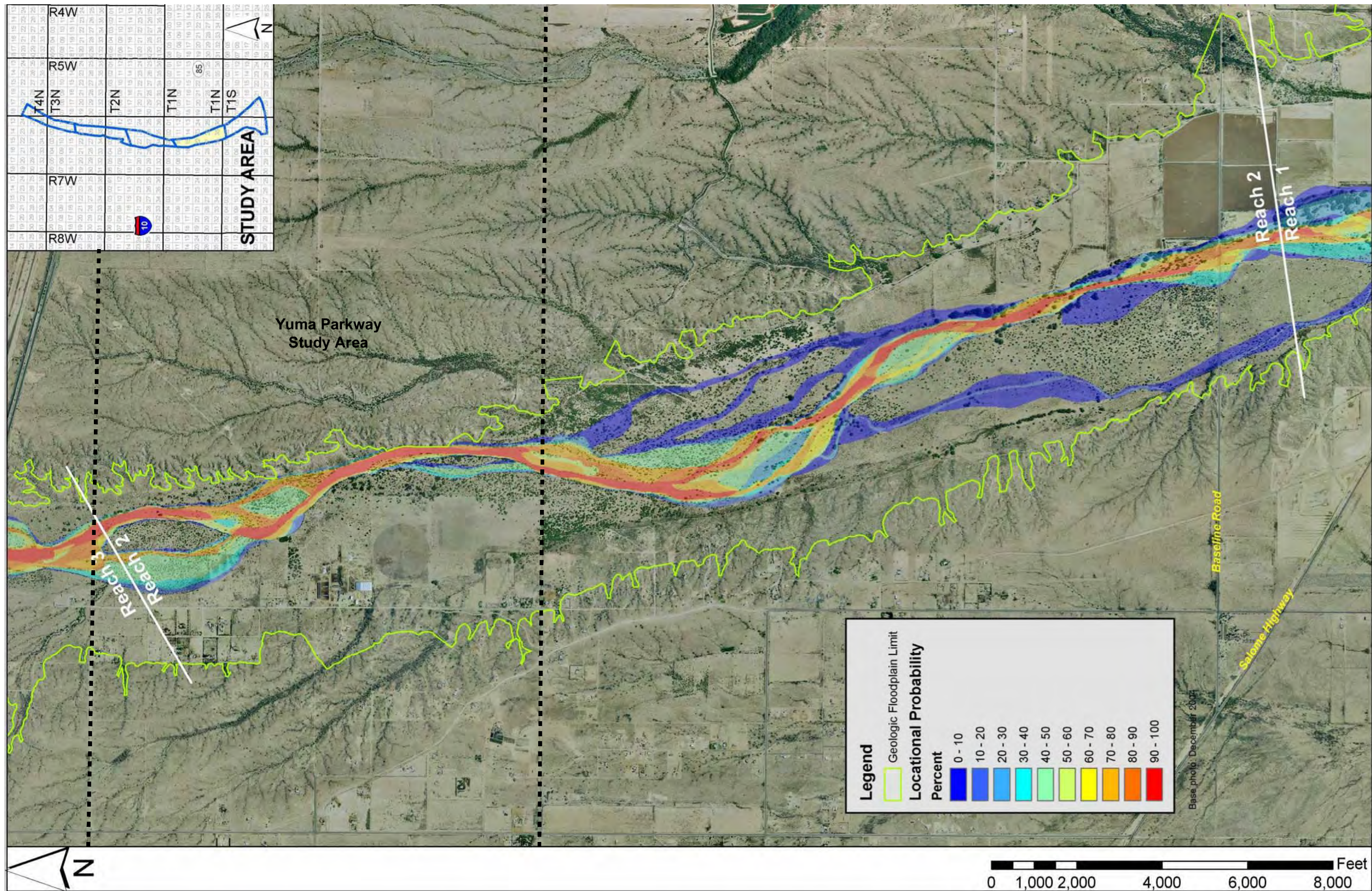
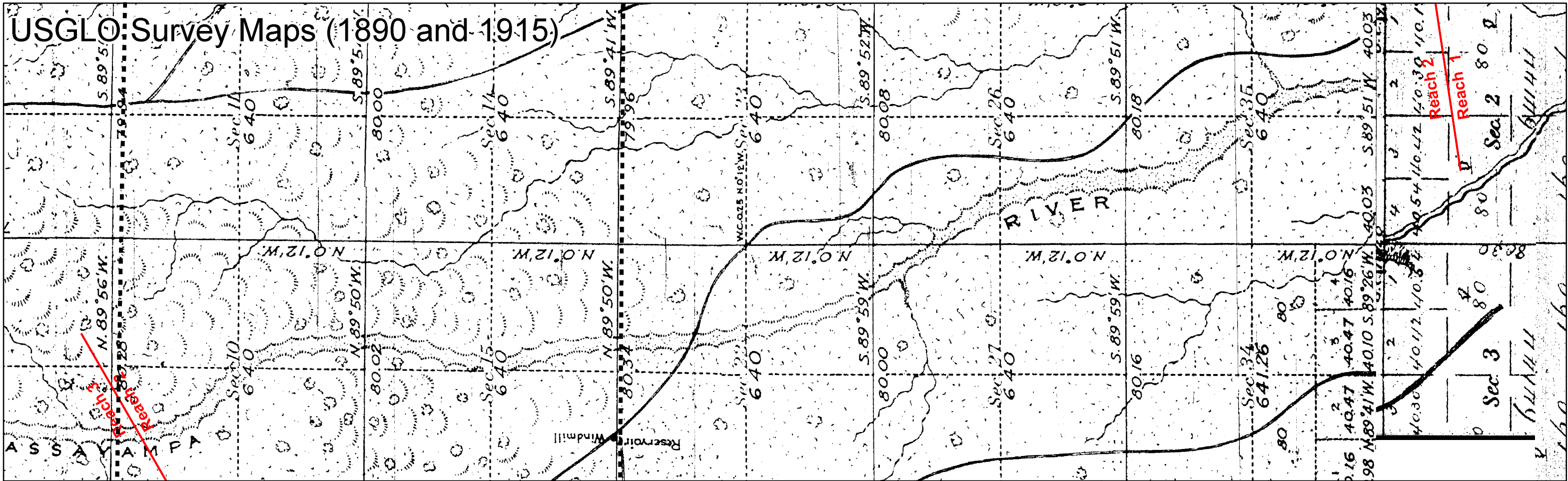
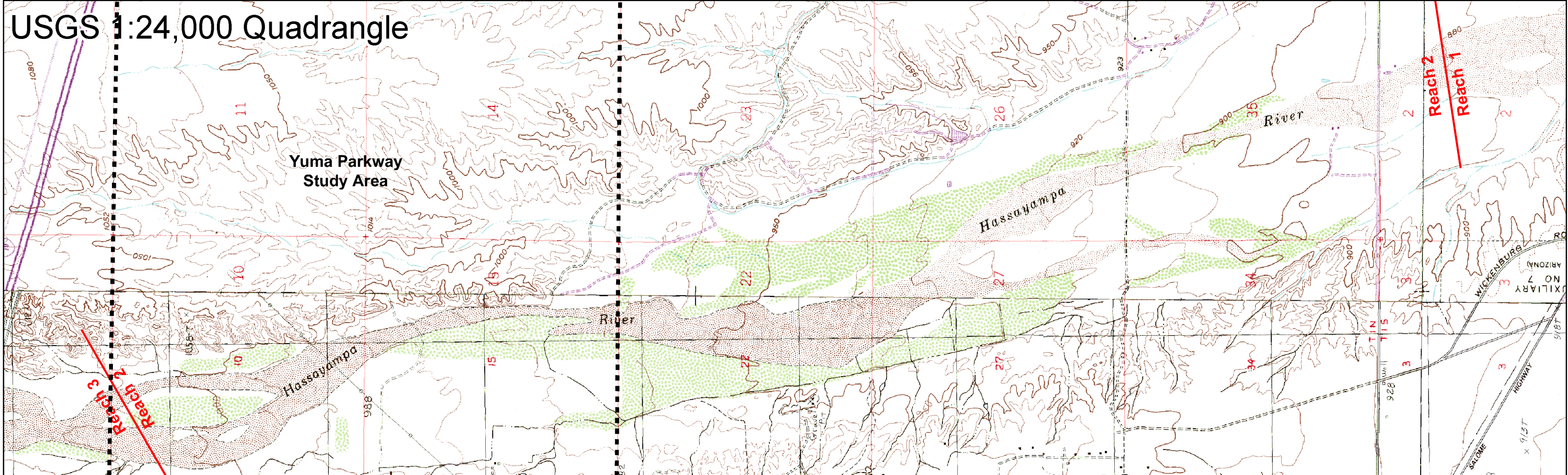


Figure 6-8. Locational Probability for Reach 2 (maximum potential number of years = 55 years)

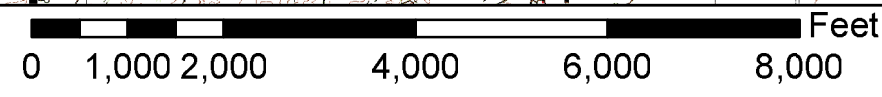
# USGLO Survey Maps (1890 and 1915)



# USGS 1:24,000 Quadrangle



# Reach 2



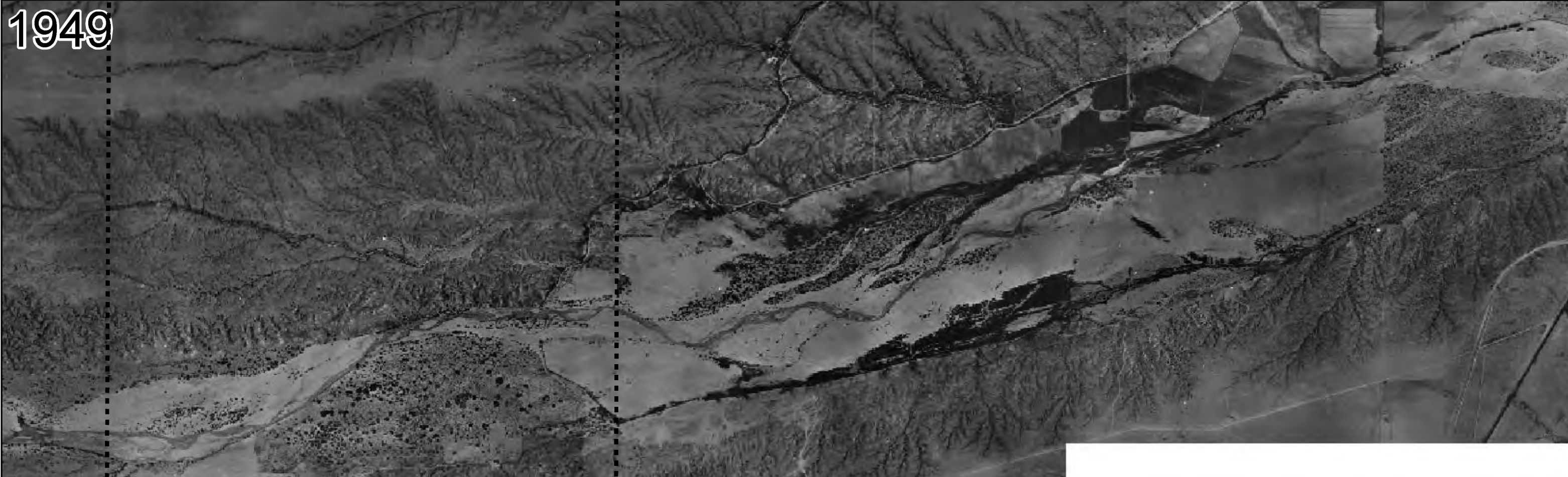
1934



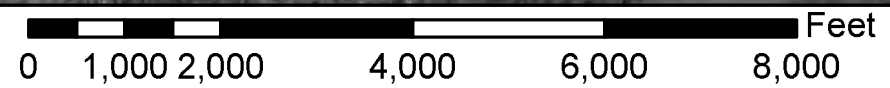
No Photo  
Coverage  
Available

Yuma Parkway  
Study Area

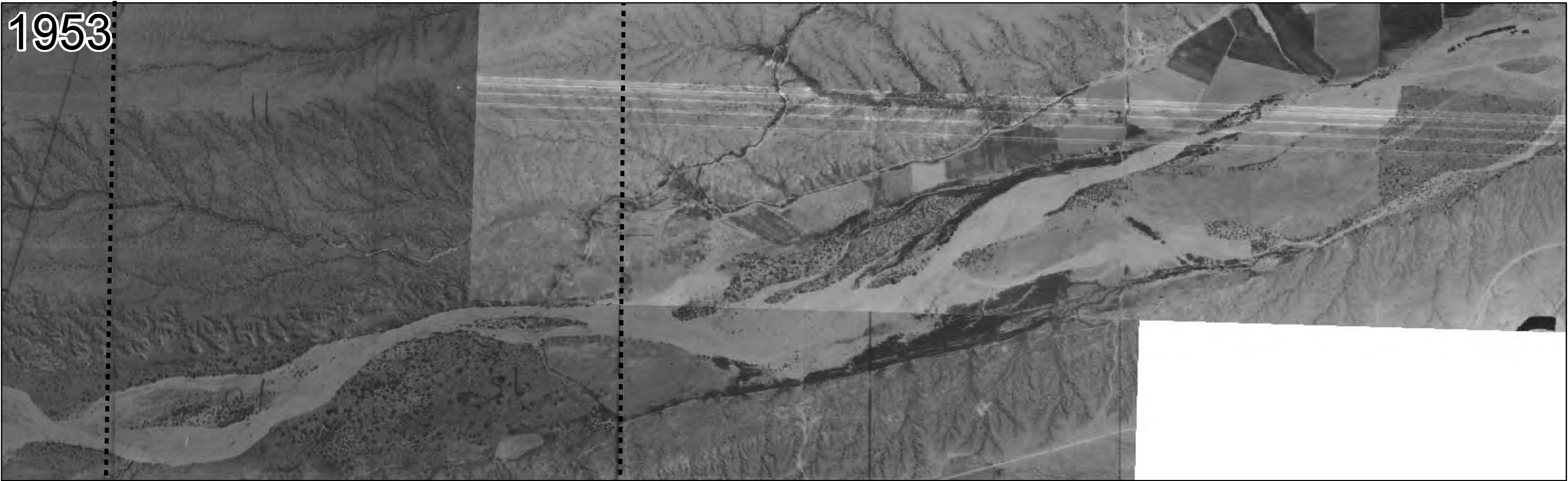
1949



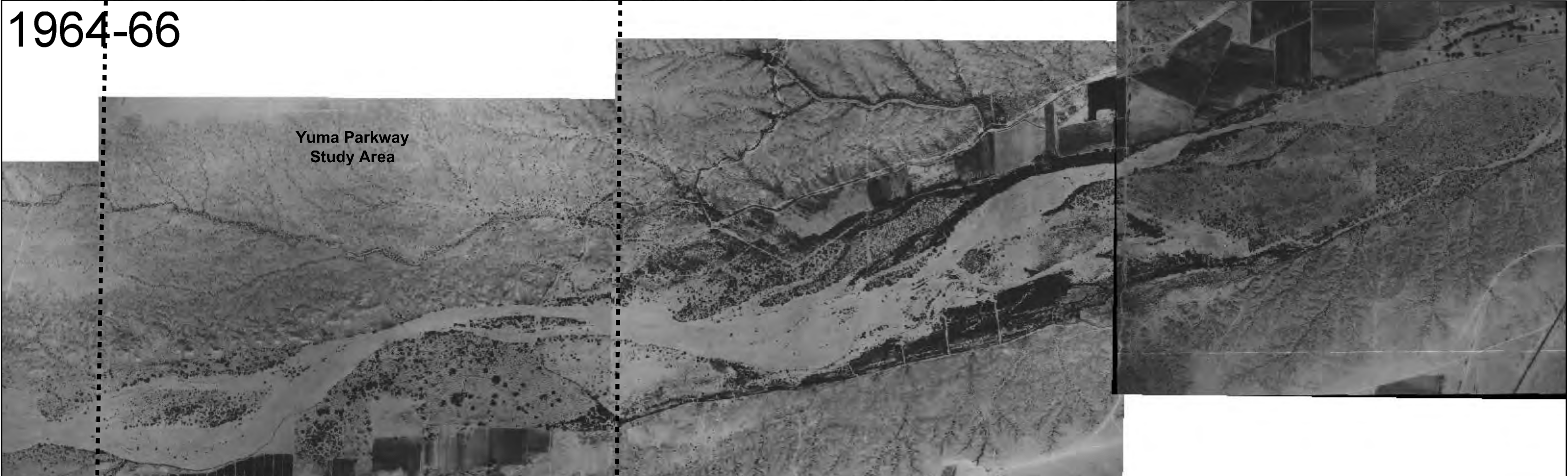
Reach 2



1953

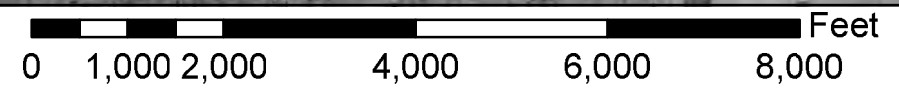


1964-66



Yuma Parkway  
Study Area

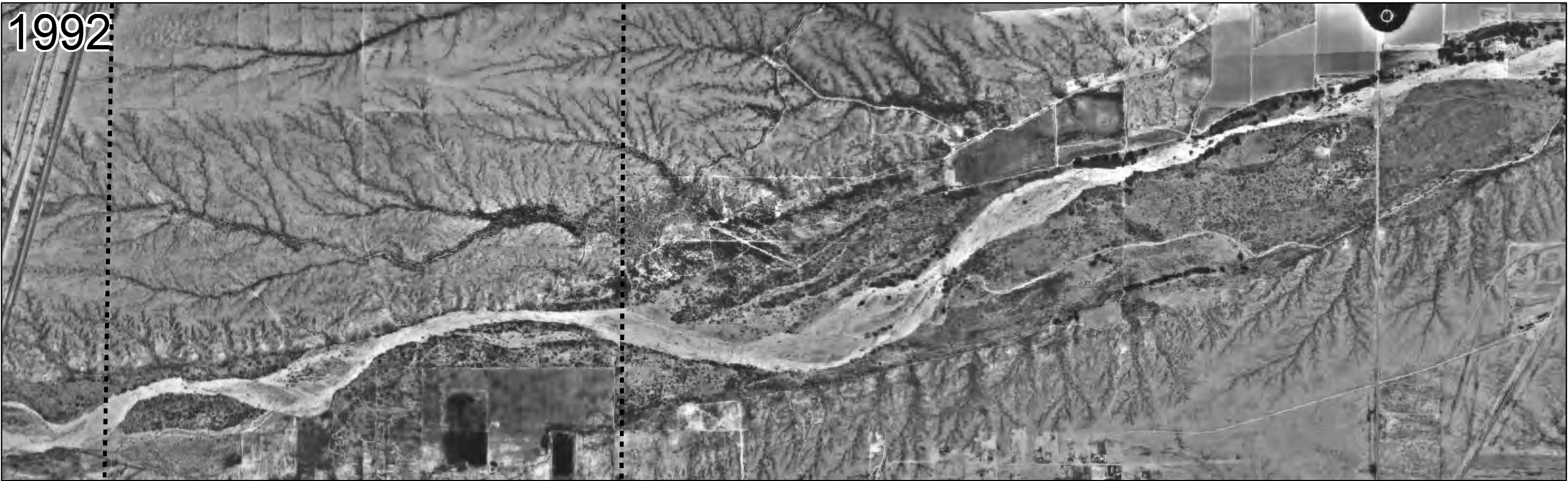
Reach 2



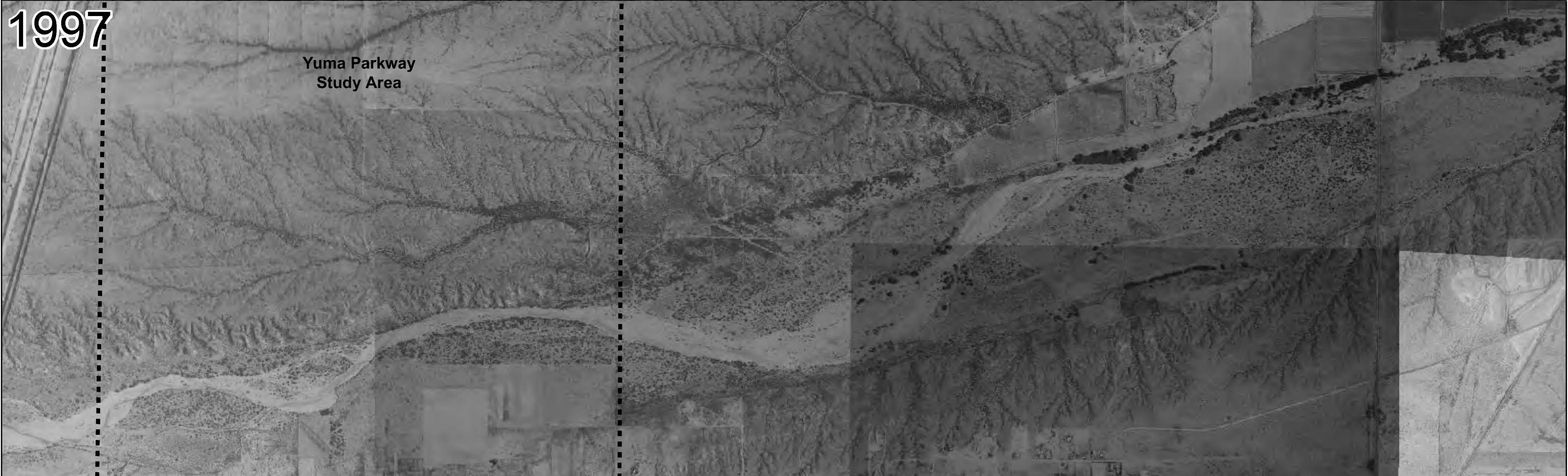
**JE FULLER**  
HYDROLOGY & GEOMORPHOLOGY, INC.



1992

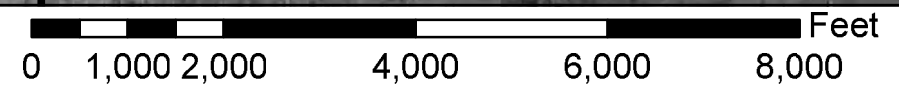


1997

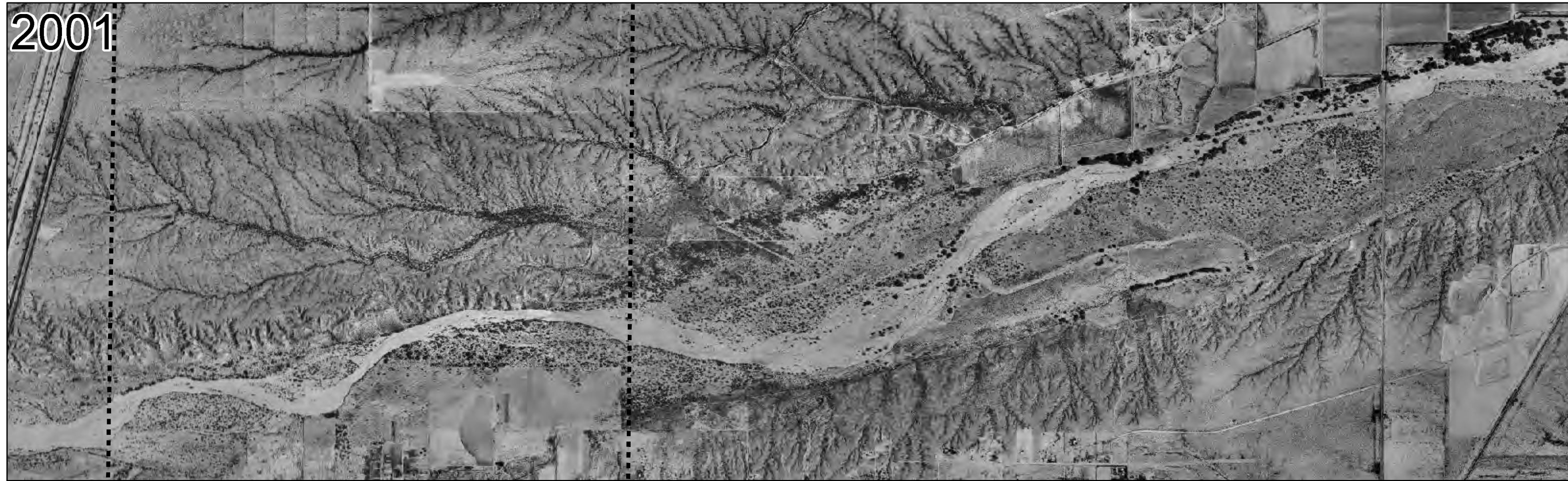


Yuma Parkway  
Study Area

Reach 2



2001

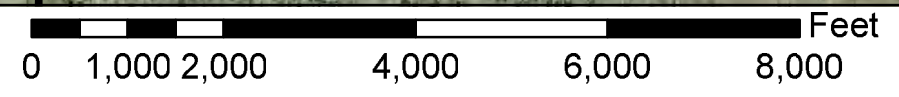


2004



Yuma Parkway  
Study Area

Reach 2



**JE FULLER**  
HYDROLOGY & GEOMORPHOLOGY, INC.






# Buckeye/Sun Valley Area Drainage Master Study

## Interim Guidelines for Development Flooding and Erosion Areas



### Legend

#### Areas of Unique Flooding and Erosion Considerations

##### AREA 1 - Buckeye

-  Undeveloped Natural Sonoran Desert Areas
-  Agricultural Lands/Fields
-  Urbanized Areas

##### AREA 2 - Hassayampa

-  Undeveloped Natural Sonoran Desert Areas
-  Agricultural Lands/Fields







##### AREA 3 - Buckeye Structures

-  Undeveloped Alluvial Fans
-  Low Density Alluvial Development

##### AREA 4 - North Sun Valley

-  Undeveloped Alluvial Fans

#### Potential Flood/Erosion Hazard Areas

-  Floodway
-  Areas of 100-year flood
-  Areas of active alluvial fan flooding
-  Areas of undetermined but possible flood hazards (not evaluated in this study)
-  Erosion Hazard Zones
-  Canal Overtopping Location

Note:  
Not all hazards within the study area have been evaluated and identified including delineations of all floodplains, erosion hazards for the Hassayampa River, etc.

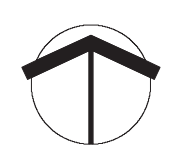
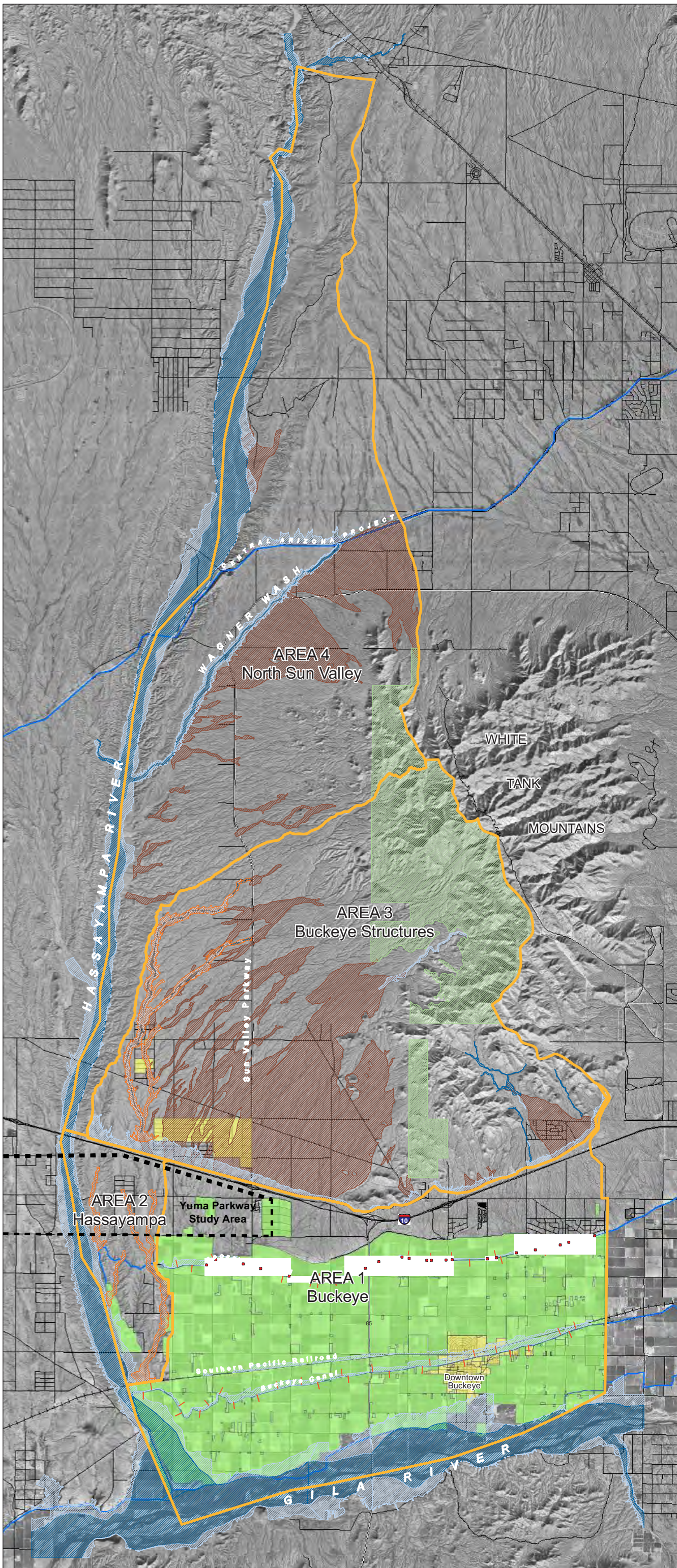
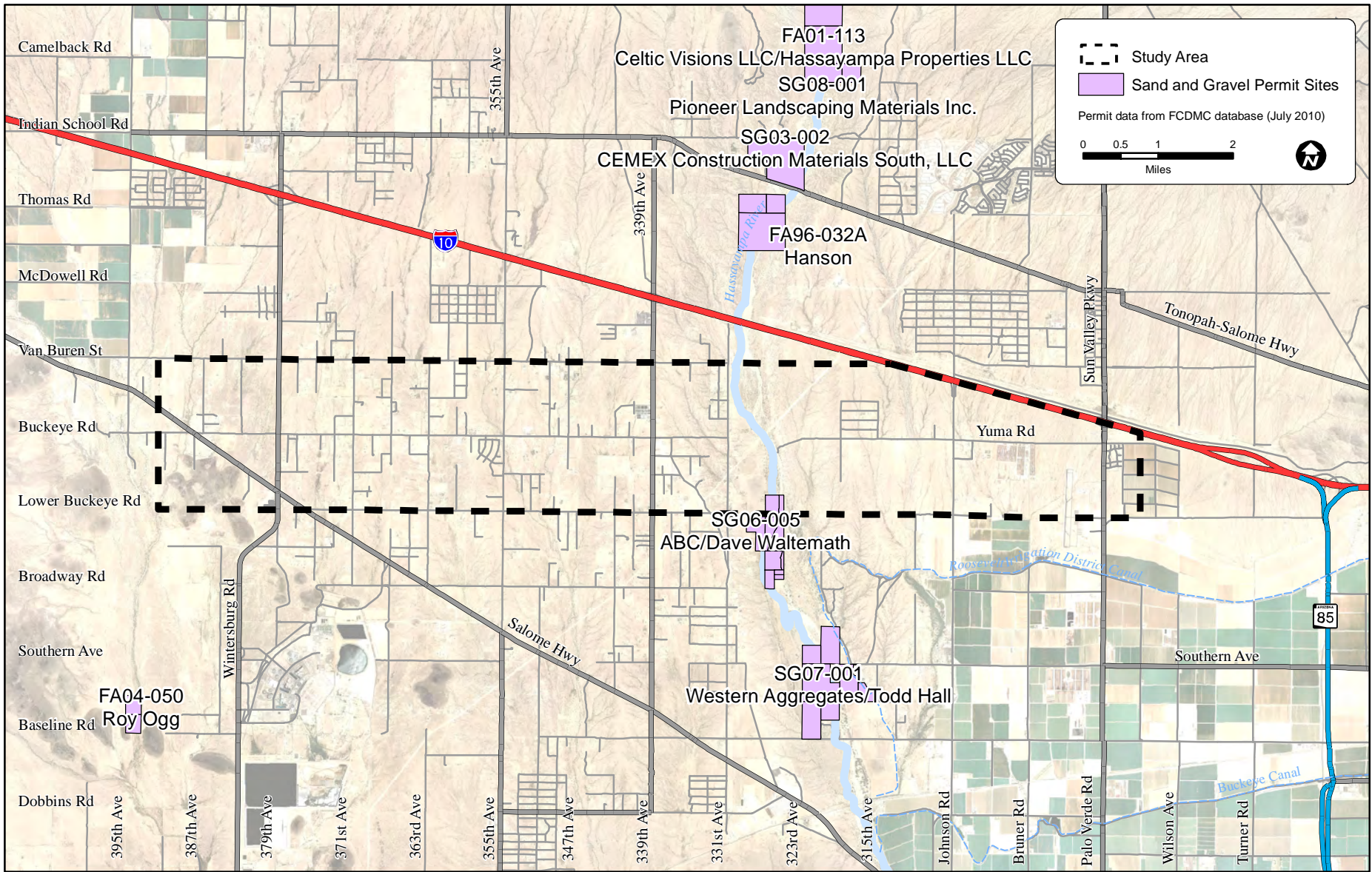


Figure 7



# **APPENDIX TM3-09**

## **SAND AND GRAVEL MINING DOCUMENTATION**



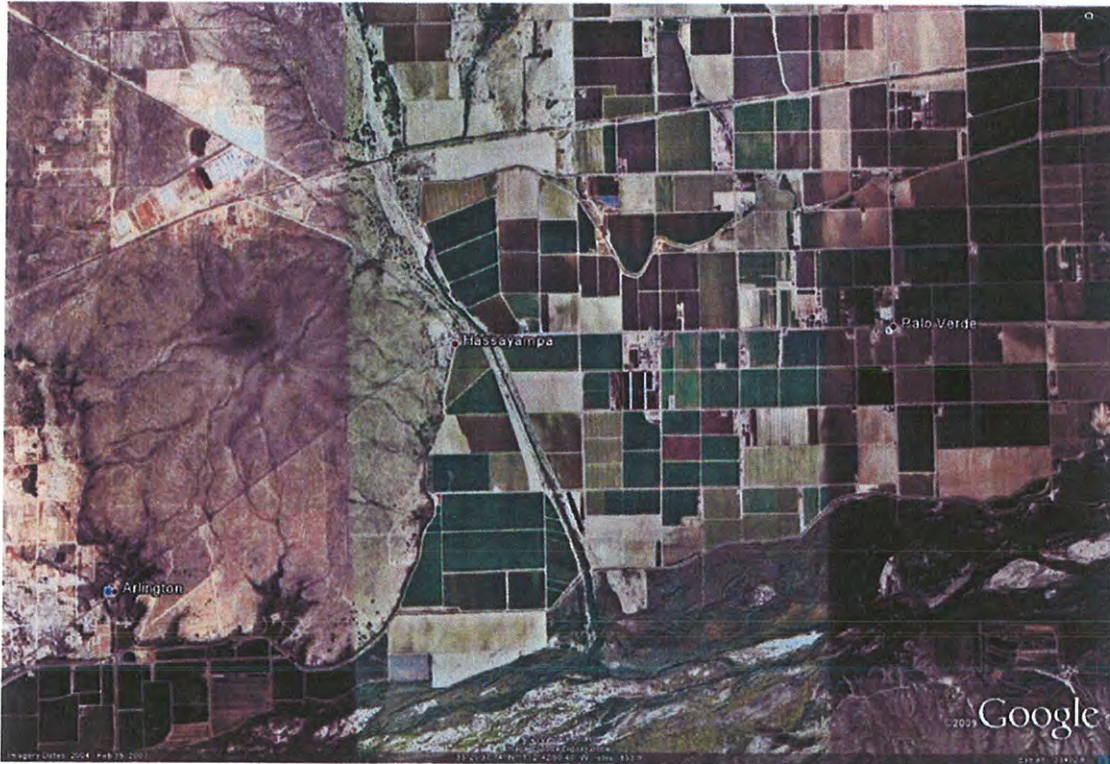
**Yuma Parkway  
Corridor Feasibility Study**

**Maricopa County, Arizona**

**Appendix TM3-09. Sand and Gravel Mining Permits**

Yuma Parkway Study Area  
highlighted in green

### FLUVIAL-12 Modeling of Sand Mining Impacts For Lower Hassayampa River



Prepared for  
 Engineering Application Development and River Mechanics Branch  
 Engineering Division  
 Flood Control District of Maricopa County

*Handwritten signature of Howard H. Chang*

May 2009



<p><b>CHANG</b> Consultants          Hydraulic and Hydrologic          Engineering          Erosion and Sedimentation</p>	<p>P.O. Box 9492          6001 Avenida Alteras          Rancho Santa Fe, CA 92067-4492          TEL: (858) 756-9050, (858) 692-0761          FAX: (858) 756-9460</p>
---	--

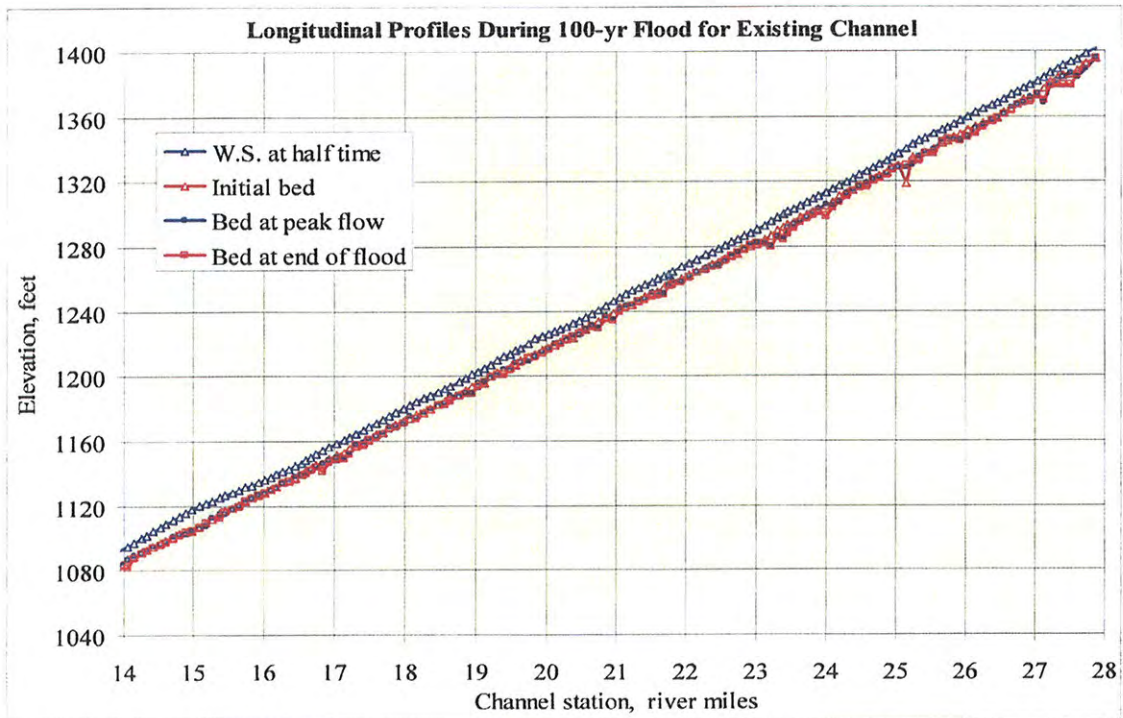
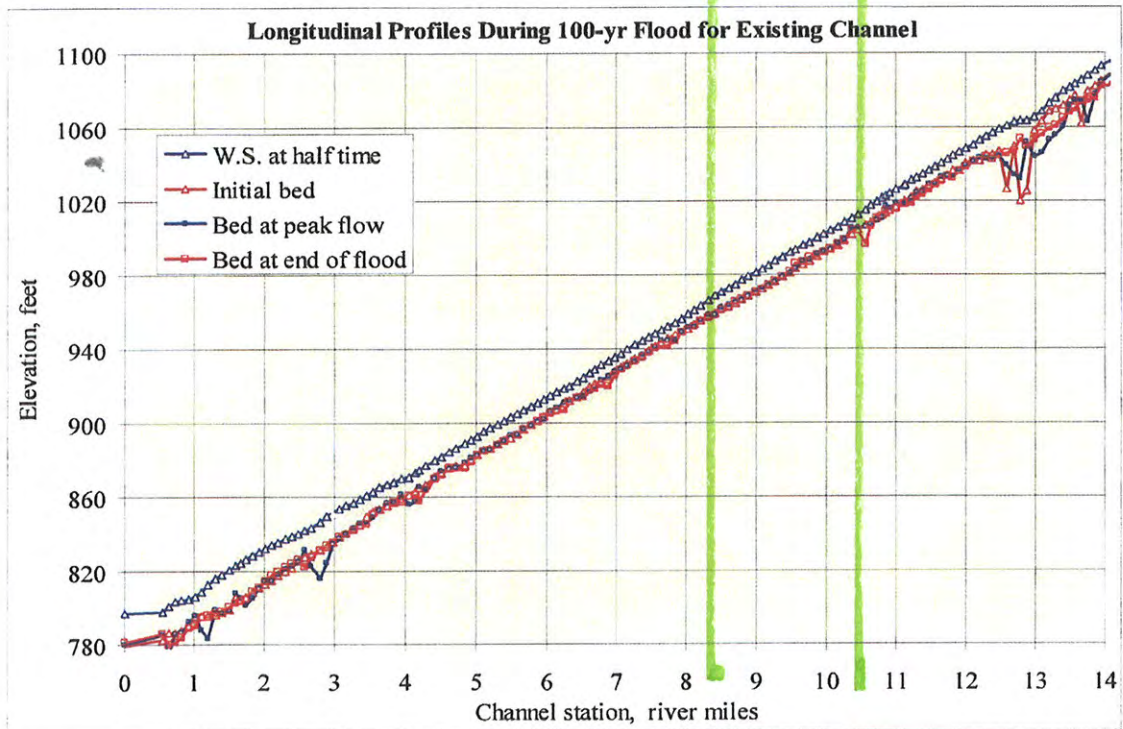


Fig. 6. Simulated water-surface and channel bed profile changes during 100-yr flood for existing conditions

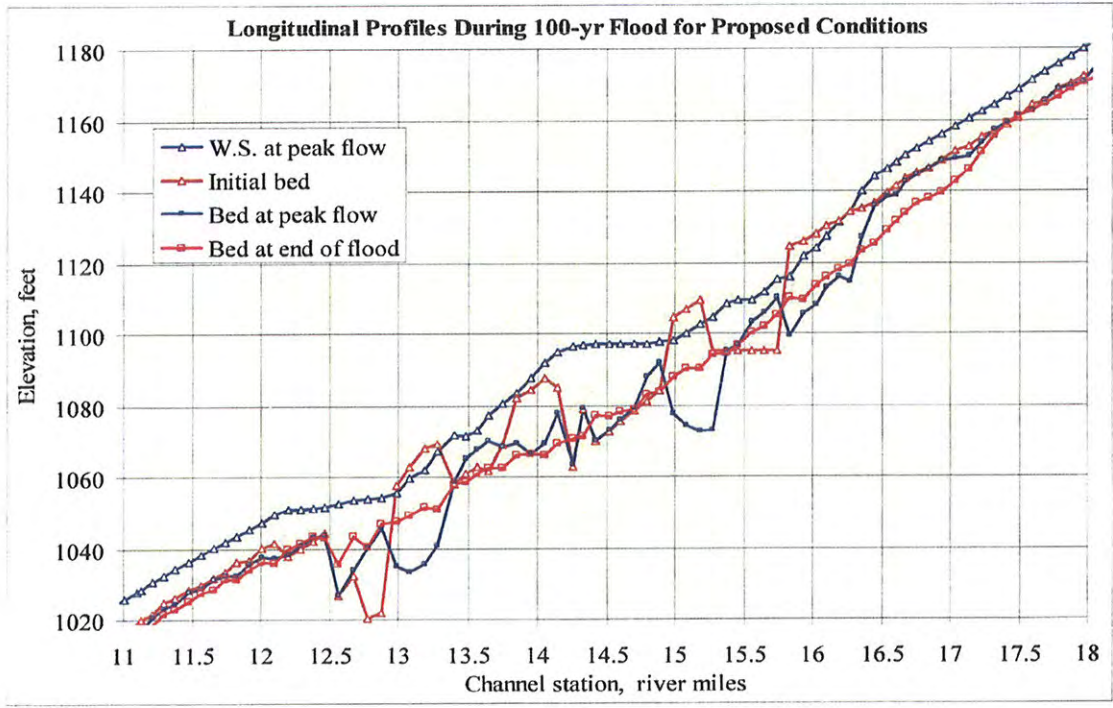
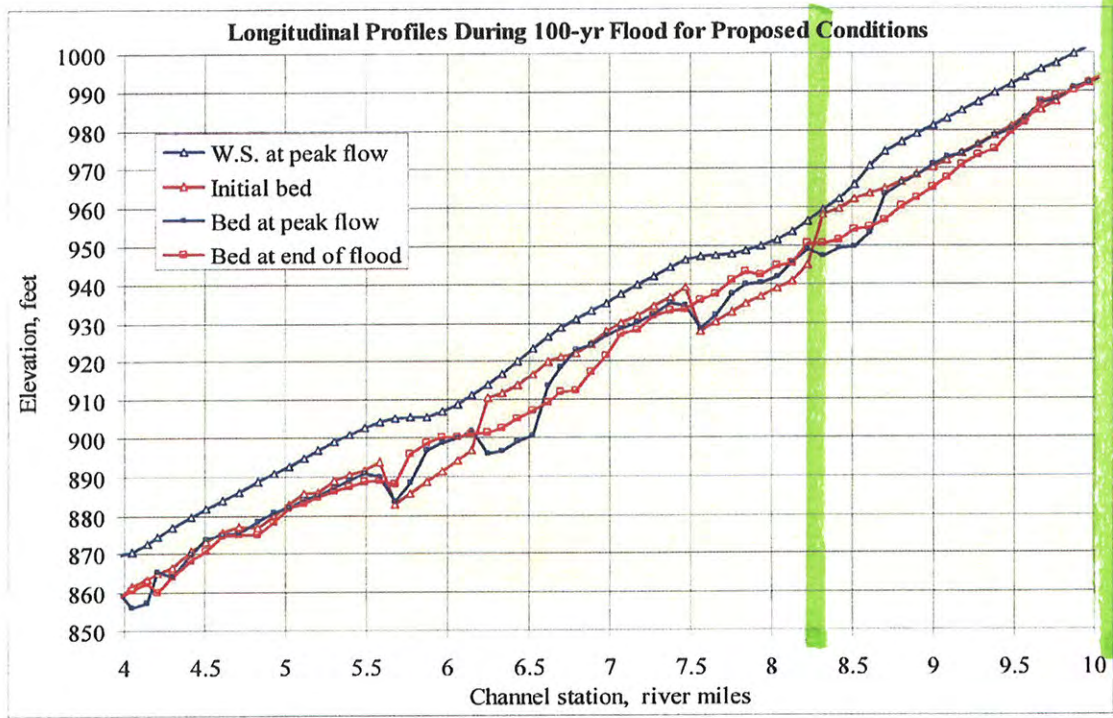


Fig. 13. Water-surface and channel-bed profile changes during 100-yr flood for proposed conditions

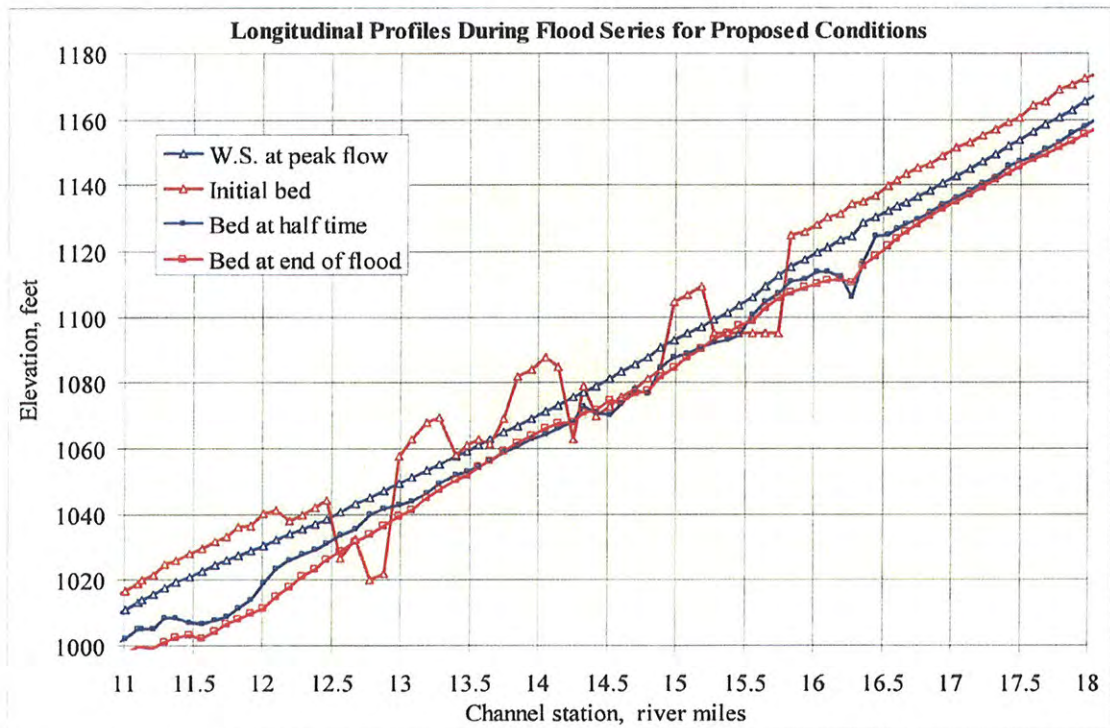
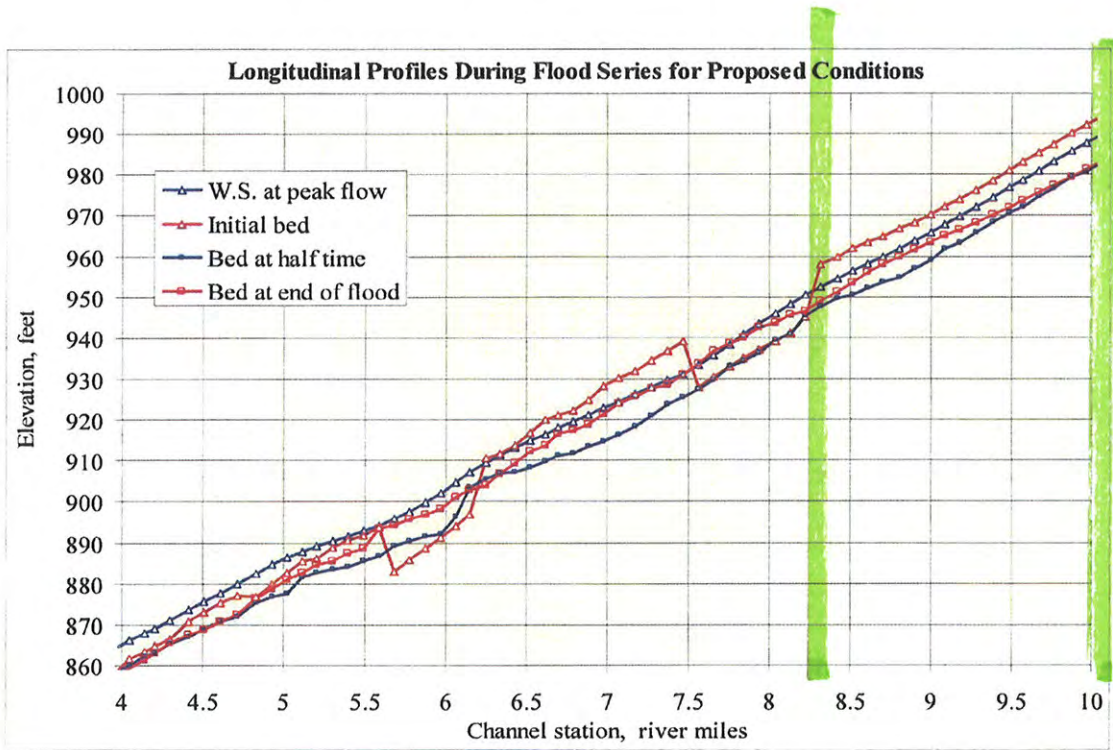


Fig. 14 (continued). Water-surface and channel-bed profile changes during flood series for proposed conditions

Table 5. Comparison of changes in sediment budget related to mining project

M: Channel reach with instream mining  
 N: Channel reaches without instream mining

River reach River miles	Change in sediment storage for existing conditions Million tons	Change in sediment storage for proposed conditions Million tons	Impacts of sand mining on sediment budget* Million tons
0.54 – 0.82 (M)	+0.22	+1.10	+0.88
0.82 – 5.57 (N)	+1.01	+0.14	-0.87
5.57 – 6.14 (M)	-0.06	+2.07	+2.13
6.14 – 7.37 (N)	+0.13	-0.24	-0.37
7.37 – 8.22 (M)	+0.29	+1.75	+1.40
8.32 – 12.09 (N)	+0.01	-1.40	-1.41
12.09 – 12.85 (M)	+1.57	+0.78	+0.79
12.85 – 13.13 (N)	+0.09	-0.33	-0.42
13.13 – 14.83 (M)	-0.02	+1.52	+1.54
14.83 – 15.02 (N)	-0.01	-0.23	-0.22
15.02 – 15.87 (M)	-0.01	+1.52	+1.53
15.87 – 26.38 (N)	-1.51	-4.38	-2.87
26.38 – 27.89 (N)	+0.83	+1.10	+0.27

\*A negative value indicates increased erosion due to sand mining for channel reach

\*A positive value indicates decreased erosion due to sand mining for channel reach

Table 1 (continued). List of minimum bed elevations at end of events

Channel Station River miles	100-yr flood Existing Feet	100-yr flood Proposed Feet	Flood series Existing Feet	Flood series Proposed Feet
7.75	944.62	943.18	945.44	939.83
7.84	948.89	942.31	947.72	942.45
7.94	949.52	944.67	949.06	943.6
8.03	953.15	945.37	951.47	945.64
8.13	954.97	950.71	953.98	946.64
8.22	956.24	950.53	955.97	949.01
8.32	957.74	951.61	959.42	951.4
8.41	960.37	954.35	961.66	953.7
8.51	961.42	954.95	962.39	956.06
8.6	964.92	956.72	963.74	958.21
8.7	966.96	960.46	964.93	959.94
8.79	968.87	962.62	967.52	961.76
8.89	970.19	965.35	968.83	963.68
8.98	972.15	967.83	971.25	965.25
9.08	974.67	970.92	973.52	966.73
9.17	976.66	973.38	974.87	968.39
9.27	978.97	974.99	977.53	970.38
9.36	981.22	979.66	979.77	972.25
9.45	984.3	982.09	981.41	973.83
9.55	986.97	987.28	983.41	975.8
9.64	989.71	988.77	985.81	977.58
9.74	990.18	990.25	987.94	979.58
9.83	991.87	992.08	989.68	981.38
9.93	993.4	993.79	992.51	983.15
10.02	995.18	995.53	995.19	985.18
10.12	998.6	999.05	996.55	987.39
10.21	1002.7	997.26	998.45	988.75
10.31	1003.67	1003.01	1000.84	990.56
10.4	999.6	998.03	1003.2	991.16
10.5	1006.79	1006.8	1004.47	992.22
10.59	1009.94	1009.71	1008.32	993.46
10.69	1011.37	1011.86	1009.38	994.61
10.73	1012.92	1012.79	1013.07	994.57
10.77	1013.32	1013.05	1013.13	996.18
10.87	1015.06	1014.87	1014.54	997.82
10.98	1015.16	1015.15	1015.94	999.46
11.01	1018.7	1017.93	1016.98	999.76
11.09	1018.77	1018.74	1018.71	999.43
11.16	1021.85	1021.7	1019.98	1001.26
11.24	1022.83	1022.82	1021.12	1002.68

Table 2 (continued). List of bed elevations reached by maximum scour during events

Channel Station River miles	100-yr flood Existing Feet	100-yr flood Proposed Feet	Flood series Existing Feet	Flood series Proposed Feet
7.84	948.9	937	944.4	929.2
7.94	949.6	939	947.5	931.4
8.03	951.3	941	949.8	936.7
8.13	954.1	945	950.3	936.6
8.22	955.8	947	953	942.2
8.32	957.5	946.7	955.2	944.2
8.41	960.2	949.7	956.6	946.2
8.51	961.3	947.8	957.5	948.4
8.6	964.8	950.2	962	951.7
8.7	966.1	954.8	964.2	954.2
8.79	968	960.4	965.8	956.4
8.89	970	964	967.5	958.2
8.98	972	966.7	969.1	960.4
9.08	973.5	969.7	971	963
9.17	975.8	972.8	972.1	965.4
9.27	978.1	974.7	973	967.8
9.36	980.3	978.9	976.2	969.9
9.45	981.5	980.5	978.5	970.5
9.55	985.4	985.4	981	974.2
9.64	987.4	987.5	982.6	976.3
9.74	989.8	990	984.4	976.4
9.83	991.7	991.7	988	978.8
9.93	993.2	993.2	988.3	981.6
10.02	994.5	994.5	990.8	983.7
10.12	998.4	998.4	994.6	984.4
10.21	1001.7	1001.7	996.4	986.1
10.31	1003.3	1003.5	997.7	987.2
10.4	996.6	997.9	997.8	988.1
10.5	1006.4	1006.3	1001.5	988.7
10.59	1008.5	1008.1	1001.6	987.8
10.69	1009.9	1009.7	1004.6	990.2
10.73	1012.7	1012.6	1006.9	990.8
10.77	1012.8	1013.1	1007	991.8
10.87	1015	1014.8	1007.2	994.1
10.98	1015.5	1014.7	1009.2	996.3
11.01	1017.6	1016.8	1013.7	997.2
11.09	1018.1	1017.3	1016.7	998
11.16	1021.7	1021.4	1017.8	999.5
11.24	1023	1022.6	1018.9	1001.4
11.33	1025.3	1025.3	1020.2	1000.4

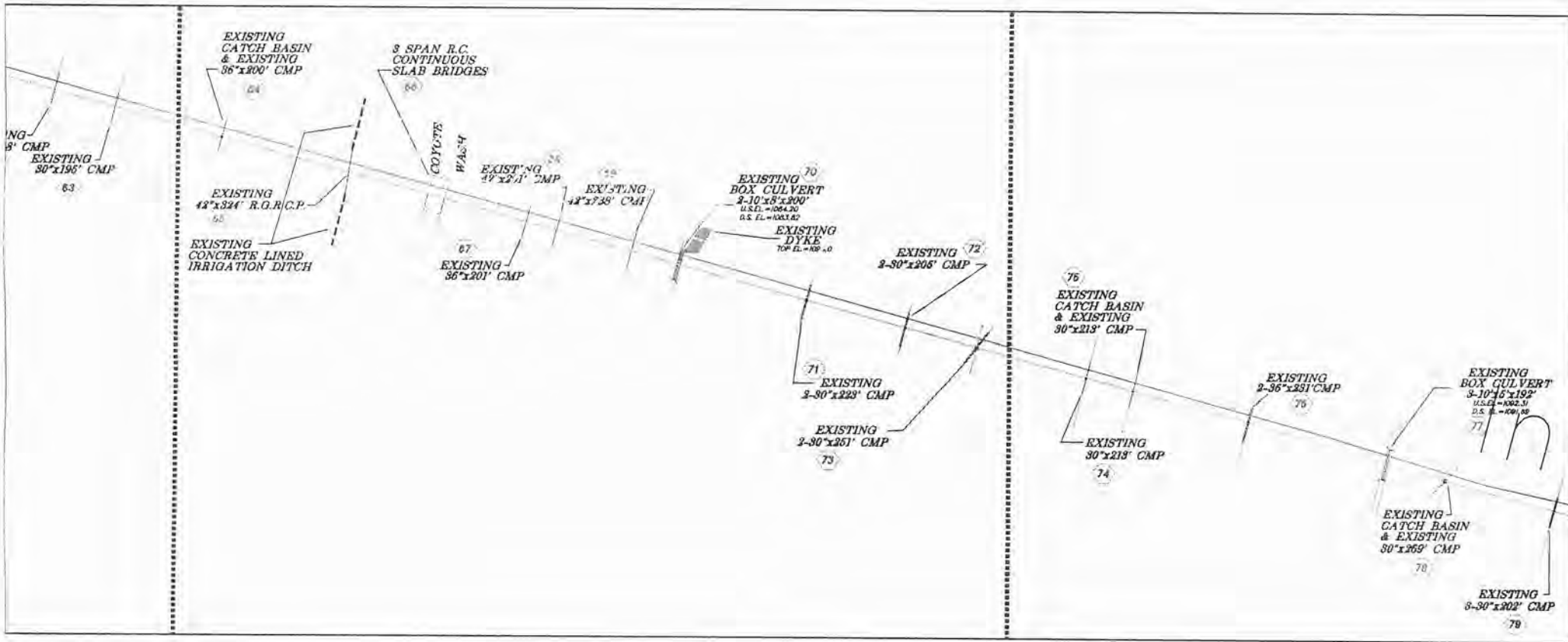
**APPENDIX TM3-10-1**  
**EXISTING DRAINAGE STRUCTURE DOCUMENTATION**  
**I-10 CULVERTS (PALO VERDE WATERSHED)**

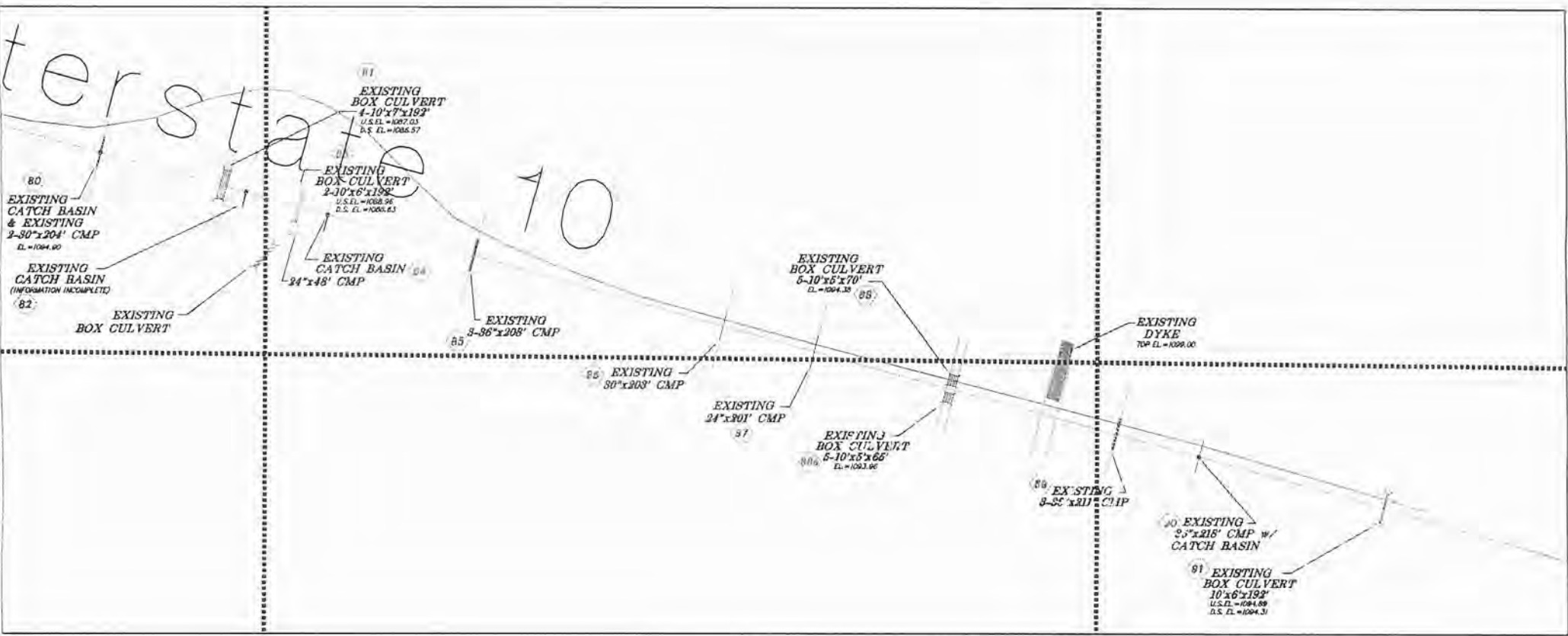
### **Methodology for I-10 Impoundment Analysis**

The culvert analysis along I-10 deal with types of culverts ranging from Box Culverts, CMP's, RGRCP's, and CMP Arch's. All culverts less than 24" in diameter were ignored since they cannot convey significant amount of flow. Flows reaching I-10 either cross the roadway at the numbered culverts within the study area, or flow mostly southeast along the roadway embankment. Therefore, the analysis was started at the west side and proceed eastward. The area contributing flow to each culvert was determined based on topographic information and delineation of upstream basins. These areas, shown in acres, are seen on the spreadsheet in the "Area Associated to Culvert Inlet" column. In addition, any flow from adjacent culverts flowing along the embankment towards the culvert were added in column "Total Accumulated Area."

An aerial photo plot along with contours are shown for each culvert and it's associated sub-basin. This plot shows the associated area and calculates flow based on Area/Runoff Relationship [ $\text{Flow} = 510 \times \text{Area (s.mi)}$ ], (see Section 4). There is an additional aerial photo plot that shows a close up of the culvert being analyzed, this plot was used to approximate the general slope around the culvert. From reviewing survey and aerial photographs, the best approach to the analysis of the culverts bypass flow was selected from either Manning's Equation or Weir Analysis (due to a berm or obstruction). FHWA Inlet Control Nomographs were used to estimate the flows through the culvert. Flow along the roadway (bypass) was based on a cross section representing either the typical conveyance path or the weir configuration. These cross sections are provided at each analysis point along with relevant calculations.

Along the two Traffic Interchanges (T.I.) located within the study area, additional analysis was required because the access ramps crossings have less capacity than the freeway crossings. The analysis sheets for these locations explain the procedures used.





### **Interstate 10 Flow Calculations for Culverts**



Culvert ID	Culvert Type	Contributing Area from the north (acres)	Contributing Area from the west (acres)	Total Area Contributing to Culvert (acres)	Target Flow (cfs)	Elevation (ft)	Culvert Flow				Manning's Equation for flow along highway			Weir Flow over obstruction					
							HW (ft)	Chart 2 or 8 HW/D	Chart 8 Q/B (cfs/ft)	Q-culvert (cfs)	Cross Section Area (s.ft)	Wetted Perimeter (ft)	Normal Depth Q (cfs)	Avg. Height HW (ft)	Length (L2) (ft)	Weighted Avg Head (H) (ft)	Q-east (cfs)	Q-total (cfs)	
						1099.5	12.7	3.63	200.00	149	4149	4149							
						1100	13.2	3.77	204.00	154	4234		4080 cfs + 154 for 42"						
							**These flows are added together for three culverts, look at spreadsheet for individual culvert flows												
The following culverts (78 to 71) are on a (+) Slope, flowing towards Culvert 71							HW (ft)	HW/D	Cfs/foot	30"CMP									
78 and 77 (20)	1-30" CMP 3-5' x 10' RCB	111	0	111	89		for box	Box											
							1094.5										**		
See Culverts 78 through 71 Analysis below)							1096.5	2	0.40	8.00	240								
							1098.5	4	0.80	24.00	720								
							1099.5	5	1.00	33.00	22.00	1012	1012						
							1100.5	6	1.20	40.00	40.00	1240							
Road Surface is 1102.5							1101.5	7	1.40	48.00	48.00	1488							
Wsel = 1102.5 (See Analysis for Culverts 67 through 78 together below)							1102.5	8	1.60	55.00	50.00	1700							
							**These flows are added together for two culverts, look at spreadsheet for individual culvert flows												
76	2-36" CMP	529	0	529	421											weir flow depth at elev > 1096.80 (Just east of Culvert 71)			
See Culverts 78 through 71 Analysis below)																			
Wsel = 1099.5 (See Analysis for Culverts 67 through 78 together below)							HW/D fo CMP	Flow cfs											
							1092										**		
							1094	2	0.67	19.00	38								
							1095	3	1.00	35.00	70								
							1098	6	2.00	70.00	140								
							1099	7	2.33	80.00	160								
							1099.5	7.5	2.50	83.00	166	166							
							1100	8	2.67	88.00	176								
							**These flows are doubled because there are two culverts												
75 and 74	1-30" CMP 1-30" CMP	19	0	19	15											weir flow depth at elev > 1096.80 (Just east of Culvert 71)			
See Culverts 78 through 71 Analysis below)																			
Wsel = 1099.5 (See Analysis for Culverts 67 through 78 together below)							1092										**		
							1094	2	0.80	16.00	32								
							1095	3	1.20	28.00	56								
							1098	6	2.40	51.00	102								
							1099	7	2.80	57.00	114								
							1099.5	7.5	3.00	60.00	120	120							
							1100	8	3.20	62.00	124								
							**These flows are doubled because there are two culverts												
73	2-30" CMP	2645	0	2645	2108											weir flow depth at elev > 1096.80 (Just east of Culvert 71)			
See Culverts 78 through 71 Analysis below)																			
Wsel = 1099.5 (See Analysis for Culverts 67 through 78 together below)							1092										**		
							1094	2	0.80	16.00	32								
							1098	6	2.40	51.00	102								
							1099	7	2.80	57.00	114								
							1099.5	7.5	3.00	60.00	120	120							
							1100	8	3.20	62.00	124								
							**These flows are doubled because												

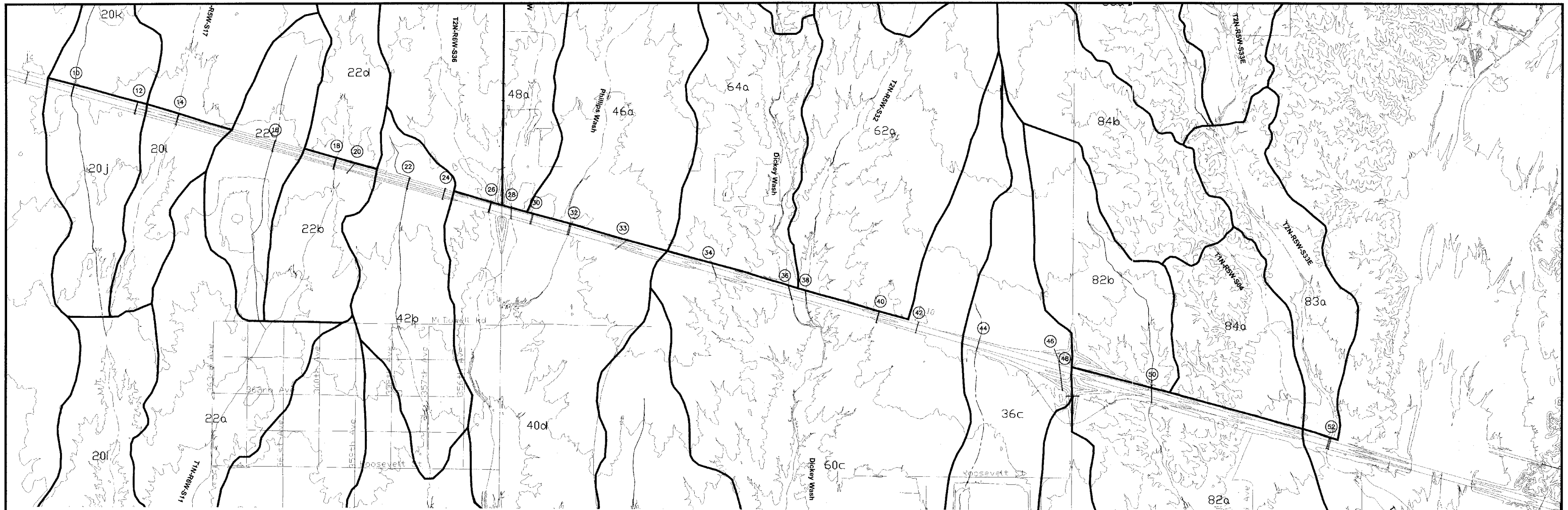
Culvert ID	Culvert Type	Contributing Area from the north (acres)	Contributing Area from the west (acres)	Total Area Contributing to Culvert (acres)	Target Flow (cfs)	Elevation (ft)	Culvert Flow				Manning's Equation for flow along highway			Weir Flow over obstruction				Q-total (cfs)
							HW (ft)	Chart 2 or 8 HW/D	Chart 8 Q/B (cfs/ft)	Q-culvert (cfs)	Cross Section Area (s.ft)	Wetted Perimeter (ft)	Normal Depth Q (cfs)	Avg. height HW (ft)	Length (L2) (ft)	Weighted Avg Head (H) (ft)	Q-east (cfs)	
72	2-30" CMP	56	0	56	45		there are two culverts							weir flow depth at elev > 1096.80 (Just east of Culvert 71)				
<b>See Culverts 78 through 71 Analysis below)</b>																		
<b>Wsel = 1099.5 (See Analysis for Culverts 67 through 78 together below)</b>																		
						1092											**	
						1094	2	0.80	16.00	32								
						1096	4	1.60	38.00	76								
						1098	6	2.40	51.00	102								
						1099	7	2.80	57.00	114								
						1099.5	7.5	3.00	60.00	120	120							
						1100	8	3.20	62.00	124								
							**These flows are doubled because there are two culverts											
71	2-30" CMP	210	0	210	168													
<b>See Culverts 78 through 71 Analysis below)</b>																		
<b>Wsel = 1099.5 (See Analysis for Culverts 67 through 78 together below)</b>																		
						1092											**	
						1094	2	0.80	16.00	32								
						1095	3	1.20	28.00	56								
						1098	6	2.40	51.00	102								
						1099	7	2.80	57.00	114								
						1099.5	7.5	3.00	60.00	120	120							
						1100	8	3.20	62.00	124								
							**These flows are doubled because there are two culverts											
											6012.00							
<b>Hydraulic Analysis for Culverts 78 through 71</b>																		
78	1-30" CMP	111	0	3570	2845													
77 (20)	3-5' x 10' RCB																**	
76	2-36" CMP	529				1091												
75	1-30" CMP	19				1092												
74	1-30" CMP					1094.1												
73	2-30" CMP	2645				1096	4	1.60		657.8								
72	2-30" CMP	56				1096.8	4.8	1.92		907.3								
71	2-30" CMP	210					**These flows are added for Culverts 78 to 71, see spreadsheet in Analysis Sheets											
The Hydraulic Calculations at EL > 1096.8 (Which is now a submerged Dyke) is shown below																		
67 and 68	1-36" CMP		0	3802	3029												**	
69 and 70	42" CMP and 2-8' x 10' RCB		1370			1097	5	2.00		3167			0.13	51.00	0.19	76.75	3244	
78 to 71			2431			1098	6	2.40		3672			0.80	306.00	1.00	1603.27	5275	
						1099	7	2.80		4172			1.47	561.00	1.72	5184.83	9357	
<b>Wsel=1098 (This Wsel is for Culverts 67 through 78)</b>																		
The following two culverts 79 to 81) are on a (-) Slope, flowing towards Culvert 81																		
79	3-30" CMP	27	0	27	22													
						1101											**	
						1103	2	0.80		48							48	
						1103.5	2.5	1.00		66							66	
						1104	3	1.20		84							84	
<b>Wsel = 1103.5 (See Analysis for Culverts 79, 80, and 81 together below)</b>																		
							**These flows are tripled because											



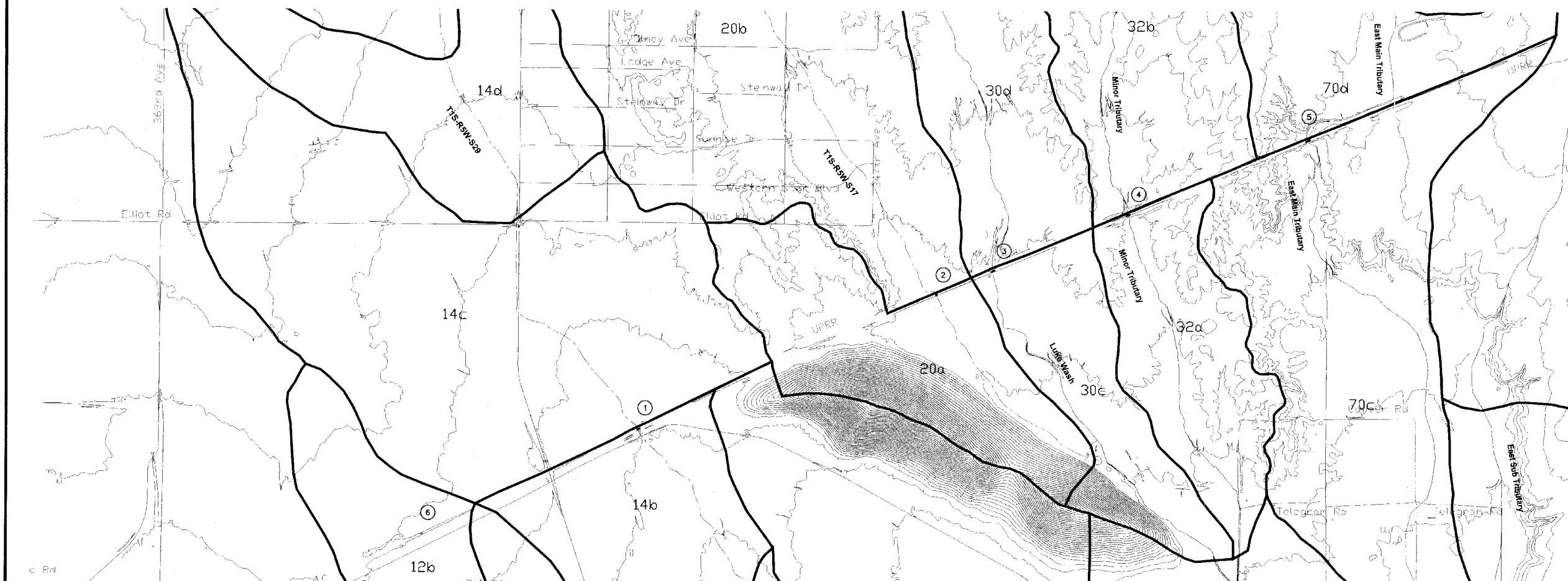
Culvert ID	Culvert Type	Contributing Area from the north (acres)	Contributing Area from the west (acres)	Total Area Contributing to Culvert (acres)	Target Flow (cfs)	Elevation (ft)	Culvert Flow			Manning's Equation for flow along highway			Weir Flow over obstruction				Q-total (cfs)	
							HW (ft)	Chart 2 or 8 HW/D	Chart 8 Q/B (cfs/ft)	Q-culvert (cfs)	Cross Section Area (s.ft)	Wetted Perimeter (ft)	Normal Depth Q (cfs)	Avg. height HW (ft)	Length (L2) (ft)	Weighted Avg Head (H) (ft)		Q-east (cfs)
						1103	3	1.50		20							20	
88 (23A)	5-5' x 10' RCB	2570	0	2560	2040		Bottom Width (ft)		10.00				Length (L) of berm (ft)		125.00			
						1096.5							weir flow depth at elev >		1100.30			
						1098	1.5	0.30	5.50	275			side slope (right) [Z:1]		202.00		275	
						1099	2.5	0.50	12.00	600							600	
						1100	3.5	0.70	19.50	975							975	
						1100.3	3.8	0.76	22.00	1100							1100	
						1100.4	3.9	0.78	22.50	1125			0.07	20.20	0.10	11.55	1137	
						1100.5	4	0.80	23.70	1185			0.13	40.40	0.18	35.17	1220	
						1101	4.5	0.90	28.00	1400			0.47	141.40	0.58	314.56	1715	
						1102	5.5	1.10	36.50	1825			1.13	343.40	1.28	1841.24	3666	
						1103.5	7	1.40	48.00	2400								
						1105	8.5	1.70	58.00	2900								
							**These flows are multiplied by 5 because there are five box culverts											
89	3-36" CMP	167	270	436	348							normal depth at elev >	1095.5					
						1095												
						1097	2	0.67									0	
						1098	3	1.00									0	
						1099	4	1.33										
						1100	5	1.67										
							The following culverts 90 to 91) are on a (+) Slope, flowing towards Culvert 90											
													weir flow depth at elev >	1103.90				
91 (24)	1-6' x 10' RCB	245	0	245	195		Bottom Width (ft)		10.00									
						1097.3												
						1100	2.7	0.45	13.00	130							130	
						1101	3.7	0.62	21.00	210							210	
						1102	4.7	0.78	30.00	300							300	
						1103.3	6	1.00	43.00	430							430	
90	1-36" CMP	41	0	213	170							bottom slope	0.001					
												side slope (right) [Z:1]	205.000					
89	3-36" CMP	167	270									side slope (left) [Z:1]	6.000					
												bottom width (ft)	0.00					
												normal depth at elev >	1095.5					
						1094												
						1096	2	0.67		74		26.38	105.54	7.58			82	
						1096.5	2.5	0.83		104		105.50	211.09	48.15			152	
						1097	3	1.00		140		237.38	316.63	141.99			282	
						1098	4	1.33		200		659.38	527.71	554.53			755	
							**These flows are multiplied by 4 because there are four identical culverts											



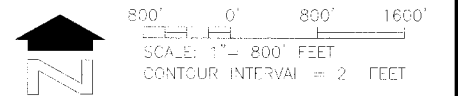
**APPENDIX TM3-10-2**  
**EXISTING DRAINAGE STRUCTURE DOCUMENTATION**  
**I-10 CULVERTS (LUKE WASH WATERSHED)**



I-10 Culverts



UPRR Bridges



FLOOD CONTROL DISTRICT  
OF MARICOPA COUNTY

LUKE WASH WATERSHED FDS  
CROSSING STRUCTURE LOCATIONS  
FOR NO DIKE CONDITIONS  
FCD 2007C020  
JULY 2008

**WOOD/PATEL**  
LAND DEVELOPMENT • WATER RESOURCES  
TRANSPORTATION / TRAFFIC  
WATER / WASTEWATER • SURVEYING  
CONSTRUCTION MANAGEMENT  
(602) 335-8500

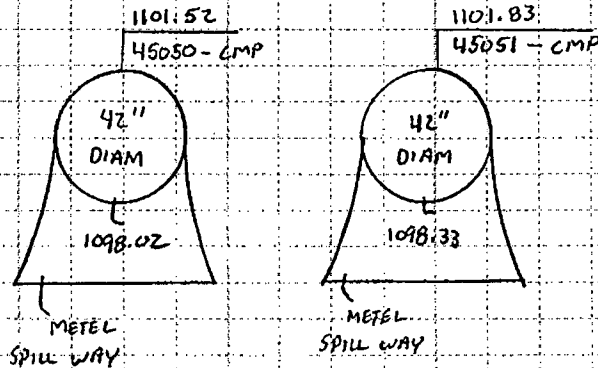
EXHIBIT  
D4.2b

Type of Structure: CMP 2-42" Date: 1-29-2008

File Name: LUKE WASH

Description Name: I-10 STA. 5266 +50 Party Chief: JEFF LAWLER

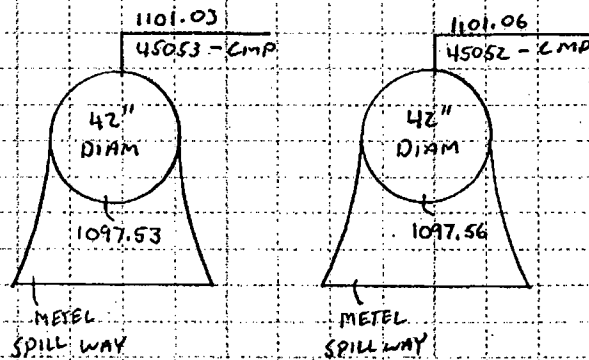
Photo Taken (UPSTREAM) NORTH



SPILLWAYS ARE 6' FROM INVERT TO END OF SPILLWAY

General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



SPILLWAYS ARE 6' FROM INVERT TO END OF SPILLWAY

General Condition of Structure GOOD

ID 12

FCDMC Contract 2007C020

Task - Luke Wash Watershed Zone AE Floodplain Delineation Study

Structure Detail Worksheet

Wood/Patel Project #073087

Type of Structure: CMP 2-36"

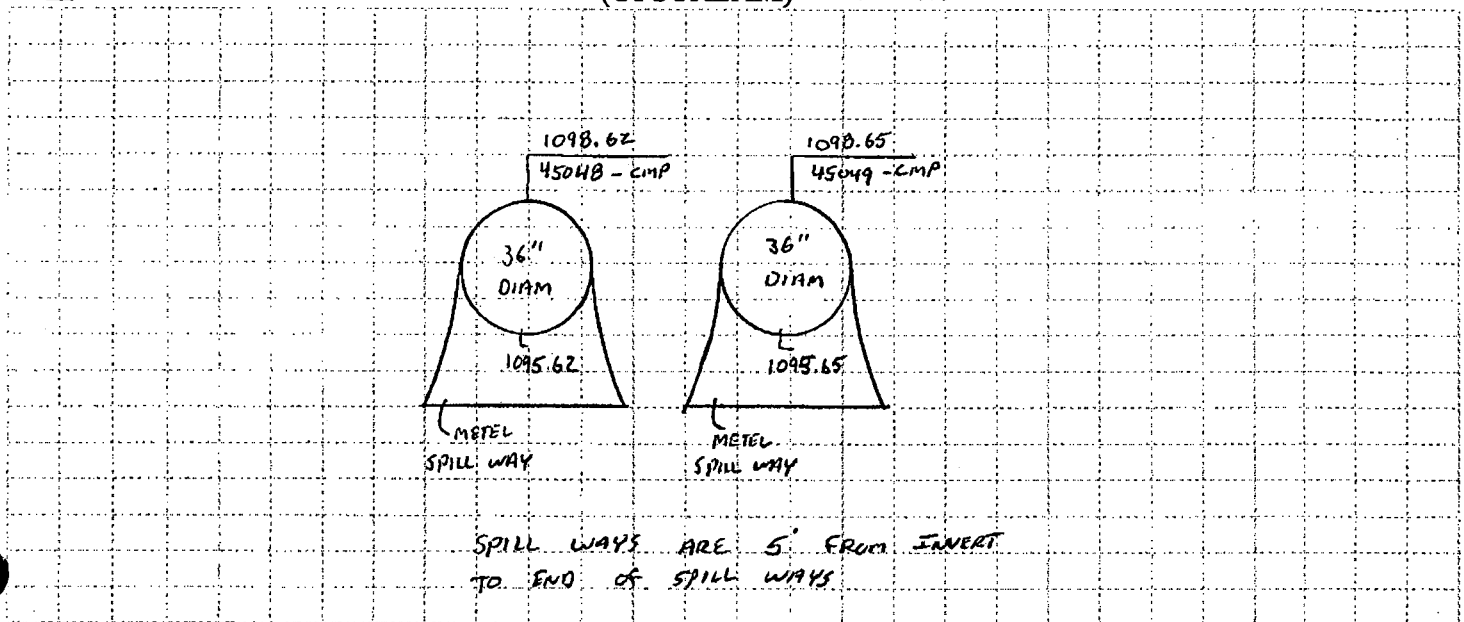
Date: 1-29-2008

File Name: LUKE WASH

Description Name: F-10 STA. 5270+50

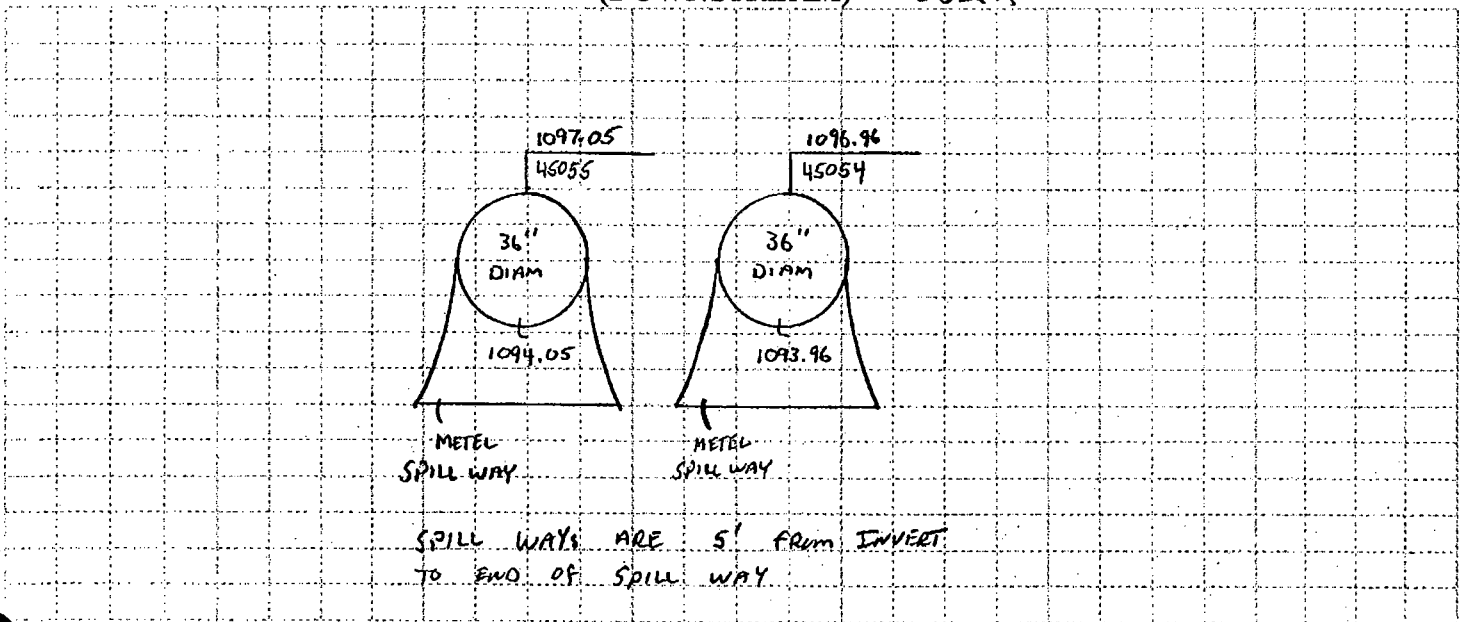
Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) NORTH



General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure GOOD

E2-1

ID 14

FCDMC Contract 2007C020

Task - Luke Wash Watershed Zone AE Floodplain Delineation Study

Structure Detail Worksheet

Wood/Patel Project #073087

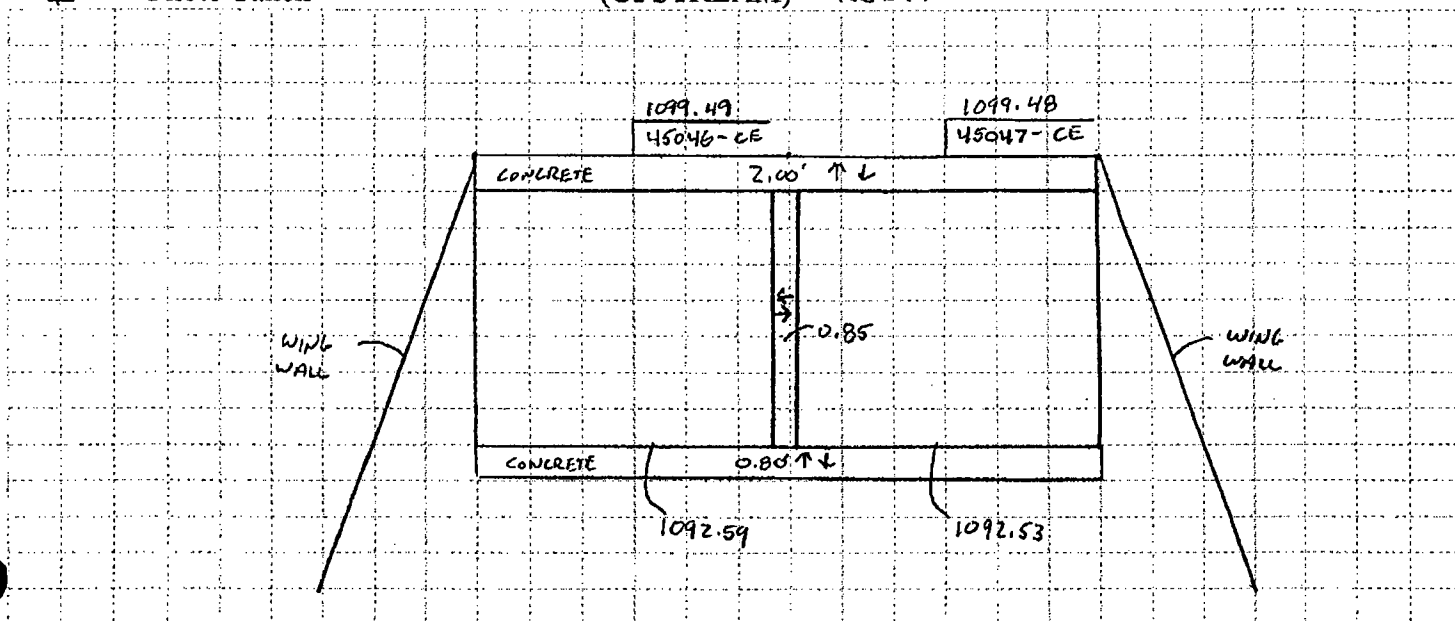
Type of Structure: BOX CULVERT 2-10'x5' Date: 1-29-2008

File Name: LUKE WASH

5286 + 25

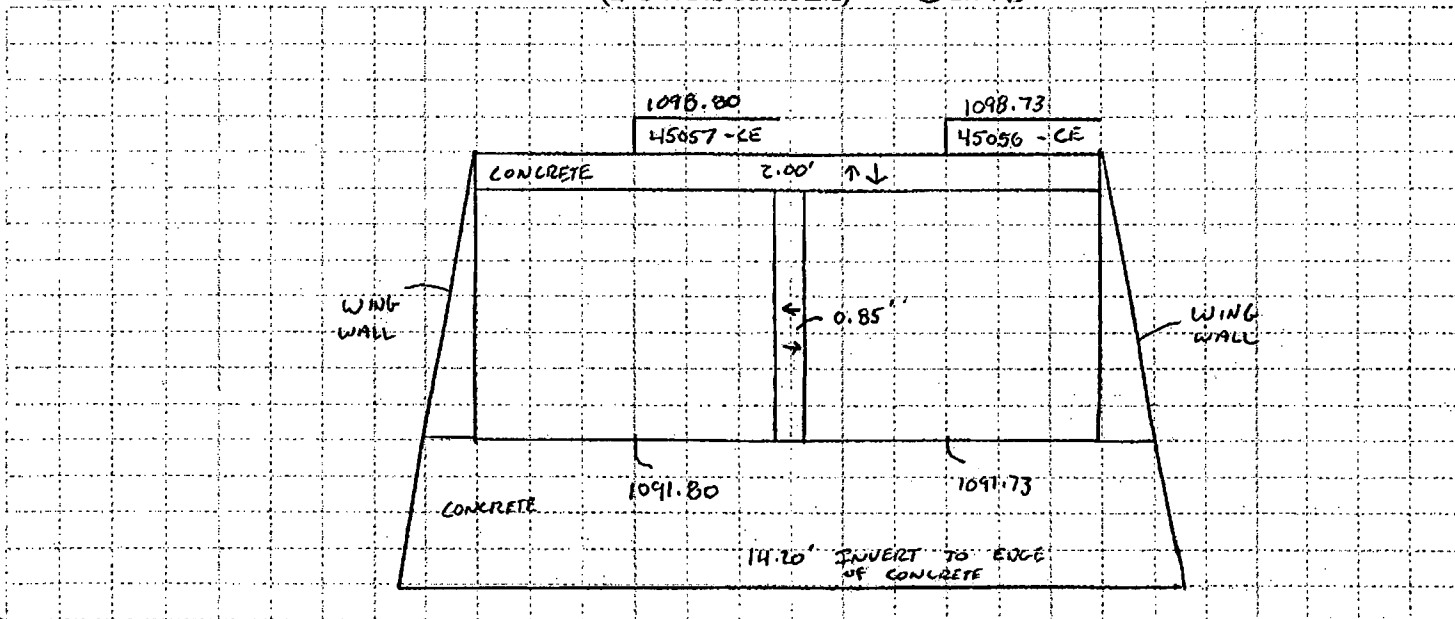
Description Name: I-10 STA. 5286 + 25 Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) NORTH



General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure GOOD

E2-3

Type of Structure: CMP 3-36"

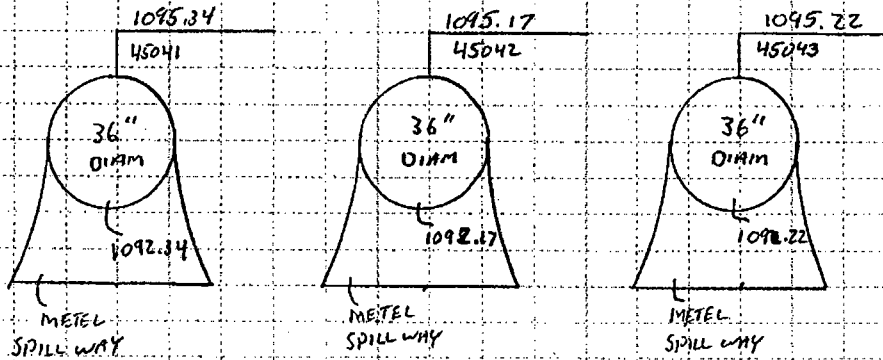
Date: 1-29-2008

File Name: LUKE WASH

Description Name: I-10 STA. 5316+10

Party Chief: JEFF LALLIER

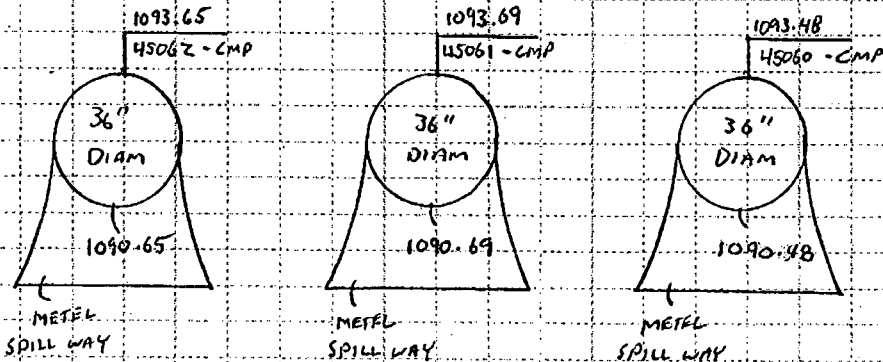
Photo Taken (UPSTREAM) NORTH



ALL SPILL WAYS ARE 5' FROM INVERT TO END SPILL WAY.

General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



ALL SPILL WAYS ARE 5' FROM INVERT TO END SPILL WAY.

General Condition of Structure GOOD

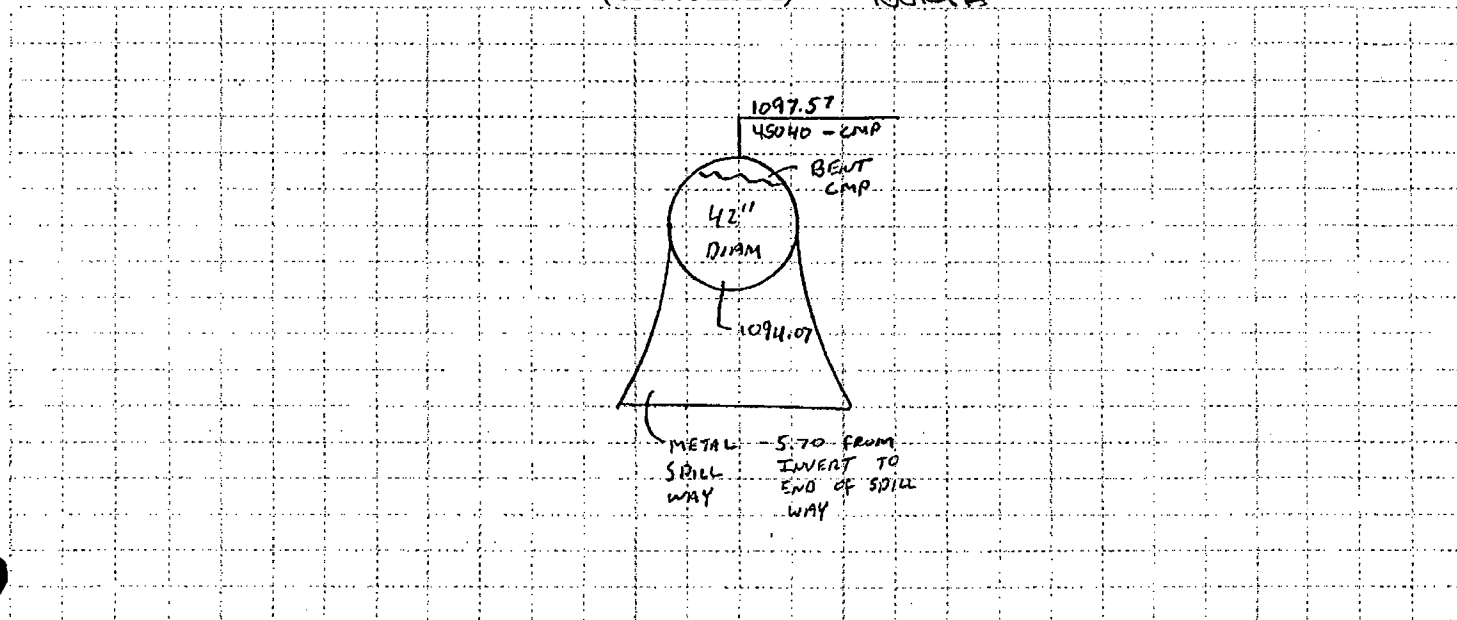
FCDMC Contract 2007C020  
Task - Luke Wash Watershed Zone AE Floodplain Delineation Study  
Structure Detail Worksheet  
Wood/Patel Project #073087

Type of Structure: CMP 42" Date: 1-29-2008

File Name: LUKE WASH

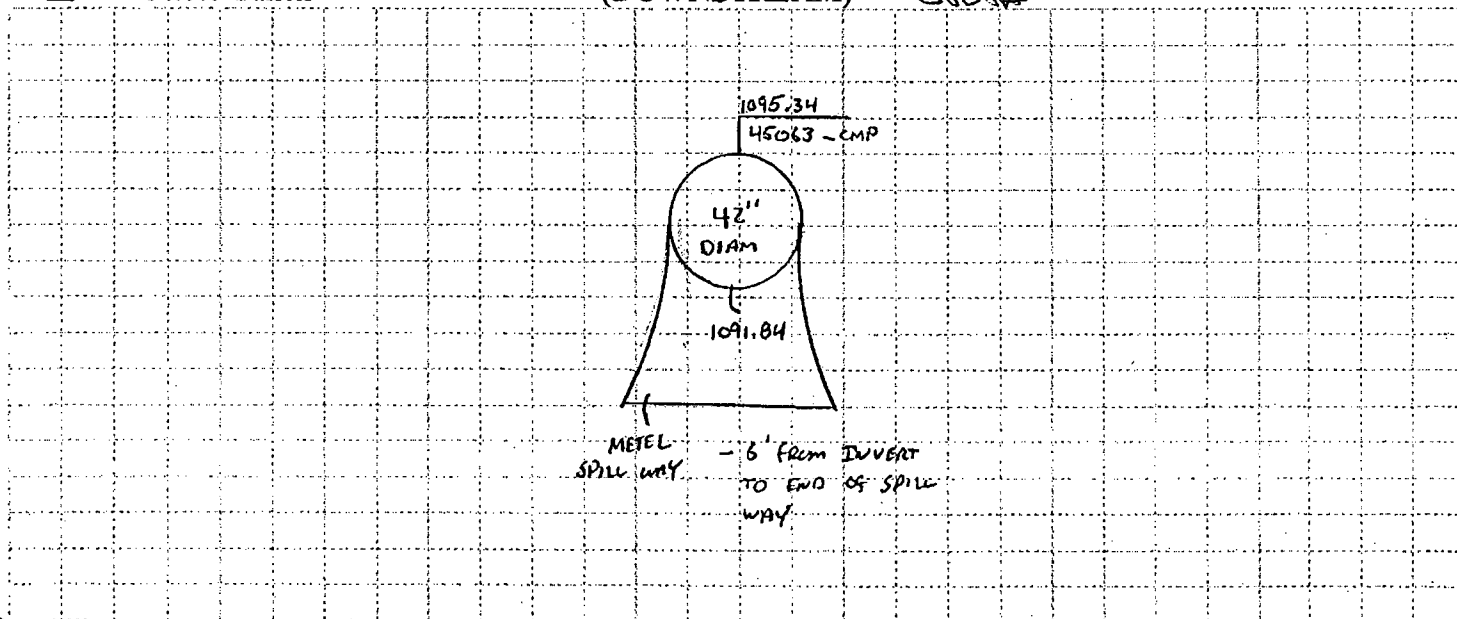
Description Name: F-10 STA. 5319+20 Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) NORSTA



General Condition of Structure TOP OF CMP BENT

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure \_\_\_\_\_

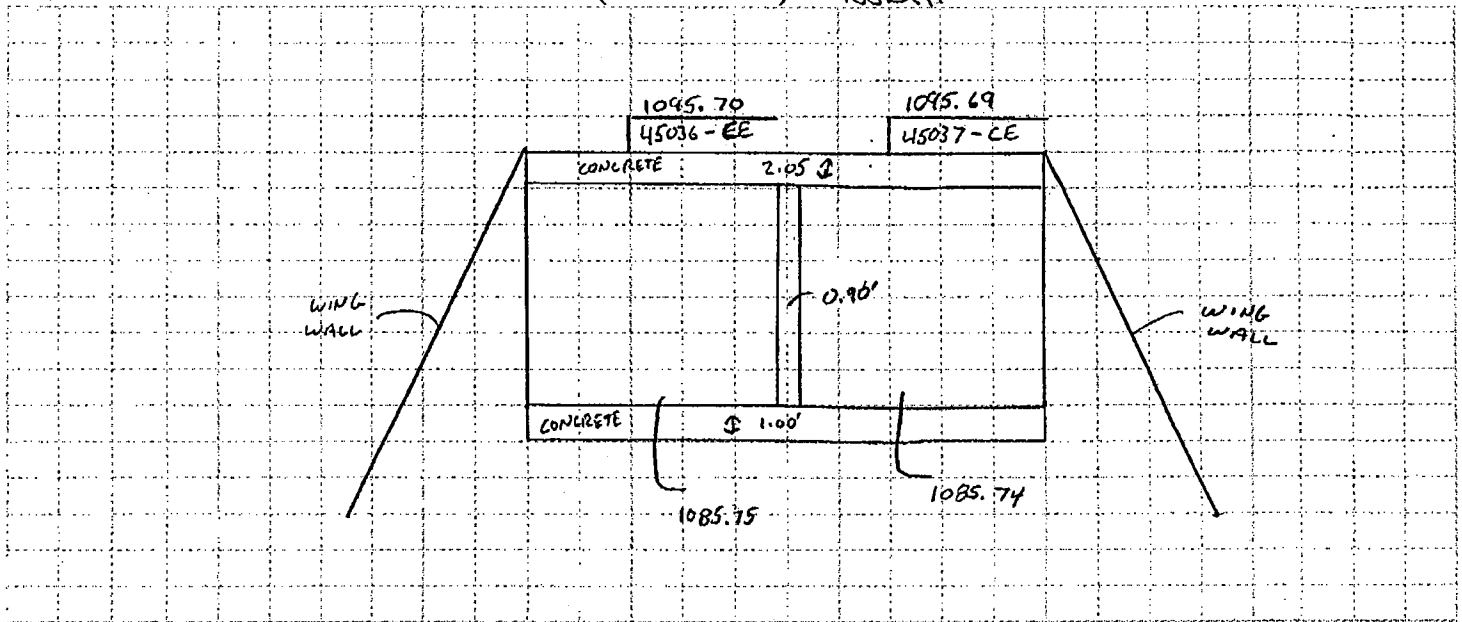
Type of Structure: Box CULVERT 2-10'x8' Date: 1-29-2008

File Name: LUKE WASH

5345-52

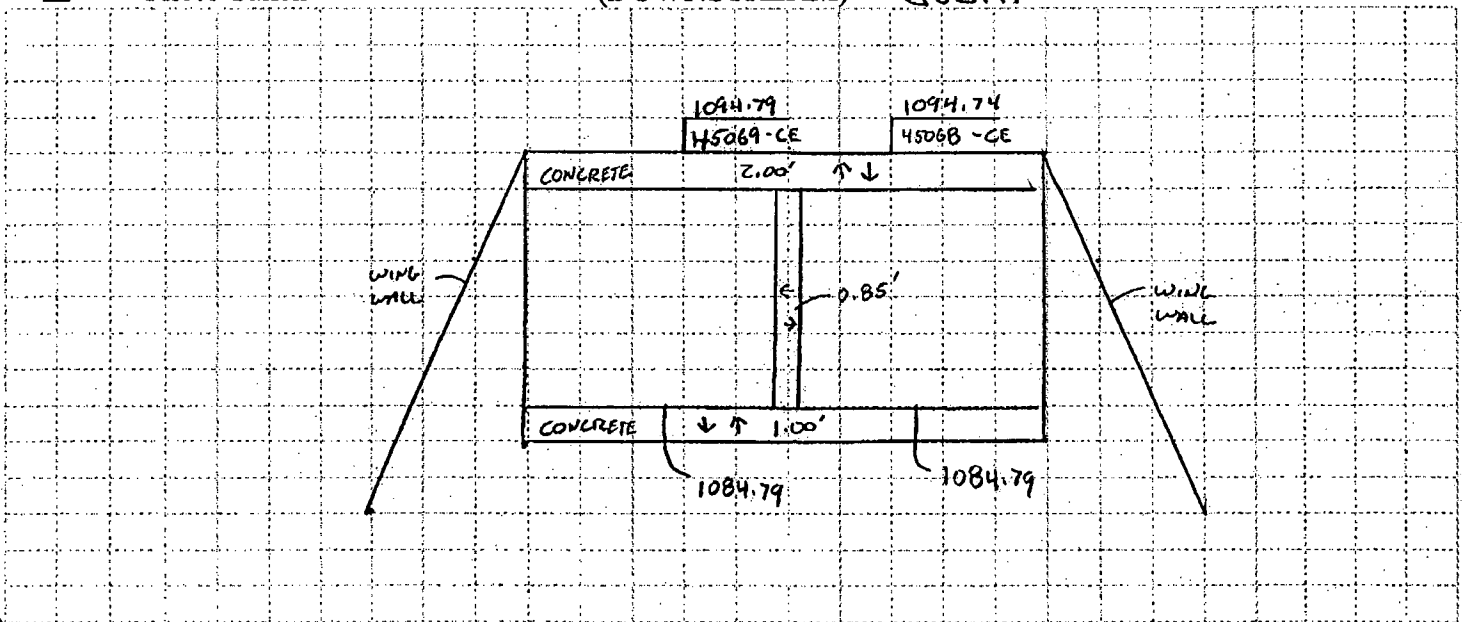
Description Name: I-10 STA. 5345+52 Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) NORTH



General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure GOOD

ID 28

FCDMC Contract 2007C020

Task - Luke Wash Watershed Zone AE Floodplain Delineation Study

Structure Detail Worksheet

Wood/Patel Project #073087

Type of Structure: 48" CMP

Date: 1-22-2008

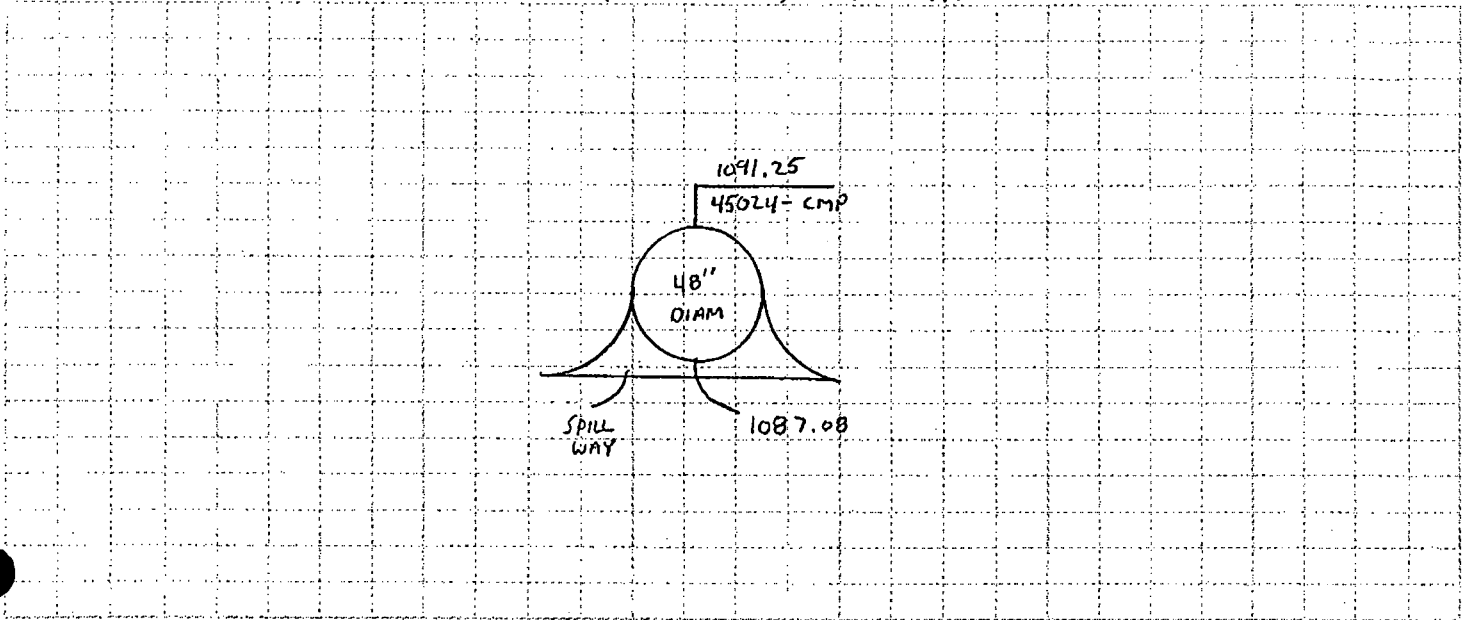
File Name: LUKE WASH

5349+50

Description Name: I-10 STA. 5349+50

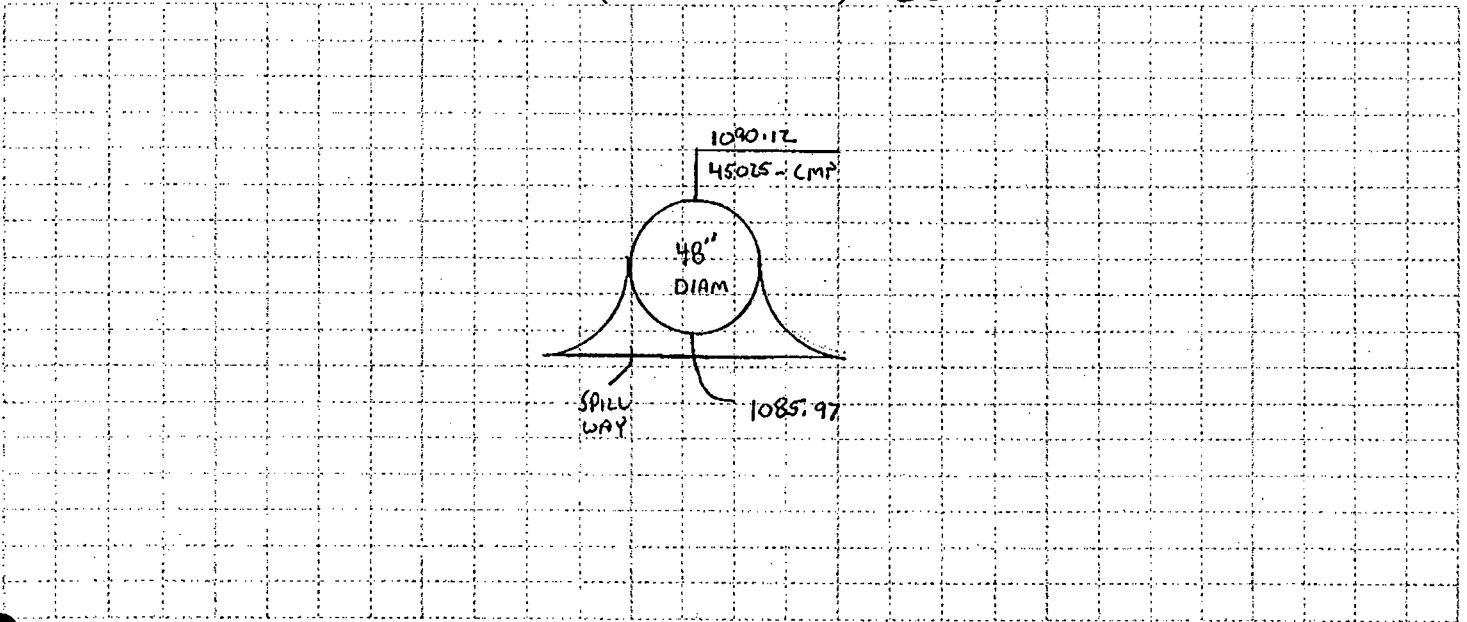
Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) NORTH



General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure GOOD

E2-7

I D 30

FCDMC Contract 2007C020

Task - Luke Wash Watershed Zone AE Floodplain Delineation Study

Structure Detail Worksheet

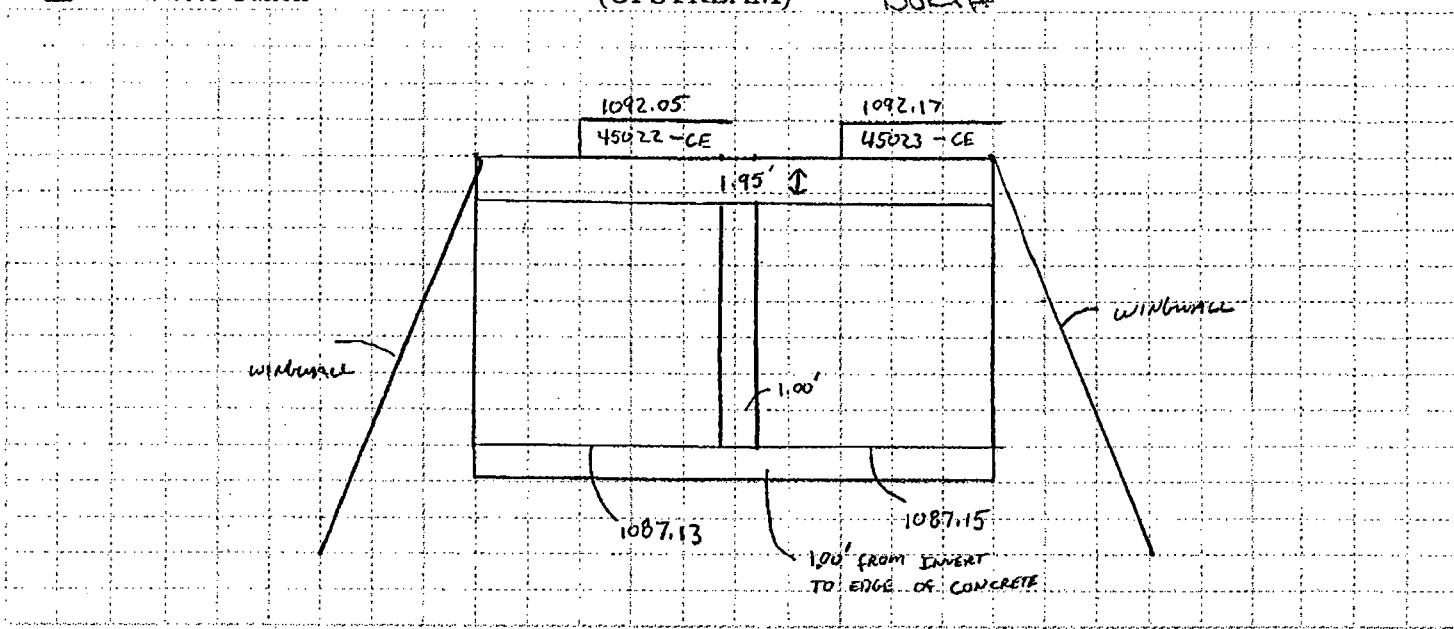
Wood/Patel Project #073087

Type of Structure: Box CULVERT 2-10'x3' Date: 1-22-2008

File Name: LUKE WASH

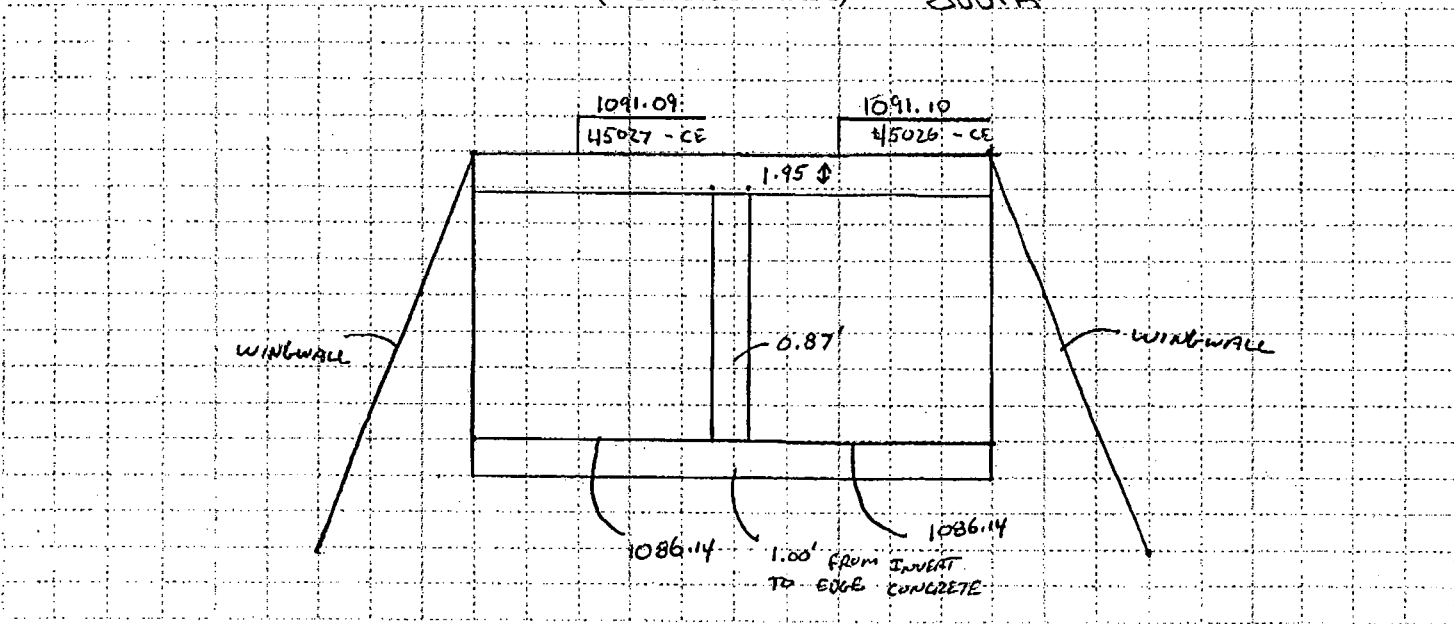
Description Name: I-10 STA. 5353+40 Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) 100ENT



General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure GOOD

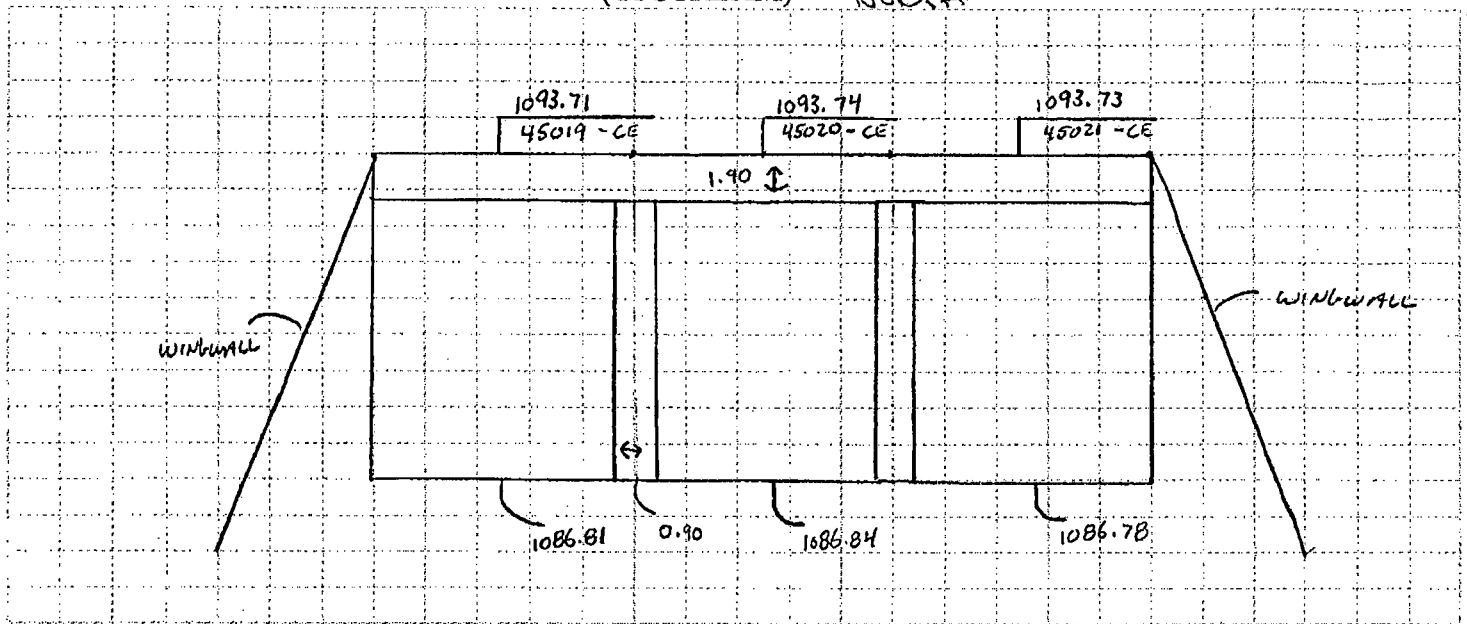
E2-8

Type of Structure: BOX CULVERT 3 - 10' x 5' Date: 1-22-2008

File Name: LUKE WASH

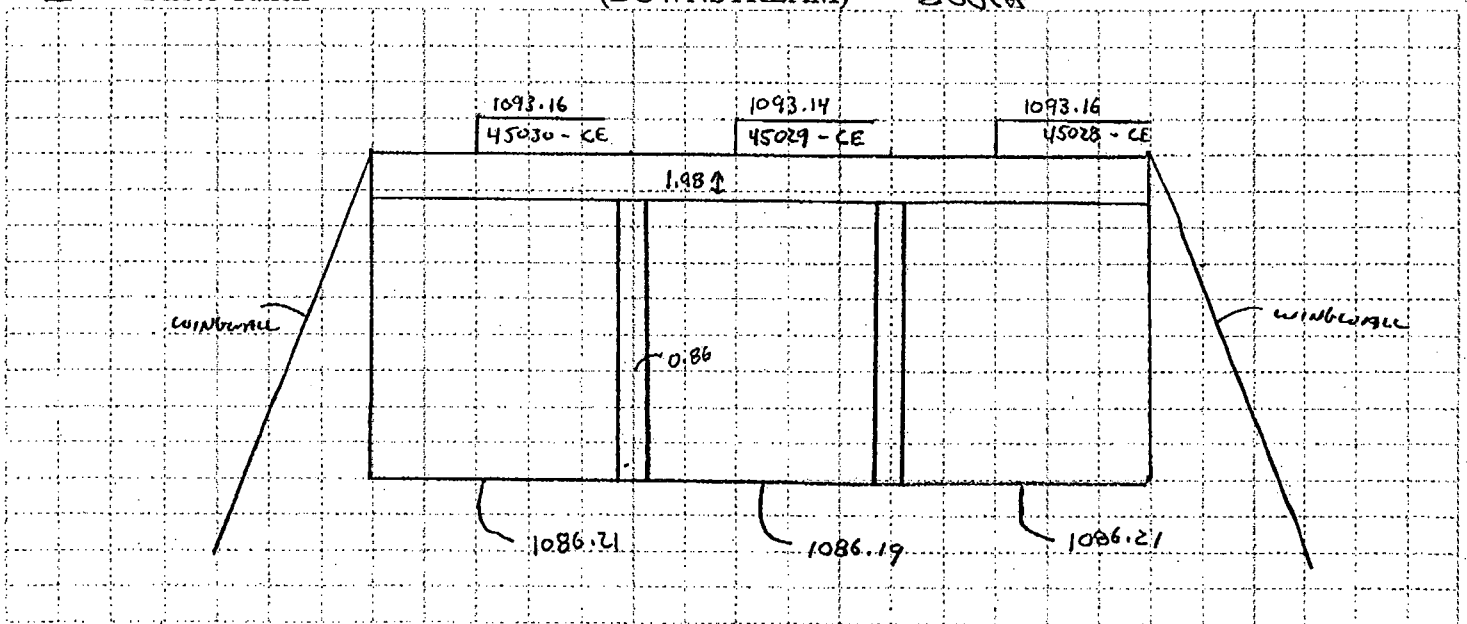
Description Name: I-10 STA. 5360+50 Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) NORTH



General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure GOOD

ID 36

FCDMC Contract 2007C020

Task - Luke Wash Watershed Zone AE Floodplain Delineation Study

Structure Detail Worksheet

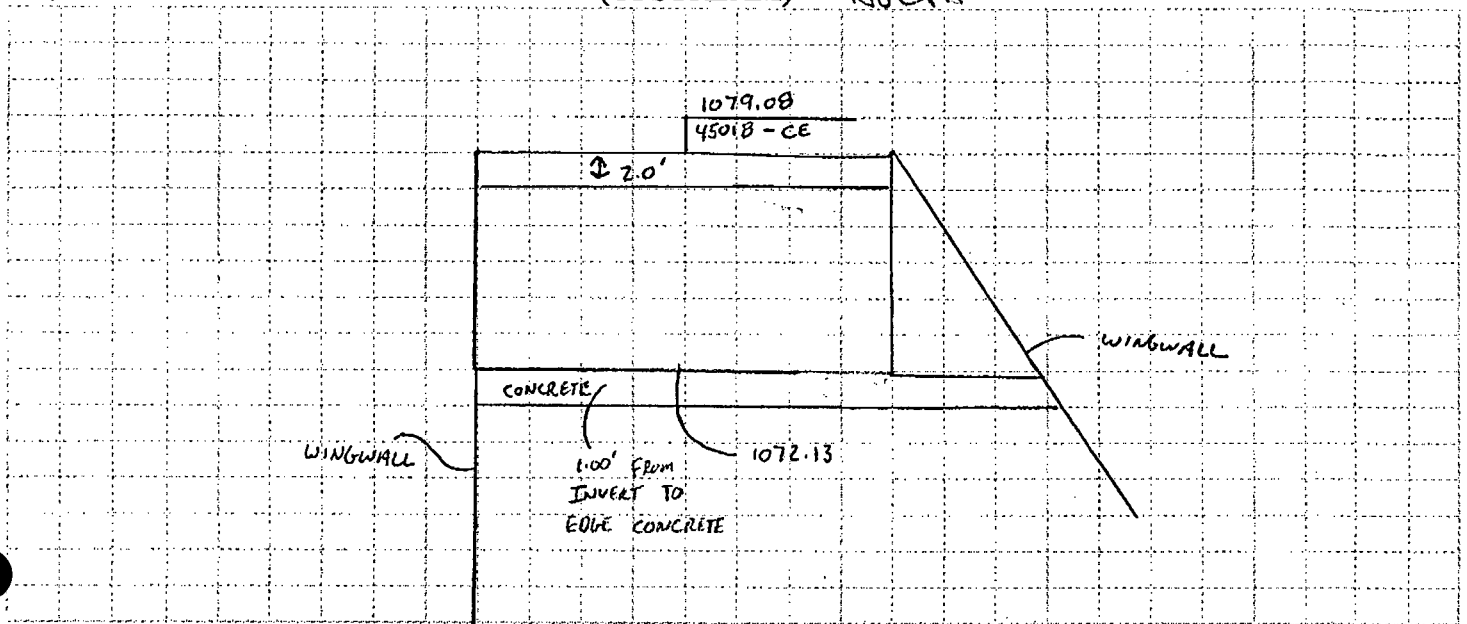
Wood/Patel Project #073087

Type of Structure: Box CULVERT 10' x 5' Date: 1-22-2008

File Name: LUKE WASH

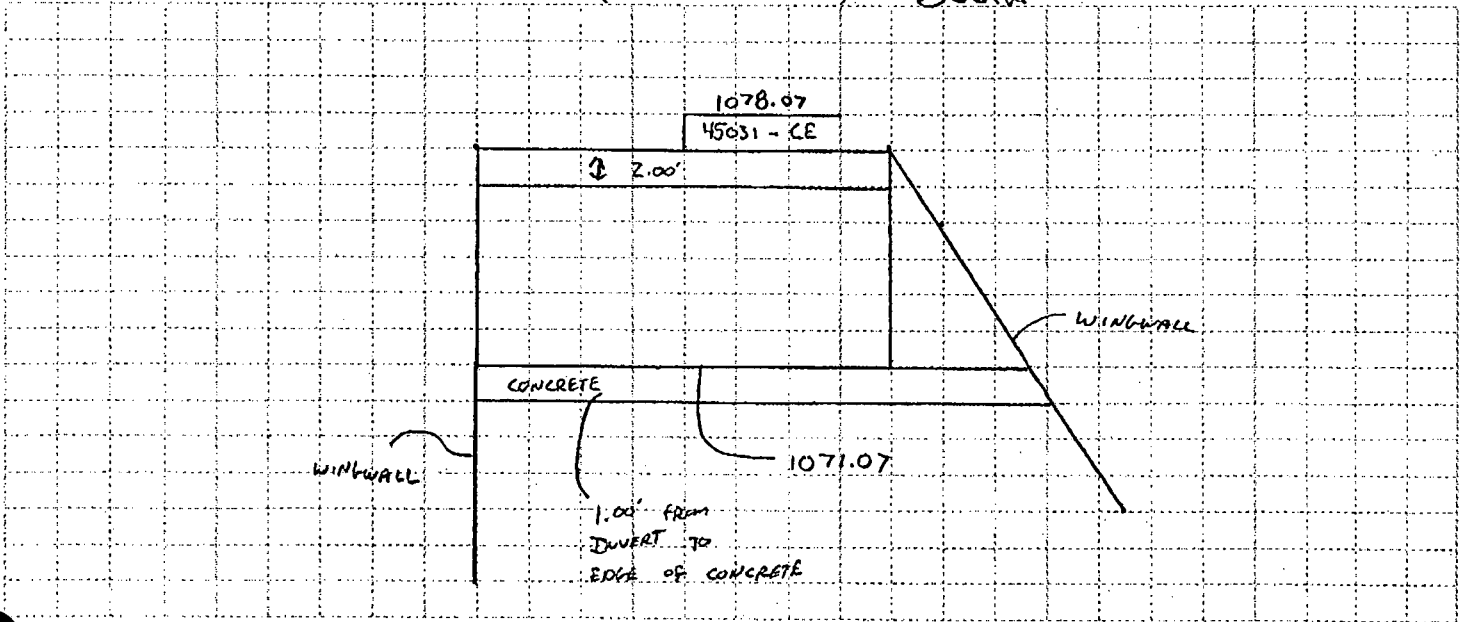
Description Name: I-10 STA. 5402+36 Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) NORTH



General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure GOOD

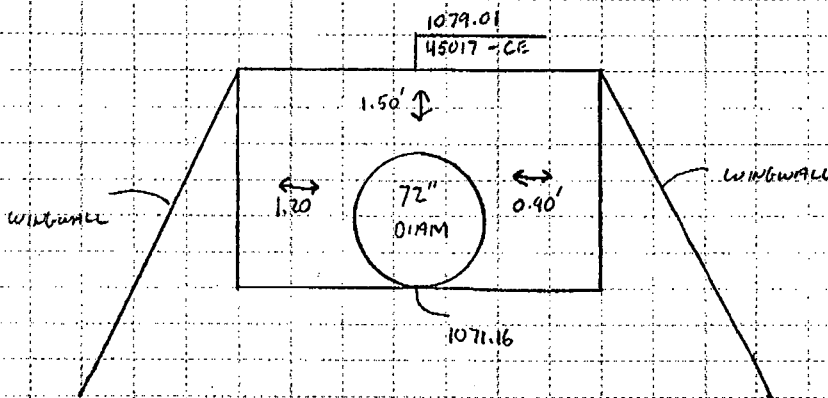
E2-1

Type of Structure: 72" CMP Date: 1-22-2008

File Name: LUKE WASH

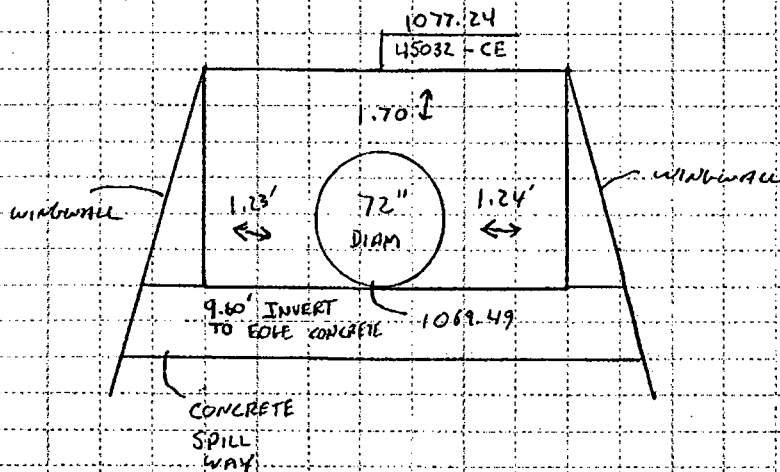
Description Name: I-10 STA. 5405+30 Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) NORTH



General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure GOOD

ID 50

FCDMC Contract 2007C020

Task - Luke Wash Watershed Zone AE Floodplain Delineation Study

Structure Detail Worksheet

Wood/Patel Project #073087

Type of Structure: 48" CMP

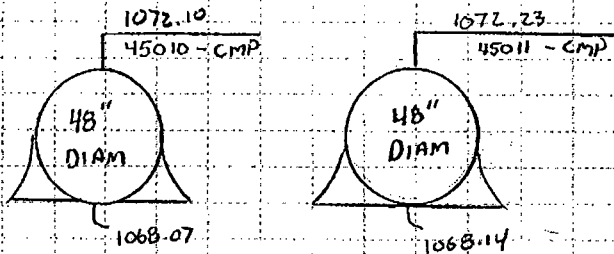
Date: 1-21-2008

File Name: LUKE WASH

Description Name: I-10 STA. 5470 + 80

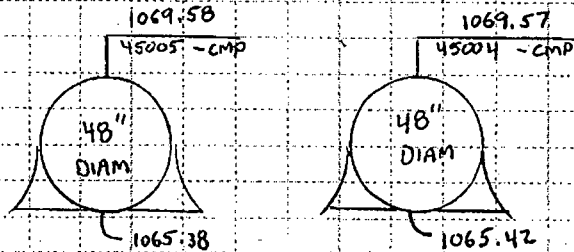
Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) UPSTREAM



General Condition of Structure GOOD

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure GOOD

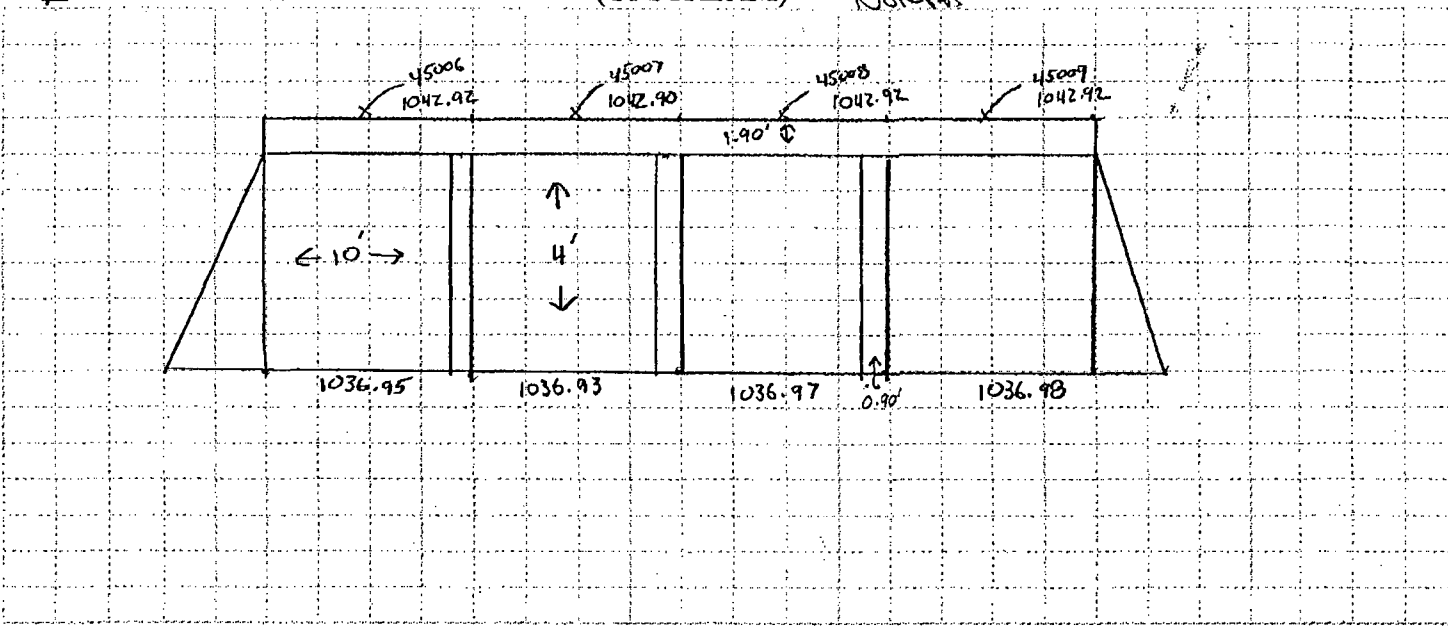
E2-15

Type of Structure: BOX CULVERT Date: 1-21-2008

File Name: LUKE WASH

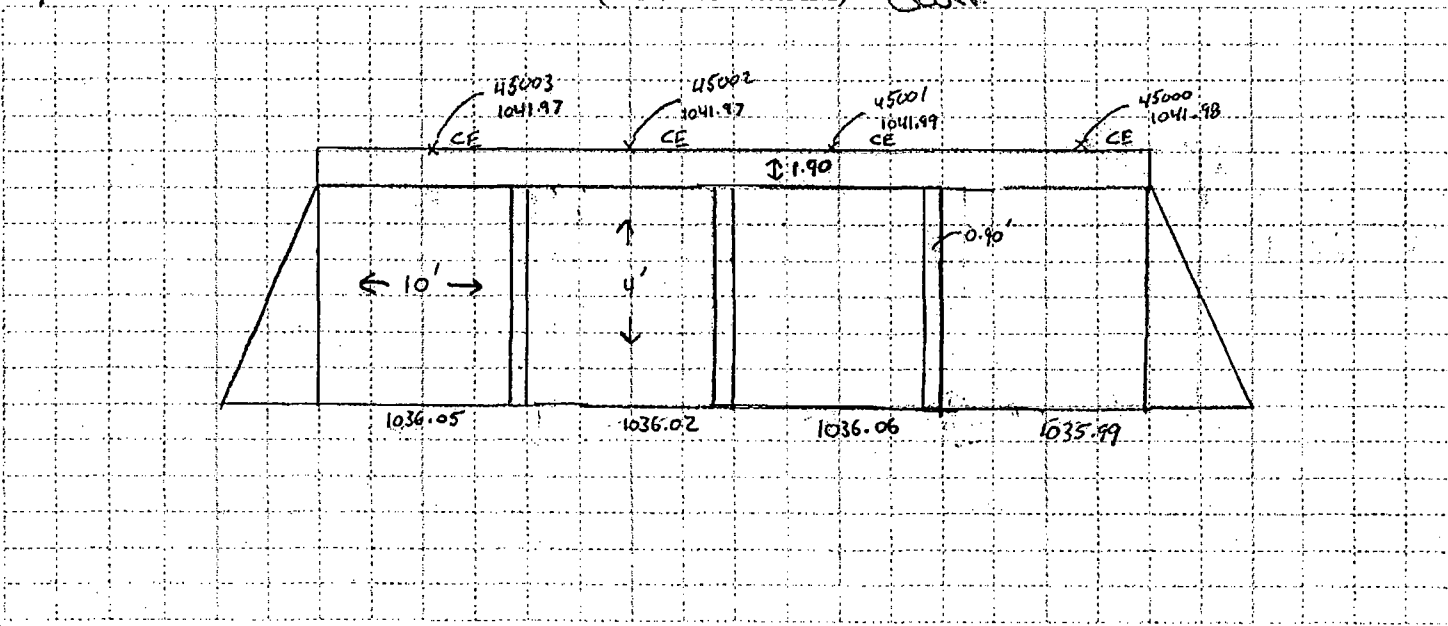
Description Name: T-10 STA. 5504 +40 Party Chief: JEFF LALLIER

Photo Taken (UPSTREAM) NORTH



General Condition of Structure Good

Photo Taken (DOWNSTREAM) SOUTH



General Condition of Structure Good

**APPENDIX TM3-10-3**  
**EXISTING DRAINAGE STRUCTURE DOCUMENTATION**  
**BUCKEYE FRS #1**

# Flood Control District of Maricopa County

## Emergency Action Plan

For the

## Buckeye Structures

Rev. June 2007



Prepared by: JE Fuller/ Hydrology & Geomorphology, Inc.  
Revised by: LTM Engineering, Inc. 6/30/2007

Exhibit A-3 - Emergency Spillway & Dambreak Inundation Areas – FRS #1  
 West (lower crest) End of FRS #1

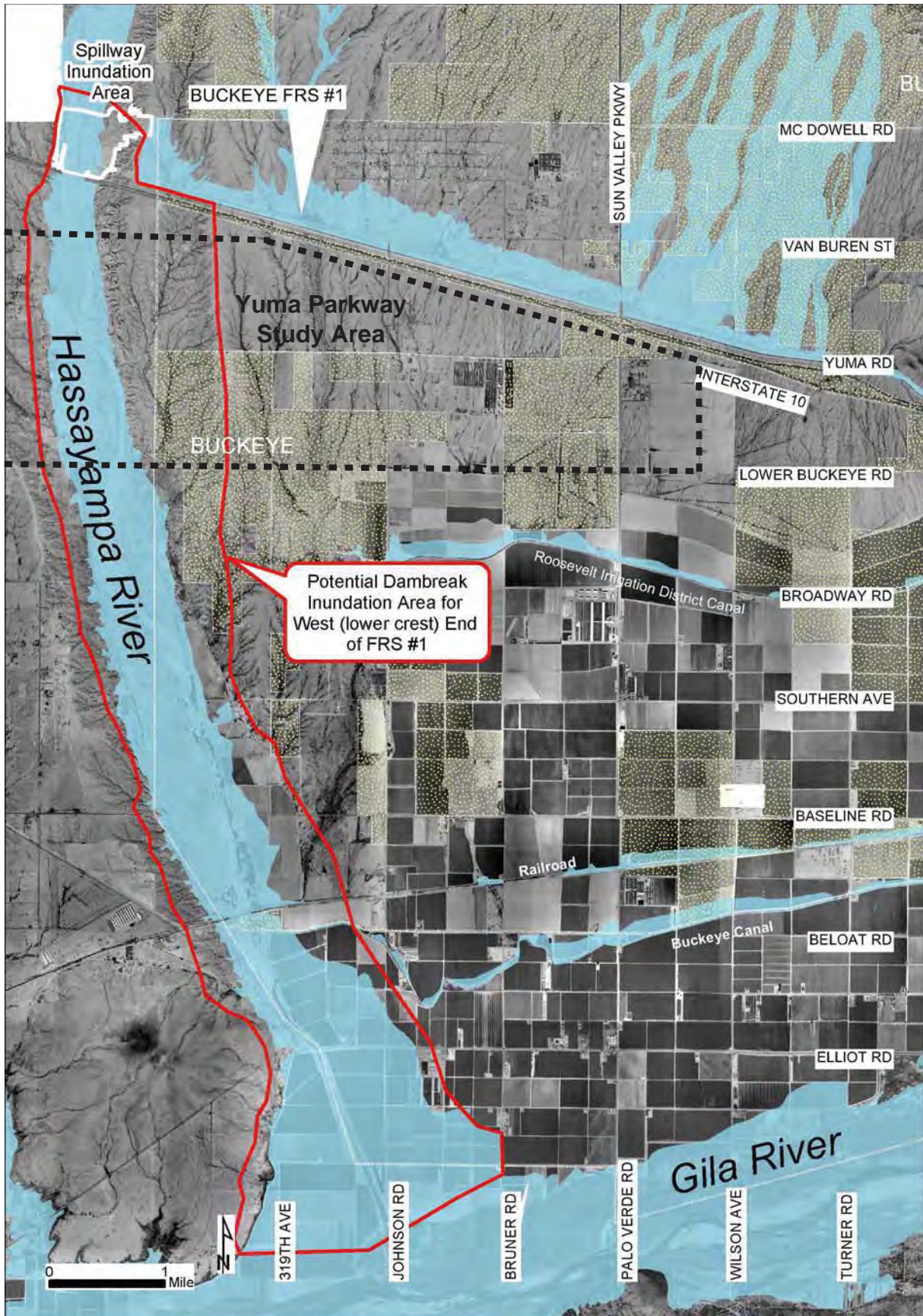


Exhibit A-4 - Emergency Spillway & Dambreak Inundation Areas – FRS #1  
Between West End and Johnson Road

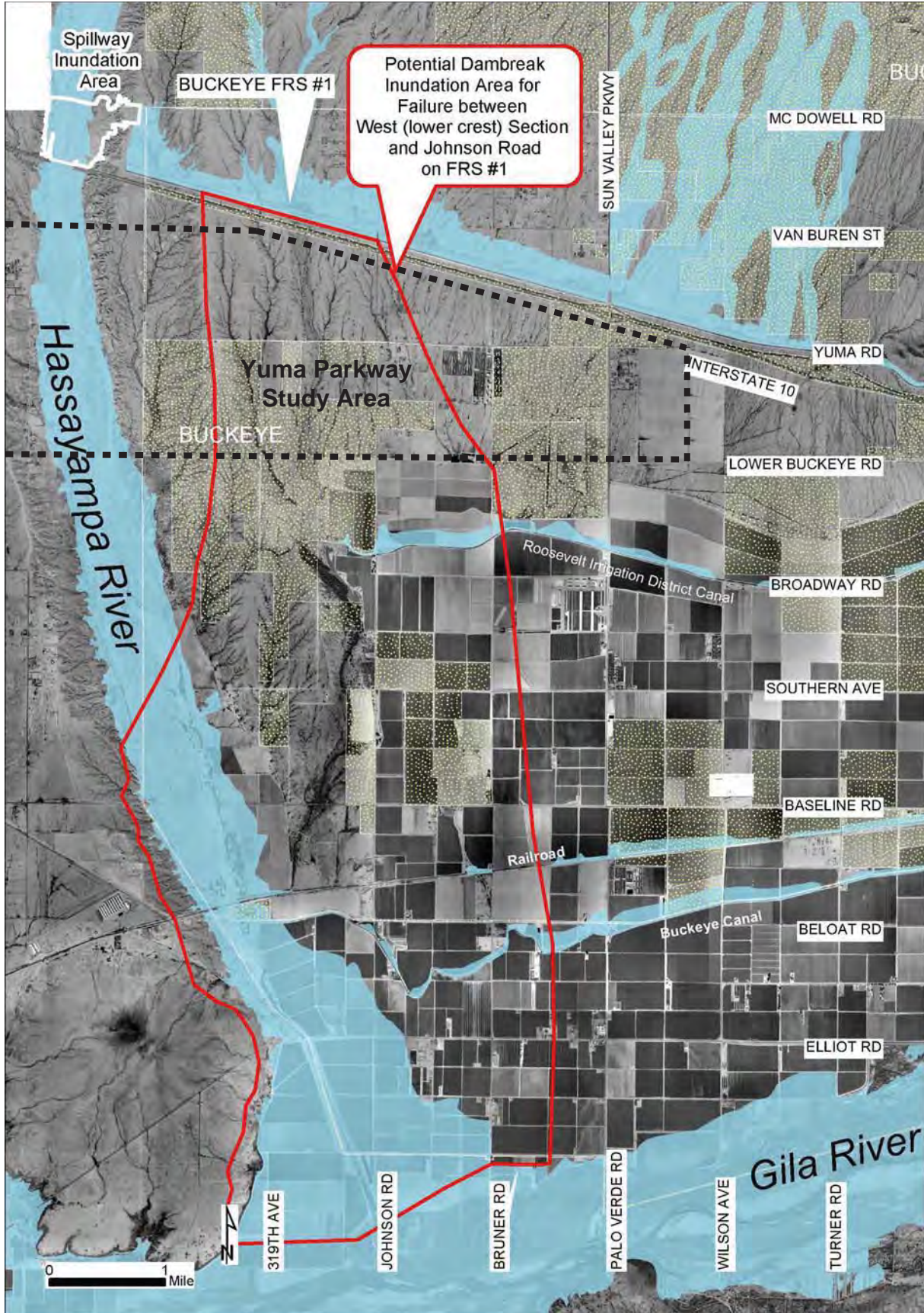


Exhibit A-5 - Emergency Spillway & Dambreak Inundation Areas – FRS #1  
Between Johnson Road and Sun Valley Parkway

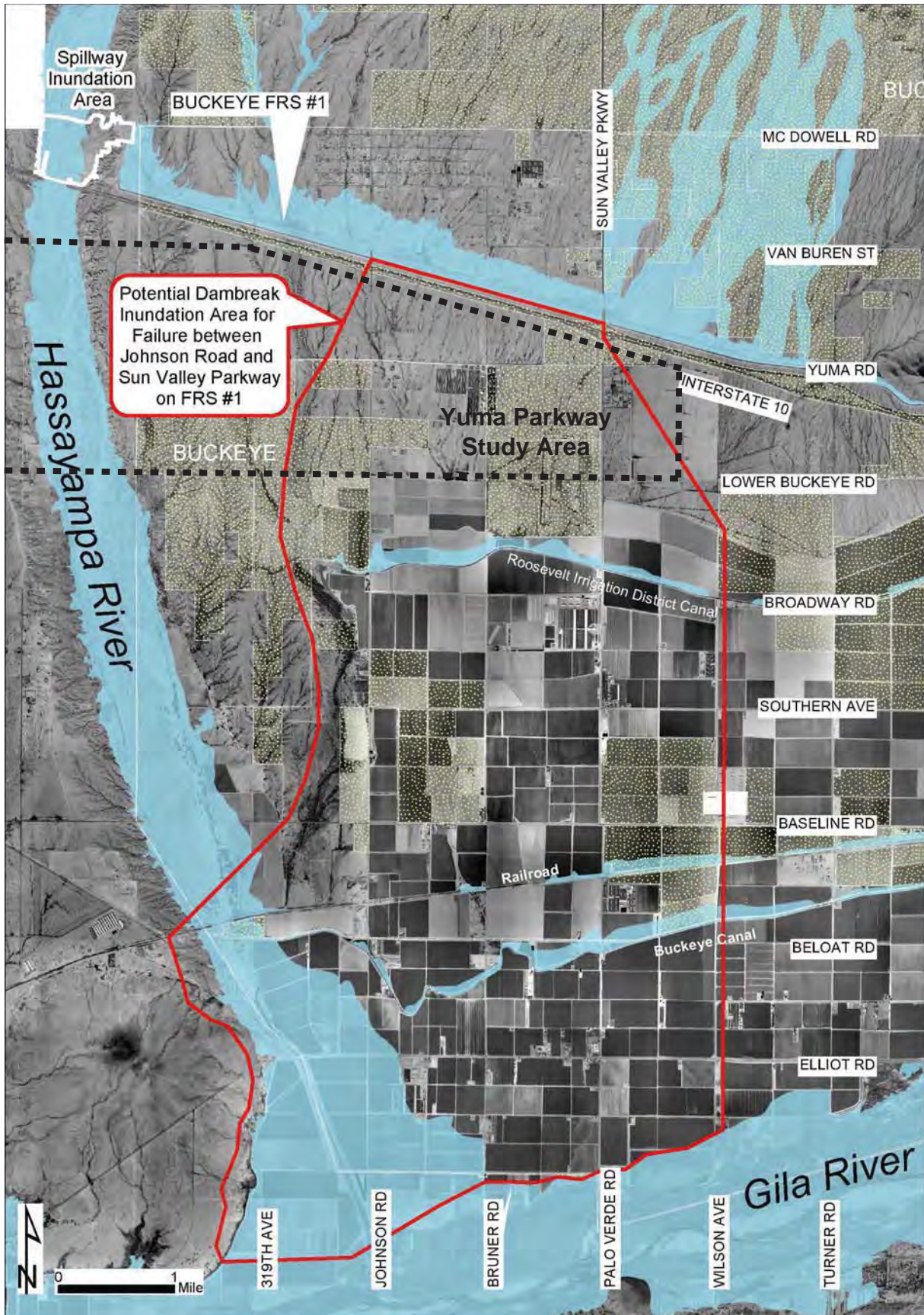
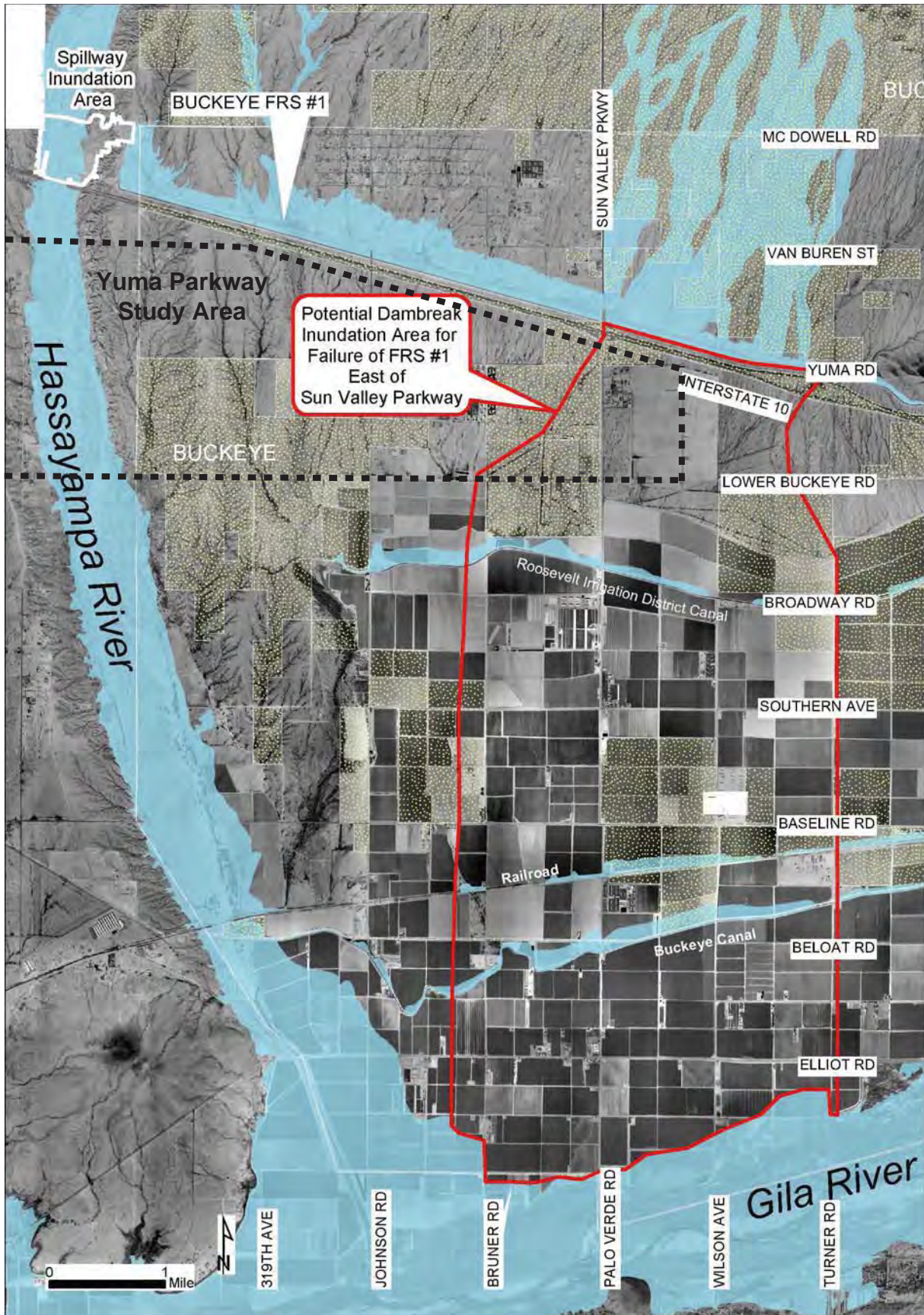


Exhibit A-6 - Emergency Spillway & Dambreak Inundation Areas – FRS #1  
East of Sun Valley Parkway



Tables - Emergency Spillway & Dambreak Inundation Hydraulics – FRS #1

Emergency Spillway Discharges			
LOCATION	DEPTH (Feet)	VELOCITY (Feet/Second)	TIME (Hours)
<u>Full Emergency Spillway Discharge (50,700 cfs)</u>			
Below FRS	6-10	10-15	-
I-10	6-10	10-15	< 0.25
<u>2/3 Emergency Spillway Discharge (33,800 cfs)</u>			
Below FRS	5-7	10-13	-
I-10	5-7	10-13	< 0.25
<u>1/3 Emergency Spillway Discharge (16,900 cfs)</u>			
Below FRS	4-6	6-10	-
I-10	4-6	6-10	< 0.25

Dam Failure			
LOCATION	DEPTH (Feet)	VELOCITY (Feet/Second)	TIME (Hours)
Below FRS	20-25	4-12	--
I-10	10-15	4-12	< .25
Lower Buckeye Road	4-5	4-9	.25-.5
Broadway Road	3-4	4-7	.5-75
Baseline Road	2-3	4-8	.75-1.5
Gila River	2-3	2-5	1.5-2



**APPENDIX TM3-11-1**  
**EXISTING HYDROLOGY RESULTS**  
**EXCERPTS FROM PALO VERDE FDS**

*Without Levee Concentration Point Controlling Storm Duration*

<b>Concentration Point</b>	<b>Drainage Area (sq mi)</b>	<b>Peak Flow (cfs)</b>	<b>Controlling Storm Duration</b>
C760GL	2.34	348	6-Hour
C760H	3.33	402	24-Hour
C760I	60.30	3312	24-Hour
C760K	60.76	3312	24-Hour
C760KL	0.46	362	6-Hour
C760L	64.08	3358	24-Hour
C760LL	61.17	3284	24-Hour
C760M	64.45	3340	24-Hour
C760O	64.91	3329	24-Hour
C770C	1.93	1109	6-Hour
C770D	67.01	3333	24-Hour
C770DL	2.10	1045	6-Hour
C770E	236.46	16800	24-Hour
C770F	237.04	16767	24-Hour
C770G	242.40	18147	24-Hour
C780C	12.61	3951	24-Hour
C780D	13.41	3661	24-Hour
C790B	2.83	2145	24-Hour
C790C	3.66	2218	24-Hour
C790D	4.66	1913	24-Hour
C790E	270.24	18236	24-Hour
C790ER	262.21	18154	24-Hour
C800A	1.32	1025	6-Hour
C800D	2.00	913	6-Hour
C800E	2.51	694	24-Hour
C800H	3.20	1080	6-Hour
C800HR	2.81	410	6-Hour
C800I	3.47	1018	6-Hour
C800J	4.64	1038	24-Hour
C800L	6.12	917	24-Hour
C800M	6.82	1693	24-Hour
C800MR	5.33	798	24-Hour
C800N	7.31	1758	24-Hour
C800O	8.03	1632	24-Hour
C800P	270.86	18217	24-Hour
C800PL	270.71	18218	24-Hour
C800R	271.53	18183	24-Hour
C800U	2.31	1029	6-Hour
C800V	274.49	18148	24-Hour

**With Levee Concentration Point Controlling Storm Duration**

<b>Concentration Point</b>	<b>Drainage Area (sq mi)</b>	<b>Peak Flow (cfs)</b>	<b>Controlling Storm Duration</b>
C740D	60.77	768	24-Hour
C740E	61.04	734	24-Hour
C750B	3.55	1050	24-Hour
C750C	3.88	1516	24-Hour
C750CL	3.71	1043	24-Hour
C750D	2.07	687	6-Hour
C750E	4.23	1516	6-Hour
C750F	4.64	1599	24-Hour
C750G	5.28	1570	24-Hour
C750H	5.78	1642	24-Hour
C750I	65.23	2009	24-Hour
C750IL	6.10	1596	24-Hour
C750J	65.60	1976	24-Hour
C750L	0.64	376	6-Hour
C750M	0.99	383	6-Hour
C750N	66.85	2063	24-Hour
C760B	0.97	570	6-Hour
C760C	1.35	299	6-Hour
C760E	0.54	464	6-Hour
C760F	0.94	398	6-Hour
C760G	2.73	551	6-Hour
C760GL	2.34	348	6-Hour
C760H	3.33	402	24-Hour
C760I	70.47	2028	24-Hour
C760K	70.93	2031	24-Hour
C760KL	0.46	362	6-Hour
C760L	74.26	2142	24-Hour
C760LL	71.34	1976	24-Hour
C760M	74.62	2096	24-Hour
C760N	73.13	379	6-Hour
C760O	90.79	424	24-Hour
C770C	76.57	1674	24-Hour
C770D	92.89	1715	24-Hour
C770DL	76.74	1338	24-Hour
C770E	237.24	7847	24-Hour
C770F	237.82	7822	24-Hour
C770G	243.18	8840	24-Hour
C780C	12.61	3951	24-Hour
C780D	13.41	3661	24-Hour

**Sub Basin Controlling Condition Summary**

8 of 11

<b>Sub Basin</b>	<b>Area (sq mi)</b>	<b>Peak Flow (cfs)</b>	<b>Controlling Storm Duration</b>
S770E	0.70	694	6-Hour
S770F	0.57	444	6-Hour
S770G	1.00	705	6-Hour
S780A	7.58	4251	24-Hour
S780B	3.72	3085	24-Hour
S780C	1.31	850	6-Hour
S780D	0.80	927	6-Hour
S780E	0.86	947	6-Hour
S790A	1.33	1354	6-Hour
S790B	1.50	1193	6-Hour
S790C	0.83	896	6-Hour
S790D	1.00	1181	6-Hour
S790E	0.88	899	6-Hour
S800A	1.01	800	6-Hour
S800B	0.31	360	6-Hour
S800D	0.69	1021	6-Hour
S800E	0.51	951	6-Hour
S800F	0.29	391	6-Hour
S800G	0.23	406	6-Hour
S800H	0.16	246	6-Hour
S800I	0.27	335	6-Hour
S800J	1.17	964	6-Hour
S800K	1.26	909	6-Hour
S800L	0.22	303	6-Hour
S800M	0.70	694	6-Hour
S800N	0.49	529	6-Hour
S800O	0.72	815	6-Hour
S800P	0.47	630	6-Hour
S800Q	0.15	310	6-Hour
S800R	0.67	895	6-Hour
S800S	1.85	1011	6-Hour
S800T	0.15	344	6-Hour
S800U	0.32	496	6-Hour
S800V	0.64	886	6-Hour
S800W	0.23	426	6-Hour
S800X	0.23	506	6-Hour
S810A	0.26	472	6-Hour
S820A	0.38	466	6-Hour
S820B	0.94	655	6-Hour
S820C	0.24	317	6-Hour

**With Levee Concentration Point Controlling Storm Duration**

<b>Concentration Point</b>	<b>Drainage Area (sq mi)</b>	<b>Peak Flow (cfs)</b>	<b>Controlling Storm Duration</b>
C900I	5.76	843	24-Hour
C900IR	4.87	772	24-Hour
C910B	0.38	391	6-Hour
C910D	0.51	340	6-Hour
C910E	6.10	822	24-Hour
C910F	6.56	830	24-Hour
C910G	6.95	821	24-Hour
C910GL	6.75	821	24-Hour
C910J	8.46	848	24-Hour
C910K	9.85	1093	24-Hour
C910KR	8.81	840	24-Hour
C910L	1.42	643	6-Hour
C910N	10.14	990	24-Hour
C910O	10.63	982	24-Hour
C920B	0.93	701	6-Hour
C920BR	0.67	514	6-Hour
C920D	11.90	1274	24-Hour
C920E	12.27	1273	24-Hour
C920F	12.75	1224	24-Hour
C920H	13.97	1203	24-Hour
C920J	14.16	1196	24-Hour
C920L	0.41	374	6-Hour
C920M	14.73	1221	24-Hour
C920N	15.29	1211	24-Hour
C920R	16.35	1213	24-Hour
C920S	17.32	1190	24-Hour
C920U	17.94	1175	24-Hour
C920W	0.54	211	6-Hour
C930B	0.35	331	6-Hour
C930D	1.61	718	6-Hour
C930DL	1.26	653	6-Hour
C930E	1.85	618	6-Hour
C930H	2.64	906	24-Hour
C930I	21.04	1632	24-Hour
C930J	22.36	1372	24-Hour
C940B	0.55	477	6-Hour
C940C	1.45	1183	6-Hour
C940F	1.59	1167	6-Hour
C940H	0.83	690	6-Hour



**APPENDIX TM3-11-2**  
**EXISTING HYDROLOGY RESULTS**  
**EXCERPTS FROM LUKE WASH FDS**

### Evaluation of Manning's n-Value on Peak Flows

The selection of Manning's "n" values impacts both hydrologic and hydraulic modeling results. In order to evaluate the impact of Manning's n-value on the peak flows, a sensitivity analysis was conducted by reducing the n-values from 0.005 to 0.01 for the channel routing operations in the HEC-1 model for both shallow-and-wide and well-defined wash cases. The modeling results were listed in Appendix D6 which shows that the n-value reduction has more significant impact on the peak flows for shallow-and-wide washes than well-defined washes.

## 4.5 Final Results

### 4.5.1 Hydrologic Analysis Results

Eight HEC-1 hydrologic models were developed for four (4) scenarios (without dike, with both dikes, with I-10 only, and with UPRR only); and two (2) storm durations (100-year, 24-hour, and 100-year, 6-hour). Peak flows from all of the 8 models are summarized in Table 4.3 on the following pages. The maximum flow at each of the concentration points and the representative model that produces the maximum flow is identified. Note that if the maximum flow is generated by more than one model the selection order is as follows: 24-hour model first, then without dike model, and finally, with both dikes. The maximum peak flows for the 100-year storm are also shown in Exhibit A6. The output files for all of the HEC-1 models are presented in the Appendix D7.

The HEC-1 model names are summarized below:

Condition	100-year, 24-hour	100-year, 6-hour
No Dike	EC24NODK.DAT	EC06NODK.DAT
With Dike (I-10 & UPRR)	EC24DIKE.DAT	EC06DIKE.DAT
With I-10 Dike	EC24I10.DAT	EC06I10.DAT
With UPRR Dike	EC24UPRR.DAT	EC06UPRR.DAT

The electronic files for the HEC-1 models are provided on the CD in Exhibit A7 (inside front cover).

Table 4.3 Peak Flow Summary Table

Hydrologic Modeling Peak Flow Summary										
Model =>	EC24DIKE	EC06DIKE	EC24I10	EC06I10	EC24UPRR	EC06UPRR	EC24NODK	EC06NODK	Maximum	Maximum
Hydrograph	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	Flow	Flow
Name									(cfs)	Model
14e	805	936	805	936	805	936	805	936	936	EC06NODK
14d	482	655	482	655	482	655	482	655	655	EC06NODK
C14d	901	1025	901	1025	901	1025	901	1025	1025	EC06NODK
14c	876	1023	876	1023	876	1023	876	1023	1023	EC06NODK
C14c	1241	1316	1241	1316	1241	1316	1241	1316	1316	EC06NODK
14b	299	404	299	404	299	404	299	404	404	EC06NODK
C14b	1138	1206	1215	1281	1138	1206	1215	1281	1281	EC06NODK
14a	312	415	312	415	312	415	312	415	415	EC06NODK
C14a	1104	1144	1174	1234	1104	1144	1174	1234	1234	EC06NODK
12b	397	532	397	532	397	532	397	532	532	EC06NODK
12a	649	797	649	797	649	797	649	797	797	EC06NODK
C12a	760	921	760	921	760	921	760	921	921	EC06NODK
CC12a	1439	1484	1602	1642	1439	1484	1602	1642	1642	EC06NODK
10b	583	721	583	721	583	721	583	721	721	EC06NODK
C10b	1786	1767	1937	1910	1786	1767	1937	1910	1937	EC24NODK
10a	812	982	812	982	812	982	812	982	982	EC06NODK
C10a	1771	1703	1887	1828	1771	1703	1887	1828	1887	EC24NODK
21d	372	494	372	494	372	494	372	494	494	EC06NODK
21c	192	261	192	261	192	261	192	261	261	EC06NODK
C21c	320	419	320	419	320	419	320	419	419	EC06NODK
21b	368	490	368	490	368	490	368	490	490	EC06NODK
C21b	366	420	366	420	366	420	366	420	420	EC06NODK
24b	274	369	274	369	274	369	274	369	369	EC06NODK
24a	367	498	367	498	367	498	367	498	498	EC06NODK
C24a	365	458	365	458	365	458	365	458	458	EC06NODK
CC24a	690	710	690	710	690	710	690	710	710	EC06NODK
21a	627	770	627	770	627	770	627	770	770	EC06NODK
C21a	791	850	791	850	791	850	791	850	850	EC06NODK
20l	153	206	153	206	153	206	153	206	206	EC06NODK
C20l	661	694	661	694	740	798	740	798	798	EC06NODK
20K	200	269	200	269	200	269	200	269	269	EC06NODK
20j	233	315	233	315	233	315	233	315	315	EC06NODK
C20j	233	315	233	315	234	317	234	317	317	EC06NODK
CC20j	688	707	688	707	787	829	787	829	829	EC06NODK
20i	277	374	277	374	277	374	277	374	374	EC06NODK
C20i	675	695	675	695	767	803	767	803	803	EC06NODK
22c	215	290	215	290	215	290	215	290	290	EC06NODK
22d	227	310	227	310	227	310	227	310	310	EC06NODK
22b	212	287	212	287	212	287	212	287	287	EC06NODK
C22b	211	287	211	287	213	293	213	293	293	EC06NODK
CC22b	404	519	404	519	407	538	407	538	538	EC06NODK
22a	367	499	367	499	367	499	367	499	499	EC06NODK
C22a	398	508	398	508	414	543	414	551	551	EC06NODK
CC20i	823	809	823	809	1026	1008	1026	1011	1026	EC24NODK
20h	885	1017	885	1017	885	1017	885	1017	1017	EC06NODK
C20h	1005	910	1005	910	1045	994	1045	997	1045	EC24NODK
20g	915	1053	915	1053	915	1053	915	1053	1053	EC06NODK
C20g	1139	1037	1139	1037	1104	1013	1104	1013	1139	EC24DIKE
20f	1005	1122	1005	1122	1005	1122	1005	1122	1122	EC06NODK
C20f	1107	988	1107	988	1097	980	1097	980	1107	EC24DIKE
20e	1198	1308	1198	1308	1198	1308	1198	1308	1308	EC06NODK
C20e	1190	1034	1190	1034	1204	1044	1204	1044	1204	EC24NODK
20d	660	851	660	851	660	851	660	851	851	EC06NODK
C20d	1175	994	1175	994	1155	989	1163	995	1175	EC24DIKE
20c	1052	1182	1052	1182	1052	1182	1052	1182	1182	EC06NODK
C20c	1209	1005	1209	1005	1178	990	1183	997	1209	EC24DIKE
20b	871	999	733	868	871	999	733	868	999	EC06DIKE

Table 4.3 Peak Flow Summary Table (continued)

Hydrologic Modeling Peak Flow Summary										
Model =>	EC24DIKE	EC06DIKE	EC24I10	EC06I10	EC24UPRR	EC06UPRR	EC24NODK	EC06NODK	Maximum	Maximum
Hydrograph	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	Flow	Flow
Name									(cfs)	Model
44b	268	359	268	359	268	359	268	359	359	EC06NODK
C44b	614	723	614	723	614	723	614	728	728	EC06NODK
44a	452	568	452	568	452	568	452	568	568	EC06NODK
C44a	615	678	615	678	615	678	615	684	684	EC06NODK
CC46a	2085	1839	2085	1839	2173	1879	2173	1889	2173	EC24NODK
40d	463	586	463	586	463	586	463	586	586	EC06NODK
C40d	2064	1807	2064	1807	2143	1845	2143	1856	2143	EC24NODK
42b	278	377	278	377	278	377	278	377	377	EC06NODK
42a	360	488	360	488	360	488	360	488	488	EC06NODK
C42a	361	459	361	459	361	459	361	459	459	EC06NODK
CC40d	2064	1806	2064	1806	2142	1840	2143	1851	2143	EC24NODK
40c	520	709	520	709	520	709	520	709	709	EC06NODK
C40c	2035	1758	2035	1758	2106	1792	2107	1803	2107	EC24NODK
40b	273	371	273	371	273	371	273	371	371	EC06NODK
C40b	2013	1719	2013	1719	2073	1751	2074	1762	2074	EC24NODK
64d	141	199	141	199	141	199	141	199	199	EC06NODK
64c	423	553	423	553	423	553	423	553	553	EC06NODK
C64c	422	530	422	530	422	530	422	530	530	EC06NODK
64b	525	648	525	648	525	648	525	648	648	EC06NODK
C64b	779	853	779	853	779	853	779	853	853	EC06NODK
64a	323	442	323	442	323	442	323	442	442	EC06NODK
C64a	761	811	761	811	761	811	761	811	811	EC06NODK
62b	241	330	241	330	241	330	241	330	330	EC06NODK
62a	498	659	498	659	498	659	498	659	659	EC06NODK
C62a	529	657	529	657	529	657	529	657	657	EC06NODK
CC64a	1002	1031	1002	1031	N/A	N/A	N/A	N/A	1031	EC06DIKE
CC62a					1002	1031	1002	1031	1031	EC06NODK
60c	678	798	678	798	678	798	678	798	798	EC06NODK
C60c	1065	995	1065	995	1336	1229	1336	1229	1336	EC24NODK
60b	702	826	702	826	702	826	702	826	826	EC06NODK
C60b	1313	1206	1313	1206	1571	1405	1571	1405	1571	EC24NODK
60a	603	756	603	756	603	756	603	756	756	EC06NODK
C60a	1276	1155	1276	1155	1507	1314	1507	1314	1507	EC24NODK
CC40b	2197	1713	2197	1713	2242	1745	2244	1756	2244	EC24NODK
40a	242	329	242	329	242	329	242	329	329	EC06NODK
C40a	2190	1688	2190	1688	2236	1730	2237	1739	2237	EC24NODK
36c	590	702	590	702	590	702	590	702	702	EC06NODK
36b	839	987	839	987	839	987	839	987	987	EC06NODK
C36b	866	904	866	904	866	904	866	904	904	EC06NODK
36a	613	784	613	784	613	784	613	784	784	EC06NODK
C36a	988	1044	988	1044	988	1044	1005	1044	1044	EC06NODK
CC36a	2291	1681	2291	1681	2482	1720	2483	1729	2483	EC24NODK
30g	628	772	628	772	628	772	628	772	772	EC06NODK
C30g	2256	1609	2256	1609	2443	1648	2444	1657	2444	EC24NODK
34b	365	476	365	476	365	476	365	476	476	EC06NODK
34a	294	399	294	399	294	399	294	399	399	EC06NODK
C34a	356	455	356	455	356	455	356	448	455	EC06DIKE
CC30g	2364	1580	2364	1580	2540	1633	2541	1635	2541	EC24NODK
30f	880	963	880	963	880	963	880	963	963	EC06NODK
C30f	2339	1540	2339	1540	2504	1589	2505	1589	2505	EC24NODK
30e	404	541	404	541	404	541	404	541	541	EC06NODK
C30e	2324	1527	2324	1527	2484	1574	2484	1574	2484	EC24NODK
30d	406	533	406	533	406	533	406	533	533	EC06NODK
C30d	2307	1510	2307	1510	2465	1555	2465	1555	2465	EC24NODK
CC20b	3106	1888			3243	1902	N/A	N/A	3243	EC24UPRR
CC20a			3154	1899	N/A	N/A	3276	1918	3276	EC24NODK
20a	277	377	350	475	277	377	350	475	475	EC06NODK

Table 4.3 Peak Flow Summary Table (continued)

Hydrologic Modeling Peak Flow Summary										
Model =>	EC24DIKE	EC06DIKE	EC24I10	EC06I10	EC24UPRR	EC06UPRR	EC24NODK	EC06NODK	Maximum	Maximum
Hydrograph	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	Flow	Flow
Name									(cfs)	Model
35a	69	96	69	96	69	96	69	96	96	EC06NODK
DUMMY	1271	1358	1271	1358	1271	1358	1271	1358	1358	EC06NODK
DUMMY	3834	2114	4140	2278	3841	2118	4144	2282	4144	EC24NODK
79b	427	581	427	581	427	581	427	581	581	EC06NODK
79a	486	665	486	665	486	665	486	665	665	EC06NODK
C79a	779	948	779	948	779	948	779	948	948	EC06NODK
80b	296	404	296	404	296	404	296	404	404	EC06NODK
80a	331	450	331	450	331	450	331	450	450	EC06NODK
C80a	453	617	453	617	453	617	453	617	617	EC06NODK
81b	367	495	367	495	367	495	367	495	495	EC06NODK
81a	121	165	121	165	121	165	121	165	165	EC06NODK
C81a	345	465	345	465	345	465	345	465	465	EC06NODK
DUMMY	3834	2109	4139	2268	3841	2112	4144	2272	4144	EC24NODK
82b	268	368	268	368	268	368	268	368	368	EC06NODK
82a	508	669	508	669	508	669	508	669	669	EC06NODK
C82a	510	619	510	619	689	808	689	815	815	EC06NODK
83l	545	719	545	719	545	719	545	719	719	EC06NODK
83k	322	442	322	442	322	442	322	442	442	EC06NODK
C83k	863	1031	863	1031	863	1031	863	1031	1031	EC06NODK
83j	141	195	141	195	141	195	141	195	195	EC06NODK
C83j	811	962	811	962	811	962	811	962	962	EC06NODK
89b	282	389	282	389	282	389	282	389	389	EC06NODK
89a	197	279	197	279	197	279	197	279	279	EC06NODK
C89a	349	498	349	498	349	498	349	498	498	EC06NODK
CC83j	1119	1191	1119	1191	1119	1191	1119	1191	1191	EC06NODK
88a	221	302	221	302	221	302	221	302	302	EC06NODK
C88a	1261	1291	1261	1291	1261	1291	1261	1291	1291	EC06NODK
83i	319	444	319	444	319	444	319	444	444	EC06NODK
C83i	1320	1309	1320	1309	1320	1309	1320	1309	1320	EC24NODK
83h	219	299	219	299	219	299	219	299	299	EC06NODK
C83h	1489	1432	1489	1432	1489	1432	1489	1432	1489	EC24NODK
83g	420	559	420	559	420	559	420	559	559	EC06NODK
C83g	1516	1408	1516	1408	1516	1408	1516	1408	1516	EC24NODK
83f	156	218	156	218	156	218	156	218	218	EC06NODK
C83f	1519	1408	1519	1408	1519	1408	1519	1408	1519	EC24NODK
83e	607	743	607	743	607	743	607	743	743	EC06NODK
C83e	1457	1261	1457	1261	1457	1261	1428	1261	1457	EC24DIKE
83d	205	282	205	282	205	282	205	282	282	EC06NODK
C83d	1371	1193	1371	1193	1371	1193	1349	1193	1371	EC24DIKE
86a	339	476	339	476	339	476	339	476	476	EC06NODK
CC83d	1384	1184	1384	1184	1384	1184	1362	1184	1384	EC24DIKE
83c	306	416	306	416	306	416	306	416	416	EC06NODK
C83c	1342	1125	1342	1125	1342	1125	1323	1125	1342	EC24DIKE
87b	135	190	135	190	135	190	135	190	190	EC06NODK
87a	229	312	229	312	229	312	229	312	312	EC06NODK
C87a	228	311	228	311	228	311	228	311	311	EC06NODK
CC83c	1387	1128	1387	1128	1387	1128	1368	1128	1387	EC24DIKE
83b	322	439	322	439	322	439	322	439	439	EC06NODK
C83b	1335	1056	1335	1056	1335	1056	1320	1056	1335	EC24DIKE
85b	251	344	251	344	251	344	251	344	344	EC06NODK
85a	281	382	281	382	281	382	281	382	382	EC06NODK
C85a	287	405	287	405	287	405	287	405	405	EC06NODK
CC83b	1359	1044	1359	1044	1359	1044	1344	1044	1359	EC24DIKE
83a	202	275	202	275	202	275	202	275	275	EC06NODK
C83a	1318	1004	1318	1004	1318	1004	1305	1004	1318	EC24DIKE
84b	301	411	301	411	301	411	301	411	411	EC06NODK
84a	268	366	268	366	268	366	268	366	366	EC06NODK



**APPENDIX TM3-11-3**  
**EXISTING HYDROLOGY RESULTS**  
**EXCERPTS FROM BUCKEYE ADMP**

**BUCKEYE ADMP EXISTING CONDITIONS HYDROLOGY UPDATE - PARAMETERS SUMMARY TABLE**  
**100 Year, 6 Hour Storm**

SUB BASIN															% INCREASE	UNIT
ADMP	AREA	SLOPE	Length	LCA	IA	DTHETA	PSIF	XKSAT	RTIMP	Tp	S-GRAPH TYPE	Kn	Lag	DISCHARGE	DISCHARGE	DISCHARGE
ADMS	(sq mi)	(ft/mi)	(ft)	(ft)	(in)		(in)	(in/hr)	(%)	(hrs)			(min)	(cfs)		(cfs/sq mi)
<b>83</b>	0.675	64.7	1.72	0.93	0.25	0.250	5.4	0.270	30.00	4.5	Phoenix Valley	0.05	39	1010	<b>29%</b>	<b>1496</b>
83	0.675	64.69	1.72	0.93	0.341	0.375	5.44	0.214	2.8	4.75	Desert Rangeland	0.05	39	781		<b>1157</b>
<b>MODEL FRW 100-yr, 6-hr</b>																
SUB BASIN															% INCREASE	UNIT
ADMP	AREA	SLOPE	Length	LCA	IA	DTHETA	PSIF	XKSAT	RTIMP	Tp	S-GRAPH TYPE	Kn	Lag	DISCHARGE	DISCHARGE	DISCHARGE
ADMS	(sq mi)	(ft/mi)	(ft)	(ft)	(in)		(in)	(in/hr)	(%)	(hrs)			(min)	(cfs)		(cfs/sq mi)
<b>1</b>	1.626	34.9	2.61	1.54	0.54	0.320	4.3	0.400	1.00	5.25	Desert Rangeland	0.079	98.3	576	<b>43%</b>	<b>354</b>
1	1.626	34.86	2.61	1.54	0.347	0.329	4.33	0.398	5.88	5	Desert Rangeland	0.05	62	1004		<b>617</b>
<b>2</b>	1.233	45.9	2.02	0.86	0.36	0.330	3.95	0.440	9.00	4.25	Desert Rangeland	0.035	30	1381	<b>32%</b>	<b>1120</b>
2	1.233	45.95	2.02	0.86	0.338	0.339	3.99	0.443	5.58	4.75	Desert Rangeland	0.05	43	1048		<b>850</b>
<b>3</b>	1.648	39.2	2.04	1.39	0.32	0.320	4	0.490	13.00	4.5	Desert Rangeland	0.033	35.2	1474	<b>106%</b>	<b>894</b>
3	1.648	39.22	2.04	1.39	1	0.298	4.03	0.546	4.13	5	Desert Rangeland	0.05	53	715		<b>434</b>
<b>4</b>	0.549	40.7	1.38	0.74	0.32	0.320	3.95	0.400	14.00	4.25	Desert Rangeland	0.032	23	956	<b>56%</b>	<b>1741</b>
4	0.549	40.65	1.38	0.74	0.306	0.332	4.02	0.485	14.55	4.75	Desert Rangeland	0.05	36	614		<b>1118</b>
<b>5A</b>	1.172	49	1.75	1.16	0.32	0.310	4.3	0.440	19.00	4.25	Desert Rangeland	0.038	34.2	1230	<b>22%</b>	<b>1049</b>
5A	1.172	49.05	1.75	1.16	0.333	0.342	4.33	0.387	5.98	4.75	Desert Rangeland	0.05	45	1008		<b>860</b>
<b>5B</b>	0.576	38.7	1.73	1.08	0.36	0.350	4.5	0.320	1.00	4.25	Desert Rangeland	0.028	25.5	913	<b>52%</b>	<b>1585</b>
5B	0.576	38.66	1.73	1.08	0.318	0.336	4.61	0.319	10.55	4.75	Desert Rangeland	0.05	46	602		<b>1045</b>
<b>15A</b>	0.588	34.6	1.45	0.48	0.37	0.330	4.4	0.390	4.00	4.25	Desert Rangeland	0.036	23	943	<b>33%</b>	<b>1604</b>
15A	0.588	34.58	1.45	0.48	0.358	0.324	4.42	0.391	2.37	4.5	Desert Rangeland	0.05	32	711		<b>1209</b>
<b>15B</b>	0.816	11	1.63	0.82	1	0.250	4.1	0.540	0.00	6.75	Agriculture	0.2	203.9	114	<b>0%</b>	<b>140</b>
15B	0.816	11.02	1.63	0.82	1	0.249	4.1	0.541	0.37	7	Agriculture	0.2	204	114		<b>140</b>
<b>16</b>	0.951	25	2.00	1.37	0.28	0.250	4.35	0.440	47.00	4.75	Phoenix Valley	0.048	55	1075	<b>2%</b>	<b>1130</b>
16	0.951	24.99	2.00	1.37	0.208	0.25	4.4	0.438	45.68	5	Phoenix Valley	0.05	57	1049		<b>1103</b>
<b>17</b>	0.607	16.9	1.43	0.71	0.25	0.250	4	0.550	30.00	4.5	Phoenix Valley	0.05	42.3	781	<b>562%</b>	<b>1287</b>
17	0.607	16.84	1.43	0.71	1	0.25	4.02	0.465	0.17	6.5	Agriculture	0.02	169	118		<b>194</b>
<b>18</b>	0.796	31	1.81	0.75	0.25	0.250	4.15	0.520	30.00	4.5	Phoenix Valley	0.05	42.1	987	<b>626%</b>	<b>1240</b>
18	0.796	30.99	1.81	0.75	1	0.291	4.13	0.479	0.12	6.5	Agriculture	0.02	168	136		<b>171</b>

**BUCKEYE ADMP EXISTING CONDITIONS HYDROLOGY UPDATE - PARAMETERS SUMMARY TABLE**  
**100 Year, 6 Hour Storm**

SUB BASIN															% INCREASE	UNIT
ADMP	AREA	SLOPE	Length	LCA	IA	DTHETA	PSIF	XKSAT	RTIMP	TP	S-GRAPH TYPE	Kn	Lag	DISCHARGE	DISCHARGE	DISCHARGE
ADMS	(sq mi)	(ft/mi)	(ft)	(ft)	(in)		(in)	(in/hr)	(%)	(hrs)			(min)	(cfs)		(cfs/sq mi)
<b>68</b>	0.413	45.6	0.96	0.33	0.52	0.290	4.35	0.370	4.00	4.5	Desert Rangeland	0.084	37.8	458	<b>-34%</b>	<b>1109</b>
68	0.413	45.58	0.96	0.33	0.374	0.334	4.37	0.374	0	4.5	Desert Rangeland	0.05	22	694		<b>1680</b>
<b>MODEL AREA 2 100-yr, 6-hr</b>																
SUB BASIN															% INCREASE	UNIT
ADMP	AREA	SLOPE	Length	LCA	IA	DTHETA	PSIF	XKSAT	RTIMP	TP	S-GRAPH TYPE	Kn	Lag	DISCHARGE	DISCHARGE	DISCHARGE
ADMS	(sq mi)	(%)	(ft)	(ft)	(in)		(in)	(in/hr)	(%)	(hrs)			(min)	(cfs)		(cfs/sq mi)
<b>A1</b>	1.628	33	2.96	1.73	0.35	0.350	4.45	0.340	0.00	4.33	Desert Rangeland	0.025	34.5	1587	<b>71%</b>	<b>975</b>
A1	1.630	32.98	2.96	1.73	0.343	0.347	4.498	0.339	2.145	5	Desert Rangeland	0.05	69	929		<b>570</b>
<b>B1</b>	0.300	57.2	1.34	0.66	0.35	0.350	4.6	0.320	0.00	4.08	Desert Rangeland	0.025	15.9	668	<b>58%</b>	<b>2227</b>
B1	0.300	57.24	1.34	0.66	0.35	0.35	4.624	0.315	0	4.42	Desert Rangeland	0.05	31	422		<b>1407</b>
<b>C1</b>	0.947	41.6	2.65	1.06	0.35	0.350	4.65	0.310	0.00	4.25	Desert Rangeland	0.025	26.3	1301	<b>72%</b>	<b>1374</b>
C1	0.950	41.6	2.65	1.06	0.35	0.35	4.669	0.311	0	4.67	Desert Rangeland	0.05	52	758		<b>798</b>
<b>D1</b>	0.687	41.1	2.05	0.98	0.35	0.350	4.65	0.320	0.00	4.25	Desert Rangeland	0.026	24.1	1072	<b>66%</b>	<b>1560</b>
D1	0.690	41.1	2.05	0.98	0.35	0.35	4.642	0.317	0	4.58	Desert Rangeland	0.05	46	646		<b>936</b>
<b>E1</b>	1.466	27.9	3.19	1.81	0.35	0.350	4.35	0.360	0.00	4.42	Desert Rangeland	0.025	37.2	1375	<b>78%</b>	<b>938</b>
E1	1.470	27.95	3.19	1.81	0.343	0.347	4.362	0.364	2.082	5.08	Desert Rangeland	0.05	75	772		<b>525</b>
<b>E2-a2</b>	1.223	27.5	2.97	1.67	0.41	0.340	4.4	0.350	1.00	4.75	Desert Rangeland	0.043	60.6	792	<b>11%</b>	<b>648</b>
E2-a2	1.220	27.48	2.97	1.67	0.348	0.343	4.461	0.354	2.288	5	Desert Rangeland	0.05	70	713		<b>584</b>
<b>E3-a2</b>	0.943	25.9	2.72	0.99	0.78	0.270	4.25	0.440	1.00	6.33	Desert Rangeland	0.145	163.9	650	<b>-41%</b>	<b>689</b>
E3-a2	0.940	25.93	2.72	0.99	0.402	0.306	4.245	0.444	1.589	4.75	Desert Rangeland	0.05	56	1095		<b>1165</b>
<b>E4</b>	0.740	29	2.00	1.24	0.56	0.300	4.15	0.420	1.00	5.25	Desert Rangeland	0.089	95.5	310	<b>-45%</b>	<b>419</b>
E4	0.740	28.98	2.00	1.24	0.389	0.324	4.185	0.421	0	4.75	Desert Rangeland	0.05	53	559		<b>755</b>