SKUNK CREEK

Between the Arizona Canal Diversion Channel
and the Central Arizona Project Canal

HEC-1 MODEL COMPARISON AND SENSITIVITY TESTS

Flood Insurance Study
FCD 89-72

October, 1990

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1.0 INTRODUCTION

As part of the Skunk Creek Flood Insurance Study (FIS), comparison and sensitivity tests have been performed on the preliminary HEC-1 model for a portion of the Skunk Creek watershed. The tests were performed in order to determine if the computed discharges are reasonable and to identify if the HEC-1 model is especially sensitive to any of the input parameters. The sole purpose of this report is to document the results of the sensitivity and comparison tests.

The HEC-1 model for the FIS involves the use of the Clark unit graph and the Green-Ampt initial abstraction methodologies, as documented in the Flood Control District of Maricopa County's (FCDMC's) Hydrologic Design Manual (Ref. 1). Sensitivity tests have been performed on various rainfall, Clark unit graph, Green-Ampt, and routing parameters. In addition, the peak discharges computed using FCDMC approved methodologies have been compared with peak discharges computed using HEC-1 with SCS methodologies, the Roeske Regression Equations, and Discharge Versus Drainage Area Curves.

2.0 METHODOLOGIES AND TEST RESULTS

2.1 Methodologies

To simplify the tests, only a portion of the Skunk Creek watershed has been used for most of the sensitivity and comparison tests. The "test watershed" is comprised of sub-basins 380, 390, and 405, with nodal point 410 being the concentration point for the test watershed. The watershed for Skunk Creek below Adobe Dam and the test watershed are indicated in Plate 1. The HEC-1 output for the sensitivity tests and comparison tests are given in Appendix II.

2.2 Comparison Tests

The FCDMC's Hydrologic Design Manual (Ref. 1) recommends the use of the Green-Ampt initial abstraction and the Clark unit graph options of the HEC-1 model, reduced point precipitation values based on Aerial Reduction Factors (ARF), and 6-hour storm distributions. The computed peak discharges for the test watershed corresponding to various initial abstraction/unit graph methodologies, rainfall events, rainfall distributions, aerial reduction factors, and antecedent moisture conditions (AMC) are summarized in Table 1.

The results of these tests indicate the following:

a. SCS initial abstraction and unit graph methodologies increased the 6-hour event discharge by approximately 30% and the 24-hour event by approximately 12% to 14%, for the typically used antecedent moisture condition.

b. The 24-hour event and the Type II rainfall distribution results in a 38% increase in the computed peak discharge, over the base run discharge of 1310 cfs.

c. The computed 100 year - 24 hour discharge computed using SCS methodologies and no ARF is 75% greater (i.e., 2300 cfs vs. 1310 cfs) than the 100 year - 6 hour discharge computed using FCDMC recommended methodologies and ARF's.

Roeske Regression Equation

In a study for ADOT, Mr. Roeske of the USGS developed regression curves for estimating the magnitude and frequency of floods in Arizona (Ref. 2). Based on these regression equations Q_{100} equals 4700 cfs (with a standard error of 66%) for the test watershed (Appendix I). This value is approximately 3.6 times greater than the 100 year - 6 hour discharge of 1310 cfs and approximately 2.6 times greater than the 100 year - 24 hour discharge of 1810 cfs. However, the standard error of 66% is high and indicates that the regression equation has a wide 90% confidence interval that appears to encompass the 100 year - 24 hour HEC-1 computed discharges.

TABLE 1
SCS VS. GREEN-AMPT/CLARK METHODOLOGIES

PARAMETER	RAINFALL AND DISTRIBUTION			
Initial Abstract. and Unit graph	100-Year - 6-Hour[2] ARF 2.93" SDV = 3	100-Year - 24-Hour[2] ARF 3.6" SCS Type II	100-Year - 24-Hour 3.9" SCS Type II	Antecedent Moisture Condition
Green-Ampt/Clark[1]	Base Run 1310 cfs	1810 cfs	2020 cfs	"Dry"[2]
Green-Ampt/Clark[1]	1440 cfs	1890 cfs	2100 cfs	"Normal"[2]
C.N/S.C.S.	620 cfs	770 cfs	970 cfs	AMC I (Dry)
C.N./S.C.S.	1700 cfs	2020 cfs	2300 cfs	AMC II (Moist)

1 Methodologies per FCDMC Hydrology Manual (Ref. 1)

2 As indicated in the FCDMC Hydrology Manual, the antecedent moisture conditions "Dry" and "Normal" are primarily a function of land use and whether or not the land is irrigated. The "Dry" condition is appropriate for the test watershed.

Discharge vs. Drainage Area Curves

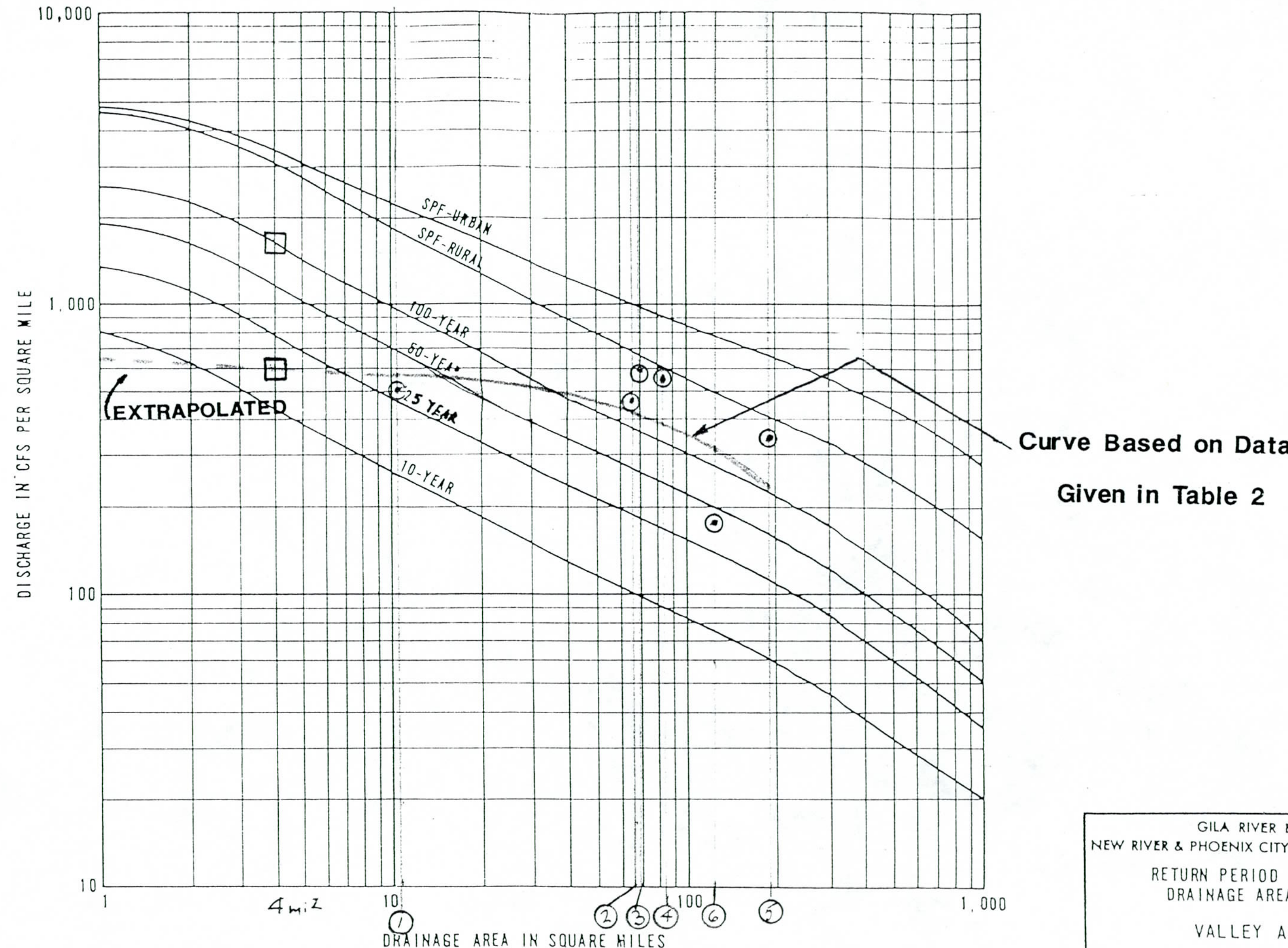
As part of the Arizona Canal Diversion Channel (ACDC) study, the Corps developed discharge versus drainage area curves for the Phoenix area (Figure 1). In addition, data for several water courses, were analyzed and plotted onto the Corps' curves (Table 2).

The historical data from the USGS was analyzed for comparison purposes only. It is important to note that there are more dissimilarities than similarities between the watershed represented by the historical data and the subject watershed. These watersheds differ with respect to topography, degree of urbanization, soil characteristics, size, and shape. The Deadman Wash watershed is relatively similar in size and geographical location to the subject watershed; however, the Deadman Wash watershed is in essentially an undistributed state and differs significantly with respect to soil characteristics, topography, and drainage patterns.

2.3 Sensitivity Tests

Clark Storage Coefficient (UC-Card: Field 2)

The Clark Storage Coefficient (R) is specified for each sub-basin and can be computed as a function of the time of concentration (Tc) and other basin parameters, as documented in the FCDMC's Hydrologic Design Manual (Ref. 1). To test the sensitivity of the model to this parameter, the R values for each sub-basin have been increased and then decreased by 50% (Test files 5 and 5A). Increasing the R values resulted in the peak discharge being increased from 1310 cfs to 1650 cfs, an increase of 26%; whereas, decreasing the R values resulted in the peak discharge decreasing from 1310 cfs to 1090 cfs, a decrease of 17%. These results indicate that the model isn't especial sensitive to R value.



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NEW RIVER & PHOENIX CITY STREAMS, ARIZONA

RETURN PERIOD DISCHARGE—
DRAINAGE AREA CURVES

VALLEY AREAS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY DESIGN MEMO NO. 2

FIGURE 1

TABLE 2

FLOOD FLOW FREQUENCY ANALYSIS (Ref. 3)

Crest Section	Drainage Area Sq. Miles	Data Years	Computed Flows in CFS (Q100)	CFS/per sq. mi. (Q100)
Deadman Wash	11.1	1959-1980	5,550	500
Skunk Creek @ I-17	64.7	1959-1989	30,600	473
New River	67.3	1962-1989	40,500	602
New River @ New River	83.3	1961-1981	48,100	577
New River @ Peoria	187.0	1963-1984	65,600	351
Cave Creek @ Cave Creek	121.0	1958-1989	22,300	184

Hydraulic Conductivity (LG-Card: Field 4)

The Hydraulic Conductivity (XKSAT) is specified for each sub-basin and is a function of soil characteristics. As indicated in Table 4.2 of the Hydrologic Design Manual (Ref. 1), the XKSAT values for loamy sand and sandy loam are 1.2 and 0.4 in/hr, respectively. Even though the physical difference between a loamy sand and a sandy loam can be only a subtle difference in the gradation of the soil, the XKSAT values for these two soil types differ by a very significant factor of three.

To test the sensitivity of the HEC-1 model to the XKSAT parameter, XKSAT was set at 0.4 and then set at 1.2, for each sub-basin (Test files 7 and 7A). Changing XKSAT from 0.4 to 1.2 resulted in the computed peak discharge decreasing 1170 to 430 cfs, respectively. This indicates that the Green-Ampt methodology is very sensitive to the specified XKSAT value, for at least relatively course soils with XKSAT values greater than 0.4 in/hr.

Computation Time Interval (IT-Card: Field 1)

The Computation Time Interval (NMIN) impacts the total duration of the HEC-1 simulation, due to the 300 ordinate limitation, and the stability of various numerical techniques used in HEC-1. To test the sensitivity of the HEC-1 model, NMIN was increased from 3 to 8 minutes, with the 8 minute value being based on criteria given the FCDMC's manual (Ref. 1). This increase in NMIN resulted in a 1% decrease of the peak discharge for the 100 year - 6 hour event.

The selection of NMIN is much critical for 24-hour events. A small NMIN value truncates the end of the hydrograph and results in an artificially high peak discharge; however, an excessively large NMIN value may result in unstable routing computations.

Time-Area Data (UA-Card)

The UA-card provides data used in the Clark unit graph methodology. The sensitivity of the HEC-1 model to the time-area data was tested by using the HEC-1 default values as apposed to the UA-data per the FCDMC's Hydrologic Design Manual (Ref. 1) for natural watersheds. Using the HEC-1 default UA-data resulted in the computed peak discharge decreasing from 1310 cfs to 1250 cfs (i.e., a 4% decrease).

The FCDMC's manual specifies a set of UA-card data for urban and natural sub-basins. Both of these sets of time-are data differ significantly from the HEC-1 default values. Hence, it appears that the computed peak discharges are not especially sensitive to the UA-data.

3.0 RESULTS AND CONCLUSIONS

As part of the Skunk Creek FIS, various comparison and sensitivity tests have been performed on the HEC-1 model for a portion of the Skunk Creek Watershed. The tests were performed to determine if the HEC-1 computed discharges, corresponding to FCDMC approved methodologies, are reasonable and to identify if the HEC-1 model is especially sensitive to any of the input parameters.

The results of the tests performed on a portion of the Skunk Creek Watershed indicate the following:

<u>Comparison Tests</u>

1. The computed 100 year-6 hour discharges, corresponding to FCDMC approved methodologies, are significantly less (i.e., 75% $\pm$) than the 100 year-24 hour discharges corresponding to SCS methodologies and no aerial reduction factors.
2. The computed 100 year-6 hour discharge (@ CP 410), corresponding to the FCDMC approved methodologies, is significantly less than the 100 year discharge computed using the Roeske regression equations (Ref. 2). However, the 100 year-6 hour discharge is nearly within one standard error of the regression equation discharge of 4700 cfs.
3. The computed 100 year-6 hour discharge based on FCDMC approved methodologies are significantly less than the 100 year discharge based on the discharge versus drainage area curves shown in Figure 1.

<u>Sensitivity Tests</u>

1. The HEC-1 model is sensitive to the specified Hydraulic Conductivity (LG Card: Field 4); in addition, the Hydraulic Conductivity values specified in the FCDMC's <u>Hydrologic Design Manual</u> (Ref. 1) are very sensitive for soil types common to Maricopa County.
2. The HEC-1 model for a 24 hour event can be very sensitive to the Computation Time Interval (IT-Card:field 1).
3. The HEC-1 model did not appear especially sensitivity to the Clark Storage Coefficient (UC-Card:field 2) and the Time Area Data (UA-Card).

In conclusion, the results of this study indicate that the peak discharges based on

FCDMC approved methodologies are sensitive to soil characteristics and generally lower than those computed using typically applied methodologies.

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4.0 REFERENCES

1. Flood Control District of Maricopa County, Special Projects Branch, Hydrology Division, Hydrologic Design Manual for Maricopa County, Arizona, Draft April 1990.

2. Roeske, R.H., Report: ADOT-RS-15(121) Final Report - Methods for Estimating the Magnitude and Frequency of Floods in Arizona prepared for the Arizona Department of Transportation, September 1978.

3. U.S. Army Corps of Engineers, Flood Flow Frequency Analysis, Users Manual, February, 1982.

APPENDIX I

COMPUTATION SHEETS

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LANDSCAPE ARCHITECTURE

Project Skunk Creek
Project No. 1090 — 050
Sheet No. ______ of ______
Calculated by PWD Date ______
Checked by ______ Date ______

Roeske Regression Equation - Region 3

$Q_{100} = 553 A^{0.61} E^{-1.30} P^{0.915}$ (Standard Error 66%)

$A = 4.0$ sq mi

$E = 1600'/1000 = 1.6$

$P = 8''$

$\therefore Q_{100} = 4688$ cfs

Range: — One Standard Error

Low: 4690 (1 −.66) = 1600 cfs
High: 4690 (1.66) = 7790 cfs

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Table 1.--Regression equations for flood magnitudes at selected recurrence intervals and corresponding standard error of estimate—Continued

Equation	Standard error of estimate, in percent
REGION 3—CENTRAL MOUNTAIN AREA (87 STATIONS)	
$Q_2 = 5.66A^{0.673}E^{-0.605}P^{1.03}$	81
$Q_5 = 31.6A^{0.650}E^{-0.868}P^{0.987}$	64
$Q_{10} = 74.7A^{0.638}E^{-1.00}P^{0.971}$	58
$Q_{25} = 186A^{0.626}E^{-1.14}P^{0.944}$	58
$Q_{50} = 329A^{0.617}E^{-1.22}P^{0.933}$	61
$Q_{100} = 553A^{0.610}E^{-1.30}P^{0.915}$	66
$Q_{500} = 1{,}530A^{0.595}E^{-1.45}P^{0.886}$	78
REGION 4—NORTHEAST PLATEAU AREA (21 STATIONS)	
$Q_2 = 1.38A^{0.491}E^{2.25}$	83
$Q_5 = 0.319A^{0.446}E^{3.60}$	74
$Q_{10} = 0.143A^{0.423}E^{4.31}$	75
$Q_{25} = 0.0590A^{0.398}E^{5.10}$	80
$Q_{50} = 0.0327A^{0.383}E^{5.60}$	85
$Q_{100} = 0.0188A^{0.369}E^{6.09}$	91
$Q_{500} = 0.0062A^{0.342}E^{7.04}$	107

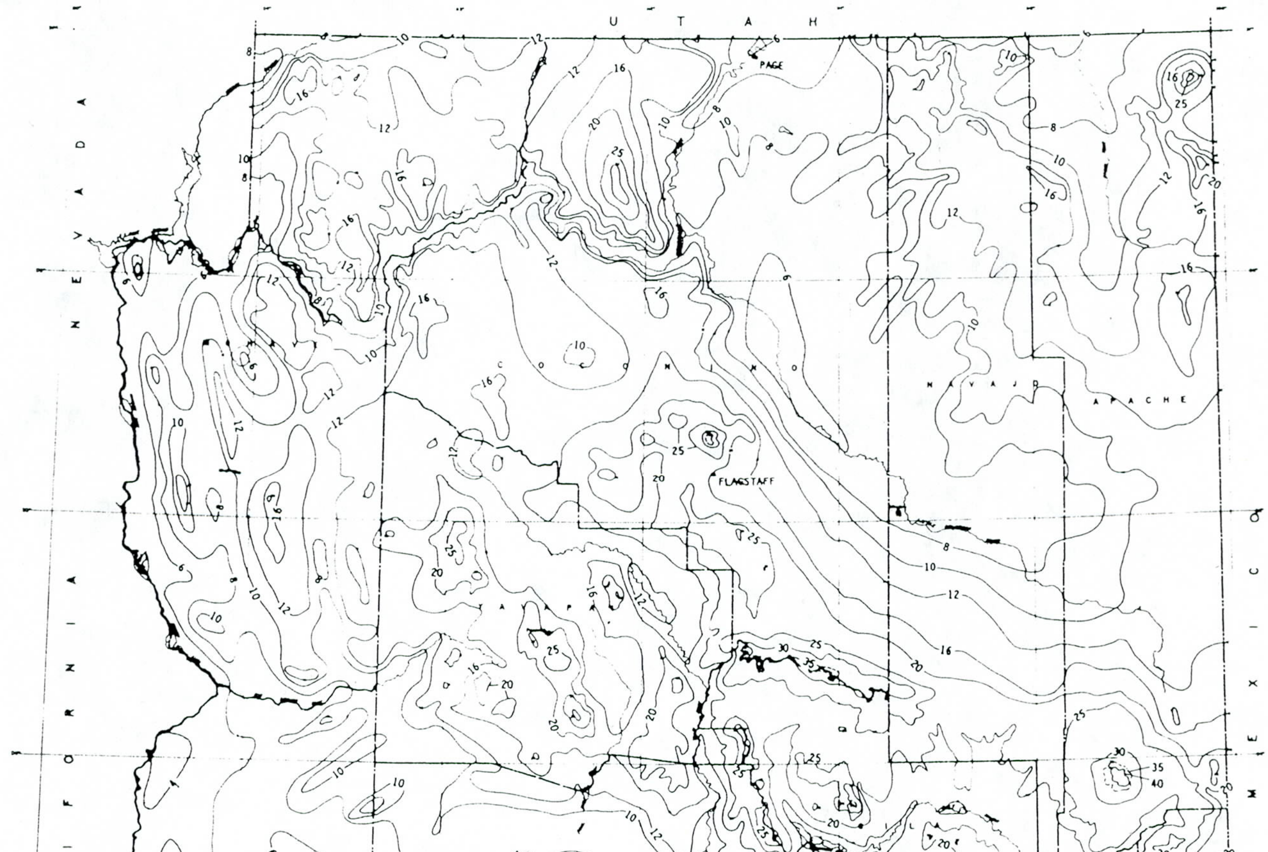

Figure 2.--Mean annual precipitation, 1931-60.

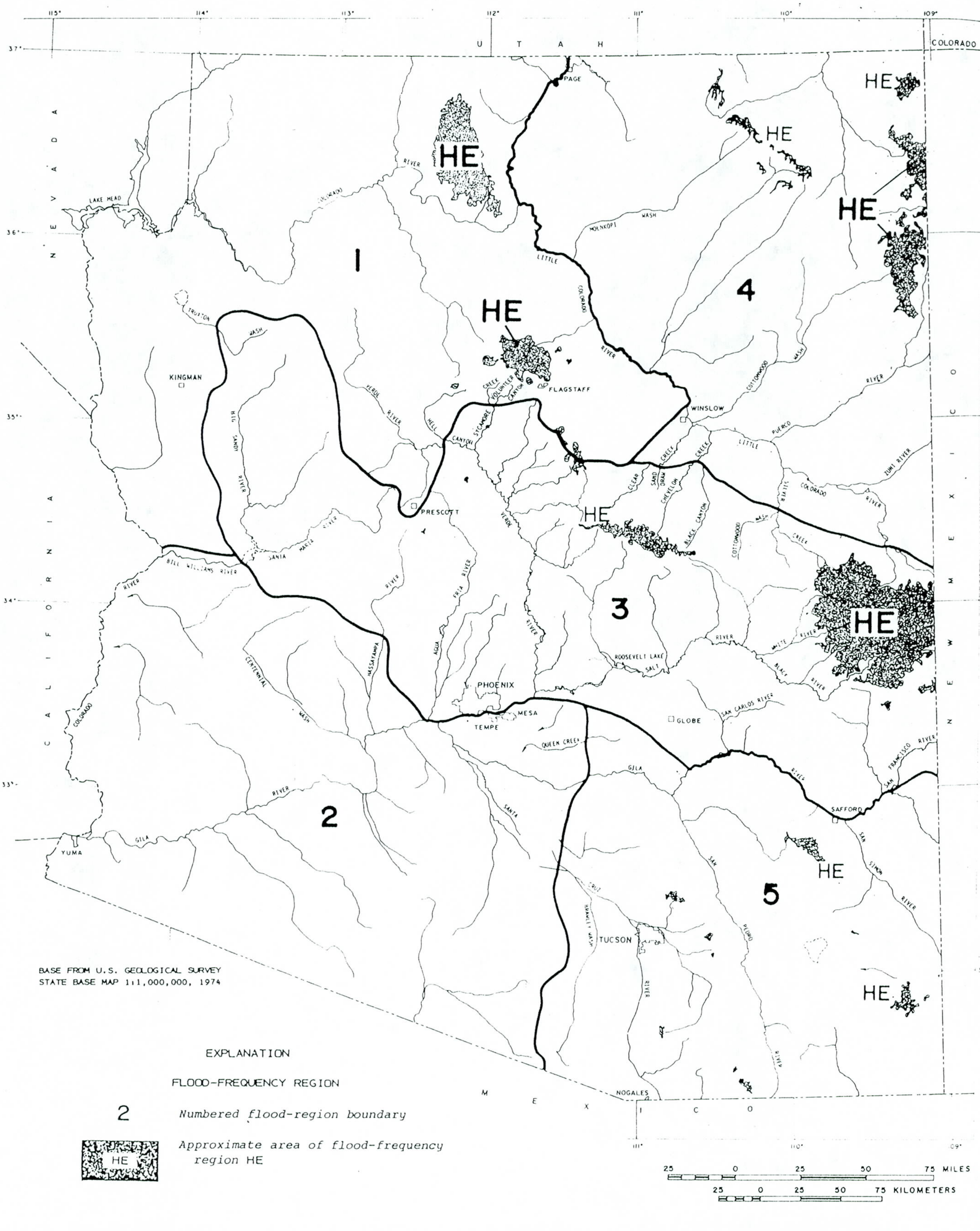

Figure 1.--Flood-frequency regions.

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Project Skunk Creek
Project No. 1090
Sheet No. ______ of ______
Calculated by DWD Date ______
Checked by ______ Date ______

100 year Q's from Return Period Curves

1) Corps Curve

For A = 4 sq mi Q_{100} cfs/mi² = 1750± ⇒ Q_{100} = 7000 cfs

2) CVL Curve (extrapolated)*

For A : 4 sq mi Q_{100} cfs/mi² = 600± ⇒ Q_{100} = 2400 cfs

* CVL's Curve is based on an analysis of recorded data for watersheds in the general vicinity of the Skunk watershed.

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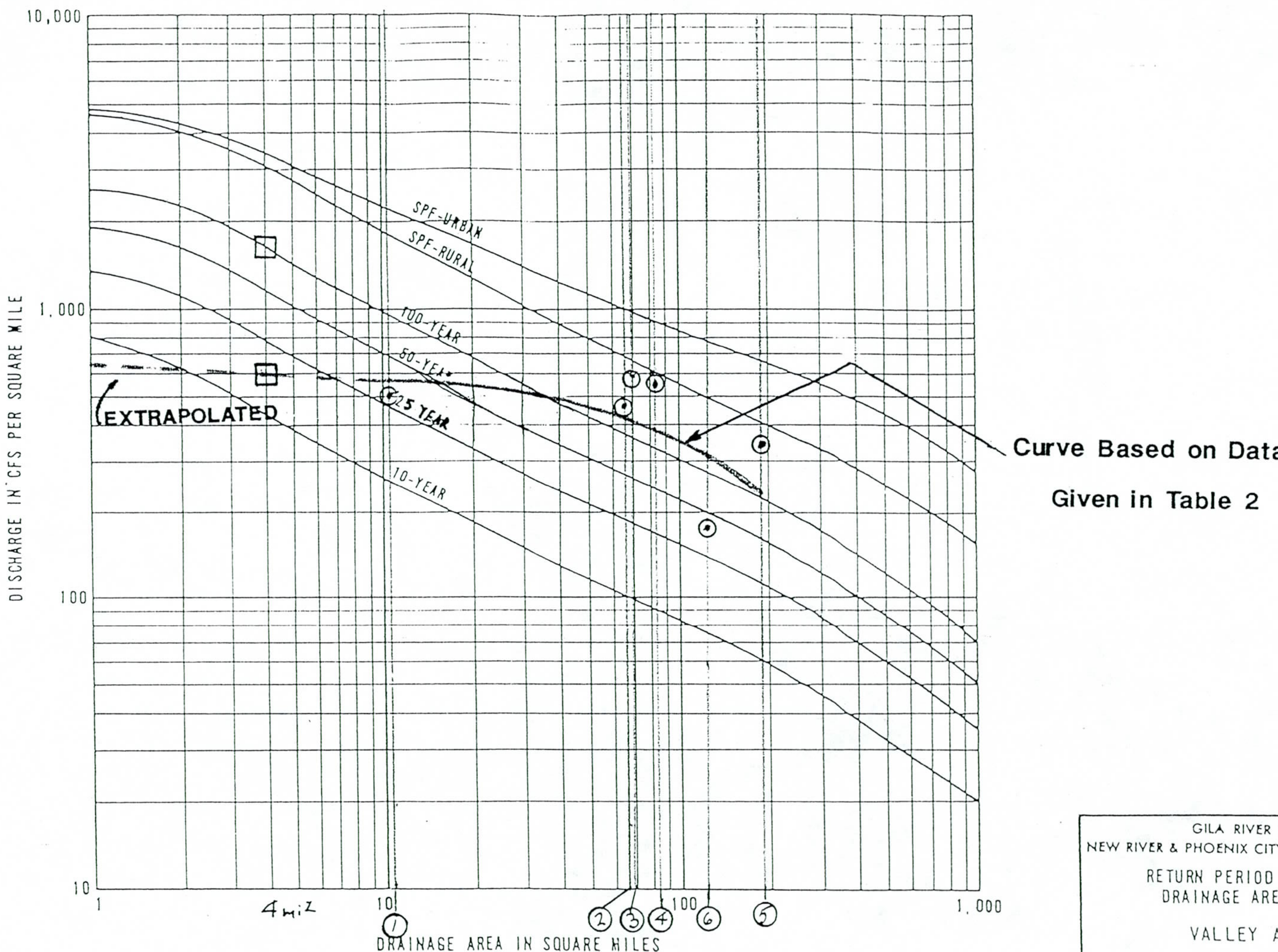

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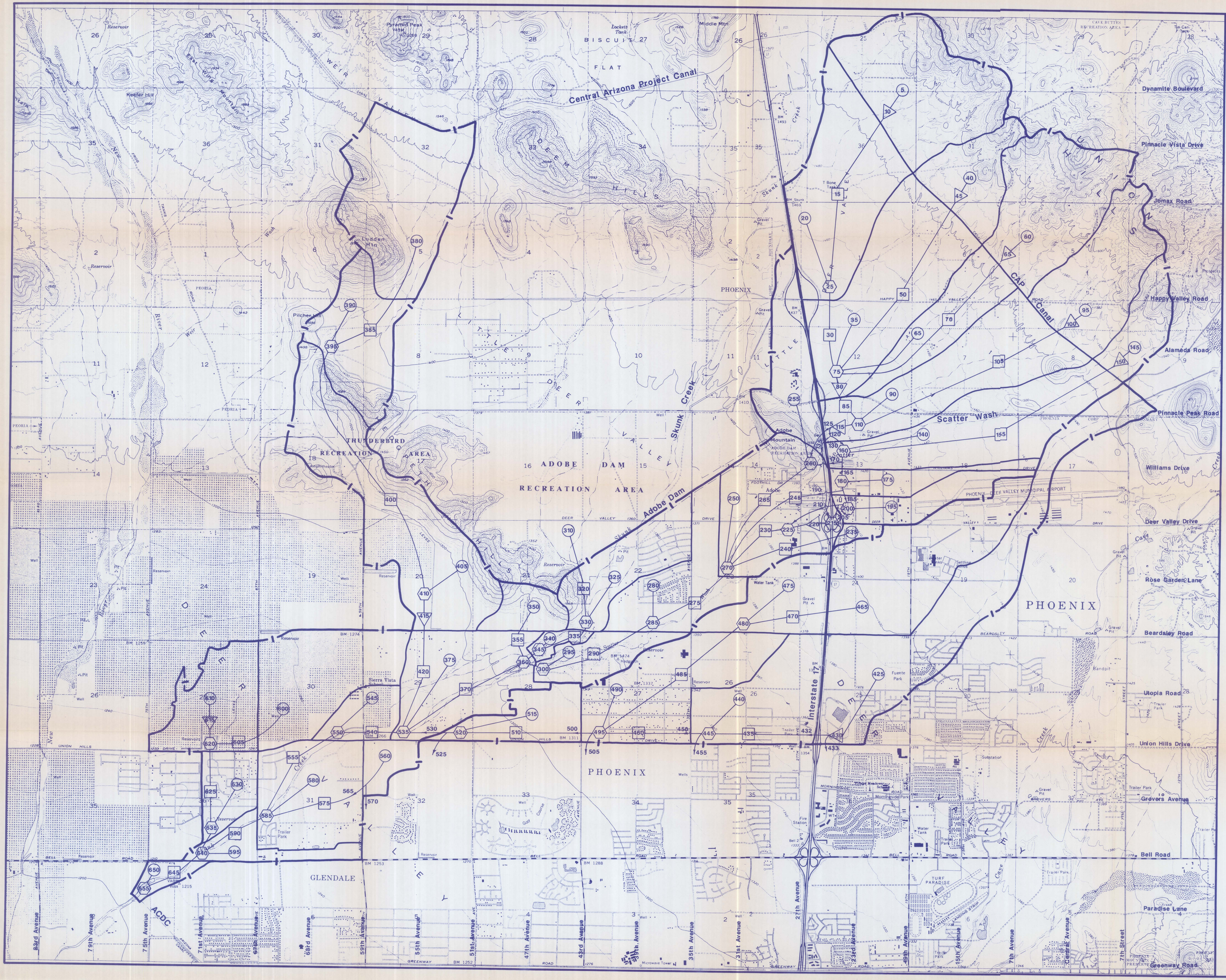
APPENDIX II

HEC-1 OUTPUT

APPENDIX III

PLATE 1



FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

SKUNK CREEK

Between ACDC and CAP

FLOOD INSURANCE STUDY

DRAINAGE AREA MAP & HEC-1 SCHEMATIC

PLATE 1

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0 1000 2000 4000 6000

NORTH