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TECHNICAL DOCUMENTATION REPORT

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Phoenix, Arizona

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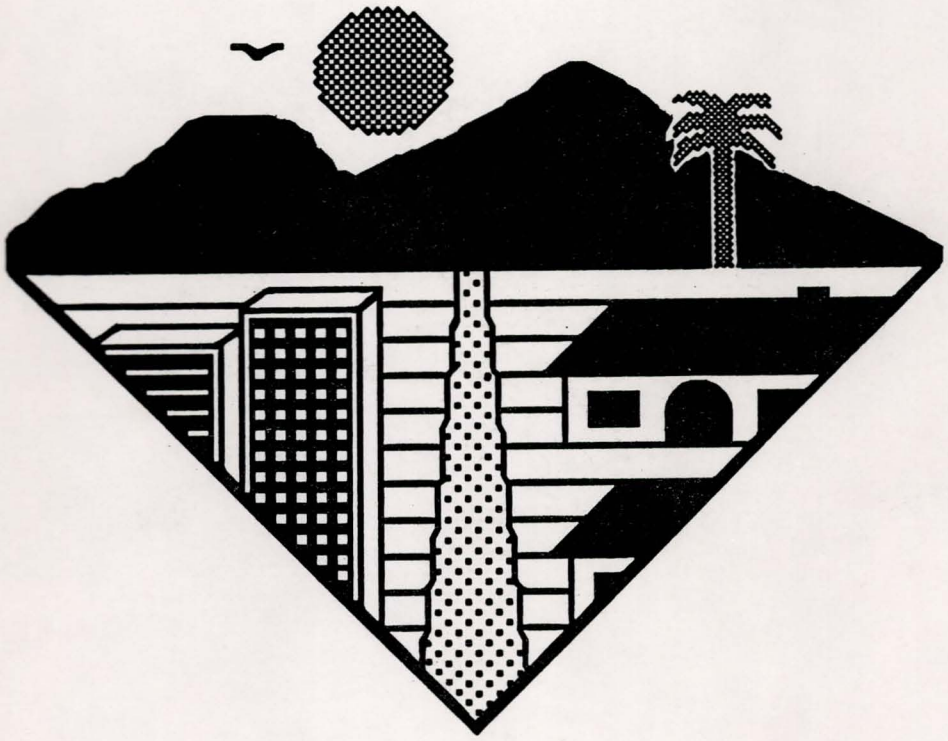

US Army Corps
of Engineers

Los Angeles District
South Pacific Division

A103.907

April 1989

REVISED: OCTOBER 1989

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PHOENIX METROPOLITAN AREA, AZ

OLD CROSS-CUT CANAL

TECHNICAL DOCUMENTATION REPORT

REVISED: OCTOBER 1989

APRIL 1989

PHOENIX METROPOLITAN AREA, AZ

OLD CROSS-CUT CANAL

TECHNICAL DOCUMENTATION REPORT

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Prepared by
Los Angeles District
South Pacific Division
Corps of Engineers
Department of the Army

OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

TECHNICAL DOCUMENTATION

SECTION A

HYDROLOGY

Prepared by
Los Angeles District
South Pacific Division
Corps of Engineers
Department of the Army

CESPL-ED-HE (1110-2-1403a) 2 November 1988

MEMORANDUM FOR RECORD

SUBJECT: Old Cross-Cut Canal Hydrology Changes of the Full Lafayette Alternative Since the F3 Conference.

1. This memorandum explains the reasons for the drop in benefit/cost ratio, since the F3 conference, as it was effected by changes in the hydrology. Each item was discussed in detail in the attached MFR which presented the hydrology results of post F3 conference, FY 88 work.

2. The F3 conference results were a product of what is referred to in the attached MFR as analysis number one. This analysis assumed that all runoff north of the Arizona Canal (AC) would be captured in the Corps' project, and thus not contribute to flooding downstream of the AC. This analysis also assumed that the north bank of the AC was lowered and a gate was installed and operated near 44th Street. Finally this analysis did not include the Papago Freeway, its related storm drains, nor the associated increase in the Old Cross-Cut Canal, in its with and without project work. These features were reversed during the post F3 analysis of the Full Lafayette Alternative, and the resulting hydrology changes are discussed below.

3. ASSUMPTION OF STORM DRAIN ALONG THE AC WAS REMOVED. The most recent results do not pick up runoff between Lafayette and the AC, but allow it to pond behind and enter the AC. This extra flow in the AC contributes to breakouts over the AC and flooding south of the AC.

4. 44TH STREET GATE AND BANK LOWERING FEATURES WERE REMOVED. The lack of these two structural features would tend to increase breaks over the AC, and downstream flooding for events larger than the 25-year frequency.

5. PAPAGO FREEWAY, ITS STORM DRAINS, AND OLD CROSS-CUT CANAL INCREASES, WAS ADDED TO THE WITHOUT PROJECT ANALYSIS. Increasing the Old Cross-Cut capacity, for both with and without project in analysis number 2, (refer to paragraph 1 of the attached MFR,) decreased the with project Old Cross-Cut breakouts at Thomas Road and McDowell Road. Incorporating the Papago Freeway and its storm drains eliminated all flood damages south of the Papago Freeway for both with and without project up to the 100-year event.

6. In summary, a more detailed analysis of this alternative rectified inappropriate assumptions of previously unavailable residual flooding information, and brought the project features more into focus. Unfortunately, this also resulted in a critical decrease in the benefit/cost ratio.

Jody Fischer
JODY FISCHER
Hydraulic Engineer

CF:
CESPL-ED-H (Evelyn)
CESPL-ED-HE (Marfice)
CESPL-ED-HH (Lara)
CESPL-PD-WC (Herbranson)

DISPOSITION FORM

For use of this form, see AR 340-15; the proponent agency is TAGO.

REFERENCE OR OFFICE SYMBOL	SUBJECT
CESPL-ED-HE (1110-2-1403a)	Old Cross Cut Project Hydrology results

TO	FROM	DATE	CMT 1
CE-SPLPD-WC ATTN: Laura Herbranson	C, CESPL-ED-H	30 Sept 1988 Mrs. Jody Fischer/pj/X3164	

1. Ref. ESR 88 2312 RH, dated 1 April 1988.

2. As requested in the referenced ESR, the following results and information leading to these results is being provided in the enclosed MFR for the Old Cross Cut study area:

a. Discharges for SPF, 100-, 50- and 25-year present conditions without project, and 100-year future conditions without project. These without project discharges reflect the construction of the Papago Freeway and its storm drains, and the increase of the Old Cross Cut Canal (OCCC) capacity to 1750 cfs at CP 302, north of McDowell, 4100 cfs at McDowell, 4500 cfs between the Papago Freeway and Washington Blvd., and 4900 cfs at the Grand Canal.

b. Discharges for 100, 50, and 25-year, future conditions with the Full Lafayette alternative. This alternative, designed for 25-year level of protection, consists of storm drains north of the Arizona Canal. It does not change the levees of the Arizona Canal, but increases the OCCC capacity to 3000 cfs below the Arizona Canal, 3800 cfs at Thomas Rd., 4100 cfs above McDowell at CP 302, and as above downstream of this point.

c. The locations of 1800 cfs for a future conditions 100-year event with 100-year project are presented in plate 3 of the MFR.

Previously provided were 100-year hydrographs for with and without project at several locations of the OCCC as requested by Harley Parr of H.W. Lockner.

4. Please call Jody Fischer 213-894-3164, for any questions you may have.

1 encl

JOSEPH B. EVELYN
Chief, Hydrology & Hydraulics Branch

CF:

CESPL-ED
CESPL-PD
CESPL-ED-H
CESPL-ED-HH
CESPL-ED-HE(3)

EVELYN
CESPL-ED-H

MARFICE
CESPL-ED-HE

FISCHER
CESPL-ED-HE

28 Sept. 1988
J. Fischer

MEMORANDUM FOR THE RECORD

Subject: Old Cross Cut Canal hydrology with Full Lafayette alternative including the Papago Freeway.

CONDITIONS WITHOUT THE CORPS PROJECT

Since the hydrology for feasibility studies report, approved in 1987, without project conditions have been revised to include the Arizona Department of Transportation's (ADOT) construction of the Papago Fwy., and the increase of the Old Cross Cut Canal (O.C.C.C.) capacity above McDowell, CP 302, from 1450 cfs to 1750 cfs. In constructing the Papago Fwy., ADOT will be increasing the O.C.C.C. capacity between McDowell and the Grand Canal to meet the design capacities of the Full Lafayette Alternative - analysis number one (see paragraph 5 of WITH PROJECT). That is, 4100 cfs above McDowell, CP 302, and 4900 cfs at the Grand Canal, see plate 1 for locations. Incremental flows have been determined by ADOT contractors as 4100 cfs at McDowell, and 4500 cfs from the Papago Fwy. to Washington Blvd.

Because the Papago Fwy. will be above grade, three ADOT drains will carry flow away from the Fwy. embankment, (see plate 2). The first carries up to 930 cfs and runs south along 52nd Street from McDowell to the Grand Canal and then into the O.C.C.C.. Drain number 2 which carries up to 300 cfs westward from 52nd Street to the O.C.C.C. along the north side of the Papago Fwy. The third drain has been designed by ADOT to protect up to the 100-year flood, capacities unknown. It will carry flow westward along the Fwy. from 40th Street to 24th Street and then south on 24th Street into the Inner Loop storm drain tunnel.

Incl 1

Flow which reaches the Papago Fwy. between the O.C.C.C. and 40th Street is expected to enter the O.C.C.C..

CONDITIONS WITH THE CORPS PROJECT - THE FULL LAFAYETTE ALTERNATIVE.

The Full Lafayette alternative consists of constructing two storm drains along Lafayette, one going westward from Invergordon Rd. to Arcadia Dr., and the other taking flow south on 44th St. from Stanford Dr. to Lafayette and then east on Lafayette from 44th St. and Arcadia Dr., see plate 1 for locations. Meeting at Arcadia Dr. and Lafayette, they will travel south and parallel to each other along Arcadia Dr., and then flow under the Arizona Canal (A.C.) and into the Old Cross Cut Canal. These storm drains will receive flow through large grates in streets.

Flow between Lafayette and the A.C. or 44th Street and the A.C. will either pond behind the north bank of the A.C. or flow directly into the A.C.. No mitigative measures are being provided. Flow which reaches or originates from the area south of the A.C. and west of the O.C.C.C. will not be collected by this Corps project. Flow which reaches or originates from the area south of the A.C. and east of the O.C.C.C. will flow into the O.C.C.C. which will be enlarged to handle the 25-year flow from this area, the storm drains above the A.C., and flow from the A.C. itself.

The O.C.C.C. will have a design capacity of 3000 cfs below the A.C., increasing to 3800 cfs at Thomas Rd. at CP 401, increasing to 4100 cfs above McDowell Rd. at CP 302, 4500 cfs from the Papago Freeway to Washington, and 4900 cfs above the Grand Canal. This study, however, ends at the Papago Fwy. because ADOT is designing for 50-year capacity with minimum damage for a 100-year event.

The O.C.C.C. may eventually be covered from Thomas Rd. to the Grand Canal.

It will have inlets and or city designed storm drains which will direct flow into it from the areas east of it. These inlets have not been designed, but are discussed in this MFR under the heading of "Effect of Covering the O.C.C.C."

Analysis number one of the Full Lafayette alternative, mentioned in the first paragraph, involved decreasing the height of the A.C. north levees and directing <u>all</u> of the 25-year flow upstream of the A.C. into a storm drain system. This second analysis of the Full Lafayette alternative, however, assumes the A.C. levees will be as presently existing, and the A.C. will collect the lower portion, about 1/3, of each subarea above the A.C.; i.e. any runoff between the A.C. and Lafayette or 44th Street will flow into the A.C. and not the Corps project's storm drain system.

O.C.C.C. DESIGN CAPACITIES

The 25-year flows in the O.C.C.C. as seen in table 3 are less than the O.C.C.C. design capacities. The flows in table 3 were derived by modeling the transposed August 1954 Queen Creek storm, while the design capacity is the sum of the storm drain peak, CP 503I=2100 cfs, and the A.C. maximum outflow, 900 cfs, which results in 3000cfs. The design capacity of 3000 cfs below the A.C. was chosen to allow SRP to retain almost all of their 1000 cfs flow right of way. This design allows for a total A.C. flow of 900 cfs to be emptied during the 25-year flood, and 700 cfs during larger events. (Refer to CP 503I as the storm drain peak.)

The O.C.C.C. design flows between McDowell Rd. and the Grand Canal were determined by ADOT contractors. In this reach, only the 4100 cfs, our flow at CP 302 above McDowell Rd., and the 49[illegible] cfs at the Grand Canal were determined by the Corps in the previous analysis of the 25-year Full Lafayette

alternative. This is because ADOT is going to be constructing the Papago Fwy. over the O.C.C.C. and wishes to increase the O.C.C.C. capacity now to a level comparable to the Corps' with project design flows and at the time of ADOT's request for this information, analysis number one of the Full Lafayette alternative was the most likely alternative to be built. By doing this, ADOT plans will accommodate the Corps project and the Corps will not have to construct this reach of the O.C.C.C.

WITH VERSUS WITHOUT PROJECT COMPARISON OF O.C.C.C. BREAKS FROM MCDOWELL TO THE PAPAGO FWY. FOR OPEN CHANNEL DESIGN.

The 100-year event without project, with Papago Freeway causes no breaks in this reach of the O.C.C.C., however, the 100-year event with project leaves 400 cfs as breakout flow at the Papago Fwy..(table 3, CP 304B). Although the 100-year event is expected to exceed the Corps design level, questions may arise as to why the with project scenario results in breakout flows when the without project with Papago Fwy. does not. This is because the O.C.C.C. capacities upstream of McDowell have not been increased to the with project design flows. This leaves extra capacity in the O.C.C.C., between McDowell Rd. and the Papago Fwy., which is available for handling flood flows from the East. As a result, the 100-year event with the Papago Fwy. and the Corps project creates more breakout flow than after the construction of just the Papago Fwy.. (without project conditions).

EFFECT OF COVERING THE O.C.C.C. FROM THOMAS ROAD TO THE PAPAGO FWY.

The analysis presented in this MFR was done as an open channel design of the O.C.C.C.. This means that all flow arriving at the O.C.C.C. from the East will enter the canal unless it is already full. With a covered channel the

restricting factor is the inlet capacity as well as the channel capacity.

The effect of including part of the project, (O.C.C.C. increase due to the Papago Fwy.,) in without project conditions poses a unique problem in covering the channel. Without the Corps project, the O.C.C.C. from McDowell Rd. to the Papago Fwy. has a capacity which can hold more than the 100-year flood. However, by covering this reach, the inlet capacity is decreased such that the extra capacity in the channel is inaccessible.

Should the canal be covered, (a final decision has not been made by ADOT) the inlet capacities would be critical to residual flows for the without project scenario at and over the O.C.C.C. from above McDowell Rd. ,CP 302, down to the Papago Fwy.. Since ADOT has not yet designed their inlets, inlet capacities were estimated by the Corps as follows. The 25-year frequency peak of all flow reaching the O.C.C.C. between CP 302 and the Papago Fwy. is 540 cfs. This was based on an interior flood control analysis of the 0.59 sq. mi. drainage area. Of this 540 cfs, 300 cfs will be conveyed in the Papago Freeway drain number 2 which runs from 52nd Street westward to the O.C.C.C. along the north side of the Papago Fwy. The remaining 240 cfs must also be accommodated.

For the covered channel with Papago Fwy. without the Corps project, the maximum breaks occur when the storm is centered directly over subarea 3. They are as follows in table 1.

Table 1

OVERFLOWS AT THE O.C.C.C. AND THE PAPAGO FWY.

COVERED CHANNEL WITH PAPAGO FWY. WITHOUT CORPS PROJECT

		Present Conditions				Future Cond.
CP	Location	SPF	100-YR	50-YR	25-YR	100-YR
304	Inflow to O.C.C.C. CP 302 to the Papago Freeway	2400	1100	760	500	1200
304B*	Breakout at the Papago Fwy.	1800	530	220	0	620

*Breakouts were based on maximum inlet capacity of 540 cfs.

None of these breaks would occur if all inflow was permitted as is the case with an open channel design. (See table 2, CP 304B.)

RESULTS

Residual peak flows and design peak flows follow on tables 2 and 3. For the covered channel without project, use table 1 above for the breakout at CP 304B, and table 2 for all other CPs.

Plate 3 presents the portion of the storm drain system which exceeds 1800 cfs for a 100-year design. This criteria is a requirement for Corps involvement, and therefore represents the portion of the storm drain system which may be constructed by the Corps. It should be noted, however, that this

alternative is ineffective if the locals do not construct the remainder of the storm drain system presented in this MFR.

Table 2
N-YEAR PEAK DISCHARGES WITHOUT PROJECT
REVISIONS TO INCLUDE PAPAGO FWY & O.C.C. CAPACITY INCREASE
OPEN CHANNEL DESIGN

CP	LOCATION	DRAINAGE AREA (SQ.MI.)	STORM CENTERING (SQ.MI.)	FUTURE CONDITIONS 100-YR (CFS)	PRESENT CONDITIONS (CFS) SPF	100-YR	50-YR	25-YR
501U	Spur Cir. U/S of A.C.	0.93	3.9	1500	3300	1500	1000	700
501D	Spur Cir. D/S of A.C.	0.93	3.9	0	260	0	0	0
502U	56th St. U/S of A.C.	0.43	3.9	710	1500	680	490	320
502D	56th St. D/S of A.C.	1.36	3.9	360	800	350	230	140
401	Thomas Rd. at O.C.C.	3.09[2]	7.6	2400	4700	2100	1500	980
401U	O.C.C. U/S Thomas Rd.	----[1]	7.6	1000	1000	1000	1000	1000
401D	O.C.C. D/S Thomas Rd.	----[1]	7.6	1250	1250	1250	1250	1250
401B	O.C.C. Breakout at Thomas Rd.	3.09[2]	7.6	2100	4500	1900	1300	730
302	McDowell above O.C.C.C.	0.96	11.3	1400	2900	1300	940	620
302D	O.C.C. D/S above McDowell	----[1]	11.3	1750	1750	1750	1750	1750
302B	O.C.C. Breakout above McDowell	4.05[2]	11.3	900	2400	830	440	120
304	Papago Fwy east of O.C.C.C. incl. storm drain of 300 cfs	0.59	17.2	850	1800	800	570	370
304I	O.C.C. at the Papago Fwy.	----[1]	17.2	2600	3500	2600	2300	2100
304B	O.C.C. Breakout at Papago Fwy.	4.64[2]	17.2	0	0	0	0	0
305B	Papago Fwy. west of O.C.C.C.	5.17[2]	17.2	1900	4900	1700	1200	810
504U	Heatherbrae U/S of A.C.	0.38	3.9	650	1400	620	440	290
504D	Heatherbrae D/S of A.C.	0.38	3.9	270	750	260	0	0
503U	48th St. U/S of A.C.	1.20	3.9	2100	4400	2000	1400	920
503D	O.C.C. D/S of A.C.	1.58[2]	3.9	1100	1900	1100	1000	680
406	Flower Pl.	2.43[2]	7.6	550	2000	530	230	160
306	38th St. & Yale St.	3.54[2]	11.3	780	2100	780	450	320
206	32nd St. & Grand Canal	5.09[2]	17.2	1100	2200	1100	710	460
505U	44th St. U/S of A.C.	0.61	3.9	1100	2300	1000	730	480
505D	44th St. D/S of A.C.	0.61	3.9	540	1700	510	360	320
506U	40th St. U/S of A.C.	0.39	3.9	650	1400	620	440	290
506D	40th St. D/S of A.C.	1.00	3.9	210	510	200	120	50
506AD	1000 ft. West of 40th St. D/S of A.C.	1.00	3.9	300	650	280	200	140
407	36th St. & Devonshire Ave.	2.15[2]	7.6	1200	3200	1200	850	560
307	30th St. & Mitchel Ave.	3.24[2]	11.3	1300	3100	1300	920	610
207	24th St. & Grand Canal	4.69[2]	17.2	1400	2900	1400	1000	650

1. The first 1000 ft^3/s in the Old Cross Cut Canal are from outside of this study area, by the way of the Arizona Canal, therefore, no drainage area is defined. Flows listed are channel capacity except CP 304I where channel capacity is 4500 cfs.

2. These areas include subareas which contain flows that cross the A.C. or O.C.C.C. and contribute to this CP.

- Ref. Rept. of June 1987 - Underlined are ratios of 100-yr

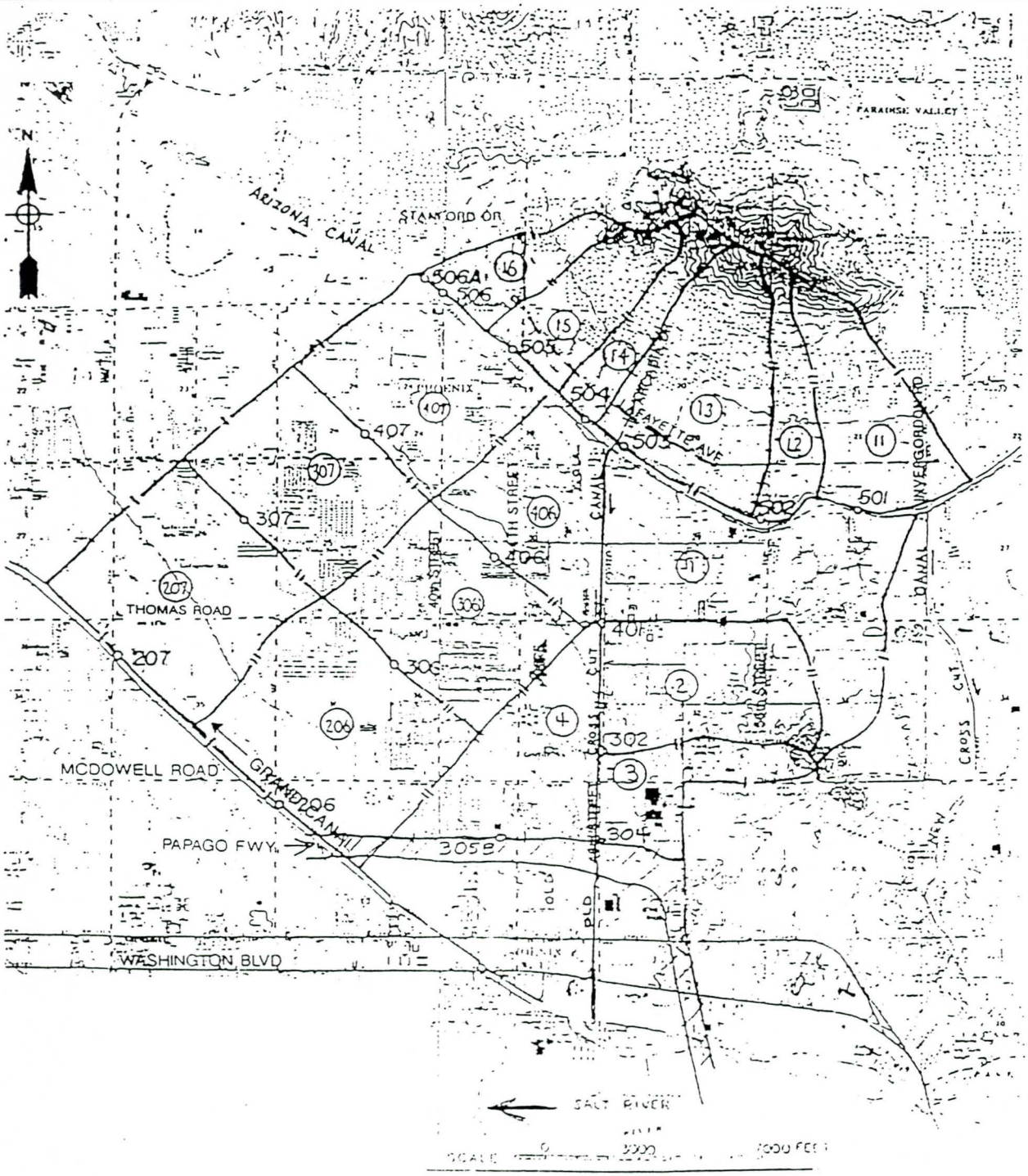
Table 3
N-YEAR PEAK DISCHARGE WITH PROJECT
WITH PAPAGO FWY OPEN CHANNEL DESIGN
-- Full Lafayette Alternative --

CP	LOCATION	DRAINAGE AREA (SQ.MI.)	STORM CENTERING (SQ.MI.)	FUTURE CONDITIONS 100-YR (CFS)	50-YR (CFS)	25-YR (CFS)
501U	Spur Cir. U/S of A.C.	0.93	3.9	1000	550	190
501D	Spur Cir. D/S of A.C.	0.93	3.9	0	0	0
502U	56th St. U/S of A.C.	1.36	3.9	470	270	90
502D	56th St. D/S of A.C.	1.36	3.9	170	100	0
401	Thomas Rd. at O.C.C.	3.09	7.6	2300	1600	1100
401D	O.C.C. D/S Thomas Rd.	----[1]	7.6	3800	3800	3100
401B	O.C.C. Breakout at Thomas Rd.	3.09[2]	7.6	1450	450	0
302	McDowell above O.C.C.	0.96	11.3	1400	1000	670
302D	O.C.C. D/S above McDowell	----[1]	11.3	4100	4100	3300
302B	O.C.C. Breakout above McDowell	4.05[2]	11.3	1000	370	0
304	Papago Fwy east of O.C.C.C. incl. storm drain of 300 cfs.	0.59	17.2	850	610	400
304I	O.C.C. at the Papago Fwy.	----[1]	17.2	4500	4500	3400
304B	O.C.C. Breakout at Papago Fwy.	4.84[2]	17.2	400	0	0
305B	Papago Fwy. west of the O.C.C.C.	4.98[2]	17.2	1100	310	200
504U	Heatherbrae U/S of A.C.	0.38	3.9	400	210	50
504D	Heatherbrae D/S of A.C.	0.38	3.9	30	0	0
503U	48th St. U/S of A.C.	1.20	3.9	1300	730	220
503D	O.C.C. D/S of A.C.	1.59	3.9	3200	2800	2300
406	Flower Pl.	2.43	7.6	330	220	140
306	38th St. & Yale St.	3.54	11.3	640	450	300
206	32nd St. & Grand Canal	5.09	17.2	1000	710	460
505U	44th St. U/S of A.C.	0.61	3.9	690	380	110
505D	44th St. D/S of A.C.	0.61	3.9	330	300	0
506U	40th St. U/S of A.C.	0.39	3.9	500	310	150
506D	40th St. D/S of A.C.	1.00	3.9	110	50	0
506AD	1000 ft. West of 40th St. D/S of A.C.	1.00	3.9	220	150	0
407	36th St. & Devonshire Ave.	2.15	7.6	930	580	200
307	30th St. & Mitchel Ave.	3.34	11.3	1000	690	330
207	24th St. & Grand Canal	4.69	17.2	1200	870	490
1D=1I	Inflow to Storm Drain at CP1	0.68	3.9	540	540	520
2D	Inflow to Storm Drain at CP2	0.29	3.9	240	240	240
2I	Storm Drain at CP2	0.97	3.9	780	780	760
3D	Inflow to Storm Drain at CP3	0.93	3.9	760	760	760
3I	Storm Drain at CP3	1.90	3.9	1540	1540	1400
6D=6I	Storm Drain at CP6	0.21	3.9	150	150	150
5D	Inflow to Storm Drain at CP5	0.45	3.9	390	390	390
5I	Storm Drain at CP5	0.65	3.9	540	540	520
4D	Inflow to storm Drain AT CP4	0.30	3.9	250	250	250
4I	Storm Drain at CP4	0.95	3.9	790	790	760
503I	Storm Drain above Old Cross Cut Canal	2.86	3.9	2300	2300	2100

1. Includes flow from outside of this study area, by the way of the Arizona Canal, therefore, no drainage area is defined. Flows listed are channel capacity except for 25-year frequency.

2. These areas include subareas which contain flows that cross the A.C. or O.C.C.C., and contribute to this CP.

- Ref. Rept of June 1987 -



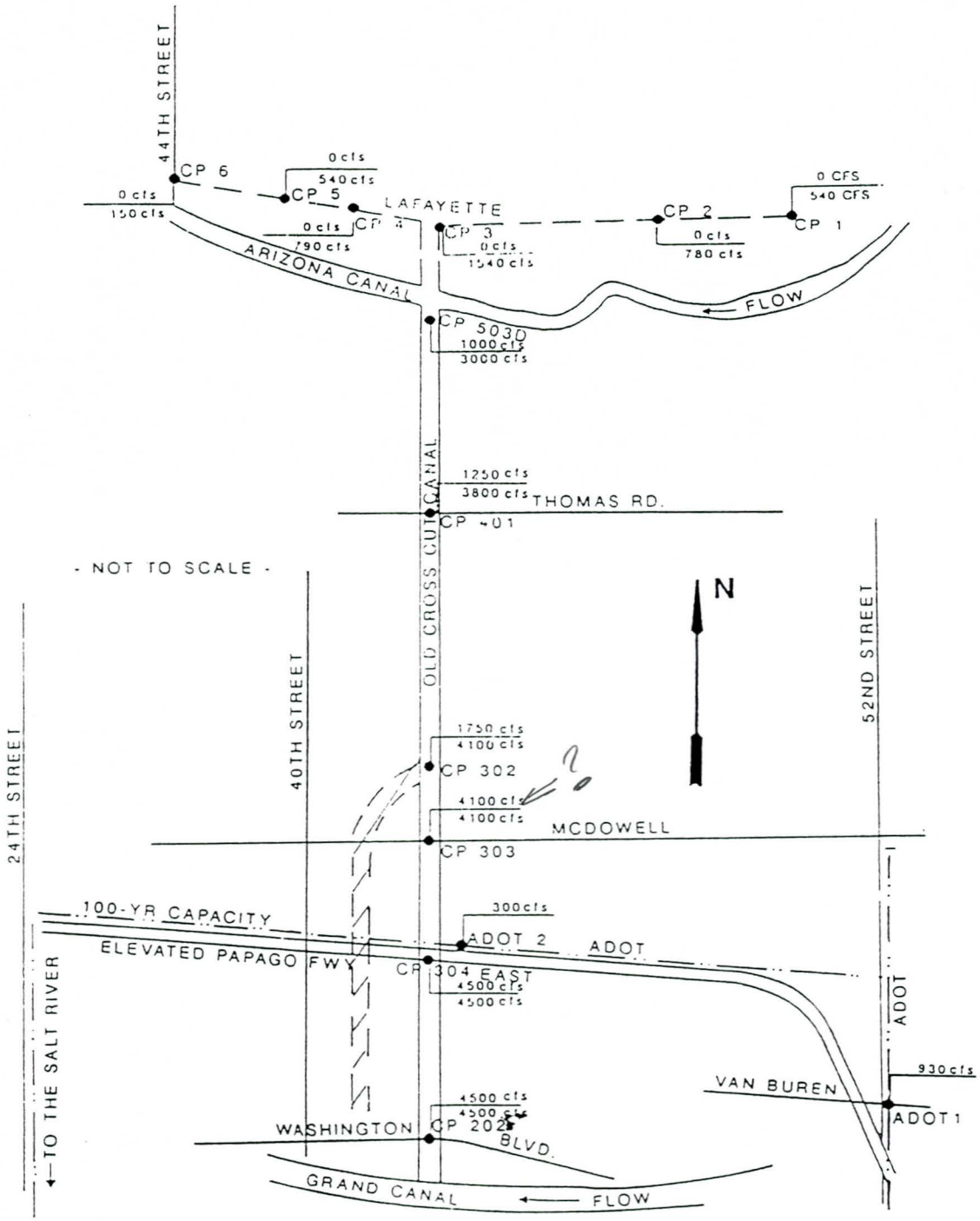
— — — — —	STORM DRAIN
o	CONCENTRATION POINT
(1)	SUBAREA NUMBER

OLD CROSS CUT STUDY

DRAINAGE AREA MAP

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

⊛ THIS & THAT SYSTEM MUST HANDLE; NOT WHAT PRESENT CONDITIONS CAN HANDLE.



WITH PROJECT STORM DRAIN

OLD ALIGNMENT OF THE OLD CROSS CUT CANAL

ADOT STORM DRAIN

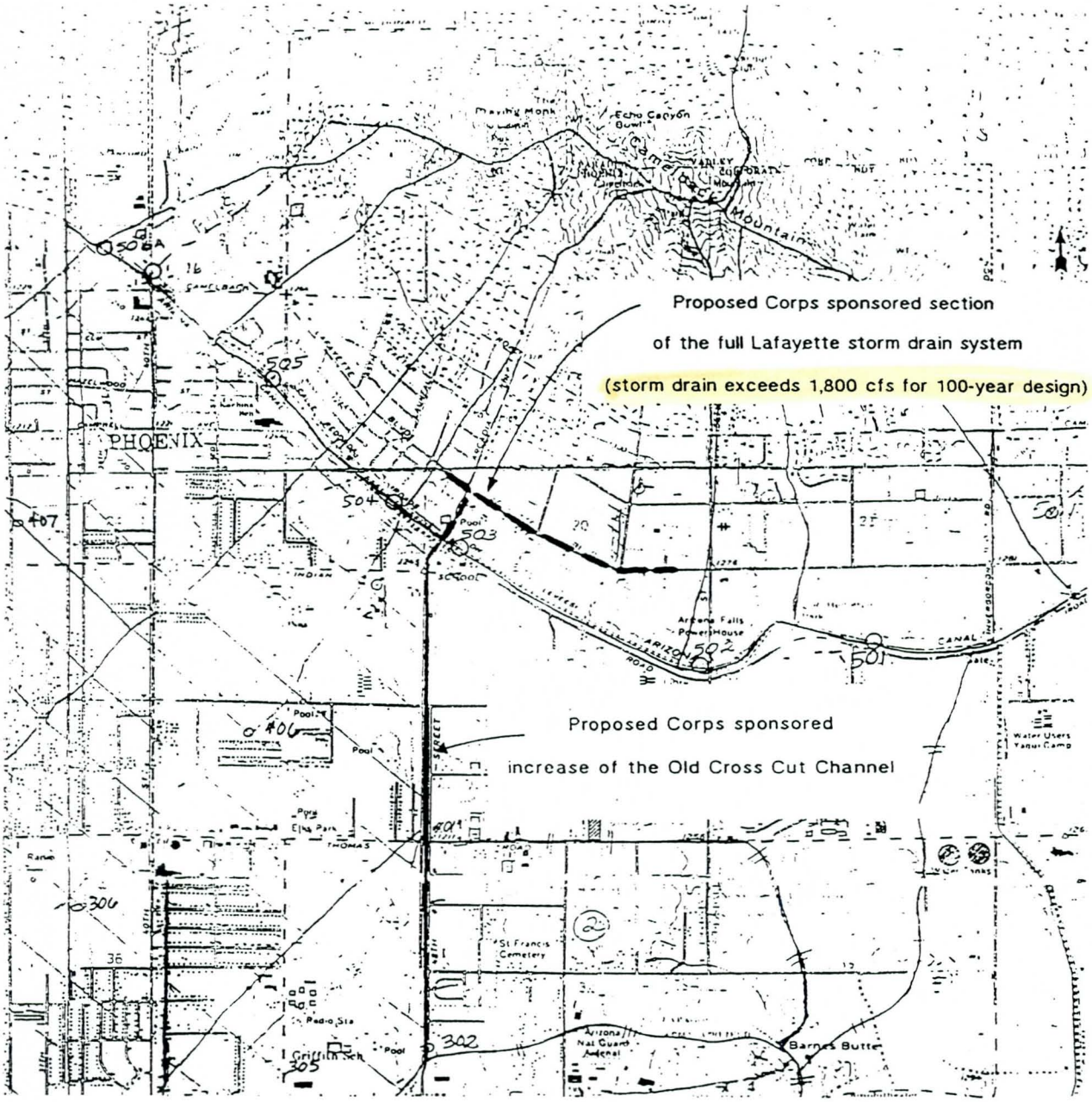
W/O PROJECT / WITH PROJECT CAPACITY

OLD CROSS CUT STUDY

DRAIN CAPACITIES

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 2



OLD CROSS CUT STUDY

PROPOSED

CORPS SPONSORED SECTION

OF THE FULL LAFAYETTE ALTERNATIVE

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 3

OLD CROSS CUT
PHOENIX, ARIZONA

HYDROLOGY FOR FEASIBILITY STUDIES FOR FLOOD CONTROL AND ALLIED PURPOSES

U.S. Army Corps of Engineers

Los Angeles District

June 1987

CESPD-ED-W (29 Jun 87/CESPL-ED-H) (1110-2-1403a) Verke/dh/6-6957
SUBJECT: Old Cross Cut Canal Feasibility Study

DA, South Pacific Division, Corps of Engineers, 630 Sansome St., Room 720, San Francisco, CA 94111-2206 03 SEP 1987

FOR: Commander, Los Angeles District, ATTN: CESPL-ED-H

The hydrology for Feasibility Studies for Flood Control and Allied Purpose, Old Cross Cut Canal, Phoenix, Arizona is approved. Plates 20 through 26 are out of sequence with the text and should be corrected for the final report.

FOR THE COMMANDER:

wd encls

A. E. WANKET
Chief, Engineering Division

DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT CORPS OF ENGINEERS

REPLY TO
ATTENTION OF

CESPL-ED-H (1110-2-1403a) June 29, 1987

MEMORANDUM FOR: Commander, South Pacific Division, ATTN: CESPD-ED-W

SUBJECT: Old Cross Cut Canal Feasibility Study

1. Request approval of discharge-frequency values, (tables 1,6,7 and 8) in enclosed report titled, "Old Cross Cut Phoenix, Arizona, Hydrology for Feasibility Studies", by 13 July 1987 to meet Feasibility Milestone F3 requirements. Milestone F3 Conference #1 is currently scheduled for 14 July 1987. The hydrology report previously submitted for approval in September 1986 is superseded by enclosure 1 and should be disregarded.

2. Additional supporting data for Milestone F3 Conference #1 are also provided as follows:

a) Hydrology (encl. 2) and Hydraulics (encl. 3) responses to pertinent comments made at the 17 November 1986, In Progress Review meeting.

b) The without-project overflow map (encl. 4)

3. For further information please contact Joseph Evelyn, 8-798-5520.

FOR THE COMMANDER:

Robert E. Kapp

4 Encls

CARL F. ENSON
Chief, Engineering Division

OLD CROSS CUT
PHOENIX, ARIZONA

HYDROLOGY FOR FEASIBILITY STUDIES FOR FLOOD CONTROL AND ALLIED PURPOSES

U. S. Army Corps of Engineers

Los Angeles District

June 1987

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1. INTRODUCTION

1.01 Purpose and Scope.

General. This report presents development of present and future condition hydrology for the Old Cross Cut Canal study area. N-year peak discharges are presented in Table 1. It also discusses seven alternatives to the flood problem and their hydrologic implications. This study area (plate 1), is between the existing Indian Bend Wash project and reach 4 of the Arizona Canal Diversion Channel.

Flood Problem. The Old Cross Cut Canal is part of the Salt River Project's (SRP's) canal system. It was originally built to transfer water from the Arizona Canal to the Grand Canal. Today it serves primarily to drain floodwaters intercepted by the Arizona Canal and local runoff downstream from the Arizona Canal, to the Salt River, plate 1. Runoff from Camelback Mountain results in sheet-flow-type flooding and ponding behind the north levee of the Arizona Canal. For the floods considered in this report (10-year floods and larger) the runoff overtops the north levee at the various locations and is partially intercepted by the Arizona Canal. During such events the Old Cross Cut Canal is used to drain the floodflows from the Arizona Canal. Up to 1000 ft^3/s can be diverted into the Old Cross Cut Canal at 48th Street. Flood waters eventually fill the Arizona Canal and overflow its south bank. Floodflows then disperse into sheet-flow, traveling through developed areas. At downstream locations some of the sheet-flow will be intercepted by the Old Cross Cut Canal. The rest will continue to flow southwestward toward the Grand Canal.

Planning Studies. Modifications of the existing drainage system are under consideration as a means to reduce ponding and sheet flow in the Phoenix area. This report analyzes the no-project conditions for the study area as well as seven alternative projects. When planning studies develop specific plans of action, additional hydrology studies may be required to analyze project conditions in more detail. For this study, peak discharges and total storm volumes were computed for various flood frequencies and the standard project flood.

1.02 Coordination With Local Interests.

The canals in this project area may be emptied at any time through the use of gates, wasteways, and diversion canals which are operated by the Salt River Project (SRP). Several alternatives in this study consist of such operations by SRP and as such would require their action to implement them. They have participated in the formulation of study alternatives and are willing to consider implementing one of these alternatives as it may benefit their interests.

2. GENERAL DESCRIPTION OF DRAINAGE AREA

2.01 Physiography and Topography.

This study area of approximately 17 square miles is located in the Phoenix region. About 20 percent of the area is mountainous with the remaining area being valley. Camelback Mountain, 2700 feet at its peak, is rugged and steep with a slope of about 60 percent. Papago Park Mountain is also rugged but has a slope of about 5 percent. The valley region, which dominates this area, is densely populated and very flat, about 1 percent slope. Land in the valley

areas originally covered by natural vegetation, as well as that used for agriculture, is almost all now urbanized. Camelback Mountain is too steep for intensive development but is experiencing limited residential building.

2.02 Runoff Characteristics.

Phoenix is located within a desert region of central Arizona. Most of the areas addressed in this report are subject to flooding from two distinct types of topography: gently sloping valley areas, and steep hills. Runoff tends to not concentrate but rather flow downhill at somewhat equal depths across an entire valley area. Valley slopes range from 30 to 50 feet per mile in most cases. Some of the basin is in a state of rapid transition from natural land to residential, commercial and industrial development. Most of it has already been developed.

The study area also includes steep terrain. Camelback Mountain peak elevation is about 2700 feet with a slope of about 3000 feet per mile. Camelback Mountain runoff concentrates in numerous small gullies rather than one major water course. Upon reaching the valley area, runoff again disperses into sheet flow.

Flow paths in the valley area are controlled by the slope of the land and manmade obstructions. When the path of flow is interrupted by embankments such as those for railroads, highways and canals, ponding and diversion may occur. Drainage boundaries at several locations for this study are defined by such embankments.

2.03 Vegetation.

This study area is mainly urbanized flat valley. The residential areas have either grass or rock as ground cover in their yards while the business areas are mostly asphalt or concrete with a high concentration of buildings. Most streets are paved while the residential alleys are not. About 20 percent of the study area is unurbanized. Camelback and Papago Mountain, where natural vegetation is sparse, are rugged, steep and undeveloped. Cacti and other desert shrubs as well as a few stunted trees, including juniper, paloverde, mesquite, ironwood and scrub oak, exist among the shrubs. Growth tends to be thicker along and adjacent to the small gullies and washes. Perennial grasses form a very small portion of the vegetation, but a good cover of annual grasses occur after the winter rains.

2.04 Geology and Soils.

Alluvium fills the valleys and covers the slopes of hills and mountains. Older alluvium consists of medium to well-cemented residual soil and talus debris. It is generally found along the side slopes of the valleys and underlying the recent alluvium. In the valleys, the older alluvium is mostly sand and silt sand containing varying amounts of caliche. Recent alluvium is found in valley areas along the streambed channels and consists of uncemented silts and sands, gravels, cobbles, and boulders. The deep dissection of the valleys in the mountains and the great extent of the alluvial fans suggest that the Phoenix area has had a long stable history. There is evidence of ancient folding and faulting, as seen in the outcrops of the older rocks, but no recent seismic activity has been recorded in the area. In general,

sediment production would be classified moderate, with a higher potential at points near the mountains and a correspondingly lesser potential in the valley areas with flatter streambed profiles.

2.05 Land Use.

Much of the land in the Old Cross Cut-Arcadia area is presently devoted to residential use. The Papago Mountains have been designated as a regional park (Papago Park) and future development is not anticipated. Present condition land use was estimated from 1982 photo revised US Geological Survey (USGS) quadrangle sheets (1:24,000 scale) for each drainage area. This information was supplemented by field surveys and photographs. Projected future development was based on the General Plan for Phoenix - 1885/2000 map prepared by the City of Phoenix to show ultimate development.

2.06 Climatology.

The climate of Phoenix and the study area is arid. Annual precipitation is about 8 inches in the study area. Most of the precipitation occurs in two distinct seasons, summer (June through September) and winter (December through March), and is about equally divided between them. Monthly, seasonal, and annual precipitation amounts vary considerably from year to year. During any season there may be many successive rainless days. Three basic types of storms can affect the Phoenix area, although some may consist of a combination of types.

General Winter Storms. Storms of this type normally move inland from the north Pacific Ocean, spreading general light to moderate precipitation over large areas. Although they can occur any time from late October through May,

they are most common and generally heaviest from December through early March. These storms frequently last several days and may occur in series with only slight breaks between storms. They usually reflect orographic effects to a great degree, so the mountains of central Arizona often receive from four to ten times as much precipitation from winter storms as do the desert areas near Phoenix. Snow frequently falls in the mountains above 6000 feet and occasionally falls at elevations below 3000 feet. Despite the normal low intensities of precipitation during general winter storms, the large areal extent and the relatively long duration of these storms, sometimes combined with snowmelt from the mountains, can produce substantial volumes of runoff and high peak discharges on the larger rivers of the region.

General Summer Storms. Storms of this type normally result from a flow of warm and very moist tropical air into the region from the southeast or south, including the Gulf of California (Sea of Cortez), the tropical Pacific Ocean south of Baja California, and, to a slight extent, the Gulf of Mexico. Such storms over Arizona are often associated with tropical storms or hurricanes. General summer storms can occur any time from late June through mid-October, but are most frequent from August through early October. They usually last from 1 to 3 days and generally consist of numerous locally heavy storm cells embedded in more widespread, general light to moderate rain. Like their general winter counterparts they usually reflect orographic influence, with higher mountains often receiving from three to eight times as much precipitation as do most of the desert areas. Some of the late September and October general storms can show characteristics of both the summer and winter types. The areal extent and duration of general summer storms are usually somewhat less than those of general winter storms, but intensities may be higher.

Because infiltration rates are normally higher during summer than during winter, runoff volumes are usually lower than from winter events, but the peak flows on intermediate-sized streams may be higher.

Local Storms. Local storms consist of heavy downpours of rain over relatively small areas (up to about 300 square miles) for short periods of time (up to about 7 hours). They are usually accompanied by lightning and thunder, and are often referred to as "thunderstorms" or "cloudbursts." They can occur any time of the year, but are most prevalent and most intense during the summer months, July to September, when tropical moisture frequently invades Arizona from out of the south or southeast. During the latter part of the summer season they are often larger, of longer duration, and more apt to be associated with general summer storms. Runoff from local storms is usually of a high-peak, low-volume type, affecting mostly the smaller creeks and washes, and is characterized by a rapidly rising and receding hydrograph. They can result in serious flash floods, sometimes with loss of life and serious local property damage.

2.07 Existing Structures Affecting Runoff.

General. Several existing bridges and canals alter flow characteristics in the study area and were considered in this study. Pertinent information on major existing and proposed structures affecting runoff is provided in this section.

Arizona Canal. The Arizona Canal is a partially entrenched water supply canal which carries water between Granite Reef Dam and Skunk Creek. During storms, water ponds behind the north bank causing flooding. If flows in the

canal exceed capacity, the south bank breaks causing flooding downstream of it. For this reason it has several wasteway structures, such as 40th Street spillway and 48th Street gates, to allow for water disposal. This canal also has diversion structures to provide water to customers. One such diversion is the New (or Arizona) Cross Cut Canal. Starting at the Arizona Canal and Invergordon Road, it brings water to the Penstock treatment plant at a rate of up to 625 ft^3/s. These structures were accounted for in the without and with project analyses.

Old Cross Cut Canal. The Old Cross Cut Canal connects the Arizona Canal to the Grand Canal. This entrenched canal runs parallel to 48th Street with a westward jog at McDowell Road (plate 1). Its capacity is 1000 ft^3/s at the Arizona Canal, and gradually increases throughout its 3.5 mile long reach to 2,000 ft^3/s at the Grand Canal. Although SRP reserves 1000 ft^3/s capacity it only uses this canal for wasting water to the Grand Canal. The remaining capacity is available for downstream storm runoff. The Old Cross Cut Canal has six box culverts, three foot bridges, and three other bridges, all of which may constrict the Canal flow during a flood.

Grand Canal. The Grand Canal runs parallel to and has the same function as the Arizona Canal. It receives flow from the New Cross Cut Canal, distributes it and wastes the excess flow into the New River. It receives flow from the Old Cross Cut Canal during floods and either brings it westward toward the New River or passes it to the Salt River through waste gates. The Grand Canal affects floodflows similarly to the Arizona Canal since it is also partially entrenched. However, the north bank does not cause the same ponding problem because the banks are generally less than one foot and the canal is mainly entrenched.

3. RAINFALL PRECIPITATION AND RUNOFF

3.01 Precipitation and Streamflow Records.

The City of Phoenix and the Maricopa County Flood Control District each have had precipitation gages installed since 1972 and 1980, respectively, but not enough data has been collected to determine a trend. No runoff gages, other than in controlled channels, exist in the area. Since there are no usable rainfall or runoff gages in this study area and the Phoenix Arizona and Vicinity, and Indian Bend Wash Projects are adjacent to it, much of the pertinent hydrology generated in the Phoenix Arizona and Vicinity studies (ref. 2 and 3, hereafter referred to as the Part 1 or 2 hydrology report) was directly adopted for this study. This provides for more consistancy between studies in the Phoenix area.

The USGS and the National Weather Service (NWS) operate a network of stream and precipitation gages in the Phoenix area. This was discussed in detail in reference 2. They were used to determine rainfall-runoff relationships and standard project flood frequencies in the Phoenix area.

3.02 Storms and Floods of Record.

General. Little is known about floods in the Phoenix area, or Arizona in general, during the early-to-mid-1800's. Rainfall records and/or historical accounts indicate that sizable floods have occurred on numerous occasions. Several events for which data are available were described in the Part 1 hydrology report. A brief description of significant storms are given in the following paragraphs.

Storm and Flood of 26-29 August 1951. The storm of 26-29 August 1951 was one of the heaviest on record at many Arizona locations. The storm developed from the remnants of an old Gulf of Mexico hurricane that crossed the Mexican mainland and turned northward towards Arizona on 26 August, combining with moisture outflow from a tropical storm west of Baja California. General, moderate rainfall, with heavy thunderstorms embedded, spread northward through Arizona on 26 and 27 August. At most stations, the maximum 24-hour rainfall, which accounted for about 65 percent of the total storm precipitation, occurred between approximately midday of the 27th and midday of the 28th. Precipitation generally tapered off during the afternoon of the 28h and ended on the 29th, although a few locations experienced a secondary burst of rain during the morning of the 29th. The total 26-29 August precipitation in and near the study area ranged from 3.85 inches at Phoenix and 3.95 inches at Prescott to 13.55 inches at Crown King. A total of 6.94 inches was observed at Waddell Dam. Total storm isohyets for 26-29 August are shown on plate 2. Because antecedent precipitation during August 1951 was relatively abundant, the ground in most areas was partially saturated at the beginning of the 26-29 August storm. Thus, the high precipitation intensities on 27 and 28 August produced heavy runoff in many areas, and caused significant flooding in some locations north and west of Phoenix. While the maximum mean daily inflow at Waddell Dam on August 29 was 23,144 ft^3/s, the peak discharge was probably considerably higher. Based on high water marks at numerous breaks on the Beardsley Canal in the Trilby Wash basin, the U.S. Soil Conservation Service estimated that a peak discharge of 35,000 ft^3/s may have occurred on Trilby Wash, assuming that all the numerous flood peaks along the canal had occurred at the same time. The peak discharge on the Hassayampa River at Box Damsite,

near Wickenburg, is estimated by the USGS to have been 27,000 ft ^{3}/s on 29 August. This storm was selected as the general type standard project storm for the Phoenix area.

Storm and Flood of 19 August 1954. Although there was no widespread general precipitation in Arizona during August 1954, one large and very intense thunderstrom occurred over the Queen Creek drainage area, approximately 50 miles east of Phoenix. The storm and flood were the most severe on record in the Queen Creek Basin. Precipitation intensities were very high during portions of the storm, especially between 5:00 and 9:00 a.m. on the 19th. The smelter at Ray (about 11 miles southeast of Superior) measured 4.05 inches of rain in less than 2 hours, while the Boyce Thompson Arboretum (about 4 miles west of Superior) measured a total of 5.3 inches for the storm, most of which fell within 3 hours. An estimated 140 square miles of area miles had over 5 inches of precipitation in the storm, and approximately 850 square miles had over 1 inch. Total storm isohyets for August 19 are shown on plate 3. This storm was selected as the local type standard project storm.

Storm and Flood of 22 June 1972. The heavy thunderstorm that occurred over northeastern Phoenix and adjacent communities on the morning of 22 June 1972 was a part of a series of early summer thunderstorms over the entire southwestern United States from 20 through 23 June 1972 that resulted from a deep flow of very moist, tropical air into the region from off the west coast of Mexico. In Phoenix the unofficial maximum rainfall was 5.25 inches during an estimated 2 hours near 4th Street and Camelback Road. Bucket survey amounts of 4.87 inches at 24th Street and Indianola Avenue and 4.8 inches at 28th Street and Indian School Road were confirmed by the National Weather

Service. The maximum recording-gage intensity was 3.85 inches in 80 minutes at 18th Street and Turney Avenue. Large hail also fell in the area. The storm was highly localized, with only 10 square miles having greater than 4 inches of rainfall and only 200 square miles with more than 2 inches. Total storm isohyets for 21-22 June are shown on plate 4. Estimates of peak discharges for 22 June made by the USGS include: Shea Wash at Shea Boulevard (1.79 square miles), 945 ft^3/s; Cudia City Wash 1000 feet upstream from McDonald Drive (2.16 square miles), 4200 ft^3/s; Dreamy Draw at 16th Street (1.62 square miles), 860 ft^3/s; Indian Bend Wash (at Indian Bend Road) near Scottsdale (142 square miles), 21,000 ft^3/s.

Ponding north of the Arizona Canal from one to four houses away occurred throughout this area. SRP shows no records of the Arizona Canal breaking in this study area other than 40th Street. However, at 56th Street, residents were flooded south of the Arizona Canal from water crossing the Canal at the depressed intersection of 56th Street and Mitchell Drive. Outside of this study area extensive flooding on Cudia City Wash south of the Arizona Canal was caused when the canal was overtopped at 32nd and 40th Streets. The Arizona Canal also broke at other locations outside this study area but the inundation was small relative to that caused by Cudia City Wash.

The U.S. Geological Survey 1972 Surface Water Records show a Cudia City Wash peak flow of 3000 ft^3/s at a location 1000 feet upstream from McDonald Drive, with a contributing drainage area of 2.16 square miles. The synthesized 50-year flood at this location is about 2700 ft^3/sec. The Salt River Project estimated a peak discharge of 3375 ft^3/s on Cudia City Wash just upstream from the Arizona Canal. The synthesized 50-year flood on Cudia City

Wash upstream from the Arizona Canal is 4400 ft^3/s derived from a 4.9 square mile contributing drainage area. This indicates that the 1972 peak flow on Cudia City Wash was approximately a 50-year frequency flood. The peak flow in Dreamy Draw at 16th Street, with a contributing drainage area of 1.62 square miles, was estimated to be 860 ft^3/s. This is approximately a 25-year event with no regulation upstream. (Dreamy Draw Dam was constructed in 1973.)

4. SYNTHESIS OF STANDARD PROJECT FLOOD

4.01 General.

The standard project flood (SPF) represents the flood that would result from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the region. Normally larger than any past recorded flood in the area, it can be expected to be exceeded in magnitude only on rare occasions and thus constitutes a design standard that will provide a high degree of flood protection. The SPF was determined using a stream system analysis approach, which requires dividing the study area into subbasins that are hydrologically and meteorologically homogeneous. Subdividing a watershed permits more accurate modeling of the runoff process, as variations in topography and urbanization, as well as changes in channel characteristics, may be incorporated into the hydrologic description of the basin. The standard project storm was then centered over the watershed in the most critical flood producing manner. Application of the rainfall loss rate function enabled determination of the rainfall excess, which was then applied to the subbasin unit hydrograph to produce the subbasin flood hydrograph. Combining and routing of subbasin flood hydrographs to the desired

concentration point, while removing percolation loss as appropriate, completed the computation. The elements involved in the computation are described below.

4.02 Standard Project Storm (Local Type).

The 19 August 1954 thunderstorm that was centered generally in the Queen Creek drainage east of Phoenix was determined to be the storm with the most severe flood-peak-producing rainfall that can reasonably be expected to occur over central Arizona. This storm was therefore used to determine the standard project flood for smaller drainage areas. The methods used to determine the total precipitation amounts, the duration of the storm, the intensity-duration relationships, and the time-distribution of the precipitation are explained in the following subparagraphs.

Total Precipitation. Total precipitation amounts for the standard project local storm were obtained from the isohyets (plate 3) of the 19 August 1954 Queen Creek thunderstorm, transposed and critically centered over the various drainage basins within the study area. Because the heaviest precipitation of this storm (7.5 inches maximum) occurred in the mountain and foothill areas where orographic influences are significant, the total storm depth was adjusted as it was transposed to the study area by means of 10-year, 6-hour precipitation values published by the National Weather Service in NOAA Atlas 2 (plate 5). The average total-storm precipitation over each basin of interest was determined by reducing the transposed maximum point precipitation by means of a family of depth-area curves (plate 6). These were constructed from the original depth-area curve developed from the isohyets of the original 1954 storm, adjusted for orographic influences. They are labeled according to the

10-year, 6-hour precipitation statistic. The depth-area curves in the higher mountain regions (where the 10-year, 6-hour precipitation is greater) decrease less rapidly with increasing area than do the curves in the deserts (where the 10-year, 6-hour precipitation is less).

Storm Duration. In the original August 1954 storm nearly all the precipitation fell within a 7-hour period according to local observations, and at many stations most of the rainfall occurred within 3 hours or less. Thus, a duration of 7 hours was used in the development of the standard project storm, with large portions of the total precipitation occurring within 1 to 3 hours.

Intensity-Duration Relationships. A time-distribution curve (mass curve) of precipitation was synthesized for each point within the August 1954 Queen Creek storm for which a total-storm precipitation measurement was made. These curves were based on the total precipitation at that location and available measurements or estimates of precipitation intensities for various durations within the storm. The curves at nearby locations within the storm were compared for consistency, and portions of the curves that were not based on firm observational data were adjusted to conform to patterns at nearby stations that were based on firm data. Maximum intensity-duration relationships for durations of approximately 2 to 7 hours were obtained from these August 1954 time-distribution curves. No extremely intense precipitation rates for durations of less than 1 hour were measured in this 1954 storm because of the lack of properly functioning recording rain gages in the area. Such high intensities have, however, been measured on a number of other occasions in central Arizona. Those rates are considered to be reasonably characteristic of the heaviest local storms in this part of the State. Therefore, maximum

intensity-duration relationships for durations of less than 2 hours were obtained from all available intense local historical storms in central Arizona and were transposed to the Queen Creek area by means of the corresponding 10-year, t-hour precipitation statistic obtained from NOAA Atlas 2. Synthesized composite values of the intensity-duration relationship for the standard project storm in the Queen Creek area were thus obtained from the August 1954 storm and from other historical storms (plate 7, intensity-duration curve no. 7). These intensity-duration values were transposed to the study area by means of the 10-year precipitation statistic for each duration from 5 minutes to 7 hours.

Time-Distribution Patterns. From the standard project intensity-duration relationship (plate 7) and the synthesized precipitation mass curves drawn for the various observation points within the 1954 Queen Creek storm, a time-distribution curve for the point-value precipitation at the center of the standard project storm in the Queen Creek area was constructed. Time-distribution curves for areal averages of standard project storm precipitation in the Queen Creek area were derived from examination of various combinations of the synthesized Queen Creek mass curves. These central-value and areal-average time-distribution curves, expressed as a percent of the total storm precipitation, are shown on plate 8. In addition to variations according to areal extent, a time-distribution pattern of an intense storm (expressed as a percent of the total storm precipitation) can become significantly smoothed in mountainous regions, where the total rainfall of a storm can become augmented by the addition of a semi-steady orographic rainfall component. Therefore, for a given drainage area, the time-distribution of precipitation in a local thunderstorm will frequently become

smoothed if the storm ascends a mountain slope. This factor was incorporated in a diagram (plate 9) that relates the time-distribution of precipitation in the local type standard project storm to both drainage area and 10-year, 6-hour precipitation. It can be seen from this diagram that patterns 1 and 2 (as a percent of the total storm) apply primarily to small drainage areas in the lower desert valleys, while patterns 4 and 5 apply to higher mountain regions (regions having higher 10-year, 6-hour precipitation), as well as to larger drainage areas.

Antecedent Rainfall. Ground conditions characteristic of standard project flood conditions are assumed to be established by 0.5 inch of precipitation occurring within a 24-hour period immediately prior to the local type standard project storm. This assumption has some basis in that a secondary storm cell formed in the same general area on the day following the Queen Creek storm of August 19, 1954. Meteorologically, this secondary storm cell could have occurred prior to the main Queen Creek storm. Therefore, when computing the SPF, the loss rate function, discussed in paragraph 4.03, was reduced to account for the antecedent rainfall.

4.03 Determination of Rainfall-Runoff Relationships.

General. Regional unit hydrograph and loss rate studies for the general Phoenix region are described in detail in the Part 1 hydrology report, (ref. 2). Twenty-two observed floods were reconstituted during these studies to derive relationships between rainfall and runoff applicable to most subbasins in the study area. Adopted rainfall-runoff relationships are discussed briefly below.

S-Graph Unit Hydrograph. A unit hydrograph is the runoff hydrograph that results from one inch of rainfall excess occurring uniformly over a watershed in specified period of time. The Los Angeles District's normal unit hydrograph procedure utilizes the S-graph, which is a summation graph of discharge in percent of ultimate discharge versus time in percent of lag time. Lag time is defined as the time required for 50 percent of the total volume (ultimate discharge) of the unit hydrograph to occur. The basin lag time for ungaged watersheds can be approximated by the use of the lag relationship presented on plate 10. The basin n-value is a variable in the lag equation that permits adjustment of the lag time depending on the type of ground cover and other characteristics for the subareas shown on plate 1 are given in table 2.

S-graph. The Phoenix Valley and the Phoenix Mountain S-graphs shown on plates 11 and 12, respectively, were used to describe the time distribution of runoff for most basins in the study area. The Phoenix Valley S-graph was derived from reconstitutions at New River at Bell Road, Skunk Creek at Phoenix, Cave Creek near Phoenix, Aqua Fria Tributary at Youngtown, and Queen Creek Tributary at Apache Junction. Similarly, the Phoenix Mountain S-Graph was derived from the New River near Rock Springs and New River at New River reconstitutions.

Basin n-Value. Basin n-values derived from the reconstituted unit hydrographs were used as a guide in establishing the following SPF basin n-values. Adjustments, based on judgement, were made to include the influence of basin characteristics that affect the lag time of the watershed.

For the highly urbanized valley area south of Arizona Canal and west of Old Cross Cut Canal, the terrain is flat and a majority of the rainfall does not concentrate. There is no storm drain system, so a majority of the flow is in streets and alleys. An appropriate method to model this overland flow across a frontal concentration point is the sheet flow unit hydrograph method described in reference 3. However, because of the complexity and many alternatives in this study, an SPF basin "n" of 0.15 which creates similar results to this method was determined and used with the Phoenix-Valley S-Graph to simplify computations.

Type of area	n-value
Mountain	0.040 to 0.045
Foothill	0.035
Valley	0.030
Highly urbanized valley	0.15

Rainfall Loss Rate Function. The variables in the H.E.C. loss rate function, which were used in this study and are shown graphically on plate 13, are: DLTKR--initial accumulated loss during which loss rate coefficient is increased; STRKR-- starting value of loss coefficient on exponential loss curve; RTIOL--ratio of loss coefficient on exponential loss curve to that corresponding to 10 inches more of accumulated loss; ERAIN-- exponent of precipitation in loss rate equation. Values for these variables to be used with both the local and the general standard project storms were taken from the Part 1 hydrology report and are reproduced on plate 14.

Baseflow and Snowmelt. Baseflow is considered negligible for this study area because runoff occurs only as a direct response to relatively high intensity rainfall. Snowmelt is not a significant contributing factor to runoff.

4.04 Flood Routing.

General. Reservoir routing was performed using the Modified Puls routing procedure. Channel routing was accomplished by the Muskingum method.

Muskingum Routing. The Muskingum coefficient, K, which can be approximated by the flood wave travel time in a reach, was determined by dividing reach length by average peak flow velocity. For channel routing (Arizona and Old Cross Cut Canals), a velocity of 2 and 4 feet per second (ft/s) respectively was determined by backwater computations for Arizona Canal, and normal depth computations for Old Cross Cut Canal. For overland routing of Arizona Canal breakouts through the swale east of Old Cross Cut (breaks from CP's 501 and 502 routed to CP401), an average velocity of 3 ft/s was used for the SPF as determined by backwater computations. For overland flow routing through the area west of the Old Cross Cut Canal and south of the Arizona Canal, a rating curve of average flow velocity versus discharge per unit cross section width were computed during hydraulic studies. The average flow velocity was weighted according to the proportion of the total discharge conveyed within the street right-of-way to the discharge conveyed beyond it. Averaged velocities were computed for SPF and 100-year floods, and ranged from 1.1 to 5.0 ft/s. The number of reaches between concentration points was determined by dividing the travel time between concentration points by the hydrograph computation time interval. Muskingum X values, which range from 0 to 0.5, were based on judgement. For improved channels, X values of 0.3 to

0.4 were used, depending on the type of improvement. For natural channels, X values used ranged from 0 to 0.3 depending on the amount of overbank flow encountered. Muskingum coefficients used in this study are given in tables 3 and 4. It should be noted that the computed peak discharges were often quite sensitive to changes in routing velocity, especially on the Old Cross Cut Canal. A schematic flow diagram is shown on plate 15 for without project routings, and on plates 16-19 for with project alternatives.

Modified Puls. The Modified Puls routing procedure was used in the Arizona Canal for breakout routing. Seven breakout locations were determined and are shown on plate 15. Elevation-storage relationships for each break were developed from September 1966, 2-foot contour maps provided by the Maricopa County Flood Control District and field inspection. The elevation-storage and elevation-spillway discharge relationships tabulated in table 5 were taken from HEC-2 runs used in hydraulic studies.

4.05 Generation of SPF Hydrograph in Highly Urbanized Areas. Section 4.03, Basin n-Value, discussed the characteristics of the highly urbanized valley area which is south of the Arizona Canal and west of the Old Cross Cut Canal. The total flood hydrograph below the Arizona Canal is comprised of the Arizona Canal breakout flow and of local runoff generated by subareas below the canal. Since flows do not concentrate, but travel mainly through very flat streets, the approach used to compute the peak discharges varied from the above paragraphs as described in the following paragraphs.

Breakout locations shown on plate 15, and hydrographs were calculated and routed to each concentration point or frontal flow line as described in section 4.04. They were then combined with the local runoff flood hydrographs.

To determine the local flow for locations below the Arizona Canal, four SPF hydrographs were computed at the Grand Canal (CP 207, 206, 205, and 204) using the unit hydrograph procedure for drainage areas between the Arizona Canal and the Grand Canal defined by combined areas (407+307+207), (406+306+206), (305+205), and (204). Next these hydrographs were ratioed proportionally by drainage area size and the slope of the peak discharge enveloping curve (plate 20) to obtain hydrographs at each upstream frontal flow line. The lag time of the hydrographs at each upstream frontal flow line was judged to be a portion of the total lag time determined by the ratio of the length of each subarea flow path to the total flow path length. The general shape of the ratioed local flood hydrograph obtained in this manner was the same as the overall computed hydrograph.

Next, the breakout flood hydrographs were routed and combined with the computed local flood hydrographs to obtain the total peak discharge at each frontal flow line (407, 406, 305). This procedure was repeated for each successive reach to the Grand Canal (307, 306, 205, and then 207, and 206).

The flow at CP 205, presented on table 1, was generated by assuming that breakouts from CP's 401B and 302B remain within the subarea contributing to CP 205 (plate 1). These two breaks actually disperse into the adjacent subareas as well as contributing to CP 205. This dispersing effect was accounted for in determining overflow depths during hydraulic studies.

4.06 Standard Project Flood Results.

Standard project flood results, computed as described above, were determined for present conditions without alternative plans. SPF peak discharges without project are presented in table 1. Future condition results

were approximately the same as present. The standard project local storm (August 1954 Queen Creek) produced the maximum peak runoff rate at all project sites (ref. 2).

5. DISCHARGE FREQUENCY ANALYSIS FOR URBANIZED AREAS

5.01 General.

Urbanization of a watershed can significantly alter the runoff characteristics and hence the discharge frequency relationship of a basin. As urbanization takes place, natural ground and soil are replaced with impervious materials in the form of roads, roof tops, sidewalks and parking lots. The result is that incident rainfall, which originally infiltrated into the natural ground cover, now runs off with little or no rainfall loss. Not only does more volume run off than under natural conditions, but the basin response to rainfall is generally faster because of storm drain systems and the increased hydraulic efficiency of paved surfaces. The net result of urbanization in terms of discharge frequency analysis is the generation of more runoff from the same series of storm events over what would be observed on an identical rural watershed. This phenomena produces a more positively skewed discharge frequency curve.

5.02 Results.

Since this study area is bounded by two other projects, Phoenix Arizona Vicinity and Indian Bend Wash, the same discharge frequency relationships used in them was adopted for this study. As stated in refernece 2, the graphical method was best suited for the Phoenix area. For this reason no expected probability adjustment was performed.

Recorded and historical floodflows were plotted during Phase 2 of the Phoenix studies for stream gages based on the median plotting positions in Beard's "Statistical Methods in Hydrology." Four long record stream gages (San Carlos River near Peridot, Gila River near Solomon, Salt River near Roosevelt, and Hassayampa River at Box Damsite) were compared for record consistency in order to estimate SPF exceedence frequency in the Phoenix Arizona and Vicinity Study. Resulting SPF exceedence percentages varied as follows: San Carlos and Hassayampa--0.2 to 0.5 percent, Solomon--0.3 percent. SPF for Roosevelt is not available. Variations were dependent on graphical or analytical curve fitting of the data. All stations show consistency through similar standard deviations. This analysis indicated that an SPF exceedence frequency of 0.2 to 0.5 percent is reasonable for areas in this study (ref. 2).

Two stream gages located in southern Arizona on catchments with significant percentages of impervious cover were used to determine the adopted n-year to SPF frequency ratios in the Part 1 hydrology report. The gages were Agua Fria Tributary at Youngtown (USGS Gage No. 9-5137) and Tucson Arroyo at Vine Avenue (USGS No. 9-4830). The discharge frequency curve for the Youngtown stream gage (plate 21) is representative of a valley watershed in Phoenix with approxi-mately 40 percent impervious cover. The data collected was from 1962 to 1968, a total of 7 points. The gage was discontinued after this. The discharge frequency curve for the Tucson stream gage (plate 22) is indicative of a more highly urbanized watershed, (60 percent impervious cover); however, the normal annual precipitation in and around Tucson is higher than the Phoenix area. The average of the ratios of the n-year flood to standard project flood for these two watersheds was used for determining discharge

frequency curves for urbanized basins in the Phoenix region (ref. 2). Since the Part 1 hydrology report, several years of data have become available for the Tucson gage. During this study, the same gage was plotted using a continuous record from 1944 to 1981 of 38 events. No data is available beyond 1981. Plate 23 presents these points superimposed on the Part 1 hydrology Tucson frequency curve. The plotted points fit the earlier frequency curve sufficiently, so no revisions were made to the frequency relationships. These relationships are as follows:

n-Year Flood	Percent of SPF for an urbanized watershed
SPF	100
100	45
50	32
40	26
25	21
20	19
10	12

Because routing velocities of breakout flows vary with the quantity of flow, the 100-year discharges were computed by multiplying the SPF hydrographs of each subarea by 45 percent (ref. above table), and routed using the 100-year peak flows to determine new routing velocities. The combined 100-year flows confirmed that the above percentage of SPF table is appropriate for this study area. Therefore, the 50- and 25-year peak discharges were determined by using the n-year to 100-year ratio of the 100-year peak discharge. This results in discharge-frequency values that plot in the same shape as the frequency curves developed from recorded runoff data.

5.03 Risk Analysis.

For any design frequency there is a corresponding risk which represents the likelihood that the design flow will be exceeded at least once in a certain number of years.

This section addresses the risk of the design flood being exceeded in an amount of time called the project life. The project life is defined as the number of years a project will last, and was assumed to be 100 years in each alternative. The risk of any one alternative being exceeded was determined by using the binomial equation, Risk = $1 - (1 - p)^n$, where p is the exceedance frequency and n is the project life. The relationships of the design exceedance frequency to risk are as follows:

Exceedance Frequency of Design (years)	Project Life (years)	Risk of being exceeded (percent)
10	100	100.0[1]
25	100	98.4
40	100	92.0
50	100	86.5
100	100	63.4

This information will be useful in determining the proper alternative and level of protection.

[1] Note: This risk is actually rounded from 99.997%.

6. PROJECT ALTERNATIVES

6.01 General.

Seven alternative plans were formulated for further study. Some require little or no construction but offer relatively small protection while those offering greater flood protection are also more expensive to implement. All

alternative plans concentrate on reducing ponding behind or breakouts over the Arizona Canal. They also utilize an improved Old Cross Cut Canal to convey flood waters to the Salt River. Alternatives 1 through 4 involve starting evacuation of the Arizona Canal prior to flood waters reaching it thus enabling the canal to provide flood protection. A sensitivity analysis which consisted of starting the canal evacuation at different times in the storm, was also completed.

6.02 Alternatives.

Alternative 1 requires no structural modifications to the system. It incorporates closing the existing radial gates at Camelback Road and releasing up to 625 ft^3/s into the Arizona Cross Cut and up to 1000 ft^3/s into the Old Cross-Cut Canals. In doing this, the canal flow decreases as floodflows into the canal increase.

Alternative 2 is the same as alternative 1 except that the Old Cross Cut Canal capacity and its gate capacity at the Arizona Canal are increased to 1200 ft^3/s, 1500 ft^3/s, and then 2000 ft^3/s.

Alternative 3 is similar to alternative 2 plus a radial gate at either 48th, 44th, or 40th Street is added to isolate the Arizona Canal between this Street and Camelback Road. Hydraulic studies determined that the most appropriate gate location for this alternative is 44th Street.

Alternative 4 is similar to alternative 3 except with an invert elevation at 48th Street of 5 feet less than exists. This lower invert will taper back to 56th and 40th Street.

Alternative 5 consists of the optimal gate sizes of alternative 3 with the canal bifurcated. The north half is for flood control and the south half is for water supply.

Alternative 6 consists of a collector channel parallel to and north of the Arizona Canal, and similar to the Arizona Canal Diversion Channel (ACDC). This channel collects water between 39th Street and 1700 feet upstream of 64th Street, and brings it to 48th Street, where it is syphoned under the Arizona Canal and released into an improved Old Cross Cut Canal. This alternative was analyzed for the 25-, 50-, and 100-year capacity.

Alternative 7 consists of a storm drain system north of the Arizona Canal which releases flow into the Old Cross Cut Canal expanded to accept the floodflows. The storm drains are located along Lafayette Boulevard and Camelback Road. These flows are collected at Arcadia Drive upstream of the Arizona Canal and then released to the Old Cross Cut Canal through a syphon. This storm drain system was studied for the 25-, 50-, and 100-year frequency floods.

6.03 Method of Analysis and Results.

Alternatives 1 through 4, which consist of varied operations of existing and proposed canal gates, were studied in order to find the most efficient way of evacuating the canal so that floodflows are captured by it instead of spilled over it. Schematics of each alternative are on plates 16-17. Because of the complexity of analyzing this system, a Hydrologic Engineering Center (HEC) program called USTDY was used to model the Arizona Canal. Using unsteady flow, this program modeled gate operations as well as additional side

inflow in order to study the possiblitiy of preventing floods by forecasting them and emptying the Arizona Canal. Two criteria for operating the canal were studied. The first was to begin operating the canal gates when floodwaters reach it, about 1 hour before the peak and 4 hours into the 7-hour Queen Creek storm. The second criteria for operating the canal gates requires flood forecasting from rainfall such that gate operations begin 2 hours prior to the peak runoff, 3 hours into the Queen Creek storm, or at least 1 hour prior to significant flow reaching the Arizona Canal. Plate 24 shows the rainfall-runoff timing for subarea 13 north of the Arizona Canal. Discharges into the Old Cross Cut Canal were used in HEC-1 to determine the Old Cross Cut Canal design capacity for the appropriate level of protection. Alternative 1 provides a 25-year level of protection without damage if the gates are operated by forecasting, as per criteria number 2, and a 20-year frequency if they are operated when flood waters reach the canal, criteria number 1. Alternatives 2, 3, and 4 provide 25, 40, and 100-year levels of protection respectively when the gates are operated by criteria number 1. Design flows are presented in table 6.

Alternatives 5 and 6 have the same hydrologic analysis but different levels of protection as determined through the USTDY program. The modeling program was HEC-1 as in the without project analysis. The flows from the subareas north of Arizona Canal are routed in the proposed canal using the Muskingum method with an X = 0.3. Routing parameters are in table 4, the schematic is on plate 18. Alternative 5 provides 10-year level of protection while alternative 6 provides protection for any frequency depending on its design. The 25, 50, and 100-year frequency discharges for alternative 6 and the 10-year frequency discharges for alternative 5 are presented in table 7.

Alternative 7, the storm drain system, is shown on plate 19. To conform to the level of detail in this study, no routing was performed. Drainage area ratios of subareas 11 through 16 were used to determine the necessary capacity of each length of storm drain. Flow at convergences were directly summed instead of combined as hydrographs. Thus these flows have a more conservative estimate of the necessary capacity of the Old Cross Cut Canal than other alternatives for the same frequency. Design flows are presented in table 8.

N-year peak discharges are presented for each alternative in tables 6, 7 and 8, and 100-year flood hydrographs at CP 401 and 401D for without and with project, respectively, are on plates 25 and 26.

6.04 Flood Forecasting.

General. Flash floods are sudden violent floods caused by heavy rain from which runoff concentrates within minutes. Flash floods can occur in the Phoenix area at any time of the year, but the predominant seasons are summer and early fall. They can occur as the result of isolated thunderstorms, tropical storms, or within general storms.

Local summer thunderstorms causing sudden runoff are common in the Phoenix area. Most intense between July and September, they consist of high-intensity rainfall over relatively small areas for short periods of time. Runoff from local storms is usually characterized by a rapidly rising and receding hydrograph. Runoff from local storms can result in flash floods, sometimes with loss of life and serious local property damage.

Flood Forecasting. Alternatives 1 through 5, discussed previously, require SRP gate operations to utilize the Arizona Canal for flood control. To do this, SRP will need a flood forecasting system which is capable of

communicating with their automated operating system. A flood forecasting system for this project area would consist of weather forecasting for the local area, rainfall gages, Arizona Canal flow gages, transmitters, data receiving equipment, an action plan which uses SRP's remotely controlled operating equipment for the Arizona Canal gates, and public involvement.

Available Resources. SRP has indicated a willingness to incorporate a flood control operation plan which includes gate operations in their canals during flood events. Since SRP is the owner/operator and has both vast experience and automated equipment with which to operate the Arizona and Old Cross Cut Canals, it is necessary to use their agency to monitor the system and activate a flood forecasting plan. At present SRP is revamping their automated gate operating system. Telephone cables are being replaced by radio communications, and a new computer system is being installed. They have no plans to install rain gages, and have no rain gages in the project area. However they will have a radio receiver connected to their computer, both of which will be available for flood forecasting as well as for their normal gate operations.

There is an existing event recording precipitation gage in the project area at the fire station near Thomas Road and 48th Street. The City of Phoenix has been receiving good data from it since 1976. Being located south of the Arizona Canal and west of the Old Cross Cut Canal, it does not represent, but may be indicative of, the rainfall which will affect the Arizona Canal. Furthermore, it is an event recording gage that does not provide information as to whether it is operating properly during dry periods.

The usefulness of this gage for forecasting versus the cost of adding a radio transmitter would have to be carefully weighed if it were to be incorporated into SRP's system.

Proposed Forecasting System. A flood forecasting system must be designed in cooperation with SRP. Two to four dependable continuous reporting gages with radio transmitters would be necessary. Redundancy of the equipment at each gage site would depend on the location and ease of access to the sites. The location of each gage is critical in order to get a good estimate of the flood potential at the Arizona Canal where the most damage is done. One gage should be located near the top of Camelback Mountain, and one should be downstream closer to the Arizona Canal. The two others should be located midway between the Arizona Canal and Camelback Mountain, one toward the western boundary and the other toward the eastern boundary. This will provide a good representation of the flood producing rainfall.

To receive and utilize this data, SRP will have available for flood forecasting, a radio receiver which will directly input data to their computer, and the local National Weather Service to aid in predicting the severity of the storm. A schematic of the system is shown on plate 27. Depending on the alternative chosen, a plan of action would be administrated by SRP using their computer system to operate gates as designated by this plan. Essential to this plan is the effective response time, or the time for rainfall over Camelback to cause runoff at the Arizona Canal. SRP has indicated that the effective response time of this area is less than one half hour. The Corps analyses indicate about 20 minutes for the SPF event (plate 24). Therefore this automated computerized system is absolutely necessary to effectively operate the proposed forecasting system.

7. ADEQUACY OF RESULTS

In order to determine the adequacy of the SPF peak discharge, three locations, CP 207, 206, and 302B, were plotted on the Arizona, New Mexico, South West Utah enveloping curve, plate 20. Each plotted point falls short of the enveloping curve to about the same order of magnitude as observed floods from local summer storms presented on this plate. Because the valley area is particularly flat, the mountain runoff is attenuated quickly at the valley's edge, where flooding occurs, and does not contribute significantly to the plotted peak flows of the valley floor. Mountain runoff is also partially diverted by the Arizona and Old Cross Cut Canals, thus causing less flow per square mile at points similar to CP 302B. The standard project flood results are reasonable as compared with the enveloping curve determined from events in the Arizona, New Mexico, South West Utah area.

8. BIBLIOGRAPHY

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TABLE 1

N-YEAR PEAK DISCHARGES WITHOUT PROJECT (PRESENT CONDITIONS)

CP	Location	Drainage Area (mi^2)	Storm Centering (mi^2)	Future Conditions 100-YR (ft^3/s)	Present Conditions (ft^3/s) SPF	100-YR	50-YR	25-YR
501U	Spur Cir. U/S of A.C.	0.93	3.9	1500	3300	1500	1000	700
501D	Spur Cir. D/S of A.C.	0.93	3.9	0	260	0	0	0
502U	56th St. U/S of A.C.	1.36	3.9	710	1500	680	490	320
502D	56th St. D/S of A.C.	1.36	3.9	360	800	350	230	140
401	Thomas Rd. at O.C.C.	3.09	7.6	2400	4700	2100	1500	980
401U	O.C.C. U/S Thomas Rd	----[1]	7.6	1000	1000	1000	1000	1000
401D	O.C.C. D/S Thomas Rd.	----[1]	7.6	1250	1250	1250	1250	1250
401B	O.C.C. Breakout at Thomas Rd.	3.09	7.6	2100	4500	1900	1300	730
302	McDowell at O.C.C.	.96	11.3	1400	2900	1300	940	620
302D	O.C.C. D/S at McDowell	--[a]	11.3	1450	1450	1450	1450	1450
302B	O.C.C. Breakout at McDowell	4.05	11.3	1200	2700	1100	740	420
203	Above Grand Canal at O.C.C.	1.72	17.2	2200	4400	2000	1400	920
203D	O.C.C. Inflow to Grand Canal	----[1]	17.2	2000	2000	2000	2000	2000
203B	O.C.C. Breakout at Grand Canal	5.77	17.2	1600	3600	1400	850	370
204	Washington & Grand Canal	0.59	17.2	410	900	410	290	190
305	44th St. & Coronado Rd.	3.59	11.3	2400	5700	2200	1600	1000
205	1500ft. west 40th St.	5.12	17.2	2100	5100	1900	1400	890
504U	Heatherbrae U/S of A.C.	0.38	3.9	650	1400	620	440	290
504D	Heatherbrae D/S of A.C.	0.38	3.9	270	750	260	0	0
503U	48th St. U/S of A.C.	1.20	3.9	2100	4400	2000	1400	920
503D	O.C.C. D/S of A.C.	1.58	3.9	1100	1900	1100	1000	680
406	Flower Pl.	2.43	7.6	550	2000	530	230	160
306	38th St. & Yale St.	3.54	11.3	780	2100	780	450	320
206	32nd St & Grand Canal	5.09	17.2	1100	2200	1100	710	460
505U	44th St. U/S of A.C.	0.61	3.9	1100	2300	1000	730	480
505D	44th St. D/S of A.C.	0.61	3.9	540	1700	510	360	320
506U	40th St. U/S of A.C	0.39	3.9	650	1400	620	440	290
506D	40th St. D/S of A.C.	1.00	3.9	210	510	200	120	50
506AD	1000 ft west of 40th St. D/S of A.C.	1.00	3.9	300	650	280	200	140
407	36th St. & Devonshire Ave.	2.15	7.6	1200	3200	1200	850	560
307	30th St. & Mitchel Ave.	3.24	11.3	1300	3100	1300	920	610
207	24th St. & Grand Canal	4.69	17.2	1400	2900	1400	1000	650

1. The first 1000 ft^3/s in the Old Cross Cut Canal are from outside of this study area by the way of the Arizona Canal therefore no drainage area is defined. Flows are channel capacity.

TABLE 2

BASIN CHARACTERISTICS

Subarea	Drainage Area (mi^2)	L (mi)	Lca (mi)	Slope (ft/mi)	Impervious Cover (%)		Basin "n"-Value	
					present	future	present	future
11	0.93	1.63	0.79	380	25	35	.04	.035
12	0.43	1.69	0.85	500	25	35	.04	.035
13	1.20	1.53	0.66	515	25	35	.04	.035
14	0.38	1.49	0.76	500	20	30	.04	.035
15	0.61	1.25	0.61	400	25	35	.04	.035
16	0.39	1.26	0.65	160	25	35	.04	.035
1	1.73	2.12	1.03	66	25	30	.04	.030
2	0.96	1.42	.60	214	25	40	.04	.030
3	1.72	1.99	1.03	196	25	40	.04	.030
204	.59	1.14	.38	~~30~~ 42	30	30	.15	.15
205	1.07	3.05	1.26	24	35	35	.15	.15
206	3.51	4.19	2.0	26	35	35	.15	.15
207	3.69	4.19	2.0	27	35	35	.15	.15
406	0.85							
407	1.15							
305	0.50							
306	1.11							
307	1.09							

TABLE 3

PERTINENT ROUTING DATA[1]
WITHOUT PROJECT

Reach[2]	Dist. (ft)	Muskingum X[3]	SPF Vel (fps)	SPF K[3] (hrs)	SPF NRCHS	100-YR Vel (fps)	100-YR K[3] (Hrs)	100-YR NRCHS
501 R 401	9600	0.0	3.0	0.89	11	0.0	--	--
502 R 401	6560	0.0	3.0	0.61	7	3.0	0.61	7
503 R 401	6000	0.3	4.0	0.42	5	4.0	0.42	5
401 R 302	4200	0.3	4.0	0.30	4	4.0	0.30	4
302 R 203	9000	0.3	4.0	0.63	8	4.0	0.63	8
401B R 305	5500	0.0	5.0	0.31	4	3.6	0.42	5
302B R 305	2000	0.0	4.2	0.13	2	3.1	0.18	2
305 R 205	6000	0.0	5.8	0.29	3	4.0	0.41	5
503B R 406	5600	0.0	4.0	0.39	5	1.8	0.85	10
504 R 406	5620	0.0	4.9	0.32	4	3.2	0.48	6
406 R 306	4800	0.0	2.9	0.46	6	1.1	1.21	15
306 R 206	6000	0.0	2.7	0.62	7	1.4	1.19	14
505 R 407	5960	0.0	4.2	0.40	5	2.1	0.61	7
506 R 407	5700	0.0	4.7	0.34	4	3.3	0.48	6
407 R 307	4800	0.0	3.4	0.39	5	2.1	0.65	8
307 R 207	6000	0.0	3.4	0.50	6	2.2	0.76	9

1. Refer to plate 15 for schematic of routing. No routing was performed for 50 and 25-year frequencies.
2. This symbolizes the reach from subarea "A1" routed through subarea "A2" ("A1" R "A2").
3. Muskingum Coefficients, travel time in hours.

TABLE 4

PERTINENT ROUTING DATA[1]
WITH PROJECT ALTERNATIVES

Reach[2]	Used in Alternative	Length (ft)	velocity (fps)	NRCHS	K[3] (hrs)	X[3]
501 R 502	5,6	3600	10	1	0.10	0.4
502 R 503	5,6	5400	10	2	0.15	0.4
506 R 505	5,6	3600	10	1	0.10	0.4
505 R 504	5,6	2900	10	1	0.08	0.4
504 R 503	5,6	1300	10	1	0.04	0.4
503 R 401	1-7	6060	22	1	0.08	0.4
401 R 302	1-7	4200	20	1	0.06	0.4
302 R 203	1-7	9000	25	1	0.10	0.4

1. Refer to plates 16-19 for schematics of routing.

2. This symbolizes the reach from subarea "A1" routed through subarea "A2" ("A1" R "A2").

3. Muskingum Coefficients, travel time in hours.

TABLE 5.

ELEVATION-STORAGE-OUTFLOW RELATIONSHIPS

CP	Locations	Elevation (ft)	Storage (ac-ft)	Outflow (ft^3/s)	
501	60th Street Break	1270	37	0	
		1272.88	148	0	
		1273.26	175	39	
		1273.49	193	100	
		1273.83	222	220	
		1274.13	249	344	
		1274.48	284	519	
		1274.99	337	803	
		1276.24	482	1655	
502	56th Street Break	---	---	---	
		1254.8	14	0	
		1255.01	19.2	50	
		1255.13	21.6	100	
		1255.14	26.0	151	
		1255.33	30.9	226	
		1255.49	35.3	337	
		1255.60	38.1	449	
		1255.81	43.4	583	
		1256.0	48.5	712	
		1256.73	69.7	1246	
		1257.0	76.8	1472	
		1257.39	88.5	1809	
503	48th Street Break	---	---	---	
		1253.7	34	0	
		1253.93	58.1	40	
		1254.0	69.1	97	
		1254.06	86.8	231	
		1254.12	105.0	420	
		1254.16	120.9	559	
		1254.19	125.2	668	
		1254.28	144.7	887	
		1254.28	144.7	1105	
		1254.47	161.3	1540	
		1254.76	193.1	1540	
		1255.21	235.3	2499	
		1255.68	295.7	3637	
504	47th Street Break	1252.4	12.0	0	
		1252.64	21.0	1	
		1253.13	23.2	39	
		1253.31	25.3	126	
		1253.46	27.1	215	No erosion for the 50,
		1253.63	29.2	334	25 & 10 yr Flood
		1254.02	34.3	640	
		1254.49	41.4	1086	
		1254.80	46.1	1403	

TABLE 5. Continued

CP	Location	Elevation (ft)	Storage (ac-ft)	Outflow (ft^3/s)
505	44th Street Break	1250.9	20	0
		1251.03	22.4	50
		1251.11	22.9	100
		1251.34	24.6	300
		1251.41	48.8	398
		1251.56	52.7	582
		1251.66	55.5	721
		1251.79	59.1	907
		1251.90	62.6	1085
		1252.04	66.3	1336
		1252.39	75.7	2023
		1252.74	84.8	2703
506	40th Street Break	---	---	----
		1250.0	8	0
		1250.19	14.1	50
		1250.30	15.6	100
		1250.30	17.3	148
		1250.31	19.1	247
		1250.34	20.8	338
		1250.41	22.5	415
		1250.50	24.2	492
		1250.60	25.8	570
		1250.70	27.4	647
506A	Spillway West of 40th Street	1248.5	3	0
		1248.84	4.2	50
		1249.01	4.6	163
		1249.86	5.8	252
		1250.17	6.6	341
		1250.51	7.6	450
		1250.79	8.4	550
		1251.06	9.2	650
		1251.36	10.0	750

TABLE 6

N-YEAR PEAK DISCHARGES (FT^3/S)
WITH PROJECT ALTERNATIVES 1-4
(FUTURE CONDITIONS)

CP	Location	Drainage Area (mi^2)	Storm Centering (mi^2)	Alternative[1] 1	1A	2	3	4
	Frequency Criteria[3]			25-Year 2	20-Year 1	25-Year 1	40-Year 1	100-Year 1
501U	Spur Cir. U/S of A.C.	0.93	3.9	720	650	720	890	1500
502U	56th St. U/S of A.C.	0.43	3.9	330	300	330	410	710
503U	48th St. U/S of A.C.	1.20	3.9	980	880	980	1200	2100
504U	Heatherbrae U/S of A.C.	0.38	3.9	300	270	300	380	650
505U	44th St. U/S of A.C.	0.61	3.9	500	450	500	620	1100
506U	40th St. U/S of A.C.	0.39	3.9	300	270	300	370	650
503D	O.C.C. D/S of A.C.	3.94[2]	3.9	840	800	1000	1400	2600
401D	O.C.C. at Thomas Rd.	5.67[2]	5.7	2000	1800	2200	2700	5000
302D	O.C.C. U/S of McDowell	6.63[2]	6.6	2400	2200	2600	3300	6000
203D	O.C.C. at Grand Canal	8.35[2]	8.4	3400	3100	3500	4400	8100
204	Washington & Grand Canal	0.59	17.2	190	170	190	240	410
305	44th St. & Coronado Rd.	0.50	11.3	90	85	90	120	200
205	1500 ft. west of 40th St.	1.07	17.2	180	160	180	220	380
406	Flower Pl.	0.85	7.6	150	140	150	190	320
306	38th St. & Yale St.	1.96	11.3	300	270	300	370	640
206	32nd St. & Grand Canal	3.51	17.2	460	420	460	570	1000
407	36th St. & Devonshire Ave.	1.15	7.6	190	180	190	240	420
307	30th St. & Mitchel Ave.	2.24	11.3	330	300	330	410	710
207	24th St. & Grand Canal	3.69	17.2	490	440	490	610	1100

1. Alternatives are described on pages 27 and 28.

2. Drainage area is dependent on the alternative.

3. Criteria 1 operates canal gates when first flood waters reach the canal.
Criteria 2 operates canal gates as per forecasting, at least 1 hour prior to first flood waters.

TABLE 7

N-YEAR PEAK DISCHARGES (FT^3/S)
WITH PROJECT ALTERNATIVES 5 AND 6
(FUTURE CONDITIONS)

CP	Location	Drainage Area ($mi.^2$)	Storm Centering (mi^2)	Alternative 6 100-YR	Alternative 6 50-YR	Alternative 6 25-YR	Alt. 5 10-YR
501	A.C. at Spur Cir.	0.93	3.9	1500	1100	720	410
502	A.C. at 56th St.	1.36	3.9	2200	1600	1000	580
503	A.C. East of O.C.C.	2.56	3.9	3700	2600	1700	980
506	A.C. at 40th St.	0.39	3.9	650	460	300	170
505	A.C. at 44th St.	1.00	3.9	1600	1100	750	430
504	A.C. at Heatherbrae	1.38	3.9	2200	1600	1000	590
503D	O.C.C. at A.C.	3.94	3.9	5900	4200	2700	1600
401D	O.C.C. at Thomas Rd.	5.67	5.7	8100	5700	3800	2100
302D	O.C.C. U/S of McDowell	6.63	6.6	8800	6200	4100	2300
203D	O.C.C. at Grand Canal	8.35	8.4	10,000	7400	4900	2700
204	Washington & Grand Canal	0.59	17.2	410	290	190	110
305	44th St. & Coronado Rd.	0.50	11.3	200	140	90	50
205	1500 ft. west of 40th St.	1.07	17.2	380	270	180	100
406	Flower Pl.	0.85	7.6	320	230	150	85
306	38th St. & Yale St.	1.96	11.3	640	450	300	170
206	32nd St. & Grand Canal	3.51	17.2	1000	700	460	270
407	36th St. & Devonshire Ave.	1.15	7.6	420	300	190	110
307	30th St. & Mitchel Ave.	2.24	11.3	710	510	330	190
207	24th St. & Grand Canal	3.69	17.2	1000	750	490	280

TABLE 8

N-YEAR PEAK DISCHARGES
WITH PROJECT ALTERNATIVE 7
(FUTURE CONDITIONS)

			50-Year			25-Year			
Pipe No.	CP	Drainage Area mi^2	Flow From U/S Pipes	Inlet Capacity ft^3/s	Pipe Capacity ft^3/s	Flow from U/S Pipes	Inlet Capacity ft^3/s	Pipe Capacity ft^3/s	Pipe Ends Into Pipe no.
1	1	.31		180	180		120	120	
	2	.45		85	270		56	180	
	3	.90		270	540		180	360	9.1
2	4	.18		110	110		73	73	9.1
3	7	.31		190	190		120	120	5
4	8	.37		200	200		130	130	5
5	9	.68	390	---	390	250	---	250	
	10	.81		350	740		230	480	
	11	1.11		260	1000		170	650	
	12	1.16		60	1060		40	690	9.2
6	13	.14		160	160		110	110	
	14	.67		430	590		280	390	
	15	.96		270	860		180	570	
	16	1.84		780	1640		510	1080	9.2
	17	NO ROUTING SO NO CHANGE			1640			1080	
7	19	.25		290	290		190	190	
	20	.36		130	420		90	280	
	21	.59		280	700		180	460	9.3
8	22	.41		240	240		160	160	
	23	.54		160	400		110	270	
	24	.60		70	470		50	320	
	25	.63		40	510		20	340	9.3
9.1	5&16	1.08	650	----	650	430	----	430	9.2
9.2	18	3.00	2700	----	3350	1770	----	2200	9.3
9.3	26	3.85	1210	----	4560	800	----	3000	Old Cross Cut Canal
	401	5.67	----	----	5700	----	----	3800	Old Cross Cut Canal
	302	6.63	----	----	6200	----	----	4100	Old Cross Cut Canal
	203	8.35	----	----	7400	----	----	4900	Old Cross Cut Canal

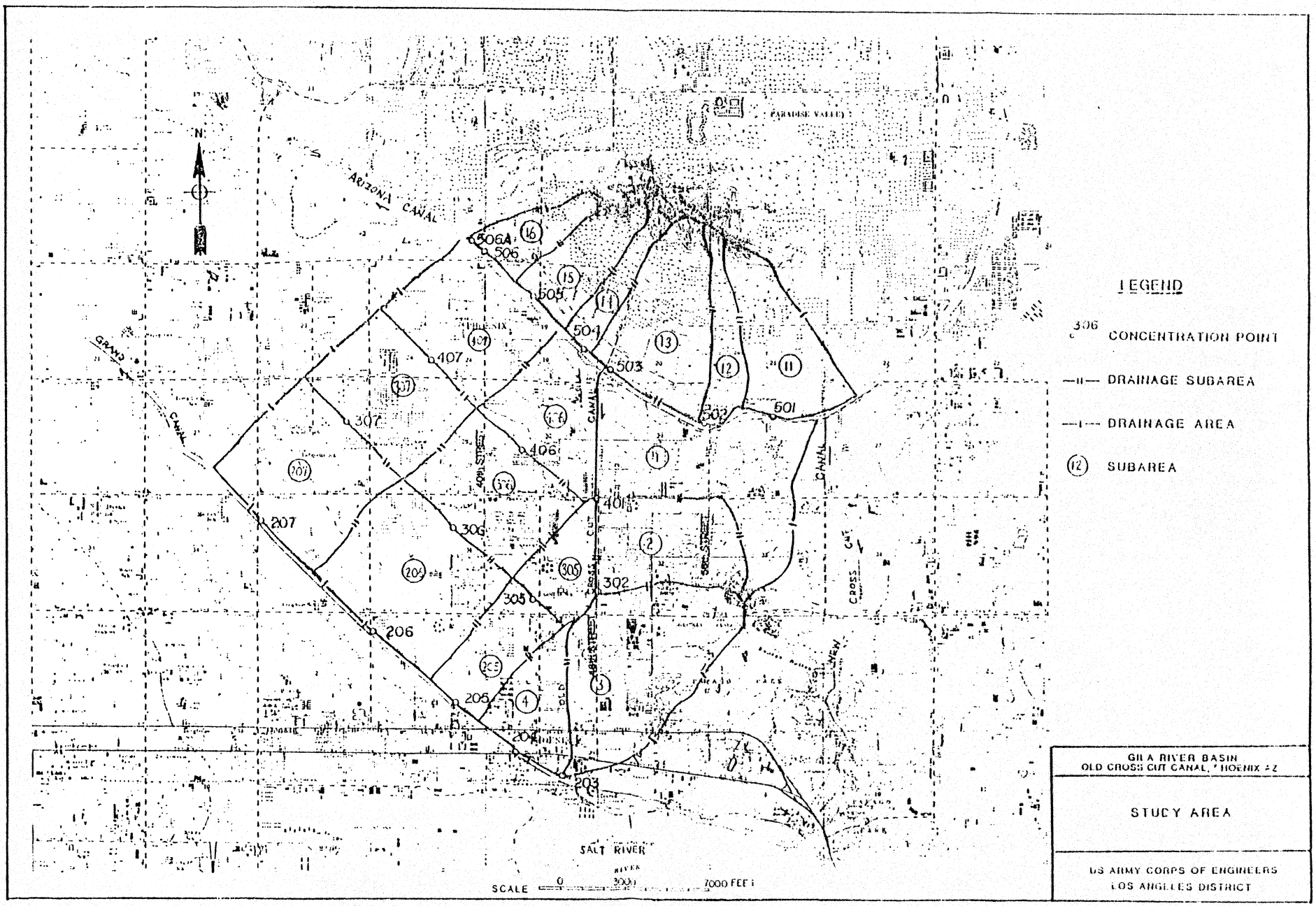
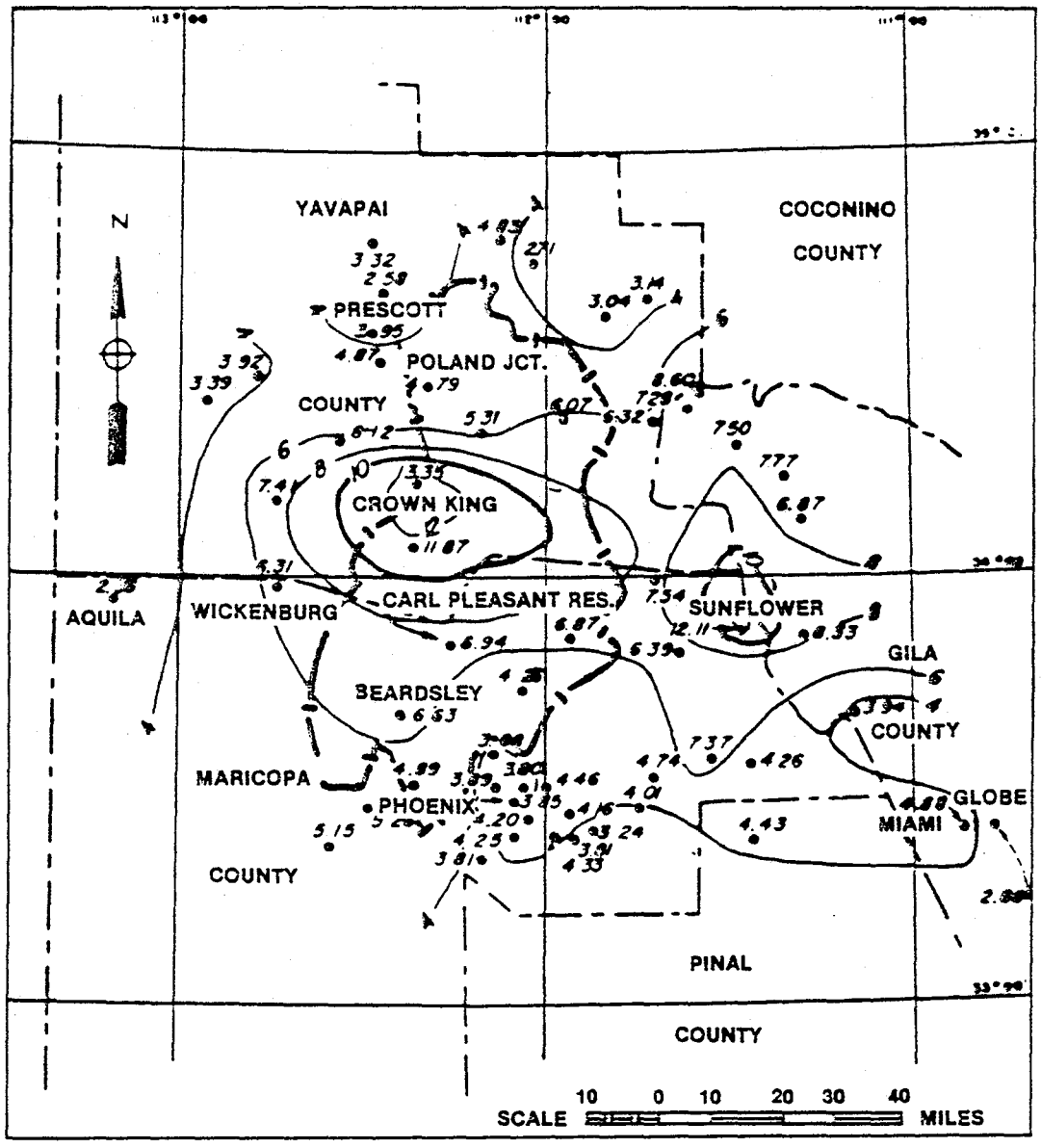

N
ARIZONA CANAL
GRAND CANAL
PARADISE VALLEY
THE SIX
OLD CROSS CUT CANAL
CROSS CUT CANAL
SALT RIVER
RIVER
SCALE 0 3000 7000 FEET
506A
506
505
504
503
502
501
407
406
401
307
306
302
305
207
206
205
204
203
LEGEND
306 CONCENTRATION POINT
DRAINAGE SUBAREA
DRAINAGE AREA
SUBAREA
GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ
STUDY AREA
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 1



LEGEND

— 1 — BOUNDARY OF DRAINAGE AREA

— 8 — LINE OF EQUAL PRECIPITATION IN INCHES

• 6.31 RECORDED PRECIPITATION DEPTH IN INCHES

(SOURCE: REF. 2)

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

ISOHYETAL MAP
STORM OF AUGUST 26-29, 1951

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

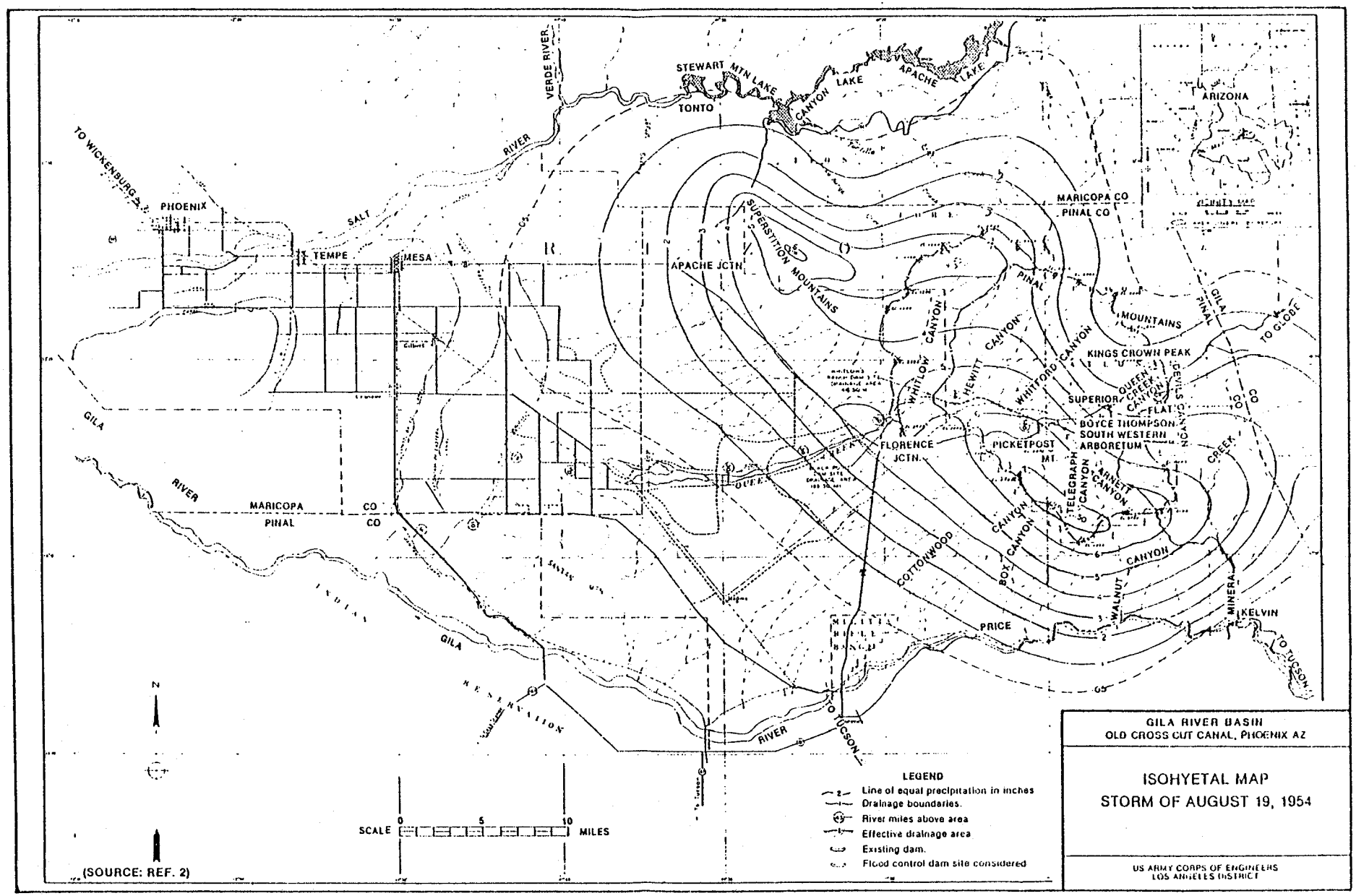
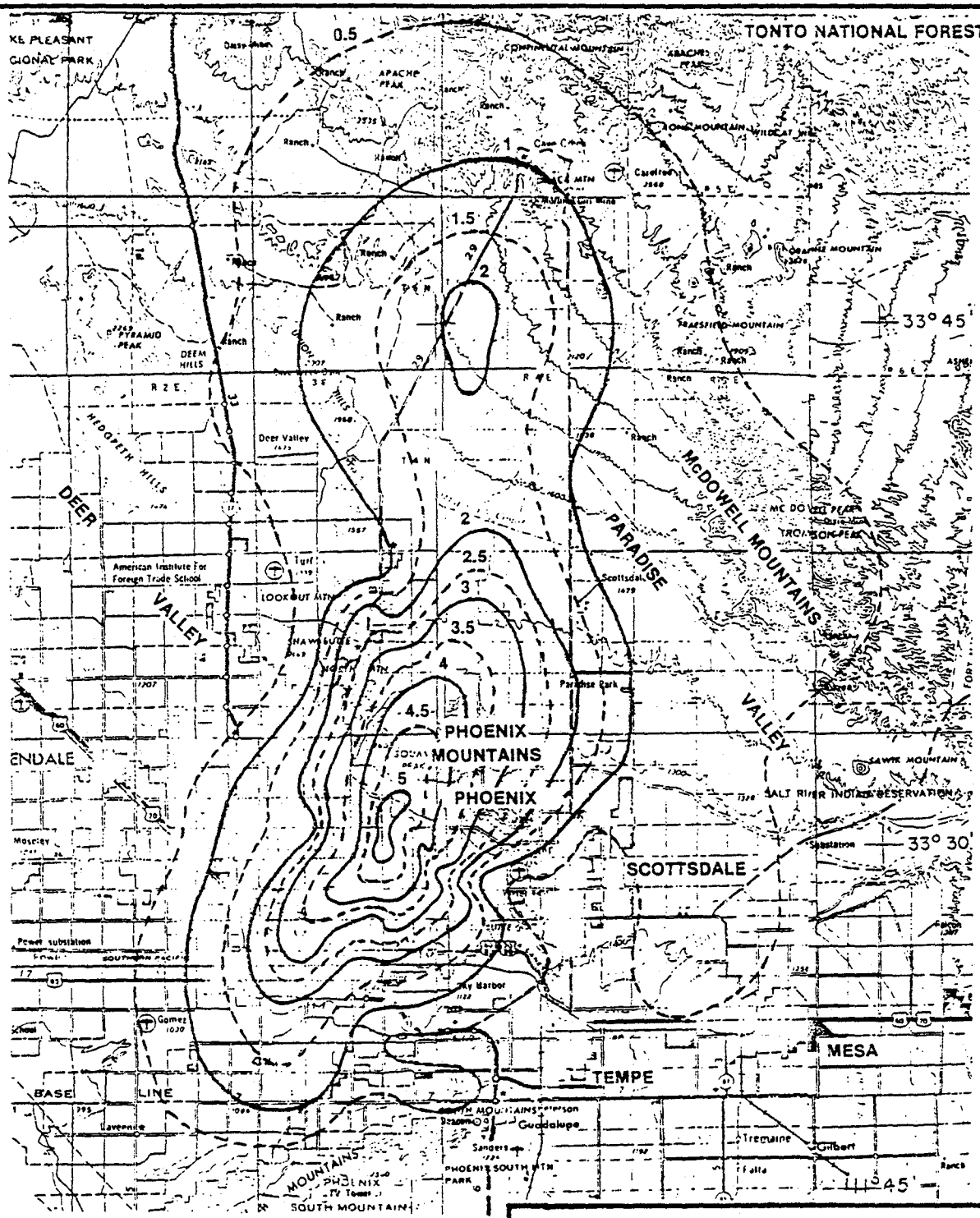

TO WICKENBURG
PHOENIX
TEMPE
MESA
SALT
RIVER
VERDE RIVER
STEWART MTN LAKE
TONTO
CANYON LAKE
APACHE LAKE
ARIZONA
MARICOPA CO
PINAL CO
APACHE JCTN
SUPERSTITION MOUNTAINS
PINAL
MOUNTAINS
GILA
PINAL
CO
TO GLOBE
KINGS CROWN PEAK
WHITLOW CANYON
HEWITT CANYON
WHITFORD CANYON
QUEEN CREEK CANYON
DEVILS CANYON
SUPERIOR
FLAT
BOYCE THOMPSON SOUTH WESTERN ARBORETUM
FLORENCE JCTN.
PICKETPOST MT.
TELEGRAPH CANYON
ARNETT CANYON
CREEK
GILA
RIVER
MARICOPA CO
PINAL CO
QUEEN
COTTONWOOD
BOX CANYON
CANYON
WALNUT
CANYON
MINERA
KELVIN
PRICE
TO TUCSON
INDIAN
GILA
RESERVATION
RIVER
TO TUCSON
N
SCALE 0 5 10 MILES
(SOURCE: REF. 2)
LEGEND
Line of equal precipitation in inches
Drainage boundaries.
River miles above area
Effective drainage area
Existing dam.
Flood control dam site considered
GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ
ISOHYETAL MAP
STORM OF AUGUST 19, 1954
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 3



GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

N

SCALE IN MILES

1 0 4 8

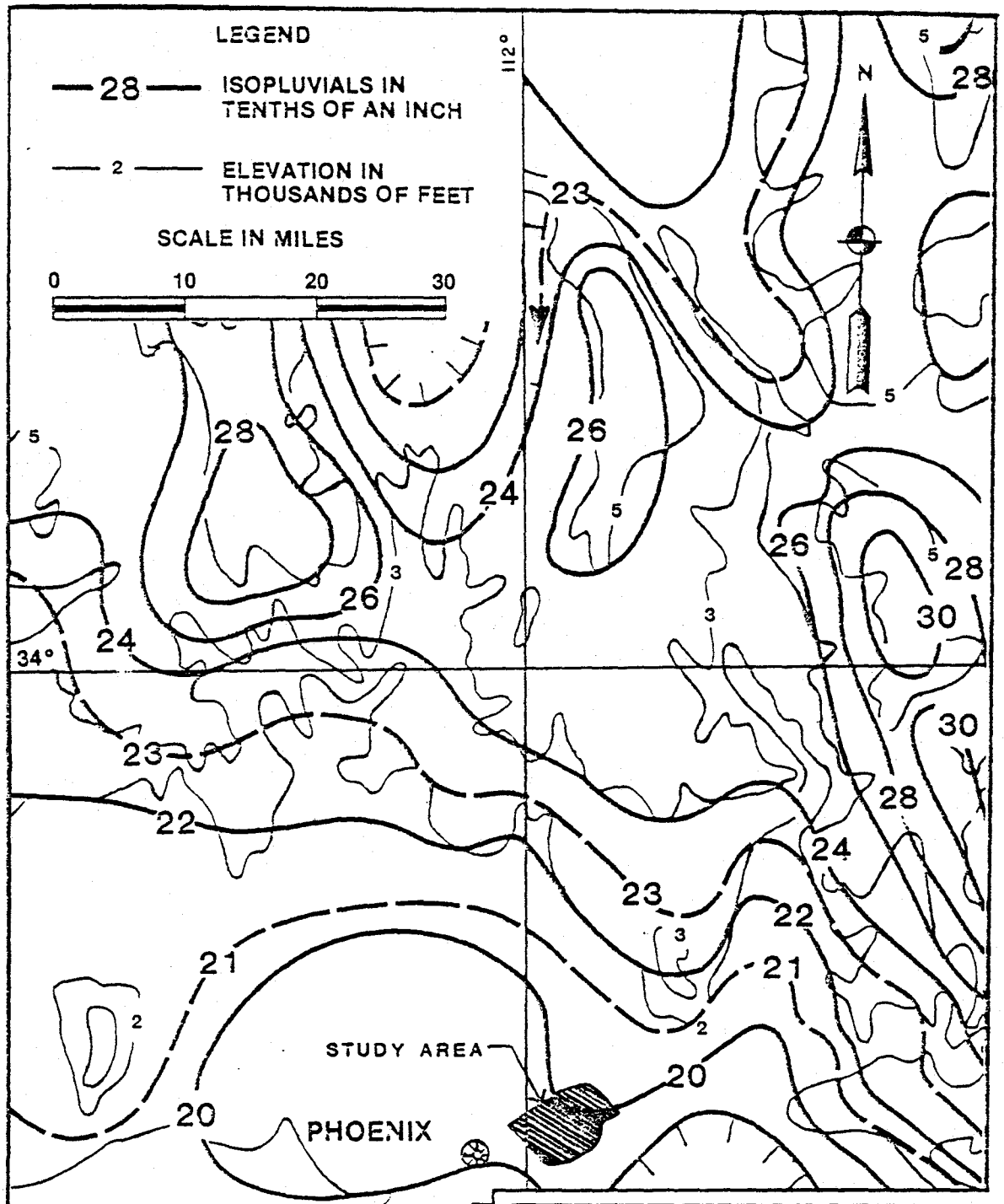
LEGEND

— 2 — LINE OF EQUAL PRECIPITATION IN INCHES

(SOURCE: REF. 2)

ISOHYETAL MAP
STORM OF JUNE 21-22, 1972

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



(SOURCE: REF. 2)

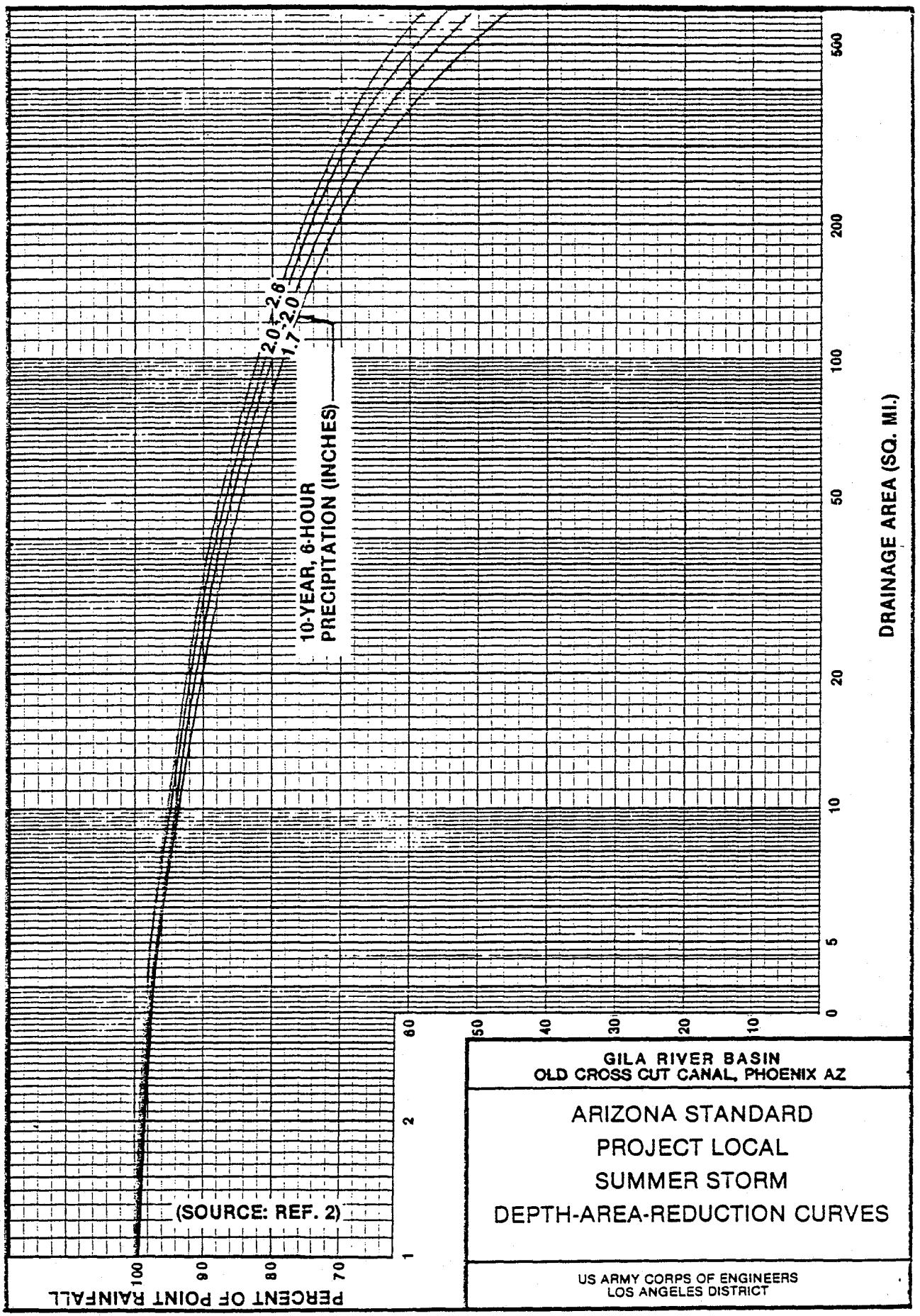
GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

10-YEAR 6-HOUR
PRECIPITATION MAP

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

(revised 2/83)

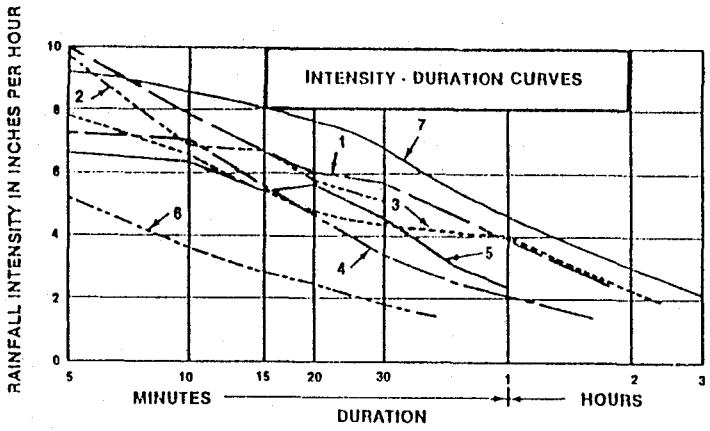
PLATE 5



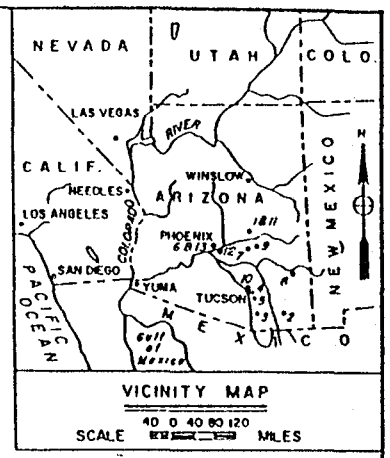
GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

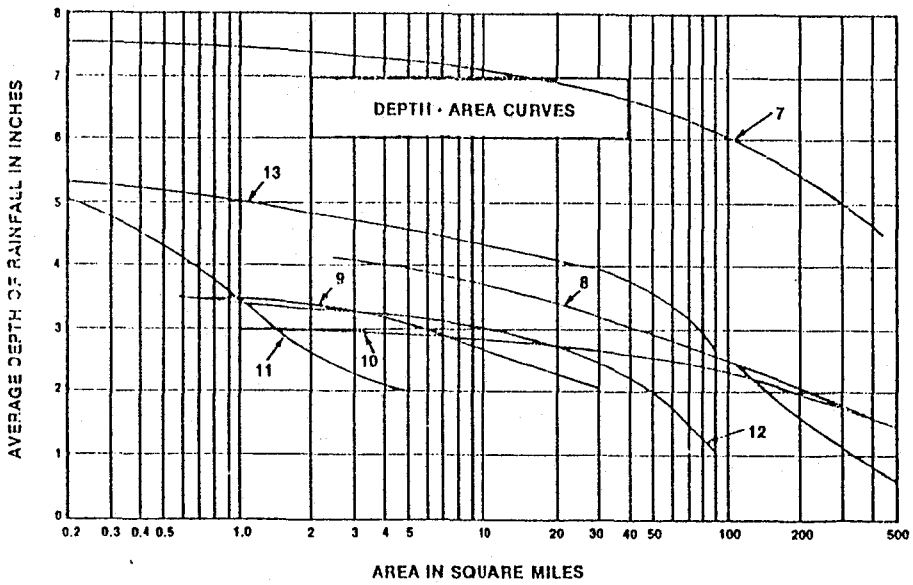
ARIZONA STANDARD
PROJECT LOCAL
SUMMER STORM
DEPTH-AREA-REDUCTION CURVES

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



NOTE:
INTENSITY-DURATION CURVE NO. 7 REPRESENTS APPROXIMATE VALUES AT THE STORM CENTER. THE CURVE IS SYNTHESIZED FROM DATA AT GAGES WITHIN THE STORM, AND IS SUPPLEMENTED BY INTENSITY-DURATION VALUES FROM OTHER SHORT DURATION STORMS IN CENTRAL ARIZONA. DATA FOR OTHER INTENSITY-DURATION CURVES ARE FOR STATIONS WITHIN THE STORM AREA BUT NOT NECESSARILY AT THE STORM CENTER.





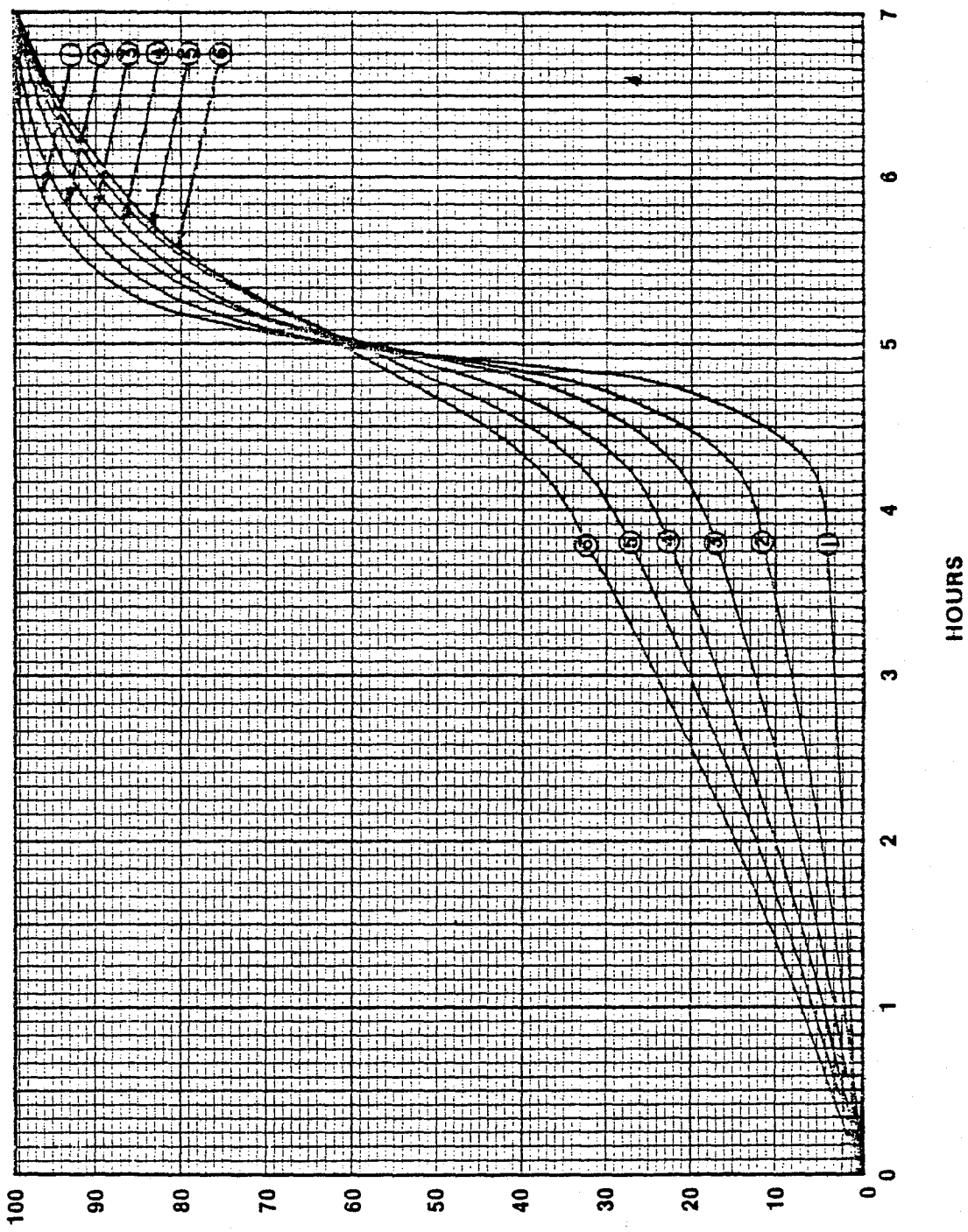
CURVE NO.	STORM			
	LOCATION	DATE	APPROXIMATE DURATION	
			HRS	MIN
1	PARKER CREEK	SEPT. 10, 1933	1	45
2	WALNUT GULCH	OCT. 4-5, 1954	0	30
3	SANTA RITA	JUNE 29, 1959	2	20
4	UNIV. OF ARIZONA	AUG. 13, 1940	1	35
5	TUCSON AIRPORT	SEPT. 24, 1943	1	0
6	PHOENIX	JULY 26, 1936	0	40
7	QUEEN CREEK	AUG. 19, 1954	7	0
8	THATCHER	SEPT. 16, 1939	1	30
9	GLOBE	JULY 29, 1954	1	0
10	TUCSON	SEPT. 24, 1943	3	0
11	PARKER CREEK	AUG. 5, 1939	2	20
12	TEMPE	SEPT. 14, 1969	1	0
13	PHOENIX	JUNE 22, 1972	2	0

(SOURCE: REF. 2)

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

INTENSITY-DURATION AND DEPTH-AREA CURVES

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



—2— PATTERN NUMBER

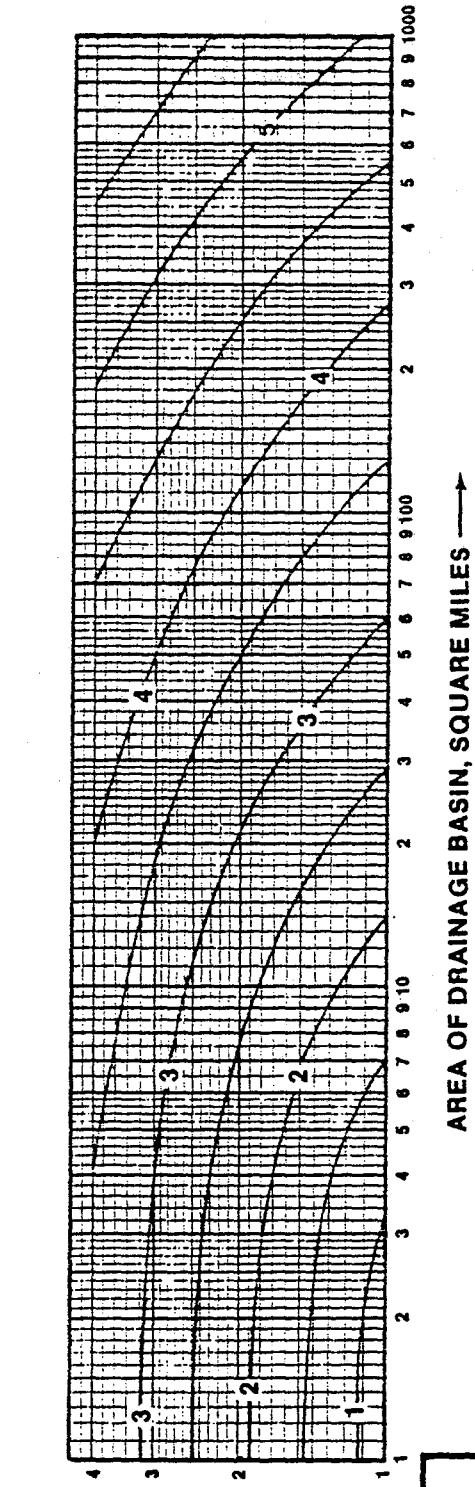
MAKE PATTERN NUMBER SELECTION ON PLATE 20

(SOURCE: REF. 2)

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

ARIZONA
STANDARD PROJECT LOCAL
SUMMER STORM
PRECIPITATION PATTERNS

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



—2— PATTERN NUMBER

REFER TO PLATE 19
FOR ACTUAL PATTERN

(SOURCE: REF. 2)

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

ARIZONA STANDARD PROJECT
LOCAL SUMMER STORM
PRECIPITATION-AREA-PATTERN
CURVES

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

	CONTRIBUTING AREA SQ. MI.	L MILES	L_{CG} MILES	S FT./MI.	LAG HOURS	ESTIMATED $\bar{n}$
1 SAN GABRIEL RIVER AT SAN GABRIEL DAM, CALIF.	162.0	23.2	11.6	350	3.3	0.050
2 WEST FORT SAN GABRIEL RIVER AT COGSWELL DAM, CALIF.	40.4	9.3	4.3	450	1.6	.050
3 SAN ANITA CREEK AT SANTA ANITA DAM, CALIF.	10.8	5.8	2.5	690	1.1	.050
4 SAN DIMAS CREEK AT SAN DIMAS DAM, CALIF.	16.2	8.6	4.8	440	1.5	.050
5. EATON WASH AT EATON WASH DAM, CALIF	9.5	7.3	4.4	600	1.3	.050
6 SAN ANTONIO CREEK NEAR CLAREMONT, CALIF.	16.9	5.9	3.0	1017	1.2	.055
7 SANTA CLARA RIVER NEAR SAUGUS, CALIF.	355.0	36.0	15.8	140	5.6	.050
8 TEMECULA CREEK AT PAUBA CANYON, CALIF.	168.0	26.0	11.3	150	3.7	.050
9 SANTA MARGARITA RIVER NEAR FALLBROOK, CALIF.	645.0	46.0	22.0	105	7.3	.055
10 SANTA MARGARITA RIVER AT YSIDORA, CALIF.	740.0	61.2	34.3	85	9.5	.055
11. LIVE OAK CREEK AT LIVE OAK DAM, CALIF.	2.3	2.9	1.5	700	0.8	.070
12. TUJUNGA CREEK AT BIG TUJUNGA DAM, CALIF.	81.4	15.1	7.3	290	2.5	.050
13 MURRIETA CREEK AT TEMECULA, CALIF.	220.0	27.2	10.3	95	4.0	.050
14 LOS ANGELES RIVER AT SEPULVEDA DAM, CALIF.	152.0	19.0	9.0	145	3.5	.050
15 PACOIMA WASH AT PACOIMA DAM, CALIF.	27.8	15.0	8.0	315	2.4	.050
16 ALHAMBRA WASH ABOVE SHORT STREET, CALIF.	14.0	9.5	4.6	85	0.6	.015
17. BROADWAY DRAIN ABOVE RAYMOND DIKE, CALIF.	2.5	3.4	1.7	100	0.28	.015
18 GILA RIVER AT CONNOR NO. 4 DAM SITE, ARIZ.	2640.0	131.0	71.0	29	21.5	.050
19. SAN FRANCISCO RIVER AT JUNCTION WITH BLUE RIVER, ARIZ.	2000.0	30.0	74.0	32	20.6	.050
20 BLUE RIVER NEAR CLIFTON, ARIZ.	790.0	77.0	37.0	65	10.3	.050
21 SALT RIVER NEAR ROOSEVELT, ARIZ.	4310.0	160.0	66.0	45	18.6	.050
22 NEW RIVER AT ROCK SPRINGS, ARIZ.	67.3	20.2	9.7	141	3.1	.045
23 NEW RIVER AT NEW RIVER, ARIZ.	85.7	23.2	13.6	145	3.7	.045
24 NEW RIVER AT BELL ROAD, ARIZ.	187.0	47.6	20.7	83	5.3	.037
25. SKUNK CREEK NEAR PHOENIX, ARIZ.	64.6	17.6	10.0	89	2.4	.033

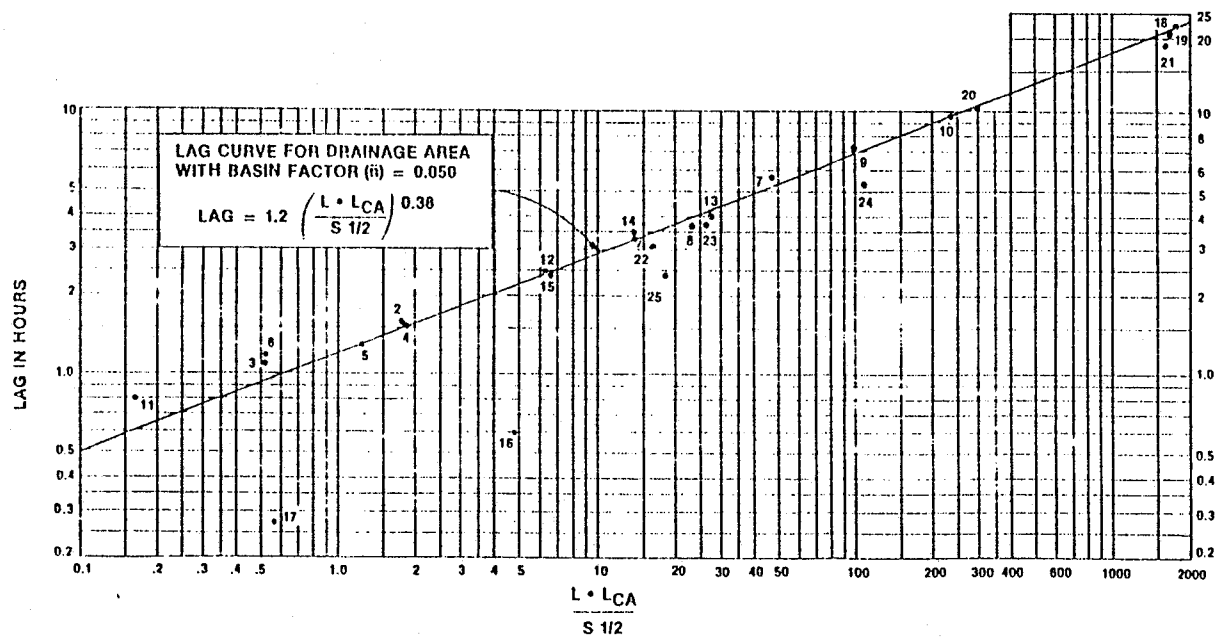
GUIDE FOR ESTIMATING BASIN FACTOR ($\bar{n}$)

$\bar{n}$ = 0.200: DRAINAGE AREA HAS COMPARATIVELY UNIFORM SLOPES AND SURFACE CHARACTERISTICS SUCH THAT CHANNELIZATION DOES NOT OCCUR. GROUND COVER CONSISTS OF CULTIVATED CROPS OR SUBSTANTIAL GROWTHS OF GRASS AND FAIRLY DENSE SMALL SHRUBS, CACTI, OR SIMILAR VEGETATION. NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}$ = 0.050: DRAINAGE AREA IS QUITE RUGGED, WITH SHARP RIDGES AND NARROW, STEEP CANYONS THROUGH WHICH WATERCOURSES MEANDER AROUND SHARP BENDS, OVER LARGE BOULDERS, AND CON- CONSIDERABLE DEBRIS OBSTRUCTION. THE GROUND COVER, EXCLUDING SMALL AREAS OF ROCK OUTCROPS, INCLUDES MANY TREES AND CONSIDERABLE UNDERBRUSH, NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}$ = 0.030: DRAINAGE AREA IS GENERALY ROLLING, WITH ROUNDED RIDGES AND MODERATE SIDE SLOPES. WATERCOURSES MEANDER IN FAIRLY STRAIGHT, UNIMPROVED CHANNELS WITH SOME BOULDERS AND LODGED DEBRIS. GROUND COVER INCLUDES SCATTERED BRUSH AND GRASSES. NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}$ = 0.015: DRAINAGE AREA HAS FAIRLY UNIFORM GENTLE SLOPES WITH MOST WATERCOURSES EITHER IMPROVED OR ALONG PAVED STREETS. GROUND COVER CONSISTS OF SOME GRASSES WITH APPRECIABLE AREAS DEVELOPED TO THE EXTENT THAT A LARGE PERCENTAGE OF THE AREA IS IMPERVIOUS.



(SOURCE: REF. 2)

TERMINOLOGY

L = LENGTH OF LONGEST WATERCOURSE.

L_{CA} = LENGTH ALONG LONGEST WATERCOURSE, MEASURED UPSTREAM TO POINT OPPOSITE CENTER CENTER OF AREA.

S = OVER-ALL SLOPE OF LONGEST WATERCOURSE BETWEEN HEADWATER AND COLLECTION POINT.

LAG = ELAPSED TIME FROM BEGINNING OF UNIT PRECIPITATION TO INSTANT THAT SUMMATION HYDROGRAPH REACHES 50% OF ULTIMATE DISCHARGE.

$\bar{n}$ = VISUALLY ESTIMATED MEAN OF THE n (MANNING'S FORMULA) VALUES OF ALL THE CHANNELS WITHIN AN AREA.

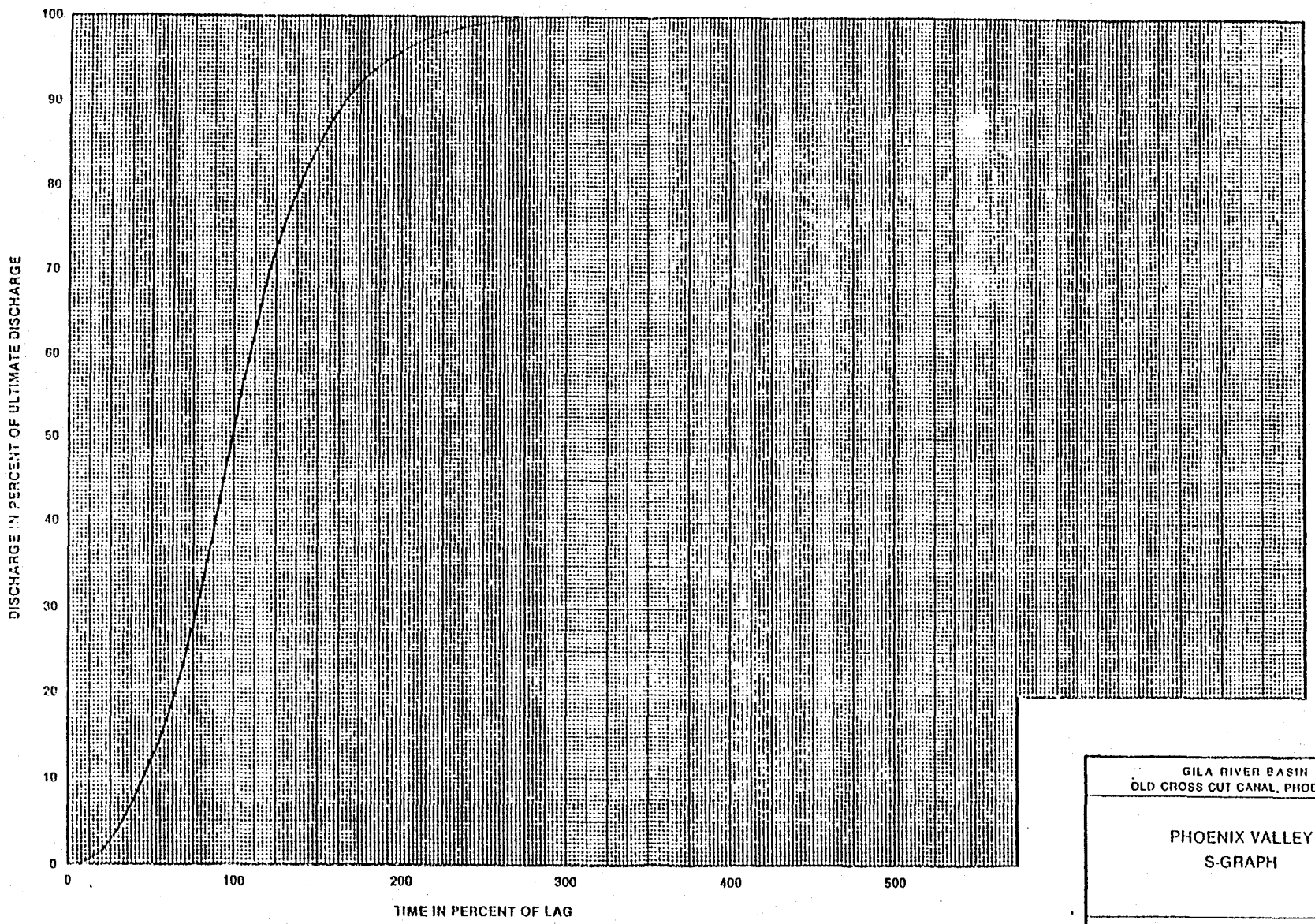
NOTE:
TO OBTAIN THE LAG (IN HOURS) FOR ANY AREA, MULTIPLY THE LAG OBTAINED FROM THE CURVE BY:

$\frac{\bar{n}}{0.050}$ OR $20\bar{n}$

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

LAG RELATIONSHIPS

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

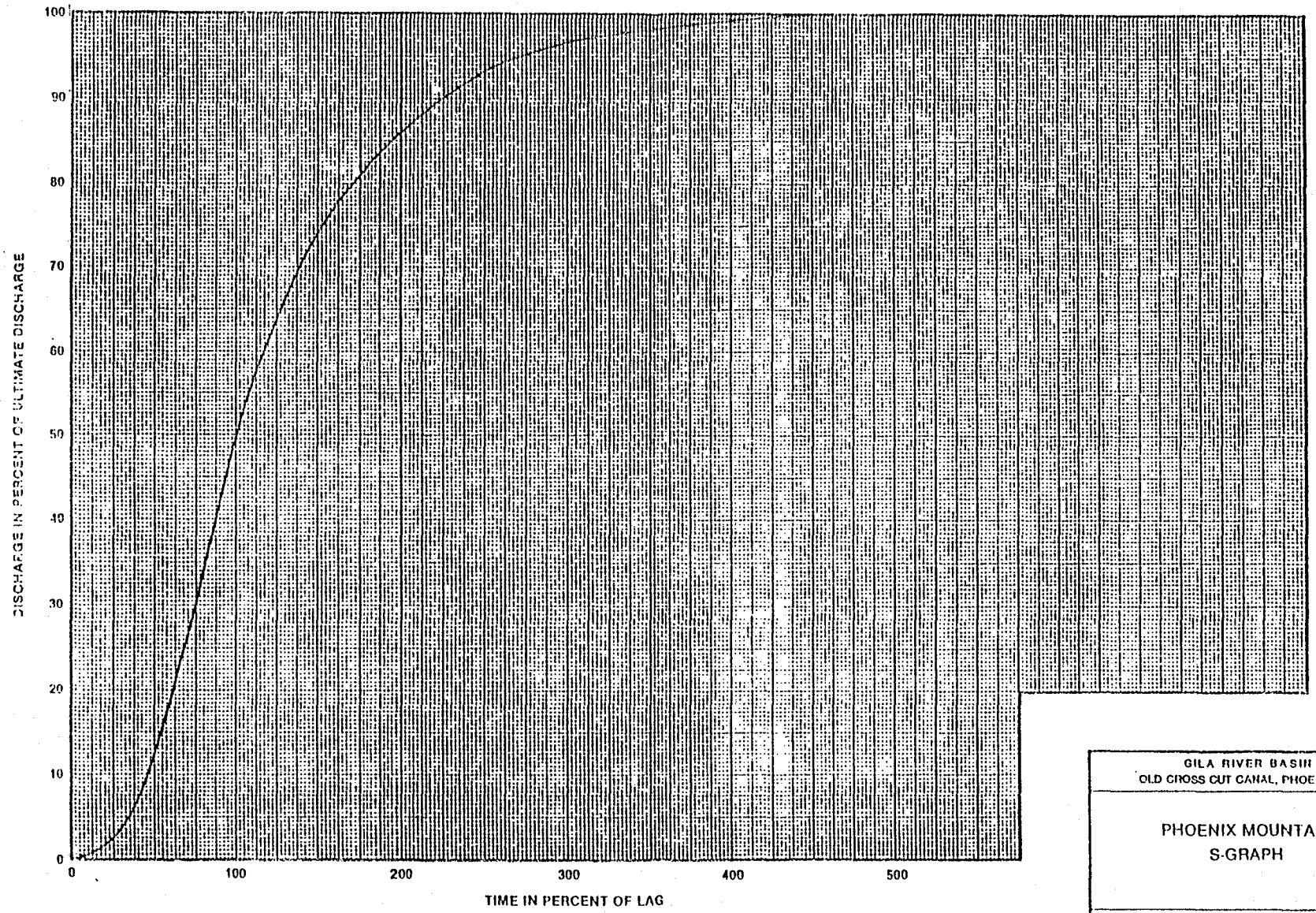


(SOURCE: REF. 2)

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

PHOENIX VALLEY
S-GRAPH

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

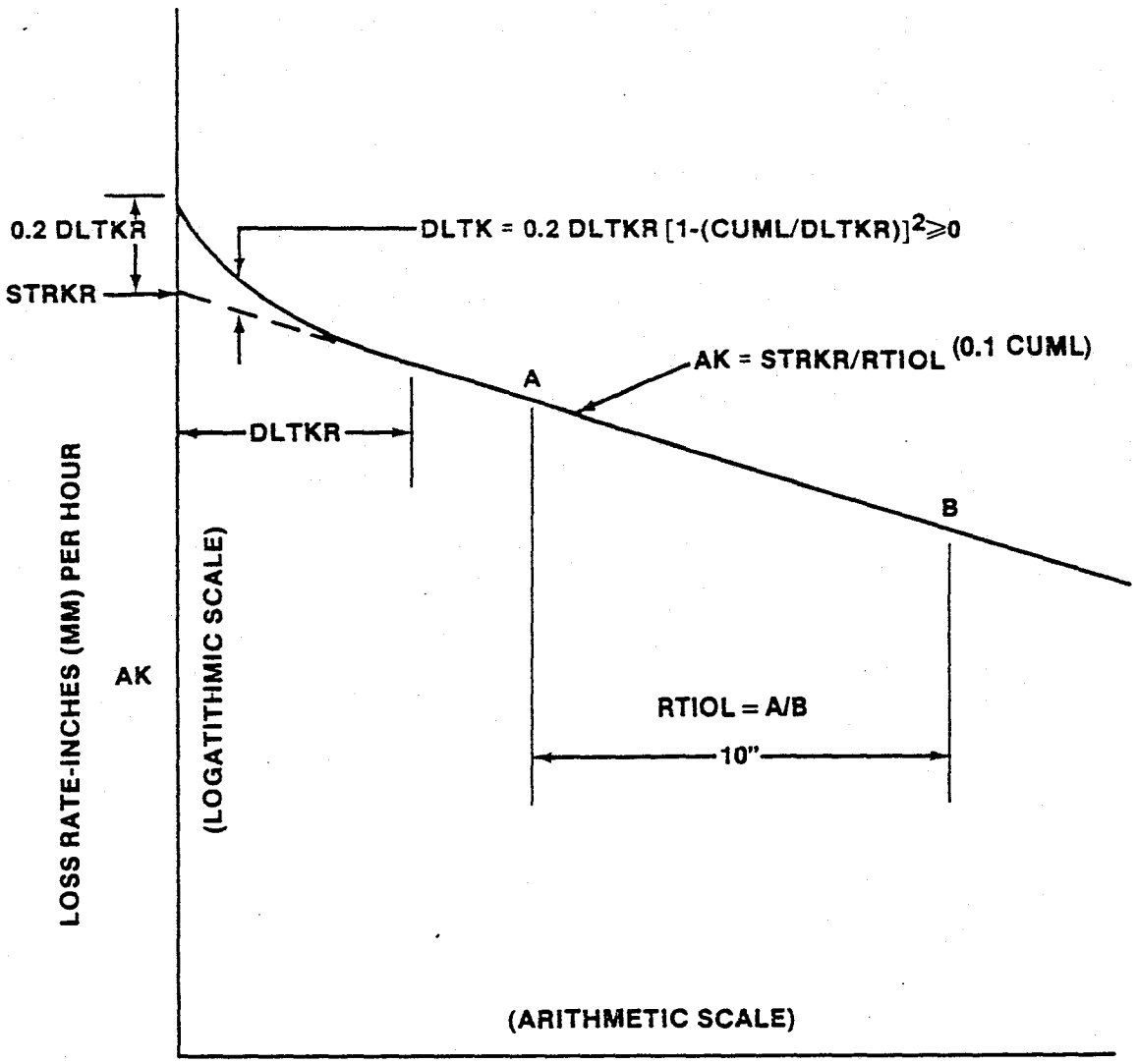


(SOURCE: REF. 2)

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

PHOENIX MOUNTAIN
S-GRAPH

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



ALOSS = (AK + DKTK) PRCP^{ERAIN}

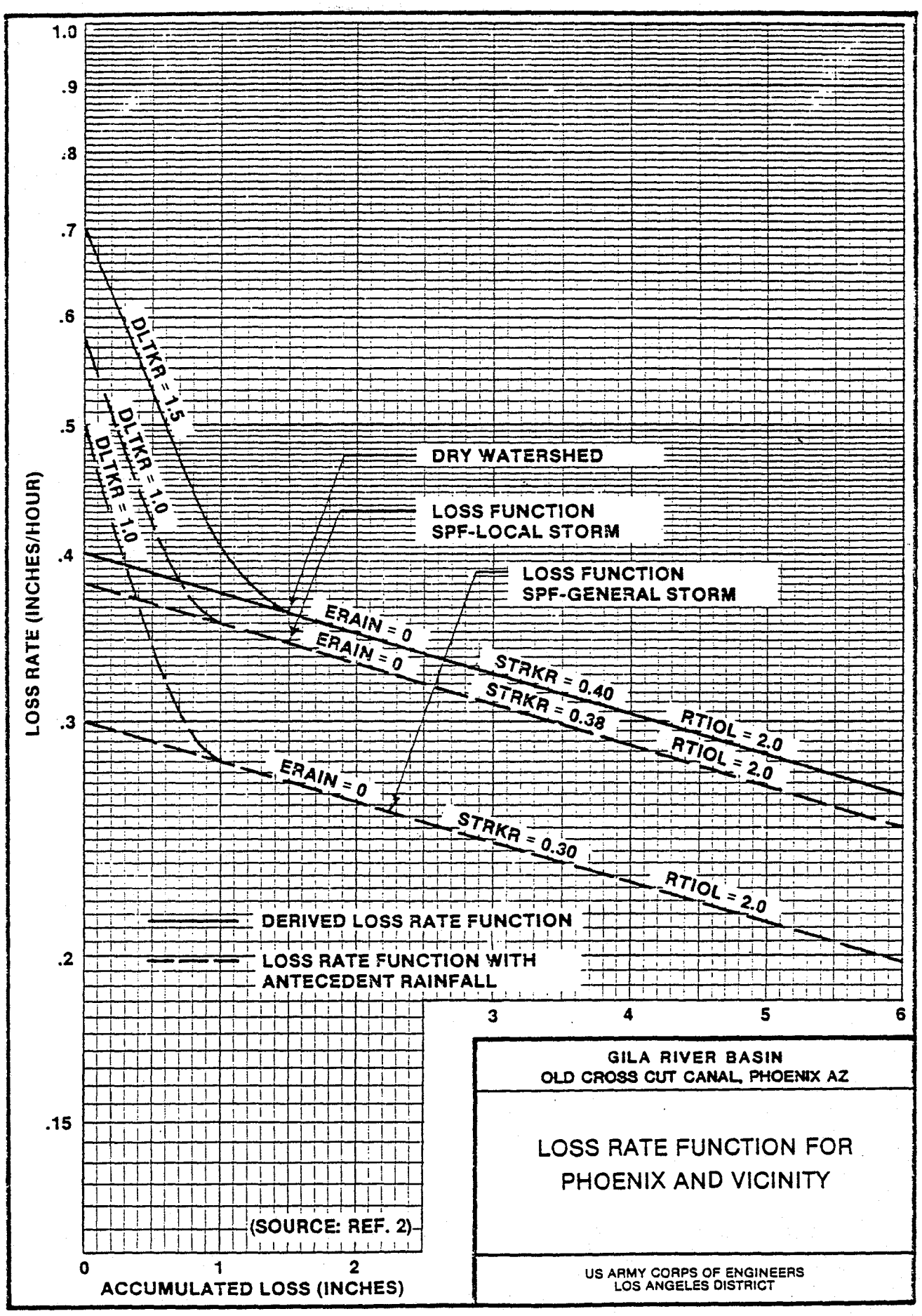
NOTE: VARIABLES ARE DEFINED IN PARA. 4.04 C OF TEXT.

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

H.E.C. LOSS RATE FUNCTION

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

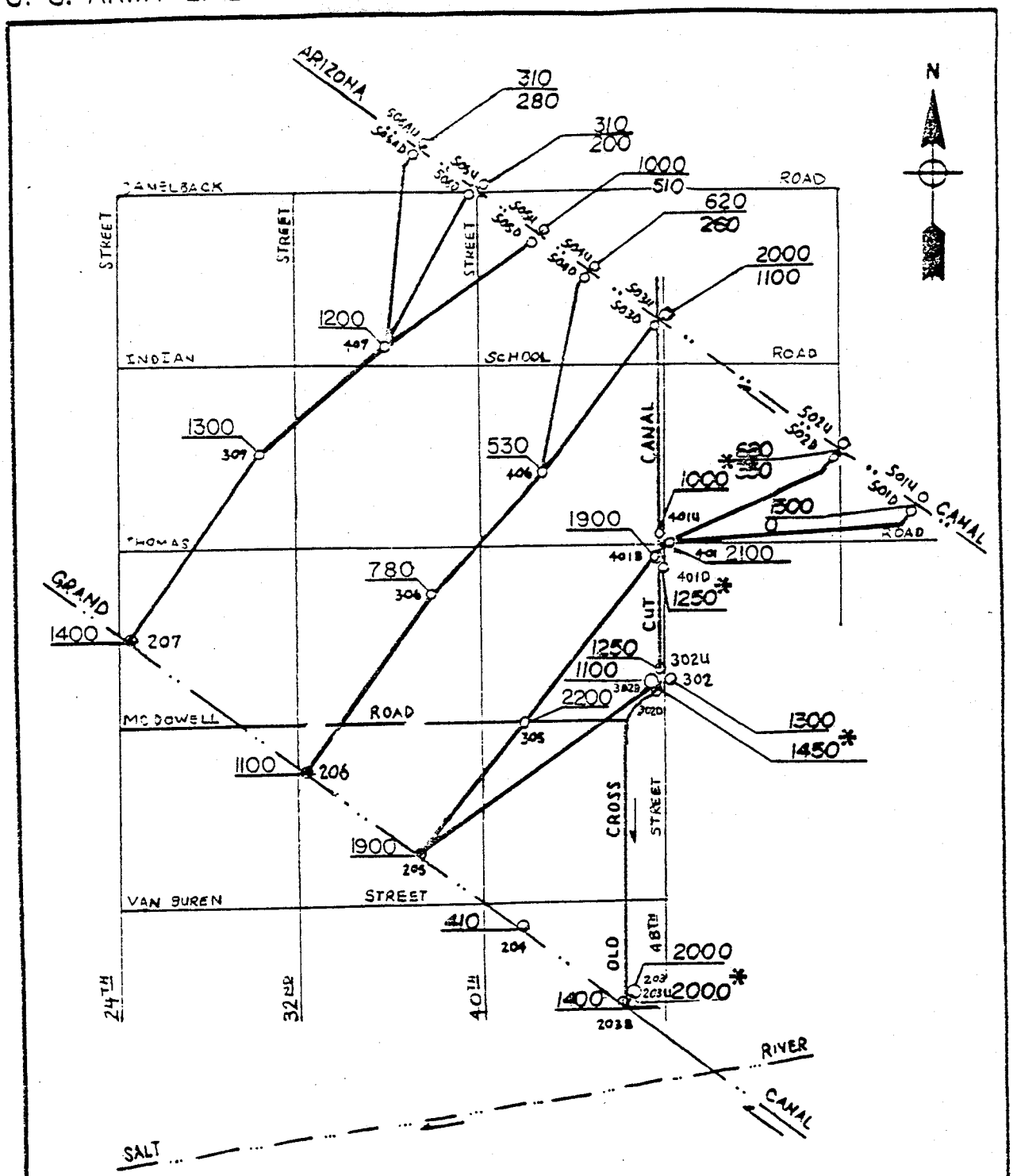
(SOURCE: REF. 2)



GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

LOSS RATE FUNCTION FOR
PHOENIX AND VICINITY

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



LEGEND

810	100 YEAR FLOOD ft^3/s
203 ○	CONCENTRATION POINT
———	STREET
—··—	CANAL
━━━	ROUTING LINE

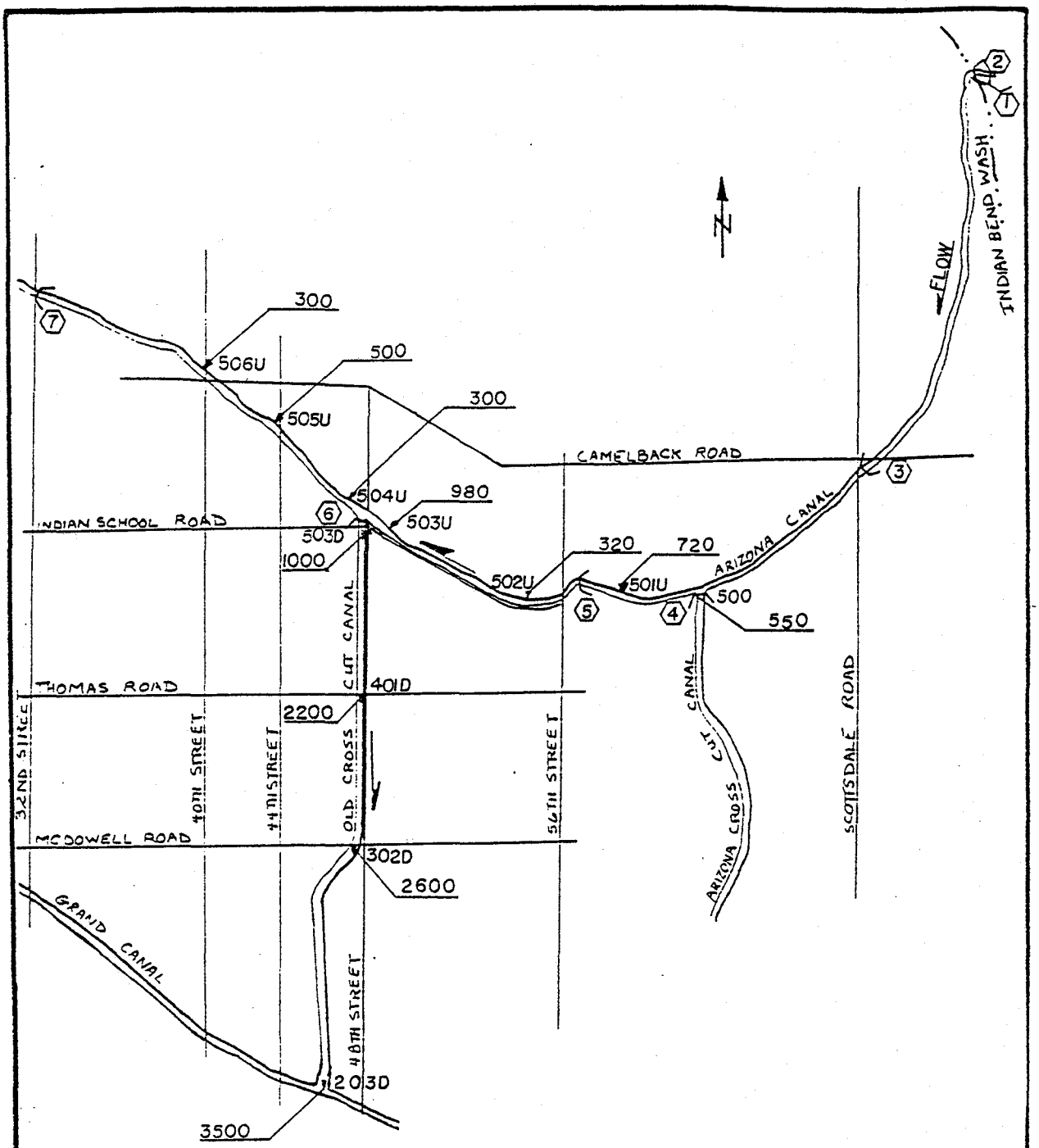
* Old Cross Cut Canal capacity at breakouts.

-- NOT TO SCALE --

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

SCHEMATIC OF EXISTING CONDITIONS

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



LEGEND

300 25 YR, ALT 2, 7HR OPERATION

506U CONCENTRATION POINT

5 CANAL GATE

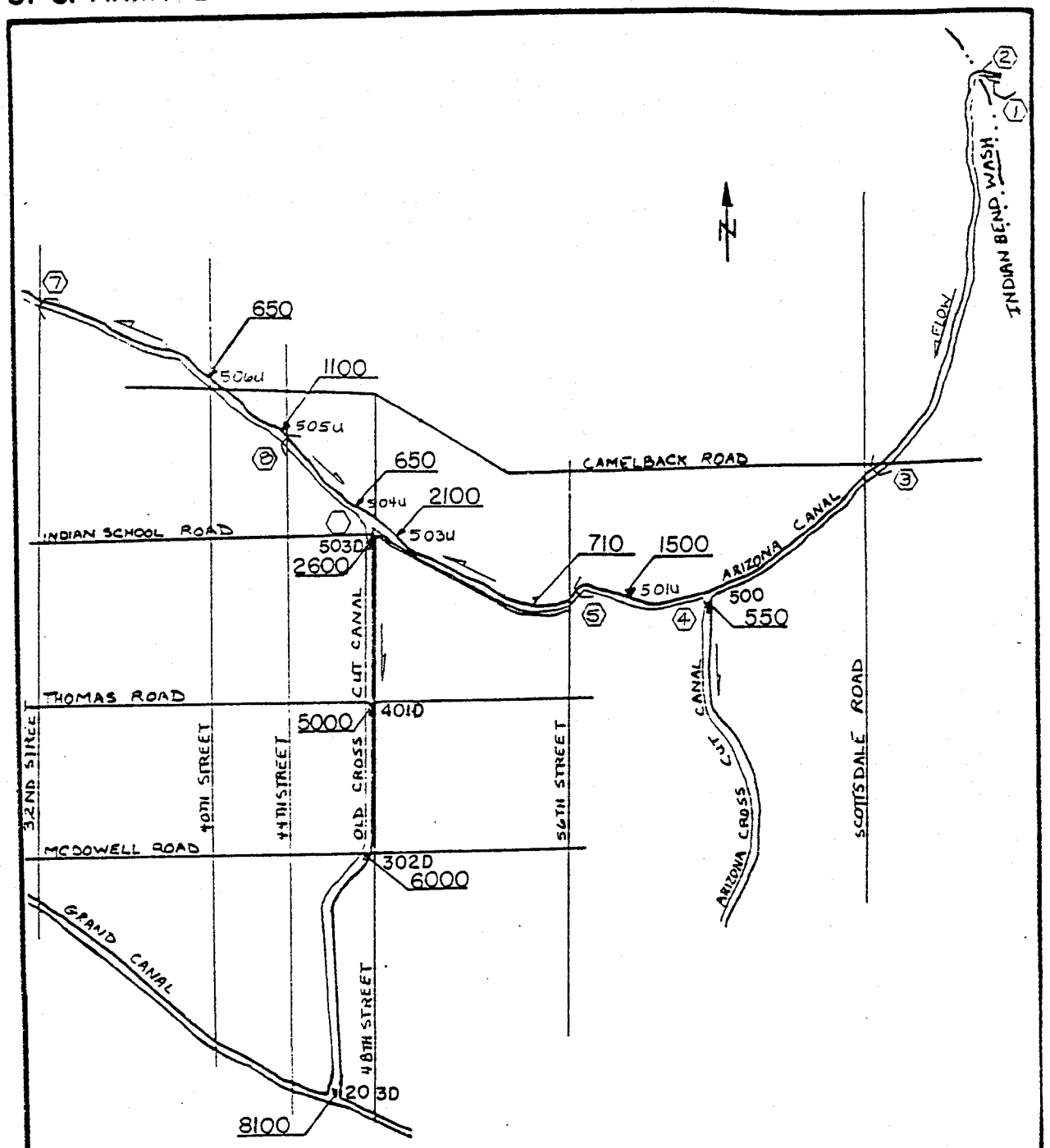
-- NOT TO SCALE --

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

SCHEMATIC OF

ALTERNATIVES 1 AND 2

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:



LEGEND

300
506u
100 YR, ALT 4
CONCENTRATION POINT
CANAL GATE

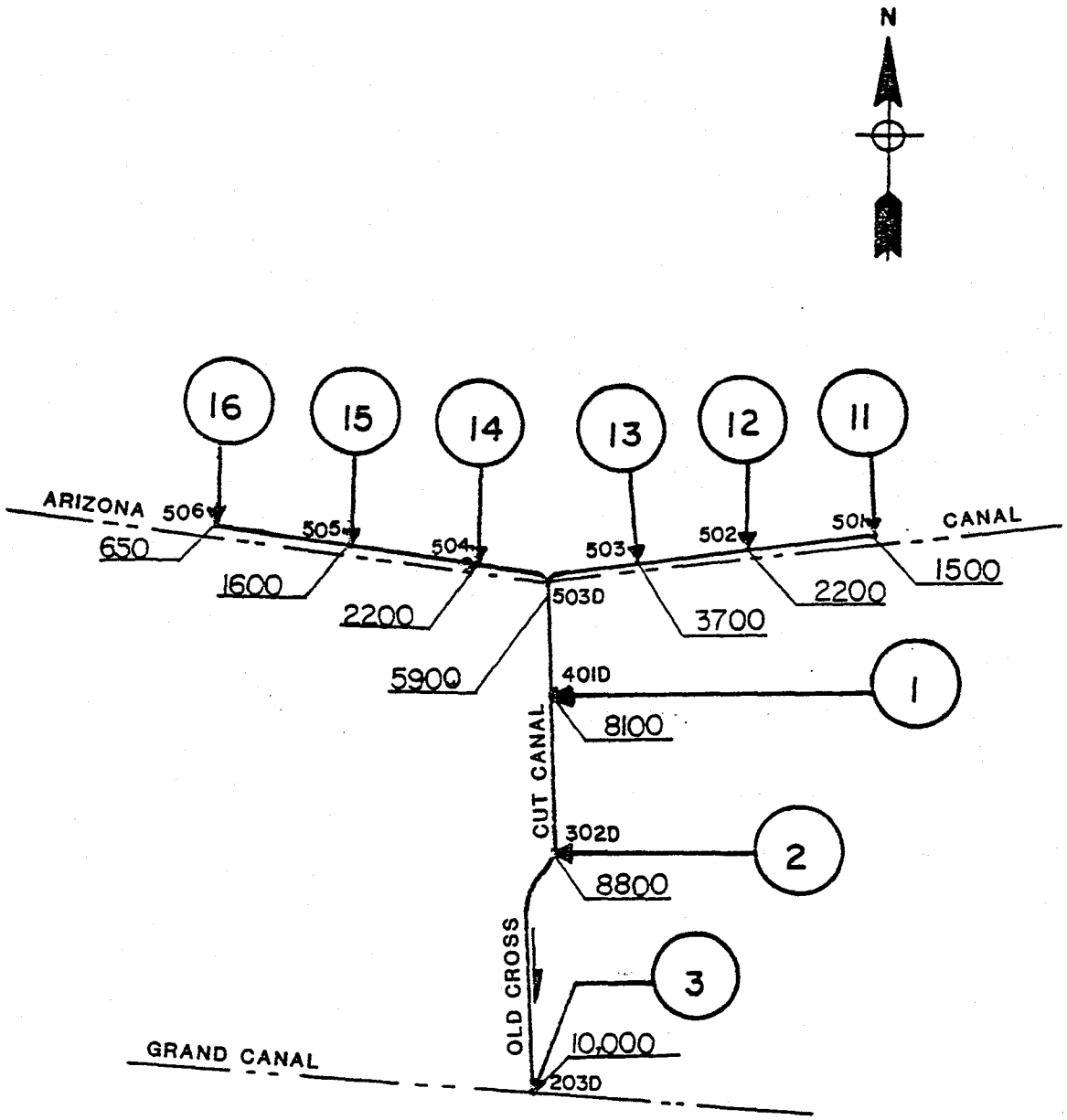
-- NOT TO SCALE --

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

SCHEMATIC OF

ALTERNATIVES 3 AND 4

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



L E G E N D

ROUTING LINE

3 CONTRIBUTING SUBAREA

650 ALT. 6 100-YEAR FLOW (FT^3/S)

506 CONCENTRATION POINT

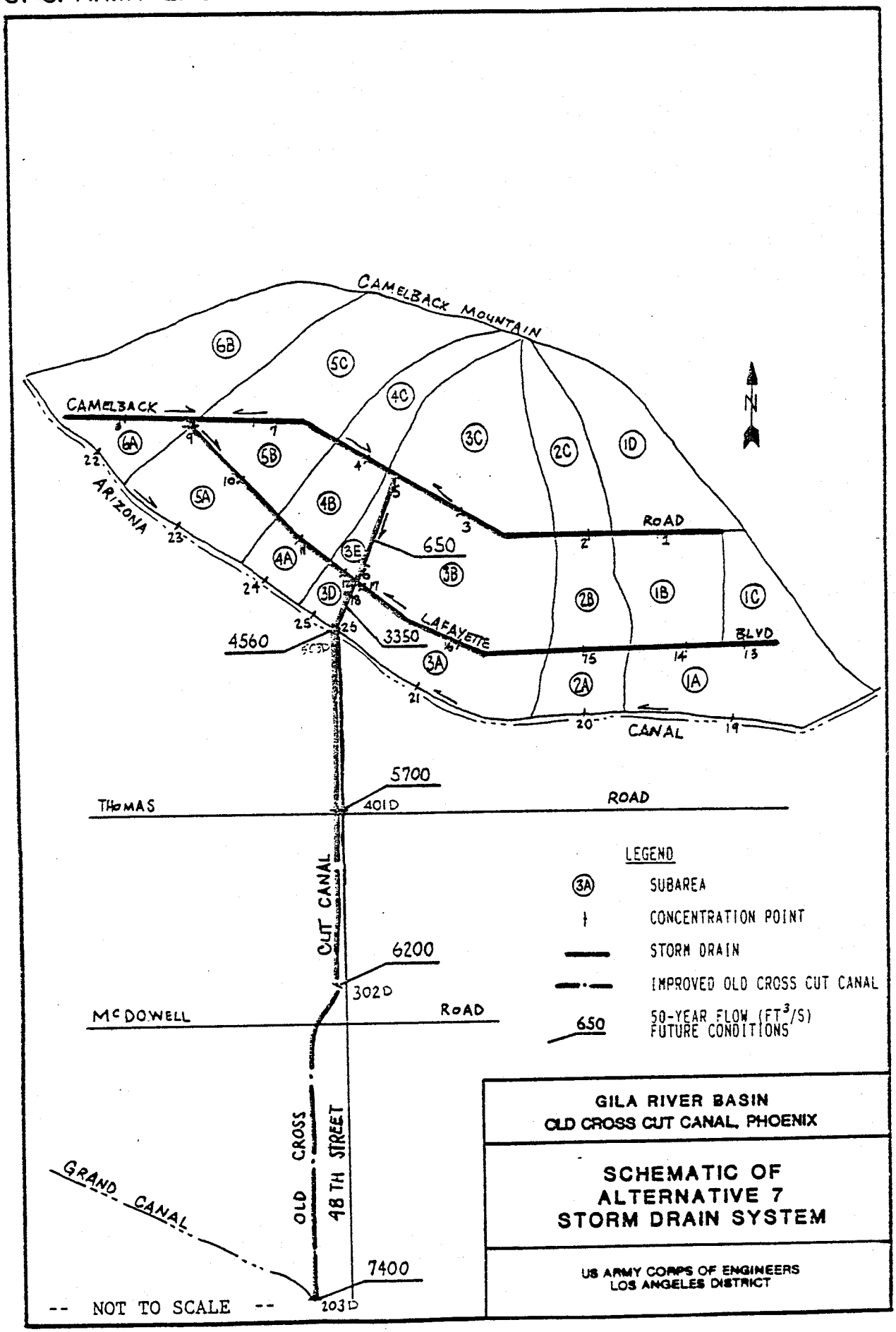
CANAL

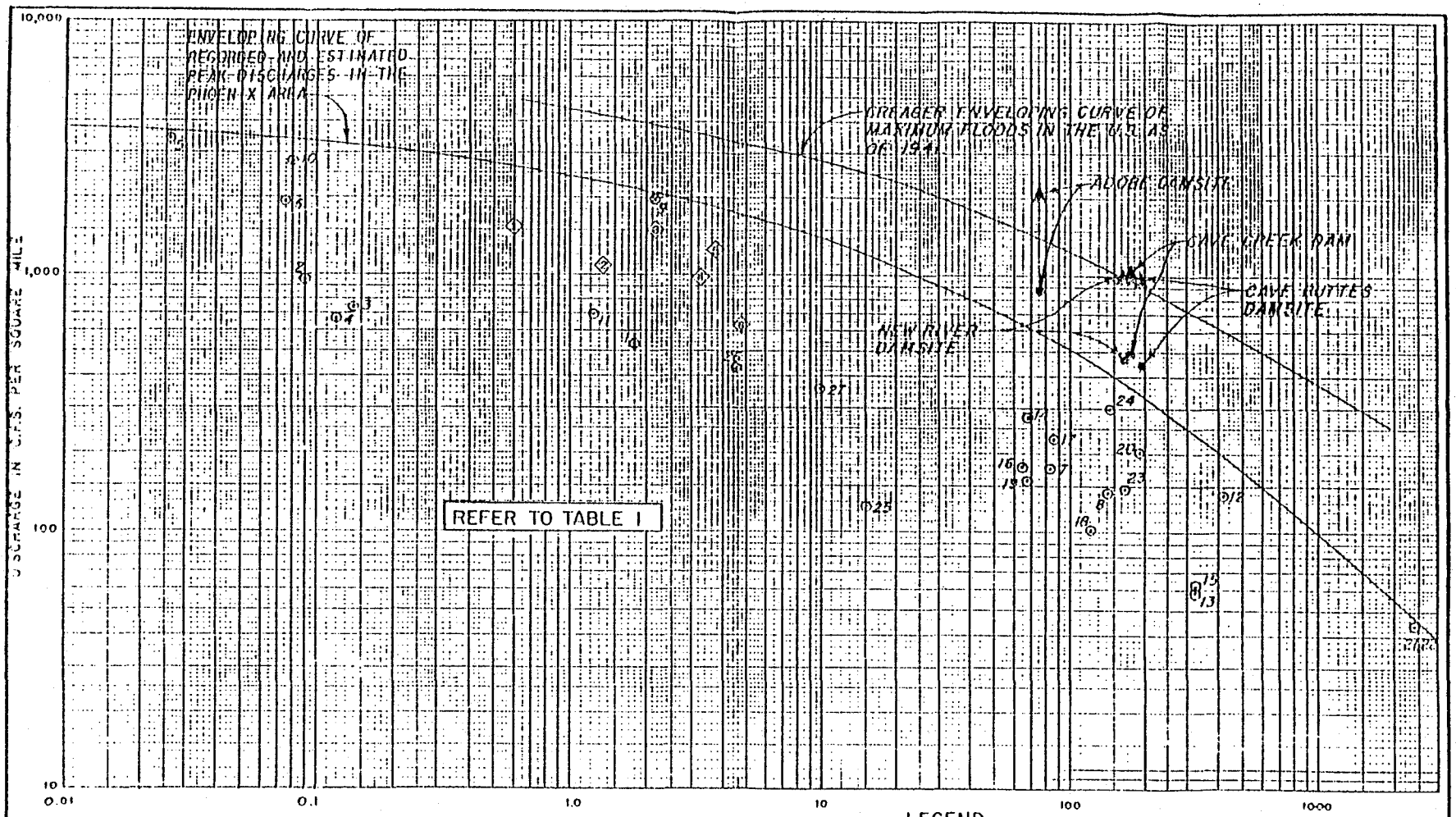
-- NOT TO SCALE --

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

SCHEMATIC OF
ALTERNATIVE 5 & 6

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


CAMELBACK MOUNTAIN
CAMELBACK
ARIZONA
ROAD
LAFAYETTE
BLVD
CANAL
THOMAS
ROAD
McDOWELL
ROAD
OLD CROSS CUT CANAL
48TH STREET
GRAND CANAL
650
4560
3350
5700
401D
6200
302D
7400
203D
N
LEGEND
SUBAREA
CONCENTRATION POINT
STORM DRAIN
IMPROVED OLD CROSS CUT CANAL
50-YEAR FLOW (FT³/S) FUTURE CONDITIONS
-- NOT TO SCALE --
GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX
SCHEMATIC OF ALTERNATIVE 7 STORM DRAIN SYSTEM
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



OLD CROSS CUT CANAL
SPF WITHOUT PROJECT

1. Washington & Grand Canal CP204
2. 56th Street u/s of A.C. CP502U
3. 36th Street & Devonshire Ave. CP407
4. 30th Street & Mitchel Ave. CP 307
5. Thomas Road at O.C.C. CP401
6. 24th Street & Grand Canal CP207

DRAINAGE AREA IN SQUARE MILES

LEGEND

⊙1 PEAK DISCHARGE FOR MAJOR RECORDED FLOOD (SEE TABLE 15 REF. 2)

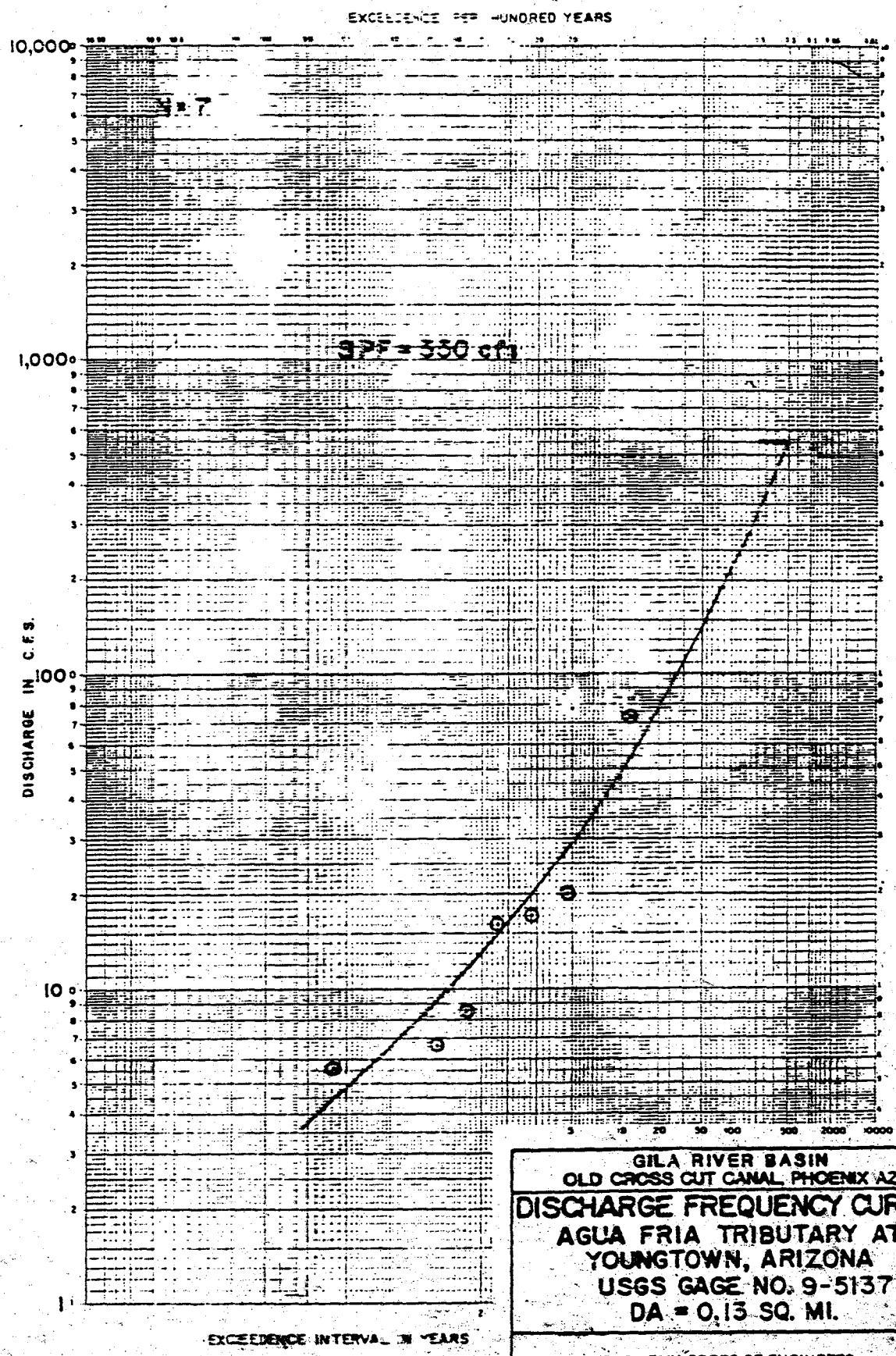
● STANDARD PROJECT PEAK DISCHARGE AT DAM OR DAMSITE.

▲ PROBABLE MAXIMUM PEAK DISCHARGE AT DAM OR DAMSITE.

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

ENVELOPING CURVE OF PEAK DISCHARGES

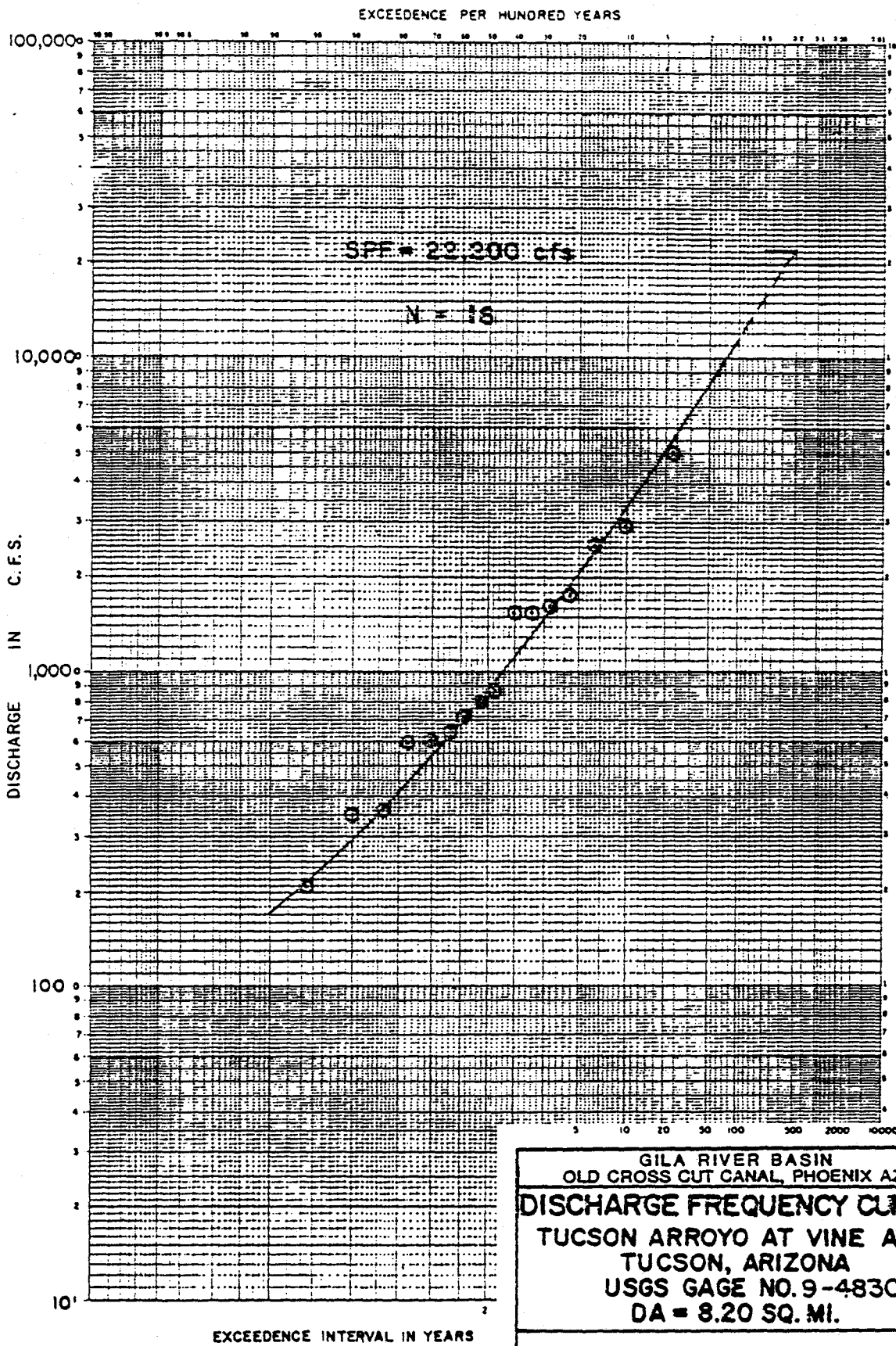
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

DISCHARGE FREQUENCY CURVE
AGUA FRIA TRIBUTARY AT
YOUNGTOWN, ARIZONA
USGS GAGE NO. 9-5137
DA = 0.13 SQ. MI.

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

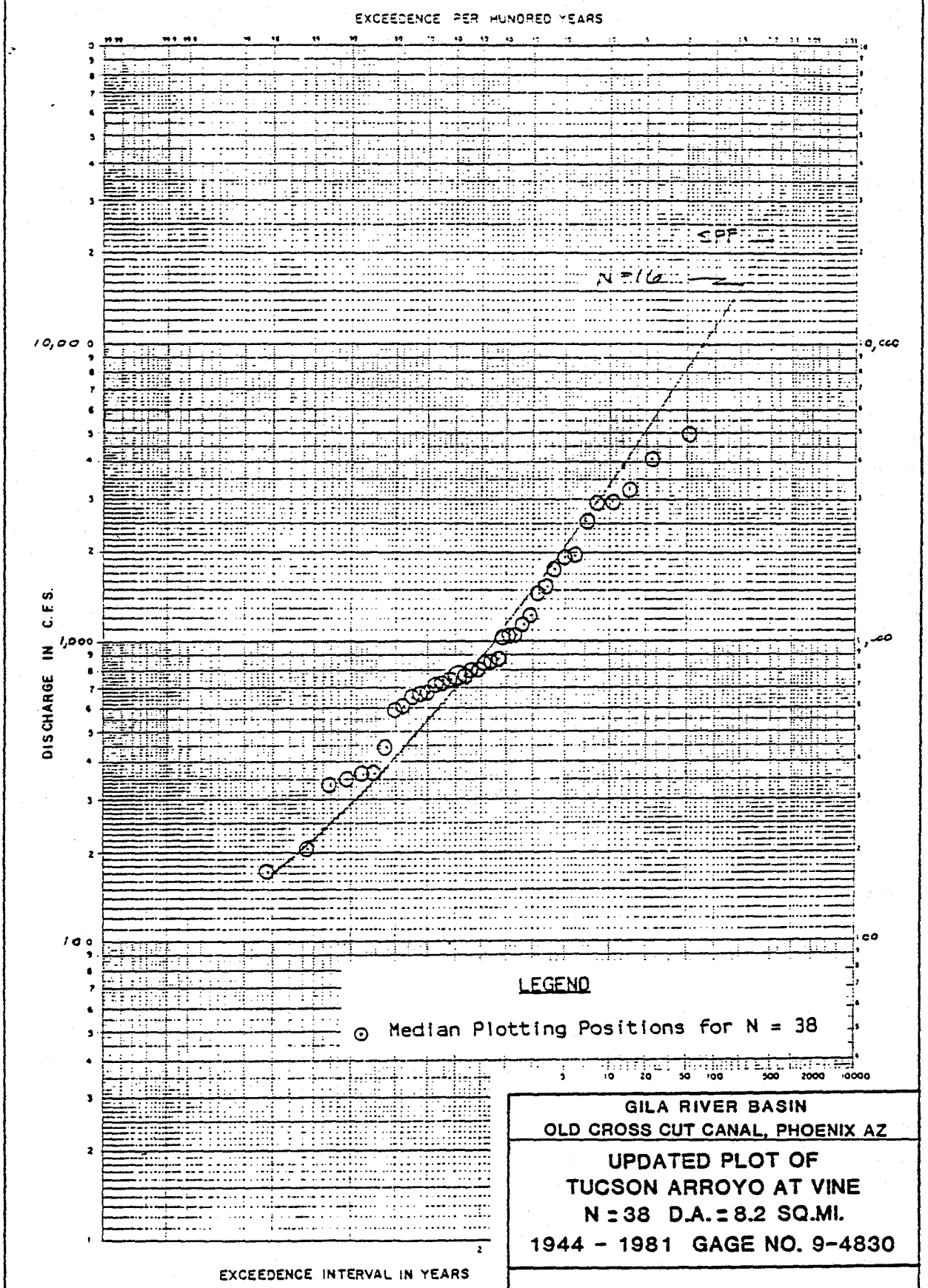


GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

DISCHARGE FREQUENCY CURVE

TUCSON ARROYO AT VINE AVE.
TUCSON, ARIZONA
USGS GAGE NO. 9-4830
DA = 8.20 SQ. MI.

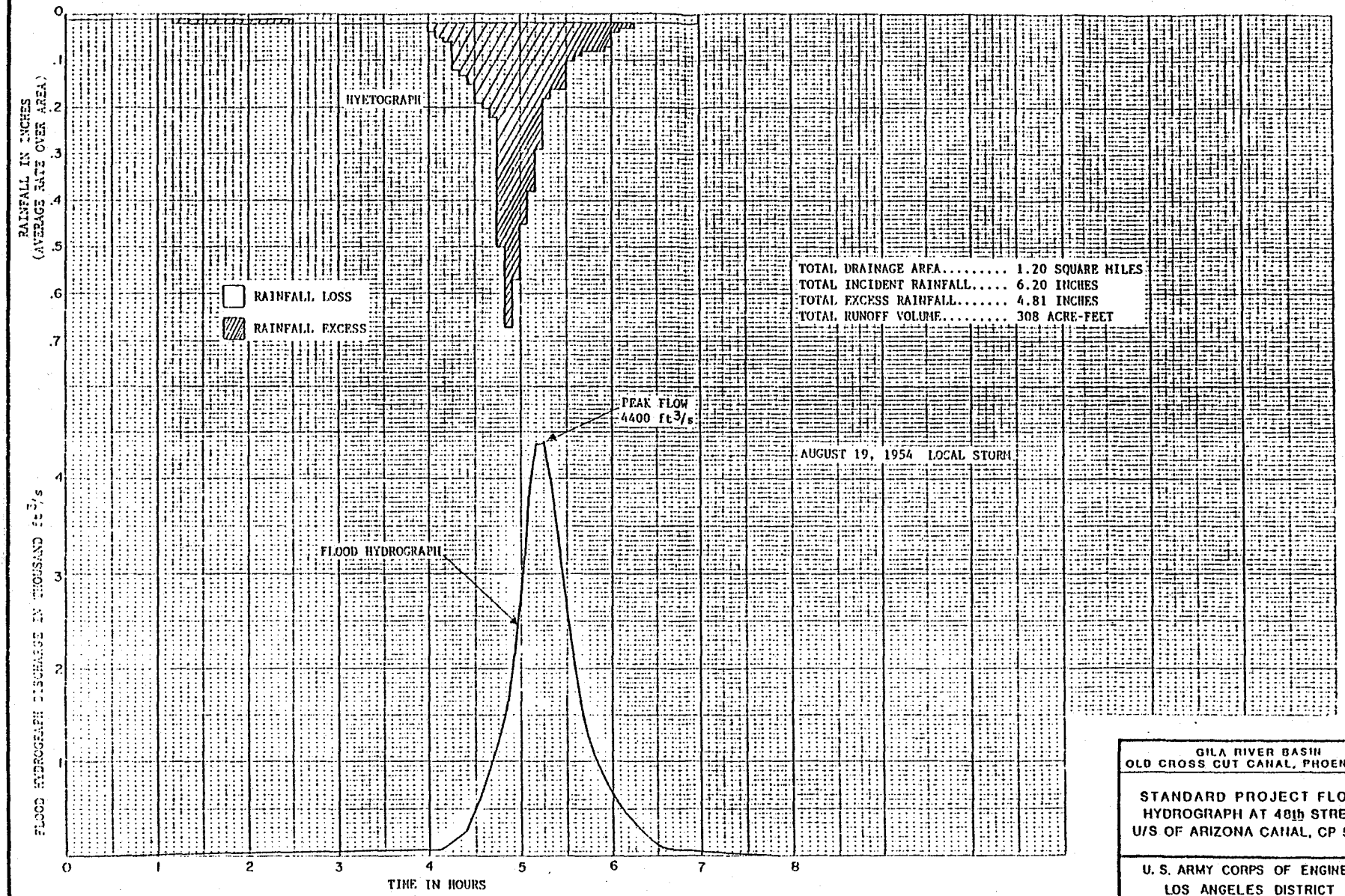
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

UPDATED PLOT OF
TUCSON ARROYO AT VINE
N = 38 D.A. = 8.2 SQ.MI.
1944 - 1981 GAGE NO. 9-4830

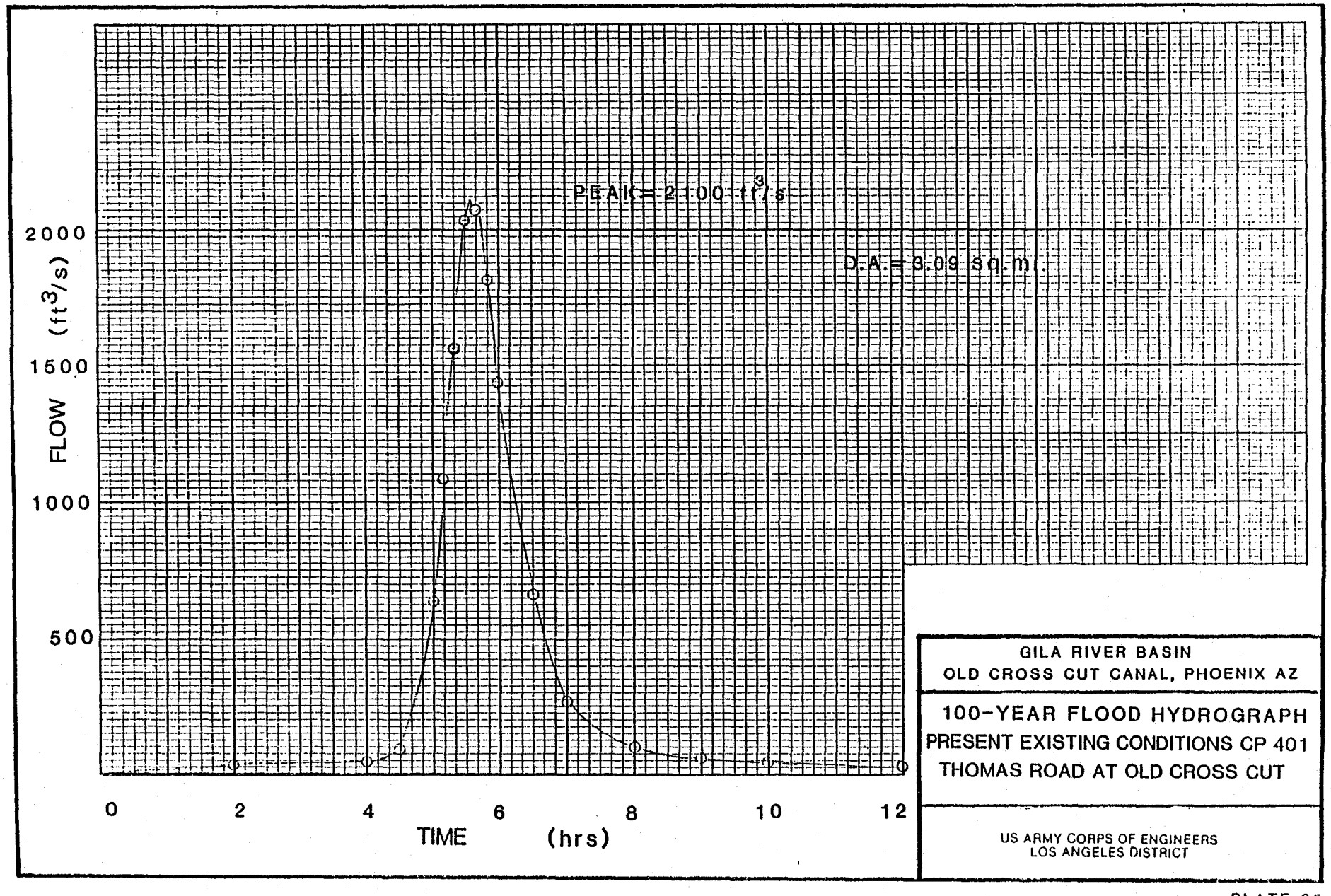
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

STANDARD PROJECT FLOOD
HYDROGRAPH AT 48th STREET
U/S OF ARIZONA CANAL, CP 503U

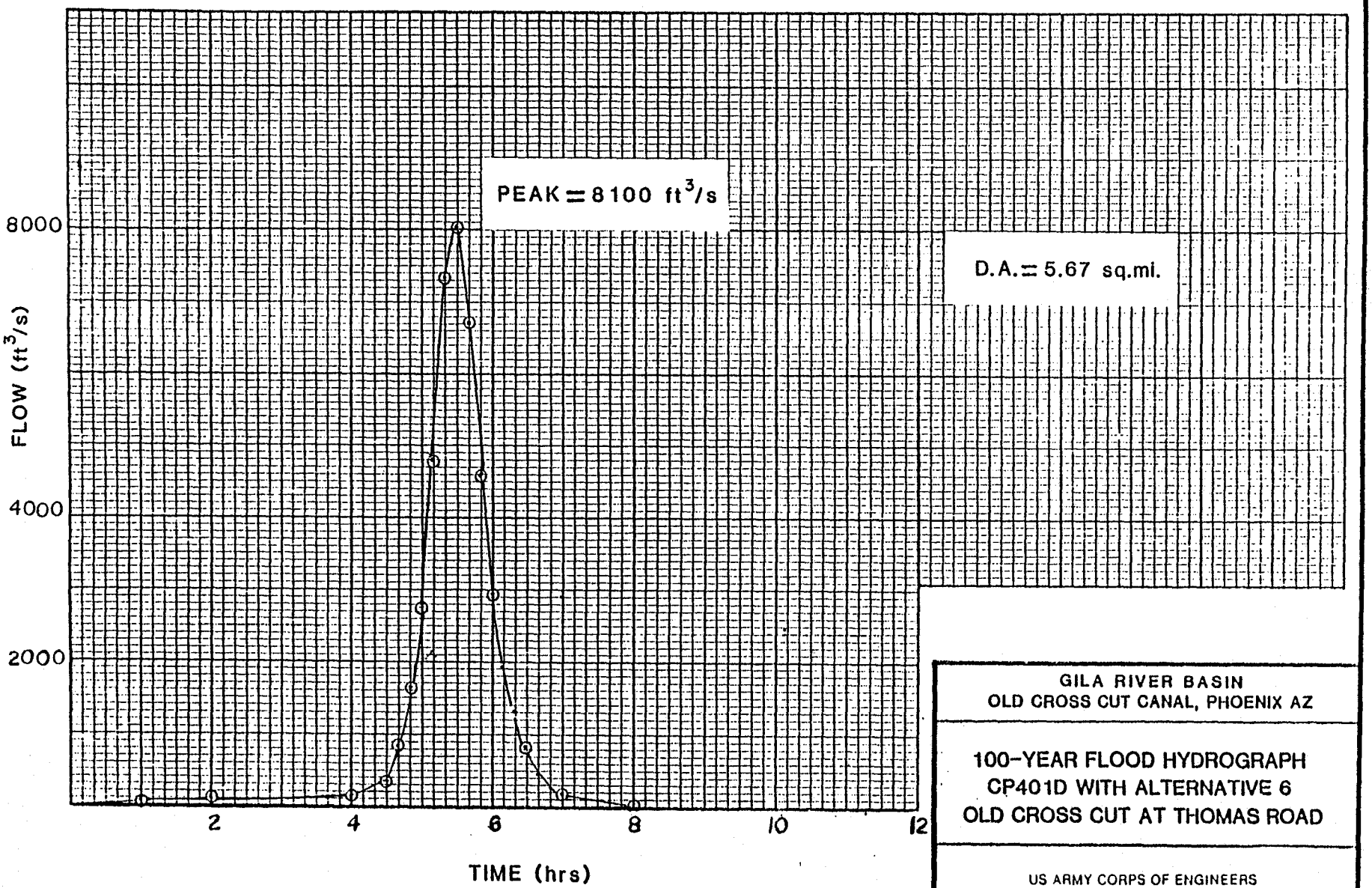
U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

100-YEAR FLOOD HYDROGRAPH
PRESENT EXISTING CONDITIONS CP 401
THOMAS ROAD AT OLD CROSS CUT

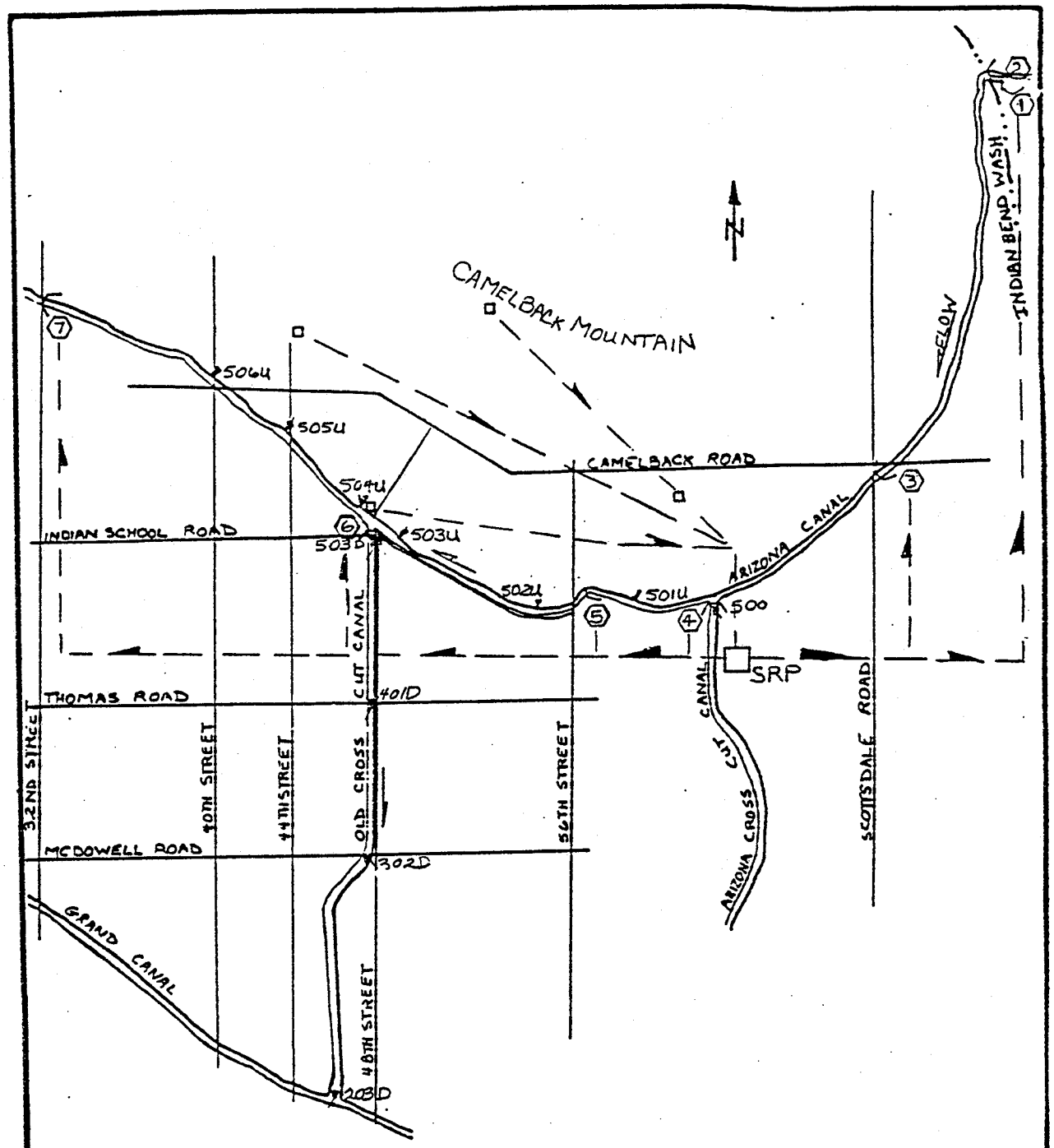
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

100-YEAR FLOOD HYDROGRAPH
CP401D WITH ALTERNATIVE 6
OLD CROSS CUT AT THOMAS ROAD

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



LEGEND

504U	CONCENTRATION POINT
5	CANAL GATE
	PROPOSED RAIN GAGE
	SRP HEADQUARTERS
	RADIO LINKS

NOT TO SCALE

GILA RIVER BASIN
OLD CROSS CUT CANAL, PHOENIX AZ

SCHEMATIC OF PROPOSED FLOOD FORECASTING SYSTEM

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

TECHNICAL DOCUMENTATION

SECTION B

HYDRAULICS

Prepared by
Los Angeles District
South Pacific Division
Corps of Engineers
Department of the Army

Building

CESPL-ED-HH 8 December 1988

MEMORANDUM FOR RECORD:

SUBJECT: Old Cross-Cut Canal Feasibility Level Design and Project Overflows for the Recommended Plan (Full Lafayette Alternative).

1. The purpose of this Memorandum For Record (MFR) is to document pertinent information and assumptions made during the Feasibility Level hydraulic design and analysis for the Old Cross-Cut Canal Project. Planning Division, Water Resources Branch, Section C (CESPL-PD-WC) issued an Engineering Service Request (reference 7d) to the Hydraulics Section (CESPL-ED-HH) in which the following was requested:

a. Reassess and affirm Full Lafayette Alternative Inlet System.

b. Develop channel improvements for the Old Cross-Cut Canal for existing and future flood flows.

c. Re-analyze downstream with- and without-project flood depths due to revised data base.

d. Reassess with-project depths above the Arizona Canal due to raising the north canal bank.

e. Coordinate with the Hydrologic Engineering Section to calculate the 25-yr flow into the Old Cross-Cut Canal.

2. The Full Lafayette Alternative was chosen by CESPL-PD-WC as the final feasibility plan and was also the locals preferred plan. The alternative consists of collecting storm runoff for the 25-yr frequency event that is tributary to the area bounded by 40th Street, Lafayette Boulevard, Invergordon Road, and the Camelback Mountains. The collected runoff is then transported and discharged into an improved Old Cross-Cut Canal by two reinforced-concrete box conduits (see Plate 1) crossing under the Arizona Canal. The conduits were designed for free-flow conditions. A two foot freeboard was added to the computed water surface profile to determine the concrete box dimensions. Water surface profiles were calculated using the computer program "WASURO". A Manning's "n" roughness coefficient of 0.0140 was applied in the design.

The East Line conduit (approximately 11,535 feet in length) was aligned along Lafayette Boulevard beginning at Invergordon Road and proceeding west to Arcadia Drive (see Plate 1). At Arcadia Drive the conduit proceeds south and crosses under the Arizona Canal to the Old Cross-Cut Canal. The 25-yr runoff tributary to the area bounded by Invergordon Road, Lafayette Boulevard, Arcadia Drive and the Camelback Mountains will be carried by the East Line conduit. Flows vary from 70 cubic feet per second (cfs) at Invergordon Road to 1570 cfs at the Old Cross-Cut Canal. Grated inlets will collect the runoff along Lafayette Boulevard at the following intersections: Invergordon Road, 62nd Street, 61st Street, Jokake Road, 58th Street, 57th Way, 56th Street, 54th

Street, Rubicon Avenue, and Arcadia Drive. These locations were chosen as inlet grate collection points based on an examination of the subarea drainage flow patterns. Regrading of streets will be required to ensure that the runoff flows reach the collection points as well as a positive ponding situation at the grates. A one foot head was assumed in determining the net open area of grate required at the collection point. Further it was assumed that 50% of the inlet grate area would be blocked by debris.

The reinforced-concrete box varies in size from 5 ft(W)X 8 ft(H) at Invergordon Road to 12.5 ft(W)X 8 ft(H) at the Old Cross-Cut Canal. Invert slopes are as follows:

INVERT SLOPE	FLOW REGIME	REACH
0.00150	Subcritical	Invergordon Road to 56th Street
0.00300	Subcritical	56th Street to north side of Arizona Canal
0.01000	Supercritical	North side of Arizona Canal to the Old Cross-Cut Canal

The West Line conduit (see Plate 1) starts at Vermont Avenue and proceeds south along 44th Street to Lafayette Boulevard. At this point the conduit turns onto Lafayette Boulevard and extends easterly to Arcadia Drive. At Arcadia Drive, the conduit runs south, crossing under the Arizona Canal, and discharging directly into the Old Cross-Cut Canal. The length of the West Line conduit is approximately 8,710 feet. The reinforced-concrete box ranges in size from 3.5 ft(W)X 4 ft(H) at Vermont Avenue to 10 ft(W)X 6.5 ft(H) at the Old Cross-Cut Canal. Invert slopes are as follows:

INVERT SLOPE	FLOW REGIME	REACH
0.00400	Subcritical	Vermont Avenue to Camelback Road
0.00190	Subcritical	Camelback Road to Arcadia Drive
0.00330	Subcritical	Along Arcadia Drive from Lafayette Boulevard to the north side of the Arizona Canal
0.01000	Supercritical	North side of the Arizona Canal to the Old Cross-Cut Canal

The conduit was designed to convey the 25-yr flood runoff for the area bounded by 44th Street, Lafayette Boulevard, Arcadia Drive, and the Camelback Mountains. Conduit discharges range from 40 cfs at Vermont Avenue to 790 cfs at the Old Cross-Cut Canal.

Grated inlets will collect the runoff at the following locations: Vermont Avenue and 44th Street, Colter Avenue and 44th Street, 44th Street north of Camelback Road, Camelback Road east of 44th Street, 44th Street and Lafayette Boulevard, 46th Street and Lafayette Boulevard, Lafayette Boulevard east of 46th Street, Launfal Avenue and Lafayette Boulevard. Again, the grate locations and necessary street modifications were predicted on the general subarea runoff patterns.

3. The Old Cross-Cut Canal was assumed improved and part of the project for both existing and future flood flow conditions (with the Full Lafayette Alternative in place) down to McDowell Road. This condition was stipulated at the Project Manager's (Laura Herbranson) request.

Because of the Arizona Department of Transportation's (ADOT) construction of the Papago Freeway and Hohokam Expressway in the vicinity of the downstream end of the Old Cross-Cut Canal, the Corps of Engineers (COE) project needed only to improve the upper reach of the Old Cross-Cut Canal down to McDowell Road. ADOT undertook the responsibility to improve the lower reach of the Old Cross-Cut Canal from McDowell Road to the Salt River.

a. Improvements to Old Cross-Cut Canal for existing flood flow conditions- The improvement consisted of a rectangular concrete channel, approximately 10,690 feet(ft) in length, from the Arizona Canal to the end of the project at McDowell Road (see Plate 2). From STA 191+90 to Sta 85+00 the channel would have a base width of 23.5 ft and a wall height of 6.5 ft. Channel flows range from 1000 to 1800 cfs with a constant invert slope of 0.00550. From STA 85+00 to STA 82+00 a transition would reduce the base width from 23.5 ft to 16 ft. The wall height would increase to 7 ft and the invert slope through the transition would be 0.03000. From STA 82+00 to STA 80+10 the channel would maintain a base width of 16 ft and wall height of 7 ft. The invert slope would decrease to 0.00530. A Manning's roughness coefficient of 0.014 was applied in the design. The improved channel follows the existing alinement.

b. Improvements to Old Cross-Cut Canal for future flood flow conditions - Again, the improvement consisted of a rectangular concrete channel. Future flood flows down the Old Cross-Cut Canal, with the COE project, range from 3000 cfs at the upstream end to 4100 cfs at McDowell Road. The improved channel for the entire reach would have a base width of 23.5 ft and a wall height of 10 ft, with an invert slope of 0.00550. The channel is operating under supercritical flow conditions.

ADOT's plan, as of April 1988, (according to one of their consultants, Mr. Harley Parr - H.W. Lockner Engineers), called for a 16 ft(W)X 12 ft(H) reinforced-concrete box flowing non pressure from McDowell Road to the Salt River. The first 200 feet south of McDowell Road would have an invert slope of 0.00530 and then increase to 0.00994. However, for a discharge of 4100 cfs, this same 200 foot reach, with an invert slope of 0.00530, operates in an unstable flow condition (normal depth = 11.7 ft, critical depth = 12.7 ft) and

provides only 0.3 feet of freeboard. Further, if the box flows full its discharge capacity would be reduced to 3400 cfs. Attempts to tie into the ADOT plan (identical dimensions and invert elevation) resulted in unstable flow conditions within the COE reach of the Old Cross-Cut Canal. Thus, there is a requirement for additional coordination between the COE and ADOT at the next phase of study for adequate tie in.

4. Without and with-project flood depths below the Arizona Canal were revised to include the construction of the Papago Freeway and Hohokam Expressway within the project boundaries. In addition to improving the Old Cross-Cut Canal capacity downstream of McDowell Road, ADOT will provide storm drains immediately north of the Papago Freeway to prevent inundation up to the 100-yr flood event. The storm drain east of the Old Cross-Cut Canal discharges the collected runoff into the improved Old Cross-Cut Canal. The storm drain west of the Old Cross-Cut Canal carries the collected storm runoff westerly to a larger storm drain located in the vicinity of the interloop of the Squaw Peak Freeway and Papago Freeway near 24th Street.

As requested by CESPL-PD-WC, without and with-project flood depths were computed for the 25, 50, and 100-yr frequency events (see Plates 3,4,5,6,7,8). Since it was determined that the degree of urbanization below the Arizona Canal for this study is similar to that of the ACDC Dreamy Draw to Cudia City Wash (reference 7m) drainage area, which is immediately to the west, the same "n" value of 0.250 was applied to all normal depth calculations. The same overflow analysis (reference 7f) was used with the revised discharges because of the impact of the ADOT project. The depths are presented in a tabular summary on USGS Quad maps and were released to the Economics Section on September 22, 1988.

5. With-project depths above the Arizona Canal for the Full Lafayette Alternative had to be reassessed. The design feature of lowering of the north bank of the Arizona Canal to the adjacent low ground elevation, was eliminated at CESPL-PD-WC's (City of Phoenix) request. Presently, based on 1966 Topo (reference 7k), the north bank of the Arizona Canal is higher than the adjacent ground elevation. This causes a ponding condition to develop along the north bank of the canal except at locations where there is natural relief for storm runoff to flow into the Arizona Canal. The lowering of the north bank would reduce flooding immediately north of the Arizona Canal. However, the City of Phoenix had a major concern that water quality would worsen and subsequently increase the perceived liability if they approved of a greater quantity of storm runoff into their water distribution system. Thus, this element of the initial Full Lafayette Alternative was eliminated from further consideration.

As a consequence of not including any modifications to the Arizona Canal, a reassessment of the flooding conditions were initiated for the 25-, 50-, and 100-year frequency storm events. The results were plotted on reference 7k. In general, increased flood depths were noted over the condition in which the north bank had been lowered. In addition, because some homes were identified as being in natural depressions, CESPL-ED-HH was requested to institute an extensive detailed analysis of the area immediately north of the Arizona Canal. As a result, specific flood depths were generated for each home or group of homes with similar depths rather than an average depth over a broad area.

Further, the results indicated that the first row of homes immediately north of the Arizona Canal still experience ponding conditions even at the design frequency storm because of the high north bank of the Arizona Canal. A possible solution to this unique ponding problem might involve a secondary runoff collection system immediately north of the Arizona Canal. It should also be noted, that this set of flood depth information was developed from one specific radial gate operation setting for the Arizona Canal system which was simulated by the unsteady flow computer program "USTDY'. Variations of the radial gate operations will result in flooding depths of different magnitudes.

6. Finally, since the Old Cross-Cut Canal from McDowell Road to the Salt River will be improved by ADOT, CESPL-PD-WC requested that the 25-yr frequency flood event discharge for the Full Lafayette Alternative be determined and released to ADOT. The Hydrologic Engineering Section (CESPL-ED-HE) routed flows in the two conduits above the Arizona Canal and found a peak flow of about 2100 cfs at the inlet to the Old Cross-Cut Canal. In addition, the Salt River Project (SRP) has the capability of diverting a maximum of 800-900 cfs into the Old Cross-Cut Canal with its two radial gates on the Arizona Canal. Thus, 3000 cfs was determined as the maximum inflow at the inlet to the Old Cross-Cut Canal.

7. References:

a. Service Request (ESR) dated 4 Feb 1987, Request Number 87 2320 RH.

b. Service Request (ESR) dated 8 May 1987, Request Number FY87 2321.

c. Service Request (ESR) dated 1 Aug 1987, Request Number FY87 2322.

d. Service Request (ESR) dated 1 Apr 1988, Request Number 88 2311 RH.

e. CESPL-ED-HH Memorandum For Record (MFR) dated 23 Oct 1987, subject: Old Cross-Cut Canal Feasibility Study Reconnaissance Level Design and Project Overflows for the Alley, Partial Lafayette, and Full Lafayette Alternative Designs.

f. CESPL-ED-HH Memorandum For Record (MFR) dated 29 June 1987, subject: Without Project Overflow Analysis for the Old Cross-Cut Canal Feasibility Study.

g. CESPL-ED-HH Memorandum For Record (MFR) dated 19 Dec 1986, subject: Old Cross-Cut Feasibility Study Reconnaissance Level Design and Project Overflows for Alternative Designs Nos. 3 and 4.

h. CESPL-ED-HH Memorandum For Record (MFR) dated 18 Aug 1986, subject: Old Cross-Cut Canal Feasibility Study Alternative Design Including Flood Operational Scenarios for the Arizona Canal.

i. CESPL-ED-HH Memorandum For Record (MFR) dated 17 Jan 1986, subject: Feasibility Overflow Study for the Old Cross-Cut Canal Project.

j. CESPL-ED-HE Memorandum For Record (MFR) dated Sept 1988, subject: Old Cross-Cut Canal Feasibility Analysis with Papago Freeway.

k. Topographic Mapping:

(1) Topo map of the Phoenix Metro area dated 9/66, by Yost and Gardner Engineers with a scale of 1"=100' and 2 foot contour intervals.

(2) USGS Quadrangle Maps for the Phoenix Metro area with a scale of 1"=2000' and 10 foot contour intervals.

l. Barkau, Robert L., "A Mathematical Model of Unsteady Flow through a Dendritic Network", Fall 1985.

m. U.S. Army Corps of Engineers, Los Angeles District, Gila River Basin; Phoenix, Arizona and vicinity (Incl. New River) Arizona Canal Diversion Channel Dreamy Draw to Cudia City Wash; Economic Analysis, March 1987.

Glenn M. Mashburn
Supervisory Hydraulic Engineer

Frank T. Lara
Hydraulic Engineer

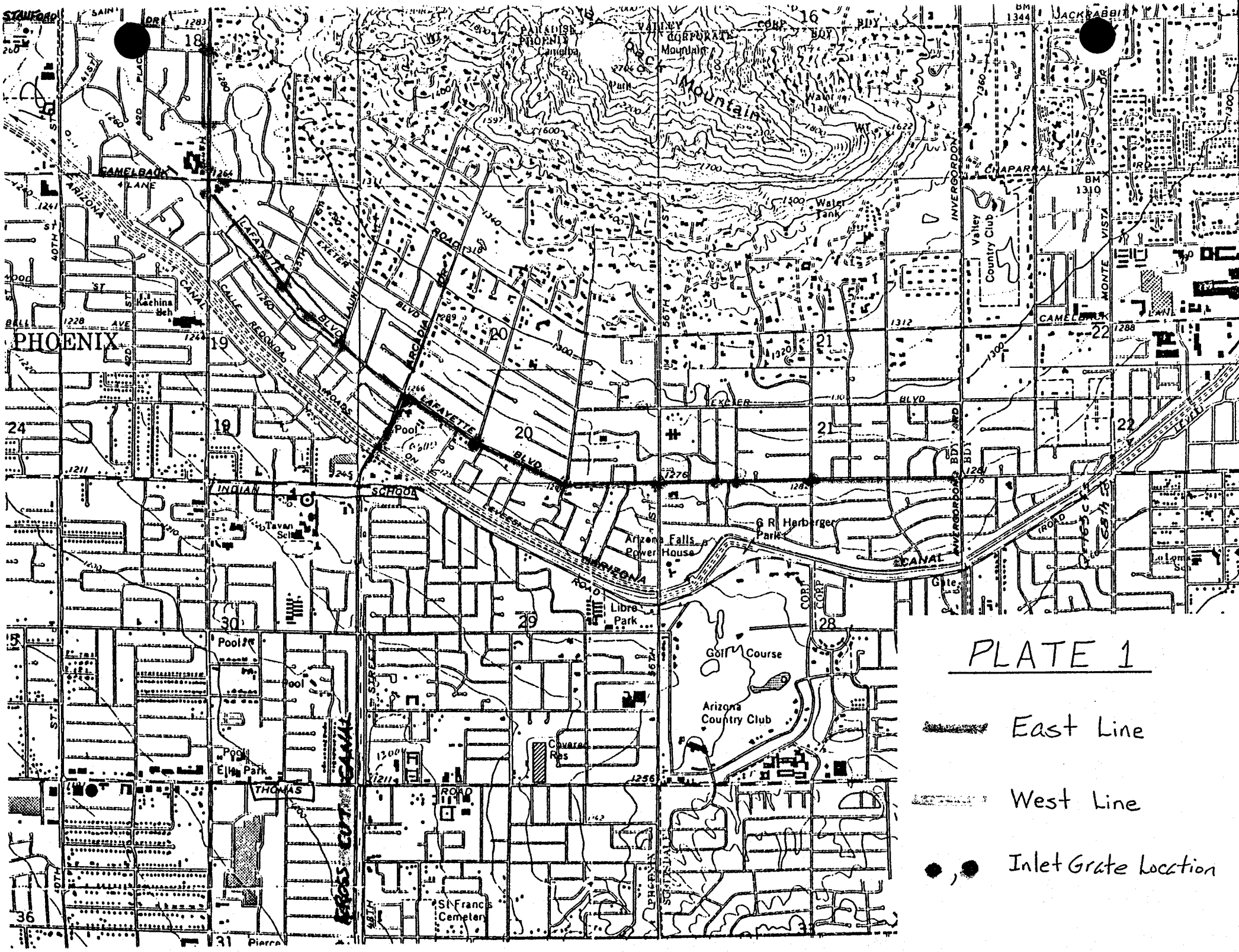

PHOENIX
Camelback Mountain
Water Tank
Valley Country Club
Arizona Falls Power House
G. R. Harberger Park
Libre Park
Golf Course
Arizona Country Club
Covered Res
St. Francis Cemetery
Pool
Tavan Sch
Kachina Sch
Pierce
CAMELBACK
LANE
INDIAN SCHOOL
ROAD
LAFAYETTE
BLVD
EXETER
ARCADIA
CALLE REDONDA
THOMAS
ROAD
ARIZONA
CANAL
CROSS CUT CANAL
INVERGORDON
CHAPARRAL
VISTA
MONTE
PLATE 1
East Line
West Line
Inlet Grate Location

PLATE 2
COE Improvement
ADOT Improvement
& new alinement
Existing alinement
STA 191+00
STA 80+10
CAMELBACK MTN. PARK
ECHO CANYON PARK
ARIZONA BILTMORE GOLF COURSE (PRIVATE)
COUNTRY CLUB (PRIVATE)
ARIZONA NATIONAL GUARD
PHOENIX MILITARY DISTRICT
PAPAGO SPORTS COMPLEX
Barnes Butte 1745
PAPAGO PARK
PAPAGO MUNICIPAL GOLF COURSE
PHOENIX ZOOLOGICAL PARK
Desert Botanical Gardens
ROLLING HILLS GOLF COURSE
Legend City (Amusement Park)
Municipal Stadium
Arizona Canal
Grand Canal
Salt River Canal
PUEBLO GRANDE PARK
ARIZONA STATE
Gerard High School
Arcadia High School
East High School
Air National Guard Headquarters
Armory
Phoenix Trap and Skeet Club
AIR STRIP
PHOENIX CITY LIMITS
TEMPE CITY LIMITS
SOUTHERN PACIFIC TRANSPORTATION CO.
CAMELBACK ROAD
INDIAN SCHOOL ROAD
THOMAS ROAD
MC DOWELL ROAD
VAN BUREN ST.
WASHINGTON ST.

DISPOSITION FORM

For use of this form, see AR 340-15; the proponent agency is TAGO.

REFERENCE OR OFFICE SYMBOL	SUBJECT
CESPL-ED-HH(1110-2-1403a)	Old Cross-Cut Canal Feasibility Study

TO CESPL-PD-WC ATTN: Jeff Owens FROM C,CESPL-ED-H DATE 30 November 1988 CMT 1

Mr. Lara/pm/6993

1. As requested from the meeting held on 1 November 1988, enclosed is the Memorandum For Record (MFR) discussing the hydraulic analysis of the Full Lafayette Alternative prior to and after the F3 Conference.

2. A draft of this MFR was sent on 8 November 1988 in support of meeting with the local sponsor.

Joseph B. Evelyn

JOSEPH B. EVELYN, P. E.
Chief, Hydrology & Hydraulics Branch

Encl

DA FORM AUG 80 2496 PREVIOUS EDITIONS WILL BE USED

☆ U.S. Government Printing Office: 1983—406-862

CESPL-ED-HH 8 NOVEMBER 1988

MEMORANDUM FOR RECORD:

SUBJECT: Old Cross-Cut Canal Feasibility Study Hydraulic Analysis of the Full Lafayette Alternative.

1. The purpose of this Memorandum For Record is to document pertinent information and assumptions made prior to and after the F3 Conference held on February 29, 1988.

2. Prior to the F3 Conference three alternatives considered were the Alley, Partial Lafayette, and Full Lafayette (see reference 5b). Key components identical to all three alternatives were as follows:

a. Lowering the north bank of the Arizona Canal to the adjacent ground elevation from approximately 56th Street to 40th Street - This was done to allow runoff, not captured by the various storm drain systems, to flow into the Arizona Canal and reduce the ponding behind the north bank. Note that the north bank could not be lowered for the reach between 56th Street and 64th Street as the Arizona Canal's operating water surface is higher than the north overbank adjacent ground elevation.

b. Add an additional radial gate to the two existing gates at the Old Cross-Cut Canal junction - This allows a greater quantity of Arizona Canal flow to be diverted down the Old Cross-Cut Canal.

c. Add a radial gate on the Arizona Canal at 44th Street - This would force a drawback of flow on the Arizona Canal to the Old Cross-Cut Canal, resulting in a quicker dewatering of the Arizona Canal.

Residuals above the Arizona Canal were analyzed for all three alternatives (see reference 5b). For both the Partial Lafayette and Full Lafayette Alternatives, results showed that a 40-year level of protection could be attained for the reach between 56th Street and 40th Street. However, for the study reach area between 56th Street and 64th Street, only a 25-year level of protection could be provided. Further, the economic analysis above the Arizona Canal assumed a 50-yr level of protection for the entire study reach area.

For the Alley Alternative, results of the residual overflow analysis above the Arizona Canal (see reference 5b), showed that a 40-year level of protection could be attained. Again, the economic analysis assumed a 50-year level of protection.

For the analysis below the Arizona Canal, flood damage assumptions were developed by the Project Manager and released to the Economics Section.

3. After the F3 Conference, the Full Lafayette Alternative was chosen as the local sponsor's (City of Phoenix) preferred plan. However, the local sponsor expressed a concern over the decrease in the quality of the Arizona Canal water as a result of additional storm runoff into the canal because of a reduction of the height of the north bank. Also, the two radial gate additions would require the need for a flood forecasting system and gate operational schedule. Therefore, these elements of the Full Lafayette Alternative were eliminated as per the Project Manager's request. Thus, there was a need to re-analyze the residual upstream overflows for this alternative.

The results of this re-analysis of residuals above the Arizona Canal indicated a reduction to a 25-yr level of protection across the entire study reach. Note, that prior to the F3 Conference, a 40-year level of protection was afforded for the same reach between 56th Street and 40th Street.

Residuals below the Arizona Canal were re-analyzed due to the Arizona Department of Transportation's (ADOT) construction of the Papago Freeway and its associated improvements to the Old Cross-Cut Canal downstream of McDowell Road. Without project conditions now had to include these improvements to the Old Cross-Cut Canal. With the capacity of the Old Cross-Cut Canal increased at McDowell Road, breakouts and resulting overflow depths were lessened. Thus, less damages occurred south of the Arizona Canal than in the analysis prior to the F3 Conference.

5. References:

a. CESPL-ED-HH Memorandum For Record (MFR) dated 1 Sept 1988, subject: Old Cross-Cut Canal Feasibility Level Design and Project Overflows for the Recommended Plan (Full Lafayette Alternative).

b. CESPL-ED-HH Memorandum For Record (MFR) dated 23 Oct 1987, subject: Old Cross-Cut Canal Feasibility Study Reconnaissance Level Design and Project Overflows for the Alley, Partial Lafayette and Full Lafayette Alternative Designs.

c. CESPL-ED-HE Memorandum For Record (MFR) dated 2 Nov 1988, subject: Old Cross-Cut Canal Hydrology changes of the Full Lafayette Alternative since the F3 Conference.

Glenn M. Mashburn

Glenn M. Mashburn

Supervisory Hydraulic Engineer

Frank T. Lara

Frank T. Lara

Hydraulic Engineer

CESPL-ED-HH 23 October 1987

MEMORANDUM FOR RECORD:

SUBJECT: Old Cross-Cut Canal Feasibility Study Reconnaissance Level Design and Project Overflows for the Alley, Partial Lafayette and Full Lafayette Alternative Designs.

1. The purpose of this MFR is to document pertinent information and assumptions made during the feasibility level hydraulic analysis for the Old Cross-Cut Canal Project. Planning Division, Water Resources Branch, Section C issued ESR's (references 6a-6c) to the Hydraulics Section in which they requested the following:

a. Develop reconnaissance level design on three alternatives for the Inlet Collector System above the Arizona Canal (reference 6a).

b. Complete with-project overflows above and below the Arizona Canal. Reassess with-out project overflows below the Arizona Canal using revised hydrology (references 6b and 6d).

c. Assess the with-project overflows below the Arizona Canal assuming the Old Cross-Cut Canal will be improved to a 25-yr capability. Complete three reconnaissance level design improvements on the Old Cross-Cut Canal (reference 6c).

2. The three inlet system alternatives above the Arizona Canal are identified as follows:

a. Alley Alternative (see Plate 1) - The structural elements of this alternative consist of an inlet collector system in place along Lafayette Boulevard and six side drains located between Dromedary Road and 40th Street. The conduit along Lafayette Boulevard is approximately 7200 feet in length beginning at Invergordon Road and proceeding west to 56th Street. At 56th Street the conduit will proceed south to the Arizona Canal and discharge directly into it. Inlet grates will be placed at six major intersections to collect the runoff into the conduit. Grading of Lafayette Boulevard may be required to make sure runoff gets to the collection points. Six side drains ranging from 1000 feet to 2000 feet in length will collect runoff between Dromedary Road and 40th Street. These side drains discharge directly into the Arizona Canal and are located in the alley west of at Dromedary Road, in the alley west of 46th Street, in the alley west of Avenida Del Puente, in the alley west of Calle Feliz, along Camelback Road, and along 40th Street. Inlet grates will be located at the upstream end of these side drains. To relieve ponding between 55th Place and Dromedary Road, the north bank of the Arizona Canal will be lowered to the adjacent low ground elevation to allow direct runoff into the Arizona

Canal. An armor coating will be added to the north bank to prevent erosion from the runoff into the Arizona Canal. From Dromedary Road to 40th Street the north bank could not be lowered to the adjacent low ground elevation as this would infringe upon the 2 foot freeboard that the Salt River Project (SRP) requested be left above its normal operational level.

b. Partial Lafayette Alternative (see Plate 2) - This alternative consists of the same design features as an inlet collector system along Lafayette Boulevard and lowered north bank of the Arizona Canal as the Alley Alternative. However, this alternative has no inlets into the Arizona Canal. Instead, an additional inlet collector system will be placed along 44th Street from Stanford Drive south to Lafayette Boulevard. This additional conduit then proceeds east along Lafayette Boulevard from 44th Street to Arcadia Drive. At this point the conduit then turns south on Arcadia Drive,under the Old Cross-Cut Canal and discharges into the Arizona Canal. At the detail design level, an inverted siphon will be designed for either the conduit or the Arizona Canal. Again, inlet grates will be placed at major intersections to collect storm runoff and the north bank of the Arizona Canal lowered. The total footage of conduit for this alternative is approximately 16,800 feet.

c. Full Lafayette Alternative (see Plate 3) - This alternative consists of an inlet collector system aligned along Lafayette Boulevard across the entire study area. Also, included is the reach along 44th Street from Stanford Drive to Lafayette Boulevard. Major intersections will have inlet grates to collect runoff that will be taken to Arcadia Drive, which in turn discharges directly into the Old Cross-Cut Canal. As in the Partial Lafayette Alternative, an inverted siphon will be designed at the crossing of the conduit and the Arizona Canal. Also, the north bank of the Arizona Canal will be lowered. The total length of conduit for this design is approximately 19,600 feet.

Note, all incident rainfall above Lafayette Boulevard is designed to be collected by the collector system. However runoff produced by rainfall below Lafayette Boulevard will not be collected by the inlet collector system. Whatever runoff that does not flow into the Arizona Canal over lowered north bank will pond against the bank and result in localized flooding.

3. To assist the SRP in operating the Arizona Canal for flood protection, two additional radial gates will be added to the Arizona Canal system for each of the three alternatives considered. One additional radial gate 13.5 feet wide will be added to the two existing gates at the Old Cross-Cut Canal junction. This will increase SRP's capability to divert 1600 cfs from the Arizona Canal to the Old Cross-Cut Canal. The additional radial gate in the vicinity of 44th Street will be 42 feet wide and used to force a quicker drawdown of the water in the Arizona Canal. From 44th Street, canal water will be diverted back to and down the Old Cross-Cut Canal. This additional gate at 44th Street is

also expected to reduce the potential for breaks occurring at the 40th Street spillway and the area in the vicinity of 32nd Street.

4. Using the unsteady flow program "USTDY" (reference 6i) the alternatives were individually incorporated into the Arizona Canal system model. All inflows into the Arizona Canal from the inlet collector system and side drains were input into the model in the form of flood hydrographs. Various gate operation settings were modeled in an attempt to either eliminate or reduce, at the peak of the storm, potential breaks in the Arizona Canal system. These gate operation settings were modeled are made as close to the peak of the storm as possible (approximately 1 hour prior) to prevent disruption of SRP's normal operation. Six control structures that regulate flow were modeled for the study and are as follows: 1.) the 32nd Street gate, 2.) the 44th Street gate addition, 3.) the Old Cross-Cut Canal Diversion (with one additional gate), 4.) the Arizona Falls structure, 5.) the New Cross-Cut Diversion, and 6.) the Scottsdale gate. The upstream boundary is the inverted siphon at Indian Bend Wash. Three key operations in using the Arizona Canal for flood control purposes are 1.) reducing the flow from the siphon at Indian Bend Wash, 2.) opening the gates on the Old Cross-Cut Canal Diversion, and 3.) partially closing the proposed 44th Street gate to force a drawdown of the canal water back to and down the Old Cross-Cut Canal. These three Arizona Canal operations must be done simultaneously to ensure effective flood control with each of the design alternatives. Operation of the other control structures in the system varies depending on the frequency of the storm event.

5. With-project flood depths above the Arizona Canal for the Alley, Partial Lafayette, and Full Lafayette Alternatives are shown in Tables 1, 2, and 3 respectively. These depths were developed as a result of a combination of incident rainfall occurring below Lafayette Boulevard, runoff surcharging the inlet collector system or side drains, and Arizona Canal breakouts into the north overbank area for frequency events higher than the design. The majority of homes in this area have solid brick walls on their property lines. Therefore it was determined that runoff that reaches the Arizona Canal flows down streets, alleys, and through openings between homes. An "effective width" was established for the total conveyance widths and a Manning's "n" value of 0.030 was applied to these effective widths. Further, flood flows were redirected to adjacent subareas when either topography or limited "effective widths" prohibit all the runoff for that subarea from reaching the Arizona Canal. Slopes were calculated using ground elevations within 1000 feet of the Arizona Canal. Based on feedback information from the COE Economics Section, flood depths below 0.5 feet were determined to be non-damaging. Based on this information, it was determined that, for the alternatives studied, a 40-year level of protection could be provided above the Arizona Canal.

As requested by Planning Section C, with-project flood depths, below the Arizona Canal, were computed for the Alley Alternative under a 50-year storm (see Plate 4), and the Partial Lafayette Alternative under a 100-year storm (see Plate 5). Since it was determined that the degree of urbanization below the Arizona Canal for this study is similar to that of the ACDC Dreamy Draw to Cudia City Wash (reference 6g) drainage area, which is immediately to the west, the same 'n' value of 0.250 was applied to the normal depth computations. For the area bounded by the Arizona Canal to the east of the Old Cross-Cut Canal, the Old Cross-Cut Canal, Thomas Road, and 64th Street, the same analysis was used as in the without project overflow analysis (see reference 1d) with revised discharges. Flood depths were not significantly reduced by the project since flooding in this area is largely effected by the localized tributary runoff.

6. References:

a. Service Request (ESR) dated 4 Feb 1987, Request Number 87 2320 RH.

b. Service Request (ESR) dated 8 May 1987, Request Number FY87 2321.

c. Service Request (ESR) dated 1 Aug 1987, Request Number FY87 2322 RH.

d. CESPL-ED-HH Memorandum For Record (MFR) dated 29 June 1987, subject: Without Project Overflow Analysis for the Old Cross-Cut Canal Feasibility Study.

e. CESPL-ED-HH Memorandum For Record (MFR) dated 19 Dec 1986, subject: Old Cross-Cut Feasibility Study Reconnaissance Level Design and Project Overflows for Alternative Designs Nos. 3 and 4.

f. CESPL-ED-HH Memorandum For Record (MFR) dated 18 Aug 1986, subject: Old Cross-Cut Canal Feasibility Study Alternative Design Including Flood Operational Scenarios for the Arizona Canal.

g. CESPL-ED-HH Memorandum For Record (MFR) dated 17 Jan 1986, subject: Feasibility Overflow Study for the Old Cross-Cut Canal Project.

h. Topographic Mapping:

(1) Topo map of the Phoenix Metro Area dated 9/66, by Yost and Gardner Engineers with a scale of 1"=100' and 2 foot contour intervals.

(2) USGS Quadrangle maps for the Phoenix area with a scale of 1"=2000' and 10 foot contour intervals.

i. Barkau, Robert L., "A Mathematical Model of Unsteady Flow through a Dendritic Network", Fall 1985.

j. U.S. Army Corps of Engineers, Los Angeles District, Gila River Basin; Phoenix, Arizona and Vicinity (Incl. New River) Arizona Canal Diversion Channel Dreamy Draw to Cudia City Wash; Economic Analysis, March 1987.

Frank T. Lara

Frank T. Lara
Hydraulic Engineer, Unit 3

Glenn M. Mashburn

Glenn M. Mashburn
Supervisory Hydraulic Engineer

TABLE 1

SUBJECT: OLD X-CUT CANAL PROJECT | DATE: 6/5/87 | PAGE OF PAGES

SOURCE OF DATA: ALLEY ALTERNATIVE W/PROJECT RESIDUALS above the Az. Canal.

COMPUTED BY: FL | CHECKED BY: | SECTION:

LOCATION		EXISTING GATES $d_{w/25}^{*}$ 25-yr event	EXISTING GATES $d_{w/25}$ 50-yr event	44TH ST GATE ADDITION $d_{w/25}$ 25-yr event	44TH ST GATE ADDITION $d_{w/25}$ 50-yr event
61ST St	to 64TH St	0.17	2.10	0.28	2.10
60TH St	to 61ST St	0.17	1.10	0.27	1.10
59TH Pl	to 60TH St	0.18	0.50	0.28	0.50
56TH St	to CALLE CAMELIA	0.14	1.35	0.42	1.35
50TH Pl	to 55TH Pl	0.36	0.47	0.42	0.47
DROMEDARY RD	to 50TH Pl	0.36	0.49	0.42	0.49
46TH St	to DROMEDARY RD	0.25	0.57	0.37	0.57
44TH St	to 46TH St	0.37	0.61	0.30	0.52
CAMELBACK RD	to 44TH St	0.40	0.57	0.21	0.44
40TH St	to CAMELBACK RD	0.17	0.60	0.21	0.29

* BREAK OCCURS AT S. BANK SPILLWAY

REVISED 6/5/87

Note: These are average flood depths in the vicinity immediately north of the Arizona Canal.

WES FORM NO. 1114
JANUARY 1961

TABLE 2

SUBJECT: OLD X-CUT CANAL PROJECT

DATE: 6/5/87

PAGE OF PAGES

SOURCE OF DATA: * PARTIAL LAFAYETTE ~~OLD X-CUT~~ ALTERNATIVE W/PROJECT RESIDUALS above the Az Canal

COMPUTED BY: FL

CHECKED BY:

SECTION:

LOCATION	$d_{w/25}$ 25-yr flood	$d_{w/25}$ 40-yr flood	$d_{w/25}$ 50-yr event	$d_{w/40}$ 40-yr flood	$d_{w/40}$ 50-yr event	$d_{w/40}$ 100-yr event
61ST St to 64TH St	0.17	0.28	2.10	0.19	1.40	3.10
60TH St to 61ST St	0.17	0.27	1.10	0.19	0.85	2.50
59TH Pl to 60TH St	0.18	0.28	0.50	0.20	0.40	1.48
56TH St to CALLE CAMELIA	0.14	0.22	1.35	0.18	0.50	2.55
50TH Pl to 55TH Pl	0.36	0.42	0.47	0.41	0.47	0.50
DROMEDARY RD to 50TH Pl	0.36	0.42	0.48	0.41	0.48	0.60'
46TH St to DROMEDARY RD	0.25	0.37	0.52	0.27	0.44	0.70
44TH St to 46TH St	0.19	0.29	0.41	0.21	0.35	0.91
CAMELBACK RD to 44TH St	0.11	0.19	0.36	0.13	0.23	0.95
40TH St to CAMELBACK RD	0.16	0.20	0.33	0.18	0.37	0.72

REVISED 6/5/87

* Renamed

Note: These are average flood depths in the vicinity immediately north of the Arizona Canal.

WES FORM NO. 1114
JANUARY 1961

TABLE 3

SUBJECT: WITH PROJECT RESIDUALS ABOVE AZ. CANAL

DATE: 7/28/87

PAGE OF PAGES

SOURCE OF DATA: FULL LAFAYETTE ALTERNATIVE 25-YR DESIGN

COMPUTED BY: FL

CHECKED BY:

SECTION: HYDRAULICS

LOCATION	$d_{w/25}$ 25-YR EVENT	$d_{w/25}$ 50-YR EVENT	$d_{w/25}$ 100-YR EVENT
61ST St to 64TH St	0.17	2.10	3.88
60TH St to 61ST St	0.17	1.10	3.07
59TH Pl to 60TH St	0.18	0.50	2.00
56TH St to CALLE CAMELIA	0.14	1.35	2.28
50TH Pl to 55TH Pl	0.12	0.29	0.37
DROMEDARY RD to 50TH Pl	0.13	0.31	0.47
46TH St to DROMEDARY RD	0.25	0.52	0.82
44TH St to 46TH St	0.18	0.42	0.71
CAMELBACK RD to 44TH St	0.11	0.31	0.54
40TH St to CAMELBACK RD	0.17	0.25	0.33

Note: These are average flood depths in the vicinity immediately north of the Arizona Canal.

WES FORM NO 1114
JANUARY 1961

TABLE 1

SUBJECT	DATE	PAGE OF PAGES
OLD X-CUT CANAL PROJECT	6/5/87	

SOURCE OF DATA: ALLEY ALTERNATIVE W/PROJECT RESIDUALS above the Az. Canal.

COMPUTED BY	CHECKED BY	SECTION
FL		

	LOCATION	EXISTING GATES $d_{w/25}$* 25-yr event	EXISTING GATES $d_{w/25}$ 50-yr event	44TH ST GATE ADDITION $d_{w/25}$ 25-yr event	44TH ST GATE ADDITION $d_{w/25}$ 50-yr event
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CAMELBACK RD	to 44TH St	0.40	0.57	0.21	0.44
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* BREAK OCCURS AT S. BANK SPILLWAY

REVISED 6/5/87

Note: These are average flood depths in the vicinity immediately north of the Arizona Canal.

WES FORM NO. 1114
JANUARY 1961

TABLE 2

SUBJECT: OLD X-CUT CANAL PROJECT | DATE: 6/5/87 | PAGE OF PAGES

SOURCE OF DATA: * PARTIAL LAFAYETTE ~~OLD X-CUT~~ ALTERNATIVE W/PROJECT RESIDUALS above the Az Canal

COMPUTED BY: FL | CHECKED BY: | SECTION:

LOCATION	$d_{w/25}$ 25-yr flood	$d_{w/25}$ 40-yr flood	$d_{w/25}$ 50-yr event	$d_{w/40}$ 40-yr flood	$d_{w/40}$ 50-yr event	$d_{w/40}$ 100-yr event
61ST St to 64TH St	0.17	0.28	2.10	0.19	1.40	3.10
60TH St to 61ST St	0.17	0.27	1.10	0.19	0.85	2.50
59TH Pl to 60TH St	0.18	0.28	0.50	0.20	0.40	1.48
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50TH Pl to 55TH Pl	0.36	0.42	0.47	0.41	0.47	0.50
DROMEDARY RD to 50TH Pl	0.36	0.42	0.48	0.41	0.48	0.60'
46TH St to DROMEDARY RD	0.25	0.37	0.52	0.27	0.44	0.70
44TH St to 46TH St	0.19	0.29	0.41	0.21	0.35	0.91
CAMELBACK RD to 44TH St	0.11	0.19	0.36	0.13	0.23	0.95
40TH St to CAMELBACK RD	0.16	0.20	0.33	0.18	0.37	0.72

REVISED 6/5/87

* Renamed

Note: These are average flood depths in the vicinity immediately north of the Arizona Canal.

WES FORM NO. 1114
JANUARY 1961

TABLE 3

SUBJECT: WITH PROJECT RESIDUALS ABOVE AZ. CANAL

DATE: 7/28/87

PAGE ___ OF ___ PAGES

SOURCE OF DATA: FULL LAFAYETTE ALTERNATIVE 25-YR DESIGN

COMPUTED BY: FL

CHECKED BY:

SECTION: HYDRAULICS

LOCATION	$d_{w/25}$ 25-YR EVENT	$d_{w/25}$ 50-YR EVENT	$d_{w/25}$ 100-YR EVENT
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44TH St to 46TH St	0.18	0.42	0.71
CAMELBACK RD to 44TH St	0.11	0.31	0.54
40TH St to CAMELBACK RD	0.17	0.25	0.33

Note: These are average flood depths in the vicinity immediately north of the Arizona Canal

WEST FORM NO. 1114
JANUARY 1961

June '87

CESPLED-HH

MEMORANDUM FOR RECORD

SUBJECT: Without Project Overflow Analysis for the Old Cross Cut Canal Feasibility Study

1. References:

a. U.S. Army Corps of Engineers, Los Angeles District, "Report on Flood of 22 June 1972 in Phoenix Metropolitan Area, Arizona," Oct. 1972.

b. Hejl, H.R., Jr., "A Method of Adjusting Values of Manning's Roughness Coefficient for Flood Urban Areas," Journal of Research, USGS, Vol. 5, Sept.-Oct. 1977, p. 541-545 (Incl. 1).

c. U.S. Army Corps of Engineers, Los Angeles District, Gila River Basin; Phoenix, Arizona and Vicinity (Incl. New River) Arizona Canal Diversion Channel Dreamy Draw to Cudia City Wash; Economic Analysis, March 1987.

d. Topographic Mapping:

1. Topo Map of the Phoenix Metro Area dated 9/66, by the Cooper Aerial Survey Co., 1" = 100' and 2 feet contours.

2. USGS Quadrangle Maps for the Phoenix area with 1" = 2000' and 10 feet contours.

e. Aerial Photo Mapping:

Phoenix Metro Area dated June 9, 1984 by the Cooper Aerial Survey Co. with a scale of 1" = 200'.

2. The purpose of this (MFR) is to document pertinent information and assumptions made for the without-project overflow analysis for subject study. Specifically, flood inundation overflow information was developed for the present condition discharge frequencies of 25-, 50-, 100-year, and SPF. The study area is approximately bounded between 40th St. and Pinto Dr. and between the south side of Camelback Mountain to the Grand Canal. See plate 1.

3. The Old Cross Cut study area is located in the City of Phoenix, Arizona. The major waterways within the study area are the Arizona Canal, Arizona Cross Cut Canal, the Grand Canal, and the Old Cross Cut Canal. The eastern boundary was assigned based on the hydrologic determination that runoff to the east of Pinto Drive would run off and contribute to the Indian Bend Wash Drainage System. The western boundary was established at the Arizona Canal spillway immediately west of 40th Street. It was assumed that the ACDC Project would be completed in the near future and that it would provide flood protection west of 40th St.

4. The Arizona Canal has an approximate channel capacity of 1150 cfs upstream of the New Cross Cut Canal to 550 cfs at 40th Street. The canal is an earth type canal with gunite side slopes. In addition, the south bank of the canal is generally higher than the north bank. There is a service road on the top of each bank. Runoff generated by storms that are centered along the south side of the Camelback Mountain result in sheet flows that tend to pond behind the north bank under severe conditions. Flood waters eventually overtop the north bank and enter the Arizona Canal. As floodflows increase, the south bank is eventually overtopped at low points along the entire length of the canal system.

5. During the preliminary phase of the overflow analysis an assessment was made of the Arizona Canal in an attempt to identify the most likely break locations. This assessment included a detailed examination of ref. 1d(1) aerial mapping and field reconnaissance. Specifically, seven most probable break locations were determined through an analysis of a profile plot of the north bank, the south bank, and the ground point elevations behind the north bank. Low points on the south bank, in combination with a rise in elevation behind the north bank, formed the basis for a potential breakout condition.

6. Based on the location of the seven potential break points, the entire study area above the Arizona canal was divided into seven subdrainage areas. Hydrologic data, in terms of peak discharge information, was developed and is presented in table 1 (Attachment 1).

7. The initial hydraulic analysis of the area above the Arizona Canal was based on a computational water balance at each of the identified break locations. Specifically, this required that the flood inflow, flood outflow and volumetric storage be accounted for, in a progressive manner along the Arizona Canal, from the most eastern subdrainage areas to the west end of the study reach. The components of the water balance involved the following:

a. Flood inflow, for each subdrainage area, consisted of inflow hydrographs which were developed by the Hydrologic Section.

b. Flood outflow, for each subdrainage area, consisted of the water that breaks over the Arizona Canal plus the water that does not break over the canal but flows to the west along the canal. Note that westward flows translate into flood inflow for the adjacent subdrainage area.

8. Flood storage in and behind the Arizona Canal was also included in the routing process. Rating curves of elevation versus storage volume were initially developed from multiple HEC-2 backwater runs along the canal for each subdrainage area. The Hydrologic Section then used the HEC-1 program and the Modified Puls Method to route the individual water balance peak discharge values along the Arizona Canal for the entire study reach. The routed peak discharges were subsequently transformed into overflow inundation information using the HEC-2 Backwater Program.

9. The HEC-2 Backwater Program, with the Split Flow Option, was extensively used in developing water balance information at the seven break locations as well as for basic overflow information above the Arizona Canal. Cross section data was geometrically modeled using the mapping cited in ref. 1.d.(1). However, in areas where the sections needed to be extended outside of the Phoenix Metro topographic maps, USGS quad maps (ref. 1.d.(2)) were used. As an initializing condition, the cross sections inside the Arizona Canal were modified and coded to reflect only a floodwater surcharging capacity (capacity above normal canal flow). Thus, discharge rates provided from the hydrologic analysis, excluded normal canal flow. This technique helped minimize dealing directly with lateral irrigation distributions along the study reach. This modeling condition was implemented because the Arizona Canal is an irrigation canal which normally operates at full capacity. Also, bridge crossings were modeled as flow obstructions with no additional conveyance capability if surcharged.

Manning's roughness coefficients ("n" values) of 0.500 for the left overbank (top of service road) and 0.017 for the channel were used throughout the Arizona Canal's modeled study reaches. For the right overbank, which is highly urbanized, the "n" values were calculated using a procedure developed by the USGS and documented in an article titled "A Method for Adjusting Values of Manning's Roughness Coefficients for Flooded Urban Areas" (ref. 1b).

Also, aerial photos taken on 9 June 1984 (ref. 1.e.) were used to describe the floodplain structures to supplement the "n" value analysis. Typical "n" values ranged from 0.050 to 0.276. Table 1 (Attachement 2) identifies the "n" values and the approximate locations where they were applied in the initial backwater analysis.

10. An integral part of the water balance at the break locations is the expected configuration of the breaks themselves during the peak flood events. Based on a detailed assessment of profile information at and along the canal, historical flood photographs, and field inspections, it was judged that the breaks would assume a shape defined geometrically as being long and shallow. The base erosion elevation would be limited to and equal to the corresponding north bank height. However, if the north bank elevation was found to be greater than the south bank elevation, then no more than 1.5 foot of bank erosion was assumed to occur.

In support of these assumptions are photos shown in figure 1. These photos were taken during the 6 June 1972 Phoenix Flood and were extracted from the report cited in ref. 1.a. Even though the flood photos were not taken in the study reach they do show typical overtopping conditions that occurred nearby. Further, since the canal walls are gunited to within 1-2 feet of the top of the service road, it was expected that there would be enough structural resistance to breach flows to prevent the canal walls from eroding out substantially during the short duration storm event. Finally, it is important to note that there has been no recordable breakouts identified in this reach

of the Arizona Canal since it was constructed in 1883 (over 104 years ago). This may be partially attributable to the nonurbanized condition in the earlier project years and may be in part due to inadequate records between 1883 and 1917 (when SRP took over ownership).

11. A final item in the development of flood information above the Arizona Canal is the flood operational impact of the Old Cross Cut Canal at the Arizona Canal.

The Old Cross Cut Canal is a fully entrenched wasteway used for draining the Arizona Canal to the Grand Canal. It intersects the Arizona Canal at 48th Street with twin radial gates. The gates are each 13.5 feet wide with a trunion height of 6.0 feet. The gates can be remotely controlled to release water from the Arizona Canal into the Old Cross Cut Canal up to a maximum discharge of 800 cfs. An agreement between the City of Phoenix and the Salt River Project (SRP), limits the discharge to 1000 cfs should the gate capacity be expanded in the future.

The storm operation procedure that SRP follows is a function of a number of human factors that cannot be modeled with certainity. In short, the time factor in terms of when the gates are opened can potentially affect the degree of available flood protection both above and below the Arizona Canal.

The incorporation of SRP flood protection into the hydraulic analysis was done in the initial analysis by assuming the following:

a. The Old Cross Cut Canal gates were non-operational until floodflows exceeded the Arizona Canal capacity. At that time, the Old Cross Cut Canal gates would be instantly opened and the Old Cross Cut Canal would experience the first 1000 cfs of excess floodflows.

b. The backwater condition developed at the Old Cross Cut Canal on the Arizona Canal, was assessed for floodflows that occurred when the gates were in a fully open position.

12. On 16 May 1986, the Hydraulic Section issued an intra-agency request with HEC-Davis for Dr. Barkau's services in using his computer program USTDY. The need to use this program was necessary in order to evaluate feasibility level design alternatives which involved unsteady flow conditions. After the USTDY program had been modified to include revised improvements to the Arizona Canal and the boundary conditions properly modeled, the Program was re-ran forthe 40-year and above storm events. The resulted correlated closely with the results that were developed in the initial hydraulic analysis. The final without project inundation information is displayed on plates 2, 3, and 4.

13. Because the north bank of the Arizona Canal is generally higher than existing ground, it significantly hampers local runoff from entering the canal. For storm events of 40-year and greater, the surcharged Arizona Canal and right overbank system dominate the severity of inundation. However, for low frequency storm events, in the area of 25-year, nuisance ponding depths can range up to 3 feet behind the canal. For the study reach west of 56th Street, the area behind the canal was examined using previously cited topographic and aerial mapping information and the measured effective floodflow openings between the homes and property walls identified. The contributing runoff drainage areas were redefined based on a generalized equalization of the calculated flood depths at the canal. The extent of the 25-year flood overflow is displayed on plate 2. For the study reach east of 56th Street, flood overflow information behind the canal was developed by a backwater model. Most of the floodflows collected by the north bank of the canal are discharged into the canal at an immediately east of 56th Street. The overflow information is also shown on plate 2.

14. At the Arizona Canal break locations, it was assumed that the breakout flows would expand away from the breach (which ranged in width from 100 to 400 feet) at an angle of 45 degrees on each end. Further, it was anticipated that, as the floodflows followed the ground slope of the floodplain and expanded under the dispersal influence of a fully urbanized area with transverse streets, the floodflows would eventually decrease to a non-damaging depth. The tracking of the concentrated Arizona Canal breakout floodflows were terminated when the average flood depths reached 0.5 feet. The development of the average flood depth information was based on using broad, normal depth, cross sections that were located approximately perpendicular to the flow pattern corresponding to the expanding boundaries of the overland flow downstream of the breach sites. Since it was judged that the degree of urbanization, below the Arizona Canal, was similar to that of the ACDC Dreamy Draw to Cudia City Wash (Reach 4) drainage area immediately to the west as documented in ref. 1.c.), an "n" value of 0.250 was applied to all wide, shallow flow, normal depth, computations below the canal for this study. Pertinent flood information for each of the break locations are presented on plates 2, 3, and 4.

15. For the study area roughly bounded by the Arizona Canal breaks to the west of the Old Cross Cut Canal, the Old Cross Cut Canal, and the Grand Canal, flood routing and average flood depth information were computed using the same coordinated hydrologic-hydraulic analyses and procedures as presented in ref. 1.c. The reasonableness of the final flood boundaries and resultant average flood depths were affirmed through a comparability assessment of flood depths in the adjacent flood subdrainage areas. Average flood depths are tabulized and displayed on plates 2, 3, and 4.

16. The Old Cross Cut Canal is a fully entrenched wasteway for the Arizona Canal. Its approximate operational capacity is about 1000 cfs near the Arizona Canal and increases to roughy 2000 cfs at the Grand Canal. However, its current north south alignment intercepts runoff from the east. For large flooding events, runoff (from the east) that reaches the canal exceed its capacity and cross over the canal to the west. It was judged that the excess floodflows that cross over the canal do so along a broad crest bank frontal pattern and eventually contribute to the sheet flow conveyance condition in the west subdrainage areas.

Routed floodflows coming down and into the Old Cross Cut Canal from the east were uniformally distributed along the intercepting reach of the canal. The excess floodflows were converted to average flood depths along the Canal's right bank and along varying frontal path widths as the analysis progressed south to the Grand Canal. Just as in the procedures for sheet flow anlaysis, the derived average flood depths, along the canal's west bank, were based on normal depth using the characteristic slope in the vicinity and an "n" value of 0.250. Computed flood depth information is presented along the Old Cross Cut Canal for each of the flooding events and is displayed on plates 2, 3, and 4.

17. For the study area roughly bounded by the Arizona Canal to the east of the Old Cross Cut Canal, the Old Cross Cut Canal, and Thomas Road, flooding was judged to concentrate in a distinctive swale condition which outleted in the vicinity of Thomas Road and 48th Street to the Old Cross Cut Canal. Consequenty, a HEC-2 backwater model was deemed appropriate to best define the flooding conditions in this area. Model development was predicated upon the following:

a. The starting water surface elevations were computed by the slope area method.

b. Cross sections were established perpendicular to the direction of floodflow and incorporated USGS quad sheet information (ref. 1.d.(2)) for basic cross section geometry.

c. Manning's roughness coefficients were determined using the USGS procedure previously cited. Field inspection and the 1984 aerial mapping (ref. 1e) supplied input into the "n" value development.

Typical flood depth information at each cross section as well as the aerial extent of overflow inundation are shown on plates 2, 3, and 4 for each of the major frequency storm events.

18. Overflow information east of the Old Cross Cut Canal and below Thomas Road were not developed because: (1) the runoff in this area is in the form of localized sheetflow of less than 0.5 feet average depth and (2) the with and without project conditions would remain the same, yielding no project consequences in this area.

19. A field inspection of the Grand Canal indicated that it is basically a fully entrenched water distribution channel. Low spots, canal facilities, and obstructions were noted. The banks are uniformally graded along the top without any significant depression or low areas to concentrate flows overtopping the banks. In no case were the raised banks, observed in the field, high enough to cause significant ponding. Consequently, it was concluded that runoff from a major storm would travel directly across the Grand Canal without any major interference, ponding, or redirection.

20. For this study, the use of the without project overflow data must also take into consideration the following:

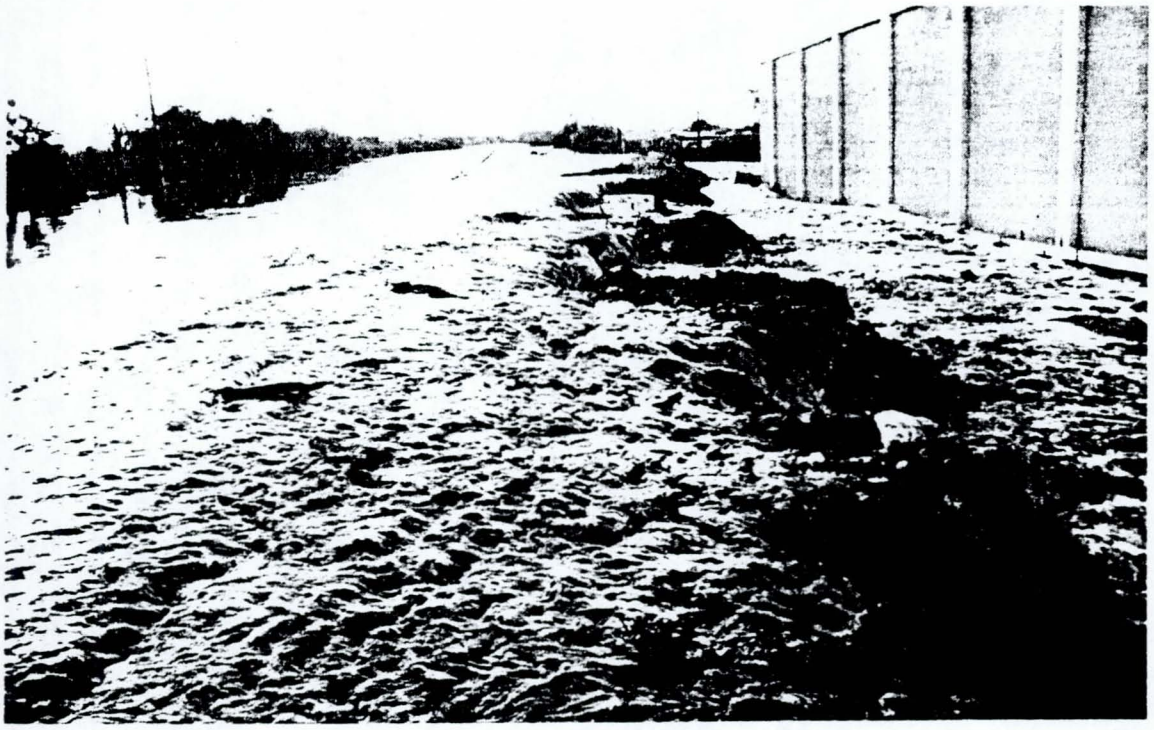
a. In the sheet flow floodplain area, below the Arizona Canal, additional flood depth information may be developed by linear interpolation.

b. In the sheet flow floodplain area, the overflow information is an idealized representation of the inundation for the subject floodplain. Average flood depths were computed over very wide cross sections using a simplified hydraulic analysis. Actual flood depths at any particular location will vary somewhat from the average depths indicated in the analysis because of local variations in topography. However, any error in the estimate of the flood damage from depths being greater or less than actual depths at a given location will be essentially cancelled out by the opposite behavior at another location.

GLENN M. MASHBURN
Supervisory Hydraulic Engineer

FIGURE 1

Children play in floodwaters that overtopped the Arizona Canal spillway on the south bank west of 40th Street in Phoenix.



Floodwaters and debris gush over the top of the southern bank of the Arizona Canal east of 16th Street in Phoenix.

ATTACHMENT #1

CP	LOCATION	SPF	EXCEEDENCE FREQUENCY 100-YR	50-YR	25-YR	10-YR
501	60th St.	3300	1500	1000	700	390
502	56th St.	1500	680	490	320	180
503	48th St.	4400	2000	1400	920	530
504	47th St.	1400	620	440	290	170
505	44th St.	2300	1000	730	480	270
506	40th St.	1400	620	440	290	170

SUBJECT: MANNING'S N FOR THE ARIZONA CANAL ROB

ATTACHMENT #2

DATE: [illegible] FILE NO.

PROJECT: OLD CROSS-CUT CANAL

CHECKED BY: DATE: SHEET NO. 2

— USGS METHOD —

N_u = ADJUSTED VALUE of Manning's "n" for Urban Areas

$N_o = 0.045$

EQUATION USED: $N_u = N_o \left[\frac{3}{2}\left(\frac{W_T}{\Sigma W_o}\right) + \left(1 - \frac{W_T}{\Sigma W_o}\right)\left(\frac{\Sigma L_o}{L_T}\right) - \frac{1}{2} \right]$

N_o = Roughness Coefficient Between obstructions
W_T = Total width of the x-section
W_o = Widths between obstruction
L_T = Total Length of the x-section
L_o = Individual Length Between obstructions

— EQ. FROM USGS. SURVEY Vol.5, No 5, oct 1977 —
Pg 341-345.

SECT NO FROM	SECT NO TO	ROB FROM	ROB TO	$W_T / \Sigma W_o$	$\Sigma L_o / L_T$	N_u
00	08	1000	2120	4.869	0.3375	0.247
00	08	2120	2800	2.5185	0.5625	0.109
08	14	1000	1370	1.3214	0.7000	0.057
08	14	1370	2800	3.7632	0.2000	0.207
14	20	1000	2310	3.3590	0.2667	0.176
14	20	2310	2800	5.444	0.3667	0.272
20	39	1000	2800	3.2727	0.2105	0.177
39	60	1000	2030	2.1458	0.1929	0.112
39	60	2030	2800	1.833	0.1548	0.095
60	70.3	1000	2060	4.9302	0.1942	0.276
60	70.3	2060	2800	1.6444	0.3951	0.077
70.3	79.3	1000	2060	1.963	0.2222	0.100
70.3	79.3	2060	3000	1.8431	0.3556	0.088
79.3	91.8	1000	2050	1.1351	0.6560	0.050
79.3	91.8	2050	3000	2.1591	0.2320	0.111
91.8	106.8	1000	2160	3.222	0.2933	0.156
91.8	106.8	2160	3000	1.750	0.6113	0.075
106.8	125.8	1000	2220	3.3969	0.2684	0.177
106.8	125.8	2220	3000	2.3626	0.2368	0.122
125.8	137.6	1000	3000	3.7736	0.3305	0.191
137.6	150	1000	1550	1.5714	0.5403	0.070
137.6	150	1550	3000	2.636	0.390	0.132
[illegible]	154.8	1000	3000	3.0769	0.3537	0.135
154.8	164.3	1000	3000	3.2707	0.2474	0.173
164.3	174.3	1000	3000	2.5641	0.250	0.133
[illegible]	184.1	1000	3000	2.6316	0.2449	0.137
184.1	196.5	1000	2220	1.7063	0.2661	0.095
184.1	196.5	2220	3000	2.2941	0.3333	0.115

WES FORM NO. 1253
REV OCT 1968

(cont. Attachment #2)

SUBJECT: (cont.)	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO 2/2

Sect No		ROB		W_T / ΣW_n	ΣL_n / L_T	N_m
FROM	TO	FROM	TO			
196.5	211.5	1000	3000	2.6316	0.2067	0.136
211.5	227	1000	3000	2.6667	0.3742	0.129
227	237	1000	3000	2.632	0.3000	0.133

NOTE:

ESTIMATE OF WIDTHS AND LENGTHS ARE FROM AERIAL SURVEY MAP FROM COOPER AERIAL SURVEY CO JUNE 9, 1984

THE RIGHT OVER BANK AREAS ARE DETERMINED BY TAKING SECTIONS THAT ARE PERPENDICULAR TO THE FLOW OF THE ARIZONA CANAL

THE LENGTHS AND WIDTHS FOR SOME SECTIONS WERE ESTIMATED SINCE THEY WERE NOT PARALLEL AND PERPENDICULAR TO THE FLOW RESPECTIVELY

TWO "N" VALUES WERE CALCULATED FOR SOME SECTIONS DUE TO THE CHANGE IN BUILDING DENSITIES

DIVISION OF AREAS WERE BASED ON BUILDING DENSITIES

DISPOSITION FORM

For use of this form, see AR 340-15; the proponent agency is TAGO.

REFERENCE OR OFFICE SYMBOL	SUBJECT
SPLED-HH	Completion of Old Cross-Cut Canal Reconnaissance Level Design Elements Including with Project Overflows

TO C, SPLPD
ATTN: C, SPLPD-W

FROM C, SPLED

DATE 18 December 1986

CMT 1
Mr. Mashburn/kh/5497

1. The work negotiated in Service Request (SR) No. 872311 RH, dated 1 Oct 1986, has been completed. Items 1 thru 3 of the (SR) were delivered on or before the requested dates to the Project Manager (Laura Herbranson).

2. Item No. 4, which dealt with the coordination with the local agencies in developing a recommended plan, was completed to the extent possible. Additional support in this area requires further data development and interactive guidance from the Project Manager and a new (SR).

3. For further information, please contact Glenn M. Mashburn, of my staff, at X5497.

Robert C. Zapli
NORMAN ARNO
for Chief, Engineering Division

Encl

DA FORM AUG 80 2496

PREVIOUS EDITIONS WILL BE USED

19 Dec. 1986

SPLED-HH

MEOMRANDUM FOR RECORD:

SUBJECT: Old Cross-Cut Feasibility Study Reconnaissance Level Design and Project Overflows for Alternative Designs Nos. 3 and 4

1. Reference:

a. Service Reguest (ESR) dated 1 Oct. 1986, Reguest Number 87 2311 RH.

b. SPLED-HH Memorandum For Record (MFR) dated 18 August 1986, subject: Old Cross-Cut Canal Feasibility Study Alternative Design Including Flood Operational Scenarios for the Arizona Canal.

c. SPLED-HH (MFR) dated 17 January 1986, subject: Feasibility Overflow Study for the Old Cross-Cut Canal Project.

d. Topographic Mapping:

(1) Topo map of the Phoenix Metro Area dated 9/66, by Yost and Gardner Engineers with a scale of 1"=100' and 2 foot contour intervals.

(2) USGS Quadrangle maps for the Phoenix area with a scale of 1"=2000' and 10 foot contour intervals.

e. HEC-2 cross sectional coding and Survey Notes on the Arizona Canal and the New Cross-Cut Canal supplied by the Salt River Project (SRP) Agency.

f. Barkau, Robert, L., "A Mathematical Model of Unsteady Flow through a Dendritic Network", Fall 1985.

2. The purpose of this MFR is to document pertinent information and assumptions made during the feasibility level hydraulic analysis for the Old Cross-Cut Canal Project. Planning Division, Water Resources Branch, Section C, issued an ESR (reference 1a), to the Hydraulic Section in which they requested the following:

a. Develop the residual overflows for the with-and without-project conditions for design Alternatives Nos. 3 and 4, as identified in reference 1b.

b. Develop a reconnaissance level design for the Old Cross-Cut Canal Channel between the Arizona Canal and the Salt River outlet.

c. Address the interior drainage problem on the north side of the Arizona Canal at a reconnaissance level.

d. Analyze the existing capacity of the Old Cross-Cut Canal between the Arizona and Grand Canals assuming that all of the bridges are removed.

19 Dec. 1986

SPLED-HH
SUBJECT: Old Cross-Cut Feasibility Study Reconnaissance Level Design and Project Overflows for Alternative Design Nos. 3 and 4

3. The residual overflows for design Alternatives Nos. 3 and 4 were modeled using an ideneified as USTDY. Unsteady state flow program The original north overbank cross sections for the Arizona Canal reach were modified and recoded into the computer program. These modifications eliminated the low points behind the north bank to an elevation that equaled the lowest adjacent north bank elevation. The low points were eliminated in order to expedite analysis since their existence exhibited minimal flow conveyance capacity. It was also assumed that these low depression areas would be filled with flood water by the rising limb of the storm hydrograph. The north overbank obstructions were modeled in the USTDY program using the computed Manning's 'n' values that were developed in refernce 1c.

4. Many areas above the north bank of the Arizona Canal have an existing ponding problem This is because the the north bank is higher than the existing ground and, as such, prevents natural drainage into the Canal. To reduce the flood inundation problem, side channel spillways were designed into the north bank. The spillway crest elevations were designed such that they matched the lowest south bank elevation on the opposite side. Both banks could not be reduced further since SRP is considering increasing the operational capacity of the canal. These spillway sections were sized to accomodate the contributing subarea peak discharge runoff at a 0.5 foot of head surcharge. However, side channel spillways will not eliminate all of the low point ponding problems. Consequently, the with-project conditions will still continue to have some residual ponding problems unless there is a collection system upstream that is integrated with the spillway desi concept. The study reach on the north side of the canal from 56th St. to 64th St. has serious flood inudation problem This is because the north bank is substantially higher relative to existing ground. In most of the reach, the canal banks are at least 5 feet higher than existing ground on the north side. Since runoff in this reach is impeded by the north bank, floodflows first pond then travels west, parallel to the Arizona Canal, until it reaches a relief point at 56th St. At this locations, flows either enter the canal and/or flow south via the bridge. Consequently, the overflow spillway design concept is not practical within the reach above 56th street because the spillway would be below the current operational level of the canal. For the with-project condition, an existing side channel, that runs parallel to the canal, would be improved to carry a greater discharge. However, the improved concrete rectangular channel, with increased grade, would be restricted in size by the limited right-of-way and would not be able to convey all of the peak discharge runoff for this reach. Along with the side channel, there would be a need for flap gates constructed in the north bank. But even with these features in place, there would still be some residual ponding that would continue to exist. In the 40-year operational design, (Alternative No. 3) north side ponding would be reduced by a 10 foot wide concrete rectangular channel. Its capacity would be 200 cfs at the upstream end and increases to 500 cfs at 56th St. In addition, 33 2-foot diameter flap gates spaced 100 feet apart, would also be required in the canal's north bank. The 100-year side channel design would consist of a 15 foot wide concrete rectangular channel with a capacity of 400 cfs on the upstream end and increases to 900 cfs at 56th St. As in the 40-year design, additional residual ponding reduction would require 33 2-foot diameter flap gates spaced at 100 feet apart. Again note, these design improvements do not totally eliminate the flooding inundation conditions on the north side of the Arizona Canal. They only lessen the extent of it. A much costly structural design alternati

is required to completely eliminate the interior drainage problem. Preliminary economic

feedback, for the with-and without-project overflow inundation comparison above the Arizona Canal, still resulted in limited benefit reduction because of the existing interior drainage problem.

5. The residual overflows for design Alternatives Nos. 3 and 4 were displayed on topo maps indicated in reference 1d(1). For both alternatives, the residual overflows were based on peak discharge flood flows. For the Arizona Canal flow exceedence conditions, it was assumed that the Arizona Canal gates would be operated in the same manner as during the optimum design conditions. Note, this assumption for flood operations may not be the optimum gate operations at the higher frequency storms events. For Alternative No. 3, which is the "additional plan component" operational at the 40-year storm event, residual overflows were generated for the 100-year with-project and 100-year without-project conditions. For the 100-year frequency storm, the USTDY model generated simulated breakouts at spillway No. 2 and at 44th St. Further, Arizona Canal breaks will also occur downstream of the study reach. For Alternative No. 3, the Old Cross-Cut Canal must be improved to accomodate the 40-year discharges as shown in Table 1. However, just below the Arizona Canal the 100-year with-project flood will exceed the downstream Old Cross-Cut channel capacity by 600 cfs. For design Alternative No. 4, which is "lowering of the invert", the 100-year design condition was analyzed for both the with-and without-project SPF storm event. The generated without-project residual analysis overflow confirmed the manitude and location of the generated breaks as presented in reference 1c. Within the study reach, the SPF with-project condition analysis simulated Arizona Canal breakouts at Spillway No. 2 and at 44th St. The with-project SPF residual overflow analysis east of 56th St. included provisions for structural measures to reduce the 100-year residual ponding conditions. The channel profiles and water surface profiles for both design Alternatives are shown on the work profiles. In addition, the location and size of the spillway sections are also displayed.

6. At and below the Arizona Canal, break locations where identified by bank surcharging. The simulated breaks were then geometrically modified as long and shallow reduced weir sections. The peak break discharges were then routed through the openings at a downstream lateral expansion flare angle of 45 degrees. Normal depth calculations were computed at three defined cross sections spaced at 100 feet apart. Below each identified Arizona Canal break location, depth and velocity information were displayed on the workmaps. Below the Arizona Canal immediate break locations, flood flows rapidly disperse across a broard front. But, because of the small associated discharges, there is relatively little to no change in the inundation pattern and depths downstream. Consequently, the flooding conditions would be simular to those exhibited in reference 1c. Table 3 illustrates approximate flood depth and velocity information below the Arizona Canal.

19 Dec. 1986

SPLED-HH

SUBJECT: Old Cross-Cut Feasibility Study Reconnaissance Level Design and Project Overflows for Alternative Designs Nos. 3 and 4

7. Improvements to the Old Cross-Cut Canal were investigated by Mr. Mauricio Munoz (SPLED-HH) at a reconnaissance level of detail. Three designs were investigated to improve the canal flood carrying capacity for design Alternatives Nos. 3. and 4. The designs involved the examination of the following: soft bottom trapezoidal channel; concrete lined trapazoidal channel; and concrete lined rectangular channel. The soft bottom and concrete lined trapazoidal channel were found to be infeasible because of limited right of way. The concrete lined rectangular channel option was sized using normal depth at an assumed 'n' value of 0.014. The design discharges are shown in Table 1. Bridge crossings were replaced by box culverts with similar channel base widths. The proposed channel conveys water from the Arizona Canal to the Salt River. The reconnaissance design were subsequently relased to the SPLED Design Section "A" for their cost analysis.

8. The existing capacity of the Old Cross Cut Canal with the bridges removed was also analyzed. The analysis was done using the HEC-2 program. The bridge sections and approaching bridge constrictions were modeled such that the replaced cross sections reflected an improved conveyance condition. Drop structures were left in placed and a Manning's 'n' value of 0.025 was used. Multiple computer runs were then performed to determine the capacity of the canal from the Arizona Canal to the Grand Canal. The capacity from the Grand Canal to Thomas Road is approximately 2500 cfs. From Thomas Road to the Arizona Canal the capacity drops to 2300 cfs. Note, increasing the canal's capacity will result in higher flow velocities that will inturn increase the canal's potential for developing erosion and bank stablility problems. The summary HEC-2 print is attached.

9. The residual overflows and the MFR, referenced in 1b, were presented to the Salt River Project and Maricopa County Flood Control District in Phoenix, Arizona on 27 and 28 of October 1986. The final residual overflow mappings were released by Craig Baba (formerly of SPLED-HH) to Laurn Herbranson (SPLPD-WC) on 4 November 1986.

GLENN M. MASHBURN
Supervisory Hydraulic Engineer

TABLE 1

OLD CROSS CUT CANAL RECONNAISSANCE FLOWS

CP	LOCATION	ALTERNATIVE #3 40 year (cfs)	ALTERNATIVE #4 100 year (cfs)
503	Old X Cut Junction	1400	2600
401	Thomas Road	2700	5000
302	McDowell Road	3300	6000
203	U.S of Grand Canal	4400	8100

Note: Received from Jody F. on 9/19/86.
CP = Concentration Point

REACH: FROM AZ CANAL TO GRAND CANAL

TABLE 2

SUMMARY PRINTOUT TABLE 150

	SECNO	XLCH	ELTRO	LLLC	ELMIN	Q	CWSEL	CRIWS	EG	10K*S	VCH	AREA	.01K
	1.000	0.00	0.00	0.00	1130.00	2500.00	1138.72	1137.07	1140.25	28.75	9.92	252.08	466.28
	6.500	550.00	0.00	0.00	1131.60	2500.00	1140.30	1138.67	1141.84	28.95	9.95	251.32	464.35
	8.800	230.00	0.00	0.00	1131.90	2500.00	1141.16	1138.57	1142.45	22.87	9.12	274.00	522.71
•	10.400	160.00	0.00	0.00	1135.20	2500.00	1142.39	1142.39	1145.18	64.07	13.41	186.44	312.33
•	12.000	160.00	0.00	0.00	1136.60	2500.00	1143.78	1143.78	1146.56	63.73	13.37	187.03	313.15
	13.000	100.00	0.00	0.00	1137.50	2500.00	1145.79	1143.69	1147.06	22.85	9.06	275.90	523.05
	14.000	100.00	0.00	0.00	1138.00	2500.00	1145.28	1145.02	1147.77	56.15	12.68	197.19	333.62
•	16.000	200.00	0.00	0.00	1140.00	2500.00	1146.87	1146.87	1149.42	63.04	12.83	194.80	314.88
	18.000	200.00	0.00	0.00	1138.70	2500.00	1149.01	1146.49	1150.25	21.99	8.95	279.37	533.08
	22.000	400.00	0.00	0.00	1139.70	2500.00	1149.81	1147.39	1151.21	23.78	9.49	263.56	512.62
	22.900	90.00	0.00	0.00	1139.94	2500.00	1150.06	1147.62	1151.45	29.69	9.47	264.11	458.79
	23.000	10.00	0.00	0.00	1135.25	2500.00	1150.53	1143.08	1151.57	7.95	8.18	305.69	886.76
	23.660	66.00	0.00	0.00	1135.25	2500.00	1150.60	1143.08	1151.63	7.87	8.15	306.90	891.21
•	23.680	2.00	0.00	0.00	1146.75	2500.00	1154.60	1154.60	1158.56	46.36	15.97	156.52	367.16
	24.000	31.00	0.00	0.00	1146.75	2500.00	1158.81	1153.39	1159.56	4.65	6.95	359.60	1159.25
	24.630	94.00	0.00	0.00	1146.75	2500.00	1158.86	1153.37	1159.61	4.59	6.92	361.46	1167.49
	24.730	10.00	0.00	0.00	1146.93	2500.00	1158.86	1153.55	1159.62	4.78	7.02	356.02	1143.25
	25.000	27.00	0.00	0.00	1147.10	2500.00	1159.15	1153.41	1159.66	6.37	5.74	435.43	990.15
	28.000	300.00	0.00	0.00	1148.00	2500.00	1159.06	1155.53	1160.12	16.21	8.25	303.11	621.01
	30.000	200.00	0.00	0.00	1148.20	2500.00	1159.39	1155.88	1160.44	16.20	8.23	303.72	621.16
	34.350	437.00	0.00	0.00	1149.00	2500.00	1159.76	1157.03	1161.24	11.44	9.77	255.93	739.14
	34.400	5.00	0.00	0.00	1149.25	2500.00	1159.72	1157.27	1161.30	12.48	10.08	247.93	707.75
	34.410	1.00	0.00	0.00	1149.25	2500.00	1159.72	1157.26	1161.30	12.47	10.08	247.96	707.89
	34.460	5.00	0.00	0.00	1149.25	2500.00	1159.73	1157.26	1161.31	12.44	10.07	248.18	708.73
	34.500	5.00	0.00	0.00	1149.40	2500.00	1160.47	1157.01	1161.48	7.24	8.08	309.45	929.38
	36.000	150.00	0.00	0.00	1149.69	2500.00	1160.51	1157.37	1161.67	8.51	8.63	289.79	857.10
•	36.450	45.00	0.00	0.00	1149.84	2500.00	1158.95	1158.95	1163.52	151.08	17.14	145.82	203.39
	36.500	5.00	0.00	0.00	1149.92	2500.00	1162.66	1154.01	1163.87	10.43	8.81	283.75	774.08
	37.000	54.00	0.00	0.00	1149.92	2500.00	1162.73	1154.01	1163.92	10.32	8.77	284.95	778.05
•	37.030	3.00	0.00	0.00	1156.50	2500.00	1164.16	1164.16	1167.04	81.17	13.64	183.33	277.49
	44.000	697.00	0.00	0.00	1158.16	2500.00	1168.52	1165.83	1169.79	21.20	9.07	275.71	543.00
	45.200	120.00	0.00	0.00	1158.45	2500.00	1168.66	1166.14	1169.99	10.36	9.25	270.24	776.85
	45.300	10.00	0.00	0.00	1158.49	2500.00	1168.68	1166.13	1170.00	10.32	9.24	270.58	778.18
	45.400	10.00	0.00	0.00	1158.45	2500.00	1168.69	1166.13	1170.01	10.29	9.23	270.93	779.52
	45.420	5.00	0.00	0.00	1158.53	2500.00	1168.67	1166.20	1170.04	10.74	9.39	266.14	762.86
	46.000	58.00	0.00	0.00	1158.66	2500.00	1168.70	1166.38	1170.16	25.19	9.71	257.44	498.07
	[illegible]	200.00	0.00	0.00	1160.00	2500.00	[illegible].98	1167.68	1170.91	36.97	11.15	224.[illegible]	411.16
	[illegible]	200.00	0.00	0.00	1161.00	2500.00	[illegible].41	1168.94	1171.99	54.06	12.89	19[illegible]	340.01
	52.000	200.00	0.00	0.00	1160.10	2500.00	1171.70	1167.77	1172.64	13.97	7.79	321.[illegible]4	668.95
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	56.15	12.20	145.36	333.62

53.560	5.00	0.00	0.00	1156.24	2500.00	1173.20	1165.33	1174.52	11.62	9.21	271.33	733.27
54.000	44.00	0.00	0.00	1156.24	2500.00	1173.26	1165.33	1174.57	11.52	9.18	272.32	736.50
* 54.030	3.00	0.00	0.00	1167.07	2500.00	1174.11	1174.11	1176.61	77.11	12.70	196.89	284.70

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SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	10K*S	VCH	AREA	*01K
55.500	447.00	0.00	0.00	1168.40	2500.00	1177.07	1175.96	1179.03	38.60	11.23	222.54	402.40
55.620	2.00	0.00	0.00	1168.42	2500.00	1177.04	1175.98	1179.08	18.54	11.46	218.11	580.57
55.940	32.00	0.00	0.00	1168.42	2500.00	1177.30	1175.98	1179.18	16.61	11.02	226.95	613.48
60.000	10.00	0.00	0.00	1168.51	2500.00	1177.27	1176.14	1179.24	17.81	11.26	222.01	592.43
62.000	200.00	0.00	0.00	1169.00	2500.00	1177.98	1176.56	1179.74	33.36	10.63	235.11	432.87
66.500	450.00	0.00	0.00	1170.00	2500.00	1179.49	1177.72	1181.18	30.63	10.42	239.87	451.75
66.900	40.00	0.00	0.00	1170.10	2500.00	1179.62	1177.77	1181.27	13.70	10.31	242.47	675.50
67.100	20.00	0.00	0.00	1170.10	2500.00	1179.67	1177.77	1181.30	13.48	10.25	243.92	681.04
67.380	28.00	0.00	0.00	1170.10	2500.00	1179.78	1177.77	1181.36	12.91	10.09	247.79	695.87
67.540	16.00	0.00	0.00	1170.30	2500.00	1179.86	1177.89	1181.39	12.65	9.92	251.92	702.93
68.000	50.00	0.00	0.00	1170.42	2500.00	1179.90	1178.05	1181.51	29.06	10.17	245.85	463.80
70.690	269.00	0.00	0.00	1171.05	2500.00	1180.71	1178.71	1182.28	27.97	10.06	248.45	472.73
71.200	51.00	0.00	0.00	1171.05	2500.00	1180.92	1178.71	1182.40	11.91	9.76	256.06	724.34
71.500	31.00	0.00	0.00	1171.27	2500.00	1180.88	1179.01	1182.56	30.29	10.41	240.27	454.26
76.000	450.00	0.00	0.00	1172.40	2500.00	1182.39	1180.05	1183.80	24.31	9.54	262.01	507.07
77.350	135.00	0.00	0.00	1172.64	2500.00	1182.32	1180.00	1184.46	20.24	11.73	213.11	555.63
77.400	5.00	0.00	0.00	1167.86	2500.00	1184.12	1175.21	1184.88	5.20	6.99	357.73	1095.99
78.080	68.00	0.00	0.00	1167.86	2500.00	1184.16	1175.21	1184.92	5.17	6.97	358.62	1099.46
* 78.090	1.00	0.00	0.00	1178.20	2500.00	1185.55	1185.55	1189.26	43.35	15.47	161.64	379.70
78.110	2.00	0.00	0.00	1179.20	2500.00	1188.69	1186.38	1189.99	10.38	9.14	273.49	776.03
78.640	146.00	0.00	0.00	1179.20	2500.00	1188.96	1186.37	1190.16	5.33	8.79	284.26	818.26
79.340	70.00	0.00	0.00	1179.20	2500.00	1189.07	1186.38	1190.24	8.94	8.66	288.74	836.01
80.100	76.00	0.00	0.00	1179.37	2500.00	1188.93	1187.09	1190.61	30.20	10.38	240.83	454.91
84.000	192.00	0.00	0.00	1181.00	2500.00	1189.07	1188.67	1191.64	54.68	12.86	194.38	338.09
87.000	300.00	0.00	0.00	1181.00	2500.00	1191.46	1188.71	1192.73	20.88	9.04	276.61	547.12
90.000	300.00	0.00	0.00	1182.20	2500.00	1191.94	1189.96	1193.57	28.94	10.24	244.20	464.74

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SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	10K*S	VCH	AREA	*01K
* 93.900	390.00	0.00	0.00	1183.31	2500.00	1192.40	1192.40	1196.99	56.14	17.20	145.38	333.66
93.950	5.00	0.00	0.00	1178.73	2500.00	1196.07	1187.82	1197.33	11.03	9.02	277.27	752.78
94.000	5.00	0.00	0.00	1178.73	2500.00	1196.08	1187.81	1197.34	10.99	9.00	277.70	754.17
94.290	29.00	0.00	0.00	1178.73	2500.00	1196.11	1187.81	1197.37	10.95	8.99	278.10	755.48
94.330	4.00	0.00	0.00	1178.73	2500.00	1196.12	1187.81	1197.37	10.94	8.99	278.23	755.92
[illegible]	45.00	0.00	0.00	1178.73	2500.00	[illegible]96.18	1187.81	1197.42	10.86	8.96	279[illegible]	758.58
* [illegible]	1.00	0.00	0.00	1188.40	2500.00	[illegible]6.02	1196.02	1198.85	29.50	13.52	1[illegible]	460.28
[illegible]	159.00	0.00	0.00	1188.50	2500.00	1196.57	1196.43	1199.58	65.58	13.92	179.58	307.77

98.000	200.00	0.00	0.00	1189.50	2500.00	1198.87	1197.21	1200.59	31.50	10.51	237.80	445.44
102.000	200.00	0.00	0.00	1190.50	2500.00	1201.11	1196.14	1201.67	7.39	6.00	416.80	919.47
104.000	200.00	0.00	0.00	1191.00	2500.00	1200.68	1198.54	1202.21	26.85	9.94	251.60	482.47
106.000	200.00	0.00	0.00	1191.60	2500.00	1201.32	1199.15	1202.74	25.05	9.59	260.76	499.06
108.000	200.00	0.00	0.00	1192.15	2500.00	1201.81	1199.70	1203.26	25.57	9.65	258.96	494.36
110.000	200.00	0.00	0.00	1192.70	2500.00	1202.26	1200.32	1203.82	27.98	10.03	249.31	472.63
114.000	400.00	0.00	0.00	1193.80	2500.00	1203.36	1201.49	1205.00	29.66	10.29	242.86	459.07
120.000	600.00	0.00	0.00	1195.50	2500.00	1205.27	1202.97	1206.60	23.05	9.23	270.80	520.70
126.000	600.00	0.00	0.00	1197.10	2500.00	1206.63	1204.68	1208.17	27.57	9.95	251.27	476.11
132.000	600.00	0.00	0.00	1198.70	2500.00	1207.74	1206.27	1209.51	15.68	10.66	234.48	631.44
132.100	10.00	0.00	0.00	1199.00	2500.00	1208.65	1205.65	1209.72	7.99	8.32	300.39	884.62
132.160	6.00	0.00	0.00	1199.00	2500.00	1208.66	1205.64	1209.73	7.95	8.31	300.87	886.54
132.940	78.00	0.00	0.00	1199.00	2500.00	1208.76	1205.65	1209.80	7.66	8.20	304.89	902.99
132.000	6.00	0.00	0.00	1200.10	2300.00	1208.70	1206.37	1209.87	9.77	8.70	264.35	735.68
* 138.000	500.00	0.00	0.00	1200.60	2300.00	1208.58	1208.58	1211.51	67.74	13.73	167.57	279.45
140.000	200.00	0.00	0.00	1201.50	2300.00	1210.77	1209.27	1212.57	34.98	10.76	213.83	388.87
142.000	200.00	0.00	0.00	1202.00	2300.00	1211.74	1209.57	1213.21	26.56	9.71	236.81	446.27

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SECNO	XLCH	ELTRC	ELLC	ELMIN	Q	CWSEL	CRTWS	EG	10K*S	VCH	AREA	.01K
144.000	200.00	0.00	0.00	1202.38	2300.00	1212.76	1209.41	1213.65	19.42	7.57	303.90	605.66
146.000	200.00	0.00	0.00	1202.50	2300.00	1212.89	1210.03	1214.07	19.99	8.72	263.75	514.43
148.000	200.00	0.00	0.00	1203.00	2300.00	1213.18	1210.92	1214.60	25.60	9.56	240.58	454.56
150.000	200.00	0.00	0.00	1203.75	2300.00	1213.56	1211.77	1215.25	31.85	10.42	220.69	407.52
152.000	200.00	0.00	0.00	1204.00	2300.00	1214.70	1211.62	1215.77	17.85	8.33	276.15	544.39
154.000	200.00	0.00	0.00	1204.50	2300.00	1214.98	1212.09	1216.20	20.58	8.84	260.23	507.01
156.000	200.00	0.00	0.00	1205.20	2300.00	1215.30	1212.98	1216.71	25.05	9.51	241.92	459.50
157.400	140.00	0.00	0.00	1205.50	2300.00	1215.63	1213.34	1217.10	26.48	9.74	236.04	446.96
158.700	130.00	0.00	0.00	1205.50	2300.00	1216.04	1213.34	1217.36	10.51	9.21	249.81	709.59
158.920	22.00	0.00	0.00	1205.50	2300.00	1216.08	1213.35	1217.38	10.40	9.17	250.75	713.19
159.460	54.00	0.00	0.00	1205.50	2300.00	1216.18	1213.35	1217.45	9.95	9.04	254.53	727.72
159.560	10.00	0.00	0.00	1205.50	2300.00	1216.20	1213.36	1217.46	9.95	9.02	254.87	729.03
* 161.000	144.00	0.00	0.00	1208.10	2300.00	1215.84	1215.84	1218.73	67.18	13.65	168.54	280.62
162.000	600.00	0.00	0.00	1209.30	2300.00	1219.88	1217.73	1221.52	31.57	10.27	223.87	409.33
165.700	370.00	0.00	0.00	1210.20	2300.00	1221.48	1217.69	1222.32	13.03	7.33	313.76	637.19
* 172.260	700.00	0.00	0.00	1218.00	2300.00	1226.07	1226.07	1228.83	65.69	13.34	172.45	283.78
* 175.000	274.00	0.00	0.00	1219.82	2300.00	1227.90	1227.90	1230.65	65.29	13.31	172.84	284.65
178.000	580.00	0.00	0.00	1221.64	2300.00	1231.66	1230.05	1233.42	34.33	10.67	215.51	392.52
* 184.400	600.00	0.00	0.00	1226.00	2300.00	1236.08	1236.08	1239.21	72.43	14.19	162.11	270.26
184.700	36.00	0.00	0.00	1226.30	2300.00	1238.90	1235.08	1239.90	7.38	8.05	285.56	846.48
184	7.00	0.00	0.00	1229.42	2300.00	[illegible].50	1237.09	1240.31	16.41	10.78	213.[illegible]	567.72
18[illegible]	15.00	0.00	0.00	1229.42	2300.00	[illegible].58	1237.09	1240.35	15.96	10.67	215[illegible]	575.65
184.[illegible]50	1.00	0.00	0.00	1229.42	2300.00	1238.58	1237.09	1240.35	15.96	10.67	215.50	575.80
185.780	86.00	0.00	0.00	1229.42	2300.00	1238.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	185.930	15.00	0.00	0.00	1228.6(	2300.00	1239.35	1236.72	1240.64	10.37	9.10	252.88	714.18
*	186.300	37.00	0.00	0.00	1229.9(	2300.00	1239.97	1239.97	1243.13	73.40	14.26	161.24	268.46

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	SECNO	XLCH	ELTRD	ELLC	ELMIN	Q	CWSEL	CRIWS	EG	10K*S	VCH	AREA	.01K
	185.000	600.00	0.00	0.00	1232.7(	2300.00	1244.37	1242.33	1245.99	30.49	10.23	224.82	416.53
*	156.450	145.00	0.00	0.00	1235.3(	2300.00	1244.88	1244.88	1247.95	71.10	14.06	163.55	272.77
	191.900	145.00	0.00	0.00	1237.9(	2300.00	1247.60	1244.50	1248.60	16.45	8.02	286.83	567.07

TABLE 3

REVISED DEPTHS FOR OLD XCUT	DATE 11/14/86	PAGE OF PAGES	
CE OF DATA BELOW AZ CANAL			
OMPUTED BY C.B F.L	CHECKED BY	SECTION HYDRAULICS	

CP	Q SRFT	DN	DC	Q	DN	DC	N	B	S
	V= 0.49			V= 0.36					
A07	2100	0.68	0.15	930	[redacted]	0.09	.174	6300	.0056
406	1500 V= 0.44	0.53	0.11	690 V= 0.31	[redacted]	0.07	.174	6600	.0054
401 REACH									
1	4300	1.91	0.63	1750	1.17	0.35	.134	1500	0.0077
2	4802	1.50	049	1954	0.88	0.27	.134	2500	0.0077
3	5305	0.99	0.38	2113	0.57	0.21	.097	4000	0.0077
307	1800 V= 0.45	0.63	0.13	810 V= 0.32	0.39	0.08	.174	6400	0.0050
306	1800 V= 0.58	0.46	0.13	820 V= 0.44	0.28	0.08	.119	6700	0.0063
25	3300	0.78	0.32	1300	0.45	0.17	0.087	3200	0.0063
202 REACH									
1	1005	—	—	409	—	—	—	—	—
2	879	1.02	0.27	358	0.59	0.15	.174	1100	0.0063
3	816	1.04	0.26	332	0.60	0.14	.174	1100	0.0077
207	2100	0.63	0.15	960	0.39	0.09	.174	6500	[illegible]
206	2200	0.51	0.15	970	0.31	0.15	.119	7000	0.0059
205	3100	0.85	0.34	1500	0.55	0.21	[illegible]	2700	0.0077
204	900	0.29	0.11	410	0.16	0.07	[illegible]	4300	0.0091
203 REACH 1	428	[illegible]	0.17	187	[illegible]	0.09	.174	1100	0.010
2	426	0.61	[illegible]	187	[illegible]	0.08	.174	1300	0.0077
3	643	0.56	[illegible]	250	[illegible]	0.11	.087	1200	0.0059
4	643	[illegible]	[illegible]	250	0.27	0.10	.087	1300	0.010
5	723	[illegible]	[illegible]	[illegible]	[illegible]	0.12	.087	[illegible]	[illegible]
6	723	[illegible]	[illegible]	[illegible]	[illegible]	0.14	.087	[illegible]	0.0077

WES FORM NO. 1114
JANUARY 1961

TABLE 3

REVISED DEPTHS FOR OLD XCUT	DATE 11/14/86	PAGE OF PAGES

SOURCE OF DATA: BELOW AZ CANAL

COMPUTED BY	CHECKED BY	SECTION
C.B F.L.		HYDRAULICS

CP	Q SPF	DN	DC	Q 100	DN	DC	N	B	S
	V_{SPF} = 0.49			V_{100} = 0.36					
A07	2100	0.68	0.15	930	[redacted]	0.09	.174	6300	.0056
A06	1500	0.53	0.11	690	[redacted]	0.07	.174	6800	.0054
	V= 0.44			V= 0.31					
A01 REACH									
1	4300	1.91	0.63	1750	1.11	0.35	.134	1500	0.0077
2	4802	1.50	049	1954	0.88	0.27	.134	2500	0.0077
3	5305	0.99	0.38	2113	0.57	0.21	.097	4000	0.0077
307	1800	0.63	0.13	210	0.39	0.08	.174	6400	0.0050
	V= 0.45			V= 0.32					
306	1800	0.46	0.13	820	0.28	0.08	.119	6700	0.0063
	V= 0.58			V= 0.44					
305	3300	0.78	0.32	1300	0.45	0.17	0.087	3200	0.0083
202 REACH									
1	1005	—	—	409	—	—	—	—	—
2	879	1.02	0.27	358	0.59	0.15	.174	1100	0.0083
3	816	1.04	0.26	332	0.60	0.14	.174	1100	0.0077
207	2100	0.63	0.15	160	0.39	0.09	.174	6500	0.0077
206	2200	0.51	0.15	970	0.31	0.15	119	7000	0.0059
205	3100	0.85	0.34	1500	0.55	0.21	0.087	2700	0.0077
204	900	0.29	0.11	410	0.18	0.07	0.087	4300	0.0091
203 REACH 1	428	0.60	0.17	157	0.35	0.09	.174	1100	0.010
2	426	0.61	0.15	167	0.35	0.08	.174	1300	0.0077
3	643	0.56	0.21	250	0.33	0.11	.087	1200	0.0059
4	643	[illegible]	[illegible]	252	0.27	0.10	.087	1300	0.010
5	723	0.56	[illegible]	255	[illegible]	0.12	.087	[illegible]	0.0077
6	727	[illegible]	[illegible]	[illegible]	[illegible]	0.14	.087	[illegible]	0.0077

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TABLE 3

REVISED DEPTHS FOR OLD X CUT	DATE 11/14/86	PAGE OF PAGES

SOURCE OF DATA: BELOW AZ CANAL

COMPUTED BY	CHECKED BY	SECTION
L.B F.L.		HYDRAULICS

CP	Q SPF	Dn	Dc	Q 100	Dn	Dc	N	B	S
	V max = 0.49			V max = 0.36					
407	2100	0.68	0.15	930	[redacted]	0.09	.174	6300	.0056
406	1500 V = 0.44	0.53	0.11	690 V = 0.31	[redacted]	0.07	.174	6800	.0054
401 REACH									
1	4300	1.91	0.63	1750	1.11	0.35	.134	1500	0.0077
2	4802	1.50	049	1954	0.88	0.27	.134	2500	0.0077
3	5305	0.99	0.38	2113	0.57	0.21	.097	4000	0.0077
307	1800 V = 0.45	0.63	0.13	810 V = 0.32	0.39	0.08	.174	6400	0.0050
306	1800 V = 0.58	0.46	0.13	820 V = 0.44	0.28	0.08	.119	6700	0.0063
305	3300	0.78	0.32	1300	0.45	0.17	0.087	3200	0.0063
202 REACH									
1	1005	—	—	409	—	—	—	—	—
2	879	1.02	0.27	358	0.59	0.15	.174	1100	0.0063
3	816	1.04	0.26	332	0.60	0.14	.174	1100	0.0077
207	2100	0.63	0.15	160	0.39	0.09	.174	6500	0.0057
206	2200	0.51	0.15	970	0.31	0.15	119	7000	0.0059
205	3100	0.85	0.34	1500	0.55	0.21	0.087	2700	0.0077
204	900	0.29	0.11	410	0.16	0.07	0.087	4300	0.0041
203 REACH 1	428	0.60	0.17	197	0.35	0.09	.174	1100	0.010
2	428	0.61	[illegible]	167	[illegible]	0.08	.174	1300	0.0077
3	643	0.56	0.21	250	0.35	0.11	.087	1200	0.0051
4	643	[illegible]	0.22	250	0.27	0.10	.087	1300	0.010
5	729	0.56	[illegible]	[illegible]	[illegible]	0.12	.087	[illegible]	0.0077
6	729	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.087	[illegible]	0.0077

WES FORM NO. 1114
JANUARY 1961

OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

TECHNICAL DOCUMENTATION

SECTION C

GEOTECHNICAL

Prepared by
Los Angeles District
South Pacific Division
Corps of Engineers
Department of the Army

US Army Corps
of Engineers
Los Angeles District

OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

APRIL 1988

GEOTECHNICAL FEASIBILITY REPORT

OLD CROSS-CUT CANAL
PHOENIX, ARIZONA

GEOTECHNICAL
FEASIBILITY REPORT

APRIL 1988

OLD CROSS-CUT CANAL
PHOENIX, ARIZONA

GEOTECHNICAL
FEASIBILITY REPORT

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OLD CROSS-CUT CANAL
PHOENIX, ARIZONA

GEOTECHNICAL
FEASIBILITY REPORT

1. INTRODUCTION

1.1 Purpose and Scope. This report presents a feasibility level geotechnical assessment of the proposed flood control improvements to Old Cross-Cut Canal, the Arizona Canal, and the area immediately north of the Arizona Canal. This evaluation is based on review of (1) geologic literature, (2) groundwater well data, (3) subsurface logs prepared by the City of Phoenix for local storm drain projects in the vicinity, (4) visual site inspection, (5) design parameters developed for the Arizona Canal Diversion Channel (ACDC), and (6) local production of concrete and other construction materials. The report describes the site conditions, presents design considerations, list sources of materials, and provides conclusions and recommendations.

1.2 Location and Description. This project is located on the east side of Phoenix, Arizona. General boundaries for the area north of the Arizona Canal, which will require a storm drain collector system, are Invergordon Road to the east, 44th Street to the west, Lafayette Boulevard to the north, and the Arizona Canal to the south. Old Cross-Cut Canal, which runs on a north south alignment, parallels 48th street from the Arizona Canal south to McDowell Road. The canal then shifts one block to the west and proceeds southward to the Salt River. A project vicinity map is presented on plate 1.

There are three alternatives for the storm drain collector system north of the canal:

1. The Alley Alternative consists of a two-branch collection system along with lowering the north bank of the Arizona Canal between Dromedary Road and 55th Place. The west branch has six conduits (approximately 4 feet in diameter), ranging from 1000 to 2000 feet in length, collecting runoff and discharging directly into the Arizona Canal. The conduits will be located in alleyways between 40th Street and Dromedary Road. The east branch, a single conduit approximately 7200 feet in length starting at Invergordon Road, will parallel Lafayette Boulevard westward to 56th Street and then turn southward along 56th to the Arizona Canal. The conduit will be approximately 10 by 10 foot by the time it discharges into the canal. All runoff flows contained in the Arizona Canal will be routed down the improved Old Cross-Cut Channel to the Salt River.

2. The Partial Lafayette Alternative is also a two branch collection system. However, the west branch, instead of running six conduits down the alleyways, will consist of a main conduit starting at 44th Street and paralleling Lafayette Boulevard eastward to 48th Street and then turning southward to the Arizona

Canal. The east branch of the collection system is the same as described in the Alley Alternative. The north bank of the canal will be lowered between Dromedary Road and 55th Place to allow direct runoff of surface flows into the canal.

3. The Full Lafayette Alternative consists of a collection system aligned along Lafayette Boulevard with 44th Street and Invergordon being the origins for the west and east conduits, respectively. The westward and eastward flows will meet at Arcardia Drive and then turn southward toward the Arizona Canal and Old Cross-Cut intersection. An inverted siphon will be used to cross under the Arizona Canal and discharge directly into the Old Cross-Cut Canal. No improvements are required to the Arizona Canal.

In all of the alternatives mentioned above, improvements to Old Cross-Cut Canal would be needed. These improvements would extend from the Arizona Canal to McDowell Road (Sta 191+90 to Sta 76+00). Two alternatives for these improvements will be evaluated. The first is a 1V : 1H grouted stone channel and the second is a covered concrete box approximately 10 by 10 foot. Both alternatives follow the existing alignment and will fit within the given right-of-way.

2. GENERAL SITE CONDITIONS

2.1 Topography and Geology. The project area is located on a gently sloping alluvial apron which extends about 5 miles from the base of the Camelback Mountain to the Salt River. Elevations vary from about 1500 feet (National Geodetic Vertical Datum) at the base of the Camelback Mountain to 1260 feet at the Arizona Canal and 1130 feet on the Salt River floodplain. Three geologic units are exposed in the project vicinity:

Recent (Quaternary) Alluvium: Unconsolidated calcareous clay, sand, gravel, cobbles, and boulders, slightly to well-cemented or calichified. This unit includes upper valley fill sediment, as well as Salt River floodplain deposits.

Tertiary Red Unit: Sandstone and conglomerate, red brown, slightly calcareous, thinly to medium-bedded, friable to moderately hard, moderately dense. Clasts vary from very fine sand to 1/2-inch size, with occasional rounded cobbles up to 8 inches in diameter. The unit includes the Camel's Head Formation of Camelback Mountain.

Precambrian Igneous Complex: granite, gneiss, schist, and quartzite. These rocks vary in composition, but tend to be fractured and weathered in the project area.

Recent Alluvium underlies most of the project area, reaching a maximum thickness of 250 feet near the Salt River. Underlying the Recent Alluvium are basement rocks of various ages, including the Red Unit and the Precambrian Igneous rocks. The Red Unit is exposed in the western portion of Camelback Mountain, in the vicinity of Papago Buttes where it reaches a maximum thickness of 2000 feet, and in the banks of the Arizona Canal upstream of 56th Street. The Precambrian Igneous rocks are exposed in the eastern portion of Camelback Mountain, and in the banks of the Old Cross-

Cut Canal between Van Buren and Washington streets.

2.2 Seismicity. The dominant seismic feature in the surrounding region is the Verde fault system, located 55 miles northeast of the project. A maximum credible earthquake of magnitude 7.0 could produce a maximum bedrock acceleration of 0.07g at the project site, however, this would require the unlikely occurrence of simultaneous movement on all segments of the system. The project is located in Seismic Zone 1 (U.S. Army Corps of Engineers, 1983), indicating that minor seismic activity may be expected, with accelerations less than 0.05g. Seismic ground shaking may occur in the Phoenix area within the project life, however, it is anticipated that the proposed structures will be able to withstand the stresses from the accompanying low accelerations.

2.3 Groundwater. The project area spans two groundwater basins which are separated by a north-south trending bedrock ridge connecting Camelback Mountain and the Papago Buttes. The ridge passes under the Arizona Canal near 56th street, and is exposed at the Arizona Falls. Groundwater lies at depths of less than 20 feet along the Arizona Canal west of 56th Street, and along the entire length of the Old Cross-Cut Canal. Due to the existence of a bedrock ridge between Camelback Mountain and the Papago Buttes, combined with a high rate of groundwater withdrawal in the Scottsdale vicinity, groundwater levels drop abruptly east of 56th Street, reaching depths as great as 300 feet near the east end of the proposed collector channel. While groundwater levels east of 56th Street have dropped as much as 200 feet since the earliest records in the 1940's, levels on the west side have been relatively stable. In general, most of the groundwater level drops experienced in the project area occurred prior to 1964; reduced pumpage over the last 20 years has resulted in slower rates of decline. During site visitations on 7-8 October 1986, the Old Cross-Cut Canal contained as much as 1 foot of water at a depth of 20 feet below the surrounding ground surface. Maximum flow was estimated at 2 cfs.

2.4 Subsidence. Land subsidence and associated earth fissure development have occurred in the Phoenix area due to major groundwater declines. A National Geodetic Survey level line has been established along the Arizona Canal, and no significant subsidence has been measured in the immediate project area. The nearest zone of measured subsidence is approximately 4 miles northeast of the site, where a 0.9-foot land surface decline occurred between 1948 and 1981. Major groundwater declines in the future could result in subsidence along the project alinement. If current trends toward reduced pumpage continue, however, groundwater level declines will be considerably less than those which have occurred in the past; consequently subsidence is not expected to affect the proposed structures. Earth fissures have not been observed in the project area; the

closest occurrences are 18 miles southeast in the vicinity of the city of Mesa, where 1 to 3 feet of subsidence has been measured. Since earth fissure formation is associated with major subsidence resulting from groundwater declines of at least 150 feet, such phenomena are not expected to occur in the project area.

3. INVESTIGATION

3.1 Previous Investigations. The City of Phoenix has conducted subsurface soil investigations in this urban area. The location of three test holes (PHX - 1,2 and 3) are shown on the vicinity map (plate 1). Depths of the test holes range from 11 to 15 feet. The materials are classified and described as silty clayey sands to sandy clays with a moderate calcareous cementation of the soil in the form of caliche below 5 feet. The soil information obtained from the city logs (shown in figure 1 and 2) was used in determining a typical soil type for the area.

3.2 Field Inspection. The area north of the Arizona canal is fully developed and consists largely of residential properties. The Arizona Canal is part of the SRP irrigation system and conforms to their design specification. Its northern bank appears to be a sandy clay material with an aggregate base course (ABC) top surface for light maintenance traffic.

Inspection of the Old Cross-Cut Canal revealed that, at the Indian School Road / Old Cross-Cut intersection, the channel embankment and foundation is composed of Recent Alluvium consisting of light brown, gravelly sandy silts and silty sands. Soil appeared to be coarser-grained with higher percentages of gravel with some cobbles in the downstream direction, and is moderately to well cemented by caliche at depths of approximately 5 to 10 feet below the ground surface. The uncemented layer above the caliche is susceptible to erosion, and in some portions of the channel, between the Arizona Canal and Osborn Road, the slopes are eroded to approximately 1V : 1/2H. The deeper cemented material has been eroded to vertical slopes. A caliche-cemented boulder deposit is exposed in the canal banks upstream of Indian School Road. The boulders are rounded, up to approximately one foot in diameter, and are embedded in a light brown, hard, dense, calcareous silty sand matrix.

Bedrock is exposed at two locations on the project alignments. Sandstone of the Red Unit is exposed in the banks of the Arizona Canal east of 56th Street in an outcrop extending about 100 feet downstream from the Arizona Falls. Precambrian quartzite is exposed along the banks of the Old Cross-Cut Canal, from about 500 feet north of Washington Boulevard to about 200 feet south of Van Buren Street. The quartzite is grayish pink, highly fractured, moderately weathered, hard, and dense. It occurs in the lower 4 to 8 feet of the canal and is overlain with as much as 10 feet of soft to moderately hard caliche.

4. DESIGN ASSESSMENT

4.1 Design Parameters. From the previous investigations by the

City of Phoenix and laboratory testing of soils for ACDC, design parameters were developed. These values represent the predominant material in the vicinity and are not necessarily representative of the entire reach. The material, a sandy clay (CL), has a moist unit weight of 132 pcf and a dry unit weight of 116 pcf with an optimum moisture content of 13.6 percent, when compacted to 90 percent of maximum density according to ASTM D-1557. Strength parameters of the material are defined by an internal angle of friction equal to 22.5 degrees and a cohesion of 250 psf. Lateral earth pressures, defined by an equivalent fluid weight, for the active (Ka) and the passive (Kp) cases are 40 and 326 pcf, respectively.

Bearing capacity for structures and other loads will be limited to 2400 psf. Reduced strengths (i.e. phi & cohesion) were used to compute the bearing in lieu of a settlement analysis. Although caliche appears in the borings and may support higher bearing capacities, areas of uncertainties exist, so the higher available strength was not used in the analysis.

4.2 Slope Stability. Stability of the 1V : 1H grouted stone side slope of the Old Cross-Cut channel was analyzed for the end of construction with and without seismic loading, and the sudden drawdown conditions. Again, the effects of the caliche, which is a strong but unpredictable material, were not considered in the analyses.

Factors of Safety

End of Construction ..... FS = 2.0
End of Construction W/ Seismic ... FS = 1.6
Sudden Drawdown ..... FS = 1.7

5. CONSTRUCTION CONSIDERATIONS

5.1 Diversion and Control of Water. Groundwater is at or near the proposed invert elevations throughout the Old Cross-Cut reach. Dewatering would be required to remove groundwater during excavation and construction of structures such as drop structures and the entrenched channel that extend below the existing canal invert. In addition, diversion and control of varying amounts of surface flow would be required for construction during any season.

5.2 Excavation. Excavation can be accomplished with conventional heavy construction equipment. Dozers with ripper blades or heavy duty hammering equipment would be required to loosen bedrock and calcareous cemented soils (i.e. caliche) where encountered in the collector system excavation or channel excavation. Blasting would not be allowed due to the surrounding urban area. Temporary excavation of slopes would be no steeper than 1V : 3/4H in soil and 1V : 1/2H in bedrock and cemented soils. Vertical trenching with shoring may be required for the collector system north of the Arizona Canal due to limited work

space. Following excavation to design grades, the foundation materials for subsurface structures or a lined invert would be compacted to at least 90 percent of the maximum density determined by ASTM test method D 1557.

5.3 Fill/Backfill. For the conduits in the collection system north of the Arizona Canal, suitable backfill material can be obtained from the required excavation. Coarse-grained soils obtained from suitable sources will be used as fill and backfill material behind channel walls and other subsurface structures subjected to high groundwater or expansive soils. Backfill and the miscellaneous fill would be compacted to at least 90 percent of maximum density. Maximum density for each soil type would be determined according to ASTM test method D 1557.

5.4 Channel/Box Conduits. A rectangular covered box culvert or trapezoidal concrete-lined or grouted stone open channel would protect the banks from erosion and prevent invert degradation. A subdrain system will be required to relieve hydrostatic pressure under the invert and behind the channel walls, as shown schematically on figure 3. The subdrain system would consist of a slotted 6-inch diameter collector pipe behind the heel of the channel walls, a gravel drain layer beneath the invert to transport ground water to the pipes, and a sand filter layer under the gravel to prevent clogging with fine grained foundation soils. The gravel drain layer would be 6 inches thick under concrete and 12 inches thick under grouted stone to account for disturbance caused by placing large stones directly on the gravel. The sand filter layer would be 6 inches thick. Subdrain outlets would be provided at intervals not exceeding 1000 feet. The pervious materials from channel excavation would be used as backfill behind the channel walls. After grading and proof-rolling, the in situ materials would provide a suitable foundation, except where bedrock or caliche is exposed in the invert. Bedrock or caliche would be over-excavated to a depth of one foot below the bottom of the concrete lining and a subdrain system and a bedding layer of pervious material would be provided.

5.5 Erosion Control. Erosion control will be needed for the north bank of the Arizona Canal for the alternatives that employ overbank flow to collect local surface runoff. Stone revetment, gabions and concrete aprons are three erosion control methods that may be used. However, the stone revetment will not be considered because it would require a 1V : 2H slope into the canal, thereby, significantly effecting the canal hydraulics.

Gabions may be used as an alternative form of stone slope protection using smaller sized stones. The slopes would be covered with 18-inch deep wire cells laid parallel to the slope. The cells would be filled with 4-inch to 8-inch diameter cobbles imported from offsite commercial sources, or possibly produced by processing material from required rock excavation in the channel.

No filter material would be required beneath the gabions. Excavation would be less extensive since gabion structures can be constructed on the surface of the embankment and are flexible enough to follow changing contours. The effect of the gabions on the canal hydraulics are unknown at this point and will require SRP (Salt River Project) approval.

Concrete aprons, strategically located, are possibly the most economical erosion control method for the north bank. The apron would provide a controlled path for the surface runoff water into the canal and have no significant effect on the canal hydraulics. The size and placement of these aprons will be determined by the contour of the surrounding ground surface, and the quantity of surface runoff.

5.6 Grouted Stone. Grouted stone may be used for slope protection on the Old Cross-Cut Canal channel. For estimating purposes, the Old Cross-Cut Canal channel would have grouted side slopes of 1V : 1H. However, hand placement of the stone may be required for this slope, so economically it would be better to flattened the slope to 1V : 1.5H (i.e. 1V : 2H is typically used for grouted stone side slopes). Grouted stone may be susceptible to cracking due to hydrostatic pressure from high ground water and from differential movement due to expansion of clay soils. Therefore, a subdrain system as described in the section 5.4, would be needed to reduce uplift forces, and all expansive soils would be removed and replaced with suitable fill. Thickness of the grouted stone is estimated to be 15 to 18 inches depending on the hydraulic design of the channel.

6. CONSTRUCTION MATERIALS

6.1 Concrete. The concrete work necessary for the Old Cross Cut Canal project will consist of the box culvert for the Old Cross Cut Canal, and the sections of the collection system which are not prefabricated. The concrete used shall be 4000 PSI concrete made with Type II cement and 1 1/2 inch maximum aggregate and will have a maximum water cement ratio of 0.45. The quantity of the cement necessary will be dependent on the alternatives selected.

6.2 Local Concrete Producers. There are numerous ready mix firms in the Phoenix area which are capable of supplying the amount of concrete of the desired specifications necessary for the completion of the job. The following is a brief description of three of the larger local firms, Blue Circle, Cal Mat of Arizona, and Tanner. Price data based on February 1988 prices for concrete delivered to the project site is shown in Table A.

Blue Circle is currently running 14 plants at 10 locations in the Phoenix area ranging in capacity from 120 to 350 cy/hr. They use both Mexican and American Type II cement and have available both Class F and Class C flyash. The Mexican cement source is not currently prequalified by WES (see Section 6.5).

Cal Mat of Arizona currently operates 12 ready mix plants in

the Phoenix metropolitan area. These facilities use Type II cement and have available both Class F and C flyashes.

Tanner currently has 13 plants in the Phoenix area with an average plant capacity of 250 yds/hr. These plants use Type II cement and Class F flyash. Tanner operates a fleet of 155 delivery trucks for their Phoenix ready mix operations.

TABLE A
Concrete Prices
Dollars per Cubic Yard
(February 1988)

SOURCE	1 1/2" Max	1" Max
BLUE CIRCLE	44.00	44.00
CAL MAT OF AZ	42.00	42.00
TANNER	47.00	47.00

6.3 GROUT. The grout to be used in the event that the grouted stone alternatives are chosen will be a 7-1/2 sack mix with 8-1/2 gallons of water per sack. It will be available from the ready mix producers previously discussed. Cost data reflecting February 1988 prices is contained in Table B.

TABLE B
Grout prices
(February 1988)

SOURCE	$/C.Y.
BLUE CIRCLE	58.00
CAL MAT OF AZ	50.00
TANNER	57.00

6.4 AGGREGATES. The three main aggregate sources in the Phoenix area are located on the Salt River, Cave Creek and the Agua Fria River. Blue Diamond, Cal Mat of Arizona, and Tanner each operate aggregate plants at both the Salt and Agua Fria Rivers. Each general source is described by the stream from which the materials are taken.

Coarse aggregates from the Salt River in sizes up to 12 inches are readily available although in some cases materials up to 2 feet in diameter can be obtained. While some sources now contain nothing larger than gravel, there is still sufficient sand for economical production.

Cave Creek contains cobbles and boulders up to two feet and a sufficient supply of coarse aggregates. Some plants have ceased to produce sands for fine aggregate.

The Agua Fria River produces materials of 18 inches maximum size, with the largest proportion of its material being sand. The sources on the Agua Fria River should be able to supply sufficient aggregate for the needs of this project.

6.5 CEMENT. There are currently two major producers of cement in the state of Arizona who have been prequalified by the Waterways Experiment Station for use in Corps of Engineer's projects. These plants are the Phoenix Portland Cement Corporation at Clarksdale, Az, and the Arizona Portland Cement Corporation at Rillito, AZ.

The Phoenix Portland Cement Corporation is located approximately 95 miles north of the job site and produces Type II cement conforming to ASTM Specification C-150 and Type IP cement which meets the requirements of ASTM C-595.

The Arizona Portland Cement Corporation produces Type II and Type V cement, both conforming to ASTM C-150, and is located approximately 115 miles southwest of the project site.

The Cement Campana plant is owned and operated by Blue Circle and is located approximately 320 miles south of the project site in Hermosillo, Mexico. This plant is not currently on the Corps of Engineer's prequalified list and therefore the cement would need to be tested and approved by the Waterways Experiment Station before its use could be authorized.

6.6 POZZOLANS. In accordance with current Federal Regulations the option to use flyash as a substitute for Portland cement will be allowed for all work on the Old Cross Cut Canal. Concrete produced in the Phoenix area generally uses flyash to offset the reactivity between the cement and the silicates in the aggregates and to reduce the heat of hydration.

Flyash which has been approved for use in Corps projects in the past is available from two sites in Arizona. Western Ash's Navajo Plant in Page, Arizona produces Class F flyash and is located approximately 390 miles north of the project site. Also producing Class F flyash is the Western Ash plant in Cochise, Az which is approximately 195 miles southeast of the project site.

Currently only Class F flyash has been approved for work in the LA District, however studies are currently being conducted to determine the acceptability of Class C flyash for future projects.

6.7 ADMIXTURES. The ready mix concrete industry in Phoenix generally makes use of two types of admixtures, air entrainers and water reducers. It is expected that both of these will be used in the Old Cross Cut Canal mix design.

6.8 WATER. Sufficient water for the mixing of concrete and grout should be available from local municipal water supplies.

7. CONCLUSIONS

7.1 General Feasibility. All of the proposed flood control alternatives for the Old Cross-Cut Canal project appear to be technically feasible. No adverse geotechnical site conditions have been discovered which would preclude the construction of any of the proposed improvements, however, the costs associated with

each type of construction can only be roughly estimated at this time due to the uncertainty of the subsurface conditions.

Field inspections and a review of geotechnical literature, water well data and boring logs indicate a generally high groundwater level and the presence of bedrock (i.e. Arizona Falls and Washington Boulevard to Van Buren Street areas) and caliche near the surface at several locations in the project area. The associated requirements for caliche and rock excavation for the various alternatives would have a significant impact on the cost of construction of collector system and canal channel improvements. The grouted stone for the channel will also have an impact on the construction costs if the slopes remains 1V:1H. This is due to the fact that the stone on a steep slope will require hand placement.

8. RECOMMENDATIONS

8.1 General Exploration and Testing. Subsurface exploration and testing of foundation and construction materials would be conducted during the design phase of the project as previously agreed upon by geotechnical and project management personnel. Geotechnical investigations would be conducted to determine depths to ground water, location and extent of caliche and bedrock, and to obtain the engineering properties of the project site, borrow area, aggregate and stone materials. Subsurface explorations would be conducted along the channel alignment and in other key areas using seismic refraction, core drilling, and hollow stem auger drilling and sampling. Subsurface exploration for aggregate, stone and borrow sources would be accomplished by bucket auger drilling or backhoe trenching. Representative samples of foundation and borrow materials would be tested at Corps laboratories to determine material properties for design and construction.

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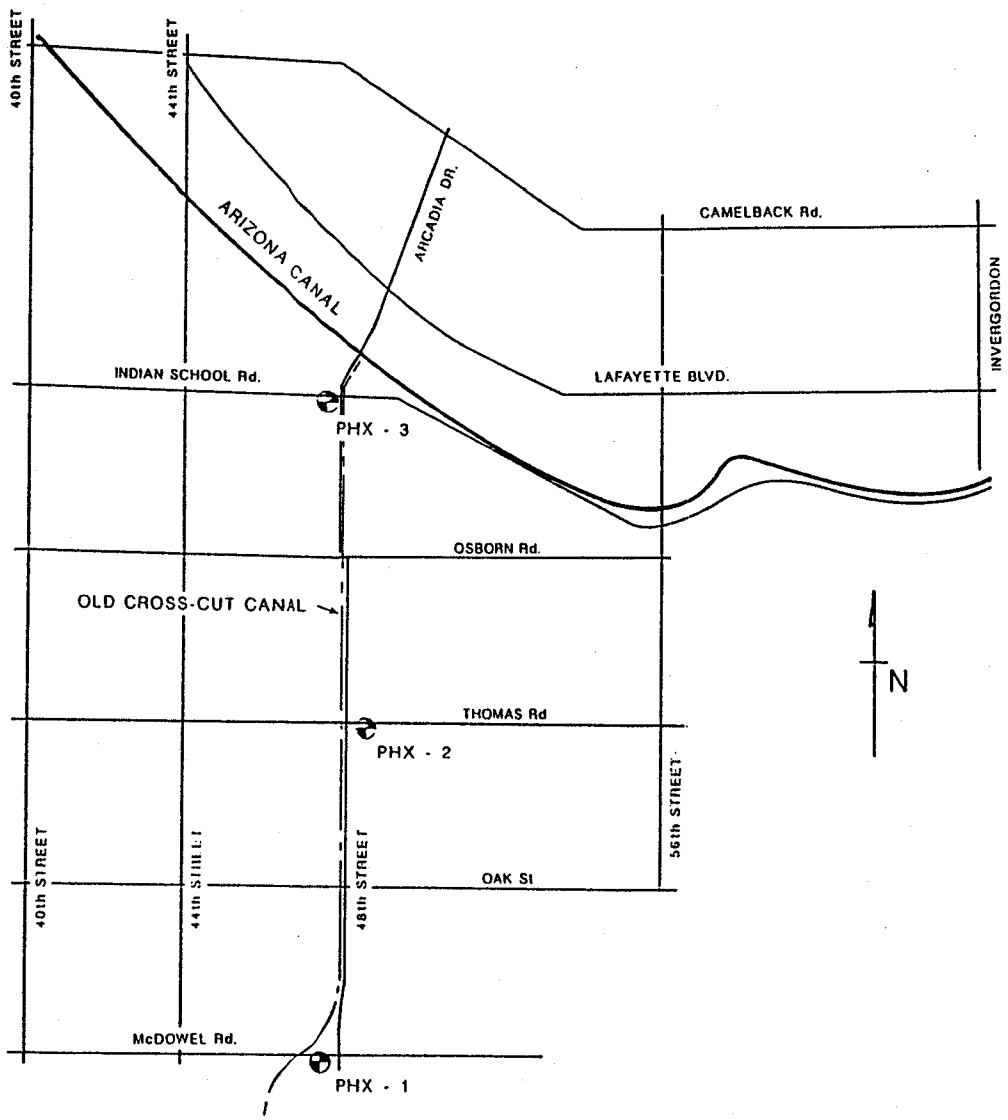
U. S. ARMY ENGINEER DISTRICT

CORPS OF ENGINEERS



LEGEND:

PHX - X TEST HOLES DONE BY THE CITY OF PHOENIX.

N

NOT TO SCALE

PHOENIX, ARIZONA

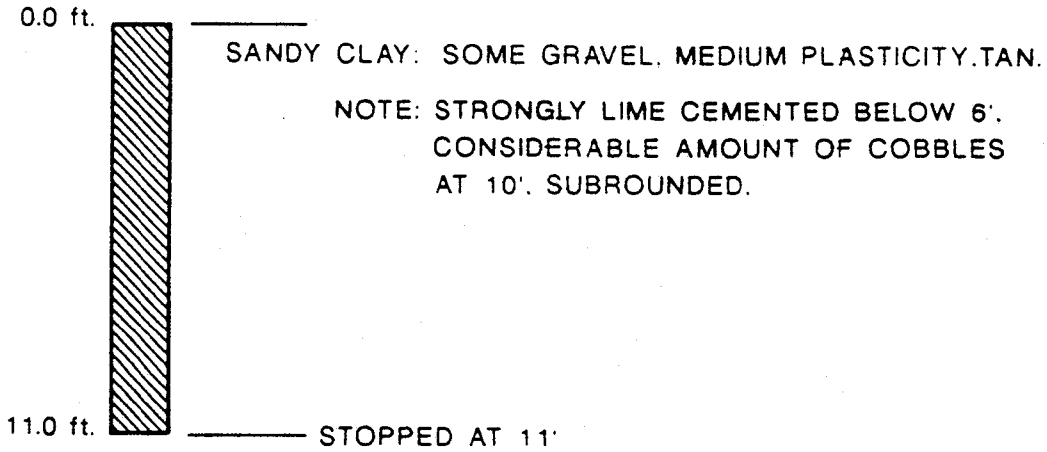
OLD CROSS-CUT

VICINITY MAP

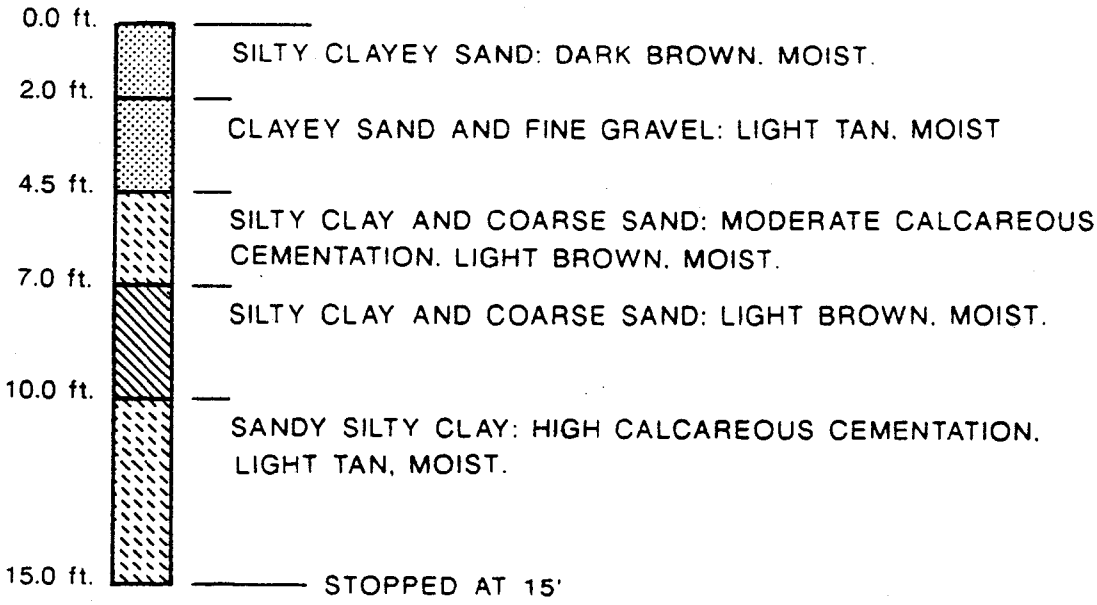
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

PLATE 1

PHX - 1



PHX - 2

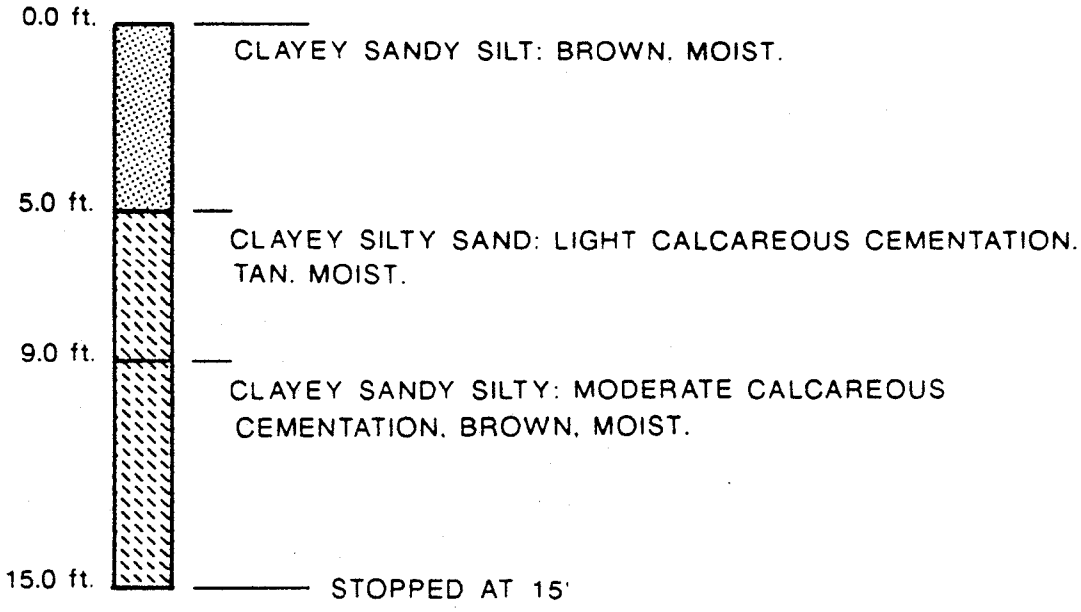


NOTE: SOIL LOGS OBTAINED FROM THE CITY OF PHOENIX, ENGINEERING DEPARTMENT.

SOIL BORING TEST HOLES

FIGURE 1

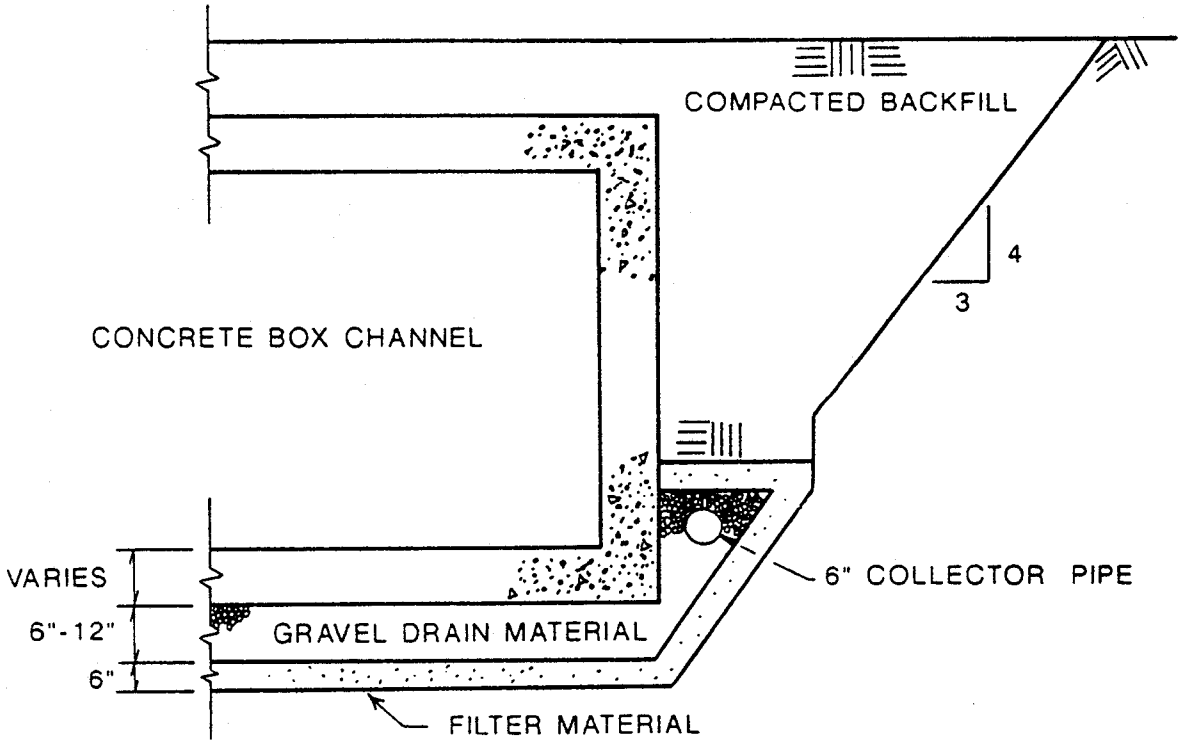
PHX - 3

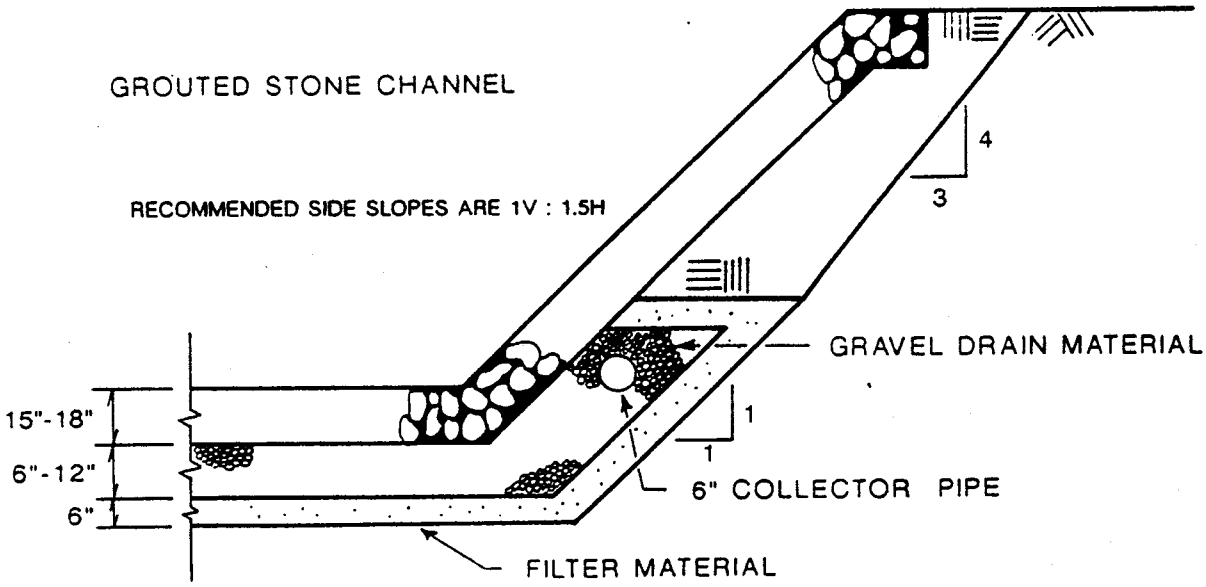


NOTE: SOIL LOGS OBTAINED FROM THE CITY OF PHOENIX, ENGINEERING DEPARTMENT

SOIL BORING TEST HOLES

FIGURE 2





SUBDRAIN DETAILS

FIGURE 3

OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

TECHNICAL DOCUMENTATION

SECTION D

DESIGN

Prepared by
Los Angeles District
South Pacific Division
Corps of Engineers
Department of the Army

DISPOSITION FORM

SPLED-DB

Subject: Reconnaissance Level Designs and Cost Estimates for the Old Cross-Cut Canal.

TO: Planning Section C

FROM: Design Section B

DATE: 11/10/87 Gallien/cwf/5534

CMT 1

1. Reference ESR FY-87-2323 RH, dated 24 August 87, requesting reconnaissance level designs and costs for the Old Cross-Cut Canal from the Arizona Canal Inlet to McDowell Road (2.2 miles).

2. Three (3) channel alternatives were identified in your request.

A. 1V on 1H grouted stone channel
B. 1V on 2H riprap channel
C. Covered box channel

3. Costs estimates were only determined for alternatives "A" and "C". With your approval, Alternative "B" was deleted because 1) side slopes of 1V on 2H or less would fall outside of the existing rights-of-way and, 2) because of the stability problems associated with the rounded stone available in Phoenix, Arizona. SPD has determined that rock riprap channel designs in this area will not have side slopes greater than 1V on 3H.

4. By your request, the costs for each alternative has been separated into three (3) reaches: Reach 1 (Arizona Canal to Osborn Road), Reach 2 (Osborn Road to Thomas Road), and Reach 3 (Thomas Road to McDowell Road). A detail cost estimate for the combined reaches for each alternative, along with typical cross-sections, are also attached.

5. Preliminary copies of the above costs estimates and typical cross-sections were telefaxed to your office 30 Oct 87.

6. The following is a summary of costs for both alternatives

Grouted Stone Channel (1V on 1H)

	Fld Control	Relocation	Total
Reach 1 Arizona Canal to Osborn Rd. Sta 191+90 to Sta 159+99....	$1.140.000	$624.000	$1.760.000
Reach 2 Osborn Rd. to Thomas Rd. Sta 158+99 to Sta 132+28....	1.100.000	478,000	1.580.000
Reach 3 Thomas Rd. to McDowell Rd. Sta 132+28 to Sta 76+00.....	2.940.000	555.000	3.500.000
TOTAL.....	$5.170.000	$1.670.000	$6.840.000

Covered Box Channel

		Fld Control	Relocation	Total
Reach 1	Arizona Canal to Osborn Rd. Sta 191+90 to Sta 158+99	$1,860,000	$154,000	$2,010,000
Reach 2	Osborn Rd. to Thomas Rd. Sta 158+99 to Sta 132+28	1,480,000	112,000	1,590,000
Reach 3	Thomas Rd. to McDowell Rd. Sta 132+28 to Sta 76+00	4,040,000	219,000	4,260,000
	TOTAL	$7,380,000	$484,000	$7,860,000

7. If you have any additional questions in regards to this DF, please contact Ms. Camille Gallien (FTS 798-5534) or Mr. Richard Torbik (FTS 798-3966).

CARL FENSON
Ch. Engineering Division

Incl.
CF:
CESPLED
CESPLED-D
CESPLED-DB (Ford)
CESPLED-DB (Gallien)
CESPLED-DB (Torbik)

Detailed First Cost Estimate
(October 1987 Price Levels)

1V ON 1H Grouted Stone Alternative

Cost Acct No.	Description	Quantity	Unit	Unit Cost	Amount Subtotal	Amount Total
	OLD CROSS-CUT CANAL--Sta 191+90 to Sta 76+00 Arizona Rd. to McDowell Rd.--Combined Reach					
	FLOOD CONTROL					
	Construction:					
09	Channel:					
	Diversion & control of water.....	1	Job	LS	$30,000	
	Clearing & grubbing	1	Job	LS	10,070	
	Channel Excavation (ripping)	202,500	CY	2.80	567,000	
	Compacted fill.....	2,550	CY	3.00	7,650	
	Excess excavated material.....	199,950	CY	1.50	299,900	
	Bedding.....	4,740	CY	14.00	66,360	
	Stone.....	26,830	CY	30.00	804,900	
	Grouting stonework...	12,060	CY	105.00	1,266,300	
	Portland cement....	90,600	CWT	6.00	543,600	
	Subtotal, channel.....				3,595,780	
30	Contingencies.....				714,220	
31	Total, channel.....					$4,310,000
	Engineering & design.....					431,000
	Supervision & administration.....					429,000
	Total, construction.....					5,170,000
	Relocations:					
	Utility Relocations.....				220,000	
	Bridge Replacement.....				1,450,000	
	Total, relocations.....				1,670,000	
	Total, flood control.....					6,840,000

Detailed First Cost Estimate
(October 1987 Price Levels)

1V ON 1H Grouted Stone Alternative

Cost Acct No.	Description	Quantity	Unit	Unit Cost	Amount Subtotal	Amount Total
	OLD CROSS-CUT CANAL--Sta 191+90 to 158+99 Arizona Canal to Osborn Rd.--Reach 1					
	FLOOD CONTROL					
	Construction:					
09	Channel:					
	Diversion & control of water.....	1	Job	LS	$10,000	
	Clearing & grubbing	1	Job	LS	2,270	
	Channel Excavation (ripping)	11,400	CY	2.80	31,920	
	Compacted fill.....	2,350	CY	3.00	7,050	
	Excess excavated material.....	9,050	CY	1.50	13,600	
	Bedding.....	1,160	CY	14.00	16,240	
	Stone.....	6,600	CY	30.00	198,000	
	Grouting stonework...	3,420	CY	105.00	359,100	
	Portland cement....	25,700	CWT	6.00	154,200	
	Total, channel.....				792,380	
	Contingencies.....				158,620	
	Total, channel.....					$951,000
30	Engineering & design.....					95,100
31	Supervision & administration.....					93,900
	Total, construction.....					1,140,000
	Relocations:					
	Utility relocations.....				48,000	
	Bridge replacement.....				576,000	
	Total, relocations.....				624,000	
	Total, flood control.....					1,760,000

Detailed First Cost Estimate
(October 1987 Price Levels)

1V ON 1H Grouted Stone Alternative

Cost Acct No.	Description	Quantity	Unit	Unit Cost	Amount Subtotal	Amount Total
	OLD CROSS-CUT CANAL--Sta 158+99 to Sta 132+28 Osborn Rd. to Thomas Rd.--Reach 2					
	FLOOD CONTROL					
	Construction:					
09	Channel:					
	Diversion & control of water.....	1	Job	LS	$10,000	
	Clearing & grubbing	1	Job	LS	2,900	
	Channel Excavation (ripping)	32,100	CY	2.80	89,880	
	Compacted fill.....	200	CY	3.00	600	
	Excess excavated material.....	31,900	CY	1.50	47,850	
	Bedding.....	1,020	CY	14.00	14,280	
	Stone.....	6,030	CY	30.00	180,900	
	Grouting stonework...	2,780	CY	105.00	291,900	
	Portland cement....	20,900	CWT	6.00	125,400	
	Subtotal, channel.....				763,710	
	Contingencies.....				152,290	
	Total, channel.....					$916,000
30	Engineering & design.....					91,600
31	Supervision & administration.....					92,400
	Total, construction.....					1,100,000
	Relocations:					
	Utility relocations.....				46,000	
	Bridge replacement.....				432,000	
	Total, relocations.....				478,000	
	Total, flood control.....					1,580,000

Detailed First Cost Estimate
(October 1987 Price Levels)

1V ON 1H Grouted Stone Alternative

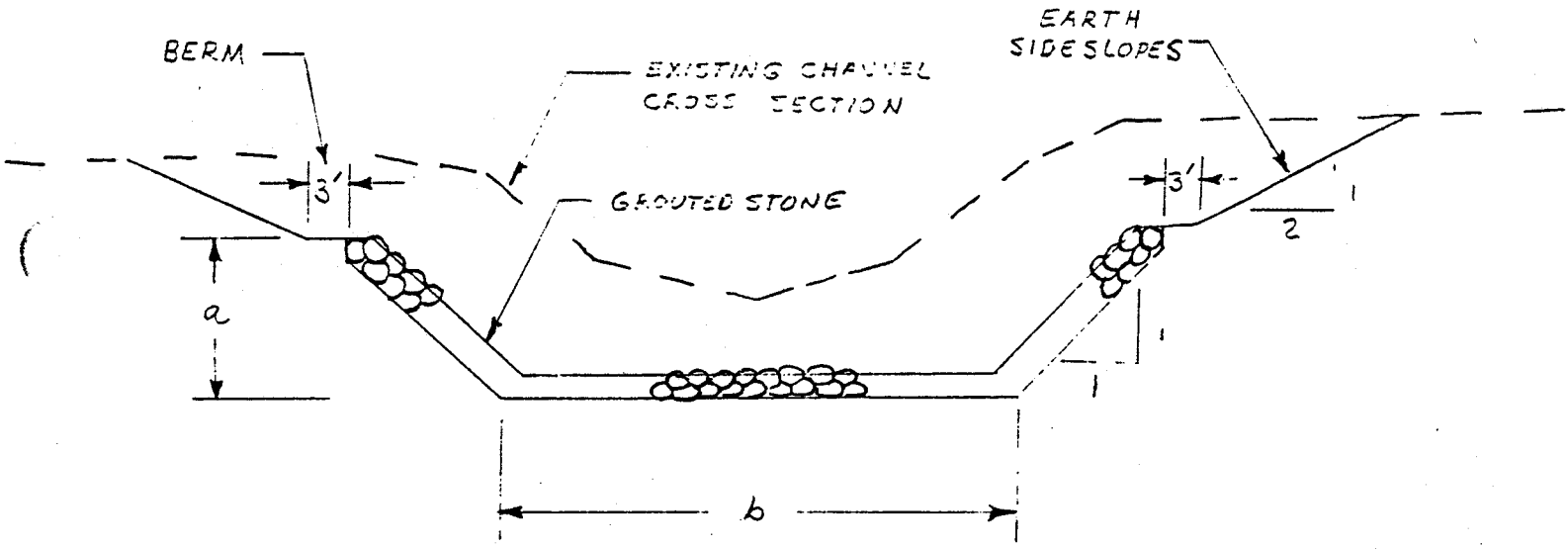
Cost Acct No.	Description	Quantity	Unit	Unit Cost	Amount Subtotal	Amount Total
	OLD CROSS-CUT CANAL--Sta 132+28 to Sta 76+00 Thomas Rd. to McDowell Rd.--Reach 3					
	FLOOD CONTROL					
	Construction:					
09	Channel:					
	Diversion & control of water.....	1	Job	LS	$10,000	
	Clearing & grubbing	1	Job	LS	4,900	
	Channel Excavation (ripping)	159,000	CY	2.80	445,200	
	Compacted fill.....	0	CY	3.00	0	
	Excess excavated material.....	159,000	CY	1.50	238,500	
	Bedding.....	2,560	CY	14.00	35,840	
	Stone.....	14,200	CY	30.00	426,000	
	Grouting stonework...	5,860	CY	105.00	615,300	
	Portland cement....	44,000	CWT	6.00	264,000	
	Subtotal, channel.....				2,039,740	
30	Contingencies.....				410,260	
31	Total, channel.....					$2,450,000
	Engineering & design.....					245,000
	Supervision & administration.....					245,000
	Total, construction.....					2,940,000
	Relocations:					
	Utility Relocations.....				123,000	
	Bridge Replacement.....				432,000	
	Total, relocations.....				555,000	
	Total, flood control.....					3,500,000

COMPUTATION SHEET

PROJECT OLD CROSS CUT CANAL
ITEM TYPICAL CROSS SECTION
IV ON 1H GROUTED STONE ALTERNATIVE
COMPUTED BY _____ CHECKED BY _____

SHEET NO. 1 OF ___ SHEETS
DATE _____, 19__
FILE _____
REF. DRWG. NO. _____

TYPICAL CROSS SECTION



	a	b
STA 76+00 to STA 144+00	10'	24
STA 144+00 to STA 191+90	7.5'	20

SPD FORM 1 OCT 74 284 EDITION OF 15 DEC 59 WILL BE USED UNTIL EXHAUSTED

Detailed First Cost Estimate
(October 1987 Price Levels)

Covered Box Alternative
(Feasibility Study)

OLD CROSS-CUT CANAL--Sta 191+90 to Sta 76+00
Arizona Canal to McDowell Rd.--Combined Reach

Cost Acct No.	Description	Quantity	Unit	Unit Cost	Amount Subtotal	Amount Total
	FLOOD CONTROL					
	Construction:					
09	Channel:					
	Diversion & control of water.....	1	Job	LS	$30,000	
	Clearing & grubbing	1	Job	LS	10,140	
	Channel Excavation (ripping)	139,000	CY	2.80	389,200	
	Compacted fill.....	198,300	CY	3.00	594,900	
	Channel Borrow.....	59,300	CY	2.70	160,110	
	Concrete, invert...	6,170	CY	86.00	530,620	
	Concrete, wall.....	8,880	CY	116.00	1,030,080	
	Concrete, top slab	4,650	CY	166.00	771,900	
	Portland cement....	111,100	CWT	6.00	666,600	
	Steel reinforcement	2,360,000	Lbs	0.40	944,000	
	Subtotal, channel.....				5,127,550	
	Contingencies.....				1,022,450	
	Total, channel.....					$6,150,000
30	Engineering & design.....					615,000
31	Supervision & administration.....					615,000
	Total, construction.....					7,380,000
	Relocations:					
	Utility relocations.....				308,000	
	Road replacement.....				176,000 *	
	Total, relocations.....				484,000	
	Total, flood control.....					7,860,000

*Includes demolition of existing bridges.

Detailed First Cost Estimate
(October 1987 Price Levels)

Covered Box Alternative
(Feasibility study)

Cost Acct No.	Description	Quantity	Unit	Unit Cost	Amount Subtotal	Amount Total
	OLD CROSS-CUT CANAL--Sta 191+90 to Sta 158+99 Arizona Canal to Osborn Rd.--Reach 1					
	FLOOD CONTROL					
	Construction:					
09	Channel:					
	Diversion & control of water.....	1	Job	LS	$10,000	
	Clearing & grubbing	1	Job	LS	2,300	
	Channel Excavation (ripping)	16,500	CY	2.80	46,200	
	Compacted fill.....	46,900	CY	3.00	140,700	
	Channel Borrow.....	30,400	CY	2.70	82,080	
	Concrete, invert...	1,590	CY	86.00	136,740	
	Concrete, wall.....	2,190	CY	116.00	254,040	
	Concrete, top slab	1,190	CY	166.00	197,540	
	Portland cement....	30,800	CWT	6.00	184,800	
	Steel reinforcement	596,000	Lbs	0.40	238,400	
	Subtotal, channel.....				1,292,800	
	Contingencies.....				257,200	
	Total, channel.....					$1,550,000
30	Engineering & design.....					155,000
31	Supervision & administration.....					155,000
	Total, construction.....					1,860,000
	Relocations:					
	Utility relocations.....				78,000	
	Road replacement.....				76,000 *	
	Total, relocations.....				154,000	
	Total, flood control.....					2,010,000

*Includes demolition of existing bridges.

Detailed First Cost Estimate
(October 1987 Price Levels)

Covered Box Alternative
(Feasibility Study)

Cost Acct No.	Description	Quantity	Unit	Unit Cost	Amount Subtotal	Amount Total
	OLD CROSS-CUT CANAL--Sta 158+99 to Sta 132+28 Osborn Rd. to Thomas Rd.--Reach 2					
	FLOOD CONTROL					
	Construction:					
09	Channel:					
	Diversion & control of water.....	1	Job	LS	$10,000	
	Clearing & grubbing	1	Job	LS	2,940	
	Channel Excavation (ripping)	23,100	CY	2.80	64,680	
	Compacted fill.....	33,400	CY	3.00	100,200	
	Channel Borrow.....	10,300	CY	2.70	27,810	
	Concrete, invert...	1,290	CY	86.00	110,940	
	Concrete, wall.....	1,790	CY	116.00	207,640	
	Concrete, top slab	960	CY	166.00	159,360	
	Portland cement....	25,000	CWT	6.00	150,000	
	Steel reinforcement	484,000	Lbs	0.40	193,600	
	Subtotal, channel.....				1,027,170	
	Contingencies.....				202,830	
	Total, channel.....					$1,230,000
30	Engineering & design.....					123,000
31	Supervision & administration.....					127,000
	Total, construction.....					1,480,000
	Relocations:					
	Utility relocations.....				62,000	
	Road replacement.....				50,000 *	
	Total, relocations.....				112,000	
	Total, flood control.....					1,590,000

*Includes demolition of existing bridges.

Detailed First Cost Estimate
(October 1987 Price Levels)

Covered Box Alternative
(Feasibility Study)

OLD CROSS-CUT CANAL--Sta 132+28 to Sta 76+00
Thomas Rd. to McDowell Rd.--Reach 3

Cost Acct No.	Description	Quantity	Unit	Unit Cost	Amount Subtotal	Amount Total
	FLOOD CONTROL					
	Construction:					
09	Channel:					
	Diversion & control of water.....	1	Job	LS	$10,000	
	Clearing & grubbing	1	Job	LS	4,900	
	Channel Excavation (ripping)	99,400	CY	2.80	278,320	
	Compacted fill.....	118,000	CY	3.00	354,000	
	Channel Borrow.....	18,600	CY	2.70	50,220	
	Concrete, invert...	3,290	CY	86.00	282,940	
	Concrete, wall.....	4,900	CY	116.00	568,400	
	Concrete, top slab	2,500	CY	166.00	415,000	
	Portland cement....	55,300	CWT	6.00	331,800	
	Steel reinforcement	1,280,000	Lbs	0.40	512,000	
	Subtotal, channel.....				2,807,580	
	Contingencies.....				562,420	
	Total, channel.....					$3,370,000
30	Engineering & design.....					337,000
31	Supervision & administration.....					333,000
	Total, construction.....					4,040,000
	Relocations:					
	Utility relocations.....				169,000	
	Road replacement.....				50,000 *	
	Total, relocations.....				219,000	
	Total, flood control.....					4,260,000

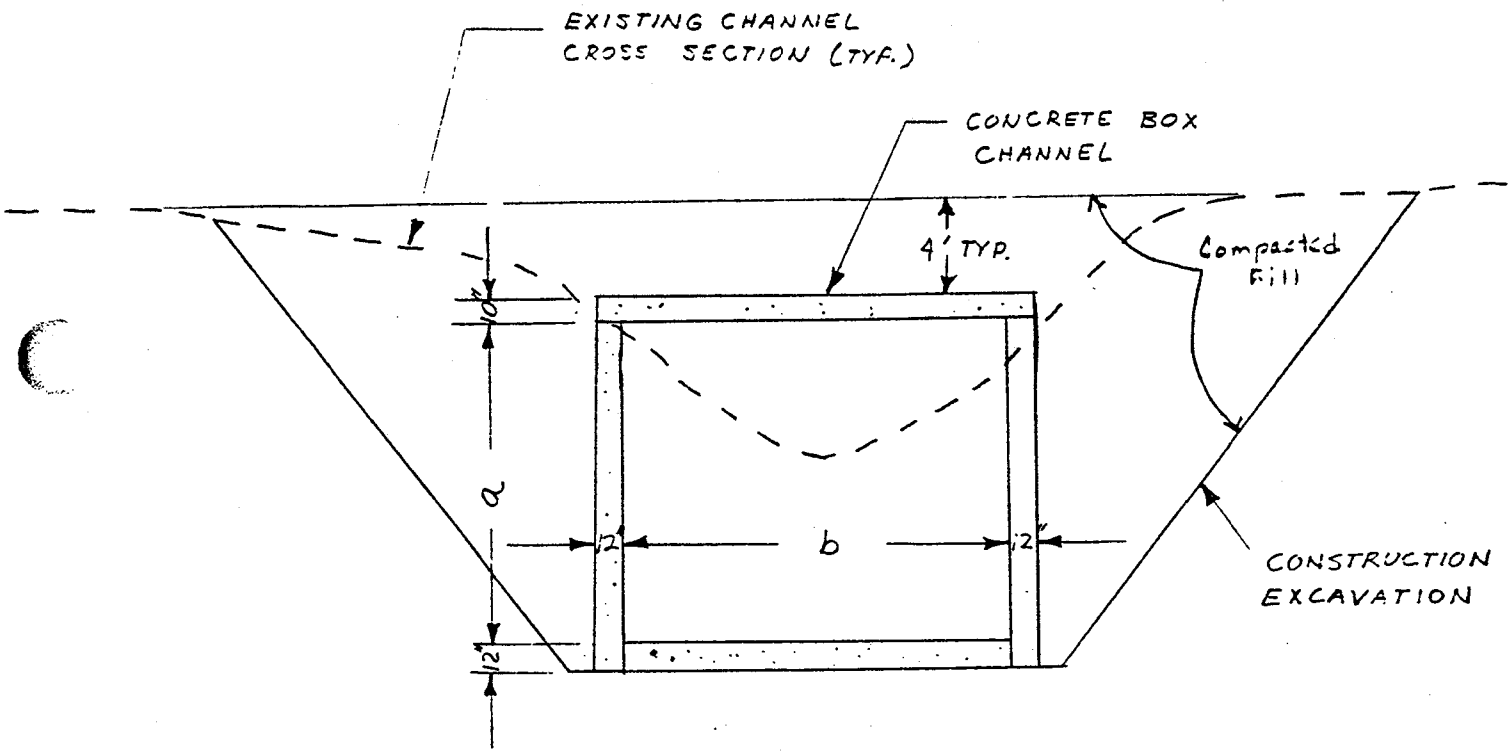
*Includes demolition of existing bridges.

COMPUTATION SHEET

PROJECT OLD CROSS CUT CANAL
ITEM TYPICAL CROSS SECTION
COVERED BOX ALTERNATIVE
COMPUTED BY _____ CHECKED BY _____

SHEET NO. 1 OF ___ SHEETS
DATE _____, 19__
FILE _____
REF. DRWG. NO. _____

TYPICAL CROSS SECTION



	a	b
STA 76+00 to STA 130+00	12'	14'
STA 130+00 to STA 191+90	9'	11'

OLD CROSS-CUT PROJECT

Alternative	Protection	Total Cost
# 2	25 yr.	163,000
# 3	40 yr.	350,000
# 4	100 yr.	6,237,000
# 5	10 yr.	4,838,000
# 6 (Collector at AZ. Canal)	25 yr.	21,385,000
	50 yr.	24,376,000
	100 yr.	30,437,000
# 6 (Collector under Streets)	25 yr.	22,698,000
	50 yr.	24,750,000
	100 yr.	31,750,000
# 7	25 yr.	37,867,000
	50 yr.	44,381,000
Canal Improvement (Rect. Channel) Concrete	50 yr.	10,131,000
	100 yr.	12,675,000
Canal Improvement (Trap. Channel) Concrete	50 yr.	10,581,000
	100 yr.	12,416,000

For the Arizona Canal Alternatives

OLD CROSS-CUT PROJECT
Alternative #2 25-yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Diversion & Control of Water	1	Job	L.S.	25000
Excavation	1910	Cu.Yd.	$2.80	5348
Compacted Fill	1360	Cu.Yd.	$3.00	4080
Excess Excavated Material	350	Cu.Yd.	$1.50	525
Concrete:				
Invert	10	Cu.Yd.	$86.16	862
Wall	170	Cu.Yd.	$116.16	19747
Gunite	1660	Sq.Ft.	$1.75	2905
Portland Cement	1020	CWT	$6.00	6120
Steel Reinforcement	8940	LBS	$0.40	3576
Wire Mesh	1660	Sq.Ft.	$1.10	1826
Radial Gates	1	each	$30,000	30000
Controls	1	Job	L.S.	20000
Demolition	4	Cu.Yd.	$100.00	400
subtotal				$120,389
Contingency 20%				24078
Engineering & Design 8%				9631
Supervision & Admin. 7%				8427
TOTAL				$162,525

OLD CROSS-CUT PROJECT
Alternative #3 40-yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Diversion & Control of Water	1	Job	L.S.	25000
Excavation	2710	Cu.Yd.	$2.80	7588
Compacted Fill	1850	Cu.Yd.	$3.00	5550
Excess Excavated Material	590	Cu.Yd.	$1.50	885
Concrete:				
Invert	70	Cu.Yd.	$86.16	6031
Wall	210	Cu.Yd.	$116.16	24394
Gunite	1660	Sq.Ft.	$1.75	2905
Portland Cement	1590	CWT	$6.00	9540
Steel Reinforcement	13090	LBS	$0.40	5236
Wire Mesh	1660	Sq.Ft.	$1.10	1826
Radial Gates	5	each	$30,000	150000
Controls	1	Job	L.S.	20000
Demolition	4	Cu.Yd.	$100.00	400
subtotal				$259,355
Contingency 20%				51871
Engineering & Design 8%				20748
Supervision & Admin. 7%				18155
TOTAL				$350,129

OLD CROSS-CUT PROJECT
Alternative #4 100-yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Diversion & Control of Water	1	Job	L.S.	100000
Excavation	175250	Cu.Yd.	$2.80	490700
Compacted Fill	28700	Cu.Yd.	$3.00	86100
Excess Excavated Material	140630	Cu.Yd.	$1.50	210945
Concrete:				
Invert	10900	Cu.Yd.	$86.16	939144
Wall	3970	Cu.Yd.	$116.16	461155
Gunite	295850	Sq.Ft.	$1.75	517738
Portland Cement	83780	CWT	$6.00	502680
Steel Reinforcement	171340	LBS	$0.40	68536
Wire Mesh	295850	Sq.Ft.	$1.10	325435
Radial Gates	7	each	$30,000	210000
Controls	1	Job	L.S.	20000
Demolition, Gate	60	Cu.Yd.	$100.00	6000
Demolition, Slab	456520	Sq.Ft.	$0.70	319564
subtotal				$4,257,997
Contingency 20%				851599
Engineering & Design 8%				340640
Supervision & Admin. 7%				298060
Utility Relocations				220893
Concrete Bridge				267670
TOTAL				$6,236,859

OLD CROSS-CUT PROJECT
Alternative #4 48th Street Bridge

Description	Quantity	Unit	Unit Cost	Total Cost
Concrete Bridge	2280	Sq.Ft.	$70.00	159600
Demolition	1	Job	L.S.	25000
subtotal				$184,600
Contingency 25%				46150
Engineering & Design 10%				18460
Supervision & Admin. 10%				18460
TOTAL				$267,670

OLD CROSS-CUT PROJECT
Alternative #4 Utility Relocations

Description	Quantity	Unit	Unit Cost	Total Cost
Gas Line, 8-in. Dia.	140	L.F.	$48.85	6839
Bolt-ups	8	Ea.	$90.90	727
Box Culvert	1000	L.F.	$45.00	45000
RGRCP, 24-in Dia.	2190	L.F.	$34.60	75774
Concrete Box	10	Cu.Yd.	$200.00	2000
Demolition	220	Cu.Yd.	$100.00	22000
subtotal				$152,340
Contingency 25%				38085
Engineering & Design 10%				15234
Supervision & Admin. 10%				15234
TOTAL				$220,893

OLD CROSS-CUT PROJECT
Alternative #5 10-yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Diversion & Control of Water	1	Job	L.S.	100000
Excavation	9620	Cu.Yd.	$2.80	26936
Compacted Fill	320	Cu.Yd.	$3.00	960
Excess Excavated Material	9260	Cu.Yd.	$1.50	13890
Concrete:				
Invert	60	Cu.Yd.	$86.16	5170
Wall	20030	Cu.Yd.	$116.16	2326685
Top Slab	30	Cu.Yd.	$166.16	4985
Gunite	1170	Sq.Ft.	$1.75	2047.5
Portland Cement	113350	CWT	$6.00	680100
Steel Reinforcement	852930	LBS	$0.40	341172
Wire Mesh	1170	Sq.Ft.	$1.10	1287
Radial Gates	2	each	$30,000	60000
Controls	1	Job	L.S.	20000
Demolition	4	Cu.Yd.	$100.00	400
subtotal				$3,583,632
Contingency 20%				716726
Engineering & Design 8%				286691
Supervision & Admin. 7%				250854
TOTAL				$4,837,903

OLD CROSS-CUT PROJECT
Alternative #6 25 yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Excavation	481320	Cu.Yd.	$2.80	1347696
Compacted Fill	283850	Cu.Yd.	$3.00	851550
Excess Excavated Material	154890	Cu.Yd.	$1.50	232335
Concrete:				
Invert	19330	Cu.Yd.	$86.16	1665473
Wall	18610	Cu.Yd.	$116.16	2161738
Top Slab	16110	Cu.Yd.	$166.16	2676838
Collector	870	Cu.Yd.	$116.16	101059
Portland Cement	309770	CWT	$6.00	1858620
Steel Reinforcement	3300	Ton	$800.00	2640000
Inlet Grates	149210	LBS	$1.17	174576
Discharge Pipe:				
2.0-Foot Dia.	4500	L.F.	$34.60	155700
2.5-Foot Dia.	15000	L.F.	$46.92	703800
3.0-Foot Dia.	13500	L.F.	$64.00	864000
Roads				63275
subtotal				$15,496,659
Contingency 20%				3099332
Engineering & Design 8%				1239733
Supervision & Admin. 7%				1084766
Utility Relocations				464964
TOTAL				$21,385,454

OLD CROSS-CUT PROJECT
Alternative #6 50 yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Excavation	601600	Cu.Yd.	$2.80	1684480
Compacted Fill	368190	Cu.Yd.	$3.00	1104570
Excess Excavated Material	178180	Cu.Yd.	$1.50	267270
Concrete:				
Invert	21110	Cu.Yd.	$86.16	1818838
Wall	20160	Cu.Yd.	$116.16	2341786
Top Slab	17590	Cu.Yd.	$166.16	2922754
Collector	1150	Cu.Yd.	$116.16	133584
Portland Cement	338480	CWT	$6.00	2030880
Steel Reinforcement	3600	Ton	$800.00	2880000
Inlet Grates	230120	LBS	$1.17	269240
Discharge Pipe:				
2.5-Foot Dia.	4500	L.F.	$46.92	211140
3.0-Foot Dia.	20000	L.F.	$64.00	1280000
3.5-Foot Dia.	8500	L.F.	$82.79	703715
Roads				63275
subtotal				$17,711,532
Contingency 20%				3542306
Engineering & Design 8%				1416923
Supervision & Admin. 7%				1239807
Utility Relocations				464964
TOTAL				$24,375,532

OLD CROSS-CUT PROJECT
Alternative #6 100 yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Excavation	753710	Cu.Yd.	$2.80	2110388
Compacted Fill	432010	Cu.Yd.	$3.00	1296030
Excess Excavated Material	256900	Cu.Yd.	$1.50	385350
Concrete:				
Invert	26330	Cu.Yd.	$86.16	2268593
Wall	25520	Cu.Yd.	$116.16	2964403
Top Slab	21940	Cu.Yd.	$166.16	3645550
Collector	1290	Cu.Yd.	$116.16	149846
Portland Cement	423410	CWT	$6.00	2540460
Steel Reinforcement	4510	Ton	$800.00	3608000
Inlet Grates	325340	LBS	$1.17	380648
Discharge Pipe:				
3.0-Foot Dia.	4500	L.F.	$64.00	288000
3.5-Foot Dia.	20000	L.F.	$82.79	1655800
4.0-Foot Dia.	8500	L.F.	$99.45	845325
Roads				63275
subtotal				$22,201,669
Contingency 20%				4440334
Engineering & Design 8%				1776133
Supervision & Admin. 7%				1554117
Utility Relocations				464964
TOTAL				$30,437,217

OLD CROSS-CUT PROJECT
Alternative #6 25 yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Clearing & Grubbing	1	Job	L.S.	120000
Excavation	481320	Cu.Yd.	$2.80	1347696
Compacted Fill	283850	Cu.Yd.	$3.00	851550
Excess Excavated Material	154890	Cu.Yd.	$1.50	232335
Concrete:				
Invert	19330	Cu.Yd.	$86.16	1665473
Wall	18610	Cu.Yd.	$116.16	2161738
Top Slab	16110	Cu.Yd.	$166.16	2676838
Collector	870	Cu.Yd.	$116.16	101059
Portland Cement	309770	CWT	$6.00	1858620
Steel Reinforcement	3300	Ton	$800.00	2640000
Inlet Grates	149210	LBS	$1.17	174576
Discharge Pipe:				
2.0-Foot Dia.	4500	L.F.	$34.60	155700
2.5-Foot Dia.	15000	L.F.	$46.92	703800
3.0-Foot Dia.	13500	L.F.	$64.00	864000
Roads				915610
subtotal				$16,468,994
Contingency 20%				3293799
Engineering & Design 8%				1317520
Supervision & Admin. 7%				1152830
Utility Relocations				464964
Lands & Damages				0
TOTAL				$22,698,106

OLD CROSS-CUT PROJECT
Alternative #6 50 yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Clearing & Grubbing	1	Job	L.S.	120000
Excavation	601600	Cu.Yd.	$2.80	1684480
Compacted Fill	368190	Cu.Yd.	$3.00	1104570
Excess Excavated Material	178180	Cu.Yd.	$1.50	267270
Concrete:				
Invert	21110	Cu.Yd.	$86.16	1818838
Wall	20160	Cu.Yd.	$116.16	2341786
Top Slab	17590	Cu.Yd.	$166.16	2922754
Collector	1150	Cu.Yd.	$116.16	133584
Portland Cement	338480	CWT	$6.00	2030880
Steel Reinforcement	3600	Ton	$800.00	2880000
Inlet Grates	230120	LBS	$1.17	269240
Discharge Pipe:				
2.5-Foot Dia.	4500	L.F.	$46.92	211140
3.0-Foot Dia.	20000	L.F.	$64.00	1280000
3.5-Foot Dia.	8500	L.F.	$82.79	8583
Roads				915610
subtotal				$17,988,735
Contingency 20%				3597747
Engineering & Design 8%				1439099
Supervision & Admin. 7%				1259211
Utility Relocations				464964
Lands & Damages				0
TOTAL				$24,749,756

OLD CROSS-CUT PROJECT
Alternative #6 100 yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Clearing & Grubbing	1	Job	L.S.	120000
Excavation	753710	Cu.Yd.	$2.80	2110388
Compacted Fill	432010	Cu.Yd.	$3.00	1296030
Excess Excavated Material	256900	Cu.Yd.	$1.50	385350
Concrete:				
Invert	26330	Cu.Yd.	$86.16	2268593
Wall	25520	Cu.Yd.	$116.16	2964403
Top Slab	21940	Cu.Yd.	$166.16	3645550
Collector	1290	Cu.Yd.	$116.16	149846
Portland Cement	423410	CWT	$6.00	2540460
Steel Reinforcement	4510	Ton	$800.00	3608000
Inlet Grates	325340	LBS	$1.17	380648
Discharge Pipe:				
3.0-Foot Dia.	4500	L.F.	$64.00	288000
3.5-Foot Dia.	20000	L.F.	$82.79	1655800
4.0-Foot Dia.	8500	L.F.	$99.45	845325
Roads				915610
subtotal				$23,174,004
Contingency 20%				4634801
Engineering & Design 8%				1853920
Supervision & Admin. 7%				1622180
Utility Relocations				464964
Lands & Damages				0
TOTAL				$31,749,869

OLD CROSS-CUT PROJECT
Alternative #6 Utility Relocations

Description	Quantity	Unit	Unit Cost	Total Cost
Asb.Cement Pipe:				
6-in. Dia	15460	L.F.	$5.23	80856
8-in. Dia.	120	L.F.	$7.48	898
Cast Iron, 4-in. Dia.	120	L.F.	$9.71	1165
PVC Pipe, 1-in. Dia.	2190	L.F.	$1.14	2497
Vit. Clay Pipe, 8-in.Dia.	15460	L.F.	$9.13	141150
Bedding Material	4940	Cu.Yd.	$15.00	74100
Gas, Electric,& Telephone	1	Job	L.S.	20000
subtotal				$320,665
Contingency 25%				80166
Engineering & Design 10%				32067
Supervision & Admin. 10%				32067
TOTAL				$464,964

OLD CROSS-CUT PROJECT
Alternative #6 Roads (Using parallel roads)

Description	Quantity	Unit	Unit Cost	Total Cost
Curb & Gutter	16120	L.F.	$7.00	112840
Sidewalk	80580	S.F.	$1.50	120870
Asphalt Conc. Paving	12300	Ton	$36.50	448950
Base Course	15530	Cu.Yd.	$15.00	232950
TOTAL				$915,610

OLD CROSS-CUT PROJECT
Alternative #6 Roads (Under access road)

Description	Quantity	Unit	Unit Cost	Total Cost
Curb & Gutter	660	L.F.	$7.00	4620
Sidewalk	3300	S.F.	$1.50	4950
Asphalt Conc. Paving	970	Ton	$36.50	35405
Base Course	1220	Cu.Yd.	$15.00	18300
TOTAL				$63,275

OLD CROSS-CUT PROJECT
Alternative #7 25 yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Excavation	787580	Cu.Yd.	$2.80	2205224
Compacted Fill	506620	Cu.Yd.	$3.00	1519860
Excess Excavated Material	204970	Cu.Yd.	$1.50	307455
Concrete:				
Invert	36310	Cu.Yd.	$86.16	3128470
Wall	31650	Cu.Yd.	$116.16	3676464
Top Slab	30220	Cu.Yd.	$166.16	5021355
Collector	820	Cu.Yd.	$116.16	95251
Portland Cement	558290	CWT	$6.00	3349740
Steel Reinforcement	5940	Ton	$800.00	4752000
Inlet Grates	299810	LBS	$1.17	350778
Discharge Pipe:				
1.5-Foot Dia.	900	L.F.	$24.96	22464
2.0-Foot Dia.	1800	L.F.	$34.60	62280
Roads				2198610
subtotal				$26,689,951
Contingency 20%				5337990
Engineering & Design 8%				2135196
Supervision & Admin. 7%				1868297
Utility Relocations				1836061
TOTAL				$37,867,494

OLD CROSS-CUT PROJECT
Alternative #7 50 yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Excavation	983080	Cu.Yd.	$2.80	2752624
Compacted Fill	622840	Cu.Yd.	$3.00	1868520
Excess Excavated Material	266810	Cu.Yd.	$1.50	400215
Concrete:				
Invert	42720	Cu.Yd.	$86.16	3680755
Wall	37450	Cu.Yd.	$116.16	4350192
Top Slab	35600	Cu.Yd.	$166.16	5915296
Collector	1220	Cu.Yd.	$116.16	141715
Portland Cement	659820	CWT	$6.00	3958920
Steel Reinforcement	7020	Ton	$800.00	5616000
Inlet Grates	451090	LBS	$1.17	527775
Discharge Pipe:				
2.0-Foot Dia.	1800	L.F.	$34.60	62280
2.5-Foot Dia.	900	L.F.	$46.92	42228
Roads				2198610
subtotal				$31,515,131
Contingency 20%				6303026
Engineering & Design 8%				2521210
Supervision & Admin. 7%				2206059
Utility Relocations				1836061
TOTAL				$44,381,487

OLD CROSS-CUT PROJECT
Alternative #7 Utility Relocations

Description	Quantity	Unit	Unit Cost	Total Cost
Asb.Cement Pipe:				
6-in. Dia	960	L.F.	$5.23	5021
8-in. Dia.	26350	L.F.	$7.48	197098
Cast Iron, 4-in. Dia.	26350	L.F.	$9.71	255859
PVC Pipe, 1-in. Dia.	3170	L.F.	$1.14	3614
Vit. Clay Pipe, 8-in.Dia.	57520	L.F.	$9.13	525158
Bedding Material	15300	Cu.Yd.	$15.00	229500
Gas, Electric,& Telephone	1	Job	L.S.	50000
subtotal				$1,266,249
Contingency 25%				316562
Engineering & Design 10%				126625
Supervision & Admin. 10%				126625
TOTAL				$1,836,061

OLD CROSS-CUT PROJECT
Alternative #7 Roads (Using parallel roads)

Description	Quantity	Unit	Unit Cost	Total Cost
Traffic Control	1	Job	L.S.	50000
Curb & Gutter	51070	L.F.	$7.00	357490
Sidewalk	79850	S.F.	$1.50	119775
Asphalt Conc. Paving	31030	Ton	$36.50	1132595
Base Course	39250	Cu.Yd.	$15.00	588750
TOTAL				$2,198,610

OLD CROSS-CUT PROJECT
Canal Improvements 50-yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Diversion & Control of Water	1	Job	L.S.	25000
Traffic Control	1	Job	L.S.	20000
Excavation	49530	Cu.Yd.	$3.27	161963
Compacted Fill	45880	Cu.Yd.	$3.00	137640
Concrete:				
Invert	13220	Cu.Yd.	$86.16	1139035
Wall	10680	Cu.Yd.	$116.16	1240589
Portland Cement	134790	CWT	$6.00	808740
Steel Reinforcement	2438280	LBS	$0.40	975312
Drop Structure	5	each	$20,000	100000
Railroad Bridge & Shoofly	1	Job	L.S.	440000
Fencing	36130	L.F.	$11.51	415856
subtotal				$5,464,135
Contingency 20%				1092827
Engineering & Design 8%				437131
Supervision & Admin. 7%				382489
Relocations:				
Storm Drain				63214
Water, Municipal				26120
Water, Irrigation				1467000
Sewer				7327
Utilities				50000
Roads & Bridges				1140587
TOTAL				$10,130,832

OLD CROSS-CUT PROJECT
Canal Improvements 100-yr Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Diversion & Control of Water	1	Job	L.S.	25000
Traffic Control	1	Job	L.S.	20000
Excavation	92670	Cu.Yd.	$3.27	303031
Compacted Fill	52540	Cu.Yd.	$3.00	157620
Excess Excavated Material	32250	Cu.Yd.	$1.50	48375
Concrete:				
Invert	17080	Cu.Yd.	$86.16	1471613
Wall	14750	Cu.Yd.	$116.16	1713360
Portland Cement	179550	CWT	$6.00	1077300
Steel Reinforcement	3457490	LBS	$0.40	1382996
Drop Structure	5	each	$20,000	100000
Railroad Bridge & Shoofly	1	Job	L.S.	440000
Fencing	36130	L.F.	$11.51	415856
subtotal				$7,155,151
Contingency 20%				1431030
Engineering & Design 8%				572412
Supervision & Admin. 7%				500861
Relocations:				
Storm Drain				63214
Water, Municipal				26120
Water, Irrigation				1467000
Sewer				7327
Utilities				50000
Roads & Bridges				1402022
TOTAL				$12,675,137

OLD CROSS-CUT PROJECT
Canal Improvements 50-yr Protection Trapezoidal Channel

Description	Quantity	Unit	Unit Cost	Total Cost
Diversion & Control of Water	1	Job	L.S.	25000
Traffic Control	1	Job	L.S.	20000
Excavation	74680	Cu.Yd.	$3.27	244204
Excess Excavated Material	74680	Cu.Yd.	$1.50	112020
Concrete:				
Invert	5580	Cu.Yd.	$86.16	480773
Side Slope	18750	Cu.Yd.	$116.16	2178000
Portland Cement	137200	CWT	$6.00	823200
Steel Reinforcement	2395850	LBS	$0.40	958340
Drop Structure	5	each	$20,000	100000
Railroad Bridge & Shoofly	1	Job	L.S.	440000
Fencing	36130	L.F.	$11.51	415856
subtotal				$5,797,393
Contingency 20%				1159479
Engineering & Design 8%				463791
Supervision & Admin. 7%				405817
Relocations:				
Storm Drain				63214
Water, Municipal				26120
Water, Irrigation				1467000
Sewer				7327
Utilities				50000
Roads & Bridges				1140587
TOTAL				$10,580,730

OLD CROSS-CUT PROJECT
Canal Improvements 100-yr Protection Trapezoidal Channel

Description	Quantity	Unit	Unit Cost	Total Cost
Diversion & Control of Water	1	Job	L.S.	25000
Traffic Control	1	Job	L.S.	20000
Excavation	109910	Cu.Yd.	$3.27	359406
Excess Excavated Material	109910	Cu.Yd.	$1.50	164865
Concrete:				
Invert	5580	Cu.Yd.	$86.16	480773
Side Slope	23120	Cu.Yd.	$116.16	2685619
Portland Cement	161850	CWT	$6.00	971100
Steel Reinforcement	3251540	LBS	$0.40	1300616
Drop Structure	5	each	$20,000	100000
Railroad Bridge & Shoofly	1	Job	L.S.	440000
Fencing	36130	L.F.	$11.51	415856
subtotal				$6,963,235
Contingency 20%				1392647
Engineering & Design 8%				557059
Supervision & Admin. 7%				487426
Relocations:				
Storm Drain				63214
Water, Municipal				26120
Water, Irrigation				1467000
Sewer				7327
Utilities				50000
Roads & Bridges				1402022
TOTAL				$12,416,051

OLD CROSS-CUT PROJECT
Water Line Relocation

Description	Quantity	Unit	Unit Cost	Total Cost
Asb.Cement Pipe				
8-in. Dia.	300	L.F.	$7.14	2142
12-in. Dia.	100	L.F.	$10.48	1048
Cast Iron Pipe				
8-in. Dia.	50	L.F.	$22.91	1146
Concrete Pipe				
48-in. Dia.	100	L.F.	$97.28	9728
54-in. Dia.	50	L.F.	$105.70	5285
subtotal				$19,349
Contingency 20%				3870
Engineering & Design 8%				1548
Supervision & Admin. 7%				1354
TOTAL				$26,120

OLD CROSS-CUT PROJECT
Sewer Line Relocation

Description	Quantity	Unit	Unit Cost	Total Cost
Vit.Clay Pipe				
8-in. Dia.	400	Cu.Yd.	$8.50	3400
10-in. Dia.	50	Cu.Yd.	$11.55	578
12-in. Dia.	100	Sq.Ft.	$14.50	1450
subtotal				$5,428
Contingency 20%				1086
Engineering & Design 8%				434
Supervision & Admin. 7%				380
TOTAL				$7,327

OLD CROSS-CUT PROJECT
Irrigation Siphon

Description	Quantity	Unit	Unit Cost	Total Cost
Grand Canal Wasteway	1	Job	L.S.	144000
Grand Canal Siphon	1	Job	L.S.	834000
subtotal				$978,000
Contingency 30%				293400
Engineering & Design 10%				97800
Supervision & Admin. 10%				97800
TOTAL				$1,467,000

OLD CROSS-CUT PROJECT
Storm Drain Relocation

Description	Quantity	Unit	Unit Cost	Total Cost
Reinf.Conc.Pipe				
8-in. Dia.	25	L.F.	$14.09	352
10-in. Dia.	55	L.F.	$16.61	914
12-in. Dia.	610	L.F.	$18.93	11547
14-in. Dia.	40	L.F.	$19.26	770
16-in. Dia.	85	L.F.	$20.94	1780
18-in. Dia.	325	L.F.	$23.96	7787
24-in. Dia.	225	L.F.	$33.35	7504
30-in. Dia.	50	L.F.	$45.42	2271
42-in. Dia.	30	L.F.	$80.77	2423
Concrete Spillway	1	Job	L.S.	5000
Corr.Metal Pipe				
18-in. Dia.	20	L.F.	$21.05	421
24-in. Dia.	40	L.F.	$29.65	1186
36-in. Dia.	115	L.F.	$42.35	4870
subtotal				$46,826
Contingency 20%				9365
Engineering & Design 8%				3746
Supervision & Admin. 7%				3278
TOTAL				$63,214

OLD CROSS-CUT PROJECT
Roads & Bridges 50 yr. Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Excavation	15700	Cu.Yd.	$3.27	51339
Compacted Fill	7020	Cu.Yd.	$3.00	21060
Excess Excavated Material	7630	Cu.Yd.	$1.50	11445
Concrete:				
Invert	950	Cu.Yd.	$86.16	81852
Wall	700	Cu.Yd.	$116.16	81312
Top Slab	760	Cu.Yd.	$166.16	126282
Portland Cement	13590	CWT	$6.00	81540
Steel Reinforcement	361500	LBS	$0.40	144600
A.C. Paving	2930	Ton	$40.00	117200
Base Course	8550	Cu.Yd.	$15.00	128250
subtotal				$844,880
Contingency 20%				168976
Engineering & Design 8%				67590
Supervision & Admin. 7%				59142
TOTAL				$1,140,587

OLD CROSS-CUT PROJECT
Roads & Bridges 100 yr. Protection

Description	Quantity	Unit	Unit Cost	Total Cost
Excavation	22150	Cu.Yd.	$3.27	72431
Compacted Fill	9460	Cu.Yd.	$3.00	28380
Excess Excavated Material	11260	Cu.Yd.	$1.50	16890
Concrete:				
Invert	1210	Cu.Yd.	$86.16	104254
Wall	950	Cu.Yd.	$116.16	110352
Top Slab	990	Cu.Yd.	$166.16	164498
Portland Cement	17810	CWT	$6.00	106860
Steel Reinforcement	473550	LBS	$0.40	189420
A.C. Paving	2930	Ton	$40.00	117200
Base Course	8550	Cu.Yd.	$15.00	128250
subtotal				$1,038,535
Contingency 20%				207707
Engineering & Design 8%				83083
Supervision & Admin. 7%				72697
TOTAL				$1,402,022

OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

TECHNICAL DOCUMENTATION

SECTION E

ENVIRONMENTAL

Prepared by
Los Angeles District
South Pacific Division
Corps of Engineers
Department of the Army

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
3616 W. Thomas, Suite 6
Phoenix, Arizona 85019

December 23, 1988

Colonel Tadahiko Ono
U. S. Army Corps of Engineers
P. O. Box 2711
Los Angeles, California 90053

Dear Colonel Ono:

This letter constitutes our report on effects the proposed Old Crosscut Canal Flood Control Project (Canal Project) in Phoenix, Maricopa County, Arizona will have on fish and wildlife resources. It has been prepared under authority of and in accordance with Section 2(b) of the Fish and Wildlife coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). This report has been developed in coordination with the Arizona Game and Fish Department as evidenced by the attached letter dated September 16, 1988.

Project data were obtained through discussions with Corps of Engineers (Corps) personnel and from maps, descriptions and reports provided to us.

DESCRIPTION OF THE PROJECT

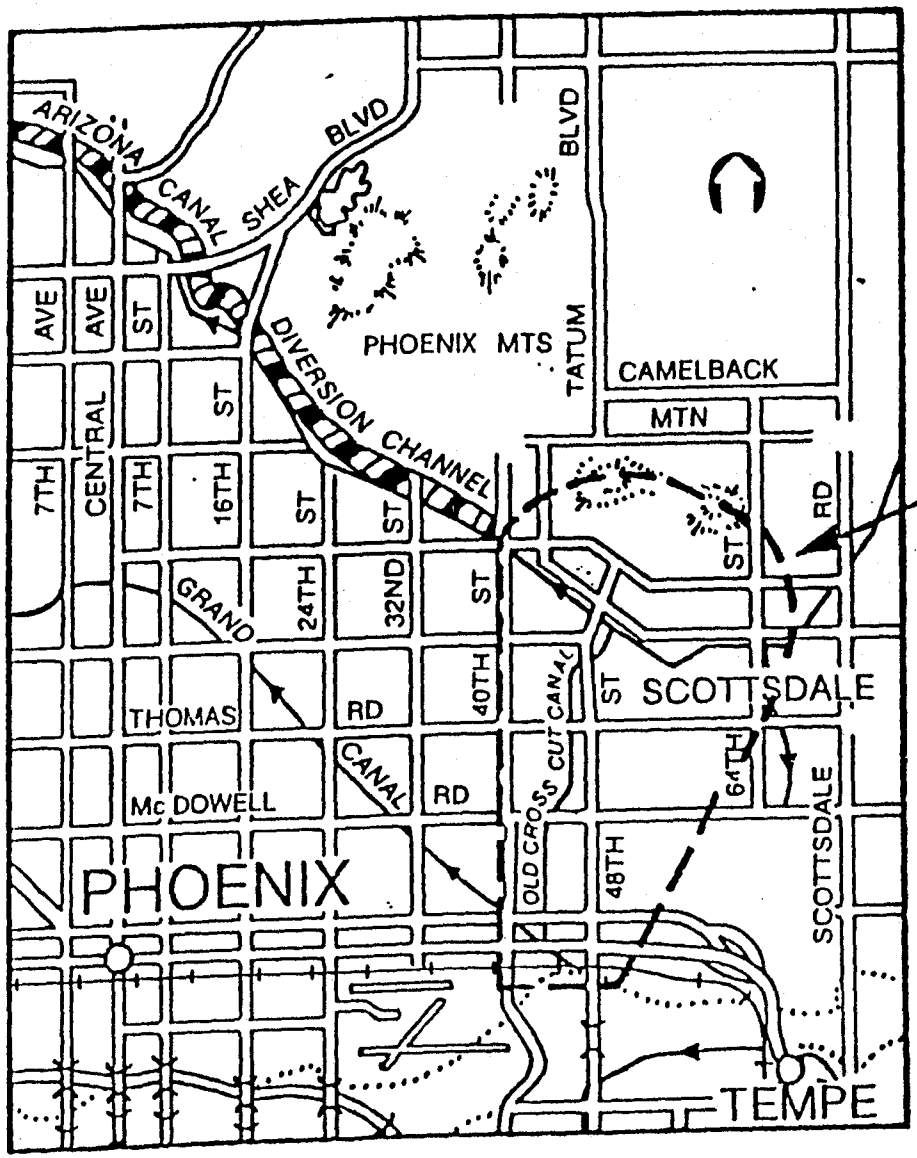
The Canal Project study was initiated to explore ways of controlling flooding in the area north and south of the Arizona Canal between 40th Street and 68th Street. Water draining off Camelback Mountain ponds behind the Arizona Canal inundates residences in the area. Major storms overtop the bank and flow into the Arizona Canal and cause flooding south of the Canal. Flood events greater than the 25 year flood overtop into the Canal.

The area between 40th and 68th Streets is the only area along the stretch of the Canal not protected by flood control projects. The Indian Bend Wash Side Drainage System manages flood water from 68th Street east to Indian Bend Wash. On the west, the Arizona Canal Diversion Channel will convey floodwaters from 40th and points west to Skunk Creek. Figure 1 shows the overall project area.

Preliminary analyses to deal with the inundation and overtopping of the Arizona Canal explored several concepts. Drainage of the Arizona Canal to provide flood storage capacity with use of the Old Crosscut and New Crosscut Canals to convey water south to the Salt River was evaluated.

U.S. ARMY ENGINEER DISTRICT

CORPS OF ENGINEERS

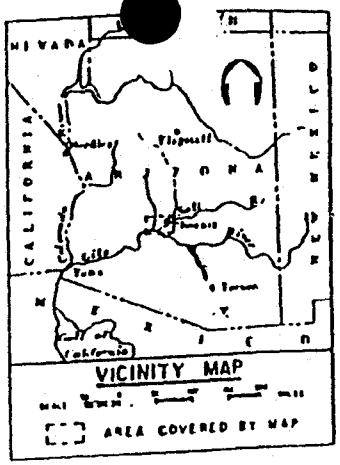


OLD CROSS CUT CANAL STUDY AREA

LEGEND

AREA UNDER STUDY

AUTHORIZED CHANNEL



GENERAL INVESTIGATIONS–SURVEYS
FLOOD DAMAGE PREVENTION STUDIES

PHOENIX METROPOLITAN AREA

OLD CROSS-CUT CANAL
ARIZONA

LOS ANGELES DISTRICT
SOUTH PACIFIC DIVISION

1 JANUARY 1985

Figure 1 Project area

However, during the evaluation some water quality problems surfaced. Water in the Arizona Canal is part of Salt River Project's municipal and agricultural supply and could be contaminated by the introduction of urban runoff.

Structural alternatives not involving the Arizona Canal were also investigated. as well. The benefit/cost ratios precluded construction of an entirely new collection and disposal system, however the combination of a collector system and modifications to the existing Old Cross Cut Canal for use as a drainage way showed potential for further examination.

Three alternatives were developed, each with several design levels of protection. Two of the alternatives, the Partial Lafayette and Alley alternatives would require use of the Arizona Canal to convey flood waters out of the area, either directly or through the Old Crosscut and New Crosscut Canals.

The third alternative, Full Lafayette, is the Corps preferred alternative. It consists of a buried inlet collector system aligned along Lafayette Boulevard across the entire study area. Also included in this alternative is the reach along 44th Street from Stanford Drive to Lafayette Boulevard. Major intersections will have inlet grates to collect runoff that would be taken to Arcadia Drive, which in turn discharges directly into the Old Cross Cut Canal. An inverted siphon will be designed at the crossing of the Arizona Canal. The total length of collector for this alternative is approximately 19,600 feet. The project is sized for the 25 year flood event.

No modifications to the Arizona Canal would be required under this alternative. Improvements to the Old Crosscut Canal would extend from the Arizona Canal to McDowell Road. Reach 1 from the Arizona Canal to Thomas Road, would be 9 feet deep and 11 feet wide at the bottom. Reach 2 from Thomas Road to McDowell Road would be 12 feet deep and 14 feet wide at the bottom. The Corps project envisions the Old Crosscut Canal as a 1:1 grouted stone channel in Reach 1 and a covered box in Reach 2. No additional right of way would be required.

The Canal Project is complicated by the overlay of two major transportation projects within the vicinity of the Corps proposed action. The Hohokam Freeway, an Arizona Department of Transportation project will extend from McDowell Road south over the Salt River to the Maricopa Freeway following the alignment of the Old Crosscut Canal from McDowell Road to the Salt River. As part of this highway project, the Department of Transportation would relocate and reconstruct the Old Crosscut Canal below McDowell and ensure it would be large enough to accommodate the Corps needs. The section below McDowell Road is not considered part of the Corps project.

The Hohokam Parkway from McDowell to Thomas will be a 4-lane wide road built by the Department of Transportation. The Old Cross Cut Canal would be a covered box under or adjacent to the Parkway. From Thomas to Indian School the Parkway would be a 2 lane road built by the City of Phoenix. The City of Phoenix would provide the funding to cover the Old Crosscut Canal in this reach and a landscaped linear park would be placed atop the covered box. This project is also not considered part of the Corps project.

EXISTING ENVIRONMENT

The proposed Canal Project would be located in the City of Phoenix, Arizona. The project area is highly urbanized and supports a mix of residential, commercial and light industrial development.

The collector system would be located in an existing residential area. Vegetation found in this area consists primarily of residential landscaping and citrus groves.

The Old Crosscut Canal between the Arizona Canal and McDowell Road is a barren earthen ditch bordered by residential and commercial development, roads and powerlines. Vegetation between the Arizona Canal and Osborn Road consists of residential landscaping immediately adjacent to the canal.

Wildlife in the project area is extremely limited and consists largely of birds and reptiles adapted to urban situations. These include tree lizards (Urosaurus ornatus), common pigeons (Columba livia), Inca doves (Scardafella inca), mourning doves (Zenaida macroura), house finches (Carpodacus mexicanus), mocking birds (Mimus polyglottos), starlings (Sturnus vulgaris), house sparrows (Passer domesticus) and great-tailed grackles (Quiscalus mexicanus). All these species utilize landscaped areas for food and cover and are found adjacent to the Old Crosscut Canal.

There are no federally listed threatened or endangered species in the proposed project area and no species from the list of "Threatened Native Wildlife in Arizona" maintained by the Arizona Game and Fish Commission.

FUTURE WITHOUT THE PROJECT

Due to the transportation projects scheduled for the Old Crosscut Canal, if the Corps project is not constructed, the existing condition would still be significantly altered and would closely resemble the "with project" condition. Along the collector system on Lafayette Boulevard,

there would be no significant difference in the "with" or "without project" scenario since the area is already urbanized and the system would be buried under the roads.

FUTURE WITH THE PROJECT

Implementation of the Corps Canal Project would not result in significant impacts on fish and wildlife resources in the project area. Some vegetation would be lost in areas near the Arizona Canal where the residences are close to the Old Crosscut Canal and some birds would be displaced because of those losses. Construction noise would cause birds to temporarily leave the area. Enlarging and lining the canal banks and creation of the covered box would eliminate annual vegetation that is available intermittently for wildlife use. However, the importance of this vegetation is overshadowed by the irrigated, urban landscape beyond the canal.

DISCUSSION

The discussion of impacts is confused by the overlay of the Hohokam Expressway and Parkway on the Canal Project. Consideration of impacts on the Salt River from the increased outflow from the Old Crosscut Canal is deferred to the Department of Transportations assessments on the Expressway and efforts to enhance wildlife habitat along the Old Crosscut Canal are superceded by the City of Phoenix commitment to a linear park in that area. These factors, plus the determination that the losses to fish and wildlife resources would be minimal, eliminate the need for a substantial mitigation commitment for this project.

The Corps could work with the City of Phoenix to design the linear park to provide wildlife habitat as well as recreational and aesthetic values. Use of native plant materials, clustering shrubs and trees to provide different strata for wildlife use and use of species combinations that provide food resources throughout the year would all contribute to wildlife values in the park.

RECOMMENDATIONS

1. The Corps should work with the City of Phoenix to incorporate wildlife needs into the linear park to be built adjacent to the Hohokam Parkway.

CONCLUSIONS

The Canal Project would provide 25 year event protection to residents north of the Arizona Canal between 40th and 68th Streets and tie into two approved flood control projects to complete protection for the larger area. It has minimal environmental impacts that would be fully mitigated by construction of the wildlife-sensitive linear park committed to by the City of Phoenix.

We appreciate your assistance and the opportunity to provide you with this report. If you have any questions, please contact Ms. Lesley Fitzpatrick or me (Telephone: 602/261-4720 or FTS 261-4720).

Sincerely,

Robert I. Mesta
Acting Field Supervisor

NORTHLAND
RESEARCH, INC.

DRAFT

The Old Arizona Cross-cut Canal Project

An Archaeological Assessment

prepared by

William S. Marmaduke, Ph. D.

and

Vera Morgan, M.A.

Department of the Army
Corps of Engineers
Los Angeles District

Purchase Order: DACW09-86-M-2189

August 1986

P.O. BOX 1401 FLAGSTAFF, AZ. 86002 (602) 774-5057

DRAFT

MANAGEMENT SUMMARY

Northland Research, Inc. has conducted an analysis of the cultural resource potential in a study area defined for the Old Arizona Cross-cut Canal Project, a planned undertaking of the U.S. Army Corps of Engineers. The Old Arizona Cross-cut Canal was originally a feeder system providing water from the Arizona Canal to the Grand Canal. Today, the Old Arizona Cross-cut Canal serves as a local storm drain, a new cross-cut canal having been built to the east.

Northland performed the analysis through a search of existing published reports and archive records, and through a foot survey of the banks of the Old Arizona Cross-cut Canal itself. Two prehistoric archaeological sites were found, one through archival research, the other in the foot survey. The former is the large site of Pueblo Grande, a sprawling site of the prehistoric Hohokam Culture. Pueblo Grande is currently listed on the National Register of Historic Places, and its core area is a City of Phoenix Park. Records suggest, however, the Pueblo Grande is much larger than the current park area, extending as far as a mile and a half north of the present park * boundaries. The other site, AZ U:9:100(NRI), also prehistoric Hohokam, exists only as a small exposure in the west bank of the Old Arizona Cross-cut Canal: it can be seen nowhere else in the vicinity, suggesting that it has been covered by historic fill in the largely residential neighborhood where it rests.

The presence of Pueblo Grande and AZ U:9:100(NRI) argue strongly that subsurface remains are likely to be found in many places in the Old Arizona Cross-cut Canal Project area. Northland recommends that an archaeological test excavation program be carried out prior to any modification of the current canal banks. An estimate of the manpower expense for such testing is provided.

* WASHINGTON TO McDOWELL

DRAFT

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DRAFT

INTRODUCTION

The Old Arizona Cross-cut Canal was a water diversion channel constructed in 1889 to connect the Grand Canal with the Arizona Canal to the north. The Grand Canal received its entire water supply through this feature, so in practical terms, the Old Arizona Cross-cut Canal was really an extension upslope of the Grand Canal. Today, the Old Arizona Cross-cut Canal serves mostly as a storm drain, a new, larger Arizona Cross-cut Canal having been built to serve the same function a little more than 2 miles to the east. The U.S. Geological Survey map quadrangle (Tempe, Ariz. 1:24,000) which covers the area of the Old Arizona Cross-cut Canal depicts the course of the old channel, but no longer identifies it by name.

Northland Research, Inc., working under purchase order DACW09-86-M-2189 issued by the Los Angeles District of the U.S. Army Corps of Engineers, conducted an examination of the Old Arizona Cross-cut Canal in July 1986 to determine the possible presence of archaeological remains along its course. Northland both looked at existing archival records and executed a foot survey of the banks of the canal, the latter focusing on the length a canal stretching from Washington Street on the south, to the south bank of the Arizona Canal in the north. For the purposes of the archival search, our project "zone" (Figure 1) was an approximately 11 square mile area bounded, roughly, by 40th Street on the west, Camelback Mountain on the north, the Southern Pacific tracks along the Salt River on the south, and, on the east, by a line running diagonally northeast from the Tovrea Stockyard across Papago Park to 66th Street in the vicinity of Indian School Road, then turning back to Camelback Mountain. The U.S. Army Corps of Engineers will use the data obtained from this effort to develop an Environmental Impact Statement for a possible rehabilitation of the Old Arizona Cross-cut Canal for duty as a flood-control feature.

Originally, the Old Cross-cut Canal traversed desert land, later put into agricultural production, and still later swallowed up in the burgeoning urban development of metropolitan Phoenix. When all this happened, there was no environmental legislation on the books, and little notice was taken of archaeological sites that might have been in the path of construction. That the Old Arizona Cross-cut Canal intersects at least one major archaeological site, Pueblo Grande, should come a little surprise, since many of the older canals built in the Phoenix area, the Grand Canal among them, were constructed along the same axis as were earlier Hohokam Indian canals, thought to have been at the height of their operation between about 600 and 900 years ago. Pueblo Grande, located at the headgates of at least 4 major prehistoric canals, rests at the juncture of the Old Arizona

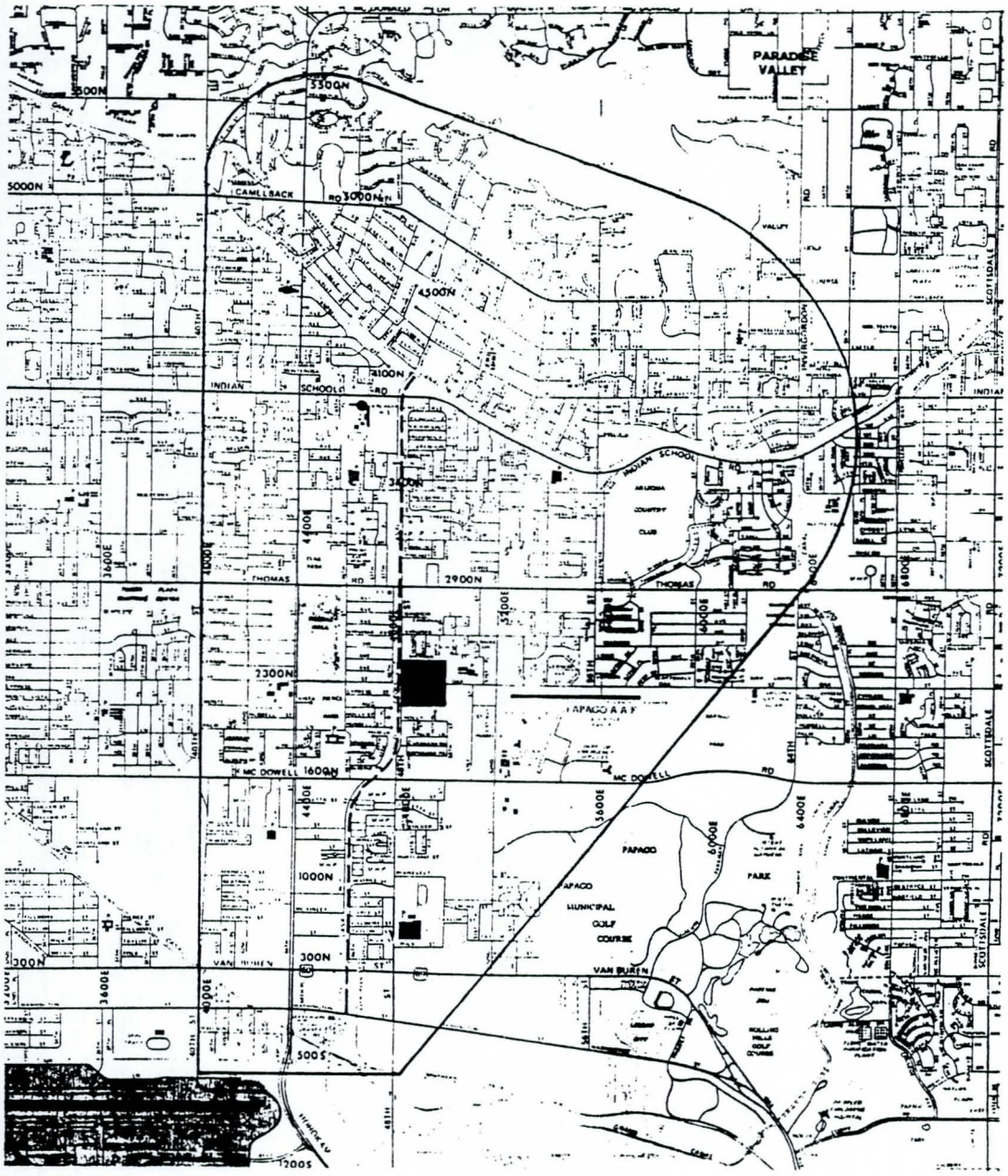


FIGURE 1: OLD ARIZONA CROSS-CUT CANAL PROJECT AREA, DEPICTING THE RESEARCH AREA AND THE SURVEY ALIGNMENT OF THE OLD ARIZONA CROSS-CUT CANAL.

SOURCE: RAND MCNALLY CITY OF PHOENIX MAP

Cross-cut Canal and its derivative, the Grand Canal, meaning that the Grand Canal formerly began in approximately the same area as the prehistoric conduits. Also, because few but the largest and most striking archaeological sites were recorded prior to the urbanization of the area, it is not unusual that Northland's foot survey recorded at least one additional archaeological site whose presence was quite unsuspected.

William S. Marmaduke, Ph.D. performed the basic archival search for this study, examining site file data from the Arizona State Museum, Arizona State University, and Gila Pueblo. Vera Morgan, M.A. did the research on the extensive site records maintained at the Pueblo Grande Museum, and performed the foot survey of the canal banks. Marmaduke wrote the basic text of the report.

ENVIRONMENTAL SETTING

The Old Arizona Cross-cut Canal runs diagonally across a gentle valley slope south of Camelback Mountain and west of the Papago Buttes, on the north side of the Salt River. Today, residential neighborhoods or light industrial parks line its entire length. Most of the residential area is at least 20 years old, developed well before the conservationist, desert-landscape ethic came into vogue. Most of the present environment of the canal could be characterized as urban "riparian," with deciduous trees and well-watered lawns in evidence everywhere. Only near its southern terminus does the canal begin to transgress desert, which was the original character of the environment.

The City of Phoenix reposes along the Salt River in the middle basin of the Gila River, well within the Arizona Uplands Division of the Sonoran Desert. The key features of the environment are "hot," and "dry," as one might expect in a desert. During the summer months, afternoon temperatures invariably rise above 100 degrees fahrenheit, sometimes considerably so. Overnight summer temperatures rarely descend below 70 degrees. Winters are mild, with daily temperature extremes of 40 and 75 degrees not uncommon in January. Rainfall is normally low, averaging only 8 inches or less in most Phoenix locations over the entire year. The bulk of this precipitation comes in high energy thunderstorms in July and August, or in less energetic winter storm front off the Pacific Ocean in the winter. Occassionally, the Phoenix area receives the moisture-laden remnants of non-seasonal tropical storms or hurricanes from the Pacific, and these account for the rare but destructive flood episodes experienced in some years.

The original desert plant community of the Old Arizona Cross-cut Canal was probably a fairly uniform cover of creosotebush (Larrea divaricata), with some occassional bursage (Franseria dumosa) mixed in. Close to the Salt River, where the Old Arizona Cross-cut Canal ends, a true riparian community probably grew to some luxuriance, if old reports and diaries can be trusted. Cottonwood and mesquite probably lined the banks of the river, and grasses may have grown thickly behind them. The origins of Phoenix itself were in a civilian hay camp constructed along the Salt in 1867 to cut natural grasses for sale to the Army at Fort McDowell, located on the east bank of the Verde River a few miles above its confluence with the Salt. One enterprising hay contractor, a former Confederate soldier and recently failed prospector named Jack Swilling, was the first to recognize that the old Hohokam Indian canals could be cleaned out and refurbished to increase the agricultural productivity of the Salt terraces where he and his cohorts harvested native grasses. This indicates that the riparian growth along the river must have been comparatively lush, a marked contrast with the scene today along undeveloped reaches of the river.

REGIONAL CULTURE HISTORY

In Arizona, there are the remains of at least 12,000 years of human occupation. They are not scattered about uniformly over the state, but evidence for all of them probably exists, or once existed, in the Phoenix metropolitan zone. For some of the rarer manifestations, such as the Paleoindian culture (ca. 8,000 - 12,000 years ago), sites remain undiscovered, but probably are present. Archaic Stage (ca. 2,000 - 8,000 years ago) sites, a little better represented, are sparse, and not frequently studied by archaeologists. The discovery of Paleoindian and Archaic sites tends to be serendipitous in the Gila Basin. By far, the majority of the known archaeological sites in the area are the remains of Hohokam camps and villages (ca. 500 - 2,000 years ago), and the detritus of the last 100 years of modern cultures. For the period between Hohokam and modern, there is a gap in our knowledge, formed by a lack of recognition of post-Hohokam Indian remains on the one hand, or by the genuine lack of Spanish, Mexican, and pre-Civil War American occupations on the other. For an in-depth discussion of the culture history of the region, one should consult Berry and Marmaduke (1982), McGuire and Schiffer (1982), and Marmaduke (1981) for a general overview, and Brown and Stone (1982), Dames and Moore (1979), McCarthy and Sires (1981), Teague and Crown (1982), and Westfall (1979) for more restricted treatments. To understand the later presentation in this report, however, a few pertinent background facts, mostly

regarding the Hohokam remains of the Salt River Valley, need clearer exposition.

The Hohokam Culture

The Hohokam were a ceramic-making, agrarian people inhabiting much of central and southern Arizona late in the prehistoric era. Their material culture ~~can~~ became distinctive either as early as 300 B.C. (Haury 1976), or as late as A.D. 500 (Schiffer 1982), depending on whose arguments of chronological data one chooses to accept. Recent excavation data from various Central Arizona Project digs suggest that the later date is probably the more accurate assessment of the situation. Whatever position one cares to take on Hohokam chronology, one fact stands out: there appears to be no evidence for any kind of gap or hiatus between the early Hohokam and the Archaic cultures that preceded them. The relationship between them, apart from chronology, remains, however, poorly understood.

Essentially, the Hohokam culture has always been a corpus of material "traits," a distinctive ceramic technology, irrigation agriculture, vestigial public architecture in ballcourts and platform mounds, cremation burial, clay figurines, slate palettes, groundstone censers, pyrite mirrors -- essentially a Formative Mesoamerican outpost plopped down in the middle of Arizona, miles away from the classical Mesoamerican sphere.

The chronology of the Hohokam Culture has been divided into 4 basic periods, which have between them 9 phases. By and large, the phases are ceramic design milestones, although some other material variation intrudes into the definition of a few of the phases. The periods, on the other hand, mark points of perceived change in the culture itself. The earliest, the Pioneer Period (Vahki, Estrella, Sweetwater, and Snaketown Phases), was a time of small, scattered sites, largely restricted to the major river valleys. During the subsequent Colonial Period (Gila Butte and Santa Cruz Phases), the size of Hohokam sites expanded and, more importantly, so did the overall range that Hohokam sites filled: uplands and minor drainages became suitable sites for habitation, and Hohokam settlement spread up several major drainages beyond the confines of the Middle Gila Basin. Figurines disappeared from use; the ballcourt emerged, the first widespread "public" architecture in the Hohokam region. In the Sedentary Period (Sacaton Phase), Hohokam sites grew to considerable sizes, although less overall territory was inhabited in southern Arizona. The final Classic Period (Soho and Civano Phases) saw an apparent revolution in Hohokam society. Many, actually most, large Sedentary Period villages were abandoned, and Classic

Period Hohokam built their houses elsewhere, in completely new site locations. Platform mounds, frequently with masonry compounds, replaced ballcourts as the dominant form of public architecture. The Classic Period also shows evidence of a good deal more influence from outside the Hohokam range than do earlier periods.

The great variety of material goods, the apparent size of the population, and the seeming extent of this culture from the south has excited considerable interest among archaeologists over the years, and it is not surprising that this has led to the creation of a number of competing explanatory models, each having its own fiercely partisan constituency. Many of these models have developed from data obtained in riverine sites. As such, they bear a heavy bias towards their local conditions, to the detriment of interpretation in outlying regions. Irrigation agriculture, the sine qua non of the Hohokam Culture in the riverine models, was almost entirely absent from the numerous Hohokam settlements located away from the Salt and Gila River terraces: these villages supported themselves through other strategies, but were still as thoroughly Hohokam as their riverine brethren. Likewise, models developed on upland data have a certain air of unreality about them when applied to riverine data.

In reviewing the explanatory models, we should begin first with the one that has proven most popular, even if recent research is proving it flawed.

The Gladwin-Haury Model

The Gladwin-Haury model originated in 2 episodes of excavation at the large, and remarkably atypical site of Snaketown on the Gila River. The first excavations (Gladwin et al. 1937; Gladwin 1942, 1948) took place in the 1930s under the aegis of Gila Pueblo, a private foundation formed, supported, directed, and, some say, ruled by Harold S. Gladwin. Emil W. Haury was one of the major players in that work, and he later returned, in the 1960s, as the director of the second set of excavations (Haury 1976) sponsored by the National Science Foundation through the University of Arizona, where Haury was a faculty member. The original Snaketown excavations were the culmination of Gladwin's earlier efforts, with his wife, to define the "red-on-buff" ceramic culture of central Arizona (Gladwin and Gladwin 1929a, 1929b, 1930a, 1930b, 1935). Haury's later work was intended to settle some of the dust that had resulted from arguments over the accuracy and validity of conclusions, mostly his conclusions, based on the 1930s

excavation. Interestingly, some of the most trenchant criticisms of the earlier work were those of Gladwin himself (1942, 1948), who became a dissenter from many of the conclusions, principally the chronological conclusions, expressed by the rest of the research team in the main site report (Gladwin et al. 1937).

The basic tenets of the Gladwin-Haury Model are that the Hohokam developed out of an indigenous base almost 2,300 years ago (300 B.C., to be precise), adopting agriculture and settling down to a sedentary lifestyle founded on the irrigation of fertile desert lands. During a long early development (800 years) known as the Pioneer Period, the Hohokam led a culturally sluggish existence, doing little other than living in small, rambling villages, farming their acreage, and experimenting with ceramic design often enough to give us 4 Pioneer Period Phases, recognizable almost exclusively by ceramic variation alone. They were a pacific, satisfied folk, apparently, until the end of the Pioneer Period (ca. A.D. 500), when, suddenly, there was a surge of expansion out into new regions, marking the onset of the aptly named Colonial Period. At this time, the comparatively advanced Hohokam came into contact with cultures possessing less well-developed technologies, to whom the passed on the fruits of their knowledge and thus qualified for the title of "culture bringers" to much of the American Southwest. The Colonial Period ended about A.D. 900, when Hohokam expansion subsided, and from then until A.D. 1100 the range of the Hohokam Culture contracted, although not back to the size it had had in the Pioneer Period. Settlement sizes increased dramatically in the Hohokam "Core;" social and technological complexity increased as well. After A.D. 1100, the Hohokam heartland received an infusion of new ideas, now termed the Saladoan "invasion," since it seemed implausible that many of these new ideas could have been accepted without the presence of outsiders to enforce their adoption. The most likely sources of these new peoples were the Anasazi and Mogollon cultures of the Colorado Plateau and eastern mountains, some of whom were beginning to experience collapse in their larger social and economic systems. The infusion of these new ideas, and probably new peoples as well, brought about the Classic Period, marked by the construction of Great Houses and Platform Mounds, which seem to have replaced the earlier form of public architecture, the ballcourt. About A.D. 1400, the entire culture seemed to disappear as a recognizable entity in the archaeological record. Haury (1976) thought it to be the result of irreversible salinization in irrigated fields. Despite the disappearance from the record, the Hohokam continue to live on, according to Haury, in the historic Pima Culture.

The DiPeso Model

Charles DiPeso arrived at his model mostly working in the uplands away from the Salt and Gila Rivers. In contrast with the popular Gladwin-Haury Model, the DiPeso Model (DiPeso 1956) is full of conflict, and implies considerable animus in the late prehistoric development of culture in southern Arizona. It also differs from the Gladwin-Haury Model in its chronology of events, suggesting that sedentary, nuclear family settlements began as early as 1000 B.C., and that the Colonial Period expansion did not occur before A.D. 900. Everything else that happened was restricted to the A.D. 900 - 1400 period.

At the heart of the DiPeso Model is the assertion that what we regard as "Hohokam" culture really represents the interaction of 2 not always compatible groups of people. One group, whom DiPeso called the O'otam, were the original, indigenous inhabitants of southern Arizona. It is their culture that we see in the late Archaic and Pioneer Period occupations. About A.D. 900, a better-organized, technologically more competent Mexican culture, the true "Hohokam" in DiPeso's view, invaded southern Arizona, sweeping aside the O'otam and relegating their remnants to the drier uplands while they themselves enjoyed the richness of the fertile river terraces. The Hohokam held sway in the region for 300 years, absorbing at least one indigenous incursion on their lands by "Membrenos," Mogollon peoples from the mountains to the east, arriving about A.D. 1100. In A.D. 1200, however, the irrigation technology of the Hohokam failed disastrously, causing the Hohokam to flee starvation, heading south into Mexico to throw themselves upon the charity of their Mesoamerican relatives. In the vacuum thus formed, the O'otam were able to reclaim the fertile riverine terraces, thus beginning a renaissance of the O'otam culture: this was the "Saladoan Invasion" in DiPeso's opinion. But it did not last. About A.D. 1300 the Hohokam reappeared, more organized than before. This time, however, their suzerainty over the Gila Basin was less complete, either by design or because the O'otam had simply become a little stronger than they had been before. The fusion of their cultures became the Classic Period Hohokam. DiPeso considered the Classic Period to be a fairly long-lived phenomena, persisting perhaps until shortly before the first Spanish entrada. DiPeso felt clearly that the Hohokam were not the ancestors of the Pima: the Pima, he believed, were late intruders who forcibly overthrew the Hohokam, and drove their remnants to the sanctuary of the settlements of Zuni and Hopi, or into the vast desert of the Papagueria.

The Schroeder Model

Al Schroeder essayed an lone attempt to reconcile the Gladwin-Haury Model with the DiPeso Model, using as a mechanism the widespread trading networks that characterized Mesoamerican culture at its height. Rather than occurring as a single work, however, Schroeder's ideas evolved in a long series of articles (1960, 1963, 1965, 1966), no one of them ever addressing his model as a single, complete thought. Nevertheless, Schroeder's ideas concerned an important facet of Southwestern prehistory, irrespective of the specific cultures involved, and the recent excavation of Shelltown and The Hind Site (Martynec et al. in prep.) has given Schroeder's concepts a new life after a period when they were not especially popular among archaeologists.

Basically, Schroeder accepted DiPeso's contention that there was an original, non-Hohokam culture in southern Arizona. Schroeder called it, in contradistinction with DiPeso's O'otam, the "Hakataya," suggesting that many other archaeological cultures of Arizona, mostly in the north and west, were also Hakatayan. The Hakatayan culture was, in Schroeder's thought, a slowly evolving desert tradition, a people long inured to the hardship of a dry land, and adept a wresting a living from it. During the Pioneer Period, these were the people of the "Hohokam," their distinction being that they, and not others of the Hakatayan tradition, could receive bits and pieces of Mesoamerican culture through a process of "unregulated diffusion," the passage of cultural elements in a casual fashion, outside of any formalized structure of activity. "Unregulated diffusion" was the result of informal trading between the Hakatayan people of the Gila Basin and Mesoamerican peoples to the south. Later, the acquisition of Mesoamerican goods and ideas became "regulated." Whole complexes of artifacts and constellations of beliefs flowed northwards to the Gila Basin through the concerted efforts of Mesoamerican trading guilds. The process was "regulated" because, presumably, the traders were providing "service' in addition to the sale, instructing the recipient Hakatayans in the proper use of the things they received. In the case of ideas, such as religion, this may have been a thoroughly mercantile behavior pattern, since the proper use of the religion may have created the need for further trading to support sacred observances. During the following Sedentary Phase, the diffusion pattern intensified further, becoming "pattern diffusion." A "pattern diffusion" occurs where there is actual colonization under peaceful circumstances, meaning that much of the observed culture is borne by outsiders as a coherent unit, yet modified to suit local needs and the social acceptance of the indigenous population. Schroeder argued that this process formed all of the Sedentary Period, and continued into the early Classic Period. Finally, there was "unit diffusion" in the late

Classic, the imposition of culture by an actual invader. It did not last long, however, and the Hakataya, survivors to the end, persisted to the present day in the cultures we know as Pima and Papago.

The Wilcox Model

David Wilcox's model (1979, Wilcox and Sternberg 1983) is the most recent of all the extant scenarios, and it is the one that makes the most use of anthropological concepts. This makes the model an intriguing departure from the models preceding it, although it must be said that many of Wilcox's best points are still speculative in nature, as are some of the key features of the other 3 models.

Initially, Wilcox argued that the Hohokam were an indigenous development in a northern portion of a widespread culture area dominated by proto-Piman speakers. Initially, only the proto-Pimans of the Salt, Gila, and Santa Cruz valleys became Hohokam, their transition to sedentism being eased by the relative richness of their riverine environment. Other peoples of the uplands remained Archaic hunter-gatherers, coexisting with the Hohokam in a symbiotic relationship of mutually beneficial trading. This was the Pioneer Period. Later, some of the outlying peoples began to adopt Hohokam behavior, and, so far as we can determine from the distance of a thousand years or more, became Hohokam themselves, giving the illusion of an "expansion." This was the Colonial Period. The expansion of the sphere of cultural ascription meant that some of the absolute advantages upon which earlier trade had been based changed as well, a circumstance that dictated change in the trading system, particularly in its size and the distances people had to travel to effect trades. Markets became regularized, with formal observances of trade activities centered on ballcourts. The high point of this development was the Sedentary Period, which featured a vast network of ballcourts located at roughly regular intervals across the landscape. But the evidence suggests that the system had begun to breakdown in the Sedentary Period, and that the response was a contraction of the Hohokam Sphere, an intensification of competition for trade, and a differentiation of Hohokam society into communities that could underwrite increasingly expensive trading relationships, and those whose poverty relegated them to mere observer or tributary status. The trend continued into the Classic Period, with local districts banding together to pool their resources to combat increasing competition. Naturally, such a concerted effort would require the formation of elites within each corporate district to insure the economical mobilization of resources. The process probably

fed itself: the more competently organized a unit was, the more wealth it could amass, making another round of intensification seem reasonable and prudent. The culmination of the trend was the construction of the great houses and the numerous platform mounds within compounds. The plan of these features appears to provide for restricted access to certain areas.

One thing that Wilcox was silent on was the fate of this system. It certainly was not in operation at the time of the first Spanish observations of the Pima. The answer may be that such highly organized, socially differentiated arrangements at that level of technology and civilization appear to be rather fragile when faced with adversity, because they are consensual systems with numerous viable alternatives available for dissenting participants. A return to hunting and gathering may not be a reasonable choice for modern Americans in the face of a crippling economic recession, but it would be for a sparsely populated agrarian society whose economic system included a fair amount of hunting and gathering in its productive fabric. Nothing is so devastating to a system like the one proposed by Wilcox as a loss of confidence (Marmaduke 1981).

Other Models

There are available a number of other models (Doyel 1977a, 1980; Grebinger 1971, 1976; Marmaduke 1981; Masse 1980; Plog 1980; Upham and Rice 1980; Weaver 1972; Wood and McAllister 1980) that have varying degrees of consistency with the available data. Few of them deal with the entire sweep of Hohokam prehistory, however, and some of them have rather glaring lapses of logic. Grebinger (1976), for example, saw the impressive late rise to prominence of the Hohokam occupation in the Tucson Basin as the logical outcome of consolidated irrigation systems, a neat little argument, dovetailing nicely with Karl Wittfogel's theory of "hydraulic societies" as the origin of civilization. Except that no one has ever identified a canal serving any large site in the Tucson Basin (Doyel 1977a). Similarly, Plog (1980) suggested that the Hohokam sowed the seeds of their own eventual demise by denuding the river valleys of their dense bosques of mesquite, the despoilment coming in an attempt to increase irrigated acreage, necessary to feed a swelling population. There is no concrete evidence for this, either. Model-building in Hohokam archaeology has become something of a cottage industry over the years because the Hohokam offer so much to work with: they were an organized society during the later stages of their development, as evidenced by their ability to erect crude public architecture whose immediate utility was low in relation to the basic physical needs of the average Hohokam person. They seem to

have traded over long distances, and they seem to be related, in some tenuous fashion, to the peoples of Mexico, where true civilizations developed autonomously, without contact with the Old World. Without a doubt, the penchant for modelling will continue, because the Hohokam continue to capture our imagination.

Post-Hohokam

No one knows for certain what happened to the Hohokam, or where the historical inhabitants of central and southern Arizona might have come from, if they came from something other than the Hohokam. Speculation abounds; facts are few. We know so little mostly because we have searched so little for answers. There have been less than 10 attempts to solve this problem (DiPeso 1951, 1953, 1956; Doyel 1977b; Fontana et al. 1962; Robinson 1976). Only 5 of them actually succeeded in studying remains from the shadowy period between the last dated Hohokam remains and the historic period in Arizona (DiPeso 1951, 1953, 1956; Doyel 1977b), and one of these (Doyel 1977b) was not an intentional attempt to do so. The plain truth is that the gap in our knowledge of these times may well be of our own making. Any archaeological site in the Phoenix area that appeared to date to this period would be important indeed.

The Anglo-European era in Phoenix is a short one. The Spanish never really managed to extend their control and settlement north beyond Tucson, and neither did the Mexicans after winning their independence from Spain. Until after the Civil War, the United States had scant interest in the area, either. Jack Swilling and his initial canal in Phoenix date to 1867. Fort McDowell had been established 2 years earlier. There appears to be nothing remaining of any Anglo-European settlement before this time in the Salt River Valley.

KNOWN CULTURAL RESOURCES

Two cultural resource properties are known to exist within the Old Arizona Cross-cut Canal Project area. One of these, AZ U:9:100(NRI), is a prehistoric Hohokam site, all but invisible except for a small exposure during recent earthmoving activities. AZ U:9:100(NRI) is a "new" property discovered in the foot survey conducted for this report. The other property is the extensive site of Pueblo Grande, which is currently listed on the National

Register of Historic Places, and which is partially preserved in a City of Phoenix park dedicated to the conservation of the archaeological heritage of the community. Phoenix derived its name from the fact that it was built on the ruins of earlier American Indian settlements. Both of these properties are directly in contact with a portion of the Old Arizona Cross-cut Canal as it exists today. Archival research failed to identify any other properties known to exist within the boundaries of the project area, although the presence of several archaeological sites just outside of the designated research area suggests that other remains might be present, but unknown at this time, within the area. Pueblo Grande is the only property currently listed on, or in nomination to the National Register of Historic Places.

AZ U:9:100(NRI)

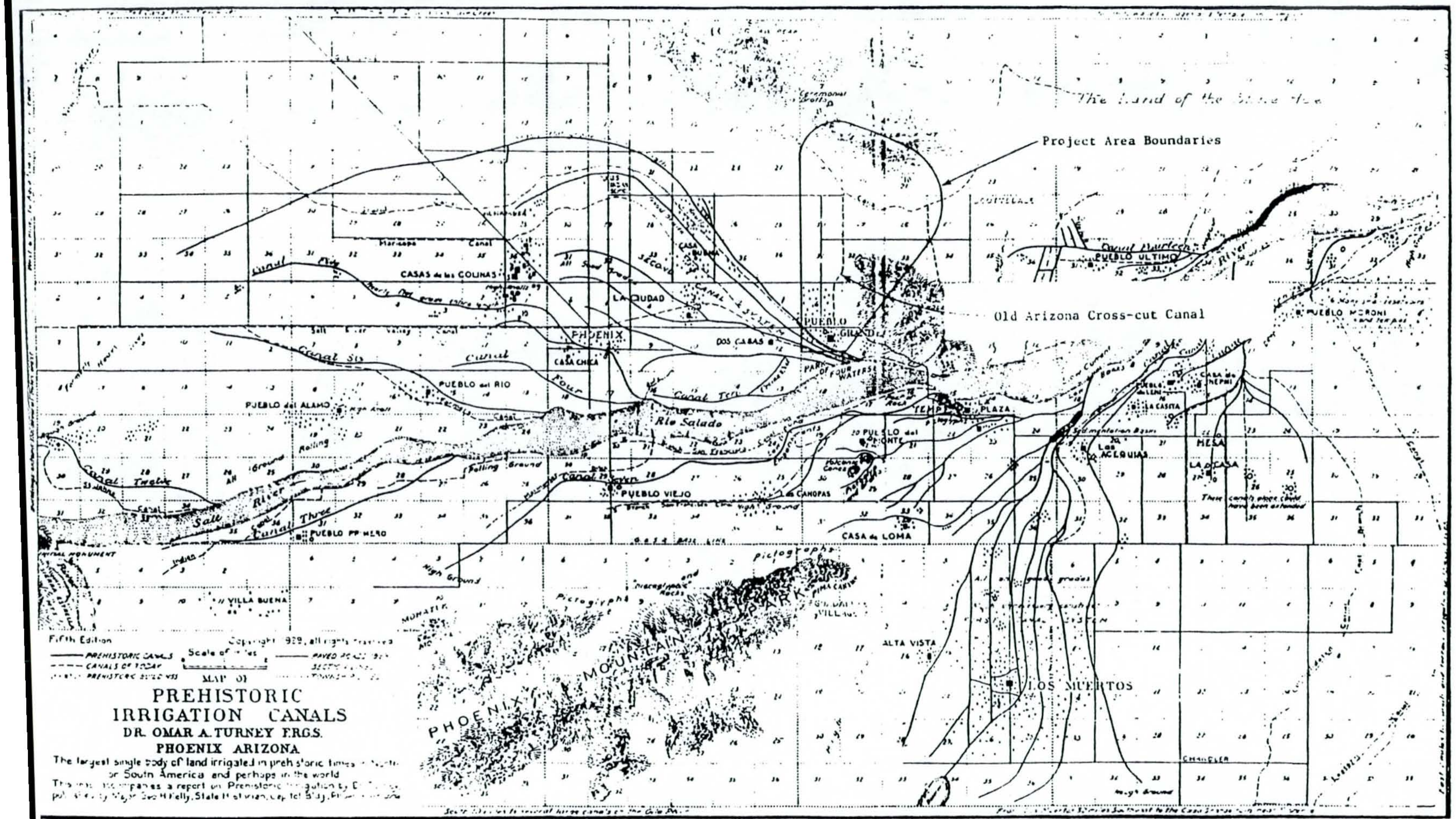
Site specific information deleted.

and precise affiliation are unknown, except to say that it is prehistoric, Hohokam, and apparently rich in artifactual remains in the area where it could be examined. The paucity of information about the site is the result of its being almost entirely buried by modern fill material lining the banks of the canal, and covering adjacent residential areas. The only exposure of the site is in a recently excavated cut in the side of the canal, possibly placed there to facilitate construction of surface drains to channel runoff from residential streets into the canal. Several such drains are presently under construction nearby. The condition of the cut suggests that it was exposed, then regraded to return it to its original condition, perhaps to cover the site exposure.

What has been uncovered at the site is largely non-diagnostic of age, except that it is thoroughly Hohokam. Plainware pottery sherds, probably Gila Plain, are the most abundant artifact type. No sherds from decorated wares could be found. Several pieces of groundstone are also present, and appear to be mostly still buried partially in their original context.

No archaeological remains are recorded for this location on any archive map or site record form. Turney's famous, "Map of Prehistoric Irrigation Canals" (Figure 2), published in 1929 before any development of the project area and clearly showing the Old Arizona Cross-cut Canal, lacks any indication of a site in the vicinity of AZ U:9:100(NRI). It is possible that the site is so small that it escaped the attention of early archaeologists like Turney. It is also quite possible that the remains observed

FIGURE 2



nal Building in the Salt River Valley with a stone hoe held in the hand without a handle. These were the original engineers, the true pioneers who built, used and abandoned a canal system when London and Paris were a cluster of wild huts.

in our survey are themselves fill material placed there during construction or maintenance of the canal.

We currently lack the data necessary to determine whether AZ U:9:100(NRI) has the quality of significance to merit formal evaluation of its eligibility for nomination to the National Register of Historic Places.

Pueblo Grande, AZ U:9:1(ASM)

Pueblo Grande is a large Hohokam village with some evidence of occupation in all of the traditional Hohokam periods: Pioneer, Colonial, Sedentary, and Classic. The largest part of the occupation appears to be from the Santa Cruz Phase (late Colonial) onwards. At least 2 ballcourts were present on the site -- Frank Midvale photographed one after it had been substantially damaged by a lateral canal off the Grand Canal, another is known to be present in the central portion of the site -- and a third may have been present to the north, where an industrial plant now sits. Easily the most impressive feature of the site is the large mound now preserved next to the Pueblo Grande Museum. No ordinary platform mound, the Pueblo Grande mound shows evidence of 3 stories of construction as a habitable structure, with sequent filling of lower stories to support the mass of upper stories. It is an unusual feature, in this respect, suggesting possibly a second "great house" in the region. A second such structure may have stood about a half a mile north of the present Pueblo Grande Park. The whole of the site seems to extend mostly west and north of this great mound, but no one seems to know exactly how far. The part of Pueblo Grande that is preserved in the city park is only a small fragment of the original site area.

Pueblo Grande bears numerous site designations. Among them are: AZ U:9:1, 2, 27, and 28(ASM); AZ U:9:45(ASU); AZ U:9:1 and 36(PG); and Mesa:1:2 and Phoenix:3:3 (Gila Pueblo). Turney's site T-3 probably also is a part of Pueblo Grande.

The extent and nature of the Pueblo Grande Site is of great importance here, because the Old Arizona Cross-cut Canal intrudes upon it from the north, bisecting several areas of known site context, and probably cutting other areas that we do not know of today. Much of Pueblo Grande was levelled during the First World War to make way for stockyards and processing facilities for agricultural products needed in the war effort. Our only means, presently, of establishing the present size of the site is by examining records made by archaeologists before most of the surrounding development took place. This can be a frustrating

exercise, since many records are blithely brief: archaeologists working 75 years ago could not have foreseen either our interest in the site, or the considerable growth of Phoenix that was to occur after 1940.

The Archive Data

A French archaeologist, Alphonse Pinart, rendered the earliest description of Pueblo Grande in a report to the Societe de Geographie in Paris. During his 1976 examination of the site, Pinart noted the great mound, and noted that extensive debris could be found extending out 450 meters (1,500 feet) to the northwest, a distance that would put the boundary of extensive remains somewhere in the angle formed by Washington Street and the Hohokam Expressway.

J.F. Stewart was the next to try his hand at describing the ruin in 1877. He noted the obvious great mound, and then stated that the site spread out to the north, east, and west, covering about 100 acres of land. This would put most of the site south of Van Buren Street.

In the same year, Hiram Hodge, writing in, "Arizona As It Is" suggested that numerous reservoirs could be seen in the site from the position of the great mound, and he opined that the associated "town" covered almost 2 square miles. Just how these 2 miles were situated with respect to the great mound was left unstated.

The next archaeologist to examine the site and leave a report was Adolph Bandelier, visiting the site in 1883 and reporting on it to the Archaeological Institute of America in 1892. Bandelier noted that the great mound sat in the southwestern corner of an extensive area of ruins. Large mounds, Bandelier reported, could be seen out to 200 meters (650 feet) to the northwest, and for a distance of a half a mile to the northeast. This last direction may have been an error in perception or transcription, since all other reports specify that the site extends north and northwest from the mound. Bandelier elaborated that small hillocks, possibly representing houses, were distributed among the mounds in a checkerboard pattern. He also noted old canal tracks (Acequia) south of the mound, probably the same canals whose portions are preserved in the Park of the Four Waters south of the Southern Pacific tracks.

Between then and 1887, when the Hemenway Expedition arrived of the scene, there were several other reports of the site, but the data in them was sketchy, even by the standards of the day.

The Hemenway Expedition, although it left the most detailed description by far of 19th century Pueblo Grande (which Cushing, Expedition Director, called El Ciudad [sic] de los Pueblitos), gave little more than brief attention to the overall size of the site. The site simply covered, "about 2 miles." (Cushing 1892) The Expedition did apparently excavate some features in a small cluster of mounds about a half a mile to the north and east of the great mound: this is thought to be the probable location of the second large structure on the site. Published details on this work are slender.

One 19th century report that could have considerable bearing on the present project is a small newspaper item. The Arizona Republican reported in 1894 that, '...Mr. J.F. Tait of the Arizona Canal Co. excavated 5 human skulls and other bones and pottery in the vicinity of Crosscut Canal Site [Pueblo Grande] from a depth of about 5 feet below the surface." The use of the name, "Crosscut Canal Site" suggests that the location of the dig could have been in the vicinity of the canal itself. The canal would have been 5 years old at the time.

Walter Fewkes visited the site in 1907 and identified several of the features described by Cushing, including the location of the non-mound excavations northeast of the great mound. He did not add much information. He deserves mention, however, because his brief description suggests that Cushing's residential excavations were about .75 mile from the great mound: an analysis of several other figures he gave for distances from the mound to still-preserved features of the site suggests that Fewkes was given to overestimation.

Our first real map of the site, drawn in the time when the observations it was based on were made, comes from the redoubtable Dr. Omar Turney, who was city engineer for Phoenix for 13 years. The site, Turney recorded, extends for 1 mile east-west, and for 2 miles north-south, covering most of Sections 6 and 7, and extending slightly into Section 8. * The total land area covered by the site was between 1.5 and 2 square miles. Turney further indicated that there was a large structure and associate trash mounds present in this area north of Van Buren Street, and that a prehistoric cemetery was located at the juncture of the Old Arizona Cross-cut Canal and Van Buren Street.

There is little more recent data concerning the size of the site. David Wilcox and David Doyel, the latter Director of the Pueblo Grande Museum, are preparing a monograph on the history, structure, and interpretation of the site. Mssrs. Wilcox and Doyel were kind enough to let us examine their unpublished manuscript, and from their interpretation of the early records we may glean the following facts. Pueblo Grance probably extends no farther south than the canal banks observable in the Park of the

* South of McDowell

Four Waters, about 1,400 feet south of the great mound. To the southeast, it runs to the base of a steep bajada slope, approximately in the middle of Section 8. To the northeast, the site stretches no further than 48th Street. To the north and west, however, there is great uncertainty. La Lomita, which Midvale thought was a separate site, may represent the most westward portion of the site at 38th Street and Van Buren. For the northern extent, Wilcox and Doyel could only speculate based on the reports of Cushing and Turney: the site may well extend 2 miles north, although much of it in this area is probably dispersed farmsteads and agricultural features.

What this all means with respect to the Old Arizona Cross-cut Canal is that the canal alignment probably enters the Pueblo Grande site area at McDowell Road, and from there south never quite leaves it. We must caution, however, that dense remains are probably not present until the canal reaches the area of Van Buren Street. From there on, the data suggest highly significant archaeological remains may be encountered all along the canal route.

The Survey in the Vicinity of Pueblo Grande

Our surface inspection yielded results complementary of the above findings. From McDowell Road to about Taylor Street, no archaeological debris was observed, despite the highly eroded nature of the canal banks which afforded excellent exposures of the natural surrounding soil profile. South of Taylor Street to Washington Street, archaeological debris is abundant, beginning at about the point where Turney reported a prehistoric cemetery existed. We were unable to find any human bone, however, in this area to confirm Dr. Turney's report. The majority of the observable material consists of potsherds and chipped stone, with some fragmentary groundstone also present.

SUMMARY OF PREVIOUS WORK IN THE PROJECT AREA

All of the prior investigations within the Old Arizona Cross-cut Canal Project have been associated with the site of Pueblo Grande. In addition to the investigations listed in the previous section, there have been the following:

1. The Arizona Antiquarian Association.

Excavations by Dr. Joshua Miller and other prominent Phoenix citizens in 1901 reopened some of Cushing's earlier sondages, and more. Working with picks and shovels, Miller and his cohorts tunnelled 70 feet into the mound at one point, passing through several episodes of rebuilding and proving the existence of numerous floor surfaces. Recovered from the great mound were pottery, shell, charcoal, turquoise, metate fragments, palettes, and some human hair. Our only records of Miller's work comes from some newspaper articles, reports written by others, and a 10 page account written by Miller himself. Miller died in July of that year, leaving the artifact collection largely uncatalogued.

2. Erich Schmidt.

Sponsored by Dwight B. Heard, Erich Schmidt cut a deep stratigraphic test trench through a trash deposit 100 feet east of the great mound in 1926. The result of this work was the first doctoral dissertation in Hohokam studies. More important, this work was a pioneering work in the stratigraphic interpretation of pottery typology in the Salt River Valley.

3. Odd Halseth.

In 1927, Odd S. Halseth became Director of the Arizona Museum, which was what the Pueblo Grande Museum was called in those days. Halseth began a long series of investigations at the site that would span 15 years, and include one of the most imaginative public education programs ever undertaken by an archaeologist. He began by mapping the great mound comprehensively. Later, Halseth conducted excavations in various parts of the site, and reported the results weekly in the Phoenix newspaper. During the Great Depression, Halseth directed a massive W.P.A. effort at the site, whose exact nature will be the subject of a forthcoming dissertation. Halseth began to cut back on his excavation of the site in 1940, and ceased them when he became the Director of City Parks in 1943. He was later appointed Phoenix City Manager in 1946. Halseth was the first to propose soil salinization as a potential explanation for the collapse of Hohokam society (Halseth 1936).

4. Julian Hayden.

Employed by the National Park Service, Julian Hayden conducted excavations at Pueblo Grande from 1936 to 1940. His were probably the most extensive investigations to date. In addition to finding additional evidence to bolster Halseth's

salinization theory (Hayden 1945), Hayden documented systematically the complex building sequence in the great mound. He also determined that the building, and the mound that had formed around it, had undergone frequent renovation and extension. Away from the great mound, Hayden excavated numerous houses, courtyards, and other features enclosed within massive compound walls.

5. Albert Schroeder.

Working under the auspices of the museum at Pueblo Grande, Albert Schroeder conducted a seminal stratigraphic survey of trash mounds in the Salt River Valley. This work included excavation of a trash mound at Pueblo Grande itself. Schroeder's results, although not without problems, were an important contribution to our early understanding of chronological sequences in the valley. In addition, Schroeder suggested that his findings supported the hypothesis of a "Saladoan Invasion" of the Salt River Valley at the conclusion of the Sacaton Phase.

6. Donald Hiser.

Donald Hiser was the City Archaeologist for Phoenix from 1954 until 1983, essentially assuming Odd Halseth's old position with a new title. Hiser sponsored a long-running series of excavations at the site using students from Arizona State University, but mostly they had little direction or apparent purpose, being mostly digging for digging's sake. The most notable outcome of this work was an increase in the collection housed at the Pueblo Grande Museum.

POTENTIAL FOR SUBSURFACE REMAINS

Obviously, the results of our archival research and ground survey indicate that subsurface cultural remains of considerable extent and importance may be present within the Old Arizona Cross-cut Canal Project area. Although Pueblo Grande is the only previously known site situated in the project area, the discovery of AZ U:9:100(NRI) in an exposed bank of the Old Arizona Cross-cut Canal intimates strongly that other sites could be present. The problem is the finding of them. With so much development in the project area, most archaeological sites would tend to be heavily masked with modern improvements: filled lots, paved streets, commercial and residential structures.

An obvious question is how AZ U:9:100(NRI) could have escaped notice during so much archaeological research in the vicinity of Pueblo Grande since the late 19th century? The answer is a simple one: most of that work predates World War 2, and most archaeologists of the prewar era gave short shrift to small sites, which AZ U:9:100(NRI) may well be. In spite of what appears to have been a fairly exhaustive effort by Turney and his colleagues, a great many comparatively small sites were never recorded. Small sites simply did not fit into the research designs of the day.

The fact is, the Old Arizona Cross-cut Canal Project is in a district of proven archaeological site richness. The surveys of early archaeologists in the Salt River Valley cannot be considered necessarily comprehensive, in spite of the time invested in their execution. In addition, recent excavation work at sites in the path of urban freeways in Phoenix demonstrate that buried Hohokam sites have survived urban development, and done so quite nicely below the modern bustle of the big city. If there are other undiscovered sites out there in the Old Arizona Cross-cut Canal Project area, they are probably well-preserved.

FURTHER WORK

If earthmoving is anticipated in the Old Arizona Cross-cut Canal Project, Northland recommends the following actions be taken to determine the presence, nature, and extent of buried archaeological remains:

1. The margins of the Old Arizona Cross-cut Canal should be investigated with test excavations in the vicinity of AZ U:9:100(NRI), and in the portion of Pueblo Grande that is traversed by the canal, to wit, that portion of the Old Arizona Cross-cut Canal between Taylor Street and the canal terminus on the Grand Canal. Test excavations should consist of cutting-back the canal bank to native soil in 5 meter (16 feet) exposures at intervals of 20 meters (66 feet) within site areas. In the case of AZ U:9:100(NRI), one cut should be placed directly over the discovery exposure, and subsequent cuts placed outwards on either side of this initial cut until no more archaeological debris is encountered.

2. The remaining length of the canal should be tested with small excavation cuts placed every 50 meters (164 feet) on one side only. This interval should be sufficient to locate

all but the smallest of Hohokam sites that may be present. There is no evidence to suggest the presence of other types of sites in the area. These small cuts need be no larger than the width of a backhoe bucket.

3. For other potential earthmoving sites in the Old Arizona Cross-cut Canal Project area, a foot survey should be conducted, assuming that natural soils can be observed in the project sites. If not, then actual construction activities should be monitored for archaeological remains that may be uncovered.

It is our professional opinion that the measures recommended here are a reasonable compromise between cost and preservation. The test excavations recommended in item #2 above would take less than 2 weeks to perform with a backhoe. The work under item #1 could require as much as 3 weeks effort, depending on results. The survey and monitoring expense under #3 would depend on the nature of the undertaking. A breakdown of the manpower required for items #1 and #2 is provided in Table 1. All estimates assume the use of a 4 person crew consisting of a professional archaeologist, an assistant, and 2 field technicians.

TABLE 1

NORTHLAND RESEARCH, INC.
OLD ARIZONA CROSS-CULTURAL PROJECT

Breakdown of Testing Manpower Expense (Manhours)

Personnel Category	Planning and Admin.	Field-work	Analysis	Report Prep.	Total
Principal Investigator	8	20	8	8	44
Project Archaeologist	8	200	60	60	328
Assistant Proj. Arch.	4	200	20	0	224
Field Labor	0	240	0	0	240
Draftsman	0	0	0	32	32
Secretary	2	0	0	20	22
Lab Technicians	0	0	32	0	32
Totals	22	660	120	120	922

Manyears of Effort = 0.44

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OLD CROSS-CUT CANAL
PHOENIX, ARIZONA

ENVIRONMENTAL RECONNAISSANCE

A. Introduction

1. Project Location. - The Old Cross-Cut Canal is located entirely within the city of Phoenix, Arizona. The study area is bounded by Camelback Mountain on the north, the Salt River on the south, and 60th and 40th Streets on the east and west, respectively. The Old Cross-Cut Canal is about four miles long and extends from the Arizona Canal to the Grand Canal. The project area is shown on plate 1.

2. Need for the Proposed Action. - Runoff from Camelback Mountain results in sheet flow and ponds behind the north levee of the Arizona Canal. Runoff from floods exceeding the 25-year event overtops the north levee at various locations and is intercepted by the Arizona Canal. Floodwaters eventually fill the Arizona Canal and overflow its south bank. Floodflows then disperse into sheet flow through developed areas below the canal. Some of the sheet flow will be intercepted by the Old Cross-Cut Canal. The remaining flows will pond along the north bank of the Grand Canal. The Standard Project Flood (SPF) overflow area is shown on plate 2.

3. Project Background. - The Phoenix Urban Study Report was completed in June, 1982 and forwarded to the Board of Engineers for Rivers and Harbors (BERH) for review. BERH approved the report in March, 1983. The report recommended further studies of the Old Cross-Cut Canal as a flood control facility.

B. Proposed Action

The Old Cross-Cut Canal would be used as a flood channel to carry waters away from the north side of the Arizona Canal and to prevent flooding along the four miles of channel between the Arizona Canal and the Salt River. The existing canal, currently utilized for the exchange of waters from the Arizona Canal to the Grand Canal, would be enlarged to carry floodflows away from the Arizona Canal. A new channel would have to be constructed from the Grand Canal to the Salt River.

C. Environmental Setting

1. General. - The Old Cross-Cut Canal traverses an area that is dominantly residential development. There is very little vacant land adjacent to the project area. Although no water quality data is available for urban runoff in the Phoenix area, some generalizations about the quality of urban runoff from other cities can be made. Contaminant concentrations are inversely related to quantity of surface flow. Small surface flow events have greater concentrations of non-point pollutants such as oil, grease, lead, etc., while large flow events tend to dilute pollutant concentrations (1). Length of time between storm events will also affect concentrations, regardless of storm-event size (1). Groundwater in the overall project area is generally of acceptable

quality (1). The project area is within an urban area and the noise is typical of an urban area: people and traffic. The intensity of the noise varies along the length of the Old Cross-Cut Canal and is dependent on the degree of development. The Canal traverses an urban area and thus a variety of visual resources. The Canal is crossed by at least six roadway bridges along its length.

2. Biological Environment. -

a. Vegetation. - Most of the natural biotic communities along the length of the Old Cross-Cut Canal have been disturbed as a result of urbanization of the Phoenix area. If any natural vegetation occurs within the area, it would be in small undeveloped patches. Species that could be expected include mesquite (*Prosopis juliflora*), catclaw acacia (*Acacia greggii*), paloverde (*Cercidium floridum*), broom baccharis (*Baccharis sarothroides*), creosotebush (*Larrea tridentata*), eucalyptus (*Eucalyptus* spp.), tree tobacco (*Nicotiana glauca*), and Russian thistle (*Salsola kali*). Most of the residential areas have used nonindigenous plants for landscaping. Because of the extensive urbanization, it is doubtful that there are any Federal or State threatened or endangered species along the length of the Old Cross-Cut Canal.

b. Wildlife. - Dominant wildlife likely to be found in the area would include small reptiles (lizards and snakes), small mammals, rodents, and birds (mostly passerine species). Because of the extensive urbanization within the Phoenix metropolitan area, no Federal or State threatened or endangered species would be expected.

3. Cultural Resources. - The Old Cross-Cut Canal was included in "An Initial Survey of Historic Resources within the Phoenix Metropolitan Area, Maricopa County, Arizona," which was prepared for the Los Angeles District by the Arizona State Historic Preservation Office in 1977. This report provides a historical overview of Phoenix and a preliminary evaluation of 45 historic structures in the vicinity of the Old Cross-Cut Canal. Four of these were identified as potentially eligible for the National Register of Historic Places and two as eligible for the State Register of Historic Places.

The Pueblo Grande Ruin, a major Hohokam village site, and the Hohokam-Pima Irrigation Sites (Park of Four Waters) are located at the southern end of the project area. Both are listed on the National Register of Historic Places and are also National Historic Landmarks. According to Dr. David Doyel, Director of the Pueblo Grande Museum and City of Phoenix Archeologist (personal communication, 1985), an extension of the Old Cross-Cut Canal was constructed through the Pueblo Grande Ruin in the 1970's, causing damage to the site.

Dr. Doyel also provided the following information concerning the archeological sensitivity of the proposed Old Cross-Cut Canal project area. The exact boundaries of the Pueblo Grande Ruin are unknown; it may extend as far north as Van Buren Street. A 1903 map of the area shows a Hohokam ballcourt adjacent to the canal halfway between Washington Street and Van Buren Street. An 1883 map shows other archeological features west of this location. Recently discovered documents indicate that a 14th century structure was excavated near the intersection of the Old Cross-Cut Canal and Van Buren

Street by Cushing, a pioneer Southwestern archeologist. In summary, Dr. Doyel believes that buried archeological materials may occur from the south end of the Old Cross-Cut Canal as far north as Van Buren Street and possibly beyond that point.

A site visit to the Old Cross-Cut Canal by a Corps archeologist indicates that much of the right-of-way adjacent to the Canal follows existing paved roads. There are, however, some areas that are relatively undisturbed. The entire right-of-way must be surveyed on foot by an archeologist to identify and evaluate any sites that may be extant on the surface. The area of high archeological sensitivity is shown on plate 1. A program for identification and evaluation of subsurface sites in the project area must also be designed. This would comprise a combination of archival research, remote sensing, subsurface excavation, and construction monitoring.

D. **Potential Environmental Effects**

1. Environmental Effects. - Because of the lack of natural habitat, little effect on vegetation and wildlife would be expected from construction of the project. The major impacts expected would be those connected with construction of the project. Because of the residential nature of the project area, noise would be a major impact. Heavy construction equipment would also disrupt local traffic patterns. At least six roadway bridges would have to be replaced. Dust from construction activities could also impact air quality. It is currently anticipated that little, if any, additional right-of-way would need to be acquired, except in the reach between the Grand Canal and the Salt River and no relocations would be needed.

2. Cultural Resources. - The proposed project would potentially impact two National Register and National Landmark properties, the Pueblo Grande Ruin and the Hohokam-Pima Irrigation Sites. The project might impact other significant prehistoric sites, some of them buried, which have not yet been identified and evaluated. There are 45 known historic structures in the vicinity of the project area, including at least four that appear to be eligible for the National Register of Historic Places and two that are eligible for the State Register of Historic Places, but there is not yet sufficient information to determine the probable impacts of the project on these properties. Although it may be possible to avoid construction-related damage to these structures, the potential adverse effects of the project on the settings of National Register historic properties must be taken into consideration.

3. Possible Mitigation and/or Avoidance Measures. -

a. Environmental. - Construction activities should take place during daylight hours on workdays to minimize noise impacts. Air quality impacts could be minimized by watering any exposed soil areas. Reseeding disturbed areas could be a mitigation measure for disturbance to habitat.

b. Cultural. - Because sites listed on the National Register of Historic Places are within the project area, this project must be coordinated with both the Arizona State Historic Preservation Office and the Advisory

Council on Historic Preservation. A plan for avoidance and mitigation of impacts to significant cultural resources must be developed and approved by these agencies. Because the two National Register listed sites are also National Historic Landmarks, and because of the magnitude of expected impacts, it may not be possible to mitigate all adverse impacts. Therefore, an Environmental Impact Statement may be required. This will be determined during the next phase of project planning.

E. Coordination

Coordination with the Arizona State Historic Preservation Office was initiated with a letter dated December 9, 1985 (Enclosure 1).

F. Estimated Costs

It is estimated that preparation of an uncoordinated draft Environmental Assessment would be about $11,180, consisting of about $4,200 hired labor, $3,000 for a cultural resources purchase order, $3,240 for U. S. Fish and Wildlife Service funding, and $740 for travel. If it is later determined that an Environmental Impact Statement would be required for this project, an undetermined amount of additional funding would be necessary.

The uncoordinated draft Environmental Assessment could be completed within 45 days after receipt of funding and an adequate project description (adequate enough to determine a probable with-project future). Public review and finalization of the report would require an additional 60 days. If an Environmental Impact Statement is determined to be necessary, considerably more time would be required.

G. References

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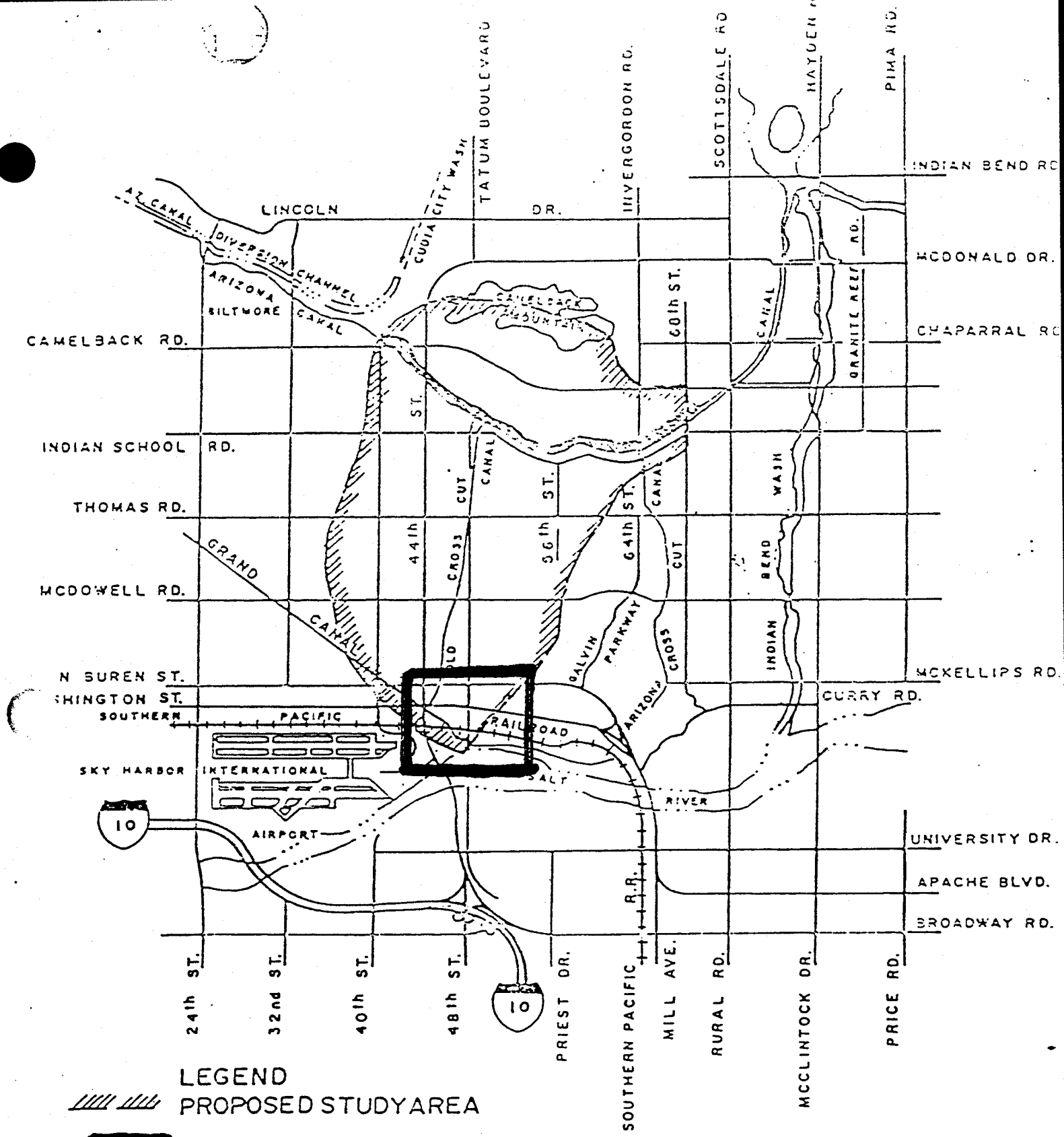


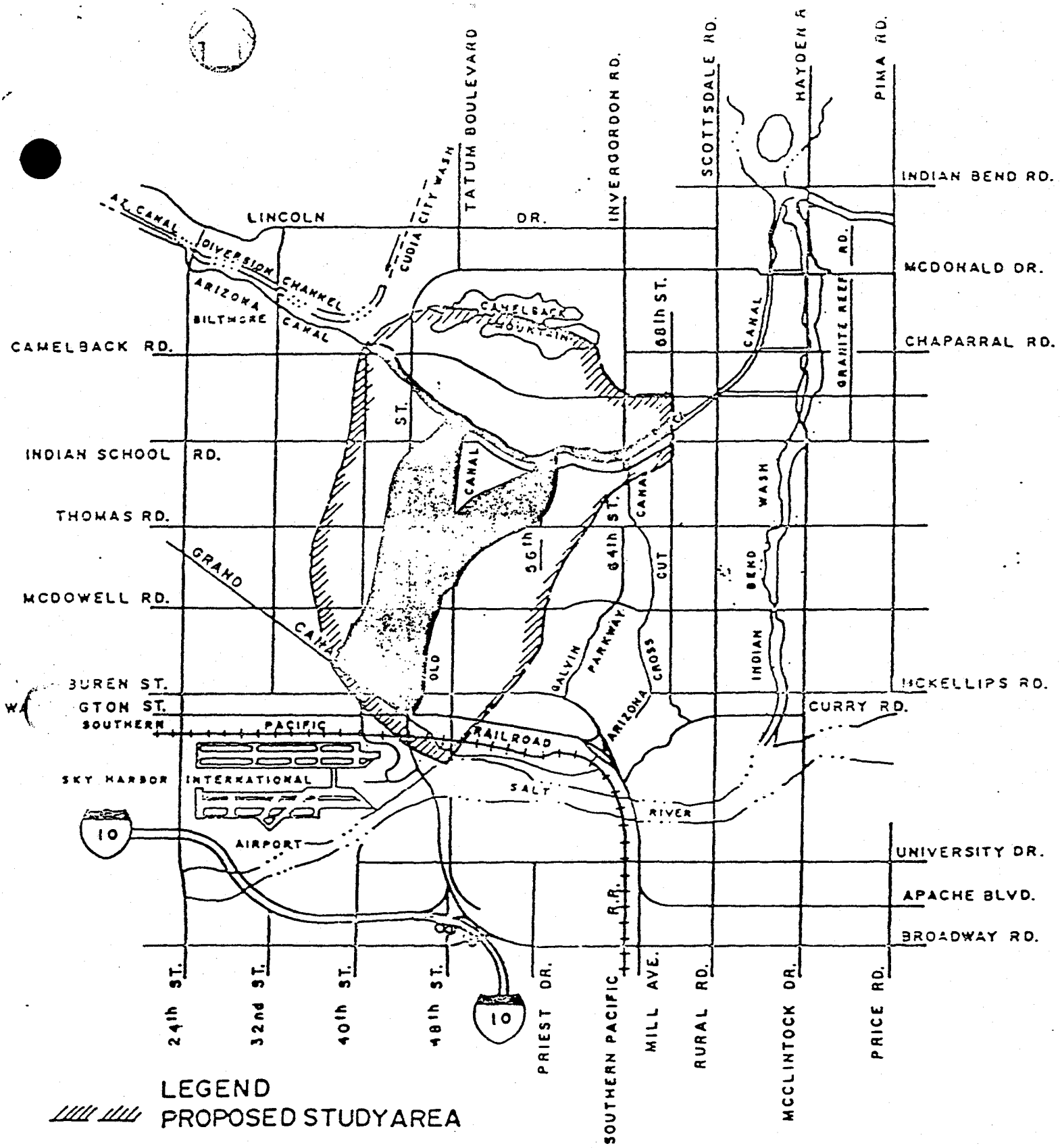
LEGEND

PROPOSED STUDY AREA

Location of National Register/ National Historic Landmark sites and predicted high archeological sensitivity

OLD CROSS-CUT CANAL PROJECT

PLATE 1



OLD CROSS-CUT CANAL PROJECT

PLATE 2

December 9, 1985

Office of the Chief
Environmental Resources Branch

Ms. Donna Schober
State Historic Preservation Officer
Arizona State Parks Board
1688 W. Adams Street
Phoenix, Arizona 85007

Dear Ms. Schober:

The Los Angeles District Corps of Engineers (LAD) has undertaken a study of proposed modifications to the Old Cross-Cut Canal in Phoenix. The purpose of this letter is to inform you of the status of this study and to request any information or concerns you may have regarding historic properties in the study area, which is shown on the enclosed map (encl 1).

The Corps is aware that two historic properties, the Pueblo Grande Ruin and the Hohokam-Pima Irrigation Sites, both of which are National Historic Landmarks, as well as National Register listed sites, are located at the south end of the study area. Information provided by Dr. David Doyel, Director of the Pueblo Grande Museum, indicates that subsurface remains associated with that site may extend at least as far north as Van Buren Street. Information on historic structures in the study area is included in "An Initial Survey of Historic Resources within the Phoenix Metropolitan Area, Maricopa County, Arizona," which was prepared for LAD by your office in 1977.

During the next phase of this study the Corps plans to award a contract for an expanded literature search and an intensive, systematic cultural resources survey of the proposed project area.

We will keep you informed of the status of this study. If you have any questions, please contact Dr. Helen Wells of the LAD archeological staff at (213) 894-0238.

Sincerely,

Carl F. Enson
Chief, Planning Division

Enclosure

Encl 1

OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

TECHNICAL DOCUMENTATION

SECTION F

ECONOMICS

Prepared by
Los Angeles District
South Pacific Division
Corps of Engineers
Department of the Army

CESPL-PD-WE 21 April 1989

MEMORANDUM FOR RECORD

SUBJECT: Summary of Old Cross-Cut Canal Economic Analysis

1. General. The economic analysis of proposed flood reduction measures in the Old Cross-Cut study area consists primarily of evaluating the inundation reduction benefits to single-family residential structures and contents. A small amount of benefits from emergency costs saved are also claimed.

2. Flooding Problem. Flooding occurs on the north side of the Arizona Canal when storm runoff from camelback Mountain ponds north of the canal. South of the Arizona Canal, widespread sheet flooding covers approximately 10 square miles of urban development and results from breakouts from the Arizona Canal, overflows from the Old Cross-Cut Canal itself, and from interior rainfall.

3. Average Depths of Flooding. Flooding depths are relatively shallow, particularly south of the Arizona Canal, with the proposed project (Full Lafayette, 25-yr level of protection) providing only minimal reduction in average depths of flooding. Table 1 shows representative cross sections and average depths for south of the Arizona Canal.

TABLE 1

Average Depths of Flooding

(Height above curb, in feet)

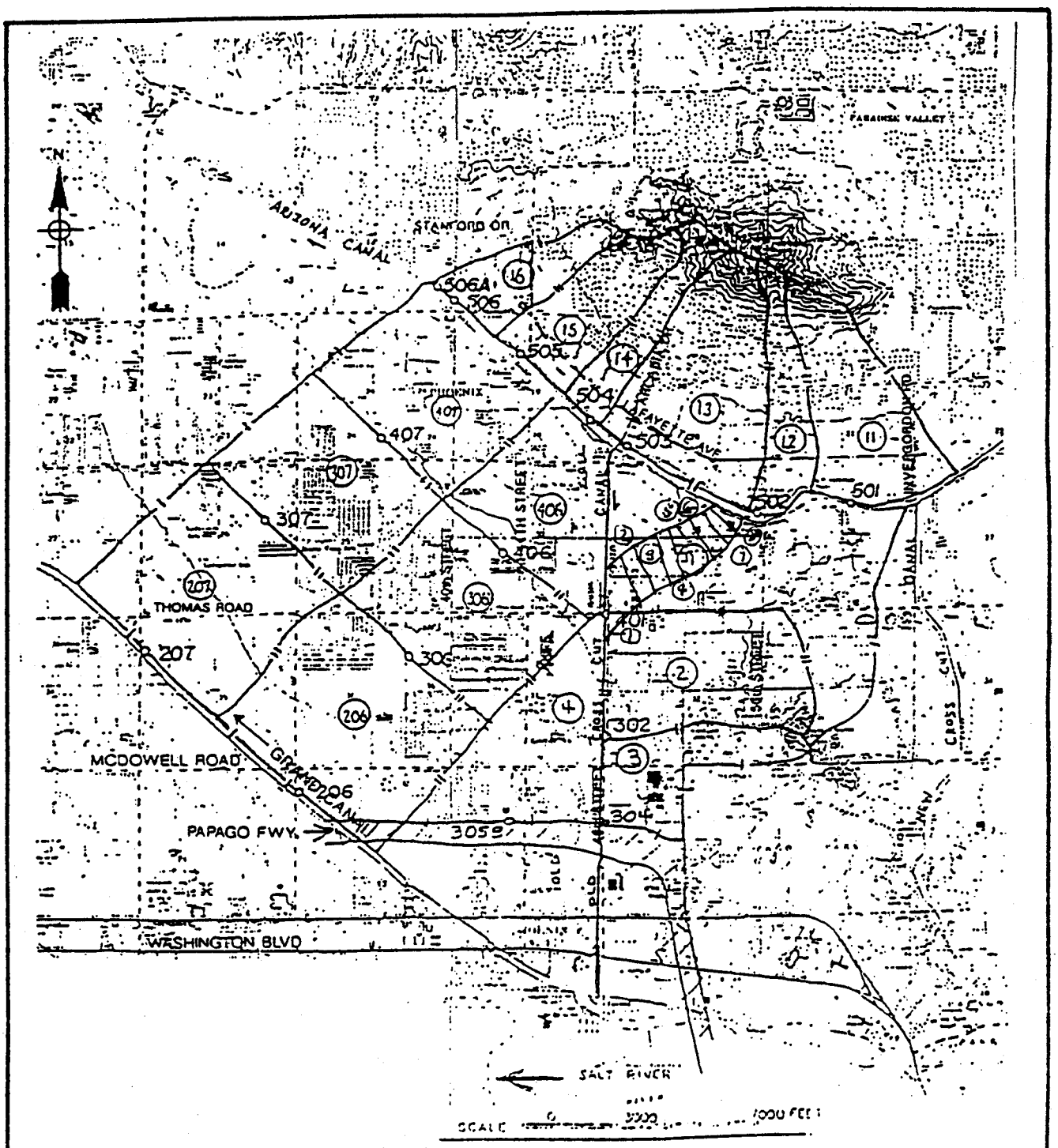
FOR 25 YR FLOWS ONLY

	Flood Magnitude							
	200		100		50		25	
Cross Section	W/O	With	W/O	With	W/O	With	W/O	With
206	0.6	0.6	0.6	0.6	0.5	0.5	0.4	0.4
207	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.3
306	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.2
307	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.3
406	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
407	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.2
502	1.3	0.0	1.3	0.0	1.0	0.0	0.7	0.0
506	0.9	0.6	0.9	0.6	0.7	0.4	0.4	0.2

(See map on following page for location of cross sections.)

4. Property Inventory. A property inventory was conducted of the study area from large-scale maps and aerial photographs.

5. First Floor Elevations. Since the depths of flooding both with and without project are quite shallow, a sample survey of first floor elevations was conducted to determine which property categories would be susceptible to flood damage. Nearly 80 percent of total structures north of the Arizona Canal were sampled; while south of the canal, approximately 5 to 10 percent of total first floor elevations were measured. The procedure was to measure the height of the first floor relative to the curb using a hand level and a survey rod. This



STORM DRAIN

CONCENTRATION POINT

SUBAREA NUMBER

OLD CROSS CUT STUDY

DRAINAGE AREA MAP

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

detailed survey indicated that the average first floor elevations for all damage categories south of the Arizona Canal except single family houses were greater than the average depths of flooding associated with the largest magnitude floods. North of the Arizona Canal, 15 multi-family structures in addition to all the single family homes were found to be damageable. Consequently, a data base was compiled for only those damageable categories as summarized in Table 2.

TABLE 2

Inventory of Damageable Structures

	Flood Magnitude			
	200	100	50	25
North of Arizona Canal				
Single-family	366	266	234	202
Multi-family	15	15	15	15
South of Arizona Canal				
Single-family	4412	4412	4412	4412
Total	4793	4693	4661	4629

6. Value of Damageable Property. Average square footage per structure was determined from aerial photographs and field estimates. Eave overhang and garage space was excluded. The Marshall and Swift Real Estate Appraisal

Service was used to determine average depreciated first floor replacement values. South of the Arizona Canal an average of $60,000 depreciated replacement value for single family houses was used, while average values north of the canal are $112,000 for single family homes and $169,000 for apartment buildings. Contents values are estimated to be 50 percent of structure values. Table 3 gives total value of structures and contents.

TABLE 3

Value of Damageable Structures and Contents

($ 1,000,000)

	200	100	50	25
South of Arizona Canal				
Residential Structures	265	265	265	265
Contents	132.5	132.5	132.5	132.5
North of Arizona Canal				
Residential Structures	44	33	29	26
Contents	22	16.5	14.5	13

7. Damages. Damages per flood event were calculated using the depth-damage curve from the Arizona Canal Diversion Channel Study. Since structures in the study area are built primarily on slabs, no damages were calculated for flooding below the first floor. Table 4 summarizes the damages to structures and contents.

TABLE 4

Damages to Structures and Contents

(By Flood Event and Average Annual)

($1,000)

	Flood Magnitude				
Without Project Damages	200	100	50	25	Average Annual
North of Arizona Canal	18,236	6,810	4,387	3,067	405
South of Arizona Canal	20,077	20,077	18,080	14,680	1,228
Total	38,313	26,887	22,467	17,747	1,633
With Project Damages					
North of Arizona Canal	18,236	6,408	2,556	0	246
South of Arizona Canal	20,077	17,613	14,484	9,385	924
Total	38,313	24,021	17,040	9,385	1,170
Damages Prevented	0	2,866	5,427	8,362	463

8. Average Annual Benefits and Costs. Table 5 shows costs, benefits, and the benefit-cost ratio. At a first cost of $19,940,000 the average annual costs are $1,894,000, including O&M. Total benefits are $515,000, resulting in a benefit-cost ratio of 0.3 to 1.0.

Service was used to determine average depreciated first floor replacement values. South of the Arizona Canal an average of $60,000 depreciated replacement value for single family houses was used, while average values north of the canal are $112,000 for single family homes and $169,000 for apartment buildings. Contents values are estimated to be 50 percent of structure values. Table 3 gives total value of structures and contents.

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TABLE 5

Average Annual Costs and Benefits

(October 1988 Price Levels)

Construction Cost	$19,940,000
Interest During Construction	860,000
Gross Investment	20,800,000
Annual Costs	
Interest and Amortization	1,794,000
Operation and Maintenance	100,000
Total Annual Cost	1,894,000
Annual Benefits	
Structures and Contents	463,000
Emergency Costs Saved [1]	52,000
Total Annual Benefits	515,000
Benefit-Cost Ratio	0.3

[1] Includes savings due to reduced flood emergency police, fire, clean-up crews, city street repairs, etc.

Peter C Womack

PETER WOMACK

Regional Economist

CF:

CESPL-PD-WC (Burton)

Rev. 10/89
WRB

SPLPD-RR 25 July 1985

MEMORANDUM FOR RECORD

SUBJECT: Field Reconnaissance of Old Cross-Cut Canal, Arizona

1. On 20-21 May 1985, a field reconnaissance was made of the Old Cross-Cut Canal by members of the Study Team and Laura Herbranson, Project Manager.

2. Study Team members included:

Jody Fischer, Hydrology, x4759
Glen Mashburn, Hydraulics, x5497
Tim Yeh, Design, x5378
Mike Easterly, Geology, x5487
Bill Halczak, Materials, x5485
Mike Quin, Soils, x0951
John O'Leary, Environmental, x0246
Chuck Evans, Econ-Soc, x5474
Ron Lockmann, Recreation, x0241

3. The Old Cross-Cut Canal extends about 3.5 miles through an entirely urban/industrial section of Phoenix. It begins at the Arizona Canal and extends nearly due southward along 48th Street to the Grand Canal. Its terminus is a short link between the Grand Canal and the Salt River. Some of the rights-of-way adjacent to the Old Cross-Cut Canal are currently utilized as bicycle and equestrian trails in the Maricopa County Trail System. The trail's market area includes the residential dwellings within the several city blocks proximate to the Canal itself. A number of signs have been posted to demarcate the bicycle trail. The trail length extends the entire 3.5 miles although its variable surface conditions, earth or broken pavement, provides no sense of unity whatever. The variable right-of-way, from over 50 feet in some places to only a few feet in others, is a further problem. Current maintenance is done by the city of Phoenix Department of Parks and Recreation. The canal is owned by the Salt River Project.

4. There is considerable potential for additional recreational development along the Old Cross-Cut Canal. Some of the most notable shortcomings of the existing trail system could be corrected with the construction of a comprehensive linear bicycle/equestrian trial system. The main deficiences of the existing system are as follows:

a. A lack of unity and continuity of the trail system; paved segments alternate with dirt surface and older paved road remnants.

b. Inadequate and occasionally confusing signage. Some signs appear to be posted along stretches with no recognizable trails and at least one other is located very near a "no trespassing" sign.

OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

TECHNICAL DOCUMENTATION

SECTION G

RECREATION AND AESTHETICS

Prepared by
Los Angeles District
South Pacific Division
Corps of Engineers
Department of the Army

c. The absence of a direct connection with the Arizona Canal, which is itself a portion of the "Sun Circle" bicycle and equestrian trail in the Phoenix metropolitan region.

d. The lack of shaded rest stops along existing trails.

5. A strong focal point should be included on the south end of the trail. The Pueblo Grande Museum affords an ideal point of interest. Presently, a large block wall screens off a view of the intersection of the Grand Canal with the Old Cross-Cut Canal. A rest area could be added to great advantage at this significant dwelling of the canal building Hohokam. Such a facility would require advance planning and coordination with local public and private sectors since portions of the right-of-way, particularly between Van Buren (where the present bicycle/equestrian trail terminates) and Washington Streets are on private land fenced to keep out the public.

6. An improved linear park concept along the Old Cross-Cut Canal would serve the local populace better than the present patchwork facility. Such a concept would provide a unified visually distinctive link within the bicycle/equestrian trail system of the Phoenix metropolitan region. Several features might well be added to ameliorate the current disjunct system:

a. A linear exercise course would fit well in the triangular lot plot at 48th and McDowell.

b. Another prime location for an outdoor activity center would be the corner of 47th and Van Buren at the existing trail head.

c. All project facilities could be marked with Hohokam design to provide thematic unity on the trail.

d. The trail could meander where rights-of-way is wide enough to permit; and rest area could be equiped with outdoor chess/checker game; children's climbing/jungle gym or other specified activity space.

The overall unity and harmony of the trail need to be reestablished. One looks in vain for evidence of trails next to the signs which read "bike trail" at present.

7. The cost estimate for a recreation development feasibility study for the Old Cross-Cut Canal is $7700.00. This cost includes the hired labor required for one month, overhead and costs for graphics and reproduction.

Ronald Lockmann

RONALD LOCKMANN
Geographer
Recreation Section

OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

TECHNICAL DOCUMENTATION

SECTION H

PUBLIC INVOLVEMENT

Prepared by
Los Angeles District
South Pacific Division
Corps of Engineers
Department of the Army

FLOOD CONTROL
DISTRICT
of
MARICOPA
COUNTY
1959

Stephen
Carpenter
Freestone
Koory, Jr.
Ed Pastor

Dear Resident:

Some of you have been flooded or could be flooded in the future. The Flood Control District and the U. S. Army Corps of Engineers are studying flooding problems in the Arcadia and Old Cross Cut Canal area and looking at possible alternatives to solve these problems. The general concept proposed is to collect the floodwaters from Camelback Mountain and elsewhere in the watershed and channel them to the Salt River in a reconstructed Old Cross Cut Canal. A watershed map is shown on the back of this letter.

You are cordially invited to participate in a Community Open House to discuss the flooding problems, flood control measures being studied, and possible locations for these measures. We would like your comments and suggestions on how flood protection can be provided to your area.

Community Open House
Old Cross Cut Study

When: Anytime between 5:00 and 8:00 p.m.
Wednesday, February 11, 1987

Where: East High School
Northeast corner of 48th Street and Van Buren
Signs will direct you to the Flood Control Meeting

We hope you will be able to join us on February 11. We want to learn of your concerns or questions about the flood control alternatives before a specific plan is developed. If you cannot attend but would like to fill out a public comment worksheet, I will be glad to send you one.

Sincerely,

Sue Mutschler
Public Involvement Coordinator

FLOOD CONTROL
DISTRICT
of
MARICOPA
COUNTY
1959

Chairman
Jim Freestone
Jim Koury, Jr.
Jim Pastor

Dear Resident:

Some of you have been flooded or could be flooded in the future. The Flood Control District and the U. S. Army Corps of Engineers are studying flooding problems in the Arcadia and Old Cross Cut Canal area and looking at possible alternatives to solve these problems. The general concept proposed is to collect the floodwaters from Camelback Mountain and elsewhere in the watershed and channel them to the Salt River in a reconstructed Old Cross Cut Canal. A watershed map is shown on the back of this letter.

You are cordially invited to participate in a Community Workshop to discuss the flooding problems, flood control measures being studied, and possible locations for these measures. We would like your comments and suggestions on how flood protection can be provided to your area.

Community Workshop
Old Cross Cut Study

When: 7:00 p.m. Monday, February 9, 1987

Where: **Hopi Elementary**
5110 East Lafayette

We hope you will be able to join us on February 9. We want to learn of your concerns or questions about the flood control alternatives before a specific plan is developed. If you cannot attend but would like to fill out a public comment worksheet, I will be glad to send you one.

Sincerely,

Sue Mutschler
Public Involvement Coordinator

OLD CROSS CUT CANAL STUDY

The U. S. Army Corps of Engineers and the Flood Control District of Maricopa County are studying the feasibility of a flood control project in the vicinity of the Arizona Canal in the Arcadia area. The Study includes using the Old Cross Cut Canal to convey the floodwaters to the Salt River.

Public meetings were held on February 9 and February 11 to explain how projects are developed and to solicit comments and concerns about flooding and possible solutions from the public. At each meeting the attendees were asked to fill out a questionnaire and a summary of the answers to the questionnaires are shown below:

1. Residence Ownership?
   47 Own house
   6 Own mobile home
   3 Attendees were representatives of organizations and agencies

2. How long have you lived in the area?
   The 53 respondents have lived in the area from five months to forty years with the average being 17.5 years.

3. What is your experience with flooding in this area?
   31 No problems
   10 Flooded yard
   11 Damage to property
   15 Street flooding

(The comments regarding flooded will be reviewed by Flood Control District and Corps of Engineers staff members.)

4. Do you feel that flood control is necessary in the area?
   41 Yes
   6 No
   2 Qualified response

5. Please indicate how important the following factors are to you in selecting a flood control plan for this area.

	Not Important				Very Important
Appearance	3	1	8	12	30
Neighborhood Safety	2	1	4	6	39
Effect on Neighborhoods	2	0	1	9	42
Flood Protection	4	0	3	8	37
Cost of Implementation	5	6	12	8	21
Environment	5	1	7	10	24

Comments:

Wants project to be attractive and add to the area.
Good opportunity to solve flooding problems.
Concern about safety of neighborhood.
Improve appearance of Canal.
Safer bike paths.
Old Cross Cut Canal is charming as it is now.
Old Cross Cut Canal should be asset to area.
No need for this project.
These meetings don't get neighborhood opinion - worthless format.
Decisions have already been made.
Phoenix is waiting for this study before they engineer Camelback Road so please proceed ASAP.
Appearance should be like Indian Bend Wash, not the L.A. River.
Move the Old Cross Cut Canal as little as possible because of the present disruption because of the Freeways.
The trailer park area will probably go commercial because of the Freeways.
Canal should have a curbing barrier and banks of non-eroding material.
Good to bring this to public's attention in early stages.
Move on this now - don't study it to death.
Wants this project to relieve flooding west of 40th Street.
Benefit/cost ratio needs to consider Arizona Canal overtopping and damage to public and private property.
Resolve problem without removal of houses and putting in concrete ditches.
Improve drainage down the New and Old Cross Cut Canals and new gates.
Drainage in Lafayette and Camelback would help a lot.
Floods don't always come from Camelback Mountain but are overtopping of Canal.
Not in favor of Alternate 4.
The widening and raising of Camelback caused problems.
Runoff from Camelback Mountain and ponding behind Canal has caused problems.
Scottsdale has storm sewers along Camelback and Lafayette.
Canal overflow, not ponding, is what causes the problem.
Shouldn't have to pay flood insurance for a house that hasn't been flooded in 30 years.
This survey is unfair - there are too many underanswered questions.
All the issues should be taken to all the residents.
Flood insurance is expensive but doesn't cover landscaping and pools.
A necessary evil and prevention can be the cure.
This flood problem has come to a head only because the City wants 48th Street as a parkway and they want flood control funds to help with the parkway.
SRP should admit responsibility for which it accepts revenues.
Developers allowed to build in and change washes thus causing flooding.
Canal should be covered and made into a park.
The facilitator kept questions from being answered.
Time should not have been taken from the meeting for this form.
Design criteria which would account for the on-site retention which is prevalent in the area would reduce the magnitude of a flood.
Water management seems more important than "flood control".
Open channels are unsafe and unsightly.
The drainage and channeling work done by Phoenix has helped.
This isn't much of a survey.
As a minimum, the 40 year option should be undertaken, and if economically possible, the 100 year option.
If the cost of this project is too much, a small amount of dollars could be applied to reducing flood insurance premiums.
Wants greenbelt park, and SRP, Phoenix, and neighborhood should dream for betterment of all.

FLOOD CONTROL DISTRICT
of
Maricopa County

3335 West Durango Street • Phoenix, Arizona 85009
Telephone (602) 262-1501

D. E. Sagramoso, P.E., Chief Engineer and General Manager

BOARD of DIRECTORS
Fred Koory, Jr., Chairman
George L. Campbell
Carole Carpenter
Tom Freestone
Ed Pastor

February 25, 1987

Dear Resident:

Thank you for attending the public meetings regarding the Old Cross Cut Canal Study presently being performed by the U. S. Army Corps of Engineers in cooperation with the Flood Control District.

For your information, I have enclosed a copy of a summary of the responses to the questionnaire distributed at the meetings.

The Corps of Engineers is in the process of gathering information concerning the proposed alternatives, and it is expected that this additional information will be complete early this summer. A second set of public meetings is planned for the summer at which time the public will have an opportunity to review this information and make additional comments. You will be notified of the meetings.

We appreciate your interest and your comments.

Sincerely,

Sue Mutschler
Public Involvement Coordinator

Enclosure

News Release
For More Information Contact:
Dick Perreault, 262-1501

Alternatives to resolve flooding problems in the Arcadia area have been developed and will be presented at a public meeting.

The Flood Control District of Maricopa County and the U. S. Army Corps of Engineers will make a presentation about the alternatives and answer questions at a meeting to be held at 7:00 p.m., Monday, May 16, 1988, at Hopi School, 5110 East Lafayette.

"The flooding problem is caused by water from Camelback Mountain ponding behind the Arizona Canal between about 40th Street to 68th Street," said Laura Herbranson, the project manager for the Corps of Engineers.

"The general concept to solve the problem is to collect the floodwaters and carry the water to the Salt River in the Old Cross Cut Canal. That is why it is called the Old Cross Cut Canal Feasibility Study," Herbranson added.

The three alternatives developed involve construction in Lafayette Boulevard, and two of the alternatives call for modifications to the Arizona Canal.

--more--

The City of Phoenix and ADOT have plans to build the Hohokam Freeway and street improvements north to Indian School Road using the right-of-way of the Old Cross Cut Canal.

"This means the Old Cross Cut will be covered between McDowell and Indian School Roads," said Dick Perreault, project manager for the Flood Control District.

"The Old Cross Cut Canal will still serve its purpose of draining the Arizona Canal and collecting storm water below Indian School Road," added Perreault, "but, with modifications, it can also drain floodwaters from the Arcadia area."

The City of Phoenix will have a public meeting to discuss transportation issues along the Old Cross Cut Canal corridor at 7:00 p.m., Thursday, May 19, at Arcadia High School.

Flood Control District and Corps of Engineers staff will be available at that meeting to answer questions about the Old Cross Cut Canal Feasibility Study.

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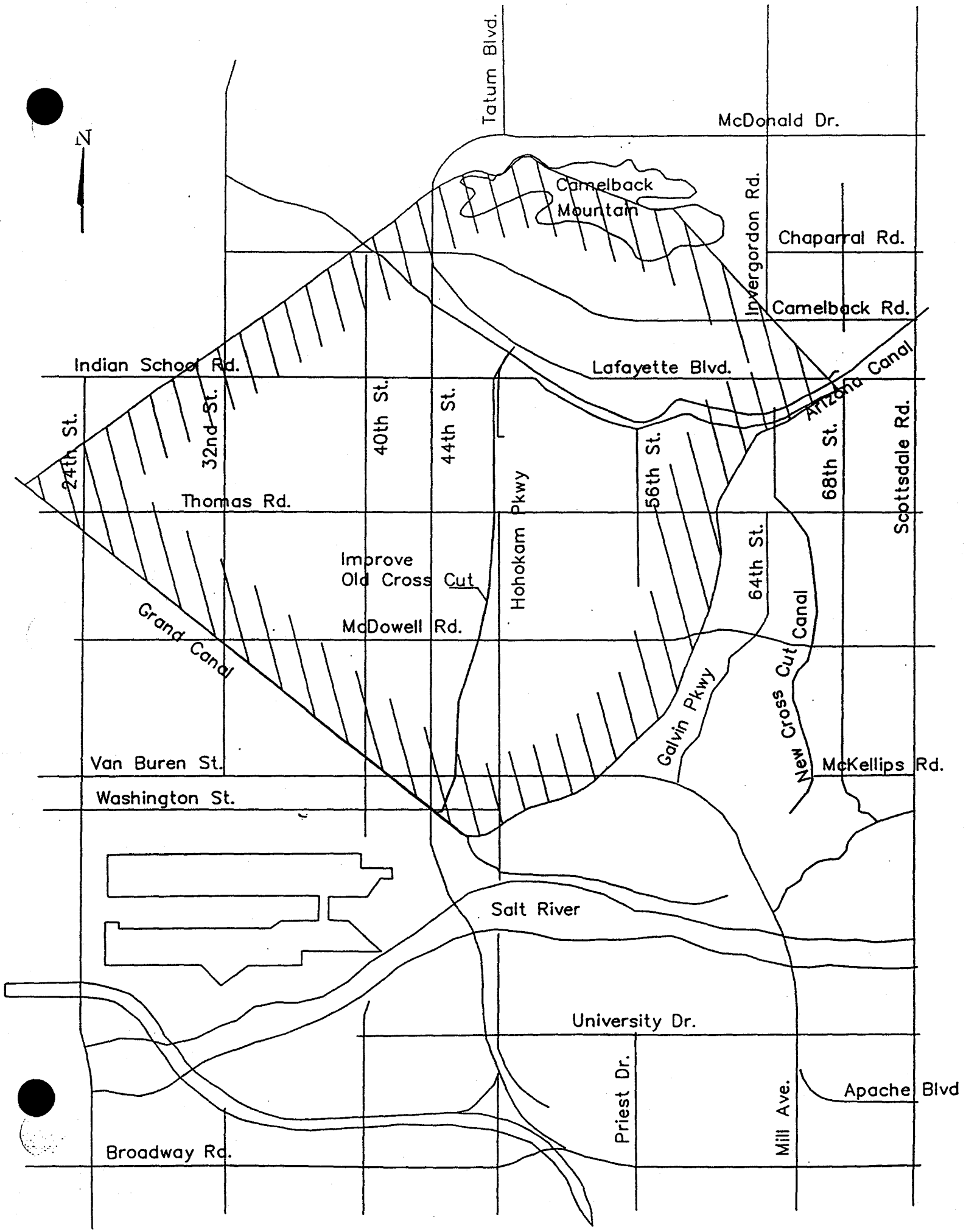

N
Tatum Blvd.
McDonald Dr.
Camelback Mountain
Invergordon Rd.
Chaparral Rd.
Camelback Rd.
Indian School Rd.
Lafayette Blvd.
Arizona Canal
24th St.
32nd St.
40th St.
44th St.
56th St.
68th St.
Scottsdale Rd.
Thomas Rd.
Hohokam Pkwy
64th St.
Improve Old Cross Cut
McDowell Rd.
Grand Canal
Galvin Pkwy
New Cross Cut Canal
Van Buren St.
McKellips Rd.
Washington St.
Salt River
University Dr.
Priest Dr.
Mill Ave.
Apache Blvd
Broadway Rd.

OLD CROSS-CUT CANAL

PHOENIX, ARIZONA

TECHNICAL DOCUMENTATION

SECTION I

OTHER

Prepared by
Los Angeles District
South Pacific Division
Corps of Engineers
Department of the Army

ALLEY ALTERNATIVE

DESIGN LEVEL: 25 Yr.

PROJECT DESCRIPTION:

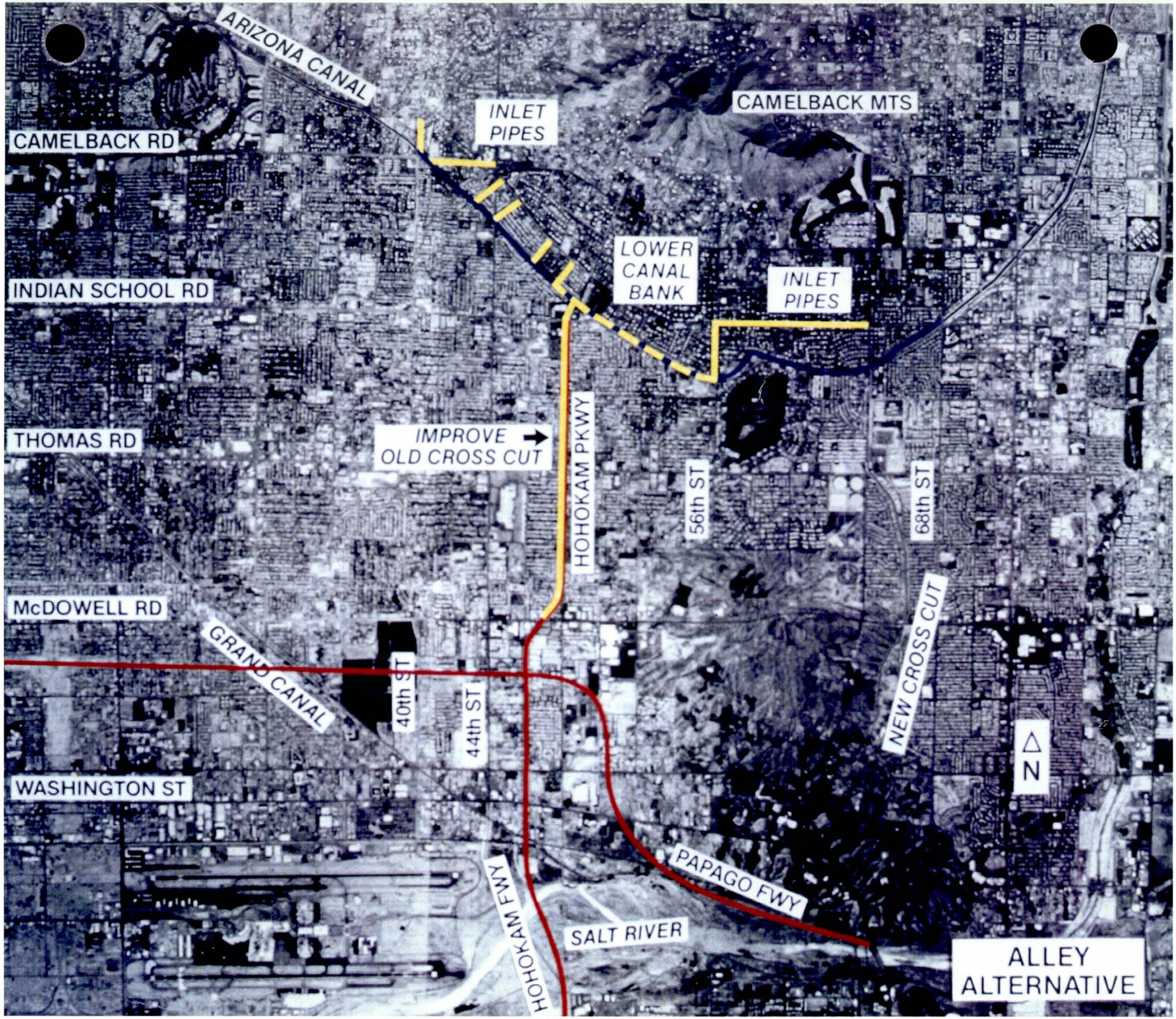
INLET SYSTEM - The structural elements of this alternative consist of an inlet collector system in place along Lafayette Boulevard and six side drains located between Dromedary Road and 40th Street. The conduit along Lafayette Boulevard is approximately 7200 feet in length beginning at Invergordon Road and proceeding west to 56th Street. At 56th Street the conduit will proceed south to the Arizona Canal and discharge directly into it. Inlet grates will be placed at six major intersections to collect the runoff into the conduit. Grading of Lafayette Boulevard may be required to make sure runoff gets to the collection points. Six side drains ranging from 1000 feet to 2000 feet in length will collect runoff between Dromedary Road and 40th Street. The total length of these side drains is approximately 7400 feet. These side drains discharge directly into the Arizona Canal and are located in the alley west of Dromedary Road, in the alley west of 46th Street, in The alley west of Avenida Del Puente, in the alley west of Calle Feliz, along Camelback Road, and along 40th Street. Inlet grates will be located at the upstream end of these side drains. To relieve ponding between 55th Place and Dromedary Road, the north bank of the Arizona Canal will be lowered to the adjacent low ground elevation to allow direct runoff into the Arizona Canal. An armor coating will be added to the north bank to prevent erosion from the runoff into the Arizona Canal. From Dromedary Road to 40th Street the north bank could not be lowered to the adjacent low ground elevation as this would infringe upon the 2 foot freeboard that the Salt River Project (SRP) requested be left above its normal operational level.

ARIZONA CANAL - To assist in operating the Arizona Canal for flood protection, two additional radial gates will be added to the Arizona Canal system. One additional radial gate 13.5 feet wide will be added to the two existing gates at the Old Cross-Cut Canal junction. This will provide capability to divert 1600 cfs from the Arizona Canal to the Old Cross-Cut Canal. The additional radial gate in the vicinity of 44th Street will be 42 feet wide, and will be used to force a quicker drawdown of the water in the Arizona Canal.

OLD CROSS-CUT - Improvements to the Old Cross-Cut Canal would extend from the Arizona Canal to McDowell Road. The Old Cross-Cut Canal has been divided into three reaches for analytical purposes. Reach 1 extends from the Arizona Canal to Osborn Road. Reach 2 extends from Osborn Road to Thomas Road. Reach 3 extends from Thomas Road to McDowell Road. Improvements in reaches 1 and 2 would consist of a 1V to 1H grouted stone channel. Improvements in reach 3 would consist of placing the Old Cross-Cut Canal in a concrete box conduit. These improvements follow the current alignment and fit within the existing right-of-way.

OPERATION - One hour before the peak of a storm event hits, the radial gates located at Scottsdale-Camelback Roads and at 44th Street would be closed. The gates into the Old Cross-Cut Canal would be opened. The Arizona Canal would

then drain through 3 outlets. The water in the Arizona Canal between 68th Street and the New Cross-Cut Canal would drain into the New Cross-Cut Canal. The water in the Arizona Canal between the New Cross-Cut Canal and 44th Street would drain down the Old Cross-Cut Canal (water in the Arizona Canal between 44th Street and the Old Cross-Cut flows back towards Old Cross-Cut). The water in the Arizona Canal between 40th and 44th Streets would continue down the Arizona Canal. Once the peak of the storm hits, the gate at 44th Street would be opened. Flood flows between 68th Street and the Old Cross-Cut Canal would drain down the Old Cross-Cut Canal and flood flows between the Old Cross-Cut Canal and 40th Street would continue down the Arizona Canal.


ARIZONA CANAL
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INLET PIPES
CAMELBACK RD
LOWER CANAL BANK
INLET PIPES
INDIAN SCHOOL RD
THOMAS RD
IMPROVE OLD CROSS CUT
HOHOKAM PKWY
56th ST
68th ST
McDOWELL RD
GRAND CANAL
40th ST
44th ST
NEW CROSS CUT
N
WASHINGTON ST
PAPAGO FWY
HOHOKAM FWY
SALT RIVER
ALLEY ALTERNATIVE

PARTIAL LAFEYETTE ALTERNATIVE

DESIGN LEVEL: 40 Yr.

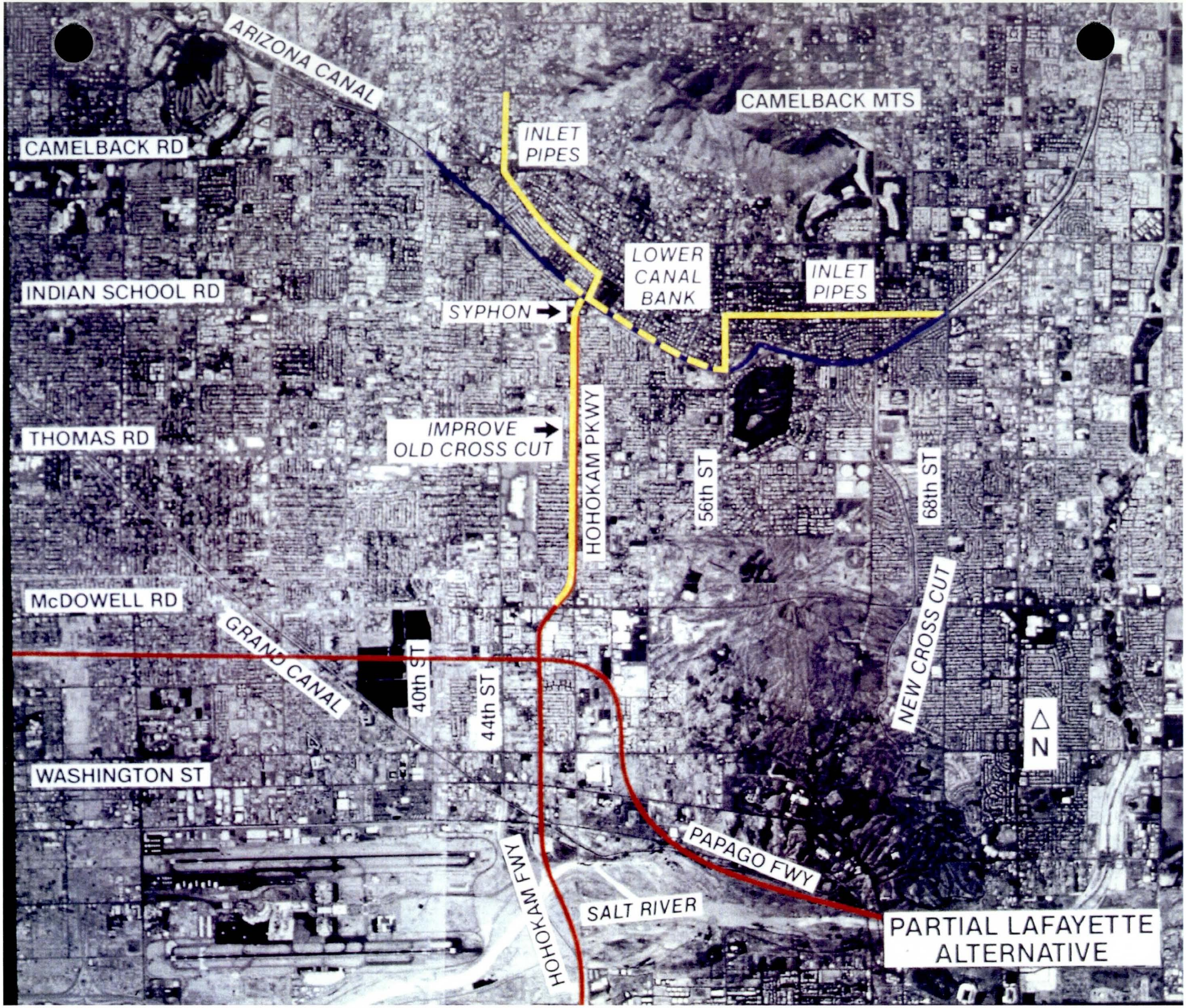
PROJECT DESCRIPTION:

INLET SYSTEM - This alternative consists of the same design features as the alley alternative, an inlet collector system along Lafayette Boulevard between Invergordon Road and 56th Street and lowered north bank of the Arizona Canal between 56th Street and Dromedary Road. However, instead of the six side drains, an additional inlet collector system will be placed along 44th Street from Stanford Drive south to Lafayette Boulevard. This additional conduit then proceeds east along Lafayette Boulevard from 44th Street to Arcadia Drive. At this point the conduit then turns south on Arcadia Drive, under the Arizona Canal and discharges into the Old Cross-Cut Canal. Again, inlet grates will be placed at major intersections to collect storm runoff and the north bank of the Arizona Canal lowered. The total footage of conduit for this alternative is approximately 16,800 feet.

ARIZONA CANAL - To assist in operating the Arizona Canal for flood protection, two additional radial gates will be added to the Arizona Canal system. One additional radial gate 13.5 feet wide will be added to the two existing gates at the Old Cross-Cut Canal junction. This will provide capability to divert 2600 cfs from the Arizona Canal to the Old Cross-Cut Canal. The additional radial gate in the vicinity of 44th Street will be 42 feet wide, and will be used to force a quicker drawdown of the water in the Arizona Canal.

OLD CROSS-CUT - Improvements to the Old Cross-Cut Canal would extend from the Arizona Canal to McDowell Road. The Old Cross-Cut Canal has been divided into three reaches for analytical purposes. Reach 1 extends from the Arizona Canal to Osborn Road. Reach 2 extends from Osborn Road to Thomas Road. Reach 3 extends from Thomas Road to McDowell Road. Improvements in reaches 1 and 2 would consist of a 1V to 1H grouted stone channel. Improvements in reach 3 would consist of placing the Old Cross-Cut Canal in a concrete box conduit. These improvements follow the current alignment and fit within the existing right-of-way.

OPERATION - One hour before the peak of a storm event hits, the radial gates located at Scottsdale-Camelback Roads and at 44th Street would be closed. The gates into the Old Cross-Cut Canal would be opened. The Arizona Canal would then drain through 3 outlets. The water in the Arizona Canal between 68th Street and the New Cross-Cut Canal would drain into the New Cross-Cut Canal. The water in the Arizona Canal between the New Cross-Cut Canal and 44th Street would drain down the Old Cross-Cut Canal (water in the Arizona Canal between 44th Street and the Old Cross-Cut flows back towards Old Cross-Cut). The water in the Arizona Canal between 40th and 44th Streets would continue down the Arizona Canal. Once the peak of the storm hits, the gate at 44th Street would be opened. Flood flows between 68th Street and the Old Cross-Cut Canal would drain down the Old Cross-Cut Canal and flood flows between the Old Cross-Cut Canal and 40th Street would continue down the Arizona Canal.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40th ST
44th ST
NEW CROSS CUT
N
WASHINGTON ST
PAPAGO FWY
HOHOKAM FWY
SALT RIVER
PARTIAL LAFAYETTE ALTERNATIVE

10/25/90
RGP

FULL LAFEYETTE ALTERNATIVE

See Memo
CEPL-ED-HH
8DEC88
Project Description varies. For Inlet

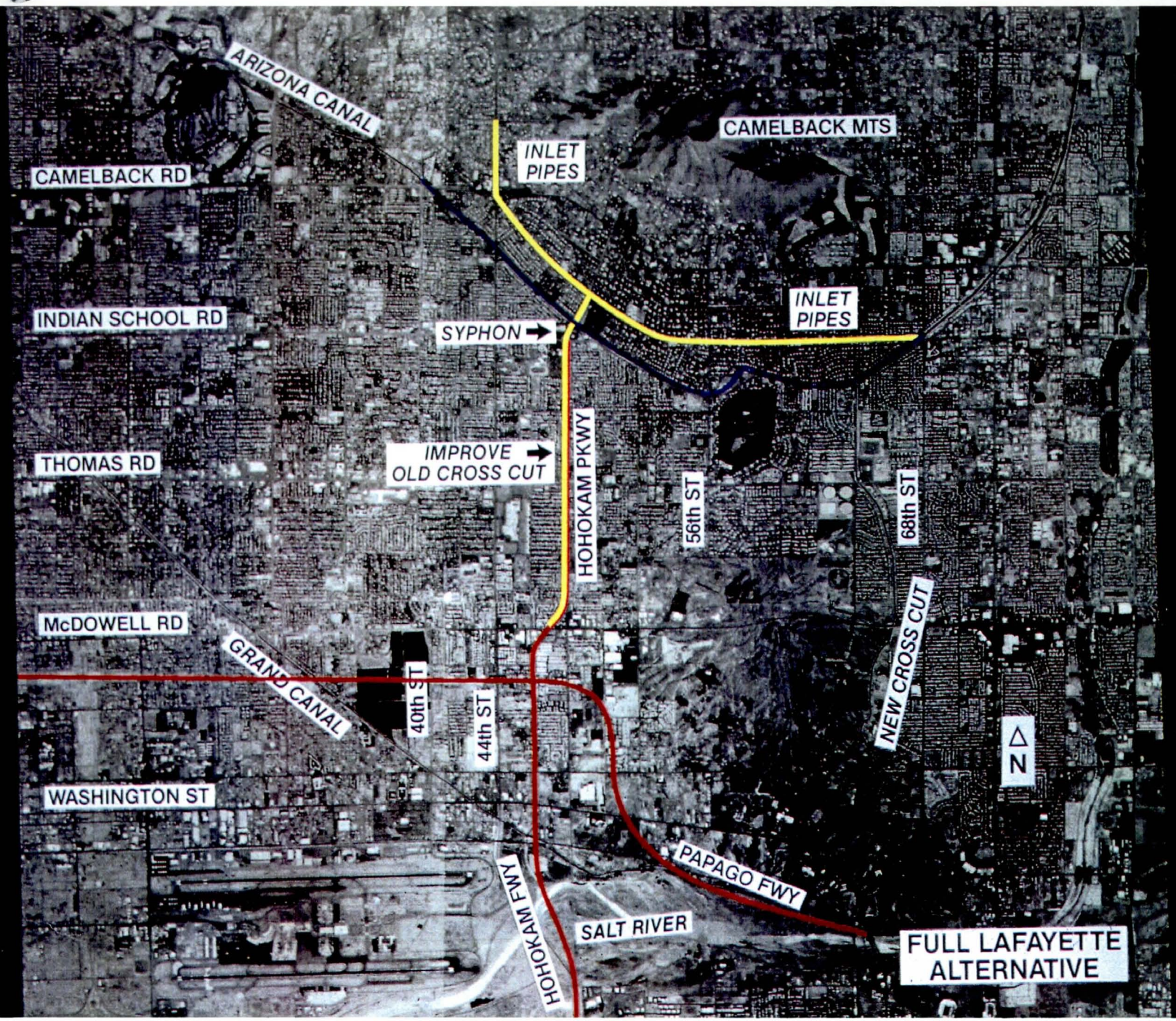
DESIGN LEVEL: 25 Yr.

PROJECT DESCRIPTION:

INLET SYSTEM - This alternative consists of an inlet collector system aligned along Lafayette Boulevard across the entire study area. Also, included is the reach along 44th Street from Stanford Drive to Lafayette Boulevard. Major intersections will have inlet grates to collect runoff that will be taken to Arcadia Drive, which in turn discharges directly into the Old Cross-Cut Canal. The total length of conduit for this design is approximately 19,600 feet.

ARIZONA CANAL - No improvements to the Arizona Canal would be required.

OLD CROSS-CUT - Improvements to the Old Cross-Cut Canal would extend from the Arizona Canal to McDowell Road. The Old Cross-Cut Canal has been divided into three reaches for analytical purposes. Reach 1 extends from the Arizona Canal to Osborn Road. Reach 2 extends from Osborn Road to Thomas Road. Reach 3 extends from Thomas Road to McDowell Road. Improvement to reaches 1 and 2 would consist of a 1V to 1H grouted stone channel. Improvements to reach 3 would consist of placing the Old Cross-Cut Canal in a concrete box conduit. These improvements follow the current alignment and fit within the existing right-of-way.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GRAND CANAL
40th ST
44th ST
NEW CROSS CUT
N
WASHINGTON ST
PAPAGO FWY
HOHOKAM FWY
SALT RIVER
FULL LAFAYETTE ALTERNATIVE

City of Phoenix
Office of Transportation Services

July 8, 1988

Colonel Tadahiko Ono
District Engineer
U. S. Army Corps of Engineers
Los Angeles District
P. O. Box 2711
Los Angeles, CA - 90053-2325

Dear Colonel Ono:

RE: OLD CROSS CUT CANAL

On January 6, 1988, I wrote to Dan Sagramoso regarding the City's tentative position on sizing the Old Cross Cut Canal. Much has happened since then and this letter is to update you on some of the decisions reached.

As I understand it, the Corps of Engineers basically approved two concepts during their F3 Milestone Conference. These were the Alley Alternative and the Full Lafayette Alternative.

For numerous reasons, I believe all of us rejected the Alley Alternative. Some of the reasons included: 1) water quality concerns, 2) potential operation problems, and 3) general public relation concerns.

The City of Phoenix has generally preferred the Full Lafayette Alternative. Our basic concern and question dealt with the level of protection, i.e., 25-, 40- or 100-year storm. We have reached a decision and on June 21, 1988, the City Council concurred with our recommendation for the Full Lafayette 25-year Alternative. For your information here is a copy of the City Council Report which was unanimously approved.

I have forwarded this information to the Flood Control District of Maricopa County (FCDMC), the local sponsor, and asked them to formally transmit this to you. I have also requested that if they agree with the flow quantities, that these be forwarded to the Arizona Department of Transportation, who are designing the Hohokam Freeway.

Laura Herbranson, of your Phoenix office, recently contacted us regarding the recreation portion of the Corps' studies. According to her, a Corps feasibility study is needed for the recreation features of the Old Cross Cut Canal and the cost of the study is estimated at $20,000. She also reported that the Corps must share this cost 50-50 with the local sponsor(s). Because of statute requirements, the FCDMC cannot participate in pure recreation items.

251 West Washington Street, Phoenix, Arizona 85003-2299 602-261-8855

Ms. Herbranson asked whether the City of Phoenix would participate in the recreation feasibility study. Our Parks, Recreation and Library Department is very interested in a cooperative design and development of the proposed Hohokam Parkway. This two mile (McDowell Road to the Arizona Canal) linear parkway would be an exciting feature in this section of Phoenix.

If necessary, the City of Phoenix will seriously consider sharing 50-50 with the Corps' cost of the recreation feasibility study. Exactly how we can contractually handle this agreement is as yet unclear. Please advise whether the City must contract with you or whether this must go through the local sponsor (FCDMC). Because of our laws, either way will require a formal Intergovernmental Agreement.

Please feel free to call if you wish to discuss the matter further.

Sincerely,

Severo

Severo Esquivel
Deputy City Manager

Attachment

53221

c: Mr. Britton
Mr. Colley
Ms. Herbranson, U. S. Army Corps of Engineers
Mr. Miguez
Mr. Sagramoso, FCDMC
Mr. Wilson, SRP
Mr. Matteson

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CITY COUNCIL REPORT — CONSENT AGENDA

DATE: June 16, 1988

DATE: June 21, 1988

TO: Mr. Esquivel
Deputy City Manager

ITEM: 6

FROM: Mr. Miguez
City Engineer

SUBJECT: OLD CROSS CUT CANAL (FLD 0612)

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The purpose of this report is to update the City Council on the status of the Old Cross Cut Canal (OXC) Project and to obtain the concurrence of the City Council on the recommended design alternative. The City Council Transportation Subcommittee unanimously approved the recommended alternative at their meeting of June 6, 1988.

BACKGROUND

The OXC runs generally along 48th Street from the Salt River to the Arizona Canal, just north of Indian School Road. Work by the Arizona Department of Transportation (ADOT) on the East Papago Freeway, the Hohokam, and related drainage works impacts the OXC south of Thomas Road.

The OXC is under the jurisdiction of the Salt River Project, but the Flood Control District of Maricopa County (FCDMC) holds easements for the drainage channel and for its maintenance.

In 1985, the U. S. Corps of Engineers (COE) began work on a study to determine the flooding problems and potential solutions in the Arcadia and Old Cross Cut areas. The study area is generally bounded by Camelback Mountain, 40th Street, 68th Street and the Arizona Canal, plus a large area south of the Arizona Canal. This is the only section of Phoenix adjacent to the Arizona Canal that will not be protected by existing or approved flood control projects. The OXC is the most logical outlet for storm water runoff from this area.

Public involvement meetings were held on February 9 and 11, 1987, and May 16 and 19, 1988. At the meetings in 1987, representatives from the City, the COE, and the FCDMC presented the OXC study and the various alternatives under consideration. Public input regarding the concerns and desires of area residents was also obtained. The meetings on May 16 and 19, 1988 were held to give interested parties an update on the status of the study, and to present the preferred design to them. The public reaction to the preferred design was generally favorable. Councilwoman Nadolski attended the recent meetings.

On December 22, 1987 the City Council gave consent to negotiate cost sharing of drainage improvements to the OXC with ADOT, FCDMC, and others.

The estimated cost of a 25-year system is $37.7 million. A 50-year system is estimated to cost $50 million. Although cost sharing has not been finalized, it appears that the City's share of a 25-year system would be approximately $4.6 million or approximately 12% of the total cost. A majority of the funds for our share were included in the 1988 Bond Election. Preliminary indications from the COE are that the City would be responsible for the entire cost of upgrading to a design greater than the 25-year system. The City's share could, therefore, be $16.8 million or approximately 34% of the total cost of the 50-year system.

The 25-year Full Lafayette Alternative is therefore the preferred alternative. This alternative has been preliminarily approved by the COE's South Pacific Division and by the FCDMC.

ADOT is currently designing the Hohokam Parkway south of McDowell Road. This includes modifications to the OXC. In order to keep this project on schedule, they have based their design on the preferred Alternative for the OXC (i.e., The Full Lafayette, 25-year Alternative).

RECOMMENDATION

The Engineering Department recommends that the City Council concur with the recommended 25-year Full Lafayette Alternative. The City Council Transportation Subcommittee has unanimously approved this alternative. Once an alternative is approved an Intergovernmental Agreement (IGA) defining the duties, responsibilities, and cost sharing will be prepared. The IGA will be brought to Council for approval at a later date.

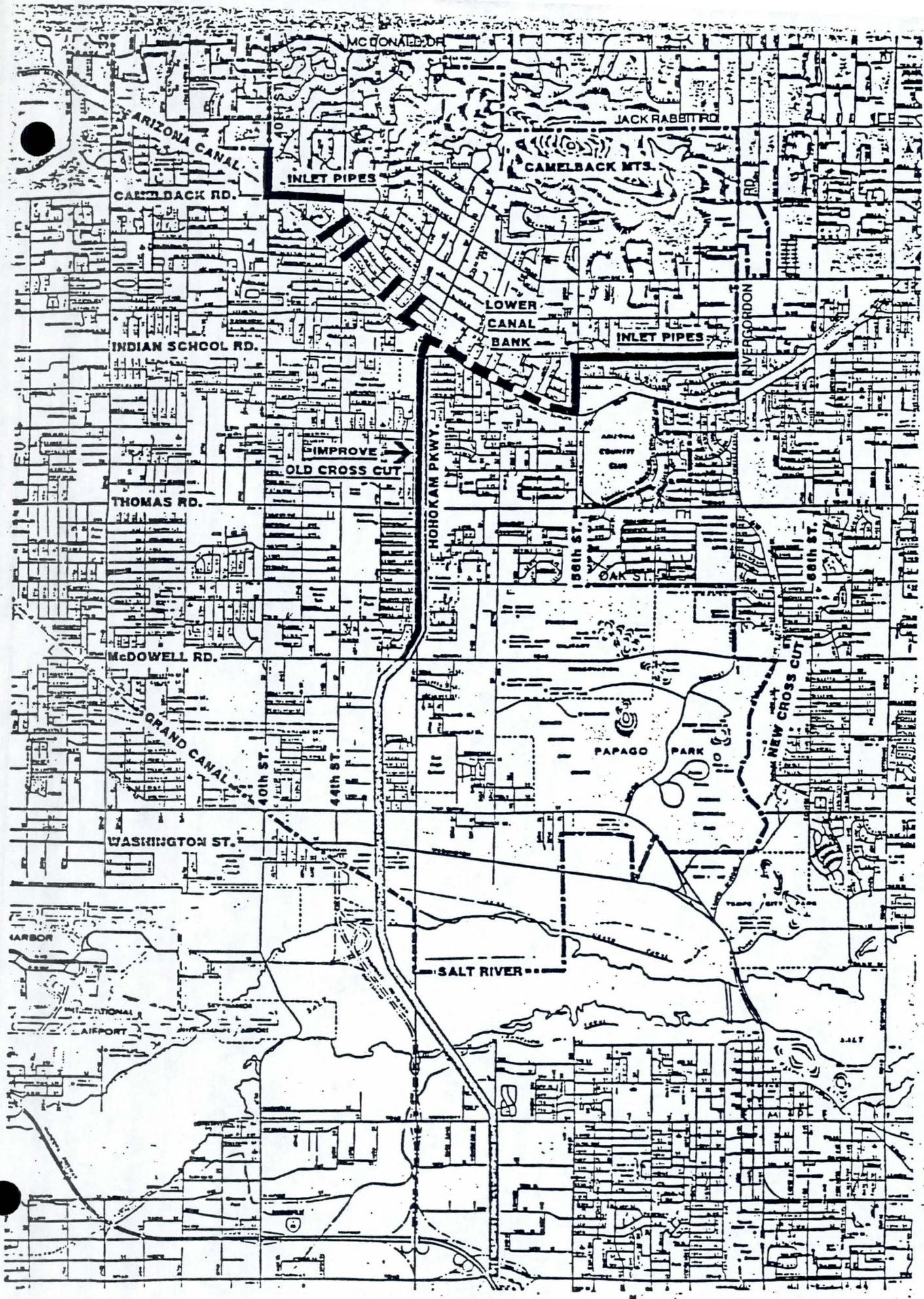
RDB:jp/6241e/50361

Attachments

c: Mr. Matteson
Mr. Harris

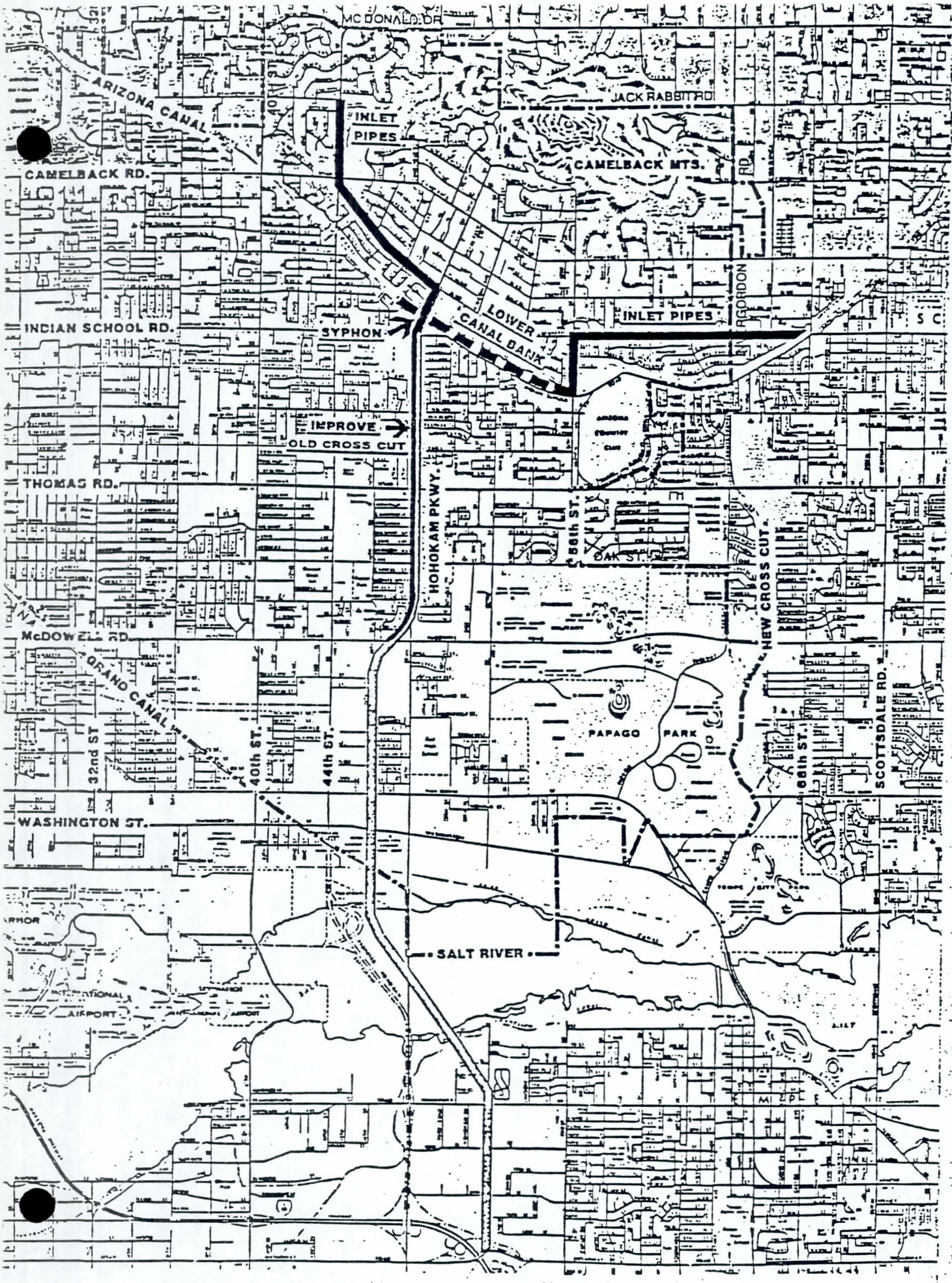
RDB:jp/6241e

6193s



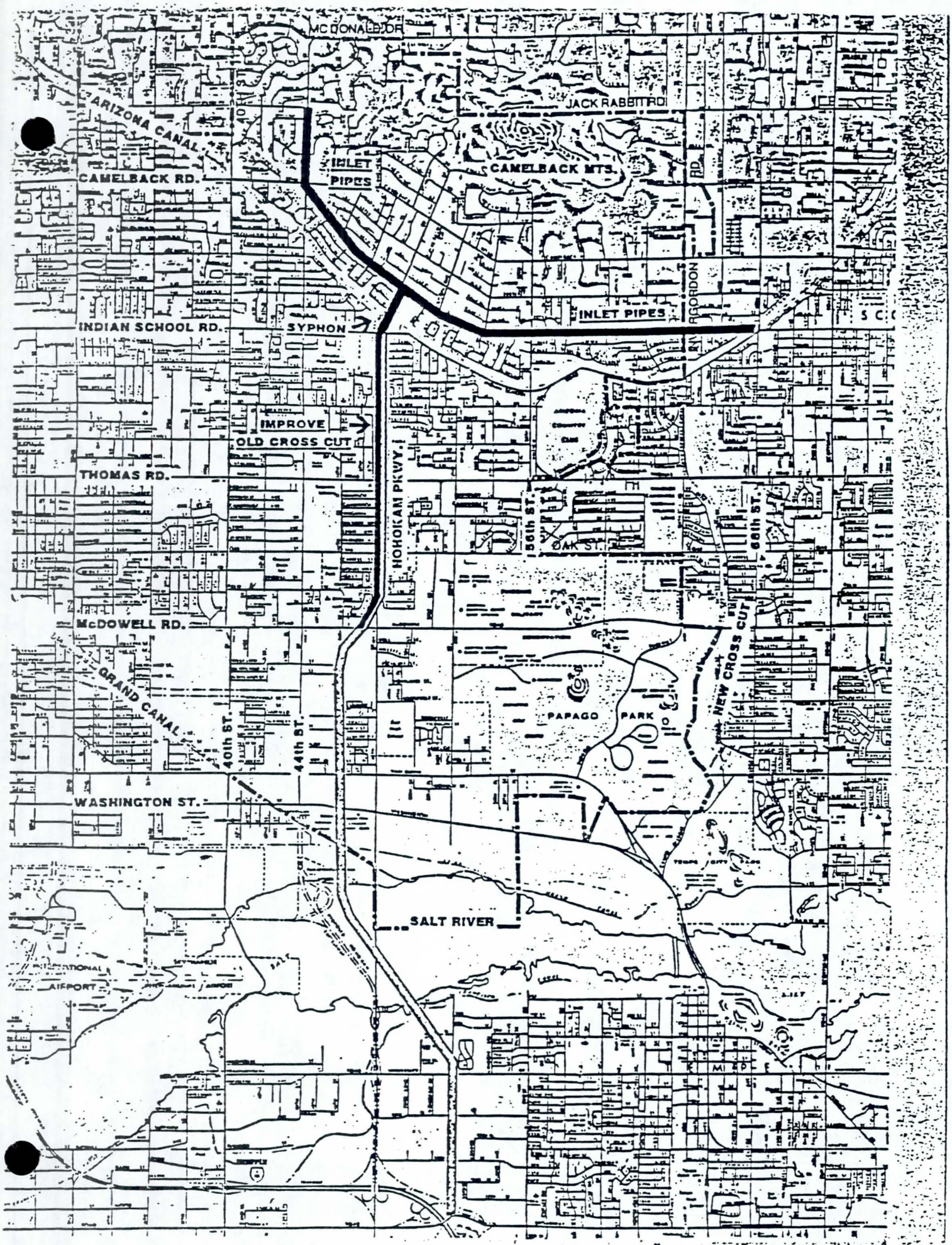
ATTACHMENT #1

ALLEY ALTERNATIVE



ATTACHMENT #2

PARTIAL LAFAYETTE



ATTACHMENT #3

FULL LAFAYETTE ALTERNATIVE

CITY OF PHOENIX

TO Ross Blakley, Engineering Supervisor, Engineering

DATE December 2, 1986

FROM Nick Ferrari, Water Quality Engineer

SUBJECT Old Cross-Cut Canal Stormwater Diversion

The Water and Wastewater Department is concerned over the Corps of Engineers' proposal to divert stormwater to the Old Cross-Cut Canal via the Arizona Canal. Our concerns center around two issues: a) Water Quality, and
b) Operational Costs

Our concerns are both philosophical and practical. On the former, although we cannot as yet cite specific technical justification, we believe it is counter to current thinking on water quality issues to deliberately introduce stormwater runoff from an urban environment into a drinking water supply. It would seem likely that as drinking water standards become more and more stringent over the next several years, this may be a regrettable decision. Should the introduction of stormwater require exotic treatment for organics removal at some future date, the City could face a capital expenditure of $60,000,000 and an annual operation cost of $10,000,000/yr to retrofit the Deer Valley and Squaw Peak Plants with Granular Activated Carbon (GAC) filters.

Regardless of speculations on future water quality standards, we do know today, however, that the introduction of stormwater results in dramatically increased operational costs at the treatment plants affected. Based on an analysis of recent storm events, we found that the unit cost of treatment chemicals per million gallons delivered increased from $17.50/MG to $44.75/MG during the period of storm runoff.

with a flow of 100 MGD each from Deer Valley and Squaw Peak Plants, the excess cost to the City for treating storm runoff from this project can be estimated to be over $135,000 per year.

For these reasons, Water and Wasteewater would urge the Corps of Engineers to explore other means of dealing with the storm flow problem in this area.

Nick Ferrari (VF)

Nick Ferrari, P.E.,
Water Quality Engineer

NF/vf
cc: Ken Spiker
Wayne Janis
Sue Keith
Attachment