PIMA COUNTY
FLOOD CONTROL

MEMORANDUM

DATE: October 15, 2018

TO: Suzanne Shields, P.E.
Director

FROM: Jacob Prietto, CFM
Principal Hydrologist

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.

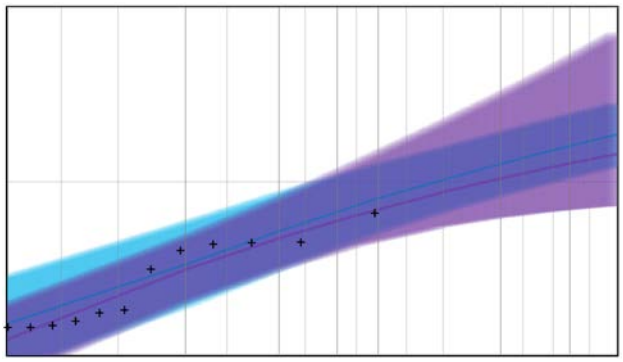
APPROVED / NOT APPROVED

Suzanne Shields, P.E.

10/16/18
Date

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

PC-HYDRO: Pima County Hydrologic Procedures Comprehensive Evaluation



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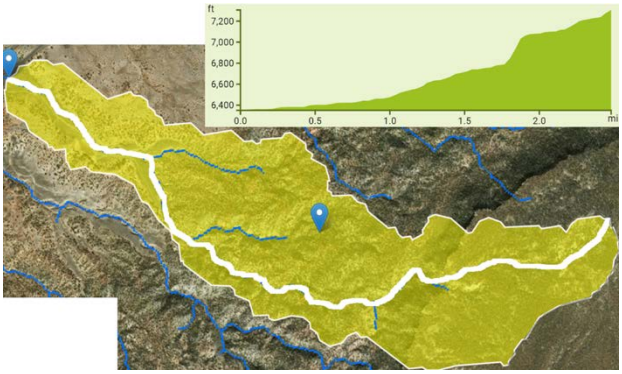

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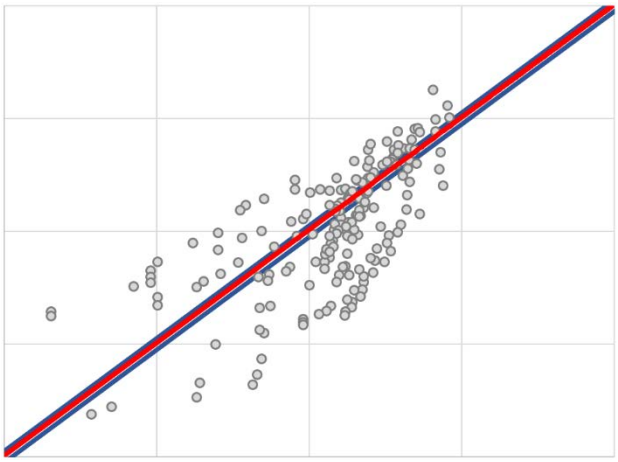

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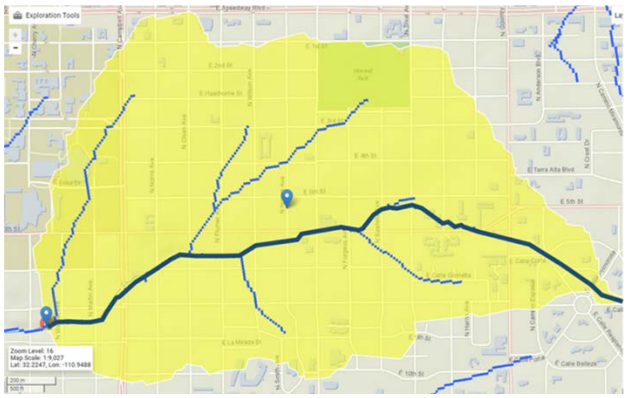

September 27, 2018

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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.

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 *Hydrology Manual for Engineering Design and Floodplain Management 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.
13. 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.

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_1 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 $P_1 = 0.88$ 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

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

Table 1. Detailed information on the selected gages

Station	Station name	Hyd. Flood Region	Drainage Area (mi²)	Years of record	Location	Has Development?
USGS [1] 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[2] 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

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[3] 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

[1] *United States Geological Survey*

[2] *Flood Control District of Maricopa County*

[3] *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):

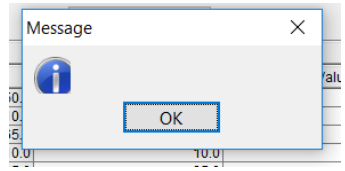


Figure 2. HEC-SSP unresolvable error message

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.

Table 2. Detailed information on the rejected gages

Station	Station name / Reason for rejection	Hyd. Flood Region	Drainage Area (mi^2)	Years of record	Location	Has Development?
USGS[1] 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[2]	Walnut Gulch 63.111 near Tombstone, AZ *(Could not locate data.)*	5	0.21	20	31°44'4"N 109°56'54"W	NO

[1] *United States Geological Survey*

[2] *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.

Table 3. Unused but potential viable gages

Station	Station name	Hyd. Flood Region	Drainage Area (mi^2)	Years of record	Location	Has Development?
USGS[1] 9496700	Cibecue 2 Tributary Carrizo Cr, AZ	4	0.06	14	33°59'17"N 110°18'40"W	NO
ARS[2] 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

[1] *United States Geological Survey*

[2] *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 *Guidelines for Determining Flood Flow Frequency* (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 (https://streamstats.usgs.gov/) 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.

Table 4. PC-Hydro sensitivity factors

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 (%)	Median value – 10%	Estimated from StreamStats, Google Earth, and other sources	Median value + 10%
Curve Number calculation	CN	Unadjusted CN	Adjusted CN	Adjusted CN
Rainfall	P (in)	Lower	Mid	Upper
# Lengths	N	2	4	8
Basin factors	n_b	Minimum per PC-Hydro User Guide	Average of minimum and maximum values specified in PC-Hydro User Guide	Maximum per PC-Hydro User Guide

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.

Table 5. Example of hypothetical length increment sensitivity data

All eight points used			*Four points used*			*Two points used*		
Index	L_i (ft)	X_i (ft)	Index	L_i (ft)	X_i (ft)	Index	L_i (ft)	X_i (ft)
1	20	0.4	1	95	0.7	1	165	1.9
2	75	0.3						
3	30	0.5	2	70	1.2			
4	40	0.7						
5	50	1.1	3	75	2.3	2	155	9.0
6	25	1.2						
7	35	3.2	4	80	6.7			
8	45	3.5						

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:

$$\Delta \ln Q = \frac{1}{2}\sqrt{\begin{array}{c}(\ln Q_{Vmax} - \ln Q_{Vmin})^2 + (\ln Q_{Imax} - \ln Q_{Imin})^2 + (\ln Q_{CNmax} - \ln Q_{CNmin})^2 + \\ (\ln Q_{Pmax} - \ln Q_{Pmin})^2 + (\ln Q_{Nmax} - \ln Q_{Nmin})^2 + \left(\ln Q_{n_b max} - \ln Q_{n_b min}\right)^2\end{array}}$$

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, $\ln Q_{Vmax}$ 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^n versus 2n). The exact computation is accomplished by taking the standard deviation of all 2^n terms (64 here). A comparison between the OFAT and Rosenblueth standard deviations is shown graphically in Figure 3.

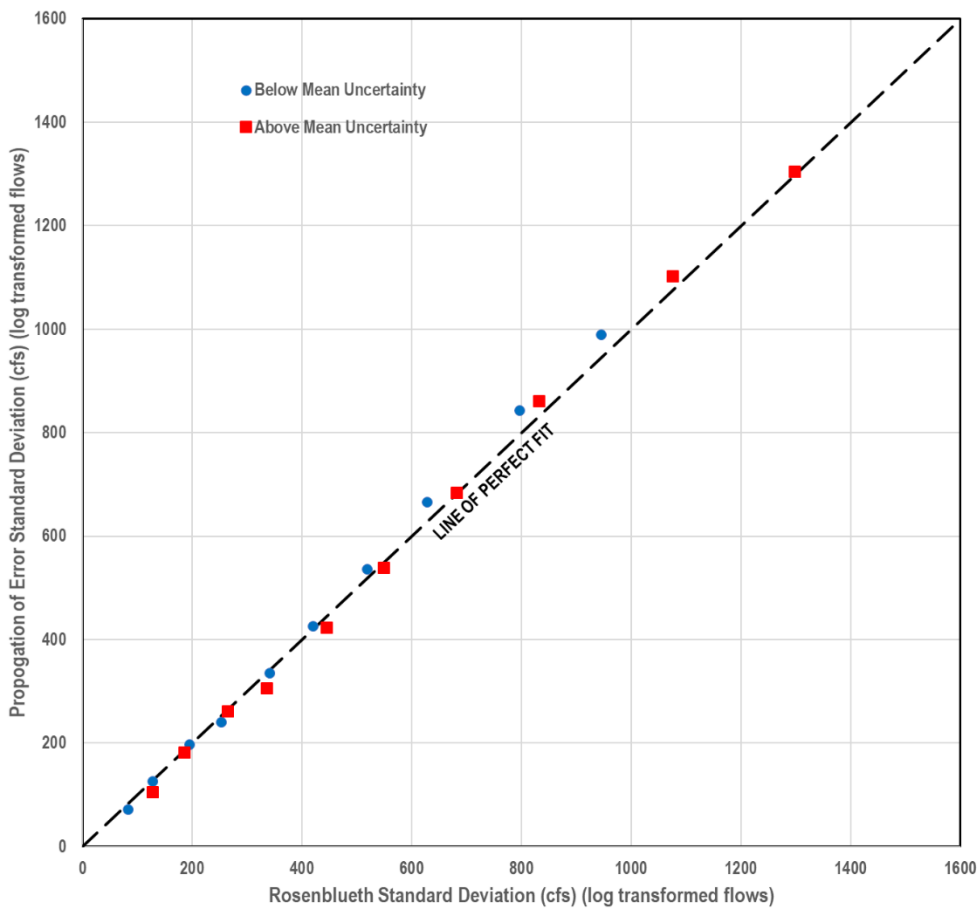


Figure 3. Peak flow uncertainty calculations by propagation of error versus Rosenblueth Standard Deviation

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.

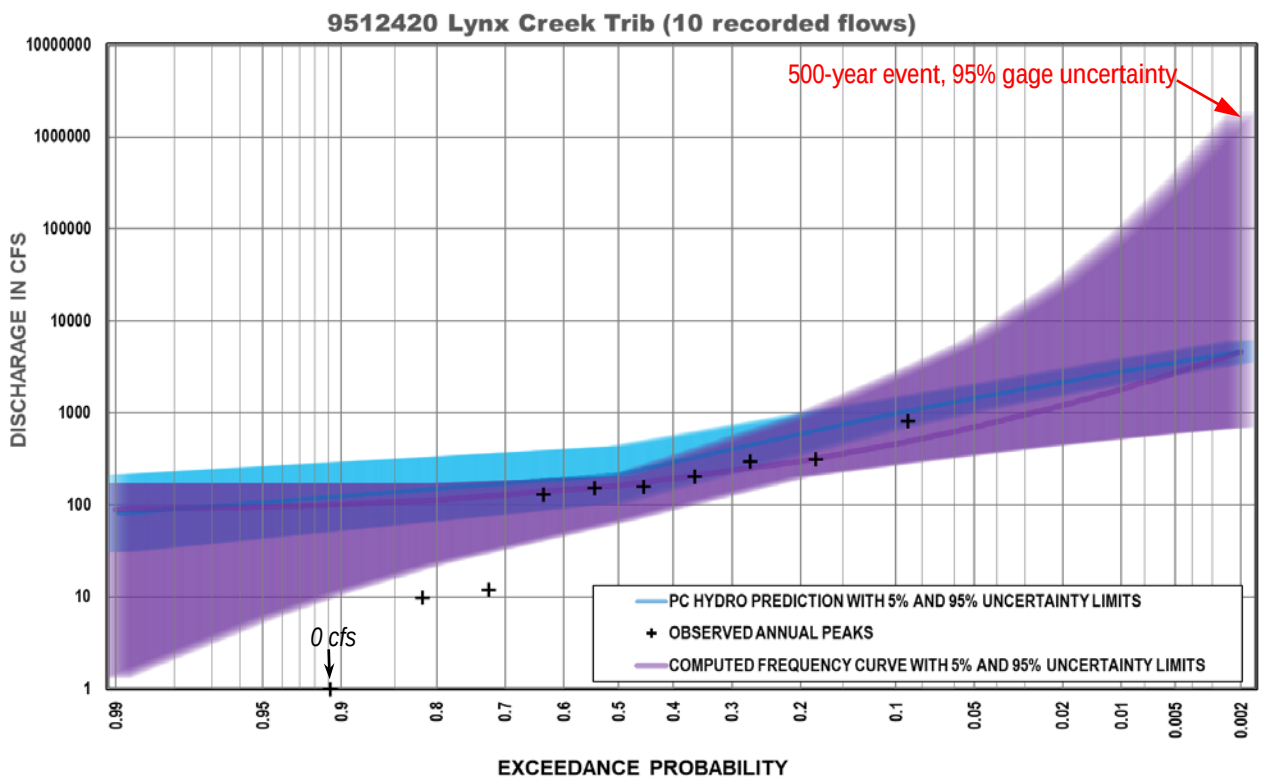


Figure 4. Lynx Creek Tributary frequency analysis results

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.

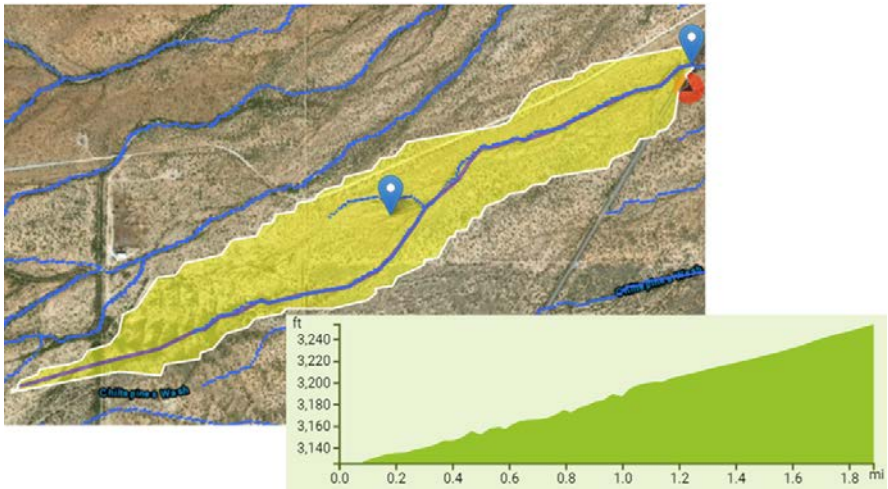
PC-HYDRO V.6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/20/2018
Project Notes:

Gage Information
Name: Chiltepines Wash near Sasabe, AZ
Agency: USGS
Station: 9486700
Northing: 31°49'8"N Easting: 111°26'18"W
(in decimal form: 31.81889,-111.43833

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.34
L Cen Grav (ft): 4300

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Valley	13.1	1426	0.009	0.035	0.027	0.050	26.9	2640	0.010	0.035	0.029	0.044	64.3	5068	0.013	0.035	0.03	0.042
None	Foothills	13.8	1214	0.011	0.035	0.030	0.040												
None	Foothills	15.0	1214	0.012	0.035	0.030	0.040	37.4	2428	0.015	0.035	0.03	0.04						
None	Foothills	22.4	1214	0.018	0.035	0.030	0.040												
None	Foothills	16.3	1267	0.013	0.035	0.030	0.040	31.5	2587	0.012	0.035	0.03	0.04	64.2	4910	0.013	0.035	0.03	0.04
None	Foothills	15.2	1320	0.012	0.035	0.030	0.040												
None	Foothills	18.0	1267	0.014	0.035	0.030	0.040	32.7	2323	0.014	0.035	0.03	0.04						
None	Foothills	14.7	1056	0.014	0.035	0.030	0.040												

Watercourse Length: 9978 ft
Mean slope: 0.013 ft/ft
Wt Basin Factors: 0.035 0.030 0.041

Mean slope: 0.013 ft/ft
Wt Basin Factors: 0.035 0.030 0.041

Mean slope: 0.013 ft/ft
Wt Basin Factor: 0.035 0.030 0.041

Soil	Percent
Type B	81%
Type C	19%
Type D	0%

Red Font: User entry
Blue font: Calculation

Figure 5. Chiltepines Wash preprocessing in Excel

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 $(\ln Q)_{ave}$] 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: $(\ln Q)_{ave} - \Delta \ln Q$;
5. Likewise, high estimates of the flows were made by adding the log transformed uncertainty to the average of the log transformed flows: $(\ln Q)_{ave} + \Delta \ln Q$;
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.

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

Property	Minimum *(Corresponding watershed)*	Median	Mean	Maximum *(Corresponding watershed)*
Drainage Area (mi^2)	0.06 mi^2 *(Cibecue 1 Tributary Carrizo Creek)*	0.63 mi^2	0.61 mi^2	1.07 mi^2 *(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% *(Multiple)*	10%	15%	*40%* *(High School Wash at Tucson, AZ)*
Vegetation (%)	5% *(Cunningham Wash Tributary near Wenden)*	11%	16%	40% *(Hull Canyon near Jerome)*

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.

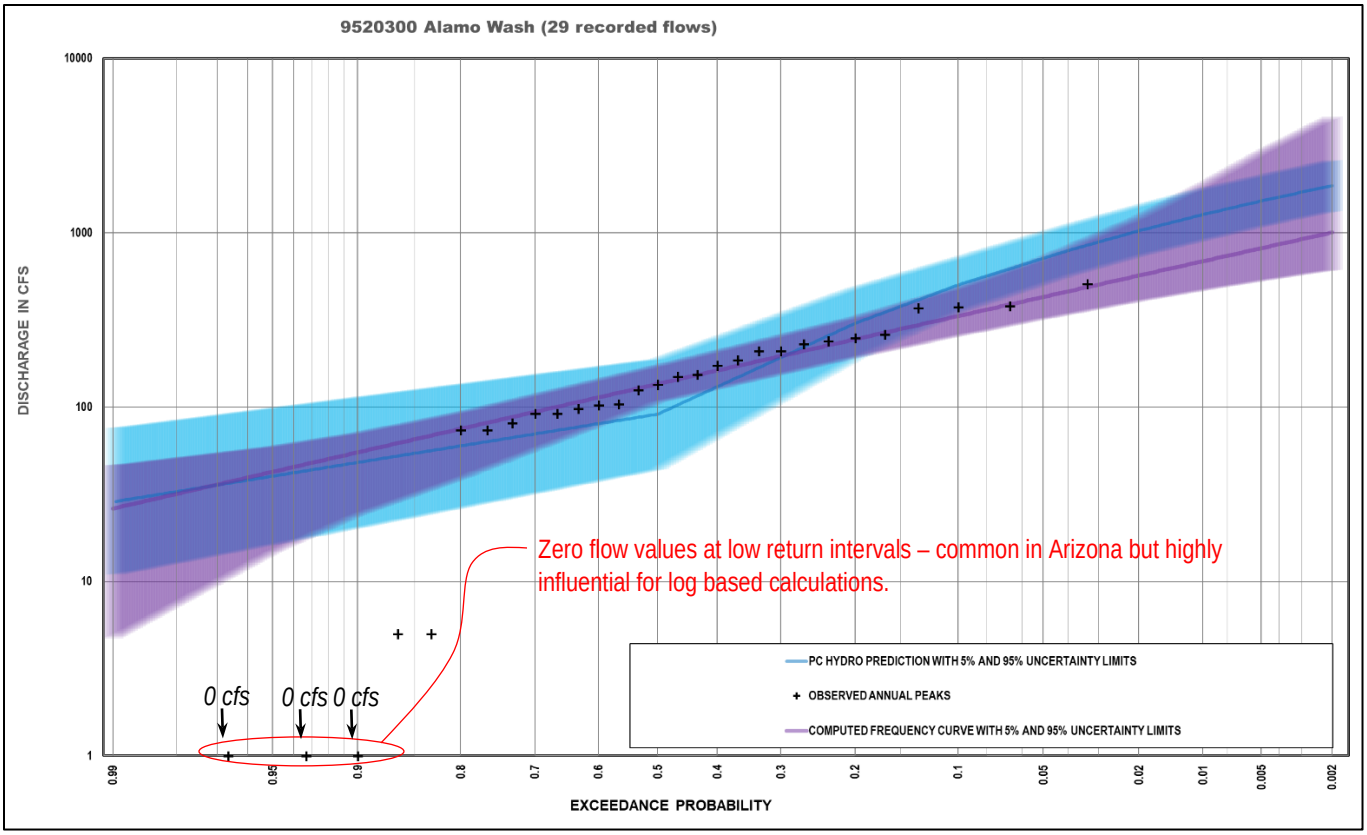


Figure 6. Comparison between PC-Hydro and recorded data frequency analysis at Alamo Wash

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^2 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 versus measured flows to the origin acknowledges the limits wherein both measured and predicted flows will always be zero, such as completely pervious soil, a zero watershed area, etc.)

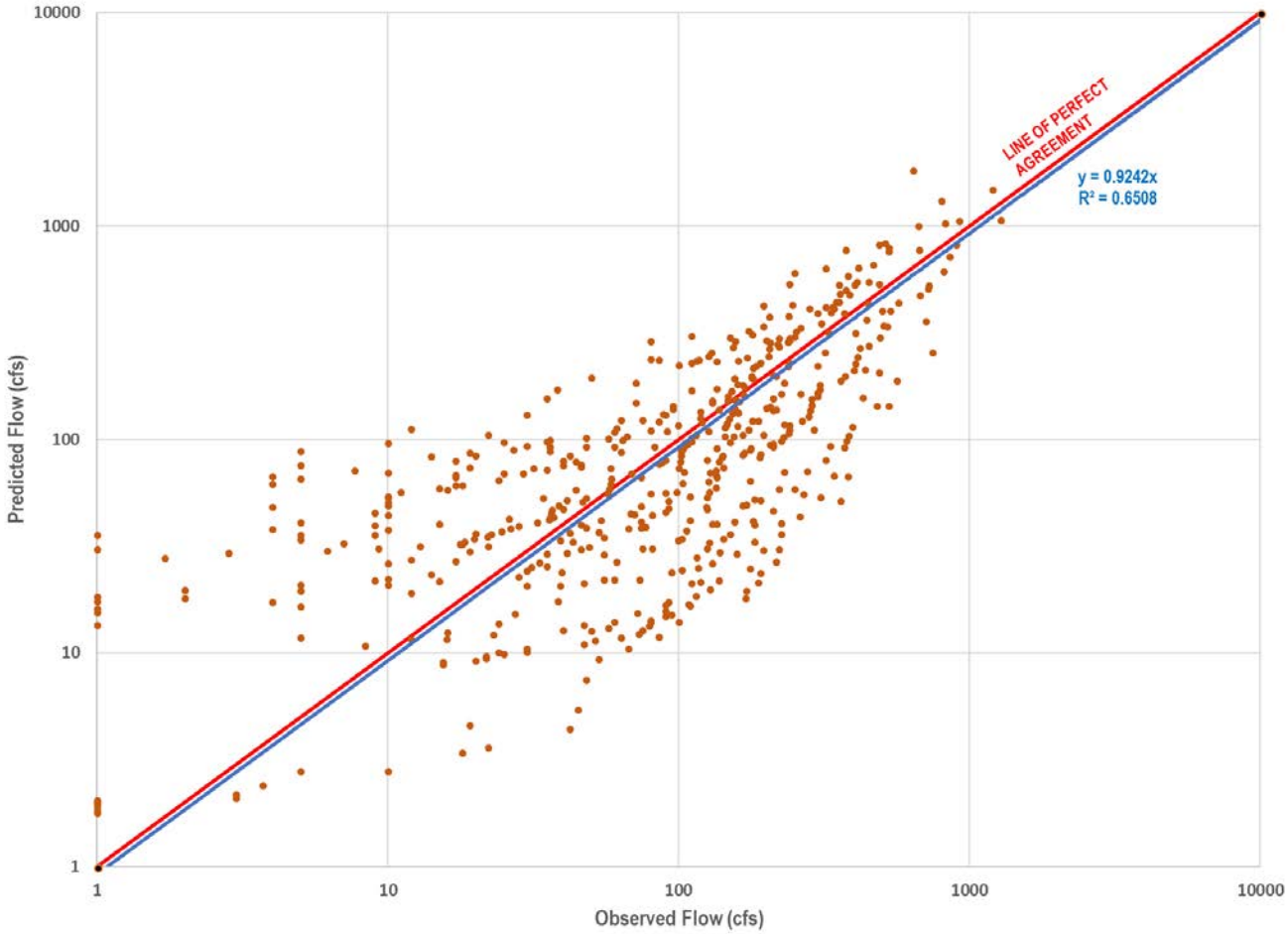


Figure 7. Comparison between PC-Hydro predictions (50% NOAA rainfall / median factors) and all gage data

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.

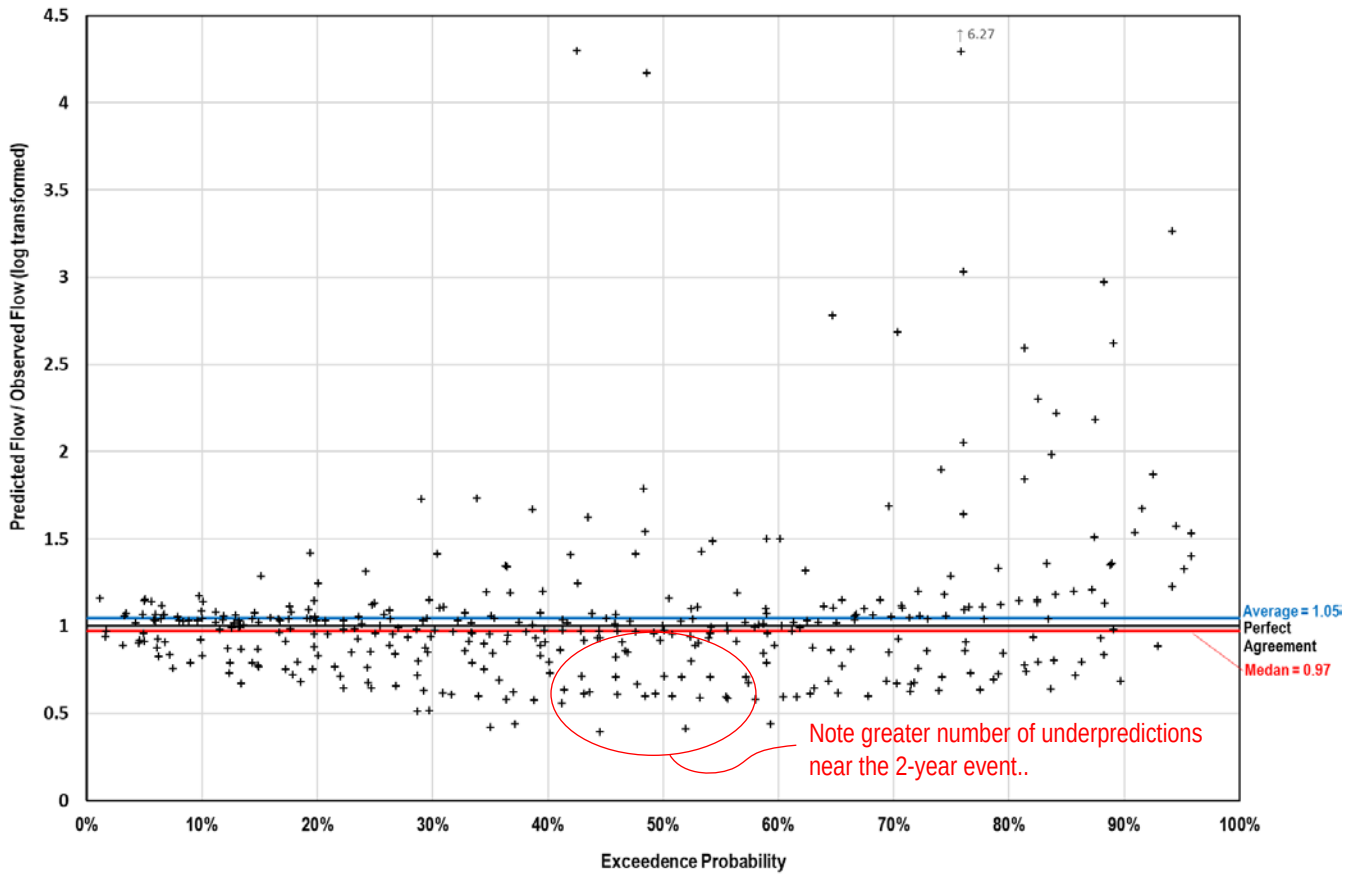


Figure 8. Ratio of log transformed PC-Hydro predictions (50% NOAA rainfall / median factors) / log transformed observed flows versus exceedance probability

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.

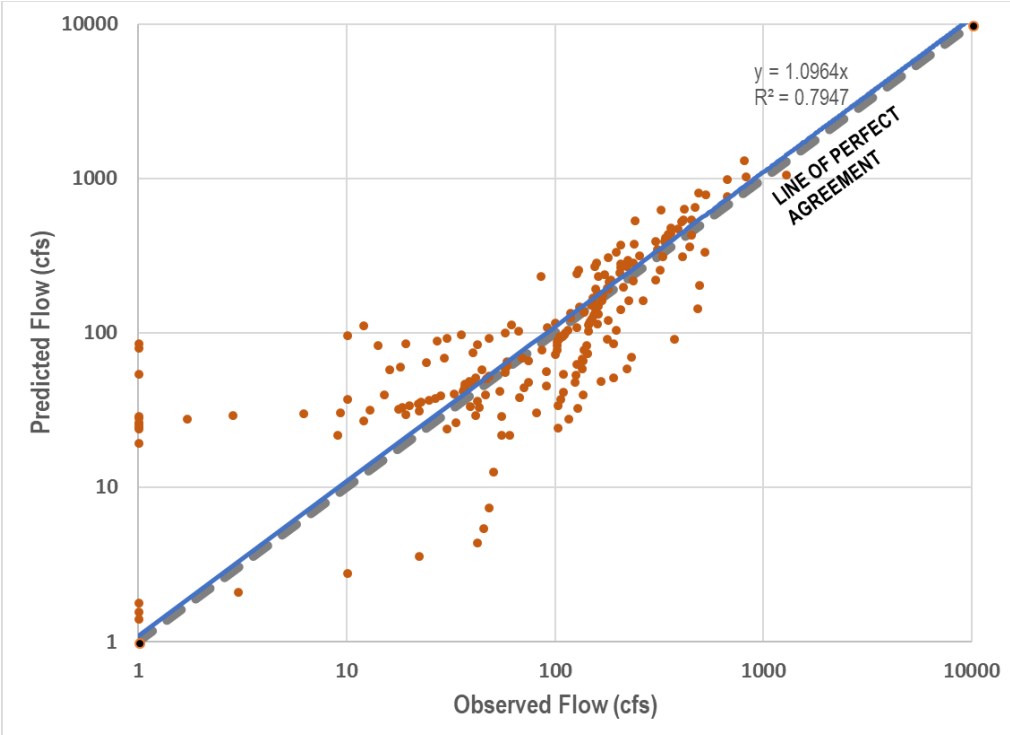


Figure 9. PC-Hydro predictions (50% NOAA rainfall / median factors) versus observed flows at 11 developed watersheds

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.

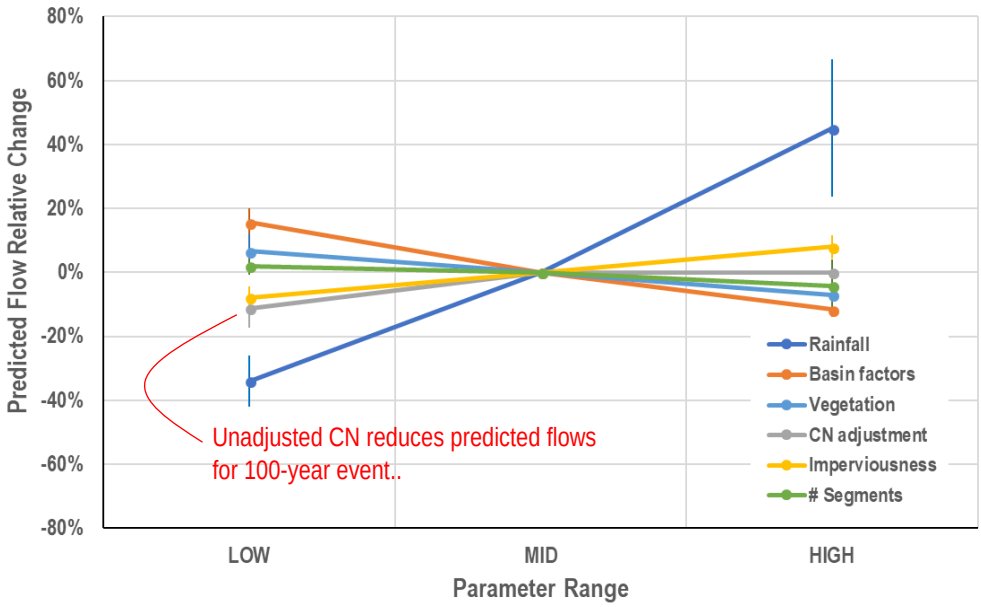


Figure 10. 100-year flood sensitivity of the tested parameters
(error bars indicate one standard deviation)

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 100-year 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.

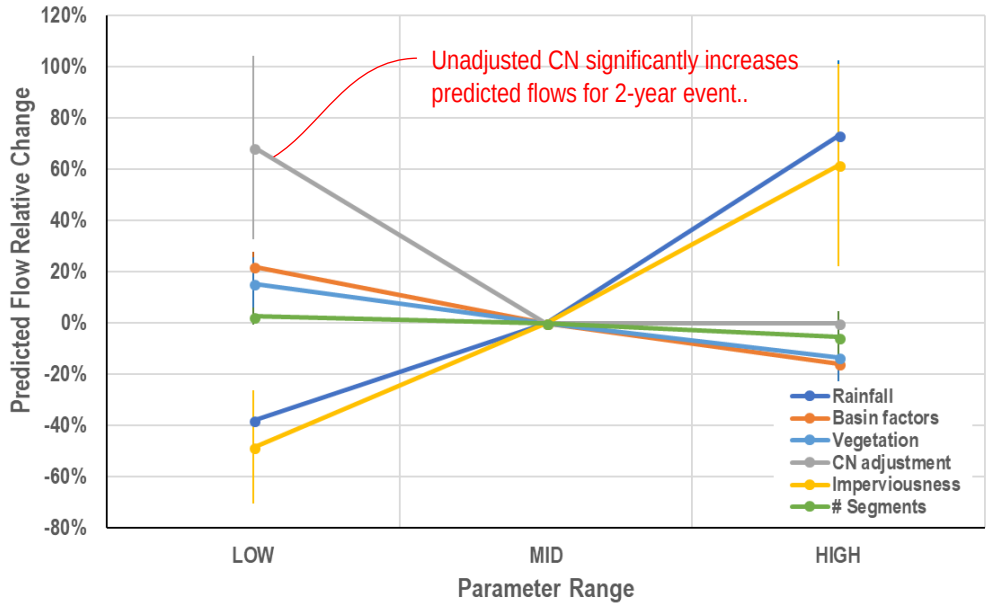


Figure 11. 2-year flood sensitivity of the tested parameters (error bars indicate one standard deviation)

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).

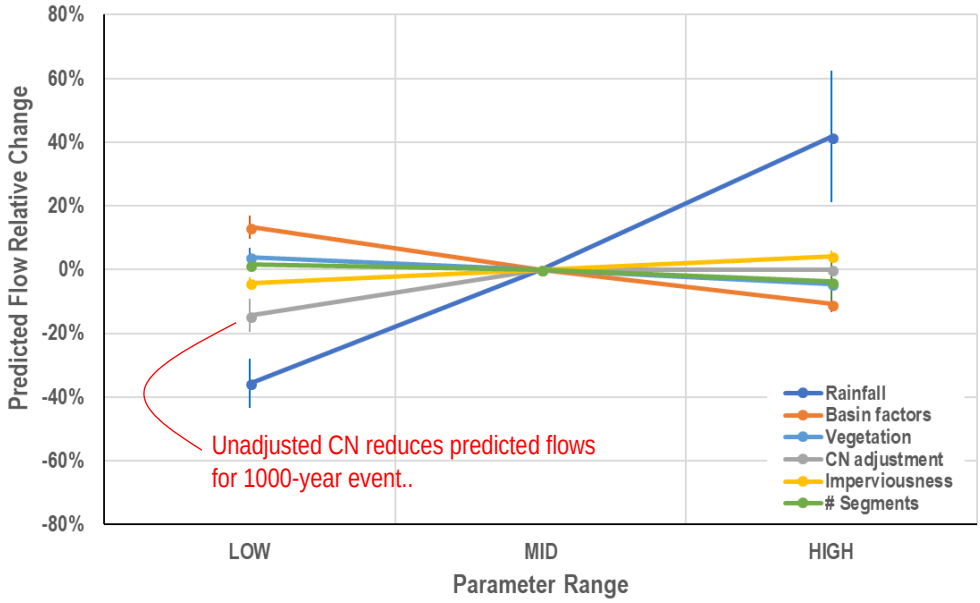


Figure 12. 1000-year flood sensitivity of the tested parameters (error bars indicate one standard deviation)

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).

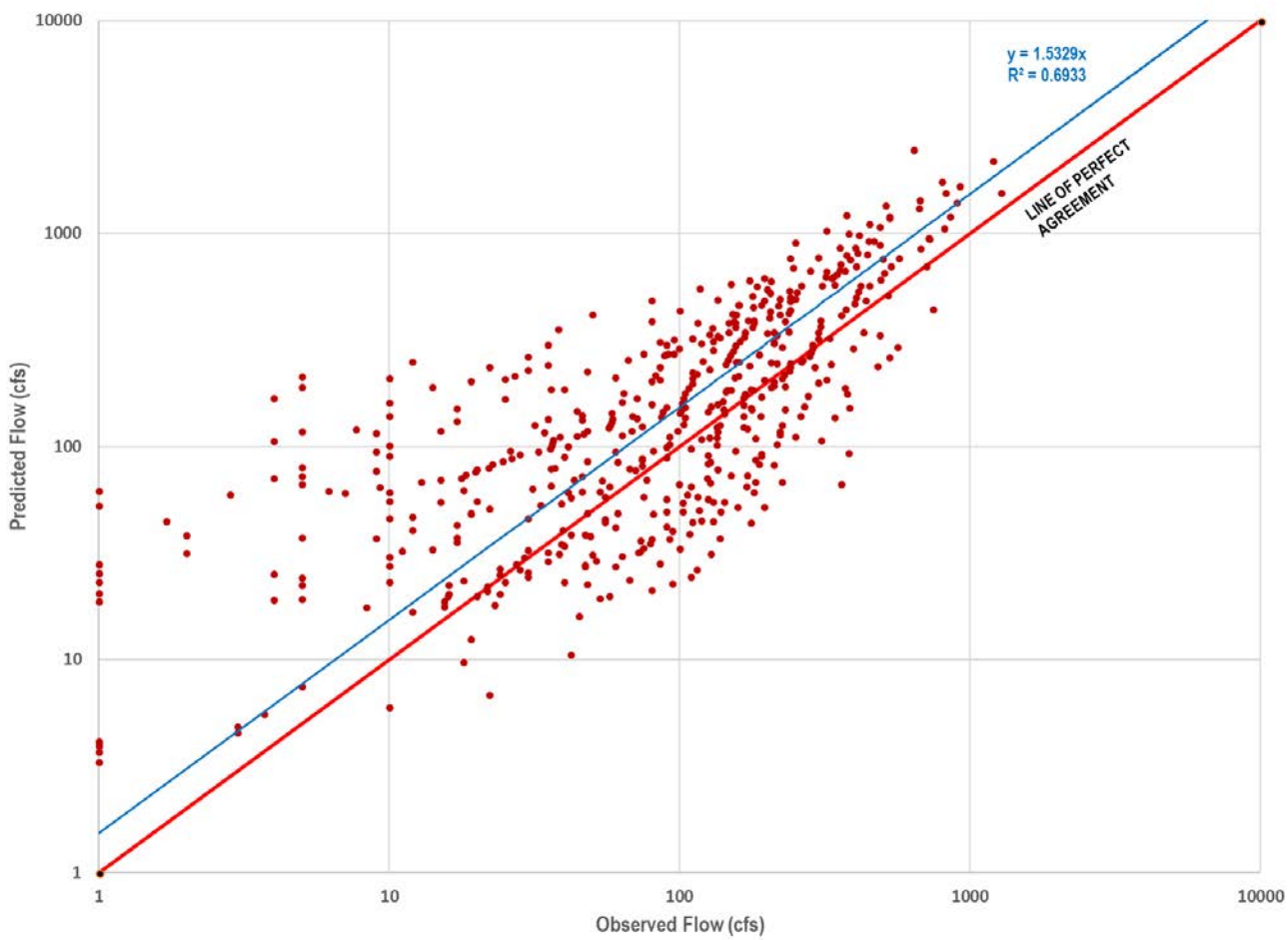


Figure 13. Comparison between design predictions (95% NOAA rainfall / median factors) and gage data

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^2 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).

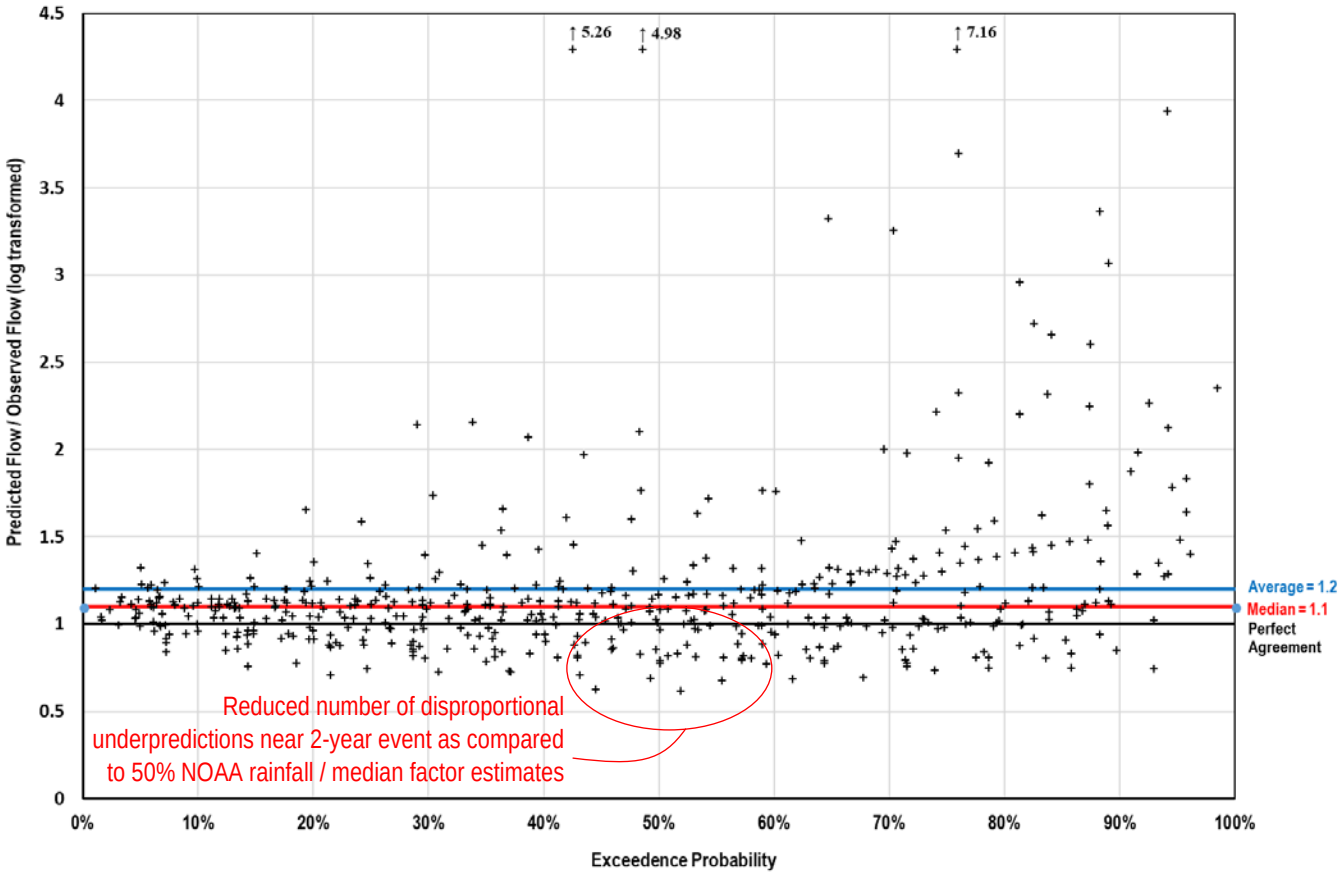


Figure 14. Ratio of log transformed design predictions (95% NOAA rainfall / median factors) / log transformed observed flows versus exceedance probability

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.

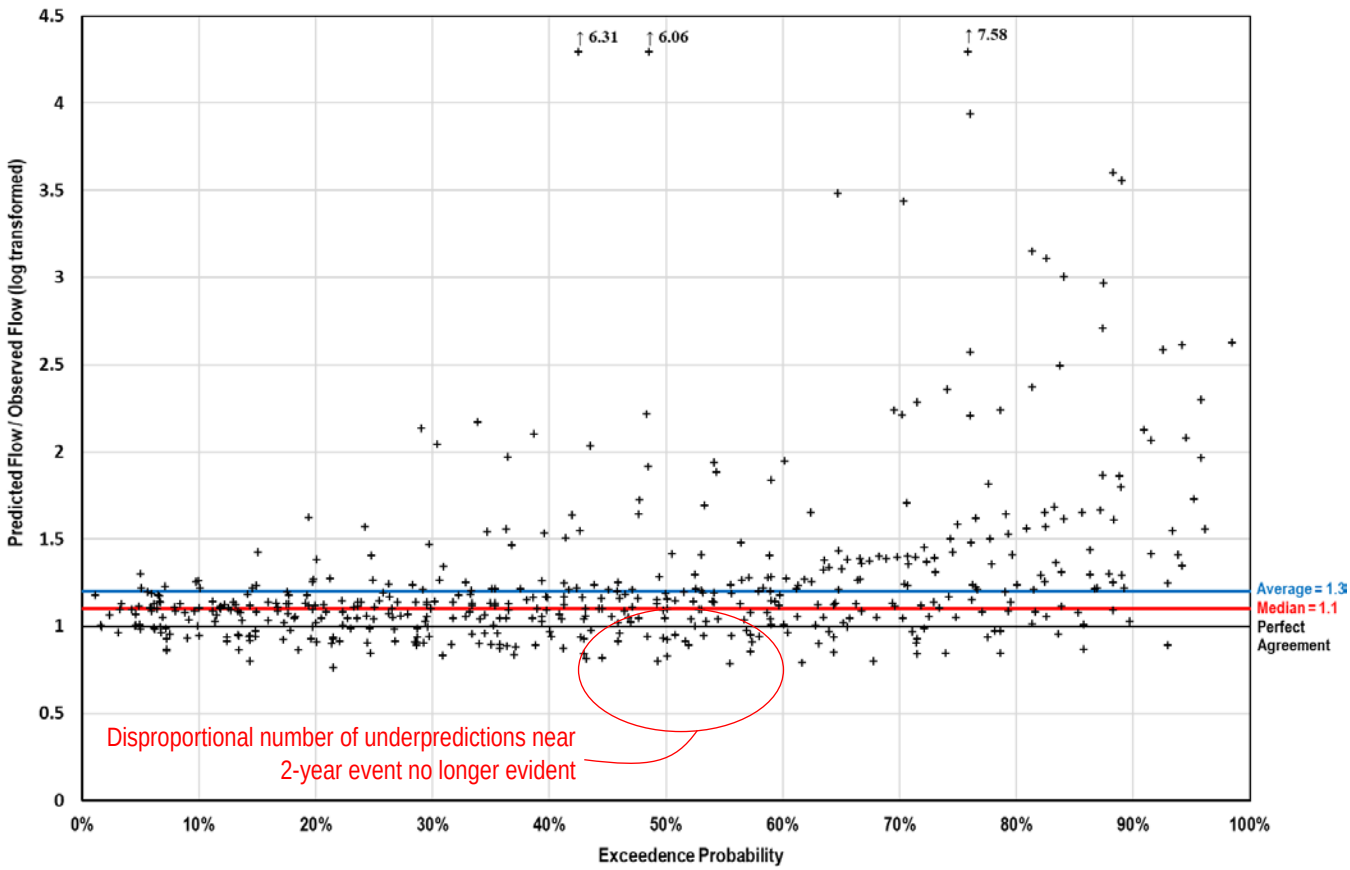


Figure 15. Ratio of log transformed unadjusted CN design predictions (95% NOAA rainfall / median factors) / log transformed observed flows versus exceedance probability

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^2 values have remained more or less than same (the slope changed from 1.53 to 1.51, and the R^2 decreased slightly from 0.69 to 0.64).

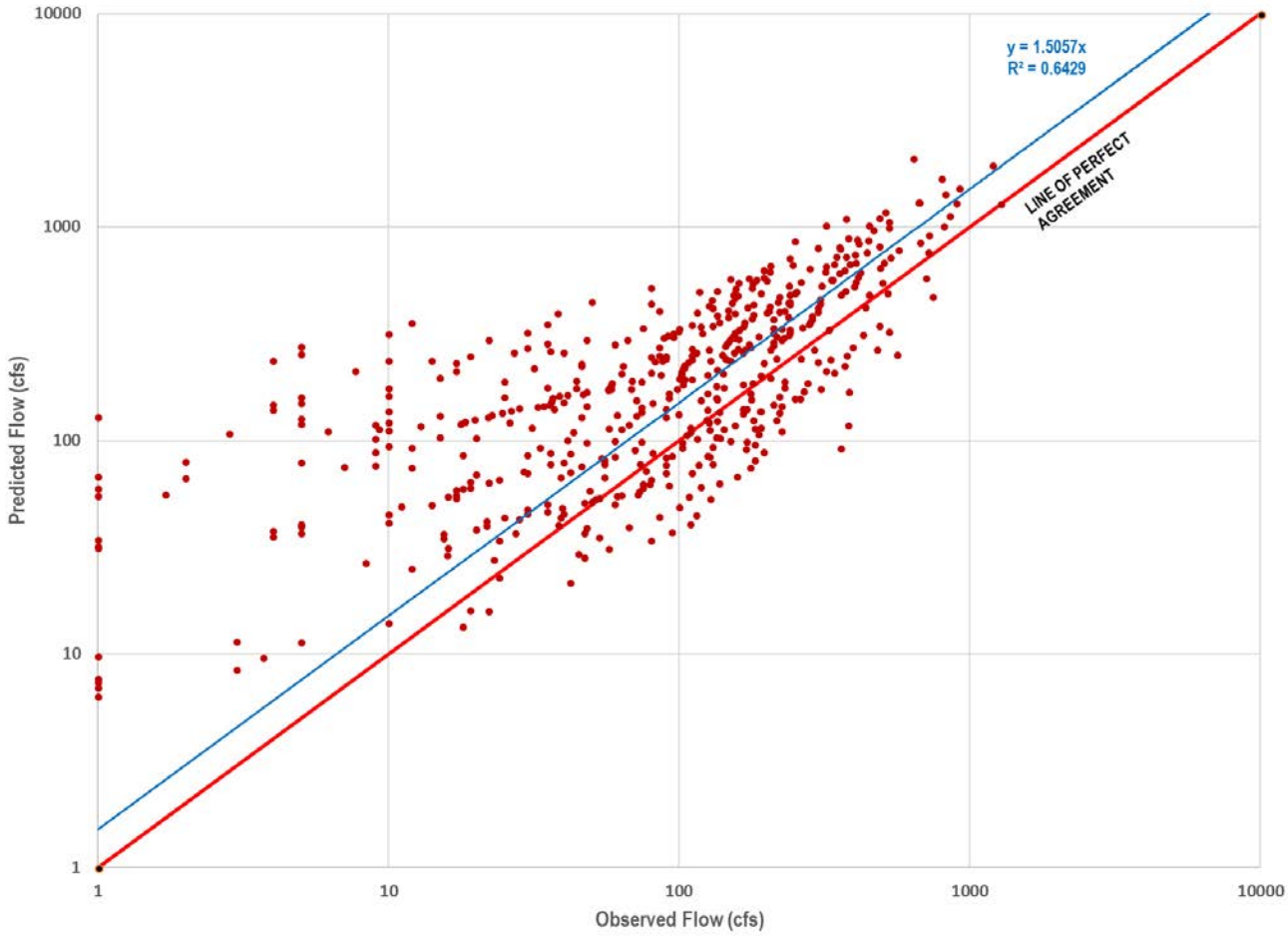


Figure 16. Comparison between PC-Hydro unadjusted design predictions (95% NOAA rainfall / median factors) and all gage data

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.

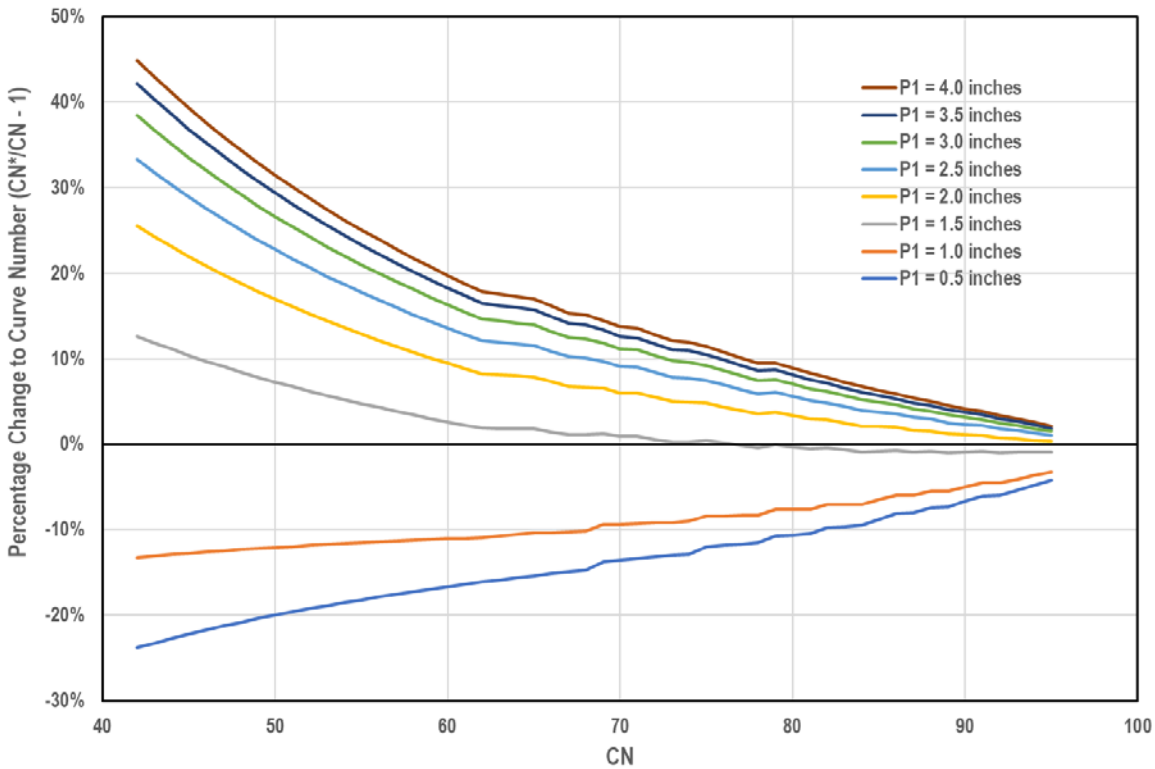


Figure 17. Percentage difference between CN* and CN

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 possible in watersheds throughout Arizona. As a result, the CN* corrections may not be accurate for 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).

Table 7. Predictive success for various design approaches

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%

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.
- 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.
  - 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^2 value and the exponent close to 0, indicating little to no relationship between area and PC-Hydro predictive accuracy.

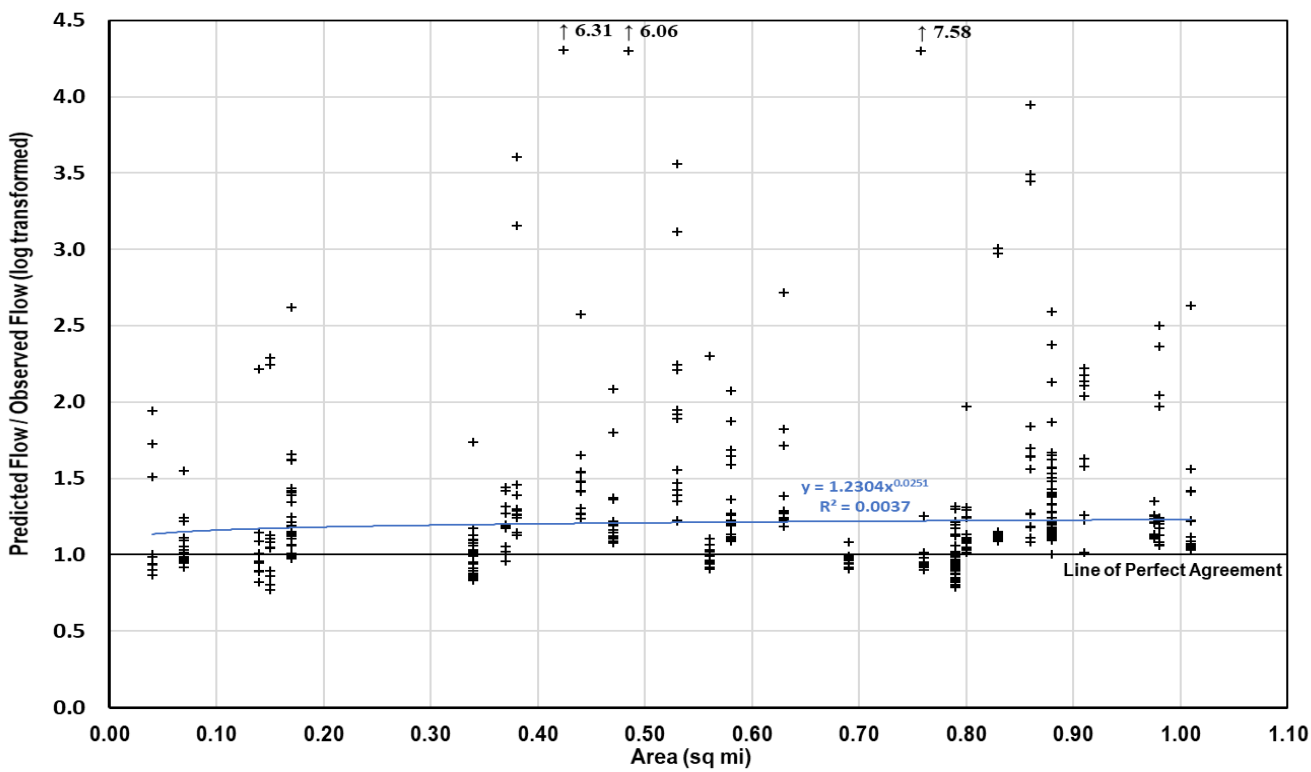


Figure 18. Observed flow / predicted flow (95% upper rainfall, non-adjusted CN) versus watershed area

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.

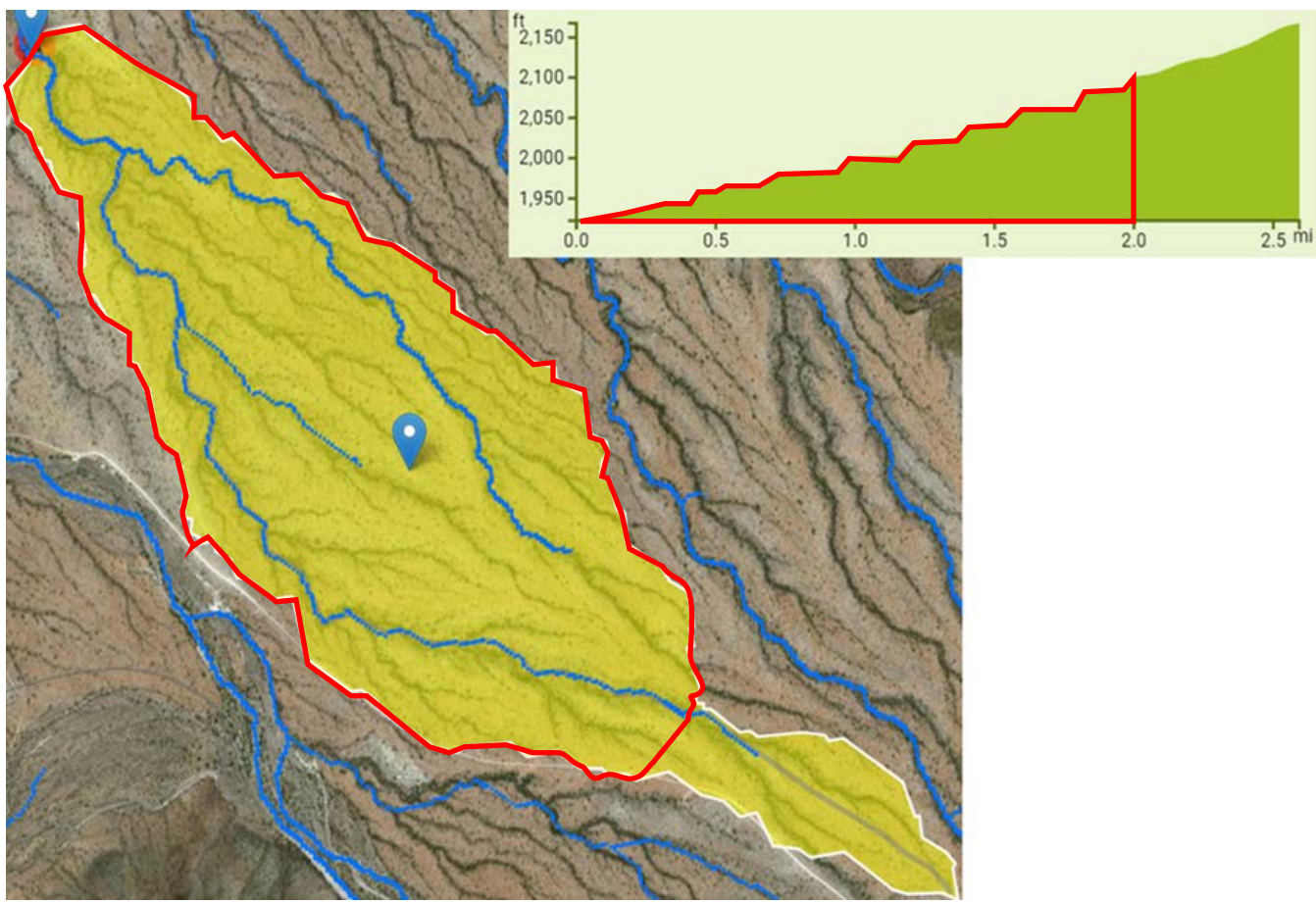


Figure 19. Alamo Wash with complete extents and contributing extents from smaller storm duration (red lines)

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

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

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 99th 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.

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Appendix A. Individual Gage and Watershed Detailed Information

Agua Fria River Trib 2 near Rock Springs, AZ

PC-HYDRO V. 6 ANALYSIS

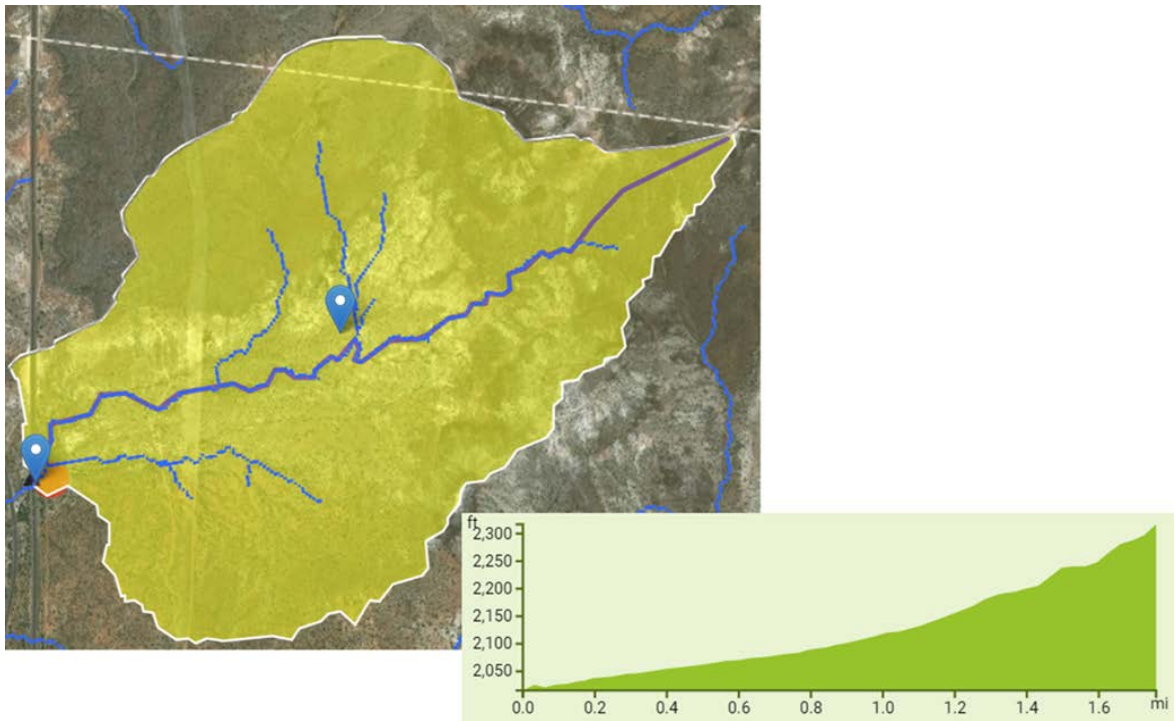
Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018

Project Notes:
00000-1

Gage Information
Name: Agua Fria River Trib 2 near Rock Springs, AZ
Agency: USGS
Station: 9512700
Northing: 34°02'00"N Easting: 112°08'42"W
(in decimal form: 34.03333,-112.14500

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 1.01
L Cen Grav (ft): 4300

	Normal	Minimum	Maximum
Veg cover (%):	15%	5%	25%
% impervious:	17%	7%	27%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	23.6	1162	0.020	0.035	0.030	0.040	43	2376	0.018	0.035	0.03	0.04	85.6	4699	0.018	0.035	0.03	0.04
None	Foothills	19.4	1214	0.016	0.035	0.030	0.040												
None	Foothills	17.1	1109	0.015	0.035	0.030	0.040	42.6	2323	0.018	0.035	0.03	0.04						
None	Foothills	25.5	1214	0.021	0.035	0.030	0.040												
None	Foothills	32.2	1109	0.029	0.035	0.030	0.040	90.8	2323	0.039	0.044	0.036	0.052	216	4593	0.047	0.048	0.038	0.057
None	Mountain	58.6	1214	0.048	0.050	0.040	0.060												
None	Mountain	49.2	1214	0.041	0.050	0.040	0.060	126	2270	0.055	0.05	0.04	0.06						
None	Mountain	76.3	1056	0.072	0.050	0.040	0.060												

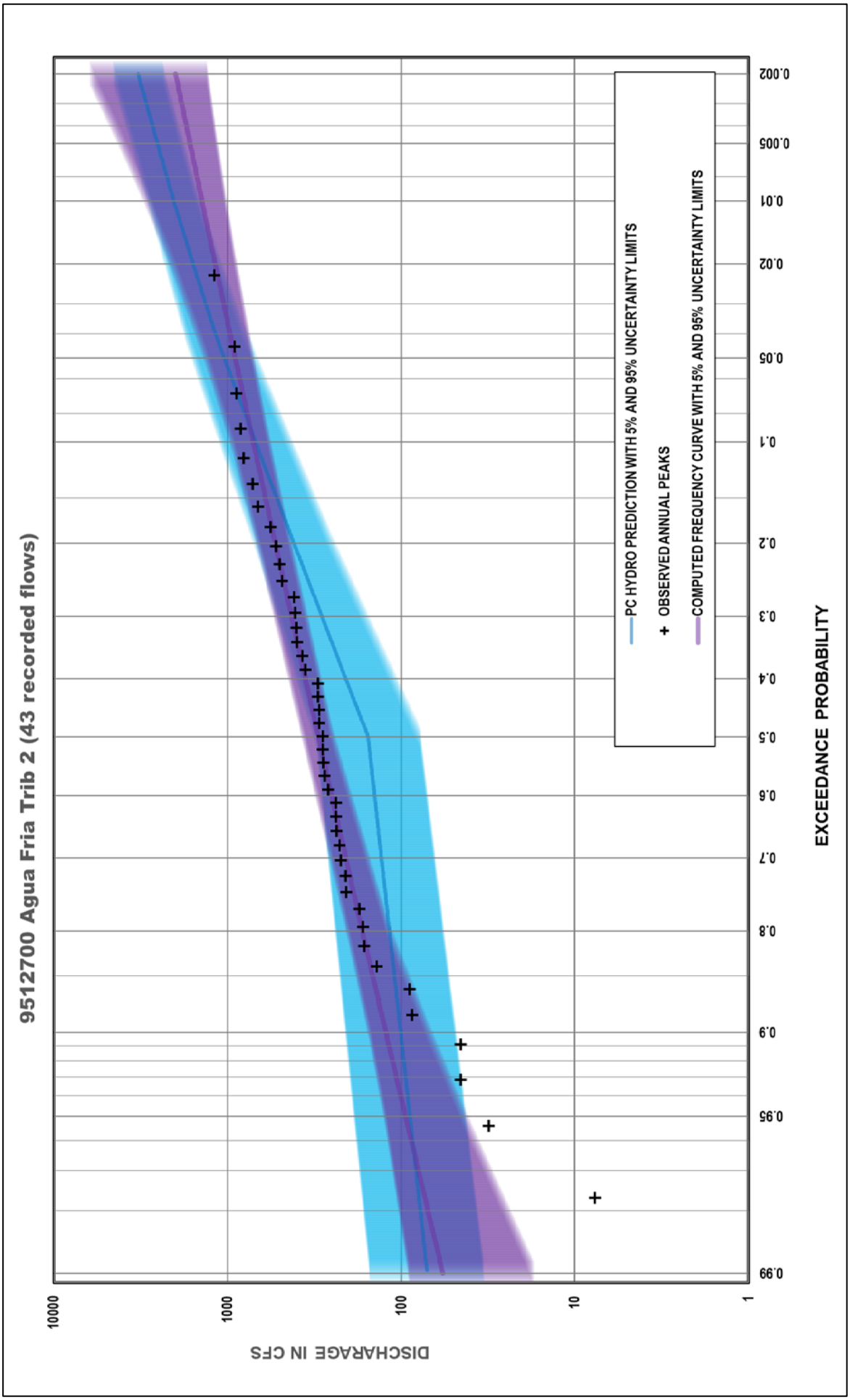
Watercourse Length: 9292 ft
Mean slope: 0.027 ft/ft
Wt Basin Factors: 0.041 0.034 0.047

Mean slope: 0.027 ft/ft
Wt Basin Factors: 0.041 0.034 0.048

Mean slope: 0.028 ft/ft
Wt Basin Factor: 0.041 0.034 0.048

Soil	Percent
Type B	20%
Type C	18%
Type D	62%

Red Font: User entry
Blue font: Calculation


9512700 Agua Fria Trib 2 (43 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
DISCHARAGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Alamo Wash Tributary near Ajo, AZ

PC-HYDRO V. 6 ANALYSIS

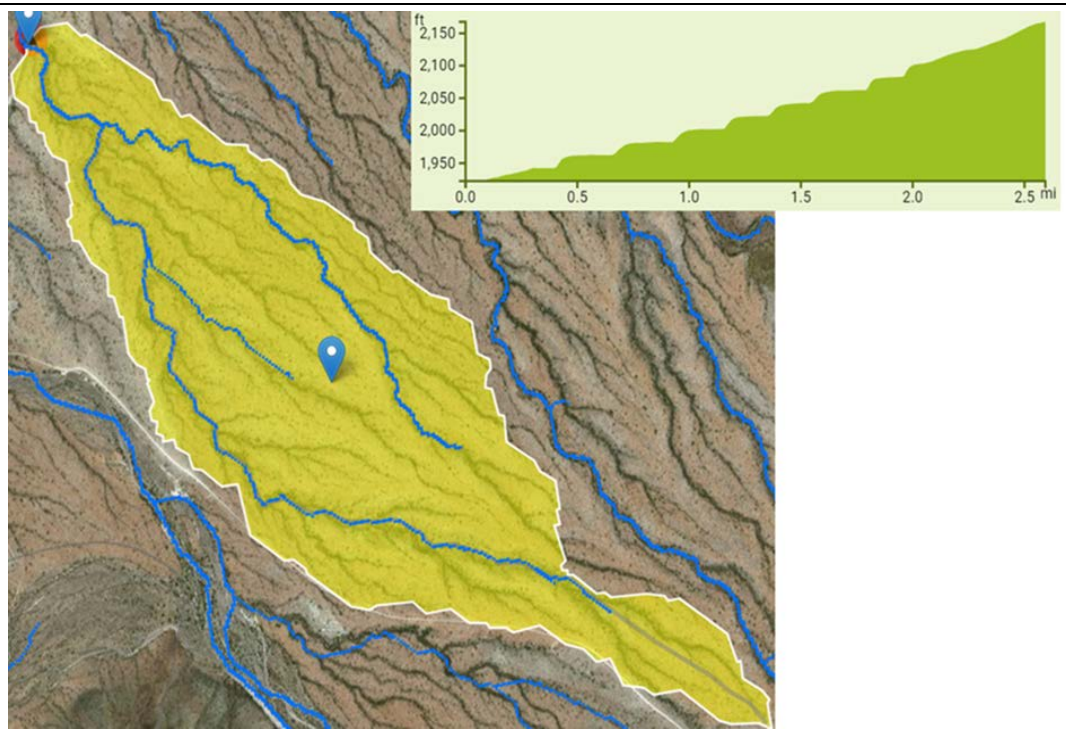
Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018

Project Notes:
0 0 0 0 0-1

Gage Information
Name: Alamo Wash Tributary near Ajo, AZ
Agency: USGS
Station: 9520300
Northing: 32°6'0"N Easting: 112°46'17"W
(in decimal form: 32.10000,-112.77139

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.83
L Cen Grav (ft): 6700

	Normal	Minimum	Maximum
Veg cover (%):	20%	10%	30%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	19.5	1742	0.011	0.035	0.030	0.040	39.9	3484	0.011	0.035	0.03	0.04	99.9	6864	0.015	0.035	0.03	0.04
None	Foothills	20.4	1742	0.012	0.035	0.030	0.040												
None	Foothills	35.6	1690	0.021	0.035	0.030	0.040	60	3380	0.018	0.035	0.03	0.04						
None	Foothills	24.4	1690	0.014	0.035	0.030	0.040												
None	Foothills	37.1	1690	0.022	0.035	0.030	0.040	60.3	3432	0.018	0.035	0.03	0.04	145	6812	0.021	0.035	0.03	0.04
None	Foothills	23.2	1742	0.013	0.035	0.030	0.040												
None	Foothills	42.6	1690	0.025	0.035	0.030	0.040	85	3380	0.025	0.035	0.03	0.04						
None	Foothills	42.4	1690	0.025	0.035	0.030	0.040												

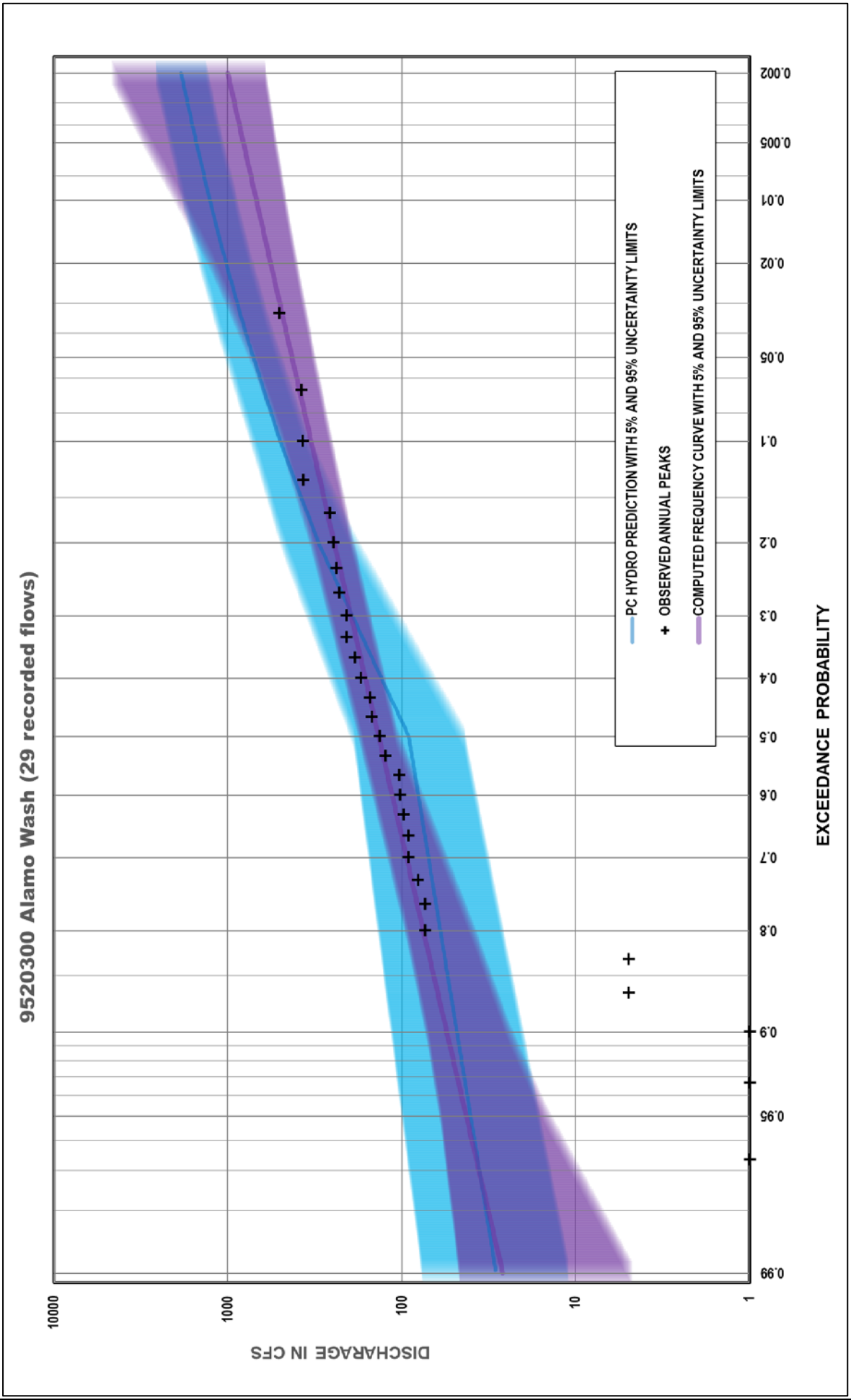
Watercourse Length: 13676 ft
Mean slope: 0.017 ft/ft
Wt Basin Factors: 0.035 0.030 0.040

Mean slope: 0.017 ft/ft
Wt Basin Factors: 0.035 0.030 0.040

Mean slope: 0.017 ft/ft
Wt Basin Factor: 0.035 0.030 0.040

Soil	Percent
Type B	18%
Type C	11%
Type D	71%

Red Font: User entry
Blue font: Calculation


9520300 Alamo Wash (29 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Black Creek Tributary near Window Rock, AZ

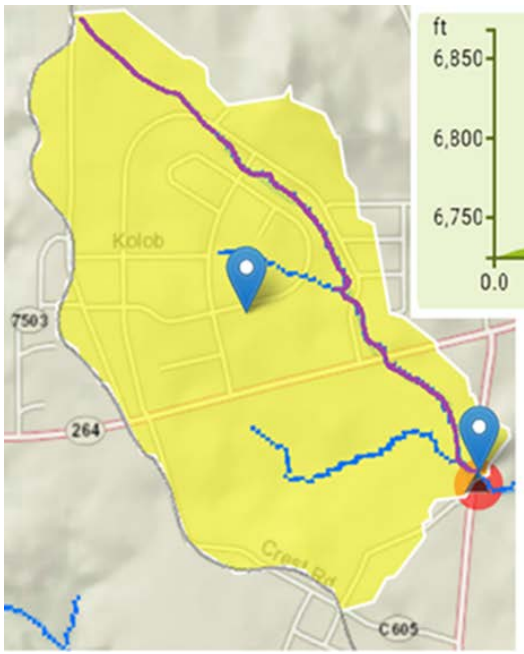
PC-HYDRO V. 6 ANALYSIS

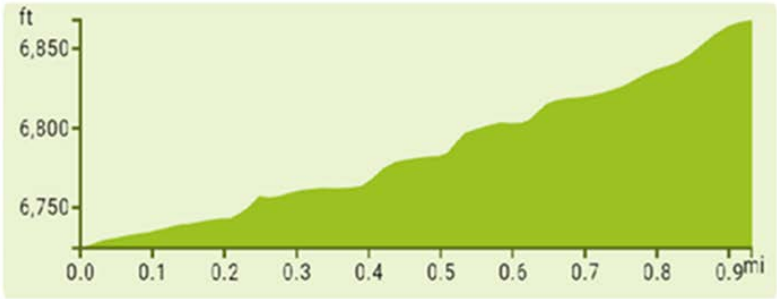
Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Black Creek Tributary near Window Rock, AZ
Agency: USGS
Station: 9395850
Northing: 35°39'15"N Easting: 109°5'22"W
(in decimal form: 35.65417,-109.08944

Watershed Information
Watershed: Suburban Foothills
Veg cover type: Mountain Brush
Area (sq. mi.): 0.34
L Cen Grav (ft): 2950

	Normal	Minimum	Maximum
Veg cover (%):	20%	10%	30%
% impervious:	20%	10%	30%





		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	11.3	581	0.020	0.035	0.030	0.040	18.8	1109	0.017	0.035	0.03	0.039	55.9	2376	0.024	0.033	0.029	0.037
<1 house/ac	Foothills	7.5	528	0.014	0.034	0.029	0.038												
1-2 houses/ac	Foothills	19.0	686	0.028	0.032	0.028	0.036	37.1	1267	0.029	0.032	0.028	0.036						
1-2 houses/ac	Foothills	18.0	581	0.031	0.032	0.028	0.036												
1-2 houses/ac	Foothills	21.7	634	0.034	0.032	0.028	0.036	38.7	1215	0.032	0.032	0.028	0.036	87.8	2535	0.035	0.033	0.029	0.037
1-2 houses/ac	Foothills	17.0	581	0.029	0.032	0.028	0.036												
1-2 houses/ac	Foothills	17.7	634	0.028	0.032	0.028	0.036	49.1	1320	0.037	0.033	0.029	0.037						
<1 house/ac	Mountain	31.4	686	0.046	0.034	0.029	0.038												

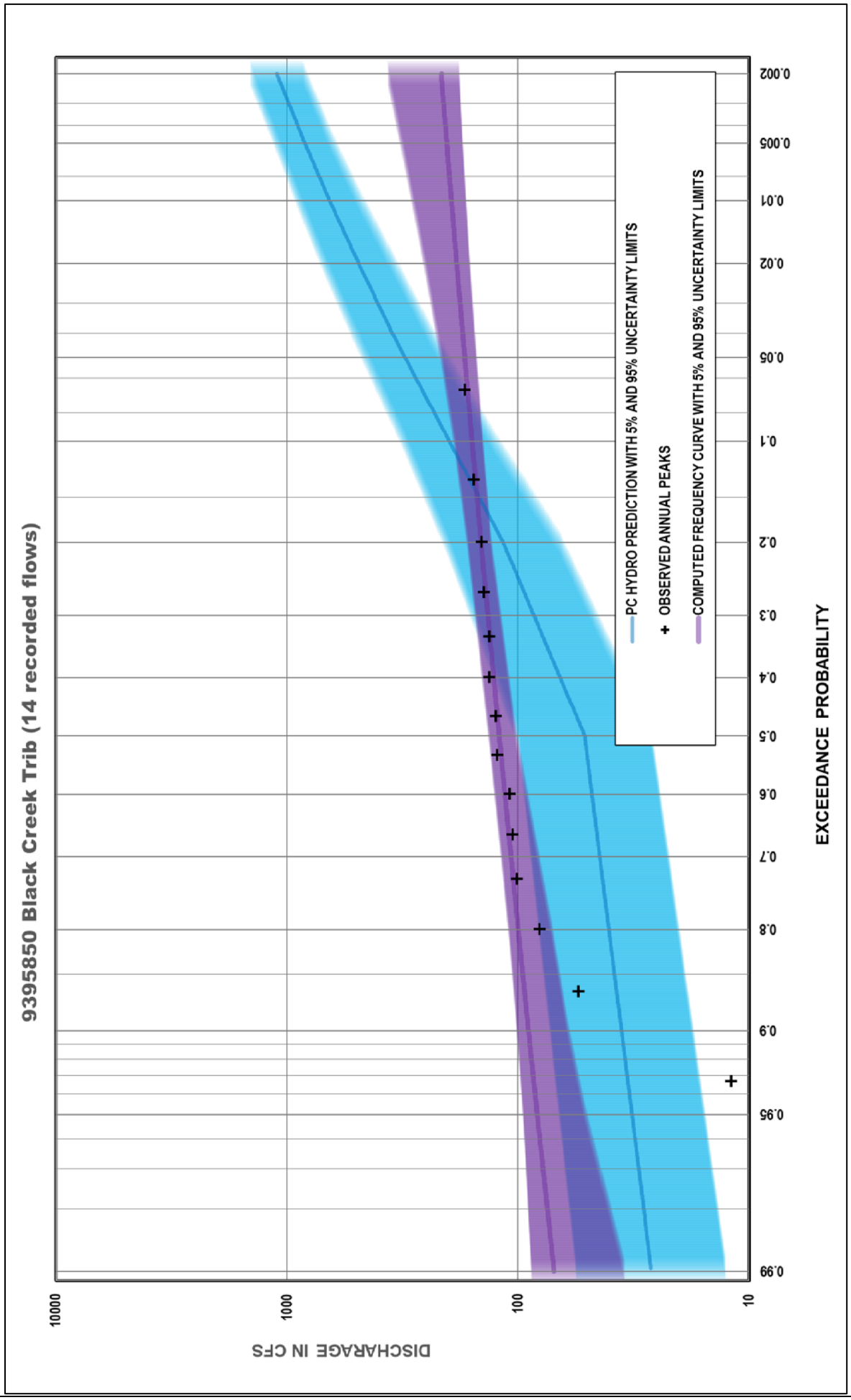
Watercourse Length: 4911 ft
Mean slope: 0.027 ft/ft
Wt Basin Factors: 0.033 0.028 0.037

Mean slope: 0.028 ft/ft
Wt Basin Factors: 0.033 0.029 0.037

Mean slope: 0.028 ft/ft
Wt Basin Factor: 0.033 0.029 0.037

Soil	Percent
Type B	
Type C	
Type D	100%

Red Font: User entry
Blue font: Calculation


9395850 Black Creek Trib (14 recorded flows)
DISCHARGE IN CFS
10000
1000
100
10
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS

Casandro Wash, AZ

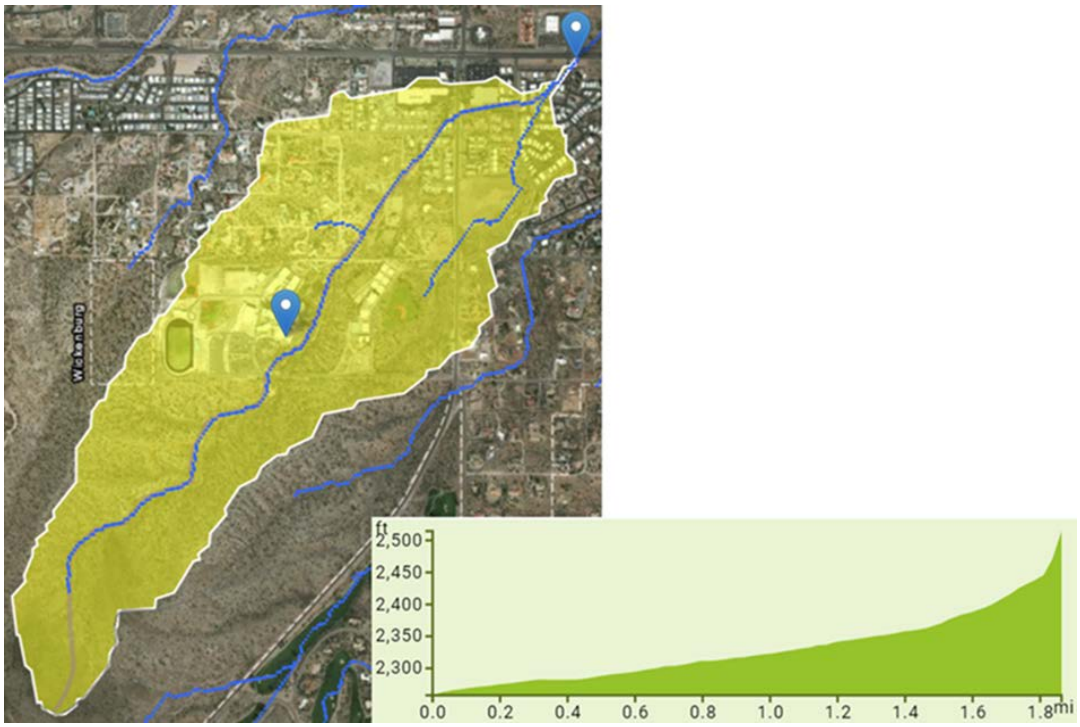
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Casandro Wash, AZ
Agency: FCDMC
Station: 7093
Northing: 33°57'43"N Easting: 112°45'54"W
(in decimal form: 33.96194,-112.76500

Watershed Information
Watershed: Suburban Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.58
L Cen Grav (ft): 5000

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	30%	20%	40%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
3-5 houses/ac[1]	Foothills	20.1	1320	0.015	0.022	0.020	0.025	29.4	2587	0.011	0.022	0.02	0.025	61.4	5015	0.012	0.025	0.022	0.028
3-5 houses/ac[1]	Valley	9.3	1267	0.007	0.022	0.020	0.025												
1-2 houses/ac	Foothills	16.6	1214	0.014	0.032	0.028	0.036	32	2428	0.013	0.027	0.024	0.031						
3-5 houses/ac[1]	Foothills	15.4	1214	0.013	0.022	0.020	0.025												
Apts / Lt Comm	Foothills	17.5	1162	0.015	0.020	0.018	0.022	38.2	2376	0.016	0.028	0.024	0.032	195	4805	0.041	0.043	0.035	0.05
None	Foothills	20.7	1214	0.017	0.035	0.030	0.040												
None	Foothills	37.9	1267	0.030	0.035	0.030	0.040	157	2429	0.065	0.047	0.038	0.055						
None	Mountain	118.9	1162	0.102	0.050	0.040	0.060												

[1] *(Detached homes)*

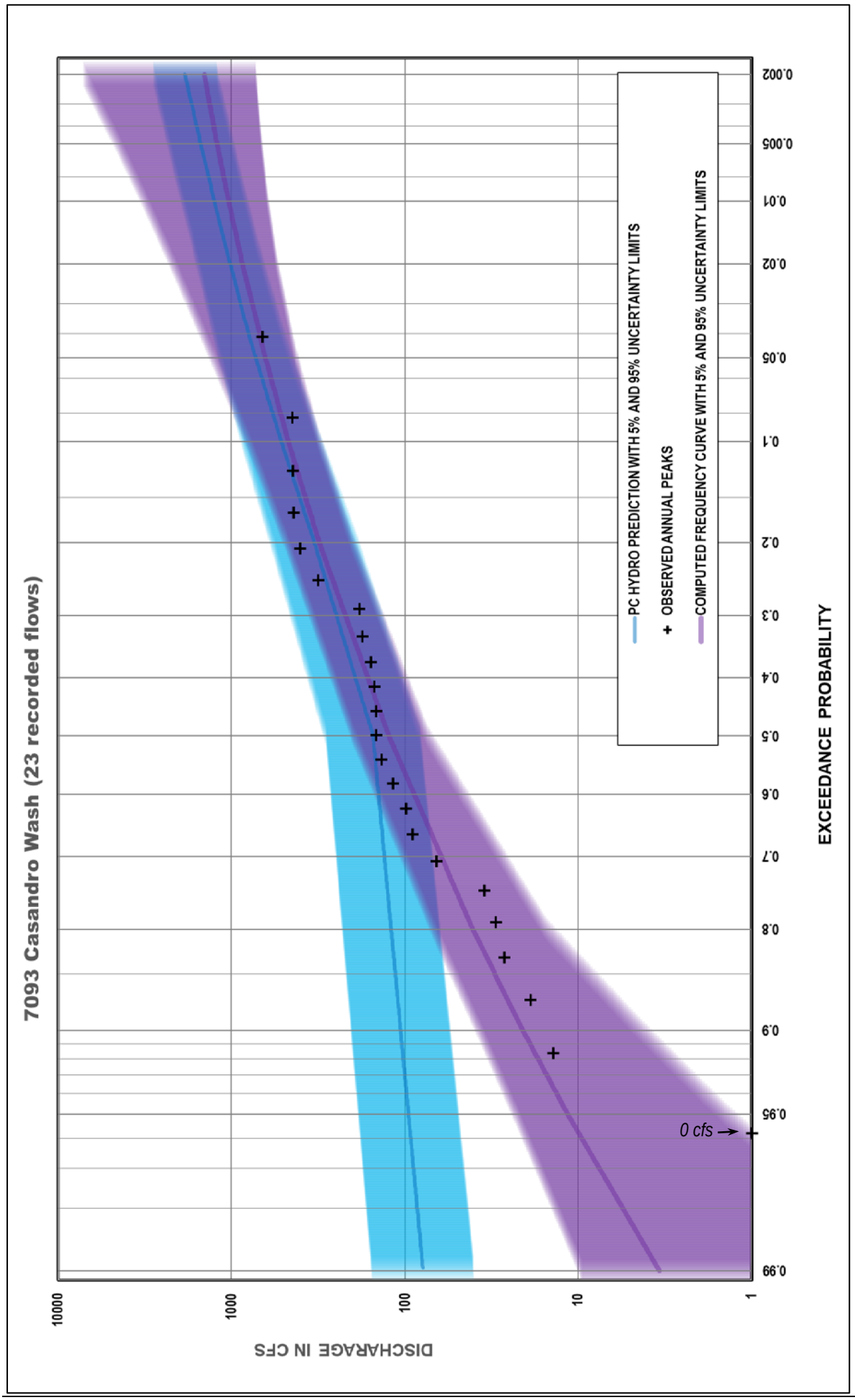
Watercourse Length: 9820 ft
Mean slope: 0.017 ft/ft
Wt Basin Factors: 0.030 0.026 0.034

Mean slope: 0.018 ft/ft
Wt Basin Factors: 0.031 0.026 0.036

Mean slope: 0.020 ft/ft
Wt Basin Factor: 0.034 0.028 0.039

Soil	Percent
Type B	40%
Type C	17%
Type D	43%

Red Font: User entry
Blue font: Calculation


7093 Casandro Wash (23 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Centennial Wash Tributary near Wenden, AZ

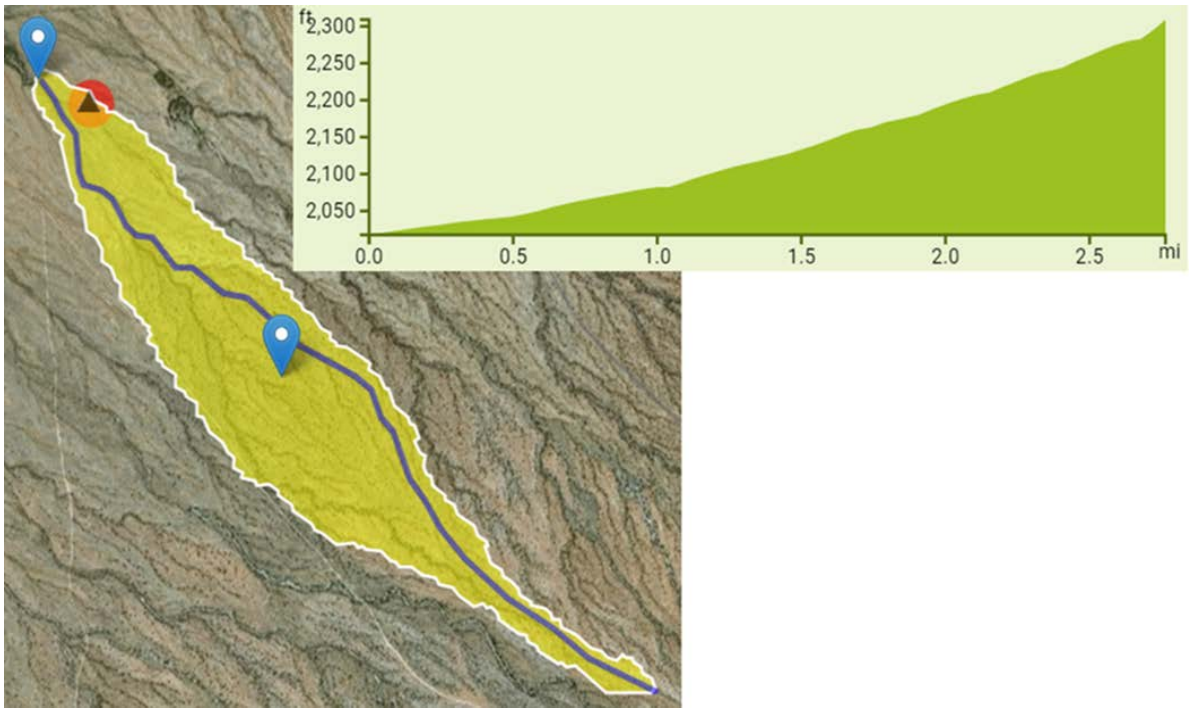
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Centennial Wash Tributary near Wenden, AZ
Agency: USGS
Station: 9517200
Northing: 33°50'40"N Easting: 113°27'2"W
(in decimal form: 33.84444,-113.45056

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.79
L Cen Grav (ft): 6750

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	19.5	1901	0.010	0.035	0.030	0.040	46.2	3907	0.012	0.035	0.03	0.04	107	7656	0.014	0.035	0.03	0.04
None	Foothills	26.7	2006	0.013	0.035	0.030	0.040												
None	Foothills	21.8	1848	0.012	0.035	0.030	0.040	60.3	3749	0.016	0.035	0.03	0.04						
None	Foothills	38.5	1901	0.020	0.035	0.030	0.040												
None	Foothills	39.1	1690	0.023	0.035	0.030	0.040	85.4	3749	0.023	0.035	0.03	0.04	193	7234	0.027	0.035	0.03	0.04
None	Foothills	46.3	2059	0.022	0.035	0.030	0.040												
None	Foothills	42.7	1637	0.026	0.035	0.030	0.040	108	3485	0.031	0.035	0.03	0.04						
None	Foothills	65.2	1848	0.035	0.035	0.030	0.040												

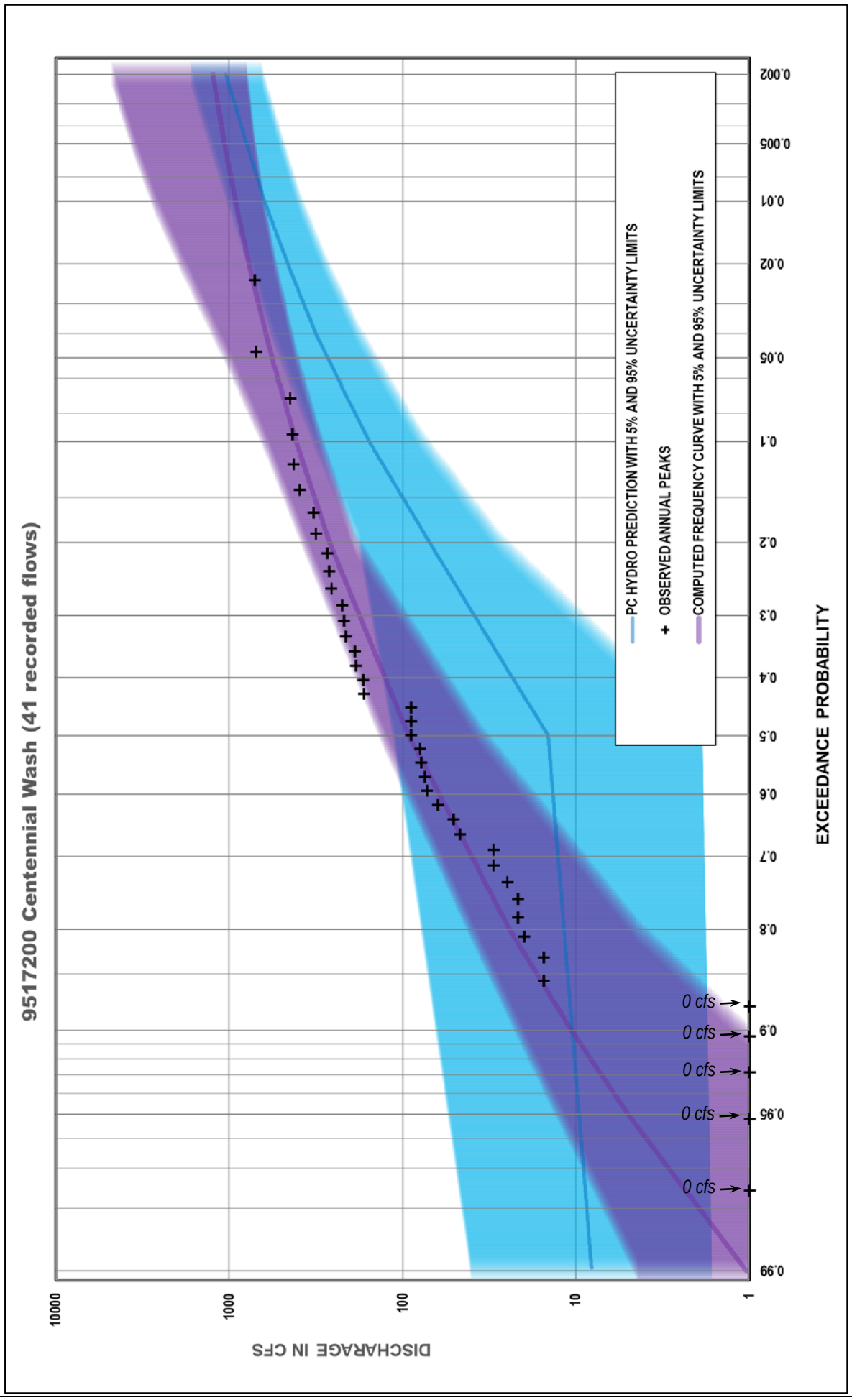
Watercourse Length: 14890 ft
Mean slope: 0.018 ft/ft
Wt Basin Factors: 0.035 0.030 0.040

Mean slope: 0.018 ft/ft
Wt Basin Factors: 0.035 0.030 0.040

Mean slope: 0.019 ft/ft
Wt Basin Factor: 0.035 0.030 0.040

Soil	Percent
Type B	100%
Type C	
Type D	0%

Red Font: User entry
Blue font: Calculation


9517200 Centennial Wash (41 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0 cfs
0 cfs
0 cfs
0 cfs
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.002
0.005
0.01
0.02
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.95
0.99

Chiltepines Wash near Sasabe, AZ

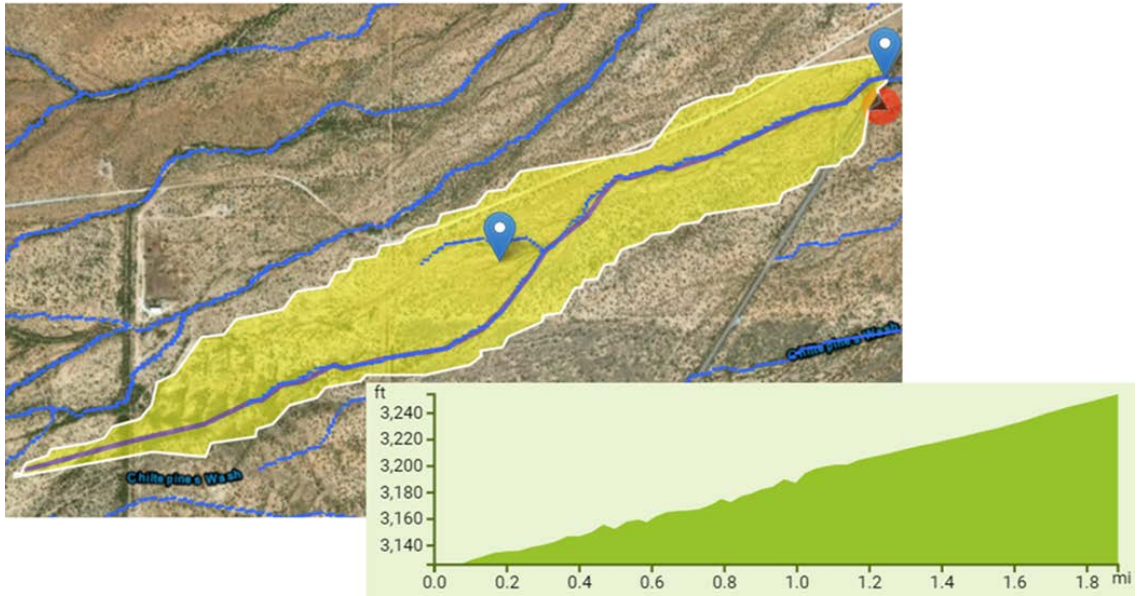
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Chiltepines Wash near Sasabe, AZ
Agency: USGS
Station: 9486700
Northing: 31°49'8"N Easting: 111°26'18"W
(in decimal form: 31.81889,-111.43833

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.34
L Cen Grav (ft): 4300

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Valley	13.1	1426	0.009	0.035	0.027	0.050	26.9	2640	0.010	0.035	0.029	0.044	64.3	5068	0.013	0.035	0.03	0.042
None	Foothills	13.8	1214	0.011	0.035	0.030	0.040												
None	Foothills	15.0	1214	0.012	0.035	0.030	0.040	37.4	2428	0.015	0.035	0.03	0.04						
None	Foothills	22.4	1214	0.018	0.035	0.030	0.040												
None	Foothills	16.3	1267	0.013	0.035	0.030	0.040	31.5	2587	0.012	0.035	0.03	0.04	64.2	4910	0.013	0.035	0.03	0.04
None	Foothills	15.2	1320	0.012	0.035	0.030	0.040												
None	Foothills	18.0	1267	0.014	0.035	0.030	0.040	32.7	2323	0.014	0.035	0.03	0.04						
None	Foothills	14.7	1056	0.014	0.035	0.030	0.040												

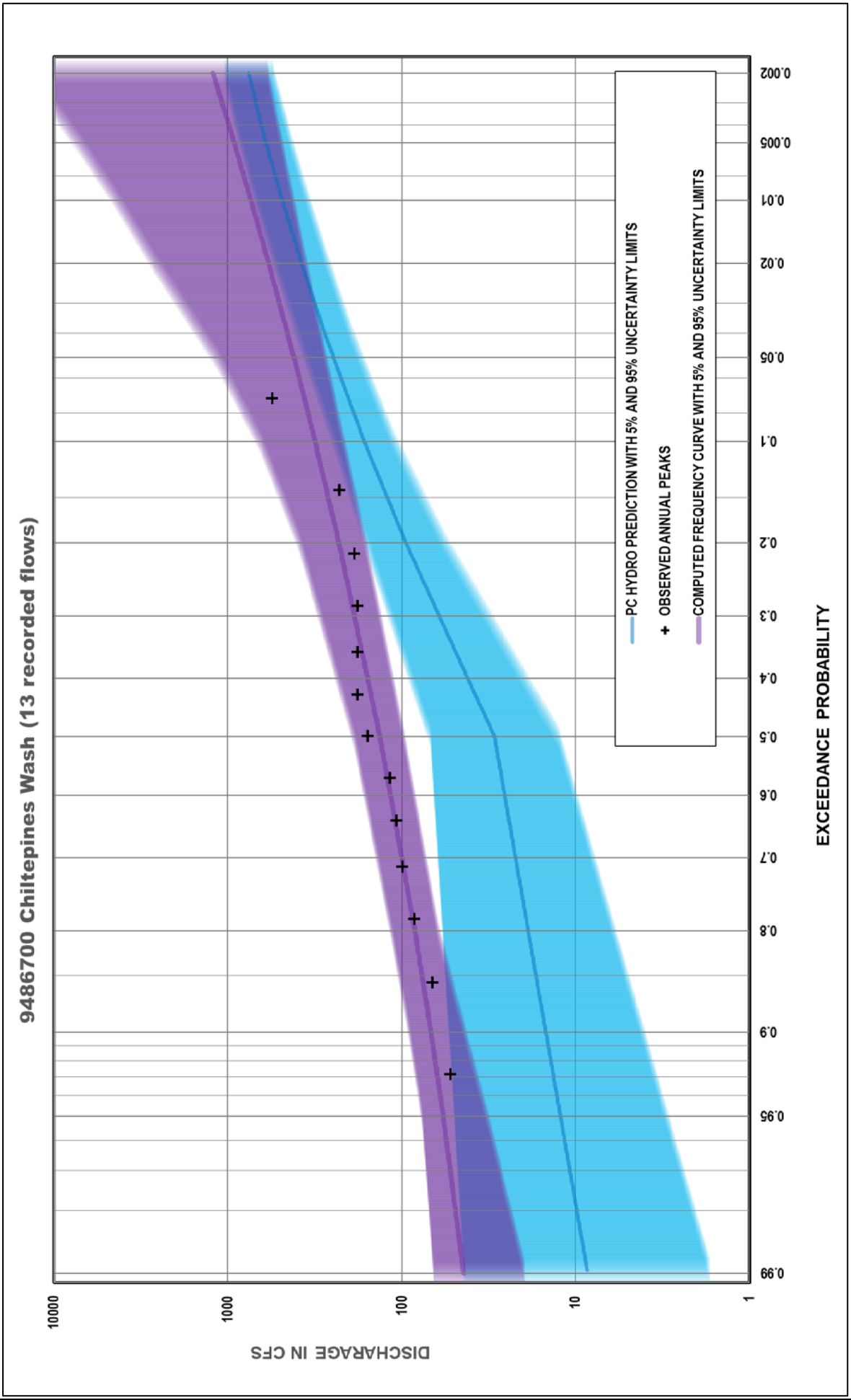
Watercourse Length: 9978 ft
Mean slope: 0.013 ft/ft
Wt Basin Factors: 0.035 0.030 0.041

Mean slope: 0.013 ft/ft
Wt Basin Factors: 0.035 0.030 0.041

Mean slope: 0.013 ft/ft
Wt Basin Factor: 0.035 0.030 0.041

Soil	Percent
Type B	81%
Type C	19%
Type D	0%

Red Font: User entry
Blue font: Calculation


9486700 Chiltepines Wash (13 recorded flows)
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS

Cibecue 1 Tributary Carrizo Creek near Show Low, AZ

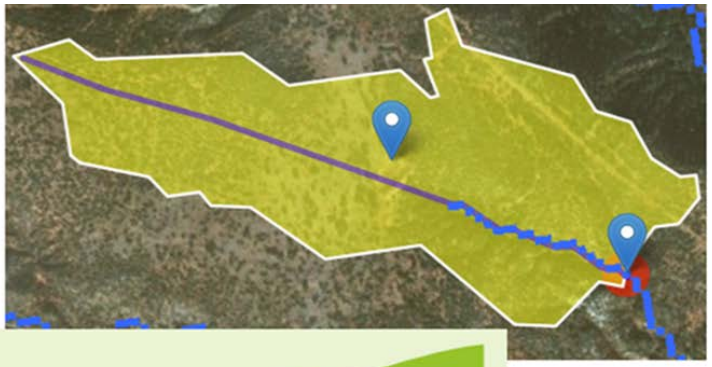
PC-HYDRO V. 6 ANALYSIS

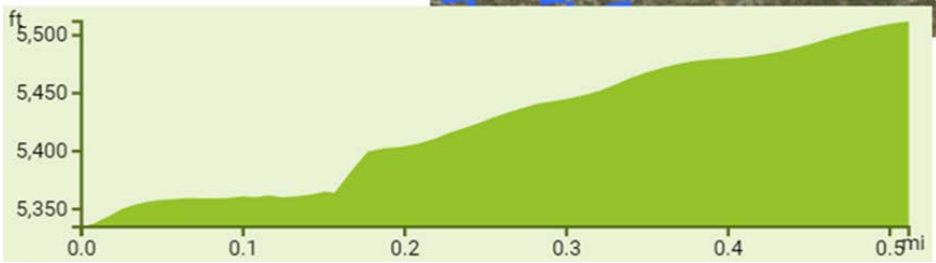
Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Cibecue 1 Tributary Carrizo Creek near Show Low, AZ
Agency: USGS
Station: 9496600
Northing: 33°59'28"N Easting: 110°19'29"W
(in decimal form: 33.99111,-110.32472

Watershed Information
Watershed: Undeveloped-Mountain
Veg cover type: Mountain Brush
Area (sq. mi.): 0.07
L Cen Grav (ft): 1150

	Normal	Minimum	Maximum
Veg cover (%):	30%	20%	40%
% impervious:	15%	5%	25%





		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Mountain	25.2	370	0.068	0.050	0.040	0.060	26.5	687	0.039	0.049	0.039	0.059	98.8	1374	0.072	0.05	0.04	0.06
None	Valley	1.3	317	0.004	0.035	0.027	0.050												
None	Mountain	42.6	370	0.115	0.050	0.040	0.060	72.3	687	0.105	0.05	0.04	0.06						
None	Mountain	29.7	317	0.094	0.050	0.040	0.060												
None	Mountain	18.8	317	0.059	0.050	0.040	0.060	45.6	687	0.066	0.05	0.04	0.06	78.7	1321	0.060	0.05	0.04	0.06
None	Mountain	26.8	370	0.072	0.050	0.040	0.060												
None	Mountain	14.2	317	0.045	0.050	0.040	0.060	33.1	634	0.052	0.05	0.04	0.06						
None	Mountain	18.9	317	0.060	0.050	0.040	0.060												

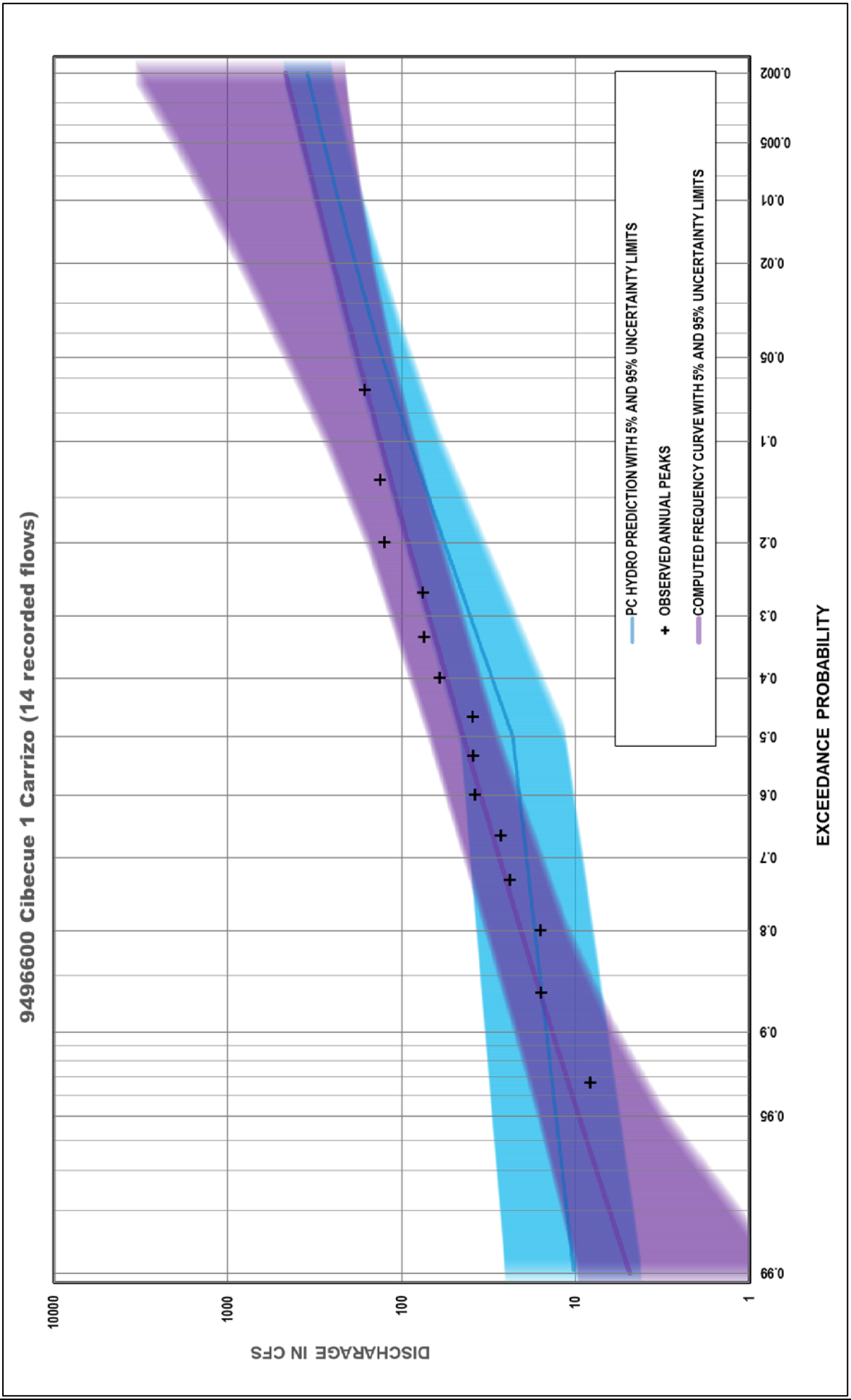
Watercourse Length: 2695 ft
Mean slope: 0.037 ft/ft
Wt Basin Factors: 0.048 0.038 0.059

Mean slope: 0.059 ft/ft
Wt Basin Factors: 0.050 0.040 0.060

Mean slope: 0.065 ft/ft
Wt Basin Factor: 0.050 0.040 0.060

Soil	Percent
Type B	0%
Type C	50%
Type D	50%

Red Font: User entry
Blue font: Calculation


9496600 Cibecue 1 Carrizo (14 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Cottonwood Wash near Camp Verde, AZ

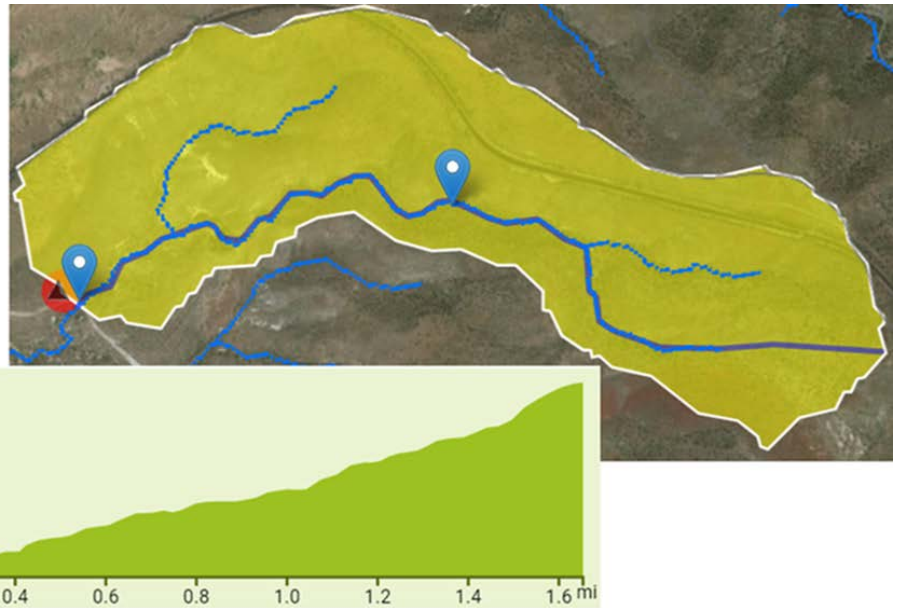
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Cottonwood Wash near Camp Verde, AZ
Agency: USGS
Station: 9505900
Northing: 34°30'20"N Easting: 111°45'12"W
(in decimal form: 34.50556,-111.75333

Watershed Information
Watershed: Undeveloped-Mountain
Veg cover type: Desert Brush
Area (sq. mi.): 0.53
L Cen Grav (ft): 4500

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	40.3	1162	0.035	0.035	0.030	0.040	102	2218	0.046	0.044	0.036	0.053	242	4489	0.054	0.047	0.038	0.057
None	Mountain	62.0	1056	0.059	0.050	0.040	0.060												
None	Mountain	82.1	1109	0.074	0.050	0.040	0.060	140	2271	0.061	0.05	0.04	0.06						
None	Mountain	57.4	1162	0.049	0.050	0.040	0.060												
None	Foothills	38.8	1003	0.039	0.035	0.030	0.040	154	2112	0.073	0.046	0.037	0.055	381	4224	0.090	0.048	0.039	0.058
None	Mountain	114.9	1109	0.104	0.050	0.040	0.060												
None	Mountain	86.5	1162	0.074	0.050	0.040	0.060	227	2112	0.107	0.05	0.04	0.06						
None	Mountain	140.3	950	0.148	0.050	0.040	0.060												

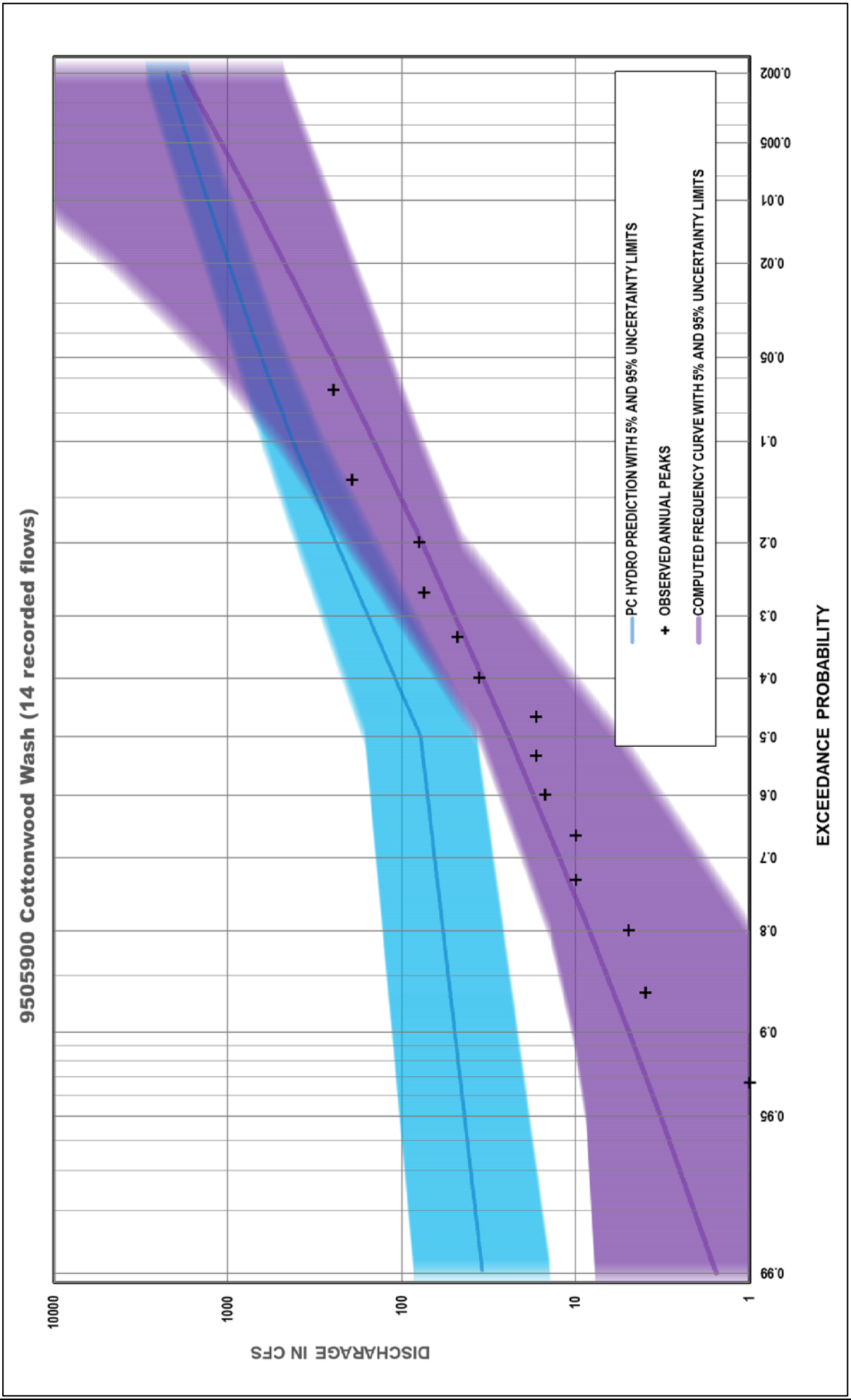
Watercourse Length: 8713 ft
Mean slope: 0.061 ft/ft
Wt Basin Factors: 0.046 0.038 0.055

Mean slope: 0.067 ft/ft
Wt Basin Factors: 0.048 0.038 0.057

Mean slope: 0.068 ft/ft
Wt Basin Factor: 0.047 0.038 0.057

Soil	Percent
Type B	0%
Type C	0%
Type D	100%

Red Font: User entry
Blue font: Calculation


9505900 Cottonwood Wash (14 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Cunningham Wash Tributary near Wenden, AZ

PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018

Project Notes:

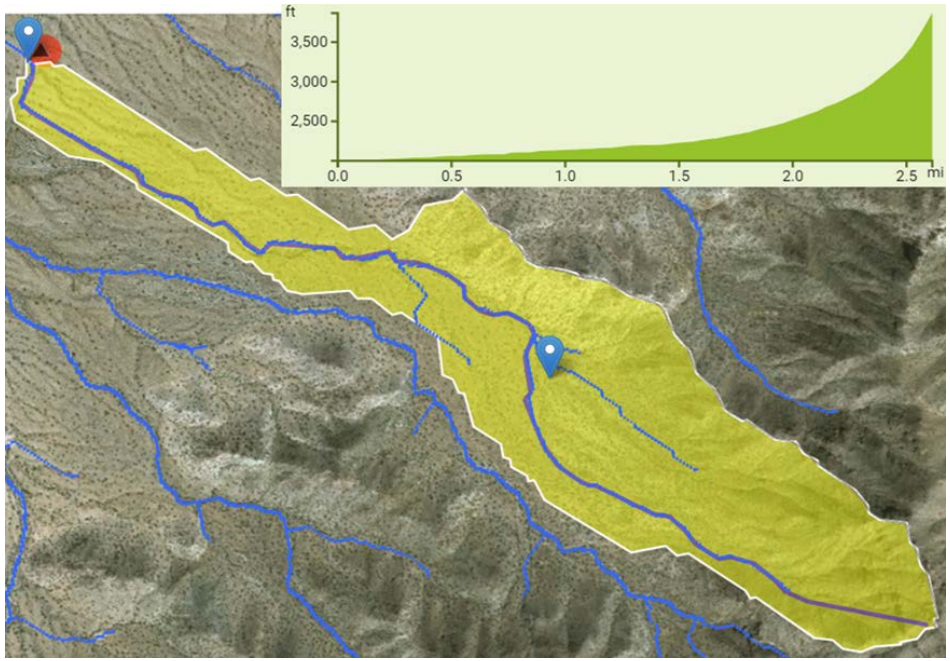
Gage Information

Name: Cunningham Wash Tributary near Wenden, AZ
Agency: USGS
Station: 9428545
Northing: 34°0'25"N Easting: 113°34'42"W
(in decimal form: 34.00694,-113.57833

Watershed Information

Watershed: Undeveloped-Mountain
Veg cover type: Desert Brush
Area (sq. mi.): 0.63
L Cen Grav (ft): 8000

	Normal	Minimum	Maximum
Veg cover (%):	5%	0%	15%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	38.1	1742	0.022	0.035	0.030	0.040	82.6	3643	0.023	0.035	0.03	0.04	196	6917	0.028	0.035	0.03	0.04
None	Foothills	44.5	1901	0.023	0.035	0.030	0.040												
None	Foothills	56.4	1584	0.036	0.035	0.030	0.040	113	3274	0.035	0.035	0.03	0.04						
None	Foothills	56.9	1690	0.034	0.035	0.030	0.040												
None	Mountain	89.9	1901	0.047	0.050	0.040	0.060	282	3432	0.082	0.05	0.04	0.06	1671	6864	0.243	0.05	0.04	0.06
None	Mountain	192.1	1531	0.125	0.050	0.040	0.060												
None	Mountain	411.5	1848	0.223	0.050	0.040	0.060	1389	3432	0.405	0.05	0.04	0.06						
None	Mountain	977.3	1584	0.617	0.050	0.040	0.060												

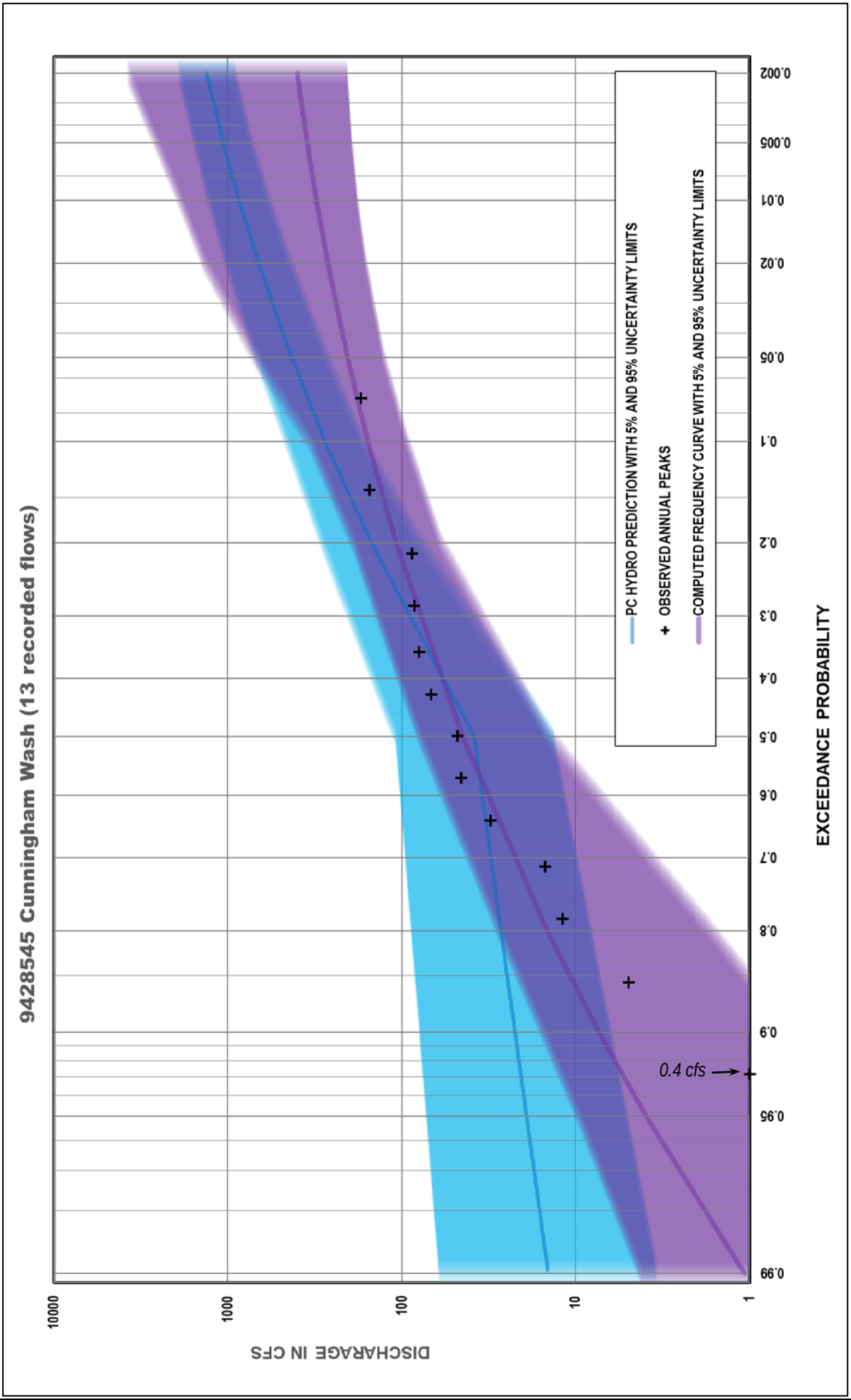
Watercourse Length: 13781 ft
Mean slope: 0.051 ft/ft
Wt Basin Factors: 0.042 0.035 0.050

Mean slope: 0.054 ft/ft
Wt Basin Factors: 0.042 0.035 0.050

Mean slope: 0.063 ft/ft
Wt Basin Factor: 0.042 0.035 0.050

Soil	Percent
Type B	0%
Type C	100%
Type D	0%

Red Font: User entry
Blue font: Calculation


9428545 Cunningham Wash (13 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0.4 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Dead Wash Tributary near Holbrook, AZ

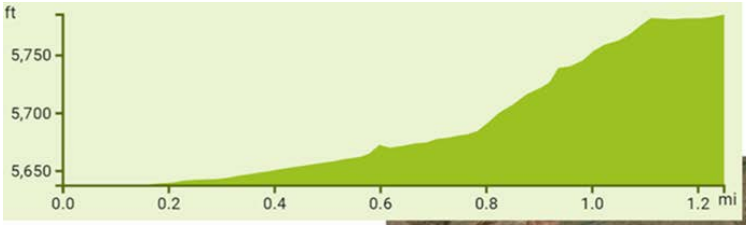
PC-HYDRO V. 6 ANALYSIS

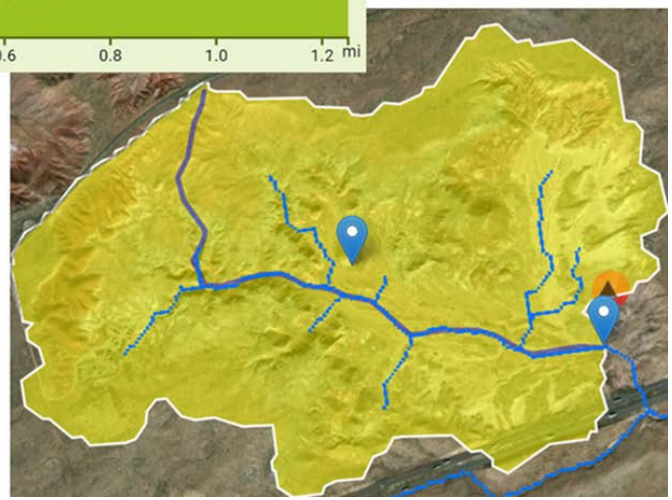
Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Dead Wash Tributary near Holbrook, AZ
Agency: USGS
Station: 9396400
Northing: 35°4'30"N Easting: 109°45'2"W
(in decimal form: 35.07500,-109.75056

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Mountain Brush
Area (sq. mi.): 0.76
L Cen Grav (ft): 3300

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	10%	0%	20%





		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
<1 house/ac	Valley	0.7	845	0.001	0.034	0.027	0.047	7.2	1690	0.004	0.035	0.027	0.05	34.2	3380	0.010	0.035	0.029	0.042
None	Valley	6.5	845	0.008	0.035	0.027	0.050												
None	Foothills	10.9	792	0.014	0.035	0.030	0.040	27	1690	0.016	0.035	0.03	0.04						
None	Foothills	16.1	898	0.018	0.035	0.030	0.040												
None	Foothills	20.3	845	0.024	0.035	0.030	0.040	67.4	1584	0.043	0.046	0.037	0.055	114	3221	0.035	0.047	0.038	0.057
None	Mountain	47.1	739	0.064	0.050	0.040	0.060												
None	Mountain	43.3	898	0.048	0.050	0.040	0.060	46.3	1637	0.028	0.049	0.039	0.059						
<1 house/ac	Valley	3.0	739	0.004	0.034	0.027	0.047												

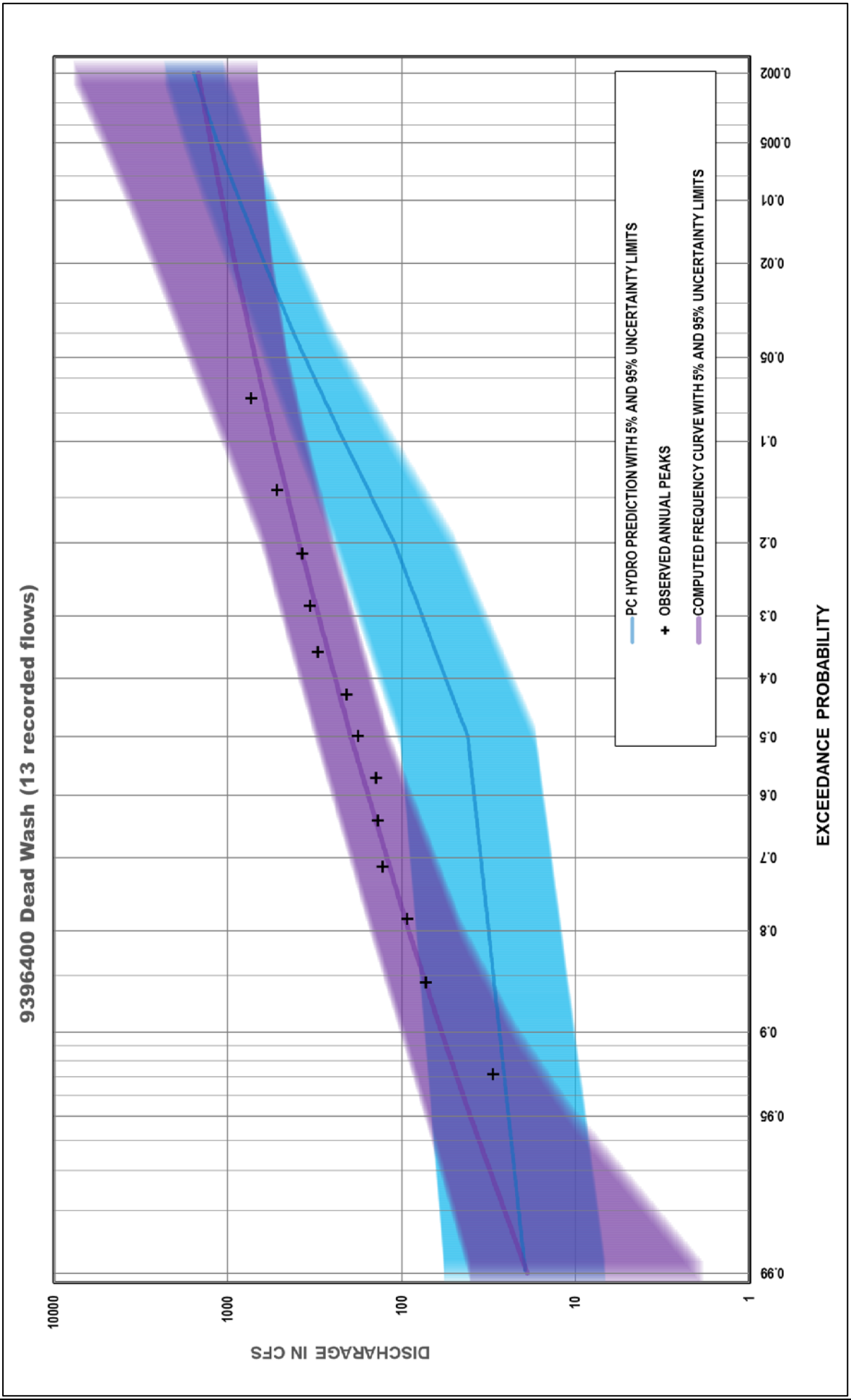
Watercourse Length: 6601 ft
Mean slope: 0.007 ft/ft
Wt Basin Factors: 0.038 0.031 0.048

Mean slope: 0.014 ft/ft
Wt Basin Factors: 0.041 0.033 0.051

Mean slope: 0.017 ft/ft
Wt Basin Factor: 0.041 0.033 0.049

Soil	Percent
Type B	23%
Type C	15%
Type D	62%

Red Font: User entry
Blue font: Calculation


9396400 Dead Wash (13 recorded flows)
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS

Demetrie Wash Tributary Near Continental, AZ

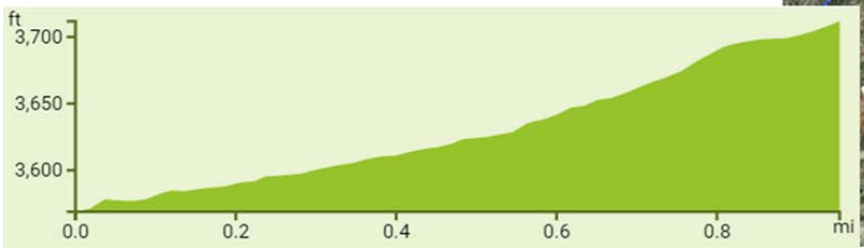
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Demetrie Wash Tributary Near Continental, AZ
Agency: USGS
Station: 9481800
Northing: 31°52'15"N Easting: 111°5'17"W
(in decimal form: 31.87083,-111.08806

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Mountain Brush
Area (sq. mi.): 0.17
L Cen Grav (ft): 2000

	Normal	Minimum	Maximum
Veg cover (%):	20%	10%	30%
% impervious:		0%	10%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	13.1	739	0.018	0.035	0.030	0.040	30.5	1478	0.021	0.035	0.03	0.04	72.3	2903	0.025	0.035	0.03	0.04
None	Foothills	17.4	739	0.024	0.035	0.030	0.040												
None	Foothills	22.4	739	0.030	0.035	0.030	0.040	41.8	1425	0.029	0.035	0.03	0.04						
None	Foothills	19.4	686	0.028	0.035	0.030	0.040												
None	Foothills	30.4	792	0.038	0.035	0.030	0.040	54.1	1478	0.037	0.035	0.03	0.04	303	2903	0.104	0.047	0.038	0.057
None	Foothills	23.7	686	0.035	0.035	0.030	0.040												
None	Mountain	80.8	739	0.109	0.050	0.040	0.060	249	1425	0.175	0.05	0.04	0.06						
None	Mountain	168.2	686	0.245	0.050	0.040	0.060												

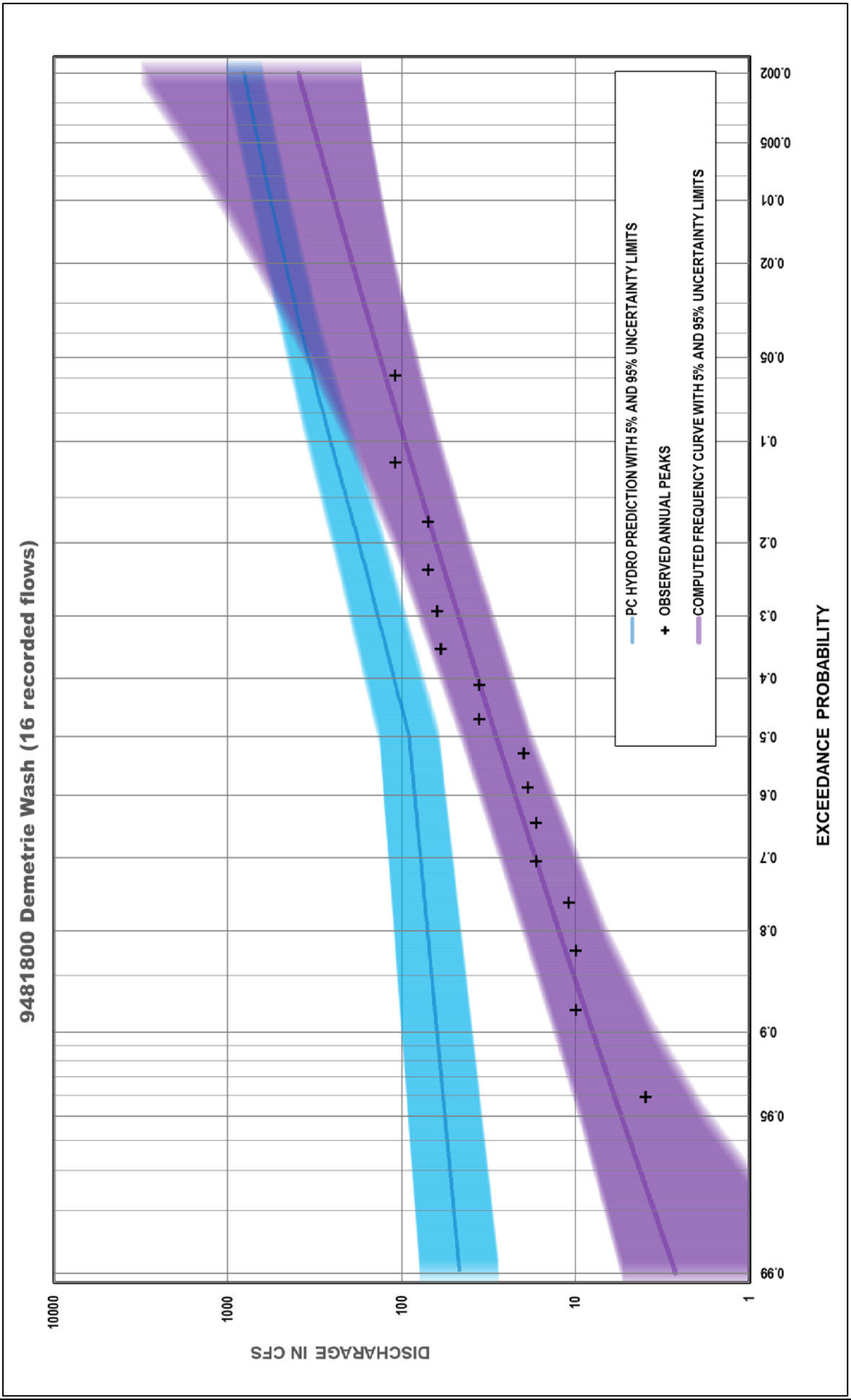
Watercourse Length: 5806 ft
Mean slope: 0.037 ft/ft
Wt Basin Factors: 0.039 0.032 0.045

Mean slope: 0.038 ft/ft
Wt Basin Factors: 0.039 0.032 0.045

Mean slope: 0.045 ft/ft
Wt Basin Factor: 0.041 0.034 0.049

Soil	Percent
Type B	14%
Type C	68%
Type D	18%

Red Font: User entry
Blue font: Calculation


9481800 Demetrie Wash (16 recorded flows)
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS

High School Wash at Tucson, AZ

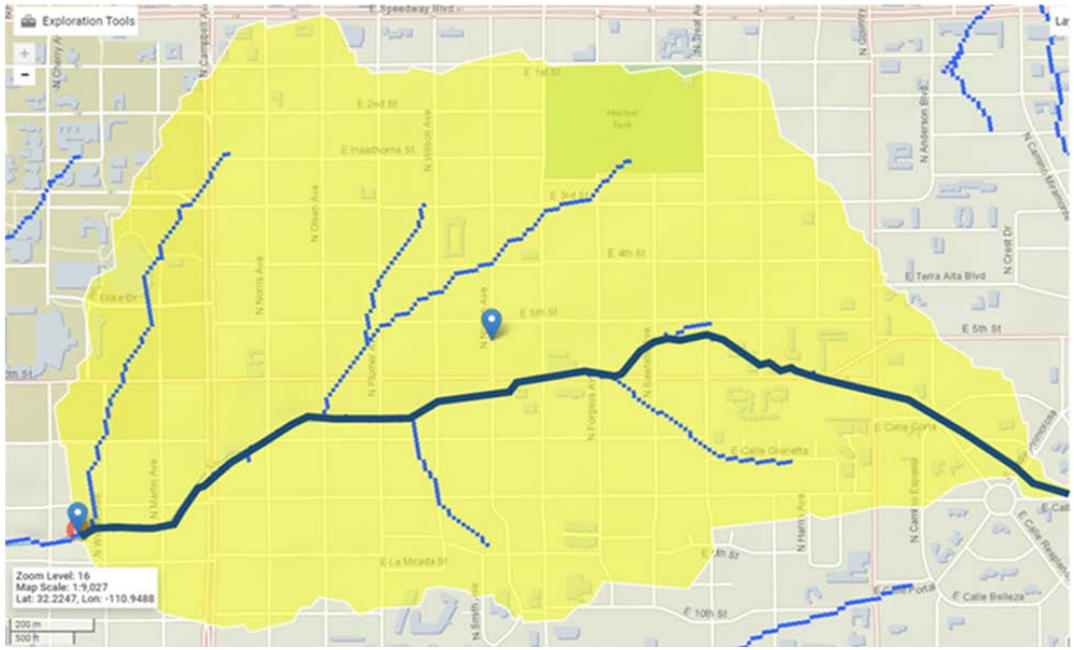
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: High School Wash at Tucson, AZ
Agency: USGS
Station: 9483010
Northing: 32°13'28"N Easting: 110°56'48"W
(in decimal form: 32.22444,-110.94667

Watershed Information
Watershed: Low Density Urbanized
Veg cover type: Urban Lawns
Area (sq. mi.): 0.9755
L Cen Grav (ft): 4300

	Normal	Minimum	Maximum
Veg cover (%):	20%	10%	30%
% impervious:	40%	30%	50%



Development	Watershed Type	Eight Points Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Four Points Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Two Points Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
3-5 houses/ac[1]	Foothills	18.0	1320	0.014	0.022	0.020	0.025	23	2640	0.009	0.022	0.02	0.025	52	5280	0.010	0.022	0.02	0.025
3-5 houses/ac[1]	Valley	5.0	1320	0.004	0.022	0.020	0.025												
3-5 houses/ac[1]	Valley	13.0	1320	0.010	0.022	0.020	0.025	29	2640	0.011	0.022	0.02	0.025						
3-5 houses/ac[1]	Foothills	16.0	1320	0.012	0.022	0.020	0.025												
3-5 houses/ac[1]	Valley	4.0	1320	0.003	0.022	0.020	0.025	22	1954	0.011	0.022	0.02	0.025	32	3326	0.010	0.022	0.02	0.025
3-5 houses/ac[1]	Foothills	18.0	634	0.028	0.022	0.020	0.025												
3-5 houses/ac[1]	Foothills	9.0	686	0.013	0.022	0.020	0.025	10	1372	0.007	0.022	0.02	0.025						
3-5 houses/ac[1]	Valley	1.0	686	0.001	0.022	0.020	0.025												

[1] *(Detached homes)*

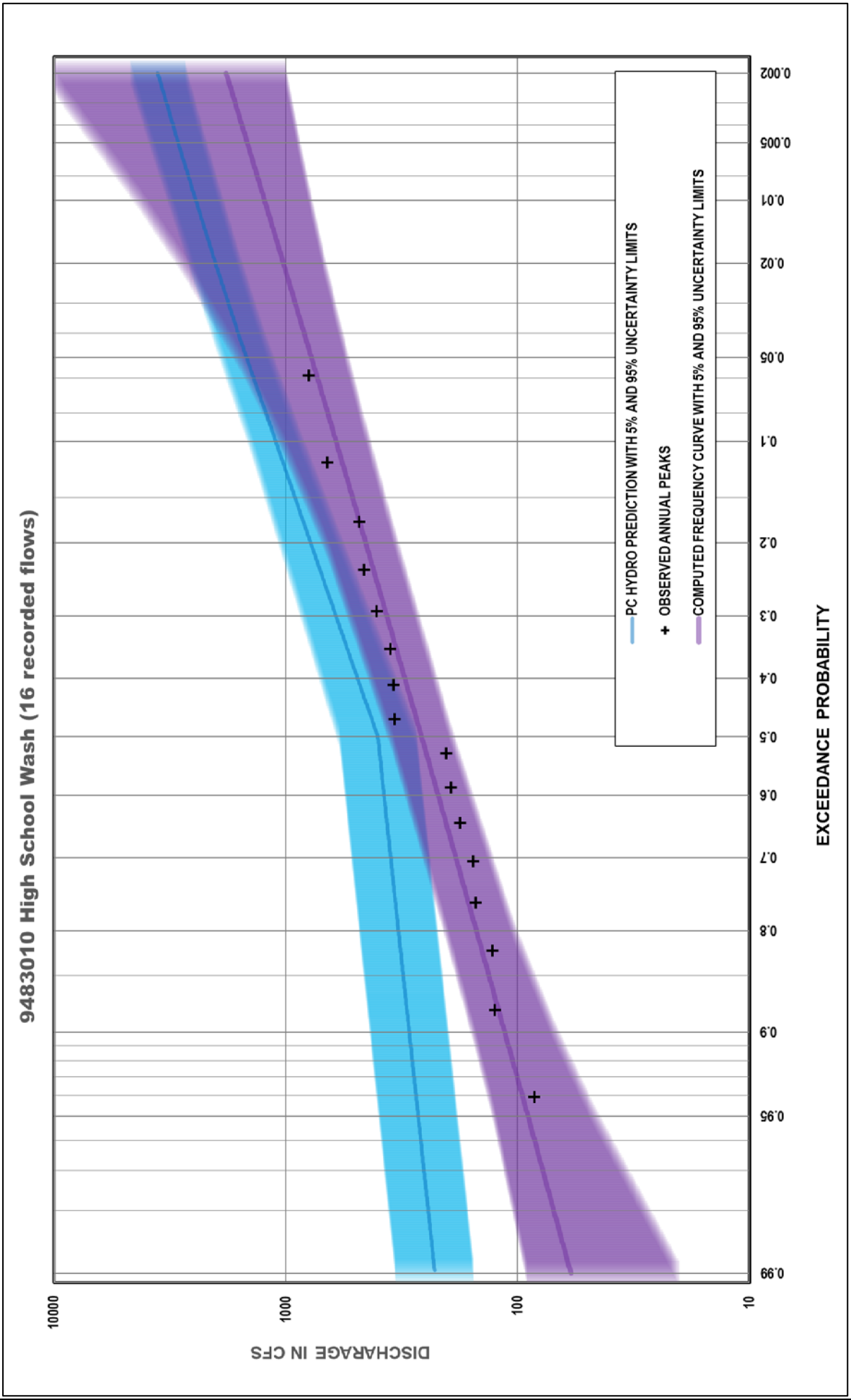
Watercourse Length: 8606 ft
Mean slope: 0.006 ft/ft
Wt Basin Factors: 0.022 0.020 0.025

Mean slope: 0.010 ft/ft
Wt Basin Factors: 0.022 0.020 0.025

Mean slope: 0.010 ft/ft
Wt Basin Factor: 0.022 0.020 0.025

Soil	Percent
Type B	0%
Type C	26%
Type D	74%

Red Font: User entry
Blue font: Calculation


9483010 High School Wash (16 recorded flows)
DISCHARGE IN CFS
10000
1000
100
10
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS

Hot Shot Arroyo near Ajo, AZ

PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Hot Shot Arroyo near Ajo, AZ
Agency: USGS
Station: 9520110
Northing: 32°20'49"N Easting: 112°48'33"W
(in decimal form: 32.34694,-112.80917

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.56
L Cen Grav (ft): 5000

	Normal	Minimum	Maximum
Veg cover (%):	20%	10%	30%
% impervious:	10%	0%	20%

		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Valley	12.4	1373	0.009	0.035	0.027	0.050	24.4	2640	0.009	0.035	0.027	0.05	50.3	5121	0.010	0.035	0.029	0.045
None	Valley	12.0	1267	0.009	0.035	0.027	0.050												
None	Foothills	13.6	1267	0.011	0.035	0.030	0.040	25.9	2481	0.010	0.035	0.03	0.04						
None	Foothills	12.3	1214	0.010	0.035	0.030	0.040												
None	Foothills	24.8	1373	0.018	0.035	0.030	0.040	46.6	2535	0.018	0.035	0.03	0.04	514	5070	0.101	0.049	0.039	0.058
None	Foothills	21.8	1162	0.019	0.035	0.030	0.040												
None	Mountain	85.1	1426	0.060	0.050	0.040	0.060	468	2535	0.185	0.05	0.04	0.06						
None	Mountain	382.6	1109	0.345	0.050	0.040	0.060												

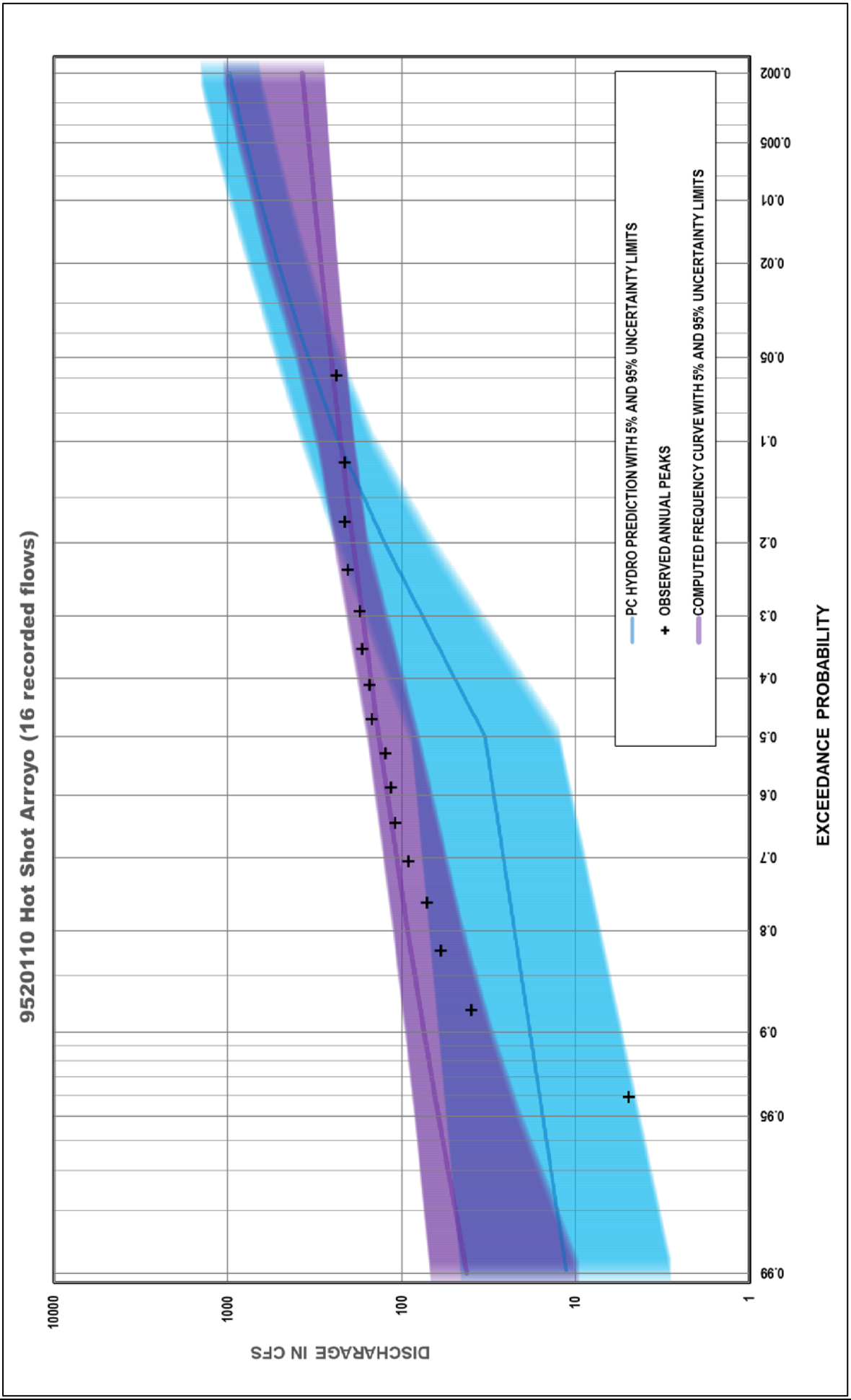
Watercourse Length: 10191 ft
Mean slope: 0.017 ft/ft
Wt Basin Factors: 0.039 0.032 0.048

Mean slope: 0.018 ft/ft
Wt Basin Factors: 0.039 0.032 0.048

Mean slope: 0.023 ft/ft
Wt Basin Factor: 0.042 0.034 0.051

Soil	Percent
Type B	69%
Type C	0%
Type D	31%

Red Font: User entry
Blue font: Calculation


9520110 Hot Shot Arroyo (16 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Hull Canyon near Jerome, AZ

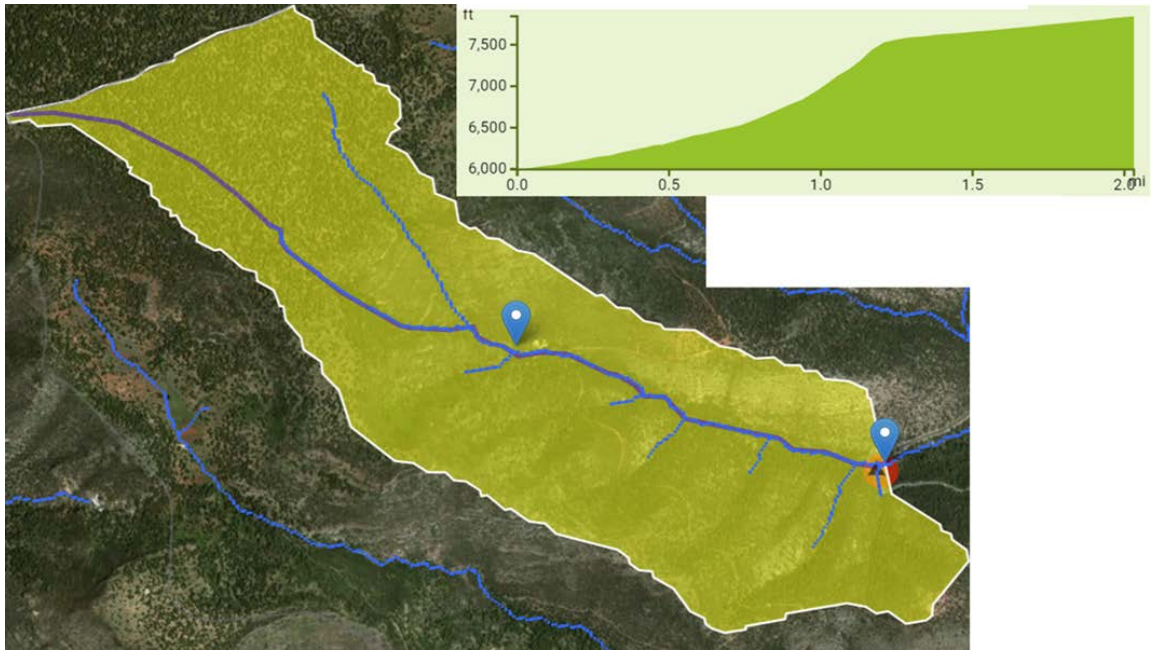
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Hull Canyon near Jerome, AZ
Agency: USGS
Station: 9504100
Northing: 34°44'20"N Easting: 112°8'37"W
(in decimal form: 34.73889,-112.14361

Watershed Information
Watershed: Undeveloped-Mountain
Veg cover type: Ponderosa Pine
Area (sq. mi.): 0.91
L Cen Grav (ft): 6000

	Normal	Minimum	Maximum
Veg cover (%):	40%	30%	50%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Mountain	154.4	1426	0.108	0.050	0.040	0.060	332	2693	0.123	0.05	0.04	0.06	1034	5385	0.192	0.05	0.04	0.06
None	Mountain	177.3	1267	0.140	0.050	0.040	0.060												
None	Mountain	279.6	1478	0.189	0.050	0.040	0.060	703	2692	0.261	0.05	0.04	0.06						
None	Mountain	423.0	1214	0.348	0.050	0.040	0.060												
None	Mountain	556.6	1373	0.405	0.050	0.040	0.060	641	2746	0.233	0.05	0.04	0.06	816	5334	0.153	0.05	0.04	0.06
None	Mountain	84.0	1373	0.061	0.050	0.040	0.060												
None	Mountain	99.0	1426	0.069	0.050	0.040	0.060	176	2588	0.068	0.05	0.04	0.06						
None	Mountain	76.7	1162	0.066	0.050	0.040	0.060												

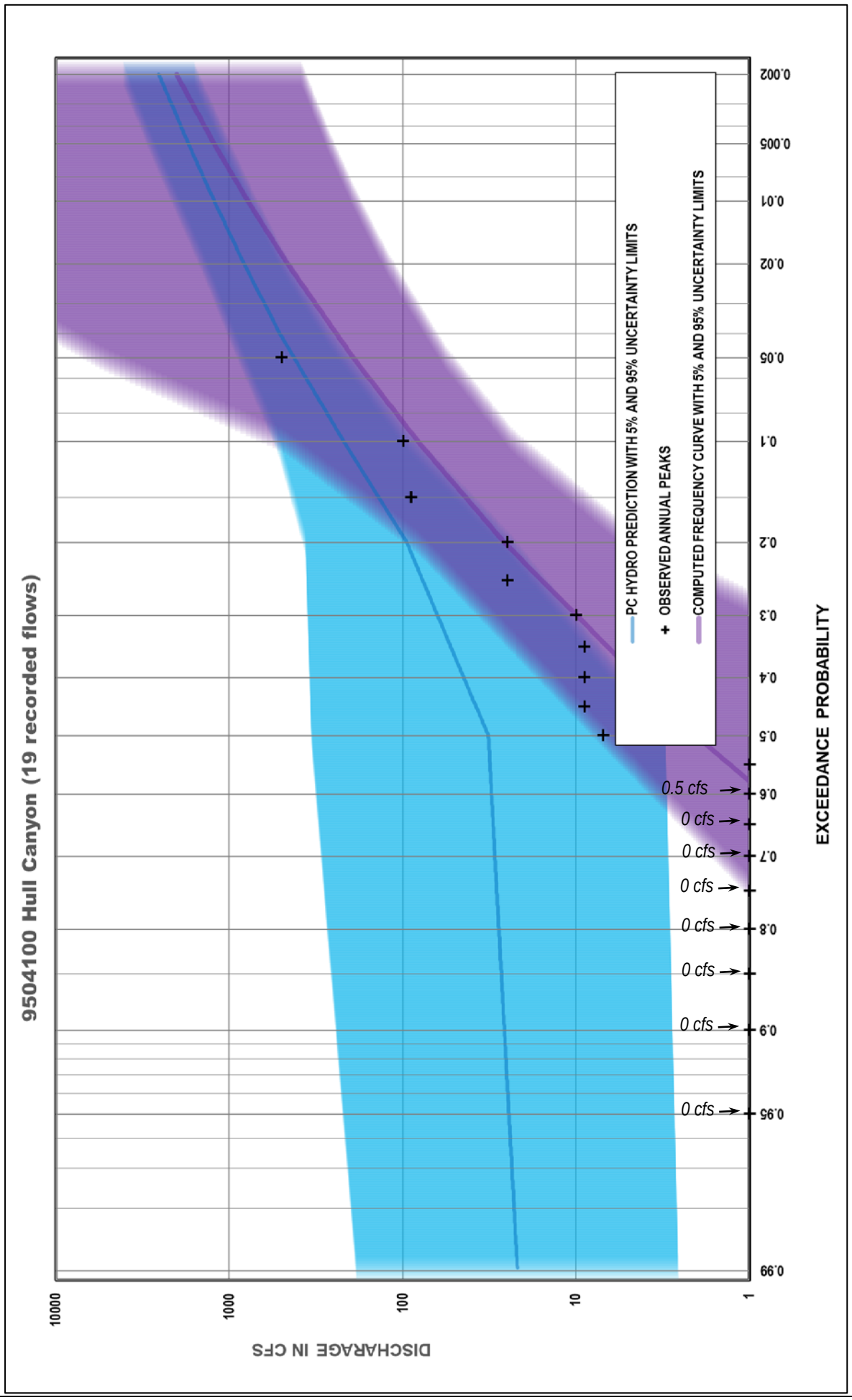
Watercourse Length: 10719 ft
Mean slope: 0.121 ft/ft
Wt Basin Factors: 0.050 0.040 0.060

Mean slope: 0.141 ft/ft
Wt Basin Factors: 0.050 0.040 0.060

Mean slope: 0.171 ft/ft
Wt Basin Factor: 0.050 0.040 0.060

Soil	Percent
Type B	0%
Type C	100%
Type D	0%

Red Font: User entry
Blue font: Calculation


9504100 Hull Canyon (19 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0.5 cfs
0 cfs
0 cfs
0 cfs
0 cfs
0 cfs
0 cfs
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.002
0.005
0.01
0.02
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.95
0.99

Jack Bench Wash Tributary near Page, AZ

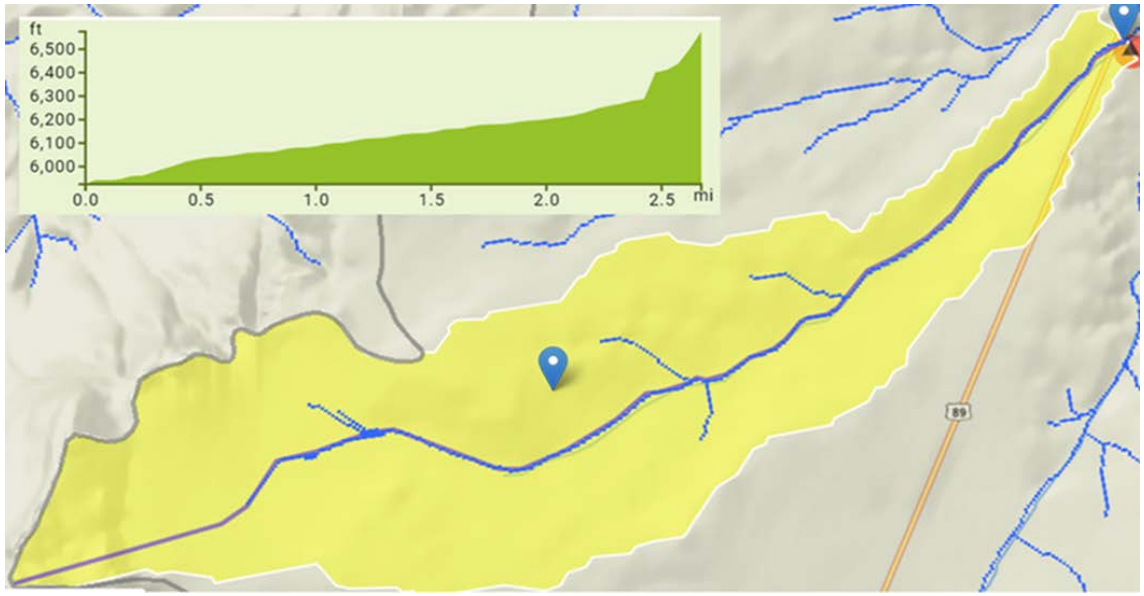
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Jack Bench Wash Tributary near Page, AZ
Agency: USGS
Station: 9379980
Northing: 36°42'49"N Easting: 111°35'32"W
(in decimal form: 36.71361,-111.59222

Watershed Information
Watershed: Undeveloped-Mountain
Veg cover type: Mountain Brush
Area (sq. mi.): 0.98
L Cen Grav (ft): 6671

	Normal	Minimum	Maximum
Veg cover (%):	15%	5%	25%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	65.3	1795	0.036	0.035	0.030	0.040	132	3696	0.036	0.035	0.03	0.04	213	7286	0.029	0.035	0.03	0.04
None	Foothills	66.9	1901	0.035	0.035	0.030	0.040												
None	Foothills	38.4	1795	0.021	0.035	0.030	0.040	80.5	3590	0.022	0.035	0.03	0.04						
None	Foothills	42.1	1795	0.023	0.035	0.030	0.040												
None	Foothills	33.8	1584	0.021	0.035	0.030	0.040	67.5	3432	0.020	0.035	0.03	0.04	437	6811	0.064	0.048	0.038	0.057
None	Foothills	33.7	1848	0.018	0.035	0.030	0.040												
None	Mountain	74.0	1795	0.041	0.050	0.040	0.060	370	3379	0.109	0.05	0.04	0.06						
None	Mountain	295.5	1584	0.187	0.050	0.040	0.060												

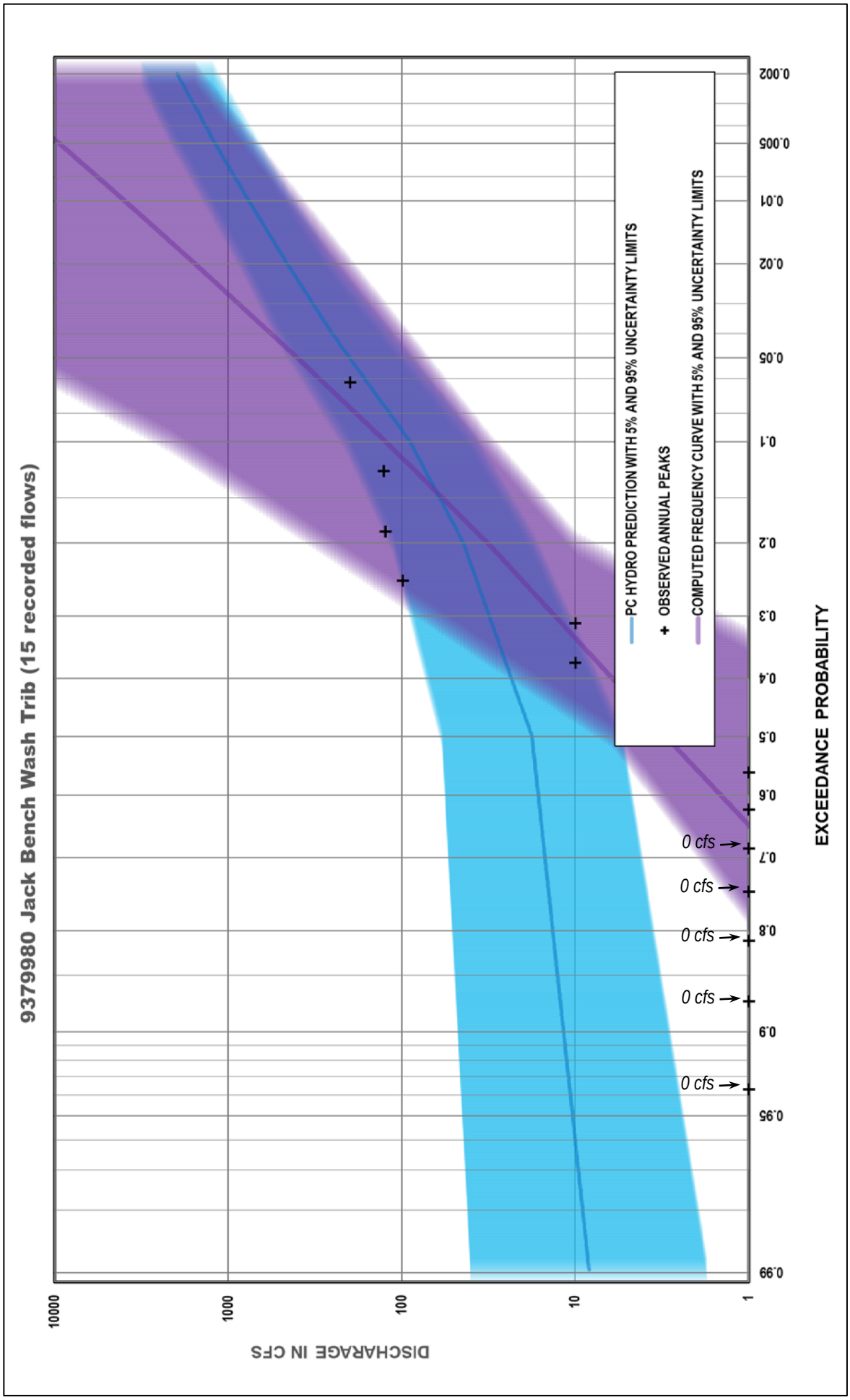
Watercourse Length: 14097 ft
Mean slope: 0.031 ft/ft
Wt Basin Factors: 0.039 0.032 0.045

Mean slope: 0.032 ft/ft
Wt Basin Factors: 0.039 0.032 0.045

Mean slope: 0.041 ft/ft
Wt Basin Factor: 0.041 0.034 0.048

Soil	Percent
Type B	37%
Type C	
Type D	63%

Red Font: User entry
Blue font: Calculation


9379980 Jack Bench Wash Trib (15 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0 cfs
0 cfs
0 cfs
0 cfs
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Klethla Valley Tributary near Kayenta, AZ

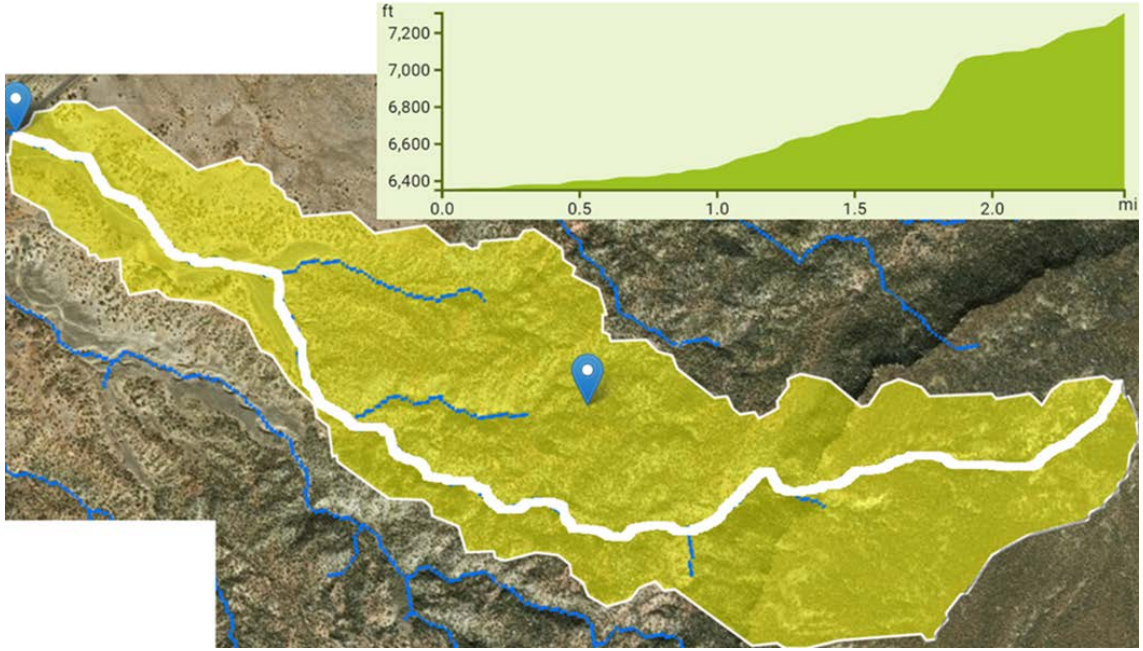
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Klethla Valley Tributary near Kayenta, AZ
Agency: USGS
Station: 9401245
Northing: 36°29'52"N Easting: 110°37'17"W
(in decimal form: 36.49778,-110.62139

Watershed Information
Watershed: Undeveloped-Mountain
Veg cover type: Juniper Grass
Area (sq. mi.): 0.79
L Cen Grav (ft): 6600

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	15%	5%	25%



Eight Points

Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high
None	Foothills	31.9	1690	0.019	0.035	0.030	0.040
None	Foothills	38.1	1690	0.023	0.035	0.030	0.040
None	Foothills	42.5	1637	0.026	0.035	0.030	0.040
None	Mountain	146.7	1584	0.093	0.050	0.040	0.060
None	Mountain	132.7	1584	0.084	0.050	0.040	0.060
None	Mountain	290.2	1690	0.172	0.050	0.040	0.060
None	Mountain	86.6	1584	0.055	0.050	0.040	0.060
None	Mountain	187.1	1637	0.114	0.050	0.040	0.060

Watercourse Length: 13096 ft
Mean slope: 0.048 ft/ft
Wt Basin Factors: 0.044 0.036 0.052

Four Points

Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
70	3380	0.021	0.035	0.03	0.04
189	3221	0.059	0.047	0.038	0.056
423	3274	0.129	0.05	0.04	0.06
274	3221	0.085	0.05	0.04	0.06

Mean slope: 0.053 ft/ft
Wt Basin Factors: 0.045 0.037 0.054

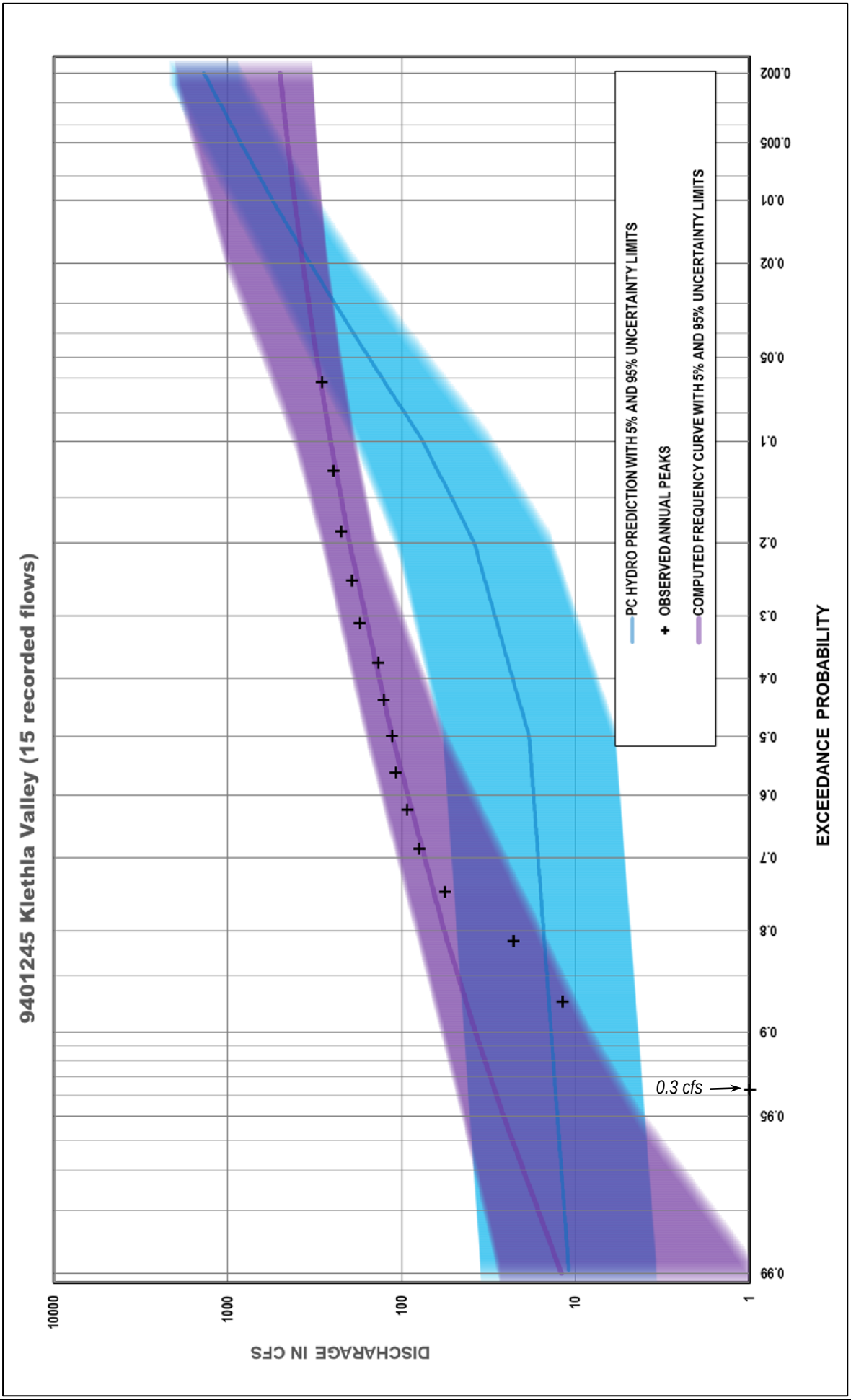
Two Points

Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
259	6601	0.039	0.044	0.036	0.052
697	6495	0.107	0.05	0.04	0.06

Mean slope: 0.061 ft/ft
Wt Basin Factor: 0.047 0.038 0.056

Soil	Percent
Type B	27%
Type C	60%
Type D	13%

Red Font: User entry
Blue font: Calculation


9401245 Klethla Valley (15 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0.3 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Little Colorado River Tributary near St Johns, AZ

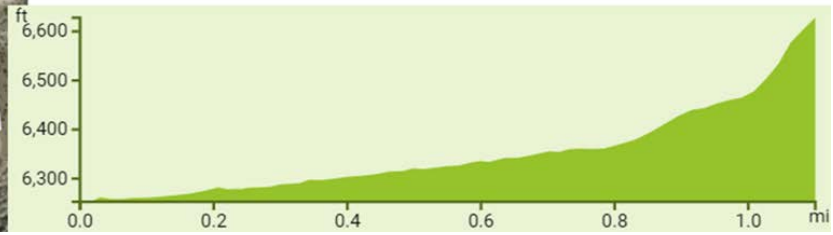
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Little Colorado River Tributary near St Johns, AZ
Agency: USGS
Station: 9385800
Northing: 34°27'4"N Easting: 109°15'25"W
(in decimal form: 34.45111,-109.25694

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Mountain Brush
Area (sq. mi.): 0.37
L Cen Grav (ft): 2900

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:		0%	10%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	13.1	739	0.018	0.035	0.030	0.040	30.5	1478	0.021	0.035	0.03	0.04	72.3	2903	0.025	0.035	0.03	0.04
None	Foothills	17.4	739	0.024	0.035	0.030	0.040												
None	Foothills	22.4	739	0.030	0.035	0.030	0.040	41.8	1425	0.029	0.035	0.03	0.04						
None	Foothills	19.4	686	0.028	0.035	0.030	0.040												
<1 house/ac	Foothills	30.4	792	0.038	0.034	0.029	0.038	54.1	1478	0.037	0.034	0.029	0.039	303	2903	0.104	0.047	0.038	0.056
None	Foothills	23.7	686	0.035	0.035	0.030	0.040												
None	Mountain	80.8	739	0.109	0.050	0.040	0.060	249	1425	0.175	0.05	0.04	0.06						
None	Mountain	168.2	686	0.245	0.050	0.040	0.060												

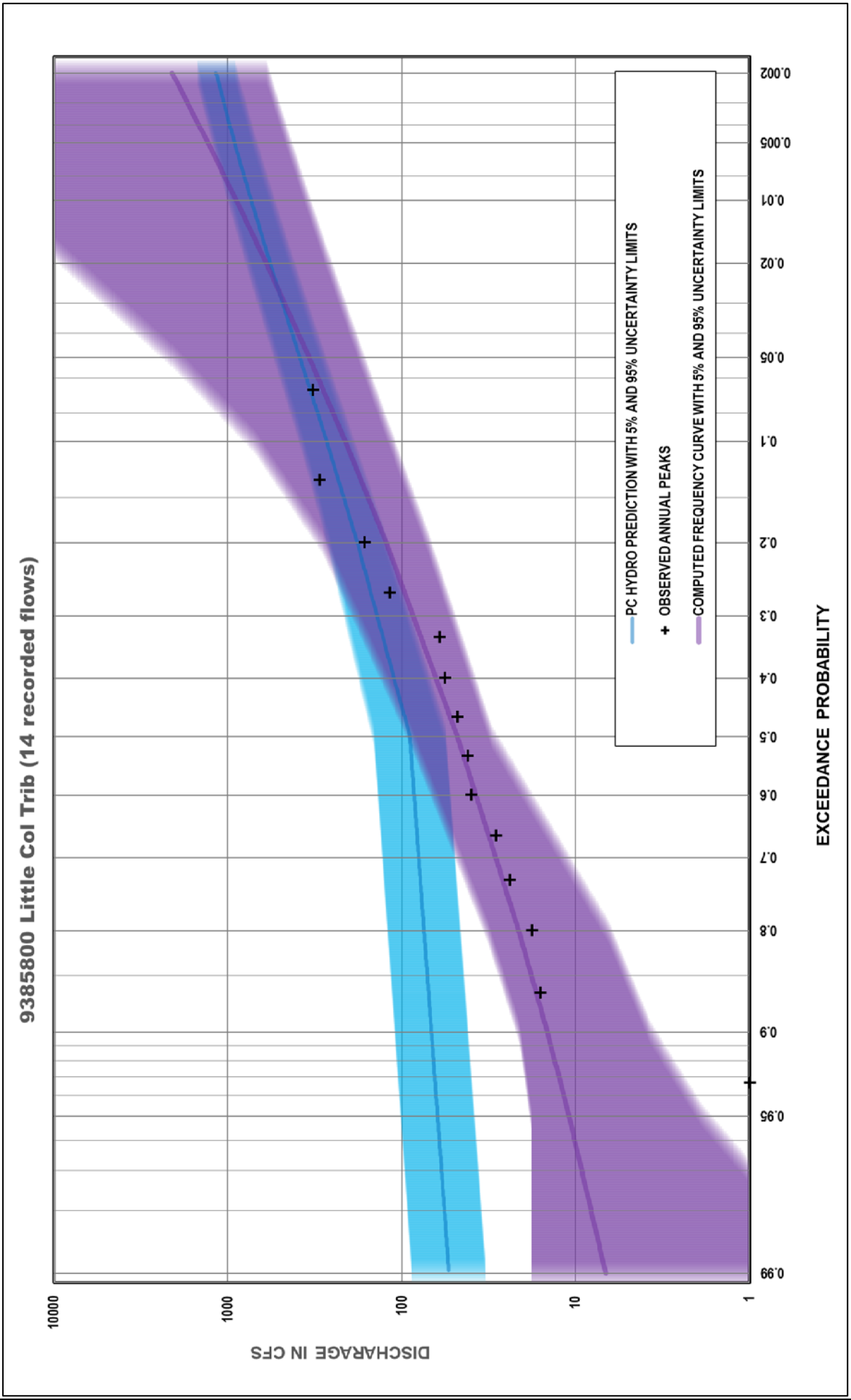
Watercourse Length: 5806 ft
Mean slope: 0.037 ft/ft
Wt Basin Factors: 0.039 0.032 0.045

Mean slope: 0.038 ft/ft
Wt Basin Factors: 0.038 0.032 0.045

Mean slope: 0.045 ft/ft
Wt Basin Factor: 0.041 0.034 0.048

Soil	Percent
Type B	48%
Type C	0%
Type D	52%

Red Font: User entry
Blue font: Calculation


9385800 Little Col Trib (14 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Lynx Creek Tributary near Prescott, AZ

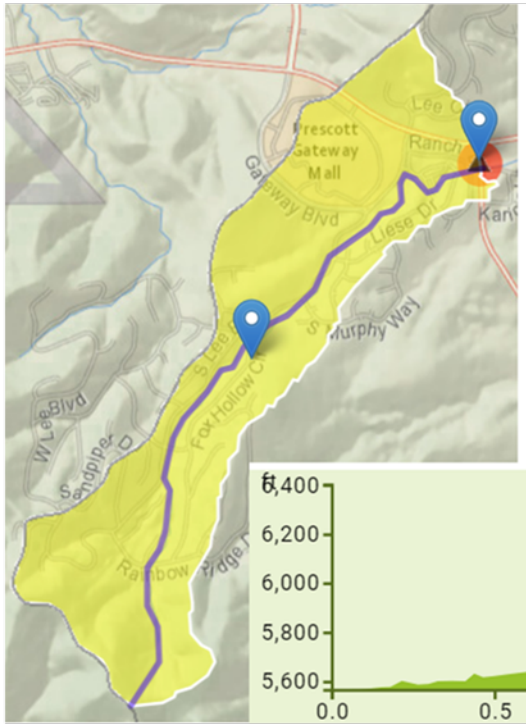
PC-HYDRO V. 6 ANALYSIS

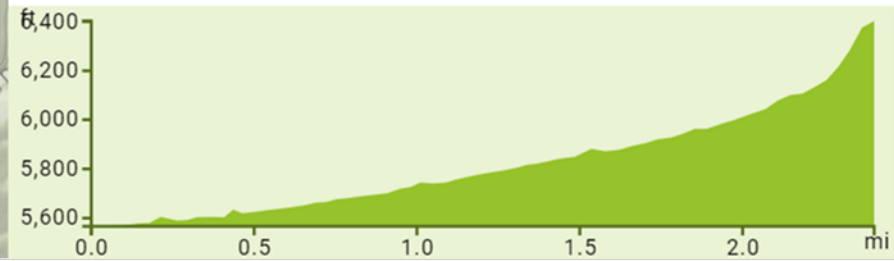
Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Lynx Creek Tributary near Prescott, AZ
Agency: USGS
Station: 9512420
Northing: 34°32'51"N Easting: 112°24'0"W
(in decimal form: 34.54750,-112.40000

Watershed Information
Watershed: Medium Density Urbanized
Veg cover type: Mountain Brush
Area (sq. mi.): 0.98
L Cen Grav (ft): 6000

	Normal	Minimum	Maximum
Veg cover (%):	25%	15%	35%
% impervious:	10%	0%	20%





		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
1-2 houses/ac	Foothills	25.4	1584	0.016	0.032	0.028	0.036	77.2	3274	0.024	0.032	0.028	0.036	219	6495	0.034	0.033	0.029	0.037
1-2 houses/ac	Foothills	51.8	1690	0.031	0.032	0.028	0.036												
<1 house/ac	Foothills	57.2	1531	0.037	0.034	0.029	0.038	142	3221	0.044	0.034	0.029	0.038						
<1 house/ac	Mountain	84.8	1690	0.050	0.034	0.029	0.038												
1-2 houses/ac	Mountain	95.6	1637	0.058	0.032	0.028	0.036	158	3115	0.051	0.032	0.028	0.036	617	6177	0.100	0.042	0.035	0.049
1-2 houses/ac	Mountain	62.0	1478	0.042	0.032	0.028	0.036												
<1 house/ac	Mountain	135.2	1531	0.088	0.034	0.029	0.038	459	3062	0.150	0.045	0.037	0.054						
None	Mountain	324.1	1531	0.212	0.050	0.040	0.060												

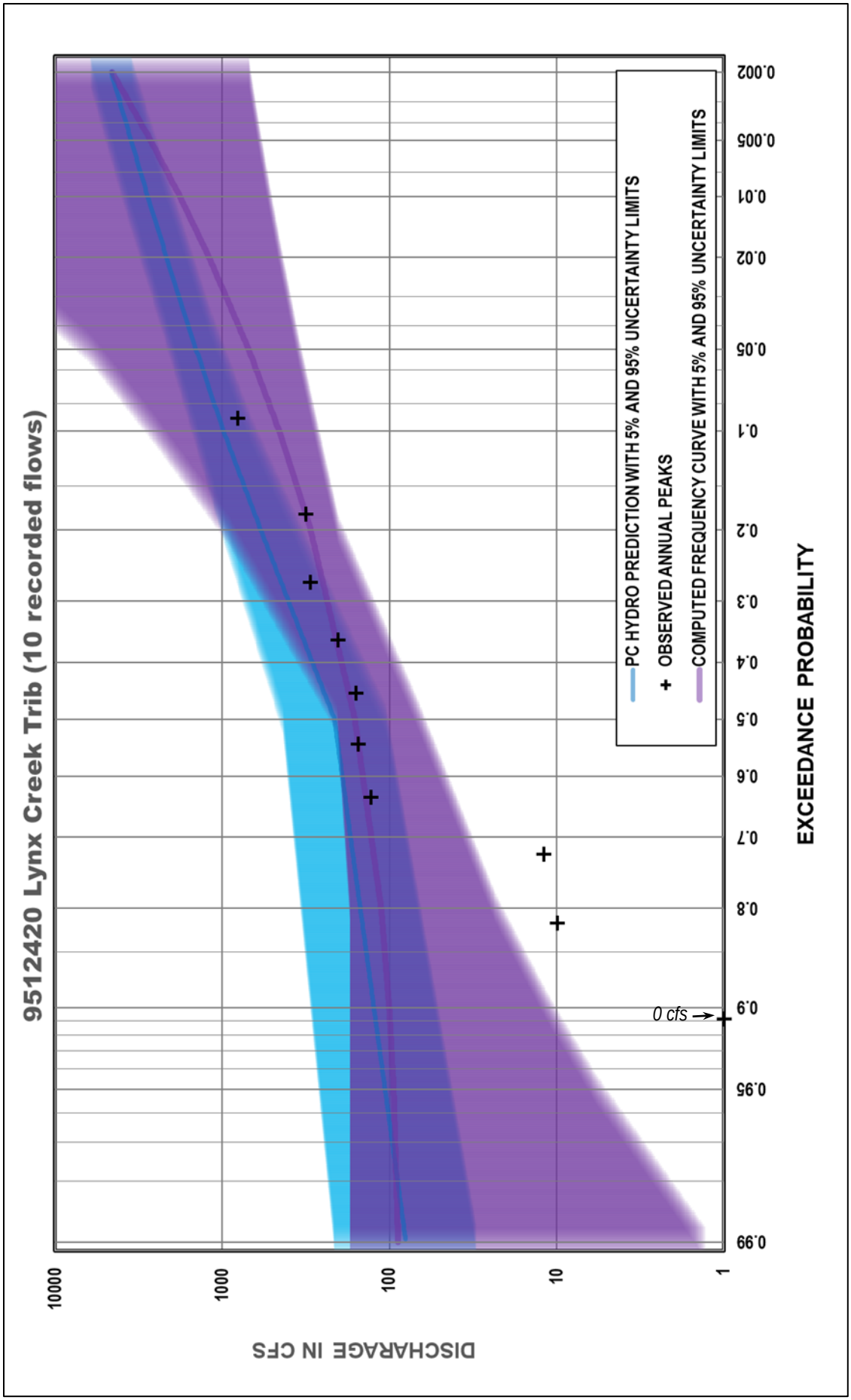
Watercourse Length: 12672 ft
Mean slope: 0.044 ft/ft
Wt Basin Factors: 0.035 0.030 0.040

Mean slope: 0.047 ft/ft
Wt Basin Factors: 0.036 0.030 0.041

Mean slope: 0.053 ft/ft
Wt Basin Factor: 0.037 0.032 0.043

Soil	Percent	SOIL CALCs:	47.5%	34.6%	17.9%
Type B	1%	20.353%		58.8%	
Type C	12%	17.900%			100.0%
Type D	87%	61.7%	100.0%	41.2%	

Red Font: User entry
Blue font: Calculation


9512420 Lynx Creek Trib (10 recorded flows)
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002
0 cfs
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS

Mittry Lake Tributary near Yuma, AZ

PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018

Project Notes:

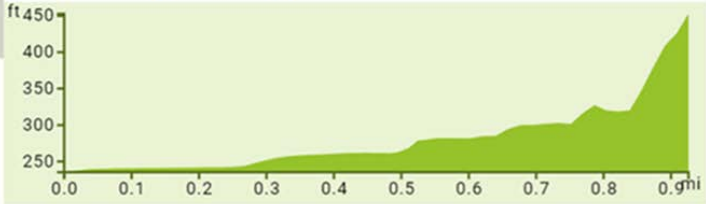
Gage Information

Name: Mittry Lake Tributary near Yuma, AZ
Agency: USGS
Station: 9429510
Northing: 32°51'35"N Easting: 114°26'7"W
(in decimal form: 32.85972,-114.43528

Watershed Information

Watershed:
Veg cover type: Desert Brush
Area (sq. mi.): 0.14
L Cen Grav (ft): 2450

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	12%	2%	22%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Valley	5.9	686	0.009	0.035	0.027	0.050	7	1320	0.005	0.034	0.027	0.049	26.3	2482	0.011	0.035	0.029	0.043
1-2 houses/ac	Valley	1.1	634	0.002	0.032	0.026	0.045												
None	Foothills	15.9	528	0.030	0.035	0.030	0.040	19.3	1162	0.017	0.035	0.03	0.041						
<1 house/ac	Valley	3.4	634	0.005	0.034	0.027	0.047												
None	Foothills	20.5	634	0.032	0.035	0.030	0.040	38.8	1215	0.032	0.035	0.03	0.04	191	2430	0.079	0.045	0.037	0.054
None	Foothills	18.3	581	0.032	0.035	0.030	0.040												
None	Foothills	18.2	634	0.029	0.035	0.030	0.040	152	1215	0.125	0.048	0.039	0.058						
None	Mountain	134.2	581	0.231	0.050	0.040	0.060												

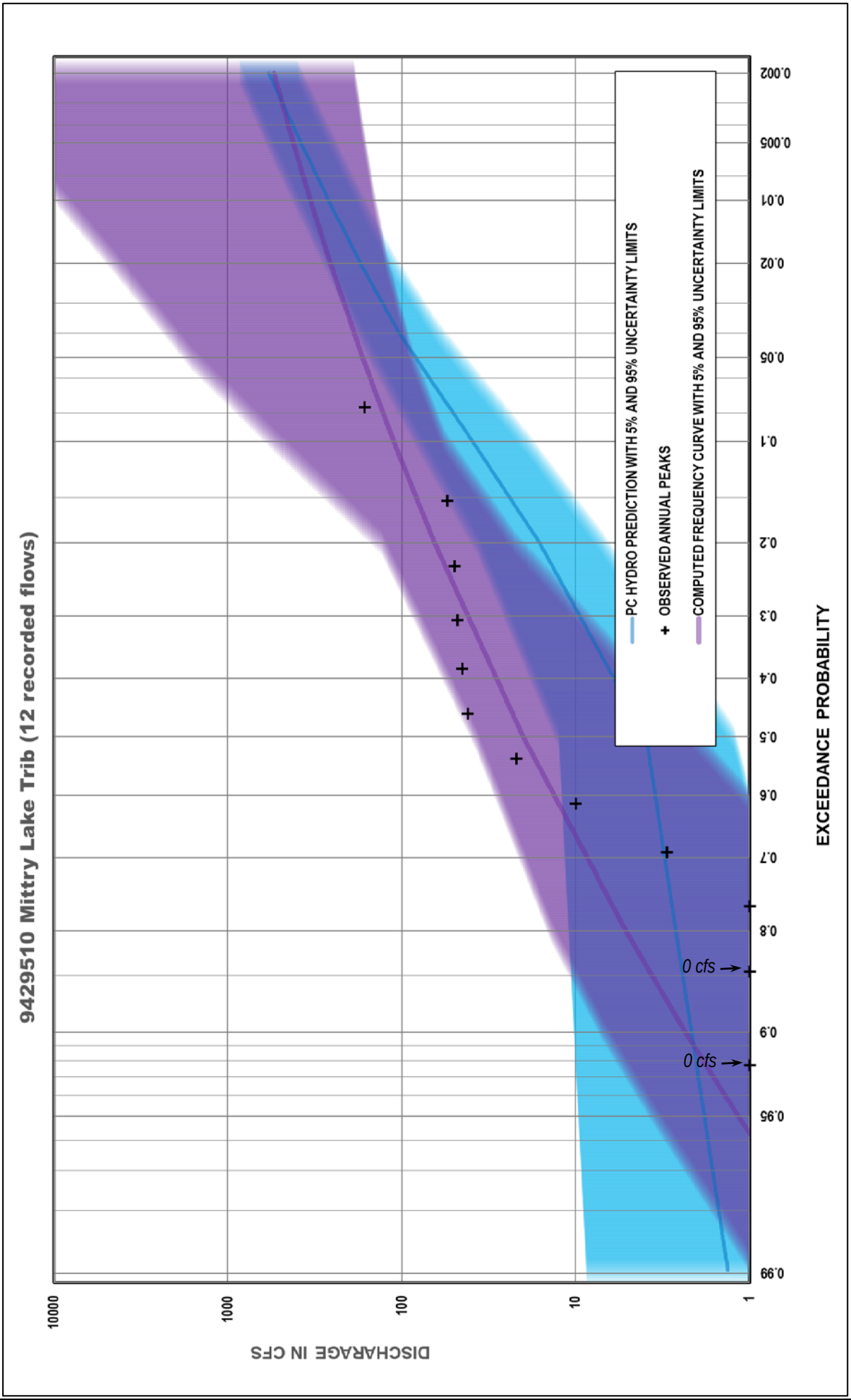
Watercourse Length: 4912 ft
Mean slope: 0.011 ft/ft
Wt Basin Factors: 0.036 0.030 0.045

Mean slope: 0.017 ft/ft
Wt Basin Factors: 0.038 0.031 0.047

Mean slope: 0.022 ft/ft
Wt Basin Factor: 0.040 0.033 0.048

Soil	Percent
Type B	0%
Type C	0%
Type D	100%

Red Font: User entry
Blue font: Calculation


9429510 Mittry Lake Trib (12 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0 cfs
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Mohawk Pass Wash at Mohawk, AZ

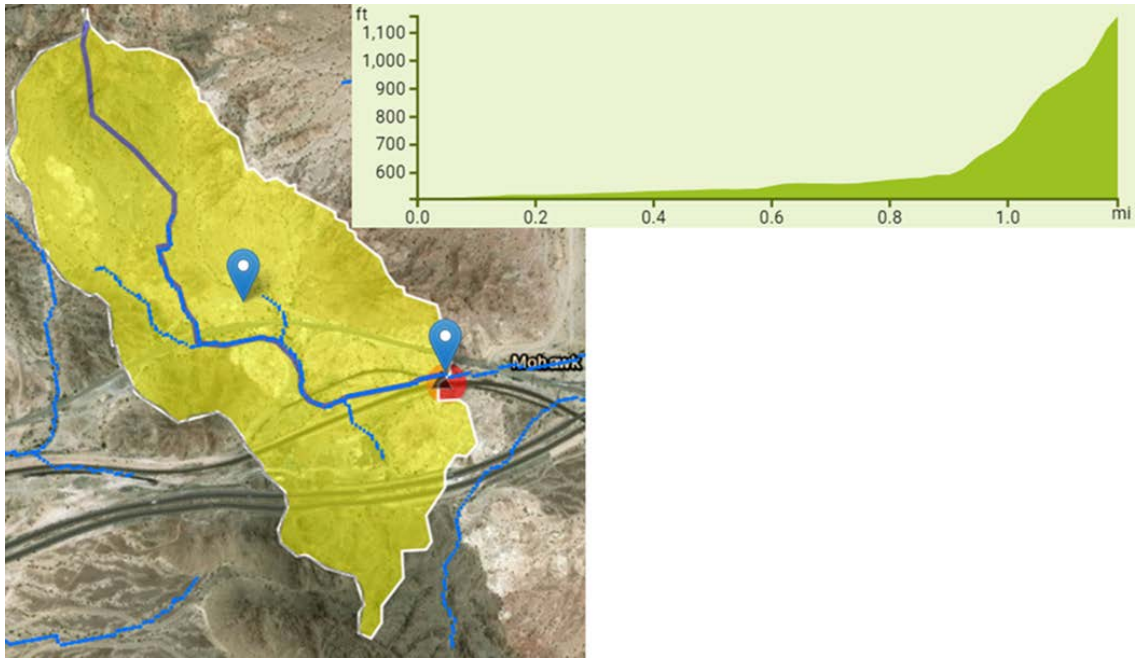
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Mohawk Pass Wash at Mohawk, AZ
Agency: USGS
Station: 9520350
Northing: 32°43'44"N Easting: 113°44'32"W
(in decimal form: 32.72889,-113.74222

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.44
L Cen Grav (ft): 3100

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	20%	10%	30%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
<1 house/ac	Foothills	14.4	845	0.017	0.034	0.029	0.038	21.5	1637	0.013	0.034	0.028	0.041	45.8	3168	0.014	0.034	0.029	0.04
<1 house/ac	Valley	7.1	792	0.009	0.034	0.027	0.047												
None	Foothills	9.7	739	0.013	0.035	0.030	0.040	24.3	1531	0.016	0.034	0.029	0.039						
<1 house/ac	Foothills	14.6	792	0.018	0.034	0.029	0.038												
None	Foothills	10.5	792	0.013	0.035	0.030	0.040	40.7	1584	0.026	0.035	0.03	0.04	606	3115	0.195	0.049	0.039	0.059
None	Foothills	30.2	792	0.038	0.035	0.030	0.040												
None	Mountain	291.9	845	0.345	0.050	0.040	0.060	566	1531	0.369	0.05	0.04	0.06						
None	Mountain	273.6	686	0.399	0.050	0.040	0.060												

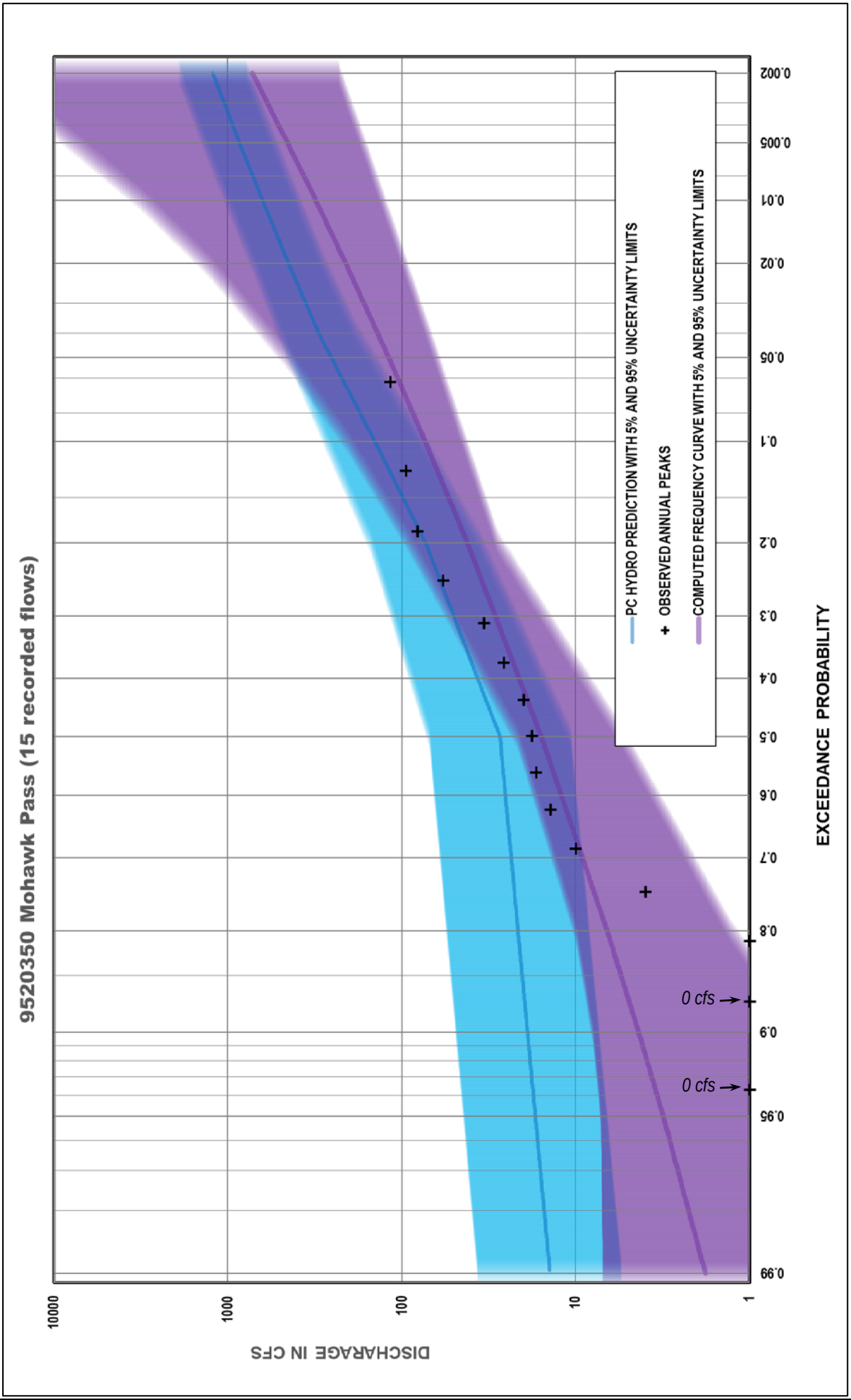
Watercourse Length: 6283 ft
Mean slope: 0.024 ft/ft
Wt Basin Factors: 0.038 0.032 0.045

Mean slope: 0.026 ft/ft
Wt Basin Factors: 0.038 0.032 0.045

Mean slope: 0.035 ft/ft
Wt Basin Factor: 0.041 0.034 0.049

Soil	Percent
Type B	84%
Type C	16%
Type D	0%

Red Font: User entry
Blue font: Calculation


9520350 Mohawk Pass (15 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0 cfs
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Oak Creek Tributary near Cornville, AZ

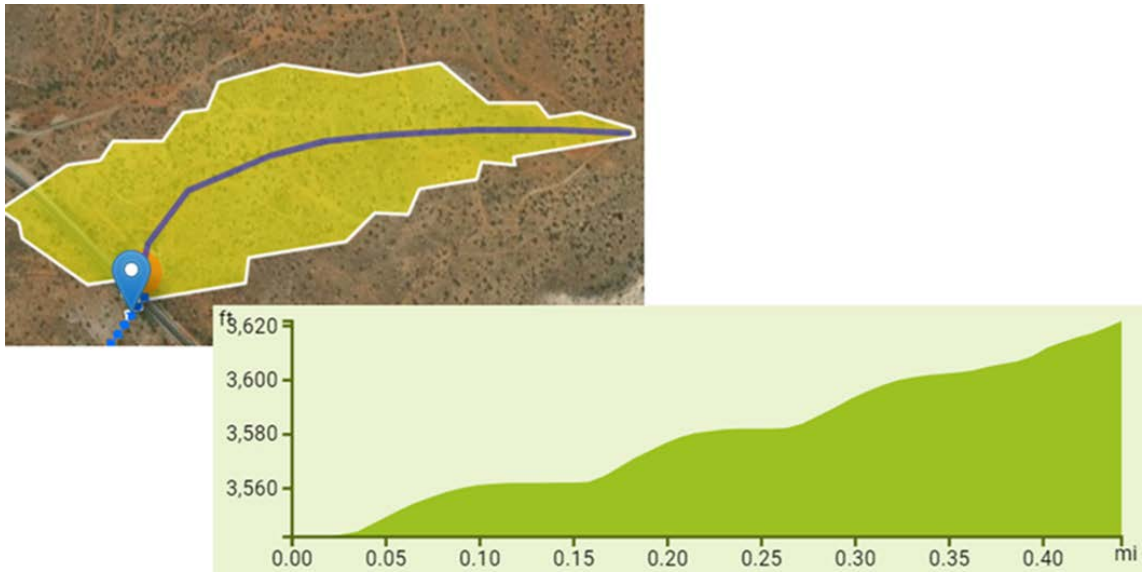
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Oak Creek Tributary near Cornville, AZ
Agency: USGS
Station: 9504800
Northing: 34°42'45"N Easting: 111°52'52"W
(in decimal form: 34.71250,-111.88111

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.04
L Cen Grav (ft): 1200

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	12.0	317	0.038	0.035	0.030	0.040	19.6	581	0.034	0.035	0.03	0.04	39.1	1162	0.034	0.041	0.034	0.049
None	Foothills	7.6	264	0.029	0.035	0.030	0.040												
None	Valley	2.9	317	0.009	0.035	0.027	0.050	19.5	581	0.034	0.048	0.038	0.059						
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	19.9	581	0.034	0.046	0.037	0.055	40.6	1162	0.035	0.046	0.038	0.055
None	Mountain	14.2	264	0.054	0.050	0.040	0.060												
None	Foothills	5.9	317	0.019	0.035	0.030	0.040	20.7	581	0.036	0.046	0.038	0.055						
None	Mountain	14.8	264	0.056	0.050	0.040	0.060												

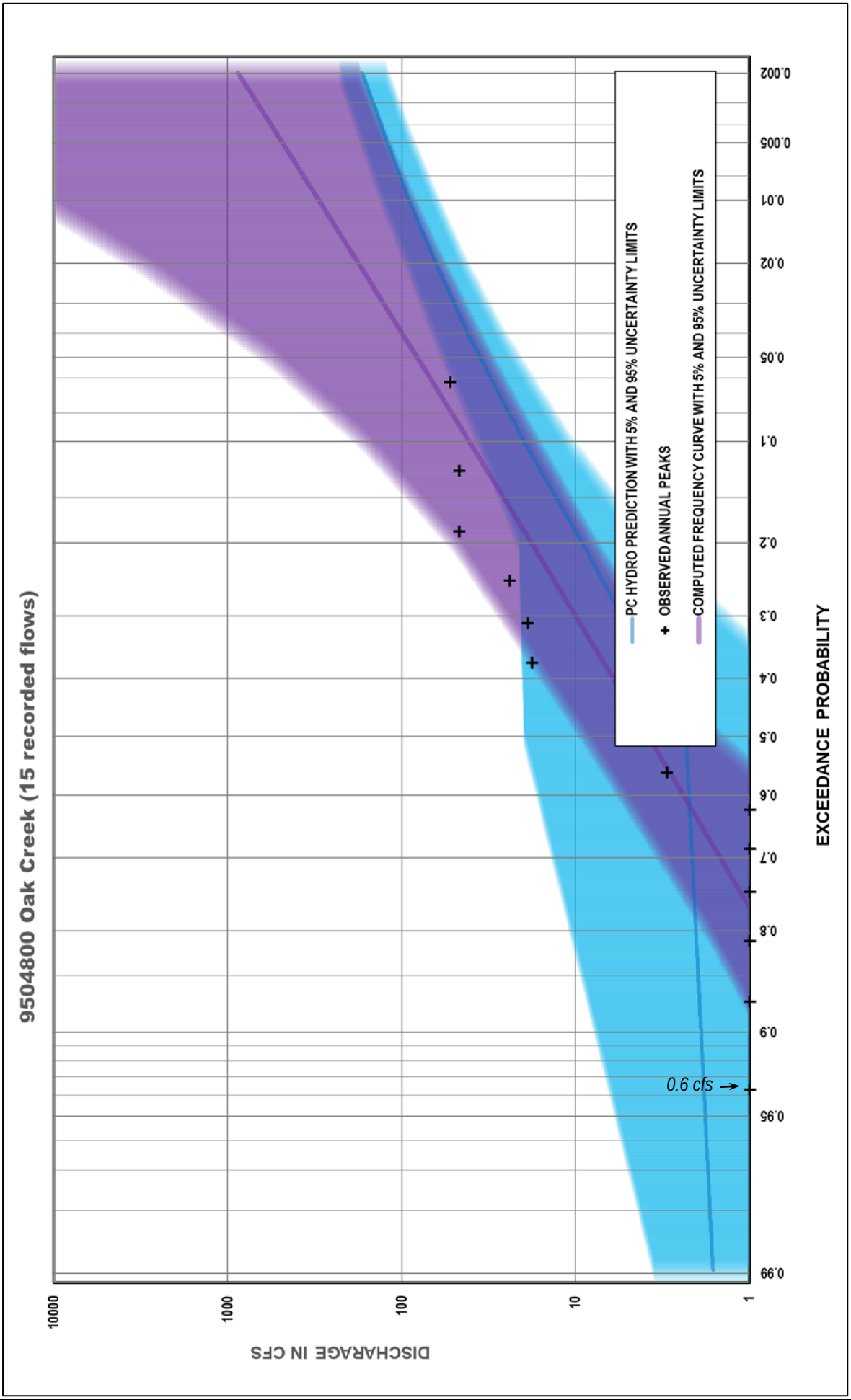
Watercourse Length: 2324 ft
Mean slope: 0.026 ft/ft
Wt Basin Factors: 0.040 0.033 0.048

Mean slope: 0.034 ft/ft
Wt Basin Factors: 0.044 0.036 0.052

Mean slope: 0.034 ft/ft
Wt Basin Factor: 0.044 0.036 0.052

Soil	Percent
Type B	100%
Type C	
Type D	0%

Red Font: User entry
Blue font: Calculation


9504800 Oak Creek (15 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0.6 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Pitchfork Canyon Tributary near Fort Grant, AZ

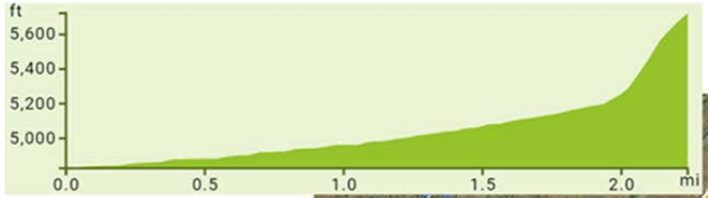
PC-HYDRO V. 6 ANALYSIS

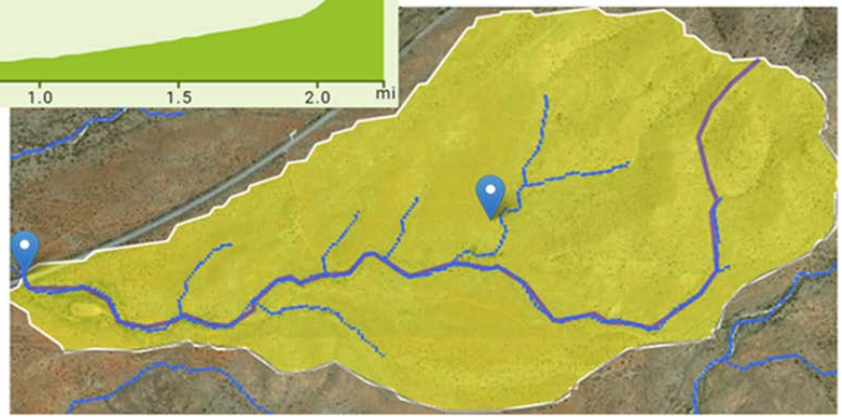
Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Pitchfork Canyon Tributary near Fort Grant, AZ
Agency: USGS
Station: 9536100
Northing: 32°35'20"N Easting: 109°54'42"W
(in decimal form: 32.58889,-109.91167

Watershed Information
Watershed: Undeveloped-Mountain
Veg cover type: Mountain Brush
Area (sq. mi.): 0.88
L Cen Grav (ft): 6000

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	10%	0%	20%





		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	33.1	1584	0.021	0.035	0.030	0.040	66.9	3062	0.022	0.035	0.03	0.04	155	6019	0.026	0.035	0.03	0.04
None	Foothills	33.8	1478	0.023	0.035	0.030	0.040												
None	Foothills	47.9	1531	0.031	0.035	0.030	0.040	88.1	2957	0.030	0.035	0.03	0.04						
None	Foothills	40.2	1426	0.028	0.035	0.030	0.040												
None	Mountain	61.0	1373	0.044	0.050	0.040	0.060	138	2851	0.048	0.05	0.04	0.06	740	5808	0.127	0.05	0.04	0.06
None	Mountain	76.6	1478	0.052	0.050	0.040	0.060												
None	Mountain	105.7	1531	0.069	0.050	0.040	0.060	603	2957	0.204	0.05	0.04	0.06						
None	Mountain	497.1	1426	0.349	0.050	0.040	0.060												

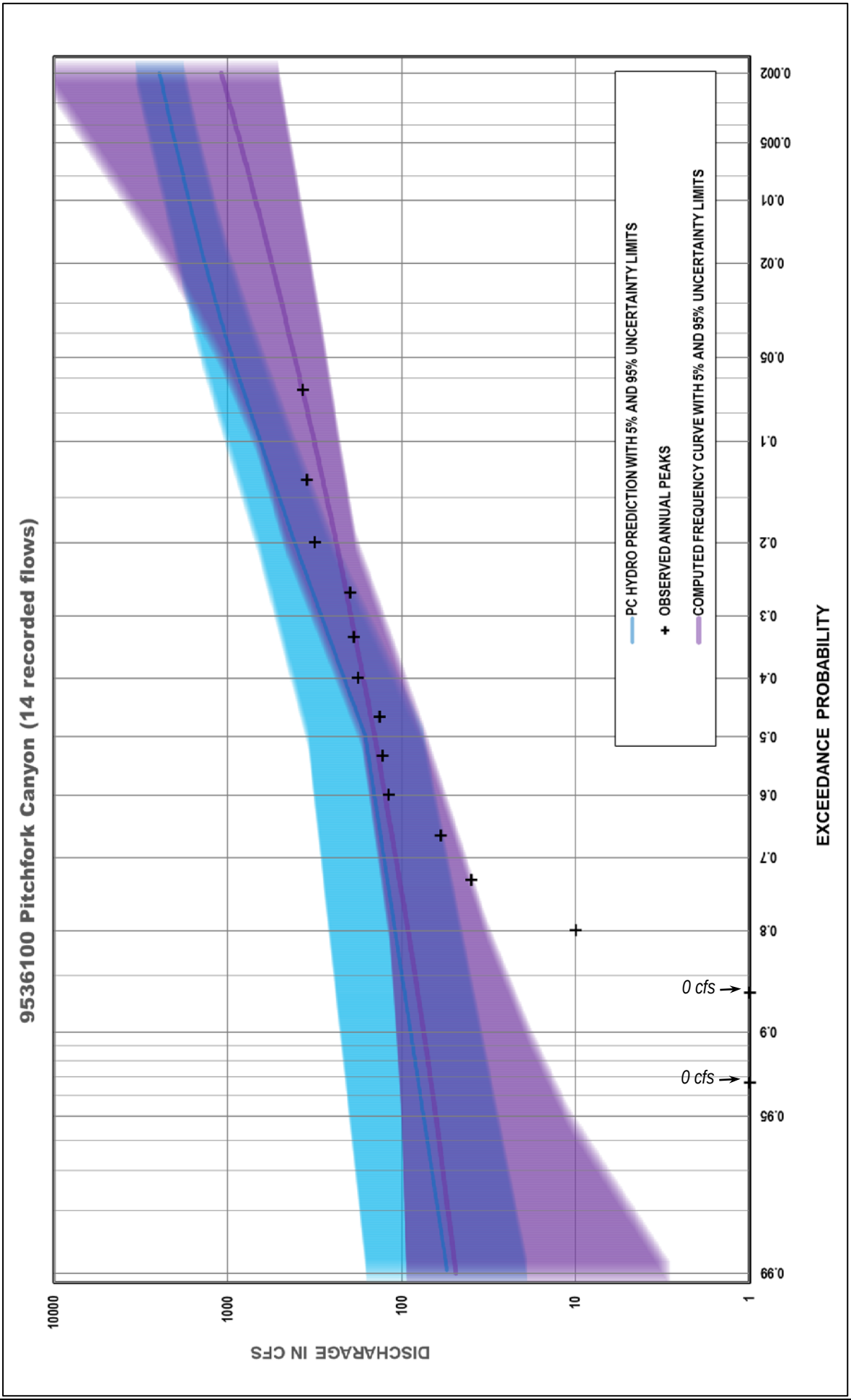
Watercourse Length: 11827 ft
Mean slope: 0.040 ft/ft
Wt Basin Factors: 0.042 0.035 0.050

Mean slope: 0.042 ft/ft
Wt Basin Factors: 0.042 0.035 0.050

Mean slope: 0.048 ft/ft
Wt Basin Factor: 0.042 0.035 0.050

Soil	Percent
Type B	0%
Type C	89%
Type D	11%

Red Font: User entry
Blue font: Calculation


9536100 Pitchfork Canyon (14 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0 cfs
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Pumping Wash near Vail, AZ

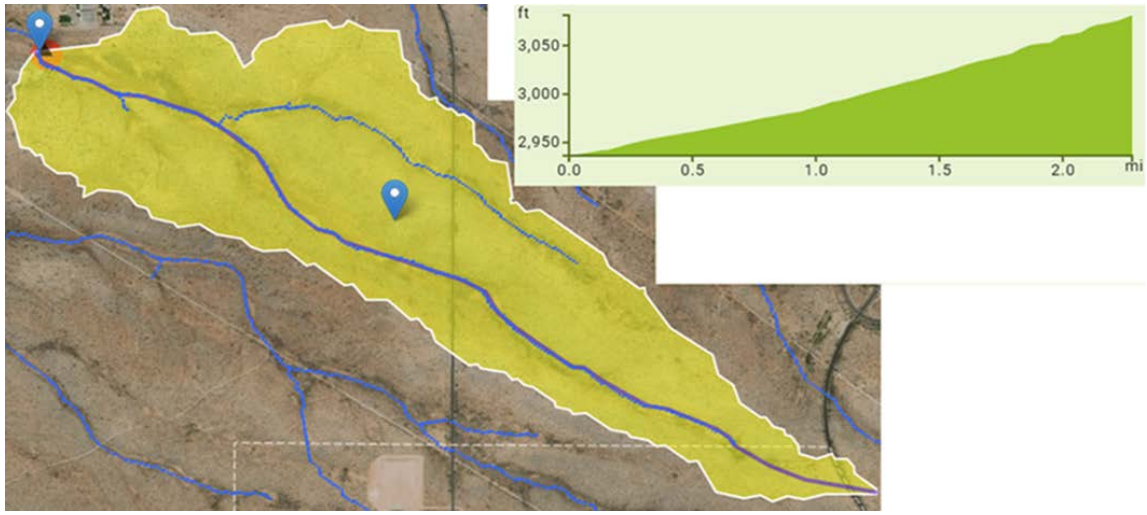
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Pumping Wash near Vail, AZ
Agency: USGS
Station: 9482330
Northing: 32°4'10"N Easting: 110°48'25"W
(in decimal form: 32.06944,-110.80694

Watershed Information
Watershed: Undeveloped-Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.8
L Cen Grav (ft): 7000

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	10%	0%	20%



Eight Points

Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high
None	Valley	16.7	1690	0.010	0.035	0.027	0.050
None	Valley	11.3	1320	0.009	0.035	0.027	0.050
None	Valley	14.5	1584	0.009	0.035	0.027	0.050
None	Foothills	19.0	1584	0.012	0.035	0.030	0.040
None	Foothills	18.9	1426	0.013	0.035	0.030	0.040
None	Foothills	22.0	1637	0.013	0.035	0.030	0.040
None	Foothills	21.3	1320	0.016	0.035	0.030	0.040
None	Foothills	20.9	1478	0.014	0.035	0.030	0.040

Watercourse Length: 12039 ft
Mean slope: 0.012 ft/ft
Wt Basin Factors: 0.035 0.029 0.044

Four Points

Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
28	3010	0.009	0.035	0.027	0.05
33.5	3168	0.011	0.035	0.029	0.044
40.9	3063	0.013	0.035	0.03	0.04
42.2	2798	0.015	0.035	0.03	0.04

Mean slope: 0.012 ft/ft
Wt Basin Factors: 0.035 0.029 0.044

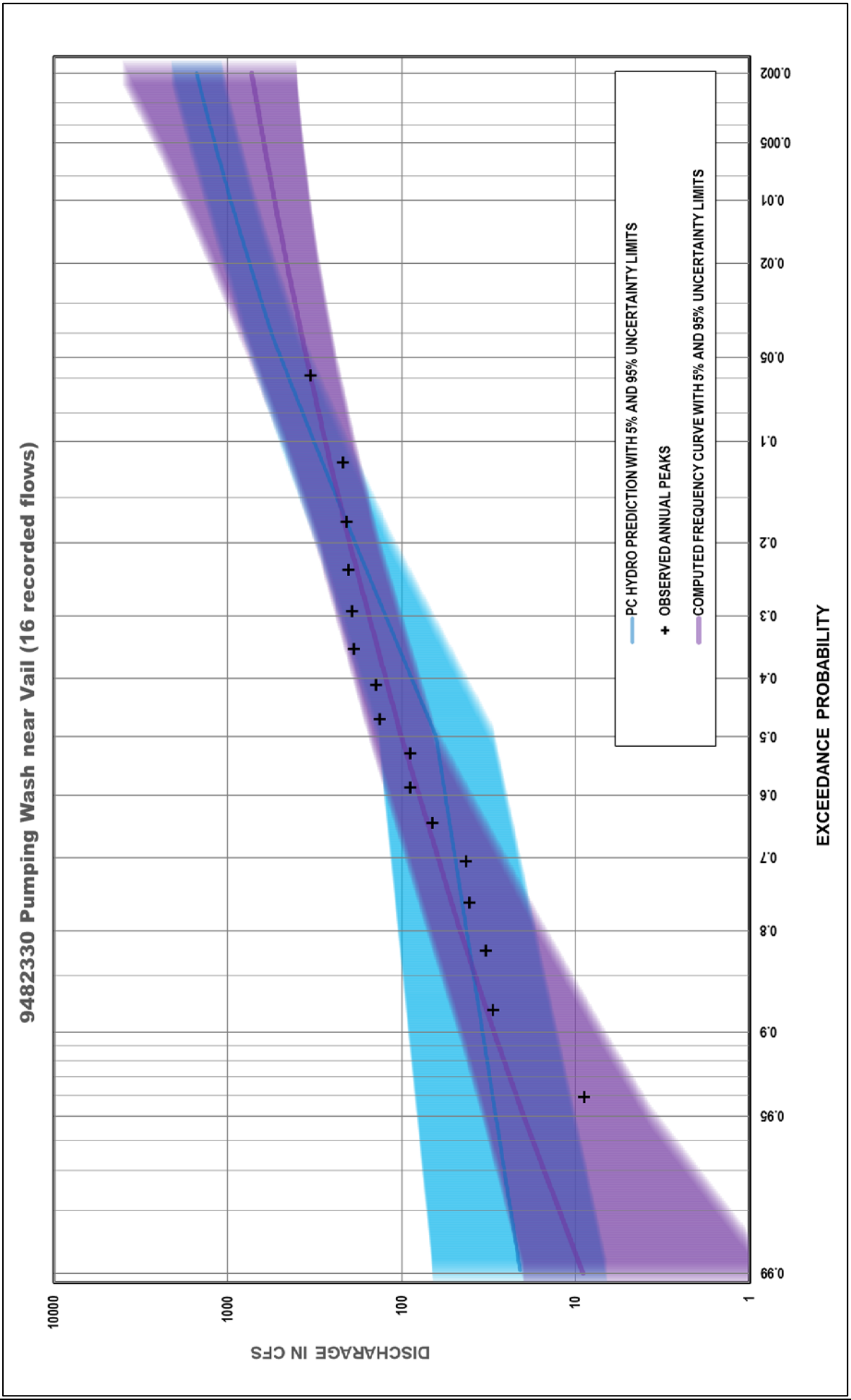
Two Points

Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
61.5	6178	0.010	0.035	0.028	0.047
83.1	5861	0.014	0.035	0.03	0.04

Mean slope: 0.012 ft/ft
Wt Basin Factor: 0.035 0.029 0.044

Soil	Percent
Type B	24%
Type C	76%
Type D	0%

Red Font: User entry
Blue font: Calculation


9482330 Pumping Wash near Vail (16 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Queen Creek Tributary A Apache Junction, AZ

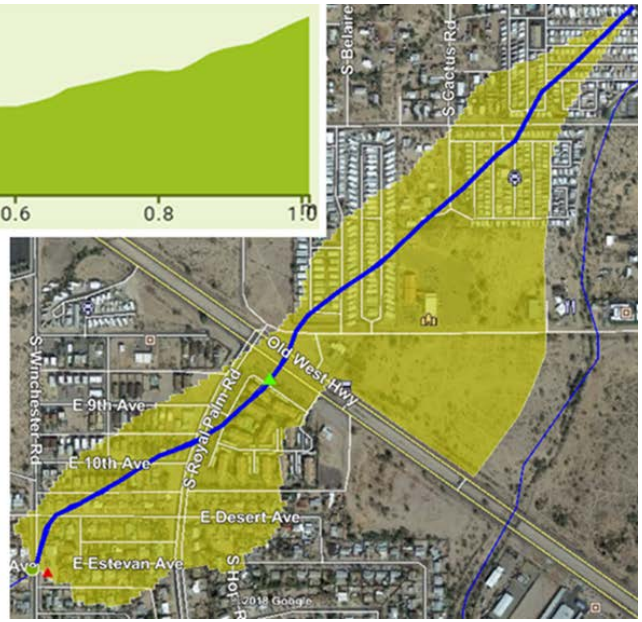
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Queen Creek Tributary A Apache Junction, AZ
Agency: USGS
Station: 9479200
Northing: 33°24'13"N Easting: 111°32'29"W
(in decimal form: 33.40361,-111.54139

Watershed Information
Watershed: Suburban Foothills
Veg cover type: Urban Lawns
Area (sq. mi.): 0.17
L Cen Grav (ft): 3039

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	40%	30%	50%



Development	Watershed Type	Eight Points Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Four Points Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Two Points Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
1-2 houses/ac	Valley	4.1	739	0.006	0.032	0.026	0.045	8.1	1373	0.006	0.032	0.026	0.045	18.8	2693	0.007	0.03	0.025	0.037
1-2 houses/ac	Valley	4.0	634	0.006	0.032	0.026	0.045												
1-2 houses/ac	Foothills	6.7	634	0.011	0.032	0.028	0.036	10.7	1320	0.008	0.028	0.025	0.032						
3-5 houses/ac[1]	Valley	4.0	686	0.006	0.022	0.020	0.025												
3-5 houses/ac[1]	Foothills	8.2	739	0.011	0.022	0.020	0.025	15.3	1373	0.011	0.022	0.02	0.025	30.2	2641	0.011	0.022	0.02	0.025
3-5 houses/ac[1]	Foothills	7.1	634	0.011	0.022	0.020	0.025												
3-5 houses/ac[1]	Valley	6.1	634	0.010	0.022	0.020	0.025	14.9	1268	0.012	0.022	0.02	0.025						
3-5 houses/ac[1]	Foothills	8.8	634	0.014	0.022	0.020	0.025												

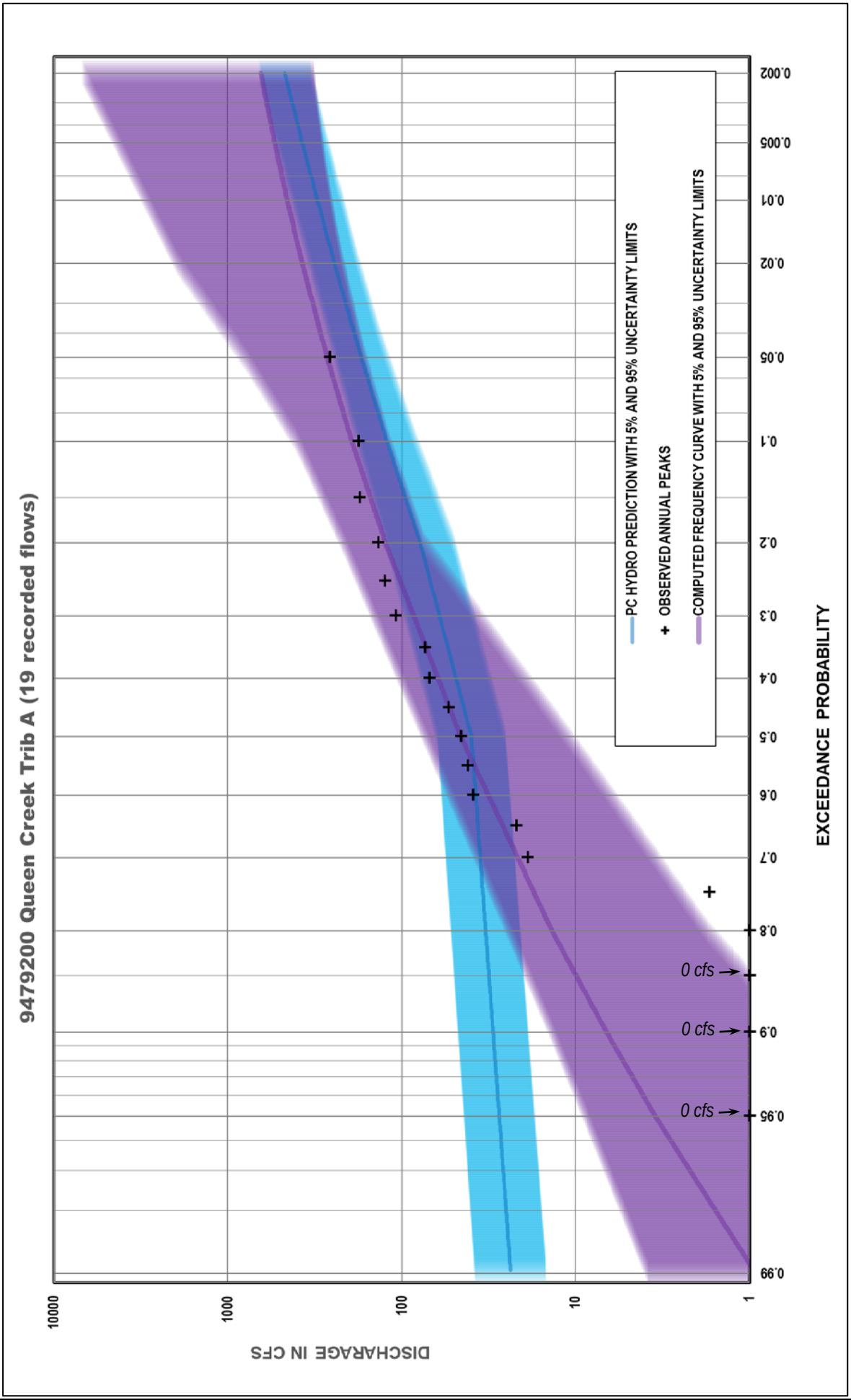
[1] *(Detached homes)* Watercourse Length: 5334 ft
Mean slope: 0.008 ft/ft
Wt Basin Factors: 0.026 0.022 0.031

Mean slope: 0.009 ft/ft
Wt Basin Factors: 0.026 0.023 0.032

Mean slope: 0.009 ft/ft
Wt Basin Factor: 0.026 0.023 0.031

Soil	Percent
Type B	8%
Type C	92%
Type D	0%

Red Font: User entry
Blue font: Calculation


9479200 Queen Creek Trib A (19 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0 cfs
0 cfs
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Queen Creek Tributary No. 3 at Whitlow Dam, AZ

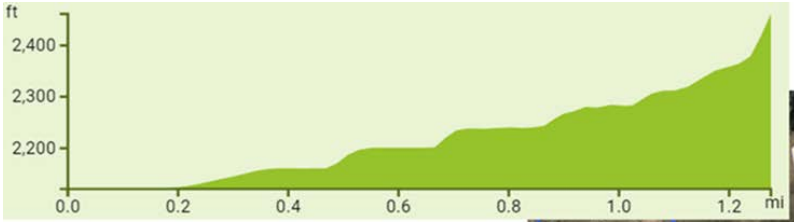
PC-HYDRO V. 6 ANALYSIS

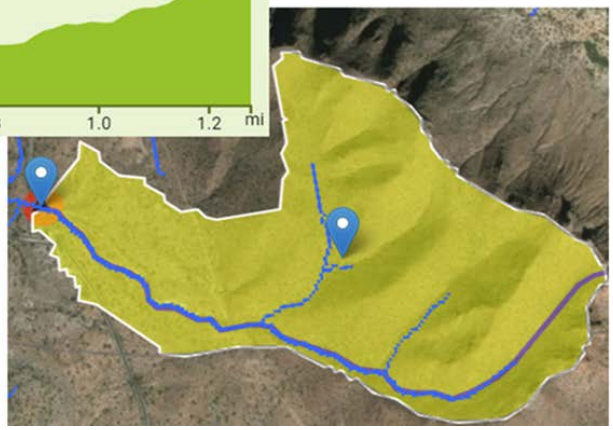
Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Queen Creek Tributary No. 3 at Whitlow Dam, AZ
Agency: USGS
Station: 9478600
Northing: 33°17'30"N Easting: 111°16'52"W
(in decimal form: 33.29167,-111.28111

Watershed Information
Watershed: Undeveloped-Mountain
Veg cover type: Desert Brush
Area (sq. mi.): 0.38
L Cen Grav (ft): 2900

	Normal	Minimum	Maximum
Veg cover (%):	30%	20%	40%
% impervious:	31%	21%	41%





		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Valley	0.3	898	0.000	0.035	0.027	0.050	30.7	1690	0.018	0.035	0.03	0.04	80	3433	0.023	0.035	0.03	0.04
None	Foothills	30.4	792	0.038	0.035	0.030	0.040												
None	Foothills	18.9	898	0.021	0.035	0.030	0.040	49.3	1743	0.028	0.035	0.03	0.04						
None	Foothills	30.4	845	0.036	0.035	0.030	0.040												
None	Mountain	39.5	845	0.047	0.050	0.040	0.060	78.1	1637	0.048	0.05	0.04	0.06	261	3327	0.078	0.05	0.04	0.06
None	Mountain	38.6	792	0.049	0.050	0.040	0.060												
None	Mountain	41.2	898	0.046	0.050	0.040	0.060	182	1690	0.108	0.05	0.04	0.06						
None	Mountain	141.2	792	0.178	0.050	0.040	0.060												

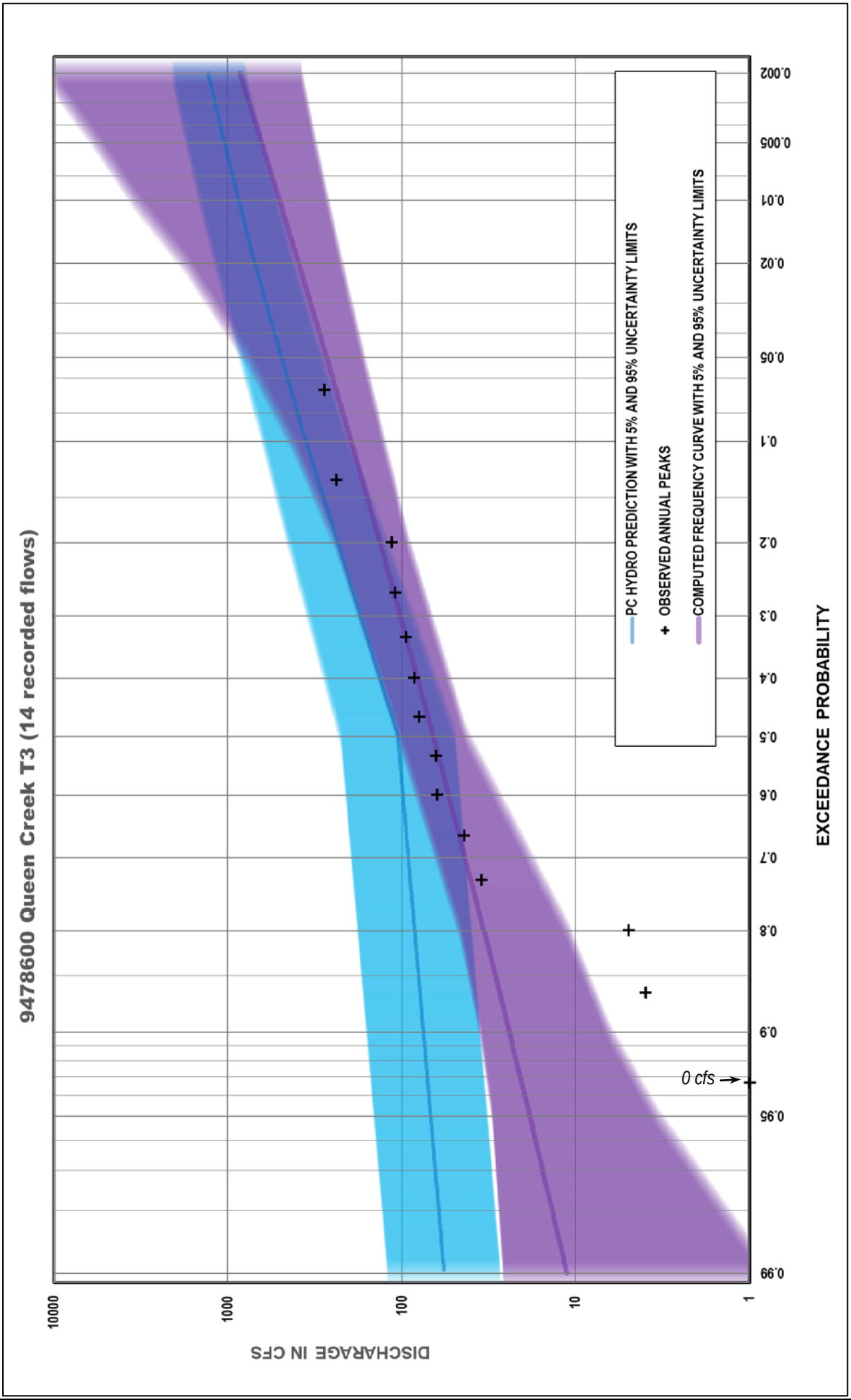
Watercourse Length: 6760 ft
Mean slope: 0.008 ft/ft
Wt Basin Factors: 0.042 0.035 0.051

Mean slope: 0.036 ft/ft
Wt Basin Factors: 0.042 0.035 0.050

Mean slope: 0.039 ft/ft
Wt Basin Factor: 0.042 0.035 0.050

Soil	Percent
Type B	
Type C	
Type D	100%

Red Font: User entry
Blue font: Calculation


9478600 Queen Creek T3 (14 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

San Joaquin Wash near Tucson, AZ

PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018

Project Notes:

0 0 0 0 0-1

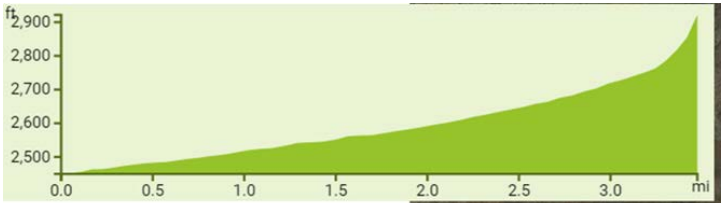
Gage Information

Name: San Joaquin Wash near Tucson, AZ
Agency: USGS
Station: 9487140
Northing: 32°10'7"N Easting: 111°8'0"W
(in decimal form: 32.16861,-111.13333

Watershed Information

Watershed: Suburban Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.69
L Cen Grav (ft): 8500

	Normal	Minimum	Maximum
Veg cover (%):	10%	0%	20%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
<1 house/ac	Foothills	31.5	2429	0.013	0.034	0.029	0.038	57.5	4699	0.012	0.034	0.029	0.038	121	9293	0.013	0.034	0.029	0.038
<1 house/ac	Foothills	26.0	2270	0.011	0.034	0.029	0.038												
<1 house/ac	Foothills	36.6	2482	0.015	0.034	0.029	0.038	63.9	4594	0.014	0.034	0.029	0.038						
<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	93	4752	0.020	0.034	0.029	0.038	351	9028	0.039	0.034	0.029	0.038
<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	258	4276	0.060	0.034	0.029	0.038						
<1 house/ac	Mountain	197.1	2270	0.087	0.034	0.029	0.038												

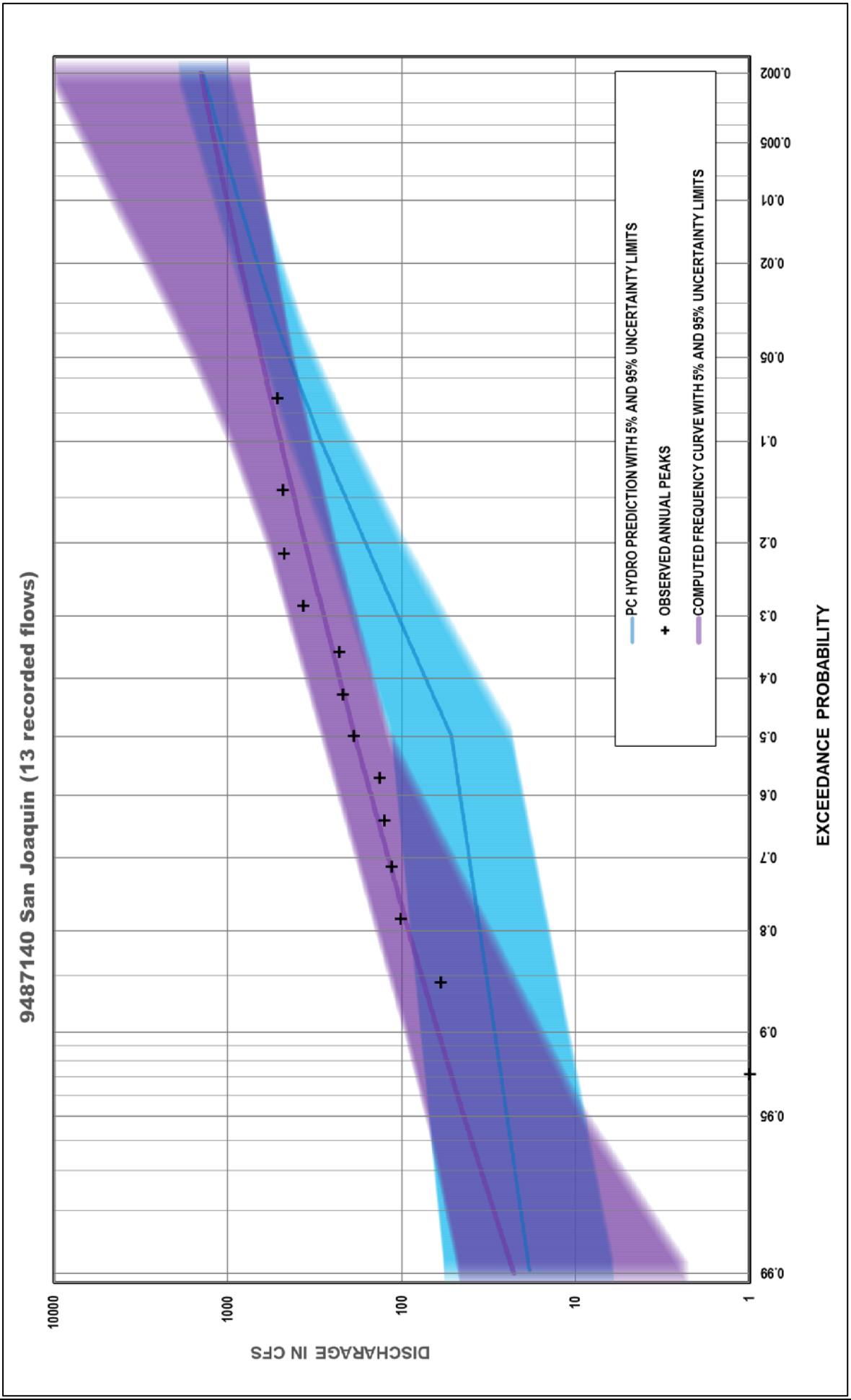
Watercourse Length: 18321 ft
Mean slope: 0.018 ft/ft
Wt Basin Factors: 0.034 0.029 0.038

Mean slope: 0.019 ft/ft
Wt Basin Factors: 0.034 0.029 0.038

Mean slope: 0.021 ft/ft
Wt Basin Factor: 0.034 0.029 0.038

Soil	Percent
Type B	0%
Type C	97%
Type D	3%

Red Font: User entry
Blue font: Calculation


9487140 San Joaquin (13 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Sevenmile Wash Tributary near Globe, AZ

PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018

Project Notes:

00000-1

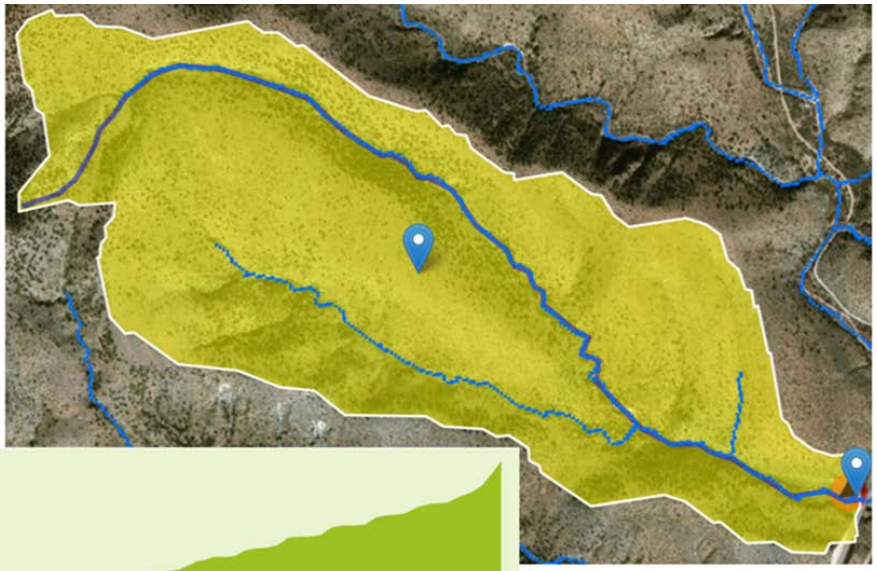
Gage Information

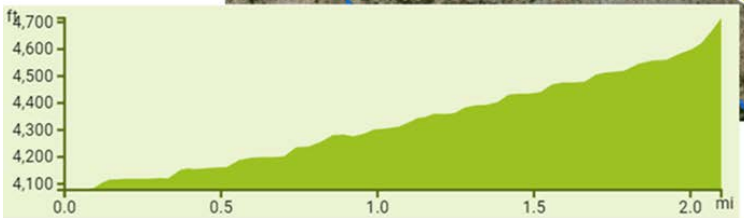
Name: Sevenmile Wash Tributary near Globe, AZ
Agency: USGS
Station: 9468300
Northing: 33°35'10"N Easting: 110°39'2"W
(in decimal form: 33.58611,-110.65056

Watershed Information

Watershed: Undeveloped-Mountain
Veg cover type: Desert Brush
Area (sq. mi.): 0.86
L Cen Grav (ft): 5200

	Normal	Minimum	Maximum
Veg cover (%):	15%	5%	25%
% impervious:	10%	0%	20%





		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	42.2	1478	0.029	0.035	0.030	0.040	112	2956	0.038	0.044	0.036	0.052	235	5649	0.042	0.047	0.038	0.056
None	Mountain	69.5	1478	0.047	0.050	0.040	0.060												
None	Mountain	66.4	1373	0.048	0.050	0.040	0.060	123	2693	0.046	0.05	0.04	0.06						
None	Mountain	56.6	1320	0.043	0.050	0.040	0.060												
None	Mountain	81.8	1478	0.055	0.050	0.040	0.060	164	2745	0.060	0.05	0.04	0.06	404	5438	0.074	0.05	0.04	0.06
None	Mountain	82.5	1267	0.065	0.050	0.040	0.060												
None	Mountain	81.5	1531	0.053	0.050	0.040	0.060	239	2693	0.089	0.05	0.04	0.06						
None	Mountain	157.7	1162	0.136	0.050	0.040	0.060												

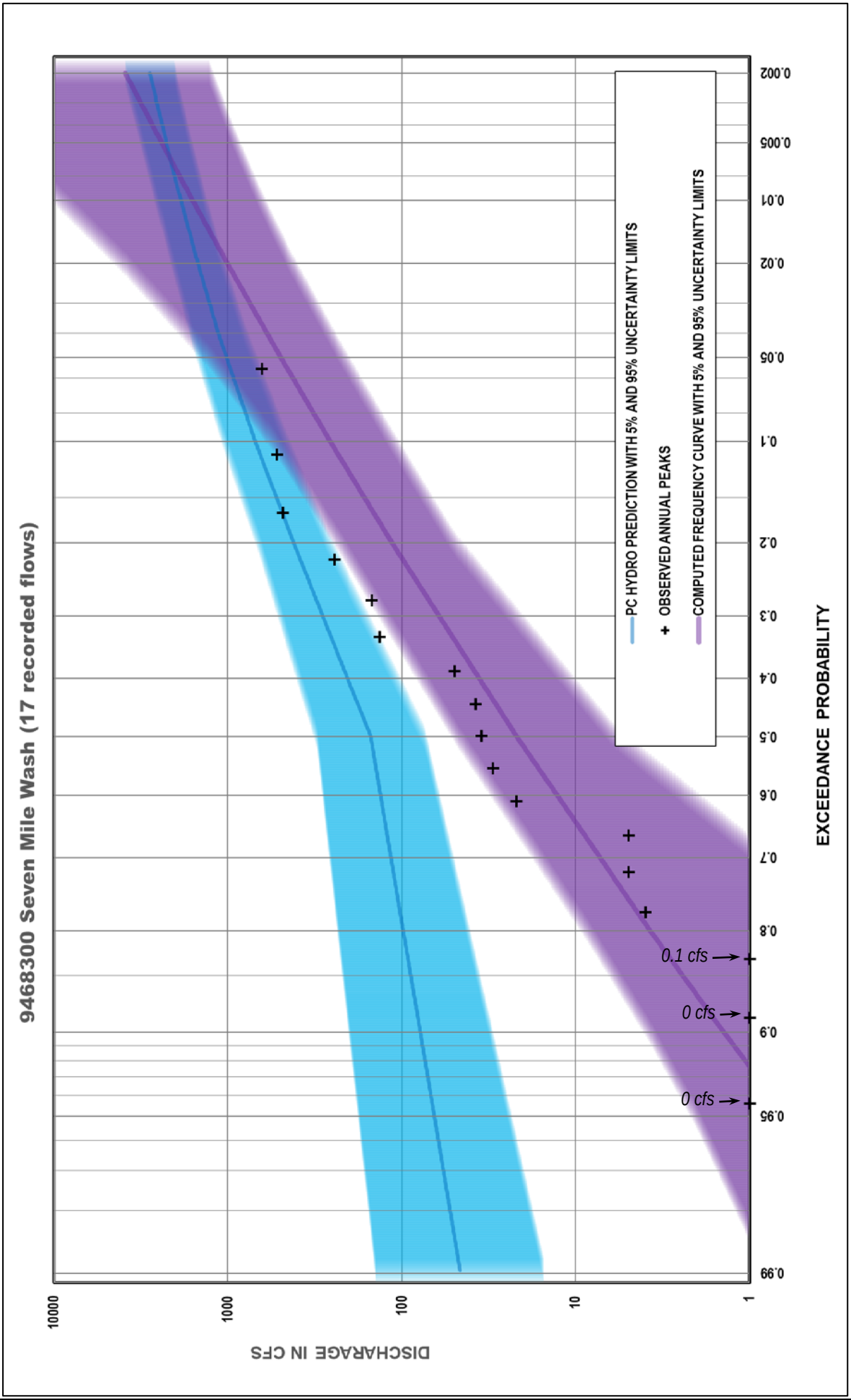
Watercourse Length: 11087 ft
Mean slope: 0.051 ft/ft
Wt Basin Factors: 0.048 0.039 0.057

Mean slope: 0.053 ft/ft
Wt Basin Factors: 0.048 0.039 0.058

Mean slope: 0.054 ft/ft
Wt Basin Factor: 0.048 0.039 0.058

Soil	Percent
Type B	0%
Type C	100%
Type D	0%

Red Font: User entry
Blue font: Calculation


9468300 Seven Mile Wash (17 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0.1 cfs
0 cfs
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

Steamboat Wash Trib. near Ganado, AZ

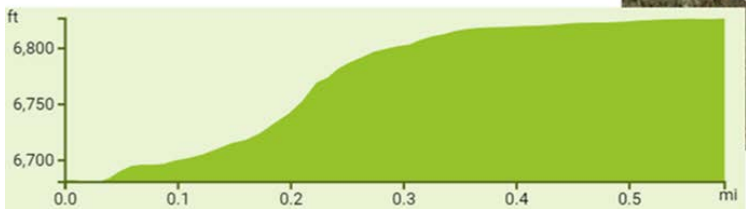
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: Steamboat Wash Tributary near Ganado, AZ
Agency: USGS
Station: 9400200
Northing: 35°45'50"N Easting: 109°48'2"W
(in decimal form: 35.76389,-109.80056

Watershed Information
Watershed: Undeveloped-Valley
Veg cover type: Mountain Brush
Area (sq. mi.): 0.15
L Cen Grav (ft): 900

	Normal	Minimum	Maximum
Veg cover (%):	12%	2%	22%
% impervious:	20%	10%	30%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
None	Foothills	13.6	422	0.032	0.035	0.030	0.040	32.8	792	0.041	0.044	0.036	0.052	120	1532	0.078	0.048	0.039	0.058
None	Mountain	19.2	370	0.052	0.050	0.040	0.060												
None	Mountain	54.2	370	0.146	0.050	0.040	0.060	86.7	740	0.117	0.05	0.04	0.06						
None	Mountain	32.5	370	0.088	0.050	0.040	0.060												
None	Foothills	16.3	422	0.039	0.035	0.030	0.040	19.4	792	0.024	0.035	0.029	0.042	24.7	1532	0.016	0.035	0.029	0.044
None	Valley	3.1	370	0.008	0.035	0.027	0.050												
None	Valley	3.6	370	0.010	0.035	0.027	0.050	5.3	740	0.007	0.035	0.027	0.05						
None	Valley	1.7	370	0.005	0.035	0.027	0.050												

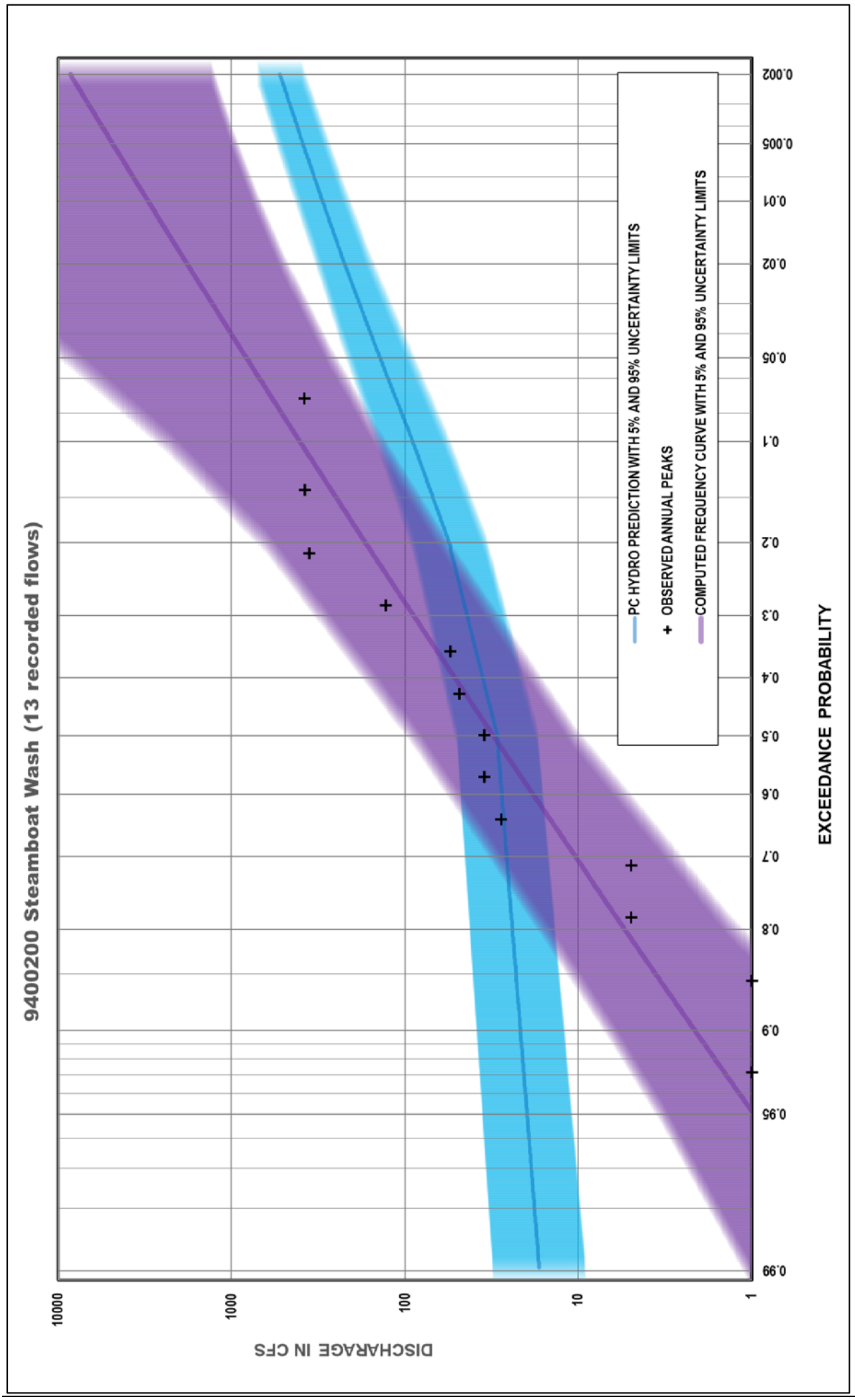
Watercourse Length: 3064 ft
Mean slope: 0.020 ft/ft
Wt Basin Factors: 0.040 0.033 0.051

Mean slope: 0.024 ft/ft
Wt Basin Factors: 0.041 0.033 0.051

Mean slope: 0.030 ft/ft
Wt Basin Factor: 0.042 0.034 0.051

Soil	Percent
Type B	27%
Type C	0%
Type D	73%

Red Font: User entry
Blue font: Calculation


9400200 Steamboat Wash (13 recorded flows)
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS

Walnut Gulch Flume 4

PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018

Project Notes:

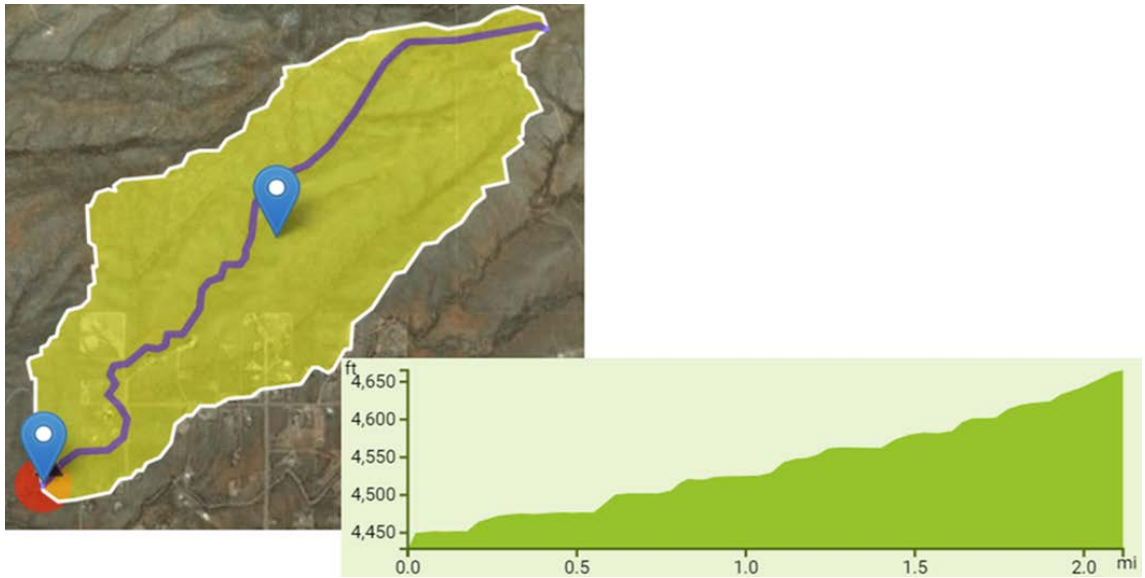
Gage Information

Name: Walnut Gulch Flume 4
Agency: ARS
Station: 6304
Northing: 31°44'00"N Easting: 110°02'01"W
(in decimal form: 31.73333,-110.03361

Watershed Information

Watershed: Suburban Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.88
L Cen Grav (ft): 6000

	Normal	Minimum	Maximum
Veg cover (%):	15%	5%	25%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
<1 house/ac	Foothills	44.2	1426	0.031	0.034	0.029	0.038	48.3	2904	0.017	0.034	0.029	0.039	102	5703	0.018	0.034	0.028	0.04
<1 house/ac	Valley	4.1	1478	0.003	0.034	0.027	0.047												
<1 house/ac	Foothills	39.4	1373	0.029	0.034	0.029	0.038	53.2	2799	0.019	0.034	0.028	0.041						
None	Valley	13.8	1426	0.010	0.035	0.027	0.050												
None	Foothills	32.8	1478	0.022	0.035	0.030	0.040	54.9	2798	0.020	0.035	0.03	0.04	136	5491	0.025	0.035	0.03	0.04
None	Foothills	22.1	1320	0.017	0.035	0.030	0.040												
None	Foothills	38.1	1373	0.028	0.035	0.030	0.040	80.7	2693	0.030	0.035	0.03	0.04						
None	Foothills	42.6	1320	0.032	0.035	0.030	0.040												

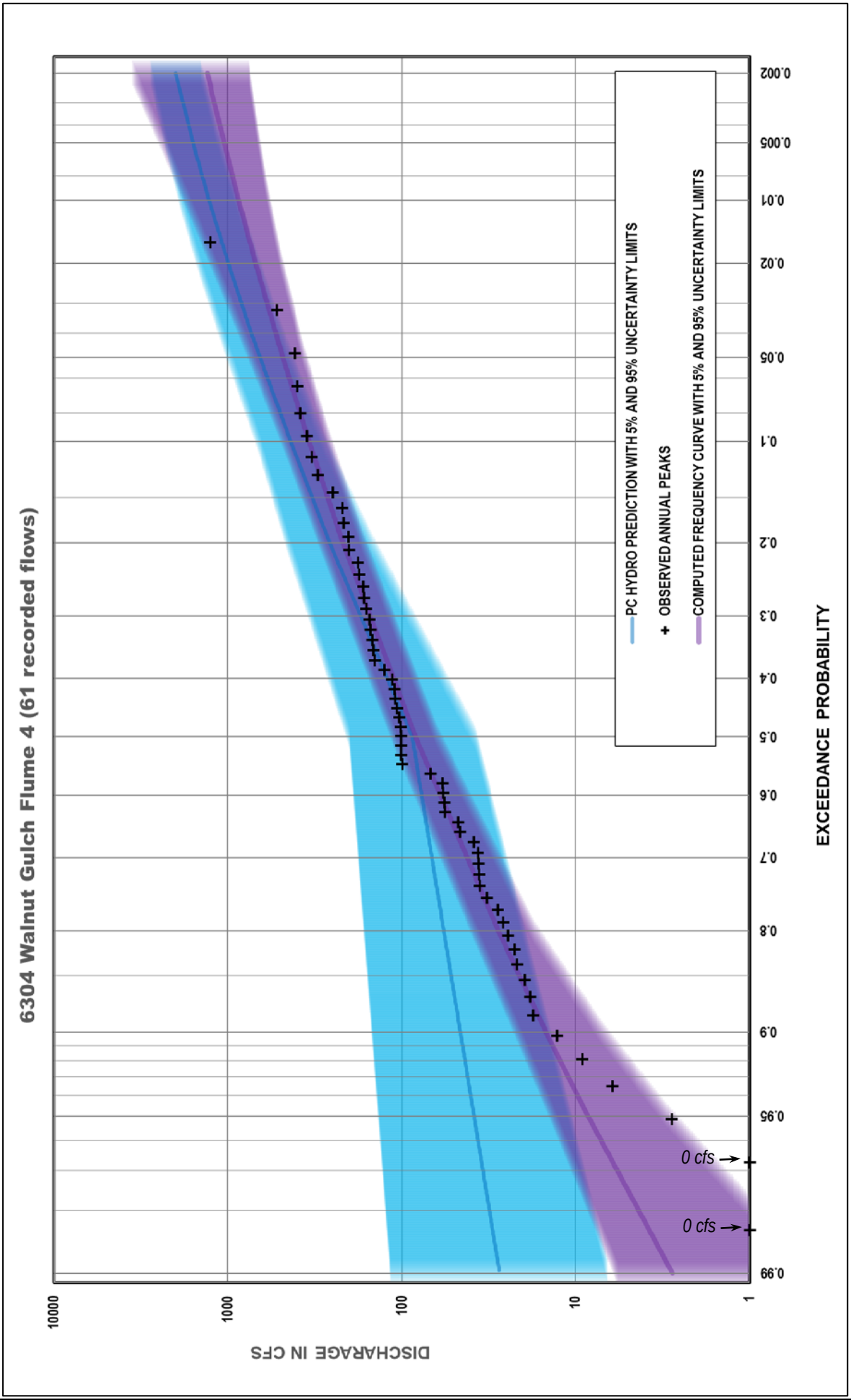
Watercourse Length: 11194 ft
Mean slope: 0.014 ft/ft
Wt Basin Factors: 0.035 0.029 0.042

Mean slope: 0.020 ft/ft
Wt Basin Factors: 0.034 0.029 0.040

Mean slope: 0.021 ft/ft
Wt Basin Factor: 0.034 0.029 0.040

Soil	Percent
Type B	55%
Type C	45%
Type D	0%

Red Font: User entry
Blue font: Calculation


6304 Walnut Gulch Flume 4 (61 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
0 cfs
0 cfs
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002

West Speedway Wash near Tucson, AZ

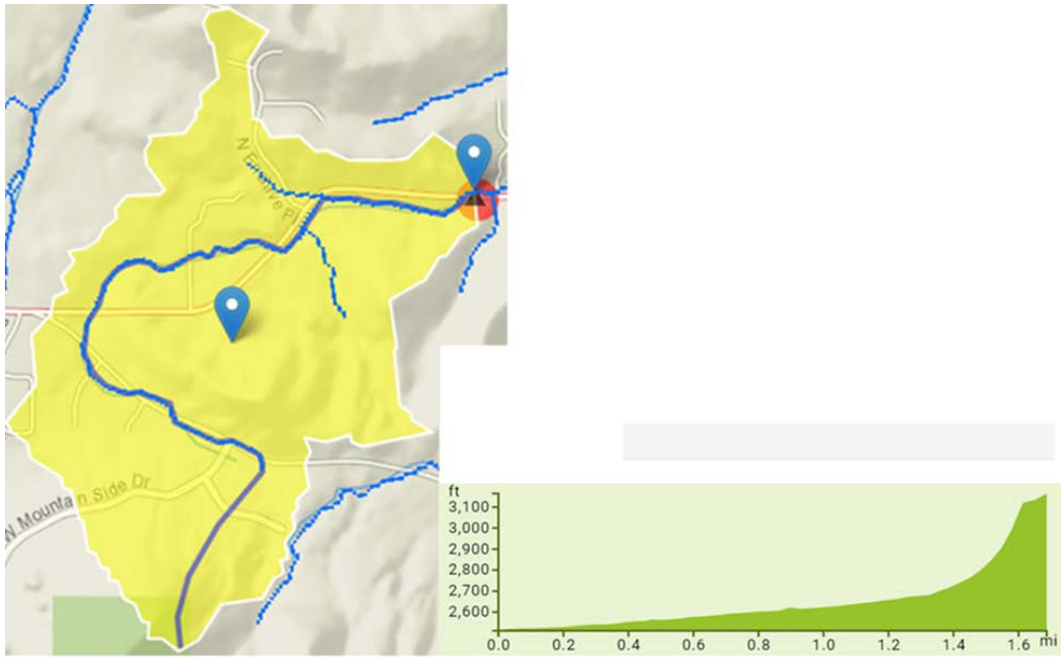
PC-HYDRO V. 6 ANALYSIS

Project Name: PC-Hydro Investigation
User Name: QBT
Client Name: Pima County
Job Number: 18*25964 Date: 6/29/2018
Project Notes:

Gage Information
Name: West Speedway Wash near Tucson, AZ
Agency: USGS
Station: 9483040
Northing: 32°14'20"N Easting: 111°2'45"W
(in decimal form: 32.23889,-111.04583

Watershed Information
Watershed: Suburban Foothills
Veg cover type: Desert Brush
Area (sq. mi.): 0.47
L Cen Grav (ft): 2904

	Normal	Minimum	Maximum
Veg cover (%):	30%	20%	40%
% impervious:	10%	0%	20%



		Eight Points						*Four Points*						*Two Points*					
Development	Watershed Type	Height (Hi, ft)	Length (Li, ft)	Slope (Si, ft/ft)	Basin Factor (Nb)	Nb low	Nb high	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High	Hi (ft)	Li (ft)	Si (ft/ft)	Nb	Nb Low	Nb High
<1 house/ac	Foothills	21.8	1214	0.018	0.034	0.029	0.038	45.8	2376	0.019	0.034	0.029	0.038	94.2	4541	0.021	0.034	0.029	0.038
<1 house/ac	Foothills	24.0	1162	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	2165	0.022	0.034	0.029	0.038						
<1 house/ac	Foothills	23.8	1109	0.021	0.034	0.029	0.038												
<1 house/ac	Foothills	26.9	1056	0.025	0.034	0.029	0.038	69.2	2218	0.031	0.033	0.028	0.037	559	4383	0.128	0.044	0.036	0.052
1-2 houses/ac	Foothills	42.3	1162	0.036	0.032	0.028	0.036												
<1 house/ac	Mountain	125.6	1056	0.119	0.034	0.029	0.038	490	2165	0.226	0.046	0.037	0.054						
None	Mountain	364.5	1109	0.329	0.050	0.040	0.060												

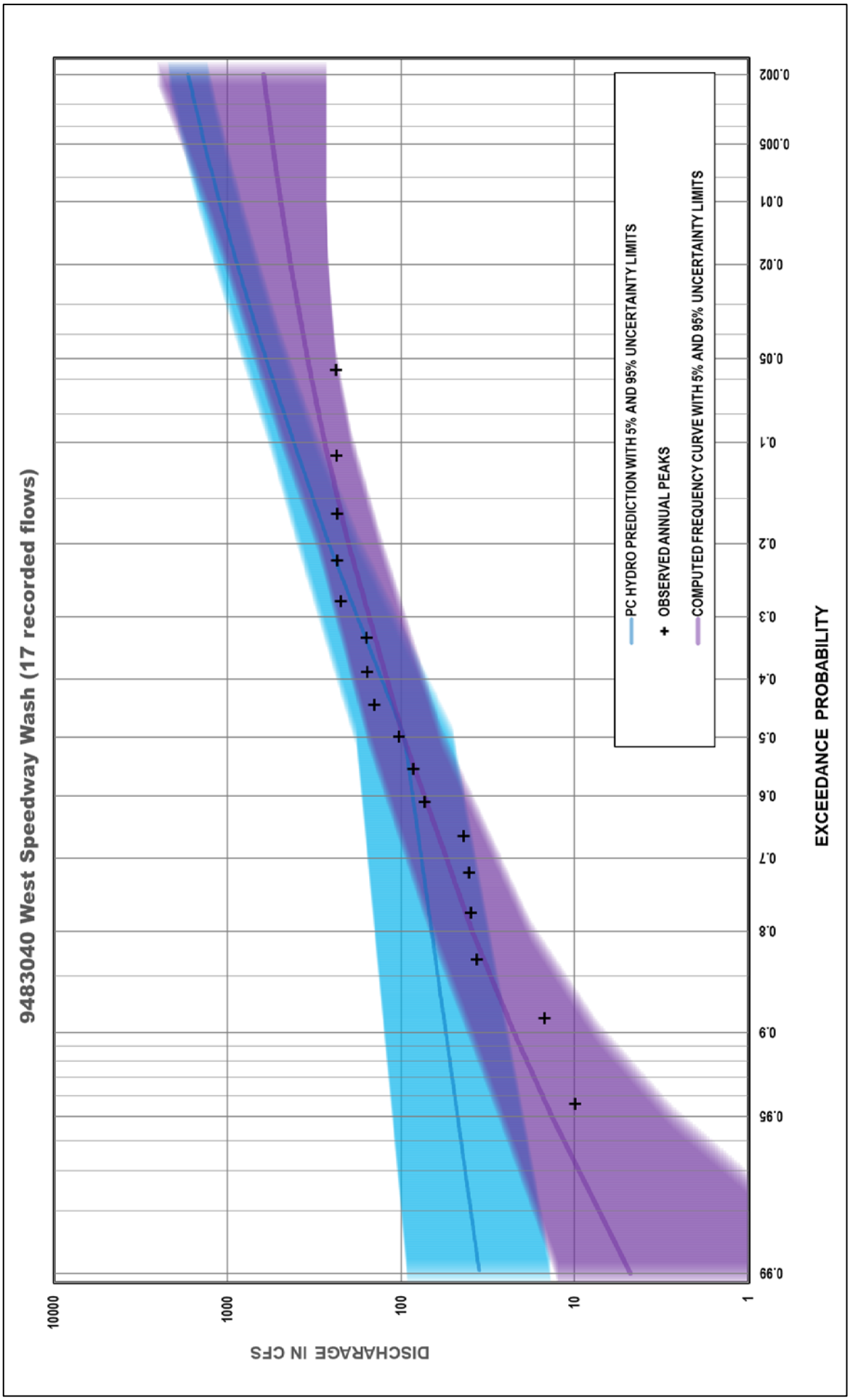
Watercourse Length: 8924 ft
Mean slope: 0.033 ft/ft
Wt Basin Factors: 0.036 0.030 0.040

Mean slope: 0.034 ft/ft
Wt Basin Factors: 0.037 0.031 0.042

Mean slope: 0.042 ft/ft
Wt Basin Factor: 0.039 0.032 0.045

Soil	Percent
Type B	1%
Type C	1%
Type D	98%

Red Font: User entry
Blue font: Calculation


9483040 West Speedway Wash (17 recorded flows)
PC HYDRO PREDICTION WITH 5% AND 95% UNCERTAINTY LIMITS
OBSERVED ANNUAL PEAKS
COMPUTED FREQUENCY CURVE WITH 5% AND 95% UNCERTAINTY LIMITS
DISCHARGE IN CFS
10000
1000
100
10
1
EXCEEDANCE PROBABILITY
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.02
0.01
0.005
0.002