CUDIA CITY WASH

FLOOD HYDROLOGY

FOR THE DESIGN OF THE ARIZONA CANAL DIVERSION CHANNEL

Prepared for

CITY OF PHOENIX
ENGINEERING DEPARTMENT

Prepared by

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Page

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TABLE OF CONTENTS

TABLES

FIGURES

EXECUTIVE SUMMARY

The procedures and practices that were used by the U.S. Army Corps of Engineers in estimating the flood discharge from Cudia City Wash for the design of the Arizona Canal Diversion Channel have been reviewed and evaluated. These procedures and practices are judged to represent the best practical technology for the estimation of the Standard Project Flood for Cudia City Wash. The design flood discharge of 6,700 cfs was adequately reproduced (6,860 cfs) using the parameters and information that are provided in the reports by the Corps of Engineers. A 100-year flood discharge of 7,030 cfs was obtained by using the procedure of the Corps of Engineers and a 100-year design rainfall. This indicates that the method used by the Corps of Engineers to reduce a Standard Project Flood to a 100-year flood is adequate for Cudia City Wash.

The Flood Control District of Maricopa County has estimated the 100-year flood discharge by an independent method. Their estimate of 6,540 cfs corroborated the design discharge of the Corps of Engineers.

The 1987 report by W.S. Gookin and Associates has been reviewed and evaluated. This report contains technical errors and is not judged to represent the best practical technology for estimating the flood discharge from Cudia City Wash.

An independent evaluation of the 100-year flood discharge from Cudia City Wash was performed. A flood peak discharge of 7,170 cfs was obtained that corroborates the design flood discharge of the Corps of Engineers.

The design flood discharge of 6,700 cfs by the Corps of Engineers for Cudia City Wash should be accepted for the design of the Arizona Canal Diversion Channel.

INTRODUCTION

This report presents the results of an evaluation of the flood hydrology that was developed to establish the design discharge for a portion of the Arizona Canal Diversion Channel (ACDC). This evaluation was prompted because of a discrepancy in design discharge estimates by the U.S. Army Corps of Engineers, and a consulting engineer employed by the Citizens Against Reach Four, W.S. Gookin and Associates, Scottsdale, Arizona. The major point of contention resulted from different magnitudes of discharge estimates for the 100-year flood from the Cudia City Wash that would enter the proposed ACDC. The report herein is limited to a consideration and discussion of the 100-year flood discharge from Cudia City Wash.

The U.S. Army Corps of Engineers have estimated the 100-year flood peak discharge into the ACDC from Cudia City Wash to be 6,700 cubic feet per second (cfs). W.S. Gookin and Associates have estimated that flood discharge to be 3,782 cfs (56 percent of 6,700 cfs). Because of this lesser estimate of flood discharge, W.S. Gookin and Associates have recommended structural alternatives to Reach Four of the ACDC and are reporting substantial cost savings that could be realized by designing for this lesser discharge. This report will not address those structural alternatives or reported cost savings.

The Flood Control District of Maricopa County also performed an independent evaluation of the 100-year flood discharge for Cudia City Wash. Their estimate of peak discharge is 6,540 cfs (98 percent of 6,700

cfs). Within the normal accuracy of flood hydrology, the Flood Control District has corroborated the design discharge established by the U.S. Army Corps of Engineers.

The evaluation performed and reported herein consists of three elements:

1. A review of the design discharge determined by the U.S. Army Corps of Engineers,
2. A review of reports prepared by W.S. Gookin and Associates and the Flood Control District of Maricopa County,
3. An independent evaluation of the 100-year flood peak discharge for Cudia City Wash.

The reports used for this review are:

1. Gila River Basin, New River and Phoenix City Streams, Arizona, Design Memorandum No. 2, Hydrology Part 1: U.S. Army Corps of Engineers, Los Angeles District, October 1974.
2. Gila River Basin, Phoenix, Arizona, and vicinity (including New River), Design Memorandum No. 2, Hydrology Part 2: U.S. Army Corps of Engineers, Los Angeles District, 1982.
3. Gila River Basin, Phoenix, Arizona, and vicinity (including New River), Arizona Canal Diversion Channel, Detention Basins Study; U.S. Army Corps of Engineers, Los Angeles District, March 1987.
4. Runoff Analysis, Preliminary Design, and Cost Estimates of Reaches 3 and 4 of the Arizona Canal Diversion Channel: W.S. Gookin and Associates, March 1987.

5. Analysis of W.S. Gookin Report on Cudia City Wash: Flood Control District of Maricopa County.

This evaluation and report was conducted by George V. Sabol, Ph.D., P.E., Consulting Engineer, at the request of the Engineering Department of the City of Phoenix. This evaluation and report was prepared during the period from 23 through 30 April 1987.

GENERAL

Flood hydrology is a science and an acquired skill as much as it is an engineering discipline. A certain amount of the knowledge that is required to perform flood hydrology can be obtained through formalized training; that is university courses, short-courses, and specialized training courses. However, proficiency in this subject can only be gained through a long period of practical and varied experience. This experience should include the preparation of numerous flood hydrology studies, initially under the direction of an experienced flood hydrologist, and the formal review of those flood hydrology studies by other experienced professionals. This experience base should be coupled with independent study of the professional literature in the professional field and possibly applied research.

The results of a flood hydrology study are very sensitive to the selection of computation methods and input parameters. Widely varied results can therefore be expected. An adequate experience base is needed for major projects that require large capital investments, and that may result in significant economic loss or loss of human life in the event of failure.

Flood hydrology studies require the selection of an appropriate computation method and the selection or generation of representative parameters as input. Modern flood hydrology often involves the selection of a computer model to perform a series of computations that convert a set of physical parameters (model input) to a flood hydrograph (model

output). Often, a misjudgment in the selection of these model inputs will drastically alter the output from the model. The proliferation of computer programs for flood hydrology in the last 15 years has resulted in well over 100 such models. Some models are adequate for relatively simply drainage studies, while other models should be utilized for more complex watersheds. Relatively few models for flood hydrology have withstood the scrutiny of review in the professional journals and review of results by practicing professionals.

Two different models have been selected by the various entities that are involved in this controversy. The U.S. Army Corps of Engineers, Los Angeles District, herein referred to as the Corps of Engineers, selected the HEC-1 Flood Hydrograph Package to perform the design flood hydrology for the ACDC. The Flood Control District of Maricopa County (FCD) also used the HEC-1 model in performing an independent assessment of the flood hydrology for Cudia City Wash. The HEC-1 model was also selected for the purpose of an independent review as presented in this report. Although these three studies used the HEC-1 model, they utilized different options within this very versatile model and, in essence, have performed three different modeling exercises of the same watershed. The HEC-1 model is a widely accepted and well regarded model for flood hydrology.

W.S. Gookin and Associates (WSG) selected a computer model, SCSHYD. The WSG report does not provide a reference for this model although they do indicate that the model is based upon the U.S. Department of

Agriculture, Soil Conservation Service (SCS) procedures. This basic methodology, as correctly stated in their report, is one of the options available in HEC-1. The SCS procedures as programmed into the SCSHYD model are often used in performing flood hydrology, but within the past few years there has been strong criticism of this procedure in the professional literature and elsewhere for the purpose of flood hydrology was applied by WSG. The fact that WSG performed the routing and the combining of flood discharges by other computer software, LOTUS spreadsheet, indicates that the SCSHYD model was probably not intended for use in complex watersheds.

REVIEW OF THE CORPS OF ENGINEERS DESIGN HYDROLOGY

The most recent report (1987) by the Corps of Engineers indicates that the design 100-year peak discharge into the ACDC from Cudia City Wash is estimated as 6,700 cfs. This estimate has been obtained by the Corps of Engineers by applying a selected storm over the watershed, estimating rainfall excess by reducing the applied rainfall to account for losses such as ponding on the surface and infiltration into the soil, and then converting that rainfall excess into a flood hydrograph at the outflow point from the watershed into the ACDC. The Corps of Engineers chose to estimate the 100-year flood by first estimating the Standard Project Flood (SPF) using the above described procedure and then reduced that flood discharge by a ratio to result in a 100-year flood discharge. The following are discussions of the input used by the Corps of Engineers in the HEC-1 model.

SPF Rainfall

The Corps of Engineers used a historic storm, the August 1954 Queen Creek storm, as the rainfall input. This actual storm resulted in about 7.5 inches of rainfall in a duration of about 7 hours. Although this rainfall exceeds our present expectation for a 100-year storm in the Phoenix area, its time distribution of rainfall for a severe summer

thunderstorm would be as expected for this area. As such, it is a reasonable selection as a design summer thunderstorm for a SPF in the Phoenix area. In transposing this storm to the Cudia City Wash watershed the 7.5 inch rainfall depth was adjusted downward based on the ratio for the 10-year, 6-hour rainfalls for the Cudia City Wash watershed to that for the location of the Queen Creek storm, and an area reduction factor was also applied to the transposed rainfall depth. The rainfall depth that was input by the Corps of Engineers to the Cudia City Wash watershed is not provided in their reports, but a stepwise regeneration of this process indicates that the rainfall depth was about 6.17 inches. The transposition of a historic storm is common practice for many flood hydrology studies. The transposition of this storm and the adjustments of rainfall depth that were performed are reasonable and credible in the development of the SPF rainfall.

Rainfall Losses

The Corps of Engineers selected a procedure called the Exponential Loss Rate to represent the manner in which some portion of the rain that falls on the watershed is lost to mechanisms such as ponding and infiltration into the soil. The values of the parameters used by this loss rate procedure were determined by reconstituting 22 observed flood events in the Phoenix area. These flood events occurred in watersheds that are similar to the Cudia City Wash watershed. This is a procedure that is often used when adequate data is available. The Corps of Engineers assumed that the SPF storm occurred within 24 hours of a previous 0.5 inch rainfall on the watershed, and this reduced some of the

rainfall loss potential for the watershed. The loss rate parameters are shown on Plate 29 of the 1982 report. These loss rates seem reasonable and are particularly attractive because they have been derived from data for 22 observed storms in the Phoenix area. If the Corps of Engineers would have performed a 100-year flood analysis directly rather than proportioning a SPF they may or may not have selected to impose the criteria that a 0.5 inch rainfall preceded the 100-year storm. Elimination of this antecedent rainfall would have resulted in somewhat different loss rate parameters and reduced runoff potential.

Unit-Hydrograph

A unit-hydrograph was used to convert the rainfall excess into a flood hydrograph. The unit-hydrograph that the Corps of Engineers selected is derived from the Phoenix Valley S-graph. The S-graph, shown in Plate 25 of the 1982 report, was developed by the reconstitution of 11 observed flood events in the Phoenix area on watersheds that are similar to the Cudia City Wash watershed. The parameter to convert this S-graph to a unit-hydrograph is lag, and the value of this parameter can be calculated by use of Plate 24 in the 1982 report. This general S-graph procedure has been used by flood hydrologists for more than 40 years, and is well accepted. The advantage of this procedure is that the regional characteristics of the watershed, such as the slope and roughness of the land surface, are incorporated directly into the overall procedure. The comments by W.S. Gookin and Associates in their 1987 report concerning the misapplication of this technique by the Corps of Engineers in not

accounting for the various slopes in the watershed are completely wrong. Their error may be a result of a lack of understanding in the development of this S-graph and in its proper application. This may be understandable because S-graphs are not often used except by experienced flood hydrologists.

100-Year Flood Discharge

The input, as just described, to the HEC-1 model resulted in an estimate of the SPF discharge. The 100-year flood discharge was then estimated by the Corps of Engineers by applying a reduction factor of 0.45 to the SPF. The development of this 0.45 reduction factor is described in the Corps of Engineers 1974 and 1982 reports. The reason that the Corps of Engineers chose to use a ratio of the SPF rather than estimate the 100-year flood discharge directly is not known. A comparison of the Corps of Engineers estimate of 6,700 cfs to other direct methods is presented in a subsequent section of this report.

REVIEW OF THE REPORT BY W.S. GOOKIN AND ASSOCIATES

The 1987 report by W.S. Gookin and Associates (WSG) indicates that their estimate of the 100-year flood from Cudia City Wash is 3,782 cfs. This estimate has been obtained by applying an assumed rainfall over the watershed, estimating rainfall excess, and using a unit-hydrograph to convert the rainfall excess to a flood hydrograph. A model called SCSHYD was selected by WSG to perform the necessary calculations.

The WSG report contains numerous technical errors and in general indicates a lack of fundamental understanding of the procedures that were used by the Corps of Engineers. No attempt is made to identify and discuss each of the items in question; rather, the selection of model input is reviewed.

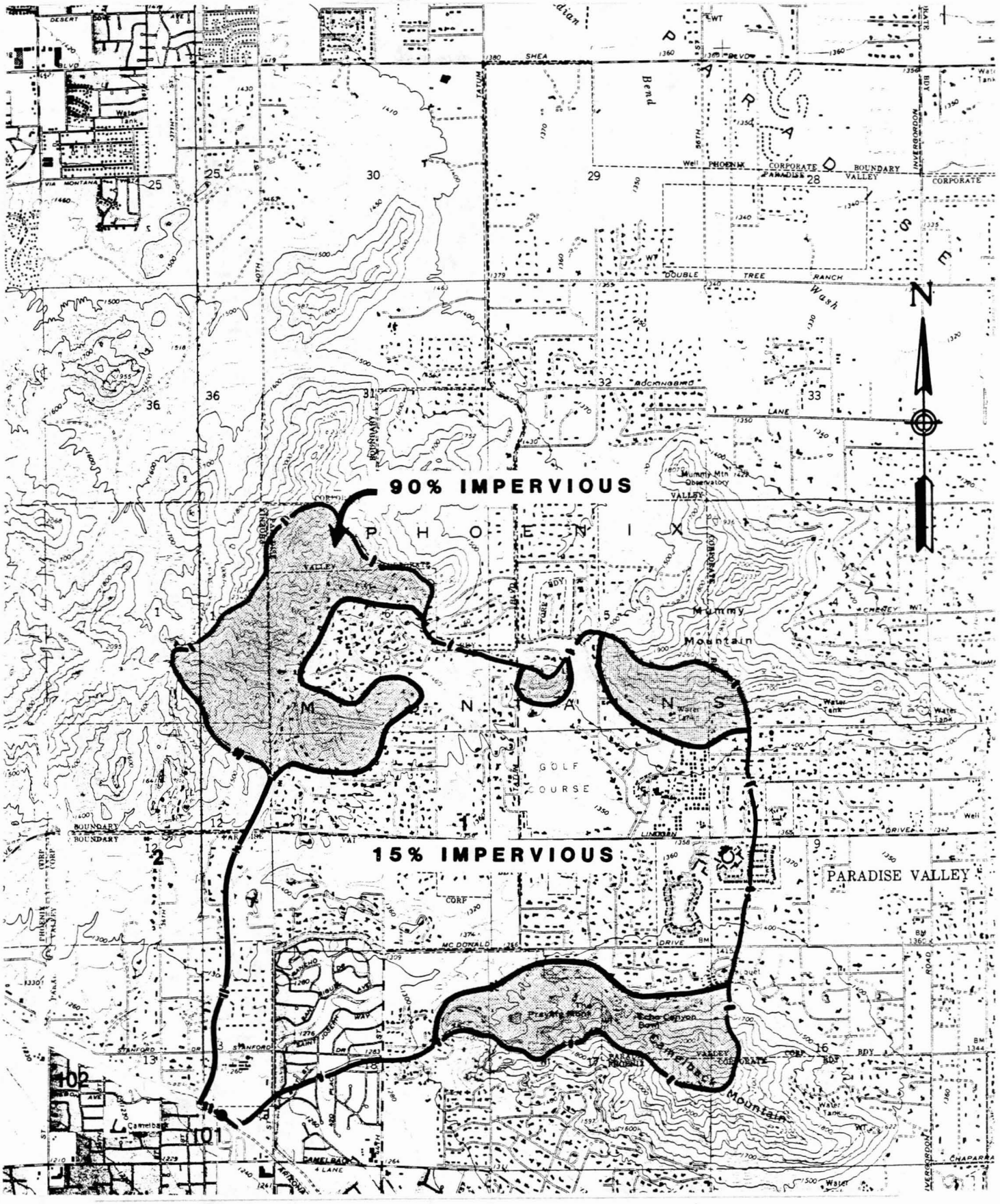
Rainfall

WSG selected the 100-year, 24-hour rainfall for the watershed from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Precipitation-Frequency Atlas for Arizona (NOAA Atlas 2). This rainfall is about 3.9 inches. A rainfall distribution (Type II A) that was developed by the U.S. Department of Agriculture, Soil Conservation Service (SCS) was used. These are reasonable selections and would certainly be considered acceptable engineering practice. However, the justification given for this selection is that this is the design criteria for the City of Scottsdale. This is peculiar since the Cudia City Wash watershed is within the City of Phoenix and the Town of Paradise Valley and the design rainfall criteria of those municipalities is not the criteria that was assumed by WSG.

Rainfall Losses

WSG selected to estimate rainfall excess by the Curve Number (CN) method as was developed by the SCS. A major disagreement between the WSG report and the design hydrology by the Corps of Engineers focuses on the estimation of appropriate loss rates. Much of the discrepancy centers on the estimation of impervious area within the watershed. The Corps of Engineers estimated that 40 percent of the total area is impervious, and WSG estimated that 12 percent (WSG, 1987, pg. 38) of the total area is impervious.

An independent check was performed on the amount of impervious area within the watershed. An outline of the watershed is shown in Figure 1, and the mountain outcropping from the land surface is stippled and is about 28 percent of the watershed. The non-stippled area is generally desert, single-dwelling houses, contains a golf course, and is about 72 percent of the watershed. WSG estimated that the impervious cover of the non-stippled area is 15 to 18 percent (SWG, 1987, pg. 36). If the mountains are 100 percent impervious and the remaining area is 15 percent impervious then the area weighted imperviousness is 39 percent, which agrees very well with the estimate by the Corps of Engineers. The mountains will have some pockets of soil cover and if it is assumed that the mountains are 90 percent impervious then the area weighted imperviousness is 36 percent. The estimate of 12 percent imperviousness by WSG does not seem justified.



CUDIA CITY WASH WATERSHED

FIGURE 1

WSG used a CN of 86.35. This may have been based on the estimate of 12 percent imperviousness and an evaluation of soil-vegetation complexes in the watershed. If the watershed imperviousness is 36 percent, than the CN would be higher. This would result in greater volumes of rainfall excess and much higher peak discharges than estimated by WSG.

Unit-Hydrograph

WSG selected to use the SCS Dimensionless unit-hydrograph developed by the SCS from data for agricultural watersheds. They have also selected to calculate time of concentration by the Kirpich equation which was developed in the 1940s for small agricultural watersheds. The use of this unit-hydrograph and this method to estimate time of concentration does not represent the application of best practical technology for an urbanized watershed with steep slopes in a semiarid environment.

Many of the comments in the WSG report concerning the comparison of lag and time of concentration are in error. The definition of lag as used in the SCS Dimensionless unit-hydrograph and the lag used with a S-graph are different thereby making direct comparisons extremely difficult.

Conclusion

The two major reasons given by WSG (1987, pg. 38) for the discrepancy between the results by the Corps of Engineers and WSG are; first, the hydraulics of runoff from watersheds with varying slopes; and second, the imperviousness of the land surface. In neither case has WSG

demonstrated that their procedures are superior to those used by the Corps of Engineers. In fact, the reasons seem to be a result of a lack of fundamental understanding by WSG regarding unit-hydrographs, and a probable error in calculating impervious area.

REVIEW OF THE REPORT BY THE FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

The report by the Flood Control District (FCD) indicates that their estimate of the 100-year flood from Cudia City Wash is 6,540 cfs. This estimate was obtained by applying an assumed rainfall over the watershed, estimating rainfall excess, and using kinematic wave routing to convert the rainfall excess to a flood hydrograph. The HEC-1 model was used, but the options selected are different than those used by the Corps of Engineers, thereby making the two models completely independent.

The FCD model was used to compare the results of another study performed by W.S. Gookin and Associates as reported by them in an October 1986 report, Cudia City Wash Runoff Analysis. In both the FCD model and the WSG model in their 1986 report, the watershed was divided into 14 sub-basins. Both of these models differ significantly from the other two modeling efforts that have been reviewed herein. Therefore, only limited comparisons of the FCD model to the other two models are possible in this report.

Rainfall

The FCD selected the 100-year, 24-hour rainfall for the watershed and the rainfall distribution that are used by the City of Phoenix and Town of Paradise Valley. This rainfall depth of 4.04 inches has been determined by an analysis by the U.S. Weather Bureau as reported in their Technical Paper 40. These are reasonable selections for design rainfall

and would be considered acceptable engineering practice. The rainfall criteria selected by the FCD and that selected by WSG (1987) are not greatly different and this difference would have only moderate impact on the estimated flood discharges.

Rainfall Excess

The FCD used the SCS CN method to estimate rainfall excess. Each of the 14 sub-basins was assigned a CN that ranged between 79 and 98. The area weighted CN is 94.5 which is greater than the 86.35 used by WSG (1987) and may be more representative of the relatively large impervious area of the watershed.

Runoff

The runoff was routed from the watershed by the kinematic wave method, and it is not possible to directly compare this method with the other methods.

INDEPENDENT FLOOD HYDROLOGY

An independent evaluation of the flood hydrology was performed. This evaluation consisted of modeling the watershed by using various inputs to the model and the comparison of results. The purpose of this was; first, to attempt to reproduce the results that others are reporting, and second, to arrive at an estimate that is independent of the methods that were used by others. The HEC-1 model was used because of its versatility and general acceptance. A brief summary of the model input and results are shown in Table 1.

The first effort was to reproduce the design flood hydrology of the Corps of Engineers (Run No. 1). The model input as summarized in Table 1 was obtained or developed from information that is contained in the 1974 and 1982 reports. This input resulted in a Standard Project Flood (SPF) of 15,240 cfs. Applying the 0.45 ratio to 15,240 cfs results in an estimate of 6,860 cfs for the 100-year flood. This is a reasonable reproduction of the 6,700 cfs that was obtained by the Corps of Engineers. The difference is probably due to differences in estimating the rainfall depth since this requires some interpretation of isohyetal map and graphs.

Run Nos. 2 and 3 are comparative scenarios to Run No. 1, and are an attempt to estimate the 100-year flood by the methods used by the Corps of Engineers except that a 100-year rainfall is used rather than the SPF rainfall. Two 100-year rainfalls have been used for such purposes in the WSG (1987) and the FCD reports, and the applied rainfall is the only difference in model input between Run No. 2 and 3.

Table 1. - Comparison of Independent Flood Hydrology Results.

Run No.	Flood Analysis	Area sq. mi	Rainfall		Rainfall Loss Procedure	Unit-Hydrograph	Peak Discharge cfs
			Depth inches	Distribution			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Corps of Engineers (SPF Rainfall)	4.91	6.17	AZ Std. Proj. Summer Thunderstorm	Exponential STRKR = .38 DLTKR = 1.0 RTIOL = 2.0 ERAIN = 0.0 RTIMP = 40	S-graph Lag = .46 hr.	15,240 (SPF) 6,860 (100-yr)
2	Corps of Engineers (100-yr rainfall)	4.91	4.04	Phoenix	same as No. 1	S-graph Lag = .64 hr.	7,030
3	Corps of Engineers (100-yr rainfall)	4.91	3.90	Type IIA	same as No. 1	same as No. 2	7,820
4	W.S. Gookin & Assoc. (Reproduce)	5.13	3.90	Type IIA	Curve Number Method CN = 86.35	SCS Dimensionless Lag = .852 hr.	4,250
5	Independent (WSG rainfall & area)	5.13	3.90	Type IIA	Initial Loss + Uniform Rate STRTL = 1.0 CNSTL = .15 RTIMP = 36	same as No. 2	7,650
6	Independent (FCD rainfall & area)	4.92	4.04	Phoenix	same as No. 5	same as No. 2	7,170
7	Independent	5.0	4.04	Phoenix	same as No. 5	same as No. 2	7,170

In both of these runs the unit-hydrograph was adjusted from that used by the Corps of Engineers. This is because the unit-hydrograph for Run No. 1 is for a SPF, which being a larger flood will result in greater hydraulic efficiency of runoff than will the 100-year flood. The 100-year flood would be expected to have a longer lag time than the SPF. A Manning's n of 0.025 was used by the Corps of Engineers to develop the SPF unit-hydrograph. A Manning's n of 0.035 was used to develop the 100-year unit-hydrograph. The lags are 0.46 hour and 0.64 hour, respectively. This type of adjustment of unit-hydrographs is accepted practice.

The peak discharges for Run Nos. 2 and 3 are 7,030 cfs and 7,820 cfs, respectively. If the Corps of Engineers had used their procedure with the 4.04 rainfall from the U.S. Weather Bureau and a 24-hour rainfall distribution for a summer thunderstorm they would have estimated a 100-year design discharge of about 7,030 cfs which is very close to their estimate of 6,700 cfs. Based on these results, the Corps of Engineers method of applying a 0.45 ratio to the SPF for Cudia City Wash appears justified.

Run No. 4 was an attempt to reproduce the WSG (1987) model. The same input was used in the HEC-1 model as WSG used in the SCSHYD model. The 100-year peak discharges are 4,250 cfs and 3,782 cfs, respectively, which is moderate agreement.

Run Nos. 5, 6 and 7 are for an independent check of the flood hydrology. The major difference from previous models is the selection of

a rainfall loss method. The method of Initial Loss plus Uniform Loss Rate was selected for the independent check. The initial loss (STRTL) accounts for all losses prior to the time that the loss rate reaches equilibrium. This loss is mainly the result of surface ponding and the initial high infiltration losses. An initial loss of 1.0 inch was selected based on past experience with similar systems. The uniform loss rate (CNSTL) is the rate at which water will infiltrate the soil after the initial losses are satisfied. A uniform loss rate of 0.15 inch per hour was selected because of the large area of Hydrologic Soil Group C in the watershed. An imperviousness of 36 percent was used as previously described and this accounts for much of the Hydrologic Soil Group D in the watershed.

The 100-year unit-hydrograph previously described was used in Run Nos. 5, 6 and 7. There is a slight disagreement in drainage area. The Corps of Engineers have used 4.91 square miles, WSG used 5.13 square miles, and the FCD used 4.92 square miles.

Run No. 5 uses the drainage area and rainfall criteria used by WSG. This results in a 100-year flood discharge of 7,650 cfs. Run No. 6 uses the drainage area and rainfall criteria used by the FCD. This results in a 100-year flood discharge of 7,170 cfs.

Run No. 7 is intended to be a completely independent flood analysis. The input to the model is not an attempt to reproduce the input that was used by either the Corps of Engineers, WSG, or the FCD. A nominal drainage area of 5.0 square miles was used along with a rainfall depth of

4.04 inches and the rainfall distribution used by the City of Phoenix and the Town of Paradise Valley. The previously discussed Initial Loss plus Uniform Loss Rate parameters and 100-year unit-hydrograph were used. The 100-year flood peak discharge is 7,170 cfs, and this is judged to be reasonable agreement with the Corps of Engineers estimate of 6,700 cfs.

CONCLUSIONS

1. The Corps of Engineers flood hydrology for Cudia City Wash has been reviewed and all procedures and parameters for the estimation of the Standard Project Flood are judged to represent best practical technology.
2. An independent modeling of the watershed using the procedures and parameters used by the Corps of Engineers has resulted in a 100-year flood peak discharge of 6,860 cfs which agrees reasonably well with the design discharge of 6,700 cfs.
3. An independent modeling of the watershed using two different 100-year design rainfall criteria and the Corps of Engineers model resulted in flood peaks of 7,030 cfs and 7,820 cfs, respectively. This indicates that the Corps of Engineers method of applying a 0.45 ratio to the SPF for Cudia City Wash appears justified.
4. The W.S. Gookin and Associates report (1987) has been reviewed. The report contains numerous technical errors and in general indicates a lack of fundamental understanding of some of the procedures that were used by the Corps of Engineers. Their estimate of imperviousness (12 percent) differs greatly from the estimate by the Corps of Engineers (40 percent) and from the independent evaluation of imperviousness (36 percent). WSG has selected procedures that do not represent best practical technology for this application and their flood peak of 3,782 cfs is not an adequate representation of the 100-year event.

5. The Flood Control District of Maricopa County report has been reviewed. Their kinematic wave model of the watershed appears to be a reasonable representation for the purposes of estimating the 100-year flood on Cudia City Wash. Their flood peak of 6,540 cfs corroborates the design flood hydrology of the Corps of Engineers.
6. An independent model was developed and a flood peak of 7,170 cfs was obtained that also corroborates the design flood discharge of the Corps of Engineers.
7. The design flood discharge of 6,700 cfs by the Corps of Engineers for Cudia City Wash should be accepted for the design of the Arizona Canal Diversion Channel.