

DATE: October 15, 2018

TO: Suzanne Shields, P.E. Director FROM:



#### SUBJECT: PC-Hydro: Comprehensive Evaluation & Revision Recommendations

At the request of Pima County Regional Flood Control District (District), WEST Consultants, Inc. (WEST) conducted a comprehensive review of the District's web-based hydrology computation program PC-Hydro.

WEST evaluated recorded stream gage data from thirty (30) different Arizona watersheds, ranging from 0.06 to 1.07 square-miles, including both developed and undeveloped conditions. Gage records ranged from 10 to 61 years of data. A full statistical analysis was conducted utilizing the HEC-SSP non-proprietary software and following the techniques outlined in Bulletin 17C.

In general, the analysis concluded that:

- The flow uncertainty bands for a given return interval was "substantial" for both the predicted flow (PC-Hydro) and measured flow (HEC-SSP), both of similar width.
- Most of the analyzed watersheds demonstrated "considerable overlap" between the PC-Hydro and HEC-SSP prediction bands, "particularly within the lower probability estimates (e.g., 100-year flow), with some deviation identified around the 2-year flow."
- Deviation of the PC-Hydro predictions near the 2-year frequency storm was found to be "directly related to the implementation of the adjusted curve number procedure".

As part of the comprehensive review, WEST was instructed to provide recommendations, if any, to improve the accuracy of PC-Hydro. It is my opinion that the following revisions, provided by WEST verbatim (Section 4.5), to be implemented.

- 1. Update the PC-Hydro User Guide and all associated publication (Pima County Hydrology Manual, etc.) to reflect the modification described.
- 2. Continue limiting use of PC-Hydro to watersheds less than one square mile.
- 3. Continue the minimum five (5) minute time of concentration requirement.
- 4. Continue using the PC-Hydro generated hydrograph for routing purposes.
- 5. Remove the adjusted curve number correction.

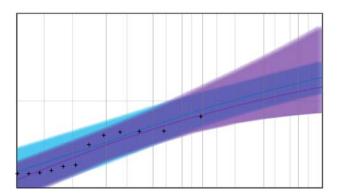
(APPROVED) NOT APPROVED

Suzanne Shields, P.E.

0/16/18

Cc: Eric Shepp, P.E., Deputy Director Evan Canfield, P.E., PhD, CFM, Civil Engineering Manager

# PC-HYDRO: Pima County Hydrologic Procedures Comprehensive Evaluation

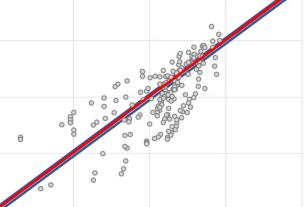


PREPARED FOR THE

Pima County Regional Flood Control District DO# 18\*25964

201 N. Stone, 9th Floor Tucson, AZ 85701 (520) 724-4627 WEBCMS.PIMA.GOV/GOVERNMENT/FLOOD CONTROL/





Prepared By:

Consultants, Inc. WEST CONSULTANTS, INC.

8950 S. 52<sup>nd</sup> Street, Suite 210 Tempe, AZ 85284 (520) 724-4600

September 27, 2018



# Contents

1. Introduction	5
2. PC-Hydro Methodology Review	6
2.1. PC-Hydro Assumptions	6
2.2. Potential Implementation Errors	6
2.2.1. Adjusted Curve Number (Equation 3)	7
2.2.2. Runoff Coefficient (Equation 4b)	7
3. Comparison Between PC-Hydro and Known Gage Data	8
3.1. PC-Hydro Update	8
3.2. Gage Data	8
3.2.1. Gage Selection Criteria	8
3.2.2. Selected Gages	8
3.2.3. Data Retrieval and Error Correction	12
3.3. PC-Hydro Data	12
<ul> <li>3.3. PC-Hydro Data</li></ul>	13
3.4. Gage Analysis	
3.5. PC-Hydro Analysis	17
3.6. Results	18
3.6.1. Overall	18
3.6.2. Development Effect	
3.6.3. Parameter sensitivity	22
3.7. Design Implications	25
3.7.1. 95% Upper Rainfall / Adjusted CN	25
3.7.2. 95% Upper Rainfall / Unadjusted CN	26
4. Recommendations	29
4.1. Adjusted versus Unadjusted CN	29
4.2. Areal Applicability	30
4.3. Time of Concentration Limitations	32
4.4. Hydrograph Output	32
4.5. Overall Recommendations for PC-Hydro Implementation	32
4.6. PC-Hydro Related Technical Policies	33
4.6.1. Design Standards for Stormwater Detention and Retention (Suppl. to Title 16, Chapter 16.48)	33
4.6.2. TECH-10: Rainfall Input for Hydrologic Modeling	33
4.6.3. TECH-12: Methods to Estimate Maximum Anticipated Scour Depth Including Optional Adjustment	
Flood Duration	
4.6.4. TECH-13: Regulation of Shaded Zone X Classifications	
4.6.5. TECH-14: Erosion Protection of Stem Wall Foundations in Floodway Fringe Areas	33

4.C.C. TECH 1E. Accontable Methods for Determining Deal, Discharges	<b>.</b>
4.6.6. TECH-15: Acceptable Methods for Determining Peak Discharges	
4.6.7. TECH-16: Acceptable Methods for Floodplain Delineation	34
4.6.8. TECH-17: Applicability of and Acceptable Methods for Sediment Transport Analysis	34
4.6.9. TECH-18: Acceptable Model Parameterization for Determining Peak Discharges	34
4.6.10. TECH-19: Standards for Floodplain Hydraulic Modeling	34
4.6.11. TECH-20: Engineering Analysis Requirements for Determining an Alternative Safe Erosion Hazard Setback Limit	34
4.6.12. TECH-25: Permitting Guidelines for Sand, Gravel and Other Excavation Operation Located within Flood and/or Erosion Hazard Areas	34
4.6.13. TECH-28: Pre-Ordinance Agricultural Berms, Channels and Stock Ponds	34
4.6.14. TECH-29: Electrical Facilities that Are Considered "Critical Facilities"	34
4.6.15. TECH-33: Criteria for Two-Dimensional Modeling	34
4.6.16. TECH-35: FLO-2D (V. 2009, Pro) Technical Guidance for Hydrologic and Hydraulic Modeling in Unincorporated Pima County, Arizona (DRAFT)	35
4.6.17. TECH-101(1): Determining Base Flood Elevations in Regulatory Floodplains with Detailed Studies. 3	35
5. Further Study	36
5.1. Watershed Parameter Updates	36
5.2. Modified Rational Method	36
5.3. Best Management Practice (BMP) Modeling	36
5.4. Investigation of the Time to Peak = Storm Duration Assumption	
5.5. Risk Analysis	38
5.5. Risk Analysis	38
5.5.2. PC-Hydro Monte Carlo Extension	38
6. Works Cited	39
Appendix Expires 03/31/19	

# 

# List of Tables

Table 1. Detailed information on the selected gages	9
Table 2. Detailed information on the rejected gages	11
Table 3. Unused but potential viable gages	
Table 4. PC-Hydro sensitivity factors	14
Table 5. Example of hypothetical length increment sensitivity data	14
Table 6. Summary statistics of data collected and design parameters applied	18
Table 7. Predictive success for various design approaches	30
Table 8. Predicted flows for Alamo Wash for both complete and limited extents (maximum shown in bold)	) 38

# List of Figures

Figure 1. Analyzed gage locations	9
Figure 2. HEC-SSP unresolvable error message 1	1
Figure 3. Peak flow uncertainty calculations by propagation of error versus Rosenblueth Standard Deviation 1	5
Figure 4. Lynx Creek Tributary frequency analysis results1	
Figure 5. Chiltepines Wash preprocessing in Excel 1	7
Figure 6. Comparison between PC-Hydro and recorded data frequency analysis at Alamo Wash 1	9
Figure 7. Comparison between PC-Hydro predictions (50% NOAA rainfall / median factors) and all gage data 2	0
Figure 8. Ratio of log transformed PC-Hydro predictions (50% NOAA rainfall / median factors) / log transformed	I
observed flows versus exceedance probability 2	1
Figure 9. PC-Hydro predictions (50% NOAA rainfall / median factors) versus observed flows at 11 developed	
watersheds 2	
Figure 10. 100-year flood sensitivity of the tested parameters 2	
Figure 11. 2-year flood sensitivity of the tested parameters	
Figure 12. 1000-year flood sensitivity of the tested parameters 2	4
Figure 13. Comparison between design predictions (95% NOAA rainfall / median factors) and gage data 2	5
Figure 14. Ratio of log transformed design predictions (95% NOAA rainfall / median factors) / log transformed	
observed flows versus exceedance probability 2	
Figure 15. Ratio of log transformed unadjusted CN design predictions (95% NOAA rainfall / median factors) / log	
transformed observed flows versus exceedance probability 2	7
Figure 16. Comparison between PC-Hydro unadjusted design predictions (95% NOAA rainfall / median factors)	
and all gage data 2	
Figure 17. Percentage difference between CN* and CN 2	
Figure 18. Observed flow / predicted flow (95% upper rainfall, non-adjusted CN) versus watershed area	
Figure 19. Alamo Wash with complete extents and contributing extents from smaller storm duration (red lines)	
	7



# **Executive Summary**

By request of the Pima County Regional Flood Control District (District), WEST Consultants, Inc. (WEST) conducted a comprehensive review of the District's web-based hydrology computation program PC-Hydro. Implementation of the District's hydrologic method within the PC-Hydro program was verified as technically sound with the exception of two equations, both of which would return erroneous values if subjected to input outside of their range of applicability. These equations were immediately corrected by the District and currently under review prior to updating the publicly accessible PC-Hydro application. The updated PC-Hydro predictions were then compared with recorded stream gage data for 30 different watersheds in Arizona. These watersheds encompassed areas from 0.06 to 1.07 square miles, included both developed and undeveloped conditions as well as both high and low vegetation. Gage data for each watershed stream gage ranged from 10 to 61 years. The non-proprietary program HEC-SSP was used to analyze the annual maximum gage data flows in accordance with Bulletin 17C techniques. This analysis allowed a full statistical consideration of the gage data, including equivalent return storm estimates and estimated uncertainty bands. Corresponding uncertainty of the PC-Hydro estimates was accounted for through error propagation techniques. This investigation found that, in general, predicted flow uncertainties for a given return interval was substantial for both predicted and measured values, with the PC-Hydro uncertainty band of similar width to the HEC-SSP uncertainty band. Most of the analyzed watershed exhibited considerable overlap between the PC-Hydro and HEC-SSP prediction bands, particularly within the lower probability estimates (e.g., 100-year flow), with some deviation identified around the 2-year flow (50% return interval). This deviation of PC-Hydro predictions near the 2-year frequency storm was found to be directly related to implementation of the adjusted curve number procedure. Further sensitivity analyses confirmed the major, often non-conservative role the curve number adjustment procedure had on the predicted outflow, and indeed the overall fit between PC-Hydro design flows and measured gage flows was improved and the number of underpredictions significantly reduced by limiting PC-Hydro design predictions to unadjusted curve numbers and the upper 95% NOAA rainfall. Accordingly, the recommendation is made to continue to use PC-Hydro but restricting design applications to only the upper 95% NOAA rainfall and without adjusting the curve numbers.

Following the comparison study, sixteen different District technical policies relating to PC-Hydro were reviewed and specific recommendations provided. Areal applicability was also investigated and no strong evidence was found of a consistent trend between PC-Hydro prediction accuracy and watershed size. Finally, some future research investigations were recommended including consideration of advances in curve number and other watershed characteristic information, determining the viability of establishing a modified Rational Method based upon PC-Hydro, applying PC-Hydro to determine Best Management Practice (BMP) analysis strategies, highly intense rainfall modeling, and risk analysis via Monte Carlo simulation.

#### PC-HYDRO

# 1. Introduction

By request of the Pima County Regional Flood Control District (District), WEST Consultants, Inc. (WEST) has prepared this comprehensive review of the District's web-based hydrology computation program PC-Hydro, evaluated in terms of implementation, documentation, and comparison with known data. The comparison to known data was accomplished by applying PC-Hydro to make predictions of flows within known, gaged watersheds that met the applicability criteria of PC-Hydro. Altogether, the evaluation provided in this report fulfills the following eight tasks:

- 1. Apply PC-Hydro to gaged watersheds and evaluate performance;
- 2. Perform a sensitivity analysis of specific PC-Hydro parameters;
- 3. Review the Pima County Hydrology Procedures and existing Technical Policies with respect to PC-Hydro application;
- 4. Provide recommendations, if any, for modifications to PC-Hydro to improve accuracy;
- 5. Provide recommendations, if any, for supporting documentation relating to the application for FEMA approval of PC-Hydro for hydrologic analysis conducted within the unincorporated Pima County;
- 6. Provide recommendations, if any, for future research;
- 7. Summarize tasks 1 through 5 in a comprehensive report;
- 8. Provide the necessary documentation for the District to submit PC-Hydro to FEMA to garner their approval for the use of PC-Hydro for hydrologic analysis conducted within the unincorporated Pima County.

# 2. PC-Hydro Methodology Review

PC-Hydro is a web-based program, administered by Pima County Regional Flood Control District (District), which calculates peak flow rates of varying frequencies for use in the analysis and design of natural and developed watersheds in unincorporated Pima County, Arizona. The web-based implementation of PC-Hydro is based on the original Visual Basic code developed in 1992. The 1992 program was in turn based on the Pima County Hydrology Procedures specified in the <u>Hydrology Manual for Engineering Design and Floodplain Management</u> within Pima County, Arizona (Pima County Department of Transportation and Flood Control District, 1979) and the associated 1979 memorandum (Pima County Department of Transportation and Flood Control District, 1979).

PC-Hydro is an extension of the Rational Method to model the hydrologic and hydraulic conditions typical of the arid southwest in general and Pima County in particular.

# 2.1. PC-Hydro Assumptions

PC-Hydro makes both computational and regional assumptions. The computational assumptions are related to the general requirements for applicability of the Rational Method as noted by Ponce (1989). Further, although the PC-Hydro algorithm is general and can be applied beyond Pima County, the program also includes supporting equations and data in tables and figures that only apply to the arid southwest.

A comprehensive list of the PC-Hydro computational and regional assumptions are as follows:

- 1. Rainfall is uniformly distributed within the watershed.
- 2. Rainfall is constant over the storm duration.
- 3. The time of concentration does not exceed 180 minutes and is less than or equal to the storm duration.
- 4. Runoff is primarily due to overland flow.
- 5. Antecedent moisture is constant and evenly distributed throughout the watershed.
- 6. No detention or retention occurs within the watershed.
- 7. The watershed area is one square mile or less.
- 8. Channel diffusion is negligible
- 9. The peak flow rate is proportional to the rainfall depth averaged over the time of concentration.
- 10. The return period corresponding to the runoff event is equal to the return period of the precipitation event.
- 11. Vegetation within the watershed is typical of the arid southwest. For example, application of the methodology to a watershed with transplanted tropical crops would be inappropriate.
- 12. Longitudinal slopes within the watershed are typical of the arid southwest, which typically range from 0.0001 ft/ft to 0.1 ft/ft.
- Infiltration processes can be reasonably described as an averaged effect as a function of the hydrologic soil groups (A, B, C, and D) (U.S. Department of Agriculture-National Resouce Conservation Service, 2009).

# 2.2. Potential Implementation Errors

The overarching approach, core equations, and most of the tables and figures used in PC-Hydro have remained fundamentally the same since development of the approach almost fifty years ago. That said, some aspects of the approach have been updated to implement new data (such as NOAA 14) and application of the methodology is now sometimes extended to include more frequent storms than was historically considered (e.g., the 2-year storm). Accordingly, the review of the PC-Hydro included consideration of both the documentation and web implementation in order to identify potential errors that could occur from application of the PC-Hydro methodology to data ranges not originally considered during its development. This review identified two potential implementation errors: the adjusted curve number calculation and the runoff coefficient computation.

#### PC-HYDRO

## 2.2.1. Adjusted Curve Number (Equation 3)

As specified in the supporting documentation, the adjusted curve number (denoted "CN\*" as opposed to the unadjusted curve number denoted simply "CN") is only applicable to 1-hour precipitation values of  $P_1 > 0.88$  inches. For most design storm events,  $P_1$  is well is excess of 0.88 inches. However, for lower return periods,  $P_1$  can be less than 0.88 inches and unfortunately the documentation does not currently provide guidance on how to proceed for these low values.

The adjusted curve number equation is

$$CN^* = \frac{R1(P_1 - 0.88) + R2}{P_1}$$

where R1 and R2 are unitless coefficients given in the PC-Hydro User Guide Appendix D and vary according to the (unadjusted) curve number.

The relationship between R1 and R2 is such that erroneously including P<sub>1</sub> values less than 0.88 inches will not usually result in an obviously incorrect CN\* value (a negative number for example) but nonetheless will be significantly different than the correct value (given by assuming a lower limit value of P<sub>1</sub> = 0.88 inches and hence CN\* = R2/0.88).

For example, if  $P_1 = 0.5$  inches and CN = 92.6, then  $CN^* = 78.14$  if the equation is used directly, versus the correct value of  $CN^* = 86.5$ .

## 2.2.2. Runoff Coefficient (Equation 4b)

The runoff coefficient C (dimensionless) is given in PC-Hydro by the equation

$$C = \frac{1}{P_1} \frac{(P_1 - 0.2S)^2}{(P_1 + 0.8S)}$$

where S (dimensionless) is the potential abstraction. Note that  $P_1 - 0.2S$  (in the numerator of the second term in the equation on the right hand side) is the one-hour rainfall runoff minus the initial abstraction (inches), estimated by 0.2S. Since the initial abstraction must always be less than the runoff,  $P_1$  must always be greater than or equal to 0.2S. However, the guide does not state this requirement. Unfortunately, because this difference is squared, the resulting error may not be obvious.

For example, if  $P_1 = 0.2$  and S = 2.5 (corresponding to a CN\* value of 80), then the initial abstraction 0.2S would be 0.5 which is significantly greater than the runoff. Accordingly, even though the actual runoff coefficient should be zero (no runoff since the rainfall is completely captured), the directly computed value would be C = 0.2.

This problem is easily resolved by simply updating PC-Hydro and all accompanying documentation to state that the given C equation is valid only for  $P_1 > 0.2S$ , and otherwise C = 0.

# 3. Comparison Between PC-Hydro and Known Gage Data

As requested by the District, a comparison was conducted of PC-Hydro flow predictions versus gage analysis. Thirty gages and their associated watersheds were chosen for this effort.

# 3.1. PC-Hydro Update

Prior to beginning the PC-Hydro/gage data comparisons, the aforementioned potential errors were brought to the District's attention and an alpha version of PC-Hydro was immediately developed that resolved those issues. Further testing confirmed that the equations were being implemented correctly and all subsequent work noted in this report used the updated alpha version of the PC-Hydro application.

# 3.2. Gage Data

**PC-HYDRO** 

## 3.2.1. Gage Selection Criteria

All gages and associated watersheds were selected based on the following criteria:

- 1. Located in Arizona.
- 2. Drainage area less than or equal to one (1) square mile. (Met with one exception see below.)
- 3. Sufficient years of reliable records to allow a statistical analysis of the gage data.
- 4. Available soils data.

Further, preference was given to those watersheds determined to include land development.

#### 3.2.2. Selected Gages

The USGS publication "Methods for Estimating Magnitude and Frequency of Floods in Arizona, Developed with Unregulated and Rural Peak-Flow Data through Water Year 2010" (Paretti, Kennedy, Turney, & Veilleux, 2014) was used to identify viable candidate watersheds. Some of these watersheds were found to be unsuitable and others were found during the investigation that were not included in the referenced publication.

All told, 30 viable gages were identified that met the criteria, although one of the analyzed gages did deviate slightly: The USGS gage located at Tributary 2 of the Agua Fria River near Rock Springs was analyzed despite the contributing watershed size of 1.07 square miles being slightly more than one square mile. This gage had 38 years of records, making it an excellent resource for testing PC-Hydro, and hence it was decided to allow it into the study.

An overview of the gage locations is shown in Figure 1, and detailed information about these locations is tabulated in Table 1.



Figure 1. Analyzed gage locations

Station	Station name	Hyd. Flood Region	Drainage Area (mi²)	Years of record	Location	Has Development?
USGS <sup>1</sup> 9512700	Agua Fria River Trib 2 near Rock Springs, AZ	3	1.07	43	34°02'00"N 112°08'42"W	NO
USGS 9520300	Alamo Wash Tributary near Ajo, AZ	3	0.83	29	32°6'0"N 112°46'17"W	NO
USGS 9395850	Black Creek Tributary near Window Rock, AZ	2	0.34	14	35°39'15"N 109°5'22"W	YES
FCDMC <sup>2</sup> 7093	Casandro Wash, AZ	3	0.58	23	33°57'43"N 112°45'54"W	YES
USGS 9517200	Centennial Wash Tributary near Wenden, AZ	3	0.84	41	33°50'40"N 113°27'2"W	NO
USGS 9486700	Chiltepines Wash near Sasabe, AZ	5	0.34	13	31°49'8"N 111°26'18"W	NO
USGS 9496600	Cibecue 1 Tributary Carrizo Creek near Show Low, AZ	4	0.06	14	33°59'28"N 110°19'29"W	NO
USGS 9505900	Cottonwood Wash near Camp Verde, AZ	4	0.53	15	34°30'20"N 111°45'12"W	NO

#### Table 1. Detailed information on the selected gages

## **Comprehensive Evaluation**

Station	Station name	Hyd. Flood Region	Drainage Area (mi²)	Years of record	Location	Has Development?
USGS 9428545	Cunningham Wash Tributary near Wenden, AZ	3	0.91	13	34°0'25"N 113°34'42"W	NO
USGS 9396400	Dead Wash Tributary near Holbrook, AZ	2	0.78	13	35°4'30"N 109°45'2"W	NO
USGS 9481800	Demetrie Wash Tributary Near Continental, AZ	5	0.15	16	31°52'15"N 111°5'17"W	NO
USGS 9483010	High School Wash at Tucson, AZ	5	0.98	16	32°13'28"N 110°56'48"W	YES
USGS 9520110	Hot Shot Arroyo near Ajo, AZ	3	0.56	16	32°20'49"N 112°48'33"W	NO
USGS 9504100	Hull Canyon near Jerome, AZ	4	0.85	19	34°44'20"N 112°8'37"W	NO
USGS 9379980	Jack Bench Wash Tributary near Page, AZ	2	0.98	15	36°42'49"N 111°35'32"W	NO
USGS 9401245	Klethla Valley Tributary near Kayenta, AZ	2	0.79	15	36°29'52"N 110°37'17"W	NO
USGS 9385800	Little Colorado River Tributary near St Johns, AZ	2	0.35	14	34°27'4"N 109°15'25"W	YES
USGS 9512420	Lynx Creek Tributary near Prescott, AZ	4	0.98	10	34°32'51"N 112°24'0"W	YES
USGS 9429510	Mittry Lake Tributary near Yuma, AZ	3	0.15	12	32°51'35"N 114°26'7"W	YES
USGS 9520350	Mohawk Pass Wash at Mohawk, AZ	3	0.44	15	32°43'44"N 113°44'32"W	NO
USGS 9504800	Oak Creek Tributary near Cornville, AZ	4	0.17	15	34°42'45"N 111°52'52"W	NO
USGS 9536100	Pitchfork Canyon Tributary near Fort Grant, AZ	5	0.9	14	32°35'20"N 109°54'42"W	NO
USGS 9482330	Pumping Wash near Vail, AZ	5	0.8	16	32°4'10"N 110°48'25"W	YES
USGS 9479200	Queen Creek Tributary A Apache Junction, AZ	5	0.39	19	33°24'13"N 111°32'29"W	YES
USGS 9478600	Queen Creek Tributary No. 3 at Whitlow Dam, AZ	5	0.38	14	33°17'30"N 111°16'52"W	NO
USGS 9487140	San Joaquin Wash near Tucson, AZ	5	0.68	13	32°10'7"N 111°8'0"W	YES
USGS 9468300	Sevenmile Wash Tributary near Globe, AZ	4	0.86	17	33°35'10"N 110°39'2"W	NO
USGS 9400200	Steamboat Wash Trib. near Ganado, AZ	2	0.17	13	35°45'50"N 109°48'2"W	NO
ARS <sup>3</sup> 63,4	Walnut Gulch Flume 4	5	0.88	61	31°44'00"N 110°02'01"W	YES
USGS 9483040	West Speedway Wash near Tucson, AZ	5	0.47	17	32°14'20"N 111°2'45"W	YES

<sup>1</sup> United States Geological Survey

<sup>2</sup> Flood Control District of Maricopa County

<sup>3</sup> Agricultural Research Service

The rejected gages and the explanation for their rejection is shown in Table 2 below. Note in particular that the Iron Spring Wash Tributary gage data was rejected due to an unknown HEC-SSP internal error. Attempts to resolve this error always terminated with the same blank error message pop-up (Figure 2):



Figure 2. HEC-SSP unresolvable error message

Due to the unresolvable nature of this error message, the gage analysis was subsequently abandoned.

The rejected gages may become useful in the future should more years of data become available, HEC-SSP updates are provided that resolve the abovementioned internal error, and/or watershed specific soils data are identified.

Station	Station name / Reason for rejection		Drainage Area (mi²)	Years of record	Location	Has Development?
USGS <sup>1</sup> 9451900	Agricul Resrch Serv Safford Watershed W-I, AZ (Could not locate data.)	4	0.73	31	32°50'27"N 109°31'19"W	NO
USGS 9498600	Cristopher Creek Tributary near Kohl's Ranch, AZ (No soils information available.)	4	0.66	11	34°19'20"N 111°4'2"W	NO
USGS 9401300	Hamblin Wash Tributary near Cedar Ridge, AZ (Majority of gage data estimated – deemed unreliable.)	2	0.1	14	36°20'54"N 111°30'17"W	NO
USGS 9424700	Iron Spring Wash Tributary near Bagdad, AZ (Unknown but unrecoverable error in HEC-SSP while processing gage data.)	3	0.63	15	34°31'20"N 113°6'45"W	NO
USGS 9470820	La Terraza Inflow Near Sierra Vista, AZ (Insufficient years of record.)	5	0.05	3	31°30'14"N 110°16'41"W	YES
USGS 9384200	Lyman Reservoir Tributary near St Johns, AZ (Gage significantly offset from estimated stream location.)	2	0.24	14	34°23'30"N 109°22'50"W	NO
USGS 9403750	Sagebrush Draw near Fredonia, AZ (Only one valid, non-zero flow measurement.)	2	0.71	15	36°54'4"N 112°22'37"W	NO
USGS 9485100	Saguaro Corners Wash near Tucson, AZ (USGS notes indicated flow data was unreliable.)	5	0.18	10	32°10'11"N 110°44'17"W	NO
USGS 9536350	Surprise Canyon near Dos Cabezas, AZ (No soils information available.)	5	0.66	14	32°0'40"N 109°21'14"W	NO
USGS 9451800	Tollgate Wash Tributary near Clifton, AZ (Gage significantly offset from estimated stream location.)	4	0.11	14	32°51'0"N 109°20'17"W	NO
ARS 9471087 <sup>2</sup>	Walnut Gulch 63.111 near Tombstone, AZ (Could not locate data.)	5	0.21	20	31°44'4"N 109°56'54"W	NO

#### Table 2. Detailed information on the rejected gages

<sup>1</sup> United States Geological Survey

<sup>2</sup> Agricultural Research Service

Finally, three other gages were identified as potential candidates for further study but not investigated. Information about these gages are tabulated in Table 3 in order to help facilitate future studies.

Station	Station name	Hyd. Flood Region	Drainage Area (mi²)	Years of record	Location	Has Development?
USGS <sup>1</sup> 9496700	Cibecue 2 Tributary Carrizo Cr, AZ	4	0.06	14	33°59'17"N 110°18'40"W	NO
ARS <sup>2</sup> 9471185	Walnut Gulch 63.103 near Tombstone, AZ	5	0.01	48	31°44'38"N 110°3'12"W	NO
USGS 9404310	Yampai Canyon Tributary near Peach Springs, AZ	2	0.27	13	35°33'6"N 113°23'19"W	NO

#### Table 3. Unused but potential viable gages

<sup>1</sup> United States Geological Survey

<sup>2</sup> Agricultural Research Service

## 3.2.3. Data Retrieval and Error Correction

Gage data was retrieved either directly from the corresponding agency's website or via the data retrieval option in the gage analysis program HEC-SSP Version 2.1.1.137, developed by the USACE (release data January 5, 2017). The following steps were taken to preprocess the data into the correct form for the subsequent frequency analysis based on draft USGS Bulletin 17C <u>Guidelines for Determining Flood Flow Frequency</u> (England Jr., et al., 2015) as implemented in the HEC-SSP program:

- 1. **Resolved data entry errors.** Occasionally gage data included typos, repeated dates, and other minor errors. These were identified and resolved.
- 2. **Identified historical flows.** Historical flows were identified by consulting with the notes accompanying USGS gage data. Historical flows were not identified in the FCDMC or the ARS data.
- 3. **Identified perception thresholds.** The USGS notes were also used to identify perception thresholds in accordance with Bulletin 17C procedures.
- 4. **Resolved uncertainties.** Sometimes the gage data was reported as uncertain. Following the examples provided in the Bulletin 17C documentation, these reported uncertainties were implemented into the data structure as +/- 10% of the data. For example, a flow of 80 cfs that was reported as uncertain would have been given a low value of 72 cfs and a high value of 88 cfs.
- 5. **Resolved missing records.** Missing records were resolved in accordance with Bulletin 17C by referencing the historical data and perception thresholds as identified above.

See Appendix A for the specific gage data, watershed characteristics, and HEC-SSP processing specifics.

# 3.3. PC-Hydro Data

The data needed for the PC-Hydro analysis was obtained via the following procedure:

- 1. The gage coordinates were used in StreamStats (<u>https://streamstats.usgs.gov/</u>) as the downstream point to delineate the watershed.
- 2. The longest watercourse was estimated from the delineated watershed.
- 3. The elevation profile for the longest watercourse was either generated directly from StreamStats utilizing their online "Explorer tools" or estimated from the profile extraction procedure available within Google Earth. This elevation profile data was then divided into eight (8) approximately equal segments.
- 4. Distance from outlet to centroid was measured in StreamStats using their measuring tool and the provided centroid location.

- 5. Drainage area was taken to be equal to the StreamStats calculation provided for the delineated watershed.
- 6. The delineated drainage basin boundary was uploaded to the USDA Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) as an "Area of Interest", from which the hydrologic soils data information was obtained. If this data was not available, soils information was attempted to be found via a literature search. If no soils data was found, the gage was rejected for further consideration. Usually watersheds had multiple soil types. These were all considered. If the available hydrologic soils information percentages did not add to 100% (typical to most of the analyzed watersheds) then the percentages were adjusted according to the ratio of available soils information. For example, if a delineated area was reported to contain 30% hydrologic soil type C, 50% hydrologic soil type D, 12% of a non-specified soil type, and 8% impervious bedrock, the soils information was input to PC-Hydro as (30%/80%) = 37.5% C and (50%/80%) = 62.5% D. Note that the impervious bedrock would be used as part of the impervious percentage calculation (discussed below).
- 7. Watershed type (valley, foothills, or mountain) was determined along each of the eight profile segments in accordance with Table 4.1 provided in the PC-Hydro User Guide.
- 8. Development extents (houses per acre, commercial, industrial, etc.) were determined for each of the eight segments by inspection of aerial and street view photographs provided by Google Earth.
- 9. The overall watershed type (Undeveloped-Foothills, Low Density Urbanized, etc.) was determined by inspecting the identified land uses and selecting the category that best fit the watershed as a whole. This was usually obvious.
- 10. Percent imperviousness was estimated by considering imperviousness information provided by StreamStats, bedrock and other impervious surface information provided by the USDA Soil Survey report, guidance in the PC-Hydro User Guide based upon land use type (Table D-3), and visual estimates based upon aerial topography and street view photographs provided by Google Earth.
- 11. Hydrologic cover type was estimated by considering information provided in the StreamStats report, soils information provided by the USDA Soil Survey report, guidance in the PC-Hydro User Guide based upon typical corresponding elevations (subsection 2.4.3.3 in the guide), and visual estimates based upon aerial topography and street view photographs provided by Google Earth.
- 12. Vegetative cover percent was estimated by considering information provided in the StreamStats report, soils information provided by the USDA Soil Survey report, guidance from the PC-Hydro User Guide Appendix E, and visual estimates based upon aerial topography and street view photographs provided by Google Earth.
- 13. The basin factors for each watercourse segment were taken directly from the "normal" values provided in Tables 4.1 and 4.2 of the PC-Hydro User Guide. When a range of these values were given, the entered value was assumed to be the average of the extremes (e.g., Table 4.1 specifies that undeveloped valleys have a normal basin factor range of 0.030 to 0.040; the implementation here assumed this value to be the average of these two values = 0.035).

All other values used in the PC-Hydro procedure (curve numbers, rainfall, etc.) were generated directly from the web-based application.

# 3.3.1. Sensitivity / Uncertainty Analysis

The identified PC-Hydro data were treated in this analysis as median values (e.g., what would be used in a purely deterministic model). However, there is considerable uncertainty surrounding all of these inputs. Here, six of the variables were identified as critical but uncertain components of the PC-Hydro calculation, either due to their subjective nature (e.g., land use, vegetation, etc.) or because they are inherently stochastic (e.g., precipitation). To quantify this uncertainty, lower and upper limits for six of the variables were identified for each application. The six variables and the limiting values are shown in Table 4 below.

Factor	Variable (units)	Lower bound	Median	Upper bound
Vegetation density	V(%)	Median value – 10%	Estimated from StreamStats, Google Earth, and other sources	Median value + 10%
Percent imperviousness	I (%)	<i>I</i> (%) Median value – 10% Estimated from StreamSta Google Earth, and other sou		Median value + 10%
Curve Number calculation	CN	Unadjusted CN	Adjusted CN	Adjusted CN
Rainfall	<i>P</i> (in)	Lower	Mid	Upper
# Lengths	Ν	2	4	8
Basin factors	n <sub>b</sub>	Minimum per PC- Hydro User Guide	Average of minimum and maximum values specified in PC- Hydro User Guide	Maximum per PC- Hydro User Guide

#### Table 4. PC-Hydro sensitivity factors

The bounds given in Table 4 were assumed to account for about 90% of the variability – about 1.6 standard deviations, which is consistent with the NOAA reported 5% and 95% rainfall values. Of course, there are practical limitations of these factors as well. For example, the ultimate limits of the vegetation density and percent impervious are 0% and 100%. Accordingly, if the estimated imperviousness for a site was taken to be 5%, then the upper bound would be set to 15% (5% + 10%) whereas the lower bound set to 0% because a negative imperviousness would not be realistic.

Treatment of the number of watercourse length segments was slightly more complicated than just adding or subtracting a given percentage. Because these are discrete values, the sensitivity analysis required standardization of the number of lengths selected, which is why eight (8) separate longest watercourse segments were always identified in each watershed. For the analysis of the median values, the eight (8) lengths and elevations were combined and entered as four (4) lengths and elevations, which is consistent with the recommendations in the PC-Hydro User Guide (Arroyo Engineering, LLC, 2007). For the sensitivity analysis, the eight (8) lengths, the suggested four (4) lengths, and the two (2) lengths effects were all analyzed. To illustrate this procedure, Table 5 demonstrates the methodology for a hypothetical watershed.

All eig	ght points used		Four points used Two points		Four points used		points u	ised
Index	L <sub>i</sub> (ft)	X <sub>i</sub> (ft)	Index	L <sub>i</sub> (ft)	X <sub>i</sub> (ft)	Index	L <sub>i</sub> (ft)	X <sub>i</sub> (ft)
1	20	0.4	1	95	0.7			
2	75	0.3	I	90	0.7	1	165	1.9
3	30	0.5	2	70	1.2	I	100	1.9
4	40	0.7	2	70	1.2			
5	50	1.1	3	75	2.3			
6	25	1.2	3	75	2.3	2	155	9.0
7	35	3.2	4	80	6.7	2	100	9.0
8	45	3.5	4	00	0.7			

#### Table 5. Example of hypothetical length increment sensitivity data

With the parameters thus identified, two methods were considered to quantify the effect these factors had on the predicted peak outflows (Q, cfs): propagation of error and the Rosenblueth standard deviation.

Propagation of error utilizes derivatives to estimate the effect of a small change to one or more of the input variables on the predicted outcome of a function. For highly complicated functions (such as the PC-Hydro procedure), determining the derivatives via calculus is not viable; instead, numerical approximations are used.

Specifically, denoting the resulting uncertainty in the log transformed peak flow prediction as  $\Delta \ln Q$  (cfs), the corresponding equation using numerical approximations of the derivatives is:

$$\Delta \ln Q = \frac{1}{2} \sqrt{\frac{(\ln Q_{Vmax} - \ln Q_{Vmin})^2 + (\ln Q_{Imax} - \ln Q_{Imin})^2 + (\ln Q_{CNmax} - \ln Q_{CNmin})^2 + (\ln Q_{Pmax} - \ln Q_{Pmin})^2 + (\ln Q_{Nmax} - \ln Q_{Nmin})^2 + (\ln Q_{n_bmax} - \ln Q_{n_bmin})^2}}$$

where the radical terms describe flow calculations made with all variables kept at their median values except for the variable denoted in the subscript. Note that consideration of the log transformed values is more appropriate here than the raw values given the highly variable nature of hydrology predictions. For example, InQ<sub>Vmax</sub> refers to the (natural) log transformed predicted flow at maximum vegetation density with all other variables kept at their median values. This approach to uncertainty analysis is often described as the "one factor at a time" (OFAT) approach. It has the advantage that minimal calculations are required (2n, where n is the number of factors, so 2n = 12 calculations here) but has the disadvantage that it is only accurate for small deviations and cannot account for interactions between variables.

To check the validity of this approach, standard deviations by both the OFAT method and the Rosenblueth standard deviation were calculated for the High School Wash at Tucson, AZ (USGS gage 9483010). The Rosenblueth standard deviation is arguably superior to the OFAT approach because it accounts for variability between all inputs, albeit at the cost of significantly more computations (2<sup>n</sup> versus 2n). The exact computation is accomplished by taking the standard deviation of all 2<sup>n</sup> terms (64 here). A comparison between the OFAT and Rosenblueth standard deviations is shown graphically in Figure 3.

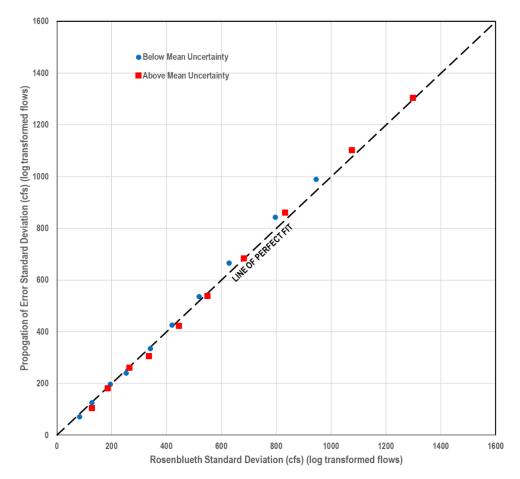


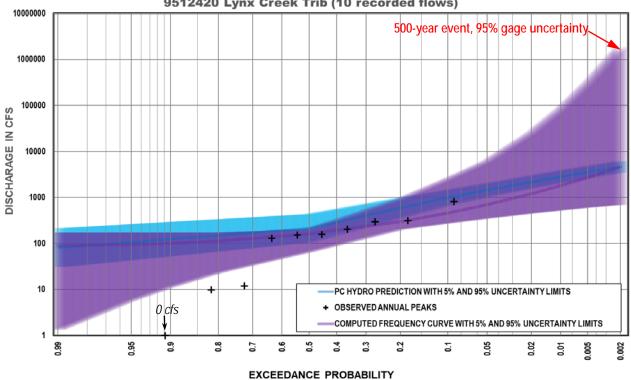
Figure 3. Peak flow uncertainty calculations by propagation of error versus Rosenblueth Standard Deviation

The figure indicates a good fit between the two approaches for this particular gage, with the OFAT approach predicting standard deviations almost exactly equal to the Rosenblueth standard deviation. This was taken as

general validity of the OFAT approach. Accordingly, the OFAT method was used for all subsequent standard deviation calculations.

# 3.4. Gage Analysis

When the preprocess step of the gage analysis was complete, the HEC-SSP program was used to execute a frequency analysis in strict accordance with the draft release of USGS Bulletin 17C (England Jr., et al., 2015). The results of the HEC-SSP analysis often included very pronounced uncertainty estimates. For example, as shown in Figure 4, the frequency analysis of the 0.98 square mile Lynx Tributary (shown as the purple shaded region) indicated a finite probability that the 500-year storm could be more than 1,000,000 cfs. This unrealistic prediction is a consequence of the highly uncertain nature of frequency analysis, particularly in the arid southwest. Also shown in the figure is the raw gage data (observed annual peaks) and the PC-Hydro standard deviation analysis which will be further explained in the next section.



9512420 Lynx Creek Trib (10 recorded flows)

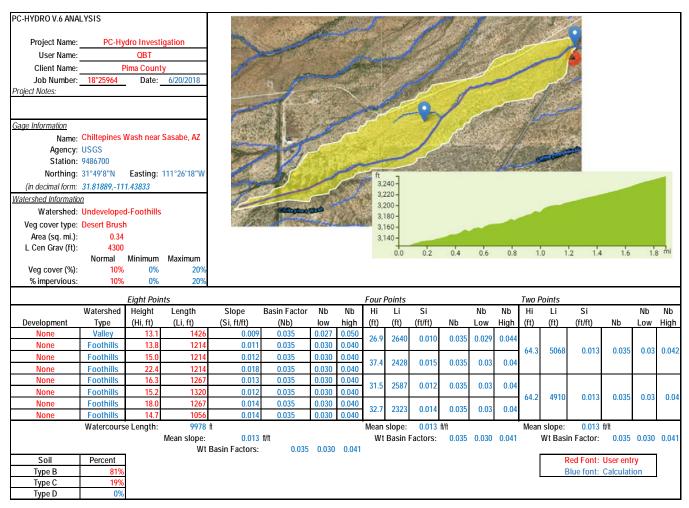
## Figure 4. Lynx Creek Tributary frequency analysis results

Hence, for purely practical reasons, the probability graphs of both the gage and PC-Hydro analyses were constructed as follows:

- 1. The flow limits were always shown between 1 and 10,000 cfs.
- 2. The PC-Hydro prediction for the 1-year return storm was assumed to be equivalent to the 99% exceedance probability, since on a probability graph the 1-year return storm corresponds to the 100% exceedance probability which cannot be shown (i.e., it is infinitely far to the left).
- 3. Gage data below 1 cfs were graphed as 1 cfs (since zero values cannot be shown with log scales) but with their actual values shown with corresponding notes on the figure. For example, in the figure above, the 0 cfs gage data point at around a 0.91 probability is graphed as 1 cfs but noted as 0 cfs.

# 3.5. PC-Hydro Analysis

With the inputs generated as described in the previous section, all of the PC-Hydro preprocessing calculations were performed in Excel. An example of this process is shown in Figure 5 below for the Chiltepines Wash.





Once all of the parameters and their corresponding sensitivity ranges were determined, 13 individual PK6 files were generated for all of the conditions. These included the median estimate (specifically the best estimates for vegetative cover and imperviousness; watercourse divided into four segments; normal basin factors as determined per the PC-Hydro User Guide, 50% NOAA 14 rainfall, and the adjusted curve number) and the 12 upper and lower bound sensitivity runs.

These files were directly uploaded to the updated version of PC-Hydro. Following the upload, the **Fetch Rainfall Data** button was pressed to upload the NOAA 14 rainfall values corresponding to the given gage coordinates. PC-Hydro was then nudged to return the curve numbers estimates. (Curve number estimates are not automatically generated after uploading the PK6 file to the current version of PC-Hydro, but can be generated by the program by making a non-quantitative change to the soil percentages (e.g. a "nudge"), such as adding a ".0" to one of the given values.) The peak discharge estimates were then determined by selecting the **Calculate Runoff Data / Peak Discharge** button. This procedure was repeated for all 13 input files and then the batch output capability was used to output the results.

Post-processing of the PC-Hydro estimates was accomplished as follows:

- 1. The PC-Hydro output file data was copied into Excel;
- 2. The log transformed uncertainty was calculated from the data for each return period using the propagation of error equation;
- 3. The average of the log transformed flows [denoted here (ln*Q*)<sub>ave</sub>] was calculated for all of the flows in each return period;
- 4. Low estimates of the flows were made by subtracting the log transformed uncertainty from the average of the log transformed flows:  $(lnQ)_{ave} \Delta lnQ;$
- 5. Likewise, high estimates of the flows were made by adding the log transformed uncertainty to the average of the log transformed flows:  $(lnQ)_{ave} + \Delta lnQ$ ;
- 6. Both the low and high estimates were transformed back into normal flow units (i.e., cfs).

# 3.6. Results

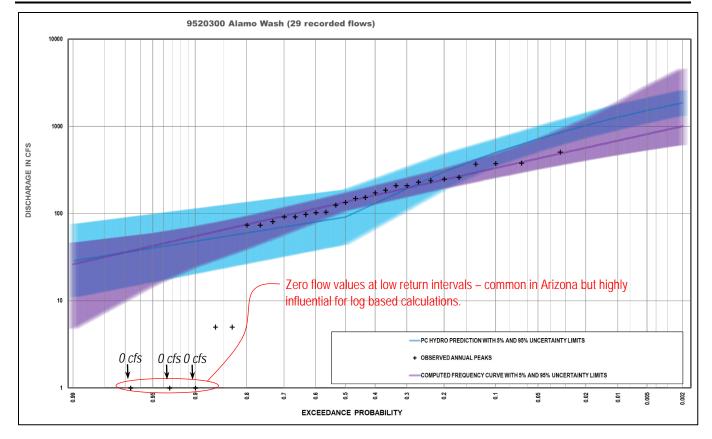
## 3.6.1. Overall

Altogether, 508 gage data points from 30 gages were identified and successfully analyzed with the HEC-SSP. The corresponding watersheds for these points ranged from mountainous to urban, and completely developed versus entirely undeveloped. Hydrologic regions 2 through 5 were represented by multiple watersheds, with 6 in region 2, 8 from region 3, 6 from region 4, and 10 from region 5. Other gage data and relevant design assessments are summarized in Table 6 below.

Property	Minimum (Corresponding watershed)	Median	Mean	Maximum (Corresponding watershed)
Drainage Area (mi <sup>2</sup> )	0.06 mi <sup>2</sup> (Cibecue 1 Tributary Carrizo Creek)	0.63 mi <sup>2</sup>	0.61 mi <sup>2</sup>	1.07 mi² (Agua Fria River Trib 2 near Rock Springs)
Years of Record (yr)	10 (Lynx Creek Tributary near Prescott)	15	18.8	61 (Walnut Gulch Flume 4)
Measured Flow (cfs)	0 cfs (multiple)	90 cfs	144 cfs	1,273 cfs (Walnut Gulch Flume 4)
Time of conc. (minutes)	6.7 min (Cibecue 1 Tributary Carrizo Creek)	31 min	47 min	270 min (Centennial Wash Tributary near Wenden)
Imperviousness (%)	10% <i>(Multiple)</i>	10%	15%	40% (High School Wash at Tucson, AZ)
Vegetation (%)	5% (Cunningham Wash Tributary near Wenden)	11%	16%	40% (Hull Canyon near Jerome)

#### Table 6. Summary statistics of data collected and design parameters applied

Although considerable variation between watersheds was seen in terms of the fit between PC-Hydro predictions and the observed gage data, a more or less representative example is provided in Figure 6 below (Alamo Wash). As expected, the range of predicted flows for a given return interval was substantial, with the PC-Hydro uncertainty band of similar width to the HEC-SSP uncertainty band. Also here, and indeed for nearly all of the analyzed gages, the PC-Hydro prediction band is seen to overlap the frequency analysis uncertainty band particularly well within the lower probability estimates (e.g., 100-year flow). The two bands are seen to deviate somewhat around the 2-year flow (50% return interval), at which point the probability analysis becomes strongly influenced by the three years of zero flow reported in the gage data. PC-Hydro does not account as well for these very frequent return storms. As will be shown later, this issue can be resolved by using the 95% upper rainfall in conjunction with the non-adjusted CN.





Taken as a whole, the analyzed data set indicates that, in general, PC-Hydro predictions under median conditions (e.g. 50% NOAA rainfall, median values for all factors), are consistent with the frequency analysis of the 30 gages. As seen in Figure 7 below, the overall agreement between PC-Hydro predicted flows and the observed flows is strong (albeit with considerable scatter – inherent to hydrologic studies), with the computed trendline (blue line) returning an R<sup>2</sup> value greater than 0.6 and a corresponding slope of 0.92, just under the perfect slope value of 1 (red line). (Note that here and henceforth, setting the intercept of trendline predicted flows will always be zero, such as completely pervious soil, a zero watershed area, etc.)

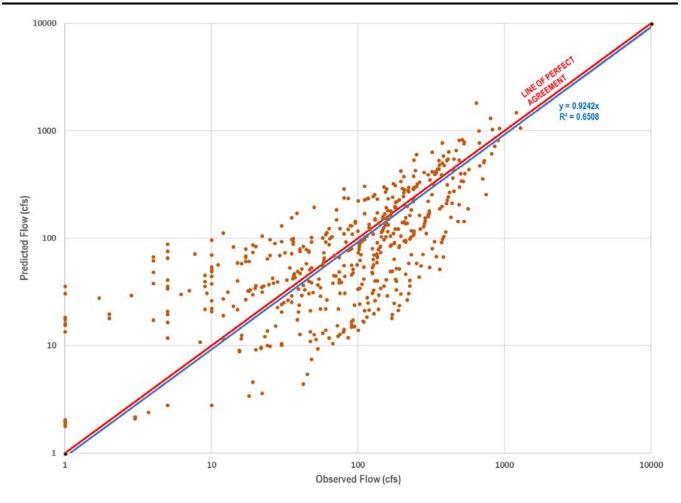


Figure 7. Comparison between PC-Hydro predictions (50% NOAA rainfall / median factors) and all gage data

These same observed flows were then used in conjunction with the HEC-SSP analysis to evaluate PC-Hydro predictions as a function of annual exceedance probability. This comparison was done by taking the ratio of the log transformed predicted versus observed flows and then graphing them as shown in Figure 8 below. A perfect agreement across all exceedance probabilities would correspond to the horizontal line at 1. Indeed, the average and median of the computed ratios are 1.05 and 0.97, respectively – very close to one, thus validating the approach.

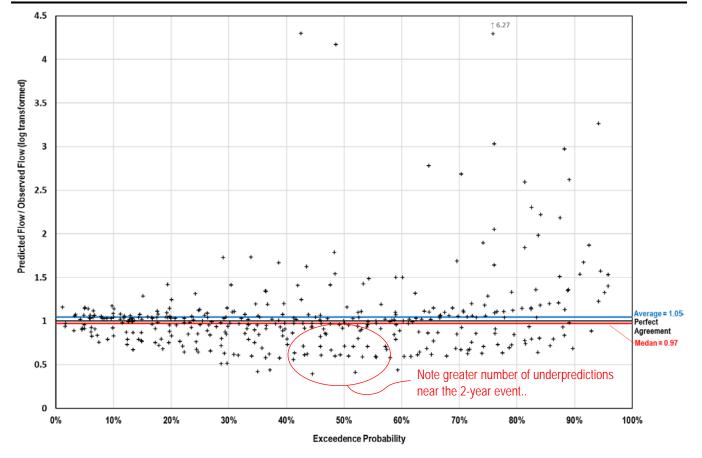


Figure 8. Ratio of log transformed PC-Hydro predictions (50% NOAA rainfall / median factors) / log transformed observed flows versus exceedance probability

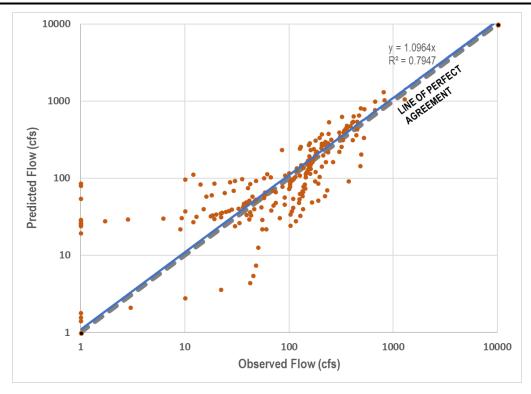
Although the overall agreement between PC-Hydro predictions and observed gage data is evident, the scatter pattern shown in Figure 8 also warrants further analysis. In particular, the number of underpredicted flows appear to group near the 50% probability (2-year storm). As will be shown in the section on design (3.7 Design Implications), this effect is improved by limiting the use of PC-Hydro to the 95% upper rainfall estimates.

## 3.6.2. Development Effect

The ability of PC-Hydro to accurately predict flows is particularly important in developed areas. To investigate PC-Hydro accuracy for developed watersheds, a comparison analysis was also conducted for the following eleven watersheds that contained development:

- 1. Mittry Lake Tributary near Yuma, AZ
- 2. Black Creek Tributary near Window Rock, AZ
- 3. Little Colorado River Tributary near St Johns, AZ
- 4. Queen Creek Tributary A Apache Junction, AZ
- 5. West Speedway Wash near Tucson, AZ
- 6. Casandro Wash, AZ
- 7. San Joaquin Wash near Tucson, AZ
- 8. Pumping Wash near Vail, AZ
- 9. High School Wash at Tucson, AZ
- 10. Lynx Creek Tributary near Prescott, AZ
- 11. Walnut Gulch Flume 4

Altogether, these gages provided 215 observed annual maximum flows. As seen in Figure 9 below, the PC-Hydro flow predictions match these observed values on average, justifying the application of PC-Hydro to developed watersheds.



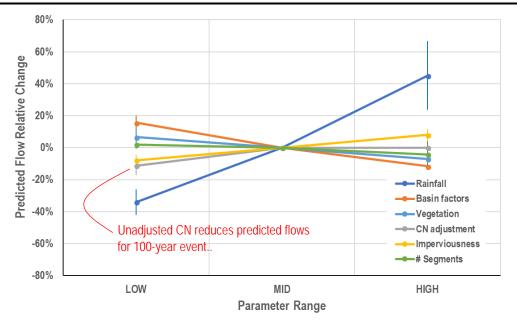


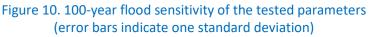
## 3.6.3. Parameter sensitivity

The PC-Hydro analysis itself is an opportunity to assess the relative sensitivity of the six investigated input parameters. To that end, all of the data was analyzed to generate the percent difference between the peak flow predicted with the median parameters values versus the low and high parameter values. These sensitivity analyses were made for the 100-year, 2-year, and 1000-year events.

## 3.6.3.1. 100-year Event

The results for the 100-year return are shown in Figure 10 below. The standard deviations have been included as error bars. Rainfall is seen to be the most impactful parameter, with the 95% rainfall value resulting in around 50% greater flow predictions and the 5% value resulting in 40% smaller predictions. The basin factors were also significant, with smaller values (and hence smoother terrain) increasing predicted flow by 15%, and larger values (rougher terrain) producing the opposite effect (a 15% decrease). The adjusted curve number (CN\*) also has a significant effect, with unadjusted curve numbers (the "low" value) reducing predicted flows by 15% on average as compared with the adjusted value. Vegetation and imperviousness both had limited effects that may not be significant in terms of predicted flows, and the number of segments chosen to delineate the longest watercourse appears to have almost no impact upon peak flow prediction.





The PC-Hydro User Guide (Arroyo Engineering, LLC, 2007) provides a similar sensitivity analysis for a 100-year storm event for a particular watershed. That sensitivity analysis applied 10% changes to rainfall, basin factor, and imperviousness (similar to what was done here) as well as to the basin area, longest watercourse length, and the actual curve number. The results of that analysis are consistent with these result: both indicate a high sensitivity to rainfall, moderate sensitivity to basin factor, and very little if any sensitivity to imperviousness.

#### 3.6.3.2. 2-year Event

As seen in Figure 11 below, sensitivity to the 2-year storm is more pronounced than the sensitivity to the 100year storm. For this much more frequent storm, the adjusted CN and imperviousness prediction have the greatest impact on flow prediction, with no curve number adjustment (the "low" value of that factor) now increasing the flow prediction by up to 100% of the median predicted value. This effect reversal is due to the lower rainfall values associated with the more frequent storms. As noted in the PC-Hydro User Guide (Arroyo Engineering, LLC, 2007), the CN\* procedure effectively lowers CN for 1-hour rainfall depths below 1.5 inches and raises it for depths greater than 1.5 inches. This sensitivity to CN\* and the overall effect on flow predictions has important design implications further explored in the next section.

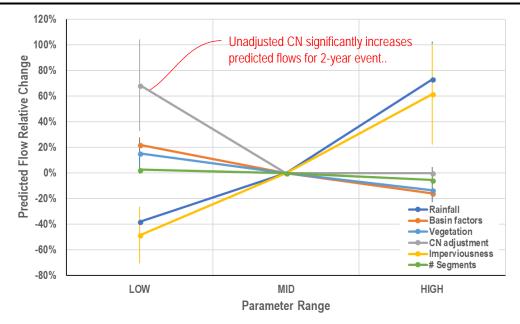
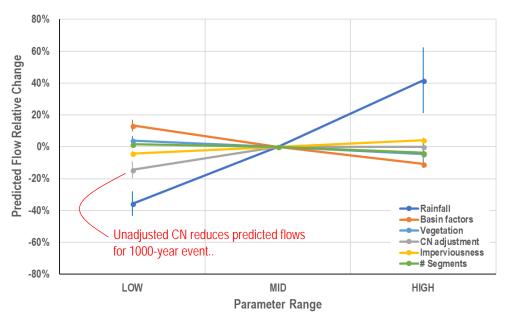


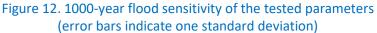
Figure 11. 2-year flood sensitivity of the tested parameters (error bars indicate one standard deviation)

Imperviousness also has a significant impact for the 2-year storm, which although almost negligible in terms of impact on the 100-year storm is seen to actually have a dramatic effect on the 2-year storm, with increasing imperviousness resulting in significantly increased 2-year peak flow predictions. The sensitivity of the other parameters remained approximately the same as the 100-year sensitivity.

#### 3.6.3.3. 1000-year Event

The most extreme event estimated by PC-Hydro is the 1000-year event. The 1000-year storm sensitivity (Figure 12 below) is almost indistinguishable from the 100-year return results, indicating that the most significant factors are rainfall and CN\* (specifically using unadjusted CN results in lower predicted flows).



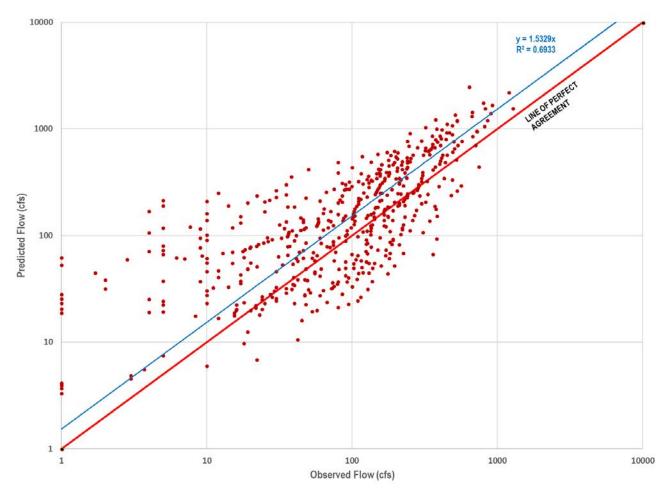


# 3.7. Design Implications

# 3.7.1. 95% Upper Rainfall / Adjusted CN

The comprehensive analysis of PC-Hydro applications versus gage data analysis indicates that PC-Hydro is successful on average at predicting rainfall but can significantly underestimate or overestimate peak flow for a specific application. This is a common challenge in hydrologic modeling and best addressed by implementing assumptions that bias the predictions into higher estimates, thereby establishing conservatively high peak flow predictions in general. In keeping with this approach, the current District design requirements specify that the 95% upper rainfall data be used. In addition, adjusted curve numbers are to be applied, which will tend to increase flow predictions for higher intensity rainfalls. Other design elements (e.g., imperviousness, roughness, etc.) are at the discretion of the analyst but are expected to be close to the median values presented in the District Hydrology Manual (Pima County Department of Transportation and Flood Control District, 1979).

To compare design versus measurement, design flow predictions were made for all of the analyzed watersheds. The results, as seen in Figure 13 below, raise the overall trend fit between predicted peak flows and measured peak flows, resulting in more conservative predictions (i.e., the slope of the trendline is well above 1).



#### Figure 13. Comparison between design predictions (95% NOAA rainfall / median factors) and gage data

As also indicated in Figure 13 (above), an additional positive effect of imposing the design requirement is that it appears to actually improve the R<sup>2</sup> values evaluated by the trend fit, implying that using the upper 95% rainfall data has actually reduced uncertainty. Further evidence of this reduced uncertainty can be seen in Figure 14 (below), in which the pronounced curvature of the predicted flows as a function of return period probability shown in Figure 8 (above) has been reduced (albeit not entirely eliminated).

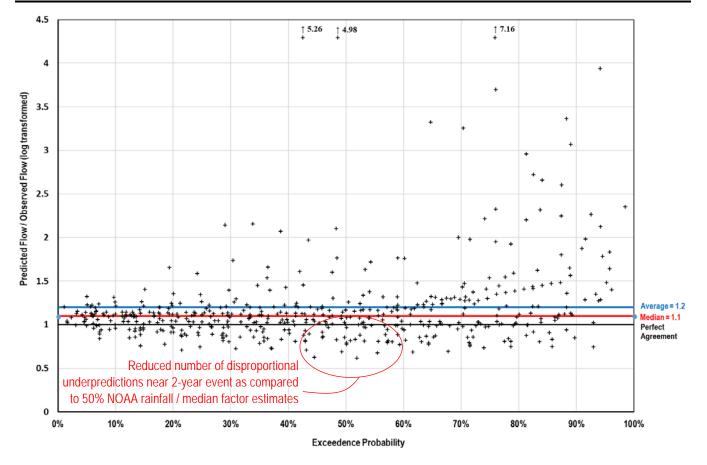


Figure 14. Ratio of log transformed design predictions (95% NOAA rainfall / median factors) / log transformed observed flows versus exceedance probability

This observed reduction in curvature residuals is actually most likely an effect of CN\*. As noted earlier in this report and stated in both the PC-Hydro User Guide (Arroyo Engineering, LLC, 2007) and in the District Hydrology Manual (Pima County Department of Transportation and Flood Control District, 1979), the adjusted curve number is lower than the raw (unadjusted) curve number for 1-hour rainfall depths less than about 1.5 inches, and higher for 1-hour rainfall depths greater than about 1.5 inches. This effect is nonlinear, with the corresponding change to flow prediction more pronounced for lower rainfall values than for upper rainfall values in general. Hence, since higher frequency rainfall will have lower 1-hour rainfall depths, adjusting the curve number may be responsible for the nonconservative predictions seen in Figure 14.

## 3.7.2. 95% Upper Rainfall / Unadjusted CN

Given the evidence noted in the last section that the CN\* impact may be adversely affecting model fit from a design standpoint, a final PC-Hydro analysis was conducted for all watersheds using the design rainfall (upper 95%) but without CN\* (e.g. raw CN values were used). The results indicate that leaving the curve numbers unadjusted will significantly reduce underpredictions overall. As seen in Figure 15 (below), the number of underpredicted values has been significantly reduced, and the previously observed curvature of the low residuals has been all but eliminated.

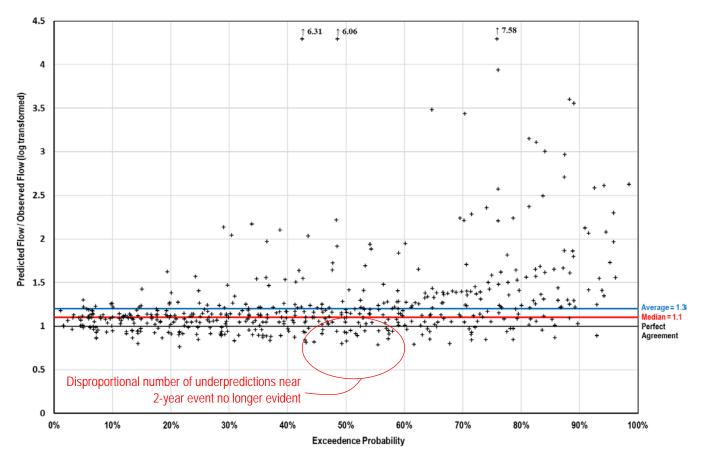


Figure 15. Ratio of log transformed unadjusted CN design predictions (95% NOAA rainfall / median factors) / log transformed observed flows versus exceedance probability

Further, using the unadjusted curve numbers has minimal impact on the match between observed and predicted flows, as seen in Figure 16 below, where the overall flow prediction trendline and R<sup>2</sup> values have remained more or less than same (the slope changed from 1.53 to 1.51, and the R<sup>2</sup> decreased slightly from 0.69 to 0.64).

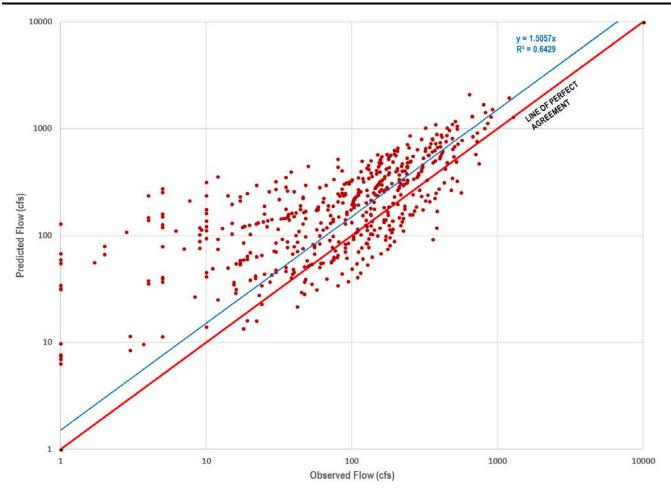


Figure 16. Comparison between PC-Hydro unadjusted design predictions (95% NOAA rainfall / median factors) and all gage data

# 4. Recommendations

# 4.1. Adjusted versus Unadjusted CN

Given the observed sensitivity of PC-Hydro to adjusted CN for the tested watersheds, a comprehensive review of the actual adjusted CN methodology was conducted. The results confirmed that the adjusted CN impact can be substantial over a wide range of CN values, as shown in Figure 17 below, which graphs the adjusted curve number difference as a percentage change to the original curve number. Note that the range for CN (42 < CN < 95) comes directly from the PC-Hydro User Guide (Arroyo Engineering, LLC, 2007) and the range of values for P1 (0.5 < P1 < 4.0) comes from the present study (hence P1 values higher and lower than this range are possible albeit unlikely). A percentage increase of 10% or more is seen for the majority of CN values when P1 > 2.5 inches, and a percentage decrease of 10% or more is seen for the majority of CN values when P1 < 1.0 inches.

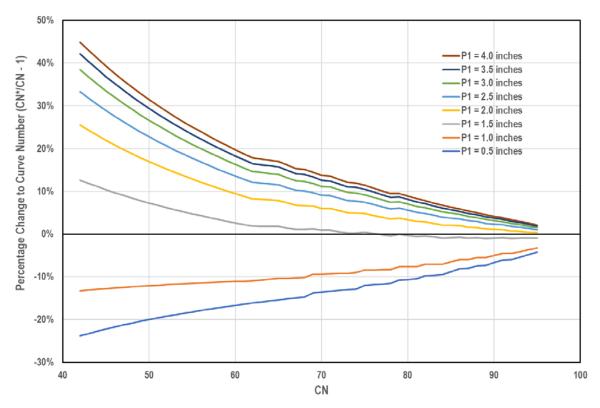


Figure 17. Percentage difference between CN\* and CN

From a design perspective, the implication of Figure 17 is that all unadjusted CN values are calibrated to approximately the 1.5 inch, 1 hour storm, and so the physical impact of other storm intensities on runoff (e.g. the caliche effect) must be corrected for with the given methodology. Indeed, the current PC-Hydro manual (Arroyo Engineering, LLC, 2007) recognizes the calibrated nature of the CN values in general and thus restricts use of the program to only those CN values published by the Arizona Highway Department Bridge Division (now ADOT) in their 1969 revision of the publication *Hydrologic Design for Highway Drainage in Arizona* (Arizona Highway Department Bridge Division, 1969). However, as also stated in the PC-Hydro manual (Arroyo Engineering, LLC, 2007), the CN adjustment equation itself was developed from the data from only one watershed (Walnut Gulch specifically) and hence is unlikely to be correctly calibrated to the wide range of CN values outside of those specific to Walnut Gulch, even if selection of CN values are limited to those listed in the ADOT 1969 publication. Moreover, this potential inaccuracy is present regardless of the extent to which the caliche effect may be present or how well the adjusted CN methodology correctly captures the underlying physical response.

In addition, limiting CN application to only those listed in ADOT (1969) means that new research into curve numbers, such as those studies providing more accurate values for specific landforms and watershed conditions, cannot be utilized by PC-Hydro. This limits potential improvements to PC-Hydro because the new data on CN values and methodologies is actually quite extensive. For example, Google Scholar reports more than 16,000 scientific articles related to curve numbers in hydrology have been published since 1969 and more than 1,000 in 2018 alone. Moreover, even outside of the scientific research, the multiple updates to CN applications within the specific ADOT and SCS (now NRCS) publications cited in the PC-Hydro manual cannot be implemented due to this CN restriction.

It is axiomatic that hydrologic model accuracy is a direct function of the accuracy of the model equations and the input parameters. Accordingly, robust hydrologic models must be flexible enough to adjust to new information and scientific progress. A critical first step toward meeting this goal for PC-Hydro would be to discontinue the use of the adjusted CN procedure.

That said, actually the stronger rationale for no longer applying adjusted CN values in PC-Hydro come from the data itself. Both the unadjusted CN values and the adjusted CN methodology are empirical. As such, the best assessment of their accuracy is direct watershed measurement studies such as this present study. The data here does not support the continued practice of adjusting the curve numbers. Indeed, as noted previously herein, when non-adjusted curve numbers are used the overall number of underpredictions is decreased, resulting in more conservatively high estimates of flow prediction. Table 7 quantifies this observation, showing that the total number of underpredictions significantly decreases by using unadjusted curve numbers in conjunction with the 95% upper rainfall (the recommended approach).

Design Approach	Underpredictions	Overpredictions	Underprediction Risk
50% Upper Rainfall / Adjusted Curve Number (Median Approach)	279	229	55%
95% Upper Rainfall / Adjusted Curve Number (Current Design Standards)	155	353	31%
95% Upper Rainfall / Unadjusted Curve Number (Recommended Approach)	108	400	22%

## Table 7. Predictive success for various design approaches

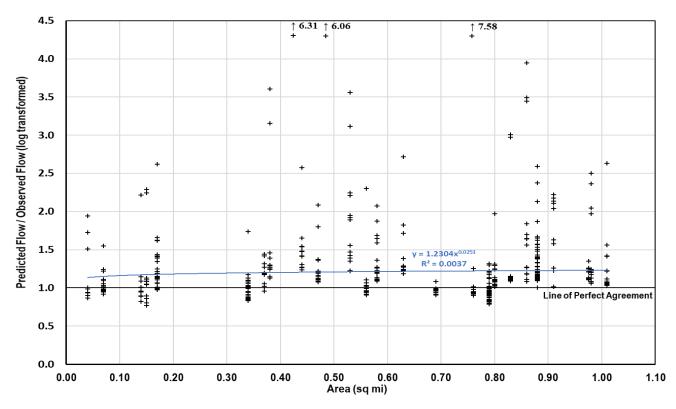
# 4.2. Areal Applicability

The collected data provide an opportunity to investigate the areal applicability limits of the Rational Method in general and the PC-Hydro application in particular. In general, larger watershed extents increase the risk of hydraulic factors becoming present that may weaken or even invalidate the applicability of the rational method. Such factors could include significant detaining areas (natural or manmade) or channelization (e.g. culverts, storm drain). Further, a larger watershed extents increases the likelihood that rainfall will not be constant over the area (another Rational Method assumption). Finally, a larger watershed generally equates to longer times of concentration, and since the storm duration is taken to be equal to the time of concentration in the Rational Method, larger watersheds decrease the likelihood of meeting the Rational Method requirement that rainfall is constant over the storm duration.

The likelihood of Rational Method assumption violation for larger watersheds has prompted most agencies that apply the Rational Method to define an upper area limit. Specifically, agencies in Arizona and the surrounding regions have applied the following aerial limits as follows:

- Within Arizona:
  - Maricopa, Pinal, Mohave, & Yavapai Counties limit Rational Method to < 160 acres.
  - La Paz County limits the Rational Method to 10 acres.
  - Scottsdale, Phoenix, Buckeye, and Glendale also apply the 160 acre limit on the Rational Method.
  - City of Flagstaff limits the Rational Method to < 20 acres.
  - ADOT originally limited Rational Method to less than 1 square mile, changed the limit to less than 80 acres, and then changed it again to the current limit of < 160 acres.</li>
- Jurisdictions outside of Arizona often use higher limits for the Rational Method:
  - The Utah Department of Transportation limits Rational Method to 0.5 square miles.
  - o Lake County, Orange County and the City of San Diego limit Rational Method to one square mile.
- The State of New Mexico restricts the Rational Method by time of concentration only (less than 1 hour).

Inspection of these agency specified Rational Method areal limits indicates considerable diversity, with values ranging from 10 acres to one square mile (640 acres), spanning almost two orders of magnitude. To address this concern with regard to PC-Hydro, the gathered database was further analyzed in terms of accuracy of prediction with the recommended approach (i.e. 95% upper rainfall and non-adjusted CN) versus watershed area. The results, shown in Figure 18 below, do not provide compelling evidence that the PC-Hydro implementation of the Rational Method changes in predictive accuracy for larger watershed areas (at least up to one square mile). In particular, a power curve fit of the data was found to be a weak predictor, with both the R<sup>2</sup> value and the exponent close to 0, indicating little to no relationship between area and PC-Hydro predictive accuracy.





# 4.3. Time of Concentration Limitations

By request of the District, the current PC-Hydro requirement of a 5-minute minimum time of concentration was vetted against the gathered data. This requirement warrants investigation because the Rational Method sets storm duration equal to time of concentration, and hence the effective rainfall intensity increases with decreasing time of concentration. As a result, imposing a minimum value could lead to maximum flow predictions less than observed.

However, the data currently do not support the reduction of the 5-minute time of concentration requirement, since all of the analyzed watersheds had times of concentration greater than or equal to 6 minutes. Future work could consider smaller sized watersheds as a direct test of this restriction, but as for now it is recommended that the currently required minimum 5-minute time of concentration be continued.

# 4.4. Hydrograph Output

Because PC-Hydro is based upon Rational Method assumptions it does not consider a hydrograph in the calculations, nor does it produce one directly. However, as an additional feature, PC-Hydro can generate hydrographs that incorporate the peak flow estimates. According to the PC-Hydro User Guide (Arroyo Engineering, LLC, 2007), these hydrographs were developed based upon earlier work by Hickok and others (Hickok, Keppel, & Rafferty, 1959). As a limited test of the accuracy of these generated hydrographs, PC-Hydro was used to predict hydrographs produced for randomly selected watersheds within the current study. The output appeared to be reasonable across all storm events, with a maximum 1% variation between PC-Hydro predicted and hydrograph peak flows. (Note that some discrepancy between peak flows is expected because the output is generated for specific time increments and therefore carry a likely likelihood of missing the exact time to peak.) Accordingly, the continued use of the hydrographs for routing purposes is recommended here. That said, note that a stronger test of this accuracy can be obtained by using PC-Hydro to route the hydrographs through sub-watersheds within larger gaged watersheds. Indeed, this is one of the recommended next steps for further implementation of PC-Hydro (see Section 5.2: Modified Rational Method).

# 4.5. Overall Recommendations for PC-Hydro Implementation

The present comparison study indicates that PC-Hydro and corresponding software implementation is a reliable predictor of return period flows for Arizona watersheds that meet the Rational Method criteria. In particular, the current design approach utilizing the upper 95% rainfall value results in conservatively high peak flow predictions on average. Given this overall success for less frequent storms (e.g., the 100-year), it is recommended that the District continue to utilize the methodology and advocate for its use for hydrologic design within Pima County. The areal limitation of one square mile is supported by the data, and no evidence was found to invalidate the use of a minimum five minute time of concentration. No evidence was found that the optional hydrograph produced by PC-Hydro is inaccurate. However, the current practice of adjusting the curve numbers is not supported by a critical review of the methodology nor by the collected data.

Hence, the four major recommendations developed regarding the use of PC-Hydro as a design methodology in Pima County can be summarized as follows:

- 1. Update the PC-Hydro User Guide and all associated publications (Pima County Hydrology Manual, etc.) to reflect the modifications described earlier to the User Guide Equations 3 and 4b;
- 2. Continue limiting use of PC-Hydro to watersheds less than one square mile.
- 3. Continue the minimum five minute time of concentration requirement.
- 4. Continue using the PC-Hydro generated hydrograph for routing purposes.
- 5. Remove the adjusted curve number correction. (Note that if this recommendation is implemented then the recommended modification to PC-Hydro User Guide Equation 3 becomes moot.)

# 4.6. PC-Hydro Related Technical Policies

The recommendations for PC-Hydro and observations developed from the data have implications with regards to other technical policies within the District. These policies and corresponding recommendations are as follows:

## 4.6.1. Design Standards for Stormwater Detention and Retention (Suppl. to Title 16, Chapter 16.48)

These standards provide clear direction regarding design and analysis of detention and retention areas to limit volume and peak flow of storms. The techniques recommended will reduce time of concentration. These applications in general and the Low Impact Development (LID) procedures specifically are unlikely to be well accounted for by PC-Hydro. Of course, some of this inaccuracy is inevitable across all hydrology methods since LID is a rapidly advancing field. However, it is critical for Pima County decision makers to be aware that LID and associated measures will introduce uncertainty to PC-Hydro estimates, and moreover it is not clear at this time whether this uncertainty is unbiased or biased. As information becomes available, it may be appropriate to add new parameters to PC-Hydro under watershed type or roughness that can account for specific installations.

## 4.6.2. TECH-10: Rainfall Input for Hydrologic Modeling

This technical policy recommends the use of the upper 95% rainfall input values from NOAA 14. The study reported herein indicates that the 50% NOAA 14 values were adequate in general, but given the considerable uncertainty inherent to hydrology, the recommendation here is to continue utilizing the upper 95% NOAA 14 data as this will result in slightly higher peak flow predictions (conservative from a flooding standpoint).

# 4.6.3. TECH-12: Methods to Estimate Maximum Anticipated Scour Depth Including Optional Adjustment for Flood Duration

This technical policy clarifies District policy on acceptable scour calculations and provides guidance on how to utilize specific methodologies developed by the District. Both time dependent and time independent hydraulic analyses are described in the accompanying literature.

PC-Hydro is well suited for the hydrologic analyses required by either the time dependent or the time independent procedures to determine the design flow, provided the other PC-Hydro assumptions are met (see Section 2.1).

# 4.6.4. TECH-13: Regulation of Shaded Zone X Classifications

This technical policy clarified the District requirements for regulatory criteria in Shaded Zone X classifications. Of particular relevance here is the requirement to model watersheds less than one square model. PC-Hydro is well suited for that task and, as such, it may behoove the District to look further into how exactly PC-Hydro could be utilized to support this policy.

## 4.6.5. TECH-14: Erosion Protection of Stem Wall Foundations in Floodway Fringe Areas

This technical policy focuses primarily on the structural aspects of erosion protection at stem wall foundations. There are several points noted in the policy where PC-Hydro could be used to compute the flows applied to the scour equations. That said, there does not appear to be a direct role for PC-Hydro in the policy.

# 4.6.6. TECH-15: Acceptable Methods for Determining Peak Discharges

This policy provides clear direction on when to apply particular peak flow calculation methods. In particular, the policy states that PC-Hydro shall be used for small watersheds (< 1 square mile) with "negligible detention or retention structures". The directive tone in this statement (i.e. "shall be used" as opposed to "can be used") differs from the stated applicability requirements per the PC-Hydro User Guide (Arroyo Engineering, LLC, 2007). The closest requirement per the Guide is that PC-Hydro is acceptable when "channel storage processes or diffusion is negligible". To avoid confusion, it is recommended that the PC-User's guide be updated to be consistent with the specific methodology requirements given in TECH-15.

#### 4.6.7. TECH-16: Acceptable Methods for Floodplain Delineation

This technical policy is specific to hydraulic modeling only and as such is not directly relevant to PC-Hydro.

#### 4.6.8. TECH-17: Applicability of and Acceptable Methods for Sediment Transport Analysis

Although this policy focuses on sediment transport, it does give specific direction on hydrograph development, for which PC-Hydro is well suited. In particular, the policy states that "For evaluation of long-term aggradation/degradation, the 10% chance flood event, or a string of anticipated future discharges shall apply." The results of the present study indicate that PC-Hydro is well suited for the 10% chance event modeling should it be required, but if the "future discharges" are significantly small then PC-Hydro may not be as accurate as other methods. It may be best to further clarify the "string of future discharges" referred to policy.

## 4.6.9. TECH-18: Acceptable Model Parameterization for Determining Peak Discharges

This technical policy focusses primarily on applicability of different methods. In particular, the policy states the PC-Hydro can be used for watersheds up to 10 square miles. The PC-Hydro Guide states this as well but also discourages the user from utilizing the method for areas greater than 1 square mile. It may make sense to include wording to that effect in this technical policy as well.

#### 4.6.10. TECH-19: Standards for Floodplain Hydraulic Modeling

Like Technical Policy 16, this technical policy is specific to hydraulic modeling only and as such is not directly relevant to PC-Hydro.

# 4.6.11. TECH-20: Engineering Analysis Requirements for Determining an Alternative Safe Erosion Hazard Setback Limit

This technical policy includes the 100-year flow as a required parameter and refers the reader to TECH-15. Accordingly, it is not directly relevant to PC-Hydro.

# 4.6.12. TECH-25: Permitting Guidelines for Sand, Gravel and Other Excavation Operation Located within Flood and/or Erosion Hazard Areas

Like Technical Policy 20, in this policy the reader is referred to TECH-15 for all matters having to do with hydrology. As this referral seems both correct and appropriate, no revisions are recommended.

#### 4.6.13. TECH-28: Pre-Ordinance Agricultural Berms, Channels and Stock Ponds

This technical policy provides guidance with regards to major water storage and diversion structures that may exist within a watershed. Hydraulic modeling is needed for most of the tasks described in the policy but the corresponding hydrologic requirements (e.g., 1% chance event) is not indicated. If deemed appropriate, adding specific instruction on the hydrologic requirement may be helpful. Part of this statement should be to caution the reader against using PC-Hydro as the presence of berms, ponds, and channels with significant storage capacity all violate the PC-Hydro assumptions.

#### 4.6.14. TECH-29: Electrical Facilities that Are Considered "Critical Facilities"

This technical policy addresses hydrology by specifying the 500-year flood as the primary design storm for critical facilities evaluation. It does not mention how to compute this flood. Accordingly, following FEMA acceptance of PC-Hydro the District may want to add a specific reference to PC-Hydro in this policy.

#### 4.6.15. TECH-33: Criteria for Two-Dimensional Modeling

Among other directions, this policy gives specific guidance on how best to apply PC-Hydro in 2D hydraulic models. This guidance is succinct and consistent with the other technical policies and requirements. Accordingly, no revisions to this technical policy are recommended.

# 4.6.16. TECH-35: FLO-2D (V. 2009, Pro) Technical Guidance for Hydrologic and Hydraulic Modeling in Unincorporated Pima County, Arizona (DRAFT)

This policy provides specific instructions on how to conduct and submit a FLO-2D study in a way acceptable to the District. Under the verification instructions, the policy lists one hydrology method (HEC-HMS). Listing acceptable hydrology methods for comparison is appropriate since FLO-2D can be used for hydrologic calculations. It is recommended that PC-Hydro be added to the list of acceptable verification methods.

4.6.17. TECH-101(1): Determining Base Flood Elevations in Regulatory Floodplains with Detailed Studies This technical policy is specific to hydraulic calculations and as such is not relevant to PC-Hydro.

# 5. Further Study

This report provides solid evidence that PC-Hydro provides reasonable hydrologic estimates when applied within the known inherent restrictions of the Rational Method assumptions. This success supports the use of PC-Hydro in a greater capacity for more specific applications, such as BMP implementations or as part of an overall routing analysis that could include detention, retention, or other hydraulic features. PC-Hydro could also be used to investigate other fundamental issues regarding hydrologic predictions in the arid southwest and in Pima County in particular, such as effects of nonlinear intensity-duration-frequency curves and parameter uncertainties.

These research questions and how PC-Hydro may be used to resolve them are considered below.

#### 5.1. Watershed Parameter Updates

With the elimination of the adjusted curve number, new research on curve numbers can be considered for inclusion within PC-Hydro. Accordingly, it is recommended that research be conducted into the applicability and benefits of advances in curve number modeling values and techniques. This research should also consider advances in modeling other watershed characteristics, such as new basin factors, vegetation, and imperviousness. Finally, implications to potential changes to calculated parameters in PC-Hydro that are dependent upon these values should be investigated (e.g. time of concentration, runoff coefficient).

## 5.2. Modified Rational Method

The success of PC-Hydro for small watersheds can be applied to larger watersheds as well, even beyond the limits of the Rational method, provided appropriate routing methodology is applied. This approach, typically referred to as the "Modified Rational Method", divides larger watersheds into smaller subareas, each of which meets the Rational Method assumptions, even if the watershed as a whole does not. Rational Method based hydrographs are then generated for each subarea and routed together using appropriate techniques.

PC-Hydro is well suited for implementation into the Modified Rational Method for the following reasons:

- 1. PC-Hydro is the only rigorously, locally confirmed hydrology methodology in Pima County.
- 2. Detention routing methodology has already been well established based on the PC-Hydro output hydrograph, as established through the District's comprehensive PC-Route-V5 Excel workbook.
- 3. The alpha version of the updated PC-Hydro application used in this study allows batch runs of multiple watersheds at once.
- 4. Unlike other methods, the limits and uncertainty of PC-Hydro are known and quantified, and hence the larger scale routing parameters and requirements needed for larger watersheds can be intelligently developed based upon well-established data. This provides a distinct advantage over other large scale methods such as HEC-HMS, which while currently accepted by the District for hydrologic predictions nonetheless include limitations and subarea component uncertainties not as well understood as the PC-Hydro inputs.
- 5. If PC-Hydro can be applied to larger watersheds via routing, the present work can be extended to provide further verification and establish limitations by direct comparison with large available database of USGS stream gage data within Arizona.
- 6. One of the major challenges of Modified Rational Method applications is to identify the appropriate storm duration, but with PC-Hydro's batch file capability multiple storm durations can be considered over extremely rapid timeframes (i.e., seconds), and hence the worst case storm duration can be found through direct consideration within a modified PC-Hydro application.

### 5.3. Best Management Practice (BMP) Modeling

Best Management Practice (BMP) is the direct implementation of sustainability within a hydrologic network. It is critical for environmental reasons and accordingly is an active area of intense, ongoing research at both the academic and governmental level. Unfortunately, and as noted in the Technical Policy comments (Section 4.6.1) regarding Design Standards for Stormwater Detention and Retention (Suppl. to Title 16, Chapter 16.48)), BMP

implementations are at best poorly understood in terms of their influence upon hydrologic parameters such as hydraulic roughness and permeability, and at worst may violate some of the underlying assumptions of the Rational Method. Understanding how and to the extent PC-Hydro should model BMP applications is an important undertaking. Research in this regard should include not only those BMP factors currently practiced but should established methodologies by which future BMP measures can be correctly modeled within the PC-Hydro methodology and website application.

## 5.4. Investigation of the Time to Peak = Storm Duration Assumption

A major assumption within the Rational Method was that the worst case storm outflow will occur when the storm duration exactly equals the time to peak, usually taken to be equal to the time of concentration. The reasoning is that for shorter duration storms, not all areas of the watershed contribute to the outflow, and hence the storm duration must at least be as long as the time of concentration. On the other hand, storms longer than the time of concentration will have lower rainfall intensities. Hence, the greatest outflow will occur when the storm duration equals the time of concentration. Although reasonable, this assumption is not necessarily always accurate. For areas with very intense, short duration storms (e.g. the arid southwest), a nonlinear relationship between duration and storm fall intensity can actually result in the highest flows occurring when the storm duration is less than the time to peak.

Consider Alamo Wash for example. As shown in Figure 19 below, the watershed extents includes a small portion on the upstream side that disproportionally influences the longest watercourse length while providing minimal extra area. If only the area shown in red in the figure is considered, the flows actually increase for all storms less than or equal to the 100-year return because the decrease in flow due to loss in watershed area is offset by the higher intensity storm corresponding to the shorter time of concentration. As a result, the predicted lower return period storms are significantly higher, as noted in Table 8 below.

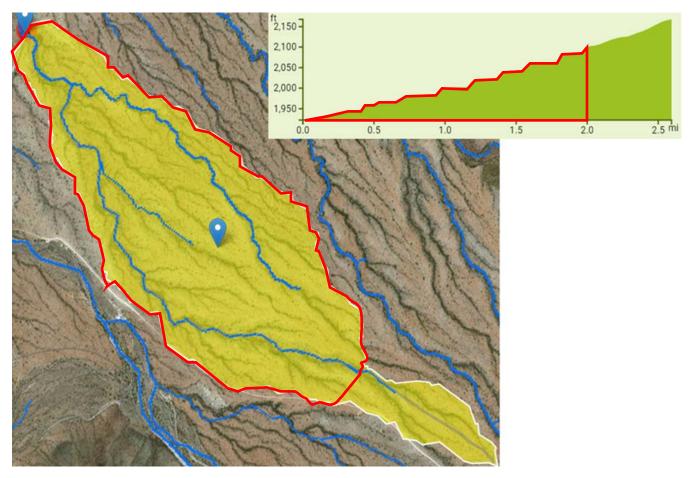


Figure 19. Alamo Wash with complete extents and contributing extents from smaller storm duration (red lines)

Return Storm	Q (full extents)	Q (limited extents)
1	96.3	103.2
2	210.9	227.5
5	486.2	491.1
10	719.8	732.7
25	1084.8	1113.1
50	1397.9	1422.9
100	1760.5	1770.5
200	2170.0	2127.4
500	2711.3	2661.8
1000	3197.7	3150.9

Table 8. Predicted flows for Alamo Wash for both complete and limited extents (maximum shown in bold)

Hence, it may be prudent to investigate if a systematic method can be developed to consider storms less than the full time of concentration duration, and if so, the extent to which PC-Hydro can automate the procedure.

#### 5.5. Risk Analysis

The research described herein made several assumptions regarding data uncertainty. These assumptions followed standard practice for estimating parameter uncertainties given limited information but, of course, well quantified parameter stochastic information would be preferable. Indeed, if the parameter inherent statistical distributions (normal, lognormal, etc.) were to be established, the PC-Hydro application could be extended to allow direct risk analysis by applying a Monte-Carlo approach, in which thousands of flow estimates are made by randomly selecting values from each parameter statistical distribution. Indeed, such an extension of PC-Hydro would be a nearly ideal risk evaluation tool. For example, if uncertainty risk was set at 1%, PC-Hydro could execute thousands of randomized runs for a given watershed, rank the resulting flows, and then report the value in the 99<sup>th</sup> percentile as the design flow. Extending PC-Hydro to allow Monte Carlo analysis would require an investigation of parameter uncertainty and then implementation of the Monte Carlo procedure. These two tasks are described henceforth.

#### 5.5.1. Parameter Uncertainty Investigation

This task would identify the statistical distributions of not just the six parameters considered in this report (vegetation, imperviousness, number of watercourse intervals, CN adjustment, NOAA rainfall, and basin factors), but all of the other PC-Hydro input parameters as well, including: CN number selection (and corresponding antecedent moisture condition assumption), watershed designation (e.g., undeveloped valley, suburban foothills), vegetative cover type (e.g., desert brush, mountain brush), watershed area (sometimes a mismatch was seen between Stream Stats estimated aerial extents and reported area), watercourse length, watercourse elevation changes, watershed center of gravity location, watercourse distance to center of gravity, and soil types. The parameters would be identified through a combination of literature research, direct measurement, database investigation, and subject matter expert interviews, the best statistical distribution and corresponding characteristics would be identified for each parameter.

#### 5.5.2. PC-Hydro Monte Carlo Extension

The input for PC-Hydro would be extended to include stochastic information of each property, and then the batch execution property of updated version of PC-Hydro would be further extended to generate a preset number of flow estimates based upon randomly generated parameters given the specific site information. PC-Hydro could then report the flows in terms of annual risk, either considering both return storm and risk or as just risk itself. An example of the first output might be that the watershed has "5%, 50%, and 95% risks of a 25-year rainfall runoff greater than 950, 700, and 550 cfs, respectively", whereas the second would directly account for the rainfall return interval risk, reporting a "1% annual risk of rainfall runoff greater than 1,100 cfs", for example.

## 6. Works Cited

Arizona Highway Department Bridge Division. (1969). *Hydrologic Design for Highway Drainage in Arizona*. Phoenix, (By Jencsok, E.I. Published December 1, 1968. Revised March, 1969.): Arizona Highway Department Bridge Division.

Arroyo Engineering, LLC. (2007). PC Hydro User Guide. Tucson: Pima County Regional Flood Control District.

- England Jr., J., Cohn, T., Faber, B., Stedinger, J., Thomas Jr., W., Veilleux, A., . . . Mason, R. (2015). *Guidelines for Determining Flood Flow Frequency – Bulletin 17C: U.S. Geological Survey Techniques and Methods 4– BXX.* Reston: USGS.
- Hickok, R., Keppel, R., & Rafferty, B. (1959). Hydrograph Synthesis for Small Arid-Land Watersheds. *Agricultural Engineering (40)*, 608-611, 615.
- Paretti, N., Kennedy, J., Turney, L., & Veilleux, A. (2014). *Methods for estimating magnitude and frequency of floods in Arizona, developed with unregulated and rural peak-flow data through water year 2010: U.S. Geological Survey Scientific Investigations Report 2014-5211.* Reston: USGS.
- Pima County Department of Transportation and Flood Control District. (1979). *Hydrology Manual for Engineering Design and Flood Plain Management within Pima County Arizona.* Tucson: Pima County.
- Pima County Department of Transportation and Flood Control District. (1979). *Memorandum to All Holders of the Hydrology Manual.* Tucson: Pima County.
- Ponce, V. M. (1989). Engineering Hydrology. Upper Saddle River: Prentice Hall.
- U.S. Department of Agriculture-National Resouce Conservation Service. (2009). Part 630: Hydrology, Chapter 7. In U. D.-N. Service, *National Engineering Handbook.* Washington, D.C.: USDA-SCS.

Appendix A. Individual Gage and Watershed Detailed Information

Agua Fria River Trib 2 near Rock Springs, AZ

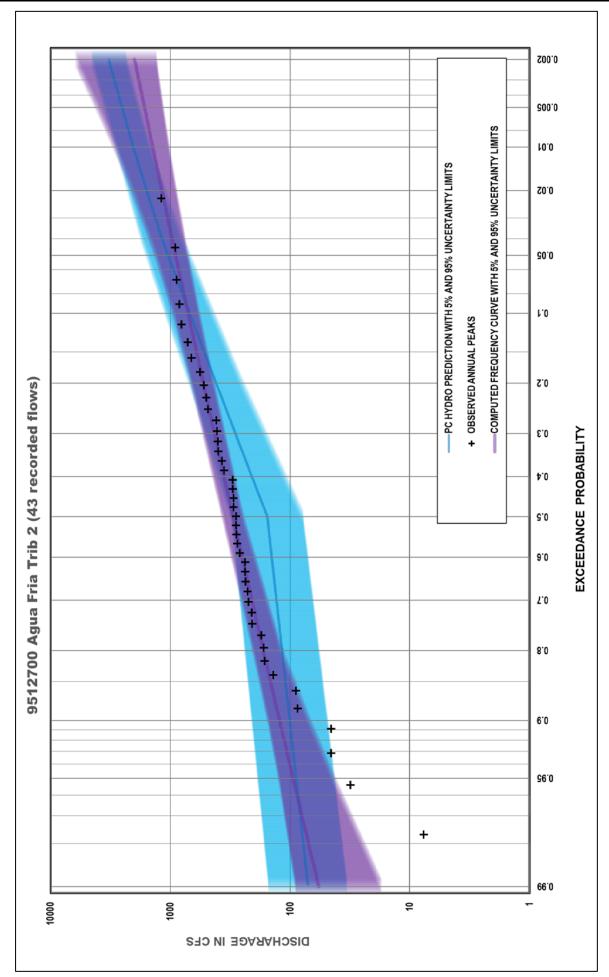
		ے ج	2	0.04		57		Q	9			
Ē		Nb High				3 0.057		0,0,0			_	
-15		Nb Low	000	0.03		0.038			v.u.	2	on	
-11		dN	0.025	0.030		0.048		/f	0.041	Jser enti	alculati	
-2:		Si (ft/ft)	010	0.010		0.047		0.028 f/f	ractol:	Red Font: User entry	Blue tont: Calculation	
-2	ints	Li (ft)	0074	4077		4593		Mean slope:	WL DASHI FACTOL:	Re	Blu	
-8	Two Points	H (ft)	01 (	0.00		216		Mean	>			
-8	-	Nb High	0.04	0.04	0.052	90.0	00		0.040			
-3		Nb Low	0.03	0.03	0.036	100	0.04		0.034			
8-		dN	0.035	0.035	0.044	0 OE	cn.u	/f	0.041			
2,2300- 2,2100- 2,1100		Si (ft/ft)	0.018	0.018	0.039	0 OEE	ccn.u	0.027 ft/f				
	oints	Li (ft)	2376	2323	2323	OFCC	7210	lope:				
	Four Points	Hi (ft)	43	42.6	90.8	106	071	Mean slope:				
		Nb high	0.040 0.040	0.040 0.040	0.040	0.060	0.060		0.047			
$h \rightarrow s \neq 1$		dN Wol	0.030	0.030 0.030			0.040		0.034 0.047			
		actor )							0.041			
		Basin Factor (Nb)	0.035	0.035			0.050	<del>4</del> / <del>4</del>	IVI			
		Slope (Si, ft/ft)	0.020 0.016	0.015 0.021	0.029	0.046	0.072	2000	Wt Basin Factors:			
		SI (Si,						Ħ	Basin F			
ation 6/29/2018 4 Springs, AZ 12°08'42"W Maximum 25% 27%		Length (Li, ft)	1162 1214	1109 1214	1109	1214	1056	9292 ft	wean supe: Wt			
tigation tuty s s Max	ints	Ler (Li							Medi			
PC-Hydro Investigation       OBT       OBT       OBT       B*25964       Pima County       8*25964     Date:       6S     6/29/2018       12700     6/29/2018       12700     02'00"N       12700     03333,-112.14500       03333,-112.14500     03333,-112.14500       developed-Foothills     10'1       4300     Morimum       15%     5%       25%     25%       17%     7%       27%	Eight Points	Height (Hi, ft)	23.6 19.4	17.1 25.5	32.2 58.6	0.00 49.2	76.3	Watercourse Length:				
	Η	ed	hills hills	hills hills	hills	ntain	ntain	rcourse		cent	20%	0 <sup>0</sup>
		W atersh Type	Foothills Foothills	Foothills	Foothills	Mountain	Mountain	Wate		Percent		
Project Name:     PC-Hydro Investi       User Name:     OBT       User Name:     OBT       User Name:     OBT       Job Number:     Pima Count       Job Number:     18*25964     Date:       Job Number:     River Trib 2 near Ro       Agency:     USGS       Station:     9512700       Northing:     34*02'00"N       Kind decimal form:     34.03333,-112.14500       ershed Information     Moreveloped-Foothills       Veg cover type:     Desert Brush       Area (sq. mi.):     1.01       L Cen Grav (ft):     Mormal Minimum       Veg cover (%):     15%       Veg cover (%):     15%		ment	er er	e e	l le l	e e	Je				B B C	ار
Project Name: User Name: Job Number: Job Number: Project Notes: 00000-1 Agency: L Station: Matershed Information Watershed Informati		Development	None None	None None	None	None	None			Soil .	Type B	י - אחפר
ā  <mark>°</mark>  ଔ  ≷												

57

PC-HYDRO V. 6 ANAL YSIS

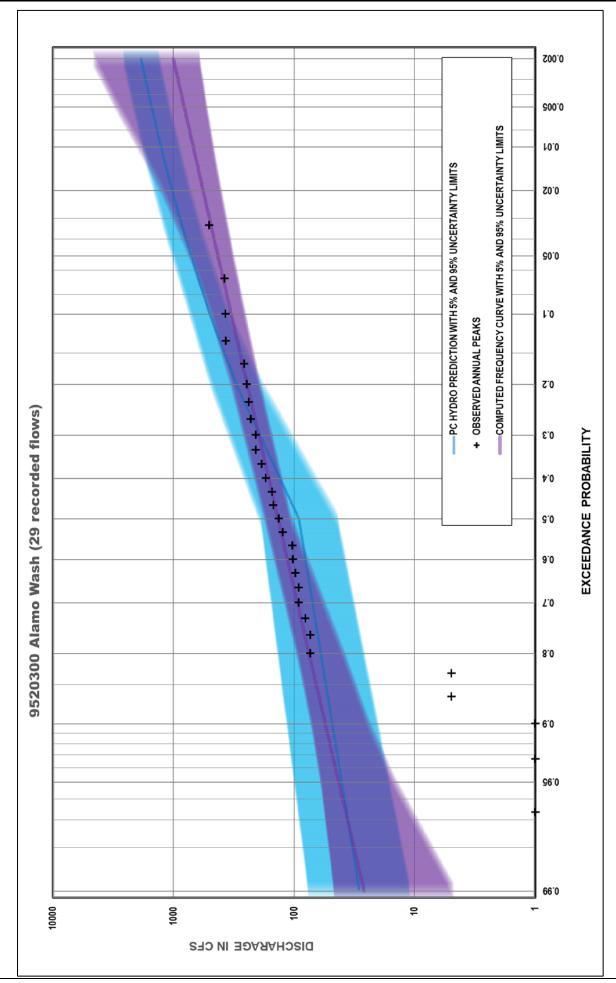
62%

Type D



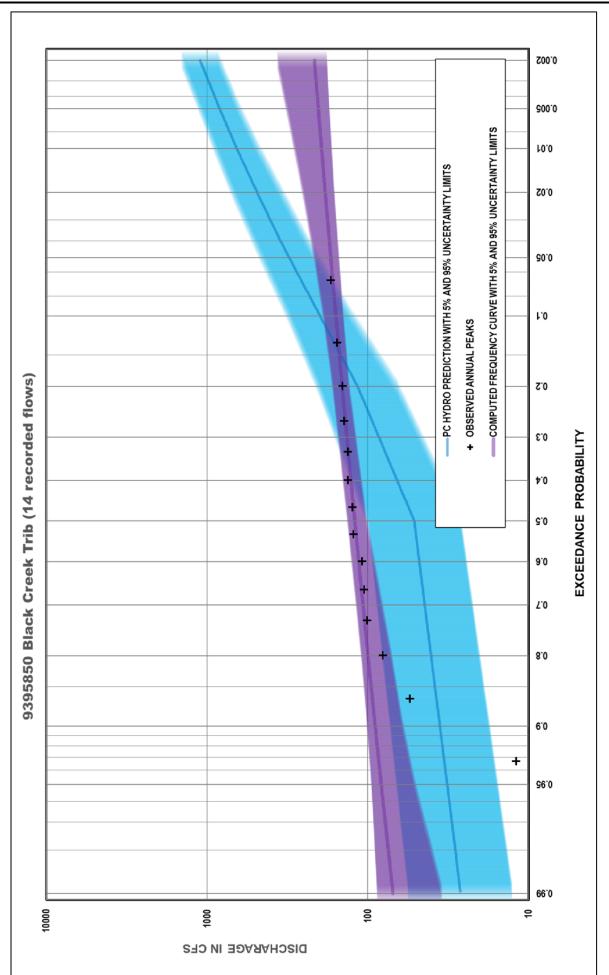
Alamo Wash Tributary near Ajo, AZ

PC-HYDRO V. 6 ANALYSIS	ALYSIS				1961		J.	2,150	-									
Project Name:		PC-Hydro Investigation	gation	C	KI	The second	1	2,100-						٦	V			
User Name:		OBT			1	C III	F	.000 C			8							
Client Name:		Pima County	λ	1	Z	1	1	1.950.										
Job Number: Droiget Nates:	18*25964	Date:	6/29/2018	And a	1	5	2	2	0.0	0.5	1.0		1.5	2.0		2.5 mi		
0000-1				1 C	PC	1		L.	P.S.	1	il de	30						
				「日本」		2	5	1	4		1 and	運						
Gage Information	3	-	:	the w	2	2	1	チンノ	2	113	Se al	in the second						
Name:	Name: Alamo Wash Iributary near Ajo, AZ	Iributary n	iear Ajo, AZ			1	0	1		1 C	in the	and						
Agency: USGS	usgs			御いた		the second	5	h	2	U	1	1 al						
Station:	Station: 9520300			ALL ALL		1	K	1	1	L	14.	The second						
Northing: 32°6'0"N	32°6'0"N	Easting:	Easting: 112°46'17"W	1 Sala	4	1	1	ľ	0	P	1.7	the second						
(in decimal form: 32.10000,-112.77139	32.10000,-112	2.77139		る料		P		P	U		1	1						
Watershed Information	됴			C.	they want	5	1	1	X	all a	a fait	3						
Watershed:	Watershed: Undeveloped-Foothills	I-Foothills		11/2		1		2	1	C.L	1	Y						
Veg cover type: Desert Brush	<b>Desert Brush</b>			T. ANNI	State of the state	J.	P			1	P.	and the						
Area (sq. mi.):	0.83			and a love		No.	)e.	}	ł	/	{	200						
L Cen Grav (ft):	6700			State - State	P.	大学の	and a	Y	apple and		2							
	Normal	Minimum	Minimum Maximum			Sal In	1	1	K	San La	Į,	2						
Veg cover (%): % impervious:	20% 10%	%0L	30% 20%	NY NY				C	E)	1	and and	7)						
		Eight Points	ts					Four Points	ts				Two Points	ints				
Douolog	ed	Height	Length	Slope	Basin Factor	٩N	dN doid	Hi Li (#) (#)	i Si	ЧN	۵N	dN محتل	Hi (#)	Li (f±)	Si	역	٩N	Nb Uich
None	Foothills	19.5	1742	0.011	0.035	0	_		1		-1		<u></u>		1111			5
None	Foothills	20.4	1742	0.012	0.035	0.030 (	0.040	39.9 34	3484 0.011	0.030	0.03	0.04	000	1707	0.015	0.025		
None	Foothills	35.6	1690	0.021	0.035	0.030	0.040	CC 07	2.200 0.010	0 0.025	000		4.44	0004	CI0.0	0.00	cn.n	0.04
None	Foothills	24.4	1690	0.014	0.035	0.030	0.040											
None	Foothills	37.1	1690	0.022		0.030	0.040	40 3 34	3432 0.018	8 0.035	0.03	0.04						
None	Foothills	23.2	1742	0.013	0.035	0.030	0.040						145	6812	0 0 1	0.035	0.03	0.04
None	Foothills	42.6	1690	0.025	0.035	0.030	0.040	95 22	2.280 0.07E	5 0.025	0.02		2	2 00	120.0	0000	0.0	5
None	Foothills	42.4	1690	0.025	0.035	0.030 (	0.040											
	Watercourse Length:	e Length:	13676 ft				2	Mean slope:	oe: 0.017 fVf	ĥVĥ			Mean slope:	lope:	0.017 fVf			
			Mean slope:	0.017 fVft				Wt Bas	Wt Basin Factors:	: 0.035	0.030	0.040	Š	Wt Basin Factor:	Factor:	0.035	0.030	0.040
			MIR	Wt Basin Factors:	0.035	0.030	0.040						L	I				
Soil	Percent													Re	d Font: 1	Red Font: User entry	_	
Type B	18%													Blu	le font: (	Blue font: Calculation	Ľ	
Type C	11%																	
Type D	71%																	٦



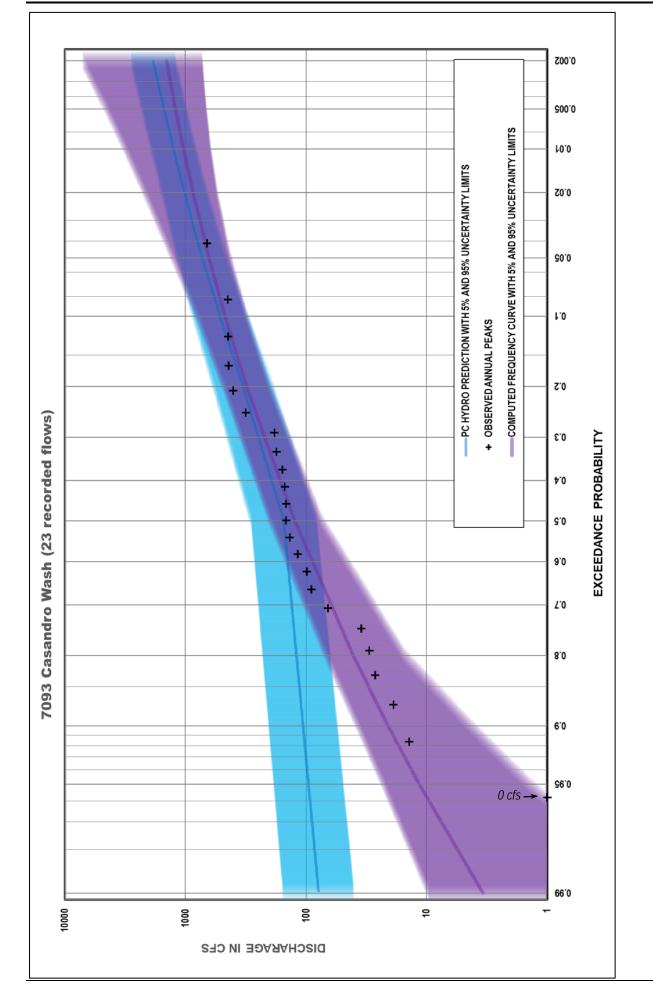
Black Creek Tributary near Window Rock, AZ

PC-HYDRO V. 6 ANALYSIS	ALYSIS							1	ft -									
Project Name:		PC-Hydro Investigation	gation	1	/				6,850-									1
User Name:		OBT		-	1	Ĵ												
Client Name:	18*25964	Pima County Date:	y 6/29/2018	~		5	-		6,800-						Ì			
Project Notes:				/			-		6,750-				Y					
				C	Kolob	6	-		4	- 6	- 6	-0	- 0	- 4	- 9	- 20	-0	i me u
Gage Information				- man		4	r	Y	0.0		7.0	0.0	t		0.0			
Name:	Name: Black Creek Tributary near Window Rock, AZ	outary near W	indow Rock, AZ	file					ľ									
Agency: USGS	NSGS							1	-									
Station:	Station: 9395850			1														
Northing:	Northing: 35°39'15"N	Easting:	Easting: 109°5'22"W	Ĩ	264	1		ζ	•									
(in decimal form: 35.65417,-109.08944	35.65417,-10	9.08944			1		3		7									
Watershed Information	ū								þ									
Watershed:	Watershed: Suburban Foothills	oothills				4		1										
Veg cover type: Mountain Brush	Mountain Br	ush				3	10											
Area (sq. mi.):	0.34			1			X											
L Cen Grav (ft):	295			7		1	\$	C 605	70									
Veg cover (%):	Normal 209	Minimum 10%	Maximum 30%															
% impervious:	20%	10%	30%															
		Eight Points	its				_	Four Points	ints				Twc	Two Points				
	Watershed	Height	Length	Slope	Basin Factor	٩N	٩N				dΝ				Si		٩N	٩N
Development	lype	(Hi, ft)	(Li, ft)	(Si, tt/tt)			high	(11)	(ft) (ft/ft)	t) Nb	Low	w High	gh (ft)	(ft)	(11/11)	qN	Low	High
None	F OOT NIIIS	11.3	180	0.020		_	0.040	18.8	1109 0.(	0.017 0.035		0.03 0.0	0.039					
<li>&lt;1 house/ac</li>	Foothills	d./	528	0.014	t 0.034	0.029	0.038						55.9	9 2376	6 0.024	4 0.033	0.029	0.037
1-2 houses/ac	Foothills	18.0	000 581	0.020		_	0000	37.1	1267 0.(	0.029 0.032		0.028 0.0	0.036					
1-2 houses/ac	Foothills	21.7	634	0.034		-	0.036						Š					
1-2 houses/ac	Foothills	17.0	581	0.029	) 0.032	0.028	0.036	38./	)'N CIZI	0.032 0.032		0.028 0.0	0.030	0 7575	0.025	E 0.033		2000
1-2 houses/ac	Foothills	17.7	634	0.028	3 0.032	0.028	0.036											100.0
<1 house/ac	Mountain	31.4	686	0.046	5 0.034	0.029	0.038	49.1	1320 0.0	0.03/ 0.033		n.u 420.0	U.U3/					
	Watercourse Length:	e Length:	4911 ft	ft				Mean slope:		0.028 f/f			Me	Mean slope:		0.028 ft/ft		
			Mean slope:	0.027 fVft	r fl/ft			Wt B;	Wt Basin Factors:	ors: 0.033		0.029 0.0	0.037	Wt Ba	Wt Basin Factor:	.: 0.033	0.029	0.037
		-	Wt	Wt Basin Factors:	0.033	0.028	0.037											
Soil	Percent														Red Font	Red Font: User entry	try	
Type B															Blue font	Blue font: Calculation	tion	
Iype C																		
Type D	100%																	٦



Casandro Wash, AZ

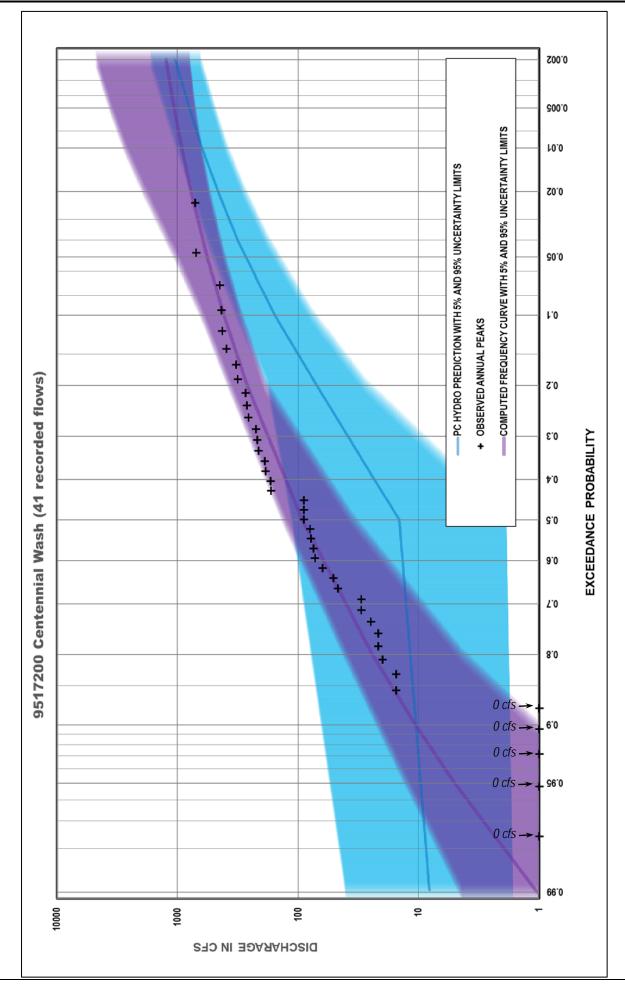
6 AMUTSIS         New:       CCANTON         New:       CCANTON       CCANTON         New:       CCANTON       CCANTON       CCANTON         New:       CCANTON       CCANTON       CCANTON       CCANTON         New:       CCANTON       CCANTON       CCANTON       CCANTON       CCANTON         New:       CCANTON       CCANTON       CCANTON       CCANTON       CCANTON       CCANTON         Not       CCANTON       CCANTON       CCANTON <th></th> <th></th> <th></th> <th></th> <th>Nb Hiah</th> <th>5</th> <th>0.028</th> <th></th> <th>0.05</th> <th></th> <th>0.039</th> <th></th> <th></th> <th></th>					Nb Hiah	5	0.028		0.05		0.039			
Print Current of I Definition (Mash, AT C Mark Current (Mash, AT C Model Date:     Print Current (Mash, AT C Model Date:     Print Current (Mash, AT C Model Date:       Print Current (Mash, AT C Model Date:     Print Current (Mash, AT C Model Date:     Print Current (Mash, AT C Model Date:     Print Current (Mash, AT C Model Date:       Model Date:     Print Current (Mash, AT C Model Date:     Print Current (Mash, AT C Model Date:     Print Current (Mash, AT C Model Date:     Print Current (Mash, AT C C Model Date:       Model Date:     Print Current (Mash, AT C C Model Date:     Print Current (Mash)     Print Current (Mash)       Model Date:     Print Current (Mash)     Print Current (Mash)     Print Current (Mash)       Model Date:     Print Current (Mash)     Print Current (Mash)     Print Current (Mash)       Model Date:     Print Current (Mash)     Print Current (Mash)     Print Current (Mash)       Model Date:     Print Current (Mash)     Print Current (Mash)     Print Current (Mash)       Mash Spect     Print Current (Mash)     Print Current (Mash)     Print Current (Mash)       Mash Spect     Print Current (Mash)     P									0.035			\ \	u	
CE-Hydro Investigation           Difference           Difference           Pine County           Difference           Pine County           Difference           Difference           Difference           C-Hydro Investigation           Difference           Difference           Colspan="2">On the County           Difference           Colspan="2">On the County           Difference         Control           Control			1.8 <sup>mi</sup>		qN					-	0.034	ser entry	alculatic	
CE-Hydro Investigation           OE-Hydro Investigation           OE-Hydro Investigation           OE           Investigation           OE           OE           Investigation           OE           OE           Investigation           OE           OE         OE           OE         OE           OE         OE         OE         OE <tr< td=""><td></td><td></td><td>-9-</td><td></td><td>Si t/ft)</td><td></td><td>0.012</td><td></td><td>0.041</td><td>0.020 11/1</td><td>actor:</td><td>Font: U</td><td>font: C</td><td></td></tr<>			-9-		Si t/ft)		0.012		0.041	0.020 11/1	actor:	Font: U	font: C	
CC-Hydro Investigation           CC-Hydro Investigation           Investigation           CHydro Investigation           Investigation           CHydro Investigation           Ger Marchann           State County			4.1	ts							in Fa	Red	Blue	
C: Hydro Investigation         C: Hydro Investigation           061         Date::			-1	wo Poin						Aean slo	Wt			
Prind Off         Exhydro Investigation Off         Prind Filth         Exhydro Investigation Off           064         Date::         2/29/2018         2/200           064         Date::         2/29/2018         2/200           064         Date::         2/29/2018         2/200           061         Date::         2/29/2018         2/200           060         Wash, AZ         2/200         2/200           070%         2/200         2/200         2/200           081         Minimum         Maximum         2/200         2/200           010%         2/200         2/200         2/200         0/2         0/0           010%         2/200         0/00         0/2         2/40         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/0         0/2         0/2         0/2         0/2         0/2         0/2         0/2         0/2         0/2         0/2         0/2			-9	Ĺ				0.032						
Privato Investigation OET           Prima County OBI         Prima County Prima Prima County Prima Prima County Prima Prima County Prima Prima County Prima Prima P			-0			2								
PC-Hydro Investigation OBT         PC-Hydro Investigation           OBT         OBT           Pima County         OBT           Pina County         OBT           Pina County         OBT           Pina County         ODT			°		dN	0.022	0.027	0.028	0.047		0.031			
PC-Hydro Investigation OBT         Processing and DBT         Processing DBT			0		Si Tt/ft)	0.011	0.013	0.016	0.065	0.018 11/	ctors:			
FC-Hydro Investigation         PC-Hydro Investigation           0BT         Date:         6/29/2018           964         Date:         6/29/2018           964         Date:         6/29/2018           97         112*45*54"W         9/4           94,112.45*54"W         9/4         9/4           94,112.75500         9/4         9/4           94,112.75500         9/4         9/4           94,112.75500         9/4         9/4           94,112.75500         9/4         9/4           94,112.75500         9/4         9/4           94,112.75500         9/4         9/4           94,112.75500         9/4         9/4           94,112.75500         9/4         9/4           91,112         112         9/4           93         20%         20%         9/4           93/8         207         112/4         9/4           910         11         11/4         11/4           911         11/4         11/4         11/4           911         11/4         11/4         11/4           911         11/4         11/4         11/4           911         11/4 <td></td> <td>- And - And</td> <td></td> <td>ints</td> <td></td> <td>1</td> <td></td> <td></td> <td></td> <td></td> <td>Б</td> <td></td> <td></td> <td></td>		- And		ints		1					Б			
FC:Hydro Investigation         CBT           OBT         OBT           Fima Country         Stating: 112:45:54*W           94:112:76500         94:112:76500           94:112:76500         94:112:76500           94:112:76500         94:112:76500           94:112:76500         94:112:76500           94:112:76500         000           94:112:76500         000           94:112:76500         000           95:00         000           008         000           008         000           008         000           008         000           009         0000           00115         1162           115:4         1214           00115         00012           00115         00012           1115         0011           1115         0012           1115         0012           1115         0012			<sup>f1</sup> ,500 <sup>-</sup> 2,450- 2,400- 2,350- 2,350- 2,300-	Four Po	Η (t					Mean sl	Wt B			
PC-Hydro Investigation         PC-Hydro Investigation           0BT         0BT           964         Date::         6/29/2018           974:112.7/6500         94:112.7/6500         94:112.7/6500           94:112.7/6500         94:112.7/6500         94:112.7/6500           94:112.7/6500         0.00         0.00           0.58         5000         0.00           5000         Maximum         10%           8ush         0.00         0.00           10%         0%         0%           0.58         0.00         0.00           10%         0.114         0.00           1162         0.10	$1 \leq -1$	$\leq \langle 1 \rangle$	11000			0.025	0.025	0.022	0.040	090.0		+00.0		
PC-Hydro Investigation         OBT         OBT           OBT         OBT         OBT           Prima County         0BT         Fina County           964         Date: 6/29/2018         6/29/2018           964         Date: 6/29/2018         6/29/2018           964         Date: 6/29/2018         6/29/2018           964         Date: 6/29/2018         6/29/2018           97         112<45'54"W					dN Wol	0.020	0.020 0.028 0.020	0.018	0.030	0.040	7000	070.0		
PC-Hydro Investigation         OBT         OBT           0BT         OBT         OBT           0BA         OBT         OBT           9664         Date:         6/29/2018           994-112.76500         43"N         Easting:           112.45500         43"N         Easting:           0.58         5000         maximum           10%         0%         20%           0.58         5000         11320           0.58         5000         11320           0.58         5000         11320           0.58         20%         20%           0.58         20%         20%           0.58         5000         1112.1320           10%         0%         20%         20%           10%         0%         20%         20%           10%         11320         0.0014           hills         11320         0.0014           hills         1162         0.0014					in Factor (Nb)	0.022	0.022 0.032 0.022	0.020 0.025	0.035	0.050	0000	000.0		
PC-Hydro Investigation           OBT           Prime County           Siged           Date:         6/29/2018           Siged         Date:         6/29/2018           Siged         Date:         6/29/2018           Prime County           Prime County           Date:         6/29/2018           Prime County           Prime Maximum           Minimum Maximum           Date:         6/20%           Date:         6/20%           Date:         6/20%           Prime         Sign           Date:         6/20%           Date         Hit      <		Onequerents	67		Basi						017 fVf	<u>é</u>		
PC-Hydro Investigation       OBT       OBT       0BT     0BT       964     Date:       6/29/201       94,-112.76500       94,-112.76500       94,-112.76500       mal       0.58       5000       mal       0.58       5000       mal       0.10%       0.58       5000       mal       0.112.76500       2       30%       2001       10%       0.58       5000       mal       0.112.76500       2       30%       2007       115.4       116       9.3       116       118 <t< td=""><td></td><td>also a</td><td></td><td></td><td>Slope (Si, ft/ft)</td><td>0.0</td><td>0.0</td><td>0.0</td><td>0.0</td><td>.0</td><td>in Eacto</td><td></td><td></td><td></td></t<>		also a			Slope (Si, ft/ft)	0.0	0.0	0.0	0.0	.0	in Eacto			
PC-Hydro Investigation       OBT       ONAsh, AZ       C       dro Wash, AZ       C       dro Wash, AZ       C       Brush       0.58       5000       mal       Minimum       10%       0%       30%       2001       Maxim       10%       0%       0.58       5000       mal       Minimum       10%       0%       10%       0%       10%       0%       118.9       118.9       118.9       118.9       Italin       118.9       Italin       118.9       Italin       118.9       Italin       11		M1	20% 20%			320	214 214 214	162 21.4	267	162 820 ft	pe: W+ D_2			
PC-Hydro Investi       OBT       0B4     Date:       964     Date:       94,-112.76500     94,-112.76500       94,-112.76500     94,-112.76500       94,-112.76500     98,-112.76500       94,-112.76500     94,-112.76500       94,-112.76500     94,-112.76500       94,-112.76500     94,-112.76500       10%     0.58       5000     mai       110%     0%       30%     20%       10%     94,-112.76500       118     9.3       hills     20.1       hills     17,5       hills     20.1       hills     20.7	ation 6/29/20	12°45'54	Maximu		Length (Li, ft)					- 6	Aean slo			
PC-Hyo Brush of Wa dro	Investig 2BT County Date:	AZ sting: 1	E % §	nt Point	ight i, ft)	20.1	7.3 16.6 15.4	17.5	37.9	118.9 nath:				
	-Hydro ( Pima	o Wash, N Ea: -112.76	n Footh rush 0.58 000 1 Min 0%				<u>s</u>	s s	s s	in urse Le		Ţ	%01	
Project Name:         User Name:         User Name:         User Name:         Job Number:         Agency:         Radention         Northing:         Northing:         Agency:         Station:         Agency:         Read (sq. mi):         Cen Grav (ft):         Cen Grav (ft):         Velopment         houses/ac1         houses/ac1         houses/ac1         None         None         None         None         None         Soil         Type B		2asandrc CDMC 093 3°57'43" 3.96194,	suburba Jesert Br 5 Norma 3		Watersh Tvpe	Foothil	Foothil Foothil	Foothil	Foothil	<u>Mounta</u> Waterco		Percen	4	`
YDROV. Yopiect I User I User I Job Nu Job Nu Job Nu Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag St Ag Ag Ag Ag St Ag Ag Ag Ag Ag Ag Ag Ag Ag Ag	6 ANAL Vame: Vame: Vame: mber:	lon Vame: C lency: F ation: 7 form: 3 rmation	shed: Structure: type: L type:			/ac1	/ac /ac1	mm and a state		_				_
	PC-HYDRO V. Project N User n Client n Job Nu Project Notes:	Informat Ag St Nori shed Info	Water eg cover Area (sq Cen Gra 'eg cove		velopme	houses	houses	s / Lt Cc None	None	None ached ho		Soil	Type B	ŀ



Centennial Wash Tributary near Wenden, AZ

Com	prehensive	Evaluation

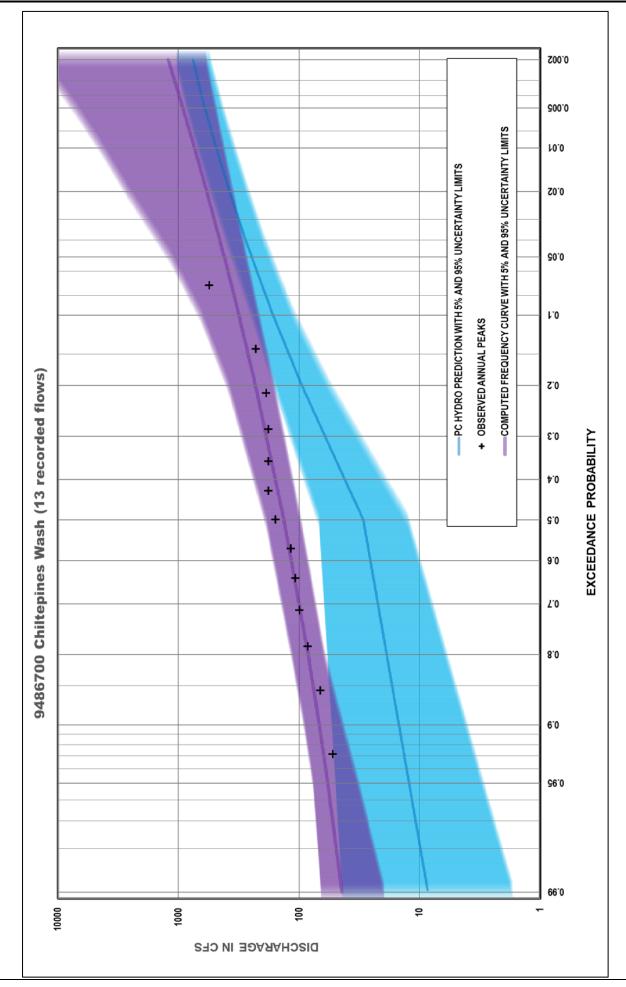
5	Ē								Nb Hiah	2	0.04			0.04			0.040				
									Nb N Low H	-	0.03		╞	0.03			0.030 0	Γ			
	2.5									-	0.035		-	0.035			0.035 0	r entry	Calculation		
									dN							0.019 fVf		t: User	t: Calc		
	2.0								Si (ft/ft)	~	0.014			0.027		0.01	n Facto	Red Font: User entry	Blue font:		
								ints	(ft)	)	7656			7234		slope:	Wt Basin Factor:	R	В		
	1.5							Two Points	H (ff		107			193		Mean slope:	5				
									Nb Hiah	0.04		0.04		0.04	0.04		0.040				
	.0.	H B	2/1-12	and	and a	Seal.	1		Nb Low	0.03	8	0.03	0.00	c0.0	0.03		0.030				
	-				I,	3			dN	0.035		0.035	0.026	CC0.0	0.035		0.035				
	10	CR.			and a	IJ	A A		Si (ft/ft)	, U U	1	0.016	CC 0 0	czu.	0.031	0.018 f/f					
	0.5	1 Alt	1 and	il il	]	C.		ts				3749 0	0 0720		3485 0		Fa				
		E.F	- Jose				A LANDAR	Four Points	li Li (ft)	6		60.3 37	0E A 27		108 34	Mean slope:	Wt Basin Factors:				
(12,300 = 2,250 = 2,200 = 2,15	2,050-0.0	-1	2					Fo	Nb Hi niah (ft)			0.040 0.040 61	0.040		0.040	-		040			
tei ci ci ci	5 6	7.0	615	1			et la			$\vdash$	_	_	-	_	_	-	0.020.0				
1 St	-F	12	1				and and		or Nb Iow	0.030	0.030	0.030	0.030	0.030	0.030						
100 M	1	اسر		J.J.	1 and		il.		Basin Factor (Nb)	0.035	0.035	0.035	0.035	0.035	0.035		0.025	0.0			
	6	1 L		1.			1		Basi								0.018 fVf	ċ			
•	11	13	E / S	CA	C P	C.	and and		Slope (Si.ft/ft)	0.010	0.013	0.012 0.020	0.023	0.022	0.026 0.035		pe: 0.018 Wf Basin Factors:	Lactur			
				-					S (Si							f	Dacin				
	9102/62/0	len, AZ	7'2"W			Maximum	20% 20%		Length (Li, ft)	1901	2006	1848 1901	1690	2059	1637 1848	14890 ft	Mean slope:				
tigation		ear Wenc	113°2	s				nts	(Li Ler												
PC-Hydro Investigation OBT Pima County		ibutary n	Easting: 113°27'2"W 45056	oothill		Minimum	%0 %0	Eight Points	Height (Hi. ft)	19.5	26.7	21.8 38.5	39.1	46.3	42.7 65.2	Watercourse Length:	)				
C-Hydr	04	Wash Tr	)"N E ∖,-113.4	oped-F	3rush 0.79	0	10% 10%	Ē		$\vdash$	sll:	lls Ils	lls	ills	sli Sli	ourse L		It	100%		
YSIS P(	18 29964	entennial	517200 3°50'40 3.84444	Indevel	lesert E	675 Normal			Watershed Tvpe	Foothills	Foothills	Foothills	Foothills	Foothills	Foothills	Waterc		Percent	-		
		lation Name: Centennial Wash Tributary near Wenden, AZ Agency: USGS	Station: 9517200 Northing: 33°50'40"N Eastin (in decimal form: 33.84444,-113.45056	ed Information Watershed: Undeveloped-Foothills	Veg cover type: Desert Brush Area (sq. mi.): 0.79	/ (ft):	r (%): ious:			$\square$					╈			$\mid$			╞
YDRO V. 6 ANA Project Name: User Name: Client Name:	Notes:	Gage Information Nai Agen	Sta North	Watershed Information Watershed: L	eg cover type: Area (sq. mi.):	L Cen Grav (ft):	Veg cover (%): % impervious:		Development	None	None	None	None	None	None			Soil	Type B	Type C	
PC-HYI	Project Notes:	Gage In	(in o	Watersh	Veg Ar	ГC	Ve %		Deve											T	F



Chiltepines Wash near Sasabe, AZ

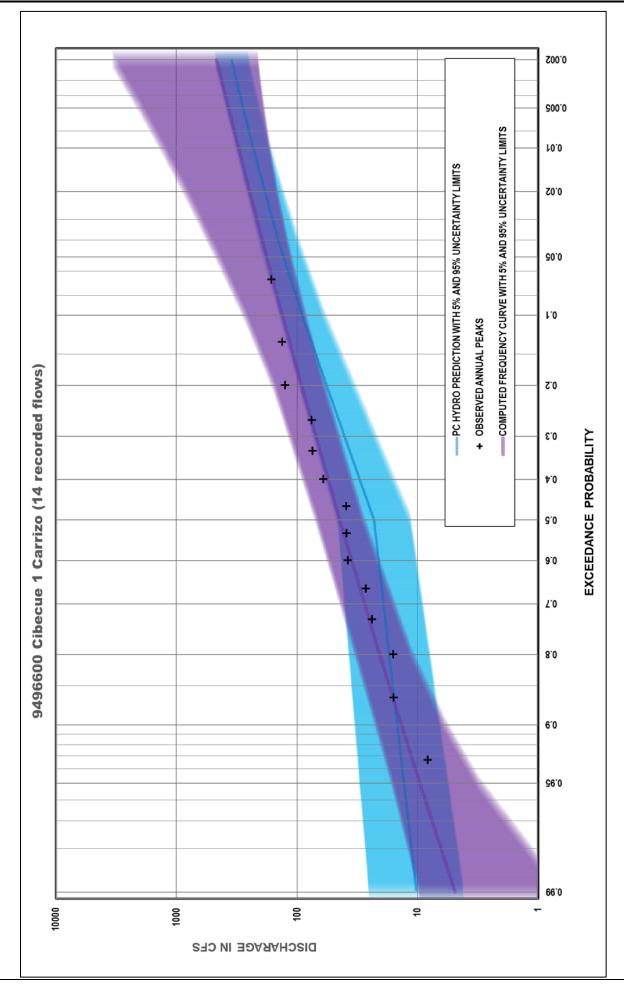
			qN	High		0.042		0.04		0.041		
	1.8 1.1		ΠN	Low	0.00	co.o	CU U	c0.0		0.030 0.041	∧ uo	]
	1.6			qN	0.025		0.025	0.000	fl/ft	0.035	Red Font: User entry Blue font: Calculation	
	1.4		Si	(ft/ft)	0.012	c 0.0	C L U U	c10.0	0.013 ft/ft	Factor:	ed Font:   lue font:	
	12-	oints	: []	(ft)	E N 6 0	0000	0101	4710	Mean slope:	Wt Basin Factor:	ě e	
	10-	Two Points	Ξ	(£f)	6 1 3	<b>C.</b> +0	6 47	04.2	Mean	-		1
	0.8		dN	High	0.044	0.04	0.04	0.04		0.041		
	0.6		Νb	Low	0.029	0.03	0.03	0.03		0.030 0.041		
	0.4			dΝ	0.035	0.035	0.035	0.035	fl/ft	0.035		
	0.2		Si	(ft/ft)	0.010	0.015	0.012	0.014	0.013 f/f	Wt Basin Factors:		
	-8	oints		(H	2640	2428	2587	2323	slope:	Basin I		
3,220 - 3,200 - 3,180 - 3,160 - 3,140 -		Four Points	Ξ	(£)	26.9	37.4	31.5	32.7	Mean slope:	Wt E		

						Si	(ft/ft		0.0			0	0.0		0.0	F act	d Fo	Blue fo		
		1.2			oints	:=	(ft)		5068			0101	4910		Mean slope:	wi basın Facı	Re	Bl		
		1.0			Two Points	Ξ	(ft)		64.3				04.2		Mean	-				
		0.8				٩N	High	0.044		0.04		0.04		0.04		1.041				
		0.6				Nb	Low	0.029		0.03		0.03	0.00	0.03		0.030				
		0.4 0					Nb I	0.035 (		0.035		0.035	0.005	0.030	0 001	0.035 0.030 0.041				
						Si	(ft/ft) I	0.010		0.015		0.012	100	0 I4	fl/f					
		0.2			<u>د</u>	S	(ft/								Ľ					
	ft 3,240 3,220 3,220 3,180 3,160 3,140	0.0			Four Points	Ξ	(ft)	9 2640		4 2428		5 2587	CCCC T		Mean slope:	WI BASIN FACTORS:				
	t n n n n n n				Fou		(ft)	0 26.9	_	37.4	_	31.5	- <i></i> (	_	Mea					
						dN	high	_	_	0.040	-		0.040	0.040		0.030 0.041				
V INTER	18					Ν	low	0.027	0.030	0.030	0.030	0.030	0.030	0.030		0.030				
						Basin Factor	(ND)	0.035	0.035	0.035	0.035	0.035	0.035	0.035		0.035				
ARA							(Si, ft/ft)	0.009	0.011	0.012	0.013	0.012	0.014	0.014		ре: U.UI3 IVII Wf Basin Factors:				
	2			% %				9	4	4 4		0	1	90	9978 ft	e: /† Basi				
. 6 ANAL YSIS Name: PC-Hydro Investigation Name: OBT Name: I8*25964 Date: 6/29/2018 Imber: 18*25964 Date: 6/29/2018 Imber: OBT Name: Chiltepines Wash near Sasabe, AZ	Easting: 111°26'18"W 43833 Foothills		Maximum	20% 20%		Length	(Li, ft)	1426	1214	1214	1267	1320	1267	1056	L66	Mean siope: Wf	i			
PC-Hydro Investigation OBT 5964 Date: 6/29/2 pines Wash near Sasabe	ng: 111 3 Nills			%0	Points			13.1	13.8	0.01	16.3	15.2	18.0	14.7		M				
ydro Investig OBT Pima County Date: Mash near S	Eastii 1.4383 1-Footh		Minimum		Eight Points	Height	(Hi, ft)	1		- (	<b>-</b> ۱	-	-		e Length:					
PC-Hyo	00 8"N 89,-11 elopec t Brush	0.34	4300 Normal	10% 10%		Watershed	pe	ley	hills	hills	slin	hills	hills	hills	Water course L		cent	81%	19%	0%
L YSIS PC-F 18*25964 Chiltepines	94867( 31°49' 31.818 <u>31.818</u> <u>In</u> Undev Desert		Nor			Water	Type	Valley	Foothills		Foothills	Foothills	Foothills	Foothills	Water		Percent			
PC-HYDRO V. 6 ANAL YSIS Project Name: User Name: Job Number: 18"2 Project Notes: Project Notes: Agency: USGS	Station: 9486700 Northing: 31°49'8"N Easting: (in decimal form: 31.81889,-111.43833 <u>Watershed Information</u> Watershed: Undeveloped-Foothills Veg cover type: Desert Brush	Area (sq. mi.):	L Cen Grav (TI):	Veg cover (%): % impervious:			Development	None	None	None	None	None	None	None			Soil	Type B	Type C	Type D
PC-HYDRO V. Project I User I User I Client I Project Notes: Gage Informat	(in d <sub>i</sub> <u>Watersh</u> Veg	- A	ٽ ب	Veç % i			Deve	-						_				Ē	μ.	μ



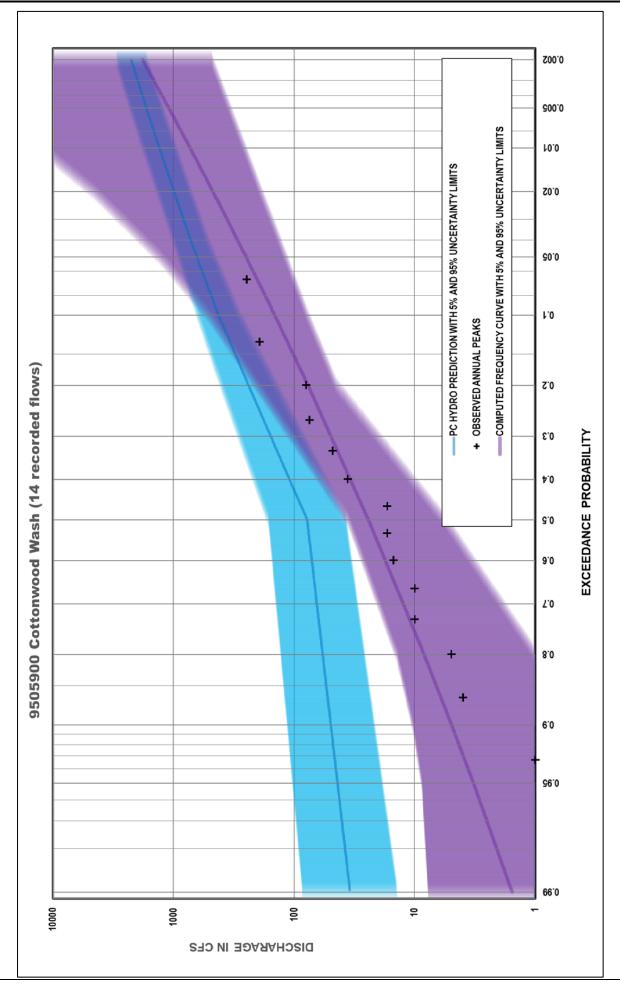
Cibecue 1 Tributary Carrizo Creek near Show Low, AZ

PC-HYDRO V. 6 ANAL YSIS	VL YSIS										100						
Project Name:		PC-Hvdro Investigation	aation					V		NAME OF COLUMN	1	A.	~{	]	1	H.	
llear Namo.		ТаО								1			~		/		
Client Name		Dima County						×			1		•		1.	~	
												1	>			/	
Job Number:	18*25964	Date:	6/29/2018							1			1			5	
Project Notes:								and a		ないのない	(	1. A	/	1			
								e al	-	in Part	A STA	>			1		ar (
								100			いいのの	いたかない	でいたので	/	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		
Gage Information								0	A STATE	the second	2000	なる		1			00.
Name:	Name: Cloecue 1 Tributary Carrizo Creek near Show Low, AZ	Carrizo Creek near	Show Low, AZ	77							ST. BERLE	見い			5	Į	
Agency: USGS	USGS			<sup>T</sup> 5,500 F													
Station:	Station: 9496600												V				
Northing.	Morthing: 33°59'28"N	Facting. 1	Facting 110°10'20"\//	5,450 -													
(in docimal form: 23 00111 110 22 172	07 (C CC		M /7 /1 01														
(III decilial ion III)	11-'11166.00	0.52412		5 400-					VI								
Watershed Information				port'o													
Watershed:	Watershed: Undeveloped-Mountain	d-Mountain		E DED			١										
Vea cover type: Mountain Brush	Mountain Br	ush		- noncin				-						F			
Area (so. mi.):	0.07			0.0		0.1		0.2		0.3		0.4		0.5mi			
I Can Grav (ft)	1150																
	Normal	Minimum	Maxim														
Veg cover (%):	30%		40%														
% impervious:	15%	5%	25%														
		Eight Points	ts				ш	Four Points	S			Г	Two Points				
	Watershed	Height	Length	Slope	Basin Factor	٩N	dN	HiLI	Si		۹N	٩N	Hi Li	Si		dΝ	٩N
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(ND)	low	high	(ft) (ft)	(ft/ft)	qN	Low	High	(ft) (ft)	(ft/ft)	qN	Low	High
None	Mountain	25.2	370	0.068	0.050			JA E 40	000 0 207	0700	0000	0.050					
None	Valley	1.3	317	0.004	0.035	0.027 0	0.050					400.0	00 0 1274	0.070	0.05		0.06
None	Mountain	42.6	370	0.115	0.050	0.040 (	0.060	77 2 69	487 0 10E	0.05		900					
None	Mountain	29.7	317	0.094	0.050	0.040 (	0.060				10.0	0.0					
None	Mountain	18.8	317	0.059	0.050	0.040 (	0.060	AE 6 60	770 0 207	U UE		90.0					
None	Mountain	26.8	370	0.072	0.050	0.040 (	090.0					0.0	1007				
None	Mountain	14.2	317	0.045	0.050	0.040 (	090.0						10./	000.0	cn.n n		00.0
None	Mountain	18.9	317	090.0	0.050	0.040 (	090.0	33. I 0.	20.U 400	cn.u	0.04	00.0					
	Watercourse Length:	e Length:	2695 ft				Z	Mean slope:	e: 0.059 ft/ft	ft/ft			Mean slope:	e: 0.065 ft/ft	5 fl/ft		
			Mean slope:	0.037 f/f	Vft			Wt Basi	Wt Basin Factors:		0.050 0.040 0.060	090.0	Wt Ba	Wt Basin Factor:		0.050 0.040 0.060	0.060
			Wt B	Wt Basin Factors:	0.048	0.048 0.038 0.059	0.059										
Soil	Percent													Red Font	Red Font: User entry	try	
Type B	%0													Blue font	Blue font: Calculation	tion	
Type C	20%																
Type D	50%																



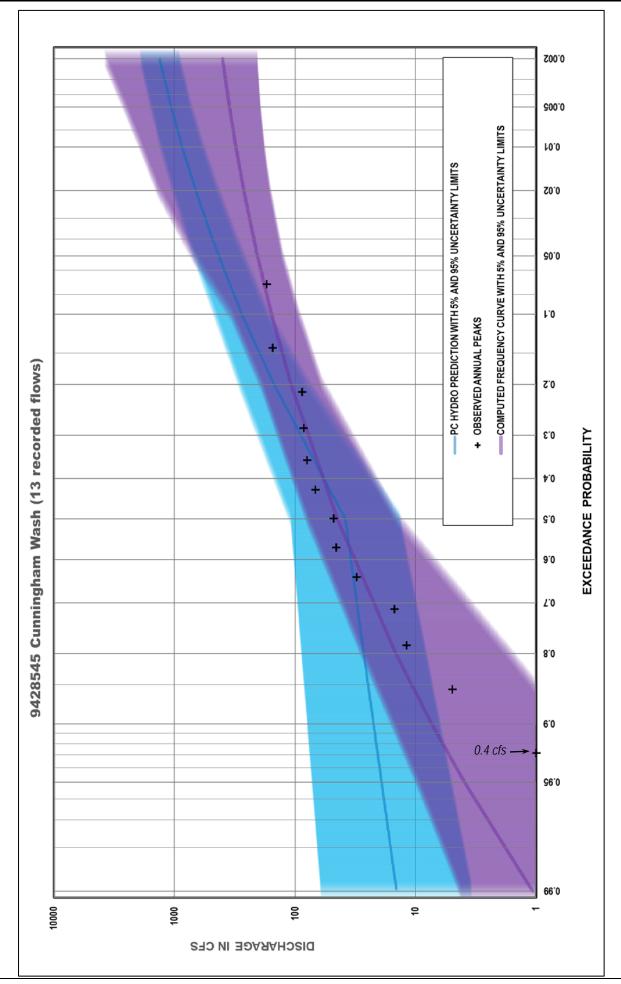
Cottonwood Wash near Camp Verde, AZ

				2018				de, AZ		E uus tu			9009	3.500	3,400-	0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 <sup>ml</sup>		mm	20%	20%	Four Points Two Points	gth Slope Basin Factor Nb Nb Hi Li Si Nb Nb Hi Li Si Nb Nb	ft) (Si, ft/ft) (Nb) low high (ft) (ft) (ft/ft) Nb Low High (ft) (ft) (ft) Tb Low High	<b>1162</b> 0.035 0.035 0.030 0.040 102 2218 0.044 0.044 0.024 0.052	0.050 0.040 0.060 102 2210 0.044 0.030	0.074 0.050 0.040 0.060 1.00 2.271 0.061 0.061 2.271 0.061 0.061 0.061 0.061 0.061 0.061 0.061 0.061 0.061		1003 0.039 0.035 0.030 0.040 154 2112 0.072 0.046 0.027 0.055		381 4224 U.U9U U.U48	950 0.148 0.050 0.040 0.060 227 2112 0.107 0.00	8713 ft Mean slope: 0.067 ft/ft Mean slope: 0.068 ft/ft	slope: 0.061 ftf 0.038 0.057 Wt Basin Factors: 0.048 0.038 0.057 Wt Basin Factor: 0.047 0.038 0.057	Wt Basin Factors: 0.046 0.038 0.055	Red Font: User entry	Blue font: Calculation		
	PC-Hydro Investigation	OBT	Pima County	Date: 6/29/2018				Name: Cottonwood Wash near Camp Verde, AZ			Easting: 111°45'12"W	5333		Aountain				inimum Maximum	%0	0%	Eight Points	Height Length	(Hi, ft) (Li, ft)	40.3	62.0	82.1	57.4	38.8	114.9	86.5	140.3	-ength:	Mean slope:					
L YSIS	PC-Hydro		Pim	18*25964				Cottonwood Was	JSGS	9505900	2:	34.50556,-111.7		Watershed: Undeveloped-Mountain	Desert Brush	0.53	4500	Normal Minimum	10%	10%	Ē	Watershed	Type (	Foothills	Mountain	Mountain	Mountain	Foothills	Mountain	Mountain	Mountain	Watercourse Length:			Percent	%0	%0	100%
PC-HYDRO V. 6 ANAL YSIS	Project Name:	User Name:	Client Name:	Job Number:	Project Notes:		Gage Information	Name: 4	Agency: USGS	Station: 9505900	Northing:	(in decimal form: 34.50556,-111.75333	Watershed Information	Watershed	Veg cover type: Desert Brush	Area (sq. mi.):	L Cen Grav (ft):		Veg cover (%):	% impervious:			Development	None	None	None	None	None	None	None	None				Soil	Type B	Type C	Type D



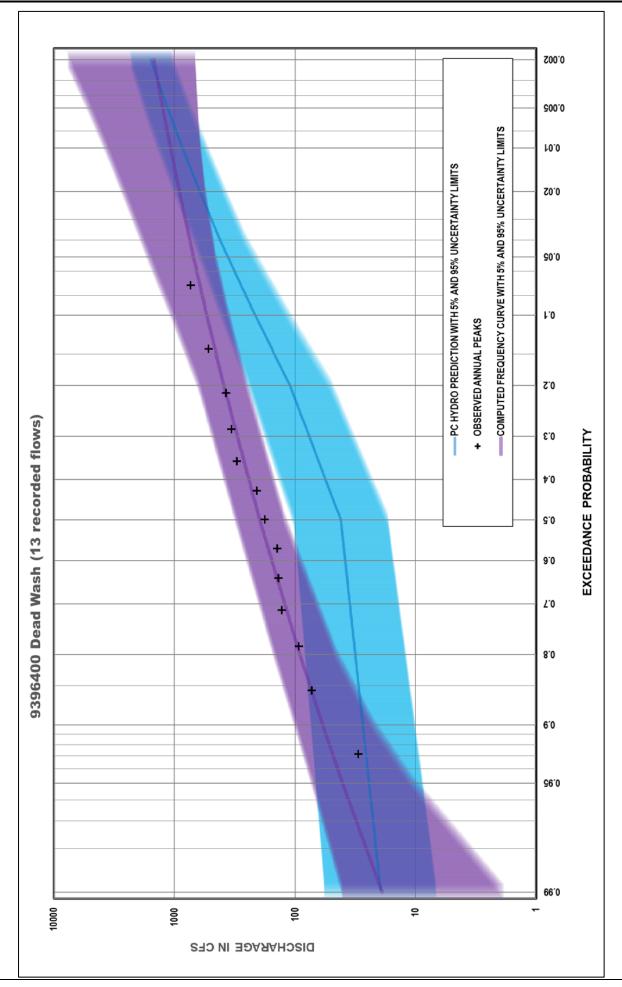
Cunningham Wash Tributary near Wenden, AZ

	PC-HYDKU V. 6 ANAL YSIS				in the second	313	ft 3 500 ]											
Project Name: User Name: Client Name: Job Number:	PC-Hyd Pi 18*25964	PC-Hydro Investigation QBT Pima County 5664 Date: 6790	gation y 6/29/2018			Ser 1	3,000 -		-0				-6					
Project Notes:				2		2	11					2						
Gage Information				and the second			and a second	2	P		1		in the					
Name: cunning Agency: USGS	Name: Cunningham Wash Tributary near Wenden, AZ gency: USGS	sh Tributary n	ear Wenden, AZ	P	X	and the		L	1	ė								
Station: 9428545	9428545						Alexa -		يمر		,	/	2					
Northing: 34°0'25"N Eastin (in decimal form: 34.00694,-113.57833	34°0'25"N 34.00694,-113	Easting: 1 8.57833	Easting: 113°34'42"W .57833	A.		Sel an		and a second	<u></u>				1					
Watershed Information								Siller Siller						/				
Watershed: Undeveloped-Mountain	<b>Undeveloped</b>	I-Mountain			「「「「「」」	to and the second	A A A A A A A A A A A A A A A A A A A		大学の		1	/						
Veg cover type: Desert Brush	Desert Brush	_			and the second			E		5		Ŋ	1					
Alea (sq. IIII.).	0000			in the second		10-10-10		and the					4		the state			
	Normal	Minimum	Maximum			の日本の				and the second			4	$\left  \right\rangle$	$\overline{\mathbf{A}}$			
Veg cover (%):	~0	%0											1					
% impervious:	10%	%0	20%															
		Eight Points	ts					Four Points	ints				Two	<b>Two Points</b>				
	Watershed	Height	Length		Basin Factor	Nb	٩N								Si		dN	Nb
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(Nb)	H	high	(ft)	(ft) (ft	(ft/ft) Nb	Low	H	High (ft)	(ft)	(ft/ft)	qN	Low	High
None	Foothills	38.1	1742	0.022	0.035	_	0.040	82.6	3643 0	0.023 0.0	0.035 0	0.03 0	0.04					
None	Foothills	44.5	1901	0.023	0.035	0.030	0.040							196 6917	0.028	3 0.035	0.03	0.04
None	Foothills	56.9	1001	0.030	0.035	_	0.040	113	3274 0	0.035 0.0	0.035 0	0.03 0	0.04					
None	Mountain	89.9	1901	0.047	0.050	-	0.060						2					
None	Mountain	192.1	1531	0.125	0.050	0.040	0.060	787	3432 U	0.082 0.	0 0.0	0.04 0	0.00					
None	Mountain	411.5	1848	0.223	0.050	0.040	0.060	1200	0 0000	0.405			1/01	0004	0.243	cn.n	0.04	00
None	Mountain	977.3	1584	0.617	0.050	0.040	0.060						<b>D</b> .					
	Watercourse Length:	e Length:	13781 ft					Mean slope:		₽J				Mean slope:	0.063 fl/fl	₽U		
		_	Mean slope:	0.051 f/f				Wt B	Wt Basin Factors:		42 0.(	0.042 0.035 0.050	)50	Wt Bas	Wt Basin Factor:		0.042 0.035	0.050
Soil	Percent		WI B	WI BASIN FACTORS:	0.042	0.035	000.0								Red Font: User entry	. Ilser en	N,	
Type B	<mark>%0</mark>														Blue font: Calculation	: Calcula	ion	
Type C	100%																	
Type D	%0																	



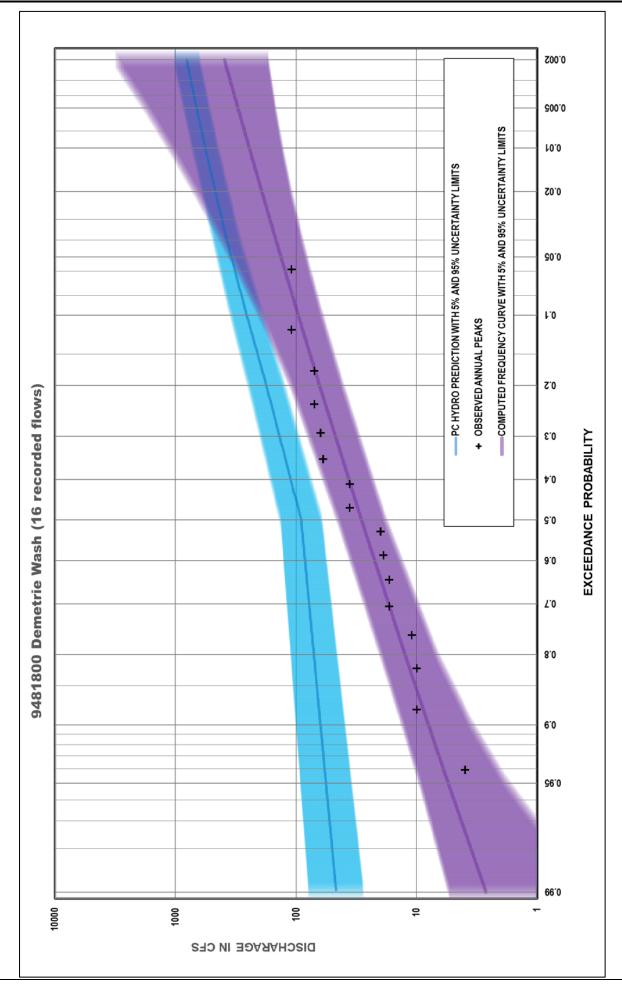
Dead Wash Tributary near Holbrook, AZ

PC-HYDRO V. 6 ANAL YSIS	JL YSIS			۲ لا													
Project Name:		PC-Hydro Investigation	gation	5,750-													
USEr Name: Client Name:		UBI Pima County		5,700 -													
Job Number:	18*25964	Date:	6/29/2018	5,650 -				-	F	ŀ				Z		1000	
				0.0	0.2	0.4	*	°0	8.0				2		1	4	
Gage Information								N ALA	1	4							
Name:	Name: Dead Wash Tributary near Holbrook, AZ	butary near	Holbrook, AZ						1		5	-	1	2			
Agency: USGS	<b>NSGS</b>							A.	いたの	/	2	(			3		
Station:	Station: 9396400							1	1		E	•	1				
Northing:	Northing: 35°4'30"N	Easting:	Easting: 109°45'2"W								1		Š	2			
(in decimal form: 35.07500,-109.75056	35.07500,-109	9.75056						N.				K		L	6	4.9 <b>8</b> 10	
Watershed Information	uo							~	1		0		L	7			
Watershed:	Watershed: Undeveloped-Foothills	I-Foothills						2			1	100					
Veg cover type: Mountain Brush	Mountain Bru	ush							0				1		5		
Area (sq. mi.):	0.76								)				(		2		
L Cen Grav (ft):	3300							181				5	1	$\left  \right\rangle$			
	Normal	Minimum	Maximum					A NOT	ALL STAN	日本の							
Veg cover (%):			20%														
% impervious:	10%	%0	20%														
		Eight Points	ts				<u> </u>	Four Points	Ś			F	Two Points	s			
	Watershed	Height	Length	Slope	Basin Factor	or Nb	dN	Hi Li	Si		Nb			i Si		dN	Νb
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(ND)	low	high	(ft) (ft)	(ft/ft)	Nb	Low	High	(ft) (ft)	(ft/ft)	dN (	Low	High
<1 house/ac	Valley	0.7	845	0.001		0.027	0.047	1 2 1 4	1690 0.004	1 0 035	0 077	0.05					
None	Valley	6.5	845	0.008		0.027	0.050						34.2 3:	3380 0.0	0.010 0.0	0.035 0.029	9 0.042
None	Foothills	10.9	792	0.014		0.030	0.040	27 16	1690 0.016	0.035	0.03	0.04					
None	Foothills	20.3	845	0.074	0.035	0.030	0.040										
None	Mountain	47.1	739	0.064		0.040	0.060	67.4 15	1584 0.043	0.046	0.037	0.055					
None	Mountain	43.3	898	0.048		0.040	090.0						114 3.	3221 0.0	0.035 0.0	0.047 0.038	8 0.057
<1 house/ac	Valley	3.0	739	0.004		0.027	0.047	40.3 103/	3/ 0.028	0.049	0.039	6CU.U					
	Watercourse Length:	e Length:	6601 ft				2	Mean slope:	ie: 0.014 ft/f	t f/ft		[	Mean slope:		0.017 fl/f		
			Mean slope:	0.007 fl/fl	fl/fl			Wt Bas	Wt Basin Factors:		0.041 0.033	0.051	Wt I	Wt Basin Factor:		0.041 0.033	3 0.049
			Wt B	Wt Basin Factors:	0.038	38 0.031	0.048										Г
Soil	Percent													Red Fo	Red Font: User entry	entry	
Type B	23%													Blue fo	Blue font: Calculation	lation	
I ype C	%GI																
I ype D	62%																



Demetrie Wash Tributary Near Continental, AZ

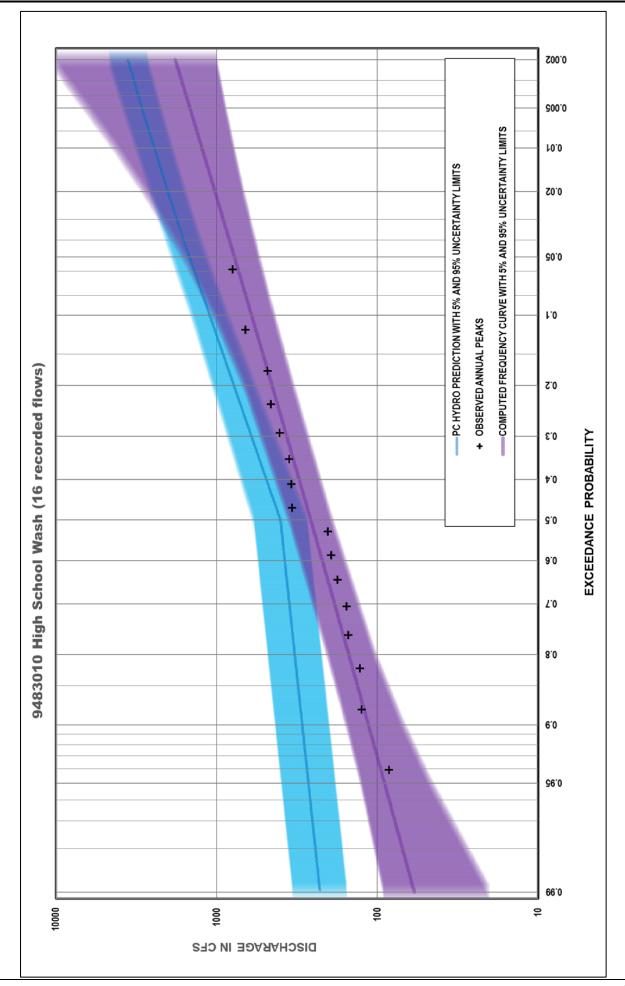
PC-HYDRO V. 6 ANAL YSIS	AL YSIS												5	and a second	and the second sec		
													5		The second	1	
Project Name:		PC-Hydro Investigation	igation										1	大学の		K	
User Name:		QBT											12.0	<i>{</i>	A Stated		
Client Name:		Pima County	~										「ないいない		1	1	
Job Number:	18*25964	Date:	6/29/2018										and the second	1		A STATE	
Project Notes:													いたので	-		P.	
													語の見		X		
													観火方			2ª	
														· 顾		1	
Gage Information																	
Name:	Name: Demetrie Wash Tributary Near Continental, AZ	Tributary Near	Continental, AZ	T T												1 and the	
Agency: USGS	USGS			3,700-												5	
Station.	Ctation: 0481800											VI.	1.100			見	
	21 ° F 214 F 114	- a citac T	1 1 1 0 L 11 T 11/VI	2 6 6 0											-	100	
Northing:	NOLIDING: 31-322 IS	Easung:	Easung: 111 3 17 W	- 000'0									-				
(in decimal form: 31.87083,-111.08806	31.87083,-11	1.08806															
Watershed Information	u			3 600-										1		<b>1</b>	
		al Fasteria		0000			Ka.									No.	
watersned:	watersned: Undeveloped-Footnills	d-Footnills		+		-		-					ſ	A Start	5	and the second	
Veg cover type: Mountain Brush	<b>Mountain Br</b>	rush		0.0		0.2		0.4	0	0.6		0.8	Ē	an freedo	「ないまた」	A REAL	
Area (sq. mi.):	0.17																
L Cen Grav (ft):	2000	_															
		Normal Minimum	Maximum														
Mor course (0/).		100/															
veg cover (%):																	
suniversions.		0.0	10.70														
		Eiaht Points	ts				Ĕ	Four Points				F	Two Points				
	Watershed		l andth	Slone	<b>Bacin Factor</b>	qN	- 4N	Hi I	7		ЧN	ЧN	Hi I	7		qN	ЧN
Development	Tvne		(Li, ft)	_	(Nb)		_		(f1/f1)	qN	_		_	(f1/f1)	Ν	MO	High
None	Foothills	13.1	739	0.018	0.035			H	1		H	-					0
None	Foothills	17.4	739	0.024	0.035	-	1	30.5 14/8	8 0.021	0.035	0.03	0.04					
None	Foothills	22.4	739	0.030	0.035		0.040				0		12.3 2903	c20.0 50	d20.0 d2	0.03	0.04
None	Foothills	19.4	686	0.028	0.035	0.030 0	0.040	41.8	620.0 c	CSU.U	0.03	0.04					
None	Foothills	30.4	792	0.038	0.035	-											
None	Foothills	23.7	686	0.035	0.035	0.030 0	0.040	54.1 14/8	8 0.03/	0.035	0.03	0.04					
None	Mountain	80.8	739	0.109	0.050	-							303 2903	0.104	0.047	7 0.038	0.057
None	Mountain	168.2	686	0 245	0.050	_	1	249 1425	5 0.175	0.05	0.04	0.06					
	Watercourse Length:	te l'anoth.	5806 ft		0000			Mean clone.	2. 0.028 A/A	A/A	1		Mean clone.		0.045.8/8		
		ac rengui.	0000		5		×		L	5				L			
			Mean slope:	0.037 tVft				Wt Basir	Wt Basin Factors:	0.039 0.032	0.032	0.045	Wt Ba	Wt Basin Factor:		0.041 0.034	0.049
		F	Wt E	Wt Basin Factors:	0.039	0.032	0.045										
Soil	Percent	,												Red Fon	Red Font: User entry	ntry	
Type B	14%													Blue fon	Blue font: Calculation	ition	
Type C	68%																
Type D	18%																
.,																	]



High School Wash at Tucson, AZ

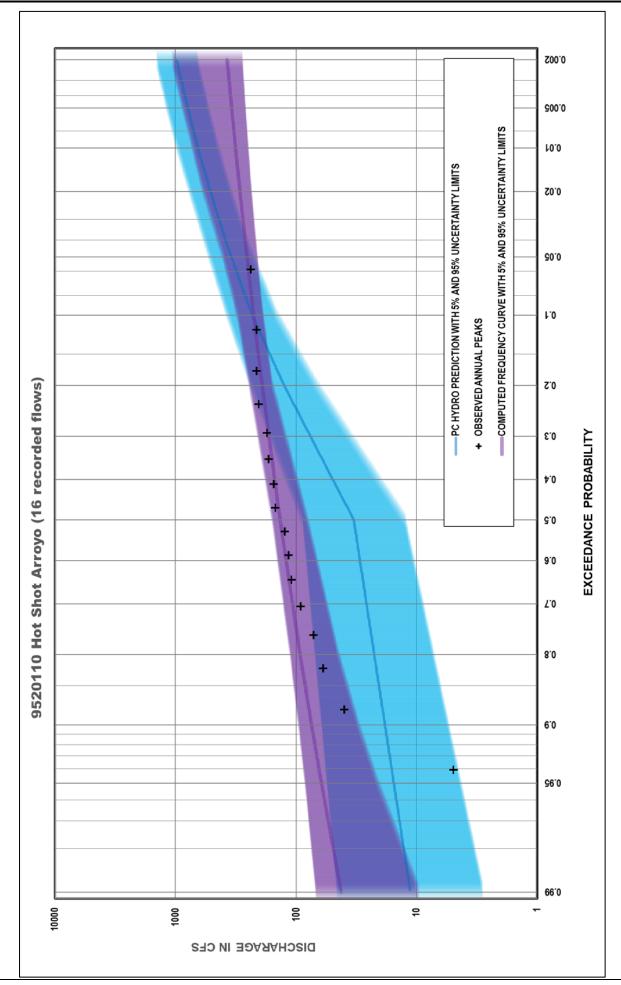
PC-HYDRO V. 6 ANAL YSIS	AL YSIS			Exploration Tools				E Speedway Bivd		-	22 July 1		-	A DOT	7	a l	
Project Name: User Name:		PC-Hydro Investigation OBT	gation	Y Luncin (	T T T			a la la	() () ()								
Client Name: Job Number:	18*25964	Pima County Date:	y 6/29/2018	ET.		1	EM	AV LONIN N							-	Camero	
Project Notes:				~			NIV GROU	-		1						ic and the	
					X	6-V1	D.N		5	2	4			U drena A	A BING N		
Gage Information					fraebr	III III N		2						N.	F		
Name:	Name: High School Wash at Tucson, AZ	Wash at Tu	ucson, AZ	-1	1			2	>		4	1			E 5/h 51		
Agency: USGS	NSGS			IN 18 mil	-		1	JALO L		1		1	1			~	
Station:	Station: 9483010	:			~		4	111	1	iv snat	1			1		7	
/in docimal form:	wortning: 32-13-28-N	Easting:	Easting: 110°56'48"W		1			Г		0.1 N	<	-		and the state	1	D.DUIL	
(III UECIIIIAI IOI III: 32.224444,-110.9400/	32.224444,-111	0.9400/				1		~				}	1	25 200	/	Ch'	
Watershed Information				0	-			-						13 of 10	Ó	Ficht	
watersned:	watershed: Low Density Urbanized	Urbanized			]				/				u.es	IN CR	2 100		
Veg cover type: Urban Lawns	Urban Lawns	\$			W.NG			ELs Weeds Sr				18:41		2		Passien	
Area (sq. mi.):	0.9755			Zoom Level: 10 Map Scale: 1:9; Lat- 32 7247 Lo	27				1				E	Stamports -	E Calla Bellaza	K	
L Cen Grav (ft):	4300			200 m 1 10.7480				10/	- cheng		6.1	1840	1		a		
	Normal	Minimum	Maximum	100 H			1	]	2	n	1	2		>		3	
Veg cover (%):	20%	10%	30%														
% impervious:	40%	30%	50%														
		Eight Points	ts				LL.	Four Points				-	Two Points	s			
	Watershed	Height	Length	Slope	<b>Basin Factor</b>	dN	dN		Si		dN	dN		Si		qN	dN
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(ND)	low	high	(ft) (ft)	(ft/ft)	ЧN	Low	High	(ft) (ft)	) (ft/ft)	dN (	Low	v High
3-5 houses/ac <sup>1</sup>	Foothills	18.0	1320	0.014	0.022	_	0.025	23 2640	0 0 00	0 0 0	0.02	0.025					
3-5 houses/ac <sup>1</sup>	Valley	5.0	1320	0.004	0.022		0.025				70.0	0.00	53	5280 0.0	0.010	0.022	0.02 0.025
3-5 houses/ac <sup>1</sup>	Valley	13.0	1320	0.010	0.022		0.025	29 2640	0.011	0.022	0.02	0.025					
3-5 houses/ac	Foothills	16.0	1320	0.012	0.022	_	0.025										_
3-5 houses/ac <sup>1</sup>	Valley	4.0	1320	0.003	0.022		0.025	22 1954	4 0.011	0.022	0.02	0.025					
3-5 houses/ac <sup>1</sup>	Foothills	18.0	634	0.028	0.022		0.025						32 3:	3326 0.0	0.010 0.0	0.022 0.	0.02 0.025
3-5 houses/ac <sup>1</sup>	Foothills	9.0	686	0.013	0.022	_	0.025	10 1372	200.0	0 0 0	0.00	0.025					
3-5 houses/ac <sup>1</sup>	Valley	1.0	686	0.001	0.022	0.020	0.025					CZ0.0					
<sup>1</sup> (Detached homes)	Watercourse Length:		8606 ft				2	Mean slope:	e: 0.010 f/f	₽J			Mean slope:		₽U		
			Mean slope:	0.006 ft/ft				Wt Basi	Wt Basin Factors:		0.022 0.020 0.025	0.025	Wt I	Wt Basin Factor:		0.022 0.020 0.025	20 0.0
			Wt B	Wt Basin Factors:	0.022	0.022 0.020 0.025	0.025										[
Soil	Percent													Red Fo	Red Font: User entry	entry	
Type B	%0													Blue fo	Blue font: Calculation	ulation	
Type C	26%																
Type D	74%																

A-36



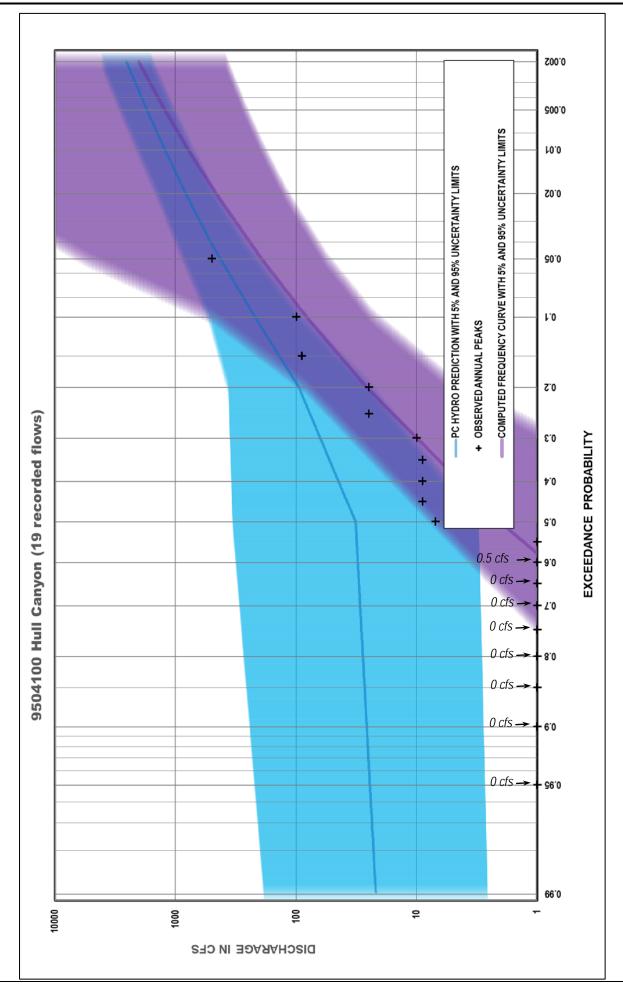
Hot Shot Arroyo near Ajo, AZ

				ء		45	Т	28	3		51				٦
	Ē		Νh	-		9 0.045	_	0 058			4 0.051				
	_ 8;		μN	Low		0.029		0 039	200		0.034	Σ	on		
				ЧN		0.035		0.049			0.042	Red Font: User entry	Blue font: Calculation		
	.e.			_			_			0.023 f/f		it: Use	nt: Cal		
	-		ŝ	(ft/ft)		0.010		0 101	5	0.0	Wt Basin Factor:	ed For	ue for		
	4.1	<u>4</u>	l i	(ft)		5121		5070		:edc	Basin	Ř	BI		
	7		Pol			50.3		514 F		Mean slope:	Wt				
	-22	F								Me					
	_ <b>e</b> ,		qN	High	0.05	8 0.04		0.04	90.0		0.0				
	-		qN	Low	0.027	0.03		0.03	0.04		0.032				
	-8.0			Nb	0.035	0.035	L	0.035	0.05		0.039 0.032 0.048				
									85	0.018 f/f					
	0.6		ŝ	(ft/ft)	0.009	0.010		0.018	0.185	0.0	Wt Basin Factors:				
	-0-		ints	(ft)	2640	2481	1010	2535	2535	lope:	asin I				
	0		<u>F our Points</u> Hi Li	(ft)	24.4	25.9		46.6	468	Mean slope:	Wt E				
	0.2	L	- dN	_	0.050	0.040	0.040	0.040	0.060		870.0	0+0			
						+ +				_					
	0.0000000		Νh		0.027	0.030	0.030	0.030	0.040	5	0.027	5			
	轻2,000- 2,100- 1,900- 1,700- 1,700-		Basin Factor	()	35	35	35 35	35	20	8	0.020	60.0			
Aqueo II			asin F	(ND)	0.035	0.035	0.035	0.035	0.050	0.0	ŧ				
					0.009	0.011	0.010	0.019	0.060	25	0.017 fl/fl				
			Slone	(Si, ft/ft)	0 0	0		0.	0 0	5	pe: 0.017 Wt Basin Factors:	ומרוב			
				(S						ŧ	Bacin				
018	33"W	num 30% 20%	th	(£	1373	1267	1373	1162	1426 1100	10191 ft	Mean slope:				
ation 6/29/2018	o, AZ 12°48'	Maximum 309 209	s Lenath	(Li, ft)							lean s				
Investig DBT County Date:	yo near Ajo, AZ Easting: 112°48'33"W 80917 Foothills		Eignt Points Height	ft)	12.4 12.0	13.6	12.3 24.8	21.8	85.1 282 6	jt:					
ydro Investig OBT Pima County Date:	yyo ne Easti .8091 -Foot	Minim 1	Eignt Po Heidht	(Hi, ft)			- ~	~	3	Fenç					
· ÷· · · · ·	<u>ge Information</u> Name: Hot Shot Arroyo near Ajo, AZ Agency: USGS Station: 9520110 Northing: 32°20'49"N Easting: 112°48 (in decimal form: 32.34694,-112.80917 (in decimal form: 32.34694,-112.80917 lershed Information Watershed: Undeveloped-Foothills Veg cover type: Desert Brush Area (sq. mi.): 0.56	Normal Minimum 20% 10% 10% 0%	_	е	еy Ус	ills	vills	ills	tain	Watercourse Length:		ent	69%	%0	31%
	ot Shc SGS 52011( 2°20'4 2°3469 2:3469 2:3469 andeve asert I	Norn	Watershed	Type	Valley	Foothills	Foothills	Foothills	Mountain	Vaterc		Percent			
ANAL me: ber:	altion Name: Hot Shol Agency: USGS Station: 9520110 orthing: 32:34694 nal form: 32.34694 Information tershed: Undevel ker type: Desert B ker type: Desert B	:(11): :(%): nus:			+	+	+	$\left  \right $		1		$\left  \right $	+	+	
YDRO V. 6 ANA Project Name: User Name: Client Name: Job Number: t Notes:	<ul> <li>Information</li> <li>Name: Hot Shot Ar Name: Hot Shot Ar Agency: USGS</li> <li>Station: 9520110</li> <li>Northing: 32:34694,-1</li> <li>atershed: Undevelope</li> <li>Watershed: Undevelope</li> <li>eg cover type: Desert Brus</li> <li>Area (sq. mi.): 0.56</li> </ul>	. cen Grav (ri): Veg cover (%): % impervious:		pment	an	ne	Je Je	ne	he	2		i,	еB	ہ د د	еп
PC-HYDRO V. 6 ANAL YSIS Project Name: User Name: Job Number: 18'2 Project Notes:	Gage Information Name: H Agency: U Station: 9! Northing: 3 (in decimal form: 3 (in decimal form: 3 Watershed Information Watershed: U Veg cover type: D Area (sq. mi.):	L cen Grav (II): Veg cover (%): % impervious:		Development	None	None	None	None	None	2		Soil	Type B	Type C	I ype U
Proje	Gag Wate	-		Δ											



Hull Canyon near Jerome, AZ

PC-HYDRO V. 6 ANAL YSIS	AL YSIS					$\backslash$			tt									
Project Name:		PC-Hydro Investigation	gation		5		7	ر	onc'/									
User Name:		QBT					1											
Client Name:		Pima County	~				1	~	6,500-									
Job Number:	18*25964	Date:	6/29/2018		4			2	6,000		50		-	10	51		imic	7
Project Notes:					مر	/		Ż		1		-83			2		2.4	5
				N.					}		5	( )						
Codo Information						کر	/		مر	/			3		10000			
	=	-	1		<b>R()</b>			1	ن بر		1			1	1			
Name:	Name: Hull Canyon near Jerome, AZ	near Jeror	ne, Az				~	/	7		}	1			7			
Agency: USGS	nses				おんて		7			(			{					
Station:	Station: 9504100						Con S				X			1	144			
Northing:	Northing: 34°44'20"N	Easting:	Easting: 112°8'37"W									1						
(in decimal form: 34.73889,-112.14361	34.73889,-11	2.14361						1			S.		L					
Watershed Information	u			4		1			ſ						1			
Watershed:	Watershed: Undeveloped-Mountain	d-Mountair	_	and the second		]			5	5					1			
Veg cover type: Ponderosa Pine	Ponderosa P	ine					ļ								~			
Area (sq. mi.):	0.91							}	Ţ		}							
L Cen Grav (ft):	0009			and a second			10		1	THE M		,	Ι	{	5			
	Normal	Normal Minimum	Maximum	語を					S. ALLER	(		)			at the			
Veg cover (%):	40%	30%	50%															
% impervious:	10%	%0	20%															
		Eight Points	Its					Four Points	nts				Two F	Two Points				
	Watershed	Height	Length	Slope	<b>Basin Factor</b>	٩N	٩N	Η	Li Si		٩N	۹N	Ξ	:=	Si		٩N	٩N
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(qN)	low	high	(ft)	(ft) (ft/ft)	t) Nb	Low	High		(ft)	(ft/ft)	Nb	Low	High
None	Mountain	154.4	1426	0.108	0.050	0.040	0.060	227	2003 U	0 1 2 0 0 0	100	1006	2					
None	Mountain	177.3	1267	0.140	0.050	0.040	0.060						102/	5385	0 102	0.05	0.01	0.06
None	Mountain	279.6	1478	0.189	0.050	0.040	0.060	703	0 090	0.261 0.05	0.04	1 0.06		2020	0.175	0.0	5	0.0
None	Mountain	423.0	1214	0.348	0.050	0.040	0.060						2					
None	Mountain	556.6	1373	0.405	0.050	0.040	0.060	441	, U 97LC	0.322 0.05	100	1006	2					
None	Mountain	84.0	1373	0.061	0.050	0.040	0.060						016	E 2 2 A	0.150	0.05		90.0
None	Mountain	0.09	1426	0.069	0.050	0.040	0.060	721	1 U U		100	1006		+ccc	cc1.0	0.0	0.0	00.0
None	Mountain	76.7	1162	0.066	0.050	0.040	0.060						0					
	Watercourse Length:	e Length:	10719 ft					Mean slope:		0.141 f/f			Mear	Mean slope:	0.171 fVf	ſŧ		
			Mean slope:	0.121 f/f	fl/ft			Wt Bä	Wt Basin Factors:		0.04	0.050 0.040 0.060	0	Wt Basin Factor:	Factor:	0.050	0.050 0.040 0.060	0.060
			Wt E	Wt Basin Factors:	0.050	0.050 0.040 0.060	0.060											
Soil	Percent													Re	Red Font: User entry	lser enti	У	
Type B	0%													Blu	Blue font: Calculation	alculati	n	
Type C	100%																	
Type D	%0																	

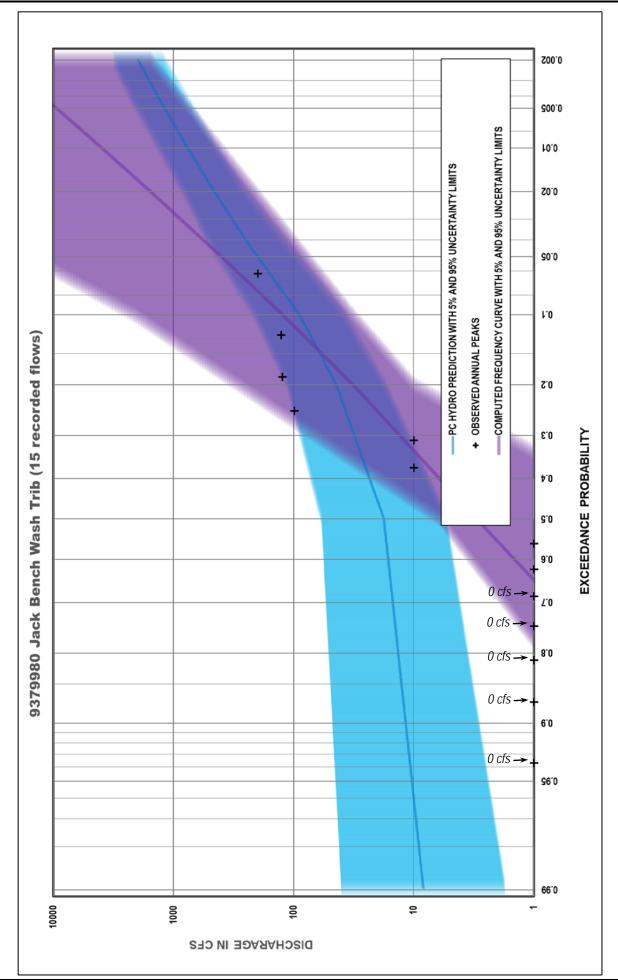


**PC-HYDRO** 

Jack Bench Wash Tributary near Page, AZ

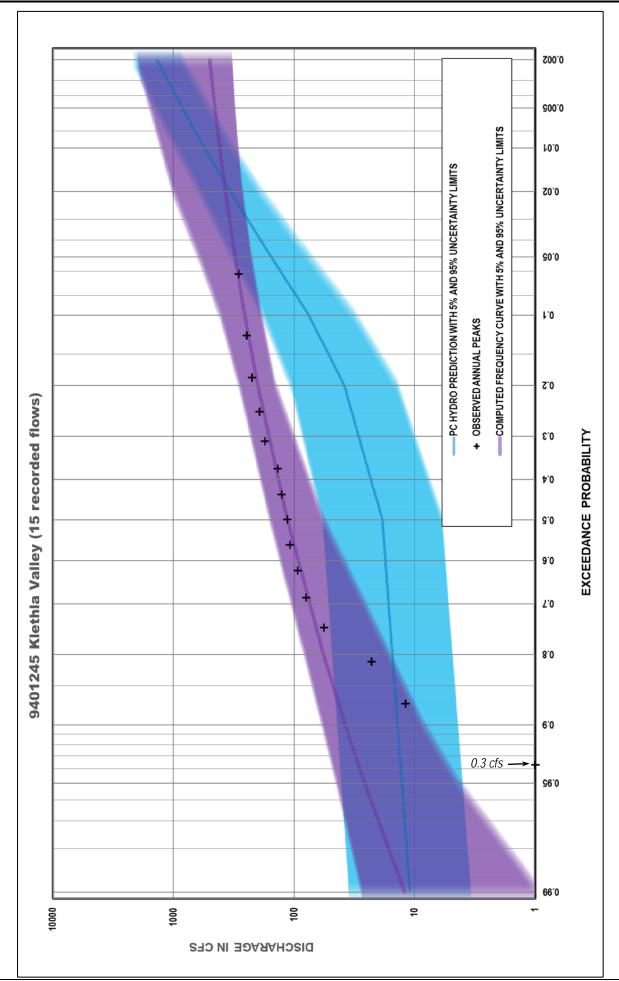
PC-HYDRO V. 6 ANAL YSIS	AL YSIS				>		2. 7		1	1			1	[			•	
				6,500											5		1	
Project Name:		PC-Hyaro Investigation	gation										1	1	Z		5	
User Name:		OBT		0029							1	1	1	1	2			
Client Name:		Pima County	>	6.100-								r	1		1			
Ich Niumbor.	10*7504	Doto:	010010017	6 000-											1		1	
. JOD NUMBEL			012712010	+			-	ſ				-			-			
Project Notes:				0.0	0 0.5	-	1.0	1.5		2.0	2.5	Ē						
				E	1	-	2		1	5					Ţ		21	
			Ī			-	1	~				)	1				1	
Gage Information				-				/					P				-	
Name:	Name: Jack Bench Wash Tributary near Page, AZ	sh Tributary ne	sar Page, AZ			2	(	/					L				-	
Agency: USGS	USGS				5	2		)		0	/						1	
Station:	Station: 9379980				1						1	1				-	<	
Northing.	Morthing: 36°42'49"N	Fasting 1	Facting: 111°35'32"W		-		1								8	7		
(in decimal form: 36 71361 -111 59222	36 71361 -117	1 59222		5	)		1	(		1		_				5	1	
	1.000			-		5			)							>		
Watershed Information	<u>on</u>			1												1		
Watershed:	Watershed: Undeveloped-Mountain	d-Mountain		1														
Veg cover type: Mountain Brush	Mountain Bru	ush		1											6	1		
Area (so. mi.):	0.98			1	(										R	1		
I Can Grav (ft).																		
		Mormal Minimum	Maximim															
Nod conor (0/).																		
veg cover (%):			%C7															
% Impervious:	10%	0%0	×0%															
		Eight Points	ts				Ľ.	Four Points	ts				Two Points	S				
	Watershed	Heiaht	Lenath	Slope	Basin Factor	qN	٩N	Hi	: Si		qN	qN	Ξ	Li Si		dΝ	۹N	q
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(qN)	low		Ŭ	f)	dN	Low	High		t)	t) Nb	_	-	dh
None	Foothills	65.3	1795	0.036	0.035	0.030	0.040										_	
None	Foothills	6.99	1901	0.035	0.035	0.030	0.040	00 201	0cU.U 070c		cu.u	0.04	7 CTC	1004007		0.035	000	
None	Foothills	38.4	1795	0.021	0.035	0.030	0.040	00 E 2E	2500 0.022	0.025	0.00							5
None	Foothills	42.1	1795	0.023	0.035	0.030	0.040					0.04						
None	Foothills	33.8	1584	0.021	0.035	0.030	0.040	47 E 2/		0.025	0.00							
None	Foothills	33.7	1848	0.018	0.035	0.030	0.040											75.7
None	Mountain	74.0	1795	0.041	0.050	0.040	0.060						43/0	001100	0.004 0.0	0.048 0.038	/ CN.N 00	/ 00
None	Mountain	295.5	1584	0.187	0.050	0.040	0.060	2/0 20	33/9 0.109	cn.u *	0.04	000						
	Watercourse Length:	e Length:	14097 ft				2	Mean slope:	pe: 0.032 fl/f	2 fl/ft			Mean slope:		0.041 ft/ft			
			Mean slope:	0.031 f/f	ft/ft			Wt Bas	Wt Basin Factors:		0.039 0.032 0.045	0.045	Wt	Wt Basin Factor:		0.041 0.034	34 0.048	048
			Wt B	Wt Basin Factors:	0.039	0.032	0.045											
Soil	Percent													Red Fo	Red Font: User entry	entry		
Type B	37%													Blue fc	Blue font: Calculation	ulation		
Type C																		
Type D	63%																	
.,																		1

A-45



Klethla Valley Tributary near Kayenta, AZ

					Nb High		0.02		0.06	056	
Ē		Ser. Com					0.036 0.0		0.04 0	0.047 0.038 0.056	
		16 M			Nb Low				0.05	47 0.0	ation
2.0					qN		0.044			ft/ft	User e Calcul
		See S			Si (ft/ft)		0.039		0.107	0.061 ft/ft actor:	Red Font: User entry Blue font: Calculation
- 5	- 5	A CONTRACTOR		ts	(£)		6601		6495	Nt Basin Factor:	Rec Blu
-		Margaret .		Two Points	H (1)		259 6		697 6	Mean slope: Wt Basi	
		< 1. S		Τw	Nb High (f	0.04	0.056	0.06	0.06		
-10						0.03 0	0.038 0.0	0.04 0	0.04 0	0.045 0.037 0.054	
					Nb Low			0.05 0	0.05 0	45 0.0	
0.5					qN	0.035	0.047			fl/f	
	196				Si (ft/ft)	0.021	0.059	0.129	0.085	an slope: 0.053 f/ft Wt Basin Factors:	
	$\left\{ \left  \right\rangle \right\}$	1		ints	Ξ (£)	3380	3221	3274	3221	lope: asin Fa	
ft 7,200 6,800 6,400 6,400	$/ \langle P \rangle$			Four Points	н (£	70	189	423	274	Mean slope: Wt Basin I	
C Ad				ш	Nb high	0.040 0.040	0.040 0.060	0.060	0.060		760.0
and the second s	5.8				dN vol	0.030 0	0.030 0 0.040 0	0.040 0 0.040 0		100	0.030
						<u> </u>	00	ö ö	0 0		0.044
	Salar				Basin Factor (Nb)	0.035	0.035	0.050	0.050	2	5
	A Course	and the			Bas					ft/ft	<i></i>
	See 12				Slope (Si, ft/ft)	0.019	0.026 0.093	0.084 0.172	0.055 0.114	0.0	WI BASIII FACIOLS:
					S (Si					ш С С	
2018	AZ "17"W	Maximum	20% 25%		gth ft)	1690 1690	1637 1584	1584 1690	1584 1637	13096 ft Mean slope: wr D	
gation y 6/29/2018	ayenta, . 110°37			its	Length (Li, ft)					Mean	
PC-Hydro Investigation OBT Pima County 5964 Date: 6/29/	utary near Kayenta, AZ Easting: 110° 37'17"W	developed-Mountain niper Grass 0.79 6600 Normal Minimum	0% 5%	Eight Points	Height (Hi, ft)	31.9 38.1	42.5 146.7	132.7 290.2	86.6 187.1	ngth:	
Pima 0	/ Tributa V Ea: 110.62	loped-Mc Grass 0.79 6600 al Min	10% 15%	Eigl			<i> </i>			Irse Le	int 27% 60%
	ıla Valley 5S 1245 29'52"h	levelopec iper Gras 0.79 6600 Jormal	5 E		Watershed Type	Foothills	Foothills Mountain	Mountain	Mountain Mountain	Water course Length:	Percent 27% 60%
NALYS	ation Name: Klethla Valley Tributary near Kayenta, AZ Agency: USGS Station: 9401245 orthing: 36°29'52"N Easting: 110°37'17 nal form: 36.49778,-110.62139	ation d: Unc e: Jun t): t): N	6): S:		Wa	йй	Ъ. Р. Р.	ŇŇ	žž	Ŵ	
YDRO V. 6 ANA Project Name: User Name: Client Name: Job Number: t Notes:	mation Name: Klethia Valley Agency: USGS Station: 9401245 Northing: 36°29'52"N imal form: 36.49778,-1'	Ished Information Watershed: Undeveloped-Mountain eg cover type: Juniper Grass Area (sq. mi.): 0.79 Cen Grav (ft): 6600 Normal Minimum	Veg cover (%): % impervious:		ment	e e	e e	e e	ele		
PC-HYDRO V. 6 ANAL YSIS Project Name: User Name: Client Name: Job Number: Project Notes:	Gage Information Name: Klethla Valley Tributary ne Agency: USGS Station: 9401245 Northing: 36°29'52"N Eastin (in decimal form: 36.49778,-110.62139	Watershed Information Watershed: Undeveloped-I Veg cover type: Juniper Grass Area (sq. mi.): 0.79 L Cen Grav (ft): 6600 Normal M	Veg cí % imp		Development	None	None None	None None	None None		Soil Type B Type C
PC-I	Gag	Wati									



Little Colorado River Tributary near St Johns, AZ

			Νb	High		0.04			0.056				0.048					
- 0 <u>-</u>			qN	Low		0.035 0.03			0.017 0.028				0.041 0.034		entry	lation		
				٩N								0.045 f/f			Red Font: User entry	Blue font: Calculation		
-83			Si	(ft/ft)		3 0.025			0 101				Wt Basin Factor:		Red For	Blue for		
		Two Points		(£		3 2903			2 2002			Mean slope:	Wt Bas					
		Two	Nb Hi	High (ft)	0.04	72.3	0.04	0000	202	0.06	00.0	Mea	0.045					
			Nb N	Low Hi	0.03		0.03			0 04			0.032 0.					
-0.4				Nb I	0.035		0.035			0.05		ļ	0.038					
-0-			Si	(ft/ft)	0.021	0	0.029	20.07	100.0	0 175	C/ I . O	0.038 fl/fl						
		oints	:=	(H)	1478		1425	1 170	14/0	1425	0741	slope:	Wt Basin Factors:					
		Four Points	Ξ	(£)	30.5	_	41.8	E 4 1	_	070		Mean slope:		10				
6,300- 6,300- 0.000-			Νb	- F	0.040			9 0.038	0.040		090.0			2 0.045				
			or Nb	Nol	0.030	0.030	0.030	0.029	0.030	0.040	0.040			0.039 0.032				
			Basin Factor	(ND)	0.035	0.035	0.035	0.034	0.035	0.050	0.050			0.0				
m and				(t)	0.018	0.030	0.028	0.038	0.035	0.109	0.245		0.037 ft/ft	ctors:				
			Slope	(Si, ft/ft)								ł		Wt Basin Factors:				
Johns, AZ °15'25"W aximum	20% 10%		Length	(Li, ft)	739	739	686	792	686	739	686	5806 ft	Mean slope:	Wt I				
adiion Ination Name: Little Colorado River Tributary near St Johns, AZ Agency: USGS Station: 9385800 Iorthing: 34.2774 "N Easting: 109°15'25"W nal form: 34.45111,-109.25694 Information tershed: Undeveloped-Foothills <i>Jer type:</i> Mountain Brush (sq. mi): 0.37 Srav (ft): 2900 Normal Minimum Maximum	%0	Eight Points	Height L	╞	13.1	22.4	19.4	30.4	23.7	80.8	168.2	ngth:						
es: <u>Ination</u> Name: Little Colorado River Tributar Agency: USGS Station: 9385800 Iorthing: 34.2774"N Eastin mal form: 34.45111,-109.25694 Information tershed: Undeveloped-Footh ver type: Mountain Brush (sq. mi): 0.37 Srav (ft): 2900 Minim.	10%	Eigl	Watershed He	_	Foothills	Foothills	Foothills	Foothills	Foothills	Mountain	Mountain	Watercourse Length:		Γ	Percent	48%	0%	52%

Development

None None

None

None

<1 house/ac

None

None

None

Veg cover (%): % impervious:

Area (sq. mi.): L Cen Grav (ft):

Watershed: Undeveloped-Foothills

Veg cover type: Mountain Brush

(in decimal form: 34.45111,-109.25694

Watershed Information

Northing: 34°27'4"N

Agency: USGS Station: 9385800

Gage Information

PC-Hydro Investigation

Project Name:

PC-HYDRO V. 6 ANAL YSIS

Pima County

Job Number:

Project Notes:

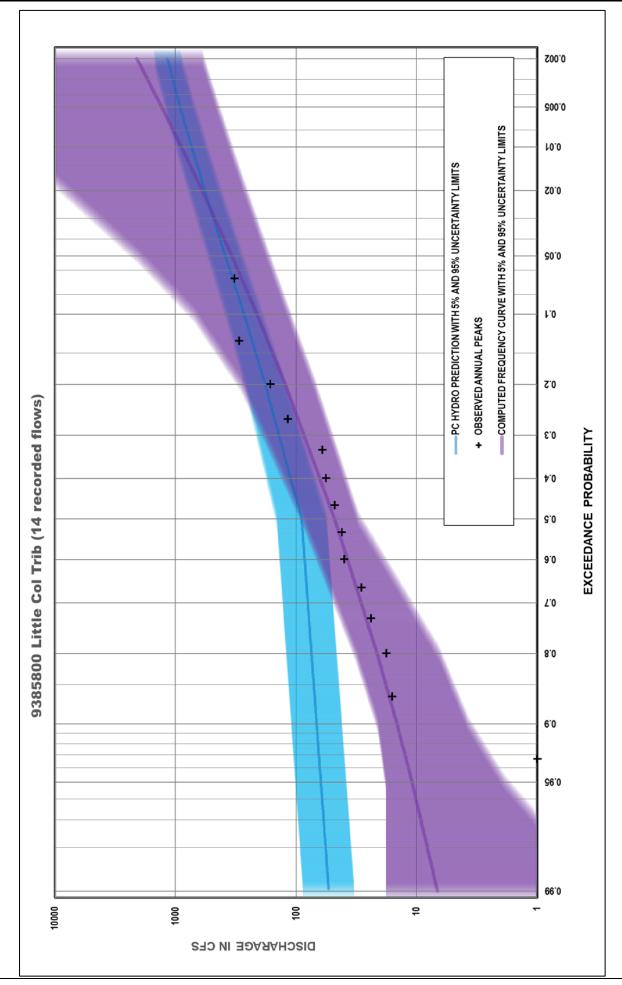
Client Name: User Name:

OBT

A-51

Soil

Type B Type C Type D



Lynx Creek Tributary near Prescott, AZ

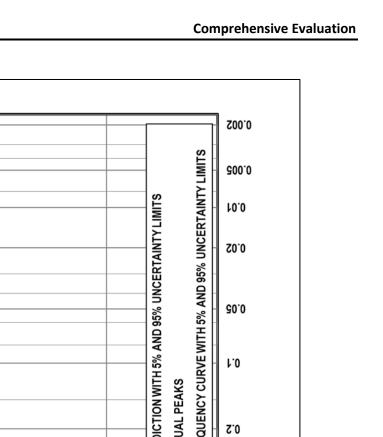
	Ē	Nb Nb Nb Nb Low High 0.033 0.029 0.037	0.042 0.035 0.049	0.053 ft/f in Factor: 0.037 0.032 0.043 Red Font: User entry Blue font: Calculation
		Li Si (ft) (ft/ft) 6495 0.034	6177 0.100	Mean slope: 0.053 ft/f Wt Basin Factor: 0.037 ( Red Font: User entry Blue font: Calculatio
	1.5 Two Points	Hi (ft) 219	617	Mean
		Nb High 8 0.036 9 0.038	8 0.036 7 0.054	0 0.041
	-1-	Nb Low 32 0.028 34 0.029	32 0.028 45 0.037	36 0.030
		Nb 4 0.032 4 0.034	1 0.032 0 0.045	0.047 ftff ctors: 0.036
and the second s	0.5	Si (ft/ft) 4 0.024	5 0.051 2 0.150	Fa
	Four Points	Hi Li ft) (ft) 77.2 3274 142 3221	158         3115           459         3062	Mean slope: 0.047 Wt Basin Factors:
Authy Authy				Ň
	t,400- 6,200- 5,800- 5,600- 0.0		0.028         0.036           0.028         0.036           0.029         0.036           0.029         0.038           0.029         0.036           0.040         0.060	
	A CON	to	0.032 0.0 0.032 0.0 0.034 0.0 0.050 0.0	0.035 34.6% 58.8%
Bast M	3		0.058 0.042 0.088 0.088	asin Fac
	mum 35% 20%	th 1584 1690 1690 1690	<u>&gt; 2 2 2</u>	12672 ft Mean slope: Wt B SOIL CALCs: 20.3533%
y 6/29/2018 Prescott, AZ 112°24'0''W	zed Maximum 20 <sup>1</sup> ts	Length (Li, ft) 16 16 16 16	1637 1478 1531 1531	Mea
ear P ear P ear P ear P	Urbaniz 15% 0%	Leng (Li, f 2 8 8 8	95.6 163 62.0 147 135.2 153 324.1 153	_ 07
ar P	aniz 18 19 10 10	l Height Leng (Hi, ft) (Li, f 25.4 51.8 57.2 84.8		se Length:

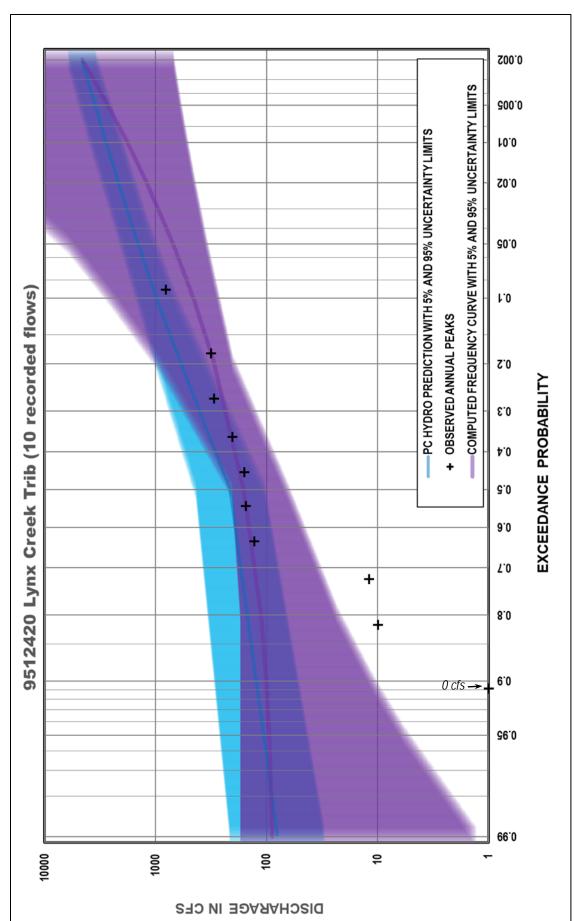
PC-Hydro Investigation

Project Name:

PC-HYDRO V. 6 ANALYSIS

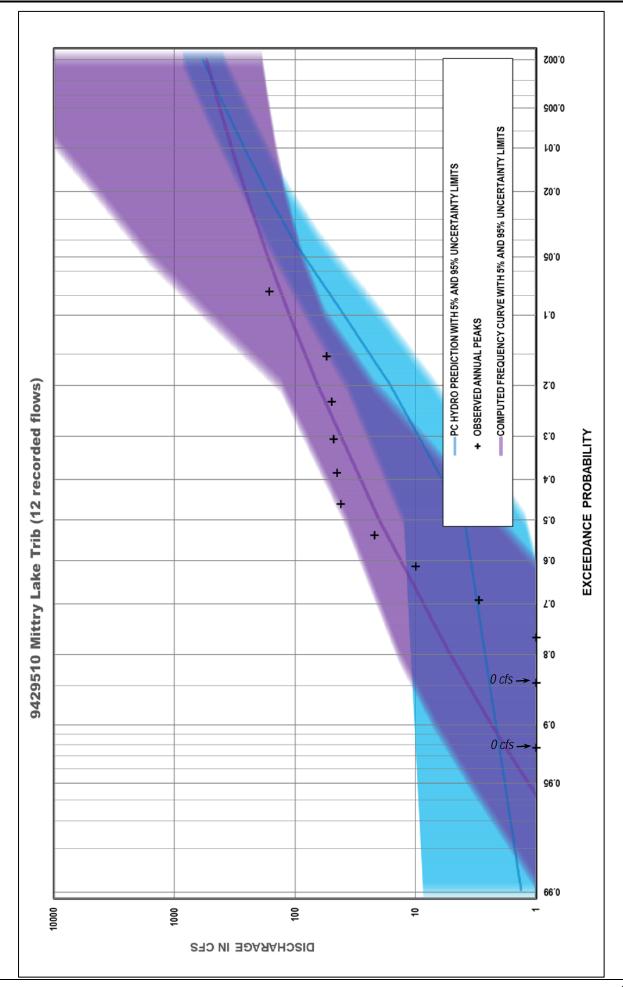
A-54





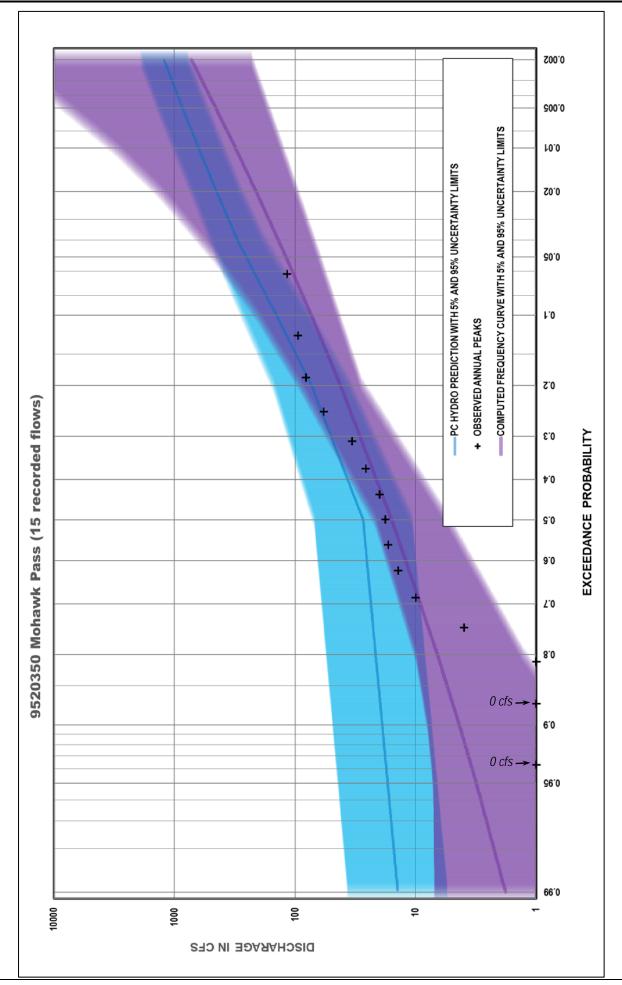
Mittry Lake Tributary near Yuma, AZ

PC-HYDRO V. 6 ANAL YSIS	VT VSIS				1	Nen P	)											
Project Name:		PC-Hydro Investigation	qation	onio	tot	10		-	1			2						
User Name:		OBT	2	Y		someth s	40	)	J									
Client Name:		Pima County	λ	and har	Z					1		~						
Job Number:	18*25964	Date:	Date: 6/29/2018		inder.	1												
Project Notes:				X	Į	10 vor			1									
						2		•	1		~	1						
Gage Information								ζ			7							
Name:	Name: Mittry Lake Tributary near Yuma. AZ	butary near	· Yuma. AZ		Cut		}				-							
Agency: USGS	uses			(		-				-								
Station:	Station: 9429510					-						*						
Northing:	Northing: 32°51'35"N	Easting:	Easting: 114°26'7"W	R.D	5	1				-		~						
(in decimal form: 32.85972,-114.43528	32.85972,-114	4.43528				J		ft 4	f14507								-	
Watershed Information	ū				7			4	400-									
Watershed:	1							e	350-									
Veg cover type: Desert Brush	Desert Brush	_						c	-006							1		
Area (sq. mi.):	0.14							° (	0.0									
L Cen Grav (ft):	2450							4	U U	-	0	0 - 0	20 0 20	20.6	0,7	a	imi	
	Normal	Normal Minimum	Maximum						0.0						1.0	0.0	6.0	
Vea cover (%):	10%	%0	20%															
% impervious:	12%		22%															
		Eight Points	ts					Four Points	ints				Two	Two Points				
	Watershed	Heiaht	Lenath	Slope	Basin Factor	r Nb	٩N	Ξ	Li S	Si		N N	Nb Hi	:=	Si		qN	٩N
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(qN)	_	high				Nb L	_			(f1/f1)	dN	Low	High
None	Valley	5.9	686	0.009	0.035	0.027	0.050	-	1220 0	0.005	0 034 0	0 200	0100					
1-2 houses/ac	Valley	1.1	634	0.002		0.026	0.045	-					763	3 2482	0.011	1 0.035	0 0 0	0 013
None	Foothills	15.9	528	0.030		0.030	0.040	10.3	1162 0	0 017 0	0.035	0.03	0 041					2
<1 house/ac	Valley	3.4	634	0.005		0.027	0.047											
None	Foothills	20.5	634	0.032			0.040	38 8	1215 0	0 032	0.035	0.03	0.04					
None	Foothills	18.3	581	0.032	0.035	0.030	0.040						101	1 2420	0.070	0.045	0.027	0.054
None	Foothills	18.2	634	0.029	0.035	0.030	0.040	150		0.105	0 010 0	0 000 0	0.050				100.0	+0.0
None	Mountain	134.2	581	0.231	0.050	0.040	0.060		0 0171				000					
	Watercourse Length:	e Length:	4912 ft					Mean slope:		0.017 fl/fl			Me	Mean slope:	0.022 fl/f	2 fl/fl		
			Mean slope:	0.011 fl/fl	ft/ft			Wt B	Wt Basin Factors:		0.038 0	0.038 0.031 0.047	047	Wt Bas	Wt Basin Factor:		0.040 0.033	0.048
			Wt E	Wt Basin Factors:		0.036 0.030 0.045	0.045											
Soil	Percent														Red Font: User entry	: User er	try	
Type B	%0														Blue font: Calculation	: Calcula	tion	
Type C	%0																	
Type D	100%																	



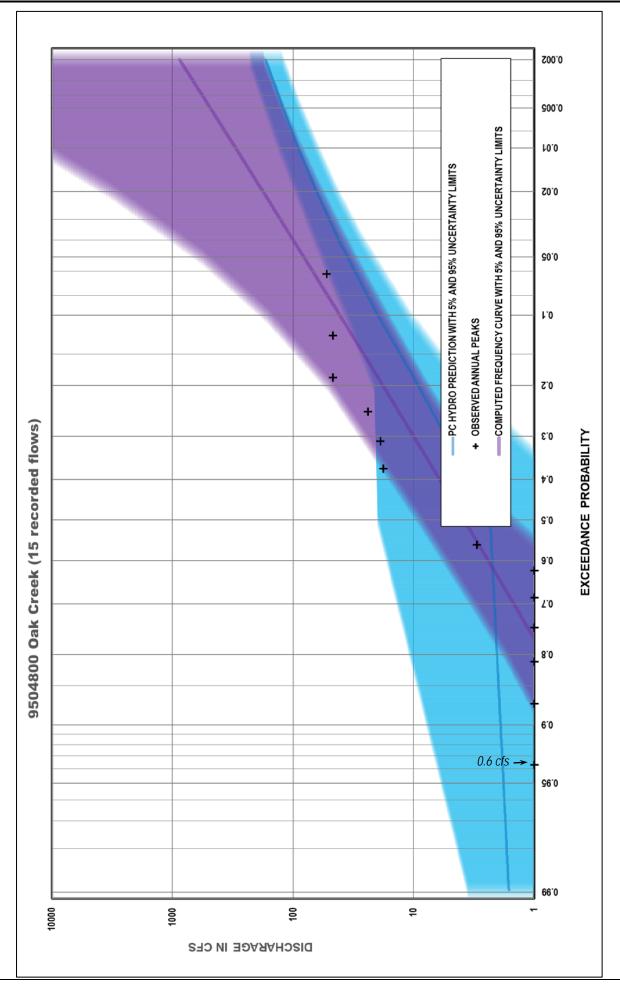
Mohawk Pass Wash at Mohawk, AZ

PC-HYDRO V. 6 ANAL YSIS	4L YSIS			al all			11.11	ft.1007										
Project Name:		PC-Hvdro Investigation	aation	5	{	ALCONT OF	and a second	1,000-										
User Name:		OBT		1		No.	Contraction of the second	- 006										
Client Name:		Pima County	>		1	and the	Ser.	700-										
Job Number:	18*25964	Date:	6/29/2018		1	Y	the state	- 009										
Project Notes:		1		() ()			1	+2		0.0	10		90	10			Ē	
					7	(	2		al al	16	t		0.0	5		2		
Gade Information				A STOR	1			ىر	10	RUNA								
	Nome: Mahanik Dece Mach at Mahanik A7	c Moch of N	Vinchow A7	and the second	ノーク	C			14/10/14	N. Notes								
Name		s wasil al I	NUIDIAWK, AC	ない	7 1	1			1110	Part of the second								
Agency: USGS	0262						1	1		Mebruik								
Northing:	Station: 9320330	Encting.	10111 CC14 A 0C F 1	A PART I	- AL	(	5		1	1								
	N 44 C4 2C	- fillion	Edouily. 113 44 34 W	Carl Carl	なたい			1										
(in decimal form: 32.72889,-113.74222	32.72889,-11:	3.74222			a financial and	T			1									
Watershed Information	<u>uo</u>					1			1									
Watershed:	Watershed: Undeveloped-Foothills	I-Foothills		A STATE		1 and the second	Contras.		and a	10.1								
Veg cover type: Desert Brush	Desert Brush	_			たいろう		5	٦		The State								
Area (sq. mi.):	0.44				あるの人	and the second	F	~	- VIII	44								
L Cen Grav (ft):	3100				Contraction of the second	and	Contraction of	-		34. 11 E								
	Normal	Minimum	Maximum	11					A Real									
Veg cover (%):	10%	%0	20%															
% impervious:	20%	10%	30%															
		Eight Points	ts				÷	Four Points	٦ts				Two F	<b>Two Points</b>				
	Watershed	Height	Length	Slope	Basin Factor	qN	٩N	Ξ	Li	Si	qN	qN	Ξ	:=	Si		qN	٩N
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(ND)	low	high		(ft) (ft/	(ft/ft) Nb	, Low	v High	(ft)	(ft)	(ft/ft)	qN	Low	High
<1 house/ac	Foothills	14.4	845	0.017	0.034	0.029	0.038	21 E 1	1627 0	0.012 0.0	0.024 0.028	110 0 80						
<1 house/ac	Valley	7.1	792	0.009			0.047						45.8	3168	0 014	0.034	0.0.0	0.04
None	Foothills	9.7	739	0.013			0.040	2/ 2	1531 0	0.016 0.0		0 0 030						
<1 house/ac	Foothills	14.6	792	0.018	0.034	0.029	0.038											
None	Foothills	10.5	792	0.013		0.030	0.040	1 7 1	158/ 0	0.026	0.035 0.03	12 0.04	V					
None	Foothills	30.2	792	0.038	0.035	0.030	0.040						406	311E	0 105		0.020	0.050
None	Mountain	291.9	845	0.345	0.050	0.040	0.060	E44 1	1521 0	0 240					0.170	0.047	40.0	
None	Mountain	273.6	686	0.399	0.050	0.040	0.060						0					
	Watercourse Length:	e Length:	6283 ft					Mean slope:		ħ/f			Mear	Mean slope:	0.035 fl/f	ft/ft		
			Mean slope:	0.024 fl/fl				Wt Ba:	Wt Basin Factors:		0.038 0.032	32 0.045	Ь	Wt Basiı	Wt Basin Factor:	0.041	0.041 0.034	0.049
			Wt Ba:	Wt Basin Factors:	0.038	3 0.032	0.045						_					
Soil	Percent													œ	Red Font: User entry	User ent	۲	
Type B	84%														Blue font: Calculation	Calculati	on	
Type C	16%																	
Type D	0%0																	



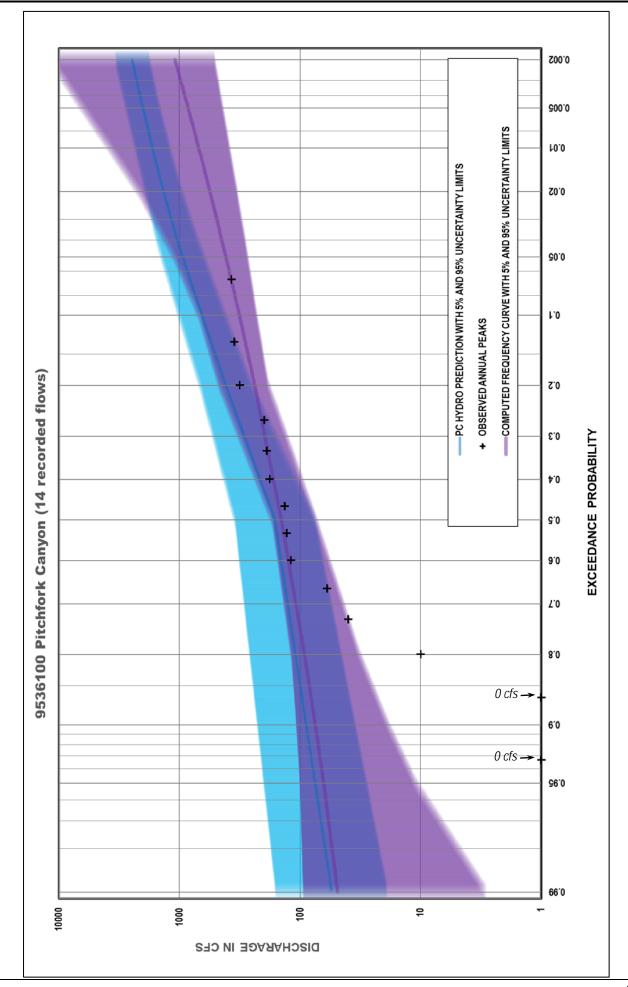
Oak Creek Tributary near Cornville, AZ

PC-HYDRO V. 6 ANAL YSIS	AL YSIS			and a state of the	Contraction of			1000		No. of Concession, Name	1. A							
Project Name:		PC-Hydro Investigation	igation		and the second						1. 1							
User Name:		QBT		and all	A MARY	a starter			J		1.3							
Client Name:		Pima County	L1								0							
Iob Mumbor.	10*75064	Dato.	6/20/2010	No. No.			- Local		٢	The second	1							
Drainet Mator:				X	1			L	No.	and the second second	100 M							
LINER INNES.					-			1	and a state	and the state	1							
				/	X	L		All and	at the lot	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1							
Gade Information				and the state		٦	1 22	and the second	ないようで	State of the second	-							
	: - - -		:	No. of Contraction	- Change	ft coo												
Name:	Name: Oak Creek Tributary near Cornville, AZ	butary near	Cornville, AZ	12 - 12 - 12	1	'S,620 =										0	N	
Agency: USGS	USGS																	
Station:	Station: 9504800					3,600-												
Northina:	Northina: 34°42'45"N	Easting:	Easting: 111°52'52"W			002.0												
(in decimal form: 34 71250 -111 88111	34 71250 -11	1 88111				3,580-												
	11-10071 1.10										i.							
Watershed Information	<u>on</u>					3,560 -												
Watershed:	Watershed: Undeveloped-Foothills	d-Foothills																
Veg cover type: Desert Brush	Desert Brush	٩				C	000	0.05	010	0.15	000		0.25	0.30	0.35	0.40	Ē	
Area (sa. mi.):	0.04					5		0.00	0.10	21.0	0.40		3	0.00	0.00	01.0		
I Con Grav (ft).																		
			Maxim															
Veg cover (%):																		
% impervious:	10%	%0 9%	20%															
		Eight Points	ıts				<u>ц</u>	Four Points	ts				Two Points	ints				
	Watershed	-	Lenath	Slope	Basin Factor	qN	٩N	Hi Li	Si		qN	qN	Η	:=	Si		qN	dN
Development	Type		(Li, ft)	(Si, ft/ft)	(qN)	low	high	_	(ft/ft) (	qN	Low	High	(ft)	(ft)	(ft/ft)	dΝ	_	High
None	Foothills	12.0	317	0.038	0.035	0.030	0.040	10.6 5	E01 0.024	1 0.025	000	10.0						
None	Foothills	7.6	264	0.029	0.035	0.030	0.040						20.1	1160	0.024	0.041	0.024	
None	Valley	2.9	317	0.009	0.035	0.027	0.050	10 F	501 0.02A	0.040	0.020	0.050			100.0			10.0
None	Mountain	16.6	264	0.063	0.050	0.040	0.060											
None	Foothills	5.7	317	0.018	0.035	0.030	0.040		E01 0.034	7007	2000	O DEE						
None	Mountain	14.2	264	0.054	0.050	0.040	090.0	C 4.4						0711	0.005			
None	Foothills	5.9	317	0.019	0.035	0.030	0.040						40.0	7011	0.000	0.040	0.0.0	ccn.u
None	Mountain	14.8	264	0.056	0.050	0.040	0.060	C /.UZ	050.0 100	0 0.040	0.030	0.00						
	Watercourse Length:	se Length:	2324 ft					Mean slope:		0.034 f/f			Mean	Mean slope:	0.034 f/f	t/ft		
			Mean slope:	0.026 fl/fl	fl/fl			Wt Bas	Wt Basin Factors:		0.044 0.036 0.052	0.052	>	Wt Basin Factor:	Factor:	0.044	0.044 0.036	0.052
		1	Wt E	Wt Basin Factors:	0.040	0.040 0.033	0.048										ĺ	
Soil	Percent													Re	Red Font: User entry	Jser enti	y	
Type B	100%													Bli	Blue font: Calculation	Calculati	uc	
Type C																		
Type D	%0																	
5																		]



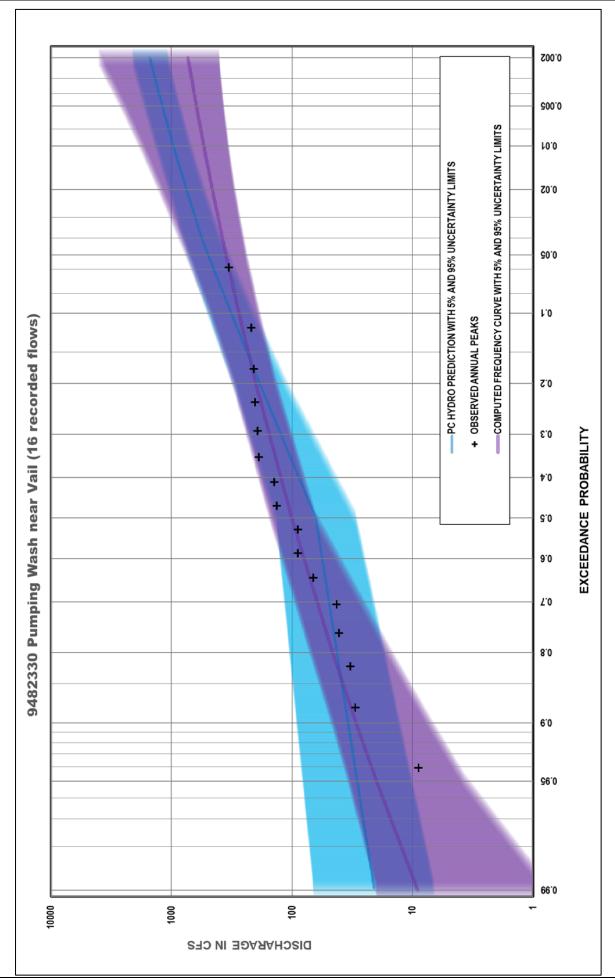
Pitchfork Canyon Tributary near Fort Grant, AZ

PC-HYDRO V. 6 ANAL YSIS	VL YSIS			ft 5,600-														
Project Name: User Name:		PC-Hydro Investigation QBT	gation	5,400- 5,200-									Ĺ		(		1	
Client Name:	10*7504	Pima County	y 10010012	5,000 -											1	5		
Project Notes:				0.0	0.5	10	1.0		1.5	2.0	E	2					~	
										R								
Gage Information							11.5		3			1	3			2		
Name:	Name: Pitchfork Canyon Tributary near Fort Grant, AZ	n Tributary ne:	ar Fort Grant, AZ				6	1	5		1		5					
Agency: USGS	USGS						Ń	١	1	2	5	)	1			1	and the second	
Station: 9536100	9536100						/	C	-	Y	,					- Contraction of the second se		
Northing:	Northing: 32°35'20"N	Easting:	Easting: 109°54'42"W				1	1			1						130 - C	
(in decimal form: 32.58889,-109.91167	32.58889,-10	9.91167					Ser. 1				1				Short S			
Watershed Information							1.00	K	ないいない	and and	A STATE	/		1	and the second		ne .	
Watershed:	Watershed: Undeveloped-Mountain	<b>J-Mountain</b>																
Veg cover type: Mountain Brush	<b>Mountain Br</b>	ush																
Area (sq. mi.):	0.88																	
L Cen Grav (ft):	0009																	
	Normal	Normal Minimum	Maximum															
Veg cover (%):	10%		20%															
% impervious:	10%	0%	20%															
		Eight Points	ts				Ŀ	Four Points	its				Two Points	Its				
	Watershed	Height	Length	Slope	Basin Factor	٩N	dN	Hi Li	i Si		qN	۹N	Ξ	Ei (	Si		٩N	٩N
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(Nb)	low h	high	(ft) (ft)	t) (ft/ft)	Nb	Low	High	(ft) (f	(ft) (ft	(ft/ft)	Nb I	Low F	High
None	Foothills	33.1	1584	0.021	0.035			7C 0 3C	306.2 0.022	0.035	0.03	70.0						
None	Foothills	33.8	1478	0.023	0.035								155	6010	0.026	0.035	0.03	0.04
None	Foothills	47.9	1531	0.031	0.035		- 1	88 1 20	2957 0.030	0 035	0.03	0.04					0	2
None	Foothills	40.2	1426	0.028	0.035													
None	Mountain	61.0	1373	0.044	0.050		0.060	138 25	2851 0.048	0.05	0.04	0.06						
None	Mountain	76.6	1478	0.052	0.050	0.040 0	0.060				10.0		TAD F	5808	0 1 2 7	0.05	0.04	0.06
None	Mountain	105.7	1531	0.069	0.050		0.060	402 20	2057 D 204	0.05	0.01	90.0			171.0	CD.D	5.0	0.00
None	Mountain	497.1	1426	0.349	0.050	0.040 0	0.060											
	Watercourse Length:	e Length:	11827 ft				Ž	Mean slope:	pe: 0.042 ft/ft	î fl/ft			Mean slope:		0.048 fl/ft			
		-	Mean slope:	0.040 fl/fl	1/ft			Wt Bas	Wt Basin Factors:		0.042 0.035 0.050	0.050	Wt	Wt Basin Factor:		0.042 0.035		0.050
		_	Wt B	Wt Basin Factors:	0.042	0.035	0.050						ļ				[	
Soil	Percent													Red F	Red Font: User entry	er entry		
Type B	%0													Blue	Blue font: Calculation	culation	c	
Type C	89%																	
Type D	11%																	٦



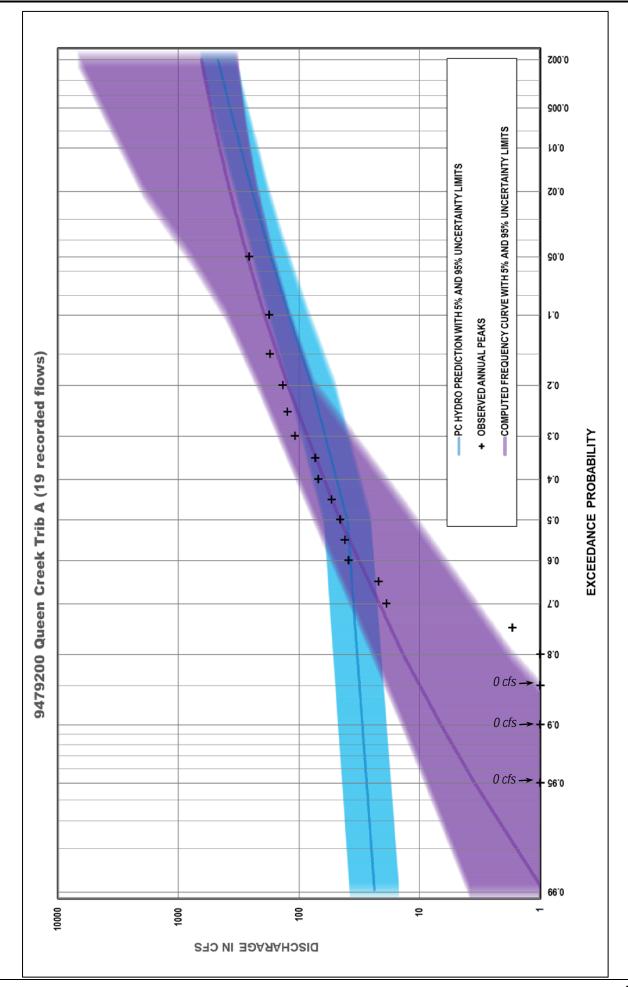
Pumping Wash near Vail, AZ

PC-HYDRO V. 6 ANAL YSIS	AL YSIS				C e		1	5	-	ft 1								
Project Name: User Name: Client Name: Job Number: Project Notes:	18*2	PC-Hydro Investigation OBT Pima County 5964 Date: 6/29/	igation y 6/29/2018		10	>V		~ / •		3,050- 3,000- 2,950-	- 20	0.5		-01	1,5		2.0	Ē
				1		1	1	1		/								
Gage Information				の方法	があっ	No and Andrews		5	C		1	140	A.	A. C.	1			
Name:	Name: Pumping Wash near Vail, AZ	ish near Va	il, AZ	Contraction of the second	Contraction of the second	1	At State	1000		1				1 mil	R.			
Agency: USGS	USGS			1	the second		1		}		1			1 3	1165			
Station: Northing:	Station: 9482330 Northing: 32°4'10"N	Easting:	Easting: 110°48'25"W	Anna			K		- Herry	7		1	\$	A	1-			
(in decimal form: 32.06944,-110.80694	32.06944,-11	0.80694		and the	A MANA		1			Star I		1	1	5	1			
Watershed Information	uc			Line and		1	1	-	4	Se .				1	1			
Watershed:	Watershed: Undeveloped-Foothills	d-Foothills				A T I WANT	「「「「「」」			-	Net .	A LON ON A		R. C.	2			
Veg cover type: Desert Brush	Desert Brush	£																
Area (sq. mi.):																		
L Cen Grav (ft):																		
		Minim	Maxim															
Veg cover (%):																		
% impervious:	10%	%0	20%															
		Eight Points	its				-	Four Points	nts				Ţ	Two Points				
	Watershed	Height	Length		Basin Factor		qN										dΝ	
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)		Nol	high	(ft)	(ft) (ft/	(ft/ft) h	Np F	Low F	High (	(ft) (ft)	(ft/ft)	dN (	Low	High
None	Valley	16.7	1690	0.010		0.027	0.050	28	3010 0	0.009	0.035 0	0.027	0.05					
None	Valley	11.3	1320	0.009	0.035	120.0	0.050						2	61.5 61	6178 0.0	0.010 0.035	35 0.028	8 0.047
None	Foothills	0.91	1584	0.012	0.035	0.030	0.040	33.5	3168 0	0.011 (	0.035 0	0.029 0	0.044					
None	Foothills	18.9	1426	0.013	0.035	0.030	0.040				1005							
None	Foothills	22.0	1637	0.013	0.035	0.030	0.040	40.4	3003 0	0.013 (	0.030	0.03	0.04					
None	Foothills	21.3	1320	0.016	0.035	0.030	0.040		0 0020	0.016	0.005	0.00		03.1 20	0.0 1000	0.014 0.030	so u.us	0.04
None	Foothills	20.9	1478	0.014	0.035	0.030	0.040				ccu.r	cu.u	0.04					
	Watercourse Length:	se Length:	12039 ft					Mean slope:		fl/f				Mean slope:		fl/fl		
			Mean slope:	0.012 ft/ft				Wt Bi	Wt Basin Factors:		0.035 0.029 0.044	).029 (	0.044	Wt B	Wt Basin Factor:		0.035 0.029 0.044	9 0.044
		F	Wt E	Wt Basin Factors:	0.035	5 0.029	0.044											Г
Soil	Percent														Red Fol	Red Font: User entry	entry	
Type B	24%	_,_													Blue to	Blue font: Calculation	lation	
Type C	/0/0																	
i ype u	0%0																	



Queen Creek Tributary A Apache Junction, AZ

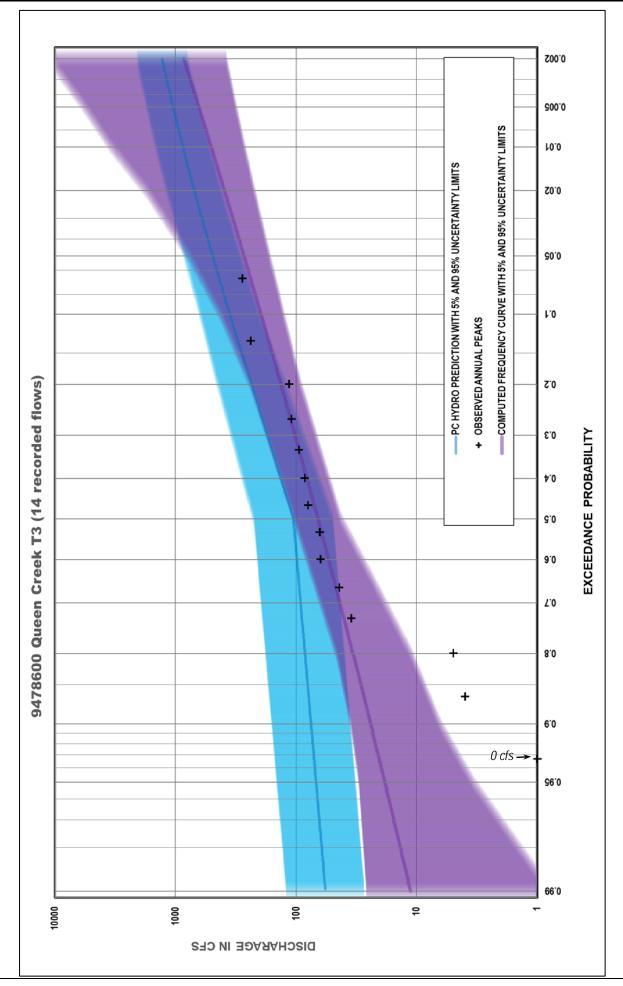
PC-HYDRO V. 6 ANAL YSIS	AL YSIS			ft,760														
				1,750-											a sni		till.	
Project Name:		PC-Hydro Investigation	igation	1.740-										子の	985	K		
User Name:		QBT		001 1									-	E v				
Client Name:		Pima County	λį	1,/30-										いに			A A	
Job Number:	18*25964	Date:	6/29/2018	1,720-									1000		~		1000	
Project Notes:				-0	0.0	0.2	0.4	4	0.6		0.8		100	n		1.55	1000	
										in the	1	1				**		
Gage Information										- Cart			1.00			100		
Name:	Name: Oueen Creek Tributary A Apache Junction, AZ	butary A Apac	he Junction, AZ							many Por	1-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2-2		Į	ୟ )-	*			
Agency: USGS	<b>USGS</b>								s-Wi	- H		145	- AN	11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		and and	1	
Station:	Station: 9479200								nche			08-11				N. N	S.S.S.	
Northing:	Northing: 33°24'13"N	Easting:	Easting: 111°32'29"W						ester			led	-			W.	100 M	
(in decimal form: 33.40361,-111.54139	33.40361,-11	1.54139							Rd	E 10th-A	SNO7	L	1		1	full		
Watershed Information	on								1 St		15		N. S.		4	-		
Watershed:	Watershed: Suburban Foothills	oothills								Contraction of the	t	Desert-		Total and	1	1		
Veg cover type: Urban Lawns	Urban Lawn	S							- AN	E-Estevan-	n-Ave	S	a la	at the second	and the			
Area (sq. mi.):											A K	Hot		1 Story		1 re	//	
L Cen Grav (ft):										Chine and		FR	J 5004	「「「	HK III	1CB	0	
		Minimum	Normal Minimum Maximum															
Veg cover (%):																		
% Impervious:	40%	30%	%nc															
		Eight Points	ıts					Four Points	ts				Two Points	nts				
	Watershed	Height	Length	Slope	Basin Factor	dN	dN	Hi Li	i Si		Νb	dN	Ηi	Li	Si		٩N	٩N
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(ND)	low	high	(ft) (ft)	(ft/ft)	Νb	Low	High	(ft)	(ft) (ft	(ft/ft)	Nb	Low	High
1-2 houses/ac	Valley	4.1	739	0.006			0.045	8 1 1,	1373 0.006	6 0.032	0 0 26	0.045						
1-2 houses/ac	Valley	4.0	634	0.006			0.045						18.8	2693	0.007	0.03	0.025	0.037
1-2 houses/ac	Foothills	6.7	634	0.011			0.036	10.7	1320 0.008	8 0.028	0.025	0.032						
3-5 houses/ac <sup>1</sup>	Valley	4.0	686	0.006			0.025											
3-5 houses/ac <sup>1</sup>	Foothills	8.2	739	0.011			0.025	15.3	1373 0.011	1 0.022	0.00	0 0 25						
3-5 houses/ac <sup>1</sup>	Foothills	7.1	634	0.011	0.022		0.025						30.2	1411	0 011	0 0 0	000	0.075
3-5 houses/ac <sup>1</sup>	Valley	6.1	634	0.010			0.025	1 0 1	1768 0.012	0 0 0 0	0.00	0.075	1.00			770.0		C 70.0
3-5 houses/ac <sup>1</sup>	Foothills	8.8	634	0.014	0.022	0.020	0.025											
<sup>1</sup> (Detached homes)	Watercourse Length:	e Length:	5334 ft				4	Mean slope:		fl/f			Mean slope:		0.009 fl/fl			
			Mean slope:	0.008 ft/ft	fl/ft			Wt Bas	Wt Basin Factors:	0.026	0.023	0.032	\$	Wt Basin Factor:		0.026 (	0.023	0.031
		-	Wt	Wt Basin Factors:	0.026	0.022	0.031						L				[	
Soil	Percent													Red	Red Font: User entry	er entry		
Type B	8%													Blue	Blue font: Calculation	Iculatio	c	
Type C	92%																	
Type D	0%																	



Queen Creek Tributary No. 3 at Whitlow Dam, AZ

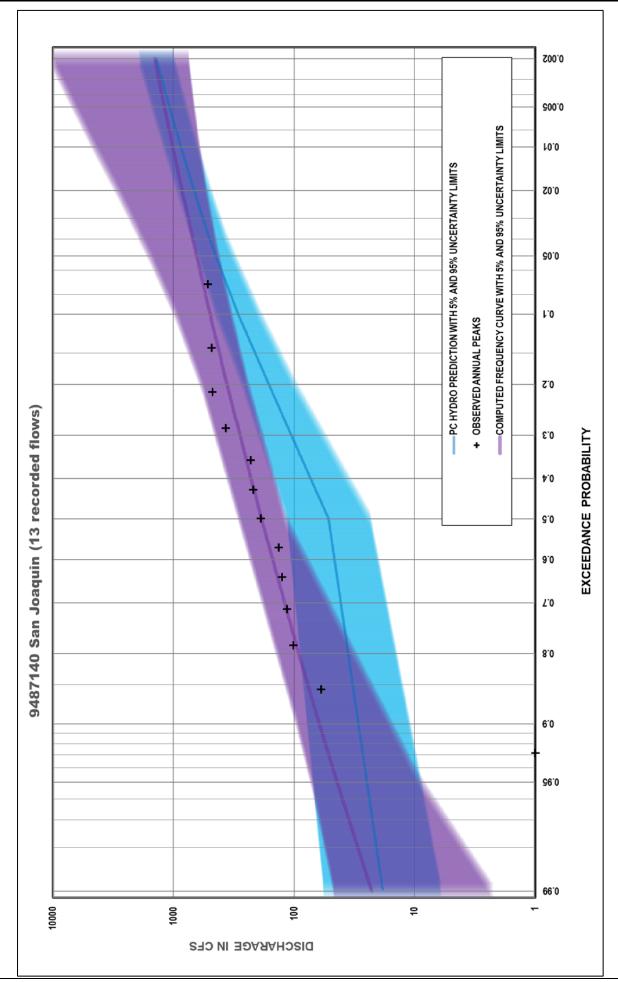
PC-HYDRO V. 6 ANAL YSIS	AL YSIS			ft tt													
				2,400-													
Project Name:		PC-Hydro Investigation	gation														
User Name:		QBT		2,300-									87	1000	ALC: NO	and the second se	
Client Name:		Pima County	>	0000									2		A STATE	「生き	
Job Number:	18*25964	Date:	6/29/2018	- 002'2										j	L' M	A State	
Project Notes:				0.0	0.2	0	0.4	0.6	0.8	1.0		1.2	Ē	1	the second	a line	
										5	0	N. R.			the party	Built	
Gade Information										-	7				/	The second	
	:		:									)		•		1	
Name:	Name: Queen Creek I ributary No. 3 at Whitlow Dam, AZ	utary No. 3 at WI	nitlow Dam, AZ							í l						P	
Agency: USGS	NSGS									1 1	1		a.			T	
Station:	Station: 9478600									- Sunda	ر	1	1			16	
Northing:	Northing: 33°17'30"N	Easting:	Easting: 111°16'52"W							S. Carlo	/	2	1	200			
(in decimal form: 33.29167,-111.28111	33.29167,-11	1.28111								ALL ALL		a sin	1	Y		Z	
Watershed Information	uo									A STATES	- A ST A ST	100 -	- HARRIS	Y		Status -	
Watershed:	Watershed: Undeveloped-Mountain	1-Mountair									S. Marine	- And	「たいい」	/		No.	
Ved cover type. Desert Britsh	Desert Brush																
Area (so. mi.):	0.38	_															
I Can Grav (ft).																	
		Normal Minimum	Maximim														
Vea cover (%):		20%															
% impervious:			41%														
		Eight Points	ts				-	Four Points	ıts				Two Points	S			
	Watershed	Height	Length	Slope	Basin Factor	qN	qN	Hi	Li Si		qN	dN	HiLi	Si		٩N	٩N
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(Nb)	low	high	(ft) (f	(ft) (ft/ft)	Nb	Low	High	(ft) (ft)	(ft/ft)	Nb	Low	High
None	Valley	0.3	898	0.000	0.035		0.050	30.7	1600 0.019	8 0.02E	0.02	10.04					
None	Foothills	30.4	792	0.038	0.035	0.030	0.040					0.04	80 24	3133 0.023	0 035	0.03	000
None	Foothills	18.9	898	0.021	0.035		0.040	10 2 1	17/13 0.0.78	0 035	0.03						F 0.0
None	Foothills	30.4	845	0.036	0.035	0.030	0.040					5.5					
None	Mountain	39.5	845	0.047	0.050		0.060	78 1 1	1637 0.048	8 0.05		0.06					
None	Mountain	38.6	792	0.049	0.050	0.040	0.060					0.00	761 22	2227 0.078	0.05		90.0
None	Mountain	41.2	898	0.046	0.050	0.040	0.060	100	1400 0 100	0.05		0.04					0.0
None	Mountain	141.2	792	0.178	0.050	0.040	0.060					00.00					
	Watercourse Length:	e Length:	6760 ft					Mean slope:		0.036 ft/ft			Mean slope:	oe: 0.039 f/f	) fl/fl		
			Mean slope:	0.008 fl/fl	fl/ft			Wt Ba	Wt Basin Factors:		0.042 0.035 0.050	0.050	Wt E	Wt Basin Factor:		0.042 0.035 0.050	0.050
			Wt E	Wt Basin Factors:	0.042	0.035	0.051										
Soil	Percent													Red Font	Red Font: User entry	ry	
Type B														Blue font	Blue font: Calculation	ion	
Type C																	
Type D	100%																

PC-HYDRO



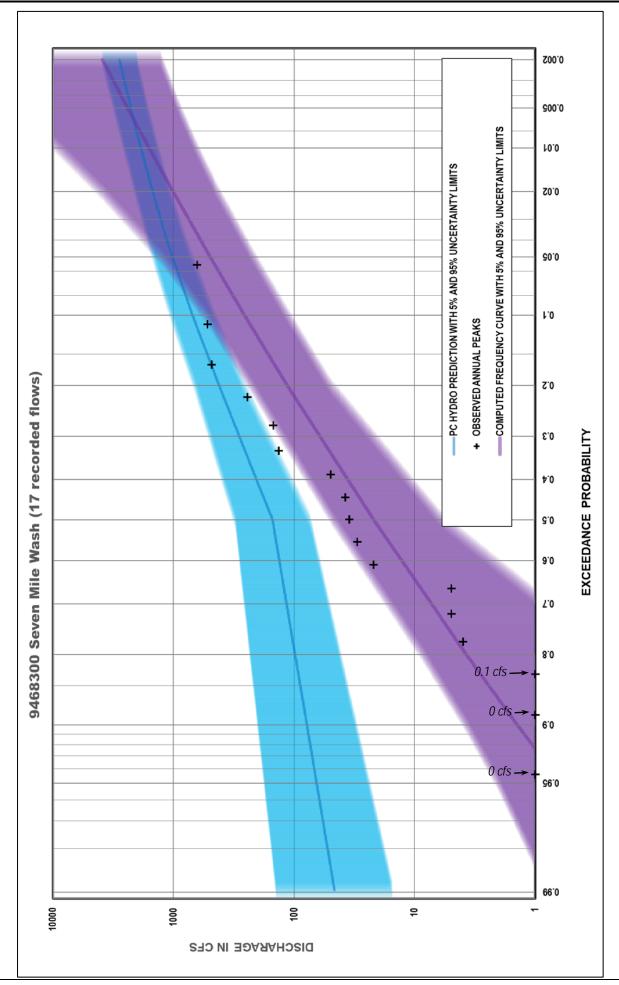
San Joaquin Wash near Tucson, AZ

PC-HYDRO V. 6 ANAL YSIS	AL YSIS			ft, oon 1									110	Sec. 19	Arrest			
				- 200								10.21		X	N Ford	1		
Project Name:		PC-Hvdro Investigation	aation	2,800-												1		
llser Name		ORT		2,700-														
Client Name		Dima County		2,600-														
				2.500-												R		
Job Number:	18~25964	Date:	6/29/2018	13	20	0	1	00	30	00		-Ē		A CAR				
Project Notes:				0.0	C.0	0.1	2	1							2			
0 0 0 0 0-1															~			
								N							~			
Gage Information												1		2	a. d	6		
Name:	Name: San Joaquin Wash near Tucson, AZ	Vash near Tu	ucson, AZ										100					
Agency: USGS	USGS											64		~				
Station:	Station: 9487140							×		1 and the		Tr				and		
Northing.	Northing 32°10'7"N	Facting.	Facting 111°8'0"W					213	- Mil			5			ない			
(in decimal form: 32 16861 -111 13333	32 16861 -11	1 13333							and the second s		1	L	~		14 A			
	11 10001-170	0000						A ST A	10000				A LA	and i C	A State	1		
Watershed Information	י - בו י							2			λ	1			14 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			
Watershed:	Watershed: Suburban Foothills	othills						1	たいのです	L - L		Ľ	ないの	Ser Ser	ALL ALL	1		
Veg cover type: Desert Brush	Desert Brush	_						2	大学		- Contraction	a la	a the	Service and		1		
Area (sq. mi.):	0.69							1			1	att of	inter at	AL D. W.	and the second	AL COL		
L Cen Grav (ft):	8500									No.		A A A	Wes .	Constant of	the state	1		
	Normal	Normal Minimum	Maximum					P		いたの	THE X	and the		である	にたれい			
Veg cover (%):	10%	%0									A COLORADO							
% impervious:	10%		20%															
		Fight Points	ts					Four Points	te				Two Points	ints				
		- A	:			:					:	:			ē		:	
Development	watersned Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	an vo	ND hiah	- :: :: ::	LI SI (ft) (ft/ft)	qN	Low Low	ND Hiah	ŦÊ	I (I)	sı (ft/ft)	qN	Low D	ND Hiah
<1 house/ac	Foothills	31.5	2429	0.013	0.034		0.038			-								<b>b</b>
<1 house/ac	Foothills	26.0	2270	0.011	0.034	0.029	0.038	4 c./c	4077 0.012	12 0.034	+ U.UZY	0.030	101	0102	0.012	0.024	0000	0.020
<1 house/ac	Foothills	36.6	2482	0.015	0.034	0.029	0.038	1 0 67	AE0.4 0.01.4	1000	0000	0000		6727	c10.0			000.0
<1 house/ac	Foothills	27.3	2112	0.013	0.034	0.029	0.038											
<1 house/ac	Foothills	38.3	2218	0.017	0.034	0.029	0.038	00	1752 0.020	0000	0000	0000						
<1 house/ac	Foothills	54.7	2534	0.022	0.034	0.029	0.038											
<1 house/ac	Foothills	61.1	2006	0.030	0.034	0.029	0.038						CS I CS	9706	0.039	0.034	V.U29	U.U38
<1 house/ac	Mountain	197.1	2270	0.087	0.034	0.029	0.038	4 8c7	42/6 0.060	00 0.034	0.029	0.038						
	Watercourse Length:	e Length:	18321 ft					Mean slope:		0.019 f/f		-	Mean	Mean slope:	0.021 ft/f	ft/ft		
		I	Mean slope:	0.018 f/f	Vft			Wt Ba	Wt Basin Factors:		t 0.02	0.034 0.029 0.038		Wt Basin Factor:	Factor:	0.034	0.034 0.029	0.038
			Wt B	Wt Basin Factors:	0.034	0.029	0.038											
Soil	Percent													Re	Red Font: User entry	User ent	٢	
Type B	%0													BI	Blue font: Calculation	Calculat	on	
Type C	%16																	
Type D	3%										ļ		ļ					



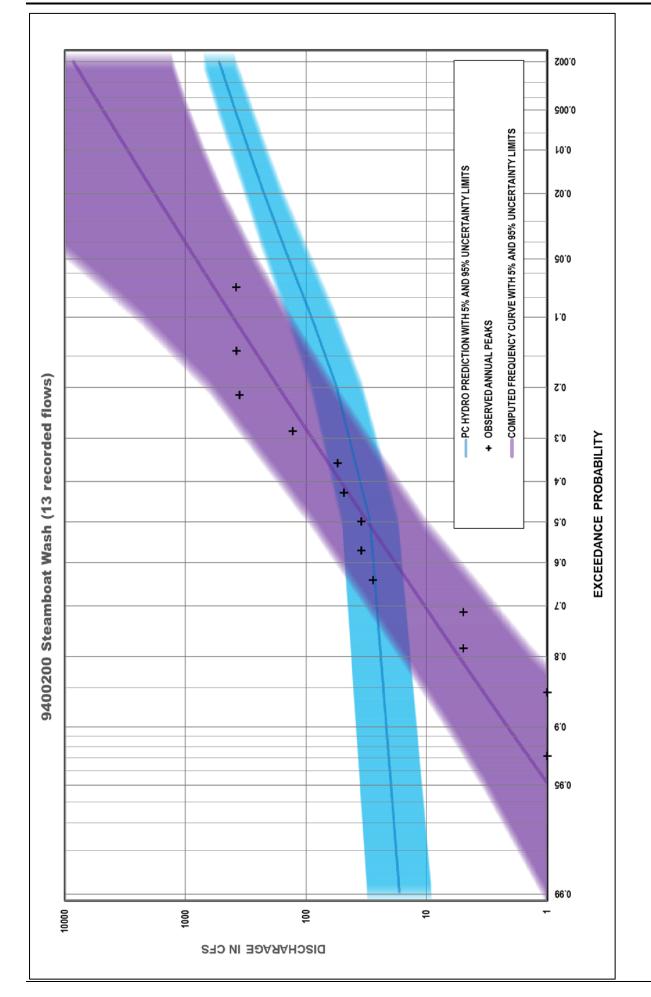
Sevenmile Wash Tributary near Globe, AZ

PC-HYDRO V. 6 ANAL YSIS	SISA T					Ł	Į		{		C		and a state	1	Y			
Project Name: User Name:	PC-Hyc	PC-Hydro Investigation OBT	gation						1			1	1			T	the list	
Client Name:		Pima County				and the second				1	<i>ξ</i>	and the second			A second	2	2257	
Job Number:	18*25964	Date:	6/29/2018			2					5	لر	1					
00000-1												1			-			
Gage Information									ł						~	1		
Name:	Name: Sevenmile W ash Tributary near Globe, AZ	Tributary nea	ir Globe, AZ							1			1	12.2			12	
Agency: USGS	USGS					1.51		the set	/		1		M		-		2	
Station: 9468300 Northing: 33°35'10	Station: 9468300 Northing: 33°35'10"N	Facting	Eacting: 110° 30'3"W			1		and the second	The state		1	l	1		-		100	
(in decimal form: 33.58611,-110.65056	33.58611,-110	0.65056		ft zoon		1			The All	a area		5	¢.	Į	7	J	R.T.	
Watershed Information	u			4,600									/			3		
Watershed:	Watershed: Undeveloped-Mountain	I-Mountair		4,500 -										A CARL	1		100	
Veg cover type: Desert Brush	Desert Brush	_		4,400 -								2	たい	and the second	The way	5		
Area (sq. mi.):	0.86			4,300-														
L Cen Grav (ft):	5200			4.100														
	Normal Minimum	Minimum	Maximum	0.0		0.5		1.0	-12	5.	5	2.0 mi						
Veg cover (%):	15%		25%															
% impervious:	10%	%0	20%															
		Eight Points	ts				ш	Four Points	ts				Two Points	nts				
	Watershed	Height	Length	Slope	Basin Factor	dΝ	ЧN	Hi Li	i Si		dΝ	qN		Li	Si		Νb	٩N
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(ND)	low	high	(ft) (ft)	) (ft/ft)	qN	Low	High	(ft)	(ft) (j	(ft/ft)	dN	Low	High
None	Foothills	42.2	1478	0.029	0.035	_	0.040	112 20	2956 0.038	0 0 0 4 4	0 036	0.052						
None	Mountain	69.5	1478	0.047	0.050		0.060						235	5649	0.042	0 047	0.038	0.056
None	Mountain	66.4	1373	0.048	0.050		0.060	123 26	2693 0.046	0.05	0.04	0.06						
None	Mountain	56.6	1320	0.043	0.050		0.060											
None	Mountain	81.8	1478	0.055	0.050		0.060	164 27	2745 0.060	0.05	0.04	0.06						
None	Mountain	82.5	1267	0.065	0.050		0.060					0.0	404	5438	0.074	0.05	0.04	0.06
None	Mountain	81.5	1531	0.053	0.050	0.040	0.060	220 2/	2602 0 080	0.05	100	90.0			-	0.0	5	0.0
None	Mountain	157.7	1162	0.136	0.050	0.040	0.060					0.00						
	Watercourse Length:	e Length:	11087 ft				2	Mean slope:	oe: 0.053 f/f	fl/f			Mean slope:	ope:	0.054 fl/fl	ļ		
			Mean slope:	0.051 fl/fl				Wt Bas	Wt Basin Factors:		0.048 0.039 0.058	0.058	M	Wt Basin Factor:	actor:	0.048	0.048 0.039 0.058	0.058
			Wt B	Wt Basin Factors:	0.048	0.039	1,40.0						L				ſ	
Soil	Percent													Red	Red Font: User entry	ser entr	~	
Type B	%0													Blue	Blue font: Calculation	alculatic	u	
Type C	100%																	
Type D	%0																	



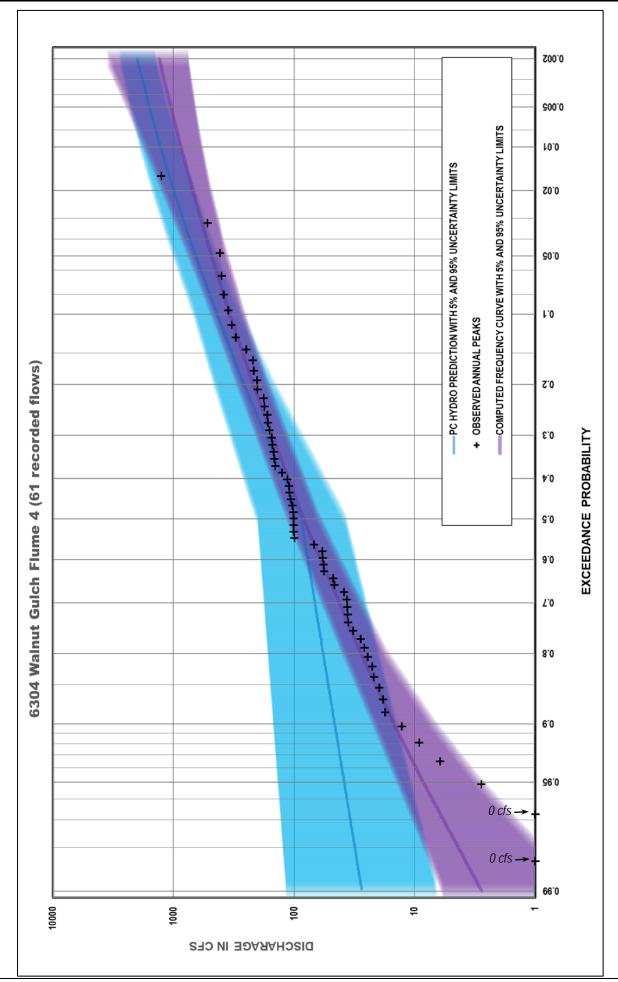
Steamboat Wash Trib. near Ganado, AZ

PC-HYDRO V. 6 ANAL YSIS	T YSIS											and the second s	5	(			1	
Project Name:	PC-Hy	PC-Hydro Investigation	igation								3					Ş		
User Name:		QBT										4		Sec. est.			10.11	
Client Name:	<b>a</b>	Pima County	,										Ļ	1			X	13
Job Number:	18*25964	Date:	6/29/2018								~							71
Project Notes:															•		Sec.	100
													-			Č,		100
												1					20	
Gage Information												J		1				
Name:	Name: Steamboat Wash Tributary near Ganado, AZ	n Tributary ne	ar Ganado, AZ	t t										1				
Agency: USGS	USGS			6,800 -									5					1000
Station: 9400200	9400200													/			1	
Northing:	Northing: 35°45'50"N	Easting:	Easting: 109°48'2"W	6,750-									1	/				
(in decimal form: 35.76389,-109.80056	35.76389,-10	9.80056												- New -	5		AL AN	
Watershed Information	u			- 00/'9														
Watershed:	Watershed: Undeveloped-Valley	1-Valley		0.0	0.1	0	0.2	0.3	0.4		0.5	Ē						
Veg cover type: Mountain Brush	Mountain Br	ush																
Area (sq. mi.):	0.15																	
L Cen Grav (ft):	006																	
	Normal	Normal Minimum	Maximum															
Veg cover (%):	12%	2%																
% impervious:	20%																	
		Eight Points	ıts					Four Points	nts				Two	Two Points				
	Watershed	Height	Length	Slope E	Basin Factor	۹N	٩N	Ξ	Li Si		qN	qN		:=	Si		٩N	ЧN
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(Nb)	low	high	(ft) (i	(ft) (ft/ft)	t) Nb	Low	v High	(ft)	(ft)	(ft/ft)	Nb	Low	High
None	Foothills	13.6	422	0.032	0.035	0.030	0.040	37 B	70.0 0.011	11 0 0 1 V	1 0.036	36 0.052	6					
None	Mountain	19.2	370	0.052	0.050	0.040	0.060	0.26					120	1532	0.078	0.048	0 030	0.058
None	Mountain	54.2	370	0.146	0.050		0.060	86.7	740 0 117	17 0.05	5 0.04	0.04						0000
None	Mountain	32.5	370	0.088	0.050		0.060						,					
None	Foothills	16.3	422	0.039	0.035		0.040	10 /	100 0 007	0.025	5 0 0 0	0.010	~					
None	Valley	3.1	370	0.008	0.035	0.027	0.050	- 7.4					7 1 7	1522	0.016	0.025	0000	
None	Valley	3.6	370	0.010	0.035		0.050	г 3	700 0 017	07 0.025	5 0 0 7	0.05			0.0.0		120.0	110.0
None	Valley	1.7	370	0.005	0.035	0.027	0.050	c.c					0					
	Watercourse Length:	e Length:	3064 ft					Mean slope:		0.024 fVf			Mea	Mean slope:	0.030 fl/fl	fl/ft		
			Mean slope:	0.020 fl/fl				Wt Ba	Wt Basin Factors:		1 0.03	0.041 0.033 0.051	<del>-</del>	Wt Basi.	Wt Basin Factor:	0.042	0.042 0.034	0.051
			Wt E	Wt Basin Factors:	0.040	0.040 0.033	0.051										ſ	
Soil	Percent													Ľ.	Red Font: User entry	User ent	Z	
Type B	27%													ш	Blue font: Calculation	Calculat	on	
Type C	0%																	
Type D	73%																	٦



Walnut Gulch Flume 4

PC-HYDRO V. 6 ANAL YSIS	VT ASIS			1 Ale	all ist				5	~								
Project Name:	PC-Hy	PC-Hydro Investigation	gation	AL.	No.	1		6										
User Name:		OBT				~				1								
Client Name:	ď	Pima County	٨	Contraction of the		2	1		7	and and								
Job Number:	18*25964	Date:	6/29/2018		1	C	1		7	1								
Project Notes:					L	~			~	No.								
				A. A.	A MAR	5		~	A									
Gage Information						2		~		Real Property								
Name:	Name: Walnut Gulch Flume 4	h Flume 4						and a										
Agency: ARS	ARS			2	2		2											
Station: 6304	6304			1	~	ł		4,650-										
Northing:	Northing: 31°44'00"N	Easting: 1	Easting: 110°02'01"W	(		- ALVE	A RUNA	4,600 -										
(in decimal form: 31.73333,-110.03361	31.73333,-110	0.03361			1	ALL ALL	4	4,550-							Vi			
Watershed Information	u			2	3	S. C. P.	New A	4 500-										
Watershed:	Watershed: Suburban Foothills	othills			00 500	1		2000't										
Veg cover type: Desert Brush	Desert Brush	_					•	4,430		-		-						
Area (sq. mi.):	0.88							0.0		0.5		1.0			1.5		2.0 mi	
L Cen Grav (ft):	0009																	
	Normal	Normal Minimum	Maximum															
Veg cover (%):	15%	5%	25%															
% impervious:	10%		20%															
		Eight Points	ts					Four Points	ıts				Two Points	oints				
	Watershed	Height	Length	Slope	Basin Factor	r Nb	۹N	Ξ	Li Si		qN	qN	Ξ	:=	Si		qN	Nb
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(ND)	_	high	(ft) (f	(ft) (ft/ft)	qN (	Low	-		(ft)	(ft/ft)	ЧN	_	High
<1 house/ac	Foothills	44.2	1426	0.031	0.034	0.029	0.038	10 2 2	700 0 117	17 0.024		0 0 0 0						
<1 house/ac	Valley	4.1	1478	0.003		0.027	0.047						100	5703	0.018	0.034	0.078	0.04
<1 house/ac	Foothills	39.4	1373	0.029		0.029	0.038	53.2	2799 0.019	19 0.034	4 0.028	8 0.041						
None	Valley	13.8	1426	0.010		0.027	0.050							T	T			
None	Foothills	32.8	1478	0.022		0.030	0.040	54.9 2	2798 0.020	20 0.035	5 0.03	3 0.04						
None	Foothills	22.1	1320	0.017		0.030	0.040						136	5491	0.025	0.035	0.03	0.04
None	Foothills	38.1	1373	0.028		0.030	0.040	80 7 D	2693 0.030	30 0.035	5 0.03	3 0.04				0	0	-
None	Foothills	42.6	1320	0.032	0.035	0.030	0.040											
	Watercourse Length:	e Length:	11194 ft				-	Mean slope:		0.020 fl/fl			Mean	Mean slope:	0.021 fVf	th		
			Mean slope:	0.014 ft/ft				Wt Ba:	Wt Basin Factors:		4 0.02	0.034 0.029 0.040		Wt Basin	Wt Basin Factor:	0.034 0.029	0.029	0.040
			Wt B	Wt Basin Factors:	0.03	0.035 0.029	0.042						L				[	
Soil	Percent													Ř	Red Font: User entry	User entr	Z	
Type B	55%												1	B	Blue font: Calculation	Calculati	uc	
Type C	45%																	
Type D	0%																	٦



West Speedway Wash near Tucson, AZ

PC-HYDRO V. 6 ANAL YSIS	AL YSIS					$\langle$												
Project Name: User Name:		PC-Hydro Investigation QBT	gation	7		Y		1	1									
Client Name: Job Number: Project Notes:	18*25964	Pima County Date:	y 6/29/2018	-		Number	1		04									
					5	5	<		~									
Gage Information						0	-	1	-									
Name:	Name: West Speedway Wash near Tucson, AZ	ıy Wash near	Tucson, AZ			>												
Agency: USUS Station: 94830	Agency: USGS Station: 9483040			1	1													
Northing:	Northing: 32°14'20"N	Easting: 1	Easting: 111°2'45"W		R													
(in decimal form: 32.23889,-111.04583	32.23889,-11	1.04583		4		5	Ĺ											
Watershed Information	<u>uo</u>			n etn.	Side Dr.	>	S	1	ft 3 100									
Watershed:	Watershed: Suburban Foothills	oothills		MONT		L	2		3,000-							-		
Veg cover type: Desert Brush	: Desert Brush	E			-		-		2,900-2,800-									
Area (sq. mi.):	0.47			27		1			2,700-									
		2904 Normal Minimum	Maximim		<u>کر</u>	-			0 0	6.0	0.4	0.6	80	1 0 1 2	1 4	1.6 mi		
Veg cover (%):		20%							2	4								
% impervious:			20%															
		Eight Points	ts				÷	Four Points	nts				Two	Two Points				
	Watershed	Height	Length	Slope	Basin Factor	r Nb	٩N	Ξ	Li Si		۹N	qN	Ξ	:=	Si		qN	٩N
Development	Type	(Hi, ft)	(Li, ft)	(Si, ft/ft)	(ND)	low	high	(ft) (t	(ft) (ft/ft)	dN (	Low	v High	h (ft)	(ft)	(ft/ft)	Nb	Low	High
<1 house/ac	Foothills	21.8	1214	0.018	0.034	0.029	0.038	45 8 2	2376 0.010	10 0.034	34 0.029	20 0.038	a					
<1 house/ac	Foothills	24.0	1162	0.021	0.034	0.029	0.038						94.2	4541	0.021	0.034	0.029	0.038
<1 house/ac	Foothills	24.6	1056	0.023	0.034	0.029	0.038	48.4 2	2165 0.022	22 0.034	34 0.029	29 0.038						
<1 house/ac	Foothills	25.0 26.9	1056	0.025	0.034	0.029	0.038						+					
1-2 houses/ac	Foothills	42.3	1162	0.036	0.032	0.028	0.036	69.2 2	2218 0.031	31 0.033	33 0.028	28 0.037						1
<1 house/ac	Mountain	125.6	1056	0.119	0.034	0.029	0.038						499 	4383	0.128	0.044	0.036	70.0
None	Mountain	364.5	1109	0.329	0.050	0.040	0.060	490 2	077.0 0017		0.040 0.03/	4c0.0 / 5	<b>4</b> C					
	Watercourse Length:	e Length:	8924 ft	<u> </u>				Mean slope:		0.034 fVft			Mear	Mean slope:	0.042 fl/fl	U/U		
		1	Mean slope:	0.033 fVft				Wt Ba	Wt Basin Factors:		37 0.0	0.037 0.031 0.042	<b>1</b> 2	Wt Basi	Wt Basin Factor:	0.039	0.039 0.032	0.045
		-	Wt E	Wt Basin Factors:	0.036	6 0.030	0.040											
Soil	Percent	<u>.</u>													Red Font: User entry	User ent	ک ا	
Time B	%1														Blue tont: Calculation	Calculat	on	
	% <b>_</b>																	
I ype D	98%																	٦

