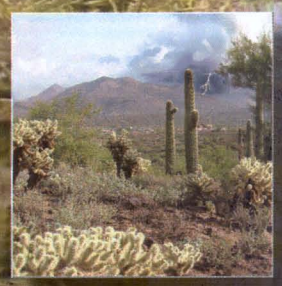
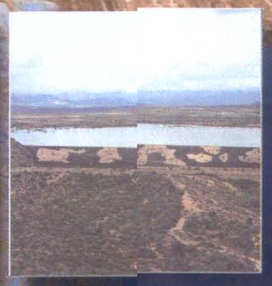
Upper New River Area Drainage Master Plan

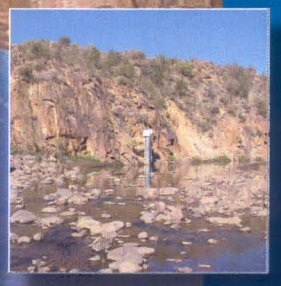
June 2008

Flood Control District of Maricopa County

Contract FCD 2005C020
Stantec Project No. 182000418







Hydrology Report

Stantec

Upper New River ADMP

Hydrology Report

PREPARED FOR:

FLOOD CONTROL DISTRICT

of

MARICOPA COUNTY

PREPARED BY:

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EXECUTIVE SUMMARY

The purpose of the Upper New River Area Drainage Master Plan (ADMP) hydrologic analysis is to estimate peak discharges for the 100-year recurrence interval storm at key flow concentration locations in the watershed. The computed peak discharges are then used in the hydraulic and erosion hazard analyses conducted for this study. The combined results from these analyses will be used to identify existing and future flood hazards and for the development of guidelines and policies regarding the management of future development in the watershed. It should be noted that the flow values obtained are for planning purposes and are not the FEMA approved effective flood flows in the reach.

Eight previous hydrologic studies have been done in the watershed: three overall hydrology studies and five studies of tributaries to New River. The ADMP hydrologic model is a composite of existing hydrologic models and new, detailed hydrology developed specifically for the ADMP. Brief descriptions of the existing studies which were used to develop the ADMP hydrology are provided in the report.

In general, the results of the Upper New River ADMP hydrology accord well with the results of previous studies. Runoff peaks for the upper portion of the watershed are lower than those found in previous studies, while the peak runoff values in the lower watershed appear to fall far short of the previous values. The major differences in hydrology arise because of physical changes in the study area, the updated ADMP precipitation values and differences in unit hydrograph methodology.

Changes to the main channel of New River since the last hydrologic study, such as borrow and gravel pits, have eliminated previously identified flow splits and created new flow diversions. The new diversions are sensitive to changes in discharge, and by diverting flow in different amounts to various side channels, can affect the overall timing of the flood peaks.

The borrow pits present in the main stem of the New River provide minimal stormwater storage in the watercourse and do not provide significant attenuation or delay to the peak discharge. The results of the HEC-1 model indicate that they have too little storage volume available compared to the volume of water being conveyed through the watercourse, and are too steeply sloped to act as effective detention/retention basins.

Development may have significant impacts on the timing of the peak discharge. This is potentially important in the main stem downstream of Sweat Canyon Wash and Deadman Wash where the hydrograph currently has two distinct peaks. Altering the timing of the study area runoff could cause the hydrographs to coincide and increase the overall flood peak. For this reason, it is very important to fully evaluate any land use that may delay the Sweat Canyon or Deadman Wash runoff hydrograph or advance the main stem hydrograph.

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1.0 INTRODUCTION

Currently, the Upper New River Area Drainage Master Plan (ADMP) watershed and study area is mostly undeveloped and relatively pristine, undisturbed Sonoran Desert. It is anticipated that wide development interest within the project area will increase over the next 5 years. Generally, the opportune time to develop an Area Drainage Master Plan is before land development significantly affects or impacts the drainage characteristics of the watershed. Floodplain managers, planners, developers, and land owners can use and implement the Upper New River ADMP for planning and designing flood mitigation solutions and for guiding or regulating development.

The Upper New River ADMP is performed for the Flood Control District of Maricopa County (the District) by Stantec Consulting under contract number FCD 2005C020.

1.1 PURPOSE

The purpose of the hydrologic analysis is to estimate peak discharges for the 100-year recurrence interval storm at key flow concentration locations in the watershed. The computed peak discharges are then used in the hydraulic and erosion hazard analyses conducted for this study. The combined results from these analyses will be used to identify existing and future flood hazards and for the development of guidelines and policies regarding the management of future development in the watershed.

1.2 LOCATION AND HYDROLOGIC SETTING

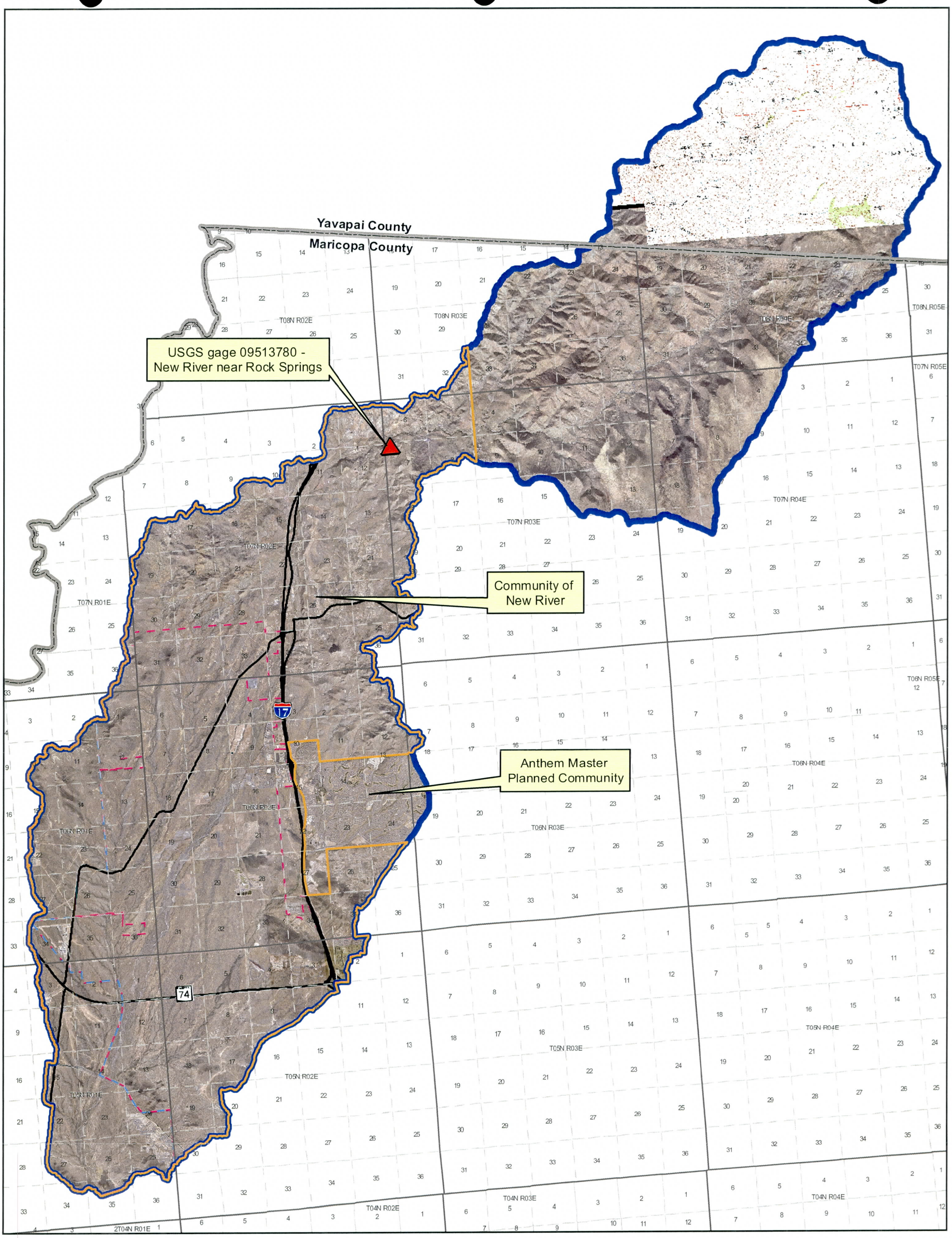
The Upper New River watershed encompasses approximately 175 square miles of the New River watershed above New River Dam in north-central Maricopa County and southern Yavapai County (Figure 1.1). The eastern boundaries of the study watershed are contiguous with the Skunk Creek watershed. The western boundaries of the study watershed are contiguous with the Agua Fria River watershed.

The New River watershed, referred to as the study watershed in this report, is naturally divided at the USGS Rock Springs gage into an upper and lower watershed with very different hydrologic characteristics. The upper watershed is primarily steep and rocky with well defined channels and areas of perennial flow. It is almost entirely undeveloped with natural vegetation and undisturbed drainage paths. Generally, the lower watershed has less elevation change across basins and therefore flatter slopes. There is more development in the lower watershed which often affects drainage paths, especially through the community of New River and along the I-17 corridor. The main channel of New River tends to be braided and distributive through portions of the lower watershed.

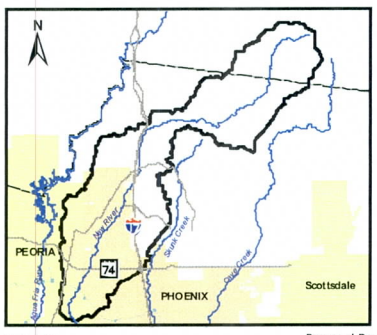
The Upper New River ADMP study area encompasses approximately 95 square miles of the Upper New River watershed. The ADMP study area includes those areas of the watershed which are subject to development, and is referred to as the "study area" in this report. It specifically does not include the United States Forest Service (USFS) land

within the watershed, and the portion of the watershed which was developed as the master planned community, Anthem.

Major transportation corridors in the study area include I-17, Carefree Highway and New River Road. Major communities within the study area include New River and development adjacent to Anthem (Figure 1.1). The study area falls within the jurisdictional areas of the City of Phoenix, City of Peoria and unincorporated Maricopa County.



Location Map:



Project No.
182000418

Prepared By:
AMG
August 2007

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Notes:

Base photography circa 2006

N

Not to scale

Legend:

- Roadway
- Project Boundary
- Watershed Boundary
- Township and Range
- Section
- Peoria Corporate Boundary
- Phoenix Corporate Boundary

Flood Control District of Maricopa County

Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
Figure 1.1
Watershed Overview

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2.0 EXISTING STUDIES

Eight previous hydrologic studies have been done in the watershed: three overall hydrology studies and five studies of tributaries to New River. Of the three overall studies, two were performed by the U.S. Army Corps of Engineers (USACE) in support of the design for New River Dam. Those studies formed the basis for the derivation of the Phoenix Valley and Phoenix Mountain S-graphs, however those studies were not directly used to develop the ADMP hydrology. The third overall study was conducted as part of a floodplain delineation study of New River upstream of New River Dam. That study set the framework for the subsequent detailed studies of the tributaries as well as new, detailed hydrology conducted as part of the Upper New River ADMP. Brief descriptions of the six existing studies which were used to develop the ADMP hydrology are provided in the following sections.

2.1 NEW RIVER FIS

Flood Insurance Study, New River, New River Dam to Rock Springs, Maricopa County, Arizona; 1987. Dated December 1, 1987

The original Flood Insurance Study (FIS) initiated by the District in the study area was performed by Coe & Van Loo (CVL) in 1987. USGS Quadrangle maps were used to delineate the watershed. The size of the watershed upstream of the dam is 170 square miles. Digital files of the HEC-1 model input and output were provided by the District. Those files are included for reference on CD in Appendix A.

The following is a summary of the methodologies, input and results.

- **Mapping:** USGS Quad maps, contour interval of 20 feet, NGVD29.
- **Subbasin Delineation:** Upper portion divided into 21 subbasins (ranging from 0.22 to 15.78 square miles), lower divided into 33 subbasins (ranging from 0.09 to 17.63 square miles).
- **Precipitation:** Different precipitation values used for the upper and lower watersheds. The upper watershed used a depth of 4.95 inches for the 100-year, 24 hour model, with an areal reduction of 0.94. The lower watershed used a rainfall depth of 4.40 inches and an areal reduction of 0.94. The SCS Type II distribution pattern was used.
- **Hydrograph**: Phoenix Mountain S-graphs used for the upper basin. The lower basin was modeled with a combination of kinematic wave and Phoenix Valley S-graphs.
- **Rainfall Losses:** SCS Curve Number, with curve numbers ranging from 85 to 90.
- **Routing Method:** Muskingum routing in upper basin, kinematic wave in lower basin.

- **Calibration:** Done by adjusting curve numbers so that the peak discharge matched the Army Corps of Engineers estimate at the New River Dam.

TABLE 2.1
Selected New River FIS Results

Concentration Point Description (1)	Q cfs (2)	Time to Peak hours (3)	Area square miles (4)
Rock Springs Gauge	34,500	14.08	70.94
New River Bridge	32,000	15.08	78.81
Frontage Road bridge	33,300	15.00	87.1
I-17 at New River	33,400	15.17	88.34
D/S of Gravel pit, U/S of West split	32,800	15.67	92.63
West Carefree Highway Bridge	21,400	12.75	29.48
East Carefree Highway Bridge	35,700	15.83	124.62
CAP crossing	54,600	13.00	157.09
New River Dam	61,500	13.08	170.02

2.2 GAVILAN PEAK WASH WATERSHED

Gavilan Peak Floodplain Study; 2000-2006

The Gavilan Peak Wash watershed (Approximately 8.4 square miles) was the subject of a hydrology study performed by the District in 2000, and updated in 2006. The HEC-1 model was developed by FCD in 1998 and revised in 2001 and 2006. Digital files of the 100-year, 24-hour HEC-1 input and output were provided by the District and are included in Appendix A.

The resulting HEC-1 model was used by Michael Baker Jr., Inc. in the Gavilan Peak Floodplain Delineation Study, which used HEC-RAS hydraulic models to delineate 19.5 linear miles of floodplain within and around the community of New River.

The following is a summary of the methodologies, input and results.

- **Mapping:** Digital USGS 7.5 Minute Digital Elevation Model at a scale of 1inch equals 2,000 feet with contour intervals of 20 or 40 feet.

- **Subbasin Delineation:** 45 subbasins with areas ranging from 0.0066 to 0.7823 square miles, delineated using WMS 5.1.

- **Precipitation:** The 100-year, 24-hour point rainfall depth is 4.74 inches with an areal reduction based on NOAA HYDRO-40 and implemented through JD cards. The temporal distribution is the SCS Type II.

- **Hydrograph**: Phoenix Mountain S-graph method with unit hydrographs computed using WMS 5.1.

- **Rainfall Losses**: Green and Ampt Loss rate with values for XKSAT ranging from 0.035 to 0.483 inches per hour.

- **Routing Method:** Normal depth channel routing with storage routes developed at culvert structures.

- **Calibration:** No calibration was performed. Indirect verification through regional regression equations and comparison with previous models indicate that the results are reasonable.

TABLE 2.2,
Selected Gavilan Peak Wash Results

Concentration Point Description (1)	Q cfs (2)	Time to Peak hours (3)	Area square mile (4)
At New River Road- culvert	780	12.25	0.4
At 27th Ave- culvert	2,260	12.5	1.65
At New River Road- culvert	4,570	12.5	3.32
Table Mountain Wash at New River Road- culvert	3,990	12.67	3.53
At Meander Road- dip	8,710	12.75	7.95
End of Model, Confluence with New River	8,750	12.83	8.37

2.3 BLACK WASH WATERSHED

New River above I-17 Floodplain Delineation Study Dated March 26, 2005

Primatech performed a detailed hydraulic analysis of New River through the community of New River and Black Wash to its confluence with New River. A hydrologic analysis was conducted for the 1.1 square mile watershed draining to Black Wash which encompassed approximately 1 square mile. The digital 100-year, 24-hour HEC-1 input and output files as well as the watershed and flow path delineation for this project were provided by the District and are included in Appendix A.

The following is a summary of the methodologies, input and results.

- **Mapping:** Where available, the 1997 and 1998 mapping prepared for Sweat Canyon and Gavilan Peak studies (4 ft or 10 ft contour intervals) was used. 1 inch 200 feet, 2 ft contour and Digital Terrain Map dated 2000 was prepared for remaining areas. Datum is NGVD29.

- **Subbasin Delineation:** 10 subbasins with areas ranging from 0.027 to 0.258 square miles.

- **Precipitation:** The 100-year, 24-hour point rainfall depth is 4.72 inches with an areal reduction of 0.993 based on NOAA HYDRO-40. The temporal distribution is the SCS Type II

- **Hydrograph**: Phoenix Mountain S-graph method option in HEC-1. Input for the UI card was generated using DDMS-W software.

- **Rainfall Losses:** Green and Ampt, parameters were calculated with DDMS-W. XKSAT values range from 0.05 to 0.22 inches per hour.

- **Routing Method:** Normal depth cross sections developed in AutoCAD from digital photography and from field investigations. Manning's n calculated using Thomsen and Hjalmarson (1991). Storage routing developed using HY-8 analysis of culverts to generate elevation-discharge curves and topography to generate elevation-storage curves.

- **Calibration:** No calibration was performed. Indirect verification results indicated that peaks were reasonable.

TABLE 2.3
Selected Black Wash Results

Concentration Point Description (1)	Q cfs (2)	Time to Peak hours (3)	Area square mile (4)
I-17 Crossing	1,680	12	0.8
I-17 Crossing	1,480	12.08	0.83
New River Road crossing	1,780	12.08	1
End of Model, Confluence with New River	1,930	12.08	1.1

2.4 SWEAT CANYON WASH WATERSHED

Sweat Canyon Wash Flood Insurance Study Dated May 1, 1999

David Evans and Associates performed the Sweat Canyon Flood Insurance Study. The study watershed is approximately 15.5 square miles and drains to Sweat Canyon Wash and its tributaries including Doe Peak Wash. Approximately 3.5 linear miles of floodplain was delineated for Sweat Canyon Wash and Doe Peak Wash.

Two-foot contour aerial mapping performed for the study was used to build HEC-1 hydrologic models and HEC-RAS hydraulic models. The digital 100-year, 6- and 24-hour HEC-1 input and output files as well as the watershed and flow path delineation for this project were provided by the District and are included in Appendix A.

The following is a summary of the methodologies, input and results.

- **Mapping:** Project specific 1997 mapping at a scale of 1 inch= 200 feet, 2-and 10-foot contour intervals. Horizontal control is NAD83, elevation is referenced to NAVD88 and converted to NGVD29.

- **Subbasin Delineation:** 43 subbasins with areas ranging from 0.017 to 0.863 square miles.

- **Precipitation:** The 100-year, 24-hour point rainfall depth is 4.6 inches, and 100-year 6-hour depth is 3.4 inches. Areal reduction was done through the use of JD cards based the depth area reduction table in the Design manual. The temporal distribution is the SCS Type II for the 24-hour storm and District Pattern 3 for the 6 hour storm.

- **Hydrograph**: Phoenix Mountain and Desert/Rangeland S-graphs. K_n values were based on subbasin gradient and connected impervious areas. DDMS (1995) was used to generate the unit hydrographs.

- **Rainfall Losses:** Green and Ampt loss rate parameters were used. Subbasin specific parameters were created using DDMS software. XKSAT values range from 0.01 to 0.38 inches per hour.

- **Routing Method:** Normal Depth channel routing was used with cross sections taken from topo and field observations. Culverts were input as stage-discharge relationships.

- **Calibration:** No calibration was performed. Results were plotted on USGS envelope curves and found to be reasonable.

Table 2.4
Selected Sweat Canyon Wash Results

Concentration Point Description (1)	Q (cfs) (2)	Time to Peak hours (3)	Area square miles (4)
Doe Peak Wash	830	12.08	0.49
At New River Road	13,000	12.75	15.06
End of Model, Confluence with New River	13,000	12.75	15.49

2.5 NEW RIVER WEST TRIBUTARIES WATERSHEDS

New River West Tributaries Flood Delineation Study. Dated September 26, 2005

Eleven watersheds, totaling approximately 13.6 square miles, south and southwest of Sweat Canyon Wash and west of New River were studied by URS for the New River West Tributaries study. Project specific topographic 2-foot contour interval mapping was used to develop HEC-1 hydrologic and HEC-RAS hydraulic models for the project. The digital 100-year, 6- and 24-hour HEC-1 input and output files as well as the watershed and flow path delineation for this project were provided by the District and are included in Appendix A.

The following is a summary of the methodologies, input and results.

- **Mapping:** 1 inch = 200 feet DTM, 2-ft contour, developed for the project. Datum is NAVD 88.

- **Subbasin Delineation:** A total of 98 subbasins ranging from 0.0009 to 0.627 square miles.

- **Precipitation:** The 100-year, 24-hour point rainfall depth ranges from 4.18 to 4.53 inches, and 100-year 6-hour depth ranges from 3.32 to 3.37 inches. Areal reduction was done through the use of JD cards, based the depth area reduction table in the Design manual. The temporal distribution is the SCS Type II for the 24-hour storm and District interpolated patterns for the 6-hour storm.

- **Hydrograph:** Maricopa County S-graphs with lag time calculated with WMS Custom Method (equation 5.11 in DDMMC- Hydrology), Phoenix Mountain or Desert Rangeland depending on the basin.

- **Rainfall Losses:** Green and Ampt based on the FCDMC GIS database. WMS 7.0 used to extract composite values. XKSAT values range from 0.012 to 0.432 inches per hour.

- **Routing Method**: Normal depth storage routing was used for most reach routes. Culvertmaster was used to form an area-discharge relation for culverts under the CAP.

- **Calibration:** The output was checked against USGS regression equations and found to be acceptable.

TABLE 2.5
Selected New River West Tributary Results

Concentration Point Description (1)	Q (cfs) (2)	Time to Peak hours (3)	Area square mile (4)
End of Model K, Confluence with New River	7,620	12.83	6.75
End of Model J, Confluence with New River	800	12.50	0.82
End of Model I, Confluence with New River	370	13.17	0.55
End of Model H, Confluence with New River	440	12.50	0.35
End of Model G, Confluence with New River	230	12.42	0.23
End of Model F, Confluence with New River	480	12.92	0.72
End of Model E, Confluence with New River	430	12.42	0.36
End of Model D, Confluence with New River	1,090	13.42	2.17
End of Model C, Confluence with New River	360	12.42	0.23
End of Model B, Confluence with New River	530	12.58	0.56
End of Model A, Confluence with New River	120	12.17	0.86

2.6 DEADMAN WASH WATERSHED

Deadman Wash Floodplain Delineation Study. Dated December 1, 1992

A floodplain delineation of Deadman Wash was completed by HNTB, from the confluence with New River to a point upstream of the I-17 Bridge. USGS Quadrangle

maps were used to delineate the 34-square mile watershed. An HEC-1 hydrologic model and HEC-2 hydraulic model were developed. The digital 100-year, 6- and 24-hour HEC-1 input and output files as well as the watershed and flow path delineation for this project were provided by the District and are included in Appendix A.

The following is a summary of the methodologies, input and results.

- **Mapping:** USGS 1 inch = 2,000 feet with 20-ft and 40-ft contour intervals.

- **Subbasin Delineation:** 14 major drainage basins with 86 total subbasins ranging from 0.033 to 2.41 square miles.

- **Precipitation:** The 100-year, 24-hour point rainfall depth is 4.38 inches, and 100-year 6-hour depth is 3.37 inches. Areal reduction was done through the use of JD cards based the depth area reduction table in the Design manual. The temporal distribution is the SCS Type II for the 24-hour storm and District interpolated patterns for the 6-hour storm.

- **Hydrograph**: Phoenix Mountain and Phoenix Valley S-Graphs converted to unit hydrographs by MCUHP2.

- **Rainfall Losses:** Green and Ampt using SGRAPH.WK1 spreadsheet program to tabulate parameters. XKSAT values range from 0.01 to 0.57 inches per hour.

- **Routing Method:** Normal Depth channel routing with reservoir storage routing and roadway overtopping analysis from HY-8 Culvert Hydraulics v.1.1. Channel transmission losses were included in the RL card. The infiltration loss rate was computed based on SCS soil maps and averaged over the routing reach. Range is from 0.010cfs/acre to 0.940 cfs/acre (low to moderate).

- **Calibration:** The model was calibrated using the March 1, 1991 storm. Streamflow gage data was taken from 09513820 (Deadman Wash near New River), and precipitation data from FCD gages #2630, 2605 and 2700.

TABLE 2.6
Selected Deadman Wash Results

Concentration Point Description (1)	Q (cfs) (2)	Time to Peak hours (3)	Area square miles (4)
Carefree highway crossing	5,550	14.17	19.07
Carefree highway crossing- culvert	4,490	14.42	0.08
Carefree highway crossing	1,300	12.58	1.58
I-17 Crossing	4,220	13.08	6.3
End of Model, Confluence with New River	9,600	13.83	34.01

3.0 METHODOLOGY

Hydrologic models prepared for this study are a composite of existing studies and new, detailed hydrology. Existing studies incorporated are:

- New River FIS
- Deadman Wash
- Gavilan Peak Wash
- Black Wash
- Sweat Canyon
- New River West Tributaries

These models or portions of models were incorporated without change, excepting changes that were necessary to integrate the models and the appropriate modifications to the rainfall input. For the purposes of this study, a single rainfall data set is estimated for the entire study watershed and applied to all models. The methodology described below applies only to the detailed hydrology that was performed for the Upper New River ADMP. The limits of the detailed study area are shown in Figure 3.1.

Method Description- Modeling was performed using the methodologies and procedures set forth in the Drainage Design Manual for Maricopa County, Volume I, Hydrology (Flood Control District of Maricopa County, 1995), which is herein referred to as the Design Manual. Rainfall-runoff modeling was accomplished using the USACE HEC-1 Computer Program, version 4.1, dated June 1998. The Drainage Design Management System for Windows Version 2.1.0 (DDMSW) was used to develop precipitation and basin input for HEC-1.

3.1 PRECIPITATION

Point Precipitation Values- A total of six storm events were modeled; the 10-, 50-, and 100-year recurrence periods were each evaluated for the 6- and 24-hour storms. In order to obtain depth-duration-frequency estimates for the watershed, values for the 2-year 6- and 24-hour storms, as well as the 100-year, 6- and 24-hour storms were estimated at the centroid of the watershed from isopluvials published in NOAA Atlas II (Figure 3.2). The resulting values were input into the PREFRE function imbedded in DDMSW, which generated the values shown in Table 3.1. These values were automatically coded into the model and used for the 50- and 100-year precipitation.

In order to approximate a 10-year runoff event for each rainfall duration, a ratio of 0.33 was applied to the runoff values from all subbasins in the watershed, including those brought in as part of previous studies. This ratio was determined by comparing the 100-year runoff (35,000 cfs) with the 10-year runoff (11,400 cfs) at the USGS New River near Rock Springs stream gaging station #9513780, shown on Figure 3.1.

Yavapai County
Maricopa County
Rock Springs
09513780 -
New River near Rock Springs
Upper New River ADMP
Detailed Study Area
Gavilan Peak
Black Wash
09513800 -
New River at New River
Sweat Canyon
09513820 -
Deadman Wash near New River
West
Tributaries
Deadman Wash
Upper New River ADMP
Detailed Study Area
T08N R02E
T08N R03E
T08N R04E
T08N R05E
T07N R01E
T07N R02E
T07N R03E
T07N R04E
T07N R05E
T06N R01E
T06N R02E
T06N R03E
T06N R04E
T06N R05E
T05N R01E
T05N R02E
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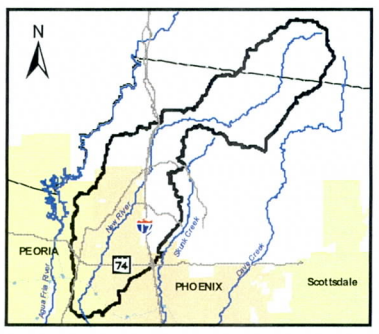
T04N R03E
T04N R04E
17
74

Location Map:



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Notes:

Sheet 1 of 1

N
Not to scale

Legend:

- USGS Gage
- Roadway
- Watershed Boundary
- Previous study area
- Upper New River ADMP Detailed Study Area
- Township and Range
- Section

Flood Control District of Maricopa County
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Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
Figure 3.1
Previous Study Areas

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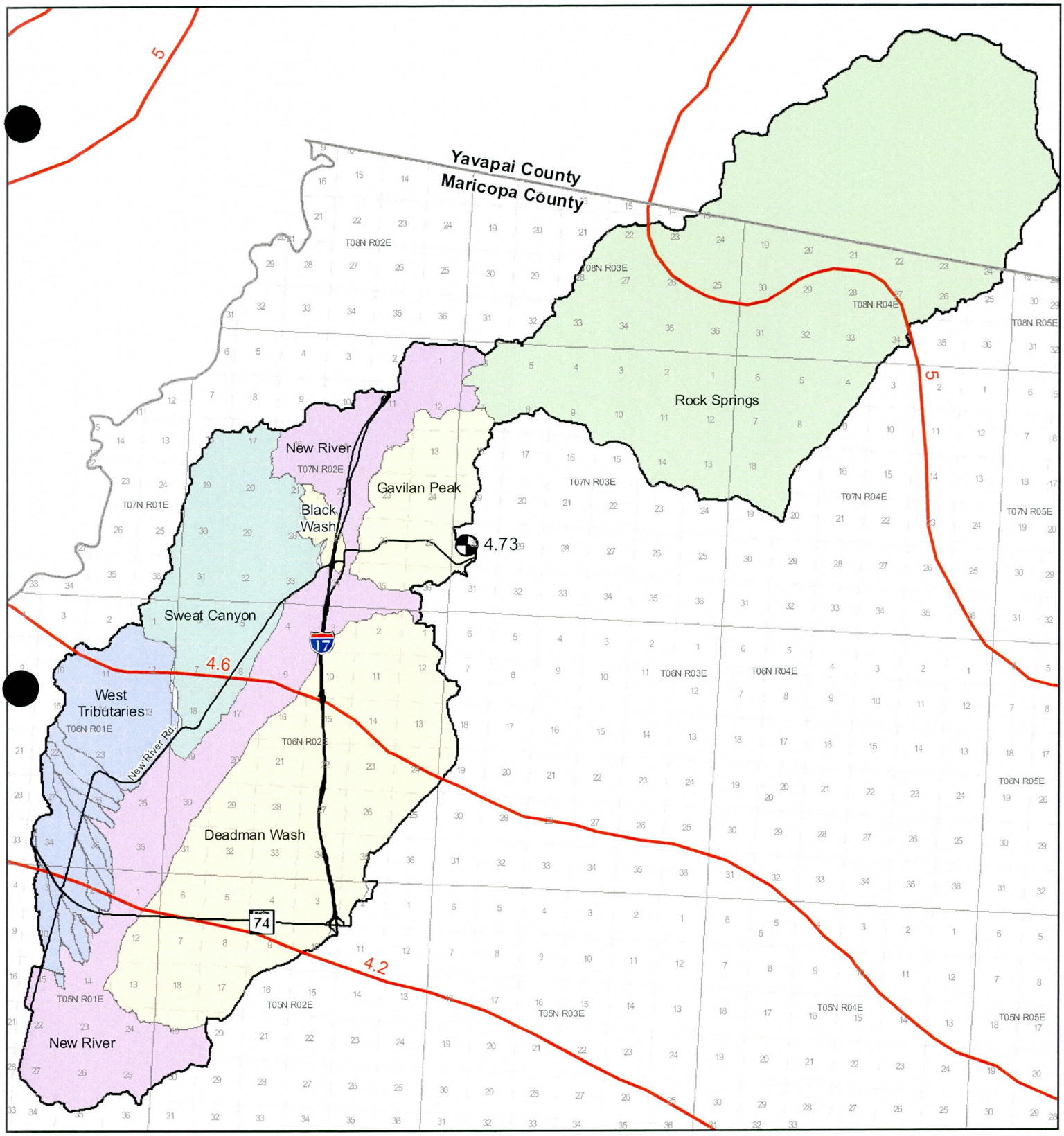

Location Map:

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Notes:

Isopluvials based on NOAAAtlas 2

Legend:

N
Not to scale

- Centroid
- Roadway
- 100-year, 24-hour isopluvial (inches)
- Township and Range
- Section
- Watershed Boundary

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Upper New River ADMP
FCD 2005CO20
Figure 3.2a
100-Year, 24-Hour Isopluvial

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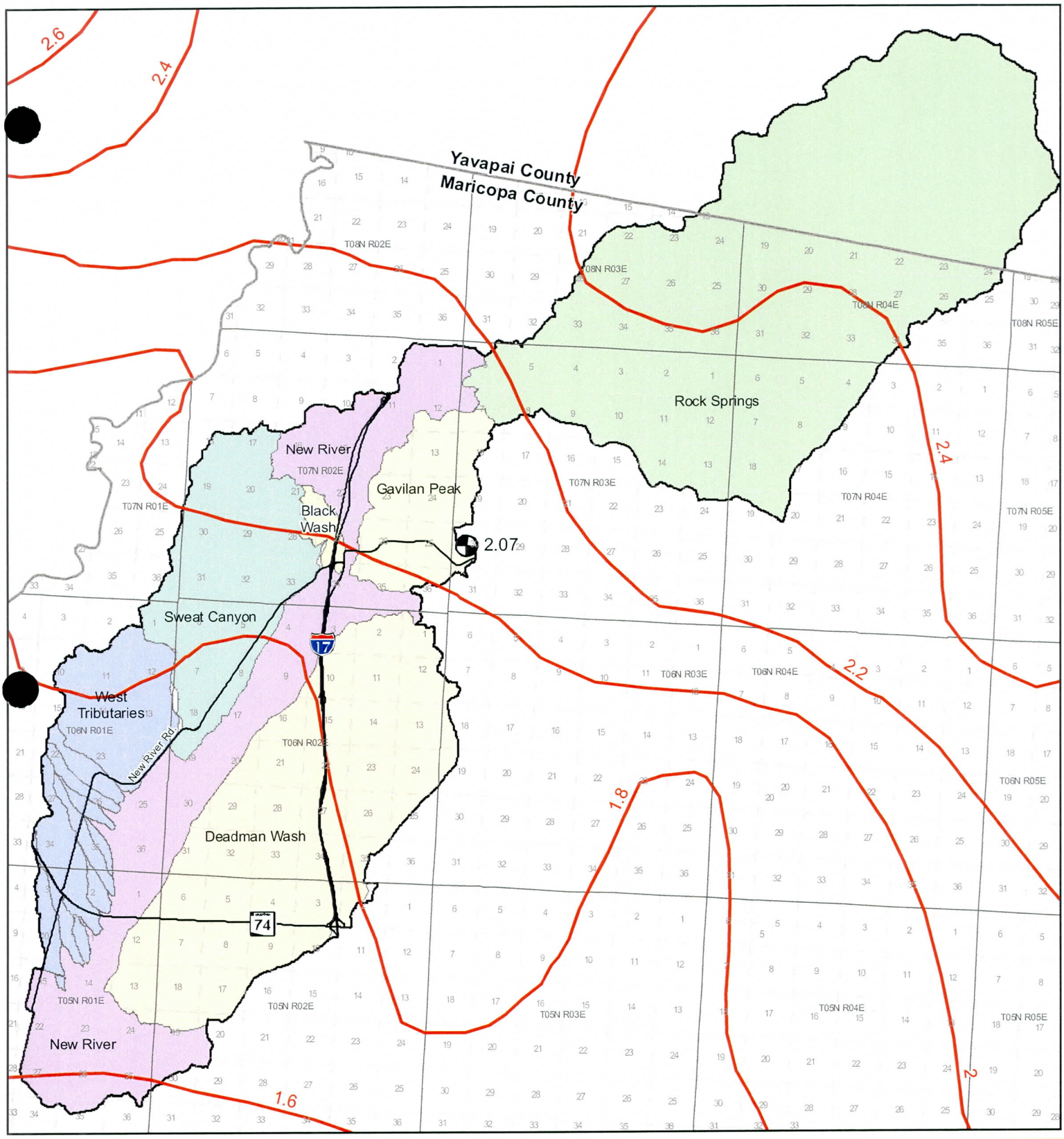

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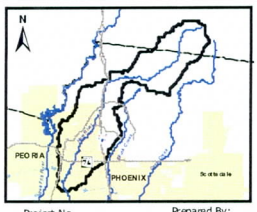

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182000418

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Notes:

Isopluvials based on NOAA Atlas 2

N
Not to scale

Legend:

- Centroid
- Roadway
- 2-year, 24-hour isopluvial (inches)
- Township and Range
- Section
- Watershed Boundary

Flood Control District of Maricopa County
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Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
Figure 3.2b
2-Year, 24-Hour Isopluvial

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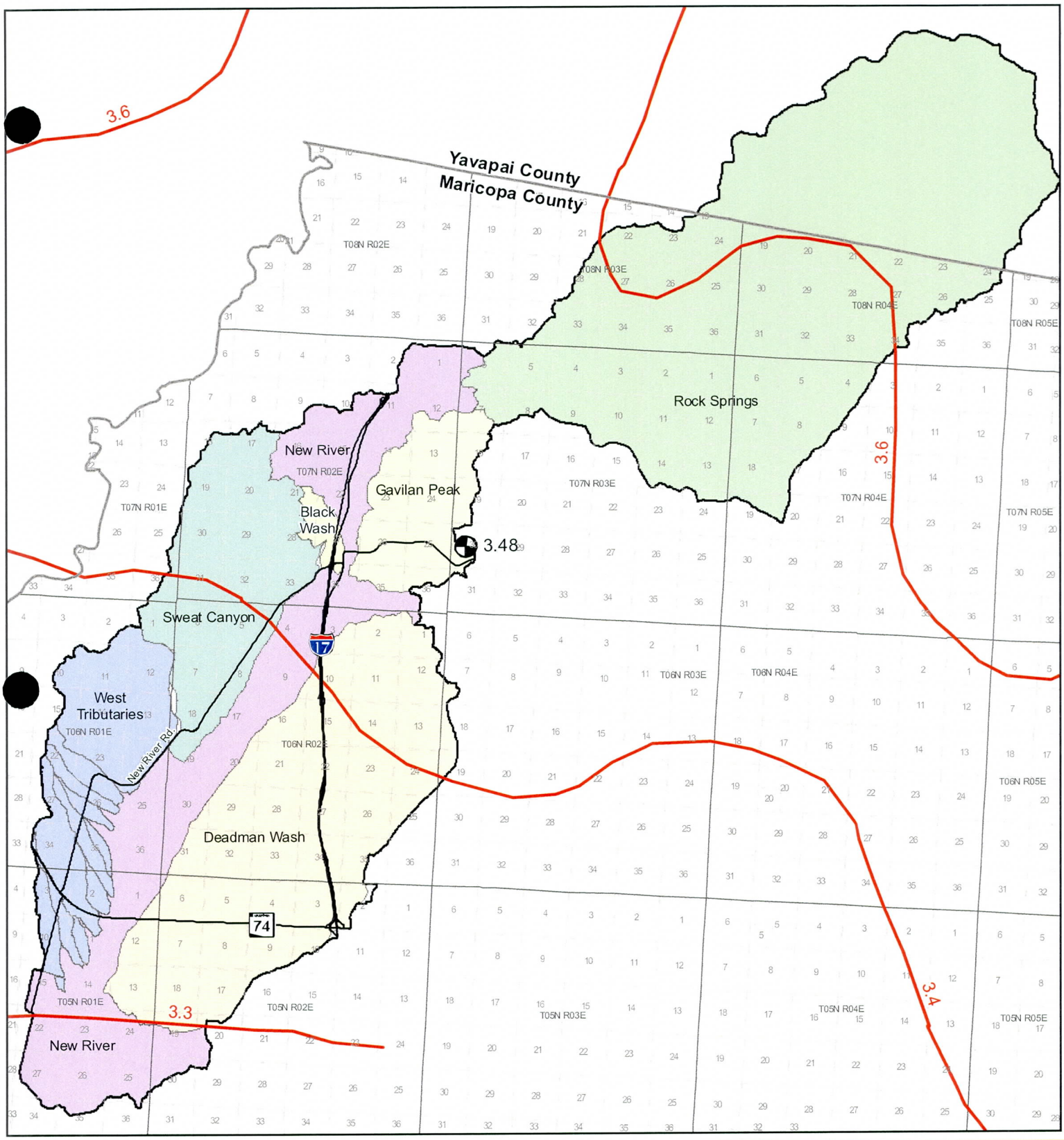

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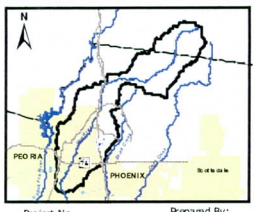

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182000418

Prepared By:
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Notes:

Isopluvials based on NOAA Atlas 2

Legend:

N
Not to scale

- Centroid
- Roadway
- 100-year, 6-hour isopluvial (inches)
- Township and Range
- Section
- Watershed Boundary

Flood Control District of Maricopa County
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Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
Figure 3.2c
100-Year, 6-Hour Isopluvial

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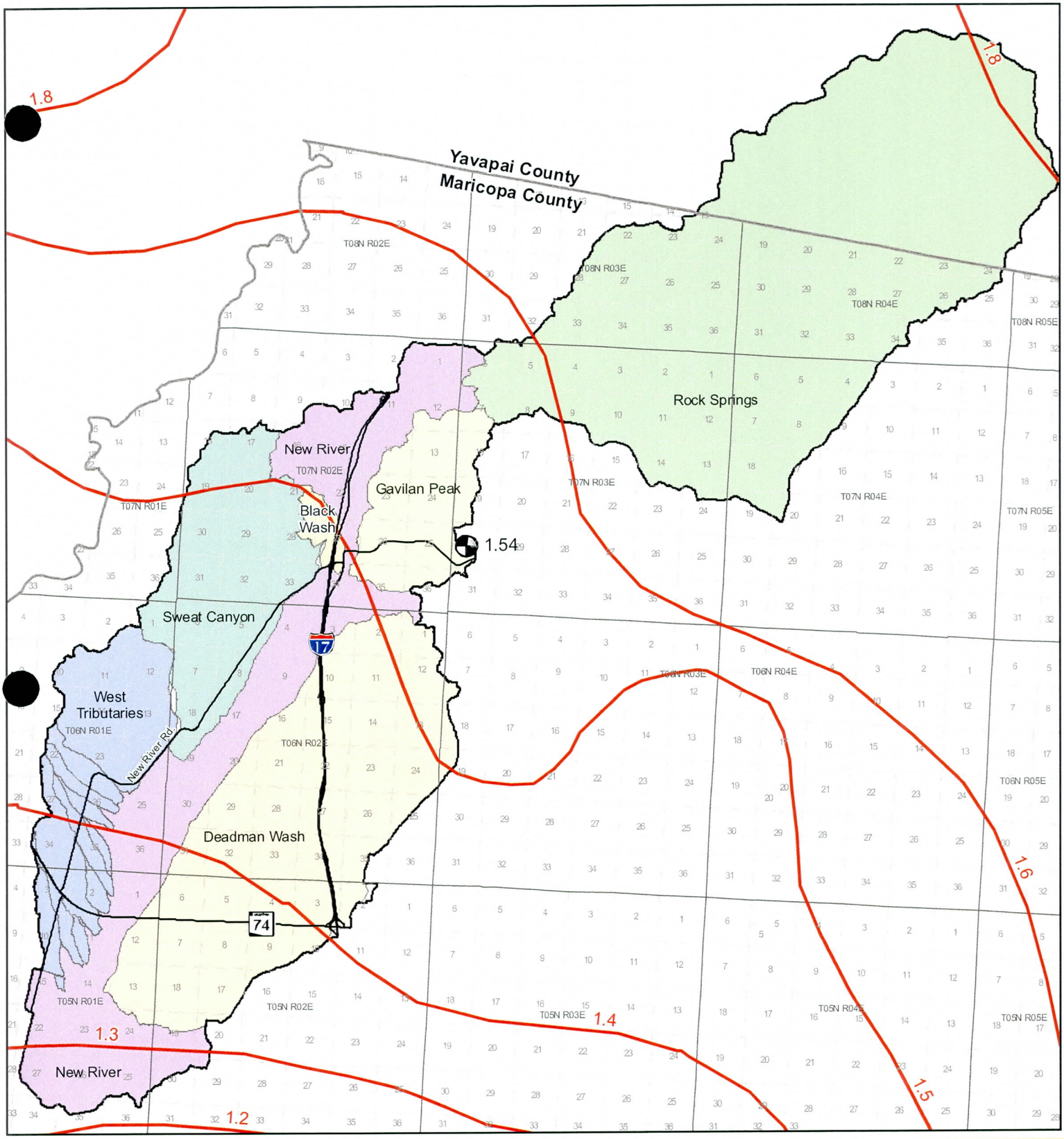
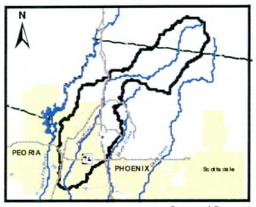


Location Map:



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Notes:

Isopluvials based on NOAAAtlas 2

Legend:

N
Not to scale

- Centroid
- Roadway
- 2-year, 6-hour isopluvial (inches)
- Township and Range
- Section
- Watershed Boundary

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Upper New River ADMP
FCD 2005CO20
Figure 3.2d
2-Year, 6-Hour Isopluvial

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TABLE 3.1
Precipitation Depth-Duration-Frequency Table for Upper New River ADMP

Duration	2	5	10	25	50	100	500
	Frequency, in years						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
5-min	0.36	0.45	0.51	0.59	0.66	0.73	0.88
10-min	0.54	0.68	0.77	0.91	1.01	1.12	1.36
15-min	0.66	0.85	0.97	1.15	1.29	1.43	1.75
30-min	0.88	1.13	1.31	1.56	1.75	1.94	2.39
1-hr	1.07	1.4	1.62	1.94	2.18	2.43	2.99
2-hr	1.23	1.6	1.86	2.22	2.51	2.79	3.43
3-hr	1.34	1.74	2.02	2.42	2.72	3.03	3.73
6-hr	1.54	2.01	2.33	2.78	3.13	3.48	4.29
12-hr	1.8	2.36	2.74	3.27	3.69	4.11	5.06
24-hr	2.07	2.71	3.15	3.77	4.25	4.73	5.83

Areal Precipitation Reduction- Precipitation reduction for the 6-hour storm is based on the depth-area curve developed for the historic storm of 1954 over the Queen Creek, Arizona area by the USACE in 1974. That depth-area curve is listed in the Design Manual. The precipitation patterns and corresponding area reduction factors are selected automatically by the enhanced version of the DDMSW program.

The precipitation reduction factors used for the 24-hour storms are listed in the Design Manual and those values were derived from information contained in the NOAA Technical Memorandum HYDRO40 (NWS, 1984). Appropriate depth area reduction for all storms and accumulated drainage areas is simulated in HEC-1 using the JD record option. Table 3.2 summarizes the basin areas, reduction factors and areally reduced point precipitation values used for the 24-hour HEC-1 models. The 6-hour aeral reduction factors are generated automatically through DDMSW and incorporated into the model.

Table 3.2
Summary of 100-year, 24-hour Areal Reduction Factors And Corresponding Drainage Areas

Basin Area square miles (1)	Areal Reduction Factor (2)	100-year Areally Reduced Point Precipitation inches (3)	50-year Areally Reduced Point Precipitation inches (4)
0.01	1.00	4.73	4.25
0.5	0.998	4.72	4.24
2	0.987	4.67	4.19
16	0.922	4.36	3.92
90	0.846	4.00	3.60
180	0.820	3.88	3.49

Temporal Distribution- Both the 6- and 24-hour duration storms are modeled for each frequency under existing and future conditions. Two storm durations are used in order to determine which storm results in the higher magnitude of discharge at the various locations in the watershed. The rainfall distributions for the 6-hour duration storm are based on watershed area, and are listed in the Design Manual. Each precipitation pattern is valid for a certain watershed area and is automatically coded into the model by DDMSW. The SCS Type II rainfall distribution is used for the 24-hour storm.

3.2 INPUT PARAMETER ESTIMATION

Hydrologic parameters for the watershed and modeling subbasins are estimated in conformance with the Design Manual. The procedures used for estimation of those parameters are discussed in the following sections. Pertinent supporting data and calculations are provided in the technical appendices as noted.

3.2.1 Basin Delineation

Watershed Boundary Delineation- The study watershed encompasses approximately 175 square miles, and falls within Maricopa and Yavapai Counties. Within Maricopa County, the watershed boundary and subbasin boundaries were delineated using the countrywide 10-foot contour interval mapping. Flight dates for the countywide mapping are December 16, 2000 and January 4, 2001. Elevations are referenced to the North American Vertical Datum, 1988 (NAVD88).

The horizontal datum is Stateplane, Zone 3176, Units International Feet, GRS 1980, North American Datum, 1983 (NAD83). The portion of the watershed in Yavapai County was delineated using USGS 7.5 Minute Series Quadrangle maps.

Where subwatershed and subbasin delineations existed as part of a previous hydrologic study, the boundaries were accepted and used to develop the overall watershed boundary. The District provided GIS shapefiles of the subwatershed delineations for Sweat Canyon, Gavilan Peak Wash, Black Wash and the New River West Tributaries. The subwatershed boundaries for Deadman Wash and above Rock Springs were not available in electronic format, and were recreated based on countywide 10-foot contours, USGS topographic mapping and figures provided in the respective reports. Watershed maps for each of these areas are provided on Plates 1 through 5.

Subbasin Delineation- New detailed hydrology is performed for an area of approximately 29 square miles. Subbasins were delineated to provide runoff values at specific locations, or concentration points. In general, concentration points were placed at:

- Major wash confluences, existing culvert or bridge crossings and future roadway crossings.
- Locations along the washes for use in the of erosion hazard setback analyses.
- Potential flow splits and areas where flow exits main channel borrow pits.

The subbasin boundaries were delineated using the countywide 10-foot contour interval mapping. Subbasin delineations were especially difficult along I-17 and in the lower watershed where flat slopes and distributary flow characteristics made it difficult to determine the runoff direction from the 10-foot contour interval mapping. Reconnaissance trips to the watershed served as guidance for delineation in locations found to be lacking sufficient topographical detail. The final watershed and subbasin boundaries are plotted on Figure 3.3.

Subbasins generally fall into two main categories, those in mountainous areas and those in the lower, flatter areas. Mountainous subbasins such as NR1-NR8, CAP 1-CAP3 and UT1-UT3 are characterized by steep slopes with dendritic and well defined drainage channels. The lower subbasins such as NR17-NR26 are characterized by smaller elevation changes and braided watercourses. Drainage channels are often poorly defined and flow can breakout from one basin to another, making these basins difficult to delineate. In areas where flow was found to cross subbasin boundaries, diversions were created within the model.

Subbasin areas were determined using ArcView. Data results were spot-checked for errors, as well as cross-checked with soil and land use polygon data obtained by the same software (soils and land use area calculations are discussed in the following section).

3.2.2 Rainfall Loss Parameters

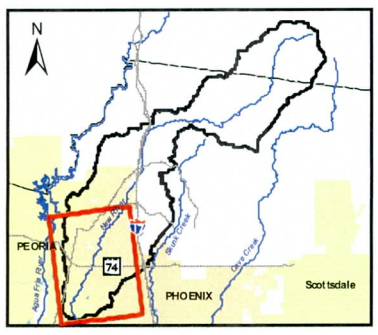
Rainfall losses for the detailed study area are estimated using the Green and Ampt loss rate method as implemented in HEC-1 and as recommended in the Design Manual. This method combines the Green and Ampt infiltration equation with surface retention to estimate the rainfall loss after accounting for impervious area. The Green and Ampt infiltration equation requires three parameters: XKSAT (hydraulic conductivity at natural saturation in inches/hour), PSIF (wetting front capillary suction in inches), DTHETA (volumetric soil moisture deficit). Values of XKSAT are selected based on soil texture and can be modified to reflect the effects of vegetative cover. PSIF and DTHETA are estimated as a function of bare ground XKSAT.

Values for surface retention (IA) are estimated based on landform and land use conditions present within the study area. Impervious area (RTIMP) is estimated to reflect naturally occurring rock outcrop and land use conditions. Final subbasin Green and Ampt method parameters were obtained for each subbasin from soils and land use data using DDMSW.

Soil Parameters - Soil properties and texture classifications are used to estimate the bare ground XKSAT variable of the Green and Ampt method. Values of XKSAT and RTIMP were assigned to each map unit based on interpretation of the NRCS soil surveys and are included as default values in DDMSW. The study area falls entirely within the Aguilla/Carefree soil survey. A summary of the soil map units found in the detailed study area and their default XKSAT and RTIMP values is shown on Table 3.3.

NR15
NR19
NR16
MATCH TO SHEET 2
NR21
NR20
NR17
NR22
NR23
NR18
NR24
NR26
NR25
NR27
CAP1
CAP2
CAP3
CAP4
170
175
180
185
190
195
200
205
215
225
226
230
241
242
243
244
250
T06N R01E
T06N R02E
T05N R01E
T05N R02E
NEW RIVER RD.
CAREFREE HIGHWAY
74

Location Map:



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Notes:

Sheet 1 of 2

10 foot contour interval
topography circa January 2001

N
Not to scale

Legend:

- Concentration Point
- Concentration Point Label
- Contour
- Roadway
- Detailed Area Subbasin Boundary
- Watershed Boundary
- Section
- Township and Range

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Upper New River ADMP
FCD 2005CO20
Figure 3.3 Sheet 1
Upper New River ADMP
Detailed Hydrology

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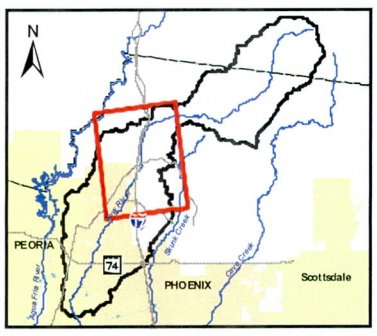
NR1
NR2
NR3
NR4
NR5
NR6
NR7
NR8
NR9
NR10
NR11
NR12
NR13
NR14
NR15
NR16
NR19
UT1
UT2
UT3
100
105
110
115
116
120
125
130
140
145
150
153
152
151
154
160
165
170
T07N R02E
T06N R02E
NEW RIVER RD.
17
MATCH TO SHEET 1

Location Map:



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Notes:

Sheet 2 of 2

10 foot contour interval
topography circa January 2001

N
Not to scale

Legend:

- Concentration Point
- Concentration Point Label
- Contour
- Roadway
- Detailed Area Subbasin Boundary
- Watershed Boundary
- Township and Range
- Section

Flood Control District of Maricopa County

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Upper New River ADMP
FCD 2005CO20
Figure 3.3 Sheet 2
Upper New River ADMP
Detailed Hydrology

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The SCS Survey soil unit mapping for detailed study area was supplied in digital format by the District. Within ArcView, the digital soil mapping was intersected with the delineated subbasins. The resulting shapefile provides the areas of each soil map unit included in each subbasin. This information was input into the DDMSW program, which calculated a log-area weighted XKSAT value and impervious/rock outcrop percentages (RTIMP) for each subbasin. DDMSW data files are provided as Appendix B.

TABLE 3.3
Summary of XKSAT and RTIMP values for soil map units within the Upper New River detailed study area

Soil Class (1)	Bare Ground XKSAT in/hr (2)	RTIMP % (3)	Soil Class (1)	Bare Ground XKSAT in/hr (2)	RTIMP % (3)
2	0.41	0	55	0.27	0
3	0.58	0	66	0.23	0
6	0.62	0	72	0.09	30
8	0.96	0	93	0.33	0
10	0.94	0	95	0.04	0
12	0.01	0	96	0.07	0
13	0.01	0	98	0.37	0
21	0.38	0	100	0.4	20
24	0.02	0	103	0.1	65
26	0.01	0	104	0.14	60
28	0.02	0	109	0.35	35
31	0.33	35	110	0.13	0
33	0.23	0	111	0.4	0
34	0.23	0	112	0.39	0
40	0.17	0	113	0.39	0
41	0.17	0	115	0.39	0
44	0.03	0	118	0.42	0
49	0.06	0	120	0.06	0
52	0.16	20	123	0.37	0

Land Use Parameters – Under existing conditions, the detailed watershed is primarily undeveloped desert mountain/rangeland with only a few isolated pockets of developed land. The natural desert consists of mountain, terrace and floodplain areas, while the developed uses include residential development and commercial/industrial areas.

Land use polygons within the study area were delineated to represent areas of unique physical characteristics which influence rainfall loss parameters. The delineation was

based on circa 2006 aerial photography supplied by the District and field reconnaissance trips.

The land use classifications were assigned values for surface retention (IA), percent of impervious area (RTIMP) and vegetative cover based on guidelines in the Design Manual and defaults available in DDMSW. Where appropriate, land use classification descriptions provided in the Design Manual were modified or new classifications were added that are representative of the conditions present in the detailed study area.

Natural desert areas were divided into four classifications based on landform characteristics and vegetation density. Vegetation transects were taken during field visits and used as a guide to estimating vegetation cover from aerial photographs and the characteristics of various desert areas. A summary of the land use classification identifiers and their descriptions are provided in Table 3.4. The land use classifications for the detailed study area are shown on Figure 3.4. DDMSW data files are provided as Appendix B.

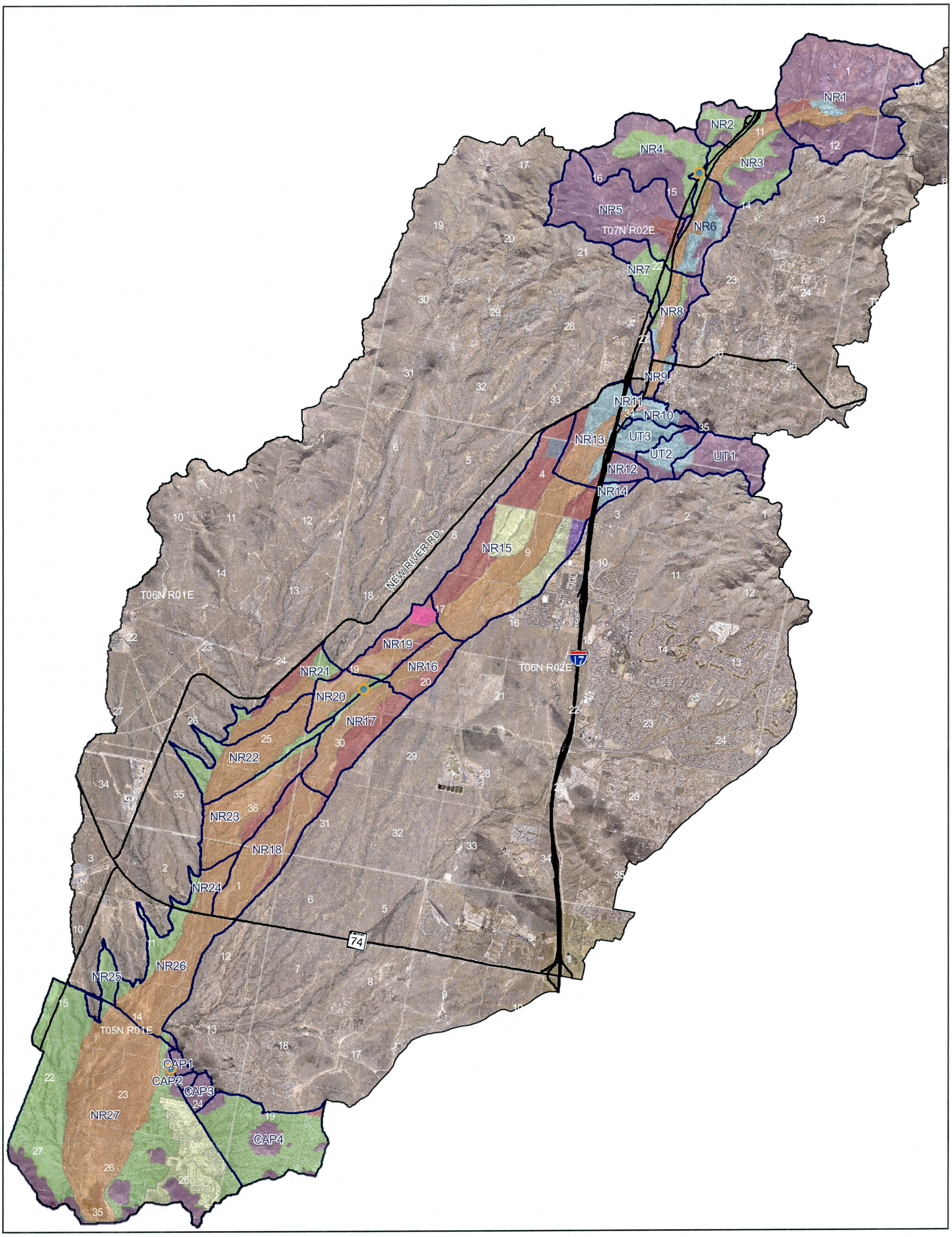
TABLE 3.4
Existing Land Use Classifications

Land Use Code	Description	IA	RTIMP	Vegetation Cover	DTHETA	K_n
		in	%	%		
V.L.D.R.	Very Low Density Residential	0.3	5	30	Normal	0.05
M.D.R.	Medium Density Residential	0.25	30	50	Normal	0.05
IND	Industrial	0.15	55	60	Normal	0.03
COMM	Commercial	0.1	80	75	Normal	0.02
GR	Gravel Roadways and Shoulders-Graded and Compacted	0.1	5	0	Normal	0.021
NDR	Undeveloped Desert Rangeland	0.35	0	45	Dry	0.05
NHS	Hillslopes, Sonoran Desert	0.15	0	34	Dry	0.05
NHSS	Hillslopes, Sonoran Desert, Sheet Flow	0.15	0	34	Dry	0.05
NMT	Mountain Terrain	0.25	0	25	Dry	0.05
P	Pavement and Rooftops	0.05	95	0	Normal	0.02

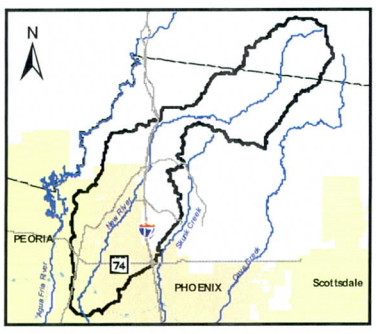
Land use polygon mapping was intersected with subbasin boundaries using ArcView. The resulting shapefile provides the areas of each land use type included in each subbasin. This information was input into the DDMSW program, which calculated composite IA, RTIMP, XKSAT, DTHETA, PSIF and K_n values for each subbasin. The resulting values are listed in Table 3.6.

3.2.3 Unit Hydrograph Parameters

For the detailed watershed area, rainfall excess is transformed to a runoff hydrograph by applying the Phoenix Mountain and Phoenix Valley S-graphs. Selection of the appropriate S-graph for each subbasin was a function of the individual subbasin



Location Map:



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Notes:

Base photography circa 2006

N
Not to scale

Legend:

- Vegetation Transect Location
- Roadway
- Watershed Boundary
- Detailed Area Subbasin Boundary
- Section
- Township and Range

Landuse

- COMM
- GR
- IND
- M.D.R.
- NDR
- NHS
- NHSS
- NMT
- P
- V.L.D.R.

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Upper New River ADMP
FCD 2005CO20
Figure 3.4
Existing Conditions Land Use

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characteristics. The Phoenix Mountain S-Graph was used for subbasins with large vertical relief and mountainous terrain, while the Phoenix Valley S-graph was used for subbasins with less elevation change.

Application of the S-graph method requires the selection of the unit duration of rainfall excess (NMIN) and the estimation of basin lag. Values of NMIN are typically selected to provide adequate definition of the unit hydrograph and should lie within the range of 0.1 to 0.25 times the minimum T_c occurring in the watershed. All previous studies in the watershed were run with an NMIN of 5 minutes, which was found to give reasonable results. For consistency and in order to simplify the addition of previous models, an NMIN of 5 minutes is used for the detailed study reach as well.

K_n (mean basin Manning's n-value) values for each land use classification were selected based on the guidance provided in the Design Manual. The Phoenix Mountain S-graph was derived from reconstitutions of flood events in the Upper New River watershed. The Phoenix Valley S-graph was derived from reconstitutions of flood events that included the New River watershed. Determination of K_n values specific to the flood events was part of the reconstitutions. Use of those values for undeveloped land use classifications present within the detailed study area provides consistency to the source data. Where the default K_n values differed from the reconstituted values, the reconstituted values were used. All values used are listed in Table 3.4.

Physical attributes from each subbasin were calculated as part of the unit hydrograph process. These attributes included the basin area, longest flow path, length to centroid and slope of the basin. Basin areas and flowpath lengths were calculated using the geometry calculator in ArcView. Similarly, subbasin centroids were calculated in ArcView and the length from the centroid to the basin outlet along the flowpath was estimated manually. A summary of physical attributes for each basin can be found in Table 3.5.

The S-graph was converted into unit hydrographs for each subbasin through the DDMSW program. A summary of the basin attributes calculated through DDMSW are presented in Table 3.6, and DDMSW data files are provided as Appendix B.

Table 3.5
Summary of unit hydrograph input data

Subbasin	Area	Flowpath Length	Length to Centroid	Slope	S-Graph
	Sq. miles	miles	miles	ft/mi	
(1)	(2)	(3)	(4)	(5)	(6)
NR1	2.33	2.41	1.00	248.9	Mountain
NR2	0.35	0.70	0.34	228.2	Mountain
NR3	0.98	1.30	0.53	92.3	Mountain
NR4	1.24	2.44	1.11	245.4	Mountain
NR5	1.44	2.34	1.21	269.6	Mountain
NR6	0.63	1.68	0.78	107.2	Mountain
NR7	0.33	1.30	0.69	192.4	Mountain
NR8	0.51	1.47	0.75	170.1	Mountain
NR9	0.11	0.81	0.39	61.6	Mountain
NR10	0.19	1.01	0.41	810.7	Mountain
NR11	0.11	0.61	0.29	128.2	Mountain
NR12	0.18	0.64	0.27	202.3	Valley
NR13	0.71	1.65	0.68	98.4	Valley
NR14	0.11	0.59	0.19	187.3	Valley
NR15	2.89	3.44	1.68	75.7	Valley
NR16	0.44	1.20	0.55	62.6	Valley
NR17	0.92	1.86	0.99	49.5	Valley
NR18	1.07	2.32	1.15	42.2	Valley
NR19	0.57	1.61	0.81	75.8	Valley
NR20	0.35	1.22	0.54	49.4	Valley
NR21	0.59	2.16	1.17	46.2	Valley
NR22	1.05	2.18	1.04	41.3	Valley
NR23	1.00	2.60	1.14	47.7	Valley
NR24	0.29	1.04	0.39	48.3	Valley
NR25	0.15	0.89	0.40	72.1	Valley
NR26	1.25	2.02	1.22	42.2	Valley
NR27	6.21	3.74	1.88	34.7	Valley
CAP1	0.06	0.18	0.10	1963.2	Mountain
CAP2	0.05	0.31	0.13	1439.1	Mountain
CAP3	0.14	0.46	0.25	516.2	Mountain
CAP4	1.44	1.59	0.79	56.6	Mountain
UT1	0.55	1.83	0.79	360.1	Mountain
UT2	0.31	1.03	0.46	801.8	Mountain
UT3	0.30	1.25	0.58	344.6	Mountain

TABLE 3.6
Summary of DDMSW subbasin output data

Subbasin (1)	K_n (2)	Lag minutes (3)	IA inches (4)	DTHETA inches (5)	PSIF inches (6)	XKSAT in/hr (7)	RTIMP % (8)
NR1	0.05	35	0.30	0.26	5.8	0.19	21
NR2	0.05	15	0.30	0.25	5.6	0.22	5
NR3	0.05	26	0.31	0.23	6.6	0.15	17
NR4	0.05	37	0.30	0.19	6.6	0.14	13
NR5	0.05	37	0.30	0.25	5	0.28	26
NR6	0.05	33	0.31	0.27	4.7	0.32	4
NR7	0.05	25	0.30	0.25	5.7	0.2	15
NR8	0.048	27	0.30	0.28	6.2	0.18	16
NR9	0.044	19	0.28	0.3	4.1	0.54	21
NR10	0.047	14	0.28	0.15	7.6	0.1	48
NR11	0.04	12	0.24	0.2	6.8	0.15	35
NR12	0.05	13	0.30	0.15	9.7	0.05	5
NR13	0.049	31	0.31	0.21	8	0.09	5
NR14	0.047	11	0.28	0.15	8.8	0.06	14
NR15	0.048	59	0.27	0.18	9.7	0.06	22
NR16	0.048	27	0.29	0.28	6.8	0.15	13
NR17	0.05	43	0.30	0.25	7.3	0.13	14
NR18	0.048	49	0.30	0.28	7	0.14	14
NR19	0.045	31	0.26	0.22	8.8	0.07	13
NR20	0.05	29	0.31	0.29	6.8	0.15	12
NR21	0.045	45	0.28	0.29	6.6	0.17	22
NR22	0.05	48	0.31	0.31	4.9	0.34	11
NR23	0.05	52	0.29	0.16	10.1	0.04	18
NR24	0.034	17	0.21	0.32	4.2	0.48	20
NR25	0.046	20	0.23	0.18	7.3	0.12	30
NR26	0.037	37	0.23	0.34	4.55	0.36	7
NR27	0.05	77	0.21	0.32	4.7	0.35	12
CAP1	0.037	3	0.22	0.32	4	0.45	13
CAP2	0.027	3	0.15	0.35	4	0.42	15
CAP3	0.026	5	0.15	0.34	3.95	0.43	21
CAP4	0.049	36	0.29	0.26	4.25	0.44	14
UT1	0.05	27	0.30	0.25	4.65	0.32	35
UT2	0.05	15	0.30	0.15	8.4	0.07	10
UT3	0.049	21	0.30	0.15	8.4	0.07	8

3.2.4 Reach Route Parameters

Routing of subbasin hydrographs was performed using the Modified Puls channel routing options in HEC-1. In general, routes along the main stem of New River were modeled using channel storage routes based on stage-discharge relations, while routes in the detailed study but outside the main stem use the normal depth option. Routing reach flow paths were delineated from the 10-foot countywide mapping and are shown on Figure 3.5. Routing reaches are identified by a name that consists of the upper and lower concentration point numbers that define the reach. For example, Reach 110120 is the reach with concentration point 110 at the upstream and concentration point 120 at the downstream point.

Hydrologic routing was not performed for all reaches connecting concentration points; those reaches that did not lag the hydrograph one time step and provide attenuation were removed from the model. These reaches are noted in Table 3.7, which gives an overview of the routing reaches.

Normal Depth Routing

Cross Section Geometry- Representative cross sectional geometry for each normal depth channel route was developed from the project-specific 2-foot contour interval mapping provided by the District. For routing reaches where the cross sectional geometry throughout the reach was relatively uniform and could easily be characterized with only eight points, the geometry was taken directly from the topographic mapping. For reaches where the cross sectional geometry varied along the reach and/or was too complex to be directly described with an eight point cross section (i.e. multiple shallow channels inset in a broad floodplain), a representative cross section was approximated by inspection of the topography along the entire reach.

Manning's n Estimates - The normal depth option of the channel storage routing method requires a Manning's n-value estimate for the main channel and both the left and right overbank. Representative Manning's n-value estimates for each routing reach were made based on photographs taken during the field reconnaissance and judgment. For the routing reaches within the limits of the detailed study watercourse, the Manning's n estimates made for the hydraulic analysis are used. Representative routing reach Manning's n-values are determined by selection of the predominant values for all cross sections located within each routing reach. In general, all routing reaches are characterized by a well defined low flow channel with bed material which can range in size from sand to large cobbles. Overbank areas are typically flat with fine grained soils and sparse vegetation..

Routing Reach Length and Slope - The normal depth option parameters of reach length and energy slope (assumed to be the channel slope) are measured from the 2-foot contour interval detailed mapping prepared for this study. Table 3.7 summarizes the values used for each routing reach.

MATCH TO SHEET 2

T06N R01E

T06N R02E

T05N R01E

T05N R02E

NEW RIVER RD.

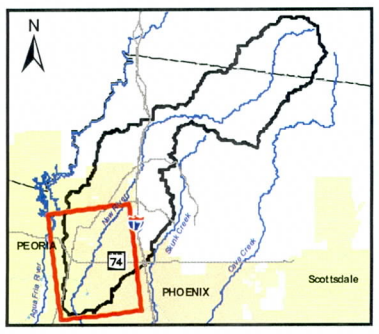
74

NR15 NR16 NR17 NR18 NR19 NR20 NR21 NR22 NR23 NR24 NR25 NR26 NR27

CAP1 CAP2 CAP3 CAP4

170 175 180 185 190 195 200 205 215 225 226 230 241 242 243 244 250

Location Map:



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AMG
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Notes:

Sheet 1 of 2

10 foot contour interval
topography circa January 2001

N

Not to scale

Legend:

- Concentration Point
- Concentration Point Label
- Roadway
- Contour
- Routing Reach
- Routing Reach and Time of Concentration
- Time of Concentration
- Watershed Boundary
- Detailed Area Subbasin Boundary
- Section
- Township and Range

Flood Control District of Maricopa County

Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
Figure 3.5 Sheet 1
Upper New River ADMP
Routing Reaches

Stantec

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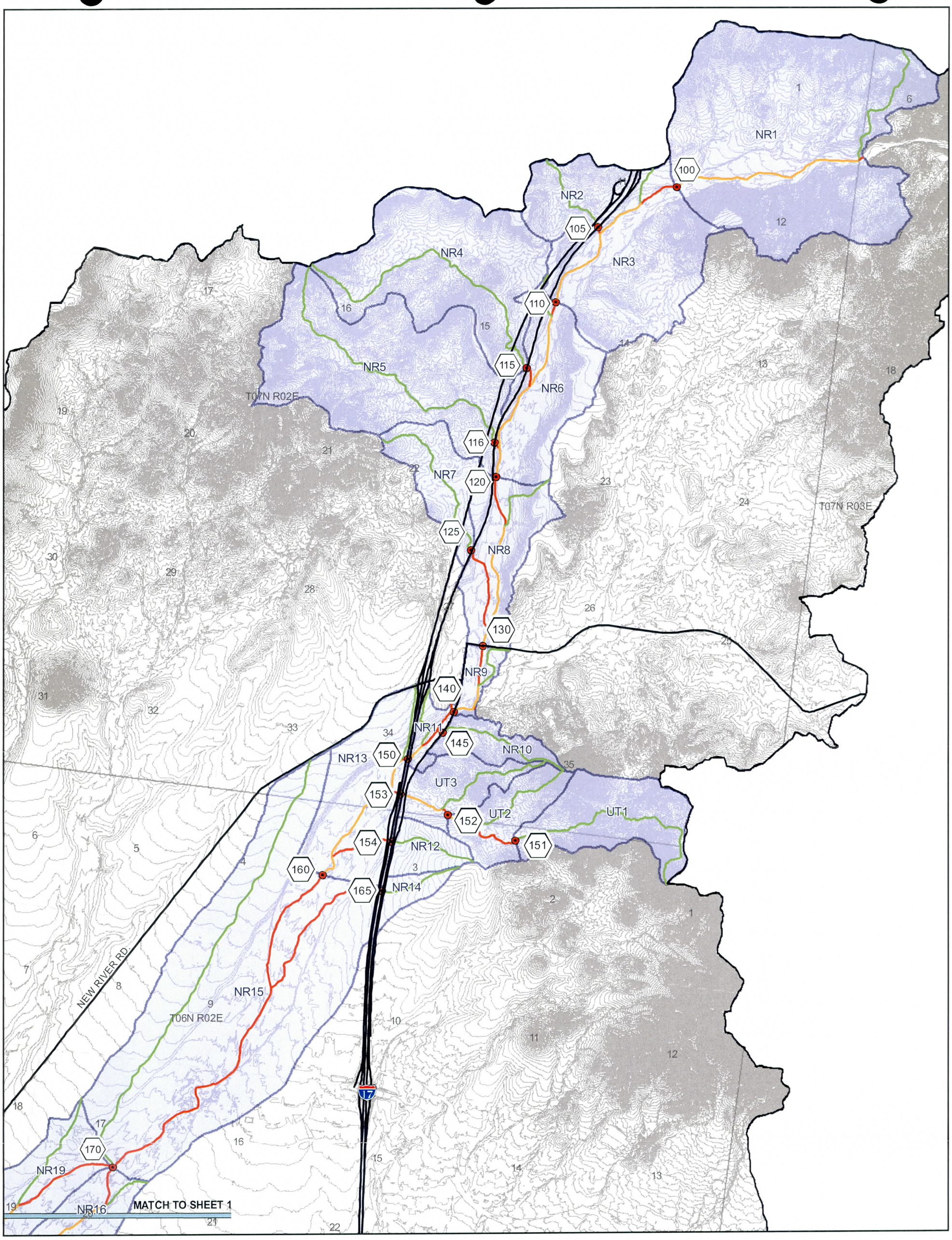
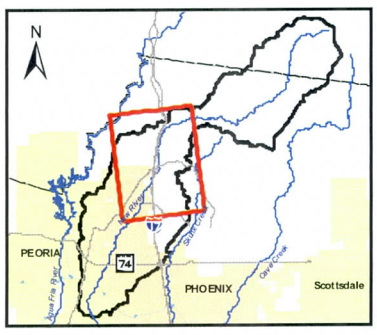
8211 S. 48th Street
Phoenix, AZ U.S.A. 85044



Location Map:



Notes:

Sheet 2 of 2

10 foot contour interval
topography circa January 2001

N
Not to scale

Legend:

- Concentration Point
- Concentration Point Label
- Roadway
- Contour
- Routing Reach
- Routing Reach and Time of Concentration
- Time of Concentration
- Watershed Boundary
- Detailed Area Subbasin Boundary
- Section
- Township and Range

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Upper New River ADMP
FCD 2005CO20
Figure 3.5 Sheet 2
Upper New River ADMP
Routing Reaches

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182000418

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AMG
August 2007

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TABLE 3.7
Summary of reach route physical data

Reach Route	Concentration Points		Subbasin	Routing Method	Length	Elevation, in feet		Slope
	Top	Bottom			miles	Top	Bottom	ft/ft
(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)	(10)
CVL100	ADD7	100	NR1	HEC-RAS developed Stage-Discharge	1.42	2320	2240	0.010669
100110	100	110	NR3	HEC-RAS developed Stage-Discharge	1.31	2240	2160	0.011583
105110	105	110	NR3	HEC-RAS developed Stage-Discharge	0.69	2220	2160	0.016543
110120	110	120	NR6	HEC-RAS developed Stage-Discharge	1.39	2160	2085	0.010256
115120	115	120	NR6	HEC-RAS developed Stage-Discharge	0.87	2150	2085	0.014100
116120	116	120	NR6	HEC-RAS developed Stage-Discharge	0.26	2110	2085	0.018050
120130	120	130	NR8	HEC-RAS developed Stage-Discharge	1.29	2085	2020	0.009561
125130	125	130	NR8	Normal Depth Channel Section	0.76	2080	2020	0.014940
130140	130	140	NR9	HEC-RAS developed Stage-Discharge	0.62	2020	1990	0.009225
GAV140	CP45	140	NR9	HEC-RAS developed Stage-Discharge	0.17	1996	1990	0.006790
140150	140	150	NR11	HEC-RAS developed Stage-Discharge	0.49	1990	1973	0.006617
BLK150	C6	150	NR11	HEC-RAS developed Stage-Discharge	0.53	1998	1973	0.008956
145150	145	150	NR11	HEC-RAS developed Stage-Discharge	0.34	2000	1973	0.015152
150160	150	160	NR13	HEC-RAS developed Stage-Discharge	1.13	1973	1918	0.009197
151152	151	152	UT2	Normal Depth Channel Section	0.59	2063	1998	0.020494
152153	152	153	UT3	Normal Depth Channel Section	0.39	1998	1970	0.013640
153160	153	160	NR13	HEC-RAS developed Stage-Discharge	0.92	1970	1918	0.010720
154160	154	160	NR13	Normal Depth Channel Section	0.65	1970	1918	0.015186
160170	160	170	NR15	HEC-RAS developed Stage-Discharge	2.87	1918	1785	0.008778
165170	165	170	NR15	Normal Depth Channel Section	3.13	1980	1785	0.011799
170180	170	180	NR16	HEC-RAS developed Stage-Discharge	1.12	1785	1730	0.009284
170175	170	175	NR19	Normal Depth Channel Section	1.47	1785	1705	0.010304
175185	175	185	NR20	Normal Depth Channel Section	0.96	1705	1680	0.004932
19A195	19A	195	NR21	Normal Depth Channel Section	2.04	1710	1630	0.007445
CK1195	CK1	195	NR21	Normal Depth Channel Section	0.54	1650	1630	0.007054
CJ1195	CJ1	195	NR21	Normal Depth Channel Section	0.29	1644	1630	0.009203

TABLE 3.7
Summary of reach route physical data

Reach Route	Concentration Points		Subbasin	Routing Method	Length	Elevation, in feet		Slope
	Top	Bottom			miles	Top	Bottom	ft/ft
(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)	(10)
CI1195	CI1	195	NR21	None	0.09	1638	1630	0.016520
195205	195	205	NR22	Normal Depth Channel Section	0.86	1630	1600	0.006609
185205	185	205	NR22	HEC-RAS developed Stage-Discharge	1.94	1680	1600	0.007799
CH1205	CH1	205	NR22	Normal Depth Channel Section	0.53	1620	1600	0.007091
180190	180	190	NR17	HEC-RAS developed Stage-Discharge	1.82	1730	1650	0.008337
190200	190	200	NR18	HEC-RAS developed Stage-Discharge	2.20	1650	1550	0.008598
205215	205	215	NR22	Normal Depth Channel Section	0.90	1600	1565	0.007378
CG1215	CG1	215	NR22	Normal Depth Channel Section	0.41	1585	1565	0.009304
215225	215	225	NR24	Normal Depth Channel Section	0.60	1565	1545	0.006294
CF1225	CF1	225	NR24	Normal Depth Channel Section	0.67	1565	1545	0.005649
CE1225	CE1	225	NR24	Normal Depth Channel Section	0.35	1552	1545	0.003756
225230	225	230	NR26	HEC-RAS developed Stage-Discharge	1.83	1545	1473	0.007471
200230	200	230	NR26	HEC-RAS developed Stage-Discharge	1.98	1550	1473	0.007378
CD1230	CD1	230	NR26	Normal Depth Channel Section	1.60	1535	1473	0.007317
CC1230	CC1	230	NR26	Normal Depth Channel Section	0.79	1500	1473	0.006512
CB1230	CB1	230	NR26	Normal Depth Channel Section	0.72	1500	1473	0.007063
226230	226	230	NR26	None	0.67	1489	1473	0.004552
DMN230	C10Y	230	NR26	None	0.22	1474	1473	0.000857
230250	230	250	NR27	HEC-RAS developed Stage-Discharge	3.39	1473	1400	0.004081
CA1250	CA1	250	NR27	Normal Depth Channel Section	3.23	1478	1400	0.004573
241250	241	250	NR27	Normal Depth Channel Section	2.70	1500	1400	0.007006
242250	242	250	NR27	Normal Depth Channel Section	2.67	1500	1400	0.007098
243250	243	250	NR27	Normal Depth Channel Section	2.56	1510	1400	0.008146
244250	244	250	NR27	Normal Depth Channel Section	2.80	1500	1400	0.006755
19014E	190	14E	NR18	Normal Depth Channel Section	2.00	1644	1566	0.0073724

Stage-Storage-Discharge Routing

The Modified Puls storage-discharge routes are based on results from an HEC-RAS hydraulic model. The HEC-RAS model was based on the original model developed by CVL as part of the 1987 study, with updated geometry from the New River Dam to the I-17 bridge to reflect project specific topography circa 2006.

The HEC-RAS model was run for 20 discharges ranging from 500 cfs to 51,000 cfs. For each discharge, water surface elevations and cumulative channel storage volumes were extracted from the model for the cross sections that corresponded to the upstream and downstream limits of the routing reaches. The stage at each discharge was determined from the water surface elevation at the upstream cross section of each reach, while the channel storage was taken as the difference between the upstream and downstream cumulative volume.

3.2.5 Reach Route Step Estimation

Estimation of the number of routing steps for input to the HEC-1 models is an iterative process. The number of routing steps for each reach may vary with the storm duration being considered. The process for estimating the number of steps is as follows:

Step 1: An initial estimate of the number of steps (NSTPS) for each reach is made assuming an average velocity of 8 feet per second in the main stem of New River and 5 fps on tributaries. The HEC-1 models are run using the assumed values.

Step 2: The reach travel time is calculated by subtracting the time-to-peak (T_p) at the beginning of the routing operation from the T_p at the end of the routing operation.

Step 3: The travel time from Step 2 is divided by the computational time interval (NMIN) to obtain a check NSTPS value.

Step 4: The result from Step 3 is compared with the NSTPS value currently coded in HEC-1 model. If the two values are not equal, the check NSTPS value is re-coded into the HEC-1 model as the new NSTPS value and the model is rerun.

Step 5: Repeat Steps 2 through 5 until the current NSTPS value and the check NSTPS value are equal. Convergence normally occurs within three iterations.

3.2.6 Storage Route Parameters

Storage routes were developed for culvert crossings under the CAP canal. The culvert diameter, material and length were inventoried during field visits and checked against previously collected information and aerial photographs. The information was then input to Culvertmaster version 1.0 and used to develop a stage-discharge relation for each culvert crossing. A stage-storage relation was built using the 2-foot contour interval mapping developed for this project. The stage-discharge and stage-storage relations were

incorporated into a storage route in HEC-1. The Culvertmaster worksheets and stage-storage relations are included in Appendix C.

Additional storage routes were developed for the borrow pits within the main channel of the New River (Figure 3.6). They were placed upstream of concentration points 175, 185 and 190, however the storage routes upstream of CP185 and CP190 produced oscillations in the output hydrographs and were removed. For the storage route at CP175, the stage-storage relation was developed from 2-foot contour interval mapping and the discharge relation was developed using normal depth calculations in FlowMaster version 6.0. FlowMaster worksheets are included in Appendix C.

3.3 SPLIT FLOW CALCULATIONS

In order to better understand the split and braided portions of the detailed study area, a FLO-2D model was developed for an area extending approximately 6 miles upstream of the Carefree Highway (Stantec, 2007). Hydrographs from the preliminary HEC-1 model were used as inputs for the FLO-2D study, which generated output hydrographs for cross sections upstream and downstream of the flow splits based on a two-dimensional analysis of the river. The results of the FLO-2D model were then used to modify the HEC-1 model.

Specifically, the FLO-2D results indicated that there were three splits or areas where flow from a single concentration point traveled to two downstream concentration points. These areas are shown on Figure 3.6, and are termed the "West split", the "Sweat Canyon split", and the "Deadman diversion". Additionally, the FLO-2D model results indicated that a majority of the flow reaching the Carefree Highway Bridge was passing under the west bridge.

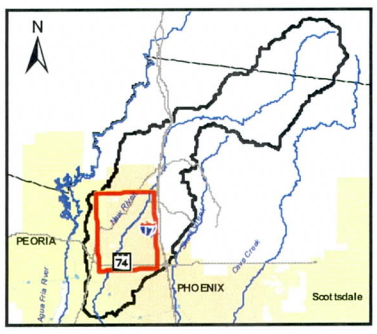
In HEC-1, each split flow was simulated using a diversion rating curve. The rating curves were derived from hydrographs extracted from the FLO-2D model results. The FLO-2D model was run for the 100-year, 24-hour storm only. The diversion rating curves developed from the FLO-2D results were applied to all other storm events and durations modeled as part of this study under the assumption that the hydraulic characteristics for multiple inflow conditions can be represented by a single rating curve. The FLO-2D hydrographs showed slightly different diversion amounts for the rising and falling limbs of the flood event, however HEC-1 permits only one diversion flow value for each discharge. Initial diversions were based on the rising limb of the FLO-2D hydrographs, and results were compared to the FLO-2D output. If the rising limb diversion curve did not provide a downstream hydrograph that was reasonably close to the FLO-2D hydrograph, the diversion curves were adjusted until the FLO-2D and HEC-1 outputs converged.

Figures 3.7 and 3.8 show hydrographs from FLO-2D and HEC-1 for the 100-year, 24-hour storm event. More hydrograph comparisons are provided in Appendix D.

HEC-1 does not automatically recognize that diverted flow increases the watershed area draining to the concentration point downstream of the diversion. The watershed area was manually diverted so that HEC-1 would use the correct aerally reduced hydrographs for

Sweat Canyon Split
Triangular Pit
Gravel Pit
West Split
Pit
Extent of Linear Borrow Pit
Deadman Diversion
SWEAT CANYON WASH
DOE PEAK WASH
NEW RIVER RD.
NEW RIVER
DEADMAN WASH
T06N R01E
T06N R02E
T05N R01E
T05N R02E
160
170
175
180
185
190
195
200
205
215
225
18
CK2
CJ1
CI1
CH1
CG1
CF1
CE1
CD1
74

Location Map:



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182000418

Prepared By:
AMG
August 2007

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Notes:

N
Not to scale

Legend:

- FLO-2D Hydrograph Input Location
- FLO-2D Hydrograph Input Location Label
- ADMP Concentration Point
- ADMP Concentration Point Label
- FLO-2D Cross Section for Hydrograph Output
- Roadway
- Existing Floodplain From Previous Studies
- Section
- Township and Range

Depth of Flow
- > 6
- 4 - 6
- 2 - 4
- <1

Flood Control District of Maricopa County

Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
Figure 3.6
Two Dimensional Analysis

Stantec

Stantec Consulting Inc.
8211 S. 48th Street
Phoenix, AZ U.S.A. 85044

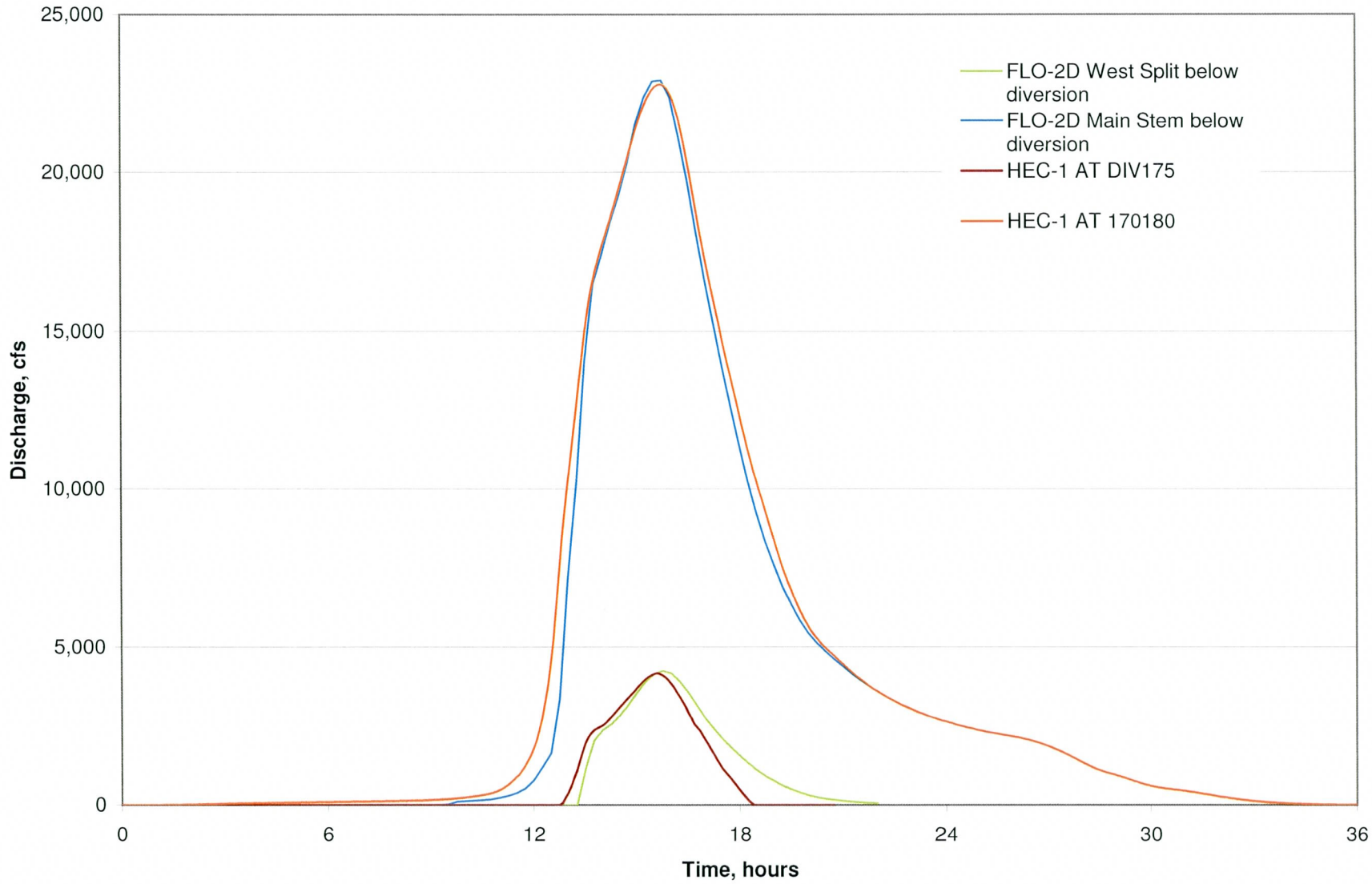


Figure 3.7- West Split Diversion Hydrographs

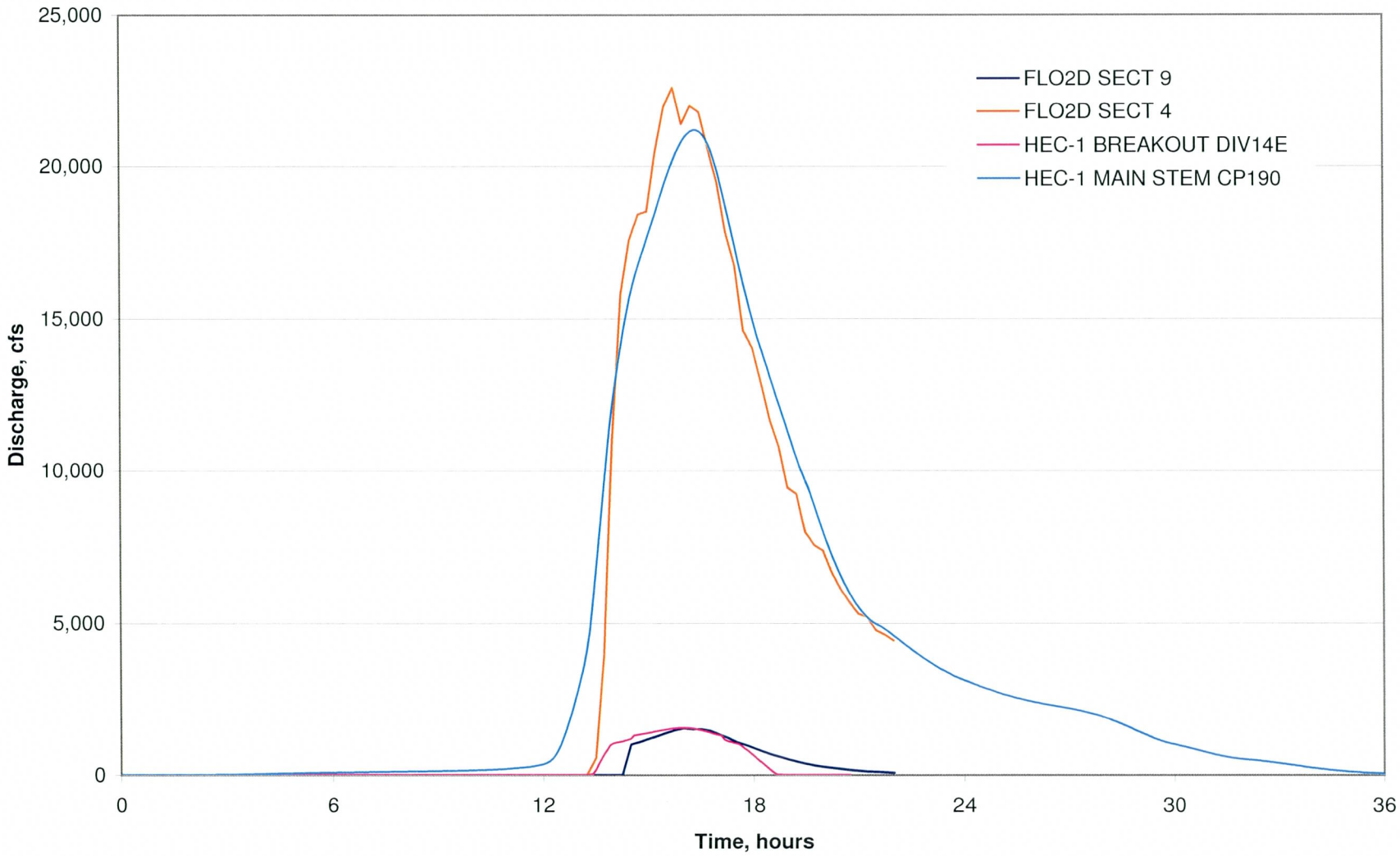


Figure 3.8- Diversion to Deadman Wash Hydrographs

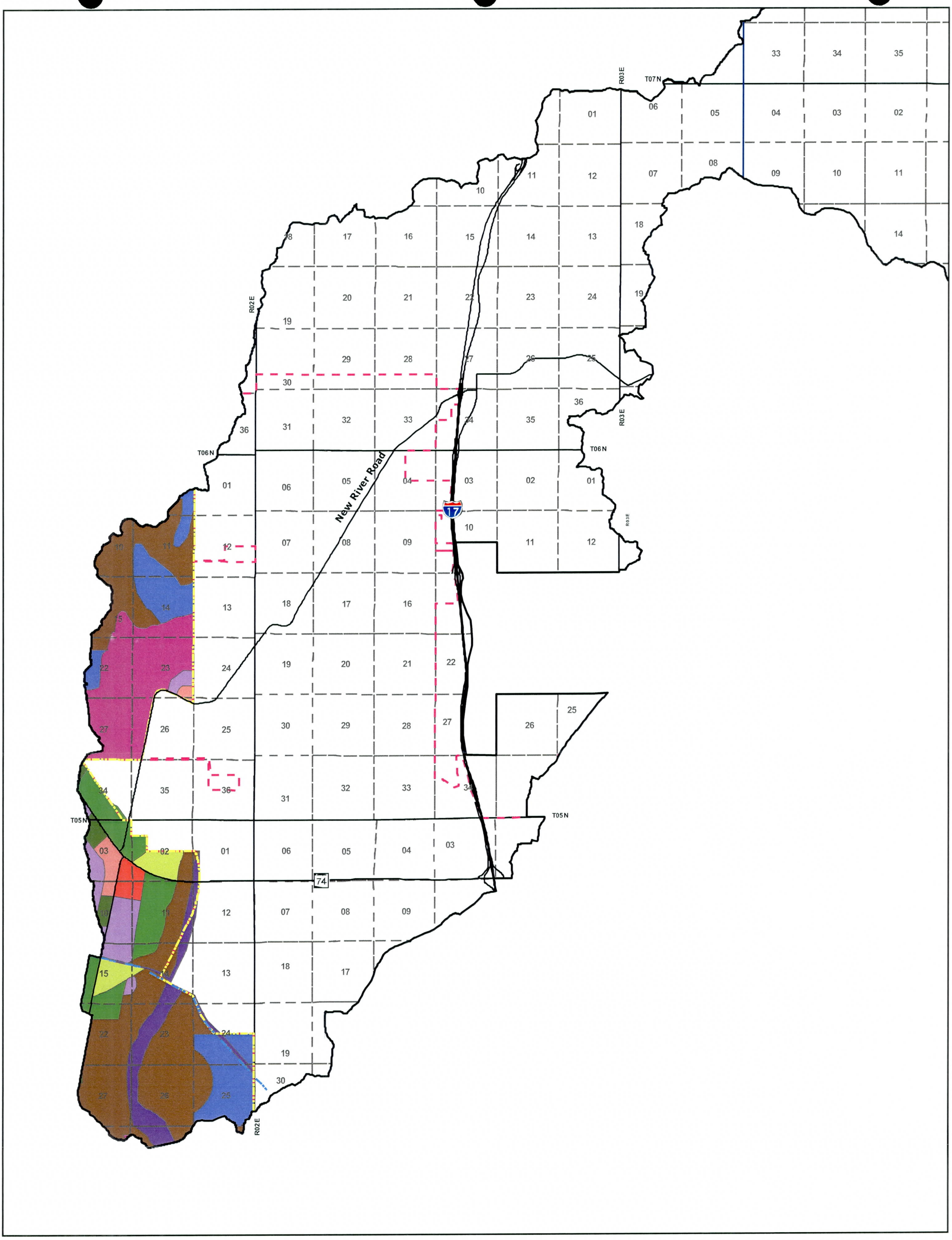
concentration points downstream of the splits. It was determined that carrying the full watershed area at the diversion through both branches of the split provided the best correlation with the FLO-2D output. For example, at the West Split (CP170), the area of the watershed which contributes runoff is 93.66 square miles. The downstream concentrations points along both branches of the split include the full 93.66 square miles as well as any additional area added after the split, resulting in a total area of 94.23 square miles for CP175 and 94.10 square miles for CP180. At the concentration point where the flow splits merge together again the overall area was manually set to the actual contributing watershed area.

3.4 FUTURE CONDITIONS

In order to evaluate the changes that may occur in the watershed under developed (build out) conditions, future conditions hydrologic models were developed for the 10-, 50- and 100-year, 6- and 24-hour storms. To simplify the modeling process, simulation of future land use conditions was limited to modification of subbasin impervious area. Changes to impervious area percentages were applied to the entire study watershed, not just the detailed study area. The exception was the area contained within the Tonto National Forest and the Anthem development in the Deadman watershed, which remained unchanged.

Future Conditions land use for the entire study watershed area is based on the General Land use Plans for the City of Peoria, City of Phoenix and Maricopa County. These land use plans are shown in Figures 3.9, 3.10, 3.11. The individual studies were seamed together to create an overall future conditions land use map. The various land use designations were then simplified into hydrologic land use classifications based largely on the proposed development densities in dwelling units/acre.

Where appropriate, land use classification descriptions used in the existing conditions land use were used, however some new classifications were added that are representative of the future conditions in the watershed. Values for impervious area were assigned to each land use classification based on guidance presented in the Design Manual. A summary listing of the classifications and their descriptions are provided in Table 3.8. The resulting land use classifications and developed conditions are shown on Figure 3.12.



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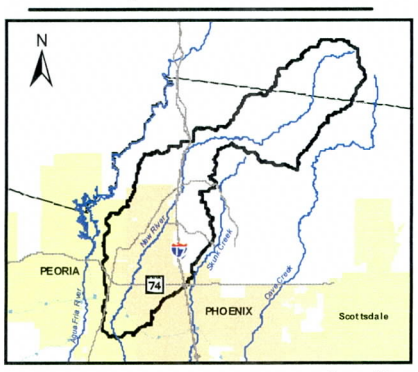

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August 2007

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Notes:

N
Not to scale

Legend:

- Roadway
- CAP Canal
- Peoria Corporate Boundary
- Phoenix Corporate Boundary
- Township & Range Line
- Section

Peoria Landuse

- Business Park
- Business Park/Industrial
- COMM
- Community Commercial
- Golf Course
- Industrial
- MU
- Mixed Use
- Mixed Use - Business Park
- Mixed Use - Neighborhood
- Mixed Use - Regional Comm
- Mixed Use - Residential L
- Mixed Use - Residential M
- Neighborhood Commercial
- Park/Open Space
- Public/Quasi-Public
- R-15+
- Regional Commercial
- Residential/Estate
- Residential/High
- Residential/Low
- Residential/Medium
- Residential/Medium High
- Water

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Upper New River ADMP
FCD 2005CO20
Figure 3.9
Future Conditions General Land Use Map
City of Peoria

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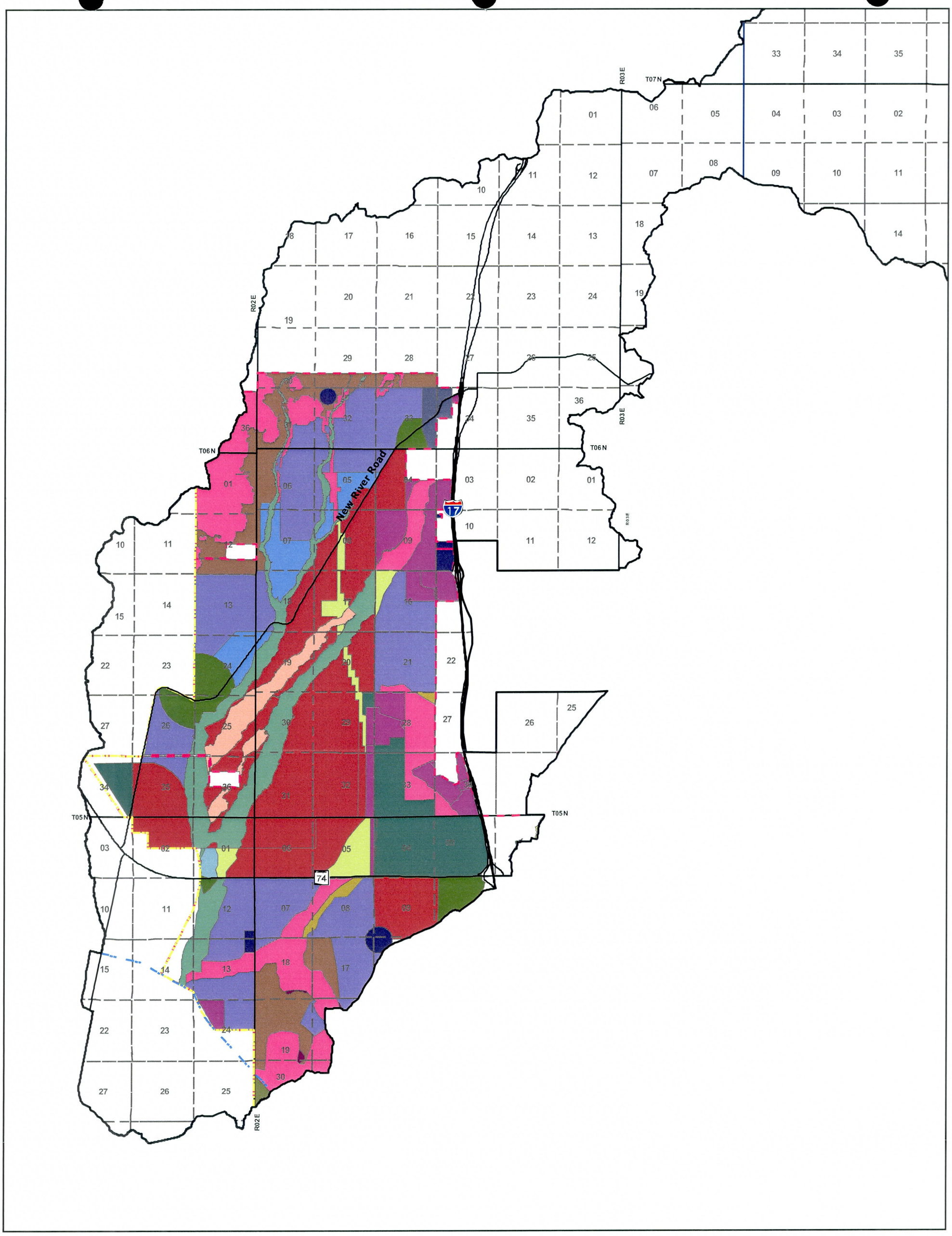

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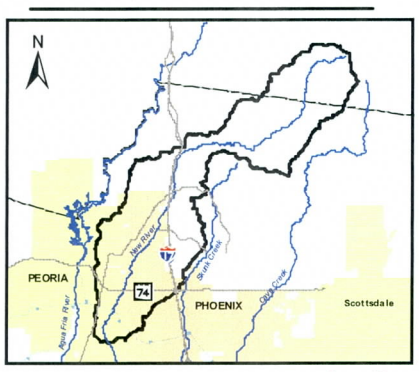

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Notes:

- Roadway
- CAP Canal
- Peoria Corporate Boundary
- Phoenix Corporate Boundary
- Township & Range Line
- Section

Phoenix Landuse

- Commercial
- Floodplain
- Mixed Use (Commerce Park, Industrial, Commercial, Public/Quasi-Public / Parks/Open Space)
- Mixed Use (Commercial / Commerce Park)
- Mixed Use (North Gateway and Northwest Area / Floodplain)
- Mixed Use (North Gateway and Northwest Area)
- Parks / Open Space - Future 1 du

N

Not to scale

Legend:

- Parks / Open Space-Public
- Preserves / 0-1 & 1-2 du / acre
- Preserves / 2-3.5 & 3.5-5 du / acre
- Preserves / Floodplain
- Preserves / Mixed Use / Commercial / Commerce Park
- Preserves / Undesignated
- Public / Quasi-Public
- Residential 0 to 1 du / acre
- Residential 0 to 2 du / acre
- Residential 2 to 3.5 du / acre
- Residential 2 to 5 du / acre
- Residential 5 to 10 du / acre
- Undesignated

Flood Control District of Maricopa County

Flood Control District
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Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
Figure 3.10
Future Conditions General Land Use Map
City of Phoenix

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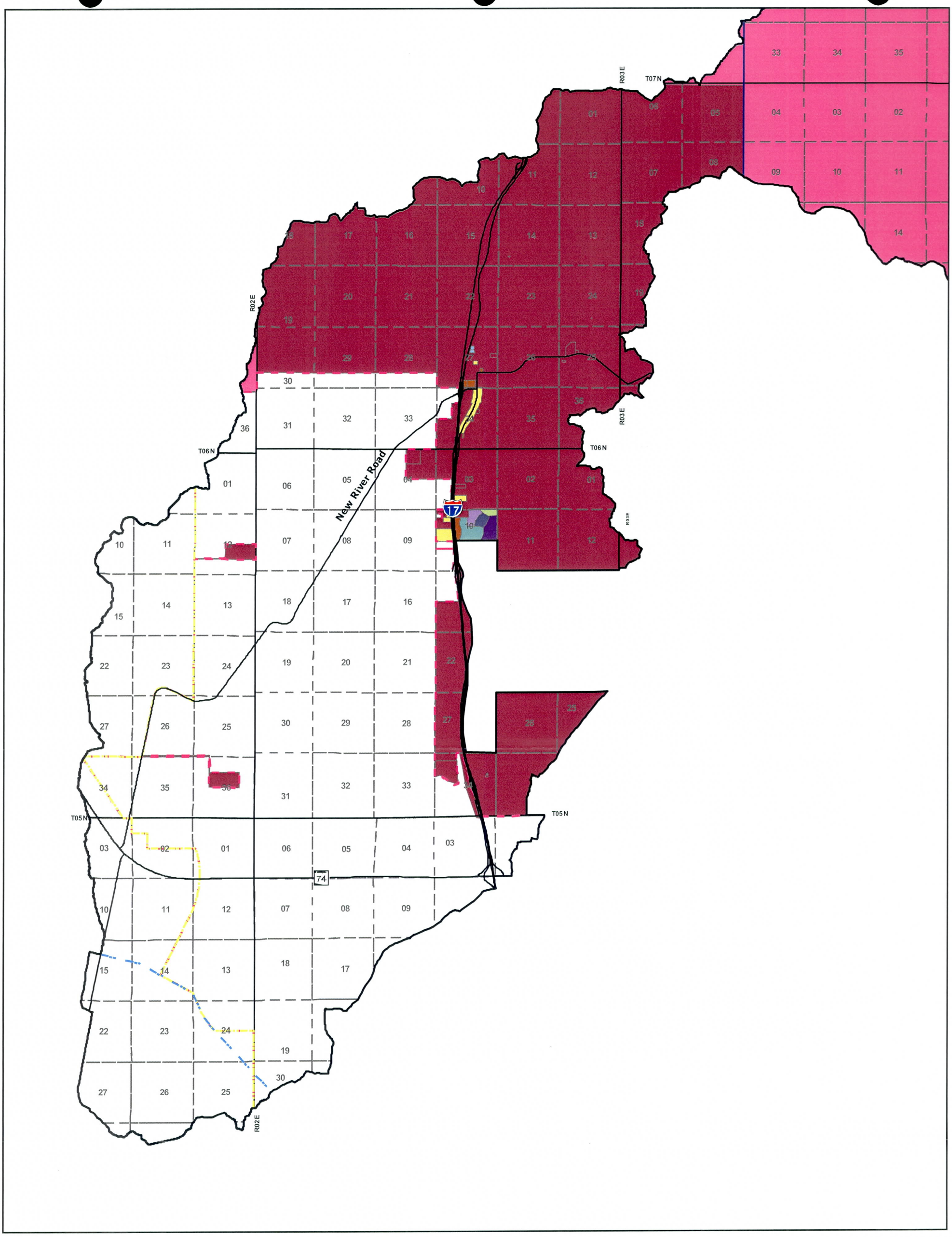
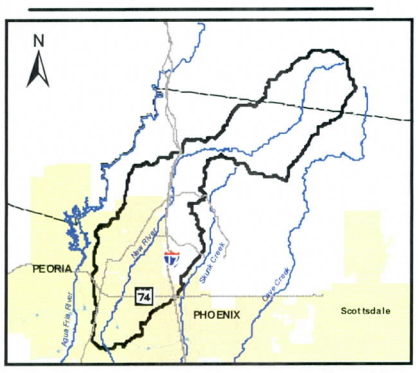


Location Map:



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Notes:

N
Not to scale

Legend:

- Roadway
- CAP Canal
- Peoria Corporate Boundary
- Phoenix Corporate Boundary
- Township & Range Line
- Section

Maricopa County Landuse

- C-2
- C-3
- R-2
- R-4
- R1-10
- R1-18
- R1-35
- R1-6
- R1-7
- R1-8
- RURAL-190
- RURAL-43

Flood Control District of Maricopa County
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Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
Figure 3.11
Future Conditions Maricopa County Land Use Map

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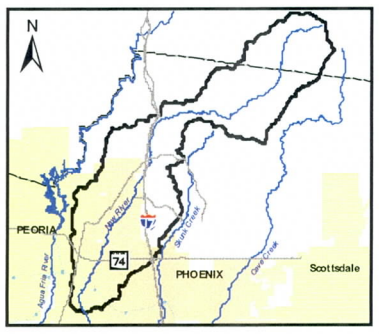
Land use unchanged from existing conditions

Yavapai County

Maricopa County

Location Map:



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Notes:

Base photography circa 2006

N

Not to scale

Legend:

- USGS Gage
- Roadway
- Phoenix Corporate Boundary
- Peoria Corporate Boundary
- Tonto National Forest
- Watershed Boundary
- Township and Range
- Section

Land Use

- ANTHEM
- COMM
- I1
- IND
- L.D.R.
- M.D.R.
- M.F.R.
- NDR
- NHS
- NMT
- OPEN
- P
- V.L.D.R.

Flood Control District of Maricopa County

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Upper New River ADMP
FCD 2005CO20
Figure 3.12
Future Conditions Land Use

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TABLE 3.8
Future Land Use Classification

Future Land Use Code (1)	Description (2)	RTIMP (%) (3)
DESERT	Desert	0
OPEN	Open Space	0
V.L.D.R.	Very Low Density Residential	5
L.D.R.	Low Density Residential	15
M.D.R.	Medium Density Residential	30
M.F.R.	Multiple Family Residential	45
IND	Industrial	55
COMM	Commercial	80
PARK	Parks	0
GR	Gravel Roadways and Shoulders - Graded and Compacted	5
NDR	Undeveloped Desert Rangeland	0
NHS	Hillslopes, Sonoran Desert	0
NHSS	Hillslopes, Sonoran Desert, Sheet Flow	0
NMT	Mountain Terrain	0
P	Pavement and Rooftops	95
I1	Industrial 1 (Ben Avery)	30

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Future Condition RTIMP values for each subbasin were obtained using DDMSW version 2.1.0, and added into the Upper New River ADMP model. Land use areas within each subbasin were calculated in ArcView using the method described in Section 3.2.2. DDMSW data files are provided as Appendix B. Table 3.9 summarizes the changes in RTIMP between the existing and future conditions models in the detailed study portion of the reach.

Table 3.9
Existing and Future Conditions RTIMP in the ADMP detailed study area

Basin ID	Existing RTIMP	Future RTIMP	Basin ID	Existing RTIMP	Future RTIMP
	%	%		%	%
(1)	(2)	(3)	(4)	(5)	(6)
NR1	17	21	NR15	10	22
NR2	0	5	NR16	0	13
NR3	13	17	NR17	0	14
NR4	8	13	NR18	0	14
NR5	21	26	NR21	0	22
NR6	1	4	NR19	1	13
NR7	10	15	NR20	0	12
NR8	13	16	NR22	0	11
NR9	4	21	NR23	0	18
NR10	42	48	NR24	0	20
NR11	9	35	NR25	0	30
UT1	31	35	NR26	0	7
UT2	8	10	CAP1	11	13
UT3	6	8	CAP2	15	15
NR12	0	5	CAP3	20	21
NR13	2	5	CAP4	5	14
NR14	3	14	NR27	8	12

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4.0 RESULTS

The model for the entire watershed was developed by combining the previous studies with the new hydrology developed in the detailed model reach. The procedure used was:

1. Develop subbasin loss rate and unit hydrograph input using DDMSW as described in Section 3.2.3.

2. Develop routing reaches between detailed area concentration points and from the outlets of previous models to detailed area concentration points using the procedure described in Section 3.2.4.

3. Combine the subbasins and routing reaches for the detailed area model and check for errors.

4. Add the previous models as well as the corresponding routing reaches to the UNR detailed area model and check for errors.

5. Export hydrographs at key locations for FLO-2D analysis.

6. Use results of FLO-2D to develop diversions at split flow locations and at Carefree Highway Bridges.

7. Run model for entire study watershed and check for errors.

The HEC-1 input and output files for each frequency, duration and land use condition are included in digital format in Appendix E. Model results at selected locations in the detailed reach for each frequency, duration and land use condition are included in Appendix F.

4.1 SUMMARY OF MODEL RESULTS

Results for the 100-year, 24-hour and 6-hour existing conditions models in the detailed hydrology reach are summarized below in Table 4.1. Full HEC-1 output for all models (10-, 50-, 100-year, 6- and 24-hour storms for both existing and future conditions) can be found in Appendix E.

Model Results can be summarized as follows:

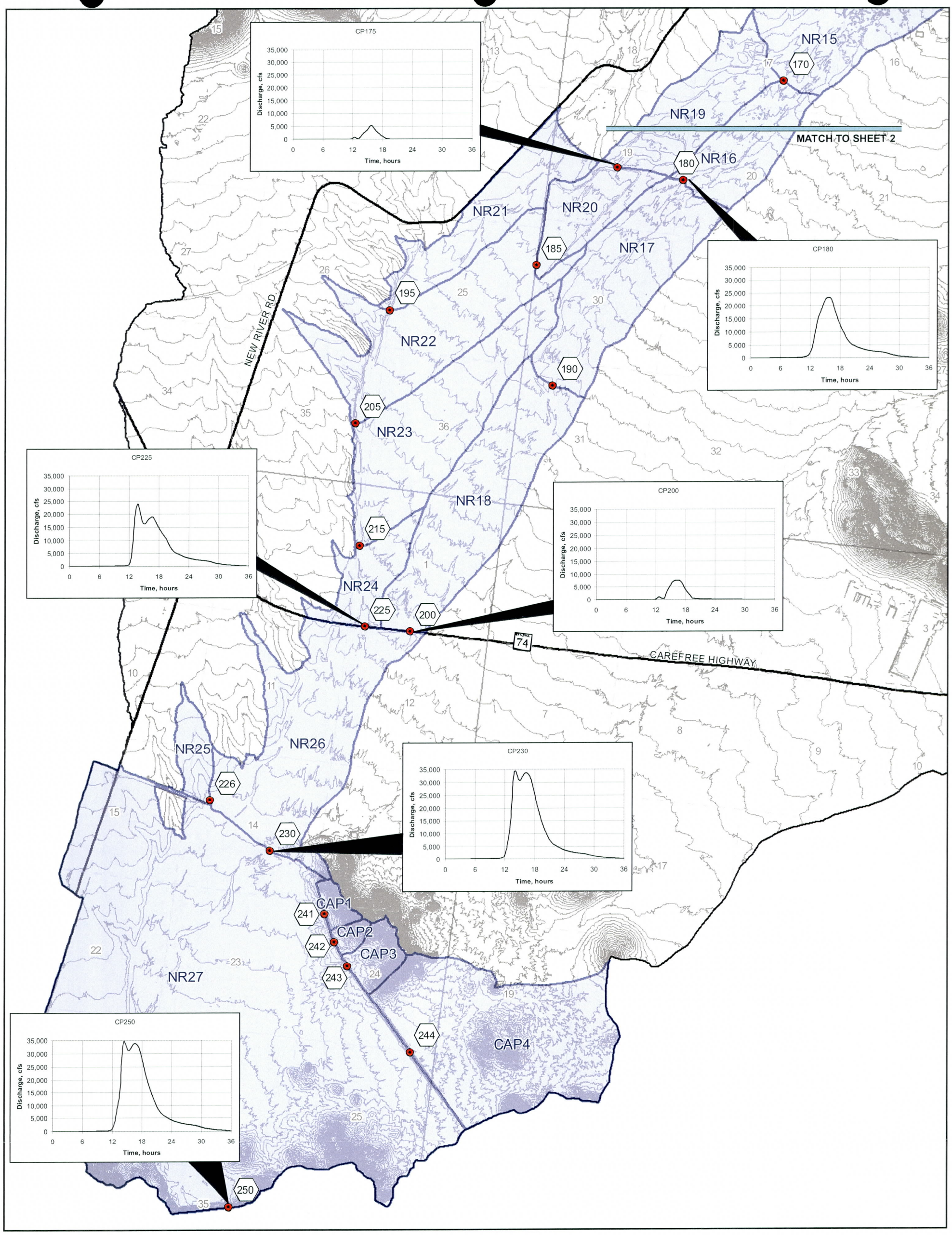
- For the 100 year event, the controlling storm (highest peak runoff value) through the main stem and larger subbasins in the watershed is the 24-hour storm, while the 6-hour storm controlled smaller and steeper basins. Selected results from 100-year existing conditions 24- and 6-hour storms are shown in Table 4.1 with the controlling (higher) discharge highlighted. Full results as well as similar tables for the 50- and 10-year events and the future conditions can be seen in Appendix F.

- A large portion of the runoff is generated in the upper basin, upstream of the Rock Springs gage. Below the gage the main channel of New River essentially acts as a conveyance corridor for the flood wave until its confluence with Sweat Canyon and Deadman Wash in the vicinity of the Carefree Highway. The flood wave experiences some attenuation as it travels, so that a peak of 29,400 at 14.17 hours at the USGS gage location is reduced to 26,300 cfs occurring at 16.92 hours at CP230, just upstream of the confluence with Deadman Wash.

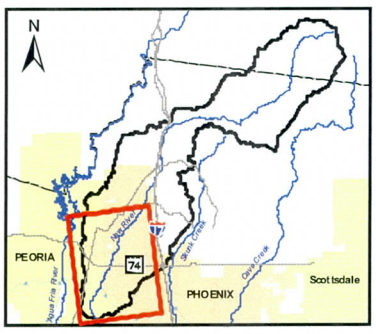
TABLE 4.1
Existing Conditions Hydrology

Concentration Point	EX100-24.DAT Q (cfs)	EX100-6.DAT Q (cfs)	Concentration Point	EX100-24.DAT Q (cfs)	EX100-6.DAT Q (cfs)
CP100	29360	24490	CP195	13360	10850
CP110	29210	24340	DIV175	5440	3180
CP120	29030	24230	CP175	5320	3140
CP130	28830	23950	SR175	5250	3110
CP140	29030	23990	DIV185	6470	5900
CP150	28990	23970	CP185	6620	3540
CP152	1160	1270	CH1205	430	490
CP153	1680	1730	CP205	16870	10740
CP160	28950	23880	CP215	17150	10730
CP170	28730	23640	DIV225	14030	12300
DIV170	23280	20290	CP225	23930	14980
CP180	23240	20200	CP230	34390	23650
CP190	23200	20100	SR241	42	44
DIV190	21630	18740	SR242	7	9
DIV200	7550	6330	SR243	51	52
CP200	7550	6320	SR244	140	140
DIVSWC	7710	5740	CP250	34580	23480

- The hydrograph downstream of the Carefree Highway has two very distinct peaks; one caused by the runoff from the Sweat Canyon, West Tributaries and Deadman watersheds, and the other caused predominantly by runoff from the area above Rock Springs gage. The two peaks are of roughly equivalent magnitudes (34,400 cfs at 14.08 hours and 33,700 cfs at 16.25 hours), and are illustrated in the hydrographs plotted on Figure 4.1. This is due in part to the characteristic discussed in the previous bullet, which is also related to the configuration of tributary inflow. Downstream of the confluence with Gavilan Peak Wash, the major tributaries flow essentially parallel to New River. Consequently, the inflow to New River over a distance of approximately 9 miles is limited to local runoff. The Deadman and Sweat Canyon subwatersheds are approximately 35 and 16 square miles, respectively, and have similar basin responses including similar peak timing. This coincidental timing, along with the travel time for runoff from the upper portion of the watershed, results in a double peaked hydrograph.



Location Map:



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Notes:

Sheet 1 of 2

10 foot contour interval
topography circa January 2001

N
Not to scale

Legend:

- Concentration Point
- Concentration Point Label
- Contour
- Roadway
- Detailed Area Subbasin Boundary
- Watershed Boundary
- Section
- Township and Range

Flood Control District of Maricopa County

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Upper New River ADMP
FCD 2005CO20
Figure 4.1 Sheet 1
Flood Wave Hydrographs

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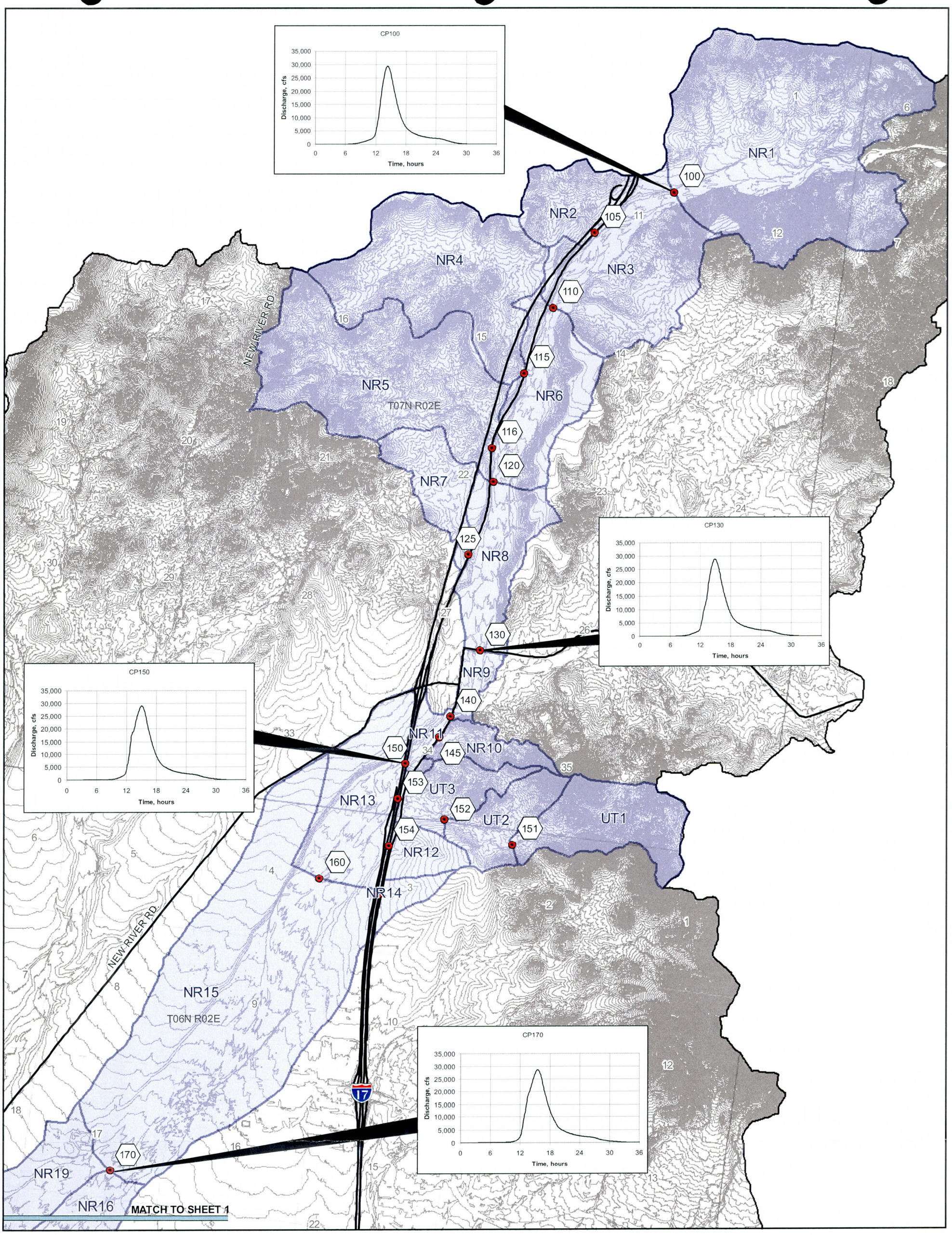

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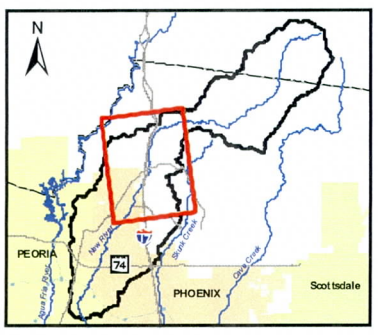

Project No.
182000418

Prepared By:
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August 2007

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Notes:

Sheet 2 of 2

10 foot contour interval
topography circa January 2001

N

Not to scale

Legend:

- Concentration Point
- Concentration Point Label
- Contour
- Roadway
- Detailed Area Subbasin Boundary
- Watershed Boundary
- Section
- Township and Range

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Upper New River ADMP
FCD 2005CO20
Figure 4.1 Sheet 2
Flood Wave Hydrographs

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- In addition to the West Split, which was identified in the 1987 CVL study, the FLO-2D model identified two additional splits. The first occurs downstream of the New River Road crossing of Sweat Canyon, where approximately 50 percent of the total flow is captured by the triangular borrow pit. The second occurs downstream of the linear borrow pit on the main stem of New River, where flow breaks out to the east and enters the Deadman Wash watershed. The splits are identified on Figure 3.6. Also, the FLO-2D results showed that a flow split identified by the previous New River FIS study does not occur. This is likely due to the influence of the linear borrow pit which did not exist at the time of the CVL study. The previously mapped floodplains, including splits, are shown on Figure 3.6 along with the new FLO-2D results.

- The amount and timing of runoff does not increase significantly in the future conditions model. At CP250, the New River Dam impoundment and the farthest downstream concentration point in the ADMP model, the 100-year, 24-hour peak runoff value was estimated at 34,600 cfs in the existing conditions model and 36,600 cfs in the future conditions model. The timing of the peak remained constant at 14.33 hours in both models. This is partly due to the modeling approach, which limited the simulation of future land use conditions to changes in the impervious area, and partly due to the large areas of clay or clayey soils. A comparison of the existing and future conditions models rounded to the nearest 100 cfs can be seen in Table 4.2.

Table 4.2
Comparison of Existing and Future Conditions Models at Key Concentration Points

Concentration Point	Description	EX100-24.DAT Q (cfs)	FU100-24.DAT Q (cfs)
CVL100	Rock Springs Gage	29,300	29,300
CP130	New River Bridge	28,800	28,900
GAV140	Confluence with Gavilan Peak Wash	8,100	8,200
CP170	Main stem above West Split	28,700	28,800
DIV170	Main stem below West Split	23,300	23,300
CP190	Exit of Linear Borrow Pit	23,200	23,200
DIV190	Main stem after diversion to Deadman	21,600	21,700
190200	Main stem upstream of Carefree Highway	21,600	21,600
CP200	East Bridge, Carefree Highway	7,600	7,600
DIVSWC	Sweat Canyon split to Triangular Pit	7,700	8,200
19A195	Sweat Canyon after split	6,900	7,400
DIV185	Diversion to Triangular Borrow Pit	6,500	6,500
CP185	Exit of Triangular Borrow Pit	6,600	6,800
CP225	West Bridge, Carefree Highway	24,000	24,900
INT230	Main stem above Deadman Confluence	25,500	26,000
CP230	Main stem at Deadman Confluence	34,400	36,300
CP250	New River Dam	34,600	36,600

4.2 HEC-1 WARNINGS AND ERRORS

The warning messages encountered in the hydrologic models summarized in this report are as follows:

1. *** WARNING *** MODIFIED PULS ROUTING MAY BE NUMERICALLY UNSTABLE FOR OUTFLOWS BETWEEN XXXX. TO XXXX.

2. XXXX * WARNING EXCESS AT PONDING LESS THAN ZERO FOR PERIOD EXCESS SET TO ZERO

3. ***** WARNING ***** POSSIBLE INSTABILITIES IN THE MUSKINGUM ROUTING FOR REACH XXXXX. ADJUST NSTPS AND/OR COMPUTATION INTERVAL TO MEET CRITERIA IN USER MANUAL).

4. WARNING --- ROUTED OUTFLOW (XXXX.) IS GREATER THAN MAXIMUM OUTFLOW (XXXX.) IN STORAGE-OUTFLOW TABLE

Of these, only the first two warnings were generated from the detailed study area. The two remaining messages are specific to the existing studies incorporated into the Upper New River model, and those warning messages are judged inconsequential to the Upper New River model results.

Of the warning messages that occurred in the detailed study area, the first warning listed above specifies a range of peak flows for which the routing numerics may be unstable. Each routing reach for which a warning message is issued was checked for the following:

1. The routed peak discharge was compared to the range listed in the warning message;

2. The routed peak discharge was compared with the inflow peak discharge to determine if an increase occurred due to the routing computations; and

3. The routed hydrograph was plotted and checked for oscillations if either item 1 or 2 above was a concern.

Examination of those plots does not give any cause to suspect the routing calculations, therefore the warning messages are considered inconsequential.

The second warning message listed above is in regard to the rainfall loss calculations performed by HEC-1 using the Green and Ampt methodology. After satisfying the surface retention loss requirement, HEC-1 then performs check calculations for each modeling time period to determine when a combination of accumulated rainfall and sufficient rainfall intensity occur to begin ponding (rainfall excess generation). All rainfall is infiltrated to that point and accounted for in the calculations. Once the program determines that ponding has occurred, an infiltration rate is then calculated for each time period and subtracted from the rainfall intensity for that same period to obtain the rate of rainfall excess. Due to imperfect numerics, it is possible to have a rainfall intensity for the modeling time period that results in the calculation of a ponding condition, yet that ponded depth is less than the calculated infiltration capacity of the soil for that time period. This results in a negative value for the rainfall excess calculation. HEC-1 issues its message and sets the loss to zero. This message is not an indication of model instability.

4.3 COMPARISON WITH PREVIOUS STUDIES

Table 4.3 presents the ADMP model results and the results obtained by previous studies at key points, rounded to the nearest 100 cfs. Differences in runoff peak and volume are to be expected, and in general are due to the differences in precipitation values used for the Upper New River ADMP model.

Specifically, the runoff magnitudes for the upper portion of the watershed are lower than those estimated in previous studies. The 1987 CVL model predicts 34,500 cfs of runoff for the 100-year, 24-hour storm a the USGS Rock Springs gage, while the Upper New River ADMP predicts 29,400 cfs. This difference is directly attributable to the differences in point precipitation values; 4.95 inches in the previous study and 4.73

inches for the ADMP. Other factors influencing the differences in results compared with the CVL model are the use of precipitation depth-area reduction factors, use of a different channel routing methodology and a different unit hydrograph.

Table 4.3
Comparison with Previous Studies

Previous Study	Concentration Point	Description	Q Previous studies (cfs)	Q EX100-24.DAT (cfs)
CVL New River	ADD7	Rock Springs at gage	34,500	29,400
CVL New River	CP130	New River Bridge	32,000	28,800
CVL New River	CP140	Frontage Road bridge	33,300	29,000
Gavilan Peak Wash	CP43	At Meander Road- dip	8,700	8,600
Gavilan Peak Wash	CP45	End of Model	8,700	8,600
Black Wash	C6	End of Model	1,900	2,300
CVL New River	CP150	I-17 at New River	33,400	29,000
CVL New River	CP170	D/S of Gravel pit, U/S of West	32,800	28,700
Sweat Canyon	18-19A	At New River Road	13,000	14,100
NRWT	CK2	At New River Road- dip	7,700	7,000
NRWT	CJ3	At New River Road- culvert	500	500
NRWT	CD4	At Carefree Highway- culvert	1,600	1,700
NRWT	CD1	End of Model	1,100	1,100
NRWT	CB4	At Lake Pleasant Road- dip	200	200
NRWT	CA2	At CAP crossing- culvert	700	700
Deadman	C10S	Carefree highway crossing	5,500	6,200
Deadman	C11G	Carefree highway crossing	1,300	1,500
Deadman	C8D	I-17 Crossing	4,200	4,800
Deadman	C10Y	End of study	9,600	11,800
CVL New River	CP230	CAP crossing	54,600	34,400
CVL New River	CP250	New River Dam	61,500	34,600

4.4 INDIRECT VERIFICATION

In order to provide a check on the assumptions made in the detailed study area HEC-1 model, external verification is needed. Because there is limited streamgage data in the detailed study area, indirect verification methods were used following the November 2003 (Draft) Drainage Design Manual for Maricopa County guidelines.

The indirect verification was performed using the results from the existing conditions, 100-year, 24-hour model (EX100-24.DAT) because it is the controlling storm for the major downstream concentration points. Five subbasins reflective of the detailed area modeling were chosen for comparison. Their areas ranged from 0.98 to 2.89 square miles. In addition, six concentration points were chosen, with tributary areas ranging from 1.15 to 172.31 square miles. Subbasins and concentration points chosen for indirect verification, as well as their physical characteristics, are shown in Table 4.4.

Table 4.4
Indirect Verification Basin Characteristics

Concentration Point	Subbasin Area	HEC-1 Peak Discharge	Unit Discharge cfs/square mile	Mean Basin Elevation
	mi^2	cfs		ft
NR3	1.0	1,500	1,563	2,220
NR4	1.2	1,500	1,239	2,460
NR5	1.4	1,700	1,199	2,440
NR1	2.3	3,000	1,269	2,540
NR15	2.9	3,300	1,151	1,920
CP130	78.8	28,800	366	3,610
CP153	1.2	1,800	1,532	2,330
CP170	93.7	28,700	307	3,490
CP195	24.2	13,400	552	2,060
CP225	122.8	23,900	195	3,370
CP250	172.3	34,700	201	3,300

Method 1: Unit Peak Discharge Curves

Unit peak discharge curves developed from unusual flooding events in the United States and abroad are provided in the draft Design Manual. Those curves represent extreme and rare events, and therefore act as an upper limit to the amount of runoff that should be expected per unit of area. The source data for each of the curves is:

A. An envelope curve based on a compilation of unusual flood discharges in the United States and abroad (data prior to 1941), by Craeger and others (1945).

B. An envelope curve of extreme floods in Arizona and the Rocky Mountain region developed by Matthai and published by Roeske (1978).

C. An envelope curve of peak streamflow data developed for Arizona by Malvick (1980).

D. An envelope curve of peak streamflow data for the Little Colorado River basin in Northern Arizona developed by Crippen (1982).

E. An envelope curve of peak streamflow data for Central and Southern Arizona developed by Crippen (1982).

F. An envelope curve of the largest floods in the semi-arid Western United States developed by Costa (1987).

G. An envelope curve of peak discharges for Arizona, Nevada and New Mexico developed by the USACE (1988).

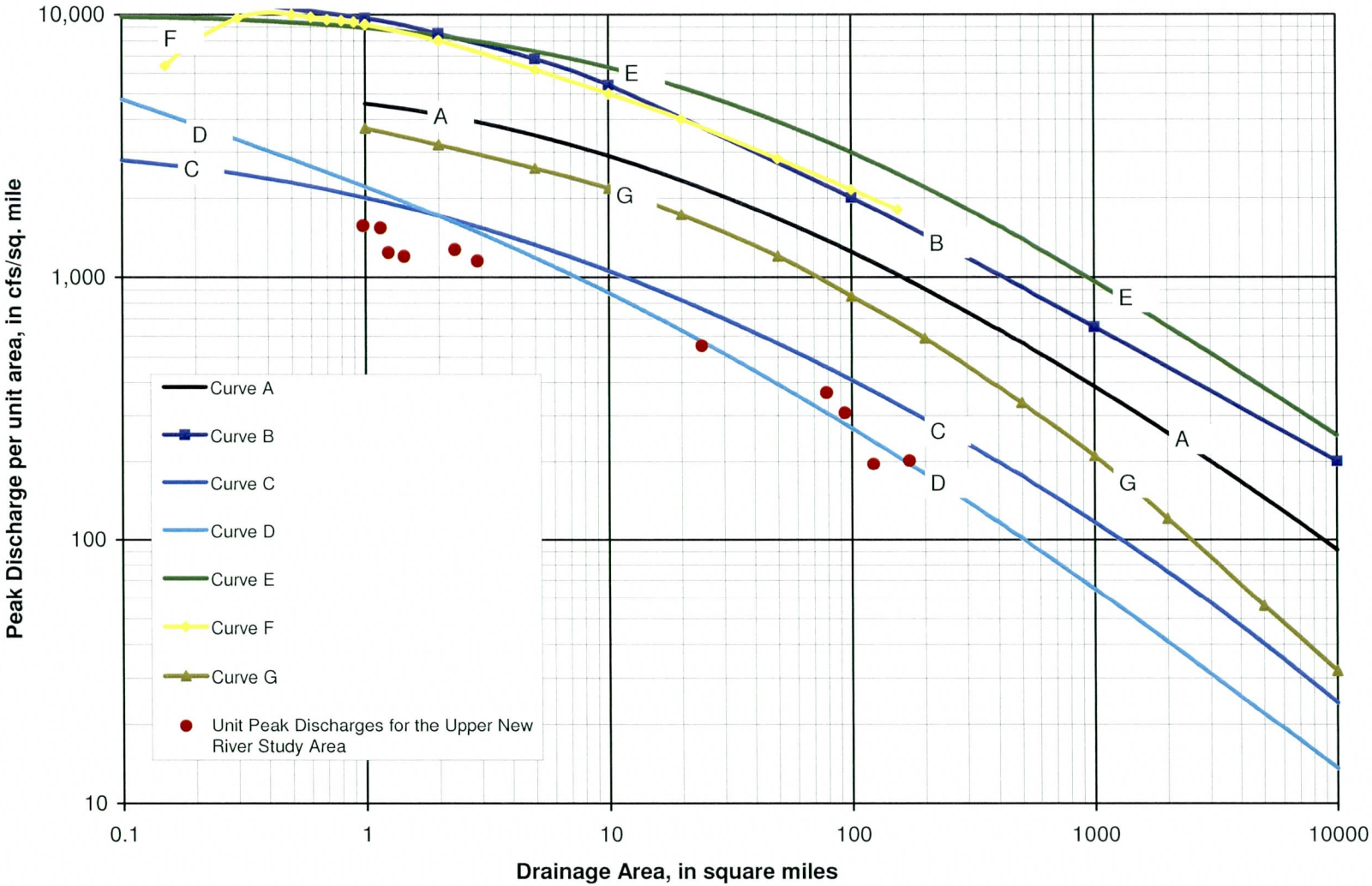

Figure 4.2- Indirect Verification Method 1

The peak flows obtained from HEC-1 were divided by the tributary area to obtain unit peak discharges for the points of interest. These values were plotted against the envelope curves and the results are shown in Figure 4.2. The ADMP peak flows fall below or between curves C and D, which indicated that they are slightly lower than the peak observed streamflows in Arizona.

Method 2: USGS Data for Arizona

The USGS has performed a log-Pearson Type 3 (LP3) analyses for 138 continuous record and 176 partial record gaging stations in Arizona. The resulting 100-year peak discharges were plotted against drainage area for each gage, and trend lines were developed for the data showing the 100-year best fit and 75 percent tolerance limits. Gage number 09513780, New River at Rock Springs, is located within the watershed. The 100-year LP3 peak discharge estimate for that gage based on 28 years of record is 34,600 cfs. At this location, the model reports a 100-year, 24-hour peak discharge of 29,400 cfs.

For other locations within the watershed, the peak discharges and tributary areas for the Upper New River ADMP model were plotted against the USGS data. Figures 4.3, 4.4 and 4.5 show the USGS data, the best fit line and 75 percent tolerance limits for the USGS data and the results from the Upper New River ADMP model. The Upper New River 100-year flood peaks are above the 100-year best fit line, although well within the USGS data scatter. This indicates that the UNR ADMP model results accord well with results from gaged watersheds in Arizona.

Method 3: Regional Regression Equations

Area specific regional regression equations were developed for the southwestern states from USGS gage data. Those regression equations are used to give a rough estimate of the 100-year peak discharge from a basin given basic basin parameters.

The Upper New River watershed falls within the Central Arizona Region (R12). For the 100-year recurrence interval, the applicable regression equation is:

$$LogQ = 6.55 - 3.17(AREA^{0.11}) - 0.454Log(ELEV)$$

Where: Q= peak discharge, in cfs

AREA= drainage area, in square miles

ELEV= mean basin elevation, in feet divided by 1,000.

The peak discharge values calculated using the regression equation were compared to the peak discharges from the HEC-1 output, and the results can be seen in Table 4.5. All of the UNR ADMP model results are within the 39 percent margin of error of the regression equation discharge relation values, indicating that the model results are reasonable. Figures 4.6 compares the elevation-area data for the selected ADMP basins to data used to develop the regression equation. Figure 4.7 is a plot of the ADMP model results

against the calculated 100-year discharges for basins in Region 12. The regression equations generally support the HEC-1 model results.

TABLE 4.5
Indirect Verification Regional Regression Equations

Concentration Point	Flood Region	Drainage Area square miles	Mean Basin Elevation feet	100-yr Peak Discharge Relation cfs	HEC-1 100-yr Peak Discharge Calculated cfs	Percent Difference from Discharge Relation ** percent
NR3	12	1	2,220	1,600	1,500	7
NR4	12	1	2,460	1,900	1,500	19
NR5	12	1	2,440	2,100	1,700	19
NR1	12	2	2,540	3,000	3,000	2
NR15	12	3	1,920	4,000	3,300	17
CP130	12	79	3,610	21,700	28,800	33
CP153	12	1	2,330	1,800	1,800	4
CP170	12	94	3,490	24,000	28,700	20
CP195	12	24	2,060	14,900	13,400	11
CP225	12	123	3,370	27,700	23,900	14
CP250	12	172	3,300	32,800	34,700	6

** 39% difference is the average standard error of the regression equations

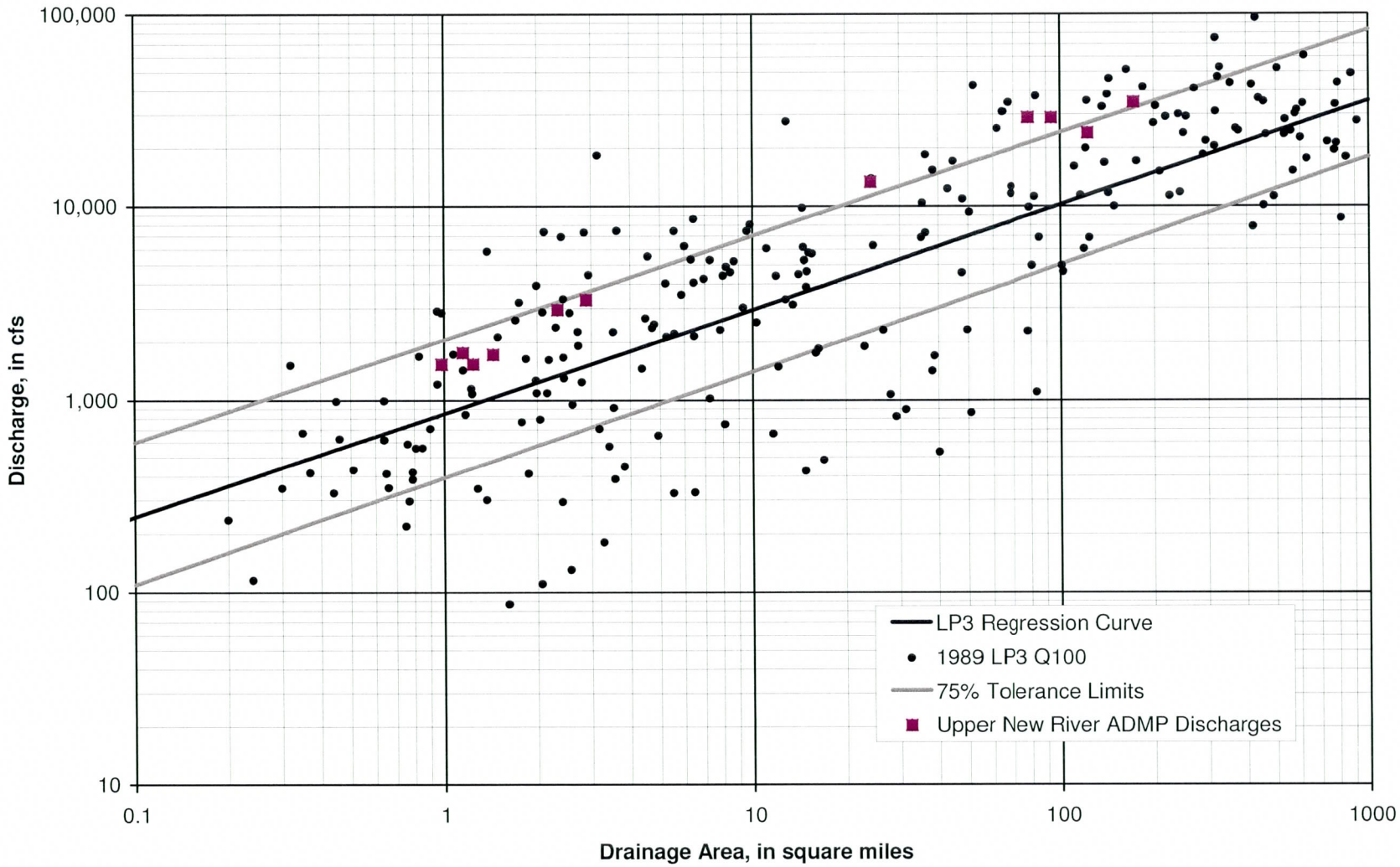

Figure 4.3- Indirect Verification Method 2

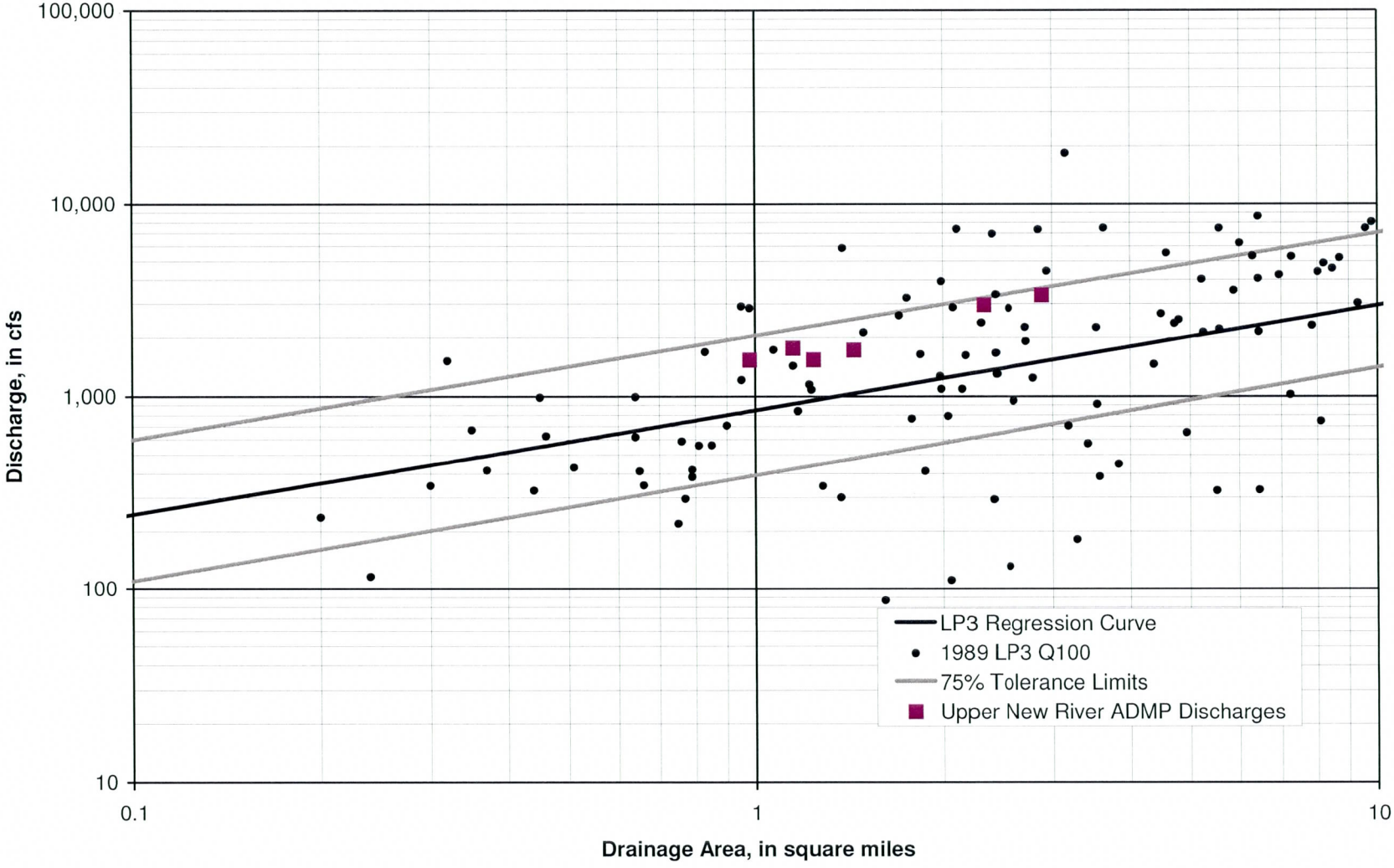

Figure 4.4- Indirect Verification Method 2

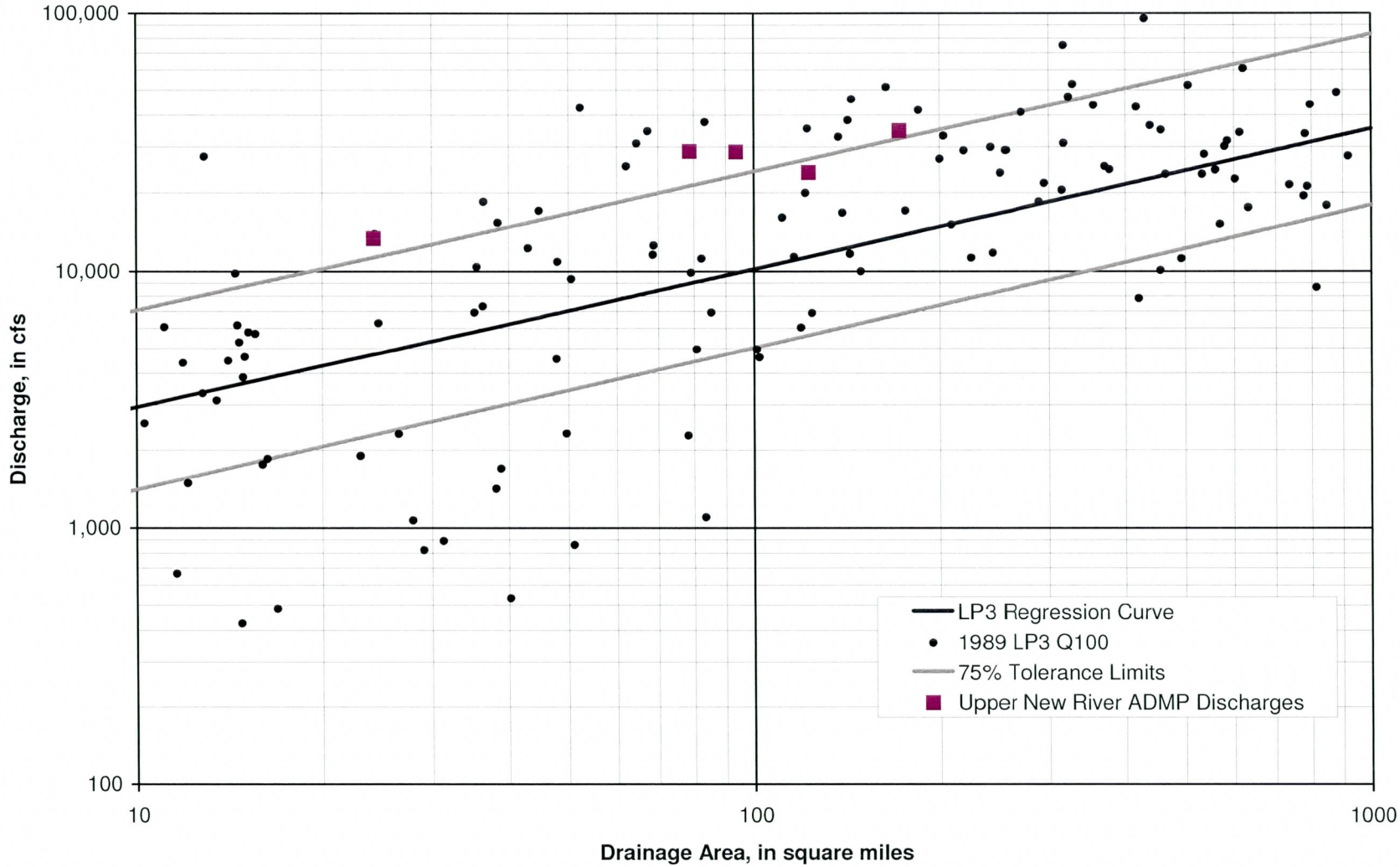

Figure 4.5- Indirect Verification Method 2

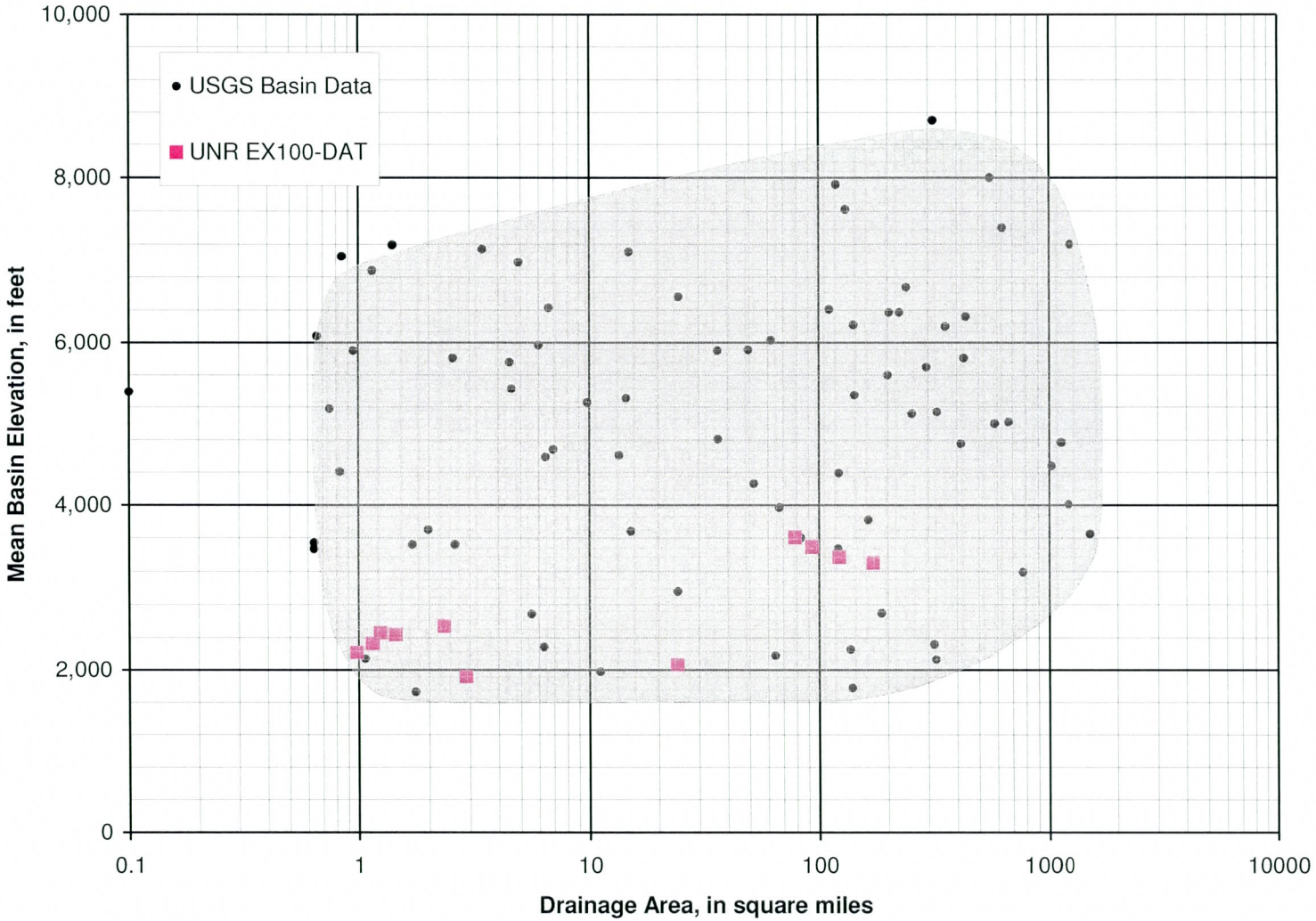

Figure 4.6- Indirect Verification Method 3

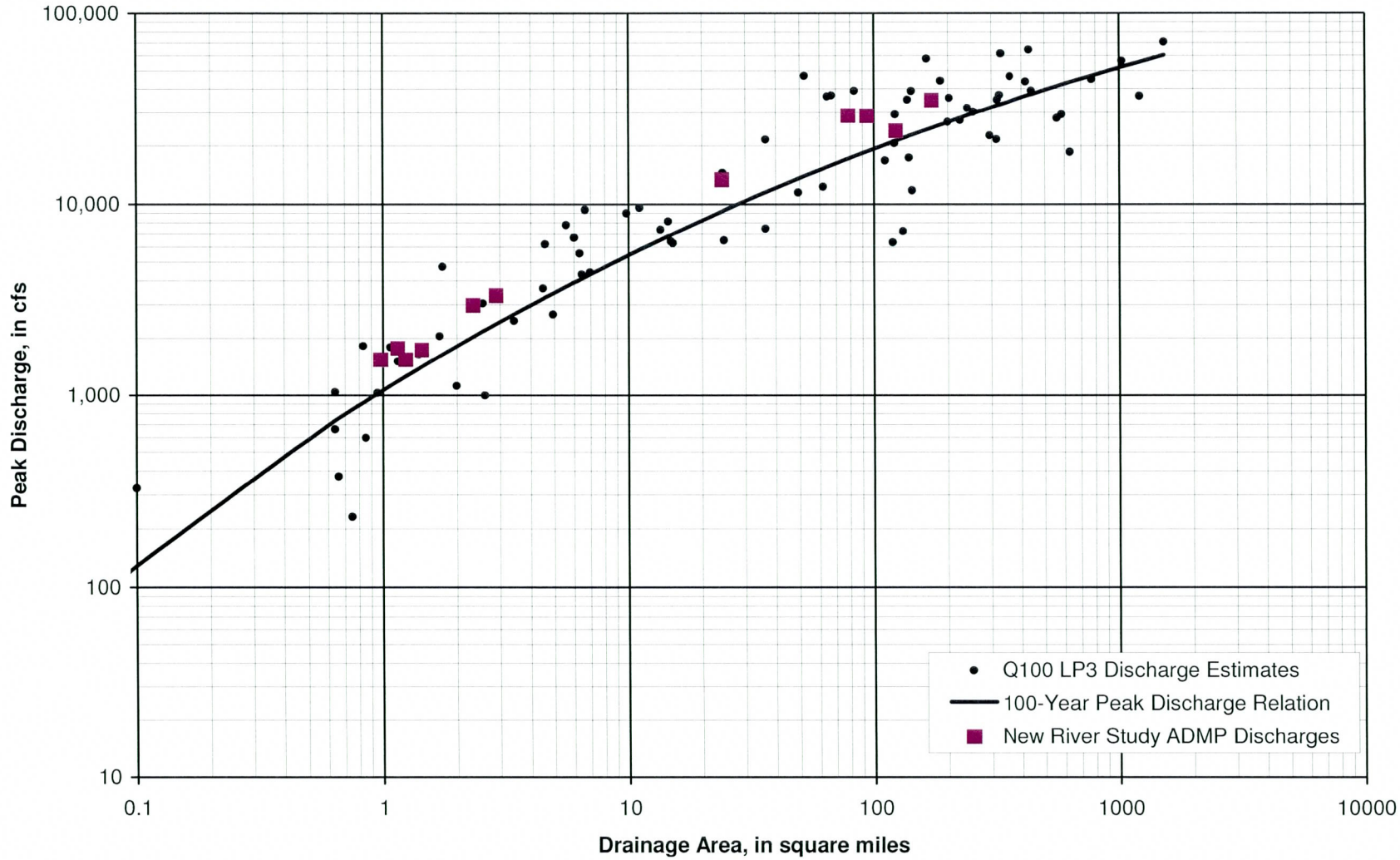

Figure 4.7- Indirect Verification Method 3

5.0 CONCLUSIONS

The results of the hydrologic modeling for the study watershed are used to quantify the magnitude of existing flood hazards and to identify potential issues and concerns. This information is intended as a guide for future development and planning activities in the watershed. Some important conclusions that can be drawn from the results are summarized below.

5.1 IMPACTS DUE TO LAND USE PLANS

The land use plans which have been developed by Phoenix, Peoria and Maricopa County are highly varied, with planning zones ranging from commercial to very low density residential. They provide only general guidance and many large areas are assigned two or more possible uses. The uncertainty of ultimate development use makes it difficult to anticipate the effects of development in the study area.

For planning purposes the future (developed) conditions were simulated by increasing the percent of impervious area (RTIMP) in each subbasin based on the anticipated use. The clayey, non-retentive soils throughout much of the study area were already causing relatively high runoff from the basins. Applying additional impervious area to subbasins did not produce a significant change in the discharge. For example, at New River Dam the difference in runoff peaks between the existing and future conditions models is approximately 2,000 cfs. Additional comparisons are provided in Table 4.2.

The relatively small difference between the existing and future conditions model results is not necessarily representative of the actual effects of development in the study area. Development may have significant impacts on the timing of the peak discharge. This is potentially important in the main stem downstream of Sweat Canyon Wash and Deadman Wash where the hydrograph currently has two distinct peaks (Figure 4.1). Altering the timing of the study area runoff could cause the hydrographs to coincide and increase the overall flood peak. For this reason, it is very important to fully evaluate any land use that may delay the Sweat Canyon or Deadman Wash runoff hydrograph or advance the main stem hydrograph.

5.2 IMPACT TO TRANSPORTATION PLANS

At full build out, it is anticipated that the transportation infrastructure in the study area will provide access for a large number of people. The low soil infiltration rates, combined with the timing differences between the upper and lower portions of the watershed, result in a long duration of runoff, so low water crossings may not be functional for much of a runoff event. Major corridors such as the Carefree Highway and New River Road will need to provide all weather access.

The double peaked hydrograph discussed in the previous section may also adversely impact transportation structures. If future conditions alter the peak timing, existing structures and those built for existing conditions could experience much higher discharges than anticipated. The proposed Loop 303 crossing and the CAP crossing of

New River may be particularly affected, as they are downstream of the confluence with Deadman Wash and currently experience non-coincident peak discharges.

5.3 SIGNIFICANCE RELATIVE TO PREVIOUS STUDIES

In general, the results of the Upper New River ADMP hydrology accord well with the results of previous studies (see Table 4.3). The major differences in hydrology arise because of physical changes in the study area, the updated ADMP precipitation values and differences in unit hydrograph methodology.

Changes to the main channel of New River, such as borrow and gravel pits, have eliminated previously identified flow splits and created new flow diversions. The new diversions are sensitive to changes in discharge, and by diverting flow in different amounts to various side channels, can affect the overall timing of the flood peaks.

The borrow pits present in the main stem of the New River provide minimal stormwater storage in the watercourse and do not provide significant attenuation or delay to the peak discharge. The results of the HEC-1 model indicate that they have too little storage volume available compared to the volume of water being conveyed through the watercourse, and are too steeply sloped to act as effective detention/retention basins.

Runoff peaks for the upper portion of the watershed are lower than those found in previous studies. The 1987 CVL model predicts 34,500 cfs of runoff for the 100-year, 24-hour storm at the USGS Rock Springs gage, while the Upper New River ADMP predicts 29,400 cfs. The differences can be attributed to the different precipitation values used in the two models. CVL used an areally reduced point rainfall of 4.65 inches for the 77 square mile upper watershed. The ADMP rainfall for 77 square miles is approximately 4.16 inches.

The peak runoff values in the lower watershed appear to fall far short of the previous values. At CP230 (the CAP canal crossing) the ADMP discharge is 34,400 cfs, while the value used in the CVL study is 54,600 cfs. The CVL model used kinematic wave to generate the unit hydrograph and route flows within the Deadman subwatershed. As a result, there is no attenuation in the lower portion of the watershed and very short travel times. Figure 5.1 shows the hydrographs for the Deadman subwatershed, and Figure 5.2 depicts the main channel hydrographs just downstream of the Deadman Wash/New River confluence. As can be seen, the large difference in runoff peaks is due to the use of kinematic wave for Deadman Wash in the CVL model.

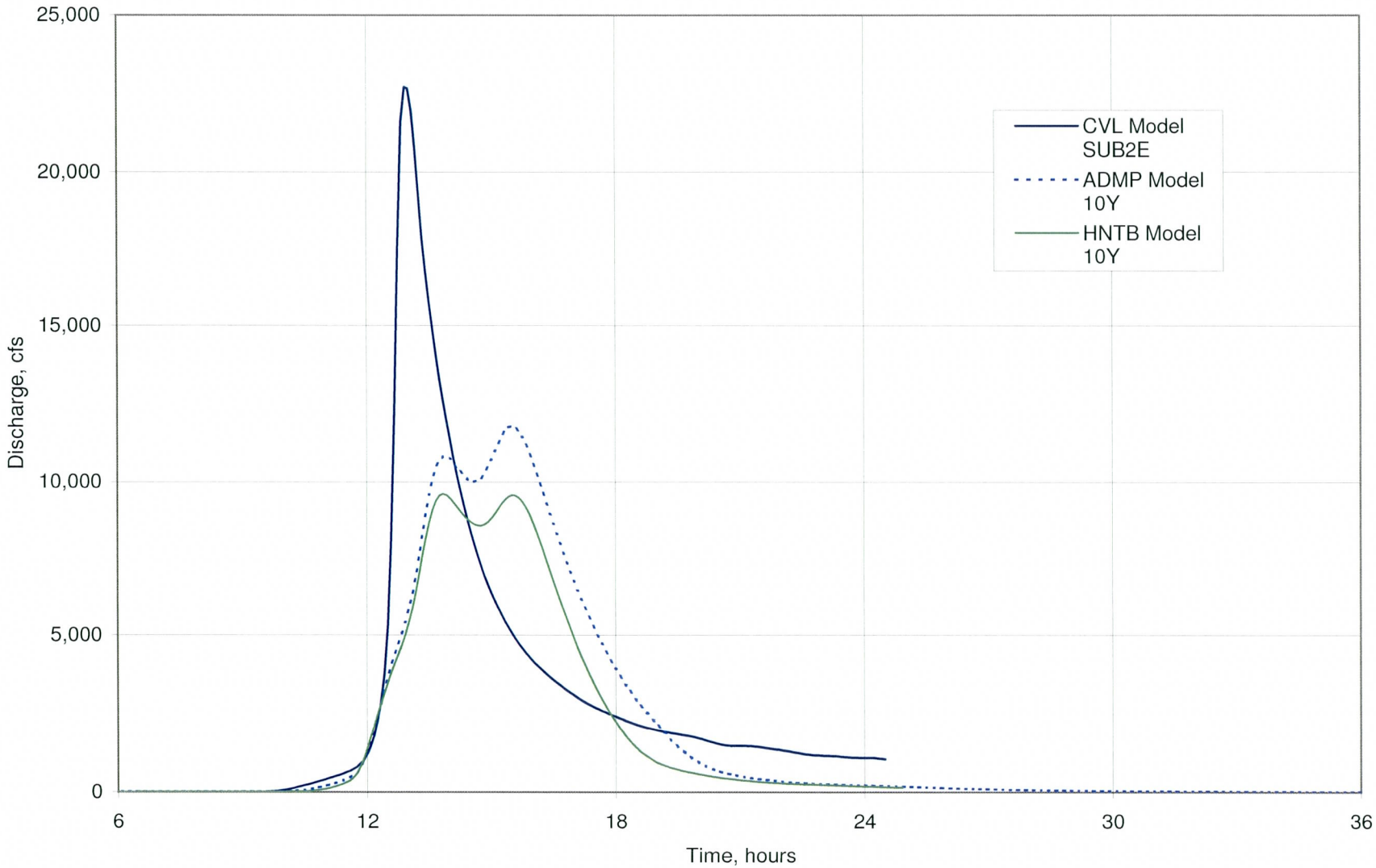

Figure 5.1, Hydrograph comparison, Deadman Subwatershed

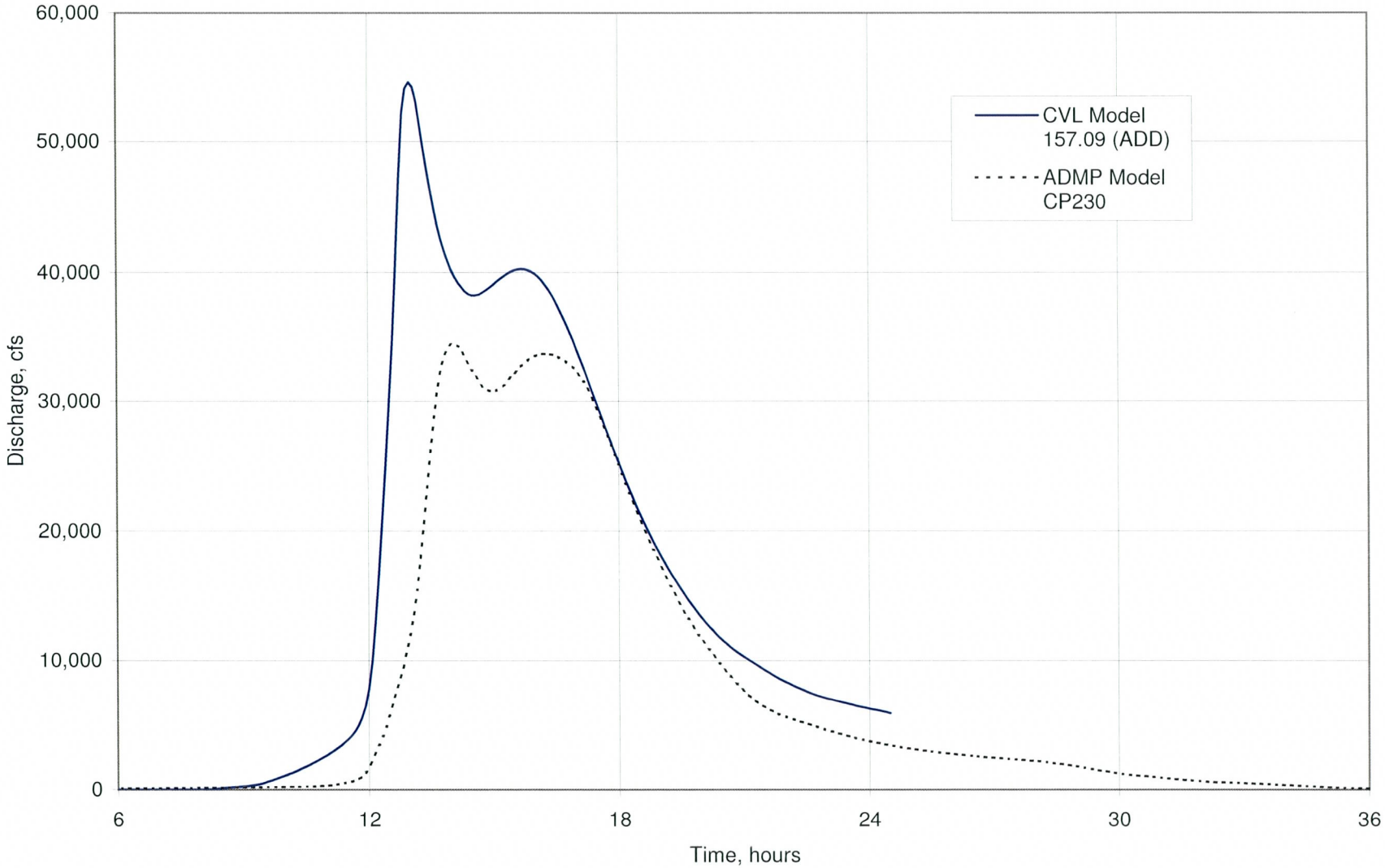

Figure 5.2- Hydrograph comparison, Main Channel at Confluence with Deadman Wash

6.0 REFERENCES

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Hydro CD 2008-OE per Theresa Pinto

Appendix A

Digital Input and Output Files Provided By the District

Appendix A

Digital Input and Output Files Provided By the District

Appendix B

DDMSW files for ADMP Existing and Future Conditions

See CD at Appendix A

Appendix C

Culvertmaster and Flowmaster Worksheets

Worksheet
Worksheet for Irregular Channel

Project Description	
Worksheet	CP175
Flow Element	Irregular Chan
Method	Manning's For
Solve For	Channel Depth

Input Data		
Slope	005545	ft/ft
Discharg	500.00	cfs

Options	
Current Roughness Meth	ved Lotter's Method
Open Channel Weighting	ved Lotter's Method
Closed Channel Weightin	Horton's Method

Results		
Mannings Coefficie	0.050	
Water Surface Elev	1,704.90	ft
Elevation Range	02.00 to 1,724.00	
Flow Area	155.2	ft²
Wetted Perimeter	88.39	ft
Top Width	87.96	ft
Actual Depth	2.90	ft
Critical Elevation	1,704.07	ft
Critical Slope	0.035857	ft/ft
Velocity	3.22	ft/s
Velocity Head	0.16	ft
Specific Energy	1,705.06	ft
Froude Number	0.43	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
1+00	11+90	0.050

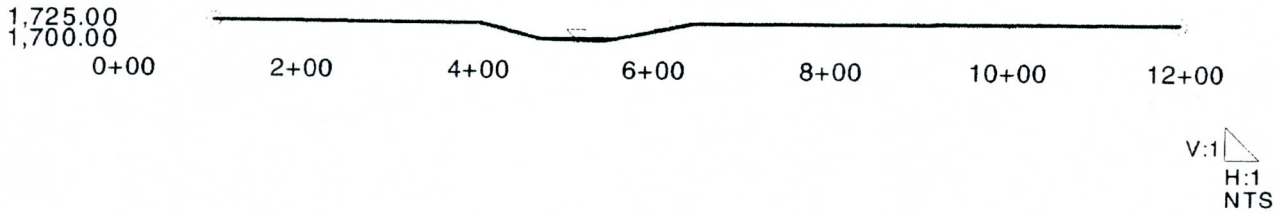
Natural Channel Points

Station (ft)	Elevation (ft)
1+00	1,724.00
4+00	1,722.00
4+70	1,704.00
5+40	1,702.00
6+40	1,722.00
11+90	1,724.00

Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	CP175
Flow Element	Irregular Chan
Method	Manning's For
Solve For	Channel Depth

Section Data		
Mannings Coefficie	0.050	
Slope	0.005545	ft/ft
Water Surface Elev.	1,704.90	ft
Elevation Range	02.00 to 1,724.00	
Discharge	500.00	cfs



Culvert Calculator Report
241

Solve For: Discharge

Culvert Summary			
Allowable HW Elevation	1,522.00 ft	Headwater Depth/ Height	7.00
Computed Headwater Elevation	1,522.00 ft	Discharge	56.13 cfs
Inlet Control HW Elev	1,522.00 ft	Tailwater Elevation	1,500.00 ft
Outlet Control HW Elev	1,520.52 ft	Control Type	Inlet Control

Grades			
Upstream Invert	1,508.00 ft	Downstream Invert	1,500.00 ft
Length	180.00 ft	Constructed Slope	0.044444 ft/ft

Hydraulic Profile			
Profile	CompositeM2Pressure	Depth, Downstream	1.99 ft
Slope Type	Mild	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	1.99 ft
Velocity Downstream	17.88 ft/s	Critical Slope	0.057595 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 ft
Section Size	24 inch	Rise	2.00 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev	1,520.52 ft	Upstream Velocity Head	4.96 ft
Ke	0.50	Entrance Loss	2.48 ft

Inlet Control Properties			
Inlet Control HW Elev	1,522.00 ft	Flow Control	Submerged
Inlet Type	Square edge w/headwall	Area Full	3.1 ft^2
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
242

Solve For: Discharge

Culvert Summary			
Allowable HW Elevation	1,522.00 ft	Headwater Depth/ Height	7.00
Computed Headwater Elevation	1,522.00 ft	Discharge	56.18 cfs
Inlet Control HW Elev	1,522.00 ft	Tailwater Elevation	1,496.00 ft
Outlet Control HW Elev	1,517.45 ft	Control Type	Inlet Control

Grades			
Upstream Invert	1,508.00 ft	Downstream Invert	1,496.00 ft
Length	180.00 ft	Constructed Slope	0.066667 ft/ft

Hydraulic Profile			
Profile	S2	Depth, Downstream	1.60 ft
Slope Type	Steep	Normal Depth	1.57 ft
Flow Regime	Supercritical	Critical Depth	1.99 ft
Velocity Downstream	20.80 ft/s	Critical Slope	0.057702 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 ft
Section Size	24 inch	Rise	2.00 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev	1,517.45 ft	Upstream Velocity Head	4.98 ft
Ke	0.50	Entrance Loss	2.49 ft

Inlet Control Properties			
Inlet Control HW Elev	1,522.00 ft	Flow Control	Submerged
Inlet Type	Square edge w/headwall	Area Full	3.1 ft^2
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
243

Solve For: Discharge

Culvert Summary			
Allowable HW Elevation	1,524.00 ft	Headwater Depth/ Height	4.80
Computed Headwater Elevation	1,524.00 ft	Discharge	79.33 cfs
Inlet Control HW Elev	1,524.00 ft	Tailwater Elevation	1,502.00 ft
Outlet Control HW Elev	1,520.59 ft	Control Type	Inlet Control

Grades			
Upstream Invert	1,512.00 ft	Downstream Invert	1,502.00 ft
Length	180.00 ft	Constructed Slope	0.055556 ft/ft

Hydraulic Profile			
Profile	S2	Depth, Downstream	1.78 ft
Slope Type	Steep	Normal Depth	1.72 ft
Flow Regime	Supercritical	Critical Depth	2.46 ft
Velocity Downstream	21.23 ft/s	Critical Slope	0.033951 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.50 ft
Section Size	30 inch	Rise	2.50 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev	1,520.59 ft	Upstream Velocity Head	4.08 ft
Ke	0.50	Entrance Loss	2.04 ft

Inlet Control Properties			
Inlet Control HW Elev	1,524.00 ft	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	4.9 ft²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
244

Solve For: Discharge

Culvert Summary			
Allowable HW Elevation	1,520.00 ft	Headwater Depth/ Height	5.00
Computed Headwater Elevation	1,520.00 ft	Discharge	262.45 cfs
Inlet Control HW Elev	1,520.00 ft	Tailwater Elevation	1,496.00 ft
Outlet Control HW Elev	1,516.73 ft	Control Type	Inlet Control

Grades			
Upstream Invert	1,500.00 ft	Downstream Invert	1,496.00 ft
Length	197.00 ft	Constructed Slope	0.020305 ft/ft

Hydraulic Profile			
Profile	CompositeM2Pressure	Depth, Downstream	3.95 ft
Slope Type	Mild	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	3.95 ft
Velocity Downstream	20.94 ft/s	Critical Slope	0.030401 ft/ft

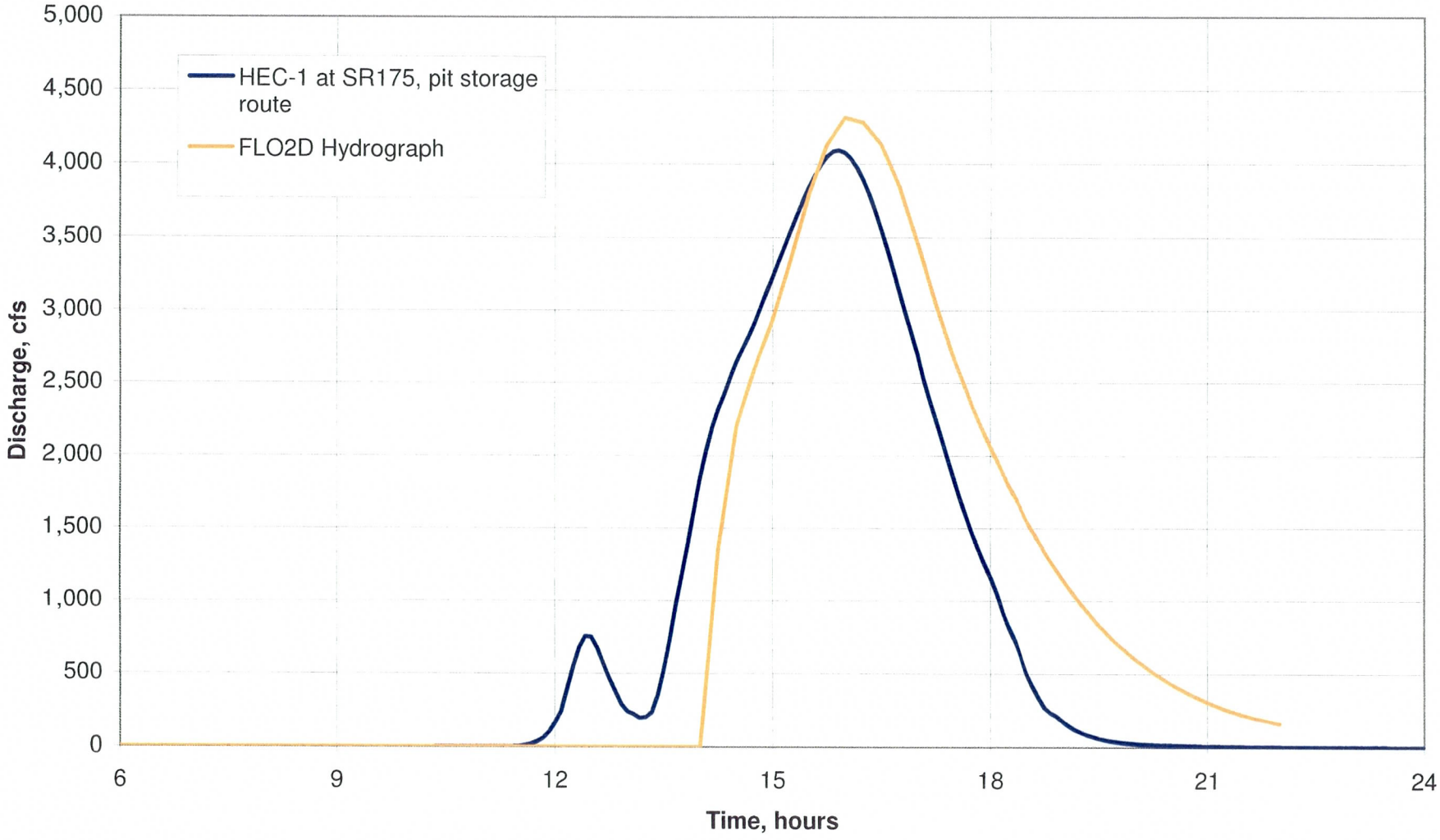
Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	4.00 ft
Section Size	48 inch	Rise	4.00 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev	1,516.73 ft	Upstream Velocity Head	6.78 ft
Ke	0.50	Entrance Loss	3.39 ft

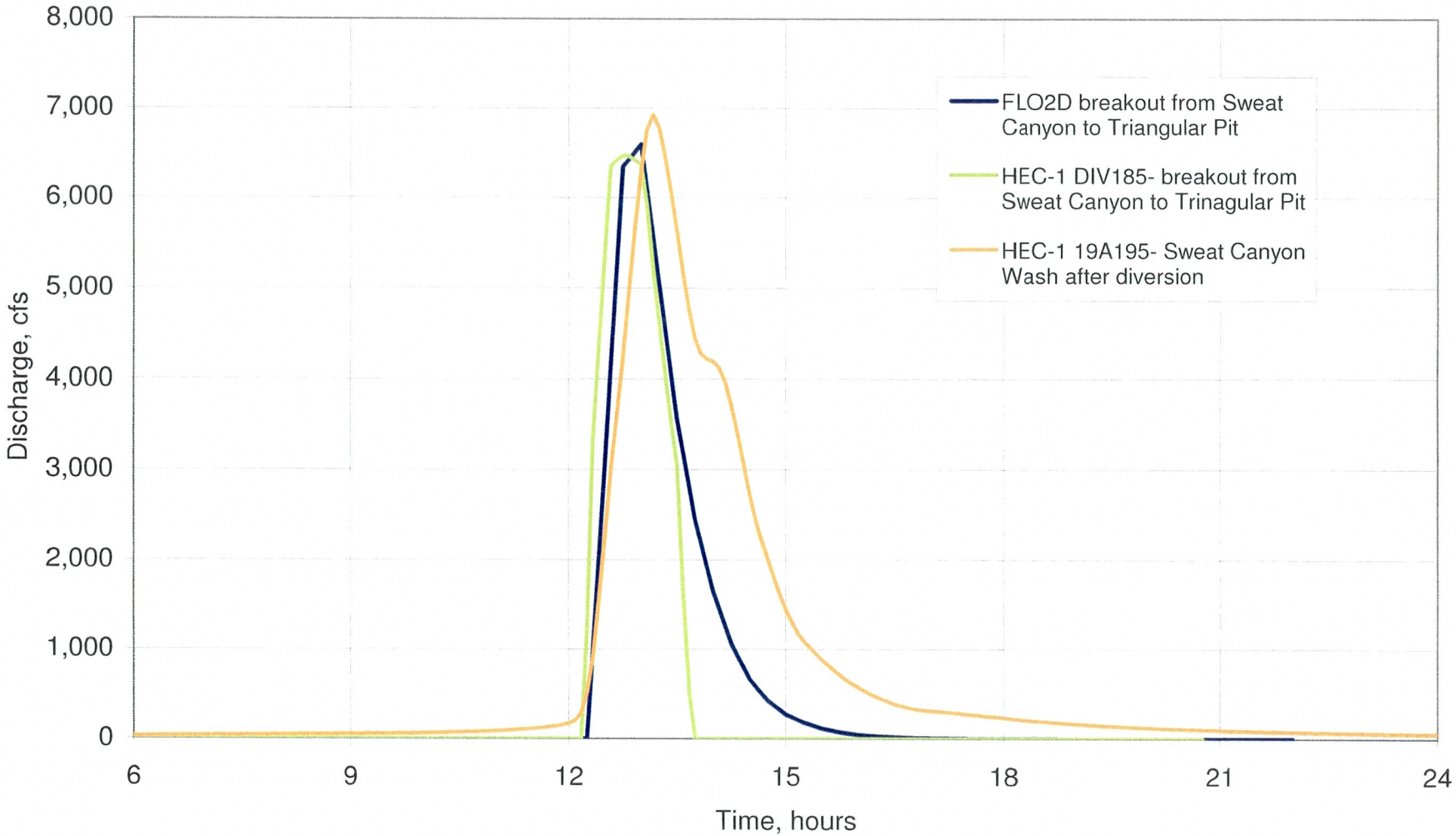
Inlet Control Properties			
Inlet Control HW Elev	1,520.00 ft	Flow Control	Submerged
Inlet Type	Square edge w/headwall	Area Full	12.6 ft²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Appendix D

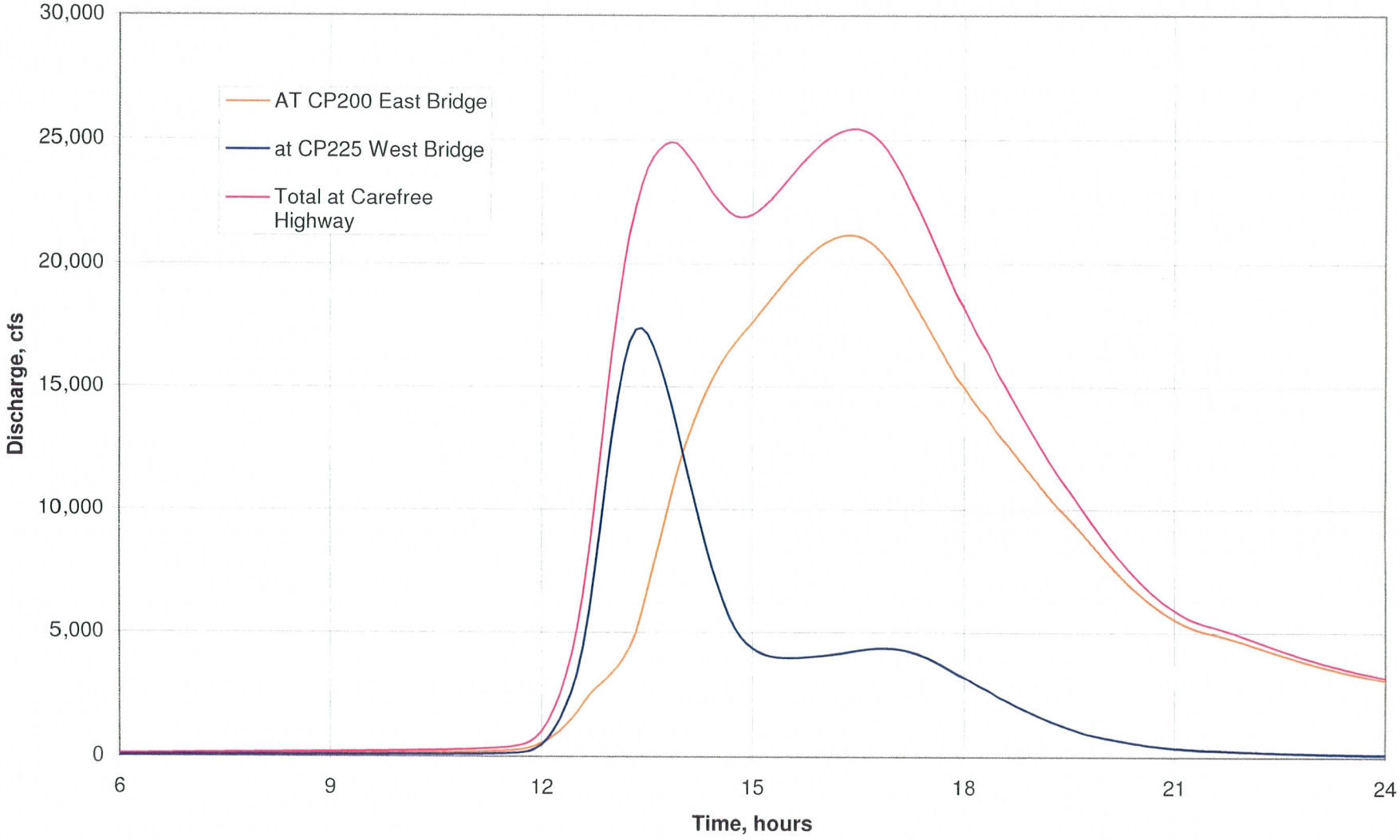
Hydrograph Comparisons for FLO-2D and HEC-1



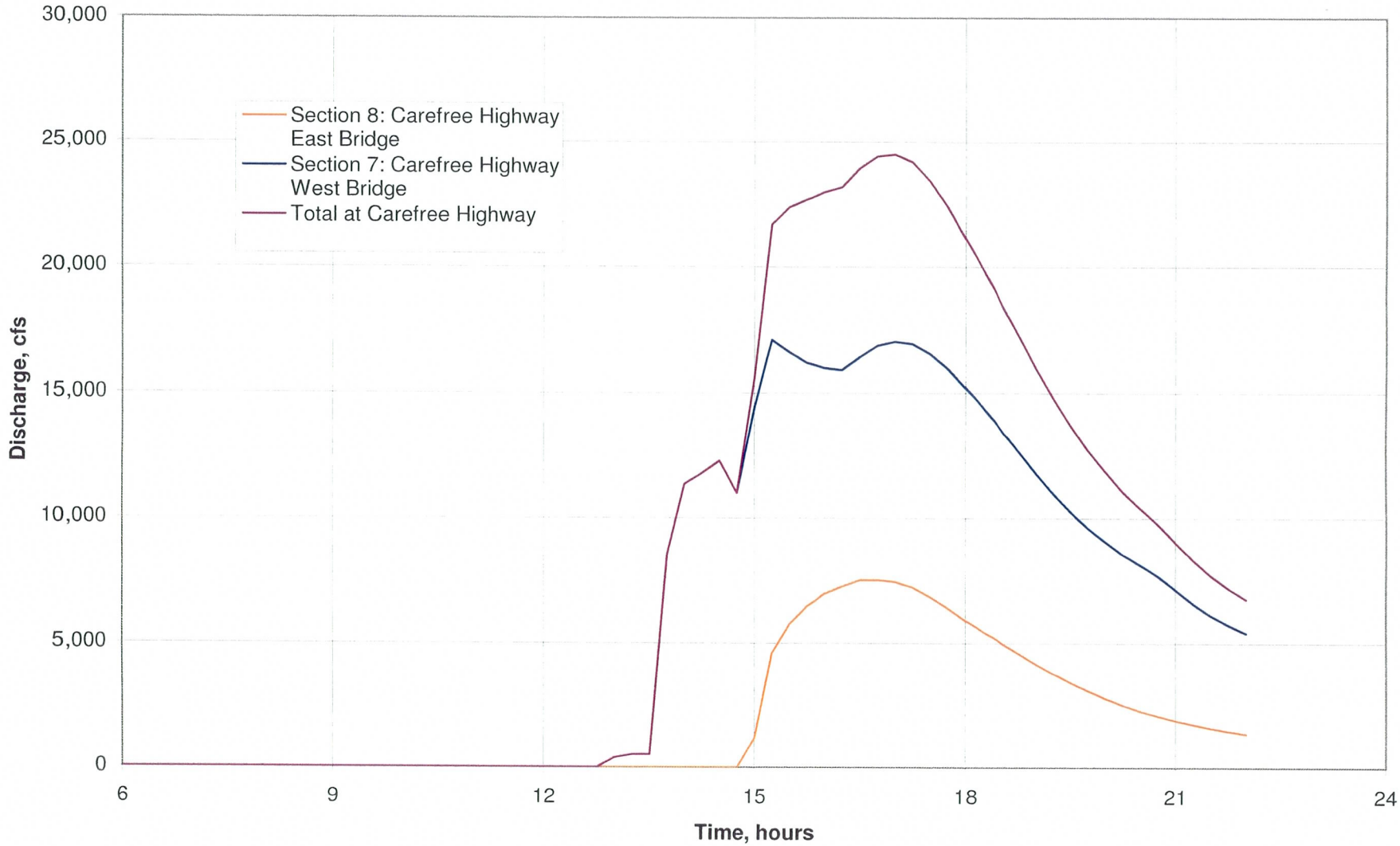
Hydrographs for pit at CP175



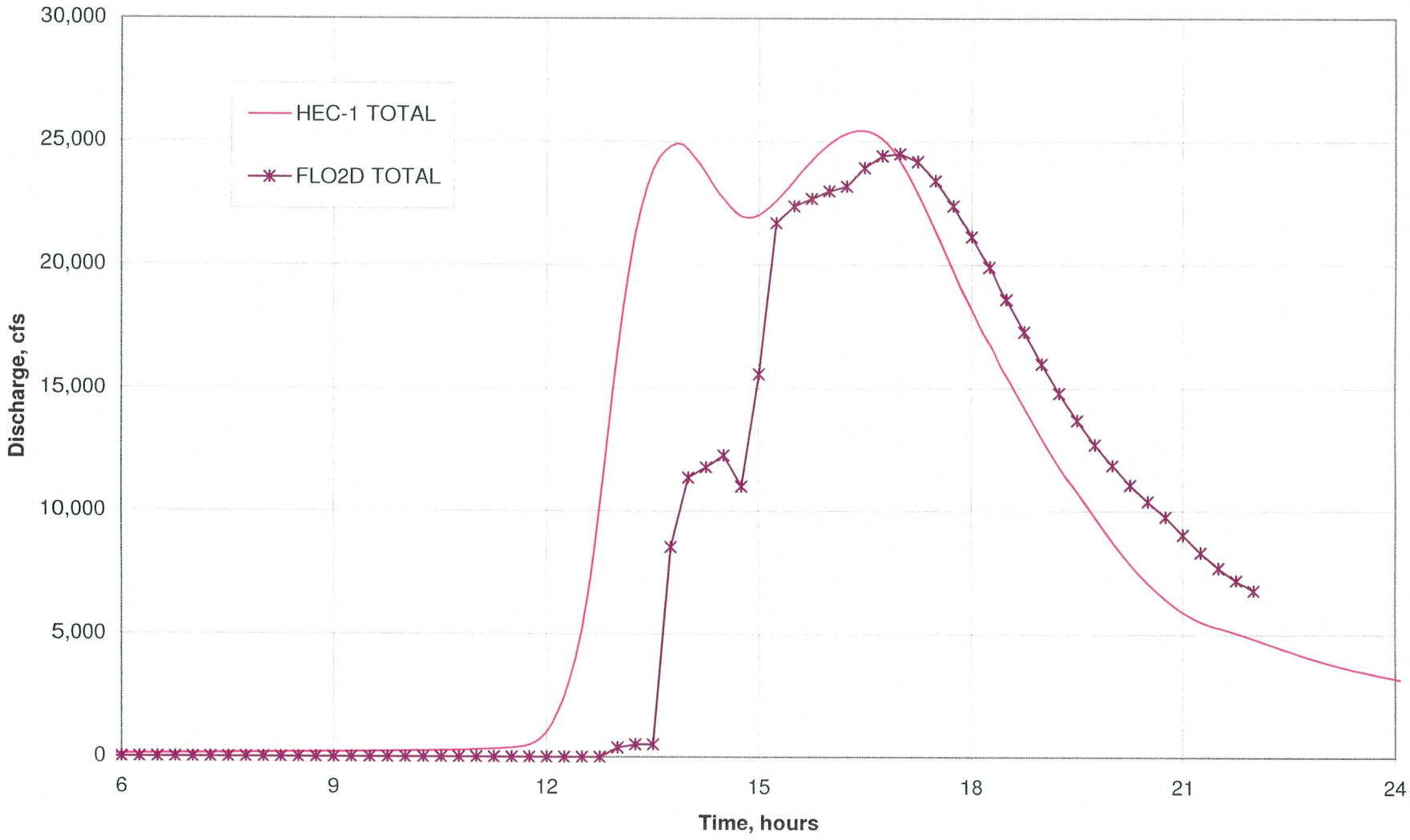
Hydrographs at the Breakout from Sweat Canyon Wash to Triangular Pit



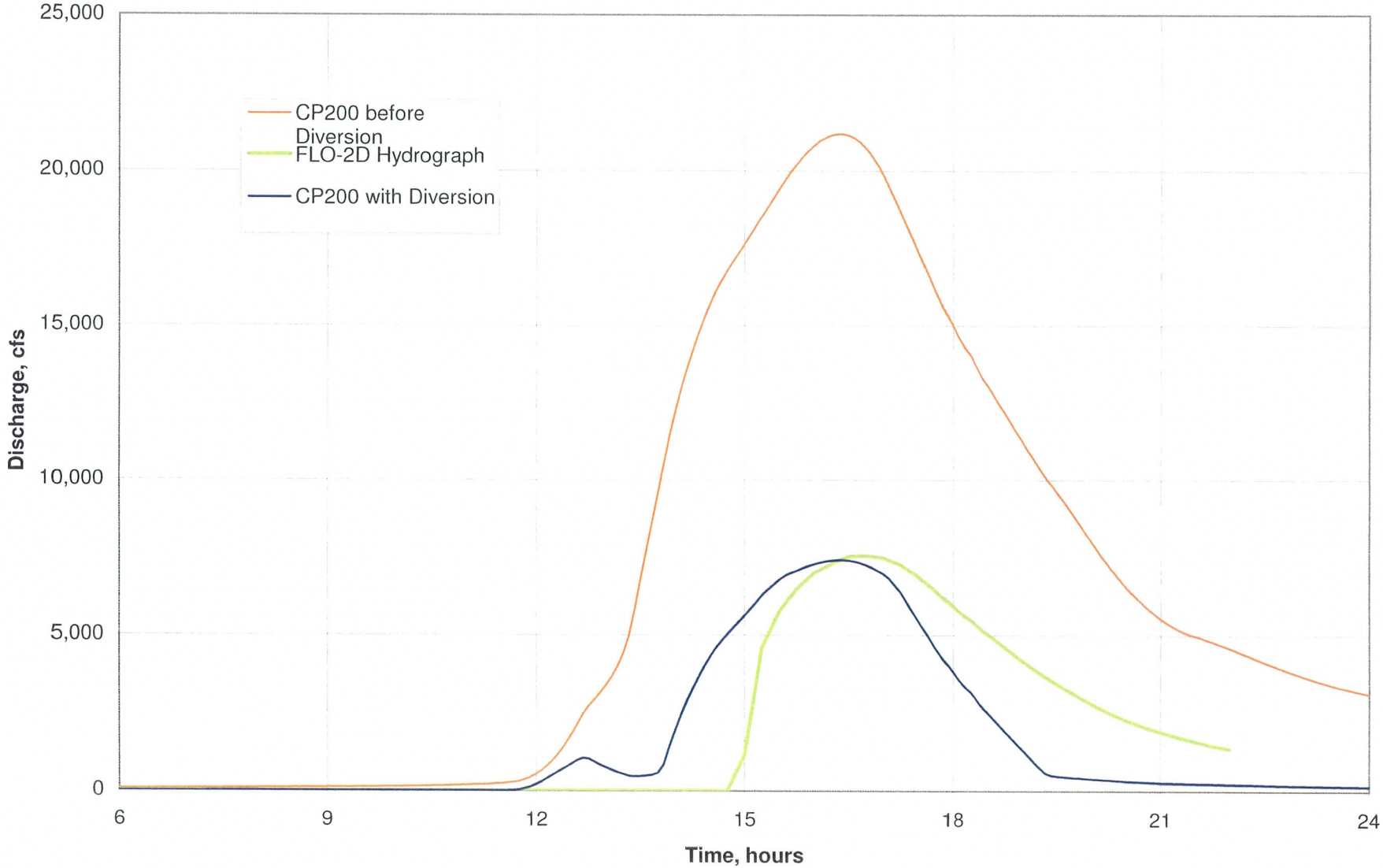
HEC-1 Hydrographs at Carefree Highway Before Flow Diversion



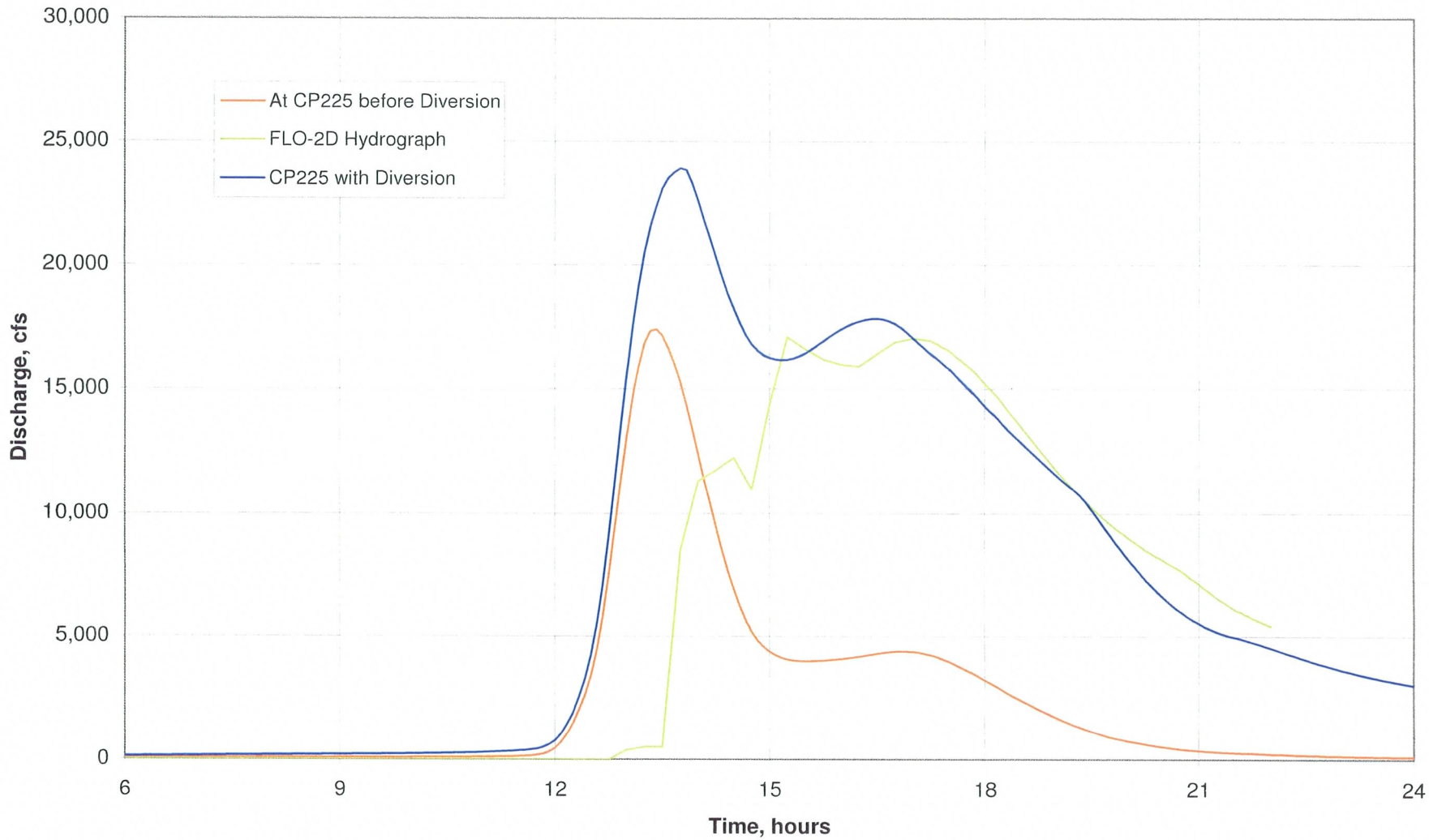
FLO-2D Hydrographs at Carefree Highway



Hydrograph Comparison at Carefree Highway before Diversion



East Bridge Hydrographs at Carefree Highway



West Hydrographs at Carefree Highway

Appendix E

HEC-1 Input and Output Files

See CD at Appendix A

Appendix F

Summary of HEC-1 Results

Existing Conditions 100-year Hydrology

Concentration Point	EX100-24.DAT Q (cfs)	EX100-6.DAT Q (cfs)	Concentration Point	EX100-24.DAT Q (cfs)	EX100-6.DAT Q (cfs)
CVL100	29321	24486	NR18	1206	1227
NR1	2956	2525	CP200	7554	6321
CP100	29356	24486	200230	7502	6148
100110	29216	24345	DIVSWC	7708	5736
NR2	729	857	19A195	6926	5472
105110	495	603	CK1195	6828	6180
NR3	1532	1574	CJ1195	764	808
CP110	29205	24342	NR21	675	759
110120	28996	24237	CP195	13355	10845
NR4	1536	1512	195205	13213	10750
115120	1351	1365	DIV175	5437	3176
NR5	1726	1642	170175	5319	3139
116120	1525	1498	NR19	968	1109
NR6	751	840	CP175	5319	3136
CP120	29034	24233	SR175	5250	3113
120130	28840	23957	175185	5162	3065
NR7	518	606	NR20	586	679
125130	468	551	DIV185	6470	5898
NR8	782	912	CP185	6622	3543
CP130	28830	23952	185205	5795	3223
130140	28757	23869	CH1205	428	492
GAV140	8129	7103	NR22	1068	1079
NR9	160	189	CP205	16868	10737
CP140	29028	23985	205215	16692	10439
140150	28999	23970	CG1215	220	254
BLK150	2180	2233	NR23	1293	1366
NR10	461	551	CP215	17148	10725
145150	364	435	215225	17009	10634
NR11	238	281	CF1225	479	534
CP150	28994	23970	CE1225	402	467
150160	28952	23880	NR24	444	523
UT1	831	968	DIV225	14029	12302
151152	800	948	CP225	23929	14981
UT2	713	843	225230	23598	14823
CP152	1157	1266	CD1230	1101	1116
152153	1152	1265	CC1230	322	390
UT3	578	684	CB1230	521	577
CP153	1675	1729	INT230	25505	17254
153160	1513	1583	NR25	310	366
NR12	486	578	NR26	1184	1137
154160	406	486	CP230	34391	23654
NR13	1216	1336	230250	33955	23512
CP160	28952	23881	CA1250	89	89
160170	28730	23639	CAP1	174	212
NR14	301	359	SR241	42	44
165170	150	181	241250	33	36
NR15	3326	3127	CAP2	125	152
CP170	28730	23636	SR242	7	9
DIV170	23280	20288	242250	6	6
170180	23239	20204	CAP3	312	373
NR16	744	867	SR243	51	52
CP180	23239	20198	243250	49	51
180190	23203	20111	CAP4	1529	1406
NR17	1212	1274	SR244	139	140
CP190	23203	20102	244250	138	138
DIV190	21628	18735	NR27	4277	3386
190200	21583	18629	CP250	34575	23475
DIV200	7554	6327			

Existing Conditions 50-year Hydrology

Concentration Point	EX50-24.DAT Q (cfs)	EX50-6.DAT Q (cfs)	Concentration Point	EX50-24.DAT Q (cfs)	EX50-6.DAT Q (cfs)
CVL100	25551	21150	NR18	1042	1050
NR1	2572	2164	CP200	6917	4744
CP100	25581	21145	200230	6801	4586
100110	25433	21013	DIVSWC	5845	4895
NR2	635	745	19A195	5500	4672
105110	419	492	CK1195	5898	5279
NR3	1343	1370	CJ1195	632	676
CP110	25428	21013	NR21	583	654
110120	25352	20932	CP195	11259	9427
NR4	1340	1305	195205	11096	9324
115120	1155	1158	DIV175	3553	2411
NR5	1497	1411	170175	3511	2367
116120	1307	1268	NR19	857	979
NR6	642	715	CP175	3511	2364
CP120	25384	20928	SR175	3493	2347
120130	25181	20696	175185	3454	2297
NR7	451	527	NR20	510	588
125130	404	476	DIV185	6122	4763
NR8	683	794	CP185	5349	2545
CP130	25181	20696	185205	4771	2035
130140	25113	20607	CH1205	373	426
GAV140	6968	5934	NR22	903	900
NR9	136	161	CP205	14277	9320
CP140	25367	20726	205215	14086	8544
140150	25355	20711	CG1215	187	214
BLK150	1918	1962	NR23	1145	1200
NR10	411	492	CP215	14402	8747
145150	325	387	215225	14291	8676
NR11	210	248	CF1225	391	433
CP150	25355	20711	CE1225	338	390
150160	25291	20622	NR24	377	444
UT1	725	845	DIV225	12860	11607
151152	686	813	CP225	20224	13390
UT2	635	749	225230	20003	13333
CP152	996	1096	CD1230	968	977
152153	997	1092	CC1230	270	330
UT3	514	607	CB1230	446	493
CP153	1461	1497	INT230	22117	15344
153160	1312	1365	NR25	273	323
NR12	434	515	NR26	1002	935
154160	355	427	CP230	29140	19934
NR13	1073	1174	230250	29048	19754
CP160	25291	20623	CA1250	86	87
160170	25081	20368	CAP1	152	186
NR14	269	320	SR241	40	42
165170	128	152	241250	29	32
NR15	2940	2744	CAP2	109	134
CP170	25081	20365	SR242	6	7
DIV170	21510	17799	242250	4	5
170180	21411	17680	CAP3	271	324
NR16	648	754	SR243	49	51
CP180	21411	17676	243250	47	49
180190	21330	17567	CAP4	1306	1173
NR17	1055	1104	SR244	131	129
CP190	21330	17561	244250	129	128
DIV190	19892	16462	NR27	3641	2761
190200	19777	16354	CP250	29159	19658
DIV200	6917	4746			

Existing Conditions 10-year Hydrology

Concentration Point	EX10-24.DAT Q (cfs)	EX10-6.DAT Q (cfs)	Concentration Point	EX10-24.DAT Q (cfs)	EX10-6.DAT Q (cfs)
CVL100	9630	8060	NR18	398	405
NR1	976	833	CP200	461	374
CP100	9641	8060	200230	450	364
100110	9587	8001	DIVSWC	3707	3258
NR2	241	283	19A195	3511	3095
105110	160	186	CK1195	1904	1778
NR3	506	519	CJ1195	206	219
CP110	9587	8001	NR21	223	251
110120	9548	7962	CP195	5215	4443
NR4	507	499	195205	5128	4361
115120	392	403	DIV175	0	0
NR5	570	542	170175	0	0
116120	439	444	NR19	320	366
NR6	248	277	CP175	264	143
CP120	9556	7962	SR175	224	131
120130	9452	7854	175185	104	74
NR7	171	200	NR20	193	224
125130	144	173	DIV185	0	0
NR8	258	301	CP185	193	265
CP130	9452	7854	185205	112	69
130140	9418	7819	CH1205	118	137
GAV140	2333	2094	NR22	352	356
NR9	53	62	CP205	5128	4449
CP140	9579	7926	205215	4645	2947
140150	9568	7918	CG1215	70	81
BLK150	643	657	NR23	427	451
NR10	152	182	CP215	4738	3007
145150	120	143	215225	4635	2958
NR11	78	93	CF1225	113	127
CP150	9568	7917	CE1225	107	125
150160	9541	7882	NR24	147	173
UT1	274	320	DIV225	8757	7121
151152	249	292	CP225	9103	7015
UT2	235	278	225230	9043	6966
CP152	341	378	CD1230	384	394
152153	338	373	CC1230	84	99
UT3	191	226	CB1230	135	147
CP153	492	517	INT230	9202	6921
153160	422	449	NR25	102	121
NR12	161	191	NR26	391	375
154160	118	142	CP230	11441	7828
NR13	401	441	230250	11359	7762
CP160	9541	7882	CA1250	63	64
160170	9410	7750	CAP1	57	70
NR14	99	119	SR241	27	30
165170	35	42	241250	8	10
NR15	1098	1032	CAP2	41	50
CP170	9410	7750	SR242	2	2
DIV170	9404	7689	242250	1	1
170180	9360	7650	CAP3	103	123
NR16	245	286	SR243	39	41
CP180	9360	7649	243250	31	34
180190	9294	7586	CAP4	505	464
NR17	400	420	SR244	81	81
CP190	9294	7583	244250	77	78
DIV190	9289	7566	NR27	1411	1117
190200	9218	7496	CP250	11431	7719
DIV200	461	375			

Future Conditions 100-year Hydrology

Concentration Point	FU100-24.DAT Q (cfs)	FU100-6.DAT Q (cfs)
CVL100	29321	24486
NR1	2986	2567
CP100	29368	24486
100110	29228	24356
NR2	736	866
105110	504	614
NR3	1543	1590
CP110	29217	24354
110120	29014	24251
NR4	1553	1537
115120	1369	1392
NR5	1753	1679
116120	1553	1537
NR6	758	850
CP120	29072	24251
120130	28878	23986
NR7	524	615
125130	474	560
NR8	787	919
CP130	28871	23981
130140	28798	23900
GAV140	8226	7221
NR9	171	203
CP140	29093	24038
140150	29065	24030
BLK150	2185	2234
NR10	462	554
145150	366	438
NR11	244	290
CP150	29060	24030
150160	29023	23936
UT1	840	981
151152	811	961
UT2	714	845
CP152	1167	1280
152153	1163	1280
UT3	579	685
CP153	1686	1746
153160	1526	1601
NR12	487	580
154160	407	488
NR13	1220	1342
CP160	29023	23936
160170	28809	23700
NR14	303	362
165170	153	185
NR15	3364	3190
CP170	28826	23697
DIV170	23306	20339
170180	23266	20255
NR16	760	891
CP180	23268	20250
180190	23235	20165
NR17	1242	1318
CP190	23240	20156
DIV190	21665	18786
190200	21621	18680
DIV200	7567	6356

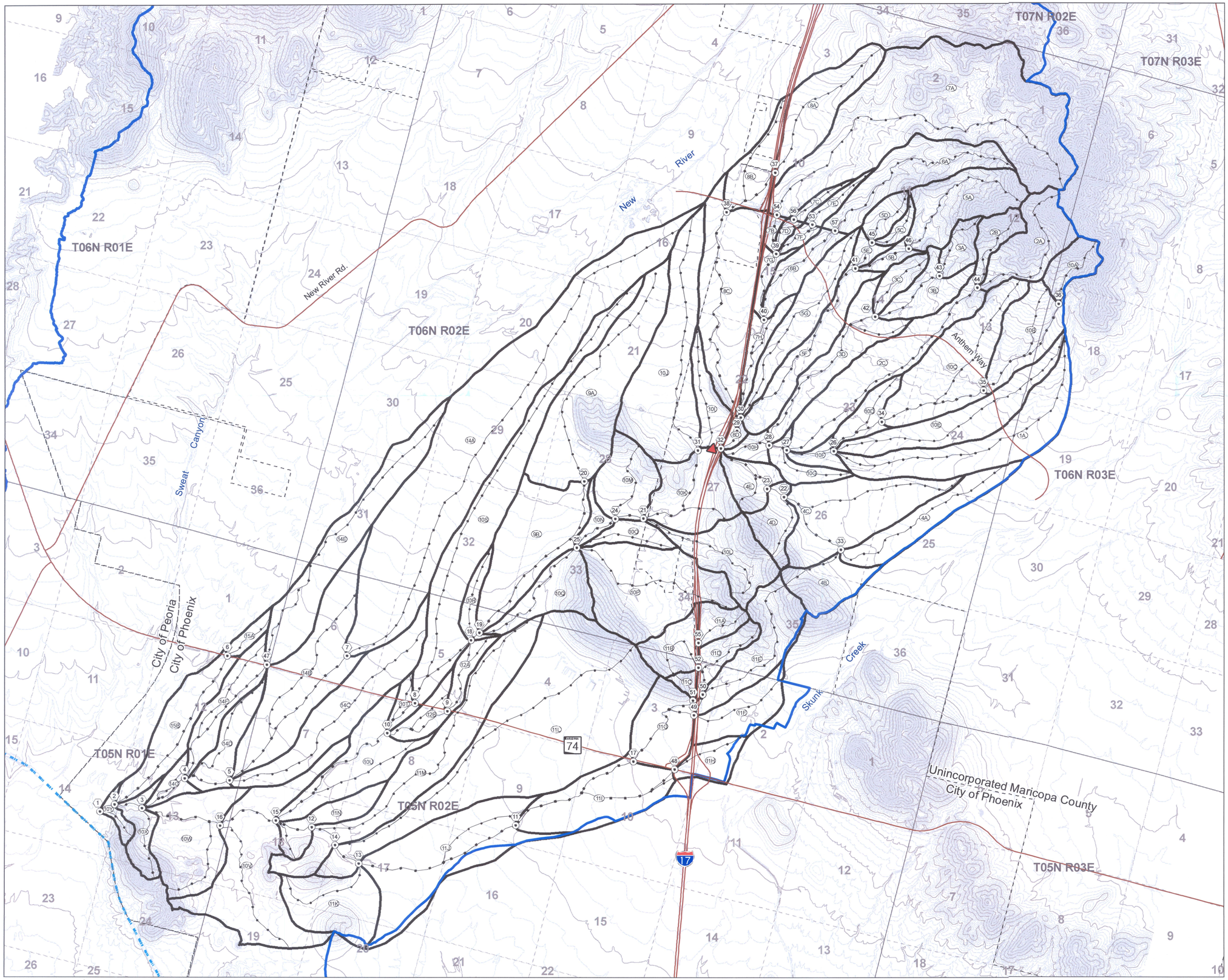
Concentration Point	FU100-24.DAT Q (cfs)	FU100-6.DAT Q (cfs)
NR18	1247	1287
CP200	7575	6350
200230	7528	6183
DIVSWC	8219	6003
19A195	7397	5733
CK1195	6990	6429
CJ1195	827	907
NR21	713	813
CP195	14086	11421
195205	13964	11329
DIV175	5520	3192
170175	5401	3155
NR19	978	1125
CP175	5401	3152
SR175	5338	3128
175185	5248	3083
NR20	599	698
DIV185	6538	6321
CP185	6775	3855
185205	6085	3570
CH1205	444	517
NR22	1118	1145
CP205	17770	11574
205215	17608	11462
CG1215	245	295
NR23	1310	1399
CP215	18098	11788
215225	17977	11712
CF1225	544	623
CE1225	453	539
NR24	481	570
DIV225	14054	12324
CP225	24872	16081
225230	24613	15973
CD1230	1220	1265
CC1230	350	430
CB1230	571	668
INT230	25971	17343
NR25	320	382
NR26	1226	1192
CP230	36283	24188
230250	35884	24076
CA1250	129	131
CAP1	174	212
SR241	42	44
241250	33	36
CAP2	125	152
SR242	7	9
242250	6	6
CAP3	313	374
SR243	51	52
243250	49	51
CAP4	1591	1487
SR244	145	146
244250	144	145
NR27	4371	3510
CP250	36626	24053

Future Conditions 50-year Hydrology

Concentration Point	FU50-24.DAT Q (cfs)	FU50-6.DAT Q (cfs)	Concentration Point	FU50-24.DAT Q (cfs)	FU50-6.DAT Q (cfs)
CVL100	25551	21150	NR18	1084	1111
NR1	2603	2207	CP200	6951	4773
CP100	25591	21145	200230	6845	4621
100110	25443	21021	DIVSWC	6149	5218
NR2	642	755	19A195	5726	4973
105110	426	505	CK1195	6074	5530
NR3	1354	1387	CJ1195	698	772
CP110	25438	21021	NR21	622	708
110120	25365	20943	CP195	11786	9977
NR4	1358	1330	195205	11635	9895
115120	1176	1185	DIV175	3582	2420
NR5	1524	1449	170175	3538	2378
116120	1337	1310	NR19	867	996
NR6	650	726	CP175	3540	2375
CP120	25415	20939	SR175	3525	2359
120130	25216	20722	175185	3484	2310
NR7	457	535	NR20	523	608
125130	411	485	DIV185	6356	5126
NR8	688	801	CP185	5727	3110
CP130	25216	20718	185205	5098	2727
130140	25150	20636	CH1205	390	453
GAV140	7060	6054	NR22	954	966
NR9	147	175	CP205	15222	9890
CP140	25428	20781	205215	14987	9576
140150	25417	20766	CG1215	211	248
BLK150	1921	1964	NR23	1163	1234
NR10	413	495	CP215	15412	9854
145150	327	390	215225	15286	9773
NR11	217	258	CF1225	459	517
CP150	25417	20766	CE1225	388	462
150160	25358	20680	NR24	414	491
UT1	734	857	DIV225	12912	11623
151152	696	829	CP225	21270	13499
UT2	635	750	225230	21049	13444
CP152	1007	1112	CD1230	1100	1139
152153	1009	1108	CC1230	302	375
UT3	515	608	CB1230	503	585
CP153	1473	1516	INT230	22555	15312
153160	1325	1384	NR25	284	339
NR12	435	517	NR26	1044	991
154160	356	429	CP230	30959	20435
NR13	1077	1180	230250	30619	20265
CP160	25358	20681	CA1250	116	115
160170	25152	20426	CAP1	152	186
NR14	270	323	SR241	40	42
165170	131	157	241250	30	32
NR15	2980	2810	CAP2	109	134
CP170	25162	20424	SR242	6	7
DIV170	21580	17853	242250	4	5
170180	21484	17735	CAP3	272	325
NR16	665	779	SR243	49	51
CP180	21484	17730	243250	47	49
180190	21408	17621	CAP4	1367	1254
NR17	1086	1149	SR244	136	136
CP190	21408	17615	244250	135	135
DIV190	19973	16510	NR27	3734	2885
190200	19858	16403	CP250	31168	20173
DIV200	6947	4779			

Future Conditions 10-year Hydrology

Concentration Point	FU10-24.DAT Q (cfs)	FU10-6.DAT Q (cfs)	Concentration Point	FU10-24.DAT Q (cfs)	FU10-6.DAT Q (cfs)
CVL100	9630	8060	NR18	411	425
NR1	985	847	CP200	466	375
CP100	9644	8060	200230	455	365
100110	9591	8004	DIVSWC	3872	3452
NR2	243	286	19A195	3672	3303
105110	162	189	CK1195	1960	1854
NR3	509	525	CJ1195	225	248
CP110	9591	8004	NR21	235	268
110120	9554	7966	CP195	5476	4768
NR4	512	507	195205	5395	4704
115120	397	411	DIV175	0	0
NR5	578	554	170175	0	0
116120	447	456	NR19	323	371
NR6	250	280	CP175	268	147
CP120	9568	7965	SR175	226	135
120130	9464	7863	175185	110	78
NR7	173	203	NR20	198	230
125130	146	176	DIV185	0	0
NR8	260	303	CP185	198	261
CP130	9464	7863	185205	119	76
130140	9431	7828	CH1205	124	146
GAV140	2364	2135	NR22	369	378
NR9	56	67	CP205	5395	4763
CP140	9601	7945	205215	4950	3306
140150	9591	7936	CG1215	77	90
BLK150	644	657	NR23	432	462
NR10	153	183	CP215	5053	3386
145150	121	144	215225	4965	3342
NR11	80	96	CF1225	135	152
CP150	9591	7936	CE1225	123	145
150160	9565	7902	NR24	159	188
UT1	277	324	DIV225	8795	7144
151152	252	297	CP225	9224	7069
UT2	236	279	225230	9167	7023
CP152	345	383	CD1230	435	460
152153	341	378	CC1230	94	114
UT3	191	226	CB1230	157	180
CP153	497	525	INT230	9352	6952
153160	425	455	NR25	106	126
NR12	161	191	NR26	404	393
154160	119	143	CP230	11738	8028
NR13	403	443	230250	11661	7954
CP160	9565	7902	CA1250	67	68
160170	9437	7772	CAP1	58	70
NR14	100	119	SR241	28	30
165170	36	44	241250	9	11
NR15	1110	1053	CAP2	41	50
CP170	9440	7771	SR242	2	2
DIV170	9440	7712	242250	1	1
170180	9395	7673	CAP3	103	123
NR16	251	294	SR243	39	41
CP180	9395	7670	243250	31	34
180190	9330	7608	CAP4	525	491
NR17	410	435	SR244	86	86
CP190	9330	7604	244250	83	83
DIV190	9328	7588	NR27	1442	1158
190200	9258	7520	CP250	11753	7902
DIV200	463	376			



Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
PLATE 1
Deadman Wash Subwatershed

Prepared By:

Stantec Consulting Inc.
8211 S. 48th Street
Phoenix, AZ U.S.A. 85044

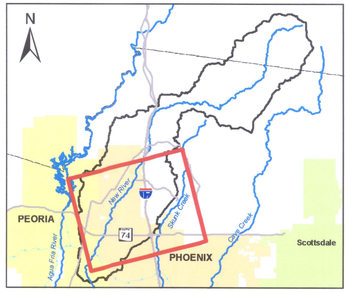
Legend:

- USGS Gage
- Concentration Point
- Concentration Point Label
- Subbasin Label
- Index Contour
- Intermediate Contour
- Roadway
- CAP Canal
- Time of Concentration Flowpath
- Routing Reach
- Subwatershed Boundary
- UNR Study Limits
- Corporate Limits
- Township & Range Line
- Section Line

Notes:

1. 10 foot contour interval topography circa January 2001.
2. Hydrologic features recreated from original mapping.
   Source: Deadman Wash Floodplain Delineation Study (HNTB, December 1992)

Location Map:



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1" = 2,000'

Project No.
182000418

Prepared By:
AMG
05 June 2007

Revision:

	By	Appd.	Date

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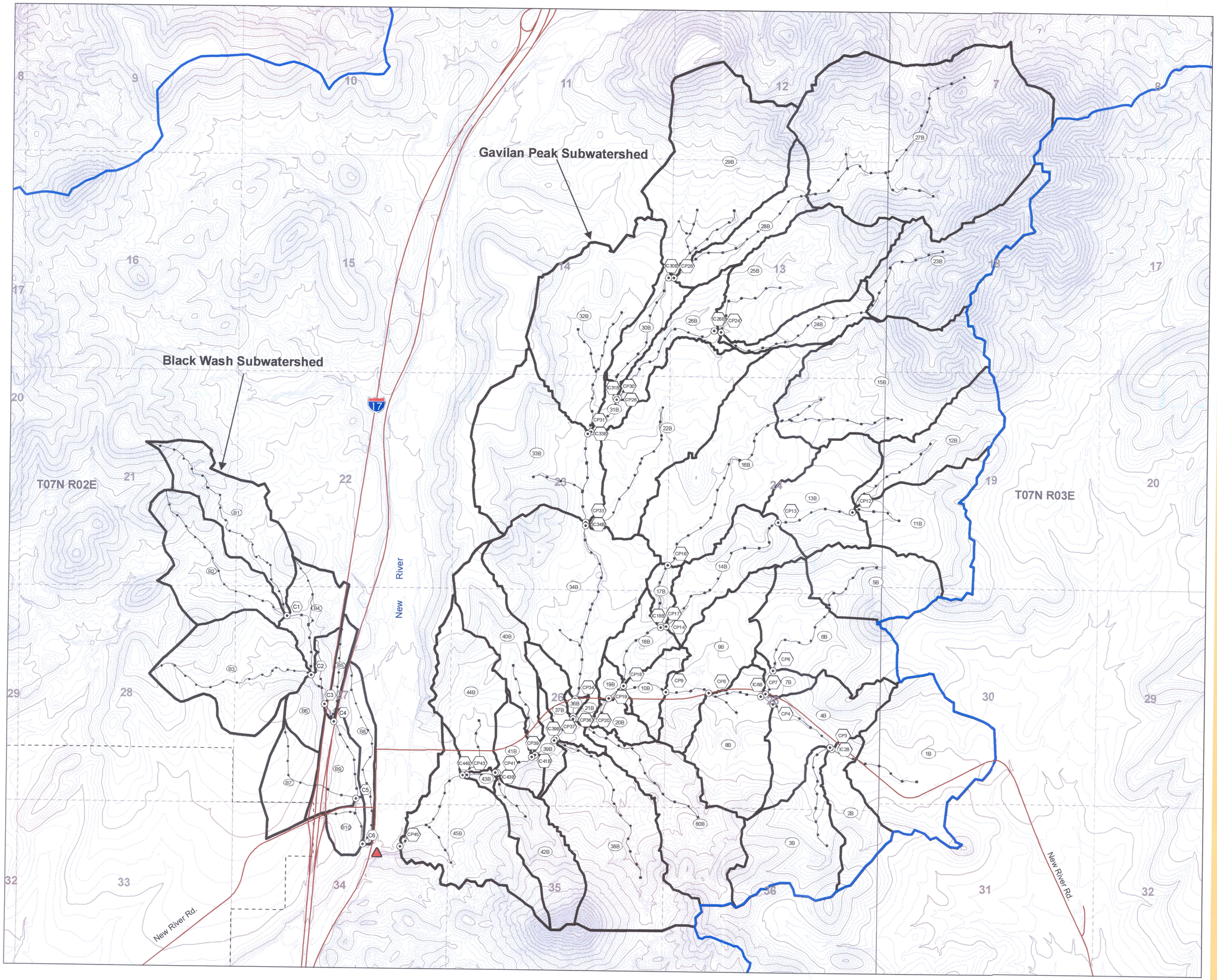


Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
PLATE 2
Black Wash & Gavilan Peak Subwatershed

Prepared By:
Stantec Consulting Inc.
8211 S. 48th Street
Phoenix, AZ U.S.A. 85044

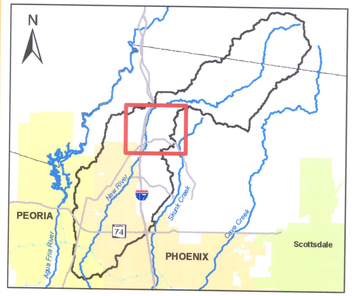
Legend:

- USGS Gage
- Concentration Point
- Concentration Point Label
- Subbasin Label
- Index Contour
- Intermediate Contour
- Roadway
- CAP Canal
- Time of Concentration Flowpath
- Routing Reach
- Subwatershed Boundary
- UNR Study Limits
- Corporate Limits
- Township & Range Line
- Section Line

Notes:

1. 10 foot contour interval topography circa January 2001.
2. Hydrologic features prepared by others and provided by FCDMC.
   Source: Black Wash: New River Above I-17 Floodplain Delineation Study, (Primatech, LLC, March 2002).
   Gavilan Peak Wash: Gavilan Peak Wash Floodplain Study, (FCDMC, October 1998).

Location Map:



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Project No.
182000418

Prepared By:
AMG
05 June 2007

Revision:

	By	Appd.	Date

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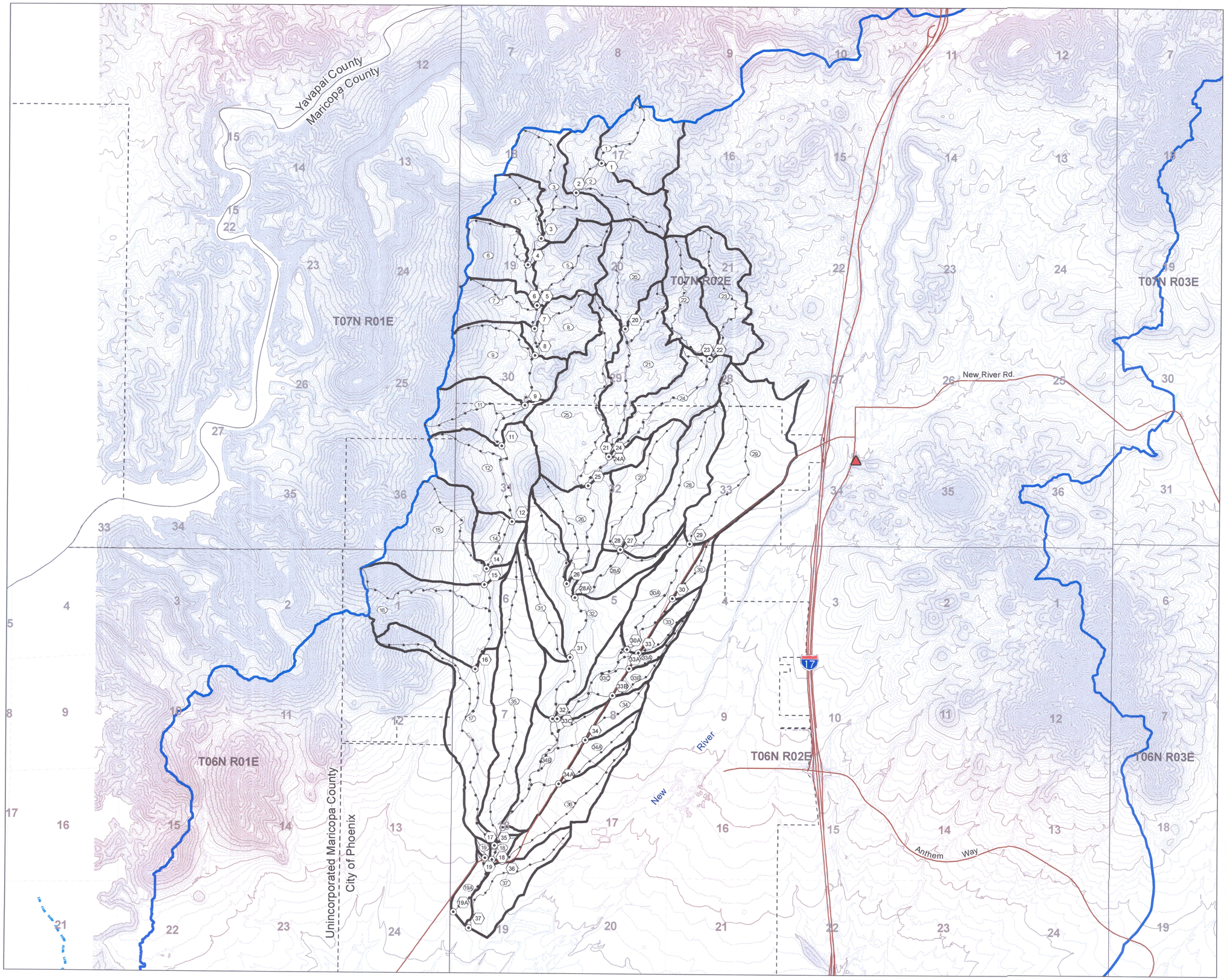


Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
PLATE 3
Sweat Canyon Subwatershed

Prepared By:

Stantec Consulting Inc.
8211 S. 48th Street
Phoenix, AZ U.S.A. 85044

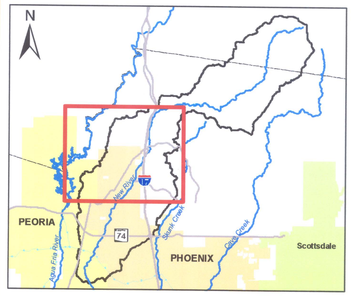
Legend:

- USGS Gage
- Concentration Point
- Concentration Point Label
- Subbasin Label
- Index Contour
- Intermediate Contour
- Roadway
- CAP Canal
- Time of Concentration Flowpath
- Routing Reach
- Subwatershed Boundary
- UNR Study Limits
- Corporate Limits
- Township & Range Line
- Section Line

Notes:

1. 10 foot contour interval topography circa January 2001.
2. Hydrologic features prepared by others and provided by FCDMC.
   Source: Sweat Canyon Wash Flood Insurance Study, (David Evans & Assoc., January 1999).

Location Map:



N

1" = 2,000'

Project No.
182000418

Prepared By:
AMG
06 June 2007

Revision:

	By	Appd.	Date

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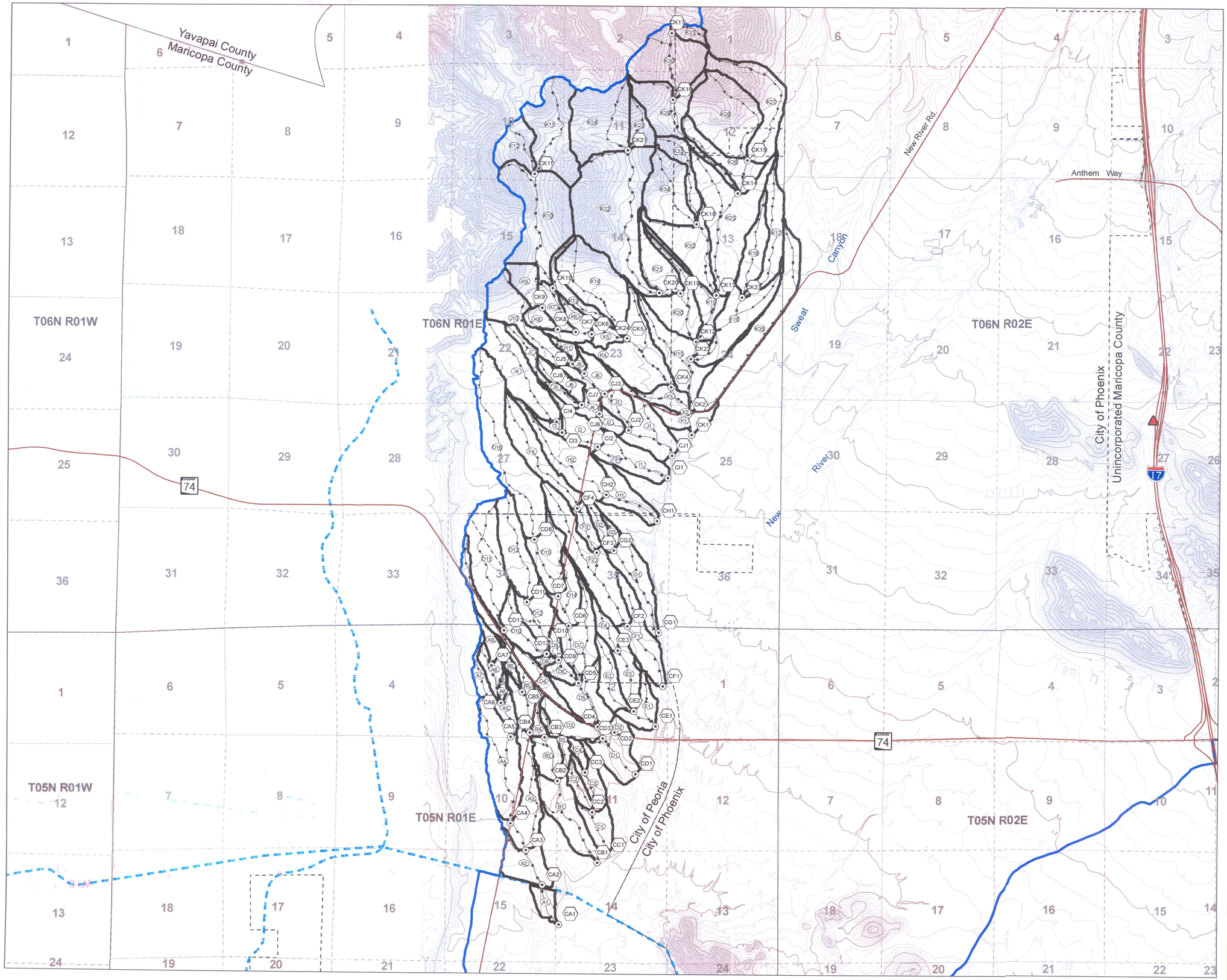


Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
PLATE 4
New River West Tributaries Subwatershed

Prepared By:
Stantec Consulting Inc.
8211 S. 48th Street
Phoenix, AZ U.S.A. 85044

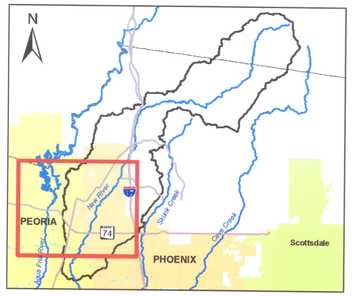
Legend:

- USGS Gage
- Concentration Point
- Concentration Point Label
- Subbasin Label
- Index Contour
- Intermediate Contour
- Roadway
- CAP Canal
- Time of Concentration Flowpath
- Routing Reach
- Subwatershed Boundary
- UNR Study Limits
- Corporate Limits
- Section Line
- Township & Range Line

Notes:

1. 10 foot contour interval topography circa January 2001.
2. Hydrologic features prepared by others and provided by FCDMC.
   Source: New River West Tributaries FDS Volume I of III Draft. Report to the Flood Control District of Maricopa County (URS, 2005).

Location Map:



N

1" = 2,000'

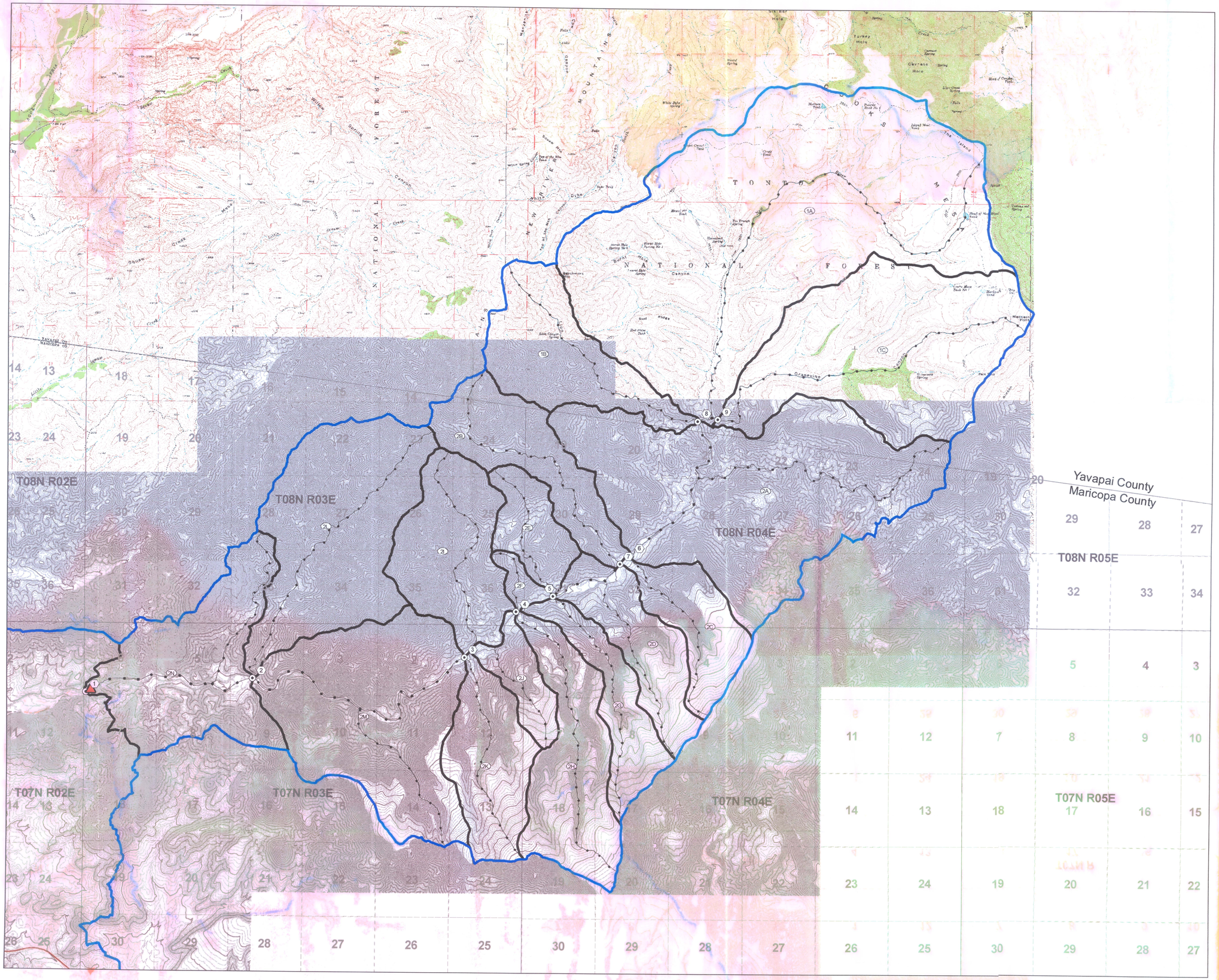
Project No.
182000418

Prepared By:
AMG
06 June 2007

Revision:

	By	Appd.	Date

W:\active\182000418\GIS\Project\MXDs\PLATE4_NRWestTrib.mxd



Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
PLATE 5
Rock Springs Subwatershed

Prepared By:

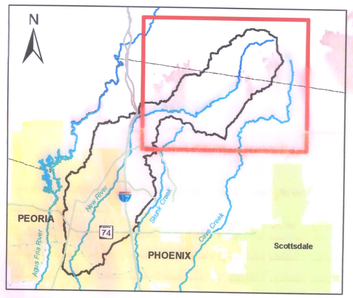
Stantec Consulting Inc.
8211 S. 48th Street
Phoenix, AZ U.S.A. 85044

Legend:

- USGS Gage
- Concentration Point
- Concentration Point Label
- Subbasin Label
- Index Contour
- Intermediate Contour
- Roadway
- CAP Canal
- Time of Concentration Flowpath
- Routing Reach
- Subwatershed Boundary
- UNR Study Limits
- Township & Range Line
- Corporate Limits
- Section Line

Notes:
1. 10 foot contour interval topography circa January 2001.
2. Hydraulic features recreated from original mapping.
   Source: Flood Insurance Study New River from New River Dam to Rock Springs, (CVL, 1987).

Location Map:



N

1" = 3,000'

Project No.
182000418

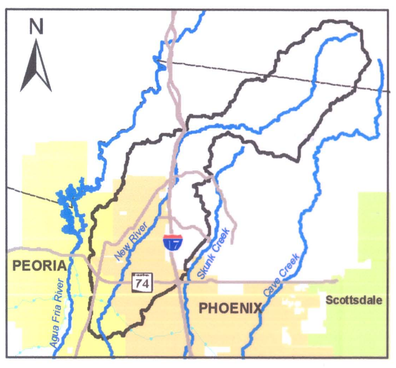
Prepared By:
AMG
06 June 2007

Revision:

	By	Appd.	Date

W:\active\182000418\GIS\Project\MXDs\PLATE5_RockSprings.mxd

Location Map



Prepared By:
AMG
August 2007

Notes:

10 foot contour interval topography circa January 2001

Revision:

By Appd Date

W:\active\182000418\GIS\Project\MXDs\PLATE6_SBasinDelineation.mxd

N

1" = 3000'

Legend:

- USGS Gage
- Concentration Point
- Concentration Point Label
- NR5 Subbasin Label
- Index Contour
- Intermediate Contour
- Roadway
- 200230 Routing Reach Label
- Time of Concentration Flowpath
- Routing Reach
- Subwatershed Boundary
- Watershed Boundary
- Corporate Limits
- Township & Range Line
- Section Line

Flood Control District of Maricopa County

Flood Control District
of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
PLATE 6
Detailed Hydrology
Physical Delineation

Stantec

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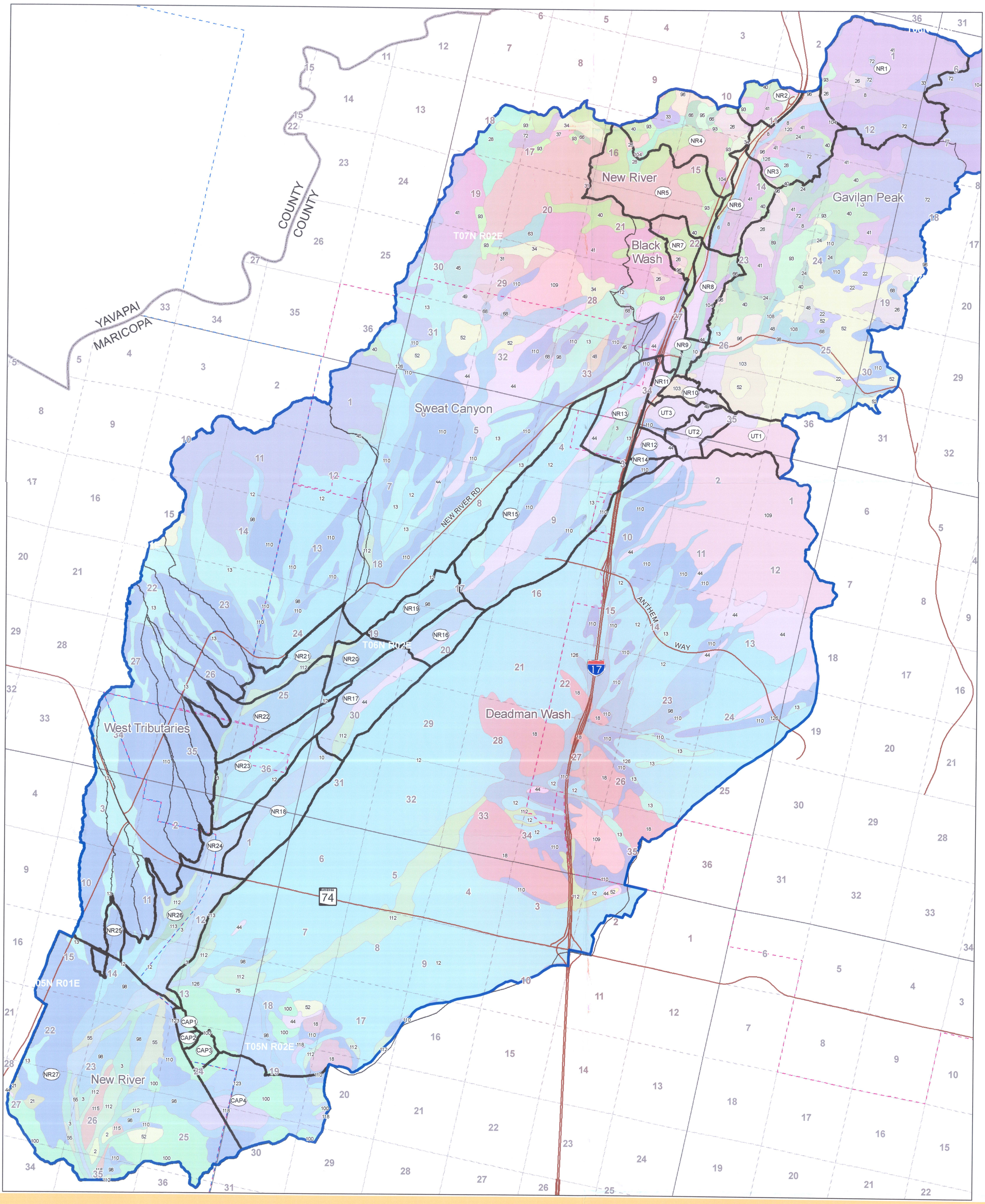
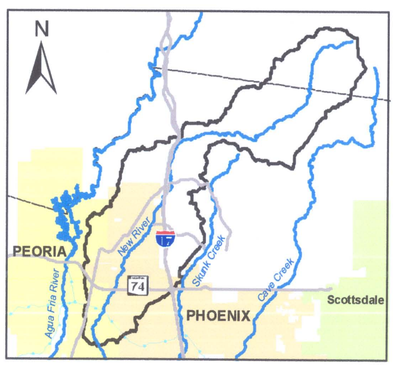
Phoenix, AZ U.S.A. 85044



Location Map



Prepared By:
AMG
August 2007

W:\active\182000418\GIS\Project\PLATE7_Soils.mxd

Notes:

Soils information taken from NRCS Aguila-Carefree Soil Survey

Revision:

By Appd Date

N

1" = 3000'

Legend:

- Roadway
- Watershed Boundary
- Subbasin Boundary
- CAP4 Subbasin Label
- Township & Range
- Section

Soil Units

2, 3, 6, 8, 10, 12, 13, 18, 21, 22, 24, 26, 28, 31, 33, 34, 37, 40, 41, 44, 45, 48, 49, 52, 55, 63, 66, 68, 72, 75, 89, 93, 95, 96, 98, 100, 103, 104, 108, 109, 110, 111, 112, 113, 115, 118, 120, 123, 126

Flood Control District of Maricopa County

Flood Control District
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Upper New River ADMP
FCD 2005CO20
PLATE 7
Soil Survey

Stantec

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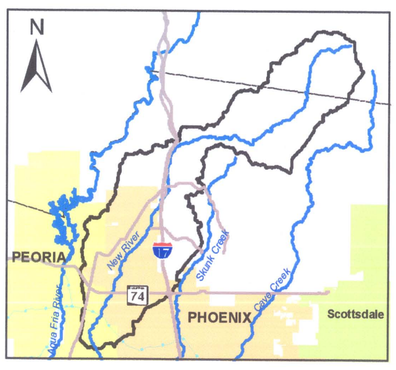
Phoenix, AZ U.S.A. 85044

Location Map



Prepared By:
AMG
August 2007
W:\active\182000418\GIS\Project\PLATE8_ExLandUse.mxd

Notes:

Base photography circa 2006

Revision:

By Appd Date

N

1" = 3000'

Legend:

- Roadway
- County Boundary
- Township & Range
- Section
- Subbasin Boundary
- Peoria Corporate Boundary
- Phoenix Corporate Boundary

Landuse

- COMM
- GR
- IND
- M.D.R.
- NDR
- NHS
- NHSS
- NMT
- P
- V.L.D.R.

Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
PLATE 8
Existing Conditions Land Use

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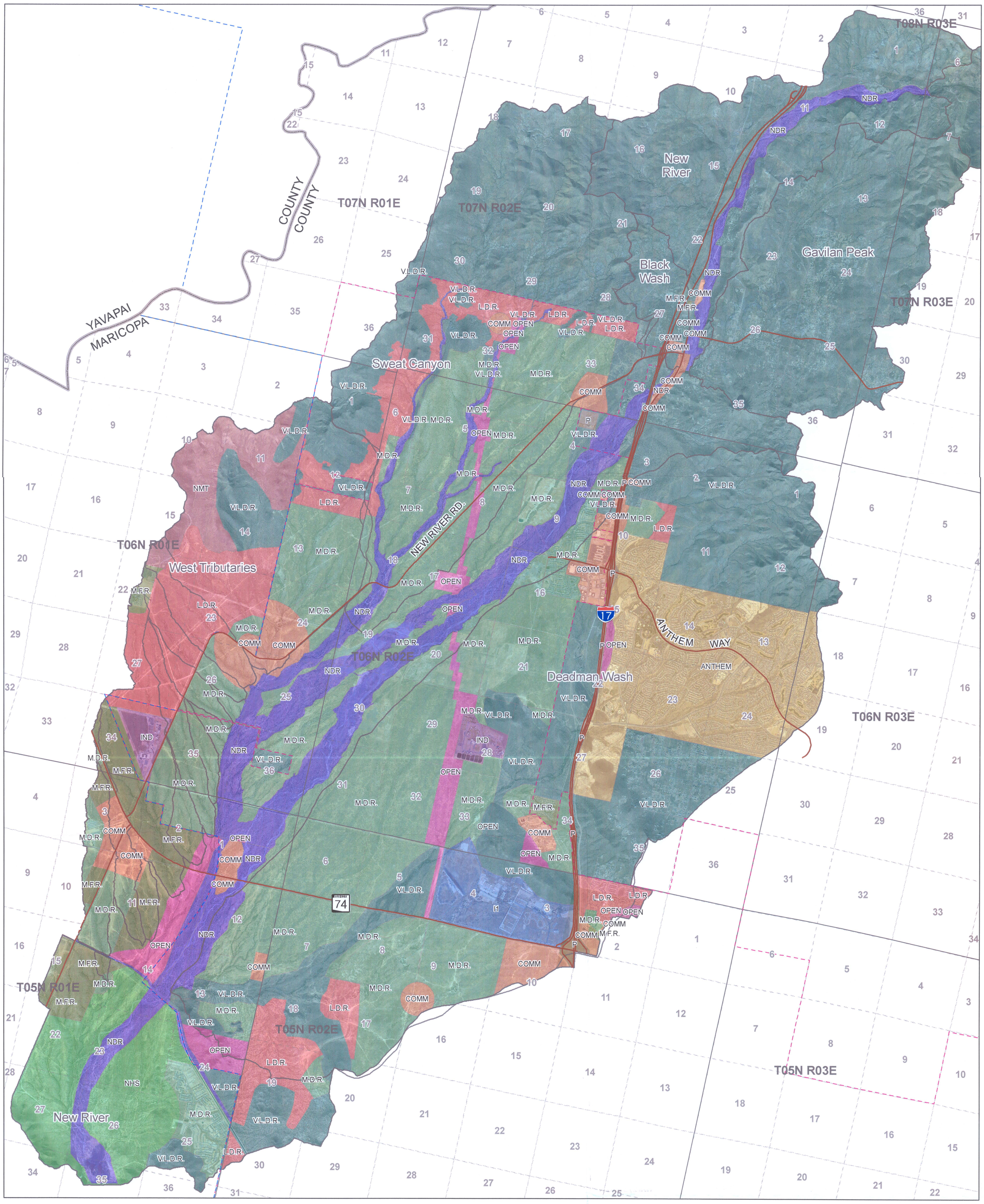
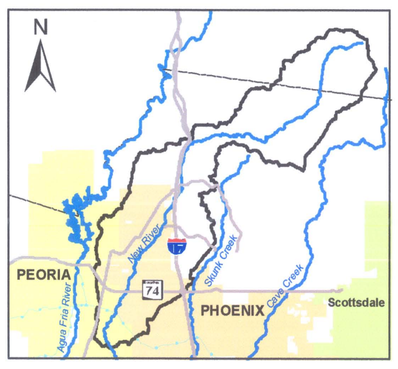
8211 S. 48th Street
Phoenix, AZ U.S.A. 85044



Location Map



Prepared By:
AMG
August 2007
W:\active\182000418\GIS\Project\PLATE10_FutureLandUse.mxd

Notes:

Base photography circa 2006

Future land use from classifications developed by Stantec

Revision:

By	Appd	Date

N

1" = 3000'

Legend:

- Roadway
- Peoria Corporate Boundary
- Phoenix Corporate Boundary
- Township & Range Line
- Section Line
- Subwatershed Boundary

Land Use

- ANTHEM
- COMM
- I1
- IND
- L.D.R.
- M.D.R.
- M.F.R.
- NDR
- NHS
- NMT
- OPEN
- P
- V.L.D.R.

Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Upper New River ADMP
FCD 2005CO20
PLATE 9
Future Conditions Land Use

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